WestJEM

Volume 20, Number 3, May 2019 Open Access at *West*JEM.com ISSN 1936-900X

Western Journal of Emergency Medicine:

Integrating Emergency Care with Population Health

Indexed in MEDLINE

Contents continued on page iii

CALIFORNIA ACEP
AMERICAN COLLEGE OF EMERGENCY PHYSICIANS

ACOEP
The American College of Osteopathic Emergency Physicians

UC Irvine Health

CALAAEM
CALIFORNIA CHAPTER DIVISION OF THE AMERICAN ACADEMY OF EMERGENCY MEDICINE

A Peer-Reviewed, International Professional Journal

VOLUME 20, NUMBER 3, May 2019

PAGES 428- 537


Austin
ACOEP's 2019
SCIENTIFIC ASSEMBLY
SAVE THE DATE
★ NOVEMBER 2 - 6, 2019 ★
JW MARRIOTT • AUSTIN, TX
Stay tuned at acoep.org for more information.

Western Journal of *Emergency Medicine*:

Integrating Emergency Care with Population Health

Indexed in **MEDLINE** and **PubMed**

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

Available in MEDLINE, PubMed, PubMed Central, CINAHL, SCOPUS, Google Scholar, eScholarship, Melvyl, DOAJ, EBSCO, EMBASE, Medscape, HINARI, and MDLinx Emergency Med. Members of OASPA.
Editorial and Publishing Office: *West*JEM/Depatment of Emergency Medicine, UC Irvine Health, 333 City Blvd, West, Rt 128-01, Orange, CA 92868, USA
Office: 1-714-456-6389; Email: Editor@westjem.org

Western Journal of *Emergency Medicine*:

Integrating Emergency Care with Population Health

Indexed in **MEDLINE** and **PubMed**

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

Available in MEDLINE, PubMed, PubMed Central, Europe PubMed Central, PubMed Central Canada, CINAHL, SCOPUS, Google Scholar, eScholarship, Melvyl, DOAJ, EBSCO, EMBASE, Medscape, HINARI, and MDLinx Emergency Med. Members of OASPA.

Editorial and Publishing Office: *West*JEM/Depatment of Emergency Medicine, UC Irvine Health, 333 City Blvd, West, Rt 128-01, Orange, CA 92866, USA
Office: 1-714-456-6389; Email: Editor@westjem.org

Western Journal of *Emergency Medicine*:

Integrating Emergency Care with Population Health

Indexed in **MEDLINE** and **PubMed**

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.

Table of Contents

VITAL STATISTICS

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 8 AAEM State Chapters.

Policies for peer review, author instructions, conflicts of interest and human and animal subjects protections can be found online at www.westjem.com.

Western Journal of *Emergency Medicine*:

Integrating Emergency Care with Population Health

Indexed in **MEDLINE** and **PubMed**

This open access publication would not be possible without the generous and continual financial support of our society sponsors, department and chapter subscribers.

Western Journal of Emergency Medicine Call for Papers:

- **Social Emergency Medicine**
- **Systematic Reviews**

CALL FOR SECTION EDITORS

- Behavioral Health
- Cardiac Care
- Ultrasound
- Clinical Practice
- Pediatric Emergencies
- Public Health
- Trauma Care
- International Medicine
- ED Administration

Send your CV and letter of interest to editor@westjem.org

Learn more at www.westjem.org

COUNCIL OF RESIDENCY DIRECTORS IN EMERGENCY MEDICINE

CALL FOR PAPERS

For The *Western Journal* of Emergency Medicine Special Issue in Educational Research and Practice

For more information go to:

http://westjem.com/cdem-cord-submission-guidelines

Submit your articles to WESTJEM.com today

All submissions due by 06/15/19

Variations in Opioid Prescribing Behavior by Physician Training

Evan L. Leventhal, MD, PhD
Larry A. Nathanson, MD
Alden M. Landry, MD, MPH

Beth Israel Deaconess Medical Center, Harvard Medical School, Department of Emergency Medicine, Boston, Massachusetts

Section Editor: Jeremy J. Hess, MD, MPH
Submission history: Submitted June 15, 2018; Revision received March 1, 2019; Accepted March 11, 2019
Electronically published April 16, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.3.39311

Introduction: Opioid abuse has reached epidemic proportions in the United States. Patients often present to the emergency department (ED) with painful conditions seeking analgesic relief. While there is known variability in the prescribing behaviors of emergency physicians, it is unknown if there are differences in these behaviors based on training level or by resident specialty.

Methods: This is a retrospective chart review of ED visits from a single, tertiary-care academic hospital over a single academic year (2014-2015), examining the amount of opioid pain medication prescribed. We compared morphine milligram equivalents (MME) between provider specialty and level of training (emergency medicine [EM] attending physicians, EM residents in training, and non-EM residents in training).

Results: We reviewed 55,999 total ED visits, of which 4,431 (7.9%) resulted in discharge with a prescription opioid medication. Residents in a non-EM training program prescribed higher amounts of opioid medication (108 MME, interquartile ratio [IQR] 75-150) than EM attendings (90 MME, IQR 75-120), who prescribed more than residents in an EM training program (75 MME, IQR 60-113) ($p<0.01$).

Conclusion: In an ED setting, variability exists in prescribing patterns with non-EM residents prescribing larger amounts of opioids in the acute setting. EM attendings should closely monitor for both over- and under-prescribing of analgesic medications. [West J Emerg Med. 2019;20(2)428-432.]

INTRODUCTION

Harm from prescription opioid misuse and overdose has increased to epidemic proportions in the United States.[1,2] Emergency physicians (EP) are often perceived to over-prescribe opioid analgesic medications,[3] thus contributing to the current public health crisis. Patients often turn to the emergency department (ED) for treatment of a variety of painful conditions, many of whom are discharged with analgesic prescriptions.[4,5]

Wide variations between specialties exist in prescribing patterns.[6] Acute pain is a typical cause of ED visits, leading EPs to commonly prescribe opioid prescriptions.[5] However, most of these prescriptions from the ED have a comparatively low pill count and a relatively small total amount of opioids.[7] Despite this, we now know there is no known safe dosing, and addiction can occur even after a short course of treatment.[8,9] While there have been many initiatives to provide alternative treatments to treat severe pain, opioids continue to have their place in providing appropriate analgesia.[10] There is known variability in the opioid prescribing patterns of EPs.[11]

It is not known if there is a difference in opioid prescribing patterns from the ED between providers of different training levels and specialty training. This study aimed to determine whether variations in physician characteristics correlated with increased amounts of opioid prescription quantities. We hypothesized that providers with the most training and experience in the ED setting – emergency medicine (EM) attendings – would prescribe the smallest amount of opioids. Conversely, we hypothesized that residents in non-EM training programs would be less likely to be familiar with ED practices and populations, and would therefore prescribe the largest quantity of opioids.

METHODS

Study Design and Setting

This was a retrospective chart review of all patients discharged from a single, urban, academic Level 1 trauma center and tertiary referral center with approximately 56,000 annual visits. All patients seen during a single academic year (June 1, 2014-June 30, 2015) were included in the study. Because it is an academic medical center, most patients are seen by a resident physician who is training either in EM or another specialty. All patients are seen by a supervising attending physician who is board certified in EM. Physician assistants and nurse practitioners did not see ED patients at this site during the study time period. This study was approved by the local institutional review board.

Patient Selection

We reviewed the charts of all patients discharged from the ED during the study period, and those with a prescription for opioid pain medications were included in this study. We excluded prescriptions for transdermal opioid medication (eg, fentanyl patches). Prescriptions with missing or invalid information were also excluded from the study.

Methods and Measurements

For each visit, we digitally extracted the following data from the electronic medical record (EMR): patient age, gender, triage Emergency Severity Index (ESI), chief complaint, pain score at time of triage (0 to 10), and any prescription for an opioid pain medication at the time of discharge. We classified combination medications (eg, those containing acetaminophen as well as an opioid) by their opioid ingredient alone. The ingredients of each medication were determined from the First Databank Drug Database (First Databank, South San Francisco, California). The quantity of prescribed opioid was reported in morphine milligram equivalents (MME) (median and interquartile ratio [IQR]) using standard conversion tables.[12] Chief complaints with sidedness specified had their sidedness removed (eg, "left wrist pain" was changed to "wrist pain"), but were otherwise grouped together unchanged.

The discharge module of our EMR allows for discharge planning to be started and modified throughout the patient visit. All discharge prescriptions are entered electronically, and are then printed on paper at the time of discharge. The EMR records the prescribing provider who entered the prescription plan into the EMR. For study purposes, this "prescribing provider" was identified and classified as either part of the primary team who first saw the patient and initiated the workup, or as part of a sign-out team who took over care for the patient at change of shift and who typically would complete a pre-established plan of care.

We grouped prescribing providers based on medical specialty and level of training: EM attending physicians, EM residents, and non-EM residents. During the study period, all providers had the ability to independently prescribe opioids. There was no opioid prescribing policy that constrained either the type or quantity of opioids prescribed. All of the relevant data fields were fully codified allowing for the extraction and classification to be automated.

Our EMR does not contain defaults for prescription quantities. Instead, it maintains a dynamic list of the most frequently written prescriptions, which are provided as shortcuts. The EMR does provide a list of suggested prescriptions grouped by condition. The only condition in our EMR that had any opioid listed during the study period was "back pain," which listed oxycodone-acetaminophen (5 milligrams (mg-325 mg) dispense 10 tablets (75 MME) as well as hydrocodone-acetaminophen (5-325 mg) dispense 15 tablets (75 MME).

Data Analysis

The primary outcome measure was the difference in prescribing quantities between the three groups of providers. We tested differences in these quantities using a one-way analysis of variance,, and we made pairwise comparisons using the posthoc Tukey test. Statistical analysis was performed with Python 3.6.3, using the open-source Pandas and SciPy library of packages.[13–15] A p value of <0.05 was

Population Health Research Capsule

What do we already know about this issue?
Opioid abuse represents an important health crisis in the United States. There are known variations in provider prescribing behavior from the emergency department.

What was the research question?
Do physicians of different training level and resident specialty prescribe different quantities of opioids?

What was the major finding of the study?
Non-emergency medicine residents prescribed more opioids than emergency-medicine trained providers.

How does this improve population health?
By better understanding inherent prescribing trends, we can better inform those attempting to characterize and modify current practice.

considered statistically significant. We used descriptive statistics to look at the specific opioid drug prescribed.

RESULTS

We reviewed a total of 55,999 ED patient visits, and of those,32,968 resulted in a discharge for outpatient care. Of those discharged, 4,431 visits included a prescription for an opioid medication (8% of all visits and 13% of discharged patient visits). No patient received more than one opioid prescription at the time of discharge. Two prescriptions for transdermal patches were excluded from the study. We also excluded 17 prescriptions that could not be filled due to invalid data elements: two were for controlled-substance refills, which is not permissible, while 15 of the excluded prescriptions specified invalid or nonspecific dispensing quantities.

The median age of included patients was 45 (interquartile ratio [IQR] 32-58). The median triage ESI was 3 (IQR 3-3), and the median pain score at the time of triage was 8 (IQR 6-10). More complete demographics for the study participants are included in Table 1. The most common chief complaints, which resulted in an opioid prescription at discharge, were "back pain," followed by "fall" and "abdominal pain" (Figure 1).

There were significant differences in the amount of opioid pain medication prescribed between the three groups ($p<0.01$) (Figure 2). EM residents prescribed the least amount (75 MME, IQR 60-113), while non-EM residents prescribed the largest amount of opioid analgesic (108 MME, IQR 75-150). EM attendings (90 MME, lQR 75-120) prescribed less than the non-EM resident providers and more than EM residents. Less than 1% of prescriptions were for extended-release formulations, and 83% of the prescriptions were for oxycodone (Table 2).

There were three outlier patients in the study. Two patients were prescribed high quantities of opioids by EM attendings for palliative care (5800 and 1900 MME). One patient was prescribed 1400 MME by a non-EM resident for postoperative pain at the request of consulting service. Inclusion of these three patients had no statistical effect.

DISCUSSION

Our study showed that physician specialty and level of training influence the amount of opioids prescribed from the ED. EPs, both residents and attendings, prescribe smaller quantities of opioid analgesic medications than non-EM trained providers in the ED. In contrast to our original hypothesis, EM residents prescribed fewer opioid quantities than EM attendings.

It is not clear why EM residents prescribed fewer opioids than the EM attendings. One possibility is that many of the attendings trained and practiced during the time when there was a greater push towards treating discomfort, and accreditation organizations were emphasizing pain evaluation and reduction.[16] By contrast, most residents have only practiced during the current opioid crisis and may be more ingrained with the concept of minimizing opioid prescribing. Overall, the total amount of opioids prescribed was quite low, consistent with prior research. Immediate-release oxycodone was overwhelmingly the primary medication prescribed; very few extended-release medications were prescribed. This is consistent with known prescribing behaviors of EPs.[7]

The dynamic nature of our frequently used prescriptions makes it difficult to measure the effect this bias would have on prescribing behaviors. However, as all providers see the same dynamic list, one would expect this to bring prescribing patterns closer together for all providers and be

Table 1. Characterisitics of patients discharged with opioid prescriptions.

	All (n=4425)	EM Attendings[1] (n=527)	EM residents[2] (n=3089)	Non-EM residents[3] (n=809)
Age (median [IQR])	45 [32-58]	44 [30-58]	46 [32-58]	46 [34-58]
Gender				
% female (n)	56% (2495)	53% (277)	56% (1742)	59% (476)
% male (n)	44% (1930)	47% (250)	44% (1347)	41% (333)
ESI				
1 % (n)	3.1% (138)	1.5% (8)	4.0% (123)	0.9% (7)
2 % (n)	14.2% (627)	9.9% (52)	15.3% (473)	12.6% (102)
3 % (n)	69.6% (3078)	68.7% (362)	68.0% (2102)	75.9% (614)
4 % (n)	12.9% (569)	18.6% (98)	12.5% (386)	10.5% (85)
5 % (n)	0.3% (13)	1.3% (7)	0.2% (5)	0.1% (1)
First pain score (median [IQR])	8 [6-10]	8 [6-9]	8 [6-10]	8 [7-10]
Prescribed by primary team % (n)	86% (3787)	80% (419)	86% (2663)	87% (705)

EM, emergency medicine; *IQR*, interquartile range; *ESI*, Emergency Severity Index.

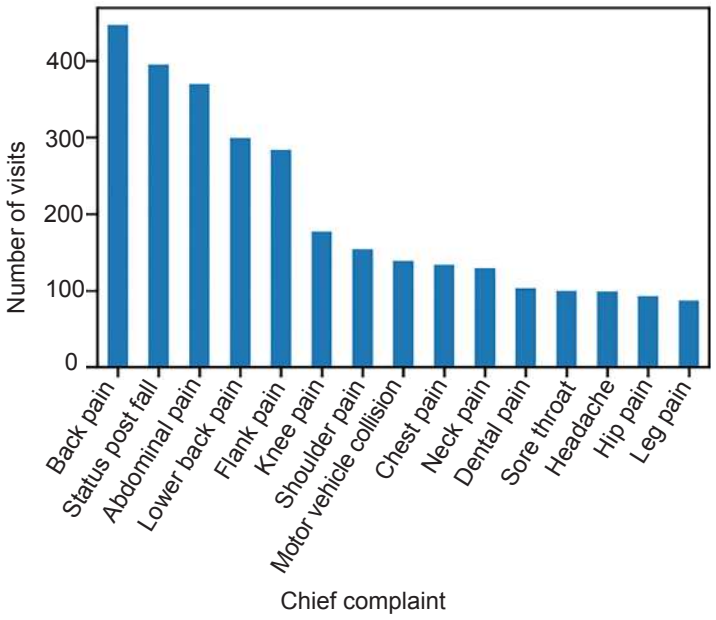


Figure 1. Most common chief complaints. Back pain was the most common chief complaint for which an opioid prescription was written. Combined, the top 15 chief complaints accounted for 52% of the opioid prescriptions.

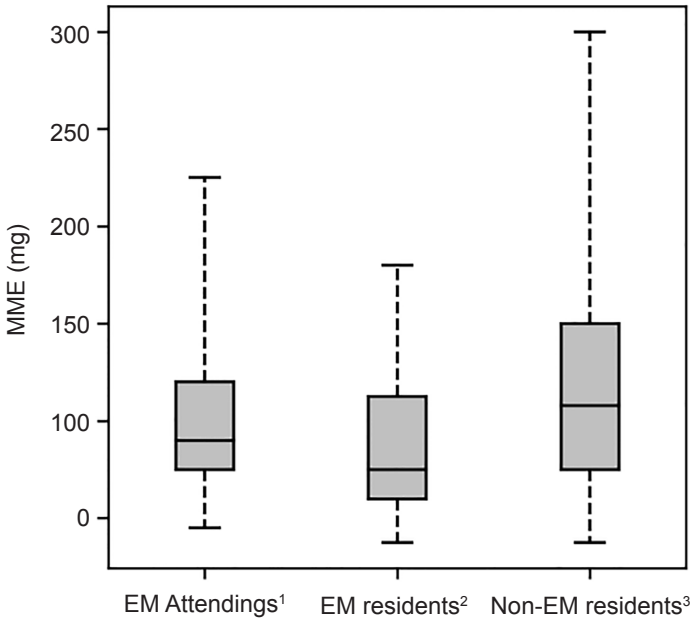


Figure 2. Total morphine milligram equivalent per patient by prescriber group.
Quantity of opioids prescribed in morphine milligram equivalent (MME) by each group of providers. Gray box shows the median and interquartile range, while the whisker lines represent the 95th percentile.
EM, emergency medicine; *mg,* milligram.

likely to bias the results toward the null hypothesis. While there was a statistically significant difference in the amount of opioids prescribed between each group, the overall prescribing quantities were generally small. Further, the difference in median MME prescribed between the highest and lowest groups was 33 MME, which converts to only four and a half tablets of the most common – oxycodone 5 mg tablets. While there is no safe dose, it is unclear whether such a small difference is clinically significant. At this time, the optimal amount of opioids to prescribe is unknown: too much and we risk contributing to the opioid epidemic,[1] and if too little we risk undertreating patients in acute pain.

LIMITATIONS

Our study was limited to a single, tertiary, academic medical center and its generalizability to other institutions must be carefully considered. As a retrospective analysis, unmeasured confounders may have biased the analysis. Only the final discharge prescription was evaluated in this study. Additionally, opioid amounts were attributed

Table 2. Distribution of prescriptions based on their opioid ingredient.

	All (n=4425)	EM Attendings[1] (n=527)	EM residents[2] (n=3089)	Non-EM residents[3] (n=809)
Codeine % (N)	1% (52)	2% (9)	1% (31)	1% (12)
Hydrocodone % (N)	6% (263)	8% (40)	6% (179)	5% (44)
Hydromorphone % (N)	3% (147)	3% (14)	3% (101)	4% (32)
Methadone % (N)	<1% (1)	0% (0)	<1% (1)	0% (0)
Morphine % (N)	<1% (9)	1% (3)	0% (0)	1% (6)
Morphine ER % (N)	<1% (5)	0% (0)	<1% (2)	<1% (3)
Oxycodone % (N)	83% (3685)	82% (434)	85% (2614)	79% (637)
Oxycodone ER % (N)	<1% (4)	0% (0)	<1% (1)	<1% (3)
Tramadol % (N)	6% (259)	5% (27)	5% (160)	9% (72)

EM, emergency medicine; *ER,* extended release.

solely to the provider who entered the final prescription into the EMR. This means we were unable to measure the effect of any discussion held between the resident trainee and the attending, nor were we able to measure a change in the planned prescribing amount prior to the patient's discharge. So, while this may not reflect what a resident had independently planned on prescribing, it accurately reflects the final supervised care.

CONCLUSION

We noted small but statistically significant variations in opioid prescribing practice between providers of different levels of training and specialty. While we did not explore the rationale for prescribing doses, we did note that those who are or have been trained in EM tend to prescribe lower doses of opiate therapy. As always, EM attendings must be cognizant of a trainee's opioid prescribing patterns.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Dr. Nathanson and Dr. Landry as co-senior authors for this article.

Address for Correspondence: Evan L. Leventhal, MD, PhD, Beth Israel Deaconess Medical Center, Harvard Medical School, Department of Emergency Medicine, 1 Deaconess Road, Boston, MA 02215. Email: eleventh@bidmc.harvard.edu.

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.

REFERENCES

1. Warner M, Chen LH, Makuc DM, et al. Drug poisoning deaths in the United States, 1980-2008. *NCHS Data Brief*. 2011;(81):1-8.
2. Jones CM, Mack KA, Paulozzi LJ. Pharmaceutical overdose deaths, United States, 2010. *JAMA*. 2013;309(7):657-9.
3. Volkow ND, McLellan TA, Cotto JH, et al. Characteristics of opioid prescriptions in 2009. *JAMA*. 2011;305(13):1299-301.
4. Cordell WH, Keene KK, Giles BK, et al. The high prevalence of pain in emergency medical care. *Am J Emerg Med*. 2002;20(3):165-9.
5. Mazer-Amirshahi M, Mullins PM, Rasooly I, et al. Rising opioid prescribing in adult U.S. emergency department visits: 2001-2010. *Acad Emerg Med*. 2014;21(3):236-43.
6. Weiner SG, Baker O, Rodgers AF, et al. Opioid prescriptions by specialty in Ohio, 2010-2014. *Pain Med*. 2018;19(5):978-89.
7. Hoppe JA, Nelson LS, Perrone J, et al. Opioid prescribing in a cross section of US emergency departments. *Ann Emerg Med*. 2015;66(3):253-9.e1.
8. Hoppe JA, Kim H, Heard K. Association of emergency department opioid initiation with recurrent opioid use. *Ann Emerg Med*. 2015;65(5):493-9.e4.
9. Alam A, Gomes T, Zheng H, et al. Long-term analgesic use after low-risk surgery: a retrospective cohort study. *Arch Intern Med*. 2012;172(5):425-30.
10. Cantrill SV, Brown MD, Carlisle RJ, et al. Clinical policy: critical issues in the prescribing of opioids for adult patients in the emergency department. *Ann Emerg Med*. 2012;60(4):499-525.
11. Hoppe JA, McStay C, Sun BC, et al. Emergency department attending physician variation in opioid prescribing in low acuity back pain. *West J Emerg Med*. 2017;18(6):1135-42.
12. Von Korff M, Korff MV, Saunders K, et al. De facto long-term opioid therapy for noncancer pain. *Clin J Pain*. 2008;24(6):521-7.
13. McKinney W. Data structures for statistical computing in Python. SciPy. 2010;6:51-6.
14. Hunter JD. Matplotlib: A 2D graphics environment. *Comput Sci Eng*. 2007;9(3):90-5.
15. Oliphant TE. Python for scientific computing. *Comput Sci Eng*. 2007;9(3):10-20.
16. Levy N, Sturgess J, Mills P. "Pain as the fifth vital sign" and dependence on the "numerical pain scale" is being abandoned in the US: Why? *Br J Anaesth*. 2018;120(3):435-8.

Association of Vital Signs and Process Outcomes in Emergency Department Patients

Nicole R. Hodgson, MD*
Karl A. Poterack, MD†
Lanyu Mi, MS*
Stephen J. Traub, MD*

*Mayo Clinic Hospital, Department of Emergency Medicine, Phoenix, Arizona
†Mayo Clinic Hospital, Department of Anesthesiology, Phoenix, Arizona

Section Editor: Gary Johnson, MD
Submission history: Submitted November 1, 2018; Revision received January 14, 2019; Accepted January 29, 2019
Electronically published April 16, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.1.41498

Introduction: We sought to determine the association of abnormal vital signs with emergency department (ED) process outcomes in both discharged and admitted patients.

Methods: We performed a retrospective review of five years of operational data at a single site. We identified all visits for patients 18 and older who were discharged home without ancillary services, and separately identified all visits for patients admitted to a floor (ward) bed. We assessed two process outcomes for discharged visits (returns to the ED within 72 hours and returns to the ED within 72 hours resulting in admission) and two process outcomes for admitted patients (transfer to a higher level of care [intermediate care or intensive care] within either six hours or 24 hours of arrival to floor). Last-recorded ED vital signs were obtained for all patients. We report rates of abnormal vital signs in each group, as well as the relative risk of meeting a process outcome for each individual vital sign abnormality.

Results: Patients with tachycardia, tachypnea, or fever more commonly experienced all measured process outcomes compared to patients without these abnormal vitals; admitted hypotensive patients more frequently required transfer to a higher level of care within 24 hours.

Conclusion: In a single facility, patients with abnormal last-recorded ED vital signs experienced more undesirable process outcomes than patients with normal vitals. Vital sign abnormalities may serve as a useful signal in outcome forecasting. [West J Emerg Med.2019;20(3)433-437.]

INTRODUCTION

"Vital signs are vital" is a common refrain in emergency medicine. Emergency physicians (EP) are taught early in their careers that persistent tachycardia at discharge should give them pause and that a hypotensive patient often isn't suitable for admission to a floor bed.

Previous studies support this traditional teaching. In discharged elderly patients, specific vital sign abnormalities (systolic blood pressure [SBP] < 97 millimeters of mercury [mmHg], heart rate > 101 beats per minute, body temperature > 37.3° C, and pulse oximetry < 92 SpO_2) were associated with twice the odds of admission within seven days of emergency department (ED) discharge, with the greatest odds found in patients with two or more abnormal vital signs.[1] Other studies focused on admitted patients, with mixed findings. Some found only tachypnea on admission to be correlated with upgrade in level of care within 24 hours,[2] whereas others found tachypnea, tachycardia, and hypoxia both on arrival to and departure from the ED, along with hypotension or hypertension on departure from the ED, to be associated with activation of a dedicated rapid-response team within 12 hours (a surrogate marker for patient decompensation).[3]

If vital sign abnormalities are consistently associated with undesirable process outcomes, artificial intelligence

(AI) programs could notify EPs prior to final disposition. We sought to determine the association of abnormal vital signs with ED process outcomes in a large population of both discharged and admitted patients in a single hospital.

METHODS

This was a retrospective analysis of routinely gathered ED operational data. This project was part of a quality improvement effort, and our institutional review board process identified it as exempt, with a waiver of the requirement for informed consent.

The Mayo Clinic Arizona ED is a tertiary care facility in Phoenix, Arizona. During the study period, there were 24 rooms and up to nine hallway spaces. There is no emergency medicine training program, but resident physicians from multiple services rotate through the ED and assist in the evaluation of approximately 5% of patients. The ED was staffed 24 hours per day with residency-trained EPs. There was no fast track and no mechanism for ED observation. Patients were allocated to physicians via rotational assignment, which removes essentially all physician discretion as to which patients a provider will evaluate.[4]

We analyzed all recorded eligible patient visits between July 1, 2012, and June 30, 2017. We defined eligible visits as those involving patients who were 18 years of age or older who were either discharged home without need for ancillary services (Group 1) or admitted to a floor (ward) bed (Group 2). We excluded patients discharged with ancillary services and admissions to intermediate or intensive care unit (ICU) beds.

Nursing staff collected vital signs from monitors, validating them for upload into the electronic health record (EHR) (Cerner Millennium; Cerner®, Kansas City, Missouri). For every visit, we obtained the last-recorded ED value for pulse, BP, respiratory rate, and temperature. These values were not necessarily obtained simultaneously. We excluded visits missing one or more vital signs. We also excluded visits with vital signs unlikely to be accurate entries (heart rate < 30 or > 200, respiratory rate (RR) < 5 or > 60, temperature < 30 or > 45, SBP < 50 or > 300, mean arterial pressure (MAP) < 20 or > 200). These values were chosen based upon an initial review of outliers in an attempt to exclude clinically improbable scenarios.

We defined tachycardia as a pulse ≥ 100. We defined hypotension as a SBP < 90 mmHg or a MAP of < 65 mmHg. We defined tachypnea as a RR > 20 breaths/minute. We defined fever as a temperature ≥ 38° C.

For Group 1, the outcomes of interest were returns within 72 hours of discharge from the ED and returns within 72 hours of discharge from ED that were subsequently admitted to our hospital or transferred to another hospital with the intention of admission. For Group 2, the outcomes of interest were transfer to a higher level of care (intermediate unit or ICU) within six hours or 24 hours after arrival to a floor bed.

We examined the frequency of vital sign abnormalities in each group and used Pearson's chi-square to test the association between vital signs and outcomes. We considered p values < 0.05 to be statistically significant. We report the relative risk of meeting a process outcome for each individual vital sign abnormality. Treating each vital abnormality as a diagnostic test to examine the precision with which it can identify a process measure, we calculated positive and negative predictive values. Data were abstracted by one investigator (SJT) from a custom operations report in Microsoft Excel (Redmond, Washington) format. We used SAS Studio 3.7 (SAS Institute, Inc, Cary, North Carolina) for the analysis.

RESULTS

We show our study flowchart in the figure, and report results in Table 1a-d. Patients with tachycardia, tachypnea, or fever more commonly met criteria for every process outcome compared to patients without these abnormalities. Patients who were hypotensive at admission more frequently required transfer to a higher level of care within 24 hours.

DISCUSSION

Indirect ICU admissions (patients initially admitted to a floor or ward bed and later upgraded to ICU) are associated with negative patient outcomes, including increased mortality at 72 hours[4] and at 30[4,5] and 60[6] days. ED returns with admissions may have increased mortality and morbidity as well; one study found a 7.1% mortality and 21.7% complication rate in patients with 72-hour revisits resulting in admission.[7]

Recent work has focused on the development of predictive tools based on ED vital signs to assist EPs in identifying patients at risk for decompensation.[8,9] One example, the PeRRT (Predicting Early Rapid Response Team) score, incorporates vital signs (among other data) to predict which patients would trigger a rapid response activation during the first 12 hours of admission.[10] Despite the associations of vital signs with negative process outcomes, most patients discharged or admitted to the floor with abnormal vital signs did not have negative outcomes, limiting the utility of vital signs alone as a predictive tool. This suggests a need to incorporate additional factors in any predictive algorithm. Age, serum bicarbonate, and lactic acid have separately been shown to be associated with inpatient deterioration.[11]

The future application of AI to ED patient data could improve predictive models to a point where they become more accurate. ED triage-based AI programs have shown promise. One algorithm incorporating age, sex, arrival mode, chief complaint, active problems and arrival vital signs showed equivalent or improved ability to detect patients needing ICU admissions, emergent procedures, and hospital admission

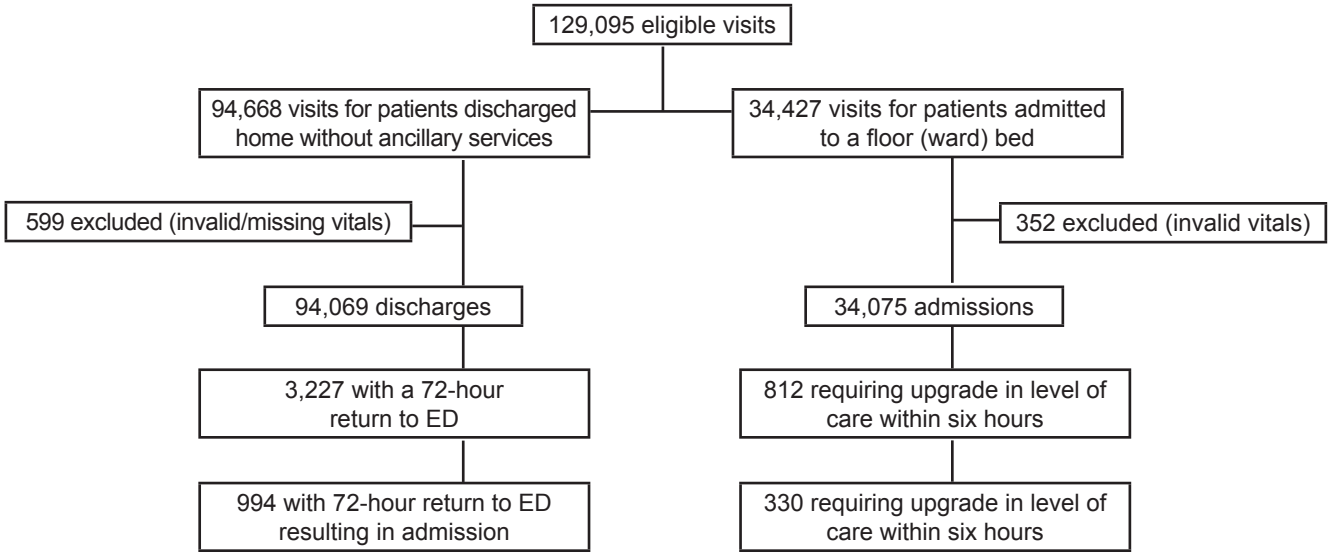


Figure. Study flowchart.
ED, emergency department.

Table 1a. Vital sign abnormalities and 72-hour returns in discharged patients.

Vital sign	Return (n=3227)	No return (n=90842)	P-value	RR (95% CI)	PPV	NPV
Hypotension	25	557	0.2501	1.25 (0.85-1.84)	4.30%	96.57%
Tachycardia	198	4662	0.0114*	1.20 (1.04-1.38)	4.07%	96.60%
Tachypnea	184	4371	0.0206*	1.19 (1.03-1.37)	4.04%	96.60%
Fever	42	576	<0.0001*	1.99 (1.49-2.68)	6.80%	96.59%

RR, relative risk; *CI,* confidence interval; *PPV,* positive predictive value; *NPV,* negative predictive value.
*Denotes statistically-significant P-values.

Table 1b. Vital sign abnormalities and 72-hour return with admission in discharged patients.

Vital sign	Return+admit (n=994)	No return+admit (n=93075)	P-value	RR (95% CI)	PPV	NPV
Hypotension	11	571	0.0486*	1.80 (1.00-3.24)	1.89%	98.95%
Tachycardia	73	4787	0.0018*	1.45 (1.15-1.84)	1.50%	98.97%
Tachypnea	89	4466	<0.0001*	1.93 (1.56-2.40)	1.95%	98.99%
Fever	25	593	<0.0001*	3.90 (2.64-5.76)	4.05%	98.96%

RR, relative risk; *CI,* confidence interval; *PPV,* positive predictive value; *NPV,* negative predictive value.
*Denotes statistically-significant P-values.

Table 1c. Vital sign abnormalities and six-hour upgrades in admitted patients.

Vital sign	Six-hour upgrade (n=330)	No six-hour upgrade (n=33745)	P-value	RR (95% CI)	PPV	NPV
Hypotension	10	593	0.0809	1.73 (0.93-3.24)	1.66%	99.04%
Tachycardia	87	3992	<0.0001*	2.63 (2.07-3.36)	2.13%	99.19%
Tachypnea	96	5444	<0.0001*	2.11 (1.67-2.68)	1.73%	99.18%
Fever	29	1100	<0.0001*	2.81 (1.93-4.10)	2.57%	99.09%

RR, relative risk; *CI,* confidence interval; *PPV,* positive predictive value; *NPV,* negative predictive value.
*Denotes statistically-significant P-values.

Table 1d. Vital sign abnormalities and 24-hour upgrades in admitted patients.

Vital Sign	24-Hour upgrade (n=812)	No 24-hour upgrade (n=33263)	P-value	RR (95% CI)	PPV	NPV
Hypotension	26	577	0.0017*	1.84 (1.25-2.69)	4.31%	97.65%
Tachycardia	188	3891	<0.0001*	2.22 (1.89-2.60)	4.61%	97.92%
Tachypnea	214	5326	<0.0001*	1.84 (1.58-2.15)	3.86%	97.90%
Fever	55	1074	<0.0001*	2.12 (1.62-2.77)	4.87%	97.70%

RR, relative risk; *CI,* confidence interval; *PPV,* positive predictive value; *NPV,* negative predictive value.
*Denotes statistically-significant P-values.

when compared to the Emergency Severity Index.[12] Similarly, AI may soon be able to prospectively identify patients at risk of both inpatient and outpatient deteriorations. Although our vital sign data by itself was insufficient to create a sensitive and specific algorithm, the addition of other clinical data could lead to the development of a useful AI tool to alert EPs to potentially unsafe dispositions.

LIMITATIONS

We did not analyze pulse oximetry data. It is difficult to extract data from our EHR regarding supplemental oxygen status, making oxygenation values difficult to interpret. Additionally, we did not examine hypertension or hypothermia. We limited our analysis to those who were discharged home with no ancillary services and those who were admitted to a floor bed. Although our methodology prevents extrapolation to other groups (such as patients discharged to home hospice or patients admitted to an intermediate setting), it removed several potentially confounding factors.

We did not account for "scheduled" ED visits, such as encounters for suture removal or wound re-checks. We believe this had little impact on our data, however, as most patients in our healthcare system present to their primary physicians for this follow-up. Additionally, we were unable to account for discharged patients who may have presented to other EDs within 72 hours, as this information was not readily obtainable in our EHR.

CONCLUSION

Patients with tachycardia, tachypnea or fever recorded as their final ED vital sign more frequently experienced undesirable process outcomes. Despite these associations, most admitted patients with abnormal vital signs did not require upgrades in level of care, and most discharged patients with abnormal vital signs did not have a return visit or a return visit with admission. Vital sign abnormalities may serve as a useful signal in outcome forecasting; however, a more nuanced model that combines vitals data with other factors is needed to make a clinically useful predictive model. AI may soon provide the necessary technology to create this tool.

Address for Correspondence: Nicole R. Hodgson, MD, Mayo Clinic Hospital, Department of Emergency Medicine, 5777 East Mayo Boulevard, Phoenix, AZ 85054. Email: Hodgson.Nicole@Mayo.edu.

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.

REFERENCES

1. Gabayan GZ, Gould MK, Weiss RE, et al. Emergency department vital signs and outcomes after discharge. *Acad Emerg Med*. 2017;24(7):846-54.
2. Farley H, Zubrow MT, Gies J, et al. Emergency department tachypnea predicts transfer to a higher level of care in the first 24 hours after ED admission. *Acad Emerg Med*. 2010;17(7):718-22.
3. Walston JM, Cabrera D, Bellew SD, et al. Vital signs predict rapid-response team activation within twelve hours of emergency department admission. *West J Emerg Med*. 2016;17(3):324-30.
4. Traub SJ, Stewart CF, Didehban R, et al. Emergency department rotational patient assignment. *Ann Emerg Med*. 2016;67(2):206-15.
5. Parkhe M, Myles PS, Leach DS, et al. Outcome of emergency department patients with delayed admission to an intensive care unit. *Emerg Med*. 2002;14(1):50-7.
6. Molina JAD, Seow E, Heng BH, et al. Outcomes of direct and indirect medical intensive care unit admissions from the emergency department of an acute care hospital: a retrospective cohort study. *BMJ Open*. 2014;4(11):e005553.
7. Cheng SY, Wang HT, Lee CW, et al. The characteristics and prognostic predictors of unplanned hospital admission within 72 hours after ED discharge. *Am J Emerg Med*. 2013;31(10):1490-4.
8. Burch VC, Tarr G, Morroni C. Modified early warning score

predicts the need for hospital admission and inhospital mortality. *Emerg Med J*. 2008;25(10):674-8.

9. Imperato J, Mehegan T, Henning DJ, et al. Can an emergency department clinical "triggers" program based on abnormal vital signs improve patient outcomes? *CJEM*. 2017;19(4):249-55.
10. Bellew SD, Cabrera D, Lohse CM, et al. Predicting early rapid response team activation in patients admitted from the emergency department: the PeRRT score. *Acad Emerg Med*. 2017;24(2):216-25.
11. Henning D, Oedorf K, Day D, et al. Derivation and validation of predictive factors for clinical deterioration after admission in emergency department patients presenting with abnormal vital signs without shock. *West J Emerg Med*. 2015;16(7):1059-66.
12. Levin S, Toerper M, Hamrock E, et al. Machine-learning-based electronic triage more accurately differentiates patients with respect to clinical outcomes compared with the Emergency Severity Index. *Ann Emerg Med*. 2018;71(5):565-74.e2.

Epidemiology of Community-Onset *Staphylococcus aureus* Bacteremia

James Y. Yarovoy, MD*
Andrew A. Monte, MD, PhD†
Bryan C. Knepper, MPH, MSc‡
Heather L. Young, MD§

*Upstate Medical University, Department of Emergency Medicine, Syracuse, New York
†University of Colorado, Department of Emergency Medicine, Denver, Colorado
‡Denver Health Medical Center, Department of Patient Safety and Quality, Denver, Colorado
§Denver Health Medical Center, University of Colorado, Department of Medicine, Denver, Colorado

Section Editor: Elissa Perkins, MD
Submission history: Submitted December 17, 2018; Revision received January 27, 2019; Accepted February 13, 2019
Electronically published April 16, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.2.41939

Introduction: *Staphylococcus aureus* bacteremia (SAB) is the second-most common cause of community-onset (CO) bacteremia. The incidence of methicillin-resistant *S. aureus* (MRSA) has recently decreased across much of the United States, and we seek to describe risk factors for CO-MRSA bacteremia, which will aid emergency providers in their choice of empiric antibiotics.

Methods: This is a retrospective cohort study of all patients with SAB at a 500-bed safety net hospital. The proportion of S. aureus isolates that were MRSA ranged from 32-35% during the study period. Variables of interest included age, comorbid medical conditions, microbiology results, antibiotic administration, duration of bacteremia, duration of hospital admission, suspected source of SAB, and Elixhauser comorbidity score. The primary outcome was to determine risk factors for CO-MRSA bacteremia as compared to methicillin-susceptible *S. aureus* (MSSA) bacteremia in patients admitted to the hospital through the emergency department.

Results: We identified 135 consecutive patients with CO-SAB. In comparison to those with MSSA bacteremia, patients with MRSA bacteremia were younger (odds ratio [OR] 0.5, 95% confidence interval [CI], 0.4-0.7) with higher Elixhauser comorbidity scores (OR 1.4, 95% CI, 1.1-1.7). Additionally, these patients were more likely to have a history of MRSA infection or colonization (OR 8.9, 95% CI, 2.7-29.7) and intravenous drug use (OR 2.4, 95% CI, 1.0-5.7).

Conclusion: SAB continues to be prevalent in our urban community with CO-MRSA accounting for almost one-third of SAB cases. Previous MRSA colonization was the strongest risk factor for current MRSA infection in this cohort of patients with CO-SAB. [West J Emerg Med. 2019;20(3)438–442.]

INTRODUCTION

Staphylococcus aureus bacteremia (SAB) is the second-most common cause of community-onset (CO) bacteremia, affecting 15-40 per 100,000 population per year.[1,2] It is associated with a 20% mortality rate[3,4] with higher mortality linked to the presence of methicillin resistance, comorbid conditions, intensive care unit admission, and prior exposure to antibiotics.[5] Three-quarters of SAB are CO bacteremia, with the majority being secondary to skin and soft tissue infections. While the incidence of hospital-acquired SAB is decreasing, the incidence of CO-SAB has remained stable.[6]

The epidemiology of methicillin-resistant *S. aureus* (MRSA) has changed over the past four decades. Initially, MRSA was identified as a healthcare-associated pathogen.[7] In the late 1980s, community-onset MRSA, primarily the USA300 strain, was first identified. It spread throughout healthy community members including children, athletes, military personnel, and inmates in the 1990s.[8,9] By the mid-

2000s, the USA300 strain became the predominant strain of MRSA in both CO and healthcare-associated cases.[10] In fact, MRSA accounted for approximately 50% of all *S. aureus* cases at its peak. Most recently, MRSA has been decreasing in comparison to methicillin-susceptible *S. aureus* (MSSA).[6]

Risk factors for CO-MRSA have been poorly described in the recent era of decreasing MRSA prevalence. An evaluation of current risk factors for CO-MRSA is important for emergency medicine (EM) providers because it can impact the choice of empiric antibiotic therapy and prompt the early initiation of infection control measures. The goal of this study was to describe risk factors for CO-MRSA in a cohort of outpatients presenting to the emergency department (ED) with CO-SAB.

METHODS

This is a retrospective cohort study of all patients with SAB at a 500-bed safety net hospital. The proportion of *S. aureus* isolates that were MRSA ranged from 32-35% during the study period. Patients were identified by review of the microbiology blood culture log. We included consecutive patients ≥ 18 years old with SAB occurring before hospital day three between June 1, 2013, and April 30, 2015, admitted through the ED. Pediatric patients, those with subsequent episodes of SAB during the study period, and those with incomplete microbiology data were excluded. Clinical and microbiological data were collected by manual review of the electronic medical record.

The primary outcome was to determine risk factors for CO-MRSA bacteremia, as compared to MSSA bacteremia. Variables of interest were predetermined before the study began and included age, comorbid medical conditions, presence of indwelling medical devices including orthopedic hardware and intravascular devices (i.e., pacemakers, prosthetic heart valves, arterial grafts, and patches), microbiology results, antibiotic administration, duration of bacteremia, duration of hospital admission, suspected source of SAB, and Elixhauser comorbidity score.[11] The Elixhauser comorbidity score is a collection of 30 variables that are predictive of inhospital mortality.

The infectious diseases service performs a consultation on all patients with SAB. The suspected source of SAB was determined by an infectious diseases specialist (Heather L. Young) reviewing the infectious diseases consultation notes and using the following guidance to define the source of SAB:

- Skin and soft tissue infection: cellulitis or purulence in the superficial skin layers without a deeper underlying source and without a history of injection drug use (IDU).
- Vascular access: (1) pain, erythema, or phlebitis at a recent or current peripheral intravenous (IV) catheter, at a recent phlebotomy site, or overlying an arteriovenous fistula; or (2) a central venous catheter, including hemodialysis catheter, with pain, erythema, or purulence at the insertion site or without those symptoms but with no other recognized source of infection.[12]
- Bone or joint infection: purulence or a positive culture for *S. aureus* isolated from bone or synovial fluid.
- IDU: skin and soft tissue infection at a site used for injecting drugs.
- Pneumonia: pulmonary infiltrates accompanied by hypoxia.
- Urinary tract infection: a urine culture positive for *S. aureus* plus dysuria, urinary frequency, or radiologic evidence of pyelonephritis.
- Other: radiologic evidence of infection plus a tissue culture positive for *S. aureus* in a body site.
- Unknown: does not fit the definition of other sites of infection.

We used descriptive statistics to characterize the population. Chi-square, Wilcoxon rank-sum, and multivariate logistic regression were used to determine the relationship between the primary outcome and the variables of interest. Factors with a univariate p-value < 0.3 were considered for the multivariate model. We performed all statistics using Statistical Analysis System version 9.0 (Cary, North Carolina). This study was approved by the Colorado Multiple Institutions Institutional Review Board.

RESULTS

During the study period, we identified 178 patients with SAB of whom 43 were excluded: 39 (22%) had a hospital-onset infection; three patients had a second case of SAB during the study period; and one SAB was not speciated. Thus, 135 patients with CO-SAB were included. The median patient age was 55.7 years (interquartile range [IQR] 48.9-63.6), and 77% (n=105) were male. The most common comorbid conditions included diabetes mellitus (n=68, 50%), chronic kidney disease (n=28, 20%), IDU (n=27, 20%), cirrhosis (n=27, 20%), and malignancy (n=15, 11%). Twenty patients (15%) had a history of MRSA infection or colonization. The median Elixhauser score was 4.0 (IQR 3.0-5.0).

Skin and soft tissue infections were responsible for the largest proportion of SAB cases (n=65, 48%), followed by unknown source (n=38, 28%) and vascular catheters (n=19, 14%). MRSA bacteremia accounted for 32% (n=43) of CO-SAB cases. In comparison to those with MSSA bacteremia, patients with MRSA bacteremia were younger (odds ratio [OR] 0.5 for 10-year increments, 95% confidence interval [CI], 0.4-0.7) with higher Elixhauser comorbidity scores (OR 1.4 for one-unit increments; 95% CI, 1.1-1.7). Additionally, these patients were more likely to have a history of MRSA infection or colonization (OR 8.9; 95% CI, 2.7-29.7) and IDU (OR 2.4; 95% CI, 1.0-5.7) (Table).

DISCUSSION

In this cohort of patients with CO-SAB, we found that patients with CO-MRSA bacteremia were younger, more likely to have previous MRSA colonization or infection, and more

Table. Demographic information plus univariate and multivariate odds ratios of risk factors for patients with community-onset methicillin-resistant and methicillin-susceptible *S. aureus* bacteremia.

	Population		Univariate		Multivariate		
Variable	MSSA N = 92	MRSA N = 43	OR	95% CI	OR	95% CI	P value
Age, median years (IQR)	58 (52-65)	52 (43-57)	0.95	0.92-0.98	0.5	0.4-0.7	< 0.0001
Elixhauser score, median (IQR)	4 (3-5)	5 (3-6)	1.18	0.98-1.41	1.4	1.1-1.7	0.01
Diabetes mellitus, n (%)	47 (51)	19 (44)	0.76	0.37-1.60			
Hemoglobin A1C, median (IQR)	9 (7-10)	9 (7-12)	1.11	0.90-1.37			
Chronic kidney disease, n (%)	21 (23)	7 (16)	0.65	0.25-1.67			
Hemodialysis, n (%)	9 (10)	3 (7)	1.45	0.37-5.63			
End-stage liver disease	18 (20)	7 (16)	0.79	0.30-2.06	0.4	0.1-1.3	0.13
Rheumatologic disease, n (%)	1 (1)	1 (2)	2.14	0.13-35.09			
Malignancy, n (%)	11 (12)	5 (12)	0.96	0.31-2.95			
Injection drug use, n (%)	14 (15)	13 (30)	2.38	1.00-5.66			
Human immunodeficiency virus, n (%)	1 (1)	2 (5)	4.39	0.39-49.80			
Intravascular device, n (%)	10 (11)	0 (0)					
History of MRSA infection or colonization, n (%)	5 (5)	14 (33)	8.4	2.78-25.34	8.9	2.7-29.7	< 0.0001
History of *S. aureus* bacteremia	5 (5)	1 (2)	0.41	0.05-3.66			
Presence of orthopedic hardware	6 (7)	5 (12)	1.89	0.54-6.56	3.2	0.8-12.8	0.10
Presumed source of infection							
Skin and soft tissue infection	28 (30)	15 (34)	1.22	0.57-2.64			
Vascular access	13 (14)	6 (14)	0.99	0.35-2.80			
Bone or joint infection	8 (9)	6 (14)	1.38	0.42-4.50			
Injection drug use	6 (6)	5 (11)	1.89	0.54-6.56			
Pneumonia	5 (5)	2 (5)	0.85	0.16-4.56			
Urinary tract infection	4 (4)	3 (7)	1.65	0.35-7.72			
Other	4 (4)	2 (5)	1.07	0.19-6.10			
Unknown source	25 (27)	5 (11)	0.37	0.13-1.06			

MRSA, methicillin-resistant *S. aureus*; *MSSA*, methicillin-susceptible *S. aureus*; *IQR*, interquartile range; *OR*, odds ratio; *CI*, confidence interval.

likely to have comorbid medical conditions than those with CO-MSSA bacteremia. We were surprised to see that both younger patients and those with comorbid conditions were at risk for CO-MRSA bacteremia. We suspect that this is due to an interaction between age and IDU (p = 0.003 on univariate analysis). Younger age was a previously described risk factor for CO-MRSA due to the USA300 strain, while increased comorbid conditions is a traditional risk factor for CO-MRSA. It would be interesting to determine if there is one predominant strain of MRSA in CO-MRSA at the current time, or if there are different strains prevalent in these two demographic groups.

Previous MRSA colonization or infection was the strongest risk factor for CO-SAB due to MRSA in our study. Our results are concordant with the work of Butler-Laporte et al.[13] who found that the presence of a positive MRSA nares screen at any time in the past was associated with a high risk of MRSA infection in the context of a presumed SAB. Similarly, Bradley et al.[14] reported that 12% of patients who newly acquire MRSA are hospitalized with an MRSA infection in the subsequent 18 months. Our study also correlates with the results of Yasmin et al.[4] who reported that the majority of CO-MRSA bacteremia cases were due to skin and soft tissue infections. Yasmin et al.[4] also found that having a central line within the previous 30 days was an independent risk factor with a calculated OR of 80 (95% CI, 2-3014). In our study, episodes of vascular access, including central line, dialysis catheters, peripheral IV, and venipuncture, were common sources of CO-SAB.

The changing epidemiology of MRSA is of interest to emergency care providers. As the first providers to evaluate

patients with community-onset infections, emergency physicians are responsible for initiating appropriate antibiotic therapy both for resistant and susceptible pathogens. There are certainly risks to providing an insufficient spectrum of antibiotics to patients in the setting of sepsis. Patients who do not receive an appropriate antibiotic within the first three hours of presenting to the ED have increased mortality as compared to those who receive antibiotics that are active against the causative pathogen.[15]

However, there are also risks associated with administering antibiotics that are too broad in spectrum, including placing patients at higher risk for *Clostridioides difficile* colitis, encouraging the emergence of multidrug resistant organisms, and suboptimally treating severe infections. While most antibiotics incur some risk for *C. difficile* colitis, broad spectrum antibiotics such as clindamycin, third-generation cephalosporins, and fluoroquinolones place a patient at the highest risk for this infection.[16] Additionally, the widespread use of an antibiotic can drive resistance in this organism within a hospital community. For example, Kim et al.[17] described a relationship between increasing numbers of vancomycin doses administered at their hospital and an increasing number of patients with vancomycin-resistant enterococcus infection. Finally, broad spectrum therapy is not always the most effective antibiotic for a particular pathogen. Vancomycin is the most common empiric treatment of suspected MRSA bacteremia, but vancomycin is associated with inferior outcomes for MSSA bacteremia as compared to cefazolin or nafcillin therapy.[18] By understanding risk factors for both MRSA and for MSSA, emergency physicians may be able to select antibiotics in a more nuanced fashion, choosing not only an adequate drug for *S. aureus* infection, but also the most effective therapy for either MRSA or MSSA based on the patient's risk factors for the organism.

Emergency care providers also have the opportunity to promptly initiate appropriate infection control measures. If a patient has risk factors for MRSA, contact precautions may be implemented while the patient is still in the ED, appropriate environmental cleaning processes may be started, and a private inpatient room can be requested to decrease the risk of transmission to other vulnerable patients.

LIMITATIONS

This study is limited by its single-center design. Results may not be applicable to facilities that care for a large population of outpatients with indwelling central lines or whose communities have different rates of MRSA. Further studies to characterize the strains of MRSA causing these infections would be an interesting correlate.

CONCLUSION

CO-SAB continues to be prevalent in our urban community, with CO-MRSA accounting for almost one-third of SAB cases. Previous MRSA colonization was the strongest risk factor for current MRSA infection in this cohort of patients with CO-SAB. The demographics of adults with CO-MRSA bacteremia continue to evolve, currently being a hybrid between chronically-ill patients and those with young age. Emergency physicians must be aware of the changing risk factors for MRSA so that optimal antibiotic therapy and infection control measures can be initiated in a timely manner.

Address for Correspondence: Heather Young, MD, Denver Health Medical Center, Department of Medicince, 601 Broadway, MC 4000 Denver, CO 80204. Email: heather.young2@dhha.org.

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. James Y. Yaroyoy, Bryan C. Knepper, and Heather L. Young report no financial conflicts of interest. Andrew A. Monte received research support from NIH K23 GM110516, although this grant was not used to support the work reflected in this manuscript.

REFERENCES

1. Laupland KB, Lyytikainen O, Sogaard M, et al. The changing epidemiology of *Staphylococcus aureus* bloodstream infection: a multinational population-based surveillance study. *Clin Microbiol Infect*. 2013;19(5):465-71.
2. Lee CC, Wang JL, Lee CH, et al. Age-related trends in adults with community-onset bacteremia. *Antimicrob Agents Chemother*. 2017;61(12). pii:e01050-17.
3. Wiggli BJ, Frei R, Laffer R, et al. Survival from methicillin-sensitive *Staphylococcus aureus* bloodstream infections over 20 years: a cohort of 1328 patients. *Swiss Med Wkly*. 2017;147:w14508.
4. Yasmin M, El Hage H, Obeid R, et al. Epidemiology of bloodstream infections caused by methicillin-resistant *Staphylococcus aureus* at a tertiary care hospital in New York. *Am J Infect Control*. 2016;44(1):41-6.
5. Yilmaz M, Elaldi N, Balkan II, et al. Mortality predictors of *Staphylococcus aureus* bacteremia: a prospective multicenter study. *Ann Clin Microbiol Antimicrob*. 2016;15:7.
6. David MZ, Daum RS, Bayer AS, et al. *Staphylococcus aureus* bacteremia at 5 US academic medical centers, 2008-2011: significant

geographic variation in community-onset infections. *Clin Infect Dis*. 2014;59(6):798-807.

7. Boyce JM, Landry M, Deetz TR, et al. Epidemiologic studies of an outbreak of nosocomial methicillin-resistant *Staphylococcus aureus* infections. *Infect Control.* 1981;2(2):110-6.
8. Herold BC, Immergluck LC, Maranan MC, et al. Community-acquired methicillin-resistant *Staphylococcus aureus* in children with no identified predisposing risk. *JAMA*. 1998;279(8):593-8.
9. Rhee Y, Aroutcheva A, Hota B, et al. Evolving epidemiology of *Staphylococcus aureus* bacteremia. *Infect Control Hosp Epidemiol*. 2015;36(12):1417-22.
10. Jenkins TC, McCollister BD, Sharma R, et al. Epidemiology of healthcare-associated bloodstream infection caused by USA300 strains of methicillin-resistant Staphylococcus aureus in 3 affiliated hospitals. *Infect Control Hosp Epidemiol*. 2009;30(3):233-41.
11. Johnston JA, Wagner DP, Timmons S, et al. Impact of different measures of comorbid disease on predicted mortality of intensive care unit patients. *Med Care*. 2002;40(10):929-40.
12. Centers for Disease Control and Prevention. Bloodstream infection event (central line-associated bloodstream infection and non-central line associated bloodstream infection). 2018. Available at: https://www.cdc.gov/nhsn/PDFs/pscManual/4PSC_CLABScurrent.pdf. Accessed February 28, 2019.
13. Butler-Laporte G, Cheng MP, Cheng AP, et al. Using MRSA screening tests to predict methicillin resistance in *Staphylococcus aureus* bacteremia. *Antimicrob Agents Chemother*. 2016;60(12):7444-8.
14. Bradley SF. Eradication or decolonization of methicillin-resistant Staphylococcus aureus carriage: what are we doing and why are we doing it? *Clin Infect Dis*. 2007;44(2):186-9.
15. Lueangarun S, Leelarasamee A. Impact of inappropriate empiric antimicrobial therapy on mortality of septic patients with bacteremia: a retrospective study. *Interdiscip Perspect Infect Dis*. 2012;2012:765205.
16. Owens RC JR, Donskey CJ, Gaynes RP, et al. Antimicrobial-associated risk factors for Clostridium difficile infection. *Clin Infect Dis*. 2008;46 Suppl 1:S19-31.
17. Kim WJ, Weinstein RA, Hayden MK. The changing molecular epidemiology and establishment of endemicity of vancomycin resistance in enterococci at one hospital over a 6-year period. *J Infect Dis*. 1999;179(1):163-71.
18. Schweizer ML, Furuno JP, Harris AD, et al. Comparative effectiveness of nafcillin or cefazolin versus vancomycin in methicillin-susceptible *Staphylococcus aureus* bacteremia. *BMC Infect Dis*. 2011;11:279.

Mortality and Thrombosis in Injured Adults Receiving Tranexamic Acid in the Post-CRASH-2 Era

Simranjeet Benipal, BS
John-Lloyd Santamarina, BS
Linda Vo, BS
Daniel K. Nishijima, MD, MAS

Universtiy of California, Davis Medical Center, Department of Emergency Medicine, Sacramento, California

Section Editor: Pierre Borczuk, MD
Submission history: Submitted November 20,2018 ; Revision received April 10, 2019 ; Accepted April 8,2019
Electronically published April 26, 2019
Full text available through open access at http://escholarship.org/uc/uciem_cpcem
DOI: 10.5811/westjem.2019.4.41698

Introduction: The CRASH-2 trial demonstrated that tranexamic acid (TXA) reduced mortality with no increase in adverse events in severely injured adults. TXA has since been widely used in injured adults worldwide. Our objective was to estimate mortality and adverse events in adults with trauma receiving TXA in studies published after the CRASH-2 trial.

Methods: We systematically searched PubMed, Embase, MicroMedex, and ClinicalTrials.gov for studies that included injured adults who received TXA and reported mortality and/or adverse events. Two reviewers independently assessed study eligibility, abstracted data, and assessed the risk of bias. We conducted meta-analyses using random effects models to estimate the incidence of mortality at 28 or 30 days and in-hospital thrombotic events.

Results: We included 19 studies and 13 studies in the systematic review and meta-analyses, respectively. The pooled incidence of mortality at 28 or 30 days (five studies, 1538 patients) was 10.1% (95% confidence interval [CI], 7.8-12.4%) (vs 14.5% [95% CI, 13.9-15.2%] in the CRASH-2 trial), and the pooled incidence of in-hospital thrombotic events (nine studies, 1656 patients) was 5.9% (95% CI, 3.3-8.5%) (vs 2.0% [95% CI, 1.8-2.3%] in the CRASH-2 trial).

Conclusion: Compared to the CRASH-2 trial, adult trauma patients receiving TXA identified in our systematic review had a lower incidence of mortality at 28 or 30 days, but a higher incidence of in-hospital thrombotic events. Our findings neither support nor refute the findings of the CRASH-2 trial but suggest that incidence rates in adults with trauma in settings outside of the CRASH-2 trial may be different than those observed in the CRASH-2 trial. [West J Emerg Med.2019;20(3):443–453.]

INTRODUCTION

Hemorrhage is the primary cause of death in the first 24 hours after trauma and is responsible for 40% of all trauma-related deaths.[1,2] Tranexamic acid (TXA), an antifibrinolytic drug that blocks plasmin-mediated fibrin clot breakdown, attenuates excessive bleeding. In patients undergoing surgery, TXA has been shown to decrease blood product transfusion requirements.[3,4] The success of TXA in the surgical setting led to the CRASH-2 trial, an international, randomized controlled trial of the early administration of TXA to bleeding adult trauma patients.[5] Compared to placebo, TXA given within three hours of injury, reduced the risk of hemorrhagic death by approximately one-third with no increase in adverse events.[6]

Administering TXA is now considered standard treatment in adults with traumatic bleeding and its use has been implemented worldwide.[7] The use of TXA for injured adults has been estimated to save 112,000 lives per year worldwide.[8] Given that the CRASH-2 trial was conducted in primarily developing countries where transfusion practices and identification of adverse events may differ compared to developed countries, we sought to

estimate the incidence of mortality and thrombotic events in injured adults in the post-CRASH-2 era.[9] Our objective was to evaluate the incidence of mortality and adverse events in studies published after the CRASH-2 trial results were published.

METHODS

Search Strategy

We searched PubMed, Embase, MicroMedex, and ClinicalTrials.gov for studies that included adult trauma patients who received TXA and reported mortality and/or adverse events (Supplemental File). References of potentially eligible articles identified in the search were further screened for relevant references missed in the database search.

Inclusion and Exclusion

We included all studies that assessed mortality and/or adverse events in adult trauma patients receiving TXA. We included studies regardless of TXA dosing or clinical setting (e.g., prehospital, military, civilian) and studies that reported only mortality or adverse events. We excluded case reports and review articles, studies that were not trauma-related or that included primarily children, and studies that did not report mortality or adverse events. We also excluded studies that were secondary analyses of the CRASH-2 trial.

Study Selection

We screened studies for inclusion initially by titles, abstracts, and then full texts. Each study title and abstract was reviewed independently by two authors. When consensus could not be reached on screened titles and abstracts, a third reviewer independently adjudicated the discrepancies. Full-text discrepancies were resolved by group consensus during in-person meetings. Prior to independent author screening, we piloted the study selection procedures as a group for several studies to enhance standardization of the selection protocol. Our study selection procedure is reported for in Figure 1 according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (See Figure 1).

Data Abstraction and Quality Assessment

Two authors independently abstracted data from each of the included studies. We abstracted study characteristics that included the following: year, country, setting (e.g., civilian, military, prehospital), design, inclusion criteria, TXA dosing, and outcomes measured. We abstracted outcome measures including mortality during any time frame, thrombotic events, and other adverse events reported, as well as adverse event definitions provided by the authors of the included study. Extraction was piloted as a group on several studies. We resolved disagreements in extracted data by group discussion and by consensus of all authors.

We assessed the quality of included studies using a quality assessment instrument previously developed by the National Heart, Lung, and Blood Institute.[11] This instrument included nine points assessing the clarity of the study objective and study population, the sequence of enrollment (consecutive vs. non-consecutive), the comparability of subjects, the clarity of the study intervention and the outcome measures, the adequacy of length of follow-up, the appropriateness of statistical methods, and the clarity of reported results.

Outcome Measures

Our primary outcomes were mortality at 28 days and in-hospital thrombotic events, as these were outcomes reported in the CRASH-2 trial.[5] We identified studies that reported mortality at 30 days and thus expanded this outcome to include mortality at both 28 and 30 days. In-hospital thrombotic events for the CRASH-2 trial were defined as any vascular occlusive event including myocardial infarction, stroke, pulmonary embolism (PE) and deep vein thrombosis (DVT). We accepted any definition of an in-hospital thrombotic event as reported by the included studies. Since the majority of the studies reported total thrombotic events rather than the number of patients with thrombosis, we reported on total number of thrombotic events (i.e., if one patient had both a DVT and stroke identified, it would count as two thrombotic events). Secondary outcomes included mortality at 24 hours, in-hospital mortality, and in-hospital PE or DVT.

Analysis

Prior to pooling the data, we assessed studies for clinical heterogeneity based on study population, setting, design, intervention, and outcome assessment. All authors participated in group discussions to determine which studies should be excluded from the meta-analyses due to significant clinical heterogeneity compared to the other studies. We performed meta-analyses using the random effects model to report incidence with 95% confidence intervals (CI). Statistical heterogeneity was assessed with I^2 where a value >75% represents considerable heterogeneity.[12] Forest plots were ordered along the Y-axis by descending sample size.[13] We did not construct a funnel plot to assess for publication bias as these have been shown to be inaccurate for assessing incidence and may cross the 0 and 100% boundaries.[14] Statistical analysis was performed using Stata 14.0 (College Station, Texas).

RESULTS

Characteristics of Studies

The search strategy yielded a total of 4100 articles. After duplicates were removed and abstracts screened, we assessed 52 full-text articles for eligibility. Of these full-text articles, 33 were excluded. Reasons for exclusion can be found in the PRISMA diagram (Figure 1). Table 1 shows the characteristics of these 19 included studies. We identified 58 studies from ClinicalTrials.gov, 10 of which met our inclusion criteria; however, all were ongoing or have not yet published results.[15]

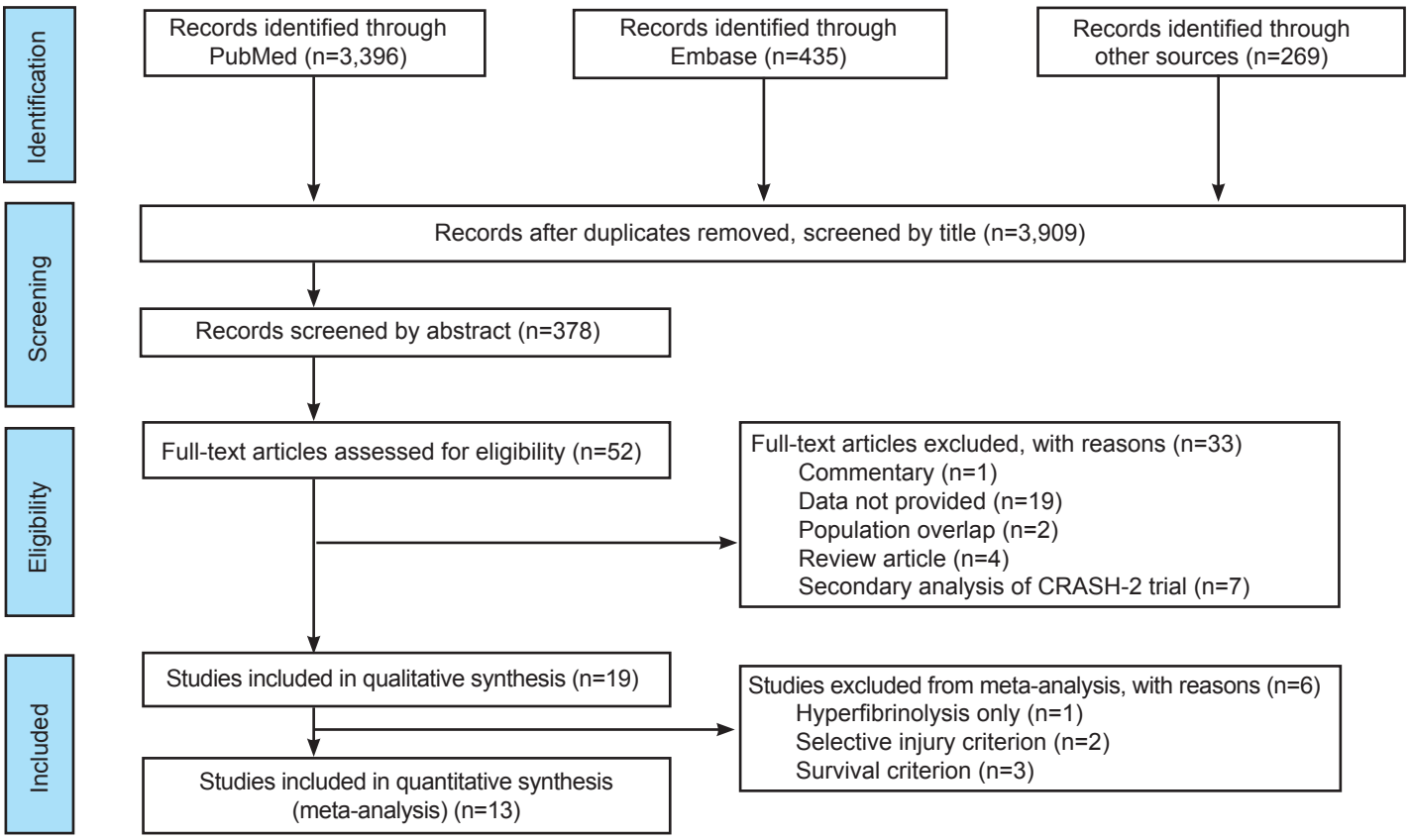


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram depicting selection of studies of articles for review.

Six studies were conducted in military hospitals[16-21] and 14 were conducted in civilian hospitals (one study included both military and civilian hospitals).[21-34] One study administered TXA in the prehospital setting.[29] There were 13 retrospective studies,[16-21,23-25,27,30,31,33] five prospective observational studies,[22,26,28,29,32] and one randomized controlled trial.[34] Ten studies[22-26,29-32,34] reported administering TXA as given in the CRASH-2 trial (1 gram [g] intravenous [IV] bolus followed by 1 g IV over eight hours); three studies[16,20,21] reported giving TXA 1 g bolus (without the maintenance dose), and six studies[17-19,27,28,33] did not report TXA dosing. Three studies[17,27,34] administered TXA within eight hours from the time of injury (as done in the CRASH-2 trial), 12 studies[16,18,21-26,29-32] administered TXA primarily within three hours from the time of injury, and four studies[19,20,28,33] did not report the timing of TXA administration.

We did not include six studies in the meta-analyses due to significant clinical heterogeneity compared to the other studies. Reasons for exclusion of these studies were as follows: only included patients with injury by firearm or explosive;[16] only included patients with hyperfibrinolysis;[24] only included combat patients who survived 24 hours after injury[27] or survived to receive treatment at a U.S. military hospital after transport from a combat hospital;[18,19] or only included patients with traumatic brain injury.[34]

Main Results

We included 13 studies[17,20-23,25,26,28-33] with 2536 adult trauma patients receiving TXA into the meta-analyses evaluating mortality at 28 or 30 days (five studies);[17,25,29,30,33] in-hospital thrombosis (nine studies);[17,21,25,26,29-33] mortality at 24 hours (four studies);[17,25,29,33] in-hospital mortality (nine studies),[20-23,26,28,31-33] and PE and/or DVT (four studies)[17,21,26,29] (Tables 1 and 2).

The pooled incidence of mortality at 28 or 30 days was 10.1% (95% CI, 7.8 to 12.4%; $I^2 = 42.7\%$) (Figure 2). This was lower than reported in the CRASH-2 trial, which had an incidence of mortality at 28 days of 14.5% (95% CI, 13.9 to 15.2%) in patients receiving TXA. The pooled incidence of in-hospital thrombotic events was 5.9% (95% CI, 3.3 to 8.5%; $I^2 = 87.6\%$) (Figure 3). This was higher than reported in the CRASH-2 trial, which had an incidence of in-hospital thrombotic events of 2.0% (95% CI, 1.8 to 2.3%). The pooled incidences of the secondary outcomes of mortality at 24 hours, in-hospital mortality, and PE and/or DVT are reported in Figures 4 to 6.

Our quality assessment suggested concerns regarding non-

Table 1. Characteristics of included studies.

Study (author, year)	Setting	Design	Patients	TXA dosing	Outcomes measured
CRASH-2 collaborators, 2010[a]	Civilian (Multinational)	RCT, May 2005 -March 2010	10,060 patients, adults with (SBP <90 mmHg or heart rate >110 bpm) or at risk of significant hemorrhage	1 g IV bolus and 1 g IV maintenance within 8 h of injury	Mortality at 28 days, vascular occlusive events, surgical intervention
Aedo-Martin et al., 2016	Military (Afghanistan)	Retrospective, March 2014-May 2014	10 patients, with injury by firearm or explosive	1 g (80%) or 2 g (20%) IV bolus within 3 h of injury	Survival 15 days after discharge, and VTE
Cole et al., 2015[b]	Civilian (UK)	Prospective, October 2010- October 2012	160 patients, >15 y with ISS >15 and admitted to the ICU	1 g IV bolus and 1 g IV maintenance within 3 h of injury	<48 h and >48 h mortality, organ failure, infection, VTE, stroke, myocardial infarction
Fernandez et al., 2012[b]	U.S. Level 1 trauma center	Retrospective, March 2011-July 2012	100 patients, received TXA for trauma	1 g IV bolus and 1 g IV maintenance within 3 h of injury	In-hospital mortality
Harvin et al., 2015	U.S. Level 1 trauma centers	Retrospective, September 2009-September 2013	98 patients, evidence of hyperfibrinolysis (LY30 ≥3%)	1 g IV bolus and 1 g IV maintenance within 3 h of injury	Mortality (in-hospital and 24 h), thrombotic complications
Howard et al., 2017[b]	Military (Afghanistan)	Retrospective, October 2010 -March 2014	849 patients, combat injured, admitted to a medical treatment facility, and received at least one unit of blood	Dose NR, <1 h from time of injury (62.3%), 1-3 h (26.5%), >3 h (10.7%)	24 h, 48 h, 30 days mortality, PE, DVT
Johnston et al., 2018	Military (Afghanistan/ Iran)	Retrospective, 2011-2015	146 patients, combat injured and treated at Walter Reed National Military Medical Center	Dose NR, ≤3 h from time of injury (95.9%), >3 h (4.1%)	Mortality, VTE
Lewis et al., 2016	Military (Afghanistan/ Iran)	Retrospective, June 2009-December 2013	335 patients, combat injured, treated at military hospital, and received blood products	Dose NR	Infection within 30 days of injury, mortality
Luehr et al., 2017[b]	U.S. Level 1 trauma center	Retrospective, 2013-2016	53 patients, survived >8.5 hours (minimum time required to receive full TXA dose), received at least a single blood product, and heart rate >120 bpm or SBP <90 mmHg	1 g IV bolus and 1 g IV maintenance within 3 h of injury	Mortality
Meizoso et al., 2018[b]	U.S. Level 1 trauma center	Prospective, August 2011-January 2015	35 patients, admitted to the ICU and had TEG completed	1 g IV bolus and 1 g IV maintenance within 3 h of injury	Acute kidney injury, acute lung injury, hyperbilirubinemia, hemodynamic instability requiring vasopressors, VTE, mortality, hospital LOS, ICU free days

TXA, tranexamic acid; *SBP,* systolic blood pressure; *bpm,* beats per minute; *RCT,* randomized controlled trial; *ICU,* intensive care unit; *LY30,* lysis time at 30 minutes (thromboelastography); *ISS,* injury severity score; *NISS,* new injury severity score; *VTE,* venous thromboembolic event; *CVC,* central venous catheter; *TBI,* traumatic brain injury; *NR,* not reported, *IV,* intravenous; *SD,* standard deviation; *PE,* pulmonary embolism; *DVT,* deep vein thrombosis; *LOS,* length of stay; *GI,* gastrointestinal; *GOS,* Glasgow Outcome Scale; *mmHg*, millimeters of mercury; *TEG*, thromboelastography; *g*, grams; *RCT*, randomized controlled trial.
[a]included as a reference; [b]included in the meta-analyses

Table 1. Continued.

Study (author, year)	Setting	Design	Patients	TXA dosing	Outcomes measured
Milligan et al., 2016	U.S. Level 2 trauma center	Retrospective, June 2013-June 2016	65 patients, received TXA for trauma and survived >24 h after injury	Dose NR, <3 h from time of injury (49.2%), >3 h (53.8%)	In-hospital mortality
Moore et al., 2017[b]	U.S. Level 1 trauma center	Prospective, 2014-2016	26 patients, >18 years, highest trauma activation, and NISS >15	Dose NR	In-hospital mortality
Morrison et al., 2013[b]	Military (Afghanistan)	Retrospective, March 2006-March 2011	406 patients, combat injured, admitted to medical treatment facility, and received at least one unit of blood	1 g IV bolus, followed by further doses at clinician's discretion	In-hospital mortality
Nadler et al., 2014[b]	Civilian and Military (Israel)	Retrospective, December 2011-August 2013	94 patients, received TXA for trauma	1 g IV bolus, <1 h (83.0%), ≥1 h (17.0%)	Mortality, thromboembolisms
Neeki et al., 2017[b]	Prehospital (U.S.)	Prospective, June 2014-March 2015	128 patients, ≥18 y with signs and symptoms of hemorrhagic shock	1 g IV bolus (prehospital) and 1 g IV maintenance within 3 h of injury	Mortality, adverse events, total blood product transfused
Shiraishi et al., 2017[b]	Civilian (Japan)	Retrospective, January 2012-December 2012	250 patients, ISS > 15	1 g IV bolus and 1 g IV maintenance within 3 h of injury	28 day mortality, cause specific mortality
Valle et al., 2014[b]	U.S. Level 1 trauma center	Retrospective, August 2009-January 2013	150 patients, underwent emergency operative intervention directly from the resuscitation area	1 g IV bolus and 1 g IV maintenance within 3 h of injury	Mortality, fluid requirements, length of stay, ICU days
Van Haren et al., 2014[b]	U.S. Level 1 trauma center	Prospective, August 2011-March 2013	27 patients, trauma ICU admission, risk assessment profile for VTE ≥10 and an indwelling CVC or arterial catheter	1 g IV bolus and 1 g IV maintenance within 3 h of admission	Mortality, VTE, LOS, ICU days
Wafaisade et al., 2016[b]	Civilian (Germany)	Retrospective, January 2012-Dec 2014	258 patients, potentially life threatening injury and treatment at a trauma center	Dose NR	Mortality, VTE, sepsis, multiorgan failure, death, LOS
Yutthakasemunt et al., 2013	Civilian (Thailand)	RCT, Oct 2008 to Aug 2009	120 patients, moderate to severe TBI	1 g IV bolus and 1 g IV maintenance within 8 h of injury, mean time from injury 6.6 h (SD 1.7 h)	Mortality, stroke, PE, DVT, GI bleed, unfavorable GOS score outcome, progressive intracranial hemorrhage, blood transfusion, neurosurgical intervention

TXA, tranexamic acid; *SBP,* systolic blood pressure; *bpm,* beats per minute; *RCT,* randomized controlled trial; *ICU,* intensive care unit; *LY30,* lysis time at 30 minutes (thromboelastography); *ISS,* injury severity score; *NISS,* new injury severity score; *VTE,* venous thromboembolic event; *CVC,* central venous catheter; *TBI,* traumatic brain injury; *NR,* not reported, *IV,* intravenous; *SD,* standard deviation; *PE,* pulmonary embolism; *DVT,* deep vein thrombosis; *LOS,* length of stay; *GI,* gastrointestinal; *GOS,* Glasgow Outcome Scale; ; *mmHg*, millimeters of mercury; *TEG*, thromboelastography; *g*, grams; *RCT*, randomized controlled trial.
[a]included as a reference; [b]included in the meta-analyses

Table 2. Reported mortality and thrombotic complications of included studies.

Study (author, year)	Mortality at 24 h, n (%)	Mortality at 28 or 30 d, n (%)	Mortality, in-hospital, n (%)	Crude thrombosis, n (%)	PE or DVT, n (%)
CRASH-2 collaborators, 2010[a]		1,463 (14.5)		204 (2.0)[c]	112 (1.1)
Aedo-Martin et al., 2016	0 (0)		0 (0)	0 (0)	0 (0)
Cole et al., 2015[b]			30 (18.8)	16 (10)[d]	
Fernandez et al., 2012[b]			42 (42)		
Harvin et al., 2015	33 (34)		39 (40)	6 (6.3)	3 (3.3)[j]
Howard et al., 2017[b]	47 (5.5)	82 (9.7)		45 (5.3)[e]	45 (5.3)
Johnston et al., 2018			1 (0.7)	50 (34.2)[f]	
Lewis et al., 2016			10 (3.0)		
Luehr et al., 2017[b]	1 (1.9)	7 (13.5)		7 (13.2)[f]	
Meizoso et al., 2018[b]			6 (17.1)	12 (34.3)[e]	12 (34.3)
Milligan et al., 2016			5 (7.7)		
Moore et al., 2017[b]			13 (50.0)		
Morrison et al., 2013[b]			57 (14.0)		
Nadler et al., 2014[b]			17 (18.1)	2 (2.4)[g]	2 (2.4)[g]
Neeki et al., 2017[b]	5 (3.9)	8 (6.3)		2 (1.6)[h]	2 (1.6)[h]
Shiraishi et al., 2017[b]		25 (10.0)		3 (1.2)[f]	
Valle et al., 2014[b]			46 (30.7)		
Van Haren et al., 2014[b]			4 (14.8)	9 (33.3)[f]	
Wafaisade et al., 2016[b]	15 (5.8)	36 (14.7)	38 (14.7)	4 (5.6)[i]	
Yutthakasemunt et al., 2013			12 (10.0)	0 (0)	0 (0)

h, hours; *d,* days; *PE,* pulmonary embolism; *DVT,* deep vein thrombosis; *MI,* myocardial infarction.
[a]included as a reference; [b]included in the meta-analyses; [c]PE, DVT, MI, or stroke; [d]VTE, MI, or stroke; [e]PE or DVT; [f]VTE only; [g]out of 83 patients; [h]DVT only; [i]out of 71 patients; [j]PE only.

consecutive patient enrollment (six studies)[18,19,26,27,31,32] and an unclear description of the intervention (six studies).[17-19,27,28,33] See Supplemental File, eTable for complete quality assessments of the studies.

DISCUSSION

Our study demonstrated some interesting findings, particularly in comparison to the CRASH-2 trial. In our study, trauma centers demonstrated a wide variation of TXA administration including dosing (bolus vs bolus + maintenance), total bolus dose (1 g vs 2 g), and timing (within three hours vs eight hours from injury). The CRASH-2 trial administered TXA as a 1 g IV bolus infusion over 10 minutes and a 1 g maintenance infusion over eight hours within eight hours from the time of injury. The varying timing of TXA adminstration noted in our study is likely a result of an exploratory analysis that demonstrated increased benefit in preventing hemorrhagic death with earlier TXA administration given within one hour.[6] The greatest benefit occurs when TXA is given within <1 hour from injury, diminished benefit if given within one to three hours from injury, and no benefit if given after three hours from injury.[6] In contrast to the CRASH-2 trial, three studies primarily administered only a bolus dose of TXA as opposed to a bolus dose with a subsequent maintenance dose.[16,20,21] This may contribute to different thrombosis and mortality rates. Current clinical trials are evaluating different TXA doses in injured patients.[15]

Compared to the CRASH-2 trial, our pooled results demonstrated a lower incidence of mortality at 28 or 30 days and a higher incidence of in-hospital thrombotic events. We do not conclude from our findings that the effectiveness and harm of TXA is different than what was demonstrated in the CRASH-2 trial, as our study included primarily observational studies. Our results instead suggest

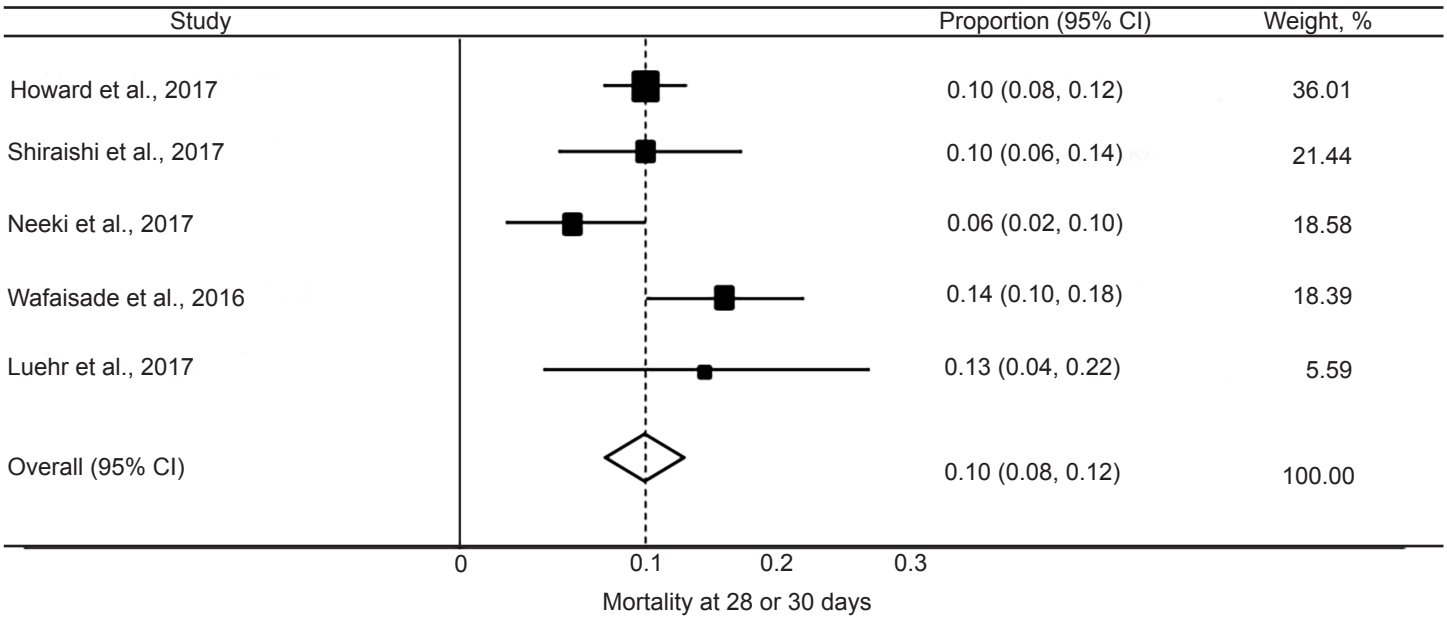


Figure 2. Forest plot of the incidence of mortality at 28 or 30 days after tranexamic acid use in injured adults.
CI, confidence interval.
Chi-square=6.98 p=.137; I^2=42.7%.

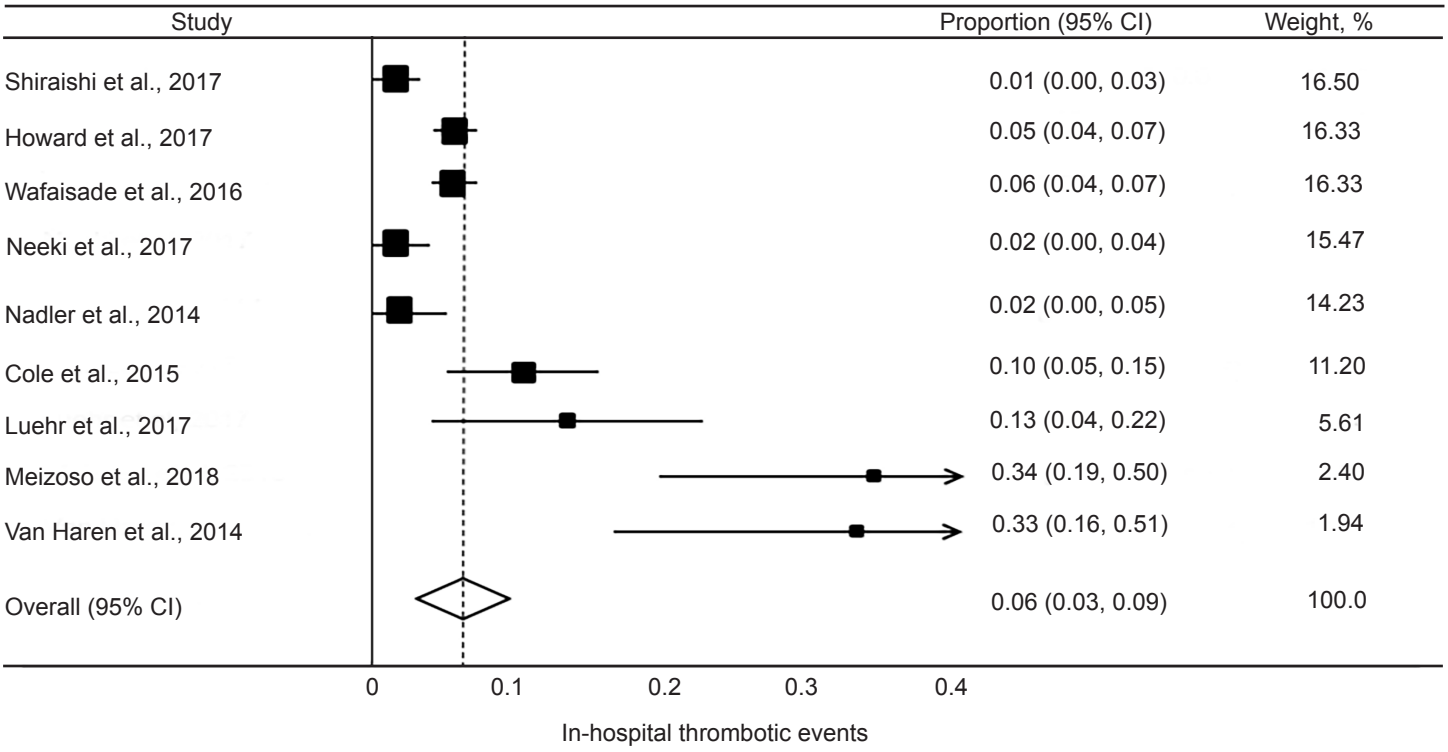


Figure 3. Forest plot of the incidence of in-hospital thrombotic events with tranexamic acid use in injured adults.
CI, confidence interval.
Chi-square=64.74 p<.0001; I^2=87.6%.

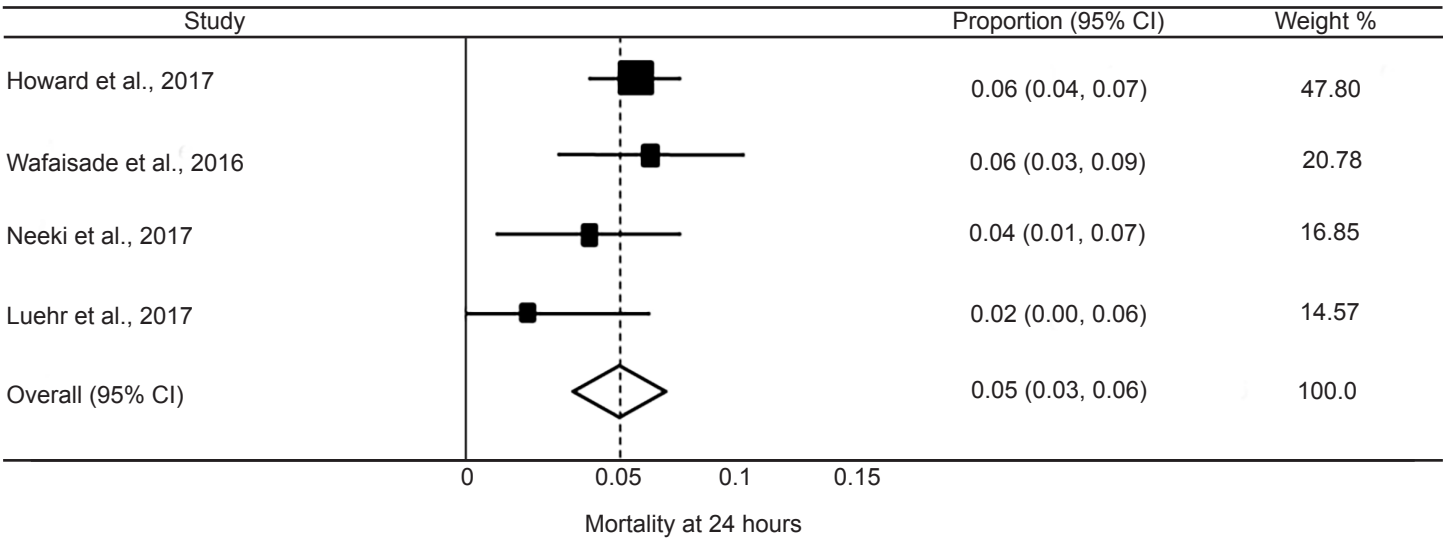


Figure 4. Forest plot of the incidence of mortality at 24 hours after tranexamic acid use in injured adults.
CI, confidence interval.
Chi-square=4.01 p=.260; I^2=25.2%.

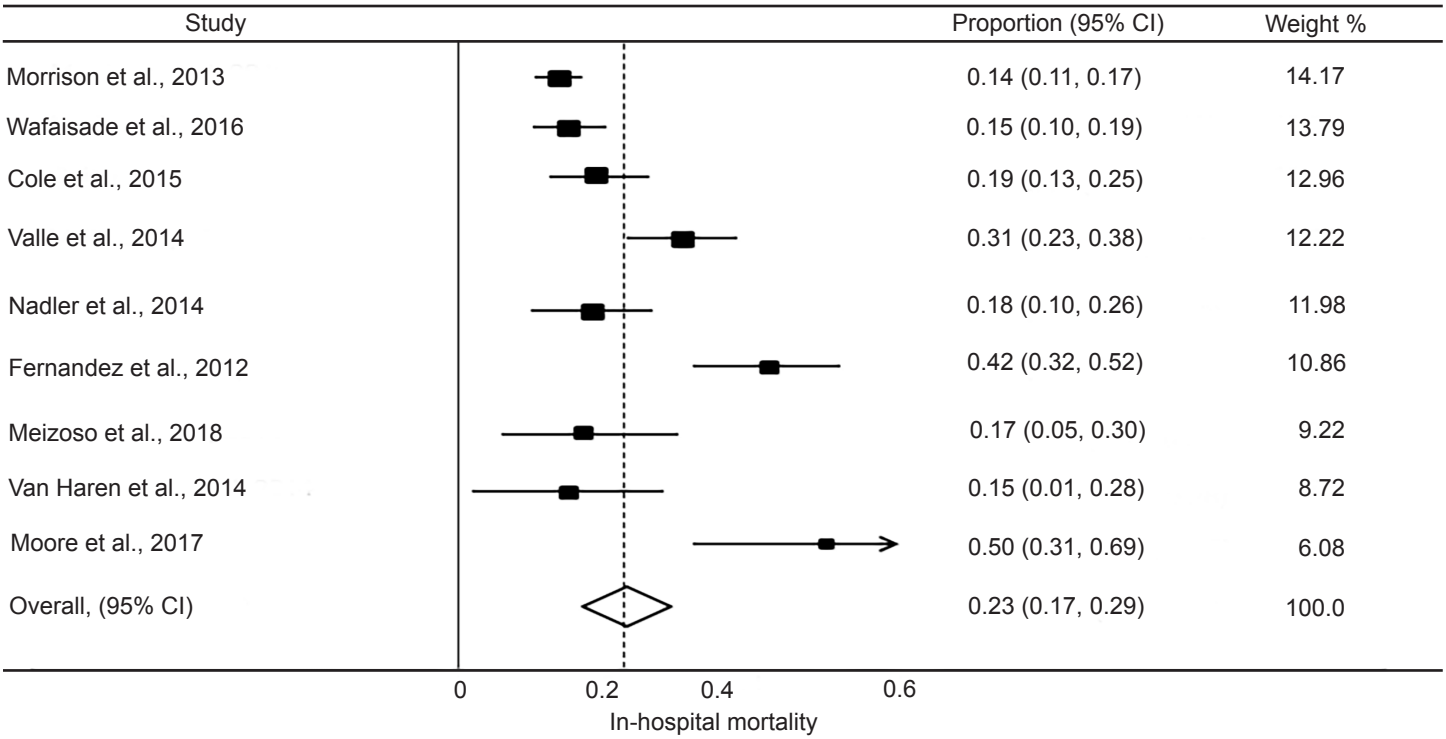


Figure 5. Forest plot of the incidence of in-hospital mortality after tranexamic acid use in injured adults.
CI, confidence interval.
Chi-square=53.35 p<.0001; I^2=85.0%.

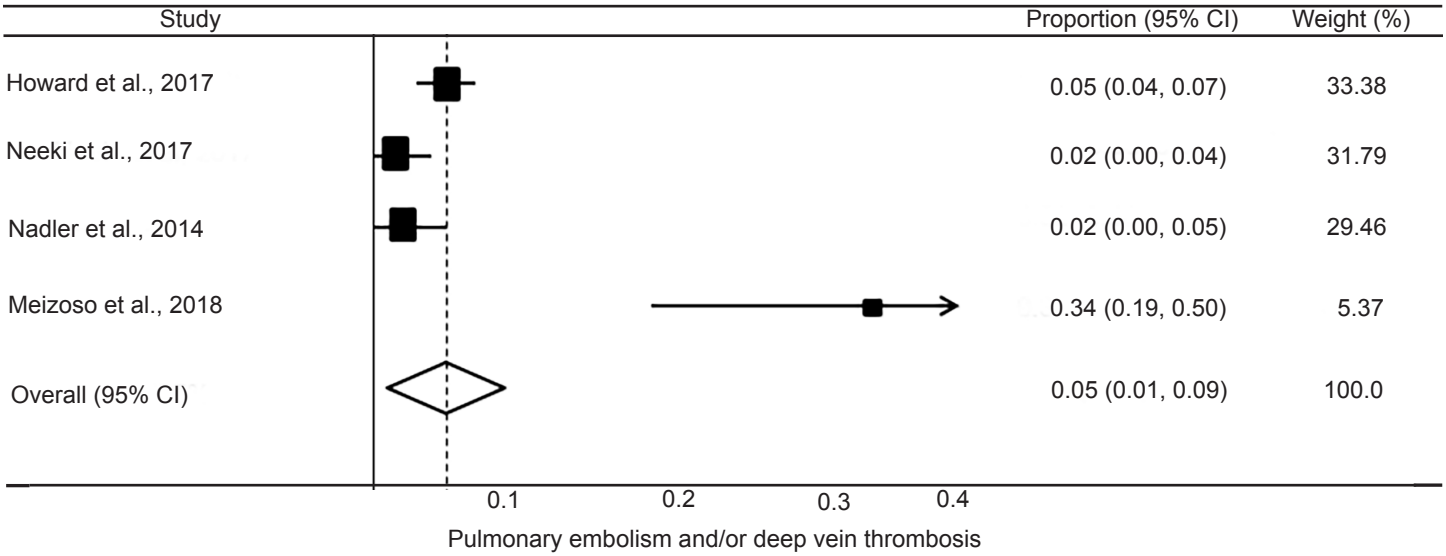


Figure 6. Forest plot of the incidence of pulmonary embolism and/or deep vein thrombosis after tranexamic acid use in injured adults. *CI,* confidence interval.
Chi-square=23.19 p<.0001; I^2=87.1%.

that the incidence rates observed in settings outside of the CRASH-2 trial might be different than what was observed in the CRASH-2 trial. This is particularly true for the incidence of thrombotic events, where our pooled results demonstrated a higher incidence of thrombotic events than what was observed in the CRASH-2 trial. The incidence rates reported in our included studies are likely biased towards under-reporting thrombotic events due to the high proportion of retrospective studies (more difficult to identify thrombotic events) and less-comprehensive definition of thrombotic event (often did not include arterial thromboses such as myocardial infarction or stroke) compared to the CRASH-2 trial.

It is unclear why there are differences in thrombotic events seen in the CRASH-2 trial and our study. It is possible that the injury severity of the two study populations is different. We were unable to compare overall patient characteristics of our included studies with those of the CRASH-2 trial. It is also possible that sites included in the CRASH-2 trial screened less for thrombotic events compared to sites included in our study. Other large trauma clinical trials enrolling similarly injured populations have also reported higher thrombotic event rates compared to the CRASH-2 trial.[35-37] Several ongoing trauma clinical trials evaluating TXA should provide additional insight into the incidence of thrombotic events in this population.[15]

Future studies evaluating TXA use in patients with hemorrhagic injuries may consider work to identify patients where the potential efficacy of TXA use is maximized and exposure to harm is minimized. Identification may be based on clinical characteristics, transport time or modality, or laboratory measurements such as thromboelastography.[38,39]

LIMITATIONS

Our results should be interpreted in the context of some limitations. First, the included studies demonstrated clinical heterogeneity, limiting the numbers of studies that could be included in the meta-analyses. Second, studies had varying definitions of in-hospital thrombosis, which may lead to differences in reported incidence rates. Third, the majority of the studies were retrospective, and this may result in less accurate data abstraction compared to prospective studies.[40] This limitation is more relevant for the thrombosis outcome measure, which may be difficult to ascertain from retrospective chart review, than for the mortality outcome measure, which is easy to ascertain regardless of study design. Fourth, the chart abstractors were not blinded to the study hypotheses. This may have led to biases during study selection and data abstraction. Finally, the incidence of thrombotic events is ideally measured with the number of patients with any thrombotic event as the numerator and the total number of patients as the denominator. However, since included studies primarily reported total number of thrombotic events, we used the total number of thrombotic events as the numerator and the total number of patients as the denominator for calculating incidence.

CONCLUSION

Compared to the CRASH-2 trial, adult trauma patients receiving TXA identified in our systematic review had a lower incidence of mortality at 28 or 30 days, but a higher incidence of in-hospital thrombotic events. Our findings neither support nor refute the findings of the CRASH-2 trial. They merely suggest that incidence rates observed in settings outside of the CRASH-2 trial may be different than those observed in the CRASH-2 trial.

ACKNOWLEDGMENTS

We would like to thank medical librarian Bruce Abbott for his expertise and assistance in database selection and search strategy creation.

Address for Correspondence: Daniel K. Nishijima, MD, MAS, University of California, Davis, Department of Emergency Medicine, 4150 V st. PSSB,2100, Sacramento, CA 95817. Email:dnishijima@ucdavis.edu.

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.

REFERENCES

1. Gruen RL, Brohi K, Schreiber M, et al. Haemorrhage control in severely injured patients. *Lancet.* 2012;380(9847):1099-108.
2. World Health Organization. World Health Statistics: Cause-specific mortality and morbidity (pp: 59-71). 2010. Available at: http://www.who.int/whosis/whostat/EN_WHS10_Full.pdf. Accessed November 13, 2018.
3. Ker K, Edwards P, Perel P, Shakur H, Roberts I. Effect of tranexamic acid on surgical bleeding: systematic review and cumulative meta-analysis. *BMJ.* 2012;344.
4. Ker K, Prieto-Merino D, Roberts I. Systematic review, meta-analysis and meta-regression of the effect of tranexamic acid on surgical blood loss. *Br J Surg.* 2013;100(10):1271-9.
5. CRASH collaborators, Shakur H, Roberts I, et al. Effects of tranexamic acid on death, vascular occlusive events, and blood transfusion in trauma patients with significant haemorrhage (CRASH-2): a randomised, placebo-controlled trial. *Lancet.* 2010;376(9734):23-32.
6. CRASH collaborators, Roberts I, Shakur H, et al. The importance of early treatment with tranexamic acid in bleeding trauma patients: an exploratory analysis of the CRASH-2 randomised controlled trial. *Lancet.* 2011;377(9771):1096-101.
7. Cochrane. The impact of Cochrane evidence on tranexamic acid for acute traumatic injury. 2016. Available at: https://www.cochrane.org/news/impact-cochrane-evidence-tranexamic-acid-acute-traumatic-injury. Accessed July 31, 2018.
8. Ker K, Kiriya J, Perel P, et al. Avoidable mortality from giving tranexamic acid to bleeding trauma patients: an estimation based on WHO mortality data, a systematic literature review and data from the CRASH-2 trial. *BMC Emerg Med.* 2012;12:3.
9. Napolitano LM, Cohen MJ, Cotton BA, et al. Tranexamic acid in trauma: how should we use it? *J Trauma Acute Care Surg.* 2013;74(6):1575-86.
10. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Medicine.* 2009;6(7):e1000097.
11. Study Quality Assessment Tools. National Heart Lung and Blood Institute. Available at: [https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools]. Accessed April 10, 2018.
12. The Cochrane Collaboration. Cochrane Handbook for Systematic Reviews of Interventions version 5.1.0: Identifying and measuring heterogeneity. 2011. Available at: http://handbook-5-1.cochrane.org/index.htm#chapter_9/9_5_2_identifying_and_measuring_heterogeneity.htm. Accessed July 23, 2018.
13. Schriger DL, Altman DG, Vetter JA, et al. Forest plots in reports of systematic reviews: a cross-sectional study reviewing current practice. *Int J Epidemiol.* 2010;39(2):421-9.
14. Hunter JP, Saratzis A, Sutton AJ, et al. In meta-analyses of proportion studies, funnel plots were found to be an inaccurate method of assessing publication bias. *J Clin Epidemiol.* 2014;67(8):897-903.
15. U.S. National Library of Medicine. Tranexamic acid| Acid. Available at: https://clinicaltrials.gov/ct2/results?cond=Trauma&term=tranexamic acid&cntry=&state=&city=&dist=. Accessed July 31, 2018
16. Aedo-Martín D, García-Cañas R, Navarro-Suay R, et al. Use of tranexamic acid in combat casualties. Experience of the Spanish medical corps. Clinical series and literature review. *Rev Esp Cir Ortop Traumatol.* 2016;60(3):200-5.
17. Howard JT, Stockinger ZT, Cap AP, et al. Military use of tranexamic acid in combat trauma: does it matter? *J Trauma Acute Care Surg.* 2017;83(4):579-88.
18. Johnston LR, Rodriguez CJ, Elster EA, et al. Evaluation of military use of tranexamic acid and associated thromboembolic events. *JAMA Surg.* 2018;153(2):169-75.
19. Lewis CJ, Li P, Stewart L, et al. Tranexamic acid in life-threatening military injury and the associated risk of infective complications. *Br J Surg.* 2016;103(4):366-73.
20. Morrison JJ, Ross JD, Dubose JJ, et al. Association of cryoprecipitate and tranexamic acid with improved survival following wartime injury:

findings from the MATTERs II Study. *JAMA Surg.* 2013;148(3):218-25.
21. Nadler R, Gendler S, Benov A, et al. Tranexamic acid at the point of injury: the Israeli combined civilian and military experience. *J Trauma Acute Care Surg.* 2014;77(3 Suppl 2):S146-50.
22. Cole E, Davenport R, Willett K, et al. Tranexamic acid use in severely injured civilian patients and the effects on outcomes: a prospective cohort study. *Ann Surg.* 2015;261(2):390-4.
23. Fernandez M, Morrison C, Pettineo G, et al. Pilot study: the use of tranexamic acid in trauma patients at a level one teaching hospital. *Crit Care Med.* 2012;40(12):53. Suppl.
24. Harvin JA, Peirce CA, Mims MM, et al. The impact of tranexamic acid on mortality in injured patients with hyperfibrinolysis. *J Trauma Acute Care Surg.* 2015;78(5):905-11.
25. Luehr E, Grone G, Pathak M, et al. Administration of tranexamic acid in trauma patients under stricter inclusion criteria increases the treatment window for stabilization from 24 to 48 hours-a retrospective review. *Int J Burn Trauma.* 2017;7(6):115-9.
26. Meizoso JP, Dudaryk R, Mulder MB, et al. Increased risk of fibrinolysis shutdown among severely injured trauma patients receiving tranexamic acid. *J Trauma Acute Care Surg.* 2018;84(3):426-32.
27. Milligan J, Dehoff K, Jurado L, et al. Effects of early versus late tranexamic acid administration in critically ill trauma patients. *Crit Care Med.* 2016;44(12):458.
28. Moore HB, Moore EE, Huebner BR, et al. Tranexamic acid is associated with increased mortality in patients with physiological fibrinolysis. *J Surg Res.* 2017;220:438-43.
29. Neeki M, Dong F, Toy J, et al. Efficacy and safety of tranexamic acid in prehospital traumatic hemorrhagic shock: outcomes of the Cal-PAT study. *West J Emerg Med.* 2017;18(4):673-83.
30. Shiraishi A, Kushimoto S, Otomo Y, et al. Effectiveness of early administration of tranexamic acid in patients with severe trauma. *Br J Surg.* 2017;104(6):710-7.
31. Valle EJ, Allen CJ, Van Haren RM, et al. Do all trauma patients benefit from tranexamic acid? *J Trauma Acute Care Surg.* 2014;76(6):1373-8.
32. Van Haren RM, Valle EJ, Thorson CM, et al. Hypercoagulability and other risk factors in trauma intensive care unit patients with venous thromboembolism. *J Trauma Acute Care Surg.* 2014;76(2):443-9.
33. Wafaisade A, Lefering R, Bouillon B, et al. Prehospital administration of tranexamic acid in trauma patients. *Crit Care.* 2016;20(1):143.
34. Yutthakasemsunt S, Kittiwatanagul W, Piyavechvirat P, et al. Tranexamic acid for patients with traumatic brain injury: a randomized, double-blinded, placebo-controlled trial. *BMC Emerg Med.* 2013;13(1):13-20.
35. Boffard KD, Riou B, Warren B, et al. Recombinant factor VIIa as adjunctive therapy for bleeding control in severely injured trauma patients: two parallel randomized, placebo-controlled, double-blind clinical trials. *J Trauma Inj Infect Crit Care.* 2005;59(1):8-18.
36. Holcomb JB, Tilley BC, Baraniuk S, et al. Transfusion of plasma, platelets, and red blood cells in a 1:1:1 vs a 1:1:2 ratio and mortality in patients with severe trauma: The PROPPR Randomized Clinical Trial. *JAMA.* 2015;313(5):471-82.
37. Wright DW, Yeatts SD, Silbergleit R, et al. Very early administration of progesterone for acute traumatic brain injury. *N Eng J Med.* 2014;371(26):2457-2466.
38. Bardes JM, Palmer A, Con J. Antifibrinolytics in a rural trauma state: assessing the opportunities. *Trauma Surg Acute Care Open.* 2017;2(1):e000107.
39. Moore EE, Moore HB, Gonzalez E, et al. Rationale for the selective administration of tranexamic acid to inhibit fibrinolysis in the severely injured patient. *Transfusion.* 2016;56 Suppl 2:S110-4.
40. Kaji AH, Schriger D, Green S. Looking through the retrospectoscope: reducing bias in emergency medicine chart review studies. *Ann Emerg Med.* 2014;64(3):292-8.

What Are We Measuring? Evaluating Physician-Specific Satisfaction Scores Between Emergency Departments

Brian Sharp, MD
Jordan Johnson, MD
Azita G. Hamedani, MD, MPH, MBA
Emilia B Hakes, MD
Brian W. Patterson, MD, MPH

University of Wisconsin School of Medicine and Public Health, BerbeeWalsh Department of Emergency Medicine, Madison, Wisconsin

Section Editor: Gary Johnson, MD
Submission history: Submitted September 24, 2018; Revision received April 1, 2019; Accepted April 3, 2019
Electronically published April 26, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.4.41040

Introduction: Most emergency departments (ED) use patient experience surveys (i.e., Press Ganey) that include specific physician assessment fields. Our ED group currently staffs two EDs – one at a large, tertiary-care hospital, and the other at a small, affiliated, community site. Both are staffed by the same physicians. The goals of this study were to determine whether Press Ganey ED satisfaction scores for emergency physicians working at two different sites were consistent between sites, and to identify factors contributing to any variation.

Methods: We conducted a retrospective study of patients seen at either ED between September 2015 and March 2016 who returned a Press Ganey satisfaction survey. We compiled a database linking the patient visit with his or her responses on a 1-5 scale to questions that included "overall rating of emergency room care" and five physician-specific questions. Operational metrics including time to room, time to physician, overall length of stay, labs received, prescriptions received, demographic data, and the attending physician were also linked. We averaged scores for physicians staffing both EDs and compared them between sites using t-tests. Multiple logistic regression was used to determine the impact of visit-specific metrics on survey scores.

Results: A total of 1,012 ED patients met the inclusion criteria (site 1=457; site 2=555). The overall rating-of-care metric was significantly lower at the tertiary-care hospital ED compared to our lower volume ED (4.30 vs 4.65). The same trend was observed when the five doctor-specific metrics were summed (22.06 vs 23.32). Factors that correlated with higher scores included arrival-to-first-attending time (p=0.013) and arrival-to-ED-departure time (p=0.038), both of which were longer at the tertiary-care hospital ED.

Conclusion: Press Ganey satisfaction scores for the same group of emergency physicians varied significantly between sites. This suggests that these scores are more dependent on site-specific factors, such as wait times, than a true representation of the quality of care provided by the physician. [West J Emerg Med. 2019;20(3)454-459.]

INTRODUCTION

Under the Affordable Care Act, increasing emphasis has been placed on delivery of healthcare that is both patient-centered and high quality with the aim of incentivizing better value and outcomes.[1,2] While an improved patient experience likely contributes to improved quality of care and outcomes, measurement of this facet of quality is difficult to accomplish.[3,4] Currently, this measurement typically involves patient survey

scores assessing both the overall experience and specific aspects of the emergency department (ED) visit, including a physician-specific section. Increasingly, payers are using these scores to modify provider reimbursement.[5]

Numerous studies conducted in the ED have demonstrated the many factors that influence patients' satisfaction with their visits. While good communication, attitude and interpersonal skills demonstrated by ED staff are associated with increased patient satisfaction scores, factors such as wait time, patient demographics and acuity, as well as crowding, also influence scores.[6-20] Some studies have even suggested that higher patient satisfaction scores are tied to more drug prescriptions and advanced imaging.[3,4,21]

Regarding physician-specific metrics, Bendesky et al. in 2016 showed that patient satisfaction scores differed for emergency physicians (EP) based on the setting in which they were practicing. Specifically, satisfaction scores were consistently lower in an ED setting when compared to an urgent care. This finding suggests that even metrics that attempt to narrowly assess the patient-provider relationship are subject to external factors.[22] Given that urgent cares have been found to be viewed favorably in terms of quality and value among patients, further study is needed to control for site-specific effects on patient satisfaction.[23]

In August 2015 our health system opened a second ED at a university-affiliated site that is staffed by the same emergency medicine faculty group. There are some operational differences between the sites, including consultant availability as well as the level of involvement of residents and advanced practice providers (APP) in care. However, most ancillary services offered are largely identical, including radiology studies (radiograph, computed tomography, ultrasound, magnetic resonance imaging) and lab services. This presents an ideal scenario to compare physician-specific Press Ganey ratings. Our objective was to evaluate consistency of physician-specific patient satisfaction scores between the two sites.

Population Health Research Capsule

What do we already know about this issue?
Physician-specific scores on patient satisfaction surveys are often used as a proxy for the quality of care delivered by emergency physicians.

What was the research question?
Do patient satisfaction scores differ for the same physicians staffing two different emergency departments?

What was the major finding of the study?
Patient satisfaction scores for the same physicians were lower at the higher volume/longer wait time site.

How does this improve population health?
Press Ganey scores, intended to measure patient satisfaction with physicians, may be more influenced by site-specific than physician-specific factors.

METHODS

This was a retrospective cohort study examining Press Ganey surveys at two different EDs. Site 1 is situated in a suburban area, has inpatient medicine services with limited subspecialty services available. It is approximately 12 miles from site 2 and has an annual ED volume of 11,221 (during the study period). Site 2 is an academic, tertiary-care hospital in an urban environment with an annual ED volume of 55,561 (during the study period). Both EDs are staffed by board-certified or board-eligible EPs. In addition to EP staffing, site 1 (smaller, suburban site) had limited APP staffing (four hours of coverage daily) during the study period, whereas site 2 (academic center) had significant resident and APP staffing with their involvement in most patients' care.

Discharged patients from both EDs received a survey (via mail or email) administered by Press Ganey Associates (South Bend, Indiana). We included in the analysis patients cared for by EPs who worked at both sites from September 2015-May 2016, a period chosen based on availability of data for analysis. Further requirements included a minimum of 10 evaluations per site per physician (which had the effect of limiting inclusion to full-time physicians with significant practice at both sites) and full survey responses. Returned surveys were linked to the encounter so that treating physician, demographics, date and time of visit, vital signs, and any tests performed could be obtained. We excluded from the analysis patients who were cared for by more than one EP within a visit.

We used patient responses to physician-specific questions. These questions included the following: overall rating of care; courtesy of the doctors who cared for you; degree to which these doctors took the time to listen to you; concern these doctors showed to keep you informed about your treatment; concern these doctors showed for your comfort while treating you; and degree to which these doctors advocated for your care. Possible ratings ranged from 1 (very poor) to 5 (very good). Additional variables were selected based on potential impact on patient experience based on prior literature; these included age, race, gender, acuity, means of arrival, time interval from arrival to rooming, time interval from arrival to leaving the ED, and whether patients received any labs or advanced imaging.[7-14,16,19,20]

We obtained data from the electronic health record (EHR), which exists in one continuous instance at both sites. Press Ganey data were linked to EHR data reports by departmental staff during the creation of the dataset. We analyzed data using

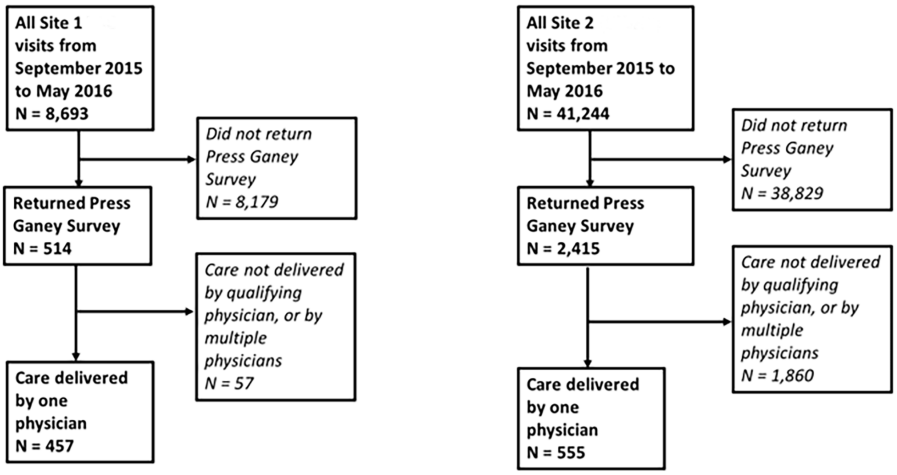
Stata 15 (Statacorp, College Station, Texas). We compared demographic and Press Ganey data using t-test for continuous data and chi^2 test for categorical data. To evaluate physician-specific metrics, we evaluated the response rate for overall rating of care as well as the sum of the five physician-specific metrics. A logistic regression model was created to evaluate the impact of site and physician on scores while controlling for covariates. Given the high proportion of returned surveys with a total score of 25 (highest rating across all scores), we dichotomized outputs into scores of 25 vs all other scores for the regression analysis. Additionally, we ranked all included physicians from highest to lowest in Press Ganey scores at both sites. Given our sample size, we expected to detect a difference in mean score of 0.18 from the mean Press Ganey scores at site 2 (the academic site) with a power level of 0.8 at an alpha of 0.05 based on a two-tailed test.

RESULTS

Characteristics of Study Subjects and Sites

After applying exclusion criteria, we included 1012 encounters in the analysis: 457 from site 1 and 555 from site 2. The Figure details patient attribution by site. Thirteen EPs met the minimum of 10 returned surveys per site and were included in the analysis. By physician, the median number of surveys returned at site 1 was 29 (range 10-82, interquartile ratio [IQR] 17-41); at site 2 the number returned was 37 (range 29-72, IQR 30-52).

Figure. Patient attribution by site.



Patient demographics were similar between sites, including age, race, gender, and mode of arrival (Table 1). Wait times differed between the two sites, with shorter arrival-to-room and arrival-to-discharge times observed at site 1. At site 1 the mean arrival-to-first attending time was 18.0 minutes (standard deviation [SD] 19.9) and the arrival-to-ED-departure time was 200.5 minutes (SD 101.0) compared to 75.8 minutes (SD 66.1) and 254.8 (126.3) respectively at site 2.

Main Results

A total of 13 EPs (48% of full-time, non-pediatric providers) met the minimum of 10 returned surveys per site and were included in the analysis. By physician, the median number of surveys returned was 29 at site 1 (range 10-82, IQR 17-41) and 37 at site 2 (range 29-72, IQR 30-52). Mean Press Ganey satisfaction scores for provider overall rating of care were higher at site 1 compared to site 2 (Table 2). The same trend was seen for the sum of the five physician-specific metrics, which included the following: courtesy of the doctors who cared for you; degree to which these doctors took the time to listen to you; concern these doctors showed to keep you informed about your treatment; concern these doctors showed for your comfort while treating you; and degree to which these doctors advocated for your care.

In the regression analysis, no individual physician was associated with a significant odds ratio for achieving or not achieving high Press Ganey scores. Being seen at site 1 and shorter arrival-to-room and arrival-to-discharge times were associated with a higher incidence of high scores. Patient-specific factors such as age, race, gender, arrival mode, and acuity were not associated with differences in scores, nor were any individual physicians associated with statistically significant increases or decreases in scores. The regression model had a c-statistic of 0.68 and a non-significant Hosmer-Lemeshow goodness of fit test at 0.278 (Table 3). When ranking physicians between sites (Table 4), we observed no discernible correlation between the two sets of rankings.

LIMITATIONS

This study was conducted within one health system and trends may differ in other organizations. Additionally,

Table 1. Respondent demographics.

	Site 1		Site 2	
Demographic Variable	Number	% (95% CI)	Number	% (95% CI)
Total responses	457		555	
Mean age (SD)	53.8 (15.7)		53.4 (17.7)	
p=0.702				
Race				
White	442	96.7 (94.6-98.0)	509	91.7 (89.1-93.7)
Other	15	3.3 (2.0-5.4)	46	8.3 (6.3-10.9)
Gender				
Male	170	37.2 (32.9-41.7)	194	34.9 (31.1-39.0)
Female	287	62.8 (58.3-67.1)	361	65.1 (61.0-68.9)
Mode of arrival				
Self/family/friends	398	87.1 (83.7-89.9)	480	86.5 (83.4-89.1)
EMS/police	59	12.9 (10.1-16.3)	75	13.5 (10.9-16.6)
Acuity				
2	76	16.6 (13.5-20.3)	130	23.4 (20.1-27.1)
3	302	66.1 (61.6-70.3)	342	61.6 (57.5-65.6)
4	76	16.6 (13.5-20.3)	81	14.6 (11.9-17.8)
5	3	0.7 (0.2-2.0)	1	0.4 (0.1-1.4)

CI; confidence interval; *SD*, standard deviation; *EMS*, emergency medical services.

Table 2. Press Ganey satisfaction scores at both sites.

	Site 1		Site 2		P value
Survey item	Mean score	95% CI	Mean score	95% CI	
Overall satisfaction with visit	4.65	4.58-4.72	4.30	4.21-4.39	<0.001
Sum of five other physician-specific scores	23.32	22.98-23.63	22.06	21.70-22.44	<0.001

CI, confidence interval.

while both sites are EDs with similar patient populations, one difference of note is that EPs who staff site 2 typically work with resident physicians and APPs, including physician assistants and nurse practitioners, which is less common at site 1. Differences in physician-specific-scores may be due to the fact that physicians at site 2 were rated along with their residents and APPs. While we would argue that this is one of the site-specific characteristics of site 2, with regard to this site it is important to note that the effect of residents or APPs overall was not directly measured and may be a major driver of the effect observed.

The study was also limited by its retrospective design. Due to the methodology of data collection (reporting from EHR records) it is possible that physicians were incorrectly matched to patient encounters in some cases, although this is unlikely as all cases with more than one assigned physician were dropped from analysis. In our setting, as has been reported in institutions elsewhere, Press Ganey survey response rates were low. While this is a common feature of Press Ganey data in general, we cannot extrapolate our results to other scenarios in which response rates were higher, in which case physician-specific ratings may be more accurate and less dependent on external factors as observed here.

DISCUSSION

This study compared physician-specific patient satisfaction scores for EPs who practice in two different EDs. We observed that Press Ganey survey scores were consistently lower for the same physicians practicing at site 2 compared to site 1. This is similar to the findings of Bendesky et al. (2016), who found that patient satisfaction scores of the same EPs differed based on the site where they were practicing.[22] Our results further support that even provider-specific patient satisfaction scores are strongly correlated with site-specific factors such as time spent

Table 3. Regression analysis of factors affecting the "overall rating of care" score.

Metric	Odds ratio	P value	95% CI
Patient age	1.018	<0.001	1.009-1.027
Race (vs. white)			
American Indian or Alaska Native	0.738	0.746	0.117-4.638
Asian	1.444	0.463	0.541-3.858
Black	0.637	0.273	0.284-1.427
Unknown	0.721	0.655	0.171-3.038
Patient gender (vs. male)			
Female	0.885	0.399	0.666-1.176
Site (vs. Site 2)			
Site 1	0.594	0.003	0.421-0.838
Acuity (vs. 2)			
3	0.880	0.471	0.623-1.245
4	0.821	0.421	0.508-1.327
5	2.301	0.474	0.236-22.467
Arrival (vs. self/ family/friends)			
EMS/police	0.736	0.137	0.491-1.103
Physician (vs. 1)			
2	0.622	0.152	0.325-1.191
3	0.705	0.282	0.372-1.334
4	0.531	0.076	0.264-1.068
5	0.775	0.513	0.362-1.661
6	0.727	0.328	0.383-1.378
7	0.975	0.938	0.510-1.864
8	0.647	0.221	0.323-1.298
9	1.717	0.191	0.764-3.856
10	1.139	0.693	0.597-2.171
11	0.583	0.096	0.309-1.101
12	0.723	0.412	0.333-1.570
13	0.843	0.635	0.417-1.705
Arrival-to-first-attending time	0.996	0.013	0.994-0.999
Arrival-to-ED-departure time	0.999	0.038	0.997-1.000

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

Table 4. Physician rankings by site based on mean of physician-specific Press ganey scores.

Rank	Site 1	Site 2
1	I	E
2	B	A
3	H	I
4	J	J
5	L	D
6	A	C
7	M	B
8	F	G
9	E	K
10	C	M
11	K	F
12	D	H
13	G	L

waiting for a room and total length of the stay. This is also consistent with prior studies that demonstrate shorter wait times are associated with increased patient satisfaction.[8-10]

While other investigators have found associations between satisfaction scores and factors such as patient age, race, acuity, and arrival mode, our analysis did not show any of these associations.[7-9, 11,19] Notably, our predominantly Caucasian patient population may imply that other ethnicities were under-represented to the extent that no difference in satisfaction could be detected. Additionally, other factors that could have impacted the physician-specific metric score difference include physician time spent with patients and the level of involvement of residents and APPs in care.

A physician's Press Ganey score is increasingly being used as a proxy for the quality of care they provide. While we feel that improved patient experience scores are a worthy goal for EPs given the multiple benefits that have been shown to correlate with an improved patient experience (compliance, decreased likelihood of malpractice lawsuits, etc),[6,7,17,24] our results further bring into question whether currently used patient- experience ratings are an accurate measurement of this. Further study is needed to control for site-specific factors to better isolate the provider-patient relationship before these ratings can be used in a meaningful way. Until then, our results suggest the need to use caution when interpreting provider-specific satisfaction scores, especially when these scores are linked to things such as financial incentives and promotion or tenure.

CONCLUSION

We found that Press Ganey scores for the same group of physicians differed between two sites. Scores were higher at the lower-volume site where wait times were shorter. These results suggest that Press Ganey scores are affected by factors outside of the physician's control. Scores should be interpreted with caution, especially when used as a proxy for the quality of care provided by the physician.

Address for Correspondence: Brian Sharp, MD, University of Wisconsin School of Medicine and Public Health, BerbeeWalsh Department of Emergency Medicine, 800 University Bay Drive, Suite 310, Mail Code 9123, Madison, WI 53705. Email: bsharp@medicine.wisc.edu.

Conflicts of Interest: By the WestJEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. This project was supported by grant number K08HS024558 from the Agency for Healthcare Research and Quality. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Agency for Healthcare Research and Quality.

REFERENCES

1. Office GP. Patient Protection and Affordable Care Act [PL 111-148] and Healthcare and Education Reconciliation Act of 2010 [PL 111-152]. 2013. Available at: https://www.gpo.gov//fdsys/pkg/PLAW-111publ148/pdf/PLAW-111publ148.pdf. Accessed May 25, 2016.
2. Services CfMaM. Special open door forum: Hospital Value-Based Purchasing proposed rule overview for facilities, providers, and suppliers. 2011. Available at: https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/HospitalQualityInits/downloads/0210_Slides.pdf. Accessed May 25, 2016.
3. Chang JT, Hays RD, Shekelle PG, et al. Patients' global ratings of their health care are not associated with the technical quality of their care. Ann Intern Med. 2006;144(9):665-72.
4. Fenton JJ, Jerant AF, Bertakis KD, et al. The cost of satisfaction: a national study of patient satisfaction, health care utilization, expenditures, and mortality. Arch Intern Med. 2012;172(5):405-11.
5. Farley H, Enguidanos ER, Coletti CM, et al. Patient satisfaction surveys and quality of care: an information paper. Ann Emerg Med. 2014;64(4):351-7.
6. Associates PG. 2011 Press Ganey Pulse Report – perspectives on American health care. 2011. Available at: http://helpandtraining.pressganey.com/Documents_secure/Pulse Reports/2011_Press_Ganey_Pulse_Report.pdf. Accessed May 26, 2016.
7. Welch SJ. Twenty years of patient satisfaction research applied to the emergency department: a qualitative review. Am J Med Qual. 2010;25(1):64-72.
8. Handel DA, French LK, Nichol J, et al. Associations between patient and emergency department operational characteristics and patient satisfaction scores in an adult population. Ann Emerg Med. 2014;64(6):604-8.
9. McCarthy ML, Ding R, Zeger SL, et al. A randomized controlled trial of the effect of service delivery information on patient satisfaction in an emergency department fast track. Acad Emerg Med. 2011;18(7):674-85.
10. Pines JM, Iyer S, Disbot M, et al. The effect of emergency department crowding on patient satisfaction for admitted patients. Acad Emerg Med. 2008;15(9):825-31.
11. Taylor C, Benger JR. Patient satisfaction in emergency medicine. Emerg Med J. 2004;21(5):528-32.
12. Soremekun OA, Takayesu JK, Bohan SJ. Framework for analyzing wait times and other factors that impact patient satisfaction in the emergency department. J Emerg Med. 2011;41(6):686-92.
13. Thompson DA, Yarnold PR, Williams DR, et al. Effects of actual waiting time, perceived waiting time, information delivery, and expressive quality on patient satisfaction in the emergency department. Ann Emerg Med. 1996;28(6):657-65.
14. Thompson DA, Yarnold PR. Relating patient satisfaction to waiting time perceptions and expectations: the disconfirmation paradigm. Acad Emerg Med. 1995;2(12):1057-62.
15. Toma G, Triner W, McNutt LA. Patient satisfaction as a function of emergency department previsit expectations. Ann Emerg Med. 2009;54(3):360-7.e366.
16. Trout A, Magnusson AR, Hedges JR. Patient satisfaction investigations and the emergency department: what does the literature say? Acad Emerg Med. 2000;7(6):695-709.
17. Sun BC, Adams JG, Burstin HR. Validating a model of patient satisfaction with emergency care. Ann Emerg Med. 2001;38(5):527-32.
18. Nerney MP, Chin MH, Jin L, et al. Factors associated with older patients' satisfaction with care in an inner-city emergency department. Ann Emerg Med. 2001;38(2):140-5.
19. Sun BC, Adams J, Orav EJ, et al. Determinants of patient satisfaction and willingness to return with emergency care. Ann Emerg Med. 2000;35(5):426-434.
20. Tekwani KL, Kerem Y, Mistry CD, et al. Emergency department crowding is associated with reduced satisfaction scores in Patients Discharged from the Emergency Department. West J Emerg Med. 2013;14(1):11-5.
21. Pham HH, Landon BE, Reschovsky JD, et al. Rapidity and modality of imaging for acute low back pain in elderly patients. Arch Intern Med. 2009;169(10):972-81.
22. Bendesky BS, Hunter K, Kirchhoff MA, et al. Same physician, different location, different patient satisfaction scores. Ann Emerg Med. 2016;68(5):531-5.
23. Qin H, Prybutok GL, et al. Quantitative comparisons of urgent care service providers. Int J Health Care Qual Assur. 2015;28(6):574-94.
24. Thomas EJ, Burstin HR, O'Neil AC, et al. Patient noncompliance with medical advice after the emergency department visit. Ann Emerg Med. 1996;27(1):49-55.

Access to Top-Cited Emergency Care Articles (Published Between 2012 and 2016) Without Subscription

Murad Al Hamzy, MBBS, MRCSI*
Dominique de Villiers†
Megan Banner, MSc†
Hein Lamprecht, MBChB, DA, PhD*
Stevan R. Bruijns, MBChB, DipPEC, MPhil, PhD†

*Stellenbosch University, Division of Emergency Medicine, Cape Town, South Africa
†University of Cape Town, Division of Emergency Medicine, Cape Town, South Africa

Section Editor: Gary Johnson, MD
Submission history: Submitted September 15, 2018; Accepted February 18, 2019
Electronically published April 16, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.2.40957

Introduction: Unrestricted access to journal publications speeds research progress, productivity, and knowledge translation, which in turn develops and promotes the efficient dissemination of content. We describe access to the 500 most-cited emergency medicine (EM) articles (published between 2012 and 2016) in terms of publisher-based access (open access or subscription), alternate access routes (self-archived or author provided), and relative cost of access.

Methods: We used the Scopus database to identify the 500 most-cited EM articles published between 2012 and 2016. Access status was collected from the journal publisher. For studies not available via open access, we searched on Google, Google Scholar, Researchgate, Academia.edu, and the Unpaywall and Open Access Button browser plugins to locate self-archived copies. We contacted corresponding authors of the remaining inaccessible studies for a copy of each of their articles. We collected article processing and access costs from the journal publishers, and then calculated relative cost differences using the World Bank purchasing power parity index for the United States (U.S.), Germany, Turkey, China, Brazil, South Africa, and Australia. This allows costs to be understood relative to the economic context of the countries from which they originated.

Results: We identified 500 articles for inclusion in the study. Of these, 167 (33%) were published in an open access format. Of the remaining 333 (67%), 204 (61%) were available elsewhere on the internet, 18 (4%) were provided by the authors, and 111 (22%) were accessible by subscription only. The mean article processing and access charges were $2,518.62 and $44.78, respectively. These costs were 2.24, 1.75, 2.28 and 1.56 times more expensive for South African, Chinese, Turkish, and Brazilian authors, respectively, than for U.S. authors ($p<0.001$ all).

Conclusion: Despite the advantage of open access publication for knowledge translation, social responsibility, and increased citation, one in five of the 500 EM articles were accessible only via subscription. Access for scientists from upper-middle income countries was significantly hampered by cost. It is important to acknowledge the value this has for authors from low- and middle-income countries. Authors should also consider the citation advantage afforded by open access publishing when deciding where to publish. [West J Emerg Med. 2019;20(3)460–465.]

INTRODUCTION

Access to key academic literature is vital for authors, scientists and clinicians, especially those working in low- and middle-income countries.[1,2] Although open access publishing has made a large contribution to improved accessibility of research, article processing costs (the cost to publish open access) can be expensive for any author.[1,3] Subscriptions and single-article access costs are also expensive, and as a result subscriptions are frequently delegated to academic libraries.[4] However, limitations in journal subscriptions available at such libraries have resulted in scientists and clinicians having to pay article access fees, find an archived copy in an online repository, or contact the author to ask for a copy of his or her work.[5] Access to published articles, and the options for publishing new work, are limited for authors, scientists and clinicians without academic library access. This problem disproportionately affects those from less developed settings,[5] and is likely to affect the local knowledge economies.[6]

Unrestricted access to research improves research progress, productivity, and knowledge translation. These in turn develop and promote the efficient dissemination of content in an ever-expanding knowledge cycle.[4] As a result, clinicians from different health institutions across the world are connected in the dissemination of new findings, and they have the information available to make the most appropriate decisions concerning patient care. Access to research literature is, therefore, an important part of disseminating emergency care information globally and locally. However, it is not known how accessible emergency care research is on a global level, nor what costs are involved. We describe access to the 500 most-cited emergency medicine (EM) articles (published between 2012 and 2016) in terms of publisher-based access (open access or subscription), alternate access routes (self-archived or author provided), and the relative cost of access (article access costs or article processing costs).

Population Health Research Capsule

What do we already know about this issue?
Access to published research is limited for those without academic library access. This disproportionately affects less developed settings.

What was the research question?
How accessible are the 500 most-cited emergency medicine articles?

What was the major finding of the study?
Around 20% of publications were not accessible. Cost of access was significantly prohibitive. This limits global dissemination of knowledge.

How does this improve population health?
Publishing open access improves dissemination of knowledge, especially for those struggling with access in less developed settings.

METHODS

This was a retrospective, cross-sectional study using secondary, published data. We searched for articles via Scopus and SciVal (both Elsevier, Amsterdam) to identify the 500 most-cited EM articles published between 2012 and 2016. Scopus is the largest abstract and citation database of peer-reviewed literature. SciVal is a powerful data engine that can be used (amongst a vast number of other functions) to interrogate the Scopus database. We used it to perform an automated keyword search for EM articles, along with citation counts and journal, author and publisher details. Articles were then ranked using their citation count to allow selection of the sample.

Each of the included articles was manually checked to identify their open access status via the publisher's websites. Where articles were not available open access from the publisher's website (subscription-based articles), we used the article title to interrogate Google, Google Scholar (https://scholar.google.co.za/), Researchgate (https://www.researchgate.net/) and Academia (https://www.academia.edu/) to determine whether an archived copy existed. Unpaywall (https://unpaywall.org/) and the Open Access Button (https://openaccessbutton.org/) browser plugins were also used for this purpose. We did not include a search of any of the shadow libraries (Libgen or Sci-Hub).[7] We accepted both published copies and archived post-prints (the post-print is the author's version of an accepted article).

For articles that were still inaccessible, the corresponding authors were contacted (using their published emails, ResearchGate or Open Access Button) and asked to provide a copy of his or her article for a university research project. Corresponding authors were given 14 days to reply and were provided with full details of the study aims if they were requested. We collected article processing and access costs from each respective journal's publisher. Publishers were contacted via email where cost information was not available on their public website.

We used the World Bank's purchasing power parity (PPP) index to calculate the relative journal article processing and access cost differences for selected countries. PPP is based on the hypothesis that similar items cost the same no matter where in the world it is purchased. For instance, a tall

Starbucks caffé latte will not just cost $2.95 in the United States (U.S.), but anywhere in the world; the only difference would be the expression of $2.95 in a foreign currency (R40.90 in South Africa). In reality, however, parity doesn't exist. The PPP index describes this deviation from parity and uses the U.S. dollars as its baseline. A tall Starbucks caffé latte in South Africa actually costs R27.00 ($1.95) and not R40.90 ($2.95). For an American tourist ordering a tall Starbucks caffé latte in South Africa, this will result in a 33% cost saving, but for a South African tourist in the U.S. this will result in a 50% cost increase. Although not directly applicable to publication cost, the PPP index offers a simplified, hypothetical comparison of the relative article processing and access cost between countries, as it does for other goods. For our analysis we included only the top publishing countries of each global publication region, as per Scopus (North America, Europe, Middle East, Asia, South America, Africa and Pacific region).[8] The top publishing country for each region were identified as the country with the largest EM publication output (number of articles) as described by SciVal. These were the U.S., Germany, Turkey, China, Brazil, South Africa, and Australia.

We employed Microsoft Excel (Redmond, Washington) for data analysis. Article accessibility was presented descriptively. The PPP index was used to calculate the factor by which publication costs differed between the included publishing countries, relative to the U.S. dollar. These were compared using a paired t-test, with significance defined as a p-value of less than 0.05. To provide an understanding of the economic burden of scientific publishing for scientists and clinicians living in middle-income countries, we calculated an equivalent local cost of article processing and access for the four middle-income countries included (South Africa, China, Turkey, and Brazil) to the U.S. cost of publishing and access, by applying the PPP index in reverse. Essentially this calculation allowed us to describe a similar out-of-pocket expense for a researcher earning in one of these four countries and the U.S.

The study protocol was reviewed and approved by both the Human Research Ethics committees of Stellenbosch University and the University of Cape Town, Cape Town, South Africa (largely due to involvement of an undergraduate researcher in the project).

RESULTS

We collected the 501 top-ranked EM articles by citation count. After excluding one article due to its retraction from circulation, we were left with 500 articles published over 29 journals. Of these journals, 22 (76%) were hybrid open access journals (i.e., publish both open access articles and paid access articles), six (21%) were open access-only journals, and one was a subscription-only journal. One journal, *Critical Care and Resuscitation*, levies no article processing cost for open access publishing. However, as a society journal, access is restricted to members of the society for the first three months following publication, after which it is made universally accessible. There were 471 (94.2%) articles with first authors from high-income countries and 25 (5%) from upper-middle income countries, with the remaining four (0.8%), split equally between articles with first authors from lower-middle and lower-income countries.

Figure 1 describes access to the top-cited 500 articles in EM. Of those articles, 111 (22%) were ultimately inaccessible without subscription. We excluded four journals from cost calculations as we were unable to locate any cost information on either the publisher's website or on enquiry from the publisher. Figure 2 provides the factor by which published costs differed between the top publishing countries from each publishing region. A higher value implies a higher relative cost. The relative cost difference between the U.S. and the top publishing countries from other publishing regions was significant ($p<0.001$) for all countries except Australia ($p=0.15$) and Germany ($p=0.27$). The table provides equitable processing and access costs for the four low- and middle-income countries included in our sample (South Africa, China, Turkey, and Brazil), if the PPP index was applied in reverse to the mean U.S. article process and access costs.

DISCUSSION

While two out of three of the top 500 cited EM articles were subscription based, only one in five were eventually found to need subscription for access. This figure broadly compares with the global open access rate, which is estimated at around

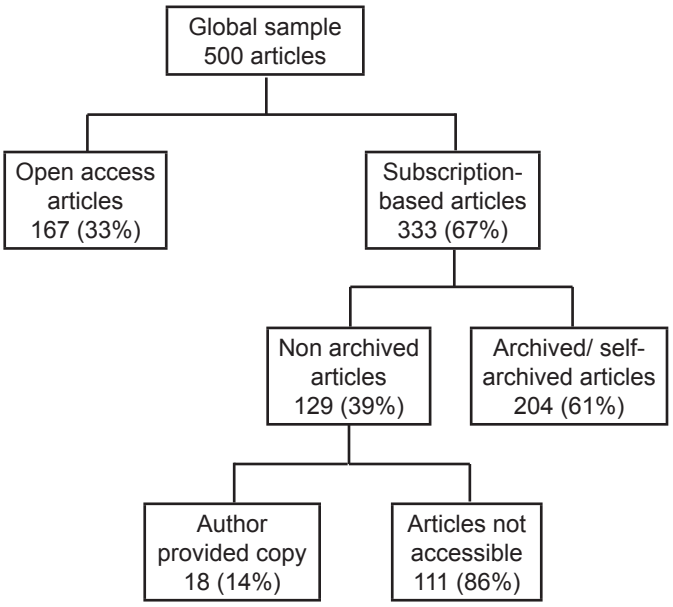


Figure 1. Flowchart describing access to the 500 most-cited emergency medicine articles between 2012-2016.

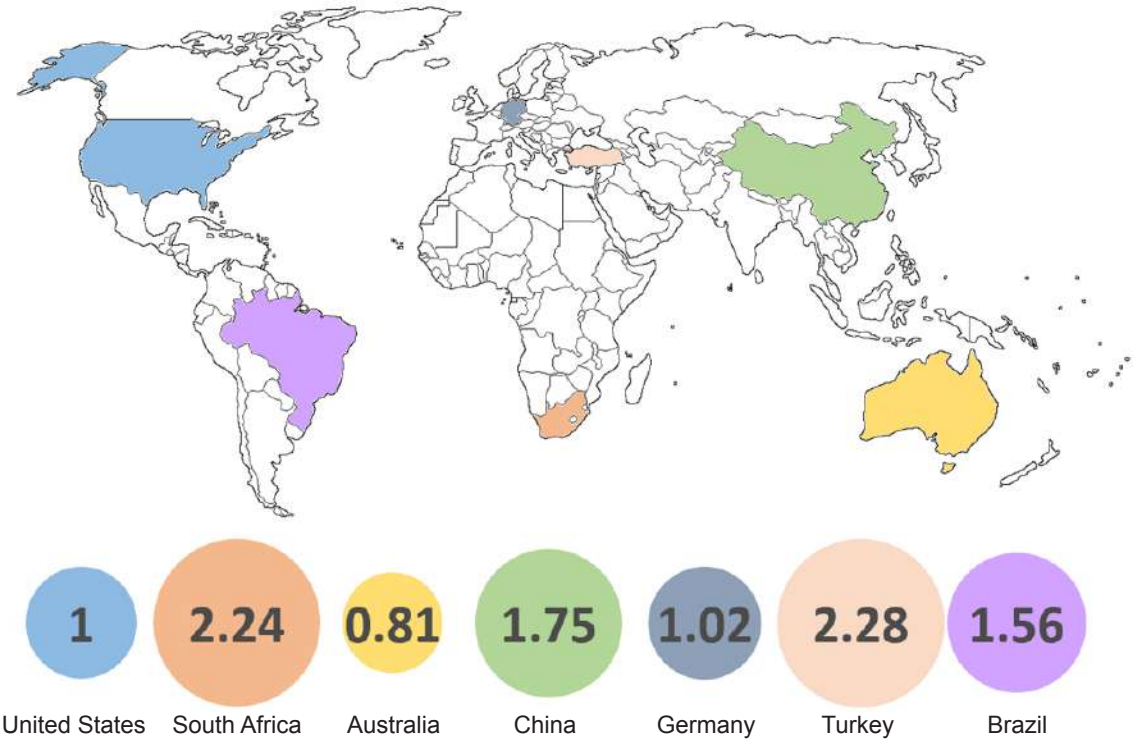


Figure 2. The factor by which publication costs differed between top publishing countries from each Scopus publishing region relative to the United States.

Table 1. Equitable processing and access costs for four low- and middle-income countries if the purchasing power parity index was applied in reverse to mean U.S. article processing and access costs.

Cost variable	Mean cost (U.S.)	South Africa	China	Turkey	Brazil
Processing	$2,518.62	$1,125.75	$1,441.30	$1,102.50	$1,613.26
Single paper access	$44.78	$20.02	$25.63	$19.60	$28.68

U.S., United States.

28% of peer-reviewed articles;[9] however, little research exists on access to EM articles. One paper describes access to African EM articles, and shows much better access than described in our study: two-thirds of articles were accessible without subscription.[1] This might be explained by the fact that authors from low- and middle-income countries can often apply for article processing cost waivers or discounts. However, authors from low-ranked institutions (which disproportionately occur in low- and middle-income countries) are less likely to publish open access despite such discounts.[3]

The cost of access to non-open access articles was significantly prohibitive for the low- and middle-income countries included in our sample. It is notable that waivers and discounts would not apply to any of these countries, as they are specifically excluded by publishers due to their *upper*-middle income status.[11] For the same reason, these countries would not have access to the Research-for-life / Hinari Programme (a World Health Organisation initiative that provides free access to research for the poorest countries).[10] It is worth noting that upper-middle income countries make up about 34% of the global population.[12] It is likely that this aspect of access contributed to the creation of the shadow library SciHub, which also originated in an upper-middle income country. (A shadow library provides access to copyrighted books and research without the permission of authors and publishers.)[7,13]

Upper-middle income countries aside, the African EM open-access study showed that the relative cost of access was much higher for low- and lower-middle income countries. Relative to the U.S., costs were 3.5 and 2.8 times more

for Ghanaian and Tanzanian authors, respectively.[1] One explanation for this is that publication costs are driven by the supply and demand generated by the larger publication volumes in high-income countries. As a result, authors from low- and middle-income countries are forced to pay high-income country rates. This is likely to affect publication volume and subsequently knowledge dissemination in low- and middle-income countries.[9]

Apart from the social responsibility, publishing open access presents authors from high-income countries with an evidence-based opportunity to improve their citation counts (which is important for promotion and grant applications). Studies have shown that publishing open access improves discovery and citation of articles, offering a significant advantage.[14]

Although applications like Unpaywall and Open Access Button make it easier to find archived publications, it is more complicated than locating an open access article directly through its publisher's website. Archiving is also dependent on publisher regulations, which often prohibit archiving for up to 12 months, and restricts which versions of an article can be archived.[3] As archiving is not an automated process, authors also have to upload their own work manually.

Author responses to publication requests were less than half of what was observed in the African open access study. As the two cohorts differed substantially we did not explore this finding further. It is possible that the philanthropic nature of African authors played a role.

LIMITATIONS

There are a number of limitations to this study. It is likely that many, or all, of these papers would be accessible through the shadow library SciHub. Publishers are clear that SciHub's business model contravenes copyright. However, research has shown that scientists are often willing to view SciHub use in less black-and-white terms.[7] Whatever the reader's opinion might be, SciHub is likely to represent a symptom of a system that many feel is unjust and in need of change. Our study only considered a snapshot of the cost of access. Specifically we only considered the top publishing countries per Scopus publication region. Countries with weaker economies will likely face a much higher local cost for publication and access. Further studies can provide clarity regarding the relative cost differences. It is important to note that the PPP index reflects a relative difference for a basket of goods that does not include publication costs. Real market value would be determined by supply and demand, which will differ between goods even within the same economy. As a specific parity index for publishing costs does not exist, we used the PPP index for our calculations.

Our study only included articles from the Scopus database. A different database might have altered the findings of the study. However, Scopus does provide the largest abstract and citation database of peer-reviewed literature (including EM) globally, which explains our choice to use it. Finally, we only included articles from EM journals, which limits the list of top papers. Many top emergency care papers are published in leading non-EM journals with different access policies. This may also have affected the findings.

CONCLUSION

In conclusion, this study showed that one in every five of the top 500 EM papers published in EM journals over a five-year period were not accessible without a subscription, and that access for scientists from low- and middle-income countries is significantly hampered by cost. It would be useful to view the uptake of open access over time to see if it is improving, as is happening in other specialties. Describing EM journals in terms of their accessibility (cost, self-archiving policies, etc.) and then linking this to journal impact might help guide authors select more accessible journals. Authors, specifically those from high-income countries, should consider the citation advantage afforded by open access publishing when deciding where to publish. It is also important to acknowledge the value this has for authors from low- and middle-income countries.

Address for Correspondence: Stevan R. Bruijns, MBChB, DipPEC, MPhil, PhD, University of Cape Town, Division of Emergency Medicine, F51-62 Old Main Building, Groote Schuur Hospital, Faculty of Health Sciences, University of Cape Town, Observatory, Cape Town, 7925, South Africa. Email: stevan.bruijns@uct.ac.za.

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.

REFERENCES

1. Bruijns SR, Maesela M, Sinha S, et al. Poor access for African researchers to African emergency care publications: a cross-sectional study. *West J Emerg Med*. 2017;18(6):1018-24.
2. van Hoving DJ, Brysiewicz P. African emergency care providers' attitudes and practices towards research. *Afr J Emerg Med*. 2017;7(1):9-14.
3. Siler K, Haustein S, Smith E, et al. Authorial and institutional stratification in open access publishing: the case of global health

research. *PeerJ*. 2018;6:e4269.
4. Tennant JP, Waldner F, Jacques DC, et al. The academic, economic and societal impacts of open access: an evidence-based review. *F1000Res.* 2016;5:632.
5. Lamanna C, Bruijns S. Measuring regional impact: the case for bigger data. *Learned Publishing.* 2018. Available at: https://doi.org/10.1002/leap.1183. Accessed July 29, 2018.
6. Jochem G. Scientists in Africa wonder if there's bias against their research. Goats And soda - stories of life in a changing world. 2018. Available at: https://www.npr.org/sections/goatsandsoda/2018/03/26/597067628/scientists-in-africa-wonder-if-theres-bias-against-their-research. Accessed July 29, 2018.
7. Bohannon J. Who's downloading pirated papers? Everyone. *Science*. 2016. Available at: http://www.sciencemag.org/news/2016/04/whos-downloading-pirated-papers-everyone. Accessed July 29, 2018.
8. The World Bank. World Development Indicators. 2018. Available at: http://databank.worldbank.org/data/reports.aspx?source=2&series=PA.NUS.PPP. Accessed July 29, 2018.
9. Piwowar H, Priem J, Larivière V, et al. The state of OA: a large-scale analysis of the prevalence and impact of open access articles. *PeerJ*. 2018;6:e4375.
10. Hinari. Hinari Eligibility. 2016. Available at: http://www.who.int/hinari/eligibility/en/. Accessed July 29, 2018.
11. Peterson T. Why APC waivers don't work globally. 2017. Available at: https://oanarchy.wordpress.com/2017/05/06/why-apc-waivers-dont-work-globally/. Accessed July 29, 2018.
12. The World Bank. World Bank Open Data. 2017. Available at: https://data.worldbank.org/. Accessed July 29, 2018.
13. The World Bank. The World Bank in Kazakhstan. 2017. Available at: https://www.worldbank.org/en/country/kazakhstan/overview. Accessed July 29, 2018.
14. Davis P. Is open access a cause or an effect? The scholarly kitchen. 2014. Available at: https://scholarlykitchen.sspnet.org/2014/08/05/is-open-access-a-cause-or-an-effect/. Accessed July 29, 2018.

Alternatives to Rapid Sequence Intubation: Contemporary Airway Management with Ketamine

Andrew H. Merelman, BS*
Michael C. Perlmutter, BA[†‡]
Reuben J. Strayer, MD[§]

*Rocky Vista University College of Osteopathic Medicine, Parker, Colorado
[†]University of Minnesota Medical School, Minneapolis, Minnesota
[‡]North Memorial Health Ambulance and AirCare, Brooklyn Center, Minnesota
[§]Maimonides Medical Center, Department of Emergency Medicine, Brooklyn, New York

Section Editor: Christopher R. Tainter, MD
Submission history: Submitted February 14, 2019; Revision received April 8, 2019; Accepted April 6, 2019
Electronically published April 26, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.4.42753

Endotracheal intubation (ETI) is a high-risk procedure commonly performed in emergency medicine, critical care, and the prehospital setting. Traditional rapid sequence intubation (RSI), the simultaneous administration of an induction agent and muscle relaxant, is more likely to harm patients who do not allow appropriate preparation and preoxygenation, have concerning airway anatomy, or severe hypoxia, acidemia, or hypotension. Ketamine, a dissociative anesthetic, can be used to facilitate two alternatives to RSI to augment airway safety in these scenarios: delayed sequence intubation – the use of ketamine to allow airway preparation and preoxygenation in the agitated patient; and ketamine-only breathing intubation, in which ketamine is used without a paralytic to facilitate ETI as the patient continues to breathe spontaneously. Ketamine may also provide hemodynamic benefits during standard RSI and is a valuable agent for post-intubation analgesia and sedation. When RSI is not an optimal airway management strategy, ketamine's unique pharmacology can be harnessed to facilitate alternative approaches that may increase patient safety. [West J Emerg Med. 2019;20(3):466-471.]

INTRODUCTION

Airway management and endotracheal intubation (ETI) are life-saving interventions frequently performed in emergency medicine (EM), critical care, and prehospital medicine. Despite its prevalence, ETI is associated with considerable patient morbidity and mortality, and is considered the riskiest commonly-performed procedure in acute care.[1,2] Rapid sequence intubation (RSI), which uses the simultaneous administration of an induction agent and paralytic, is the most common method of facilitating ETI. Traditional RSI, however, is burdened by the crucial risks of hypoxia and acidosis should ETI and assisted ventilation fail, as well as hypotension and hypoperfusion caused by the abrupt transition from negative-pressure to positive-pressure ventilation.[3]

Ketamine, a dissociative anesthetic classically used to facilitate painful procedures in non-intubated patients, has unique properties that offer patient-safety advantages over traditional RSI induction agents. These properties can be leveraged in novel ways to permit alternative pharmacologic approaches that mitigate RSI risks. Because dissociative doses of ketamine disconnect the patient from external stimuli while brainstem function remains intact, painful or distressing procedures such as ETI can be performed on the unaware, dissociated patient while cardiorespiratory tone is preserved or augmented.[4] This allows the provider to modify traditional RSI in ways that address the most important RSI risks.

Two alternatives to RSI have emerged that harness ketamine's unique pharmacology to improve airway management safety in specific clinical scenarios: delayed sequence intubation (DSI) – the use of ketamine to allow airway preparation and preoxygenation in the agitated patient; and ketamine-only breathing intubation (KOBI), which uses ketamine without a paralytic to facilitate ETI as the patient continues to breathe spontaneously. In this narrative review we discuss these techniques, neither of which at present is supported by clear evidence.

In conventional RSI, ketamine has become a preferred induction agent because of its relative hemodynamic stability (compared to propofol, midazolam, and thiopental) and long

duration of action (compared to propofol and etomidate). Additionally, ketamine provides analgesia, amnesia, and sedation in a single agent, making it well-suited for post-intubation sedation.

DISCUSSION

Ketamine to Facilitate Preoxygenation in the Uncooperative Patient: Delayed Sequence Intubation

Many patients who require intubation do not allow appropriate preparation for intubation–most importantly preoxygenation–due to agitation, which may be from hypoxia, intoxication, or a variety of other cooperation-impairing conditions. This dangerous scenario is particularly common when clinicians attempt to use face mask noninvasive ventilation (continuous positive airway pressure or bilevel positive airway pressure) for preoxygenation. Performing RSI on a hypoxemic patient significantly increases morbidity and mortality,[5-7] and an adequate period of preoxygenation is the most important strategy in prolonging the period of RSI-induced apnea during which ETI is safely completed.[8] The patient ripping off his or her face mask is often the patient most in need of optimal oxygenation techniques and the most likely to be harmed by suboptimal preparation and preoxygenation.

DSI uses a dissociative dose of ketamine to render the patient unconscious while airway, breathing, and circulatory tone are maintained so that preparation and preoxygenation can proceed to completion. The original DSI study demonstrated the technique for use in preoxygenation or for pre-intubation nasogastric tube placement in upper gastrointestinal hemorrhage.[9] DSI starts with dissociative-dose ketamine: 1-2 milligrams per kilogram (mg/kg) intravenously (IV) or 4-6 mg/kg intramuscularly. Once the patient is dissociated and unconscious, providers have achieved control of a dangerous, uncontrolled situation and can proceed with preoxygenation and other preparations such as placement of adequate vascular access, assembly of necessary equipment and personnel, and initiation of therapies targeting the patient's underlying condition. Once preparation and preoxygenation are complete, a usual paralytic dose is administered and laryngoscopy proceeds, as in RSI.

In the original case series of 62 emergency department (ED) and intensive care unit (ICU) patients, oxygen saturation improved from 90% to 99% on average with DSI, and two asthma patients improved sufficiently following ketamine administration that they no longer required intubation. More recently, a prehospital package of care including DSI, apneic oxygenation, video laryngoscopy, and proper positioning reduced adverse events when compared to patients undergoing standard RSI.[10] Additional publications have demonstrated the effectiveness of DSI when undertaken by flight paramedics[11] and suggested its utility in critically ill pediatric patients.[12,13] When ketamine is pushed IV, as a quick bolus, it may cause a brief period of apnea that is usually self-limited but is undesired and can typically be avoided by administering ketamine over 30-60 seconds, which may require dilution.[4,14] Providers should be prepared to proceed immediately with paralytic administration and laryngoscopy if dangerous hypoventilation or airway compromise occurs during the period of dissociation.

Ketamine to Facilitate ETI in the Spontaneously Breathing Patient: Ketamine-only Breathing Intubation

The use of ketamine monotherapy–without a paralytic–to facilitate intubation is an emerging technique that offers pivotal benefits over RSI in specific circumstances. Its effectiveness has been demonstrated in field and military environments but has not yet been widely adopted in EM.[15,16] Performing ETI using only induction agents has a long history in prehospital medicine and is generally referred to as medication-assisted intubation (MAI), where deep sedation is induced using a combination of fentanyl and midazolam or diazepam, followed by laryngoscopy. MAI has performed poorly when studied and is associated with failed intubation attempts, vomiting, hypoxia, hypotension, cardiac arrest, and under-sedation.[17-19] Midazolam has been shown to substantially diminish airway muscle activity.[20] Dissociative-dose ketamine, however, reliably renders the patient impervious to and amnestic of ETI (or any other painful stimuli) while airway reflexes, respiration, and blood pressure are typically maintained.[4] Ketamine-only breathing intubation (KOBI) is the use of dissociative-dose ketamine to facilitate intubation in the spontaneously breathing patient, with or without the addition of topical anesthesia. This technique has been described as ketamine-assisted intubation, ketamine-facilitated intubation, ketamine-only intubation, ketamine-supported intubation, and dissociated awake intubation.[21-23] Etomidate may also be used without a paralytic to facilitate a breathing airway technique.[18] Procedural sedation experience suggests that etomidate is more likely to cause myoclonus or muscle rigidity, however, compared to ketamine.[24,25]

Despite a growing interest in KOBI, there is a lack of published experience with the procedure; the description and recommendations herein are based on expert opinion and intended to provide a framework for safety and efficacy. KOBI allows ETI to be performed while the patient continues to breathe, in the fashion of what is often called an awake intubation; however, the term *awake* applies poorly to the unconscious, dissociated patient; strategies employed with the goal of preserving spontaneous respirations are better referred to as breathing techniques. KOBI is primarily useful in airways that are known or predicted to be anatomically difficult (e.g., anatomic factors such as obesity, limited neck mobility, or oropharyngeal tumor that may hinder the operator from visualizing the glottis or passing the endotracheal tube through the vocal cords). These patients are typically managed in elective anesthesia settings using thorough local anesthesia and flexible endoscopy (e.g., fiberoptic bronchoscopy). However, this truly awake technique requires time and patient cooperation, as well as skills and equipment that may not be available to emergency or prehospital providers. KOBI may provide a similar degree of safety to traditional awake flexible

endoscopic intubation, does not require additional time or a cooperative patient, and uses pharmacology and laryngoscopy techniques familiar to all acute care airway operators.

The second group of patients who may benefit from continuous breathing throughout airway management have signs of physiologic difficulty, insofar as they are predicted to clinically deteriorate during or immediately after intubation – in particular, patients who may not tolerate even a brief period of apnea. The most common example is patients who have a high oxygenation deficit, which is evident when oxygen saturation cannot be improved above 95% on high-flow supplemental oxygen using either a face mask, or non-invasive ventilation. These patients, who may have pneumonia, acute respiratory distress syndrome, or other forms of structural lung disease, are at high risk to dangerously desaturate immediately after breathing slows and ceases during RSI; using a breathing technique to facilitate ETI may, therefore, have important safety benefits. Because ketamine-dissociated patients are sedated they may develop reduced minute ventilation. But in patients where reduced minute ventilation is significantly advantageous compared to apnea, using a breathing technique to facilitate ETI may have important safety benefits compared to paralysis. Very hyperdynamic patients with high heart rate and blood pressure (e.g., severe alcohol withdrawal, thyroid storm) are a less-recognized group that desaturate quickly from their high oxygen extraction and may similarly benefit from a breathing technique during airway management.

Profoundly acidemic patients (e.g., diabetic ketoacidosis, toxic alcohol ingestion, lactic acidosis) have a high ventilation deficit and require very high minute ventilation. Because they are also at high risk for peri-intubation decompensation, they may benefit from allowing spontaneous respiration as an alternative to RSI-induced apnea. Serum pH is not monitored continuously as is oxygen saturation; thus, these patients are not recognized as deteriorating and instead develop "sudden" cardiac arrest during or after airway management.

Another category of patient who may benefit from KOBI is the patient with dangerous hypotension and a high perfusion deficit, whose predisposition to deteriorate during or after intubation is mitigated by an induction that has minimal impact on hemodynamics. Apnea and the transition from negative- to positive-pressure ventilation reduces venous return and, in physiologically marginal patients, may precipitate circulatory collapse.[26] Using a breathing technique during intubation followed by gentle and gradually augmented pressure support afterward may improve outcomes in critically ill patients requiring airway management.

Whether or not a breathing technique such as KOBI is used, all physiologically marginal patients should be explicitly evaluated for their potential to develop critical hypoperfusion during and after ETI; point-of-care sonography to assess cardiac contractility and volume status may have particular value in this context.[27] Patients who are judged to be a high physiologic risk should be resuscitated prior to intubation to the extent possible by maximizing therapies directed at the underlying pathophysiological insults such as crystalloid or blood, antibiotics, and vasopressor support.

Dissociated patients may have muscle rigidity, including a clenched jaw, which can typically be mitigated using small doses of a conventional sedative such as midazolam or propofol, or a sub-induction dose of etomidate; however, these adjuncts may also cause hypoventilation or apnea. Furthermore, patients intubated using any breathing technique, including KOBI, may develop vomiting, laryngospasm, and apnea,[28] for which the operator must be prepared. Compared to breathing techniques, the use of a paralytic during ETI provides the optimal view of the glottis and abolishes airway reflexes such as coughing and gagging that may hinder glottic exposure and tube placement. For these reasons, a fast-acting paralytic (rocuronium or succinylcholine) must be readily available in syringe when performing KOBI to address laryngospasm, muscle rigidity, or inadequate view due to muscle tone. Until and unless alternative methods for preventing or treating ketamine-related muscle rigidity are demonstrated, KOBI should only be undertaken if a neuromuscular blocking agent is available.

Providers may also address some of these disadvantages of intubating the spontaneously breathing patient by using a bougie or flexible endoscope, and by providing topical anesthesia to the posterior oropharynx as time, patient cooperation, and resources allow. We recommend the application of 4% lidocaine using a flexible-tipped atomization device, just ahead of the gradually advanced laryngoscope, to blunt sensation in the soft palate, periglottic tissues, and vocal cords. If glottic view is adequate but airway reflexes or vocal cord movement prevent successful tube or bougie placement, administration of a paralytic as laryngoscopy is maintained is an appropriate breathing technique modification, especially when the initial concern was anatomic difficulty.

The relative benefits and risks of RSI vs a breathing technique should be considered for every intubation procedure: the more features of an anatomically or physiologically difficult airway, the more time available, and the lower the risk of vomiting, the greater the potential benefit of using a breathing technique. Appropriate preparation for any emergency airway procedure includes material readiness with all relevant airway equipment at the bedside including a paralytic agent drawn up in a syringe, as well as cognitive readiness through formulating and verbalizing a comprehensive airway management plan prior to commencing the procedure.

Ketamine in Traditional Rapid Sequence Intubation

In standard RSI, when apnea caused by the induction agent is not a concern (as apnea is intentionally caused by the paralytic agent), ketamine has advantages over other agents: primarily its positive or neutral hemodynamic effect in most patients.[29] Peri-intubation hypotension correlates with mortality,[5,6,30] and ketamine is therefore favored in hemodynamically compromised patients. As a weak sympathomimetic, ketamine is more likely to maintain tissue perfusion during and after RSI, compared to

fentanyl, midazolam, thiopental, and especially propofol.[29,31-33] In patients with a high shock index, ketamine has been demonstrated to maintain blood pressure[34] and is associated with post-intubation hypotension less frequently than other induction agents.[35,36] However, ketamine, like any sedative, can cause or worsen hypotension in catecholamine-depleted patients in shock.[37] Patients with high perfusion deficits who require ETI are therefore ideally resuscitated prior to intubation, and the induction dose of ketamine – like all induction agents – should be reduced by at least half (from 1-2 mg/kg to 0.5-1 mg/kg IV) in these cases.[38] Profoundly hypoperfused or obtunded patients should receive even smaller doses, and the peri-arrest comatose patient may be more likely to be harmed than helped by even a small dose of an induction agent and may be reasonably intubated with a paralytic only. Ketamine should be dosed based on ideal body weight, as estimated by patient height, not actual body weight.[39]

Ketamine's long duration of action, compared to etomidate, and especially propofol, is an important advantage in EM and prehospital medicine, as post-intubation sedation is often delayed in these environments.[40,41] Ketamine is also thought to have intrinsic action as a bronchodilator and is the preferred induction agent for patients being intubated for obstructive lung disease.[42]

Ketamine for Post-Intubation Analgesia and Sedation

Patients intubated in the ED or prehospital may receive suboptimal post-intubation analgesia and sedation,[43-45] especially those who received long-acting paralytic agents and therefore do not show signs of distress. Acute care providers may find it technically difficult to administer and titrate both analgesic and sedative drips and may be reluctant to use conventional agents in hemodynamically tenuous patients. Ketamine is safe and effective for post-intubation analgosedation[46-48] and has two primary benefits over alternatives: ketamine is catecholaminergic and therefore stimulating to heart rate and blood pressure, and ketamine has both analgesic and sedative properties, which allow ketamine to be used as monotherapy in the intubated patient. Use of ketamine in mechanically ventilated patients also allows dose reductions of conventional sedatives,[49] which have been linked to prolonged ICU length of stay and delirium.[50]

Although experience is limited, ketamine seems best suited to provide analgosedation in the period immediately after intubation, when the goal is deep unconsciousness during the resuscitative phase of critical illness. During this period, ketamine may be used in dissociative doses, using a 1-2 mg/kg bolus (if ketamine was not used as the induction agent during ETI), followed by a drip rate of 1-5 mg/kg per hour, titrated to effect. Patients given subdissociative doses of ketamine are conscious and often experience psychoperceptual effects that may cause psychiatric distress; it is therefore more challenging to use ketamine as a post-intubation analgosedative when the patient has stabilized, and lighter planes of anesthesia are desired. If ketamine is used in subdissociative doses, psychiatric distress is effectively managed with conventional sedatives such as benzodiazepines, propofol, or butyrophenone neuroleptics, if needed. Particularly advantageous to chaotic emergency and prehospital environments, ketamine may be used in dissociative bolus dosing to immediately effect patient stillness and unawareness, as drips are being set up or titrated.

CONCLUSION

The introduction of paralytics and RSI into airway management performed outside the operating room was an important advance in patient safety and in the development of prehospital and emergency medicine. Since then, the rise of video laryngoscopy has diminished the advantage of paralysis in improving the view of the glottis, and the expanded use of ketamine has revealed that dissociated patients tolerate laryngoscopy as the patient continues to breathe spontaneously. Contemporary airway operators have learned to harness the advantages of video laryngoscopy and ketamine's unique properties to develop RSI alternatives that offer safety benefits during airway management for patients who do not allow optimal preparation or are especially likely to be harmed using a paralytic (See Figure). These strategies currently have a limited base of experience and evidence, and as with any airway management technique should be executed with planning, deliberation, and caution.

Address for Correspondence: Andrew H. Merelman, Rocky Vista University College of Osteopathic Medicine, 8401 South Chambers Road, Parker, Colorado 80134. Email: Andrew.merelman@rvu.edu.

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.

REFERENCES

1. Cook TM, MacDougall-Davis SR. Complications and failure of airway management. *Br J Anaesth*. 2012;109 Suppl 1:i68-i85.
2. Ko BS, Ahn R, Ryoo SM, et al. Prevalence and outcomes of endotracheal intubation–related cardiac arrest in the ED. *Am J Emerg Med*. 2015;33(11):1642-5.
3. Mort TC. Complications of emergency tracheal intubation: hemodynamic alterations - part I. *J Intensive Care Med*. 2007;22(3):157-65.
4. Tobias JD, Leder M. Procedural sedation: a review of sedative agents, monitoring, and management of complications. *Saudi J Anaesth*.

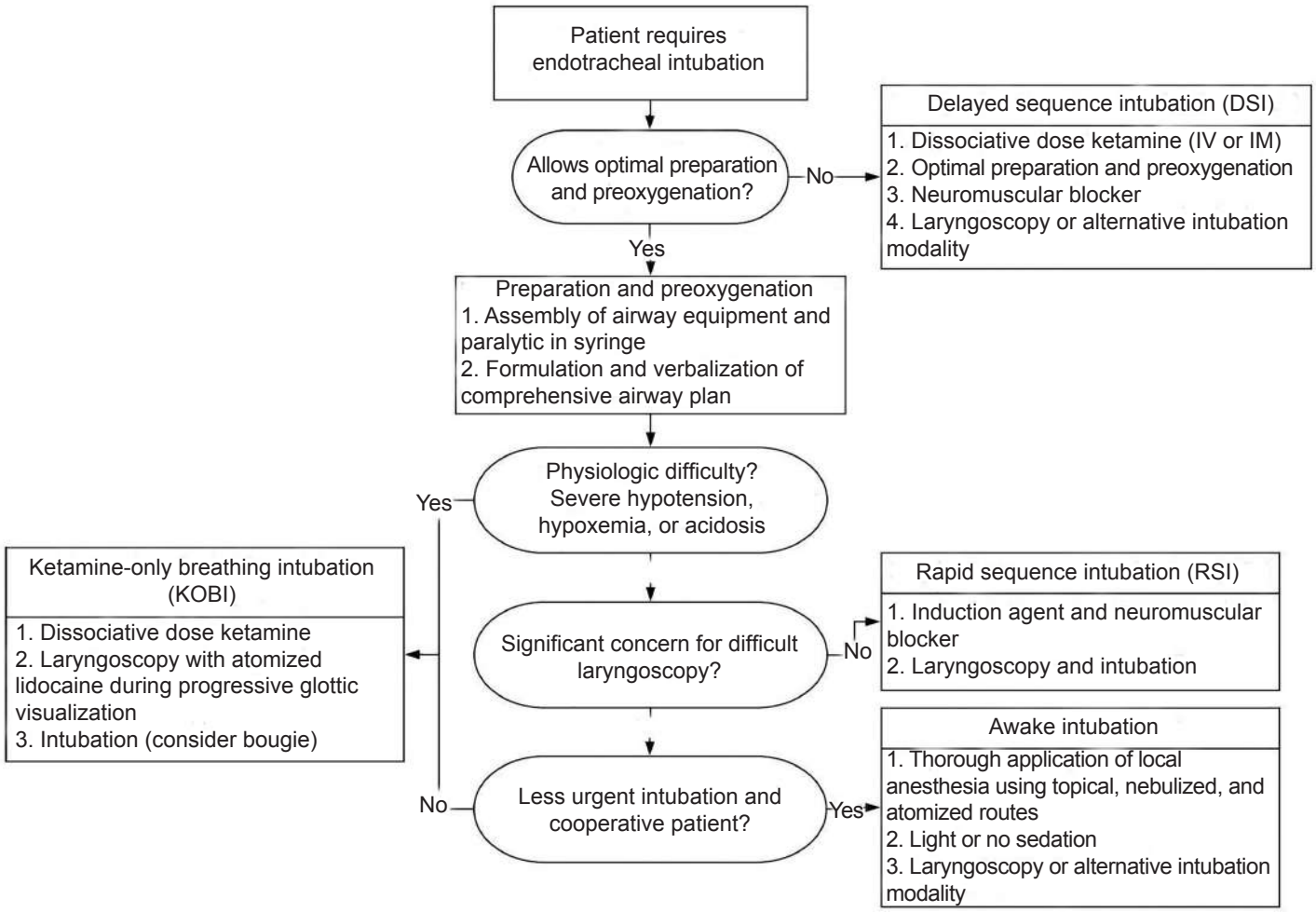


Figure. Algorithm providing general guidance for determining which is the most appropriate technique for urgent or emergent endotracheal intubation.
IV, intravenous; *IM*, intramuscular.

2011;5(4):395-410.

5. Heffner AC, Swords DS, Neale MN, et al. Incidence and factors associated with cardiac arrest complicating emergency airway management. *Resuscitation*. 2013;84(11):1500-4.
6. De Jong A, Rolle A, Molinari N, et al. Cardiac arrest and mortality related to intubation procedure in critically ill adult patients. *Crit Care Med*. 2018;46(4):532-9.
7. Mort TC. The incidence and risk factors for cardiac arrest during emergency tracheal intubation: a justification for incorporating the ASA Guidelines in the remote location. *J Clin Anesth*. 2004;16(7):508-16.
8. Weingart SD, Levitan RM. Preoxygenation and prevention of desaturation during emergency airway management. *Ann Emerg Med*. 2012;59(3):165-75.e1.
9. Weingart SD, Trueger NS, Wong N, et al. Delayed sequence intubation: a prospective observational study. *Ann Emerg Med*. 2015;65(4):349-55.
10. Jarvis JL, Gonzales J, Johns D, et al. Implementation of a clinical bundle to reduce out-of-pospital peri-intubation hypoxia. *Ann Emerg Med*. 2018;72(3):272-279.e1.
11. Waack J, Shepherd M, Andrew E, et al. Delayed sequence intubation by intensive care flight paramedics in Victoria, Australia. *Prehosp Emerg Care*. 2018;22(5):588-94.
12. Löllgen RM, Webster P, Lei E, et al. Delayed sequence intubation for management of respiratory failure in a 6-year-old child in a paediatric emergency department. *Emerg Med Australas*. 2014;26(3):308-9.
13. Schneider ED, Weingart SD. A case of delayed sequence intubation in a pediatric patient with respiratory syncytial virus. *Ann Emerg Med*. 2013;62(3):278-9.
14. Gao M, Rejaei D, Liu H. Ketamine use in current clinical practice. *Acta Pharmacol Sin*. 2016;37(7):865-72.
15. Gofrit ON, Leibovici D, Shemer J, et al. Ketamine in the field: the use of ketamine for induction of anaesthesia before intubation in injured patients in the field. *Injury*. 1997;28(1):41-3.
16. Svenson JE, Abernathy MK. Ketamine for prehospital use: new look at an old drug. *Am J Emerg Med*. 2007;25(8):977-80.
17. Wang HE, O'Connor RE, Megargel RE, et al. The utilization of

midazolam as a pharmacologic adjunct to endotracheal intubation by paramedics. *Prehosp Emerg Care*. 2000;4(1):14-8.
18. Reed DB, Snyder G, Hogue TD. Regional EMS experience with etomidate for facilitated intubation. *Prehosp Emerg Care*. 2002;6(1):50-3.
19. Roantree RAG, Goldstein S. (2018). *EMS, Facilitated Intubation Without Paralytics*. Treasure Island, Florida: StatPearls Publishing.
20. Drummond GB. Comparison of sedation with midazolam and ketamine: effects on airway muscle activity. *Br J Anaesth*. 1996;76(5):663-7.
21. Strayer R. When RSI isn't the right SI. *Emergency Medicine Updates*. 2014. Available at: https://emupdates.com/when-rsi-isnt-the-right-si/. Accessed on August 15, 2018.
22. Weingart S, DuCanto J. Podcast 73 – Airway tips and tricks with Jim DuCanto, MD. *EMCrit RACC Pod*. 2012. Available at: https://emcrit.org/emcrit/james-ducanto-airway-tips/. Date Accessed: August 15, 2018.
23. Braude D, Palomo O, Beamsley A. Sedation only intubation. EM:RAP. 2013. Available at: https://www.emrap.org/episode/november2013/sedationonly. Accessed on August 15, 2018.
24. Salen P, Grossman M, Grossman M, et al. A comparison of ketamine versus etomidate for procedural sedation for the reduction of large joint dislocations. *Int J Crit Illn Inj Sci*. 2016;6(2):79-84.
25. Falk J, Zed PJ. Etomidate for procedural sedation in the emergency department. *Ann Pharmacother*. 2004;38(7-8):1272-7.
26. Soni N, Williams P. Positive pressure ventilation: What is the real cost? *Br J Anaesth*. 2008;101(4):446-57.
27. Natt BS, Malo J, Hypes CD, et al. Strategies to improve first attempt success at intubation in critically ill patients. *Br J Anaesth*. 2016;117 Suppl 1:i60-8.
28. Driver BE, Reardon RF. Apnea after low-dose ketamine sedation during attempted delayed sequence intubation. *Ann Emerg Med*. 2017;69(1):34-5.
29. Morris C, Perris A, Klein J, et al. Anaesthesia in haemodynamically compromised emergency patients: Does ketamine represent the best choice of induction agent? *Anaesthesia*. 2009;64(5):532-9.
30. Heffner AC, Swords D, Kline JA, et al. The frequency and significance of postintubation hypotension during emergency airway management. *J Crit Care*. 2012;27(4):417.e9-13.
31. Sivilotti ML, Ducharme J. Randomized, double-blind study on sedatives and hemodynamics during rapid-sequence intubation in the emergency department: the SHRED study. *Ann Emerg Med*. 1998;31(3):313-24.
32. White PF. Comparative evaluation of intravenous agents for rapid sequence induction--thiopental, ketamine, and midazolam. *Anesthesiology*. 1982;57(4):279-84.
33. Reich DL, Hossain S, Krol M, et al. Predictors of hypotension after induction of general anesthesia. *Anesth Analg*. 2005;101(3):622-8.
34. Miller M, Kruit N, Heldreich C, et al. Hemodynamic response after rapid sequence induction with ketamine in out-of-hospital patients at risk of shock as defined by the shock index. *Ann Emerg Med*. 2016;68(2):181-8.e2.
35. Zuin M, Rigatelli G, Dell'Avvocata F, et al. Ketamine and midazolam differently impact post-intubation hemodynamic profile when used as induction agents during emergency airway management in hemodynamically stable patients with ST elevation myocardial infarction. *Heart Vessels*. 2018;33(3):213-25.
36. Van Berkel MA, Exline MC, Cape KM, et al. Increased incidence of clinical hypotension with etomidate compared to ketamine for intubation in septic patients: A propensity matched analysis. *J Crit Care*. 2017;38:209-14.
37. Stollings JL, Diedrich DA, Oyen LJ, et al. Rapid-sequence intubation: a review of the process and considerations when choosing medications. *Ann Pharmacother*. 2014;48(1):62-76.
38. Leeuwenburg T. Airway management of the critically ill patient: modifications of traditional rapid sequence induction and intubation. *Crit Care Horizons*. 2015;1:1-10.
39. Brunette DD. Resuscitation of the morbidly obese patient. *Am J Emerg Med*. 2004;22(1):40-7.
40. Jacknin G, Overbeck MC. Succinylcholine in ED patients with unanticipated hyperkalemia: the authors respond. *Am J Emerg Med*. 2016;34(8):1706-7.
41. Robey-Gavin E, Abuakar L. Impact of clinical pharmacists on initiation of postintubation analgesia in the emergency department. *J Emerg Med*. 2016;50(2):308-14.
42. Goyal S, Agrawal A. Ketamine in status asthmaticus: a review. *Indian J Crit Care Med*. 2013;17(3):154-61.
43. Weingart GS, Carlson JN, Callaway CW, et al. Estimates of sedation in patients undergoing endotracheal intubation in US EDs. *Am J Emerg Med*. 2013;31(1):222-6.
44. Jaffrelot M, Jendrin J, Floch Y, et al. Prevention of awakening signs after rapid-sequence intubation: a randomized study. *Am J Emerg Med*. 2007;25(5):529-34.
45. Bonomo JB, Butler AS, Lindsell CJ, et al. Inadequate provision of postintubation anxiolysis and analgesia in the ED. *Am J Emerg Med*. 2008;26(4):469-72.
46. Umunna BP, Tekwani K, Barounis D, et al. Ketamine for continuous sedation of mechanically ventilated patients. *J Emerg Trauma Shock*. 2015;8(1):11-5.
47. Benken ST, Goncharenko A. The future of intensive care unit sedation: a report of continuous infusion ketamine as an alternative sedative agent. *J Pharm Pract*. 2017;30(5):576-81.
48. Radosevich J, Tafoya C, Patanwala A. Effect of ketamine on vasopressor use and hemodynamic parameters in critically ill patients. *Crit Care Med*. 2016;44(12) Supplement 1:304.
49. Groetzinger LM, Rivosecchi RM, Bain W, et al. Ketamine infusion for adjunct sedation in mechanically ventilated adults. *Pharmacotherapy*. 2018;38(2):181-8.
50. Devabhakthuni S, Armahizer MJ, Dasta JF, et al. Analgosedation: a paradigm shift in intensive care unit sedation practice. *Ann Pharmacother*. 2012;46(4):530-40.

A Geospatial Analysis of Freestanding and Hospital Emergency Department Accessibility via Public Transit

Lucas C. Carlson, MD, MPH*†
Olesya N. Baker, PhD*
Jeremiah D. Schuur, MD, MHS*‡

*Brigham and Women's Hospital, Department of Emergency Medicine, Boston, Massachusetts
†Harvard Medical School, Department of Emergency Medicine, Boston, Massachusetts
‡Brown University, Alpert Medical School, Department of Emergency Medicine, Providence, Rhode Island

Section Editor: Shira A. Schlesinger, MD, MPH
Submission history: Submitted October 24, 2018; Revision received February 4, 2019; Accepted March 10, 2019
Electronically published April 16, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.3.41385

Introduction: Emergency departments (ED) are an important source of care for underserved populations and represent a significant part of the social safety net. In order to explore the effect of freestanding emergency departments (FSED) on access to care for urban underserved populations, we performed a geospatial analysis comparing the proximity of FSEDs and hospital EDs to public transit lines in three United States (U.S.) metropolitan areas: Houston, Denver, and Cleveland.

Methods: We used publicly available U.S. Census data, public transportation maps obtained from regional transit authorities, and geocoded FSED and hospital ED locations. Euclidean distance from each FSED and hospital ED to the nearest public transit line was calculated in ArcGIS. We calculated the odds ratio (OR) of an FSED, relative to a hospital ED, being located within 0.5 miles (mi) of a public transit line using logistic regression, adjusting for population density and median household income and with error clustered at the metropolitan statistical area (MSA) level.

Results: The median distance from FSEDs to public transit lines was significantly greater than from hospital EDs across all three markets. In Houston, Denver, and Cleveland, the median distance between FSEDs and public transit lines was greater than from hospital EDs by 1.0 mi, 0.2 mi, and 1.6 mi, respectively. The OR of a public transit line being located within 0.5 mi of an FSED, as compared with a hospital ED, across all three MSAs was 0.21 (95% confidence interval [CI], 0.13–0.34) unadjusted and 0.20 (95% CI, 0.11–0.40) adjusted for population density and median household income.

Conclusion: In comparison with hospital EDs, FSEDs are located farther from public transit lines and are less likely to be within walking distance of public transportation. These findings suggest that FSEDs are unlikely to directly increase access to care for patients without private means of transportation. Further research is necessary to explore both the direct and indirect impact of FSEDs on access to care, potentially through effects on hospital ED crowding and overall healthcare expenditures, as well as the ultimate role and responsibility of FSEDs in improving access to care for underserved populations. [West J Emerg Med. 2019;20(3)472-476.]

INTRODUCTION

Since 2009 the number of freestanding emergency departments (FSED) in the United States (U.S.) has increased more than fourfold,[1] with over 400 facilities currently operating across the country. This growth has taken place primarily in large urban areas, especially in Texas, Colorado, and Ohio.[2]

Recently, policymakers have begun to question the impact of FSEDs on access to care for underserved populations.[3] Although FSEDs have the potential to meet the growing demand for acute unscheduled care,[3] prior studies have demonstrated that FSEDs are preferentially located in socioeconomically advantaged areas,[2] and so it is unclear whether expansion of FSEDs will improve access to care for the underserved.

While 15% of patients use ambulances and emergency medical services to access emergency care, an overwhelming majority of patients rely on independent means of transportation to reach the ED.[4] For low-income populations in urban areas who often rely solely on public transportation,[5] location of healthcare services in close proximity to public transportation is an important factor in access. To assess the potential effect of the growth of FSEDs on access to care for urban, underserved populations, we performed a geospatial analysis comparing the proximity of public bus, light rail, and metro lines to FSEDs and hospital EDs in three metropolitan areas across the U.S.

METHODS

Data Sources

We collected data for this analysis from multiple sources and combined them using the geographic information system (GIS) software package, ArcMap 10.1 (Environmental Systems Research Institute, Redlands, California). We obtained hospital ED addresses from the 2013 American Hospital Association database and FSED addresses from state departments of health as well as through a comprehensive systematic online search of "freestanding" or "satellite" EDs, as described elsewhere.[2] We geocoded hospital ED and FSED addresses using the U.S. Census Geocoder.[6] Addresses that could not be geocoded through this system were manually geocoded using Google Maps (Google Maps, Mountain View, California). We obtained values for population density and median household income for each census tract from 2010 U.S. Census data.[6]

We selected Houston, Denver, and Cleveland for inclusion in our analysis, as they had a high density of FSEDs as well as publicly available transit geodata. We defined the total study area for each city using metropolitan statistical areas (MSA), which are used by the U.S. Census Bureau to demarcate greater metropolitan areas for statistical purposes (Houston-The Woodlands-Sugar Land; Denver-Aurora-Lakewood; and Cleveland-Akron-Canton).[6] We contacted regional transit authorities in each metropolitan area and the surrounding regions to obtain the most current available public transit route data. We chose route line data for this analysis over bus and metro stop point data because up-to-date stop data were not available across all three MSAs and the use of line data avoided any potential confounding from stop density along a single route.

Data Analysis

Maps were projected in the respective state plane coordinate systems for each MSA. Using these maps, we calculated the shortest Euclidean distance from each FSED and hospital ED to a public transit line. We also calculated the number of public transit lines within a 0.25 mile (mi) and 0.5 mi radius of each FSED and hospital ED. We selected 0.25 mi and 0.5 mi as reasonable walking distances. These data along with population density and median household income of the census tract in which each ED was located were extracted from the GIS database for further analysis.

To compare the likelihood of FSEDs and hospital EDs being located within walking distance of a public transit line, we used logistic regression to calculate the odds of an FSED being located within 0.5 mi of a public transit line, relative to hospital EDs. We additionally adjusted our model for population density and median household income to account for potential confounding between public transit proximity and population density and socioeconomic factors. Odds ratios (OR) were calculated for all MSAs together with error clustered at the MSA level. As this study was an analysis of publicly available data not including human subjects, it was exempt from institutional review board approval.

RESULTS

The median distance to public transit lines was greater for FSEDs than hospital EDs across all three MSAs (see Table 1). The difference between median distances from FSEDs and hospital EDs to public transit lines was greatest in Cleveland, with 1.6 mi ([interquartile range {IQR}, 0.4 – 6.2] for FSEDs compared with < 0.1 mi [IQR, 0.0–7.0] for hospital EDs). This difference was smallest in Denver with FSEDs having a median

Table 1. Proximity of freestanding emergency departments and hospital emergency departments to public transit lines.

	Houston		Cleveland		Denver	
	FSED (N=78)	HED (N=68)	FSED (N=9)	HED (N=26)	FSED (N=12)	HED (N=19)
Distance to transit line (mi)	1.1 [0.0; 3.6]	0.1 [0.0; 0.3]	1.6 [0.4; 6.2]	<0.1 [0.0; 7.0]	0.2 [0.0; 0.4]	<0.1 [0.0; 0.1]
No. lines within 0.25 mi radius	0 [0.0; 1.0]	1.5 [0.0; 5.5]	0 [0.0; 0.0]	2.5 [0.0; 7.0]	1 [0.0; 2.0]	2 [1.0; 4.0]
No. lines within 0.5 mi radius	0 [0.0; 1.0]	2 [1.0; 12.0]	0 [0.0; 1.0]	7 [0.0; 17.0]	2 [1.0; 2.0]	4 [2.0; 6.0]

FSED, freestanding emergency department; *HED*, hospital emergency department; *ED*, emergency department; *No.*, number; *mi*, miles. Median, [interquartile ratio].

distance of 0.2 mi (IQR, 0.0–0.4) to public transit lines compared with < 0.1 mi (IQR, 0.0–0.1) for hospital EDs.

The median number of public transit lines within a 0.25 mi radius of FSEDs was 0 for both Houston and Cleveland. For hospital EDs, the median number of public transit lines within a 0.25 mi radius was 1.5 (IQR, 0.0–1.5), 2.5 (0.0–7.0), and 2 (1.0–4.0) in Houston, Denver, and Cleveland, respectively. Similar patterns were seen within a 0.5 mi radius, with the median ranging from 0 to 2 for FSEDs and 2 to 7 for hospital EDs across the three MSAs. These patterns are further depicted in the Figure.

The unadjusted OR of a public transit line being located within 0.5 mi of an FSED compared to an hospital ED was 0.21 (95% confidence interval [CI], 0.13–0.34); and the OR adjusted for median household income and population density was 0.20 (95% CI, 0.11–0.40). See Table 2.

DISCUSSION

The role and responsibility of FSEDs in improving access to care for the underserved is the subject of active debate. Many independent FSEDs, operated by non-hospital, for-profit entities, are not recognized by the Center for Medicare and Medicaid Services; thus, they do not accept Medicare or Medicaid and are otherwise cost-prohibitive for most low-income individuals.[1,3] Policymakers have cited concerns regarding FSEDs' ability to improve care for the underserved and their lack of commitment to these communities.[3] Conversely, however, the rapid expansion and uptake of their services continues to demonstrate the substantial demand for FSED services in the healthcare market.

While further research and dialogue are necessary to determine the ultimate responsibility of FSEDs to underserved populations, the findings of our study support claims that FSEDs have limited potential to directly increase access to care for urban underserved populations based on their current locations. In addition to being located nearer to patient populations with relatively higher socioeconomic status,[2] our analysis showed that FSEDs located farther from public transit lines than hospital EDs are less likely to be within walking distance of public transportation, and are therefore less accessible for individuals without access to private means of transportation. As transportation represents a crucial barrier to care for low-income groups,[8,9] it is therefore less likely that FSEDs will directly improve access to acute unscheduled care for urban underserved populations.[5] Still, the effect of FSEDs on hospital ED crowding, wait times, and overall healthcare costs, and the potential indirect impact of these effects on access to care for underserved populations, has yet to be studied and further research is necessary to evaluate these considerations.

In prior analyses in Texas, Colorado and Ohio, FSEDs were shown to be located in areas with higher population growth, higher incomes, greater private insurance coverage, lower Medicaid prevalence, and more hospital EDs.[2] The differences in FSED and hospital ED proximity to public

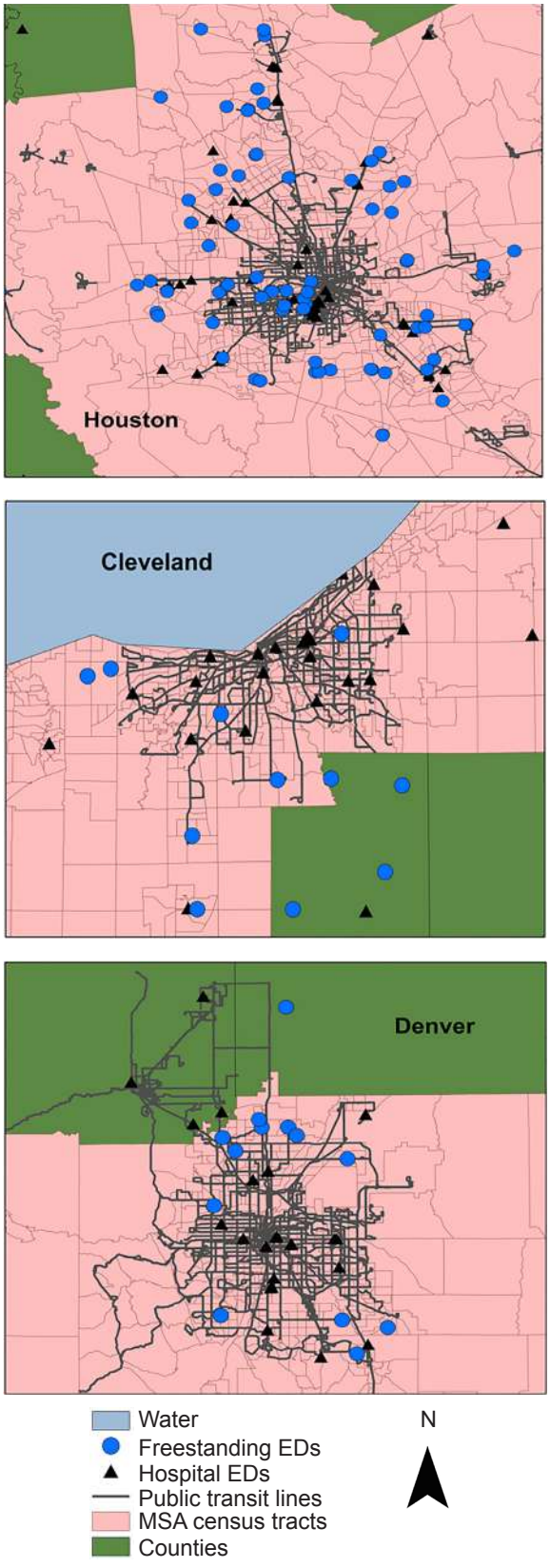


Figure. Freestanding emergency departments and hospital emergency department (ED) locations in relation to public transit routes.
MSA, Metropolitan Statistical Area.

Table 2. Logistic regression of the likelihood of freestanding emergency departments being located within 0.5 miles of public transit relative to hospital emergency departments.

	Unadjusted OR	Adjusted OR
Public transit line located within 0.5 miles	0.20 [0.13 - 0.34]	0.20 [0.11 - 0.40]
Population density (in 1,000s)		1.18 [1.08 - 1.28]
Median household income (in 1,000s)		1.02 [1.02 - 1.03]

OR, odds ratio; *CI*, confidence interval; *FSED*, freestanding; *ED*, emergency department.
OR [95% CI].

transportation are reflective of active choices made, primarily, by FSEDs. Developers of FSEDs likely have multiple motivations for selecting a particular location, including population density or growth, a well-reimbursing payer mix, and lack of competing services. Proximity to public transit lines correlates with higher proportions of low-income families and, consequently, those who are uninsured or dependent on Medicaid and Medicare.[5] It also reflects location accessibility for similar populations reliant on public transportation. The choice by FSED developers not to locate near transit routes could be an active decision, in order to avoid certain types of patients, or it could also reflect another confounding location decision, such as a preference to locate in new commercial developments. Further study will be necessary to assess the implications of these location decisions on healthcare delivery and local health systems.

LIMITATIONS

The findings of this analysis must be interpreted in the context of several limitations. First, we used Euclidean distances. Although these are potentially less precise than walking distances, prior research has demonstrated Euclidean distances to be highly correlated with travel distance while being more practical for geographic studies.[10] Next, FSEDs are rapidly expanding and, as of yet, there is no national registry of FSEDs. Our findings are based on a rigorous, multifaceted search strategy, but given that this is a rapidly evolving market, it is probable that new FSEDs have been constructed and some of those included have been closed since completing this search. Additionally, smaller suburban public transit lines that are not managed by regional transit authorities may have also been overlooked by our methods. Our analysis also did not account for patients who use other means of transportation to EDs, such as taxis, bicycles, or walking. Lastly, there may be other geospatial factors affecting ED location that were not included in this analysis, such as local healthcare policy, traffic patterns, or physical terrain.

CONCLUSION

The success of FSEDs in the free market continues to demonstrate the demand for FSED services by the general public, but their potential value to urban underserved populations is limited by their present locations and accessibility by public transportation. Further research should aim to evaluate the effects of FSEDs on ED crowding, population health, and healthcare costs, as well as their indirect impact on access to care for underserved populations. Policy makers must also continue to define what obligation FSEDs ultimately have to underserved populations to guide regulatory efforts for this expanding model of emergency care delivery.

Address for Correspondence: Lucas C. Carlson, MD, MPH, Brigham and Women's Hospital, Department of Emergency Medicine, 75 Francis Street, NH-2, Boston, MA 02115. Email: lccarlson@partners.org.

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. Funded in part by a Health Policy grant of the Emergency Medicine Foundation. The funder had no role in the research.

REFERENCES

1. Patidar N, Weech-Maldonado R, O'Connor SJ, et al. Contextual factors associated with hospitals' decision to operate freestanding emergency departments. *Health Care Manage Rev*. 2017;42(3):269-79.
2. Schuur JD, Baker O, Freshman J, et al. Where do freestanding emergency departments choose to locate? A national inventory and geographic analysis in three states. *Ann Emerg Med*. 2017;69(4):383-92.e5.
3. Dolan K. Health council recommends denial of ER. Warwick Beacon. Published: March 24, 2016. Available at: http://warwickonline.com/stories/health-council-recommends-denial-of-er,110643. Accessed March 30, 2016.
4. Burt CW, McCaig LF, Valverde RH. Analysis of ambulance transports and diversions among US emergency departments. *Ann Emerg Med*. 2006;47(4):317-26.
5. Glaeser EL, Kahn ME, Rappaport J. Why do the poor live in cities? The role of public transportation. *J Urban Econ*. 2008;63(1):1-24.
6. Data Tools and Apps. United States Census Bureau. Available at: http://www.census.gov/data/data-tools.html. Accessed June 22, 2016.

7. Primary Care Service Area Data Download – 2010 (Census Tract Basis). HRSA Data Warehouse. Available at: http://datawarehouse.hrsa.gov/data/datadownload/pcsa2010download.aspx. Accessed June 22, 2016.
8. Jacob R, Arnold LD, Hunleth J, et al. Daily hassles' role in health seeking behavior among low-income populations. *Am J Health Behav*. 2014;38(2):297-306.
9. Cheung PT, Wiler JL, Lowe RA, et al. National study of barriers to timely primary care and emergency department utilization among Medicaid beneficiaries. *Ann Emerg Med*. 2012;60(1):4-10.e2.
10. Boscoe FP, Henry KA, Zdeb MS. A nationwide comparison of driving distance versus straight-line distance to hospitals. *Prof Geogr*. 2012;64(2).

Are Rural and Urban Emergency Departments Equally Prepared to Reduce Avoidable Hospitalizations?

Margaret B. Greenwood-Ericksen, MD, MPH*
Michelle L. Macy, MD, MS†
Jason Ham, MD‡
Michele M. Nypaver, MD§,¶,‖
Melissa Zochowski, MBA#
Keith E. Kocher, MD, MPH§,¶

*University of New Mexico, Department of Emergency Medicine, Albuquerque, New Mexico
†Ann & Robert H. Lurie Children's Hospital of Chicago and Feinberg School of Medicine, Northwestern University, Chicago, Illinois
‡University of Michigan, Department of Internal Medicine, Ann Arbor, Michigan
§University of Michigan, Department of Emergency Medicine, Ann Arbor, Michigan
¶University of Michigan, Institute for Healthcare Policy and Innovation, Ann Arbor, Michigan
‖University of Michigan, Department of Pediatrics, University of Michigan, Ann Arbor, Michigan
#University of Michigan, College of Engineering, XTRM Labs, Ann Arbor, Michigan

Section Editor: Niels K. Rathlev, MD
Submission history: Submitted December 20, 2018; Revision received February 11, 2019; Accepted February 16, 2019
Electronically published April 16, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.2.42057

Introduction: Attempts to reduce low-value hospital care often focus on emergency department (ED) hospitalizations. We compared rural and urban EDs in Michigan on resources designed to reduce avoidable admissions.

Methods: A cross-sectional, web-based survey was emailed to medical directors and/or nurse managers of the 135 hospital-based EDs in Michigan. Questions included presence of clinical pathways, services to reduce admissions, and barriers to connecting patients to outpatient services. We performed chi-squared comparisons, regression modeling, and predictive margins.

Results: Of 135 EDs, 64 (47%) responded with 33 in urban and 31 in rural counties. Clinical pathways were equally present in urban and rural EDs (67% vs 74%, p=0.5). Compared with urban EDs, rural EDs reported greater access to extended care facilities (21% vs 52%, p=0.02) but less access to observation units (52% vs 35%, p=0.04). Common barriers to connecting ED patients to outpatient services exist in both settings, including lack of social support (88% and 76%, p=0.20), and patient/family preference (68% and 68%, p=1.0). However, rural EDs were more likely to report time required for care coordination (88% vs 66%, p=0.05) and less likely to report limitations to home care (21% vs 48%, p=0.05) as barriers. In regression modeling, ED volume was predictive of the presence of clinical pathways rather than rurality.

Conclusion: While rural-urban differences in resources and barriers exist, ED size rather than rurality may be a more important indicator of ability to reduce avoidable hospitalizations. [West J Emerg Med. 2019;20(2)477–484.]

INTRODUCTION

Emergency departments (ED) play a critical role in the delivery of acute ambulatory and inpatient care. EDs now serve as the primary source of hospital admissions[1,2] and increasingly serve as a hub for unplanned acute care needs.[3,4] As emergency providers are on the frontlines of admission decisions, their ability to identify opportunities for outpatient pathways as alternatives to an admission is critical to optimizing hospitalization practices. In other clinical contexts, low-value care has been defined as patient care that provides no net health benefit.[5] Similarly and in the context of this work, low-value hospitalizations are conceptualized as those admissions that are unlikely to provide an overall benefit, particularly when safe and effective outpatient alternatives exist. Avoiding such hospitalizations can reduce costs and potentially improve longer term population health outcomes by preventing the exposure to adverse events tied to the inpatient setting.

In efforts to improve the integration of care delivery within a local health system and better use of alternative pathways to hospitalization, some EDs and their hospitals have invested resources in comprehensive care coordination efforts.[6-8] EDs may embed personnel such as care managers and discharge planners to support this work. EDs have also developed clinical pathways to standardize care, frequently specifying criteria to determine safe disposition to hospital inpatient or observation unit vs home with additional services. These clinical pathways commonly include mechanisms to accelerate outpatient follow-up in an effort to reduce reliance on inpatient admissions for consultations and tests that can be obtained in an outpatient setting.[9] However, to date the majority of publications describing such innovations are from urban, suburban, and academic EDs,[10-13] and therefore little is known about the presence of pathways to avoid low-value admissions in community and rural EDs.

As rural populations are health disparity populations, studying rural populations and their sites of emergency care delivery is critical to understanding and improving rural health outcomes. Rural populations are of particular interest as they may be at higher risk for low-value admissions from the ED as a result of several factors. Rural patient populations tend to be older, with more chronic conditions[14] and less access to primary care[15,16] when compared to urban populations. As a result, rural areas may have fewer resources by which to reduce avoidable admissions. To explore this hypothesis, we conducted a cross-sectional, web-based survey of hospital-based EDs in Michigan. We examined differences in the availability of pathways to avoid low-value admission from the ED, as well as resources available in the community that may prevent these admissions.

Population Health Research Capsule

What do we already know about this issue?
Emergency departments (EDs) serve as the primary source of hospitalizations. Optimizing these practices requires identifying opportunities for alternative outpatient pathways of care.

What was the research question?
What are the perceived barriers and availability of alternative pathways to hospitalization from the ED and are there urban vs rural differences?

What was the major finding of the study?
Both urban and rural EDs have implemented alternative pathways but confront challenges related to social support, and patient and provider preferences.

How does this improve population health?
Perceived poor integration of the ED into outpatient settings limits the success of building alternatives to hospitalization programs for both urban and rural communities.

METHODS

Subjects

We developed a list of all 135 hospital-based EDs in the state of Michigan. Contact information for medical directors and/or nurse managers was collected through professional relationships and web-based searches conducted by the study team.

Survey Development

This study was performed by the coordinating center of the Michigan Emergency Department Improvement Collaborative (MEDIC). MEDIC is a physician-led, collaborative, quality improvement network supported through a partnership with Blue Cross Blue Shield of Michigan and Blue Care Network within the Value Partnerships program.[17,18] MEDIC measures performance relative to evidence-based, consensus quality goals across several domains to improve outcomes. One of the unique quality initiatives within MEDIC is the Program on Alternatives to Hospitalization (M-PATH). This program works with MEDIC partner hospitals and providers throughout the state of Michigan to support the development, implementation, and evaluation of clinical pathways designed to improve the quality and value of admission decisions made in the ED.

The M-PATH team designed an online survey as part of an environmental scan to inform future quality improvement efforts by understanding the scope of the problem of avoidable

admissions and use of clinical pathways to guide admission decisions. The target study population was medical directors and/or nurse managers at all 135 EDs in the state of Michigan. The institutional review board of the University of Michigan approved this study.

The survey contained 14 questions developed by a team of emergency physicians and health services researchers (Appendix). Questions were structured with fixed-choice responses and a free-text option for "other" responses. The survey was designed to be completed in less than 15 minutes. Questions explored the use of clinical pathways and protocols for ED care, factors contributing to the decision to admit a patient from the ED, hospital and community resources available to avoid hospitalization, and hospital characteristics including annual ED visits and number of ED beds. We inquired specifically about the presence of diagnosis- or complaint-related clinical pathways or protocols. (Examples provided included asthma, atrial fibrillation, chest pain, and head injury.)

Questions also requested information on the presence of community or health system standardized services (including extended care facilities, wound care, observation units, home healthcare and rapid follow-up to primary or specialist care), along with resources available to reduce/avoid admission, barriers in connecting patients to outpatient services (such as lack of family and/or social support, primary care/specialty care preference for admission, lack of time/support for care coordination, and lack of timely access to outpatient or home-care services), and individuals who may influence admission decisions (primary care, specialists, physical therapists, ED-based pharmacists, and care coordinators). We also asked respondents for information on the number of annual ED visits, number of ED beds, staffing model, and typical ED boarding times at their facility.

Survey Testing

After initial survey development, we conducted pilot testing of the survey to ensure clarity of the questions and response options with three individuals from within the state of Michigan and six individuals outside of Michigan representing backgrounds in general and pediatric emergency medicine and general emergency medicine as well as expertise in research or leadership in observational medicine. The survey was refined based on the feedback from pilot testing.

Survey Administration

Surveys were distributed via email with an embedded link to the medical directors and/or nurse managers of each ED in Michigan. The first request for participation was sent in late July 2016 and up to three reminder messages were sent over the subsequent eight weeks to those subjects who did not complete the survey. We used the Qualtrics (Provo, Utah) platform for survey administration and data collection.

Data Analysis

We performed descriptive statistics and tests of significance where appropriate using chi-squared analysis. In our analysis of barriers to connecting patients to outpatient services, we defined the presence of five or more of the eight answer choices as clinically significant, as this would represent a majority of barriers being selected. We categorized EDs as urban or rural by their county location in accordance with the Office of Management and Budget definitions (OMB). Those EDs in metropolitan statistical areas were categorized as urban, with micropolitan and non-metro categorized together as rural.

In our multivariable analysis, we constructed logistic regression models to determine if rurality predicted the primary outcome of presence of clinical pathways. Models adjusted for the following covariates: presence or absence of key healthcare access indicators of timely outpatient primary care and specialty care follow-up; outpatient resources such as wound care or home healthcare; and presence of significant barriers to avoiding admission, which was defined as hospitals reporting the presence of five or more of the eight answer choices (the majority). Additionally, the models were adjusted for the average ED boarding time (continuous variable), and number of ED beds (continuous variable). Finally, we also included the staffing model (hospital employee or contracted physician group) as a covariate given its hypothesized influence on hospitalization decisions, as these arrangements could correlate with particular financial incentives and familiarity with local protocols. We assessed whether to also include the covariate of annual ED visit volume but found it to be collinear with number of ED beds. Statistical significance was set at 0.05; we analyzed all data from the surveys using STATA (Version 14, College Station, Texas).

RESULTS

Description of Emergency Departments

Of the 135 hospital-based EDs, we received responses for 64 (47%). Of these, 33 were classified as urban and 31 were classified as rural in accordance with the OMB definition. ED characteristics are displayed in Table 1.

Presence of Clinical Pathways and Programs to Reduce Admission

The presence of pathways to guide admission decisions was reported at 45% of all respondent EDs, without significant difference between rural and urban centers (41.4% vs 58.6%; p=0.304). Most EDs (74.2% rural and 66.7% urban) reported the presence of one or more standardized programs or services designed to reduce avoidable inpatient admissions (Table 2). Of these standardized programs and services, wound care (62.5% vs 33.3%, p=0.028) and extended care facilities (52.2% vs 21.4%, p=0.022) were more likely to be reported in rural compared with urban EDs. In contrast, observation units were less likely in rural

Table 1. Characteristics of participating emergency departments with associated descriptive statistics.

Characteristics	All EDs (n=64)	Urban EDs (n=33)	Rural EDs (n=31)
ED bed number (median [IQR])	20 [9-34]	34 [26-50]	9.5 [6-14]
Annual ED visit number (median [IQR])	26,413 [11,852-57,500]	57,000 [42,000-72,000]	12,061 [6,850-20,128]
Emergency physicians are hospital employees (average %)*	22.2%	17.4%	27.3%
Estimated ED boarding time (average min, [SD])	96.8 [74.7]	123.6 [84.1]	70.1 [53.7]

IQR, interquartile range; *ED*, emergency department.
*Number of hospitals reporting their emergency physicians are hospital employees (not a contracted physician group).

Table 2. Hospitals reporting presence of pathways and programs to prevent or reduce avoidable admissions.

Clinical pathways	Urban EDs, proportion (95% CI)	Rural EDs, proportion (95% CI)	P value
Overall presence	66.7% (48.6, 80.9)	74.2% (55.6, 86.9)	0.51
Home health	60.9% (39.2, 78.9)	69.6% (47.3, 85.3)	0.54
Wound care*	33.3% (19.1, 51.5)	62.5% (41.3, 79.8)	0.03
Extended care facility*	21.4% (9.6, 41.1)	52.2% (31.6, 71.9)	0.02
Primary care follow-up	21.7% (8.9, 44.0)	34.8% (17.8, 56.8)	0.33
Observation units*	51.5% (34.4, 68.3)	35.4% (20.4, 54.1)	0.04

ED, emergency department; *CI*, confidence interval.
Chi-squared analysis performed with percent of rural and urban EDs who report such pathways displayed.
*Indicates statistically significant results; significance is at the p=.05 level.

compared with urban EDs (35.4% vs 51.5%, p=0.042). Same or next day access to primary care follow-up was uncommon overall (23.8%) with 34.8% in rural EDs and 21.7% in urban EDs (p=0.326). Home healthcare was reported equally at both rural and urban EDs (69.6% and 60.9%, respectively). ED-based procedures (such as peripherally-inserted central catheter line placement or infusions), telemedicine, community paramedicine, and rapid specialist follow-up were all uncommon across both types of EDs.

Barriers to Avoiding Admission

Overall, barriers were high across all sites, with 74.2% of rural and 80.0% of urban sites reporting at least one barrier. Commonly reported barriers to avoiding admission in both rural and urban EDs included lack of social support (88.0% and 76.0%, p=0.27), patient/family preference (68.0% and 68.0%, p=1.0), primary care preference (40.0% and 50.0%, p=0.48), and specialist preference (76.0% and 54.2%, p=0.13) (Figure 1). Rural EDs faced more barriers than urban EDs for time required for care coordination (88.0% vs 66.7%, p=0.05) and fewer barriers to home care (21.7% vs 48.0%, p=0.05).

Influence on ED Provider's Decision to Admit

Rural EDs reported low levels of primary care (36% vs 56%, p=0.16) and specialist influence on their decision to admit (28% vs 56%, p=0.04) when compared to urban EDs. Overall, few sites reported that social workers, care managers, physical therapy and ED-based pharmacy had influence on the decision to admit, regardless of location.

Does Urban-Rural Status Predict Ability to Reduce Low-Value Care?

In our unadjusted multivariable analysis, rurality did not predict presence of clinical pathways; 51.5% (95% confidence interval [CI], 21.5-55.8) of urban and 38.7% of rural (95% CI, 34.4-68.5) had clinical pathways (p=0.3). After adjustment, the relationship remained non-significant (Table 3), although ED volume (number of beds) and average ED boarding time were significant. Of note, given the expected relationship between rurality and ED size, we did evaluate for multicollinearity; the variance inflation factor of 2.03 and indications of multicollinearity were not found. Adjusted predicted proportions showed a non-significant difference between the proportion of urban (40.9%, 95% CI, 23.9-57.9) and rural (59.4%, 95% CI, 46.1-72.8) EDs having clinical pathways after accounting for covariates. We further explored the relationship between ED size, as measured as the number of ED beds, and presence of clinical pathways while adjusting for urban/rural status. We found that each additional ED bed increased the likelihood of having a clinical pathway by 12.3%; for an ED with 25 beds the predicted probability of having clinical pathways was 51.1% and greater than 98% for

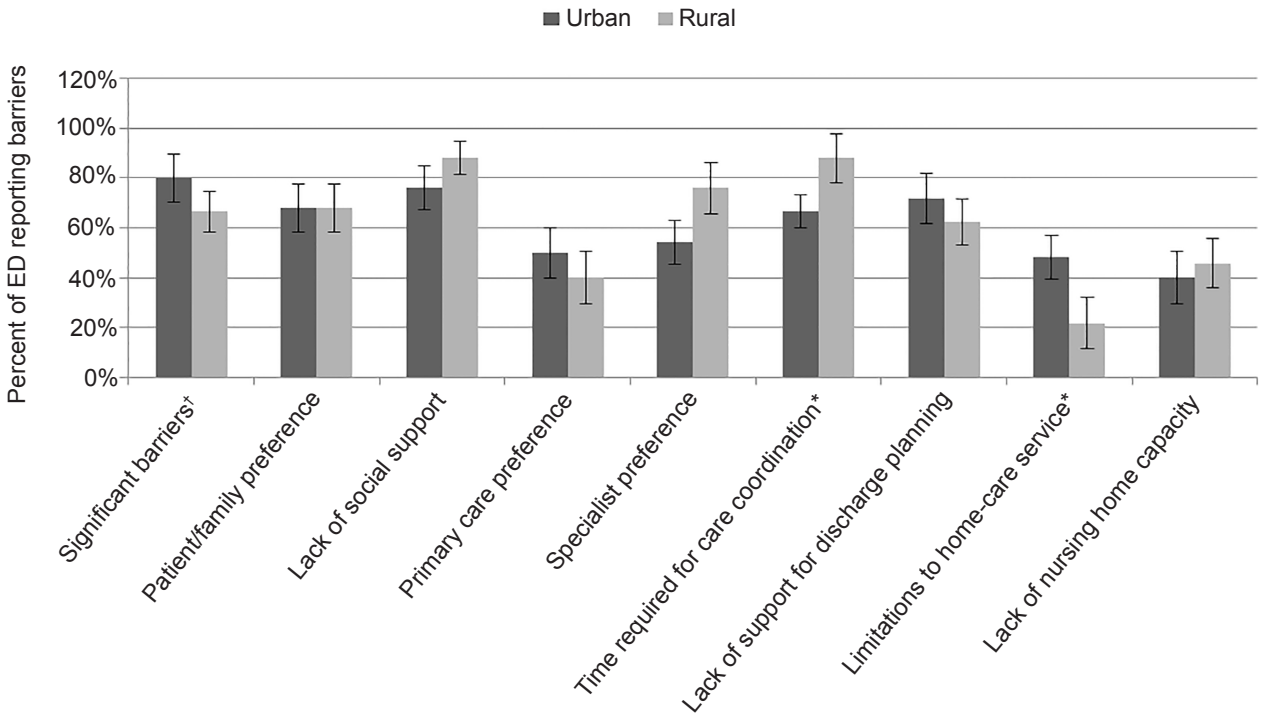


Figure 1. Barriers to avoidable admission reported by hospitals. Chi-squared analysis performed, with percent of rural and urban emergency departments (EDs) reporting barriers with associated 95% confidence intervals. Significant barriers defined as hospitals reporting the presence of five or more of the eight answer choices (the majority). Significance is at the p=.05 level. Data reported from responses to Q14 in Appendix.

*Indicates a statistically significant result.

†Significant barriers is defined as the presence of five or more of the eight answer choices as this would represent a majority of barriers being selected.

those with 70 beds or greater (Figure 2). Thus, the relationship between the ED volume was predictive of the presence of a clinical pathway rather than rurality.

DISCUSSION

As EDs are the primary source of acute hospitalizations in the United States (U.S.), they are positioned to link patients to alternative outpatient management strategies. However, the decision to hospitalize a patient is complex, and requires efficient, safe, and cost-effective outpatient care options for these alternative opportunities to be considered by ED providers and to be effective for patients. This survey of Michigan ED leaders regarding their local practices and resources demonstrates that about half of responding hospitals have clinical pathways to guide admission and discharge decisions. Yet despite the presence of standardized programs such as home healthcare or observation units to reduce avoidable admissions, most also reported significant barriers to discharging patients home from the ED, such as lack of social support, patient/family preference, and primary care and specialist preferences. As a result, regardless of location, both rural and urban EDs confront challenges to reducing avoidable hospitalizations even when clinical pathways exist.

In our analysis on the influence of rurality on our outcomes, we found that location did not predict the presence

Table 3. Selected characteristics of emergency departments (ED) evaluated as predictors of the presence of clinical pathways; adjusted odds ratios with associated confidence intervals and p-values are reported.

Predictors	AOR (95% CI)	P value
Rurality	0.13 (0.01, 5.67)	0.29
Outpatient resources	0.63 (0.06, 6.97)	0.71
Significant barriers	0.30 (0.06, 1.52)	0.15
PCP follow-up	1.68 (0.14, 20.7)	0.69
Specialist follow-up	1.19 (0.15, 9.46)	0.87
Employment-type	0.02 (0.00, 1.69)	0.08
Boarding time	0.96 (0.93, 0.99)	0.01
ED bed number	1.2 (1.02, 1.42)	0.03

AOR, adjusted odds ratio; *CI*, confidence interval; *PCP*, primary care physician.

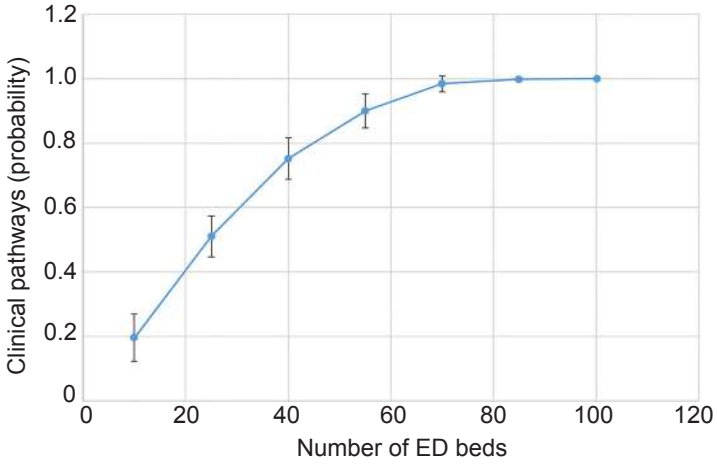


Figure 2. Adjusted proportion of emergency departments (ED) reporting clinical pathways. Error bars show 95% confidence intervals. Adjusted for presence of timely outpatient primary care follow-up, timely outpatient specialty care follow-up, outpatient resources (examples, wound care, or home healthcare), and presence of significant barriers to avoiding admission: defined as hospitals reporting the presence of five or more of the eight answer choices (the majority).

of clinical pathways, follow-up with primary or specialist care, barriers to avoiding admission, or presence of/access to outpatient resources. Instead, we found that as ED volume increased, so did the probability of having clinical pathways – indicating that larger EDs are more likely to use such pathways, regardless of location. This finding is consistent with literature demonstrating that clinical decision tools and pathways are more likely to be found in higher-volume EDs.[19] In addition, while we found that geographic differences in the presence of services, programs, and barriers exist, rural EDs demonstrated robust efforts and appear to have services available to facilitate reducing avoidable hospitalizations.

Connecting to Outpatient Care

Regardless of location, the perceived availability of primary and specialist care follow-up was low, indicating ongoing challenges related to fragmentation of care, particularly with respect to unscheduled acute care within the U.S. health system. This finding is consistent with trends demonstrating that fewer than half of acute care visits are managed by a patient's personal physician; a growing share is now taking place in the ED[4] with EDs increasingly supporting primary care practices to provide rapid, complex diagnostic work-ups, as well as after-hours demand for care.[20] While this evolution in location of care is well documented, little research has been done to explore current patterns and barriers to emergency and primary care physician communication and coordination.[21]

As primary care continues to build capacity, partnering with local EDs in their efforts and in decision-making around admission or discharge will be important to overall success.[6] While rural primary care practices may face barriers to care delivery due to lack of a robust primary care and specialist staffing pool as well as limited economies of scale,[15] our data show potential for greater primary care availability in the rural setting. This may indicate that ED-primary care communication is easier within smaller communities with closer personal connections, and rural ED-primary care collaborations may be one model by which to improve rural population health.[22]

Presence of Programs to Reduce Avoidable Hospitalizations

With the majority of sites reporting the presence of programs designed to avoid low-value hospitalizations, it appears that Michigan EDs are embracing efforts to reduce avoidable admissions. Some geographic variation exists, with greater awareness of wound care services and extended care facilities available to respondents in the rural setting, whereas observation units are more likely to be available to EDs found in the urban setting. This may reflect the needs of rural populations, which are traditionally older with multiple chronic conditions – both of which would require access to skilled nursing, wound care, and rehabilitation facilities. Home healthcare was consistently highly available to respondents from all EDs, matching national trends toward expanding home health services to support outpatient management strategies and meet the needs of an aging U.S. population.[23] The second most reported service was observation units, with over 50% of urban EDs and 35% of rural EDs indicating presence of an ED observation unit. As urban hospitals are usually higher volume than rural, our finding is consistent with literature demonstrating that observation units are more commonly found in higher volume hospitals.[24] While lower rates of observation units in rural EDs may reflect less perceived need or interest, the finding that one-third of rural EDs report their presence speaks to the penetration of this model of care in avoiding admission. While cost savings and perceived effectiveness of observation units by ED providers have been demonstrated,[25,26] the impact of clinical pathways to improve patient outcomes while decreasing hospitalizations has not been rigorously studied and has been limited by variable implementation strategies and suboptimal research designs.[27]

It is unknown if ED providers routinely rely on home health, wound care, and care facilities as an alternative to hospitalization. The utilization of these resources was not studied in our survey, and future work should determine if presence and use are related. Further, these services are time consuming to arrange (over 70% of respondents indicated time required for care coordination and lack of support for discharge planning as a barrier) and may only be available to ED providers during business hours, limiting their impact. Finally, admission may be the only safe course of action for patients with complex social history or limited social support.

Barriers

Barriers to avoiding low-value admissions were reported across all EDs, highlighting social and community challenges that extend beyond the ED setting. The least reported barrier was for rural EDs and home healthcare (21.7%), and the remaining barriers were present according to greater than 40% of respondents regardless of location. Remarkably, greater than 75% of all EDs reported lack of social support as a barrier to reducing avoidable admissions, followed by over 65% reporting family preference as a barrier. At present, the role for EDs in addressing issues of social isolation and home environment is limited. While there is a movement in the U.S. healthcare system to encourage primary care to address social determinants of health[28] - or conditions in which people are born, grow, live, work and age – the success of this approach is unknown. EDs can play a role in identifying patients with significant social needs; however, this would require additional support since one of the other greatest barriers identified in our survey was the time required for care coordination and lack of support for discharge planning in the ED setting of care. Future work exploring patient and family needs would be helpful in understanding why a hospital admission is preferred and what services and support are critical in addressing these barriers.

LIMITATIONS

There are several limitations to our study. First, it may suffer from response bias, as approximately half of Michigan EDs did not complete the survey. This could have been from a lack of interest in the topic, inadequate time to complete the survey, or improper selection of a contact person who felt comfortable answering these questions. While the results cannot be generalized to other states and environments, we did obtain a diverse set of responses from an important range of ED practice settings. Further, with equal representation between urban and rural sites, the validity of the comparison is strengthened despite the overall response rate. Respondents may also have been from "higher functioning" EDs or those with highly motivated administrators who have put robust efforts toward avoiding hospitalization or EDs that perceive avoiding hospitalization as important, even if not successful. The survey results suffered from missing data, as not all sites answered all the questions; however, the missing data appeared equally distributed between urban and rural EDs. Finally, our overall small sample size likely prevented us from detecting statistically and clinically important differences between sites, as several p-values approached significance.

CONCLUSION

Both rural and urban EDs have an important role to play in reducing low-value hospitalizations but confront significant barriers to accomplishing this goal. In particular, a key obstacle universally identified was in connecting patients to timely, outpatient follow-up care, which could be bolstered by better integrating local EDs into patient-centered medical home efforts. While both urban and rural EDs in our study have implemented clinical pathways, the high prevalence of barriers and lack of connections to primary and specialty physicians limit the potential for their success without additional resources to build and strengthen alternatives to admission programs.

Address for Correspondence: Margaret B. Greenwood-Ericksen MD, MPH, University of New Mexico, Department of Emergency Medicine, 1 University of New Mexico, Albuquerque, NM 87131. Email: margaretge@gmail.com.

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.Support for the Michigan Emergency Department Improvement Collaborative (MEDIC) is provided by Blue Cross and Blue Shield of Michigan and Blue Care Network as part of the BCBSM Value Partnerships program. Although Blue Cross Blue Shield of Michigan and MEDIC work collaboratively, the opinions, beliefs and viewpoints expressed by the authors do not necessarily reflect the opinions, beliefs and viewpoints of Blue Cross Blue Shield of Michigan or any of its employees.

REFERENCES

1. Kocher KE, Dimick JB, Nallamothu BK. Changes in the source of unscheduled hospitalizations in the United States. *Medical Care*. 2013;51(8):689-98.
2. Schuur JD, Venkatesh AK. The growing role of emergency departments in hospital admissions. *N Engl J Med*. 2012;367(5):391-3.
3. Pines JM, Lotrecchiano GR, Zocchi MS, et al. A conceptual model for episodes of acute, unscheduled care. *Ann Emerg Med*. 2016;68(4):484-91.e3.
4. Pitts SR, Carrier ER, Rich EC, et al. Where Americans get acute care: Increasingly, it's not at their doctor's office. *Health Aff (Millwood)*. 2010;29(9):1620-9.
5. Mafi JN, Russell K, Bortz B, et al. Low-cost, high-volume health services contribute the most To unnecessary health spending. *Health Aff (Millwood)*. 2017;36(10):1701-4.
6. Agrawal S, Conway PH. Integrating emergency care Into a patient-

and outcome-centered health care system. *Ann Emerg Med*. 2013;61(3):301-2.

7. Braithwaite SA, Pines JM, Asplin BR, et al. Enhancing systems to improve the management of acute, unscheduled care. *Acad Emerg Med*. 2011;18(6):39-44.
8. Selevan J, Kindermann D, Pines JM, et al. What accountable care organizations can learn from Kaiser Permanente California's acute care strategy. *Popul Health Manag*. 2015;18(4):233-6.
9. Venkatesh AK, Geisler BP, Chambers JJG, et al. Use of observation care in US emergency departments, 2001 to 2008. *PLoS ONE*. 2011;6(9):e24326.
10. Ross MA, Hockenberry JM, Mutter R, et al. Protocol-driven emergency department observation units offer savings, shorter stays, and reduced admissions. *Health Aff (Millwood)*. 2013;32(12):2149-56.
11. Mace SE, Graff L, Mikhail M, et al. A national survey of observation units in the United States. *Am J Emerg Med*. 2003;21(7):529-33.
12. Mahler SA, Riley RF, Hiestand BC, et al. The HEART Pathway randomized trial. *Circ Cardiovasc Qual Outcomes*. 2015;8(2):195-203.
13. Barrett TW, Storrow AB, Jenkins CA, et al. The AFFORD clinical decision aid to identify emergency department patients with atrial fibrillation at low risk for 30-Day adverse events. *Am J Cardiol*. 2015;115(6):763-70.
14. Moy E, Garcia MC, Bastian B, et al. Leading causes of death in nonmetropolitan and metropolitan areas — United States, 1999–2014. *MMWR Surveill Summ*. 2017;66(1):1-8.
15. Mackinney AC, Ullrich F, Mueller KJ. Patient-centered medical home services in 29 Rural primary care practices : a work in progress. *Rural Policy Brief*. 2011;20116:1-4.
16. Meit M, Knudson A, Gilbert T, et al. The 2014 update of the rural-urban chartbook. Bethesda, MD: Rural Health Reform Policy Center. October 2014. Available at: https://ruralhealth.und.edu/projects/health-reform-policy-research-center/pdf/2014-rural-urban-chartbook-update.pdf. Accessed February 28th, 2019.
17. Share DA, Campbell DA, Birkmeyer N, et al. How a regional collaborative of hospitals and physicians in Michigan cut costs and improved the quality of care. *Health Aff (Millwood)*. 2011;30(4):636-45.
18. Blue Cross Blue Shield of Michigan. Value Partnerships.com — Blue Cross Blue Shield of Michigan. Available at: http://www.valuepartnerships.com/. Accessed March 12, 2018.
19. Kinlin LM, Bahm A, Guttmann A, et al. A survey of emergency department resources and strategies employed in the treatment of pediatric gastroenteritis. Baren JM, ed. *Acad Emerg Med*. 2013;20(4):361-6.
20. Gonzalez MK. The evolving role of emergency departments in the United States. *RAND Corp*. 2013;17:1-63.
21. Carrier E, Yee T, Holzwart R. Coordination between emergency and primary care physicians. *NIHCR*. 2011;3:1-39.
22. Greenwood-Ericksen MB, Tipirneni R, Abir M. An emergency medicine–primary care partnership to improve rural population health: expanding the role of emergency medicine. *Ann Emerg Med*. 2017;70(5):640-7.
23. Landers S, Madigan E, Leff B, et al. The future of home health care. *Home Health Care Manag Pract*. 2016;28(4):262-78.
24. Macy ML, Hall M, Alpern ER, et al. Observation-status patients in children's hospitals with and without dedicated observation units in 2011. *J Hosp Med*. 2015;10(6):366-72.
25. Baugh CW, Venkatesh AK, Hilton JA, et al. Making greater use of dedicated hospital observation units for many short-stay patients could save $3.1 billion a year. *Health Aff (Millwood)*. 2012;31(10):2314-23.
26. Kocher KE, Haggins AN, Sabbatini AK, et al. Emergency department hospitalization volume and mortality in the United States. *Ann Emerg Med*. 2014;64(5):446-57.
27. Jabbour M, Curran J, Scott SD, et al. Best strategies to implement clinical pathways in an emergency department setting: study protocol for a cluster randomized controlled trial. *Implement Sci*. 2013;8(1):55.
28. Alley DE, Asomugha CN, Conway PH, et al. Accountable health communities — addressing social needs through Medicare and Medicaid. *N Engl J Med*. 2016;374(1):8-11.

Burnout, Drop Out, Suicide: Physician Loss in Emergency Medicine, Part I

Christine R. Stehman, MD*
Zachary Testo, MD†
Rachel S. Gershaw, DO, MPH†
Adam R. Kellogg, MD†

*Indiana University School of Medicine, Department of Emergency Medicine, Indianapolis, Indiana
†University of Massachusetts Medical School-Baystate Health, Department of Emergency Medicine, Springfield, Massachusetts

Section Editor: John Burkhardt, MD, MA
Submission history: Submitted September 17, 2018; Revision received April 3, 2019; Accepted April 8, 2019
Electronically published April 23, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.4.40970

Each year more than 400 physicians take their lives, likely related to increasing depression and burnout. Burnout—a psychological syndrome featuring emotional exhaustion, depersonalization, and a reduced sense of personal accomplishment—is a disturbingly and increasingly prevalent phenomenon in healthcare, and emergency medicine (EM) in particular. As self-care based solutions have proven unsuccessful, more system-based causes, beyond the control of the individual physicians, have been identified. Such system-based causes include limitations of the electronic health record, long work hours and substantial educational debt, all in a culture of "no mistakes allowed." Blame and isolation in the face of medical errors and poor outcomes may lead to physician emotional injury, the so-called "second victim" syndrome, which is both a contributor to and consequence of burnout. In addition, emergency physicians (EP) are also particularly affected by the intensity of clinical practice, the higher risk of litigation, and the chronic fatigue of circadian rhythm disruption. Burnout has widespread consequences, including poor quality of care, increased medical errors, patient and provider dissatisfaction, and attrition from medical practice, exacerbating the shortage and maldistribution of EPs. Burned-out physicians are unlikely to seek professional treatment and may attempt to deal with substance abuse, depression and suicidal thoughts alone. This paper reviews the scope of burnout, contributors, and consequences both for medicine in general and for EM in particular. [West J Emerg Med. 2019;20(3)485–494.]

INTRODUCTION

"Burnout" evokes images of harried, sleep-deprived, hungry physicians, overwhelmed with "paperwork," administrative complaints of missed metrics, and pending tasks for family and patients. For the physician suffering from burnout, recovery can seem daunting or even impossible. For healthcare, burnout has been branded an epidemic, with societal and human economic and personal costs.[1] This article, the first of two parts, synthesizes information on burnout—the scope of the problem, its causes and consequences—from the perspective of the emergency physician (EP). Part II will focus on wellness and seek to make recovery less daunting.

Burnout: Definition and Measurement

Burnout is a complex condition with a history in many disciplines. Based on his research, Freudenberger used "burnout" as shorthand for a psychological syndrome with three dimensions: emotional exhaustion, depersonalization, and reduced personal accomplishment.[2] Maslach subsequently summarized the dimensions of burnout as "exhaustion," "cynicism," and "inefficacy," providing more identifiable definitions of each dimension that align well with her measurement tool.[3] Those who score high in "exhaustion" feel over-extended, their emotional and physical resources depleted.[3] High scorers in "cynicism" (depersonalization) appear more callous or detached than would be expected for normal "coping."[3] Those lacking confidence or feeling they have achieved little work success score high in the "inefficacy" (reduced personal accomplishment) dimension.[3] Overall, sufferers from burnout are frequently exhausted, diminished in their ability to care, and feel as though their work makes little difference.

Maslach used these definitions to create the most frequently used assessment tool for identifying burnout, the Maslach Burnout Inventory (MBI). This tool contains 22 questions addressing the three dimensions and provides scores in each. The higher the score, the higher the burnout in that dimension.[4] Rather than a dichotomous cutoff score of burnout as a diagnosis, the MBI describes a spectrum with higher scores equating to more severe symptoms and consequences.[5] While the MBI has been modified and abbreviated for specific populations and ease of use, it remains proprietary. The next most common tool used in healthcare burnout research, the Oldenburg Burnout Inventory, focuses on emotional exhaustion and depersonalization/ disengagement, while leaving out personal accomplishment.[6] A list of burnout assessment tools appears in Appendix 1; however, readers may consider simply asking physicians if they are burned out: In one study, self-reported burnout accurately predicted meeting MBI burnout criteria 72% of the time.[7]

METHODS

Keywords

We chose "burnout" and its main components ("emotional exhaustion," "depersonalization," "cynicism," "job dissatisfaction") as the endpoint keywords. Because healthcare burnout researchers leave out the "lack of personal accomplishment" dimension, we did the same here.[8] "Depression" and "suicide," the ultimate consequences of burnout, were also included as endpoints. These keywords were paired with population keywords: "physicians," "residents," "medical students," and "emergency medicine" (EM) to find relevant articles in the medical literature.

Search

We searched all combinations of pairings of each "endpoint" keyword with a "population" keyword from 1974 to the present in both Ovid Medline and PubMed. To ensure more esoteric sources were included we conducted searches for "endpoint" keywords on various EM/critical care blogs and lay press Web sites.[9]

Article Inclusion Criteria

We categorized all search results into primary research studies, commentary/opinion pieces, and review articles. Primary research studies, inclusive of their relevant references, provided the database of supporting information for the composition of the review. Additionally, we attempted to identify the primary literature for all Internet-based resources.

RESULTS

Scope of Burnout in Physicians

Freudenberger and Maslach initially identified and studied burnout in non-medical fields; however, as early as 1981, research began to focus on burnout in physicians and medicine.[10] In 2012 a landmark study identifying burnout as high scores in either the MBI's depersonalization or emotional exhaustion dimension found that 37.9% of physicians met criteria for burnout compared to 27.8% of the general United States (U.S.) workforce.[8] Since 2013, Medscape has published the results of an annual survey of physicians. Per this report, the percentage of physicians experiencing burnout has steadily risen.[11] Most recently, 44% of respondent physicians indicated feeling burned out, a percentage that correlates with the most recent survey by Shanafelt et al. (43.9% respondents had at least one symptom of burnout).[11,12]

Burnout has been studied at all levels of medical training and starts early: one study identified 52.8% of students (an equal mix of all four years) from seven medical schools meeting criteria.[13] Burnout continues during residency, though it has been less frequently explored. In 2002 Shanafelt et al. found that 76% (n = 87/115) of one internal medicine program's residents met criteria for burnout.[14] In a 2018 study, researchers surveying 3588 second-year resident physicians across multiple specialties found that 45.2% experienced at least one symptom of burnout at least weekly.[15] A recent systematic review and meta-analysis aggregated 26 studies including 4664 residents of multiple specialties and found a burnout prevalence of 35.7%, consistent with previous work.[16] This early-career burnout seems to predict later-career burnout, as suggested by a small study of internal medicine residents (N = 81) over 10 years.[17] They found high univariate correlations between emotional distress in residency and later emotional exhaustion (correlation coefficient=0.30, P = 0.007) and depersonalization (correlation coefficient=0.25, P = 0.029).[17] For an expanded list of different burnout and wellness surveys and scales, please see Table 1 in the Appendix.

Causes of Burnout

Historically, medicine saw burnout as a sign of personal weakness or of being ill-suited to the profession.[18] Without consideration of organizational and societal influences on burnout development, authors suggested that "self-rescue" would occur if one simply recognized his or her condition and engaged in improved communication and management-skills training or routine exercise.[19-21] Even leading researchers espoused these beliefs: Shanafelt et al. stated that physician burnout was related to stressful work, doing too much and putting others' needs before their own.[22] However, the results of Shanafelt's landmark 2012 study on the prevalence of burnout appeared to have changed his views, and he called on others to take a different perspective:

"The fact that almost 1 in 2 U.S. Physicians has symptoms of burnout implies that the origins of this problem are rooted in the environment and care delivery system rather than in the personal characteristics of a few susceptible individuals."[8]

Although individual characteristics do contribute to burnout susceptibility, and physicians cope with burnout using exercise and meditation, the problem has not improved.[11,23]

Individual physicians seem to recognize the importance of outside forces on their experience of burnout, even if society and organizations have not fully embraced this. The responses to the yearly Medscape survey now lists only organizational and environmental causes for burnout, such as bureaucratic tasks, long work hours, electronic health records (EHR), lack of respect, lack of control/autonomy, and profits over patients.[11] The following discussion will focus on three contributing factors: EHRs, financial concerns, and the "second victim" syndrome (SVS).

Electronic Health Records

While charting was once used to communicate relevant clinical information between members of the healthcare team, the EHR has shifted medicine's focus to billing, coding, and protection from litigation. EHRs are independently associated with higher rates of burnout among users.[24] Clinical time spent more on the computer than with patients impairs patient contact (ie, "the best part of being a doctor"). Less one-on-one time with patients leads to a decrease in humanism and conflicts with physicians' inherent altruism. This in turn increases the risk of burnout and substantiates the views of the Medscape respondents: profits over patients.[25, 26]

EHRs impact physician workflow as time-consuming distractions that create new problems, such as downtimes and electronic-prescription system failures. Downtimes are typically scheduled at "slow times" for the hospital in the middle of the night, when EPs and emergency departments (ED) are often busiest and staffing scarce. The EHR's billing-centric design slows chart-completion, and online availability can lead to uncompensated charting at home.[26,27] While physicians generally agree that EHRs have improved access to medical records and provide some benefits, they decrease patient interaction, worsen work-life balance, and decrease job satisfaction, resulting in overall net harm to physicians.[27]

Financial Concerns

While Medscape respondents mention "lack of compensation/reimbursement," their concerns may be tied to medical school debt.[11] The cost of medical education continues to rise; physicians who graduated in 2016 carry an average debt over $190,000, which correlates with burnout.[28,29] Additionally, physicians feel under-prepared to navigate their finances while transitioning to attending-level income.[30] This lack of preparation may lead to living above their means, worsening their debt despite high income, resulting in increased stress and burnout.[31]

Second Victim Syndrome

Another likely contributor to *and* consequence of burnout is the SVS phenomenon.[34-36] SVS embodies the psychological trauma healthcare workers suffer from involvement in an "adverse event." Typically related to committing a medical error resulting in a poor patient outcome, SVS may also involve any adverse patient outcome, expected or unexpected, with the physician becoming the "second victim."[37] One study found that 30% of physicians (all specialties) experienced emotional issues related to a "bad outcome," while another found up to 60% of surgical residents experienced SVS.[38, 39]

Society sets a zero-mistake standard for physicians.[32] This high standard may isolate those who make mistakes leaving them without healthy ways to cope, resulting in dysfunctional approaches to recovery.[32,35,36] Poor responses (isolation, anger, sadness, substance abuse, and callousness toward patients and colleagues) place the physician more at risk for burnout.[35,36] When suffering from SVS, the perception of not being supported or even of being victimized by one's own hospital or organization can exacerbate the syndrome.[32,40] This sense of victimization comes despite research suggesting that medical errors leading to poor patient outcomes stem from system failures and not just the individual who committed the error.[41,42] This is a continuous chain of events; if a physician is burned out, he or she is more likely to commit an error during patient care, which puts them at risk for SVS and litigation stress and likely exacerbates their burnout.[32,36,43-45] This cycle and its associated emotional toll lead to negative consequences, which may include depression and departing medicine by either attrition or suicide.[35]

Consequences of Burnout

Additional consequences of burnout include poor clinical care, increased mistakes, patient dissatisfaction, dysfunctional interactions between colleagues, the contagion of burnout, substance abuse/self-medication, depression, and suicide.

Clinical Care

Health systems now recognize the negative impact of burnout on healthcare quality, patient safety, and financial performance.[46] A study of U.S. surgeons found both an increased rate of medical errors and greater medicolegal risk for physicians experiencing burnout.[47] A recent meta-analysis found a statistically significant negative relationship between physician burnout and patient safety ($r = -0.23$), as well as burnout and quality of care ($r = -0.26$).[48] As clinical care suffers, so does patient satisfaction, which in turn may further decrease health outcomes.[49,50] Burnout may also affect a physician's colleagues by being contagious: burned-out physicians negatively interact with co-workers and perform more poorly at their jobs, creating a negative work environment and putting others at risk for burnout.[3,51,52]

Leaving Jobs/Medicine

Physicians suffering burnout are significantly more likely to leave healthcare.[53,54] Physicians first reduce work hours or change jobs or specialties, negatively affecting the health system. The estimated cost to replace a physician is

$160,000–$1,000,000, depending on specialty and experience. This estimate does not include intangibles such as team disruption.[11,46,55-57] If this job change does not help, physicians may seek administrative positions or leave medicine entirely.[58]

Depression and Self-medication

Burnout occurs on a continuum with depression. The 2012 study by Shanafelt et al. found that 37.8% of respondents screened positive for depression on a standardized and validated two-question screening tool.[8] The most recent Medscape survey indicated that 15% are not only burned out, but also are either "colloquially" or clinically depressed.[11] Multiple barriers separate physicians from depression assistance. Such barriers include feeling that they do not require professional intervention and, perhaps more importantly, fearing the loss of medical licensure and hospital credentialing.[11,59] A 2014 survey found that nearly 40% of physicians would be reluctant to seek care for mental health due to licensure concerns.[60]

While many physicians deal with burnout and depression in isolation, some have developed harmful coping strategies such as alcohol and drug use.[11] In general, older research suggests that approximately 10-12% of physicians will develop at least one substance abuse disorder, similar to the general population rate.[61] More recent data suggest physicians primarily abuse alcohol, with 12.9% of male physicians and 21.9% of female physicians affected, numbers higher than the general population. (Overall 6.2% of the U.S. population 18 years or older has an alcohol use disorder, 8.4% of men and 4.2% of women.)[62,63]

Suicide

Society is shocked when a physician commits suicide. It is estimated that 400 physicians in the U.S. die by suicide each year.[64] Compared to the general population, male and female physicians are at greater relative risk (RR) of suicide (RR = 3.4 and RR = 5.7, respectively).[65,66] Shanafelt, et al. reported that 6.4% of respondents had considered suicide in the previous year.[8] In the most recent Medscape report, 14% of respondents had considered suicide and 1% of respondents had attempted suicide, results similar to a study of female physicians (1.5% attempted suicide).[11,67] Physicians in training are not immune to these risks. Approximately 10% of medical students report suicidal ideation, and suicide is the second leading cause of death among resident trainees in the U.S. (4.1 per 100,000, or approximately five residents per year).[68-70]

While these rates of physician depression and suicidal ideation do not significantly differ from those of the general working population (37.8% and 6.4%, respectively), there are reasons to believe that physician depression is both under-reported and under-treated.[8] Physicians are less likely to seek treatment since depression remains stigmatized in medical culture.[41,71] Depressed physicians may feel like failures, isolated and cut off from their colleagues whom they believe are coping better. Feelings of isolation, loss of belonging, and failure, combined with the perception of being a burden on partners, family, friends and society, drive some to see suicide as an answer.[72]

Given that physicians do not seek help and approximately one in seven has considered suicide, someone reading this may be suffering from depression and contemplating suicide. If that is you, please reach out to a friend, a helpline (call 1-800-273-8255 or text HOME to 741741), a therapist, or to an employee assistance program. Anyone with concerns that a colleague is suffering should reach out, ask, listen, and assist him or her in finding help. For a comprehensive list of suicide prevention and self help resources, please see Table 2 in the Appendix.

DISCUSSION

In medicine, EM is unique in its hours, patient population and stressors. This uniqueness translates into more EP burnout. A four-year survey published in 1996 found that 60% of EP respondents "registered in the moderate to high burnout ranges" on the MBI.[7] In the 2012 landmark burnout study, EM was the most burned-out specialty (~65%), over 10% more "burned out" than the next closest specialty (general internal medicine), and close to 20% more than the mean rate for all physicians responding.[8] While burnout in EM has continued, the most recent Medscape report indicates that EM is the fifth most burned-out specialty behind urology, neurology, physical medicine and rehabilitation, and internal medicine.[11] Like other specialties, burnout in EM starts early, with studies showing between 65-74% of residents (all levels) meet criteria for burnout.[73,74]

Causes of Burnout in Emergency Medicine

The unique stressors in EM may easily lead EP burnout to be attributed to personal characteristics such as poor coping skills or lack of exercise, rest, and hobbies, a view that continues to this day. However, organizational and environmental causes of burnout certainly apply to EPs. One notable exception is the usual connection between burnout and increased work hours. For non-EPs, burnout appears to directly correlate with increasing work hours.[11] On the contrary, while EPs are the least likely specialists to work excessive hours (>40 hours/week), the necessity of working nights and on weekends and holidays may contribute to burnout.[11] Furthermore, the lack of support staff and medical infrastructure during these "off" hours, coupled with high intensity work (heavy workload, multiple sick patients, frequent task-switching, patient and colleague rudeness, and constant uncertainty) may have a similar effect on EP emotional health as the longer hours of other specialists.[75-79]

With fewer weekly hours than other specialties, EPs have the ability to "pick up" extra shifts, increasing their work hours and the associated stress. Many EPs work extra shifts

to pay off debt, another stressor and contributor to burnout.[80] In 2016 the median debt of EM residents in one study was $212,000.[81] This debt caused stress and changed plans: getting out of debt reportedly took priority over pursuing further educational opportunities, vacations, and spending time with family, all things that might counter burnout.[80,81] The ability to "pick up" extra shifts to pay down debt and the perception that they are working less than other physicians are examples of particular attributes of EM that increase susceptibility to burnout.[82] Three other causes of burnout in EM deserve mention: clinical pressures/expectations, litigation stress, and fatigue/sleep loss.

Clinical Pressures and Expectations

Society perceives EM as a world of excitement, drama, and miraculous saves.[83] While not wholly inaccurate, television dramas do not show the persistent demand for immediate and error-free care despite limited resources.[84] This mismatch between demands and resources, coupled with constant diagnostic uncertainty, significantly stresses EPs and promotes burnout and emotional exhaustion.[79,84-86]

Both EDs and EPs are limited resources: EDs are closing while visits are increasing, and there is a national shortage of EPs, particularly in less geographically desirable areas.[87,88] Despite a consistent increase in EM first-year residency training positions (1786 in 2014 to 2278 in 2018, 27.5% increase), only 61% of U.S. emergency care providers are EPs, with the rest a combination of advanced practice providers (APPs) (24.5%) and non-EPs (14.3%).[89, 90] This shortfall particularly affects rural areas where only 44.8% of rural emergency care providers are EPs.[90] Despite this shortfall, EPs provide care for 85.3% of ED patients, meaning they are working more clinical hours while being responsible for care being provided by APPs.[88, 91]

Compensation is often based on productivity, patient satisfaction, and "quality" measures.[92] With more patients and less time to see them, EPs who are judged on patient satisfaction may choose to acquiesce to requested, but not medically indicated, care. This occurs despite patient satisfaction correlating poorly with quality of care.[93-97] Similarly, the guidelines and care metrics nominally designed to improve patient care (eg, door-to-doc/needle/antibiotics time) are rigorously enforced despite lack of evidence of patient benefit.[98-99] Such metrics and guidelines, particularly prominent in EM as the initial provider of care, deprive physicians of autonomy and the ability to practice the art of medicine, leading to job dissatisfaction and burnout.[82, 100]

Litigation Stress

Being the first care provider for so many sick patients means inevitably dealing with a malpractice claim, another cause of burnout.[101] Annually, EPs face malpractice claims at a slightly higher rate than the average physician (8.7% vs 7.2%).[102] Each litigation episode can last years, and physicians are counseled not to discuss such cases with anyone, adding to the isolation and lack of peer support.[103,104] Annually, up to 73% of EPs admit to practicing "defensive medicine," ordering extra tests to avoid missing anything, and cite fear of litigation as the reason.[105] This practice leads to physician cynicism and disengagement (precursors to burnout), and increases healthcare spending (by an estimated $750 billion in 2010).[106]

Sleep loss and fatigue

One reason EPs likely face higher litigation rates is that they simply encounter more sick patients than other physicians, as their work environment is available at all times. To fulfill the 24-hour need for high quality emergency care, EM is built around shift work. The resulting disruption of circadian rhythms leads to sleep loss and its associated detrimental effects on health: increased cardiovascular disease, metabolic syndrome, sleep disorders, and possibly even increased mortality.[107,108] The effects of shift work are felt early (84% of five cohorts of EM residents felt a need for intervention for their sleep deprivation and self-perceived exhaustion) and become more pronounced with age.[109,110] Sleep deprivation is associated with worse patient care, decreased job satisfaction, and less personal well-being, all of which contribute to burnout.[111]

Consequences of Burnout in Emergency Medicine

While the consequences of burnout for EPs are similar to those for physicians in general, certain areas deserve specific mention: clinical care, depression, substance abuse, SVS, and suicide.

Clinical Care

Like other physicians, burned-out EPs self-report delivering suboptimal clinical care and more often perceive they have erred medically.[73] Such EPs also have lower patient satisfaction scores and perform worse during high-fidelity simulations compared with their peers who are not burned out.[111, 112]

Physician Drop Out

Although attrition from EM has historically been low (1.7% per year, in a 2010 study), attrition rates do not account for those feeling "trapped" in their current jobs due to debt.[81,113] This may be one reasons why EPs are the second least happy at work behind physical medicine and rehabilitation.[11] EPs may forego further training or changing jobs due to debt, creating a feeling of hopelessness that further contributes to stress and burnout.[81] Ironically, further training in a subspecialty of EM could serve to reduce burnout by adding variation to an EP's work schedule and duty.[114]

Depression

Researchers have found rates of depression in EPs (12.1% - 19.3%) consistent with the Medscape survey of depression rates

in all respondents (11-15%). [11,115-116]

Self-medication

Both EPs and EM residents experience higher rates of substance abuse than other specialties, with studies estimating that 4.9-12.5% of EM residents drink daily.[116,117] Other research suggests that 7-18% of the physicians treated for substance abuse are EPs, despite only 4.7% of all physicians being EPs.[118-120]

Second Victim Syndrome

While no specialty-specific numbers exist, EPs seem especially susceptible to SVS. EPs rarely have time to debrief or grieve after an adverse patient outcome, because there is always the next patient.[37] Most EPs have a story about a patient dying despite their best efforts and then having to see a lower acuity patient unhappy because of an extended wait. This lack of processing time for patient deaths or medical errors may make EPs more susceptible to SVS and, by extension, burnout. Conversely, burned-out physicians are more likely to commit a medical error and have poorer job-coping skills. SVS is complex and intimately tied to depression and burnout, with all three contributing to and resulting from the others.[37] However, they are related: SVS, burnout, and depression may all result in an EP leaving the specialty in the most final way – suicide.

Suicide

While no specialty-specific data exists and the Medscape data may contain biased responses, extrapolation from that data suggests that, in the last year, as many as 6,000 EPs have contemplated and up to 400 have attempted suicide.[11,121] The following factors may explain why these numbers are so high: (a) EM seems to have a higher rate of gender-based harassment of women (45.3% vs 20.3%) than the medicine average;[122] (b) female physicians have a much higher rate of suicide than their general population counterparts (130% higher);[123] (c) there is an association between workplace harassment, depression and suicide;[122] and (d) physicians tend to "succeed" in their suicide attempts more often than the general population.[72]

CONCLUSION

While suicide is its ultimate tragic outcome, burnout is a complex condition resulting in many consequences. Since EPs are particularly vulnerable to burnout due to the system, culture and society in which they practice, we need to understand the complicated interaction between the signs, symptoms, causes, and consequences of burnout (Figure 1). This understanding can help create a path to recovery, both individually and as a specialty. As practitioners of a specialty who experience burnout at such high levels, EPs should take the lead in this recovery. Resources to aid in recovery will be found in Part II of this series, which discusses mitigating burnout and its consequences through *wellness*, "the anti-burnout."

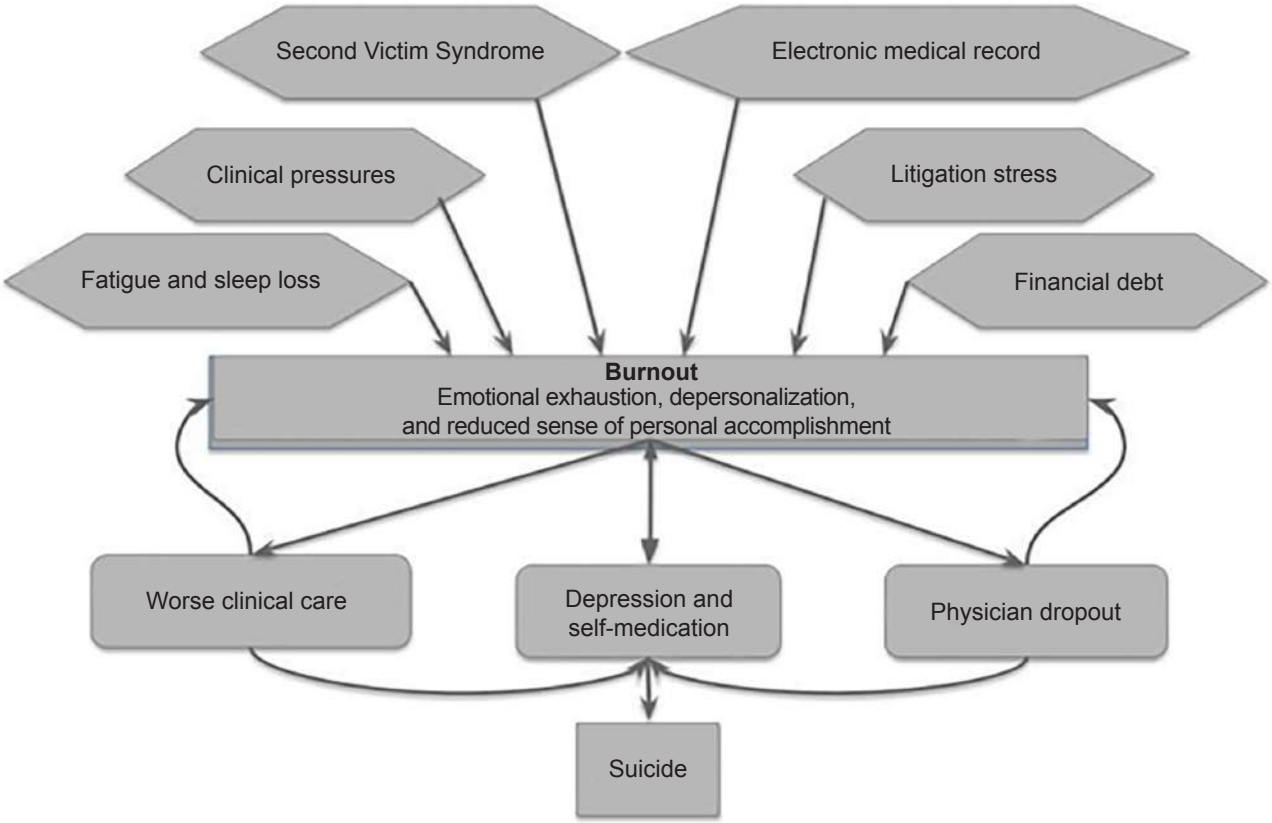


Figure 1. The causes and consequences of physician burnout.

Address for Correspondence: Adam R. Kellogg, MD, University of Massachusetts Medical School-Baystate Health, Department of Emergency Medicine, 759 Chesnut Street, Springfield, MA 01199. Email: adam.kellogg@baystatehealth.org.

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.

REFERENCES

1. West CP, Dyrbye LN, Erwin PJ, et al. Interventions to prevent and reduce physician burnout: a systematic review and meta-analysis. *Lancet*. 2016;388(10057):2272-81.
2. Freudenberger HJ. Staff burn-out. *J Soc Issues*. 1974;30(1):159-65.
3. Maslach C, Schaufeli WB, Leiter MP. Job burnout. *Annu Rev Psychol.* 2001;52:397-422.
4. Maslach C, Jackson S, Leiter M. The Maslach Burnout Inventory Manual. In: Zalaquett CP, Wood RJ, ed. Evaluating Stress: A Book of Resources. Lanham, MD: The Scarecrow Press; 1997:191-218.
5. Palamara K, Linzer M, Shanafelt TD. Addressing uncertainty in burnout assessment. *Acad Med.* 2018;93(4):518.
6. Halbesleben JR, Demerouti E. The construct validity of an alternative measure of burnout: investigating the English translation of the Oldenburg Burnout Inventory. *Work & Stress*. 2005;19(3):208-20.
7. Goldberg R, Boss RW, Chan L, et al. Burnout and its correlates in emergency physicians: four years' experience with a wellness booth. *Acad Emerg Med.* 1996;3(12):1156-64.
8. Shanafelt TD, Boone S, Tan L, et al. Burnout and satisfaction with work-life balance among US physicians relative to the general US population. *Arch Intern Med*. 2012;172(18):1377–85.
9. Emergency Medicine and Critical Care. Life in the Fast Lane Web site. Available at: https://litfl.com/emcc/. Accessed February 23, 2019.
10. Battle CU. The iatrogenic disease called burnout. *JAMWA* (1972). 1981;36(12):357.
11. Peckham C. Medscape National Physician Burnout & Depression Report 2019. Medscape. 2019. Available at: https://www.medscape.com/slideshow/2019-lifestyle-burnout-depression-6011056#2. Accessed February 23, 2019.
12. Shanafelt TD, West CP, Sinsky C, et al. Changes in burnout and satisfaction with work-life integration in physicians and the general US working population between 2011 and 2017. 2019. *Mayo Clin Proc*. In press.
13. Dyrbye LN, Massie FS, Eacker A, et al. Relationship between burnout and professional conduct and attitudes among US medical students. *JAMA*. 2010;304(11):1173-80.
14. Shanafelt TD, Bradley KA, Wipf JE, et al. Burnout and self-reported patient care in an internal medicine residency program. *Ann Intern Med*. 2002;136(5):358-67.
15. Dyrbye LN, Burke SE, Hardeman RR, et al. Association of clinical specialty with symptoms of burnout and career choice regret among US resident physicians. *JAMA*. 2018;320(11):1114–30.
16. Rodrigues H, Cobucci R, Oliveira A, et al. Burnout syndrome among medical residents: a systematic review and meta-analysis. *PloS One*. 2018;13(11):e0206840.
17. Raimo J, LaVine S, Spielmann K, et al. The correlation of stress in residency with future stress and burnout: a 10-year prospective cohort study. *J Grad Med Educ*. 2018;10(5):524-31.
18. Suran BG, Sheridan EP. Management of burnout: training psychologists in Professional Life Span Perspectives. *Prof Psychol Res Pr.* 1985;16(6):741-52.
19. Orlowski JP, Gulledge AD. Critical Care Stress and Burnout. *Crit Care Clin*. 1986;2(1):173-81.
20. Graham J, Ramirez AJ, Cull A, et al. Job stress and satisfaction among palliative physicians. *Palliat Med*. 1996;10(3):185-94.
21. Fields AI, Cuerdon TT, Brasseux CO, et al. Physician burnout in pediatric critical care medicine. *Crit Care Med*. 1995;23(8):1425-9.
22. Shanafelt TD, Bradley KA, Wipf JE, et al. Burnout and self-reported patient care in an internal medicine residency program. *Ann Intern Med*. 2002;136(5):358-67.
23. Deary IJ, Blenkin H, Agius RM, et al. Models of job-related stress and personal achievement among consultant doctors. *Br J Psychol.* 1996;87(1):3-29.
24. Shanafelt TD, Dyrbye LN, Sinsky C, et al. Relationship between clerical burden and characteristics of the electronic environment with physician burnout and professional satisfaction. *Mayo Clin Proc*. 2016;91(7):836-48.
25. Arndt BG, Beasley JW, Watkinson MD, et al. Tethered to the EHR: primary care physician workload assessment using EHR event log data and time-motion observations. *Ann Fam Med*. 2017;15(5):419-26.
26. Alexander AG, Ballou KA. Work-life balance, burnout, and the electronic health record. *Am J Med*. 2018;131(8):857-8.
27. Friedberg MW, Chen PG, Van Busum KR, et al. Factors affecting physician professional satisfaction and their implications for patient care, health systems, and health policy. *Rand Health Q*. 2014;3(4):1.
28. Wisenberg Brin, D. Taking the sting out of medical school debt. Association of American Medical Colleges Web site. 2017. Available at: https://news.aamc.org/medical-education/article/taking-sting-out-medical-school-debt/. Accessed March 9, 2019.
29. West CP, Shanafelt TD, Kolars JC. Quality of life, burnout, educational debt, and medical knowledge among internal medicine residents. *JAMA*. 2011;306(9):952-60.
30. Ahmad FA, White AJ, Hiller KM, et al. An assessment of residents' and fellows' personal finance literacy: an unmet medical education

need. *Int J Med Educ*. 2017;8:192-204.
31. Butcher L. A real education for future doctors: dealing with debt. American Association for Physician Leadership. 2018. Available at: https://www.physicianleaders.org/news/a-real-education-dealing-with-debt. Accessed March 9, 2019.
32. Wu AW. Medical error: the second victim. The doctor who makes the mistake needs help too. *BMJ*. 2000;320(7237):726-7.
33. Grissinger M. Too many abandon the "second victims" of medical errors. *Pharm Ther*. 2014;39(9):591-2.
34. Coughlan B, Powell D, Higgins MF. The second victim: a review. *Eur J Obstet Gynecol Reprod Biol*. 2017;213:11-16.
35. Tamburri LM. Creating healthy work environments for second victims of adverse events. *AACN Adv Crit Care*. 2017;28(4):366-74.
36. Gispen F, Wu AW. Psychological first aid: CPR for mental health crises in healthcare. *JPSRM*. 2018;23(2):51–3.
37. Lam R. Bouncing Back: The struggle of second victim syndrome. *Emergency Medicine News*. 2018;40(1):16.
38. Scott SD, Hirschinger LE, Cox KR, et al. Caring for our own: deploying a systemwide second victim rapid response team. *Jt Comm J Qual Patient Saf*. 2010;36(5):233-40.
39. Marmon LM, Heiss K. Improving surgeon wellness: the second victim syndrome and quality of care. *Semin Pediatr Surg*. 2015;24(6):315-8.
40. Denham CR. TRUST: the 5 rights of the second victim. *J Patient Saf*. 2007;3(2):107-19.
41. Wallace JE. Mental health and stigma in the medical profession. *Health (London)*. 2012;16(1):3-18.
42. Pham JC, Story JL, Hicks RW, et al. National study on the frequency, types, causes, and consequences of voluntarily reported emergency department medication errors. *J Emerg Med*. 2011;40(5):485-92.
43. Burlison JD, Scott SD, Browne EK, et al. The second victim experience and support tool: validation of an organizational resource for assessing second victim effects and the quality of support resources. *J Patient Saf*. 2017;13(2):93-102.
44. Quillivan RR, Burlison JD, Browne EK, et al. Patient safety culture and the second victim phenomenon: connecting culture to staff distress in nurses. *Jt Comm J Qual Patient Saf*. 2016;42(8):377-AP2.
45. Seys D, Scott S, Wu A, et al. Supporting involved health care professionals (second victims) following an adverse health event: a literature review. *Int J Nurs Stud*. 2013;50(5):678-87.
46. Dyrbye LN, Shanafelt TD, Sinsky CA, et al. Burnout among health care professionals: a call to explore and address this underrecognized threat to safe, high-quality care. National Academy of Medicine. 2017. Available at: https://nam.edu/burnout-among-health-care-professionals-a-call-to-explore-and-address-this-underrecognized-threat-to-safe-high-quality-care/. Accessed March 16, 2019.
47. Shanafelt TD, Balch CM, Bechamps G, et al. Burnout and medical errors among American surgeons. *Ann Surg*. 2010;251(6):995-1000.
48. Salyers MP, Bonfils KA, Luther L, et al. The relationship between professional burnout and quality and safety in healthcare: A meta-analysis. *J Gen Intern Med*. 2017;32(4):475-82.
49. Halbesleben JR, Rathert C. Linking physician burnout and patient outcomes: exploring the dyadic relationship between physicians and patients. *Health Care Manage Rev*. 2008;33(1):29-39.
50. Haas JS, Cook EF, Puopolo AL, et al. Is the professional satisfaction of general internists associated with patient satisfaction? *J Gen Intern Med*. 2000;15(2):122-8.
51. Smith KP, Christakis NA. Social networks and health. *Annu Rev Sociol*. 2008;34:405-29.
52. Christakis NA, Fowler JH. Social contagion theory: examining dynamic social networks and human behavior. *Stat Med*. 2013;32(4):556-77.
53. Landon BE, Reschovsky JD, Pham HH, et al. Leaving medicine: the consequences of physician dissatisfaction. *Med Care*. 2006;44(3):234-42.
54. Sinsky CA, Dyrbye LN, West CP, et al. Professional satisfaction and the career plans of US physicians. *Mayo Clin Proc*. 2017;92(11):1625-35.
55. Dewa CS, Loong D, Bonato S, et al. How does burnout affect physician productivity? A systematic literature review. *BMC Health Serv Res*. 2014;14:325.
56. Shah S. The real cost of emergency department physician turnover. The Studor Group. 2016. Available at: https://www.studergroup.com/resources/articles-and-industry-updates/insights/january-2016/the-real-cost-of-emergency-department-physician-tu. Accessed March 10, 2019.
57. Berg S. At Stanford, physician burnout costs at least $7.75 million a year. The American Medical Association. 2017. Available at: https://www.ama-assn.org/practice-management/physician-health/stanford-physician-burnout-costs-least-775-million-year. Accessed March 16, 2019.
58. Page L. Tired of Medicine? 20 Nonclinical Career Options. Medscape. 2018. Available at: https://www.medscape.com/viewarticle/893481_11. Accessed December 3, 2018.
59. Hengerer A, Kishore S. Breaking a culture of silence: The role of state medical boards. National Academy of Medicine. 2017. Available at: https://nam.edu/breaking-a-culture-of-silence-the-role-of-state-medical-boards/. Accessed March 9, 2019.
60. Dyrbye LN, West CP, Sinsky CA, et al. Medical licensure questions and physician reluctance to seek care for mental health conditions. *Mayo Clin Proc*. 2017;92(10):1486-93.
61. Hughes PH, Brandenburg N, Baldwin DC, et al. Prevalence of substance use among US physicians. *JAMA*. 1992;267(17):2333-9.
62. Oreskovich MR, Shanafelt T, Dyrbye LN, et al. The prevalence of substance use disorders in American physicians. *Am J Addict*. 2015;24(1):30-8.
63. Alcohol Facts and Statistics. National Institute on Alcohol Abuse and Alcoholism. 2019. Available at: https://www.niaaa.nih.gov/alcohol-health/overview-alcohol-consumption/alcohol-facts-and-statistics. Accessed March 14, 2019.
64. Kishore S, Dandurand DE, Mathew A, et al. Breaking the culture of silence on physician suicide. National Academy of Medicine. 2016. Available at: https://nam.edu/breaking-the-culture-of-silence-on-

physician-suicide/Accessed March 15, 2019.
65. Lindeman S, Laara E, Hakko H, et al. A systematic review on gender-specific suicide mortality in medical doctors. *Br J Psychiatry*. 1996;168(3):274-9.
66. Schernhammer ES, Colditz GA. Suicide rates among physicians: a quantitative and gender assessment (meta-analysis). *Am J Psychiatry*. 2004;161(12):2295-302.
67. Frank D. Dingle AD. Self-reported depression and suicide attempts among U.S. women physicians. *Am J Psychiatry*. 1999:156(12):1887-94.
68. Dyrbye LN, Thomas MR, Massie FS, et al. Burnout and suicidal ideation among U.S. medical students. *Ann Intern Med*. 2008;149(5):334-41.
69. Yaghmour NA, Brigham TP, Richter T, et al. Causes of death of residents in ACGME-accredited programs 2000 through 2014: implications for the learning environment. *Acad Med*. 2017;92(7):976-983.
70. Association of American Medical Colleges. 2017 State Physician Workforce Data Report. Available at: https://members.aamc.org/eweb/upload/2017%20State%20Physician%20Workforce%20Data%20Report.pdf. Accessed March 16, 2019.
71. Center C, Davis M, Detre T, et al. Confronting depression and suicide in physicians: a consensus statement. *JAMA*. 2003;289(23):3161-6.
72. Joiner T. The interpersonal-psychological theory of suicidal behavior: current empirical status. American Psychological Association. 2009. Available at: http://www.apa.org/science/about/psa/2009/06/sci-brief.aspx. Accessed March 13, 2019.
73. Lu DW, Dresden S, McCloskey C, et al. Impact of burnout on self-reported patient care among emergency physicians. *West J Emerg Med*. 2015;16(7):996-1001.
74. Kimo Takayesu J, Ramoska EA, Clark TR, et al. Factors associated with burnout during emergency medicine residency. *Acad Emerg Med*. 2014;21(9):1031-5.
75. Muller IR, Eldakar-Hein ST, Ames SE, et al. Potential association between physician burnout rates and operating margins: specialty-specific analysis. *J Med Pract Manage*. 2017;32(4):233.
76. Westbrook JI, Raban MZ, Walter SR, et al. Task errors by emergency physicians are associated with interruptions, multitasking, fatigue and working memory capacity: a prospective, direct observation study. *BMJ Qual Saf*. 2018;27(8):655-63.
77. Chang BP, Carter E, Ng N, et al. Association of clinician burnout and perceived clinician-patient communication. *Am J Emerg Med*. 2018;36(1):156-8.
78. Mareiniss DP. Emergency medicine burnout and abuse—one doctor's perspective. *Am J Emerg Med*. 2018;36(4):720-1.
79. Moukarzel A, Michelet P, Durand AC, et al. Burnout syndrome among emergency department staff: prevalence and associated factors. *BioMed Res Int*. 2019;(4):1-10.
80. Glaspy JN, Ma OJ, Steele MT, et al. Survey of emergency medicine resident debt status and financial planning preparedness. *Acad Emerg Med*. 2005;12(1):52-6.
81. Young TP, Brown MM, Reibling ET, et al. Effect of educational debt on emergency medicine residents: a qualitative study using individual interviews. *Ann Emerg Med*. 2016;68(4):409-18.
82. Silverman M. Beating the burnout blues. Emergency Physicians Monthly. 2015. Available at: http://epmonthly.com/article/beating-the-burnout-blues/. Accessed March 16, 2019.
83. Harris D, Willoughby H. Resuscitation on television: Realistic or ridiculous? A quantitative observational analysis of the portrayal of cardiopulmonary resuscitation in television medical drama. *Resuscitation*. 2009;80(11):1275-9.
84. Kuhn G, Goldberg R, Compton S. Tolerance for uncertainty, burnout, and satisfaction with the career of emergency medicine. *Ann Emerg Med*. 2009;54(1):106-13.
85. Schaufeli WB, Leiter MP, Maslach C. Burnout: 35 years of research and practice. *Career Dev Int*. 2009;14(3):204-20.
86. Niska R, Bhuiya F, Xu J. National Hospital Ambulatory Medical Care Survey: 2007 emergency department summary. *Natl Health Stat Report*. 2010;(26):1-31.
87. Committee on the Future of Emergency Care in the United States Health System. Hospital-based emergency care: at the breaking point. National Academies Press. 2007:17-27.
88. Rui P, Kang K. National Hospital Ambulatory Medical Care Survey: 2015 Emergency Department Summary Tables. Centers for Disease Control. Available at: http://www.cdc.gov/nchs/data/ahcd/nhamcs_emergency/2015_ed_web_tables.pdf. Accessed March 15, 2019.
89. National Resident Matching Program, Results and Data: 2018 Main Residency Match®. National Resident Matching Program, Washington, DC. 2018.
90. Hall MK, Burns K, Carius M, et al. State of the national emergency department workforce: who provides care where? *Ann Emerg Med*. 2018;72(3):302-7.
91. Hooker RS, Klocko DJ, Luke Larkin G. Physician assistants in emergency medicine: the impact of their role. *Acad Emerg Med*. 2011;18(1):72-7.
92. Fenton JJ, Jerant AF, Bertakis KD, et al. The cost of satisfaction: a national study of patient satisfaction, health care utilization, expenditures, and mortality. *Arch Intern Med*. 2012;172(5):405-11.
93. Kravitz RL, Epstein RM, Feldman MD, et al. Influence of patients' requests for direct-to-consumer advertised antidepressants: a randomized controlled trial. *JAMA*. 2005;293(16):1995-2002.
94. Macfarlane J, Holmes W, Macfarlane R, et al. Influence of patients' expectations on antibiotic management of acute lower respiratory tract illness in general practice: questionnaire study. *BMJ*. 1997;315(7117):1211-4.
95. Pham HH, Landon BE, Reschovsky JD, et al. Rapidity and modality of imaging for acute low back pain in elderly patients. *Arch Intern Med*. 2009;169(10):972-81.
96. Kennedy GD, Tevis SE, Kent KC. Is there a relationship between patient satisfaction and favorable outcomes? *Ann Surg*. 2014;260(4):592-8.
97. Farley H, Enguidanos ER, Coletti CM, et al. Patient satisfaction surveys and quality of care: an information paper. *Ann Emerg Med*. 2014;64(4):351-7.

98. Kalantari A, Rezaie S. Challenging the one-hour sepsis bundle. *West J Emerg Med*. 2019; 20(2)185-90.
99. Spiegel R, Farkas JD, Rola P, et al. The 2018 surviving sepsis campaign's treatment bundle: when guidelines outpace the evidence supporting their use. *Ann Emerg Med*. 2019.
100. Lathrop D. Disenfranchised grief and physician burnout. *Ann Fam Med*. 2017;15(4):375-78.
101. Chen KY, Yang CM, Lien CH, et al. Burnout, job satisfaction, and medical malpractice among physicians. *Int J Med Sci.* 2013;10(11):1471.
102. Jena AB, Seabury S, Lakdawalla D, et al. Malpractice risk according to physician specialty. *N Engl J Med*. 2011;365(7):629-36.
103. Charles SC. Coping with a medical malpractice suit. *West J Med*. 2001;174(1):55.
104. Andrew LB. Litigation Stress. MD Mentor. Available at: http://mdmentor.com/resources/eMedicine+Litigation+Stress.pdf. Accessed March 16, 2019.
105. Kanzaria HK, Hoffman JR, Probst MA, et al. Emergency physician perceptions of medically unnecessary advanced diagnostic imaging. *Acad Emerg Med*. 2015;22(4):390-8.
106. Jackson Healthcare. Physician study: quantifying the cost of defensive medicine. Available at: https://jacksonhealthcare.com/media-room/surveys/defensive-medicine-study-2010/. Accessed March 16, 2019.
107. Hartenbaum NP, Zee PC. Shift work and sleep optimizing health, safety, and performance. *J Occup Environ Med*. 2011;53(5)S1-10.
108. Violanti JM, Hartley TA, Gu JK, et al. Life expectancy in police officers: a comparison with the US general population. *Int J Emerg Ment Health*. 2013;15(4):217.
109. Papp KK, Stoller EP, Sage P, et al. The effects of sleep loss and fatigue on resident-physicians: a multi-institutional, mixed-method study. *Acad Med*. 2004;79(5):394-406.
110. Nelson D. Prevention and treatment of sleep deprivation among emergency physicians. *Pediatr Emerg Care*. 2007;23(7):498-503.
111. Machi MS, Staum M, Callaway CW, et al. The relationship between shift work, sleep, and cognition in career emergency physicians. *Acad Emerg Med*. 2012;19(1):85-91.
112. Lu DW, Weygandt PL, Pinchbeck C, et al. Emergency medicine trainee burnout is associated with lower patients' satisfaction with their emergency department care. *AEM E&T*. 2018;2(2):86-90.
113. Ginde AA, Sullivan AF, Camargo CA. Attrition from emergency medicine clinical practice in the United States. *Ann Emerg Med*. 2010;56(2):166-71.
114. Cameron PA. Will Subspecialization benefit the practice of Australasian emergency medicine? Yes. *Emerg Med Australas*. 2016;28(4):471-2.
115. Katz ED, Sharp L, Ferguson E. Depression among emergency medicine residents over an academic year. *Acad Emerg Med*. 2006;13(3):284-7.
116. McBeth BD, Ankel FK, Ling LJ, et al. Substance use in emergency medicine training programs. *Acad Emerg Med*. 2008;15(1):45-53.
117. Hughes PH, Conard SE, Baldwin DC, et al. Resident physician substance use in the United States. *JAMA*. 1991;265(16):2069-73.
118. Hughes PH, Storr CL, Brandenburg NA, et al. Physician substance use by medical specialty. *J Addict Dis*. 1999;18(2):23-37.
119. Cottler LB, Ajinkya S, Merlo LJ, et al. Lifetime psychiatric and substance use disorders among impaired physicians in a physicians health program: comparison to a general treatment population. *J Addict Med*. 2013;7(2):108.
120. McLellan AT, Skipper GS, Campbell M, et al. Five year outcomes in a cohort study of physicians treated for substance use disorders in the United States. *BMJ*. 2008;337:a2038.
121. Active Physicians in the Largest Specialties, 2017. American Association of Medical Colleges. Available at: https://www.aamc.org/data/workforce/reports/492556/1-1-chart.html. Accessed March 14, 2019.
122. Frank E, Brogan D, Schiffman M. Prevalence and correlates of harassment among US women physicians. *Arch Intern Med*. 1998;158(4):352-8.
123. Schernhammer E. Taking their own lives -- the high rate of physician suicide. *N Engl J Med*. 2005;352(24):2473-6.

Response to: "Emergency Medicine Physician Assistant Postgraduate Training Programs: Program Characteristics and Training Curricula"

Chadd Kraus, DO, DrPH, MPH* *Geisinger Health System, Department of Emergency Medicine, Danville, Pennsylvania
Terry E. Carlisle, PA-C, MPAS† †University of Missouri-Columbia, Department of Emergency Medicine, Columbia, Missouri
Devin M. Carney, BHS‡ ‡University of Missouri-Columbia, Columbia, Missouri

Section Editor: Mark I. Langdorf, MD, MHPE
Submission history: Submitted November 19, 2018; Accepted December 14, 2018
Electronically published April 23, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.12.43459
[West J Emerg Med. 2019;20(3)495-496.]

Dear Editor:

We thank Mr. Wu, PA-C, MHS (President, the Society of Emergency Medicine Physician Assistants [SEMPA]) for his insightful letter in response to our paper, "Emergency Medicine Physician Assistant (EMPA) Postgraduate Training Programs: Program Characteristics and Curricula."[1,2]

As Mr. Wu notes, SEMPA continues to lead the EM specialty-specific training of EMPAs, including through their postgraduate training and practice standards.[3,4] The discussion in our paper was approached from the perspective and framing of EMPA training and certification in the context of physician postgraduate training found in EM residency programs. As our results suggest, there are some similarities, although variability remains in EMPA training program curricula. The rapid growth of EMPA postgraduate programs highlights the appetite for this training and underscores the need to establish formalized educational and curriculum standards such as those developed by SEMPA to provide structure and quality assurance for new and old programs alike. As with EM residency and fellowship programs for physicians, accreditation and certification are key to ensuring the best education and training for EMPAs in the context of a rapid expansion in the number of EMPA programs.

The training standards developed by EMPA program directors and endorsed by SEMPA are voluntary. The next step in the evolution of EMPA postgraduate training would be for these SEMPA standards to become codified in a way that EMPA training programs would be required to use, in the same way that accredited EM training programs use the "Model of the Clinical Practice of Emergency Medicine,"[5] which outlines the core content of knowledge, skills, and abilities expected of an emergency physician certified by the American Board of Emergency Medicine.

The intent of our paper was to compare the current pathway for EMPA postgraduate training to EM residency training. While EMPAs have continuing education requirements related to their national certification and state licensure and can earn and maintain certificate of added qualification in EM, there remains an opportunity for the development of formal certification and maintenance of certification (analogous to board certification for emergency physicians) for those PAs who have completed EM-specific postgraduate training or who might be "grandfathered" via a practice track. While the accreditation process of the Accreditation Review Commission on Education for the Physician Assistant (ARC-PA) is in abeyance, our opinion is that an accrediting organization similar to the Accreditation Council for Graduate Medical Education for medical residencies could accomplish the goal of required, rather than voluntary, standards for EMPA training.

We agree with SEMPA that there remain several pathways to becoming an EMPA, including practice-based training. However, in the future, workforce and market demands might require formal training in order to be competitive from an employment standpoint, although that is currently not the case. Additionally, formal training might allow EMPAs to recognize their unique and specialized training and skills and to distinguish themselves from other providers in EM, and from PAs in other fields of medical practice.

We agree with Mr. Wu and SEMPA that EMPAs are invaluable members of the EM workforce now and into the future. And we applaud the ongoing work of SEMPA in the development of EMPA training. We hope that our research provides a foundation for future development of standardized, accredited training programs for emergency medicine physician assistants.

Address for Correspondence: Chadd Kraus, DO, DrPH, MPH, Geisinger Health System, Department of Emergency Medicine, MNC:20-05, 100 North Academy Avenue, Danville, PA 17822. Email: chaddkraus@gmail.com

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.

REFERENCES

1 Kraus CK, Carlisle TE, Carney DM. Emergency Medicine Physician Assistant (EMPA) postgraduate training programs: program characteristics and training curricula. *West J Emerg Med*. 2018;19(5):803-807.

2 Wu F. Letter to the Editor: Emergency Medicine Physician Assistant (EMPA) postgraduate training programs: program characteristics and training curricula. *West J Emerg Med*. 2019;20(2):305-6.

3 Society of Emergency Medicine Physician Assistants (SEMPA). Emergency Medicine Physician Assistant Postgraduate Training Program Standards. 2015. Available at: https://www.sempa.org/globalassets/sempa/media/pdf/professional-development/sempa-postgraduate-training-program-standards.pdf. Accessed November 16, 2018.

4 Society of Emergency Medicine Physician Assistants (SEMPA). Emergency Medicine Physician Assistant Postgraduate Training and Emergency Medicine Physician Assistant Practice Guidelines. Available at: https://www.sempa.org/globalassets/sempa/media/pdf/about-sempa/ns---sempas-training-and-empa-practice-guidelines.pdf. Accessed November 16, 2018.

5 The American Board of Emergency Medicine (ABEM). 2016 Model of the Clinical Practice of Emergency Medicine. Available at: https://www.abem.org/public/docs/default-source/default-document-library/2016-em-model.pdf?sfvrsn=0. Accessed: November 16, 2018.

Antivenom Treatment Is Associated with Fewer Patients using Opioids after Copperhead Envenomation

Caroline E. Freiermuth, MD*
Eric J. Lavonas, MD†
Victoria E Anderson, MPH†
Kurt C. Kleinschmidt, MD‡
Kapil Sharma, MD‡
Malin Rapp-Olsson, MS†
Charles Gerardo, MD*
Copperhead Recovery Workgroup (Page 503)

*Duke University, Division of Emergency Medicine, Durham, North Carolina
†Denver Health and Hospital Authority, Rocky Mountain Poison and Drug Center, Denver, Colorado
‡University of Texas Southwestern Medical Center, Department of Emergency Medicine, Dallas, Texas

Section Editor: Jeffrey Suchard, MD
Submission history: Submitted February 7, 2019; Revision received March 29, 2019; Accepted March 20, 2019
Electronically published April 26, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.3.42693

Introduction: Copperhead envenomation causes local tissue destruction, leading people to seek treatment for the pain and swelling. First-line treatment for the pain is opioid medications. There is rising concern that an initial opioid prescription from the emergency department (ED) can lead to long-term addiction. This analysis sought to determine whether use of Fab antivenom (FabAV) for copperhead envenomation affected opioid use.

Methods: We performed a secondary analysis using data from a randomized clinical trial designed to determine the effect of FabAV on limb injury recovery following mild to moderate copperhead envenomation. Opioid use was a defined secondary outcome in the parent trial. Patients were contacted after discharge, and data were obtained regarding medications used for pain and the patients' functional status. This analysis describes the proportion of patients in each treatment group reporting opioid use at each time point. It also assesses the interaction between functional status and use of opioids.

Results: We enrolled 74 patients in the parent trial (45 received FabAV, 29 placebo), of whom 72 were included in this secondary analysis. Thirty-five reported use of any opioids after hospital discharge. A smaller proportion of patients treated with FabAV reported opioid use: 40.9% vs 60.7% of those in the placebo group. The proportion of patients using opioids remained smaller in the FabAV group at each follow-up time point. Controlling for confounders and interactions between variables, the model estimated that the odds ratio of using opioids after hospital discharge among those who received placebo was 5.67 times that of those who received FabAV. Patients who reported higher baseline pain, those with moderate as opposed to mild envenomation, and females were more likely to report opioid use at follow-up. Patients with ongoing limitations to functional status had an increased probability of opioid use, with a stronger association over time. Opioid use corresponded with the trial's predefined criteria for full recovery, with only two patients reporting opioid use in the 24 hours prior to achieving full limb recovery and no patients in either group reporting opioid use after full limb recovery.

Conclusion: In this study population, the proportion of patients using opioids for pain related to envenomation was smaller in the FabAV treatment group at all follow-up time points. [West J Emerg Med. 2019;20(3)497–505.]

INTRODUCTION

Between 5000 and 9000 persons in the United States (U.S.) seek treatment in an emergency department (ED) for snakebite each year.[1] There were 2048 calls to U.S. poison control centers in 2016 from patients who experienced copperhead bites, of whom 1962 sought treatment in a healthcare facilty.[2] There were close to another 2000 calls in which the type of snake was not identified.[2] Severe manifestations of crotaline envenomation include coagulopathy, hypotension, shock and death; however, these are rare complications in copperhead envenomations.[3,4,5]

Essentially all copperhead envenomations cause local tissue injury, leading to inflammation, necrosis and endothelial damage.[6,7,8] Edema and pain are the predominant symptoms that contribute to the morbidity of disease in the weeks following a copperhead envenomation.[6,7,8] Expert consensus guidelines recommend avoiding aspirin and nonsteroidal anti-inflammatory drugs (NSAID) due to concern for bleeding, platelet dysfunction, and risk for prerenal toxicity.[9,10] This leaves opioids as the current recommended means of pain control for patients suffering a copperhead envenomation.[9,10]

The current overuse and abuse of opioids has been declared an epidemic. The Centers for Disease Control and Prevention recently published guidelines to minimize the duration of opioid prescriptions.[11] Many states have enacted legislation to limit prescriptions for opioid medications.[12] Emerging data suggest that opioid prescriptions from the ED may contribute to long-term opioid use and potential abuse.[13,14] Regardless of the cause for pain, increasing the duration of the initial opioid prescription decreased the likelihood that patients would discontinue opioids.[15] Balancing the benefit of pain control and the risk of opioids, including potential for addiction, is clinically challenging.[16]

The primary objective of this secondary analysis was to describe post-discharge opioid use in subjects who suffered mild to moderate copperhead envenomation and were randomized to receive Crotalidae polyvalent immune Fab (ovine) antivenom (CroFab®, BTG International Inc., West Conshohocken, Pennsylvania) or placebo. A secondary objective was to explore the correlation between post-discharge opioid use and limb function recovery.

Population Health Research Capsule

What do we already know about this issue?
Expert consensus guidelines call for avoidance of nonsteroidal anti-inflammatory drugs in patients suffering from copperhead envenomation. Opioids continue to be the recommended medication for their pain management.

What was the research question?
Does treatment with Fab antivenom (FabAV) in patients who experience a copperhead envenomation affect opioid use?

What was the major finding of the study?
The proportion of patients using opioids for copperhead envenomation pain was smaller in the FabAV group in comparison to placebo.

How does this improve population health?
The risk of iatrogenic addiction when prescribing opioids from the emergency department remains uncertain. This study suggests FabAV treatment decreases likelihood of opioid use after a copperhead envenomation.

METHODS

Study Design

This study is a secondary analysis of a multicenter, randomized, double-blind, placebo-controlled trial of Fab antivenom (FabAV) vs placebo in patients with mild or moderate copperhead snake envenomation. The methods of this trial, including participant selection, randomization, treatment, and the full study protocol have been previously published.[17] Use of opioid medications was defined as a secondary outcome measure during the design of the parent study. Patients aged 12 years or older with a mild or moderate copperhead envenomation to the distal arm or leg presenting within 24 hours of envenomation were randomized to receive FabAV or saline placebo. Mild bites were defined as swelling that crossed 0-1 major joints (wrist, elbow, ankle or knee) and moderate bites were defined as swelling that crossed two major joints. The randomization was stratified by severity (mild vs moderate), age (adult vs adolescent), and extremity affected (upper vs lower). Patients were identified and enrolled in the ED.

Study Protocol

Patients randomized to FabAV received an initial dose of six vials in 250 milliliters (mL) of normal saline solution. A repeat dose of six vials of FabAV was administered to patients who failed to achieve initial control after the first dose. All patients were then administered two vials of FabAV at 6, 12, and 18 hours after initial control. Patients randomized to receive placebo received normal saline solution. Patients were treated by the emergency physician on duty upon presentation. Consult with poison control or a toxicologist was at the discretion of the treating physician.

All other therapies administered to patients, including fluids, antiemetics, and pain medications, were at the discretion of the treating clinicians. Patients were admitted to the hospital or observed in the ED based on local hospital practice. Any medications prescribed at discharge were also decided upon by the treating clinician.

Measures

The primary outcome measure for this secondary analysis was patient-reported, post-discharge opioid analgesic use during the 28 days following envenomation from a copperhead snakebite. We defined opioid analgesic use as an a priori secondary outcome of the initial study. Patients were evaluated on days 3, 7, 10, 14, 17, 21, 24, and 28 post-envenomation. At each post-envenomation time point, patients were asked to report all concomitant medication use. This included all analgesic medications used in the 24 hours prior to each assessment. They were asked specifically to report only on analgesic medications used to treat the pain associated with their snakebite. Analgesic use was classified as a dichotomous variable: "Opioid use" (including tramadol and combination products) and "No opioid use," which included reported use of prescription analgesics (non-opioid), non-prescription analgesics, and no analgesics.

A secondary outcome for this study was to explore the relationship between the main trial's primary measure of limb function recovery, the Patient-Specific Functional Scale (PSFS)[18], and post-discharge opioid analgesic use. The PSFS was administered at all follow-up visits. This measure asked patients to report their ability to perform three self-identified important activities that they were unable to do or were having trouble doing as a result of their snakebite on a scale of 0 ("unable to perform activity") to 10 ("able to perform activity at the same level as before injury or problem"). We calculated the mean score of all three activities, with larger values indicating more complete limb function recovery and a mean score of 10 indicating full recovery.

Data Analysis

We conducted all statistical analyses on the modified intent-to-treat population. Two patients were excluded: one in the placebo group was lost to follow-up after discharge and did not have any post-discharge assessments completed; and a second in the treatment group who had falsified his snakebite was discontinued from the study by the treating investigator prior to unblinding of treatment arm. The patient with the falsified snakebite was included in the analyses for the parent paper, and was the only patient in the FabAV treatment group taking opioids at the 28-day follow-up. He was excluded from this analysis, as our primary goal was to determine whether FabAV for the treatment of copperhead snake envenomation affected use of opioids. The decision to exclude him from the secondary analysis was made prior to the design of the analysis plan.

We used summary statistics to describe characteristics of patients with any post-discharge, opioid analgesic use and those with no post-discharge opioid use. Additionally, the proportion of patients reporting opioid analgesic use was summarized for each follow-up time point, separated by treatment group. The differences between treatment groups are presented with exact 95% confidence intervals and p-values from a two-tailed Wald equivalence test.

To study the relationship between opioid use, functional status, and treatment with FabAV, we modeled the mean probability of opioid use across all visits using generalized estimating equations (GEE). A first-order autoregressive covariance structure was chosen to model the within-subject variance from visit to visit. The GEE model included effects for treatment group, visit number, PSFS score, envenomation severity (mild vs moderate), envenomation location (upper vs lower extremity), sex, age category (adolescent vs adult), time to treatment, and the interactions between treatment group and PSFS score, treatment group and visit number, and visit number and PSFS. We performed a backward stepwise regression and sequentially removed non-significant effects (defined as $p>0.10$ for interaction terms and $p>0.05$ for main effects). Once the model was finalized, each excluded term was added back separately to ensure that it did not drastically affect the results of the model, ensuring that there were no interactions unaccounted for in the final model. Results are presented as the mean probability of opioid use across all visits and the odds ratio of opioid use among patients treated with FabAV compared to those treated with placebo.

Missing values for opioid use and PSFS scores were imputed using the last observation carried forward method.

RESULTS

Demographics and clinical characteristics

We included 72 patients in this secondary analysis. Thirty-five (48.6%) patients reported use of an opioid at least once at a post-discharge, follow-up time point. A greater proportion of patients in the placebo group, those with moderate severity envenomation, females, and those patients with higher baseline pain scores reported post-discharge opioid analgesic use (Table 1). Rates of opioid use were similar between patients who suffered an upper extremity envenomation when compared to those who suffered a lower extremity envenomation.

Primary outcome

A greater proportion of patients treated with placebo reported opioid analgesic use at each follow-up time point compared to those treated with FabAV (Figure 1). All patients who experienced a copperhead snake envenomation and were treated with FabAV discontinued opioids by 21 days post-envenomation. There were patients within the placebo group who reported opioid use at each time point assessed (Table 2).

Table 1. Demographic and clinical characteristics of subjects with mild or moderate copperhead envenomation, reported by use of post-discharge opioid analgesics.

	Any post-discharge opioid use N=35	No post-discharge opioid use N=37	Total N=72
Treatment, N (%)			
FabAV	18 (40.9%)	26 (59.1%)	44
Placebo	17 (60.7%)	11 (39.3%)	28
Age in years: mean (SD)	41.3 (15.95)	45.3 (19.28)	43.3 (17.73)
Age category, N (%)			
Adolescent	4 (50.0%)	4 (50.0%)	8
Adult	31 (48.4%)	33 (51.6%)	64
Baseline pain score*: mean (SD)	6.8 (2.57)	4.9 (2.83)	5.8 (2.85)
Envenomation location, N (%)			
Lower extremity	22 (48.9%)	23 (51.1%)	45
Upper extremity	13 (48.1%)	14 (51.9%)	27
Envenomation severity, N (%)			
Mild	29 (45.3%)	35 (54.7%)	64
Moderate	6 (75.0%)	2 (25.0%)	8
Gender, N (%)			
Female	19 (54.3%)	16 (45.7%)	35
Male	16 (43.2%)	21 (56.8%)	37
Hours to treatment mean (SD)	6.8 (5.06)	7.4 (5.53)	7.1 (5.28)

*Pain scores were evaluated using the 11-point numerical rating scale, with values ranging from 0 (no pain) -10 (worst pain ever).
FabAV, Fab antivenom; *SD*, standard deviation.

In the main outcomes publication, Figure 3 does show that there was opioid use in the FabAV group at day 28.[17] This represented one patient, who was one of the two patients excluded from this secondary analysis. This patient was found to have falsified a snakebite; thus, opioids taken would not have been used for treatment of pain associated with envenomation.

Secondary outcomes

The final GEE model included the effects for treatment, visit number, PSFS score, the interaction between treatment and visit number, and the interaction between visit number and PSFS score. The model estimated mean probability of subjects using an opioid, after adjusting for time, PSFS, and the interaction between the two, was lower for the FabAV treatment group than the placebo group (Table 3). Overall, adjusting for other factors, patients in the placebo group were 5.67 times as likely to use an opioid post-discharge compared to patients in the FabAV group (p=0.008; Table 3).

In the GEE model, multiple variables were found to influence each other. The interaction between treatment and visit number was significant, indicating the effect of treatment on opioid use was dependent on time (p=0.028; Table 4). The estimated odds of opioid use was higher in the group treated with FabAV at each time point, with increasing odds as time passed. At three days post-envenomation, the estimated odds of using opioids among the group treated with placebo was 1.38 times that of the FabAV group (95% CI 0.58, 3.27); by 14 days post-envenomation, the odds were 4.63 times for the placebo group in comparison to FabAV (95% CI 1.47, 14.62). The interaction between visit number and PSFS score was significant (p=0.042; Table 4). Patients with poor functional recovery, demonstrated by lower PSFS scores, were more likely to use opioids; this association also appeared stronger over time. At three days post-envenomation, PSFS score of one point lower was associated with a 1.08 times greater odds of opioid use (95% CI 0.97, 1.20). At 14 days post-envenomation, the odds were 1.29 times greater (95% CI 1.14, 1.47) and at 28 days post-envenomation the odds increased to 1.65 (95% CI 1.26, 2.17).

Finally, only two patients (both in the FabAV group) reported using opioids in the 24 hours prior to achieving full limb function recovery on the PSFS, and no subjects in either treatment group reported using opioids after reaching full recovery.

Missing Values

Overall, only 3.5% of missing opioid use values were imputed. Within the placebo group, three patients had a total of eight imputed values; for the treatment group, six patients had a total of 12 imputed values.

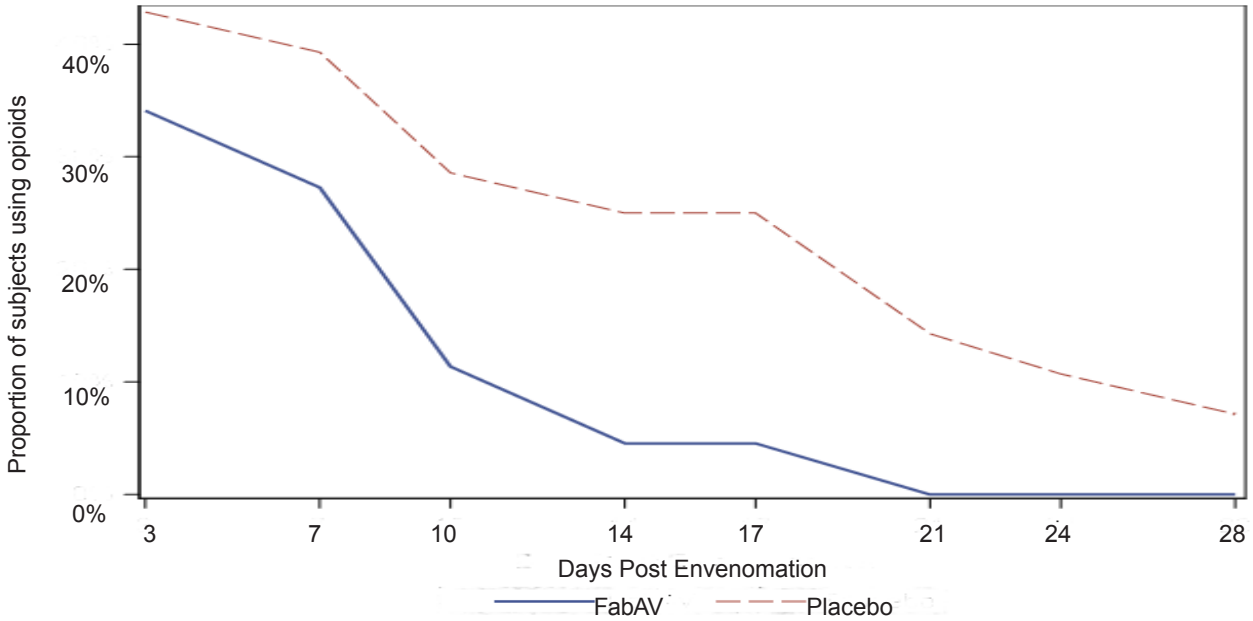


Figure 1. Proportion of subjects with mild or moderate copperhead envenomation who reported using opioid analgesics in the previous 24 hours.
FabAV, Fab antivenom.

DISCUSSION

Although antivenom administration is the standard of care for rattlesnake envenomation, its use in copperhead envenomation has been controversial.[9,10,17,19-21] This debate has been influenced by the low mortality associated with these bites, questionable effects on coagulation, the high cost of the drug, and the prior uncertainty about the efficacy for recovery from tissue injury.[20, 22-24] There is also concern about allergic reaction to antivenom, although this is a rare occurrence since the ovine preparation used in FabAV was developed.[25,26] A recent study did find that patients had earlier return of limb function following mild to moderate copperhead envenomation after treatment with FabAV.[17] This same study found that subjects who were treated with FabAV also had lower pain scores and less opioid use than those subjects who were treated with placebo.[17] The main argument against antivenom that now remains is one of cost vs benefit.[27,28]

It is often hard to predict how long patients will require pain control when they are seen at the time of initial injury. In general, patients with mild to moderate envenomation due to a copperhead bite have ongoing pain and swelling on average for about two weeks, although some have symptoms for prolonged periods of time.[6,7,17,29] This secondary analysis found that less than half of all patients who suffered a copperhead envenomation required any use of opioids as an outpatient. Of note, those patients who were treated with FabAV had a decreased likelihood of opioid use and ceased use of opioids sooner than those subjects who received placebo.

There is no consensus in the literature about what initial duration or amount of opioid leads to addiction. In the opioid-naïve patient, it has been found that opioid prescriptions from the ED are associated with a lower risk of progression to long-term use than those prescribed in other settings.[30] However, emerging data suggest that receipt of initial opioid prescriptions from the ED can contribute to long-term opioid abuse and addiction.[14,15] There is a sharp increase in the probability of ongoing opioid use at one year when the initial prescription is for a duration of more than five days (hazard ratio for discontinued use one year after a 3-4 day supply 0.70; hazard ratio for discontinued use one year after a 5-7 day supply 0.48).[15] This suggests that the risks of side effects from opioids and potential for long-term addiction should play a role in the decision-making process when considering treatment with antivenom following a copperhead envenomation. The risk and resultant cost of treatment for long-term addiction must also factor into any cost benefit analyses when discussing treatment with FabAV.

No current literature defines the number of patients who develop opioid use disorder after suffering a copperhead envenomation. Male gender and a younger age are both risk factors for the development of opioid use disorder.[32] These same patient characteristics are associated with increased risk of unintentional snake envenomation.[33,34] Although males are at higher risk for opioid use disorder, the rate at which females overdose on prescription opioids is much higher.[35] In this study, we found that females were more likely to use opioids after a snake envenomation. While we do not know what the rate of opioid overdose might be in this specific

Table 2. Proportion of subjects with mild or moderate copperhead envenomation who reported using opioid analgesics in the previous 24 hours by time post-envenomation and treatment group.

Days from envenomation	Treatment	Opioid use (%)	Difference between treatment groups (95% CI)	P-value
3	Fab AV	34.1%	-8.8% (-31.8%, 14.3%)	0.456
	Placebo	42.9%		
7	Fab AV	27.3%	-12.0% (-34.4%, 10.4%)	.0293
	Placebo	39.3%		
10	Fab AV	11.4%	-17.2% (-36.4%, 2.0%)	0.079
	Placebo	28.6%		
14	Fab AV	4.5%	-20.5% (-37.6%, -3.3%)	0.020
	Placebo	25.0%		
17	Fab AV	4.5%	-20.5% (-37.6%, -3.3%)	0.020
	Placebo	25.0%		
21	Fab AV	0.0%	-14.3% (-27.2%, -1.3%)	0.031
	Placebo	14.3%		
24	Fab AV	0.0%	-10.7% (-22.2%, 0.7%)	0.067
	Placebo	10.7%		
28	Fab AV	0.0%	-7.1% (-16.7%, 2.4%)	0.067
	Placebo	7.1%		

FabAV, Fab antivenom; *CI*, confidence interval.

patient population, any treatment that decreases the need for opioids, and therefore the risk for opioid dependence and addiction, should be considered.

There is another sharp increase in the probability of opioid use at one year when the initial prescription went beyond 30 days.[15] Receiving a refill opioid prescription was also associated with an increased risk of ongoing opioid use at one year.[15] In this secondary analysis, all copperhead snake envenomation subjects in the FabAV treatment arm had discontinued opioids by day 21, while 7% of the patients in the placebo group reported ongoing opioid use at 28 days post-envenomation. We did not follow patients beyond 28 days post-envenomation, but this raises concerns that the patients in the placebo group who continued to use opioids were at risk for development of opioid use disorder.

The parent study used the PSFS to report limb function disability following envenomation. This scale was initially designed to measure functional changes in patients with musculoskeletal disorders.[18] It has since been validated in snakebite-envenomation patient populations.[7,29,31] In this secondary analysis, we find that cessation of opioids correlates to an improvement in the PSFS. This further validates use of PSFS as a marker for patient recovery. It is especially concerning that the risk of opioid use with lack of improved PSFS scores, indicating ongoing disability, increased with time.

LIMITATIONS

This study is a secondary analysis of data that were collected prospectively in a blinded fashion during the parent clinical trial. Use of opioid analgesics was defined as a secondary outcome measure a priori; this analysis was planned prior to any data review. However, the results should be treated as exploratory due to the design limitation. Future studies should focus on opioid use as a primary outcome and ultimately the impact of antivenom on opioid dependence consequent to snake envenomation. The latter will require large numbers and pragmatic designs.

These analyses relied on patient self-reported use of analgesics. We did not collect data on the doses that patients were taking or whether the medication was from an initial prescription or if they required a second prescription due to ongoing pain. Further study would be needed to determine whether non-opioid medications or non-pharmacologic means of pain treatment are as effective as opioids and whether they can be safely used to treat pain associated with copperhead envenomations.

The parent study did not limit use of concomitant treatments in the ED, such as pain medications, fluids or antiemetics. It is possible that use of these may influence patient experience of acute pain and need for ongoing treatment for pain after discharge. Additionally, opioid prescriptions were given at the discretion of the blinded treating physician and not determined by the study protocol. Simply receiving a prescription for opioids may influence whether patients take these medications.

Table 3. Model estimated marginal mean probability of opioid analgesic use in subjects with mild or moderate copperhead envenomation.

Treatment group	Mean (standard error) probability of opioid use	Odds ratio	p-value
FabAV	0.036 (0.019)		0.008
Placebo	0.175 (0.047)	5.67 (1.57, 20.45)	

FabAV, Fab antivenom.

Table 4. Results of generalized estimating equations model of probability of opioid use in subjects with mild or moderate copperhead envenomation by fixed effect.

Effect	Chi-square	p-value
Treatment	1.83	0.177
Time (visit number)	0.14	0.707
PSFS score	1.77	0.183
Time *treatment interaction	4.84	0.028
Time *PSFS interaction	4.15	0.042

PSFS, Patient-specific functional scale.

This study only enrolled patients with a mild or moderate copperhead envenomation. As these envenomations tend to be less severe than those of other Crotalinae snakes, it is unclear whether opioid use would differ based on FabAV treatment for envenomations of other snake species. It is also unclear whether the more common systemic effects in other snake envenomations may affect the use and duration of opioid treatments. We were unable to perform subanalyses to determine whether the degree of envenomation (mild vs moderate) affected opioid use due to the low number of patients in the subgroups. This would be important to study if future studies enroll a larger number of patients.

CONCLUSION

In a randomized, double-blind, placebo-controlled trial of Fab antivenom vs placebo, patients who received FabAV had a decreased likelihood of opioid use. Lower numbers on the Patient-Specific Functional Scale, indicating ongoing disability when compared to baseline, correlated with a greater probability of opioid use.

Address for Correspondence: Caroline Freiermuth, MD, University of Cincinnati, Department of Emergency Medicine, 231 Albert Sabin Way Box 670769, Cincinnati, OH 45267-0769. Email: eadyce@ucmail.uc.edu.

Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. The original trial was funded by BTG International Inc. Funding for the statistical analysis for this secondary analysis was also provided by BTG International Inc. Drs Gerardo and Lavonas report receiving grants from BTG during the original trial and outside of the submitted work. Dr. Kleinschmidt and Ms. Anderson report receiving study-related funds from BTG.

Members of the Copperhead Recovery Working Group:

Sean Bush, MD[1]
Michael Mullins, MD[2]
Spencer Greene, MD[3]
Eric Toschlog, MD[4]
Eugenia Quackenbush, MD[5]
S. Rutherford Rose, PharmD[6]
Richard Schwartz, MD[7]
Nathan Charlton, MD[8]
Brandon Lewis, DO[9]
Nicklaus Brandehoff, MD[10]

[1]Brody School of Medicine, Department of Emergency Medicine, Greenville, North Carolina
[2]Washington University School of Medicine, Division of Emergency Medicine, St. Louis, Missouri
[3]Baylor College of Medicine, Department of Emergency Medicine, Houston, Texas
[4]Brody School of Medicine, Department of Surgery, Greenville, North Carolina
[5]University of North Carolina, Department of Emergency Medicine, Chapel Hill, North Carolina
[6]Virginia Commonwealth University, Department of Emergency Medicine, Richmond, Virginia
[7]Medical College of Georgia, Department of Emergency Medicine and Hospital Services, Augusta, Georgia
[8]University of Virginia, Department of Emergency Medicine, Charlottesville, Virginia
[9]Texas A&M Health Science Center, Department of Emergency Medicine, College Station, Texas
[10]Rocky Mountain Poison and Drug Center, Denver, Colorado

REFERENCES

1. O'Neil ME, Mack KA,Gilchrist J, et al.. Snakebite injuries treated in the United States emergency departments, 2001-2004. *Wilderness Environ Med*. 2007;18(4):281-7.
2. Gummin DD, Mowry JB, Spyker DA, et.al. 2016 Annual Report of the American Association of Poison Control Centers' National Poison Data System (NPDS): 34th Annual Report. *Clin Toxicol*. 2017;55(10):1072-1252.
3. Zad O, Cooper H, Crocker P, et al. Shock, respiratory failure, and coagulopathy after an intravenous copperhead envenomation. *Am J Emerg Med.* 2009;27(3):377.e1-377.e5.
4. Kopec KT, Yen M, Bitner M, et.al. Marker hypofibrinogenemia and gastrointestinal bleeding after copperhead (Agkistrodon contortix) envenomation. *Wilderness Environ Med.* 2015;26(4):488-90.
5. Gerardo CJ, Vissoci JR, Brown MW, et al. Coagulation parameters in copperhead compared to other Crotalinae envenomation: secondary analysis of the F(ab')2 versus Fab antivenom trial. *Clin Toxicol (Phil).* 2017;55(2):109-14.
6. Spiller HA and Bosse GM. Prospective study of morbidity associated with snakebite envenomation. *J Toxicol Clin Toxicol.* 2003;41(2):125-30.
7. Roth B, Sharma K, Onisko N, et al. Prospective evaluation of pain, swelling, and disability from copperhead envenomation. *Clin Toxicol (Phil)*. 2016;54(3):271-6.
8. Ruha AM, Kleinschmidt KC, Greene S, et.al. The epidemiology, clinical course, and management of snakebites in the North American Snakebite Registry. *J Med Toxicol.* 2017;13(4):309-20.
9. Lavonas EJ, Ruha AM, Banner W, et.al. Unified treatment algorithm for the management of crotaline snakebite in the United States: results of an evidence-informed consensus workshop. *BMC Emerg Med*. 2011;11:2.
10. Kanaan NC, Ray J, Stewart M, et.al. Wilderness Medical Society Practice Guidelines for the Treatment of Pit Viper Envenomations in the United States and Canada. *Wilderness Environ Med*. 2015;26(4):472-87.
11. Dowell D, Haegerich TM, Chou R. CDC guideline for prescribing opioids for chronic pain - United States, 2016. *MMWR Recomm Rep.* 2016;65(1):1-49.
12. NCSL. Prescribing policies: states confront opioid overdose epidemic. National Conference of State Legislatures. 2017. Available at: https://mypages.unh.edu/sites/default/files/behavioralhealthinitiative/files/prescribingopioids_final01-web.pdf. Accessed [Date].
13. Hoppe JA, Kim H, Heard K. Association of emergency department opioid initiation with recurrent opioid use. *Ann Emerg Med.* 2015;65(5):493-9.
14. Butler MM, Ancona RM, Beauchamp GA, et.al. Emergency department prescription opioids as an initial exposure preceding addiction. *Ann Emerg Med.* 2016;68(2):202-8.
15. Shah A, Hayes CJ, Martin BC. Factors influencing long-term opioid use among opioid naïve patients: an examination of initial prescription characteristics and pain etiologies. *J Pain.* 2017;18(11):1374-83.
16. Beauchamp GA, Winstanley EL, Ryan SA, et al. Moving beyond misuse and diversion: the urgent need to consider the role of iatrogenic addiction in the current opioid epidemic. *Am J Public Health*. 2014;104(11):2023-9.
17. Gerardo CJ, Quackenbush E, Lewis B, et.al. The efficacy of Crotalidae polyvalent immune Fab (ovine) antivenom versus placebo plus optional rescue therapy on recovery from copperhead snake envenomation: a randomized, double-blind, placebo-controlled, clinical trial. *Ann Emerg Med.* 2017;70(2):233-44.
18. Stratford P, Gill C, Westaway M, et.al. Assessing disability and change on individual patients: a report of a patient specific measure. *Physiother Can.* 1995;47(4):258-63.
19. Walker JP and Morrison RL. Current management of copperhead snakebite. *J Am Coll Surg.* 2011;212(4):470-4.
20. Gale SC, Peters JA, Allen L, et.al. FabAV antivenin use after copperhead snakebite: Clinically indicated or knee-jerk reaction? *J Venom Anim Toxins Incl Trop Dis.* 2016;22:2.
21. Larson KW, Schaefer KR, Austin C, et.al. Management of tissue loss after Agkistrodon snakebite: appropriate use of Crotalidae-Fab antivenom. *J Trauma Nurs.* 2016;23(3):169-72.
22. Lavonas EJ, Gerardo CJ, O'Malley G, et.al. Initial experience with Crotalidae polyvalent immune Fab (ovine) antivenom in the treatment of copperhead snakebite. *Ann Emerg Med*. 2004;43(2):200-6.
23. Caravati EM. Copperhead bites and Crotalidae polyvalent immune Fab (ovine): routine use requires evidence of improved outcomes. *Ann Emerg Med*. 2004;43(2):207-8.
24. Ali AJ, Horwitz DA, Mullins ME. Lack of coagulopathy after copperhead snakebites. *Ann Emerg Med.* 2015;65(4):40-9.
25. Schaeffer TH, Khatri V, Reifler LM, et al. Incidence of immediate hypersensitivity reaction and serum sickness following administration of Crotalidae polyvalent immune Fab antivenom: a meta-analysis. *Acad Emerg Med.* 2012;19:121-31.
26. Kleinschmidt K, Ruha AM, Campleman S, et al. Acute adverse events associated with the administration of Crotalidae polyvalent immune Fab antivenom without the North American Snakebite Registry. *Clin Toxicol (Phila).* 2018:1-6.
27. Borek HA, Rizer J, Ngo A. Fab antivenom controversy continues. *Ann Emerg Med.* 2017;70(6):928-29.
28. Chiang W, Harding SA, Tassin SA, et.al. In response to "The efficacy of Crotalidae polyvalent immune Fab (ovine) antivenom versus placebo plus optional rescue therapy on recovery from copperhead snake envenomation. *Ann Emerg Med.* 2017;70(6):930-1.
29. Lavonas EJ, Gerardo CJ, Copperhead Snakebite Recovery Outcome Group. Prospective study of recovery from copperhead snake envenomation: an observational study. *BMC Emerg Med.* 2015;15:9.
30. Jeffery MM, Hooten WM, Hess EP, et.al. Opioid prescribing for opioid-naïve patients in emergency departments and other

settings: characteristics of prescriptions and association with long-term use. *Ann Emerg Med.* 2018;71(3):326-36.

31. Anderson VE, Burnham RI, Gillman SM, et.al. Validation of Patient Specific Functional Scale in copperhead snakebite patients. *Clin Toxicol.* 2015;53(7):649.
32. Cochran BN, Flentje A, Heck NC, et al. Factors predicting development of opioid use disorders among individuals who receive an initial opioid prescription: mathematical modeling using a database of commercially-insured individuals. *Drug Alcohol Depend.* 2014;138:202-8.
33. Abbey JM, Jaffar NA, Abugrara HL, et al. Epidemiological characteristics, hospital course and outcome of snakebite victims in West Texas. *Hosp Pract (1995).* 2015;43(4):217-20.
34. O'Neil ME, Mack KA, Gilchrist J, et al. Snakebite injuries treated in United States emergency departments, 2001-2004. *Wilderness Environ Med.* 2007;18(4):281-7.
35. Centers for Disease Control and Prevention (CDC). Vital signs: overdoses of prescription opioid pain relievers and other drugs among women—United States, 1999-2010. *MMWR Morb Mortal Wkly Rep*. 2013;62(26):537-42.

Availability of Bedside and Laboratory Testing for Carbon Monoxide Poisoning in the Upper Midwestern United States

Thomas Masters, MD
Brian Willenbring, MD
Bjorn Westgard, MD
Jon Cole, MD
Stephen Hendriksen, MD
Joseph Walter, MD
Christopher Logue, MD
Travis Olives, MD, MPH, MEd

Hennepin Healthcare, Department of Emergency Medicine, Minneapolis, Minnesota

Section Editor: Brandon Wills, DO, MS
Submission history: Submitted October 25, 2018; Revision received February 6, 2019; Accepted February 16, 2019
Electronically published April 16, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.2.41428

Introduction: The objective of this study was to assess the ability to test patients for carbon monoxide (CO) exposure in all hospitals in three United States (U.S.) Midwestern states.

Methods: We surveyed hospitals in three states. Telephone queries assessed processes for measuring carboxyhemoglobin, including capacity for real-time vs send-out testing. Facilities were separated based on their location's population size for further analysis. Descriptive statistics are reported.

Results: Of the 250 hospitals queried, we ultimately excluded 25. Nearly all (220, 97.8%) reported a process in place to test for CO exposure. Over 40% (n=92) lacked real-time testing. Testing ability was positively associated with increasing population size quartile (range 32.6% - 100%). Hospitals in the lowest-quartile population centers were more likely to report that they were unable to test in real time than those in the largest-quartile population centers (67.4% vs 0%).

Conclusion: In a large geographic region encompassing three states, hospital-based and real-time capacity to test for CO exposure is not universal. Hospitals in smaller population areas are more likely to lack real-time testing or any testing at all. This may have significant public health, triage, and referral implications for patients. [West J Emerg Med. 2019;20(3)506–511.]

INTRODUCTION

Carbon monoxide (CO) is an odorless and invisible gas that may not be apparent to individuals exposed to it. Yet as a byproduct of combustion from sources such as furnaces, heaters, and engines, CO is pervasive in modern life. CO poisoning occurs when an individual is exposed to the gas at sufficient concentrations to cause symptoms with or without end-organ dysfunction. It is one of the leading causes of poisoning in the United States (U.S.) and around the world.[1] It has been estimated that CO poisoning is responsible for 50,000 emergency department (ED) visits in the U.S. annually.[2] Public health and legislative efforts have sought to increase awareness of CO poisoning and the use of CO detectors. This has contributed to fewer ED visits and deaths, particularly among intentional exposures. However, accidental exposures have diminished at a slower pace, and the rate of hospitalizations for CO poisoning remains essentially unchanged.[3-6]

Legislation requiring CO detectors in certain settings has helped to make significant environmental

exposures less frequent and, when present, more apparent to clinicians.[7,8] In the absence of scene alarms or source exposure history, the vague and nonspecific nature of presenting symptoms can make diagnosis a challenge. Patients may present with symptoms ranging from headache and dizziness, nausea and vomiting, to coma.[9] While history and physical findings may point to the diagnosis, clinicians must maintain a high degree of suspicion. A missed diagnosis can have significant consequences, as CO poisoning can cause acute and persistent neurologic and cardiac injury,[10] and therapy, whether with normobaric or hyperbaric oxygen, must be initiated in a timely manner.[11] It is recommended that the diagnosis of CO poisoning should be confirmed by detecting an elevated carboxyhemoglobin (HbCO) level in the context of clinical symptoms.[12,13] In the absence of real-time testing, therapy, hospitalization and referrals may be necessary based on clinical suspicion alone.

In the U.S., two common methods to detect HbCO in poisoned patients are a venous blood assay and finger CO-oximetry. A blood assay is the oldest method, but requires a laboratory equipped to perform the test.[14,15] While the blood assay is the gold standard, non-invasive finger CO-oximetry has been touted as a potential cost-effective surrogate for screening.[16-18] However, it is unclear how available either of these methods are to practicing clinicians. The goal of this study was to evaluate hospital capabilities of detecting carbon CO poisoning in three states in the upper Midwest.

Population Health Research Capsule

What do we already know about this issue?
Carbon monoxide poisoning is one of the leading causes of poisoning in the United States.

What was the research question?
How available are methods for detecting carbon monoxide (CO) poisoning in hospitals in the upper Midwest?

What was the major finding of the study?
Hospitals serving smaller population areas are more likely to lack real-time testing for CO exposures.

How does this improve population health?
Understanding resource gaps could spur increased availability of point of care testing in smaller communities.

METHODS

We conducted a cross-sectional study of hospitals distributed over three Midwestern U.S. states (Minnesota, North Dakota, and South Dakota) served by both a single regional poison center – the Minnesota Poison Control System – and a single center for hyperbaric medicine with emergent treatment capabilities – the Hennepin County Medical Center Department of Undersea and Hyperbaric Medicine. We used multiple available sources, including state trauma databases, state health department websites, and the regional poison-center's hospital database, to identify and compile all of the hospitals within the three-state area. All the identified hospitals were contacted by phone and surveyed from August 1, 2017 – May 3, 2018. Facilities were excluded if they did not have an emergency department (ED) (such as freestanding clinics) or if the hospital was no longer open.

We surveyed each facility in a standardized format regarding its ability to test for CO poisoning. Specific inquiries included whether the facility possessed in-house spectrophotometric HbCO assays, bedside CO-oximetry, or any manner to test for CO exposure on site. Additionally, facilities were queried regarding their use of send-out testing for CO exposure, as well as whether a process was in place to facilitate real-time testing.

We directed initial inquiries to the hospital-based clinical laboratory. A standardized greeting and introduction was followed by a simple query regarding capability to assay HbCO in the hospital lab, and a subsequent query with respect to the availability of bedside CO-oximetry at the facility. If the study inquiries were unanswered by laboratory staff or laboratory supervisor, a follow-up call to the ED was made. Following standardized introduction, a query was repeated with respect to the availability of bedside CO-oximetry to the supervising nurse on duty.

The reported populations of towns and cities housing each hospital were abstracted from the most recent United States Census Bureau dataset (USCB, 2010). These populations were divided into settlement hierarchy[19] quartiles of ≤2,500, 2,501 - 25,000, 25,001 - 250,000, and ≥250,000 inhabitants with the assumption that hospitals in larger communities would be more likely to have a full range of care resources. Hospitals were further described with respect to their American College of Surgeons (ACS) trauma designation as an additional possible marker of available resources. For example, Level IV trauma center certification by the ACS requires 24-hour laboratory coverage, while Level V certification does not.[20]

Descriptive statistics characterizing study data were calculated in Stata/IC 15.0 for Mac (College Station, Texas). Relationships between the binary availability of HbCO

testing and independent variables, including locale size, and American Trauma Society (ATS) trauma designation are reported using x^2 or Fisher's exact tests, as appropriate.

RESULTS

We identified 250 facilities within the catchment area of the regional poison center and hyperbaric medicine unit. Included in the final analysis were 225 facilities (Table 1). Of the 25 facilities excluded, none were excluded due to failed contact, but three were excluded because the facility was no longer operational. Thirteen were specialty centers without a functioning ED, and nine were clinics or long-term care facilities (Figure 1). The population of the cities in which all hospitals were located, based on 2010 USCB results, ranged from 446 to 382,578 people.

Most facilities (181, 80.4%) were located in areas populated by less than 25,000 people. Hospital density per population was not equally distributed across the three states, with one for every 42,094 in Minnesota, one facility for every 15,286 inhabitants in North Dakota, and one for every 14,803 in South Dakota (Figure 2). Similarly, higher ATS trauma classification hospitals were more common to Minnesota than North Dakota or South Dakota.

Nearly all hospitals (n=220, 97.8%) reported some means of testing for CO poisoning (Table 2). A majority of facilities (n=133, 59.11%) reported some capacity for real-time testing. Facilities with more advanced trauma designations typically had greater ability to evaluate HbCO levels (Table 2). The proportion of hospitals capable of real-time HbCO measurement increased with population size from the lowest quartile at 32.6% to the highest quartile at 100% (Fisher's exact test = 0.000). Smaller population size was associated with a higher proportion of hospitals reporting the use of send-out HbCO assays (Fisher's exact test = 0.000). We also identified a strong association between reporting a lack of real-time testing and the use of send-out labs (Pearson's $x^2 = 90$, p = 0.000), an association that persisted across all hospital population strata.

Table 1. Distribution of responding hospitals.

City size	All states	Minnesota	North Dakota	South Dakota
Total n (%)*	225	126	44	55
<2,500	89 (39.6)	31 (24.6)	29 (65.9)	29 (52.7)
2,501 – 25,000	92 (40.9)	67 (53.2)	7 (15.9)	18 (32.7)
25,001 – 250,000	34 (15.1)	18 (14.3)	8 (18.2)	8 (14.6)
>250,000	10 (4.44)	10 (7.94)	0 (0.00)	0 (0.00)

* Percentage of responding hospitals located in cities of a given size.

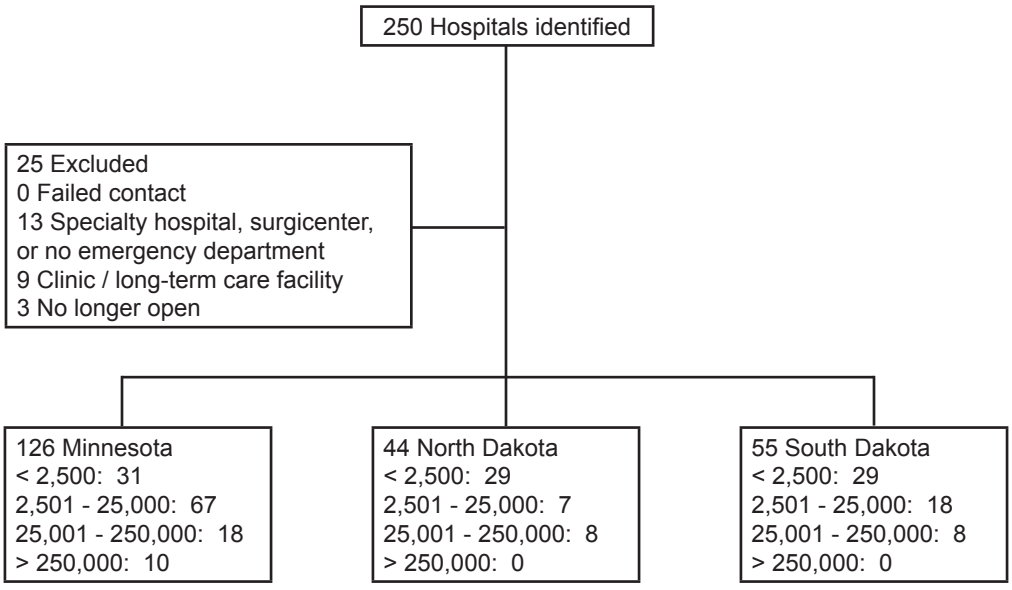


Figure 1. Study flow diagram of hospital capability to test for carbon monoxide poisoning.

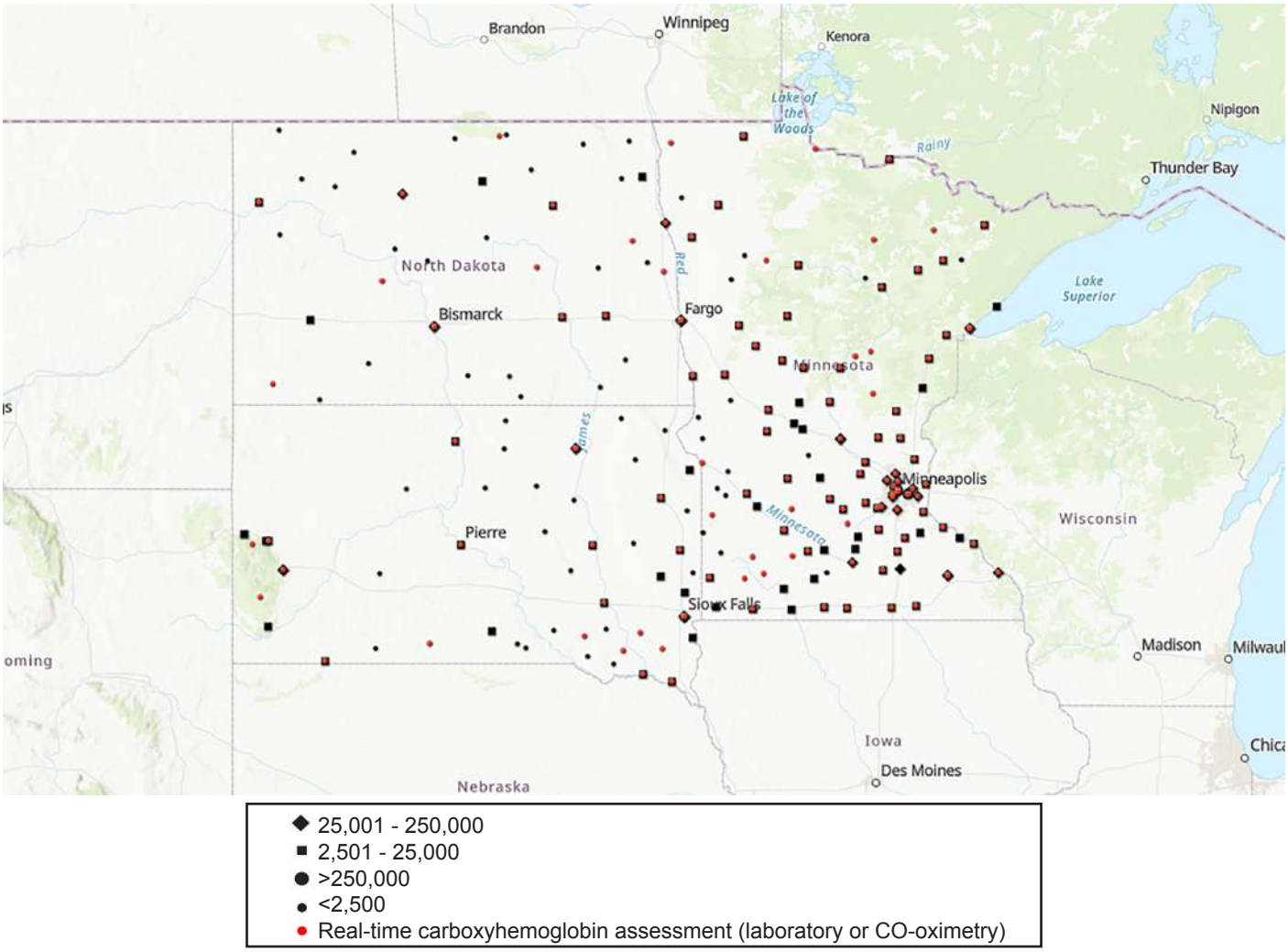


Figure 2. Distribution of responding hospitals and real-time carboxyhemoglobin monitoring by community size. *CO*, carbon monoxide.

Table 2. Availability of carboxyhemoglobin assessment.

	COHb lab assay	Finger CO-oximetry	Real-time COHb	Unable to test
Total n (%)	91 (29.6)	78 (25.4)	133 (43.3)	5 (1.62)
Population size				
<2,500	9 (10.1)	23 (25.8)	29 (32.6)	5 (5.62)
2,501 – 25,000	48 (52.2)	38 (41.3)	65 (70.7)	0 (0.00)
25,001 – 250,000	24 (70.6)	15 (44.1)	29 (85.3)	0 (0.00)
>250,000	10 (100.0)	2 (20.0)	10 (100.0)	0 (0.00)
ACS trauma designation				
I	5 (100.0)	4 (80.0)	5 (100.0)	0 (0.00)
II	12 (80.0)	5 (33.3)	15 (100.0)	0 (0.00)
III	25 (89.3)	12 (42.9)	27 (96.4)	0 (0.00)
IV	40 (35.4)	43 (38.1)	67 (59.3)	1 (0.88)
V	3 (7.0)	7 (16.3)	8 (18.6)	4 (9.30)
n/a	6 (28.6)	7 (33.3)	11 (54.2)	0 (0.00)

COHb, carboxyhemoglobin; *CO*, carbon monoxide; *ACS*, American College of Surgeons.

DISCUSSION

In this study of all hospitals in a three-state area, we found that most hospitals have some capacity for real-time testing of patients' HbCO levels. However, smaller population areas were associated with gaps in real-time testing for HbCO and the use of send-out assays. Although it has been widely suspected that CO poisoning is underdiagnosed and under-reported in general, to our knowledge there have been no other studies looking at regional capabilities of detecting CO exposure and associated poisoning in the past decade, with only one similar study done in a different region of the U.S. in 2003 – 2004.[21]

A Centers for Disease Control and Prevention editorial noted concerns that CO poisoning may also be under-reported to poison centers in particular.[22] Our data suggest that most hospitals in areas of less than 2500 people lack the ability to do real-time testing for CO exposure. Given that send-out assays often involve significant turnaround time and resources,[23] it is possible that under-reporting and underdiagnosis of associated CO poisonings may be related to gaps in the capacity to detect HbCO levels.

The invisible nature of the gas and the vague presenting symptoms can make CO poisoning difficult to suspect and diagnose clinically, requiring a high degree of suspicion.[9] Without a readily available means of testing, clinicians are unable to confirm the diagnosis. It is conceivable then that gaps in the regular availability of confirmatory testing might lead to cognitive biases[24] that would prevent clinicians from suspecting or settling upon the diagnosis of CO poisoning in atypical presentations. Without suspicion or diagnosis, patients cannot be appropriately triaged or treated in a timely manner, whether with normobaric oxygen, hyperbaric oxygen, or other therapies. This study did not look into hospital referral patterns; however, previous studies have shown that 90% of patients referred for hyperbaric oxygen therapy come from facilities capable of testing in real time.[21] Although referrals may be based on clinical suspicion, we suspect that this presents a clinical conundrum for both the referring clinician and the accepting facility.

Many of the facilities that we surveyed were in rural areas. Although facilities located in larger urban or suburban areas tended to possess better testing capabilities, rates of CO poisoning have been shown to be higher in rural areas.[4] Work-related exposures and faulty furnaces account for significant sources of CO poisonings (45% in one study).[25] Indeed, given current rural infrastructure and livelihoods, our concern is that individuals using gas heating implements or working on heavy and possibly running machinery in poorly-ventilated areas such as barns and sheds are more likely to be exposed, to go undiagnosed or be misdiagnosed, and to then return to the same practices that led to the exposure, compounding morbidity and increasing the likelihood of mortality from CO poisoning.

Historically, the majority of CO exposures in the U.S. have occurred in the Midwest, particularly accidental exposures.[22] Indeed, sparse populations and rural areas with less infrastructure, particularly in North Dakota and South Dakota, do make these states distinct from much of the country. This area of the country also experiences significant cold-weather seasons, leading people to spend significant periods of time indoors with heaters, furnaces, and other sources of combustion, and it is during these colder months that the greatest number of poisonings occur.[4-6] It is therefore of significant concern that many facilities in this upper Midwestern region do not have real-time capacity for detection of CO.

We believe that every hospital should possess some manner of real-time testing for CO poisoning. Delayed or missed diagnosis can have real effects on clinical outcomes.[11] In addition, although prevention is key, all exposed patients should be afforded an opportunity to be appropriately evaluated for and diagnosed with CO poisoning so that they receive timely, appropriate treatment.

LIMITATIONS

There are several limitations to this study. First, it is possible that we did not survey every hospital in the three states of concern. However, given our efforts to cross-reference multiple sources, we feel that this is a representative and nearly comprehensive sampling of hospitals in this geographic area. Second, it is possible that the individuals describing testing capabilities were inaccurate in their characterizations. However, we feel that the senior staff surveyed are likely to reflect a reasonable knowledge of the facility's capabilities. Third, we did not quantify the turnaround time for send-out labs at each facility. Given that many of these hospitals are in remote areas, it is reasonable to assume that it would be at the very least several hours for results to return, especially when snowstorms and other weather events impact the region.

Additionally, we did not inquire about prehospital or out-of-hospital detection capacity or other established processes that might facilitate the diagnosis and treatment of CO poisoning, nor did we inquire about specific algorithms regarding the management of suspected CO poisoning, both of which are beyond the scope of this study. Finally, it is difficult to know if we can extrapolate the data from these three upper Midwestern states to the rest of the U.S. However, our data do compare favorably with a previous study.[21] Additionally, if these gaps in testing capacity are present in areas with a high incidence of CO poisoning, they might well be suspected in areas of lower incidence across the country.

CONCLUSION

In the geographic region encompassing Minnesota, North Dakota, and South Dakota, hospital-based and real-time capacity to test for CO exposure is not universal. In smaller population areas, hospitals are more likely to lack real-time testing or any testing at all. These findings may have significant public health, triage, and referral implications for patients who may be victims of CO exposure.

Address for Correspondence: Thomas Masters, MD, Hennepin Healthcare, Department of Emergency Medicine, 701 Park Ave, Minneapolis, MN 55415. Email: Thomas.masters@hcmed.org.

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.

REFERENCES

1. Raub JA, Mathieu-Nolf M, Hampson NB, et al. Carbon monoxide poisoning - a public health perspective. *Toxicology*. 2000;145(1):1-14.
2. Hampson NB, Weaver LK. Carbon monoxide poisoning: a new incidence for an old disease. *Undersea Hyperb Med.* 2007;34(3):163-8.
3. Hampson NB. U.S. mortality due to carbon monoxide poisoning, 1999-2014. Accidental and intentional deaths. *Ann Am Thorac Soc*. 2016;13(10):1768-74.
4. Mukhopadhyay S, Hirsch A, Etienne S, et al. Surveillance of carbon monoxide-related incidents — implications for prevention of related illnesses and injuries, 2005–2014. *Am J Emerg Med*. 2018;36(10):1837-44.
5. Stearns D, Sircar K. National unintentional carbon monoxide poisoning estimates using hospitalization and emergency department data. *Am J Emerg Med*. 2018.
6. QuickStats: Number of deaths resulting from unintentional carbon monoxide poisoning,* by month and year — National Vital Statistics System, United States, 2010–2015. *MMWR Morb Mortal Wkly Rep*. 2017;66(8):234.
7. Weaver LK, Deru K, Churchill S, Legler J, Snow G, Grey T. Carbon monoxide poisoning in Utah: 1996-2013. *Undersea Hyperb Med*. 2016;43(7):747-58.
8. Hampson NB. Cost effectiveness of residential carbon monoxide alarms. *Undersea Hyperb Med.* 2017;44(5):393-97.
9. Ng PCY, Long B, Koyfman A. Clinical chameleons: an emergency medicine focused review of carbon monoxide poisoning. *Intern Emerg Med*. 2018;13(2):223-9.
10. Weaver LK. Carbon monoxide poisoning. *N Engl J Med*. 2009;360(12):1217-25.
11. Weaver L, Hopkins R, Chan K, et al. Hyperbaric oxygen for acute carbon monoxide poisoning. *N Engl J Med.* 2002;347(14):1057-67.
12. Hampson NB, Piantadosi CA, Thom SR, et al. Practice recommendations in the diagnosis, management, and prevention of carbon monoxide poisoning. *Diving Hyperb Med*. 2013;43(3):172.
13. CDC. Clinical guidance for carbon monoxide (CO) poisoning after a disaster. Cdc.Gov. 2015. Available at: https://www.cdc.gov/disasters/co_guidance.html. Accessed January 25, 2019.
14. Johansson MB, Wollmer P. Measurement of carboxyhaemoglobin by spectrophotometry and gas chromatography. *Clin Physiol*. 1989;9(6):581-6.
15. Veronesi A, Pecoraro V, Zauli S, et al. Use of carboxyhemoglobin as a biomarker of environmental CO exposure: critical evaluation of the literature. *Environ Sci Pollut Res*. 2017;24(33):25798-809.
16. Zaouter C, Zavorsky GS. The measurement of carboxyhemoglobin and methemoglobin using a non-invasive pulse CO-oximeter. *Respir Physiol Neurobiol*. 2012;182(2-3):88-92.
17. Sebbane M, Claret P-G, Mercier G, et al. Emergency department management of suspected carbon monoxide poisoning: role of pulse CO-oximetry. *Respir Care*. 2013;58(10):1614-20.
18. Hullin T, Aboab J, Desseaux K, et al. Correlation between clinical severity and different non-invasive measurements of carbon monoxide concentration: a population study. *PLoS One*. 2017;12(3):1-9.
19. Settlement characteristics - Revision 4 - GCSE Geography - BBC. Available at: https://www.bbc.com/bitesize/guides/zyyvtyc/revision/4. Accessed January 26, 2019.
20. American Trauma Society. Trauma center levels explained. 2016. Available at: http://www.amtrauma.org/?page=TraumaLevels. Accessed January 25, 2019.
21. Hampson NB, Scott KL, Zmaeff JL. Carboxyhemoglobin measurement by hospitals: implications for the diagnosis of carbon monoxide poisoning. *J Emerg Med*. 2006;31(1):13-6.
22. Centers for Disease Control and Prevention (CDC). Carbon Monoxide Exposures — United States, 2000–2009. *MMWR Morb Mortal Wkly Rep.* 2011. Available at: http://www.ncbi.nlm.nih.gov/pubmed/21814166. Accessed January 25, 2019.
23. Clinical Laboratory and Standards Institute. Selecting and Evaluating a Referral Laboratory. Vol 18.; 1998. November 1998. Available at: http://demo.nextlab.ir/getattachment/ac74de5f-6db3-47db-a5f3-37ec94625b63/CLSI-GP09-A.aspx. Accessed January 24, 2019.
24. Croskerry P. Achieving quality in clinical decision making: cognitive strategies and detection of bias. *Acad Emerg Med*. 2002;9(11):1184-204.
25. Grieb G, Simons D, Schmitz L, et al. Glasgow Coma Scale and laboratory markers are superior to COHb in predicting CO intoxication severity. *Burns*. 2011;37(4):610-5.

Feasibility of Telesimulation and Google Glass for Mass Casualty Triage Education and Training

C. Eric McCoy, MD, MPH*
Rola Alrabah, MD‡
Warren Weichmann, MD, MBA*
Mark I. Langdorf, MD, MHPE*
Cameron Ricks, MD†
Bharath Chakravarthy, MD, MPH*
Craig Anderson, PhD, MPH*
Shahram Lotfipour, MD, MPH*

*University of California, Irvine School of Medicine, Department of Emergency Medicine, Irvine, California
†University of California, Irvine School of Medicine, Department of Anesthesiology, Irvine, California
‡King Abdullah Bin Abdulaziz University Hospital, Department of Emergency Medicine, Riyadh, Saudi Arabia

Section Editor: Joshua B. Gaither, MD
Submission history: Submitted August 29, 2018; Accepted March 27, 2019
Electronically published April 26, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.3.40805

Introduction: Our goal was to evaluate the feasibility and effectiveness of using telesimulation to deliver an emergency medical services (EMS) course on mass casualty incident (MCI) training to healthcare providers overseas.

Methods: We conducted a feasibility study to establish the process for successful delivery of educational content to learners overseas via telesimulation over a five-month period. Participants were registrants in an EMS course on MCI triage broadcast from University of California, Irvine Medical Simulation Center. The intervention was a Simple Triage and Rapid Treatment (START) course. The primary outcome was successful implementation of the course via telesimulation. The secondary outcome was an assessment of participant thoughts, feelings, and attitudes via a qualitative survey. We also sought to obtain quantitative data that would allow for the assessment of triage accuracy. Descriptive statistics were used to express the percentage of participants with favorable responses to survey questions.

Results: All 32 participants enrolled in the course provided a favorable response to all questions on the survey regarding their thoughts, feelings, and attitudes toward learning via telesimulation with wearable/mobile technology. Key barriers and challenges identified included dependability of Internet connection, choosing appropriate software platforms to deliver content, and intercontinental time difference considerations. The protocol detailed in this study demonstrated the successful implementation and feasibility of providing education and training to learners at an off-site location.

Conclusion: In this feasibility study, we were able to demonstrate the successful implementation of an intercontinental MCI triage course using telesimulation and wearable/mobile technology. Healthcare providers expressed a positive favorability toward learning MCI triage via telesimulation. We were also able to establish a process to obtain quantitative data that would allow for the calculation of triage accuracy for further experimental study designs. [West J Emerg Med. 2019;20(3)512-519.]

INTRODUCTION

Acts of terrorism, mass casualty incidents (MCI), and natural disasters continue to occur and overwhelm medical systems nationally and globally.[1-3] An MCI is any incident where emergency medical services (EMS) resources are overwhelmed by the number and severity of casualties. Terrorism, both

domestic and global, has recently been increasing. Specifically, the number of active shooter events and bombings has risen rapidly in the United States, with more than a third of events since 2000 occurring in the last three years.[4-5] This increasing frequency has required healthcare providers to become more familiar with how to respond to these public health threats and emergencies.

Historically, the educational methods for these topics have included standard didactics and tabletop exercises (a low-fidelity type of simulation). However, passive educational delivery methods such as didactic lecture have been associated with the lowest average knowledge-retention rates compared to more active methods of learning.[6-7] Simulation has been effectively used to train providers in areas such as EMS and critical care and provides a way to improve the quality of education and training to respond to these public health emergencies.

Simulation encompasses any process or technology that recreates a contextual background allowing the learner to make decisions, experience success, make mistakes, receive feedback, and gain confidence in an environment that is void of patient risk.[8] Research has suggested that simulation is superior to conventional educational delivery methods in emergency and critical care medicine.[9-12] However, in many areas around the world where healthcare providers must respond to acts of terror, there is a paucity or absence of simulation resources. Telesimulation is an innovative educational delivery method that can address this need.

Telesimulation is a process by which telecommunication and simulation resources are used to provide education, training, and/or assessment to learners at an off-site location.[13] Because telesimulation is a new niche within simulation, the evidence demonstrating its effectiveness is scant. To our knowledge, no studies exist that evaluate the feasibility of telesimulation to deliver an EMS-based course to healthcare providers across continents. The objective of this study was to evaluate the feasibility and effectiveness of using telesimulation to deliver an EMS-based course on MCI training to healthcare providers on a different continent.

Population Health Research Capsule

What do we already know about this issue?
The increasing frequency of global terrorism has required healthcare providers to become familiar with how to respond to these public health threats and emergencies.

What was the research question?
Can telesimulation be used to deliver a mass casualty incident training course to healthcare providers overseas?

What was the major finding of the study?
We demonstrated the successful implementation of an intercontinental mass casualty incident triage course using telesimulation and wearable/mobile technology.

How does this improve population health?
Leveraging technology to improve knowledge and skills at the provider level allows for the optimization of healthcare delivery at the population level.

METHODS

Study Design and Setting

We performed a feasibility study to establish the process for successful delivery of educational content through a telesimulation course, that would yield data amenable for qualitative and quantitative analysis. The study was conducted over a five-month period with content creation, delivery, and broadcast from the University of California, Irvine Medical Simulation Center, a 65,000 square-foot state-of-the-art medical education center that provides telemedicine and simulation-based educational programs and continuing medical education courses for thousands of healthcare providers each year.[14] Resources for education and training include a full-scale operating room, an inpatient ward room, emergency department resuscitation bay, obstetrical suite, and a critical care unit. The simulation center has a complement of full-time staff, including full-time simulation specialists.

Selection of Participants

Participation in the study was obtained from registrants in an EMS-based course in MCI triage that was designed for this study and offered in collaboration with King Abdullah Bin Abdulaziz University Hospital and Princess Nourah bint Abdulrahman University Simulation and Skills Development Center in Riyadh, Saudi Arabia.

The study was open to all healthcare providers with a focus on emergency medical technicians, paramedics, nurses and physicians. The sole exclusion criterion was the inability to understand and speak the English language as the course and content materials were in English. The study was approved by the university's institutional review board, and subjects provided informed consent.

Interventions

The educational intervention in this study included an EMS-based course on MCI training on Simple Triage and Rapid Treatment (START) in the prehospital care setting. Mass casualty triage occurs when there is more than one casualty and the available resources require a provider to initiate care for one

patient over another.[15] The START system, developed by Hoag Hospital and the Newport Beach Fire Department (Newport Beach, California), helps prepare emergency personnel to quickly organize their resources to handle multi-casualty emergencies.[16] It is designed to allow the provider to triage each patient in less than 60 seconds. This knowledge base and skill set is particularly critical for healthcare professionals responding to MCIs including active shooters and explosive devices. Currently, START remains the most commonly used mass casualty triage algorithm in the U.S.[17]

Methods and Measurements

The MCI course content was delivered using various telecommunication software resources. The course introduction and orientation was performed using join.me (https://www.join.me). Join.me is a web-based collaboration software application for screen sharing and online meetings. The course content was delivered using this software application as it allows real-time teleconferencing with simultaneous educational content broadcast. Educational content materials were delivered via PowerPoint (Version 12.0, Microsoft Corporation, Redmond, Washington). The course content was delivered by physicians who were board certified in both emergency medicine and EMS, and experienced in simulation course design, creation, and implementation. The course was delivered over 2.5 hours (which included a half-hour online check in and pre-course software testing period) (Figure 1) .

Time	Activity
8:30 P.M.	Online check-in/software start up
9:00 P.M.	Course introduction/orientation
9:15 P.M.	Course content
10:00 P.M.	Live interactive MCI scenario session
10:20 P.M.	Question and answer session Virtual simulation orientation Distribution of data collection forms
10:30 P.M.	Virtual simulation component
10:50 P.M.	Post virtual-simulation feedback Collect data forms Question and answer session
11:00 P.M.	End

Figure 1. Timeline for telesimulation course from United States-based broadcasting institution.
MCI, mass casualty incident.

After core content delivery of MCI education pertaining to START triage, the students underwent a live interactive training session to apply the knowledge gained. The course core content, live interactive training session, virtual simulation component, and question/answer sessions occurred over a two-hour time period (Figure 1). A MCI scenario was created and staged at the broadcasting institution simulation center using a combination of live standardized patients and high-fidelity simulation mannequins. We used the software platform EyeSight (Pristine Eyesight, Austin, Texas) for the live interactive MCI practical application training session. EyeSight allows real-time audio and video collaboration via smart glasses (Google Glass, Mountain View, California) and mobile devices (Figure 2A).

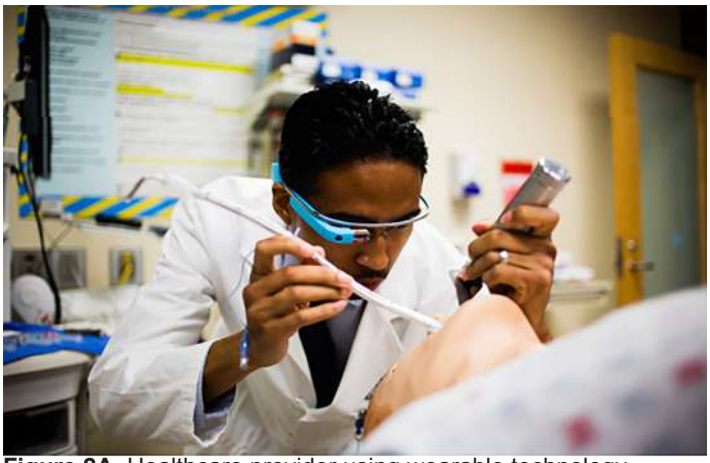


Figure 2A. Healthcare provider using wearable technology (Google Glass) while performing advanced airway procedure.

During this live interactive scenario, the course instructor played the role of a paramedic walking through a MCI scenario evaluating each patient and verbalizing information needed for participants to assign each patient the appropriate triage category. Course instructors at the receiving institution were available to answer any questions during the session (Figure 2B). After the live scenario was complete, a debriefing walkthrough of each patient ensued with the course instructors reviewing the appropriate assessment and triage categorization of each patient. The START triage method results in the assignment of patients into one of four categories: black (expectant), red (immediate), yellow (delayed), and green (minor).

The virtual simulation component of the course followed the live interactive MCI practical application training session. The virtual simulation consisted of a MCI of an active shooter in an office building. The virtual simulation was created, staged and recorded in an actual high-rise office building using standardized patients and moulage to create realistic-looking wounds. The simulation was recorded in the first-person perspective of an individual performing a continuous walkthrough of the MCI scene using Google Glass (Figure 2C). Each standardized patient

Figure 2B. Broadcasting institution location with laptop showing live feed to classroom at receiving location. Instructors at broadcasting institution were able to communicate live to students and instructors overseas via Google Glass, laptop, desktop, and wall-mounted TV monitors.

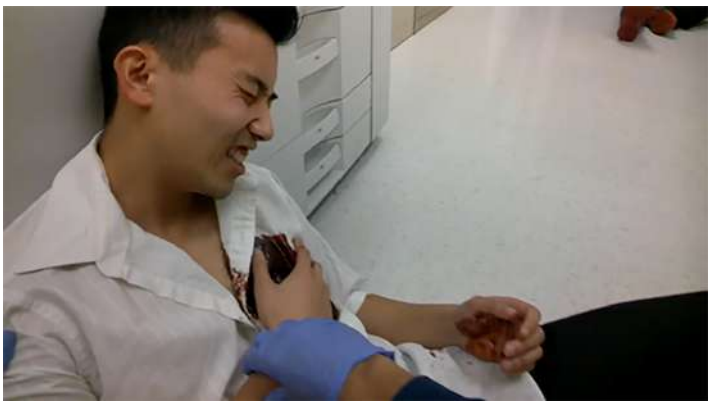


Figure 2C. Photograph depicting first-person view frame captured from Google Glass during the virtual simulation component scenario of a mass casualty incident training course. Students at the receiving institution experienced real-time, first-person perspective triage after a staged, active-shooter scenario.

underwent a pre-course training session regarding their roles and setting and also followed a pre-written script for his or her specific role. This pre-recorded MCI scenario served as the standardized resource that was used for individual participant assessment. Each student viewed the Google Glass recording of the high-rise active shooter incident and was responsible for categorizing each victim using START triage.

Outcomes

The primary outcome of this feasibility study was to demonstrate the successful implementation of an EMS-based educational course on MCI management to healthcare providers in a different country via telesimulation. Designing, implementing, and reporting upon the process to deliver educational content to healthcare providers overseas was the major goal of this project. We also sought to obtain data amenable for both qualitative and quantitative analysis. The qualitative component of this study consisted of a survey to evaluate the learners' thoughts, feelings, and attitudes about taking an EMS-based course in MCI triage via telesimulation. We used the quantitative data obtained to demonstrate the process and feasibility of collecting data to evaluate the diagnostic accuracy of triage performed by the learners in a course delivered via telesimulation.

Analysis

We used descriptive statistics to express the percentage of participants with favorable responses to survey questions. Survey response categories consisted of ordinal data using a five-point Likert scale ranging from "strongly disagree" to "strongly agree." Triage accuracy was summarized as percent correct.

RESULTS

A total of 32 participants enrolled in the course: 12 physicians (37%); four nurses (13%); and five EMT/paramedics (16%). As the course offerings were open to all participants who could be responsible for providing service in a MCI, participants with varying backgrounds also enrolled, including two pharmacists (6%), and eight in "other" category (25%), which included educators, administrators and technicians. One participant (other*) did not fill out his or her profession on the survey.

We evaluated feasibility by the successful utilization of resources for specific goals and in delivering the final product to the learners – an educational course on the EMS-based topic of MCI triage. Course participants' thoughts, feelings, and attitudes toward learning EMS-based content on MCI triage were obtained by an immediate post-course survey that maintained subject anonymity. Learners reported that this experience added educational value beyond learning from standard lectures and that this method of virtual simulation is more effective than standard tabletop exercises to learn the MCI triage method (Figure 3). The participants also supported the notion that wearable technology can be an effective tool to transmit critical patient information in the prehospital care setting between providers. Furthermore, they reported that the telesimulation course enhanced their ability to provide care for patients involved in a MCI (Figure 3). Participants provided a favorable response to all questions on the survey regarding their thoughts, feelings, and attitudes toward learning EMS-based content via telesimulation.

For triage accuracy, we were able to collect data in real time of participants' assessment of patients during the virtual simulation component of the course. These data allow the calculation of triage accuracy according to provider category and experience. As this feasibility study was not intended or designed

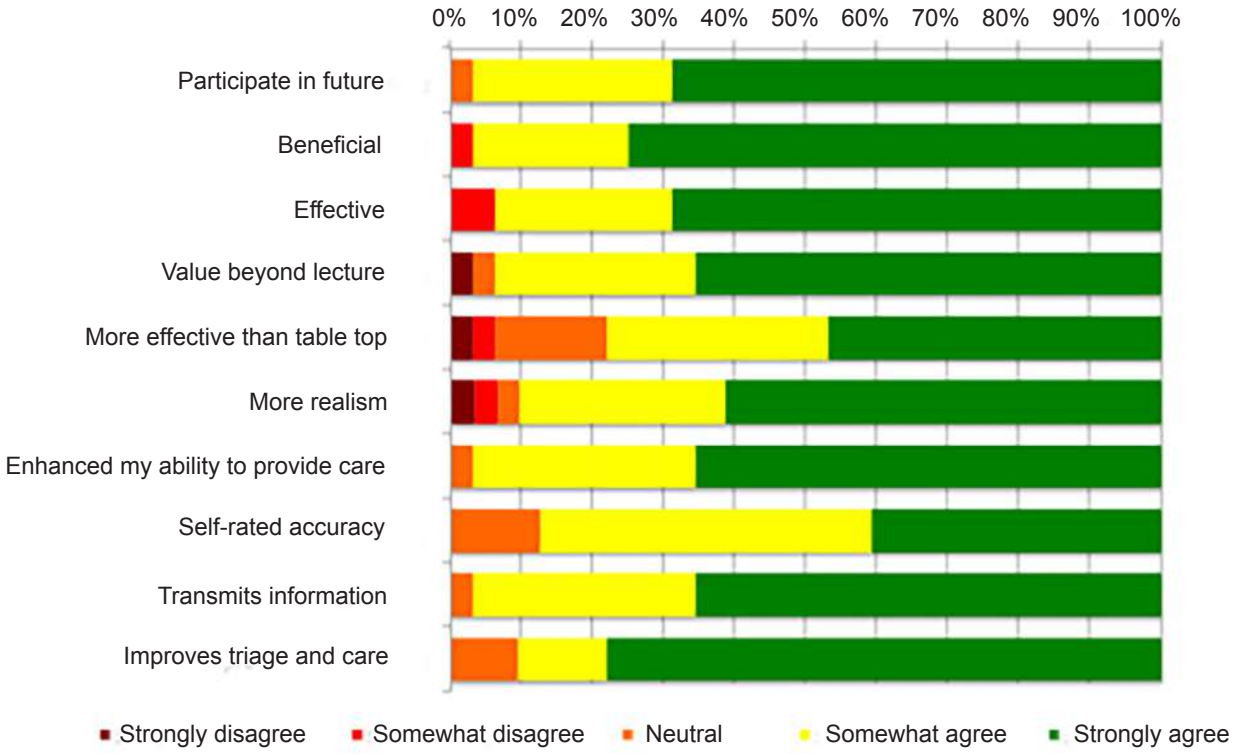


Figure 3. Survey results according to all response categories.

as an observational-analytical study to evaluate the triage accuracy of participants, data are presented as simple descriptive statistics for illustrative purposes, without any inferences being stated or implied about the larger population from which the sample was drawn (Table 1).

Table 1. Diagnostic triage accuracy according to profession.

Group	N	% correct triage
Physicians	12	84
Nurses	4	88
EMT/Paramedics	5	60
Pharmacists	2	85
Educator/technician/other	8	78

EMT, emergency medical technician.
n=sample size; other=educator, technician, administration.

DISCUSSION

In this feasibility study we demonstrated the successful implementation of an EMS-based educational course on MCI triage training to healthcare providers overseas via telesimulation. This process allowed the collection of data amenable for both qualitative and quantitative analysis. As telesimulation is a relatively new niche, there is a paucity of literature to support the evidence base behind its use.

Our survey results revealed an overall positive view toward learning EMS content of MCI triage with telesimulation. Participants reported that this teaching experience added educational value above and beyond their learning from standard lectures and that this method of virtual simulation was more effective than standard tabletop exercises to learn the MCI triage method. The participants also supported the notion that wearable technology can be used as an effective tool to transmit critical patient information in the prehospital care setting between providers and reported that the telesimulation course enhanced their ability to provide care for patients involved in a MCI. Research has provided evidence to suggest that simulation is superior to conventional educational delivery methods in emergency and critical care medicine education.[9-12] Our learner-favorability responses are consistent with those found in the telesimulation and simulation literature and support the research suggesting that simulation is superior to conventional educational-delivery methods.

The positive thoughts, feelings, and attitudes expressed by our learners toward telesimulation supports the findings in previous telesimulation studies. In a study using telesimulation to provide distance medical education, the authors used

telesimulation to teach emergency scenarios with a remote expert providing instruction.[18] A Likert-scale questionnaire revealed overwhelming satisfaction with the simulation-based distance training, and the authors concluded that simulation-based distance medical training proved to be a highly effective tool in improving emergency medical skills of junior physician trainees. They also reported that international simulation-based training may ultimately prove the most realistic platform for large-scale training of emergency medical personnel in less-developed countries and in rural/remote regions of the globe.

A military study designed to assess the efficacy and feasibility of training isolated emergency medical personnel at a naval hospital concluded that human patient simulation improves perceived preparedness and self-efficacy in U.S. Navy emergency medical personnel.[19] They also reported that simulation and distance education allows isolated medical personnel the opportunity to practice skills unconstrained by time or distance.[19] Telesimulation has also received favorable reviews in fields such as pediatric critical care and neonatal resuscitation.[20-22]

For the quantitative data collection component of the study, we were able to capture real-time learner assessment data during the virtual simulation component of the course. Using Google Glass to record the triage scenario used to assess participant triage accuracy provided a standardized experience for each learner from the first-person perspective. This immersive method of education and training is in stark contrast to abstract learning experiences such as standard didactics or tabletop exercises, which lack the virtual reality, stressful depiction, moulaged victims, high-stakes responsibility, personal perceived danger, and time pressure of a simulated first-person immersive experience. Research has shown that learning during emotional stress is associated with enhanced declarative memory for emotionally arousing events.[23] The time learners had to evaluate each patient and make a decision with regard to their triage category – less than 60 seconds per patient – was consistent with that intended by the triage decision tool.

We were also able to demonstrate the successful implementation of wearable technology in the creation and delivery of an intercontinental MCI training course. Google Glass is a hands-free, wearable device that allows healthcare providers to evaluate and manage patients while simultaneously recording or transmitting data. The utility of wearable technology in healthcare has been evaluated in medical specialties including surgery,[24-26] cardiology,[27,28] ophthalmology,[29] and emergency medicine.[30,31] Our study contributes to the scientific knowledge pertaining to the utility of wearable technology in healthcare in the field of EMS and emergency medicine.

EMS is a relatively new subspecialty in emergency medicine, recognized by the American Board of Emergency Medicine (ABEM) in 2010, with the first certification exam in 2013.[32] Literature regarding telesimulation in EMS is virtually nonexistent, and as a result there is limited research to support its evidence base.

Two previous reports using Google Glass have been described, both with substantial methodology limitations. In a feasibility study to determine the effect telemedicine has on the accuracy and timeliness to perform triage in an airplane-related MCI, the authors reported that there was no increase in triage accuracy when paramedics evaluated victims using Google Glass.[33] They also reported that telemedicine required more time than conventional triage. Although reported as a feasibility study, the authors measured and reported quantitative metrics similar to that reported in an observational-analytical study with a nonrandomized intervention and control group. The small sample size (total of four paramedics), lack of randomization, different number of patients triaged by the teams, and unintended technology challenges that precluded real-time transmission of audio and video data through Google Glass, are significant limitations. The second related study used Google Glass during a full-scale exercise to perform visually guided triage and to identify casualties and collect georeferenced notes, photos, and videos into the debriefing.[34] The authors reported that Google Glass is a promising technology both for telemedicine applications and augmented-reality disaster response support to increase operators' performance, helping them to make better choices in the field.[34]

The aforementioned studies are similar to this report, in that Google Glass was used as an evaluative tool to collect data for assessment and/or educational purposes. This study differs by virtue of its use of wearable/mobile technology to provide *real-time* training in a live, simulated MCI with integrated debriefing with participant interaction. The wearable technology was also used to create the evaluation resource that was used during the virtual simulation component of the course. To our knowledge, this is the first study of its kind to implement an intercontinental MCI triage course to healthcare providers via telesimulation with Google Glass.

We also considered or encountered barriers and challenges when implementing this telesimulation course. We define barriers as those minimum requirements that must be attained or resources that must be obtained to conduct a telesimulation course. The major barriers include limited availability of telecommunication equipment, simulation resources, and personnel experienced in designing and delivering simulation-based course content (Table 2). Challenges pertain to those problems that educators may encounter in the interim between securing the minimum resources to conduct a telesimulation course and successfully delivering on the educational course protocol. The challenges we encountered were primarily operational. Choosing a software program proved to be an initial challenge as the country we were broadcasting to had strict limitations on the type of software platforms that could be used. Other challenges included Internet connectivity and live broadcasting to an institution 10 hours ahead in time.

Table 2. Barriers and challenges to telesimulation course implementation.

Barriers
Acquiring telecommunication resources
Acquiring simulation resources
Securing subject matter expert(s)
Securing educators experienced in simulation
Financing
Challenges
Internet connectivity
Choosing appropriate multimedia software
Familiarity with technology
Course scheduling (for different time zones)
Establishing inter-institutional relationships

LIMITATIONS

The course delivered in this feasibility study was geared toward healthcare providers who would be responsible for managing patients in a MCI. Enrollment for the course was voluntary; thus, the sample may not be representative of all the professions that may be responsible for patient care during a MCI. However, we also believe that those responsible for managing patients during a MCI would be more enthusiastic to engage in this type of course.

The study was not designed as an observational-analytical study, nor was it powered to detect any specific significant difference between the groups. Having noted this, our results are consistent with triage performance demonstrated by healthcare providers undergoing START triage training using non-immersive educational methods.[35,36] We believe this feasibility study makes possible future interventional studies to test whether specific content can be taught effectively with a new educational delivery method. And finally, the course was intended primarily for healthcare providers. However, professionals in the educational setting also participated. The background of this group ("other" category) was heterogeneous and their summary performance measure may not be representative of any particular individual profession in that group.

This telesimulation obviated the need for expert instructors from the sending site to travel to the recipient site to deliver the content, saving cost. Nevertheless, substantial infrastructure investments were necessary on both ends to make the telesimulation possible.

CONCLUSION

This study demonstrates that implementation of an intercontinental MCI-triage training course, and the use of wearable/mobile technology to create and deliver the content though telesimulation, was feasible and well-accepted by learners. Further study is needed to validate telesimulation as a content delivery method to emergency providers.

Address for Correspondence: C. Eric McCoy, MD, MPH, University of California, Irvine, Department of Emergency Medicine, 333 City Boulevard West, Suite 640, Orange, CA. Email: cmccoy@uci.edu, ericmccoymd@gmail.com.

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.

REFERENCES

1. Schenk E, Wijetunge G, Mann NC, et al. Epidemiology of mass casualty incidents in the United States. *Prehosp Emerg Care*. 2014;18(3):408-16.
2. FBI releases study on active shooter incidents. *FBI*. Available at: https://www.fbi.gov/news/stories/2014/september/fbi-releases-study-on-active-shooter-incidents/fbi-releases-study-on-active-shooter-incidents. Accessed April 19, 2017.
3. Guha-Sapir D, Hoyois P, Below R. Annual Disaster Statistical Review 2015: The numbers and trends. Centre for Research on the Epidemiology of Disasters (CRED). Institute of health and Society (IRSS) Universite catholique de Louvain – Brussels, Belgium. Available at: http://www.cred.be/sites/default/files/ADSR_2015.pdf. Accessed April 19, 2017.
4. Blair J, Schweit K. A study of active shooter incidents in the United States between 2000 and 2013. Texas State University and Federal Bureau of Investigation, U.S. Department of Justice, Washington D.C. 2014. Accessed January 1, 2017.
5. National Consortium for the Study of Terrorism and Response to Terrorism (START). 2016. Global Terrorism Database. Available at: https://www.start.umd.edu/gtd/. Accessed January 3, 2017.
6. The Learning Pyramid. National Training Laboratories. Bethel, Maine. Available at: https://siteresources.worldbank.org/DEVMARKETPLACE/Resources/Handout_TheLearningPyramid.pdf. Accessed April 19th, 2017.
7. Masters K. Edgar Dale's Pyramid of Learning in medical education: a literature review. *Med Teach*. 2013;35(11):e1584-93.

8. Gaba DM. The future vision of simulation in healthcare. *Qual Saf Health Care.* 2004;13(Suppl):i2-10.
9. McCoy CE, Menchine M, Anderson C, et al. Prospective randomized crossover study of simulation vs. didactics for teaching medical students the assessment and management of critically ill patients. *J Emerg Med.* 2011;40(4):448-55.
10. Sullivan N, Duval-Arnould J, Twilley M, et al. Simulation exercise to improve retention of cardiopulmonary resuscitation priorities for in-hospital cardiac arrest: A randomized controlled trial. *Resuscitation.* 2015;86:6-13.
11. Zakhary BM, Jam LM, Kaufman BS, et al. The utility of high-fidelity simulation for training critical care fellows in the management of extracorporeal membrane oxygenation emergencies: a randomized controlled trial. *Crit Care Med.* 2017;45(8):1367-73.
12. Steadman RH, Coates WC, Huang YM, et al. Simulation-based training is superior to problem-based learning for the acquisition of critical assessment and management skills *Crit Care Med.* 2006;34(1):151-7.
13. McCoy CE, Sayegh J, Alrabah R, et al. Telesimulation: an innovative tool for health professions education. *AEM Education and Training.* 2017;1:132-6.
14. Medical Education Simulation Center. University of California, Irvine. Available at: http://www.medsim.uci.edu/index.asp. Accessed April 28, 2017.
15. Lerner E, Schwartz R, McGovern J. Prehospital triage for mass casualties. In: Cone D, Brice J, Delbridge T, Myers J, eds. *Emergency Medical Services Clinical Practice and Systems Oversight*. 2nd ed. Wiley. 2015:288-91.
16. Critical Illness and Trauma Foundation, Inc. Simple Triage and Rapid Treatment – background of START. Available at: http://citmt.org/Start/default.htm. Accessed April 28, 2017.
17. START adults triage algorithm. U.S. Department of Health & Human Services. Available at: https://chemm.nlm.nih.gov/startadult.htm#more. Accessed April 28, 2017.
18. von Lubitz DK, Carrasco B, Gabbrielli F, et al. Transatlantic medical education: preliminary data on distance-based high-fidelity human patient simulation training. *Stud Health Technol Inform.* 2003;94:379-85.
19. Treolar D, Hawayek J, Montgomery JR, et al. On-site and distance education of emergency medicine personnel with a human patient simulator. *Mil Med.* 2001;166(11):1003-6.
20. Everett T, Ng E, Power D, et al. The Managing Emergencies in Paediatric anaesthesia global rating scale is a reliable tool for simulation-based assessment in pediatric anaesthesia crisis management. *Paediatr Anaesth* 2013;23(12):1117-23.
21. Everett B, Bould D, Elaine M, et al. Board 152 – Program innovations abstract transcontinental telesimulation: the global proliferation of the Managing Emergencies in Paediatric Anaesthesia (MEPA) course. Available at: http://journals.lww.com/simulationinhealthcare/Abstract/2013/12000/Board_152___Program_Innovations_Abstract.62.aspx. Accessed May 8, 2017.
22. Manhas D, Anderson J. Educational perspectives: telesimulation in neonatal resuscitation. *NeoReviews* 2014;15(12). Available at: http://neoreviews.aappublications.org/content/15/12/e514. Accessed May 8, 2017.
23. Cahill L, McGaugh JL. Mechanisms of emotional arousal and lasting declarative memory. *Trends Neurosci.* 1998;21(7):294-9.
24. Davis, CR, Rosenfield LK. Looking at plastic surgery through Google Glass: Part 1. Systematic review of Google Glass evidence and the first plastic surgical procedures. *Plast Reconstr Surg.* 2015;135:918-28.
25. Iversen MD, Kiami S, Singh K, et al. Prospective, randomized controlled trial to evaluate the effect of smart classes on vestibular examination skills. *BMJ Innov* 2016;2:99-105.
26. Liebert CA, Zayed MA, Aalami O, et al. Novel use of Google Glass for procedural wireless vital sign monitoring. *Surg Innov.* 2016;23:366-73.
27. Duong T, Wosik J, Christakopoulos GE, et al. Interpretation of coronary angiograms recorded using Google Glass: a comparative analysis. *J Invasive Cardiol* 2015;27(10):443-6.
28. Jeroudi OM, Christakopoulos G, Christopoulos G, et al. Accuracy of remote electrocardiogram interpretation with the use of Google Glass technology. *Am J Cardiol.* 2015;115:374-7.
29. Trese MG, Khan NW, Branham K, et al. Expansion of severely constricted visual field using Google Glass. *Ophthalmic Surg Lasers Imaging Retina.* 2016;47(5):486-9.
30. Chai PR, Wu RY, Ranney ML, et al. Feasibility and acceptability of Google Glass for emergency department dermatology consultations. *JAMA Dermatol.* 2015;151(7):794-6.
31. Wu TS, Dameff CJ, Tully JL. Ultrasound-guided central venous access using Google Glass. *J Emerg Med* 2014;47:668-75.
32. EMS – Overview. American Board of Emergency Medicine. Available at: https://www.abem.org/public/subspecialty-certification/emergency-medical-services/ems-overview. Accessed May 11, 2017.
33. Cicero MX, Waish B, Soledad Y, et al. Do you see what I see? Insights from using Google Glass for disaster telemedicine triage. *Prehosp Disaster Med.* 2015;30(1):4-8.
34. Carenzo L, Barra FL, Ingrassia PL, et al. Disaster medicine through Google Glass. *Eur J Emerg Med.* 2015;22(3):222-5.
35. Risavi BL, Salen PN, Heller MB, et al. A two-hour intervention using START improves prehospital triage mass casualty incidents. *Prehosp Emerg Care.* 2001;5(2):197-9.
36. Sapp RF, Brice JH, Hinchey P. Triage performance of first-year medical students using a multiple-casualty scenario, paper exercise. *Prehosp Disaster Med.* 2010;25(3):239-45.

Targeted Simulation-based Leadership Training for Trauma Team Leaders

Elizabeth D. Rosenman, MD*
Marie C. Vrablik, MD, MCR*
Sarah M. Brolliar, BS*
Anne K. Chipman, MD, MS*
Rosemarie Fernandez, MD†

*University of Washington School of Medicine, Department of Emergency Medicine, Seattle, Washington
†University of Florida College of Medicine, Department of Emergency Medicine, Gainesville, Florida

Section Editor: Michael Epter, DO
Submission history: Submitted October 24, 2018; Revision received February 6, 2019; Accepted February 22, 2019
Electronically published April 16, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.2.41405

Introduction: Effective team leadership is linked to better teamwork, which in turn is believed to improve patient care. Simulation-based training provides a mechanism to develop effective leadership behaviors. Traditionally, healthcare curricula have included leadership as a small component of broader teamwork training, with very few examples of leadership-focused curricula. The objective of this work is to describe a novel simulation-based team leadership curriculum that easily adapts to individual learners.

Methods: We created a simulation-based team leadership training for trauma team leaders in graduate medical education. Participants included second- and third-year emergency medicine and surgery residents. Training consisted of a single, four-hour session and included facilitated discussion of trauma leadership skills, a brief didactic session integrating leadership behaviors into Advanced Trauma Life Support®, and a series of simulations and debriefing sessions. The simulations contained adaptable components that facilitated individualized learning while delivering set curricular content. A survey evaluation was administered 7-24 months following the training to assess self-reported implementation of trained material.

Results: A total of 36 residents participated in the training and 23 (64%) responded to the survey. The majority of respondents (n = 22, 96%) felt the training was a valuable component of their residency education and all respondents reported ongoing use of at least one behavior learned during the training. The most commonly cited skills for ongoing use included the pre-arrival brief (n = 21, 91%) and prioritization (n = 21, 91%).

Conclusion: We delivered a leadership-focused, simulation-based training that 1) adapted to learners' individual needs, and 2) was perceived to impact practice up to 24 months post-training. More work is needed to understand the impact of this training on learner knowledge and behavior, as well as patient outcomes. [West J Emerg Med. 2019;20(3)520–526.]

INTRODUCTION

Leadership is important in healthcare resuscitation teams, such as trauma teams, that function under complex, dynamic, and time-pressured conditions.[1,2] Effective team leadership is linked to better teamwork,[3] which in turn is believed to improve patient care.[4] Despite consensus on the importance of leadership training, clinical team leadership is most frequently a small component of broader teamwork-focused training, with very few examples of leadership-focused curricula.[5] As a result, leadership skills can vary markedly within a cohort of trainees.

Simulation-based training provides a mechanism to develop effective leadership behaviors. However, structured implementation of a context-specific leadership curriculum, such as a trauma leadership curriculum, requires 1) authentic reproduction of the environmental components present during a trauma resuscitation, 2) re-creation of a

large, multidisciplinary team with scripted roles, and 3) the ability to address individual learner needs.

To address this gap in training practices, we designed a simulation-based, trauma team leadership curriculum intended for graduate medical education. This approach was novel in its use of simulation to individualize training in a dynamic setting. The objective of this article is to describe the team leadership curriculum. We also present a self-report of trained leadership skill implementation 7–24 months following training.

METHODS

Overview

We designed and implemented a novel, simulation-based team leadership training for trauma team leaders. The training was administered monthly, from June 2016-November 2017. We surveyed trained participants 7-24 months following training to determine the perceived value of this training. The institutional review board at the University of Washington approved the study.

Participants and Setting

Participants included second- and third-year emergency medicine (EM) and surgery residents rotating as the trauma team leader at a Level 1 trauma center within an academic healthcare system. To be eligible, the participants were required to a) be in good standing with the Office of Graduate Medical Education, b) have completed the Advanced Trauma Life Support® (ATLS) course, and c) have at least four weeks prior experience in emergency department (ED) trauma care. Residents were approached and consented by a study coordinator. Participation was voluntary and participants were compensated with a $100 gift card for study participation. Leadership training took place at the WWAMI (Washington, Wyoming, Alaska, Montana, and Idaho) Institute for Simulation in Healthcare, an 8,000-foot simulation suite, using a SimMan® human patient simulator (Laerdal Medical, Wappingers Falls, New York).

Leadership Behaviors

A conceptual model for team leadership provided the foundation for the training.[6] Leadership behaviors were translated into "communication events" tightly linked to key time points during an ATLS-driven resuscitation. These communication events became the behaviors that were the focus of training. By linking leadership concepts (e.g., setting priorities) to key steps in ATLS, the training helped learners anchor new behaviors on an existing knowledge scaffolding. The learning objectives, organized by communication event, are provided in Table 1.

Training Design and Implementation

Training consisted of a single, four-hour session and included a group discussion, a brief lecture, and a series of simulations and debriefing sessions. Each training session was delivered to a pair of learners. A core group of four emergency physicians and one emergency nurse served as instructors, with at least three instructors present at every session. Prior to training implementation, we piloted the curriculum with four EM residents over two sessions, using participant feedback to make minor adjustments to the timing and the content.

Facilitated Discussion and Lecture

The training session started with a brief introduction followed by a 30-45 minute facilitated discussion in which the learners discussed examples of effective and ineffective team leadership that they had observed in the clinical setting. Through this discussion, learners generated a list of desirable leadership behaviors and a list of barriers to implementing effective leadership. Following this discussion there was a 30-minute lecture reviewing the leadership behaviors as outlined in the learning objectives in Table 1. Learners were also provided a leadership checklist created from the learning objectives (Supplemental Figure 1). This checklist was used to facilitate learner observations during simulations and peer-to-peer feedback during debriefing.

Simulation Scenarios

Four trauma-resuscitation simulation scenarios were created by two members of the research team (EDR, RF) and reviewed by two additional members of the research team (Marie C. Vrablik, Anne K. Chipman) for content and flow. Scenarios were designed using event-based training design principles, which uses embedded triggers to ensure case progression regardless of learner performance.[8]

To facilitate transfer of learned behaviors to the clinical environment, we optimized the realism of the simulated environment, specifically focusing on the environmental and team factors that can contribute to the stress of leading a trauma resuscitation team. To reproduce the noise typical of an ED, actual background sound from the ED, without identifying information, was used. This sound was played during simulated cases. We recruited hospital volunteers to function as team members, allowing us to have up to 10 people representing different disciplines, in the simulation space. We introduced interruptions such as overhead pages and phone calls from nursing staff taking care of other patients. We were also cognizant of the impact of space on team interactions, and physically enclosed an area within the simulation suite to match the dimensions of the clinical environment at our institution. All four scenarios involved trauma patients presenting to the ED via emergency medical services. A detailed description of the scenarios is provided in the Supplemental Figure 2.

Observation and Debriefing

During the simulation component, a single learner functioned as the team leader, while the second learner observed using the leadership checklist. Debriefing occurred immediately following the simulation, and the learner in

Table 1. Learning objectives for the trauma team leadership curriculum.

Communication event	Event description	Specific team leader behaviors[a]
Assumes leadership	Prior to or upon patient arrival	•Explicit statement of role as team leader
Pre-arrival brief	Information exchange prior to arrival that occurs at the bedside to facilitate interprofessional and interdisciplinary involvement.	•Summarizing facts •Assigning or confirming roles •Creating and verbalizing a plan •Setting and verbalizing priorities
Arrival brief	Information exchange just following patient arrival and pre-hospital report to confirm or change plan as indicated.	•Highlighting any new information learned upon patient presentation •Highlighting any change in plan based on patient presentation
Huddle	Information exchange to update team as indicated during the resuscitation. Potential times include after: the primary survey, the secondary survey, a change in clinical status, or a change in team composition.	•Updating the team with summary of facts •Gathering information from team •Verbalizing primary diagnosis or problem •Setting and verbalizing priorities for next steps •Soliciting ideas from team •Asking about potential barriers or delays
Communication between services	Occurs throughout the resuscitation when new team members arrive or consultants are called.	•Updating new team members •Using SBAR[b] to communicate •Promoting a shared mental model by explicitly asking team members and consultants to share decision making
Transferring leadership	Facilitating the hand-off of leadership to a team member when initial team member must leave the room, or engage in a procedure or other task that requires focus on a subset of the patient's care.	•Handing off leadership when performing a procedure or leaving patient care area •Using SBAR[b] to inform new team leader •Making transfer of leadership explicit to entire team

[a]Team leader behaviors are based on a conceptual model of team leadership.[6]
[b]Situation, background, assessment, recommendation (SBAR) is a component of the TeamSTEPPS® training program.[7]

the observer role was encouraged to actively participate. The learners switched roles for the second simulation. Following the first round of simulations and debriefings, both learners identified three specific behaviors to work on in the subsequent simulations. These self-identified areas for improvement, as well as observations made by the instructors, informed the content of the subsequent simulations. The second round of simulations was structured similarly, with each participant functioning as the team leader once, and as an observer once, with a group debriefing after each scenario. The three previously identified behaviors were specifically reviewed and a plan created for each learner to facilitate implementation of these behaviors in the clinical environment.

Adaptive Simulation Component

The initial simulation provided a basic platform to allow learners to perform trained leadership behaviors. As noted above, the second simulation was individualized, based on learner- and instructor-identified weaknesses raised during the initial debriefing. To accomplish this we started with a scenario scaffold, and then selected from several pre-scripted options related to content (e.g., different injuries), team roles (e.g., disruptive team member), and environmental stimuli (e.g., distractions from other patients) (Supplemental Table). For example, if a learner needed to practice handing off leadership, the scenario would be modified to ensure there was a procedure (e.g., intubation, chest tube) and the team was instructed to not perform the procedure (e.g., the team "intern" would state he/she was not trained on that procedure yet), thereby forcing the team leader to do the procedure. Finally, if needed, a team member would prompt leadership hand-off if the learner did not initiate it (e.g., the "attending" would enter the room and would use escalating prompts to ensure the learner eventually handed off leadership).

Evaluation

We developed an 18-item survey to evaluate the perceived value of the training and the extent to which trained leadership behaviors were implemented following training (Supplemental Figure 3). The survey included demographic questions, followed by multiple-choice questions related to the quality

of the training, the relative value of the training compared to other leadership trainings, the realism of the simulations, and the frequency with which participants used and/or taught the learned behaviors. In addition, three questions allowed participants to provide free-text commentary on the value of the training and recommendations for improving the training. The survey was administered at the end of the academic year after the last training session was conducted. We sent a total of four email requests on a weekly basis to encourage participation. We collected data using REDCap (Research Electronic Data Capture) tools hosted at the University of Washington's Institute of Translational Health Sciences.[9] Surveys were anonymous.

Data Analysis

We computed descriptive statistics (median and interquartile range as appropriate) for results from the Likert questions.

RESULTS

A total of 36 residents completed the training, with one participant only completing half of the training due to a scheduling conflict. The survey was sent to all 36 participants, and 23 (64%) responded. The demographic composition of the participants who responded to the survey was similar to the larger group of trained participants (Table 2).

The majority of respondents felt the training was a "very valuable" component of their residency education (n=20, 87%) and "very valuable" to their current practice (n=16, 70%). The remaining respondents felt the training was either "valuable" or "fairly valuable," with no respondents reporting it as "not valuable" or only "slightly valuable." Table 3 provides the median responses for questions related to the value and the realism of the training.

All respondents indicated some ongoing use of the skills learned during the training, with the majority using the skills "daily" (n=6, 26%) or "several times weekly" (n=10, 43%). The most commonly cited skills for ongoing use included the pre-arrival brief (n=21, 91%) and prioritization (n=21, 91%) (Figure). The most commonly cited skills that participants taught to others included the pre-brief (n=20, 87%) and the huddle (n=18, 78%).

A total of 20 respondents (87%) answered one or more of the free-response questions. The majority of respondents (n=13, 50%) felt the training should be a standard, or even mandatory, part of the residency curriculum. Several components of the training were identified as being useful, including the following: 1) small groups of learners; 2) the realism of the training environment; 3) the focus on non-clinical skills; and 4) cycling between simulation and debriefing. The most common suggestion for improving the training was to offer similar training opportunities more frequently. Other suggestions included allowing participants to review their own videos, and providing follow-up coaching in the clinical environment. Table 4 has examples of responses organized by theme.

Table 2. Demographics of training participants and training evaluation survey respondents.

	All participants* (n=36) N(%)	Survey respondents (n=23) N (%)
Gender		
Male	22 (61)	14 (61)
Female	14 (39)	9 (39)
PGY during training		
2	23 (64)	14 (61)
3	13 (36)	9 (39)
PGY at time of survey*		
2		6 (26)
3		9 (39)
4		6 (26)
5		0 (0)
Fellow or attending		2 (9)
Ethnicity		
Hispanic	2 (6)	2 (9)
Not Hispanic	34 (94)	20 (87)
Unknown or not reported		1 (4)
Race		
AN/AI	0 (0)	0 (0)
Asian	7 (19)	3 (13)
Native Hawaiian or Pacific Islander	0 (0)	0 (0)
Black	0 (0)	0 (0)
White	27 (75)	18 (78)
More than one	2 (6)	2 (9)
Specialty		
Emergency medicine	31 (86)	20 (87)
Surgery	5 (14)	3 (13)

PGY, post-graduate year; *AN*, Alaskan Native; *AI*, American Indian.
*The All Participant data was taken from the demographic survey completed by participants at the time of training with the exception of the "PGY at the time of survey," which was only available for those participants who responded to the follow-up survey.

DISCUSSION

We created a four-hour, simulation-based team leadership training for trauma team leaders in graduate medical education. Survey results showed nearly universal support for the training program. We acknowledge that the 36% of participants who did not respond to the survey may have viewed the training less favorably. The time interval between training and the evaluation ranged from 7-24 months. This timing meant all participants had completed at least two years of postgraduate training, with

Table 3. Survey results for the perceived value and realism of the simulation-based leadership training.

Question and anchors	Median score (IQR)
Value of training to residency education 1 - Not valuable, residency training should not include this training 3 - Fairly valuable, residents in my specialty should have the option of taking this training 5 - Very valuable, it should be a part of all residency programs in my specialty	5 (5,5)
Value of training to current practice 1 - Not valuable, it was much less impactful than other teamwork or leadership training 3 - Fairly valuable, it was as impactful as other teamwork or leadership training 5 - Very valulable, it was more impactful than any other leadership or teamwork training	5 (4,5)
Realism of the simulations 1 - Not realistic, the simulation did not represent the stress and environment present in a trauma resuscitation 3 - Fairly realistic, some elements of the stress and environment of a trauma resuscitation were well-represented 5 - Very realistic, the stress and environment of a trauma resuscitation were well-represented	4 (4,5)

IQR, interquartile range.

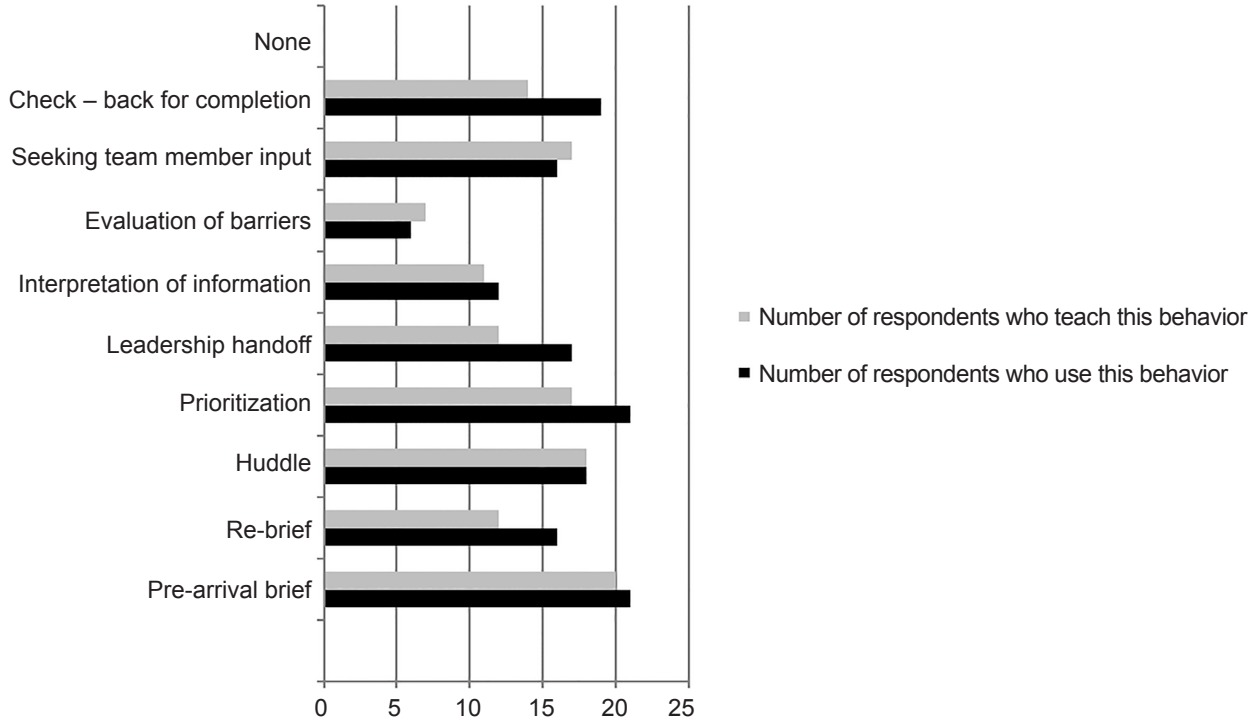


Figure. Most frequently implemented behaviors from the trauma team leadership curriculum.

some respondents having completed residency training. Despite this time interval, and the concurrent learning opportunities, the evaluations suggest the training had a meaningful and lasting impact for most learners.

We believe the strength of the training was the learner-focused content, facilitated by small groups of learners and cycling between multiple simulations and debriefings. The facilitated discussion provided instructors with insight into the participants' baseline level of knowledge and their individual challenges. The initial simulations were targeted to the learner based on prior knowledge of the learner and the facilitated discussion. Finally, the pre-scripted options for the second round of simulations facilitated rapid scenario modification to individualize the training. Together, this structure provides a semi-standardized approach to delivering team leadership training that can adapt to the learner.

Although not cited by the learners, we felt there was also value in incorporating peer observations and feedback, and using cognitive aids to help maintain focus on team leadership rather than clinical care. We were initially uncertain

Table 4. Examples of survey free-text responses organized by themes.

Themes (Number of related comments)	Examples of comments
Training should be required (13)	• Should be mandatory. • Please incorporate this in our training! It is one of the single most helpful things I have done in residency regarding leadership. This has absolutely changed my practice. • Mandatory for all residents before leading a code. • Excellent training which gives a framework for myriad roles in daily clinical medicine. Should be a component of every resident's training. • Excellent, should be provided to all EM residents in all residency programs, it helps the quality of care in our specialty.
Useful components of the training	
Realism of the simulations (SIM) (3)	• This was very helpful, and far more realistic than the average SIM. It would be valuable for all residents to receive this training! • The authenticity and stressful environment made this great training.
Non-clinical focus (1)	• This was one of the most valuable simulations I participated in and made me a much more confident leader in these situations. Prior to the simulation I was a bit of a wallflower but this gave me some basics with which to take command and fall back on in difficult situations. Rather than focusing on the basics of resuscitation the emphasis on teamwork was key. I recently had a very difficult code and was able to take command with many of the specific skills that I learned in this training.
Small learner group (1)	• Nothing to make it better, but the very small group (two people) was very helpful.
Repetition of simulations and debriefings (1)	• Opportunity to do multiple SIMs after discussing how the first one went, and getting a second chance to incorporate the teachings.
Opportunity for improvement	
Coaching and performance review (5)	• Ability to see feedback videos. Real-time feedback in a real clinical scenario. • More check-ins after the training to see how things were going.
More frequent training (4)	• We need more of this kind of training. One day spent doing this training drastically changed my performance during traumas and medics codes and really helped with my confidence. • More of it. More repetitions.
Timing of training (4)	• If it had happened earlier in my training, at the end of R1 or beginning of R2, before I had certain set habits. • Ideal for junior residents to set them on the correct path.
Other (6)	• Critical training, not covered elsewhere. Invaluable. Made me a better team leader.

EM, emergency medicine; *R1*, first-year resident; *R2*, second-year resident.

whether our learners would feel comfortable discussing their perceived strengths and challenges, or participating in peer-to-peer feedback. Ultimately, the addition of peer observers and peer-guided feedback was beneficial, allowing learners to observe strengths and weaknesses of different leadership styles exhibited by their peers. Furthermore, it augmented the realism of the scenarios by adding an element of stress that replicated the stress of performing in a crowded resuscitation bay.

Several participants suggested the training should be provided early in residency (eg, beginning of second year, prior to leading a code). However, determining the "right" time to administer this type of training is complicated. It was our impression that more senior residents, who were more clinically confident, seemed to get more immediate benefit out of the training. They were less likely to get distracted by the medicine, allowing them to focus more on leadership skills. It may be, however, that more junior learners actually achieve more long-term value from this type of training, even if it isn't immediately apparent in the simulation lab. There is an argument for introducing teamwork and team leadership training earlier in medical education,[10] rather than waiting to introduce leadership skills until the individual is already in a formal leadership role. Learning good habits from the start may be better than trying to add or modify them later.

LIMITATIONS

There are several limitations to this work. Most importantly, the evaluation of the training was limited to learner perception, which is a level one outcome in Kirkpatrick's framework.[11] Further work is needed to determine the impact of this training, however well received, on learner knowledge, behavioral change, and clinical care. In addition, our response rate was 64%. We

intentionally delayed survey assessments to gain learner insight into skill implementation, knowing the trade-off would be a decrease in response rate. While this response rate is within the range of previously reported response rates for surveys of phyisicians,[12,13] it introduces the possibility of a selection bias favoring the training.

CONCLUSION

We designed and implemented an adaptable, simulation-based team leadership training that had a lasting impact on the learners, as demonstrated by participant survey responses up to two years post-training. Given the resource-intensive nature of the training, more work is needed to understand the impact of this training on learner knowledge and behavior, and patient outcomes, and to understand the optimal timing for delivery of the training.

Address for Correspondence: Elizabeth Rosenman, MD, University of Washington School of Medicine, Department of Emergency Medicine, 325 9th Ave Box 359702, Seattle, WA 98104. Email: er24@uw.edu.

Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. Funding and support for this project was provided by the Agency for Healthcare Research and Quality (1R18HS022458-01A1[RF, EDR]). The funding source had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, approval, or decision to submit the manuscript. REDCap at ITHS is supported by the National Center for Advancing Translational Sciences of the National Institutes of Health under Award Number UL1 TR002319.

REFERENCES

1. Sundstrom E, De Meuse KP, Futrell D. Work teams: applications and effectiveness. *Am Psychol.* 1990;45(2):120-33.
2. Rosenman ED, Fernandez R, Wong AH, et al. Changing systems through effective teams: a role for simulation. *Acad Emerg Med.* 2018;25(2):128-43.
3. Kozlowski SW, Gully S, McHugh P, et al (1996). A dynamic theory of leadership and team effectiveness: developmental and task contingent leader roles. In: Ferris GR, editor. *Research in Personnel and Human Resources Management*. Greenwich, Connecticut: JAI Press.
4. Neily J, Mills PD, Young-Xu Y, et al. Association between implementation of a medical team training program and surgical mortality. *JAMA.* 2010;304(15):1693-700.
5. Rosenman ED, Shandro JR, Ilgen JS, et al. Leadership training in health care action teams: a systematic review. *Acad Med.* 2014;89(9):1295-306.
6. Rosenman ED, Branzetti JB, Fernandez R. Assessing team leadership in emergency medicine: the Milestones and beyond. *J Grad Med Educ.* 2016;8(3):332-40.
7. Agency for Healthcare Research and Quality. TeamSTEPPS 2.0. Available at: https://www.ahrq.gov/teamstepps/instructor/fundamentals/index.html. Accessed February 1, 2016.
8. Fowlkes J, Dwyer DJ, Oser RL, et al. Event-Based Approach to Training (EBAT). *Int J Aviat Psychol.* 1998;8(3):209-21.
9. Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform.* 2009;42(2):377-81.
10. Jardine D, Correa R, Schultz H, et al. The need for a leadership curriculum for residents. *J Grad Med Educ.* 2015;7(2):307-9.
11. Kirkpatrick DL (1975). *Evaluating Training Programs.* New York City, New York: Tata McGraw-Hill Education.
12. Kellerman SE, Herold J. Physician response to surveys: a review of the literature. *Am J Prev Med.* 2001;20(1):61-7.
13. Burns KE, Duffett M, Kho ME, et al. A guide for the design and conduct of self-administered surveys of clinicians. *Can Med Assoc J.* 2008;179(3):245-52.

The Flipped Classroom: A Critical Appraisal

Aaron S. Kraut, MD*
Rodney Omron, MD, MPH†
Holly Caretta-Weyer, MD‡
Jaime Jordan, MD§
David Manthey, MD¶
Stephen J. Wolf, MD‖
Lainie M. Yarris, MD, MCR#
Stephen Johnson, MLS**
Josh Kornegay, MD††

*University of Wisconsin School of Medicine and Public Health, Berbee Walsh Department of Emergency Medicine, Madison, Wisconsin
†Johns Hopkins School of Medicine, Department of Emergency Medicine, Baltimore, Maryland
‡Stanford University School of Medicine, Department of Emergency Medicine, Palo Alto, California
§David Geffen School of Medicine at UCLA, Department of Emergency Medicine, Los Angeles, California
¶Wake Forest School of Medicine, Department of Emergency Medicine, Winston-Salem, North Carolina
‖Denver Health Medical Center, Department of Emergency Medicine, Denver, Colorado
#Oregon Health and & Science University, Department of Emergency Medicine, Portland, Oregon
**University of Wisconsin School of Medicine and Public Health, Library Services, Madison, Wisconsin
††Oregon Health and & Science University, Department of Emergency Medicine, Portland, Oregon

Section Editor: Danya Khoujah, MBBS
Submission history: Submitted September 18, 2018; Revision received December 16, 2018; Accepted February 16, 2019
Electronically published April 16, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.2.40979

Introduction: The objective of this study was to review and critically appraise the medical education literature pertaining to a flipped-classroom (FC) education model, and to highlight influential papers that inform our current understanding of the role of the FC in medical education.

Methods: A search of the English-language literature querying Education Resources Information Center (ERIC), PsychINFO, PubMed, and Scopus identified 296 papers related to the FC using either quantitative, qualitative, or review methods. Two reviewers independently screened each category of publications using previously established exclusion criteria. Eight reviewers then independently scored the remaining 54 publications using either a qualitative, quantitative, or review-paper scoring system. Each scoring system consisted of nine criteria and used parallel metrics that have been previously used in critical appraisals of education research.

Results: A total of 54 papers (33 quantitative, four qualitative, and 17 review) on FC met a priori criteria for inclusion and were critically appraised and reviewed. The top 10 highest scoring articles (five quantitative studies, two qualitative studies, and three review papers) are summarized in this article.

Conclusion: This installment of the Council of Emergency Medicine Residency Directors (CORD) Academy Critical Appraisal series highlights 10 papers that describe the current state of literature on the flipped classroom, including an analysis of the benefits and drawbacks of an FC approach, practical implications for emergency medicine educators, and next steps for future research. [West J Emerg Med. 2019;20(3)527–536.]

INTRODUCTION

The Council of Emergency Medicine Residency Directors (CORD) Academy Critical Appraisal Series approaches important, relevant educational problems with a rigorous literature review, systematic article scoring, and summary of the top papers to provide an understanding of the topic and describe practical implications for emergency medicine (EM) educators. In this installment of the series, we address the flipped classroom (FC) model in medical education. Traditional classroom (TC) didactics and lectures remain a common format in medical education despite well described limitations.[1,2] The FC approach has been suggested as one technique to overcome some of these limitations.

The working definition of the FC describes a technique where foundational knowledge is acquired independently by a learner prior to a classroom encounter. This knowledge is then applied during in-person interactions facilitated by an instructor, often in the form of case-based discussions, allowing for higher-level problem solving.[3,4] Components of FC may also be applied in a more heterogeneous "blended learning" approach, where online or asynchronous activities may supplement foundational concepts that are taught in a traditional face-to-face learning environment.[5] For the purposes of this critical appraisal, we will define FC to include instructional techniques that incorporate independent knowledge acquisition prior to a classroom encounter focused on the application of that knowledge. Despite the recent interest in the FC, little is known about optimal implementation strategies and the impact of this model on learning outcomes.[6]

This review applies a previously published method to search and critically appraise the literature regarding the FC model in medical education.[7,8] The objective of this appraisal was to summarize and highlight the top scoring papers in medical education regarding the FC, as well as present implications for EM educators and suggest future areas for research surrounding this important topic.

Population Health Research Capsule

What do we already know about this issue?
The flipped classroom (FC) approach to didactics is becoming increasingly popular among medical educators and has several ideal applications.

What was the research question?
To critically appraise the literature to help define the role of the FC in medical education.

What was the major finding of the study?
Key themes from the top 10 papers on the FC are summarized.

How does this improve population health?
This study provides guidance to medical educators looking to adopt an FC approach in the education of the next generation of physicians.

METHODS

Article Identification

A research librarian performed the literature search, querying Education Resources Information Center (ERIC), PsychINFO, PubMed, and Scopus to identify articles – limited to the English language – mapped to the medical subject headings terms "flipped classroom," or "inverted classroom," or "flipped learning," or "blended learning." Although the primary aim was to review FC papers, we found these terms are often used interchangeably in the literature, and instructional techniques universally fall somewhere on the spectrum between true "flipped classroom" and "blended learning."[5] Therefore, all terms were included for the initial search. An initial search found 296 papers using either quantitative (hypothesis-testing or observational investigations of educational interventions), qualitative (exploring important phenomena in EM education), or review methods. The literature search was conducted in March 2017.

Inclusion and Exclusion Criteria

We included publications relevant to the education of medical students, residents, attending physicians, and other healthcare professionals. Medical education studies were defined as hypothesis-testing investigations, evaluations of educational interventions, explorations of educational problems using either quantitative or qualitative methods, or review papers that synthesized existing literature to provide a new understanding of the topic. We excluded publications if 1) they were not considered to be peer-reviewed research (such as opinion pieces, commentaries, or curricula descriptions without outcomes data); 2) upon further review, the topic of the paper was not FC, but rather small-group interactive learning in the classroom setting or other teaching strategies; 3) they were not relevant to EM learners (such as reports on education of prehospital personnel or international studies that could not be generalized to EM training outside of the country in which they were performed); 4) they were single-site survey studies of individual curricula; 5) they were studies that examined outcomes limited to an expected learning effect without a comparison group; or 6) they were studies where the abstract or manuscript could not be obtained from the libraries of any of the authors.

Data Collection

Four authors (AK, JK, LY, and HCW) independently screened 296 abstracts from all retrieved publications and applied the exclusion criteria. After the first pass, they identified 68 manuscripts. Two separate authors (DM and RO) then performed a second-pass exclusion, reviewing all remaining manuscripts and excluding those that either had an exclusion criterion that was missed, or were not felt to have the potential to impact education theory or practice (e.g., studies that supported a widely accepted theory and lacked novelty, or those with methods that would be difficult to replicate for the majority of educators). All differences in opinion were resolved by direct discussion, which included the first author of this appraisal and negotiated consensus. We maintained retrieved publications in a Microsoft Excel 2010 (Microsoft Inc., Redmond, Washington) database. After complete review, 54 final publications were made electronically available to all reviewers (Figure 1).

Scoring

The publications were first assigned to a scoring system based on whether they were primarily quantitative studies, qualitative studies, or review articles. The quantitative studies used scoring criteria that were developed in 2009 and then continually optimized and iteratively modified since then.[9] Quantitative studies were scored in nine domains for a maximum total score of 25 points. The domains included the following: introduction (0-3 points); measurement (0-4 points); data collection (0-4 points); data analysis (0-3 points); discussion (0-3 points); limitations (0-2 points); innovation (0-2 points); generalizability (0-2 points); and clarity of writing (0-2 points). Each of the domains were scored based on predefined criteria to make scoring as objective as possible.

Using a previously published parallel scoring sheet developed based on guidelines for qualitative research and subsequently updated to reflect newer recommendations for increasing rigor and iteratively modified since then, we assessed and scored qualitative studies in nine domains, parallel to those applied to the quantitative studies, for a maximum total score of 25 points.[10] These also included the domains of measurement, data collection, and data analysis criteria, as defined specifically for high-quality qualitative research. Review papers were scored according to criteria established through an iterative process for the inaugural critical appraisal work, which includes the same nine domains as the quantitative and qualitative scoring instruments.[8]

To establish response process validity, pairs of authors read each scoring instrument aloud to ensure agreement in the interpretation of each scoring category. To establish reliability, each author read one quantitative, one qualitative, and one review paper and scored them using the appropriate scoring instrument, with good agreement. Inter-rater reliability by Shrout-Fleiss interclass correlation for absolute agreement was 0.646 across multiple raters.

All scoring scales are presented in Supplemental Tables 1, 2, and 3.

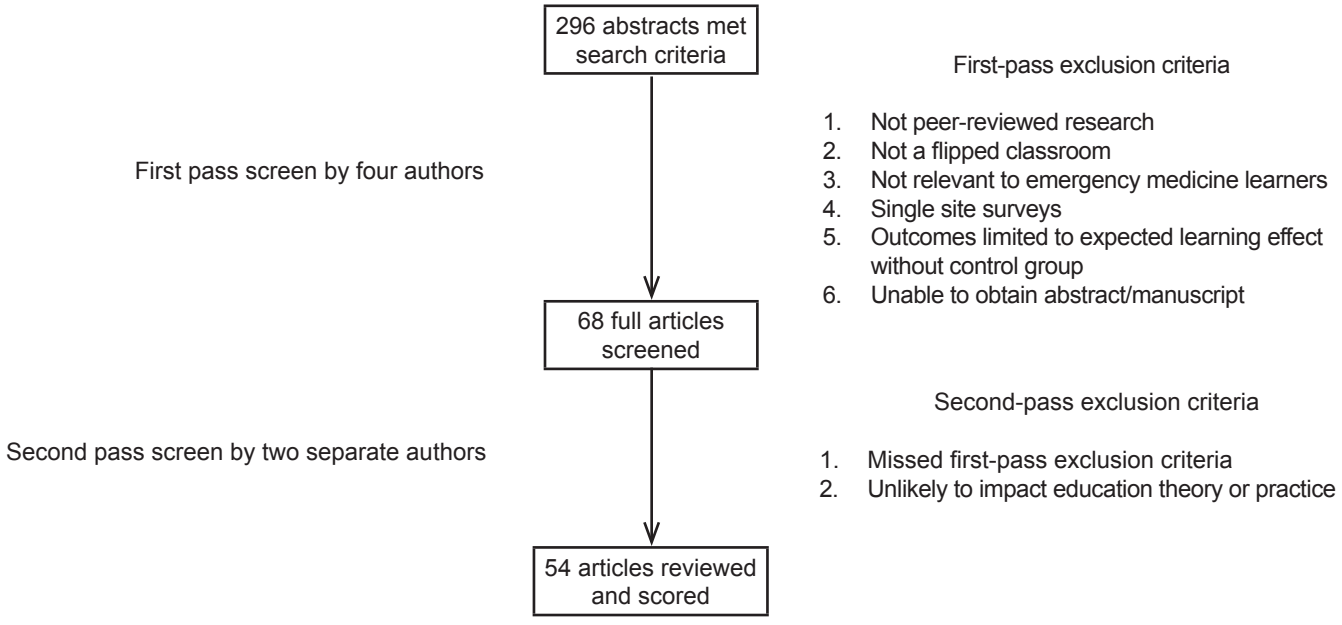


Figure 1. Selection process for articles that focus on the flipped classroom model in medical education.

Data Analysis

Reviewers were excluded from scoring publications in which there was deemed to be significant conflict of interest (own publication, own institution, or had a vested interest in the authors or work). We separated publications by category (quantitative, qualitative, or review), and authors were assigned to small groups to read and score a comparable number of papers in a particular category. Assignments were based on methodological expertise of the scorer, and we ensured that all qualitative and review papers were scored by the same two reviewers, and that each paper was independently scored by two separate authors. Each reviewer first read a sample paper in their assigned category, scored it independently, and then read aloud the scoring instrument to other members of the group to ensure items were interpreted and scored consistently. Figure 2 illustrates the author breakdown for publication review. Each reviewer independently reviewed and scored each publication in his or her assigned category, except those excluded for conflict of interest.

A total rating score was calculated for each article and entered into a spreadsheet using Microsoft Excel 2010 (Microsoft Inc., Redmond, Washington). Average scores for each article were calculated and all categories were analyzed by the first and last author to determine a natural cutoff that separated the top articles from the rest. For all three categories, quantitative, qualitative and review, a score of 18/25 represented a cutoff below which the majority of the papers clustered. Therefore, a decision was made to include the five quantitative, two qualitative, and three review papers that scored above 18. Finally, we included several additional studies as supplemental resources for readers interested in learning more about FC development and implementation. The decision to include these additional papers was based upon consensus discussion between authors AK and JK.

Theme synthesis

After the top scoring papers were identified, two authors (AK and JK) performed a constant comparative qualitative analysis of the themes represented through independently coding the themes and subthemes of each paper, and then conducting an iterative round of discussions to reach consensus on four prevailing and consistent themes and best practices.

Reviewer	Quantitative	Qualitative	Review
Reviewer #1	1-14		
Reviewer #2	7-21		
Reviewer #3	14-28		
Reviewer #4	1-7 and 21-28		
Reviewer #5	29-33	1-4	
Reviewer #6	29-33	1-4	
Reviewer #7			1-14
Reviewer #8			1-14

Figure 2. Article review breakdown by author.

RESULTS

A total of 296 papers satisfied the search criteria, 54 of which met the inclusion criteria (33 quantitative studies, four qualitative studies, and 17 review papers). All 54 papers were critically appraised and scored independently by two reviewers. Five quantitative studies met criteria as methodologically superior publications with a potential to impact current educational practices, with a range of mean scores from 18 to 20.5 (maximum 25 points).[11-15] Two qualitative studies met criteria as superior publications with a range of mean scores from 18 to 21 (maximum 25 points).[16,17] Three review papers met criteria as superior publications with a range of mean scores from 19.5 to 23.5 (maximum 25 points).[18-20] All top papers are listed in alphabetical order by study design and summarized in Tables 1-3. Finally, two additional studies – one quantitative[21] and one review[22] – were noted to be useful references by reviewers and are included as supplements in Table 4. The identified consensus themes and best practices around implementation of an FC along with suggested future areas for research are summarized in Table 5.

DISCUSSION

Although there has been a great deal of enthusiasm for the FC model, educators unfamiliar with this instructional approach may struggle to identify appropriate applications and potential drawbacks. Furthermore, potential adopters of the FC should be armed with a thorough understanding of its relative efficacy for knowledge dissemination when compared to a "traditional" lecture approach. In our literature review and critical appraisal, several themes emerge that help define the current state of the FC in medical education.

A Flipped Classroom or Blended Learning Approach is Effective for Procedural Learning

One common application of the FC model across the continuum of medical education is in procedural education. Procedural instruction has traditionally occurred via traditional classroom modalities including lecture-based demonstrations or in-person skills stations. As blended learning and the FC model have become more prevalent, educators have successfully implemented these innovations in the delivery of procedural skills training ranging from Advanced Cardiac and Pediatric Advanced Life Support courses to more focused training sessions such as instructing students in suturing techniques and general surgical procedures.[11,17]

Lehman et al.[11] identified that learners who received a procedural curriculum via a blended learning model

Table 1. Top-scoring quantitative papers.

Citation	Aims	Findings	Contributions to current knowledge
Bonnes SL et al.[14] Flipping the Quality Improvement Classroom in Residency Education	To develop and validate an instrument to measure resident perceptions of a quality improvement (QI) curriculum delivered via an FC vs a TC approach	QI knowledge increased significantly in those residents exposed to the FC vs the TC curriculum. Residents who had no experience with an FC environment had larger improvement of scores than those who had previous FC experience, suggesting novelty as a factor.	Pre-class activity and in-class application serve to enhance learning. This reinforces the concept of cognitive load and the requirement for the instructor to be present for the application, not the acquisition, of new knowledge.
Lehmann R et al.[11] Improving Pediatric Basic Life Support Performance Through Blended Learning With Web-Based Virtual Patients: Randomized Controlled Trial	To investigate the impact of a blended learning approach, including web-based virtual patients (VPs) and standard pediatric basic life support (PBLS) training, on procedural knowledge, objective performance in a simulated case, and trainee self-assessment.	Procedural knowledge in the blended learning group was significantly better than that of the control group after the preparation period. After the hands-on training, the blended learning group showed significantly better adherence to a resuscitation algorithm and better procedural quality of PBLS in objective measures than did the control group.	For complex procedures, a blended learning approach may be superior to traditional teaching methods. VPs may be helpful in bridging the gap between knowledge and practice.
Morton DA et al.[12] Measuring the Impact of the Flipped Anatomy Classroom: The importance of Categorizing an Assessment by Bloom's Taxonomy	To determine whether FC instruction is superior to TC instruction for learning gross anatomy.	The FC method significantly improved students' ability to analyze material on a final examination relative to the TC. No difference was observed in FC and TC students' ability to recall or recognize (knowledge level) material on a final examination.	Students in an FC setting may perform better than those in a TC on assessments requiring higher cognition (e.g., analysis), but the same on those requiring lower cognition (e.g., memorization and recall)
O'Connor EE et al.[13] Flipping Radiology Education Right Side Up	To compare the effects of FC vs TC on students' academic achievement, task value, and achievement emotions.	Assessment of task value and achievement emotions showed greater task value, increased enjoyment, and decreased boredom with FC as compared to TC.	The positive emotional effects of FC on medical students' motivational beliefs and achievement emotions can enhance academic performance. The FC approach provides medical students with the opportunity to develop self-directed learning skills while also providing opportunities to solidify already acquired knowledge and concepts through active learning strategies.
Rui Z et al.[15] Friend or Foe? Flipped Classroom for Undergraduate Electrocardiogram Learning: A Randomized Controlled Study	To observe whether FC teaching improved learner performance as compared to a TC model. To investigate the attitudes of learners and teachers toward the FC.	The students in the FC group scored significantly higher than those in the TC group. The majority of students held positive attitudes toward the FC, but also supported the TC method. Teachers invested more time and energy into the FC, but also felt it to have greater learning effects than the TC.	While an FC model appeared more effective for student learning, it required significantly more teacher time and effort for material design than a TC model.

FC, flipped classroom; *TC*, traditional classroom.

demonstrated superior procedural knowledge, higher procedural quality via objective measures, and a higher adherence to the clinical care algorithms when compared to a control group who received instruction via traditional lecture and skills station teaching. Similarly, Liebert et al.[17] reported that procedural skills-based video sessions were among the highest rated components of a new FC curriculum among students enrolled in a surgical clerkship.

Importantly, this reveals that FC and blended learning curricula that use meaningful and interactive pre-work (that prime the learner to think critically about the rationale for and mentally rehearse the steps of a procedure) may better prepare

Table 2. Top scoring qualitative papers.

Citation	Aims	Findings	Contribution to current knowledge
Khanova J et al.[16] Student Experiences Across Multiple Flipped Courses in a Single Curriculum	To examine student perspectives of the FC model across multiple courses.	Students liked the FC model and identified multiple benefits, but these were conditional on effective implementation. They noted challenges of an increased workload and the importance of high-quality instructional materials, alignment of pre-class and in-class learning activities, and the critical role of the instructor.	This study provides insight into the learner experience of the FC model across multiple courses and highlights multiple elements that may be important for effective design and implementation of this model.
Liebert CA et al.[17] Student Perceptions of a Simulation-based Flipped Classroom for the Surgery Clerkship: A Mixed-Methods Study	To evaluate learner perceptions of a simulation-based FC curriculum in a third- year surgical clerkship.	Learners viewed the curriculum very positively and valued succinct videos, use of multiple teaching modalities, and content that was high yield and relevant. Students felt that this model created an interactive and engaging environment that promoted self-directed learning and accountability. Perceived benefits of the curriculum included preparation for clinical rotations and knowledge tests, improved comfort with clinical skills, and positive interactions with peers and faculty.	This study demonstrates that an FC model can be incorporated into a third-year surgical clerkship, and that it is well received by learners. The authors recommend best practices for implementation of an FC into a core clerkship based on study results and their personal experience.

FC, flipped classroom; *TC*, traditional classroom.

Table 3. Top scoring review papers.

Citation	Aims	Findings	Contribution to current knowledge
Liu Q et al.[18] The Effectiveness of Blended Learning in Health Professions: Systematic Review and Meta-Analysis	To assess the effectiveness of blended learning for health professionals compared with a TC model or purely e-learning model.	A blended learning approach was often more effective than non-blended instruction (either traditional lecture or purely e-learning) with regard to learner knowledge acquisition. Unfortunately, the significant heterogeneity of studies included in the meta-analysis limits generalizability.	This systematic review and meta-analysis supports the concept that a blended learning model is at least as efficacious as either a TC or purely e-learning model with regard to learner knowledge acquisition.
McCutcheon K et al.[19] A Systematic Review Evaluating the Impact of Online or Blended Learning vs. Face-to-Face Learning of Clinical Skills in Undergraduate Nurse Education	To determine if the use of an online or blended learning paradigm has potential to enhance the teaching of clinical skills in undergraduate nursing education.	Online or blended learning methods were as effective as TC methods when teaching clinical skill to nursing students.	This review highlights the important role that online and blended learning approaches have for teaching technical clinical skills when compared to face-to-face modalities. Online or blended instructional approaches may allow for more learner and instructor flexibility when neither party is tied to a traditional classroom setting.
Ramnanan CJ et al.[20] Advances in Medical Education and Practice: Student Perceptions of the Flipped Classroom	To identify trends in learner perception of the pre-class and in-class phases of the FC approach and to identify the impact of the FC method on learning.	The most commonly applied methods for pre-class and in-class activities in an FC model are video-based learning and case-based learning. The FC methodology appears well received by learners as it has been demonstrated to increase motivation, engagement and attendance. Although learners perceive that the FC model leads to improvements in their knowledge base relateive to the TC model, evidence for this is mixed.	This review highlights important trends in the development of FC learning models as they pertain to early learners. It further demonstrates the high satisfaction rates of this method with learners, although it is still unclear whether an FC approach leads to improvements in knowledge acquisiton when compared to a TC model.

FC, flipped classroom; *TC*, traditional classroom.

learners to perform procedural skills compared to traditional teaching methods.

We acknowledge that the FC approach may be equally effective for non-procedural learning, although this has been studied less frequently, perhaps because procedural learning is particularly well suited to an FC model.

Students in a Flipped Classroom Setting May Learn More Than Students in a Traditional Classroom Setting

Beyond the realm of procedural skills education, there is emerging evidence that an FC model may outperform traditional lecture-based education in a much broader context, both in terms of knowledge and skills acquisition. While this effect is not universally reported, the FC model appears to be at least non-inferior to the standardized lecture-based educational format.[11,14] Learners particularly valued the FC model's ability to promote active learning, engagement, and facilitation of peer and faculty interaction; thus, it is important that in-class activities be designed with this in mind.[16,20] Activities such as simulation sessions, clinical cases, problem-based learning, team-based learning, and discussion activities align well with these values and were particularly appreciated.[16,17,20]

The Flipped Classroom Model is Beneficial for Learning Higher Cognition Tasks

When faculty are aiming to teach high-order Bloom's objectives, such as analysis or evaluation, TC or isolated e-learning alone may not be the most effective approach. With these more advanced objectives, an FC or blended learning approach using both TC and e-learning seems to be preferred and result in greater learning. This is particularly true when accompanied by in-class active learning, such as case-based or self-assessment exercises.[12,15,19] This large positive effect favoring the FC or blended learning model is seen when comparing those two modalities to TC or e-learning alone and proves to be consistent across disciplines and course settings.[18]

Furthermore, relatively recent work by Morton et al.[12] suggests that FC is better suited to teach analysis or application of knowledge than memorization of general facts. When the FC model is used in a manner that builds upon foundational concepts or previously-mastered facts, it may facilitate focused learning in these higher-order skills by optimizing a learner's germane cognitive load. However, when used to teach basic concepts that are easily grasped, the FC model may serve only to increase the extraneous cognitive load placed on the student and not increase their mastery of the subject.[12]

Learners Are More Engaged with Flipped Classroom, but Satisfaction Depends Largely on Teacher Prep Work

When applied in the appropriate context, the FC model seems to promote superior student engagement as compared to the TC model. According to O'Connor et al., "subjects who participated in the flipped learning cohorts had greater interest in learning, increased enjoyment, and higher task value than the traditional didactic instruction cohorts."[13] The finding that FC increases learner engagement is consistent with educational theory that posits that learners who take an active role in their learning may be more motivated to learn, and instruction that builds upon a common foundation may be more engaging.[23]

Like any curriculum, use of the FC model also requires high-quality, pre-class material and in-class learning activities, aligned with course goals and objectives and matched to learner level and needs, to be successful. While learners generally viewed the FC model positively, they also noted that design and implementation of the curriculum was important for outcomes. Learners valued pre-class materials that were specifically designed for the FC model, were easy to access and use, and included content that was concise, relevant, well organized, and delivered by a variety of modalities.[16,17,20] High-quality videos of approximately 20-30 minutes duration were particularly valued as a means of delivering this content.[16] While learners generally appreciated the self-directed aspect of the FC model, they also called attention to the importance of realistic expectations in terms of workload of pre-class material to avoid cognitive overload or lack of completion of assignments in preparation for the in-class component.[16]

It is also important that instructors be well trained in the FC model and consistent in their delivery and expectations, as deviation from this approach can negatively impact learners.[16] Careful attention must be paid to provide an adequate transition between pre-class and in-class work while avoiding both redundancy and introduction of completely new material in the in-class portion in order for the sessions to be most effective.[16]

As with any other program of study, instructors must also ensure that assessment tools are in line with the goals and objectives of the course and curricular model. All of this requires deliberate and purposeful planning and delivery on the part of course directors and instructors wishing to implement the FC model. In fact, our review found that preparation in terms of cost and faculty time may be significant and this should be considered prior to implementing the FC model. It may be beneficial to secure sources of funding, support staff, and infrastructure such as high-speed internet capacity and information technology support in advance to assist in successful implementation.[22]

Next Steps for Research

With a deeper understanding of both the advantages and limitations of the FC model, education scholars are poised to begin exploring the next steps and identify future research questions to understand how best to employ this educational strategy. Further studies are needed to explore which platforms are most effective for presenting pre-course portions of the FC model. The determination of which procedural skills are best taught through FC needs

Table 4. Additional resource papers.

Citation	Aims	Findings	Contribution to current knowledge
Heitz C et al.[21] Does the Concept of the "Flipped Classroom" Extend to the Emergency Medicine Clinical Clerkship?	To determine whether clerkship students achieve better mastery of educational objectives when an FC approach to clerkship is used as opposed to a TC model.	There was no observed difference in level of mastery of clerkship educational objectives using the FC approach (asynchronous modules before clinical shifts) vs the TC approach to clerkship learning.	There are many barriers to using an FC model to prepare emergency medicine clerkship students for "themed clinical shifts" including difficulty in students adhering to the set protocol. Additionally, it is does not appear that the FC model helps students to achieve a higher level of mastery than the TC model.
O'Flaherty J et al.[22] The Use of Flipped Classrooms in Higher Education: A Scoping Review	To provide a review of relevant research on the FC including how key aspects contribute to its effectiveness as a learning modality.	Core features of the FC approach include 1. content in advance (generally recorded lectures) 2. educator awareness of level of student understanding, higher level learning in classroom setting 3. significant time investment for faculty to create asynchronous learning resources 4. trend toward improved test scores and improved opportunities for students to develop teamwork and communication skills in FC model vs TC model, although paucity of high-quality data and absence of demonstrated educational benefit in long term 5. apparent lack of pedagogical understanding of how to operationalize FC from traditional teaching model.	This resources serves as an excellent review of concepts integral to the success of the FC model and includes suggestions for additional measures of student engagement, a hallmark of success in the FC model.

FC, flipped classroom; *TC*, traditional classroom.

Table 5. Consensus themes and best practices.

Themes and associated references	Current understanding	Areas of future research
FC and Procedural Learning[11,17]	FC and blended learning models may result in greater procedural competency and knowledge as well as greater satisfaction on the part of learners when compared with TC model of instruction.	What is the best pre-course approach for flipped classroom procedural teaching? Which procedures lend themselves best to a FC approach?
FC Better for Learning than TC[11,12,14]	FC is at least non-inferior to TC in terms of general knowledge acquisition on the part of learners, and may be superior for teaching analysis and application of concepts.	Is FC superior to TC or simply non-inferior? What aspects of the FC approach seem to help most when teaching higher-level concepts? Do learners simply spend more time with the material, or is in-person application of knowledge with faculty guidance the key?
FC Excels with Higher Cognition Tasks[12,15,18,19]	FC helps to optimize the germane cognitive load of the learner to outperform TC for tasks requiring analysis of information, such as case-based learning.	Which approach has the best outcomes when comparing among blended learning, FC, and TC?
Learners More Engaged with FC, but Satisfaction Depends Largely on Teacher Prep Work[13,16,17,20,23]	FC promotes higher task value and greater interest in learning than TC. FC preparation materials must be concise, well organized, easy to access, and designed specifically for the FC.	Does learner engagement directly translate to improved knowledge transfer? What are the best ways to objectively evaluate learner engagement and perceptions of different learning modalities?

FC, flipped classroom; *TC*, traditional classroom.

further elucidation. Additionally, while preliminary research suggests that higher-level skills such as analysis and application are better suited to FC methods than acquisition of facts, further exploration of the specific learning outcomes that are optimally suited to FC curricula would be useful to educators. While this appraisal demonstrates that FC is associated with a higher level of learner engagement than TC, it will be important to determine if this level of engagement directly translates to a higher level of knowledge transfer and learner performance than other methods. Finally, additional studies comparing outcomes among FC, TC, or a blended approach incorporating both of these strategies are greatly needed to advance our understanding on the best practices for classroom didactics.

LIMITATIONS

This critical appraisal had several important limitations. Although the scoring instruments have been previously published, threats to validity remain, as it is possible the instruments did not measure what we intended them to measure. In addition, we specifically highlighted methodologically rigorous papers with our scoring system. It is possible that papers that were not as methodologically rigorous may still have resulted in important theoretical findings and could have been missed by our method.

As we aimed to identify the papers that rose to the top, rather than selecting a score cutoff in advance, we planned on evaluating the scores to identify a natural cutoff. We selected a cutoff of 18/25 as the majority of paper scores clustered below this, allowing us to highlight and analyze in more depth a small number of superior papers. While this cutoff was consistent with that used for prior similar critical appraisals, papers just below the cutoff may also have had important results that were missed.

Furthermore, several of the exclusion criteria used in this appraisal are admittedly subjective. By limiting our reviewed manuscripts to those that were deemed relevant to emergency medicine learners and that were felt to have the potential to impact education theory and practice, we may have excluded important studies. Additionally, while we elected to exclude all single-site survey studies of individual courses that might be limited in their generalizability, there was not a similar exclusion of single-site qualitative or mixed-methods studies, which may be prone to similar biases.

Finally, we note that this appraisal includes a disproportionally large number of studies on an FC application to procedural teaching as opposed to knowledge or non-procedural skills acquisition. This likely reflects a publication bias toward FC procedural curricula in the medical literature, as these are inherently easier to implement and study than curricula targeted at knowledge or non-procedural skills acquisition.

CONCLUSION

Our understanding of the role of the FC in medical education has steadily grown over the last 10-15 years since it was first introduced. This CORD Academy critical appraisal highlights several rigorous and relevant publications on FC theory and application, in order to serve as both a resource and summary for educators.

Address for Correspondence: Aaron S. Kraut, MD, University of Wisconsin School of Medicine and Public Health, Berbee Walsh Department of Emergency Medicine, 800 University Bay Drive Suite 310, Mail Code 9123, Madison, WI 53705. Email: askraut@medicine.wisc.edu.

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.

REFERENCES

1. Knowles MS. (1970). *The Modern Practice of Adult Education: Andragogy versus Pedagogy*. New York: Associate Press.
2. Sadosty AT, Goyal DG, Gene Hern H Jr, et al. Alternatives to the conference status quo: summary recommendations from the 2008 CORD Academic Assembly Conference Alternatives workgroup. *Acad Emerg Med.* 2009;16 Suppl 2:S25-31.
3. Jensen JL, Kummer TA, Godoy PD. Improvements from a flipped classroom may simply be the fruits of active learning. *CBE Life Sci Educ.* 2015;14(1):ar5.
4. 4.Galway LP, Corbett KK, Takaro TK, et al. A novel integration of online and flipped classroom instructional models in public health higher education. *BMC Med Educ.* 2014;14:181.
5. Garrison DR, Kanuka H. Blended learning: uncovering its transformative potential in higher education. *Internet High Educ.* 2004;7(2):95-105.
6. Chen F, Lui AM, Martinelli SM. A systematic review of the effectiveness of flipped classrooms in medical education. *Med Educ.* 2017;51(6):585–97.
7. Fisher J, Lin M, Coates WC, et al. Critical appraisal of emergency medicine educational research: the best publications of 2011. *Acad Emerg Med.* 2013;20(2):200–8.
8. Kornegay JG, Kraut A, Manthey D, et al. Feedback in medical

education: a critical appraisal. *AEM Educ Train.* 2017;1(2):98-109.
9. Farrell SE, Coates WC, Kuhn GJ, et al. Highlights in emergency medicine medical education research. 2008. *Acad Emerg Med.* 2009;16(12):1318-24.
10. O'Brien BC, Harris IB, Beckman TJ, et al. Standards for reporting qualitative research: a synthesis of recommendations. *Acad Med.* 2014;89(9):1245-51.
11. Lehmann R, Thiessen C, Frick B, et al. Improving Pediatric Basic Life Support performance through blended learning with web-based virtual patients: randomized controlled trial. *J Med Internet Res.* 2015;17(7):e162.
12. Morton DA, Colbert-Getz JM. Measuring the impact of the flipped anatomy classroom: the importance of categorizing an assessment by Bloom's taxonomy. *Anat Sci Educ.* 2017;10(2):170-5.
13. O'Connor EE, Fried J, McNulty N, et al. Flipping Radiology Education Right Side Up. *Acad Radiol.* 2016;23(7):810-22.
14. Bonnes SL, Ratelle JT, Halvorsen AJ, et al. Flipping the quality improvement classroom in residency education. *Acad Med.* 2017;92(1):101-7.
15. Rui Z, Lian-Rui X, Rong-Zheng Y, et al. Friend or foe? Flipped classroom for undergraduate electrocardiogram learning: a randomized controlled study. *BMC Med Educ.* 2017;17(1):53.
16. Khanova J, Roth MT, Rodgers JE, et al. Student experiences across multiple flipped courses in a single curriculum. *Med Educ.* 2015;49(10):1038-48.
17. Liebert CA, Mazer L, Bereknyei Merrell S, et al. Student perceptions of a simulation-based flipped classroom for the surgery clerkship: A mixed-methods study. *Surgery.* 2016;160(3):591-8.
18. Liu Q, Peng W, Zhang F, et al. The effectiveness of blended learning in health professions: systematic review and meta-analysis. *J Med Internet Res.* 2016;18(1):e2.
19. McCutcheon K, Lohan M, Traynor M, et al. A systematic review evaluating the impact of online or blended learning vs. face-to-face learning of clinical skills in undergraduate nurse education. *J Adv Nurs.* 2015;71(2):255-70.
20. Ramnanan CJ, Pound LD. Advances in medical education and practice: student perceptions of the flipped classroom. *Adv Med Educ Pract.* 2017;8:63-73.
21. Heitz C, Prusakowski M, Willis G, et al. Does the concept of the "flipped classroom" extend to the emergency medicine clinical clerkship? *West J Emerg Med.* 2015;16(6):851-5.
22. O'Flaherty J, Phillips C, Karanicolas S, et al. The use of flipped classrooms in higher education: a scoping review. *Internet High Educ.* 2015;25:85-95.
23. Knowles, M. (1975). Self-directed learning: a guide for learners and teachers. New York, NY: Cambridge, the Adult Education Company.

This Article Corrects: "Best Practices for Evaluation and Treatment of Agitated Children and Adolescents (BETA) in the Emergency Department: Consensus Statement of the American Association for Emergency Psychiatry"

Ruth Gerson, MD*
Nasuh Malas, MD, MPH†
Vera Feuer, MD‡
Gabrielle H. Silver, MD§
Raghuram Prasad, MD¶
Megan M. Mroczkowski, MD‖

*Bellevue Hospital/New York University, Department of Psychiatry, New York, New York
†University of Michigan, Departments of Psychiatry and Pediatrics, Ann Arbor, Michigan
‡Northwell Health, Department of Psychiatry, New Hyde Park, New York
§Weill Cornell Medical College, Department of Psychiatry, New York, New York
¶Children's Hospital of Philadelphia, Department of Psychiatry, Philadelphia, Pennsylvania
‖Columbia University Medical Center, Department of Psychiatry, New York, New York

Electronically published February 19, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.4.43550

West J Emerg Med. 2019 March;20(2):409-419
Best Practices for Evaluation and Treatment of Agitated Children and Adolescents (BETA) in the Emergency Department: Consensus Statement of the American Association for Emergency Psychiatry
Gerson R, Malas N, Feuer V, Silver GH, Prasad R, Mroczkowski MM

Erratum in
West J Emerg Med. 2019 May;20(3):537. Pediatric BETA Consensus Guideline Working Group members should not be included in full author list. The author list has now been corrected on this erratum.

Abstract
Introduction: Agitation in children and adolescents in the emergency department (ED) can be dangerous and distressing for patients, family and staff. We present consensus guidelines for management of agitation among pediatric patients in the ED, including non-pharmacologic methods and the use of immediate and as-needed medications.

Methods: Using the Delphi method of consensus, a workgroup comprised of 17 experts in emergency child and adolescent psychiatry and psychopharmacology from the the American Association for Emergency Psychiatry and the American Academy of Child and Adolescent Psychiatry Emergency Child Psychiatry Committee sought to create consensus guidelines for the management of acute agitation in children and adolescents in the ED.

Results: Consensus found that there should be a multimodal approach to managing agitation in the ED, and that etiology of agitation should drive choice of treatment. We describe general and specific recommendations for medication use.

Conclusion: These guidelines describing child and adolescent psychiatry expert consensus for the management of agitation in the ED may be of use to pediatricians and emergency physicians who are without immediate access to psychiatry consultation.

PMCID: PMC6404720 [PubMed - indexed for MEDLINE]

CPC*EM* Clinical Practice & Cases

CALL FOR SUBMISSIONS

-Patient Care Case Reports

-Images in Emergency Medicine

Fully open-access, peer reviewed, well indexed: CPC-EM is available anywhere with an internet connection at **CPCEM.org**

Clinical Practice and Cases in Emergency Medicine is an internationally recognized journal affiliated with the MEDLINE-indexed ***Western Journal of Emergency Medicine***

CPC-EM encourages submissions from junior authors and countries with developing emergency medicine programs

CPC*EM* Clinical Practice & Cases

CALL FOR CPC-EM SECTION EDITORS!

- Medical-Legal Case Reports
- Case Reports/Images in Emergency Medicine

Send your CV and letter of interest to editor@cpcem.org

Xth MEDITERRANEAN EMERGENCY MEDICINE CONGRESS

AAEM™ AMERICAN ACADEMY OF EMERGENCY MEDICINE
CHAMPION OF THE EMERGENCY PHYSICIAN

Mediterranean Academy of Emergency Medicine
MAEM

JOIN US!

REGISTER TODAY

MEMC19 embraces a true multinational collaboration of teaching and learning, based on the belief that every emergency care practitioner has knowledge and experience that will benefit all of us.

Our focus is to move away from a uni-centric practice model towards a model of best practices that embraces genuine cultural competency, diversity, and respect for the variety of resource availability that characterizes the true practice of emergency medicine on a global scale.

You may count on a diverse and stimulating curriculum which will prove to be be impactful to both new and seasoned physicians, residents and medical students; as well as nurses, researchers and scientists, pharmacists, nutritionists, and anyone involved in the delivery of emergency care.

We invite you to explore all that this historic city, located on the Adriatic Sea, and its surrounding areas have to offer.

Abstract Submissions Now Open!

Visit the website to learn more.

MEMC19

www.aaem.org/MEMC19
#MEMC19

Dubrovnik CROATIA

22-25 SEPTEMBER 2019

Kern Medical

WE'RE HIRING!

Emergency Medicine Faculty Position

Kern Medical is in search of an enthusiastic, academically minded, Emergency Medicine trained physician who is interested in a faculty position in our Emergency Medicine Residency Program. Our residency program maintains full accreditation by the RRC/ACGME and is affiliated with UCLA.

Candidate Requirements

Candidates must be residency-trained

Board certified/eligible

Fellowship training a plus

Strong interest in academic emergency medicine

Eligible for license to practice medicine in California

Pursue faculty appointment at UCLA

Benefits

Competitive compensation package, commensurate with qualification and experience

Full-time, employed position

Salary, additional shifts, starting bonus, relocation bonus

Vacation, Sick, Paid Education Leave and CME Reimbursement

Health Benefits, Retirement

Malpractice and tail coverage provided

Loan Forgiveness Program Qualification

Kern Medical Overview

We train over 200 medical students, residents and fellows with graduate medical education programs in many specialties including Emergency Medicine. The hospital is the only designated level II trauma center in Kern County and serves as a tertiary medical center. Our emergency department cares for approximately 49,000 patients a year and is an accredited stroke center. The emergency medicine residency is affiliated with UCLA and has been in operation since 1976. Our department has enjoyed strong, responsible and ongoing institutional support.

Located in California's San Joaquin Valley just 90 minutes north of Los Angeles, Kern County is within driving distance of beaches, mountains and several national parks, including Yosemite.

Qualified and interested individuals should contact:

Melanie Brassfield | Director of Physician Recruitment
Melanie.Brassfield@KernMedical.com
(661) 326.2610

JOIN CAL/AAEM!

CALAAEM

CALIFORNIA CHAPTER DIVISION OF THE
AMERICAN ACADEMY OF EMERGENCY MEDICINE

Championing individual physician rights and workplace fairness

BENEFITS

- *Western Journal of Emergency Medicine* Subscription
- CAL/AAEM News Service email updates
- Discounted AAEM pre-conference fees
- And more!

CAL/AAEM NEWS SERVICE

- Healthcare industry news
- Public policy
- Government issues
- Legal cases and court decisions

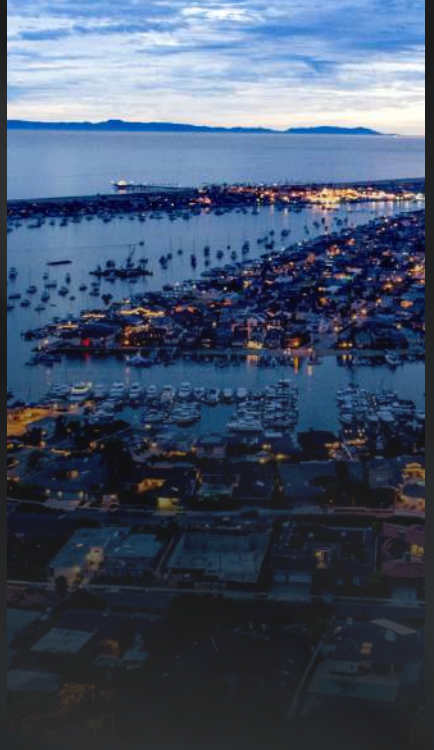
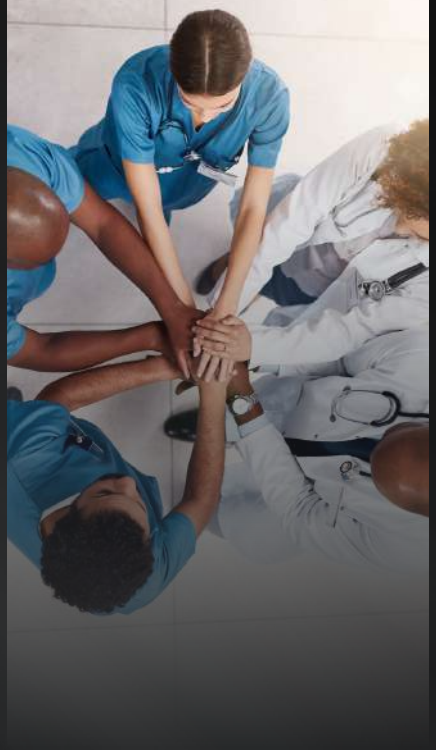
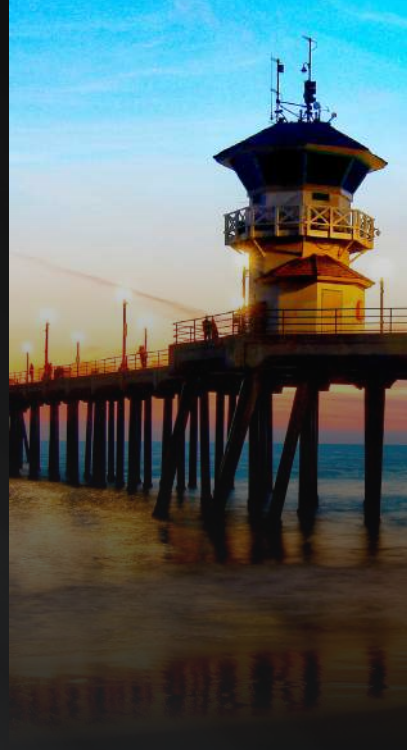
In collaboration with our official journal

WestJEM Integrating Emergency Care with Population Health

FACEBOOK.COM/CALAAEM

FOLLOW US @CALAAEM

HTTP://WWW.CALAAEM.ORG

ADVANCED›

YOUR LIFE IN EMERGENCY MEDICINE

› CALIFORNIA ACEP'S ANNUAL CONFERENCE 2019

Education is targeted to Medical Students and Residents, but all are welcome to attend.

Friday, September 20, 2019
Hyatt Regency, Orange County, CA

CALIFORNIA ACEP
AMERICAN COLLEGE OF EMERGENCY PHYSICIANS