WestJEM

Volume 25, Number 1, January 2024 Open Access at WestJEM.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 25, NUMBER 1, January 2024

PAGES 1-143

ACOEP stands with all emergency physicians and providers on the front line. We thank you for your tireless work and effort.

ACOEP
The American College of Orthopaedic Emergency Physicians

www.acoep.org

Penn State Health Emergency Medicine

About Us:

Penn State Health is a multi-hospital health system serving patients and communities across central Pennsylvania. We are the only medical facility in Pennsylvania to be accredited as a Level I pediatric trauma center and Level I adult trauma center. The system includes Penn State Health Milton S. Hershey Medical Center, Penn State Health Children's Hospital, and Penn State Cancer Institute based in Hershey, Pa.; Penn State Health Hampden Medical Center in Enola, Pa.; Penn State Health Holy Spirit Medical Center in Camp Hill, Pa.; Penn State Health St. Joseph Medical Center in Reading, Pa.; Penn State Health Lancaster Pediatric Center in Lancaster, Pa.; Penn State Health Lancaster Medical Center (opening fall 2022); and more than 3,000 physicians and direct care providers at more than 126 outpatient practices in 94 locations. Additionally, the system jointly operates various health care providers, including Penn State Health Rehabilitation Hospital, Hershey Outpatient Surgery Center, Hershey Endoscopy Center, Horizon Home Healthcare and the Pennsylvania Psychiatric Institute.

We foster a collaborative environment rich with diversity, share a passion for patient care, and have a space for those who share our spark of innovative research interests. Our health system is expanding and we have opportunities in both academic hospital as well community hospital settings.

Benefit highlights include:

- Competitive salary with sign-on bonus
- Comprehensive benefits and retirement package
- Relocation assistance & CME allowance
- Attractive neighborhoods in scenic central Pa.

PennState Health

FOR MORE INFORMATION PLEASE CONTACT:

Heather Peffley, PHR CPRP - Penn State Health Lead Physician Recruiter
hpeffley@pennstatehealth.psu.edu

Western Journal of *Emergency Medicine*:

Integrating Emergency Care with Population Health

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

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

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, 3800 W. Chapman Ave. Suite 3200, 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, PubMed, and Clarivate Web of Science, Science Citation Index Expanded**

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

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, 3800 W. Chapman Ave. Suite 3200, 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, PubMed, and Clarivate Web of Science, Science Citation Index Expanded**

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

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, PubMed, and Clarivate Web of Science, Science Citation Index Expanded**

Table of Contents *continued*

Western Journal of *Emergency Medicine*:

Integrating Emergency Care with Population Health

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

Western Journal of *Emergency Medicine*:

Integrating Emergency Care with Population Health

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

Save the Date

Spring Seminar 2024 | April 27 – May 1

Signia Orlando Bonnet Creek • Orlando, Florida

#ACOEP24

ACOEP
The American College of
Osteopathic Emergency Physicians

Call for Section Editors

- Behavioral Emergencies
- Cardiac Care
- Geriatrics
- Musculoskeletal
- Trauma
- Toxicology
- Legal Medicine

WestJEM Integrating Emergency Care with Population Health
westjem.org

Send CV and letter of interest to Editor@WestJEM.org

WestJEM Integrating Emergency Care with Population Health

NEW: HEALTH EQUITY SECTION

Call for Reviewers and Manuscripts

Send CV and letter of interest to Editor@WestJEM.org

CALL FOR REVIEWERS!

WestJEM Integrating Emergency Care with Population Health
westjem.org

CPCEM Clinical Practice & Cases

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

Crisis Intervention in a Local Community Emergency Department Inspires Growth of Peer Support Services

Phillip Moschella, MD, PhD*
Mirinda Gormley, PhD*
Sarah Fabiano, MD*
Christopher Carey, MD*
Karen Lommel, MD†
Jess Hobbs, MD*
Rich Jones, MSW‡
Alain H. Litwin, MD, MPH§

*University of South Carolina School of Medicine Greenville, Department of Emergency Medicine, Greenville, South Carolina
†University of South Carolina School of Medicine Greenville, Department of Psychiatry, Greenville, South Carolina
‡FAVOR Faces and Voices of Recovery, Greenville, South Carolina
§University of South Carolina School of Medicine Greenville, Department of Internal Medicine, Greenville, South Carolina

Section Editors: Marc Martel, MD, and Wendy Macias-Konstantopoulos, MD, MPH, MBA
Submission history: Submitted April 1, 2023; Revision received October 7, 2023; Accepted November 1, 2023
Electronically published December 20, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.60600

In early 2018, the opioid epidemic slammed into the state of South Carolina precipitating an unprecedented rise in overdoses. In response, our local health system partnered with state agencies to implement a novel crisis intervention named the Faces and Voices of Recovery (FAVOR) Overdose Recovery Coaching Evaluation (FORCE). This was the first program in the state to use certified peer support specialists (CPSS) as supplied from a local recovery organization (FAVOR) to engage with overdose patients in the emergency department (ED). Supported by the South Carolina Department of Alcohol and Other Drug Abuse Services, the program ran from January 1–December 31, 2018 within a local community ED in Greenville, South Carolina (~95,000 adult patients/year).

FAVOR is a community-subsidized, "free" local recovery organization, accredited by the Council on the Accreditation of Peer Recovery Support Services. The CPSSs are individuals who have been in active recovery for at least one year and received training as a CPSS and an assertive community engagement specialist certified by the National Certification Commission for Addiction Professionals and who is a member of the National Association of Alcohol and Drug Abuse Counselors.

All adult patients aged 18 and older, who presented to the ED with an unintentional or accidental opioid overdose were approached to participate in this institutional review board-approved intervention. Patients with an intentional overdose or suicidal intent, known pregnancy, and individuals in police custody were excluded.

Education on the intervention was provided to medical staff through various presentations and email notifications. A "Best Practice Advisory" alert was created in the electronic health record (Epic Systems Corporation, Verona, WI) and would trigger a referral order with additional instructions to call the CPSS when any medical staff member ordered naloxone or documented a diagnosis of opioid use disorder, withdrawal, or accidental overdose. An on-call CPSS would arrive within 30 minutes and, using motivational interviewing, match the patient to an array of resources including the following: 12-step programs; counseling; detox; inpatient rehabilitation; sober living; recovery coaching; and medication-assisted treatment (MAT). The CPSSs collected verbal informed consent, but participants could accept recovery services without consent. A total of 182 patients were approached, and 178 (98%) agreed to participate. Of those patients 109 (61%) were linked with services from the ED, and 114 (64%) remained actively engaged with CPSSs one year later. Fifteen patients (8.4%) returned to the hospital for any reason, and three (1.6%) died of overdose. Reported living situation of participants, at time of index visit, were as follows: 67/178 (38%) with family; 47 (26%) on their own; 25 (14%) homeless; 15 (8%) in a residential recovery center; three (1.70.5%) in "shelters"; one (0.6%) in jail; and 22 (12%) declined to answer.

This data including a 98% initial engagement and 64% remaining actively engaged at one year were compelling. Initially, emergency clinicians and leadership were reluctant to integrate CPSSs into the clinical environment over concerns that patients presenting with an overdose would refuse a consultation and because of a negative perception of the CPSS's capabilities. By the end of this intervention, team members recognized the importance of CPSSs so much so that during the COVID-19 pandemic, FAVOR CPSSs were offered vaccination within the same priority group as the rest of the ED staff. Overall, this crisis intervention provided

crucial experience and intriguing preliminary data that inspired Prisma Health to initiate the following programs through both external grants and internal funding: 1) launching a network of outpatient buprenorphine treatment programs (both clinic-based and mobile units) that have capacity to see uninsured patients (HRSA:HB147075); 2) implementing Screening, Brief Intervention and Referral to Treatment (SBIRT) programs within our busiest urban and rural EDs including seven full-time CPSSs to engage patients and provide harm reduction with take-home naloxone and 3) ED-based MAT initiation (National Institutes of Health HEAL Initiative:NCT05123027, and SAMHSA: H79TI083300). Overall, while CPSSs have spread across the state in multiple EDs and other SBIRT programs their results have been mixed.[1] This FORCE intervention did supply preliminary data for the CTN multisite "PILOT" trial (CTN-107), which is investigating two models of care using CPSSs across both short-term and long-term CPSS engagement (FORCE model). Prisma Health is one of three participating sites. Overall, this clinical intervention provided the foundation for growth of addiction-related services within our health system and provided preliminary data supporting a National Institute on Drug Abuse-sponsored nationwide clinical trial.

Address for Correspondence: Phillip Moschella, MD, PhD, University of South Carolina School of Medicine Greenville, Department of Emergency Medicine, 701 Grove Rd., Greenville, South Carolina, USA 29605. Email: Phillip.Moschellal@prismahealth.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. This study was supported by the South Carolina Department of Alcohol and Other Drug Abuse Services (DAODAS) Grant.

REFERENCES

1. Gormley MA, Pericot-Valverde I, Diaz L, et al. Effectiveness of peer recovery support services on stages of the opioid use disorder treatment cascade: a systematic review. *Drug Alcohol Depend*. 2021 Dec 1;229(Pt B):109123.

Validity of Computer-interpreted "Normal" and "Otherwise Normal" ECG in Emergency Department Triage Patients

Ashley Deutsch, MD
Kye Poroksy
Lauren Westafer, DO
Paul Visintainer, PhD
Timothy Mader, MD*

*University of Massachusetts Chan Medical School, Baystate Medical Center, Springfield, Massachusetts

Section Editors: Patrick Maher, MD, MS, and Matthew Prekker, MD, MPH
Submission history: Submitted August 22, 2022; Revision received October 5, 2023; Accepted October 20, 2023
Electronically published December 6, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.58464

Introduction: Chest pain is the second most common chief complaint for patients undergoing evaluation in emergency departments (ED) in the United States. The American Heart Association recommends immediate physician interpretation of all electrocardiograms (ECG) performed for adults with chest pain within 10 minutes to evaluate for the finding of ST-elevation myocardial infarction (STEMI). The ECG machines provide computerized interpretation of each ECG, potentially obviating the need for immediate physician analysis; however, the reliability of computer-interpreted findings of "normal" or "otherwise normal" ECG to rule out STEMI requiring immediate intervention in the ED is unknown.

Methods: We performed a prospective cohort analysis of 2,275 ECGs performed in triage in the adult ED of a single academic medical center, comparing the computerized interpretations of "normal" and "otherwise normal" ECGs to those of attending cardiologists. ECGs were obtained with a GE MAC 5500 machine and interpreted using Marquette 12SL.

Results: In our study population, a triage ECG with a computerized interpretation of "normal" or "otherwise normal" ECG had a negative predictive value of 100% for STEMI (one-sided, lower 97.5% confidence interval 99.6%). None of the studied patients with these ECG interpretations had a final diagnosis of STEMI, acute coronary syndrome, or other diagnosis requiring emergent cardiac catheterization.

Conclusion: In our study population, ECG machine interpretations of "normal" or "otherwise normal" ECG excluded findings of STEMI. The ECGs with these computerized interpretations could safely wait for physician interpretation until the time of patient evaluation without delaying an acute STEMI diagnosis. [West J Emerg Med. 2024;25(1)3–8.]

INTRODUCTION

Background

Each year there are more than nine million emergency department (ED) visits for acute nontraumatic chest pain in the United States.[1] This is the second most common chief complaint for patients undergoing emergent evaluation.[2] Expedited identification of life-threatening, acute ST-segment elevation myocardial infarction (STEMI), a diagnosis made solely by recognition of characteristic patterns of heart injury on electrocardiogram (ECG), is critical to timely intervention and optimal patient outcomes. The current American Heart Association (AHA) recommendation is for all ED chest pain ECGs to be obtained within 10 minutes of patient arrival and immediately screened for STEMI by a clinician.[3] Computerized software algorithms can analyze and print a preliminary ECG interpretation in real time; however, the interpretation algorithms are proprietary and manufacturer-specific.[4–6] The degree of variability in diagnostic accuracy among computer programs was significantly greater than that among cardiologists.[5–7]

Importance

Approximately 60% of triage ECGs at our institution are interpreted as "borderline" or "abnormal" and necessitate immediate clinician screening for acute coronary syndrome (ACS) and possible STEMI. The remainder are interpreted as "normal" or "otherwise normal" ECG (eg, sinus bradycardia-otherwise normal) by the computer. There are limited studies investigating whether these latter readings are reliable in ruling out STEMI.[8–10] Recent evidence suggests that computerized interpretation of normal sinus rhythm/normal ECG—the so called "normal/normal"—has a negative predictive value (NPV) of 99% (confidence interval [CI] 97–99%) with no reported cases of missed ACS or STEMI, which may obviate the need for immediate clinician verification.[9,10] The study provided some insights into the reliability of these interpretations but included small numbers of ECGs and did not evaluate ECGs read as "otherwise normal."

We reasoned that while immediate physician interpretation of ECGs in patients with chest pain is recommended by the AHA to screen for ECGs that meet STEMI criteria, it may not be necessary in some triage ECGs. To understand the impact of delaying immediate interpretation to the time of patient encounter, it is important to understand whether this delay would potentially delay diagnosis of this time-sensitive finding.

Population Health Research Capsule

What do we already know about this issue?
The American Heart Association recommends screening ED triage electrocardiograms (ECG) within 10 minutes for evidence of ST-elevation myocardial infarction (STEMI).

What was the research question?
What is the reliability of an ECG machine interpretation of a "normal" or "otherwise normal" ECG in ruling out STEMI?

What was the major finding of the study?
The negative predictive value for STEMI of ECGs with these interpretations is 100% (one-sided, lower 97.5% confidence interval limit: 99.6%).

How does this improve population health?
This study further confirms that physician interpretation of triage ECGs with these computerized interpretations may be safely deferred until the time of patient evaluation.

Goals of this Investigation

We performed a prospective cohort study of all adult triage patients in our ED who received an ECG during the study period to compare the computerized ECG interpretation of "normal" or "otherwise normal" ECG to that of the attending cardiologist. Our aim was to determine the NPV of these computerized interpretations for STEMI and ECG signs of acute ischemia.

MATERIALS AND METHODS

Study Design and Setting

This was a prospective cohort study of triage ECGs performed by patient care technicians or triage nurses according to the standard triage protocol in the adult ED of a large academic hospital. This ED is one of the busiest in the Northeast US, serving a population base of over one million people and caring for more than 130,000 patients annually, of whom approximately 8,000 have a chief complaint of acute chest pain. Our medical center is the regional tertiary-care facility for interventional cardiology, and it is the second busiest interventional cardiology lab in the state. This study was approved by the institutional review board. We have adhered to the Strengthening of Reporting of Observational Studies in Epidemiology (STROBE) statement.

Selection of Participants

We included all patients ≥18 years old who had a triage ECG performed by patient care technicians (PCT) or triage nurses according to a standard triage protocol in the adult ED (≥18 years of age). The nurse triage ECG protocol required obtaining an ECG on patients with a chief complaint of chest pain, chest pressure, chest tightness, weakness, unusual fatigue, palpitations, syncope, dyspnea, or any atypical symptoms consistent with ACS such as nausea and vomiting or pain in the jaw, upper back, or upper abdomen. The ECGs were collected at all hours of the day seven days per week from June 2018–October 2021, with recruitment paused for approximately 18 months due to the COVID-19 pandemic (Figure 1). There were no changes in ECG protocols or cardiac catheterization lab protocols during that time.

Interventions

Triage ECGs were obtained per protocol and immediately presented to an attending emergency physician for review. Upon return to triage, PCTs printed a copy of the ECG and

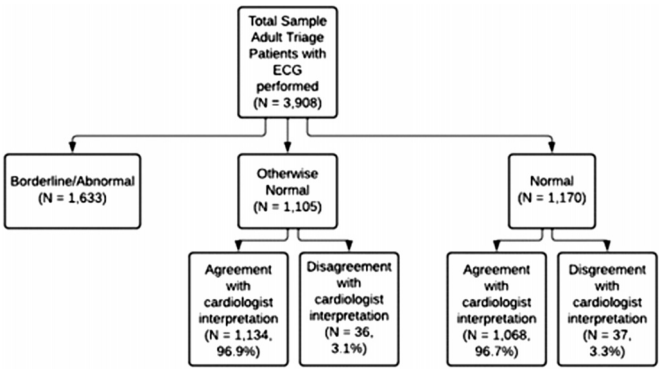


Figure 1. Results of a comparison of computer-read vs cardiologist interpretation of electrocardiograms performed at triage.

placed it in a collection box for research staff. The screened ECGs were then placed in the patients' charts for the treating physicians to review at the time of the patient evaluation. The ECGs performed according to triage protocol during the designated study period were prospectively collected by research associates.

The ECGs were obtained with a GE MAC 5500 (GE Healthcare, Waukesha, WI) and interpreted using Marquette 12SL (GE Healthcare). The ECGs were uploaded to a secure hospital server. Board-certified cardiologists blinded to all aspects of the study reviewed the ECGs and entered the final interpretation into the medical health records as per standard operating procedure.

Measurements

The primary outcome of interest was the number of ECGs with a computerized interpretation of "normal" ECG or "otherwise normal" ECG that were interpreted by a cardiologist as STEMI. Secondarily, we examined the number of patients who had ECGs with these computerized interpretations and an end diagnosis of ACS or STEMI, or had a cardiac catheterization during their hospitalization for that index visit.

A sample-size calculation demonstrated the need for at least 1,000 ECGs with a computerized interpretation of "normal" ECG and 1,000 with a computerized interpretation of "otherwise normal" ECG to adequately answer our proposed question. Given that we were evaluating a process change that would alter patient triage for ECGs in the ED, we wanted a high degree of precision in our estimates. Thus, a sample size of 3,000 records would provide a 95% CI that would be no wider than ±2 percentage points for estimates of predictive values.

All patients with a triage ECG reported as "normal" or "otherwise normal" by computer interpretation had a chart review performed by ED research associates experienced in chart review to extract patient demographics, ascertain the triage ECG indication, determine the cardiologist's final interpretation, and document the patient's ED disposition and final discharge diagnosis with specific attention to the presence or absence of ACS or STEMI. The data abstraction form was piloted by a research coordinator and research assistant prior to implementation. Research associates were blinded to the study hypothesis. Study data were collected and managed using REDCap electronic data capture tools hosted at our institution[11,12] REDCap (Research Electronic Data Capture) is a secure, web-based software platform designed to support data capture for research studies, providing 1) an intuitive interface for validated data capture; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for data integration and interoperability with external sources. Paper ECGs were kept in a secured room to reference as needed to verify the database.

We compared each ECG interpreted by the computer as "normal" or "otherwise normal" ECG to the cardiologist's final interpretation. If the cardiologist interpretation was also "normal" or "otherwise normal" this was considered an accurate computer interpretation. If the cardiologist's interpretation differed, we considered the computerized ECG interpretation to be inaccurate. Validation of the data entered by research staff was completed for 100% of ECGs with cardiologist disagreement (n = 74) and 15% (n = 341) randomized patients by the principal investigator (AD). We collected additional variables including gender, age, race/ethnicity, ED disposition, and final discharge diagnosis.

Finally, blinded board-certified emergency physicians were asked to evaluate any ECG with a final cardiologist interpretation of STEMI or a final diagnosis of ACS to evaluate whether ECGs would have been interpreted in real time by a clinician as indicating ACS and requiring emergent intervention.

Outcomes

The primary outcome of this study was discordance of a computerized interpretation of "normal" or "otherwise normal" ECG, and a cardiologist interpretation of STEMI or "consider ischemia." Secondary outcomes included final patient-encounter diagnosis of ACS and proportion of patients who received cardiac catheterization during hospitalization.

Analysis

For descriptive analyses, continuous variables are represented with means and standard deviations. Categorical variables are presented with frequencies and proportions. Agreement or disagreement between computer and cardiologist ratings are presented as proportions with 95% CIs. Given that we selected only normal computer-read EKGs, the NPV is the only screening characteristic provided that was able to be estimated. To assess whether age or

gender influenced disagreement in ratings, we compared records for which cardiologist and computer agreed to those where there was disagreement. For age, we used a *t*-test to compare the two groups on age and a chi-square test to compare the groups on gender.

RESULTS

Characteristics of the Study Subjects

A total of 2,275 patients were included in the study. The median age of the study population was 47 years (interquartile range [IQR] 27; IQR interval 33–60). Within the cohort, 1,262 were women (55.5%) and 73.4% were White (Table 1). The indication for ECG was chest pain in 58% of patients, followed by cardiac arrhythmia (19%). Of patients with ECG machine-interpretations of "normal" or "otherwise normal," 98.6% were discharged from the ED. None of the patients included in the analysis had a STEMI or final diagnosis of ACS. There was no difference in mean age between the cases where there was agreement (n = 2,201) vs no agreement (n = 74). Mean age for agreement was 47.3 (±17.0) vs disagreement 50.7 (±17.9), $P = 0.12$. Similarly, no difference in agreement emerged for gender. The agreement was 96.9% (1,223/1,262) for females and 96.5% (978/1,013) for males ($P = 0.64$).

Main Results

Cardiologists agreed with the machine-interpretation of "normal" or "otherwise normal" ECG in 96.7% (n = 2,201) of cases. Of the 3.3% (n = 74) of ECGs where cardiologists did not agree with the machine interpretation, none were interpreted by the cardiologist as STEMI. The NPV for STEMI of ECGs with these interpretations is 100% (one-sided, lower 97.5% CI limit: 99.6%). In 35 (49.3%) of the ECGs in which the cardiologists disagreed with the machine-interpretation, these ECGs were read by the machine as "otherwise normal" but the cardiologist interpreted "borderline" or "abnormal." Ultimately none of the 2,275 patients with machine-interpreted ECGs included in the study had a discharge diagnosis of STEMI or ACS. Only 1.4% required hospital admission for any indication. Because no ECGs with these initial machine interpretations had a final interpretation of STEMI or diagnosis of ACS, further review by blinded board-certified emergency physicians was not required.

DISCUSSION

This study found that in our triage patient population, a computerized ECG Marquette 12SL interpretation of "normal" or "otherwise normal" ECG reliably rules out a finding of STEMI. Patients who had triage ECGs with these computerized interpretations did not have a discharge diagnosis of ACS and did not require emergent catheterization. Very few patients with these ECG interpretations were admitted to the hospital. In our study

Table 1. Patient characteristics.

Variables (N = 2,275)	Summary
Patient Age in years Median (IQR)	47.0 (27.0)
Gender, n (%)	
Female	1,262 (55.5)
Male	1,013 (44.5)
Computer Read, n (%)	
Normal/normal	1,170 (51.4)
Otherwise/normal	1,105 (48.6)
Patient race, n (%)	
American Indian/Alaska Native	6 (0.3)
Asian	33 (1.5)
Black/African American	334 (14.7)
Hispanic/Latino	92 (4.0)
Native Hawaiian/Pacific Island	11 (0.5)
White	1669 (73.4)
Unknown/refused	130 (5.7)
ECG indication when algorithm disagrees with cardiologist (n = 74), n (%)	
Suspected acute MI, STEMI	1 (1.4)
Non-traumatic chest pain	40 (54.1)
Dyspnea	3 (4.1)
Cardiac arrhythmia	9 (12.2)
Electrolyte imbalance	1 (1.4)
Syncope	6 (8.1)
Other	8 (0.8)
Indication not provided	6 (8.1)
Hospital admission, n (%)	
No	2243 (98.6)
Yes	32 (1.4)
LWBS, n (%)	
No	2266 (99.6)
Yes	9 (0.4)
Discharge diagnosis c/w ACS, n (%)	
No	65 (89.0)
NA (LWBS/AMA/etc.)	8 (11.0)
Cardiology agree? n (%)	
Disagree	74 (3.3)
Agree	2201 (96.7)
Cardiologists reading (ECG paper read) to (cardiologists read), n (%)	
Normal/normal to otherwise normal	10 (14.1)
Normal/normal to borderline or abnormal	26 (36.6)
Otherwise normal to borderline or abnormal	35 (49.3)

ECG, electrocardiogram; *LWBS*, left without being seen; *AMA*, against medical advice; *STEMI*, ST-elevation myocardial infarction; *ACS*, acute coronary syndrome.

population, a computerized interpretation of "normal" or "otherwise normal" ECG" had a NPV of 100%. No patients with these ECGs had a final diagnosis of STEMI or ACS.

This study suggests that Marquette 12SL machine-interpreted "normal" or "otherwise normal" may safely rule out STEMI or other acute signs of ACS needing immediate cardiac catheterization. This finding adds to a growing body of evidence from smaller studies that immediate emergency physician interpretation of triage ECGs with this computerized interpretation may be safely deferred until the time of patient evaluation.[7–10] While other research has focused on a computerized interpretation of "normal" ECG this study is one of the first investigations of the reliability of a computerized interpretation of "otherwise normal" ECG. Previous research has demonstrated that immediate emergency physician interpretation of triage ECGs to screen for STEMI is time-consuming for physicians and support staff.[13] By using this time to more directly perform patient-centered care departments could alleviate interruptions in workflow and improve patient safety.

LIMITATIONS

While this study includes one of the largest cohorts yet of similar studies, it is limited to a single academic institution using a single type of ECG machine (Marquette 12SL). Thus, the findings may not be generalizable to other institutions and ECG machine interpretation algorithms.[4] We chose to use a board-certified cardiologist's final interpretation as the gold standard of ECG interpretation because this is the commonly accepted standard. Originally, we designed the study so that ECGs that had a computerized interpretation of "normal" or "otherwise normal" but a cardiologist interpretation of STEMI or a final hospital diagnosis of ACS would be reviewed by blinded, board-certified emergency physicians; however, as there were none in this large sample, this step was unnecessary. Moreover, we know from chart review, disposition, and diagnosis that none of these ECGs had an interpretation of STEMI by the emergency physician who evaluated the patient in real time.

Given that we focused on the NPV of normal computer-interpreted ECGs, we did not collect data on abnormal computer-read records. Thus, we are unable to report estimates of all screening characteristics (eg, sensitivity, specificity, and positive predictive value). The NPV of computer-read ECGs is the only characteristic reported in the study. We did not conduct follow-up after the index hospital visit and, therefore, cannot comment on 30-day major adverse cardiac events in this population. The safety of this approach is dependent on the lower bound of the CI of the sensitivity for STEMI. While this study addresses the outcome of STEMI addressed by the AHA's guideline, it does not directly address other outcomes of interest to an emergency physician such as acute coronary occlusion MI (OMI) which may benefit from timely reperfusion therapy and is not meant to encourage physicians to forgo physician ECG interpretation even at the time of physician interpretation. Moreover, there is a growing body of literature supporting a paradigm shift from evaluating ECGs for STEMI vs no STEMI as an indicator of OMI that may benefit emergent reperfusion to evaluating ECGs for signs of acute total OMI (inclusive of STEMI negative OMI) vs non-OMI.[14,15]

CONCLUSION

In our study population, Marquette 12SL ECG machine interpretations of "normal" or "otherwise normal" ECG excluded STEMI. Electrocardiograms with these computerized interpretations could safely wait for physician interpretation until the time of patient evaluation without delaying an acute STEMI diagnosis.

Address for Correspondence: Ashley, Deutsch MD, University of Massachusetts Chan Medical School, Baystate Medical Center, Department of Emergency Medicine, 759 Chestnut Street, Springfield, MA 01107. Email: Ashley.DeutschMD@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. Bhuiya FA, Pitts SR, McCaig LF. Emergency department visits for chest pain and abdominal pain: United States, 1999–2008. *NCHS data brief.* 2010;(43):1–8.
2. Centers for Disease Control and Prevention. National Hospital Ambulatory Medical Care Survey: 2010 Emergency Department Summary. Available at: http://www.cdc.gov/nchs/data/ahcd/nhamcs_emergency/2010_ed_web_tables.pdf. Accessed August 13, 2014.
3. American Heart Association. Recommendations for Criteria for STEMI Systems of Care. Available at: http://www.heart.org/HEARTORG/Professional/MissionLifelineHomePage/EMS/Recommendations-for-Criteria- for-STEMI-Systems-of-Care_UCM_312070_Article.jsp -.WtaFoS-ZPyw. Accessed April 17, 2018.
4. Lyon A, Minchole A, Martinez JP, et al. Computational techniques for ECG analysis and interpretation in light of their contribution to medical advances. *J R Soc Interface.* 2018;15(138):20170821.
5. Schlapfer J and Wellens HJ. Computer-interpreted electrocardiograms: benefits and limitations. *J Am Coll Cardiol.* 2017;70(9):1183–92.

6. Snyder CS, Fenrich AL, Friedman RA, et al. The emergency department versus the computer: which is the better electrocardiographer? *Pediatr Cardiol.* 2003;24(4):364–8.
7. Noll S, Alvey H, Jayaprakash N, et al. The utility of the triage electrocardiogram for the detection of ST-segment elevation myocardial infarction. *Am J Emerg Med.* 2018;36(10):1771–4.
8. Mulcahy D, Mulcahy R, Reardon B, et al. Can a computer diagnosis of "normal ECG" be trusted? *Ir J Med Sci.* 1986;155(12):416–8.
9. Hughes KE, Lewis SM, Katz L, et al. Safety of computer interpretation of normal triage electrocardiograms. *Acad Emerg Med.* 2017;24(1):120–4.
10. Winters LJ, Dhillon RK, Pannu GK, 1074208 et al. Emergent cardiac outcomes in patients with normal electrocardiograms in the emergency department. *Am J Emerg Med.* 2022;51:384–387.
11. 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.
12. Harris PA, Taylor R, Minor BL, et al. REDCap Consortium, The REDCap consortium: Building an international community of software partners. *J Biomed Inform.* 2019;95:103208.
13. Villarroel NA, Houghton CJ, Mader SC, et al. A prospective analysis of time to screen protocol ECGs in adult emergency department triage patients. *Am J Emerg Med.* 2021;46:23–6.
14. Meyers HP, Bracey A, Lee D, et al. Accuracy of OMI ECG findings versus STEMI criteria for diagnosis of acute coronary occlusion in myocardial infarction. *IJC Heart Vasc.* 2021;33:10077.
15. Bracey A, Meyers HP, Smith SW. Emergency physicians should interpret every triage ECG including those with a computer interpretation of "normal." *Am J Emerg Med.* 2022;55:180–2.

Emergency Physician-performed Echocardiogram in Non-ST Elevation Acute Coronary Syndrome Patients Requiring Coronary Intervention

Ting Xu Tan, MD*†
Donald Wright, MD, MHS*
Cristiana Baloescu, MD, MPH*
Seohyuk Lee, MD‡
Christopher L. Moore, MD*

*Yale University School of Medicine, Department of Emergency Medicine, New Haven, Connecticut
†St. Joseph's Medical Center, Department of Emergency Medicine, Stockton, California
‡Yale University School of Medicine, New Haven, Connecticut

Section Editors: J. Fields, MD, and Yanina Purim-Shem-Tov, MD, MS
Submission history: Submitted March 23, 2023; Revision received October 25, 2023; Accepted November 1, 2023
Electronically published December 22, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.60508

Introduction: Identification of patients not meeting catheterization laboratory activation criteria by electrocardiogram (ECG) but who would benefit from early coronary intervention remains challenging in the emergency department (ED). The purpose of this study was to evaluate whether emergency physician (EP)-performed point-of-care transthoracic echocardiography (POC TTE) could help identify patients who required coronary intervention within this population.

Methods: This was a retrospective observational cohort study of adult patients who presented to two EDs between 2018–2020. Patients were included if they received a POC TTE and underwent diagnostic coronary angiography within 72 hours of ED presentation. We excluded patients meeting catheterization laboratory activation criteria on initial ED ECG. Ultrasound studies were independently reviewed for presence of regional wall motion abnormalities (RWMA) by two blinded ultrasound fellowship-trained EPs. We then calculated test characteristics for coronary intervention.

Results: Of the 221 patient encounters meeting inclusion criteria, 104 (47%) received coronary intervention or coronary artery bypass grafting (CABG) referral. Overall prevalence of RWMA on POC TTE was 35% (95% confidence interval [CI] 29–42%). Presence of RWMA had 38% (95% CI 29–49%) sensitivity and 68% (95% CI 58–76%) specificity for coronary intervention/CABG referral. Presence of "new" RWMA (presence on EP-performed POC TTE and prior normal echocardiogram) had 43% (95% CI 10–82%) sensitivity and 93% (95% CI 66–100%) specificity for coronary intervention/CABG referral. The EP-performed POC TTE interpretation of RWMA had 57% (95% CI 47–67%) sensitivity and 96% (95% CI 87–100%) specificity for presence of RWMA on subsequent cardiology echocardiogram during the same admission.

Conclusion: Presence of RWMA on EP-performed POC TTE had limited sensitivity or specificity for coronary intervention or referral to CABG. The observed specificity appeared to trend higher in subjects with a prior echocardiogram demonstrating absence of RWMA, although a larger sample size will be required to confirm this finding. The EP-performed POC TTE RWMA had high specificity for presence of RWMA on subsequent cardiology echocardiogram. Further evaluation of the diagnostic performance of new RWMA on EP-performed POC TTE with a dedicated cohort is warranted. [West J Emerg Med. 2024;25(1)9–16.]

INTRODUCTION

Every year, an estimated 600,000 patients present to the emergency department (ED) with acute myocardial infarction (AMI).[1] Acute myocardial infarctions are historically divided into ST-elevation acute coronary syndrome (STE-ACS) and non-ST-elevation acute coronary syndrome (NSTE-ACS) based on electrocardiogram (ECG) findings of STE in regional leads. In patients with STE-ACS, guidelines recommend immediate coronary angiography and revascularization (Class I recommendation).[2] However, in patients presenting with symptoms concerning for ACS without classic STE on their initial ED ECG, ED workup aimed at identifying patients likely to benefit from coronary intervention remains challenging. The current American Heart Association (AHA) guidelines for patients suspected to have NSTE-ACS recommend serial ECGs and cardiac troponins every 3–6 hours (both Class I recommendations).[3] These approaches are time consuming and could delay coronary intervention, as well as impact downstream morbidity and mortality.[4]

Approximately 25% of NSTE-ACS patients have been subsequently found to have occlusive coronary disease.[4] This population fares poorly, with larger infarcts, higher cardiac biomarkers, and greater mortality than those without obstructive disease.[5,6] Among studies that evaluated patients with high-risk NSTE-ACS, such as the RIDDLE NSTEMI and Sisca trials, early reperfusion was associated with reduced risk of death or new MI and cumulative incidence of death, MI, or urgent revascularization at 30 days, respectively.[7,8] For these reasons, higher risk patients with findings in the ED concerning for an occlusive coronary process are likely to benefit from expedited intervention.

Prior studies of cardiology-performed transthoracic echocardiography (cardiology TTE) have shown that in patients presenting with symptoms concerning for ACS, RWMA appeared earlier than ECG changes and were more sensitive for AMI and critical coronary stenosis.[9–12] Much of the prior research has focused on using RWMA to identify patients with AMI and predict in-hospital complications and long-term cardiac events.[9–11,13–15] While several studies have highlighted the rates of revascularization and acute coronary occlusion in their patient population, these were done by non-emergency physicians (EP) or in a non-ED setting.[9,12–14,16,17] In addition, many of these studies focused on the capability of RWMA to detect AMIs (as determined by cardiac biomarkers, clinical symptoms, and/or ECG changes) instead of the identification of patients likely to receive intervention based on the presence of acute coronary occlusion as evidenced by cardiac catheterization.[9–11,13,14,16,17]

In ED patients without STE on initial ECG, EP-performed point-of-care transthoracic echocardiography (POC TTE) may help identify patients who have an intervenable coronary lesion but have been incompletely investigated. This is supported by a prior small case series, which showed that detection of RWMA by EP-performed POC TTE correlated with the vessel territories on subsequent intervention.[18] In this study, our primary objective was to describe the diagnostic test characteristics of RWMA found on EP-performed POC TTE for percutaneous coronary intervention (PCI) or referral for coronary artery bypass grafting (CABG) among NSTE-ACS patients. The secondary objective was to perform subgroup test characteristic analysis based on troponin elevation and prior cardiology TTE without RWMA.

Population Health Research Capsule

What do we already know about this issue?
Presence of regional wall motion abnormalities (RWMA) can indicate cardiac ischemia and may predict occlusive disease in non-ST elevation acute coronary syndrome (NSTE-ACS) patients.

What was the research question?
Are RWMAs associated with coronary intervention in NSTE-ACS patients?

What was the major finding of the study?
RWMA had 38% (95% CI 29–49%) sensitivity and 68% (95% CI 58–76%) specificity for coronary intervention or surgical referral.

How does this improve population health?
Understanding the diagnostic test performance of RWMA in NSTE-ACS has the prospect to improve use of early angiography for high-risk individuals.

METHODS

Study Design and Setting

This was a retrospective observational cohort study conducted at an urban academic hospital system that includes a quaternary-care academic center ED with 80,600 annual visits and a freestanding suburban ED with 24,600 annual visits. The academic center has 24-hour catheterization laboratories and in-house interventional cardiology. Patients requiring cardiology consultation or admission in the freestanding ED are transferred to the academic center for further care. The study was approved by the institutional review board prior to commencement.

Participants

Patients who presented to the EDs between 2018–2020 were included if they were 1) >18 years old; 2) received an EP-performed POC TTE during the visit; and 3) underwent diagnostic cardiac catheterization for suspected ACS within 72 hours of ED presentation. Patients were excluded if they had an initial ED ECG that met catheterization laboratory activation criteria or if inadequate images were obtained to evaluate RWMA on EP-performed POC TTE.

Outcome Variables

The primary outcomes of the study were diagnostic test characteristics (sensitivity, specificity, positive and negative likelihood ratios) of RWMA identified on EP-performed POC TTE for coronary intervention or referral for coronary artery bypass grafting (CABG) in patients undergoing coronary angiography. A priori subgroups were designated based on troponin elevation and prior absence of RWMA on cardiology TTE.

Data Sources/Measurement

Investigators included three emergency ultrasound fellowship-trained EPs, two emergency medicine residents, and one medical student. All attending/resident investigators received emergency ultrasound training during residency and/or fellowship.

Patient data was deidentified, given a unique study ID, and stored in a HIPAA-compliant cloud-based storage application (Box, Inc., Redwood City, CA). Procedure reports and inpatient notes were reviewed to identify patients who underwent PCI or were referred for CABG within 24 hours of coronary angiography as a composite outcome. Prior cardiology TTE reports were also coded for existing RWMA. Chart abstraction was performed by a resident author who was blinded to EP-performed POC TTE result using a standardized abstraction form with identical fields for each encounter.

The EP-performed POC TTE studies were obtained from Qpath (Telexy Healthcare, Maple Ridge, British Columbia, Canada), the storage and workflow manager where all studies obtained in the ED are stored. Initial studies were collected in the usual course of clinical care by clinicians and learners involved in the care of the patient with common indications including evaluation for pericardial effusion, left ventricular function, and right ventricular dilation. Of note, dedicated assessment of regional walls is not a routine part of our institutional EP-performed POC TTE protocol.

RWMA on EP-performed POC TTE was independently assessed by two ultrasound fellowship-trained attendings, who were blinded to the other's initial interpretation and to all chart/outcome data. Interpretation of these parameters was based on global qualitative assessment as "present," "absent," or "uninterpretable" due to insufficient images obtained. Uninterpretable ultrasounds were excluded. An a priori adjudication plan was in place to evaluate any cases in which the two reviewers disagreed on the interpretability of an ultrasound or presence of RWMA. In these cases, the studies were jointly reviewed and discussed until a final interpretation was identified.

All ECGs obtained in the ED during the visit were screened by a senior resident author who was blinded to other chart data and EP-performed POC TTE result. The interpretations were performed based on AHA guidelines for STEMI and the modified Sgarbossa's criteria.[2,19] Patients with any ED ECG potentially meeting STEMI criteria had their initial ED ECG independently interpreted by the two attending authors to assess whether they would activate the catheterization laboratory based on the ECG, assuming there were symptoms consistent with acute coronary syndrome. Any disagreements were reviewed by a third attending EP, who provided the final adjudication. We excluded patients with an initial ED ECG who were felt to meet catheterization laboratory criteria.

Both troponin I (Abbott Laboratories, Chicago, IL) and troponin T (Roche Diagnostics, Basel, Switzerland) were available in the ED for this study population. We included all troponin values obtained while the patient was in the ED. Institutional laboratory threshold values were used to delineate whether a troponin was positive. A positive troponin I value was >0.08 nanograms per milliliter (ng/mL). A positive troponin T value was >0.01 ng/mL.

We performed a planned subgroup analysis on subjects with a potentially "new" RWMA, defined as those with a prior echocardiogram on file in which the most recent report explicitly commented on the absence of any RWMA.

Statistical Methods

Based on prior unpublished pilot data, power analysis suggested that to minimize the 95% confidence interval [CI] to a width of 20% or less for sensitivity of RWMA in patients receiving coronary intervention/referral, 104 subjects would be required in each outcome group.

We conducted data analysis in R (R Foundation for Statistical Computing, Vienna, Austria) using the RStudio interface (RStudio Inc., Boston, MA). Demographic characteristics were tabulated by whether subjects received a coronary intervention and/or referral to CABG with differences evaluated by the *t*-test for continuous variables and chi-square test for categorical variables. We calculated diagnostic performance characteristics with the epiR package.

RESULTS

A total of 221 patient encounters were included in the study, of whom 104 (47%) received a coronary intervention and/or referral to CABG (Figure 1). Mean age of subjects was 64.8 years, and 33.9% of the sample was female

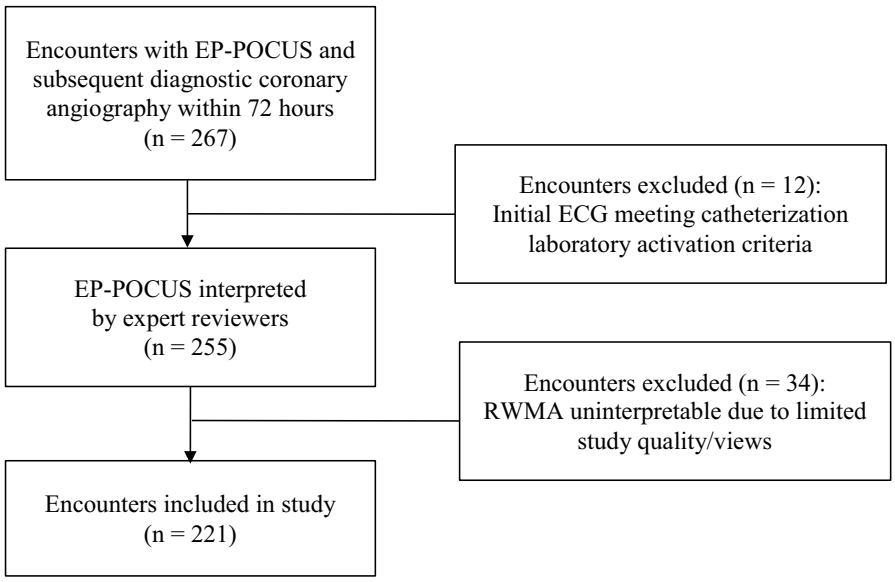


Figure 1. Flow diagram of screened and included patient encounters among subjects evaluated with emergency physician-performed point-of-care echocardiography (during assessment for acute coronary syndrome).
EP, emergency physician; *POC TTE*, point-of-care transthoracic echocardiogram; *ECG*, electrocardiogram; *RWMA*, regional wall motion abnormality.

Table 1. Demographics of participants by coronary intervention status.

Patient characteristics	No coronary intervention (n = 117)	Coronary intervention (n = 104)	Total (n = 221)	*P*-value
RWMA present on EP-POC TTE, no. (%)	38 (32.5%)	40 (38 5%)	78 (35.3%)	0.62
ED setting, no. (%)				
Quaternary care academic ED	104 (88.9%)	90 (86.5%)	194 (87.8%)	0.74
Suburban freestanding ED	13 (11.1%)	14 (13.5%)	27 (12.2%)	
Age, mean, yr (SD)	62.8 (14.1)	67.1 (12.1)	64.8 (13.4)	0.01*
Female, no. (%)				
Female	53 (45.3%)	22 (21.2%)	75 (33.9%)	<0.01*
Male	64 (54.7%)	82 (78.8%)	146 (66.1%)	
Ethnicity, no. (%)				
Hispanic or Latino	13 (11.1%)	9 (8.7%)	22 (10.0%)	0.83
Non-Hispanic	103 (88.0%)	94 (90.4%)	197 (89.1%)	
Other/unknown	1 (0.9%)	1 (1.0%)	2 (0.9 %)	
Race, no. (%)				
Asian	3 (2.6%)	3 (2.9%)	6 (2.7%)	0.04*
Black	23 (19.7%)	7 (6.7%)	30 (13.6%)	
White	81 (69.2%)	86 (82.7%)	167 (75.6%)	
Other/unknown	10 (8.5%)	8 (7.7%)	18 (8.1%)	

RWMA, regional wall motion abnormality; *POC TTE*, point-of-care transthoracic echocardiogram.

Table 2. Diagnostic test characteristics of presence of regional wall motion abnormality on emergency physician-performed point-of-care transthoracic echocardiography for coronary intervention.

Group	Prevalence, % (95% CI)	Sensitivity, % (95% CI)	Specificity, % (95% CI)	Positive likelihood ratio (95% CI)	Negative likelihood ratio (95% CI)
All encounters n = 221	35% (29–42%)	38% (29–49%)	68% (58–76%)	1.18 (0.83–1.69)	0.91 (0.75–1.11)
Elevated troponin n = 193	37% (30–45%)	41% (30–51%)	66% (56–75%)	1.18 (0.82–1.71)	0.90 (0.72–1.13)
No prior RWMA n = 21	19% (5–42%)	43% (10–82%)	93% (66–100%)	6.00 (0.75–47.71)	0.62 (0.32–1.19)

CI, confidence interval; *RWMA*, regional wall motion abnormality; *CI*, confidence interval.

(Table 1). The coronary intervention/referral group was statistically older (mean age 67.1), more likely to be male (78.8%), and less likely to identify as Black.

In our overall study population, RWMA was present in 35% (95% CI 29–42%) of cases. Interrater reliability for presence of RWMA prior to adjudication was 0.37 (95% CI 0.25–0.49). Presence of RWMA had 38% (95% CI 29–49%) sensitivity and 68% (95% CI 58–76%) specificity for coronary intervention/referral. The positive likelihood ratio was 1.18 (95% CI 0.83–1.69) and negative likelihood ratio was 0.91 (95% CI 0.75–1.11). Prevalence of RWMA and test characteristics for intervention were similar in the subgroup of patients with an elevated troponin at any time in the ED. Among these cases, RWMA was present in 37% (95% CI 30–45%). Presence of RWMA had 41% (95% CI 30–51%) sensitivity and 66% (95% CI 56–75%) specificity for coronary intervention/referral. The positive likelihood ratio was 1.18 (95% CI 0.82–1.71) and negative likelihood ratio was 0.90 (95% CI 0.72–1.13).

We identified a small subgroup of 21 encounters with the most recent cardiology TTE explicitly documenting the absence of any RWMA. In this subgroup, RWMA was now present in 19% (95% CI 5–42%). Presence of RWMA had 43% (95% CI 10–82%) sensitivity and 93% (95% CI 66–100%) specificity for coronary intervention/referral. The positive likelihood ratio was 6.00 (95% CI 0.75–47.71) and negative likelihood ratio was 0.62 (95% CI 0.32–1.19). A summary of all test characteristics is shown in Table 2 for each group.

In 158 encounters (71.5%), a subsequent cardiology TTE was identified, which explicitly commented on the presence or absence of RWMA during the same admission. The ED RWMA had 57% (95% CI 47–67%) sensitivity and 97% (95% CI 87–100%) specificity for RWMA on cardiology TTE. There were only two cases in which an RWMA was felt to be present in the ED but not on cardiology TTE.

DISCUSSION

The determination of which ED NSTE-ACS patients would benefit from expedited coronary intervention has been a longstanding challenge. The traditional paradigm of dividing patients into STE-ACS vs NSTE-ACS groups resulted in about 25% of missed acute coronary occlusion that would have been potentially amenable to more urgent intervention.[4] More recently, a new paradigm of stratifying patients into occlusion myocardial infarction (OMI) vs non-occlusion myocardial infarction (NOMI) has been proposed.[20] This paradigm is similar to the distinction made in the 2022 American College of Cardiology Expert Consensus Decision pathway on the Evaluation of Acute Chest Pain in the Emergency Department, which makes a distinction in management recommendations between NSTE-ACS Type 1 (occlusive disease related to atherosclerotic plaque rupture and thrombosis) and Type 2 (non-occlusive process related to an oxygen supply/demand mismatch).[21] Our study adds to this body of work by demonstrating the potential role for detection of RWMA on EP-performed POC TTE as part of a comprehensive evaluation for suspected occlusive coronary disease.

To our knowledge, this is the first large study evaluating the test characteristics of RWMA on EP-performed POC TTE for coronary intervention or referral to CABG. Our study demonstrated a relatively modest 68% specificity of RWMA on EP-performed POC TTE for intervention/referral. This finding is lower although comparable to earlier studies showing RWMA in cardiology-performed TTE to be 78% specific for significant coronary artery disease (CAD) in the NSTE myocardial infarction (NSTEMI) population.[14] The 35% prevalence of RWMA in our NSTEMI population was comparable to rates reported by Ha et al in their review.[22] Our reported sensitivity of RWMA for coronary intervention/CABG referral in patients with elevated troponins does appear to be lower than previously reported.

Prior studies noted RWMA on cardiology TTE in the ED in 77–92% of NSTEMI patients.[13,14,17] In the prehospital setting, Bergmann et al found that prehospital RWMA on EP-performed POC TTE was higher at 91% sensitivity for NSTEMI and correlated to occluded coronary vessels seen in 85% of PCI cases.[17] Peels et al found RWMA to be 88% sensitive in significant CAD.[14] Differences in test

characteristics may be partially attributable to inclusion of subjects with prior known CAD, history of MI, congestive heart failure, or prior RWMA, when other studies excluded these patient populations.[12,14,17]

Another likely factor contributory to our lower sensitivity is the inclusion of EP-performed POC TTE for indications other than assessment of RWMA, as dedicated assessment of regional walls is not part of our typical institutional EP-performed POC TTE protocol. These studies were primarily conducted for the assessment of alternative non-ACS entities in the clinical differential and, thereby, may have inadequately visualized some regional walls. Images were also obtained by a variety of individuals, including attending physicians, resident physicians, other clinicians, and learners. The combination of diverse indications for studies and variable experience of those performing sonography likely also contributed to the limited interrater reliability on subsequent expert interpretation due to variable image quality and the high rate of studies felt to be uninterpretable due to insufficient views obtained. In retrospect, given the lower than expected interrater reliability, future studies should consider more robust adjudication schemes such as a third rater and prescribed protocols for image acquisition to ensure adequate study quality.

It should also be noted that presence of a positive ED troponin did not significantly impact our EP-performed POC TTE test characteristics. This is likely related to the observation that most patients in the study had an elevated troponin at some time during their ED stay.

The most interesting subgroup in this study consisted of encounters with "new" RWMA on EP-performed POC TTE. While findings in this population were limited by sample size, the likelihood ratio and specificity appeared to trend higher than the overall study population. This suggests they may be a promising population for further ED-based studies, particularly as electronic health record integration progresses, and higher numbers of patients have accessible prior cardiology TTE reports. The presence of a new RWMA in a patient with a previously normal echocardiogram does seem reasonably likely to represent an occlusive coronary process given the physiology of RWMA development, although the time course of this event likely depends on the age of the prior echocardiogram.

While our results yielded a mildly positive point estimate for the positive likelihood ratio of any RWMA in predicting need for intervention, the width of the CIs prevents us from making any definitive conclusions about newly identified RWMA. It is feasible that a larger sample size, or one that is prospectively collected and intended to focus on RWMA, could be more definitive. As old myocardial scarring may cause RWMA, it makes sense that not all RWMA are indicative of acute occlusion, and we were hampered in determining the presence of "new" RWMA by the relative paucity of prior normal TTEs.

Finally, we found EP-performed POC TTE interpretation of RWMA to be 96% specific to cardiology detection of RWMA. This finding is comparable to Saglam et al who found a specificity of 92% when comparing EP and cardiology TTE interpretation.[23] Overall, these results suggest that RWMAs diagnosed by EPs are persistent on subsequent echocardiography. The lower sensitivity may partially relate to temporal effects, as cardiology TTEs were performed later during the admission after which further ischemia may have led to the development of an RWMA not present at the time of ED assessment.

LIMITATIONS

This study was conducted at an academic quaternary-care system with an active emergency ultrasound training program, which may limit the generalizability of the results to institutions with less expertise in point-of-care ultrasound. However, ultrasound training has become widespread throughout EM residency training, and there is likely general and growing familiarity with point-of-care ultrasound in non-academic settings. Prior studies have also shown that EM attendings and residents with limited prior ultrasound experience can be effectively trained to detect RWMA abnormalities on POC TTE.[18,23–25] Because the study population only included patients not meeting catheterization laboratory activation criteria on initial ED ECG, but who underwent coronary angiography, these patients were likely considered higher risk for intervenable occlusion by either the ED or inpatient team. Thus, our RWMA findings in EP-performed POC TTE should be interpreted with caution in patients in lower risk categories. We did not include patients who may have had OMI on coronary angiography but were medically managed as these patients could not be reliably identified with the available clinical documentation. Additionally, the specific walls involved on EP-performed POC TTE were not correlated to the involved vessels on angiography, presenting an area for further research. Finally, given the study design it was not possible to establish a causal relationship between RWMA and coronary intervention.

CONCLUSION

Presence of regional wall motion abnormalities on emergency physician-performed point-of-care transthoracic echocardiogram had limited sensitivity or specificity for coronary intervention or referral to coronary artery bypass grafting. The observed specificity was higher in subjects with a prior echocardiogram demonstrating absence of RWMA, but the certainty of this finding was limited by our small sample size. Emergency physician-performed POC TTE RWMA had high specificity for presence of RWMA on subsequent cardiology TTE. Future studies to evaluate the test characteristics in a larger group of subjects

with prior absent RWMA on cardiology TTE are needed.

ACKNOWLEDGMENTS

The authors would like to acknowledge and thank Dr. Rachel Liu for her support in reviewing and providing adjudication for electrocardiograms in the study.

Address for Correspondence: Ting Xu Tan, MD, St. Joseph's Medical Center, Department of Emergency Medicine, 2102 N. California Street, Stockton, CA. 95204. Email: tingxu.tan@commonspirit.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. Pendyal A, Rothenberg C, Scofi JE, et al. National trends in emergency department care processes for acute myocardial infarction in the United States, 2005 to 2015. *J Am Heart Assoc.* 2020;9(20):e017208.
2. Kushner FG, Hand M, Smith SC, et al. 2009 focused updates: ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction (updating the 2004 guideline and 2007 focused update) and ACC/AHA/SCAI guidelines on percutaneous coronary intervention (updating the 2005 guideline and 2007 focused update) a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol.* 2009;54(23):2205–41.
3. Amsterdam EA, Wenger NK, Brindis RG, et al. 2014 AHA/ACC Guideline for the Management of Patients with Non-ST-Elevation Acute Coronary Syndromes: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol.* 2014;64(24):e139–e228.
4. Khan AR, Golwala H, Tripathi A, et al. Impact of total occlusion of culprit artery in acute non-ST elevation myocardial infarction: a systematic review and meta-analysis. *Eur Heart J.* 2017;38(41):3082–9.
5. Wang TY, Zhang M, Fu Y, et al. Incidence, distribution, and prognostic impact of occluded culprit arteries among patients with non-ST-elevation acute coronary syndromes undergoing diagnostic angiography. *Am Heart J.* 2009;157(4):716–23.
6. Pride YB, Tung P, Mohanavelu S, et al. Angiographic and clinical outcomes among patients with acute coronary syndromes presenting with isolated anterior ST-segment depression: A TRITON–TIMI 38 (Trial to Assess Improvement in Therapeutic Outcomes by Optimizing Platelet Inhibition with Prasugrel–Thrombolysis In Myocardial Infarction 38) Substudy. *JACC Cardiovasc Interv.* 2010;3(8):806–11.
7. Milosevic A, Vasiljevic-Pokrajcic Z, Milasinovic D, et al. Immediate versus delayed invasive intervention for non-STEMI patients: the RIDDLE-NSTEMI study. *JACC Cardiovasc Interv.* 2016;9(6):541–9.
8. Reuter PG, Rouchy C, Cattan S, et al. Early invasive strategy in high-risk acute coronary syndrome without ST-segment elevation. The Sisca randomized trial. *Int J Cardiol.* 2015;182:414–8.
9. Kontos MC, Arrowood JA, Paulsen WH, et al. Early echocardiography can predict cardiac events in emergency department patients with chest pain. *Ann Emerg Med.* 1998;31(5):550–7.
10. Sabia P, Afrookteh A, Touchstone DA, et al. Value of regional wall motion abnormality in the emergency room diagnosis of acute myocardial infarction. a prospective study using two-dimensional echocardiography. *Circulation.* 1991;84(3 Suppl):I85–92.
11. Sabia P, Abbott RD, Afrookteh A, et al. Importance of two-dimensional echocardiographic assessment of left ventricular systolic function in patients presenting to the emergency room with cardiac-related symptoms. *Circulation.* 1991;84(4):1615–24.
12. Di Pasquale P, Cannizzaro S, Scalzo S, et al. Sensitivity, specificity and predictive value of the echocardiography and troponin-T test combination in patients with non-ST elevation acute coronary syndromes. *Int J Cardiovasc Imaging.* 2004;20(1):37–46.
13. Sobczyk D, Nycz K, Andruszkiewicz P. Validity of a 5-minute focused echocardiography with A-F mnemonic performed by non-echocardiographers in the management of patients with acute chest pain. *Cardiovasc Ultrasound.* 2015;13:6.
14. Peels CH, Visser CA, Kupper AJ, et al. Usefulness of two-dimensional echocardiography for immediate detection of myocardial ischemia in the emergency room. *Am J Cardiol.* 1990;65(11):687–91.
15. Ioannidis JP, Salem D, Chew PW, et al. Accuracy of imaging technologies in the diagnosis of acute cardiac ischemia in the emergency department: a meta-analysis. *Ann Emerg Med.* 2001;37(5):471–7.
16. Sobczyk D, Nycz K, Żmudka K. Usefulness of limited echocardiography with A-F mnemonic in patients with suspected non-ST-segment elevation acute coronary syndrome. *Pol Arch Med Wewn.* 2014;124(12):688–94.
17. Bergmann I, Büttner B, Teut E, et al. Pre-hospital transthoracic echocardiography for early identification of non-ST-elevation myocardial infarction in patients with acute coronary syndrome. *Crit Care.* 2018;22(1):29.
18. Frenkel O, Riguzzi C, Nagdev A. Identification of high-risk patients with acute coronary syndrome using point-of-care echocardiography in the ED. *Am J Emerg Med.* 2014;32(6):670–2.
19. Smith SW, Dodd KW, Henry TD, et al. Diagnosis of ST-elevation myocardial infarction in the presence of left bundle branch block with the

ST-elevation to S-wave ratio in a modified Sgarbossa rule. *Ann Emerg Med.* 2012;60(6):766–76.

20. Aslanger EK, Meyers HP, Smith SW. Time for a new paradigm shift in myocardial infarction. *Anatol J Cardiol.* 2021;25(3):156–62.
21. Kontos MC, de Lemos JA, Deitelzweig SB, et al. 2022 ACC expert consensus decision pathway on the evaluation and disposition of acute chest pain in the emergency department. *J Am Coll Cardiol.* 2022;80(20):1925–60.
22. Ha ET, Cohen M, Fields PJ, et al. The utility of echocardiography for non-ST-segment elevation myocardial infarction: a retrospective study. *J Diagn Med Sonogr.* 2020;36(2):121–9.
23. Sağlam C, Ünlüer EE, Yamanoğlu NGÇ, et al. Accuracy of emergency physicians for detection of regional wall motion abnormalities in patients with chest pain without ST-elevation myocardial infarction. *J Ultrasound Med.* 2021;40(7):1335–42.
24. Farsi D, Hajsadeghi S, Hajighanbari MJ, et al. Focused cardiac ultrasound (FOCUS) by emergency medicine residents in patients with suspected cardiovascular diseases. *J Ultrasound.* 2017;20(2):133–8.
25. Kerwin C, Tommaso L, Kulstad E. A brief training module improves recognition of echocardiographic wall-motion abnormalities by emergency medicine physicians. *Emerg Med Int.* 2011;2011:483242.

Interruptions During Sign-out Between Emergency Medicine Residents Before and After Implementation of Group Sign-out Process

Andrea Lin, BS*
Makenna Brezitski, BS†
Marko Zegarac, MD†
Sue Boehmer, MA‡
Robert P. Olympia, MD†§

*Penn State College of Medicine, Hershey, Pennsylvania
†Penn State Hershey Medical Center, Department of Emergency Medicine, Hershey, Pennsylvania
‡Division of Biostatistics, Department of Public Health Services, Penn State Hershey Medical Center, Pennsylvania
§Penn State Hershey Children's Hospital, Department of Pediatrics, Hershey, Pennsylvania

Section Editor: Donna Mendez, MD, EdD
Submission history: Submitted November 22, 2022; Revision received October 10, 2023; Accepted November 16, 2023
Electronically published December 22, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.59486

Introduction: Interruptions that occur during sign-out in the emergency department (ED) may affect workflow, quality of care, patient safety, errors in documentation, and resident education. Our objective in this study was to determine the frequency and classification (emergent vs non-emergent, in-person vs phone call) of interruptions that occur during emergency medicine (EM) resident sign-out before and after the institution of a group sign-out process involving residents and attending physicians.

Methods: A convenience sample of sign-out observations between EM residents were observed and coded between April–December 2021. We excluded sign-out observations of pediatric patients (<18 years of age) and observations not conducted in the main ED. Collected data included number of patients signed out during each observation; total duration in minutes for each observation; total number of interruptions during each observation; and type of interruption (emergent vs non-emergent, in-person vs phone call). We further stratified data before and after the institution of a group sign-out process (July 2021).

Results: We performed data analysis on 58 individual and 65 group sign-out observations, respectively. Although the total number of patients signed out, the total duration of sign-outs observed, mean number of patients signed out per minute, and mean duration of sign-out per observation were more for the group sign-out aggregate compared with the individual sign-out aggregate, the total number of interruptions (44 vs 73, $P = 0.007$), number of interruptions per minute (0.05 vs 0.16, $P < 0.001$), total number of non-emergent interruptions (38 vs. 67, $P = 0.005$), and total number of in-person interruptions (14 vs 44, $P < 0.001$) was less in the group sign-out compared with the individual sign-out totals.

Conclusion: Based on our sample, although the total duration of group sign-out with both residents and an attending was longer than individual resident-to-resident sign-out, the total number of interruptions, number of interruptions per minute, total number of non-emergent interruptions, and total number of in-person interruptions was less in the group sign-out. Group sign-out may be an option to limit the negative effects of interruptions in the ED. [West J Emerg Med. 2024;25(1)17–21.]

INTRODUCTION

The sign-out of patient information from one emergency physician to the next is a critical time that requires their undivided attention. Essential information—such as the history of present illness, past medical history, physical examination findings and vital signs, differential diagnosis, emergency department (ED) management, and disposition based on the response to interventions and diagnostic testing—is often communicated during the sign-out process.[1] Yet the sign-out process is frequently interrupted for both emergent and non-emergent reasons.

Previous literature has described disturbances during the ED shift with clear delineations between "multitasking" and interruptions.[2] Some authors have also detailed the quantity and quality of interruptions experienced by emergency physicians.[3] Specifically, interruptions took place most frequently during information exchange at nursing and doctor stations, and in-person interruptions were the most common type of interruption. Such interruptions have resulted in residents experiencing decreased efficiency and productivity ultimately measured by increased documenting time, more frequent patient readmissions, less face-to-face patient interaction time, and additional phone calls from consultants, nurses, and other healthcare staff about incorrect orders.[4]

These interruptions can manifest as loss of critical patient information or misinterpretation of patient status, which ultimately pose a risk to patient safety.[1] Lastly, oncoming physicians who assume responsibility of patients must summarize each patient encounter and create an addendum in the electronic health record (EHR). As reliance on the EHR increases, errors in documentation and communication may increase due to frequent interruptions during the sign-out process. Unanticipated or anticipated stressors may contribute to mistakes, which may result in auditing of notes or other legal implications that could have been otherwise avoided.[5] In addition to the effect that interruptions have on the quality of care provided, patient safety, and physician documentation, resident physicians may be subjected to disjointed education when lessons are frequently incongruent, as their peers and educators are often called away to answer questions, address complaints, and assist patients because of interruptions that may or may not be emergent or urgent.[6]

To our knowledge, there have been no published studies examining the frequency and classification of interruptions that occur during an emergency medicine (EM) resident sign-out, nor have there been descriptions of these interruptions based on individual resident to resident vs group sign-out process involving both residents and attending physicians. In this study our objective was to determine the frequency and classification (emergent vs non-emergent, in-person vs phone call) of interruptions that occur during EM resident sign-out at Penn State Hershey Medical Center before and after the institution of a group sign-out process.

Population Health Research Capsule

What do we know about this issue?
Depending on setting, some signout methods are more effective. No known study has examined quantitative differences between one-to-one versus a group signout at an academic institution.

What was the research question?
How do individual versus group signouts in the ED differ in types and frequency of interruptions experienced?

What was the major finding of the study?
Group sign-outs take longer (8.0 vs. 13.7 minutes) but experience less frequent interruptions (0.05 vs. 0.16 per minute) when compared to individual sign-outs in the emergency department.

How does this improve population health?
Less frequent interruptions during shift change allow for accurate and timely exchange of patient information critical to care during patients' stays in the emergency department.

METHODS

We conducted a prospective, observational cohort study at Penn State Hershey Medical Center Level I trauma, a designated, tertiary care academic ED in central Pennsylvania, between April 2021–December 2021. A convenience sample of sign-out observations between EM residents were observed and coded by research assistants (RA). The RAs were instructed to record the time at shift change when residents began to verbally sign out with one another, and document total time as well as frequency and type of interruptions. We excluded sign-out observations of pediatric patients (<18 years of age), sign-out observations involving non-EM residents and medical students, and sign-out observations that were not conducted in the attending physician/nurses' station of the main ED.

We excluded pediatric patients since the number of interruptions involving medical command and medical/traumatic resuscitations involving children would likely be less frequent. Sign-out observations involving non-EM residents and medical students were also excluded since most

emergent interruptions would be handled by EM residents, and the majority of adult patients in the Level I ED were managed by EM residents. We excluded sign-outs that occurred outside the attending physician/nurses' station of the main ED (only applicable during the individual sign-out phase) since we wanted to capture all in-person interruptions due to the nature of their central location.

Emergency medicine residents were notified by email regarding the purpose of the research study, the role of the RA during the sign-out process, and that the presence of the RA would not affect the overall process of sign-out. Nurses and other staff were not aware this study was ongoing. Due to the nature of the teaching hospital, the presence of two additional medical students in an area with high visibility and other learners would be unlikely to influence the frequency of interruptions.

Data collected by the RA for each sign-out observation included the following: number of patients signed out during each observation; total duration in minutes for each observation; total number of interruptions during each observation; and type of interruption (emergent vs non-emergent, in-person vs phone call). Emergent interruptions included command calls (requests) or medical/traumatic resuscitations for patients in the ED, and often occurred by phone call or overhead announcements. Non-emergent interruptions included in-person and phone call interruptions for scenarios that did not require the resident's immediate response or action (non-resuscitation scenarios). The RAs were available to observe and collect data during the three sign- out periods spread out during the day: 6 AM to 8 AM, 2 PM to 6 PM, and 10 PM to midnight. The total time of sign-out included whether the resident had to address either emergent or non-emergent interruptions and the sign-out would resume where it had been left off following resolution of the interruptions.

At our institution we adopted a group sign-out process involving all residents and one attending physician starting on July 1, 2021, with the hope of increasing attending physician presence at sign-out to streamline care of patients and limit errors associated with the sign-out process, as well as increase the amount of education provided to all learners. Prior to July 1, 2021, the sign-out process occurred "one-on-one" between the outgoing and incoming resident around computers located at the attending physician/nurses' station of the main ED. After July 1, 2021, the sign-out process occurred as a group of attending physicians, residents and medical students, discussing all the patients assigned to the team, around the attending computer located at the attending physician/nurses' station of the main emergency department (see Figure 1). Each EM resident carries a mobile phone assigned to them for each shift, and can be contacted at any time during their shift by ED or other hospital staff (such as consultants, primary care physicians, social workers, patient logistics, etc).

Data collected by the RA were imported in REDcap, a secure, web-based software platform designed to support data capture for research studies hosted at Penn State. Descriptive statistics were generated and included the means, medians, standard deviations and 95% confidence intervals for continuous variables; percentages were calculated for categorical variables. To compare the group vs individual sign-out process as continuous variables, we used a two-sample *t*-test. To compare between the group and individual sign-out process as categorical variables, we used a binomial test for proportions. All tests were two-sided and were considered statistically significant if the *P*-value was <0.05. The statistical analysis was performed using SAS software, version 9.4 (SAS Institute Inc, Cary, NC).

The institutional review board approved the study. No funding or grants were received for research or preparation of this manuscript.

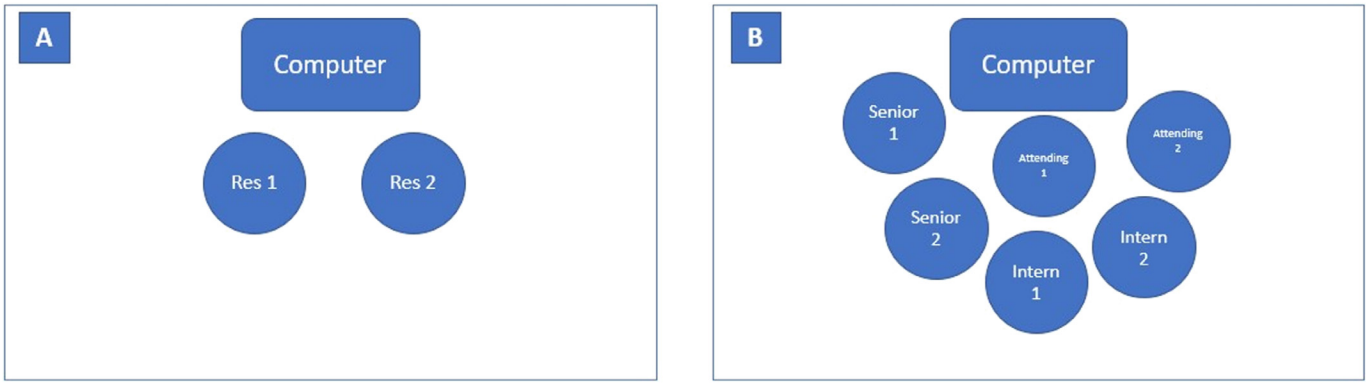


Figure 1. Diagram of individual sign-out (A) compared to group sign-out (B). Individual sign-out consisted of the outgoing resident (Res 1) signing out patients to the incoming resident (Res 2); this would be intern to intern, senior to senior, etc. The group sign-out process included the outgoing attending, senior, and intern (1) signing out patients to the incoming attending, senior, and intern (2). With this group sign-out format, each member of the physician team heard about all patients.
Res, resident.

Table 1. Characteristics of individual and group sign-out observations.

	Individual sign outs, mean ± SD (95% CI)	Group sign outs, mean ± SD (95% CI)	*P*-value
Mean number of patients signed out per minute	0.63 ± 0.26 (0.56, 0.70)	0.79 ± 0.26 (0.73, 0.86)	<0.001
Mean duration of sign-out per observation (minutes)	7.97 ± 5.79 (6.44, 9.49)	13.66 ± 5.34 (12.34, 14.99)	<0.001
Total number of interruptions recorded for all observations	73 (62.4%)	44 (37.6%)	0.007
Mean number of interruptions per minute	0.158 ± 0.21 (0.10, 0.22)	0.049 ± 0.06 (0.03, 0.06)	<0.001
Total number of emergent interruptions	6 (50.0%)[a]	6 (50.0%)[b]	1.00
Total number of command calls	4 (50.0%)	4 (50.0%)	1.00
Total number of non-emergent interruptions	67 (63.8%)	38 (36.2%)	0.005
Total number of phone call interruptions	23 (46.9%)	26 (53.1%)	0.67
Total number of in-person interruptions	44 (75.9%)	14 (24.1%)[c]	<0.001

[a]For emergency interruptions during the individual sign-out observation period (n = 6), all interruptions were overhead announcements.
[b]For emergent interruptions during the group sign-out observation period (n = 6), two interruptions were in person and four interruptions were overhead announcements.
[c]Of the 14 in-person interruptions during the group sign-out observation period, two were emergent interruptions.
CI, confidence interval.

RESULTS

We performed data analysis on 58 individual sign-out observations and 65 group sign out observations. (Six individual sign-out observations and one group sign-out observation was excluded due to missing data on duration of sign-out observation). Although the total number of patients signed out, the total duration of sign- out observed, mean number of patients signed out per minute, and mean duration of sign-out per observation were more for the group sign-out aggregate compared with the individual sign-out aggregate, the total number of interruptions (44 vs 73, $P = 0.007$), number of interruptions per minute (0.05 vs 0.06, $P < 0.001$), total number of non-emergent interruptions (38 vs 67, 0.005), and total number of in-person interruptions (14 vs 44, $P < 0.001$) was less in the group sign-out aggregate compared with the individual sign-out aggregate (Table 1).

DISCUSSION

Patient handoff is a critical time that has been estimated to contribute to approximately 80% of medical errors, even outside the ED when transitioning between facilities.[7] The effectiveness of the hand-off process has been studied in one non-academic institution that uses electronic sign-outs to increase the number of admits from the ED to the inpatient hospital team; however, in doing so, it also increased the total duration of sign-outs.[8] No prior studies have examined the hand-off process between ED residents to one another, or as a team in the presence of an attending. Yet with the nation's healthcare systems relying heavily on EHR, electronic sign-outs may be a component of care that could help minimize interruptions and improve efficiency. Thus, understanding the multiple variables that can influence the hand-off process and time can indirectly optimize transitions between patient care. Our study compares the change from one process involving hand-offs between ED resident to ED resident, to a team of residents and one attending at an academic institution. Ultimately, this study provides some insight into the clinical operations that occur during the hand-off process.

The objective of our study was to determine the frequency and classification (emergent vs non-emergent, in-person vs phone call) of interruptions that occur during EM resident sign-out at our institution before and after the institution of a group sign-out process that included multiple residents and one attending physician. Based on our results, although the total duration of group sign-out was longer than individual sign-out, the total number of interruptions, number of interruptions per minute, total number of non-emergent interruptions, and total number of in-person interruptions were less in the group sign-out aggregate. This data signifies that by using a team-based, collective sign-out process, there are fewer interruptions, which could ultimately result in improving ED workflow, quality of care provided, patient safety and outcomes, errors in physician documentation, and resident education provided or learned.

Although there was a statistically significant difference in the total duration of sign-out per observation, the benefits of group sign-out, such as ED attending physician presence to streamline care of patients and limit errors associated with the sign-out process, to increase the amount of education provided to all learners, and to reduce interruptions, may outweigh the increased time spent during the sign-out process. Ultimately this process may be more efficient on multiple fronts, as there were more patients signed out per minute.

The reduction in the total number of interruptions, number of interruptions per minute, total number of non-emergent interruptions, and total number of in-person interruptions after institution of a group sign-out process may be due to the fact that ED staff may be less likely to ask questions and discuss less emergent details when a large team is visibly signing out together, especially when the ED attending physician is present. There was no evidence to suggest that there was a statistically significant difference in the number of emergent interruptions; thus, implementing a group sign-out process would not hinder the team from acting appropriately in the event there was an emergency that appropriately warranted interruption. While the frequency of emergent interruptions cannot be controlled for, the goal of implementing a group sign-out process was to reduce the number of non-emergent interruptions, a decrease that was statistically significant from our study's data. This can be attributed to multiple reasons that may not be able to be dissected, as a multitude of factors could be at play, including individuals being less inclined to interrupt a large group of individuals, the presence of the attending physician, or greater visibility and awareness of the sign-out process.

LIMITATIONS

There are several limitations associated with our study. Our study was conducted at a single site at a Level I trauma-designated, tertiary-care academic ED in central Pennsylvania; therefore, our results may not be generalizable to all EDs in the United States. We conducted a convenience sample of sign-out observations limited to adult patients and involving only EM residents, and thus our results may not be applicable to pediatric EDs and sign-out involving non-ED residents. Furthermore, our study was conducted during the COVID-19 pandemic, and because of guidelines to protect healthcare workers (use of personal protective equipment, social distancing, etc), the frequency and classification of interruptions may not reflect non-pandemic times. Lastly, although our objective in this study was to determine the quantity and classification of interruptions that occur during EM resident sign-out, we did not determine whether these interruptions ultimately affected ED workflow, quality of care provided, patient safety and outcomes, errors in physician documentation, and resident education provided or learned.

CONCLUSION

Based on our sample, although the total duration of group sign-out was longer than individual sign-out, the total number of interruptions, number of interruptions per minute, total number of non-emergent interruptions, and total number of in-person interruptions were less in the group sign-out aggregate compared with the individual sign-out aggregate. Group sign-out may be an option to limit the negative effects of interruptions in the ED, such as the effect on workflow, quality of care provided, patient safety and outcomes, errors in physician documentation, and resident education provided or learned.

Address for Correspondence: Andrea Lin, BS, Penn State Hershey Medical Center, 69 University Manor East, Hershey, Pennsylvania 17033. Email: andrea.lin920@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. Thompson RJ, Sharp B, Lee A, et al. Pardon the interruption(s)-enabling a safer emergency department sign out. *WMJ*. 2018;117(5):214–8.
2. Chisholm CD, Collison EK, Nelson DR, et al. Emergency department workplace interruptions: Are emergency physicians "interrupt-driven" and "multitasking"? *Acad Emerg Med*. 2000;7(11):1239–43.
3. Berg LM, Källberg A, Göransson KE, et al. Interruptions in emergency department work: an observational and interview study. *BMJ Quality & Safety* 2013;22(8):656–63.
4. Joseph JW, Kennedy M, Nathanson LA, et al. Reducing emergency department transfers from skilled nursing facilities through an emergency physician telemedicine service. *West J Emerg Med*. 2020;21(6):205–9.
5. Schnapp BH, Alvarez A, Ham J, et al. An interactive session to help faculty manage difficult learner behaviors in the didactic setting. *MedEdPORTAL*. 2018;14:10774.
6. Rattray NA, Flanagan ME, Militello LG, et al (2021). The art of effective handoff communication among medical and surgery residents. *J Cog. Eng Decis Mak*. 2021;15(2–3):66–82.
7. Janagama SR, Strehlow M, Gimkala A, et al. Critical communication: a cross-sectional study of signout at the prehospital and hospital interface. *Cureus*. 2020;12(2):e7114.
8. Singleton JM, Sanchez LD, Masser BA, et al. Efficiency of electronic signout for ED-to-inpatient admission at a non-teaching hospital. *Intern Emerg Med*. 2018;13(7):1105–10.

Rocuronium Dosing by Ideal vs Total Body Weight in Obesity: A Prospective, Observational Non-inferiority Study

Marc McDowell, PharmD[*]
Amanda Lewandowski, PharmD[*]
Dharati Desai, PharmD[†]
Stephany Nunez Cruz, PharmD[†]
Nicole Glowacki[‡]
Alaa Sulh, PharmD[§]
Michael Cirone, MD[‖¶]
Nadine Lomotan, PharmD[*]
Mary Hormese, PharmD[#]

[*]Department of Pharmacy, Advocate Christ Medical Center, Oak Lawn, Illinois
[†]Department of Pharmacy, Rush University Medical Center, Chicago, Illinois
[‡]Advocate Aurora Research Institute, Advocate Aurora Health, Wilwaukee, Wisconsin
[§]Department of Pharmacy, Loyola University Medical Center, Maywood, Illinois
[‖]Department of Emergency Medicine, Advocate Christ Medical Center, Oak Lawn, Illinois
[¶]University of Illinois – Chicago, Chicago, Illinois
[#]Department of Pharmacy, Northwest Community Hospital, Arlington Heights, Illinois

Section Editor: Wendy Macias-Konstantopoulos, MD, MPH, MBA
Submission history: Submitted April 16, 2023; Revision received July 24, 2023; Accepted September 12, 2023
Electronically published December 6, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.60713

Background: Providing adequate paralysis and appropriate sedation is challenging in patients with obesity during rapid sequence intubation (RSI). Pharmacokinetic parameters play an important role in dosing of rocuronium due to low lipophilicity. Rocuronium may be dosed based on ideal body weight (IBW). Current guidelines do not offer recommendations for dosing in the setting of obesity. Dosing depends on clinician preference based on total body weight (TBW) or IBW.

Objectives: In this study we performed non-inferiority analysis to compare the intubation conditions, duration of paralysis, and incidence of new-onset tachycardia or hypertension after intubation in obese patients requiring RSI in the emergency department (ED).

Methods: This was a single-center, prospective, observational study. Eligible for enrollment were adult patients with a TBW ≥30% IBW or body mass index ≥30 kilograms per meters squared who presented to the ED requiring RSI with the use of rocuronium. Rocuronium was dosed according to intubating physicians' preference. Physicians completed a survey assessing intubation conditions. Height and weight used for the calculation of the dose, the dose of rocuronium, time of administration, and time of muscle function recovery were recorded. Endpoints assessed included grading of view during laryngoscopy, first-past success, and duration of paralysis.

Results: In total, 96 patients were included, 54 in TBW and 42 in IBW. The TBW cohort received a mean of 1 milligram per kilogram (mg/kg) compared to 0.71 mg/kg in the IBW group. Excellent intubation conditions were observed in 68.5% in the TBW group and 73.8% in the IBW group. The non-inferiority analysis for relative risk of excellent intubation was 1.12 ($P = 0.12$, [90% CI 0.80–1.50]).

Conclusion: Non-inferiority analysis suggests that IBW dosing provides similar optimal intubation conditions when compared to TBW dosing, but the noninferiority comparison did not reach statistical significance. This study was unable to show statistical non-inferiority for IBW dosing. [West J Emerg Med. 2024;25(1)22–27.]

Keywords: *rocuronium; rapid sequence intubation; intubation conditions; obesity; ideal body weight; total body weight.*

INTRODUCTION

Background

Approximately one third of adults in the United States suffer from obesity.[1] Caring for this population is becoming more common in the emergency department (ED). Patients with obesity pose a unique challenge to the successful performance of rapid sequence intubation (RSI).[2] Factors potentially influencing RSI include neck circumference, anterior neck adipose tissue, and prevalence of concomitant lung disorder. These anatomic concerns have led to obesity being identified as an independent risk factor for difficult intubation.[3]

The ED setting poses inherent difficulty in the dosing and pharmacokinetics of RSI medications. An unfasted, unstable, or anatomically complex patient provides a true challenge in the dosing of RSI medications.[4] Further confounding this issue are patients presenting with obesity. Weights used to dose RSI medications often rely on clinician estimations. Clinical staff in the ED have demonstrated an unreliable ability to estimate patients total body weight (TBW), with only 23% of physicians accurately estimating within 10% of actual patient weight in patients with a body mass index (BMI) >30 kilograms per meters squared.[5] Inaccurate estimations may result in inappropriate amounts of paralytics. Underdosing may lead to difficult intubation conditions, increasing the risk of aspiration of gastric contents, airway trauma, hypoxia, and death.[6] Conversely, supratherapeutic dosing of paralytic agents may lead to unrecognized under-sedation, resulting in patient awareness. This may increase the risk of hypertension, tachycardia, difficulty obtaining timely neurologic exam and, ultimately, post-traumatic stress disorder.[7]

Rocuronium is a routinely used neuromuscular blocking agent in the ED.[8] It has a relatively low lipophilicity, moderate serum protein binding, and small volume of distribution compared to other commonly administered paralytics.[9] This allows therapeutic serum levels of rocuronium to be achieved using ideal body weight (IBW), as accumulation is not expected to occur in adipose tissue. Due to the paucity of data surrounding appropriate dosing weight for rocuronium in patients with obesity, dosing remains dependent on practitioner preference. The few studies that have compared rocuronium dosing in patients with obesity typically occurred in surgical settings.[10,11]

Goals of This Investigation

In this study our goal was to compare, via non-inferiority analysis, the intubation conditions, duration of paralysis, and incidence of new-onset tachycardia or hypertension after intubation in obese patients requiring RSI in the ED.

Population Health Research Capsule

What do we already know about this issue?
About one third of adults in the US suffer from obesity. Patients with obesity pose a challenge in dosing of rocuronium in the setting of rapid sequence intubation.

What was the research question?
This study compared rocuronium dosing based on ideal body weight (IBW) and total body weight (TBW).

What was the major finding of the study?
Results suggest similar efficacy in optimal intubation conditions between IBW (73.8%) and TBW (68.5%, p = 0.12 [0.8–2.5]), as well as shorter duration of paralysis when dosing patients based off IBW (43 vs 71 minutes, p < 0.001).

How does this improve population health?
Given challenges in determining a patient's TBW, rocuronium dosing in patients with obesity may be done using their IBW, but this study failed to show the two to be statistically equivalent.

METHODS

Study Design and Setting

We conducted this prospective, observational study at a single, tertiary, community teaching ED. Study recruitment occurred from December 1, 2018–May 2, 2021. Patients were included if they presented to the ED while a clinical pharmacist was on duty, underwent RSI with rocuronium, had a BMI ≥30, or TBW ≥30% of IBW. Patients were excluded if they were under the age of 18, had known neuromuscular disease, known allergy or sensitivity to rocuronium, or concomitant medications known to interfere with neuromuscular transmission. Design of this observational study was done in alignment with the STROBE checklist. Study approval was granted by the local institutional review board.

Interventions

Immediately prior to the procedure, the intubating physician would ask the clinical pharmacist to dose rocuronium based on IBW or TBW. The IBW dose was obtained via the pharmacist using a measuring tape bedside and the Devine formula, with dosing at 1milligram per kilogram (mg/kg). Dosing by TBW used recent chart

documentation within the prior three months, measured bed weight, or estimation by the medical team. Both dosing strategies were capped at 100 mg. All patients were weighed after intubation. Upon administration of the paralytic, the pharmacist at bedside announced passage of time at 15-second intervals. Laryngoscopy was performed at the discretion of the intubating physician based on passage of time, diaphragmatic movement, and patient-specific clinical factors.

Measurements

The pharmacist noted height and weight used for the calculation of the dose, dose of rocuronium, time of medication administration, time of intubation, need for repeat dose of paralytic, use of bougie, post-rocuronium hypoxia defined as a pulse oximeter reading of <90%, and the education level of the intubating physician. Time of muscle function recovery was observed and documented by either the nurse or clinical pharmacist present at the bedside. This was determined by spontaneous movement or spontaneous breathing. Post-intubation sedation selection and dosing was initiated at the discretion of the intubating physician. Data collection was performed prospectively, and abstractors were not blinded to the study hypothesis.

Outcomes

The primary outcome measured was the incidence of poor, good, or excellent intubation conditions, measured using a validated nine-point Good Clinical Research Practice Guidelines Airway Assessment survey (Figure 1), which was provided to the intubating physician.[12] Secondary endpoints included first-pass success, duration of paralysis, and incidence of suboptimal sedation defined as post-intubation systolic blood pressure and/or tachycardia greater than 30% of baseline.

Statistical Analysis

Using non-inferiority analysis, we analyzed the null hypothesis that intubating conditions (excellent/good/poor) in patients with obesity undergoing RSI in the ED did not differ based on use of IBW or TBW to calculate rocuronium doses. This resulted in an estimated subject sample size of 90 patients, on the assumption of "excellent" conditions occurring in 80% of intubations, with a 10% non-inferiority margin, and 80% power. We used the Farrington-Manning method for the non-inferiority analysis. Descriptive statistics were calculated for all variables and presented as mean ±SD for continuous variables and count/percentages for categorical variables. We made comparisons between groups for all outcomes using chi-square or Fisher exact tests as necessary for categorical data and Student *t*-tests or Mann-Whitney tests as appropriate for all continuous data. All tests were two-tailed and a *P*-value of 0.05 was considered statistically significant in all analyses.

RESULTS

Characteristics of Study Subjects

We collected data on 104 patients. Eight were excluded as they did not meet pre-specified obesity criteria (Figure 2). The remaining 96 patients were included for analysis. The TBW cohort included 54 subjects, while 42 were included in the IBW arm. (Summary of demographics can be found on in Table 1). Median actual body weight was similar in the TBW group (98.0 kg) as compared to the IBW group (98.9 kg). The TBW arm consisted of 51.9% females as compared to 64% in the IBW arm. Median age was similar between both cohorts, 60 and 65 years in TBW and IBW, respectively. Etomidate was the most routinely selected induction agent (92.6% and 90.5%). Median rocuronium dose used was 100 mg compared to 70 mg, respectively ($P < 0.001$) (Table 1). Median dosing weight used was 98 kg in TBW and 70 kg in

	Excellent	Good	Poor
Laryngoscopy			
Jaw relaxation	Relaxed	Not fully	Poor
Resistance to laryngoscope	None	Slight	Active
Vocal cords			
Position	Abducted	Intermediate	Closed
Movement	None	Moving	Closing
Intubation response			
Movement of limbs	None	Slight	Vigorous
Coughing	None	Slight	Sustained

Figure 1. Good Clinical Research Practice Guidelines Airway Assessment.
Intubating conditions: excellent = all qualities excellent; good = all qualities are excellent or good; poor = any quality is poor.

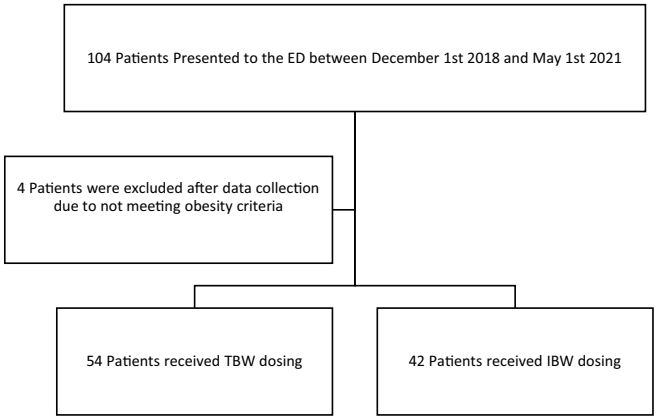


Figure 2. CONSORT (Consolidated standards of reporting trials) diagram.
ED, emergency department; *TBW*, total body weight; I*BW*, ideal body weight.

the TBW ($P < 0.001$). Mean rocuronium dose based on actual body was 1 mg/kg (±0.01) in TBW and 0.71 mg/kg (±0.12) in the IBW cohort.

Main Results

The primary outcome, excellent intubation condition, was observed in 68.5% of patients in the TBW group and 73.8% in the IBW group (Table 2). Non-inferiority analysis for relative risk of excellent intubation was 1.12 ($P = 0.12$, 90% confidence interval [CI] 0.80–1.50) (Table 3). Pertinent secondary outcomes analyzed included first-pass success which was achieved in 92.6% of the TBW cohort compared to 85.7% in IBW cohort ($P = 0.27$). Duration of paralysis, measured by median time to muscle recovery, was observed at 71 minutes and 43 minutes, respectively ($P < 0.001$). Hypoxia was observed in 17.8% of subjects in TBW arm compared to 3.45% in the IBW cohort ($P = 0.07$). Incidence of post-intubation hypertension was 44.4% and 23.8% ($P = 0.04$). The incidence of new-onset tachycardia was similar between groups, 35.2% and 33.3%. Level of physician training did not differ between groups ($P = 0.92$). An ad hoc analysis was performed comparing the combination of excellent and good views compared to a poor view. All patients in the IBW were assessed as having a good or excellent view compared to 94.4% in the TBW arm ($P = 0.04$, 90% CI 0.94–2.16).

DISCUSSION

The results of the study suggest that there is no difference in good/excellent intubation conditions when rocuronium is dosed based on IBW or TBW. Time to muscle recovery was statistically significant between IBW and TBW dosing. There was a direct correlation to longer duration of action of rocuronium in patients who were dosed based on their TBW. Post-intubation hypertension occurred more frequently in the TBW cohort, which may indicate underdosing of sedation. Curiously, hypoxia was found to be higher in the TBW cohort with an incidence approaching 18%. While not statistically significant this finding is greater than anticipated without obvious evidentiary explanation.

In supporting studies, Pappal et al assessed the prevalence of awareness with paralysis in ED patients who received

Table 1. Patient baseline demographics.

Baseline characteristics	TBW (n = 54)	IBW (n = 42)	*P*-value
Age, median (IQR)	60 [51–76]	65 [57–81]	0.70
Height (in), median (IQR)	67 [64–71]	68 [66–71]	0.07
Weight (kg), median (IQR)	98 [82–106]	98.9 [83–120]	0.74
Dosing weight (kg), median (IQR)	98 [82–100]	70 [60.0–75.0]	<0.001
Female gender, No. (%)	28 (51.9)	27 (64.3)	0.11
Sedative agent			
Etomidate	50 [92.6%]	38 [90.5)	0.93
Ketamine	3 [5.6%]	3 [7.1)	
None	1 [1.9%]	1 [2.4)	
Intubating physician, n (%)			
PGY1	12 (22.2)	7 [16.7)	0.92
PGY2	13 (24.1)	10 [23.8)	
PGY3	23 (42.6)	20 [47.6)	
Attending	6 (11.1)	5 [11.9)	
Use of bougie	5 (11.1)		
Rocuronium dose (mg), median (IQR)	100 [90–100]	70 [60–80]	<0.001

TBW, total body weight; *IBW*, ideal body weight; *IQR*, interquartile range; *kg*, kilogram; *PGY*, postgraduate year; *mg*, milligram.

Table 2. Intubation condition.

Outcomes	TBW (n = 54)	IBW (n = 42)	*P*-value
Good Clinical Research Practice Guidelines Airway Assessment, n (%)			
Excellent	37 (68.5)	31 (73.8)	0.3
Good	14 (25.9)	11 (26.2)	
Poor	3 (5.6)	0 (0)	
First-pass success, n (%)	50 (92.6)	36 (85.7)	0.27
Post-rocuronium hypoxia, n (%)	8 (17.8)	1 (3.45)	0.07
Duration of paralysis (min), median (IQR)	71 (57–96)	43 (39–54)	<0.001
Incidence of post-intubation hypertension, n (%)	24 (44.4)	10 (23.8)	0.04
Incidence of post-intubation tachycardia, n (%)	19 (35.2)	15 (33.3)	0.85

TBW, total body weight; *IBW*, ideal body weight; *IQR*, interquartile range.

Table 3. Non-inferiority analysis.

Outcomes	TBW (n = 54)	IBW (n = 42)	*P*-value	95% CI
Good Clinical Research Practice Guidelines Airway Assessment, n (%)				1.12 [0.80–1.50]
Excellent	37 (68.5)	31 (73.8)	0.12	
Good/poor	17 (31.5)	11 (26.2)		

TBW, total body weight; *IBW*, ideal body weight; *CI*, confidence interval.

mechanical ventilation.[6] They found awareness with paralysis was significantly higher in patients who were exposed to rocuronium. Levin et al assessed the association of rocuronium dosing on first-attempt success and adverse outcomes among ED patients.[8] Their results demonstrated a higher incidence of first-pass success in rocuronium doses ≥1.4 mg/kg. This is in contrast to our findings. Considerations for this discrepancy may be due to the conventional "capping" of doses at our institution of 100 mg and the relative body habitus from the Levin et al cohort. In their ≥1.4 mg/kg arm, the documented weight was remarkably low with a mean of 67.3 kg, and only 13.2% of the 2,302 subjects met obesity criteria. Meyhoff et al conducted a study in which rocuronium dosing was compared in morbidly obese patients scheduled for laparoscopic banding or gastric bypass. Dosing was based on either ideal body weight, 20% of corrected body weight (CBW) and 40 % of CBW.[10] Similar to our results, they report IBW provided a shorter duration of action without significantly prolonging onset time or compromising intubation conditions. However, this cohort drastically differed from ours as it occurred in a controlled surgical setting and did not include critically ill patients.

LIMITATIONS

The main limitations of this study include the observational nature of the study design, the use of a convenience sample, the fact that chart abstractors were not blinded to the study, and a lack of standardized time from rocuronium administration to laryngoscopy. First-pass success is a complicated outcome fraught with many contributing factors, not necessarily related to paralytic dose. Variability exists in the scoring of ideal conditions, as it may depend on comfort level with the procedure itself. Lastly, the patients' duration of paralysis was based on a subjective nature of observation by clinicians.

CONCLUSION

The results of this study suggest that, while similar intubation conditions appear to be produced with ideal body weight or total body weight dosing, this study did not show statistically significant non-inferiority between TBW and IBW. Additionally, a shorter duration of paralysis was observed when dosing was based on ideal body weight. However, additional prospective studies of an interventional nature are needed to determine optimal dosing of rocuronium in obesity.

Address for Correspondence: Marc McDowell, PharmD, Advocate Christ Medical Center, Department of Pharmacy, 4440 West 95th Street, Oak Lawn, IL 60453. Email: Marc.mcdowell@aah.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. Ogden CL, Carroll MD, Kit BK, et al. Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA* 2014;311:806–14.
2. Dargin J and Medzon R. Emergency department management of the airway in obese adults. *Ann Emerg Med* 2010;56:95–104.
3. Carron M, Safaee Fakhr B, Iepparіello G, et al. Perioperative care of the obese patient. *Br J Surg*. 2020;107:e39–55.
4. Brown CA, Bair AE, Pallin DJ, et al. Techniques, success, and adverse events of emergency department adult intubations. *Ann Emerg Med* 2015;65:363–70e361.
5. Kahn CA, Oman JA, Rudkin SE, et al. Can ED staff accurately estimate the weight of adult patients? *Am J Emerg Med*. 2007;25(3):307–12.
6. Mechlin MW and Hurford WE. Emergency tracheal intubation: techniques and outcomes. *Respiratory Care*. 2014;59(6):881–94.
7. Pappal RD, Roberts BW, Mohr NM, et al. The ED-AWARENESS Study: a prospective, observational cohort study of awareness with paralysis in mechanically ventilated patients admitted from the emergency department. *Ann Emerg Med*. 2021:S0196-0644(20):31314–7.
8. Levin NM, Fix ML, April MD, et al. The association of rocuronium dosing and first-attempt intubation success in adult emergency department patients. *Can J Emerg Med* 2021;23(4):518–27.
9. Rocuronium. Lexi-Drugs. Lexicomp. Wolters Kluwer Health, Inc. Riverwoods, IL. Available at: http://online.lexi.com. Accessed May 9, 2019.
10. Meyhoff SC, Lund J, Jenstrup TM, et al. Should dosing of rocuronium in obese patients be based on ideal or corrected body weight? *Anesth Analg* 2009;109:787–92.
11. Leykin Y, Pellis T, Lucca M, et al. The pharmacodynamic effects of rocuronium when dosed according to real body weight or ideal body weight in morbidly obese patients. *Anesth Analg*. 2004;99:1086–9.
12. Fuchs-Buder T, Claudius C, Skovgaard LT, et al. Good clinical research practice in pharmacodynamic studies of neuromuscular blocking agents II: the Stockholm revision. *Acta Anaesthesiol Scand*. 2007;51(7):789–808.

Lung Ultrasound Score in COVID-19 Patients Correlates with PO_2/FiO_2, Intubation Rates, and Mortality

Shin-Yi Lai, MD[*†]
Jesse M Schafer, MD[*]
Mary Meinke, MD, MPH[*]
Tyler Beals, MD[*]
Michael Doff, MD[*]
Anne Grossestreuer, PhD[*]
Beatrice Hoffmann, MD, RDMS[*]

[*]Beth Israel Deaconess Medical Center, Department of Emergency Medicine, Boston, Massachusetts
[†]St Vincent Hospital, Department of Emergency Medicine, Associated Physicians of Harvard Medical Faculty Physicians, Worcester, Massachusetts

Section Editor: Gayle Galletta, MD
Submission history: Submitted January 23, 2023; Revision received September 14, 2023; Accepted October 19, 2023
Electronically published December 22, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.59975

Introduction: The point-of-care lung ultrasound (LUS) score has been used in coronavirus 2019 (COVID-19) patients for diagnosis and risk stratification, due to excellent sensitivity and infection control concerns. We studied the ratio of partial pressure of oxygen in arterial blood to the fraction of inspiratory oxygen concentration (PO_2/FiO_2), intubation rates, and mortality correlation to the LUS score.

Methods: We conducted a systematic review using PRISMA guidelines. Included were articles published from December 1, 2019–November 30, 2021 using LUS in adult COVID-19 patients in the intensive care unit or the emergency department. Excluded were studies on animals and on pediatric and pregnant patients. We assessed bias using QUADAS-2. Outcomes were LUS score and correlation to PO2/FiO2, intubation, and mortality rates. Random effects model pooled the meta-analysis results.

Results: We reviewed 27 of 5,267 studies identified. Of the 27 studies, seven were included in the intubation outcome, six in the correlation to PO_2/FiO_2 outcome, and six in the mortality outcome. Heterogeneity was found in ultrasound protocols and outcomes. In the pooled results of 267 patients, LUS score was found to have a strong negative correlation to PO_2/FiO_2 with a correlation coefficient of −0.69 (95% confidence interval [CI] −0.75, −0.62). In pooled results, 273 intubated patients had a mean LUS score that was 6.95 points higher (95% CI 4.58–9.31) than that of 379 non-intubated patients. In the mortality outcome, 385 survivors had a mean LUS score that was 4.61 points lower (95% CI 3.64–5.58) than that of 181 non-survivors. There was significant heterogeneity between the studies as measured by the I^2 and Cochran Q test.

Conclusion: A higher LUS score was strongly correlated with a decreasing PO_2/FiO_2 in COVID-19 pneumonia patients. The LUS score was significantly higher in intubated vs non-intubated patients with COVID-19. The LUS score was significantly lower in critically ill patients with COVID-19 pneumonia that survive. [West J Emerg Med. 2024;25(1)28–39.]

INTRODUCTION

The novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), first described in December 2019,[1] is responsible for an estimated 768 million infections and nearly 7 million deaths worldwide.[2] Approximately 17–35% of hospitalized patients with coronavirus disease 2019 (COVID-19) develop hypoxemic respiratory failure and acute respiratory distress syndrome (ARDS) requiring intensive care unit (ICU) admission[2] with invasive ventilation required in 29–91%.[3] This wide variability reflects

the evolution of pharmacotherapies and various practice patterns through different waves of the pandemic in addition to social and economic factors such as vaccination rates and availability of ICU-level resources in different countries.[4] Given the scale of the pandemic and significant morbidity/mortality related to COVID-19, efforts have been undertaken toward the testing and identification of COVID-19 positive patients at risk for significant morbidity/mortality based on clinical or radiographic parameters.

Radiographic modalities commonly used in the evaluation of COVID-19 pneumonia lung involvement include chest radiograph (CXR) as well as computed tomography (CT). However, CXR may miss up to 45% of COVID-19 polymerase chain reaction (PCR)-confirmed cases[5,6] and correlates poorly with the clinical picture compared to lung ultrasound (LUS) and CT.[6,7] Computed tomography is considered the gold standard imaging modality for the investigation of patients with COVID-19 pneumonia[8] but is limited by resource allocation and transport risks.[9,10] Studies have found the sensitivity of LUS for COVID-19 diagnosis to be close to 86–90%[11,12] when performed by experienced operators, with a 85–92% specificity,[13–15] which is comparable to CT and PCR testing. Lung ultrasound has the added benefits of being inexpensive, noninvasive, free of radiation exposure, and easily repeated.

Due to workflow availability and infection control measures, bedside point-of-care ultrasound (POCUS) has increasingly been used in the diagnosis and risk stratification of emergency department (ED) patients as well as to monitor the progression of COVID-19 disease in the ICU.[16] Ultrasound as a point-of-care imaging modality is well-suited to COVID-19 patients because COVID-19 lung changes are sonographically detectable and are prominent in the lung periphery.[17] In particular, sonographic features of COVID-19 pneumonitis include increased number of B-lines, pleural line irregularities, and sub-pleural consolidations.[18]

The LUS score was introduced to grade ultrasound findings based on examination of several lung regions in the anterior, lateral, and posterior aspects of the left and right chest wall. Several protocols have been published and differ in the number of lung zones examined.[19–21] Each region is scored according to four ultrasound aeration patterns with the final LUS score comprised of the sum of scores in the evaluated regions. Scores can range from 0-36 depending on the protocol and number of total examined lung fields. (See further illustration and detailed discussion of various LUS protocols by Allinovi et al in Supplement 1).[22] A higher LUS score correlates with an increasing degree of pulmonary involvement[19] and has been shown to correlate with disease severity and predicts mortality as highlighted by the Berlin criteria in patients with ARDS.[23,24]

Little is known about the correlation between LUS findings and abnormalities of gas exchange in COVID-19. The PO_2/FiO_2 ratio is considered a global index of tissue aeration.[25] It is currently used to assess the severity of respiratory failure in patients with ARDS[26] and correlates to mortality rate.[27] In COVID-19, many patients present with respiratory alkalosis with hypoxia that does not correlate with pulse oximetry measurements.[28] This is primarily due to the left shift of the oxygen–hemoglobin dissociation curve secondary to alkalosis and low pCO_2 levels.[28] Therefore, the PO_2/FiO_2 ratio is the standard measurement used for evaluation of blood oxygenation in these patients and was chosen as an outcome for analysis. The LUS score likely identifies the degree of damaged lung regions that contribute to hypoxemia through impaired aeration, vasoconstriction, and shunt,[29] and it has a strong negative correlation with PO_2/FiO_2 values.

Our study objective was to determine whether the LUS score correlated with the clinical parameters of PO_2/FiO_2, intubation rates, and mortality, thus identifying patients at a high risk of clinical deterioration.

METHODS

In accordance with systematic review guidelines, the study protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO ID CRD42020217983). We conducted a systematic review of the literature with principles from the Preferred Reporting Items for Systematic Review and Meta-analysis Protocols (PRISMA-P).[30,31] Included studies evaluated patients ≥18 years of age who tested COVID-19 positive by confirmed PCR testing and used bedside LUS with a reported LUS numerical scoring system in the ED or ICU. We excluded animal studies, as well as studies on pediatric patients, asymptomatic patients, pregnant patients, those without PCR confirmation of COVID-19 pneumonia, and studies without a clear description of LUS abnormalities in numerical scoring. Outcome measures were intubation rates, mortality, and PO_2/FiO_2 ratio.

A comprehensive search for available research was performed by a health sciences librarian (MM) with expertise in systematic review search strategies. Databases Medline, Embase, Pubmed, Web of Science, Cochrane databases that mentioned POCUS, ultrasound and COVID-19, SARS CoV2, and LUS were searched until a cutoff date of November 30, 2021. The PROSPERO database was also queried for ongoing or recently completed systematic reviews. (The PUBMED search strategy is illustrated in Appendix 1.) Eligible studies selected for further assessment included the following: randomized and non-randomized controlled studies; prospective and retrospective cohort studies; and observational studies. We excluded case reports, non-original research, and letters to the editor.

Search results were collected in EndNote X9. Two review authors individually screened the titles and abstracts yielded by the search against inclusion criteria. Review authors

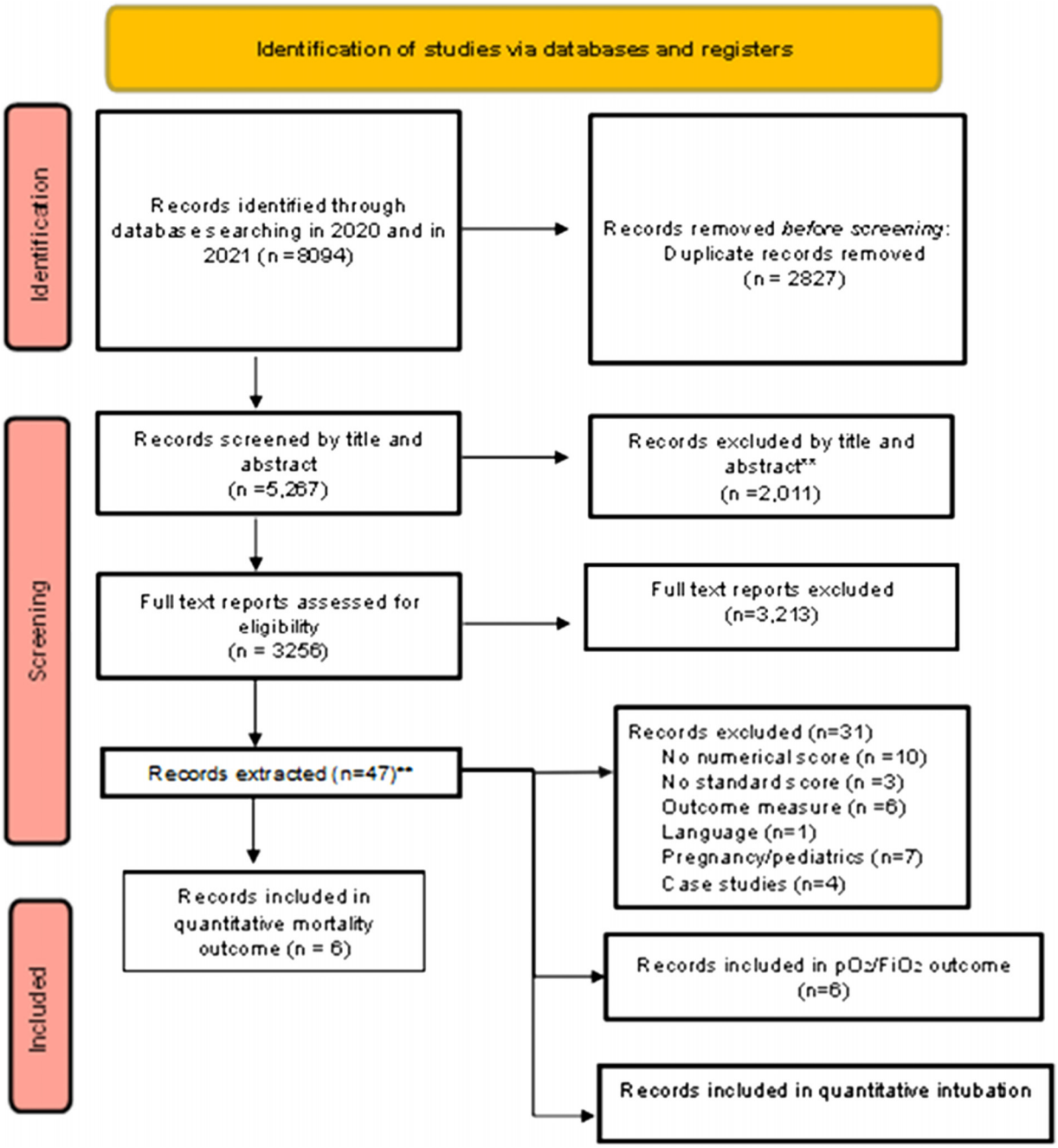


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-analysis extension for scoping review flow diagram (PRISMA-ScR). **Note: Studies included in meta-analysis (n = 16).
Three articles are in more than one group: Bosso is in both mortality and PO_2/FiO_2 outcome; Rojatti is in both mortality and PO_2/FiO_2 outcome; and de Alencar is in both intubation and death outcome.
PO_2/FiO_2, ratio of partial pressure of oxygen in arterial blood to the fraction of inspiratory oxygen concentration.

obtained full-text reports of titles that met inclusion criteria or where there was any uncertainty. The full-text reports were screened including whether they met including criteria. Disagreements were resolved through discussion and. if necessary, a third reviewer. A list of excluded studies was recorded based on the reasons for exclusion (Supplement 2). Results of the search and selection process are illustrated in Figure 1 and reported according to the PRISMA extension for scoping review flow diagram (PRISMA-ScR).[32] The two initial review authors were not blinded to the journal titles, study authors, or institutions.

One reviewer extracted data for studies that met inclusion criteria by standardized forms. Extracted results were reviewed by a separate author to minimize errors.

Data abstracted included study characteristics (author, journal reference, study design, inclusion/exclusion criteria, index text used, reference test used, general setting), demographic information, sample size, intervention details, experience of the operator, timing of the LUS protocol, and reported patient outcomes. Quantitative data on relative risk, odds ratio was extracted from original articles and collected using an Excel-based form (Microsoft Corp, Redmond, WA). We performed a meta-analysis in Cochrane RevMan 5.4 using a random effects model.[33] For studies with missing outcomes, the original researchers were contacted for additional information.

We assessed the methodological quality of reported research using the QUADAS-2 tool (Bristol Medical School: Population Health Sciences, University of Bristol, UK).[34] The domains were evaluated for each included study and are reported in Supplement 3. QUADAS-2 includes four main domains: patient selection; index test; reference standard; and flow and timing. In domain one, patient selection, we omitted the question "Was a case-control design avoided?" since we did not include any case series or case reports. In domain three, reference test, we added signal questions referring to operators' expertise and background, technical features of the US hardware and appropriateness of the ultrasound protocol.

To reduce bias, the core outcome set was searched in COMET (Core Outcome Measures in Effectiveness Trials) Database.[35] The Core Outcome Set for Clinical Trials on Coronavirus Disease 2019 (COS-COVID) had several outcomes for severity type (composite events, length of hospital stay, PaO_2/FiO_2, duration of mechanical ventilation, time to 2019 nCoV RT-PCR negativity) and one outcome for critical type (all-cause mortality).

We identified a total of 8,094 studies, and 5,267 remained after duplicates were removed. After screening the titles or abstracts of 5,267 publications, 2,011 were excluded, 3,256 articles were screened for eligibility, and 47 articles underwent detailed review. Seven articles were included in the final meta-analysis for intubation outcome, six articles were included in the correlation of LUS score to PO_2/FiO_2 outcome, and six articles were included in the qualitative synthesis for mortality outcome (Figure 1). Bosso[36] and Rojatti[37] papers are both included in the mortality and correlation to PO_2/FiO_2 outcomes, and de Alencar[38] is included in both intubation and mortality outcomes.

We extracted information from 16 articles according to predefined criteria. The included studies used LUS in PCR-confirmed COVID-19-positive patients and had been published between March 2020–November 2021 with sample sizes ranging from 10 in Dargent 2020[39] and Tan 2020[40] to 312 in Secco 2021.[41] Retrospective studies predominated. There was significant heterogeneity between the studies regarding ultrasound protocols, performing personnel, and outcomes reported.

For the meta-analysis, 11 prospective studies, five retrospective studies, and one cross-sectional study were identified (Table 1). The studies in the meta-analysis were all conducted outside the United States, namely in Brazil, France, China, Italy, Sweden, and Israel. Between the initial

Table 1. Overview of study characteristics of included studies.

	Design	N	Setting	LUS scoring	US operators	Outcomes
Bonadia 2020[53]	Single-center prospective cohort	41	ED	14 zones	ED staff 5 years POCUS experience	Mortality, LUS patterns correlation with ICU and invasive ventilation
Bosso 2020[36]	Single-center prospective observational	53	COVID-19 unit	12 zones	Expert clinicians	Mortality, degree of hypoxemia
Castelao 2021[45]	Single-center prospective observational	63	Inpatient and respiratory intermediate care unit	12 zones	Unknown operator	Distribution of US findings, LUS correlation with P/F ratio
Dargent 2020[39]	Single-center prospective observational	10	ICU patients	12 zones	LUS trained practitioners until interobserver agreement	Clinical course, intubation, ventilator associated pneumonia
De Alencar 2021[38]	Single-center prospective cohort	180	ED	12 zones	Emergency physicians	Death, intubation, ICU admission

(*Continued on next page*)

Table 1. Continued.

	Design	N	Setting	LUS scoring	US operators	Outcomes
Deng 2020[20]	Single-center retrospective cohort	128	ICU patients	8 zones WINFOCUS	Sonographers with 2–10 years experience blinded and undefended observers	Correlation of LUS scores to CT scores
Duclos 2021[46]	Multicenter retrospective observational	57	ICU	12 zones	LUS operators-academic teacher with publications or expert	LUS to predict 28-day mortality
Li 2021[48]	Single-center prospective observational cohort	48	ICU	12 zones	Unknown, then senior ICU physician CCUSG certified interpretation	LUS score correlation to PaO_2/FiO_2, APACHE II, 28-day mortality
Lichter 2020[49]	Single-center retrospective observational	120	ICU and inpatients	12 zones	3 cardiologists	All-cause mortality and composite endpoint composed of death or new need for invasive mechanical ventilation
Perrone 2021[54]	Single-center prospective cohort	52	Internal medicine ward	14 zones	Expert physician >15 years of experience in thoracic US	LUS score association to clinical worsening- high flow oxygen support, ICU admission, or 30-day mortality
Persona 2021[47]	Single-center prospective observational	28	ICU	12 zones	Unknown	LUS score in patients on admission and discharge from ICU
Rojatti 2020[37]	Two-center retrospective observational	41	ICU	8 zones	Unknown	Severity of gas exchange impairment and IL-6
Secco 2021[41]	Single-center prospective cohort	312	ED	12 zones	Emergency physicians	LUS score and mortality at 30 days
Seiler 2021[51]	Single-center prospective cohort	72	ICU and inpatients	12 zones	5 consultant anesthesiologists	LUS score and indication for invasive mechanical ventilation, PO_2/FiO_2
Sumbul 2021[52]	Single-center cross-sectional	44	ICU and inpatient	12 zones	Two radiology specialists experienced in lung US	Modified LUS and severity of disease, PO_2/FiO_2 and pro-BNP
Tan 2020[40]	Single-center prospective cohort	12	ICU or isolation ward	10 zones; Buda scoring system for interstitial lung disease	ICU physicians received training and obtained qualifications	Modified LUS to evaluate the severity and treatment of COVID-19
Zieleskiewicz 2020[16]	Multicenter retrospective observational	100	ED and ICU	12 zones	Emergency or ICU physicians	LUS vs chest CT for assessment of COVID-19 pneumonia

LUS, lung ultrasound; *US*, ultrasound; *POCUS*, point-of-care ultrasound; *ED*, emergency department; *ICU*, intensive care unit, *CT*, computed tomography; COVID-19, coronavirus 2019; *IL-6*, interleukin-6; *PO_2/FiO_2*, ratio of partial pressure of oxygen in arterial blood to the fraction of inspiratory oxygen concentration; *BNP*, B-type natriuretic peptide.

time frame of search and data analysis, Lu et al[42] had been retracted, and so we did not include it. We regarded the published data as sufficient to perform meta-analysis on LUS score correlation to intubation rates and PO_2/FiO_2 and quantitative synthesis on mortality outcome. Other reviewed studies were excluded due to population, age, use of different scoring systems, non-English language of publication, and case studies (Supplement 2).

There was significant heterogeneity between studies regarding ultrasound protocols. The LUS protocols systematically evaluate lung parenchyma by the examination of anatomic zones of each thorax. Each hemithorax is

systematically divided into regions for evaluation: two anterior, two lateral, and two posterior demarcated by anatomical landmarks set by the anterior and posterior axillary lines. Each region is then divided into superior and inferior halves for ultrasonographic examination. In each zone, findings of a normal lung pattern receive a score of 0; well defined B lines receive a score of 1; coalescent B lines are scored as 2; and findings of parenchymal consolidation are scored as 3. The sum of scores assigned to each lung field on both hemithoraces is tabulated and comprises the LUS score.

An 8-zone protocol, described by Volpicelli,[43] was used by Deng[20] and Rojatti[37] and evaluated two anterior and two lateral zones per hemithorax. The posterior lung fields are omitted from evaluation in the 8-zone Volpicelli protocol and are subsequently included in protocols with additional views. The 10-zone protocol used by Tan[40] evaluates one additional posterior lung field on each hemithorax compared to the 8-zone Volpicelli protocol. The 12-zone evaluation, commonly used in the BLUE protocol[44] evaluates two additional lung fields. In addition to the anterior and lateral locations, this protocol includes one inferior and one superior zone. The 12-zone protocol was used by Bosso,[36] Castelao,[45] Dargent,[39] Duclos,[46] de Alencar,[38] Persona,[47] Li,[48] Lichter,[49] Secco,[50] Seiler,[51] Sumbul,[52] and Zieleskiewicz[16] studies. Lastly, the 14-zone protocol used by Bonadia[53] and Perrone[54] was described by Soldati et al[21] in 2020. The protocol evaluates an additional three posterior lung fields on each hemithorax in addition to the two anterior and lateral locations. All study protocols used curvilinear probes except for Lichter,[49] which used a phased array probe for evaluation.

Ultrasounds were performed by a range of personnel from cardiologists and sonographers to ED and ICU staff with varying levels of training and experience. All the analyzed studies but Rojatti described the experience of the ultrasound operators. No training protocol assessments were discussed, except for Dargent, which trained operators until good inter-observer reliability was achieved. Interpretations of images were also performed by personnel with differing levels of training ranging from study authors to radiologists to cardiologists. Since ultrasound is heavily operator-dependent this may have contributed to the heterogeneity of results.

The QUADAS-2 review (Supplement 3) showed that most studies had significant patient selection biases. Some studies enrolled convenience samples rather than consecutive patients due to resource constraints. Studies excluded patients with history of congestive heart failure, interstitial lung disease, pneumothorax, patients who were unable to sit up or participate in an exam, or who had DNR/DNI status, <6-month life expectancy, congenital heart disease, or recent chest surgery. While these exclusions may have affected accuracy of outcome results given that the presence of comorbidities increases morbidity and mortality, it also served to make the LUS findings more specific for COVID-19.

RESULTS

In the six studies included in the meta-analysis focused on the correlation between LUS score and PO_2/FiO_2, there were a total of 267 patients. We found a significant negative correlation between increasing LUS score and pulmonary gas exchange measurement of PO_2/FiO_2. In pooled results, the correlation coefficient was −0.69 (95% −0.75, −0.62). There was significant heterogeneity between the studies as measured by the I^2 and Cochran Q test. Rojatti[37] and Li[48] studies included only patients in the ICU while other studies were performed on patients in COVID-19 units (Bosso,[36] Castelao,[45] Sumbul,[2]) and hospital ward (Perrone[54]). See Figure 2.

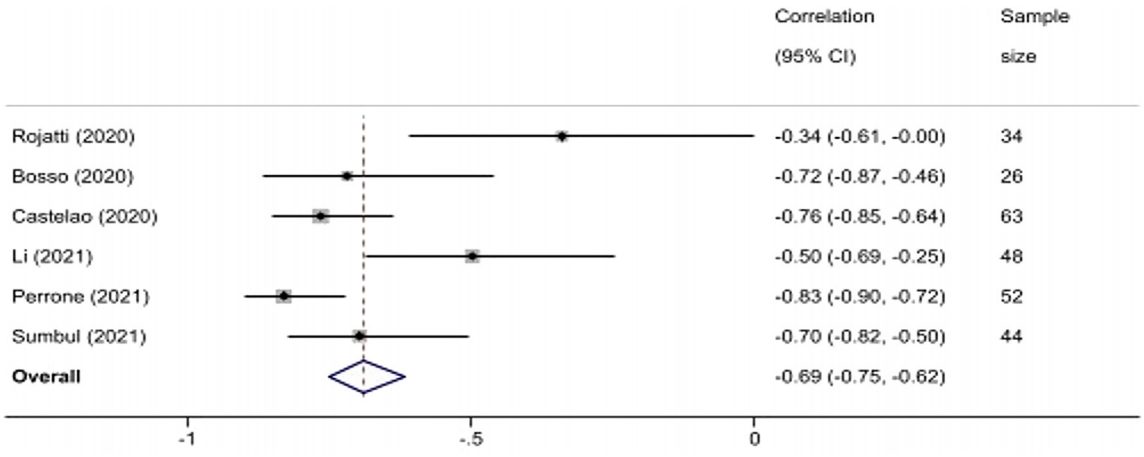


Figure 2. Forest plot of correlation between lung ultrasound and PO_2/FiO_2. In pooled results, the correlation coefficient was −0.69 (95% −0.75, −0.62). There was significant heterogeneity between the studies as measured by the I^2 and Cochran Q test. *CI*, confidence interval; *PO_2/FiO_2*, ratio of partial pressure of oxygen in arterial blood to the fraction of inspiratory oxygen concentration.

The meta-analysis comparing LUS scores for the intubation outcome included 273 intubated and 379 non-intubated patients. In pooled results, intubated patients had a mean LUS score that was 6.95 points higher (95% CI 4.58–9.31) than that of non-intubated patients. Mean LUS scores for intubated patients ranged from 15.7 (SD 2.6) in Deng 2020 to 47.25 (SD 6.28) in Tan 2020. The mean LUS score of the remaining studies fell between these values. Mean LUS scores for non-intubated patients ranged from 8.1 (SD 3.4) in Deng 2020 up to 36.6 (SD 12.5) in Tan 2020. Notably, Deng[20] used an 8-zone LUS score while Tan[40] used a 10-zone LUS score, which may partially account for the large spread of LUS score results (Figure 3).

Subgroup analysis was performed on the studies that used the 12-zone protocol (Lichter,[49] Zieleskiewicz,[16] Seiler,[51] Dargent,[39] de Alencar[38]) as the most frequently used protocol. In pooled results of the subgroup analysis, the 193 intubated patients had a mean LUS score that was 6.74 points higher (95% CI 3.41–10.08) than that of the 319 non-intubated patients (Figure 4). Protocol notwithstanding, LUS scores were higher in intubated patients than non-intubated patients consistent with the finding that LUS score increases with more diffuse lung involvement[19] and, therefore, severity of illness. There was significant heterogeneity between the studies as measured by the I^2 and Cochran Q test.

In the six studies included in the quantitative analysis of mortality, there was a total of 566 patients, with 385 patients who survived and 181 who did not survive. In pooled results, survivors had a mean LUS score that was 4.61 points lower (95% CI 3.64–5.5) than that of non-survivors. The LUS scores of those who survived ranged from 11 (SD 7) in Secco 2021[41] up to 26.8 (SD 9.3) in Persona 2021.[47] The LUS scores of non-survivors ranged from 13.9 (SD 2.8) in Rojatti 2020[37] up to 26.2 (SD 9.9 in Persona 2021.[47] Secco 2021 was conducted in an ED setting while Persona 2021[47] and Rojatti 2020[37] used patients in an ICU setting. Depending on the patient population and factors in the study location epidemiology, ED settings may have had a patient population less critically ill than patients in ICU, which would have led to the studies conducted in EDs to have baseline lower LUS scores. A study using a 12-zone protocol also contributes to higher overall LUS scores since LUS score is calculated with the cumulative scores of the number of zones. Persona[47] and Secco[41] used the 12-zone protocol, while Rojatti 2020[37] used the 8-zone protocol (Figure 5).

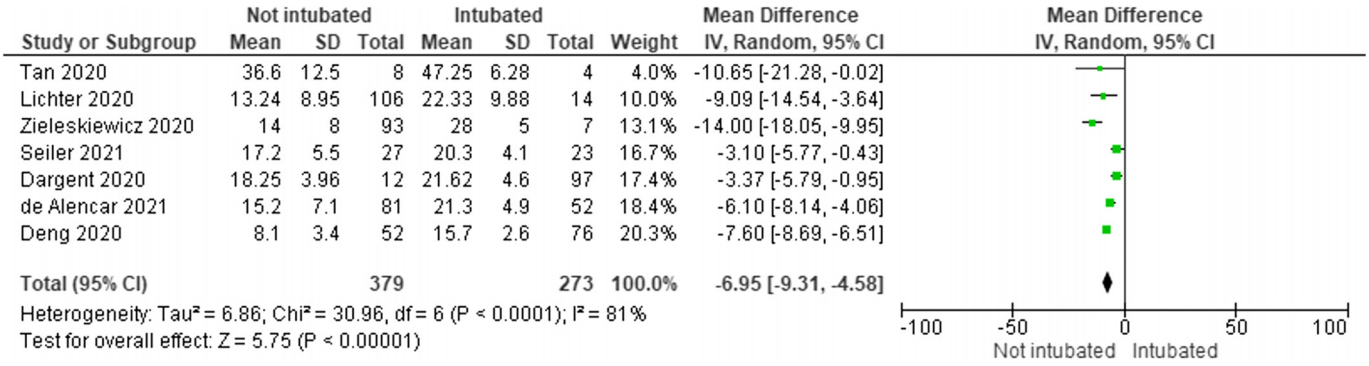


Figure 3. Differences in lung ultrasound (LUS) scores for intubated/non-intubated subjects. I^2 of 81% and Cochran Q test show significant heterogeneity between the studies of LUS scores of intubated vs non-intubated patients.

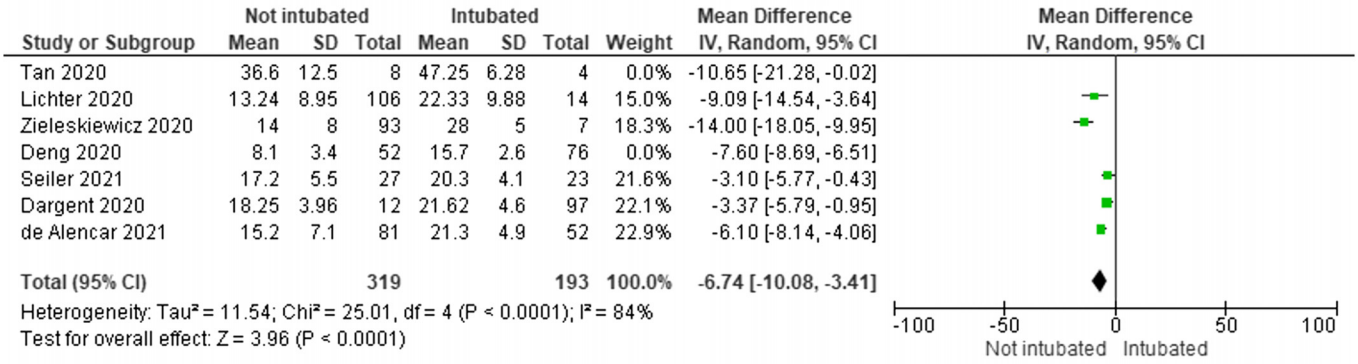


Figure 4. Differences in lung ultrasound (LUS) scores for intubated/non-intubated subjects in subgroup analysis of 12-zone protocol studies. I^2 of 84% and Cochran Q test show significant heterogeneity between the studies of LUS scores of intubated vs non-intubated patients.

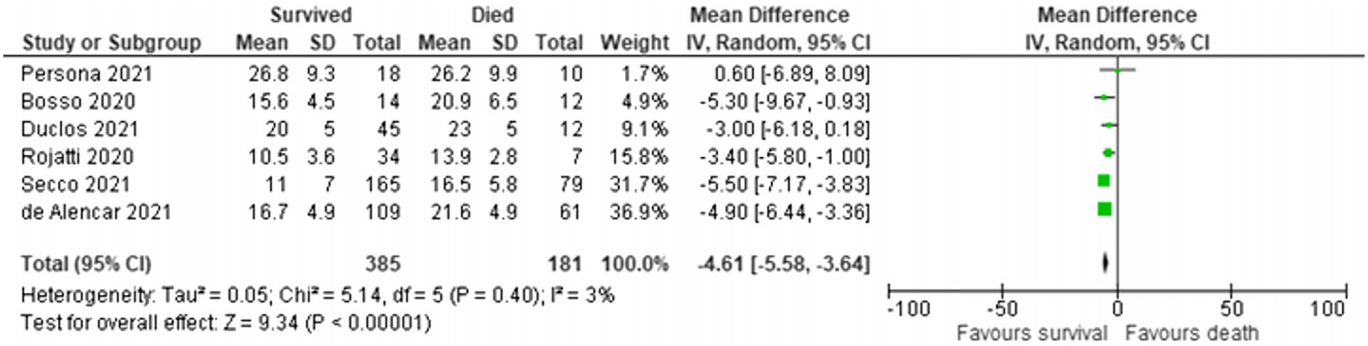


Figure 5. Differences in lung ultrasound (LUS) scores for survivors vs non-survivors. The I^2 of 3% and the p-value for heterogeneity of 0.4 show little evidence of publication bias in the included studies of LUS scores for survivors vs non-survivors.

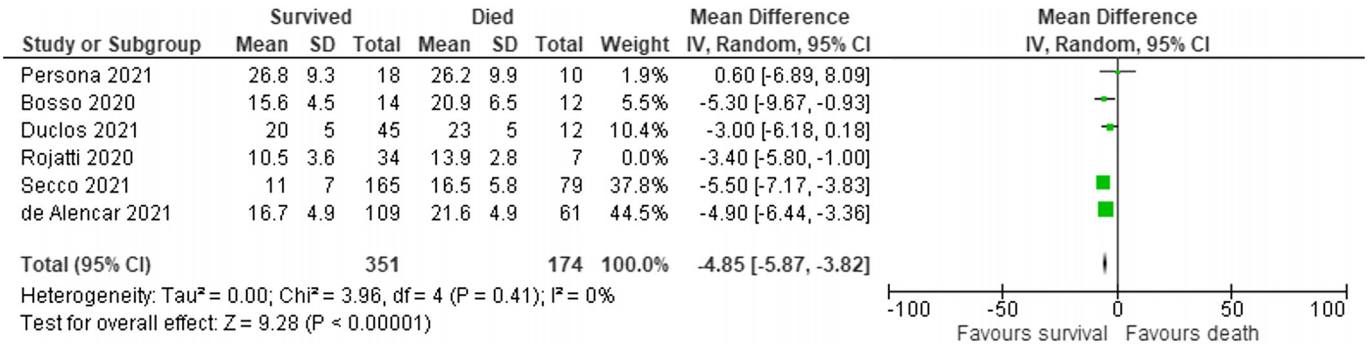


Figure 6. Differences in lung ultrasound (LUS) scores for survivors vs non-survivors in subgroup analysis of 12-zone protocol studies. The I^2 of 0% and the *P*-value for heterogeneity of 0.4 show little evidence of publication bias in the included studies of LUS scores for survivors vs non-survivors.

Subgroup analysis was performed on the studies using the 12-zone protocol (Persona,[47] Bosso,[36] Duclos,[46] Secco,[41] de Alencar[38]). In pooled results of the subgroup analysis, the 351 survivors had a mean LUS score that was 4.85 points lower (95% CI 3.82–5.87) than that of the 174 non-survivors (Figure 6). Despite the different ultrasound protocols, patients with lower ultrasound score and, therefore, less lung involvement[19] were found to be more likely to survive. Among the included studies, there was no evidence of significant heterogeneity, as measured by the I^2 and Cochran Q test.

Mean scores did appear higher in intubated patients than in patients who died. We speculate that this could have been multifactorial, possibly secondary to timing of scans in disease course and limitations of resource allocation in height of the pandemic. The de Alencar[38] study, which looked at both intubation and mortality outcomes, had a LUS score that would be as expected—higher in intubated patients and higher still in patients who died.

DISCUSSION

Our meta-analysis found that a higher LUS score was strongly correlated with a decreasing PO_2/FiO_2 in patients diagnosed with COVID-19 pneumonia. The LUS score was also found to be significantly higher in intubated vs non-intubated patients and in critically ill patients who did not survive with COVID-19 pneumonia.

The LUS has been well established in the diagnosis of pneumothorax, lung consolidation, alveolar-interstitial syndrome and pleural effusion.[55] We sought to determine whether LUS abnormalities in COVID-19 patients correlated to abnormalities in pulmonary gas exchange as a LUS score was found to be a valid tool to assess regional and global lung aeration.[56] Our quantitative meta-analysis found that LUS score was inversely correlated to PaO_2/FiO_2 ratio, which would be expected. As LUS score increases in COVID-19 with increasing interstitial edema and consolidation, lung aeration worsens, thereby causing an increase in shunting and hypoxemia and a decrease in the PaO_2/FiO_2 ratio. The correlation of an increasing LUS with worsening PaO_2/FiO_2 ratio and increasing intubation rates suggests that ultrasonographic monitoring reflects illness severity and disease progression. This indicates the potential value of LUS for dynamic lung monitoring as reported by Deng,[20] Dargent[39] in the ICU population, and Casella[57] in the non-ICU setting. Patients with COVID-19 at higher risk of adverse outcomes may benefit from more intensive monitoring or earlier intervention with noninvasive

respiratory support in anticipation of deteriorating clinical course.

In pooled results, we found significant correlation between LUS score and mortality rates in patients with COVID-19 pneumonia. Various published studies have looked at LUS cutoffs for mortality and adverse outcomes. Ji found LUS score >12 predicted adverse outcomes with a specificity and sensitivity of 90.5% and 91.9%,[59] while Secco found LUS score >13 had a 77.2% sensitivity and a 71.5% specificity in predicting mortality.[50] Sun found that LUS score >15 had a sensitivity of 92.9% and specificity of 85.3% for prediction of mortality,[60] while Lichter found that mortality increased with LUS score >18.[49] De Alencar found LUS score ≥26 had 90% specificity for mortality,[38] and Li found that for LUS score >22.5, the sensitivity and specificity were 83.3% and 72.2% for predicting mortality.[48] Finally, Trias-Sabra found that LUS score ≥24 had a higher risk of ICU admission or death.[61] There is currently no consensus, which we speculate is secondary to the various ultrasound protocol used, since the number of zones measured has a direct effect on the cumulative LUS score.

We chose ultrasound protocols in an attemp to find the optimal balance between the acquisition time and accuracy. There is no standardized LUS protocol for the evaluation of COVID-19 pneumonia, with current protocols ranging from an 8-zone evaluation[43] to a 14-zone evaluation[21] with nominal scale. Protocols also often required modification in supine critically ill patients, as posterior segments were difficult to evaluate. Soldati[21] proposed a 14-point protocol modified to 7 points in critically ill supine patients for the international standardization of the use of LUS in COVID-19.

A study comparing the different protocols showed that the posterior areas are fundamental to capture the most important findings in patients with COVID-19 pneumonia.[62] A 12-zone system maintains balance between acquisition time and accuracy, although a 10-point system is sufficiently accurate if the basal posterior regions are included.[62] Recently, an abbreviated 8-zone protocol was found to be as accurate as the previously validated 12-zone protocol for prognostication of clinical deterioration in non-ventilated COVID-19 patients. Scanning times were 50% shorter in the 8- vs 12-zone protocol, although specific times were not delineated. [63] A shorter protocol with sufficient accuracy could decrease risk of contagion by limiting operator exposure and thereby increase operator safety.

A LUS has been reported to have higher sensitivity than CXR, especially early in infection, for detecting COVID-19-associated lung lesions with a reported sensitive of 92–96% compared to 46–69% for CXR.[64–68] Lichter[49] found that higher LUS score predicted intubation and mortality independent of CXR findings. Patients with a higher percentage of lung involvement on CXR were found to have higher intubation rates[69,70,71,72] as well as higher mortality.[69,73] Spogis[74] found that changes in CXR appeared more sensitive for predicting ICU treatment than LUS; however, LUS was more specific. Both modalities were found to be good discriminators with each modality having its own advantages and disadvantages.

Advantages of CXR include its wide availability, lack of examiner dependency, ease of comparing previous examinations, and ability to examine the entire lung in one image. A LUS can produce real-time dynamic images and is accurate, reproducible, without ionizing radiation, and easily disinfected. However, LUS requires more time to perform than CXR increasing exposure risk to clinician. There may be greater total time from CXR performance to interpretation depending on the individuals who are performing and interpreting the scans. Advantages of one modality over another may be institutional, resource, and patient dependent.

The results of this meta-analysis and systematic review show that the LUS score has significant correlation to PO_2/FiO_2 ratio and to clinical outcomes of intubation rate and mortality in COVID-19 positive patients with pneumonia. Especially in cases of surge capacity, this would provide important prognostication information to aid clinicians in resource allocation and the identification of patients at a higher risk of deterioration for the appropriate level of care. The LUS score contributes to the classification of disease severity and the monitoring of disease progression, and it can influence the decision to escalate drug treatment or early ventilatory support. It also has the advantage of reducing the number of exposed healthcare workers, limiting resource consumption and environmental contamination. Implementation of bedside LUS will be dictated by specific institutional workflows, resource availability, and patient volume. Timely and accurate classification of patients is crucial during the pandemic since the excessive influx of patients can place hospital and patient care organizations in crisis and alter the efficiency and services of EDs.

LIMITATIONS

Limitations of POCUS LUS include the inability to evaluate lung lesions that are deep and intrapulmonary, difficulty in scanning posterior basilar regions, and relative lower sensitivity than CT. A LUS has lower specificity than CT for COVID-19 as B lines can also be found in pulmonary edema due to cardiac disease, pulmonary aspiration, ARDS, interstitial lung disease, or pneumonia.[43] Subpleural consolidations and effusions are observed in both COVID-19 and other viral and non-viral pneumonia and pulmonary embolism.[43] A LUS needs to be used in conjunction with other confirmatory tests such as PCR for increased accuracy.

There was significant selection bias in included studies. Studies did not include COVID-19 patients with symptoms that were extra-pulmonary in nature, which currently include gastrointestinal symptoms, anosmia, ageusia, rhinorrhea,

and altered mental status.[17] It is unclear whether patients with other presenting symptoms would have an abnormal LUS, which would make LUS less sensitive as a testing modality. In addition, many studies did not exclude patients with baseline pulmonary disease and comorbidities that may alter baseline LUS. A LUS was often performed in patients with worse illness severity, also contributing to selection bias.

Additional limitations of this meta-analysis include study heterogeneity, lack of a standardized guideline for POCUS lung evaluation in COVID-19, performance of LUS by operators with different levels of training, and a lack of specified training protocol. Lack of unifying definitions and inconsistencies with reporting COVID-19 lung abnormalities limit comparisons between different studies, geographical areas, and patients.

CONCLUSION

This meta-analysis shows that a higher lung ultrasound score is significantly negatively correlated to PaO_2/FiO_2 and positively correlated to intubation rates and mortality rates in COVID-19 positive patients with pneumonia. In the ED and ICU settings, a LUS score may be a useful modality in determining patient disposition and aiding in prognostication of care and resource allocation.

Address for Correspondence: Shin-Yi Lai, MD, Beth Israel Deaconess Medical Center, Department of Emergency Medicine, One Deaconess Road, Rosenberg 2, Boston, MA 02215. Email: slai2@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. Zhu N, Zhang D, Wang W, et al. A novel coronavirus from patients with pneumonia in China, 2019. *N Engl J Med.* 2020;382(8):727–33.
2. World Health Organization. WHO Coronavirus (COVID-19) Dashboard. Available at: https://covid19.who.int. Accessed July 1, 2023.
3. Grasselli G, Zangrillo A, Zanella A, et al. Baseline characteristics and outcomes of 1591 patients infected with SARS-CoV-2 Admitted to ICUs of the Lombardy region, Italy. *JAMA.* 2020;323(16):1574–81.
4. Wunsch H. Mechanical ventilation in COVID-19: Interpreting the current epidemiology. *Am J Respir Crit Care Med.* 2020;202(1):1–4.
5. Stephanie S, Shum T, Cleveland H, et al. Determinants of chest X-Ray sensitivity for COVID-19: a multi-institutional study in the United States. *Radiol Cardiothorac Imaging.* 2020;2(5):e200337.
6. Yoon SH, Lee KH, Kim JY, et al. Chest radiographic and CT findings of the 2019 novel coronavirus disease (COVID-19): analysis of nine patients treated in Korea. *Korean J Radiol.* 2020;21(4):494–500.
7. Tierney DM, Huelster JS, Overgaard JD, et al. Comparative performance of pulmonary ultrasound, chest radiograph, and CT among patients with acute respiratory failure. *Crit Care Med.* 2020;48(2):151–7.
8. Ai T, Yang Z, Hou H, et al. Correlation of chest CT and RT-PCR testing for coronavirus disease 2019 (COVID-19) in China: A Report of 1014 Cases. *Radiology.* 2020;296(2):E32–40.
9. Jia L, Wang H, Gao Y, et al. High incidence of adverse events during intra-hospital transport of critically ill patients and new related risk factors: a prospective, multicenter study in China. *Crit Care.* 2016;20:12.
10. Liew MF, Siow WT, Yau YW, et al. Safe patient transport for COVID-19. *Crit Care.* 2020;24(1):94.
11. Brenner DS, Liu GY, Omron R, et al. Diagnostic accuracy of lung ultrasound for SARS-CoV-2: a retrospective cohort study. *Ultrasound J.* 2021;13(1):12.
12. Zanforlin A, Strapazzon G, Falk M, et al. Lung ultrasound in the emergency department for early identification of COVID-19 pneumonia. *Respiration.* 2021;100(2):145–53.
13. Gil-Rodrigo A, Llorens P, Martinez-Buendia C, et al. Capacidad diagnostica de la ecografia clinica pulmonar en pacientes con COVID-19. [Diagnostic yield of point-of-care ultrasound imaging of the lung in patients with COVID-19.] *Emergencias.* 2020;32(5):340–4.
14. Lu W, Zhang S, Chen B, et al. Nicht-invasive Beurteilung von pulmonalen Läsionen bei Patienten mit Coronavirus-Erkrankung (COVID-19) durch Ultraschall direkt am Krankenbett. [A clinical study of noninvasive assessment ultrasound of lung lesions in patients with coronavirus disease-19 (COVID-19) by bedside.] *Ultraschall Med.* Jun 2020;41(3):300–307.
15. Tung-Chen Y, Marti de Gracia M, Diez-Tascon A, et al. Correlation between chest computed tomography and lung ultrasonography in patients with coronavirus disease 2019 (COVID-19). *Ultrasound Med Biol.* 2020;46(11):2918–26.
16. Zieleskiewicz L, Markarian T, Lopez A, et al. Comparative study of lung ultrasound and chest computed tomography scan in the assessment of severity of confirmed COVID-19 pneumonia. *Intensive Care Med.* 2020;46(9):1707–13.
17. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet.* 2020;395(10223):497–506.
18. Peng QY, Wang XT, Zhang LN. Chinese Critical Care Ultrasound Study G. Findings of lung ultrasonography of novel corona virus pneumonia during the 2019–2020 epidemic. *Intensive Care Med.* 2020;46(5):849–50.

19. Lichtenstein DA and Mezière GA. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. *Chest.* 2008;134(1):117–25.
20. Deng Q, Zhang Y, Wang H, et al. Semiquantitative lung ultrasound scores in the evaluation and follow-up of critically ill patients with COVID-19: a single-center study. *Acad Radiol.* 2020;27(10):1363–72.
21. Soldati G, Smargiassi A, Inchingolo R, et al. Proposal for international standardization of the use of lung ultrasound for patients with COVID-19: a simple, quantitative, reproducible method. *J Ultrasound Med.* 2020;39(7):1413–9.
22. Allinovi M, Parise A, Giacalone M, et al. Lung ultrasound may support diagnosis and monitoring of COVID-19 pneumonia. *Ultrasound Med Biol.* 2020;46(11):2908–17.
23. Ferguson ND, Fan E, Camporota L, et al. The Berlin definition of ARDS: an expanded rationale, justification, and supplementary material. *Intensive Care Med.* 2012;38(10):1573–82.
24. Li L, Yang Q, Li L, et al. The value of lung ultrasound score on evaluating clinical severity and prognosis in patients with acute respiratory distress syndrome. *Chin Crit Care Med.* 2015;27(7):579–84.
25. Karbing DS, Kjaergaard S, Smith BW, et al. Variation in the PaO_2/FiO_2 ratio with FiO_2: mathematical and experimental description, and clinical relevance. *Crit Care.* 2007;11(6):R118.
26. Force ADT, Ranieri VM, Rubenfeld GD, et al. Acute respiratory distress syndrome: the Berlin definition. *JAMA*. 20 2012;307(23):2526–33.
27. Villar J, Blanco J, del Campo R, et al. Assessment of $PaO_{(2)}/FiO_{(2)}$ for stratification of patients with moderate and severe acute respiratory distress syndrome. *BMJ Open*. 27 2015;5(3):e006812.
28. Ottestad W, Seim M, Maehlen JO. Covid-19 med stille hypoksemi. [COVID-19 with silent hypoxemia.] *Tidsskr Nor Laegeforen.* 2020;140(7).
29. Gattinoni L, Chiumello D, Caironi P, et al. COVID-19 pneumonia: different respiratory treatments for different phenotypes? *Intensive Care Med.* 2020;46(6):1099–102.
30. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ.* 2009;339:b2700.
31. Moher D, Liberati A, Tetzlaff J, et al. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: the PRISMA statement. *PLoS Med.* 2009;6(7):e1000097.
32. Moher D, Shamseer L, Clarke M, et al. Preferred Reporting Items for Systematic Review and Meta-Analysis protocols (PRISMA-P) 2015 statement. *Syst Rev.* 2015;4(1):1.
33. *Review Manager (RevMan)*. Version 5.4. The Cochrane Collaboration; 2020.
34. Whiting PF, Rutjes AW, Westwood ME, et al. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. *Ann Intern Med.* 2011;155(8):529–36.
35. COMET initiative. Core Outcome Measures in Effectiveness Trials. Available at: https://www.comet-initiative.org. Accessed January 23, 2023.
36. Bosso G, Allegorico E, Pagano A, et al. Lung ultrasound as diagnostic tool for SARS-CoV-2 infection. *Intern Emerg Med.* 2021;16(2):471–6.
37. Rojatti M, Regli IB, Zanforlin A, et al. Lung ultrasound and respiratory pathophysiology in mechanically ventilated COVID-19 patients-an observational trial. *SN Compr Clin Med.* 2020;2(11):1970–7.
38. de Alencar JCG, Marchini JFM, Marino LO, et al. Lung ultrasound score predicts outcomes in COVID-19 patients admitted to the emergency department. *Ann Intensive Care.* 2021;11(1):6.
39. Dargent A, Chatelain E, Kreitmann L, et al. Lung ultrasound score to monitor COVID-19 pneumonia progression in patients with ARDS. *PLoS One.* 2020;15(7):e0236312.
40. Tan G, Lian X, Zhu Z, et al. Use of lung ultrasound to differentiate coronavirus disease 2019 (COVID-19) pneumonia from community-acquired pneumonia. *Ultrasound Med Biol.* 2020;46(10):2651–8.
41. Secco G, Salinaro F, Bellazzi C, et al. Can alveolar-arterial difference and lung ultrasound help the clinical decision making in patients with COVID-19? *Diagnostics (Basel).* 2021;11(5):761.
42. Lu X, Zhang M, Qian A, et al. Lung ultrasound score in establishing the timing of intubation in COVID-19 interstitial pneumonia: A preliminary retrospective observational study. *PLoS One.* 2020;15(9):e0238679.
43. Volpicelli G, Elbarbary M, Blaivas M, et al. International evidence-based recommendations for point-of-care lung ultrasound. *Intensive Care Med.* 2012;38(4):577–91.
44. Lichtenstein DA. BLUE-protocol and FALLS-protocol: two applications of lung ultrasound in the critically ill. *Chest.* 2015;147(6):1659–70.
45. Castelao J, Graziani D, Soriano JB, et al. Findings and prognostic value of lung ultrasound in COVID-19 pneumonia. *J Ultrasound Med.* 2021;40(7):1315–24.
46. Duclos G, Bazalguette F, Allaouchiche B, et al. Can thoracic ultrasound on admission predict the outcome of critically ill patients with SARS-CoV-2? A French multi-centric ancillary retrospective study. *Adv Ther.* 2021;38(5):2599–612.
47. Persona P, Valeri I, Zarantonello F, et al. Patients in intensive care unit for COVID-19 pneumonia: the lung ultrasound patterns at admission and discharge. An observational pilot study. *Ultrasound J.* 2021;13(1):10.
48. Li L, Qin A, Yang X, et al. Findings and prognostic value of lung ultrasonography in coronal virus disease 2019 (COVID-19) pneumonia. *Shock.* 2021;56(2):200–5.
49. Lichter Y, Topilsky Y, Taieb P, et al. Lung ultrasound predicts clinical course and outcomes in COVID-19 patients. *Intensive Care Med.* 2020;46(10):1873–83.
50. Secco G, Delorenzo M, Salinaro F, et al. Lung ultrasound presentation of COVID-19 patients: phenotypes and correlations. *Intern Emerg Med.* 2021;16(5):1317–27.
51. Seiler C, Klingberg C, Hardstedt M. Lung ultrasound for identification of patients requiring invasive mechanical ventilation in COVID-19. *J Ultrasound Med.* 2021;40(11):2339–51.
52. Sumbul HE, Koc AS, Pinar A, et al. modified lung ultrasound score in evaluating the severity of Covid-19 pneumonia. *Ultrasound Med Biol.* 2021;47(8):2080–9.

53. Bonadia N, Carnicelli A, Piano A, et al. Lung ultrasound findings are associated with mortality and need for intensive care admission in COVID-19 patients evaluated in the emergency department. *Ultrasound Med Biol.* 2020;46(11):2927–37.
54. Perrone T, Soldati G, Padovini L, et al. A new lung ultrasound protocol able to predict worsening in patients affected by severe acute respiratory syndrome coronavirus 2 pneumonia. *J Ultrasound Med.* 2021;40(8):1627–35.
55. Bouhemad B, Dransart-Raye O, Mojoli F, et al. Lung ultrasound for diagnosis and monitoring of ventilator-associated pneumonia. *Ann Transl Med.* 2018;6(21):418.
56. Chiumello D, Mongodi S, Algieri I, et al. Assessment of lung aeration and recruitment by CT scan and ultrasound in acute respiratory distress syndrome patients. *Crit Care Med.* 2018;46(11):1761–8.
57. Casella F, Barchiesi M, Leidi F, et al. Lung ultrasonography: A prognostic tool in non-ICU hospitalized patients with COVID-19 pneumonia. *Eur J Intern Med.* 2021;85:34–40.
58. Pierrakos C, Lieveld A, Pisani L, et al. A lower global lung ultrasound score is associated with higher likelihood of successful extubation in invasively ventilated COVID-19 patients. *Am J Trop Med Hyg.* 2021;105(6):1490–7.
59. Ji L, Cao C, Gao Y, et al. Prognostic value of bedside lung ultrasound score in patients with COVID-19. *Crit Care.* 2020;24(1):700.
60. Sun Z, Zhang Z, Liu J, et al. Lung ultrasound score as a predictor of mortality in patients with COVID-19. *Front Cardiovasc Med.* 2021;8:633539.
61. Trias-Sabria P, Molina-Molina M, Aso S, et al. Lung ultrasound score to predict outcomes in COVID-19. *Respir Care.* 2021;66(8):1263–70.
62. Mento F, Perrone T, Macioce VN, et al. On the impact of different lung ultrasound imaging protocols in the evaluation of patients affected by coronavirus disease 2019: How many acquisitions are needed? *J Ultrasound Med.* 2021;40(10):2235–8.
63. Levy Adatto N, Preisler Y, Shetrit A, et al. Rapid 8-zone lung ultrasound protocol is comparable to a full 12-zone protocol for outcome prediction in hospitalized COVID-19 patients. *J Ultrasound Med.* 2022;41(7):1677–87.
64. Ng MY, Lee EYP, Yang J, et al. Imaging profile of the COVID-19 infection: Radiologic findings and literature review. *Radiol Cardiothorac Imaging.* 2020;2(1):e200034.
65. Gibbons RC, Magee M, Goett H, et al. Lung ultrasound vs. chest X-Ray study for the radiographic diagnosis of COVID-19 pneumonia in a high-prevalence population. *J Emerg Med.* 2021;60(5):615–25.
66. Mateos González M, García de Casasola Sánchez G, Muñoz FJT, et al. Comparison of lung ultrasound versus chest X-ray for detection of pulmonary infiltrates in COVID-19. *Diagnostics.* 2021;11(2):373.
67. Pare JR, Camelo I, Mayo KC, et al. Point-of-care lung ultrasound is more sensitive than chest radiograph for evaluation of COVID-19. *West J Emerg Med.* 2020;21(4):771–8.
68. Shumilov E, Hosseini ASA, Petzold G, et al. Comparison of chest ultrasound and standard X-ray imaging in COVID-19 patients. *Ultrasound Int Open.* 2020;6(2):E36–40.
69. Balbi M, Caroli A, Corsi A, et al. Chest X-ray for predicting mortality and the need for ventilatory support in COVID-19 patients presenting to the emergency department. *Eur Radiol.* 2021;31(4):1999–2012.
70. Toussie D, Voutsinas N, Finkelstein M, et al. Clinical and chest radiography features determine patient outcomes in young and middle-aged adults with COVID-19. *Radiology.* 2020;297(1):E197–206.
71. Xiao N, Cooper JG, Godbe JM, et al. Chest radiograph at admission predicts early intubation among inpatient COVID-19 patients. *Eur Radiol.* 2021;31(5):2825–32.
72. Patnayak G, Rastogi R, Khajuria L, et al. Role of chest radiograph in predicting the need for ventilator support in COVID-19 patients. *Afr J Thorac Crit Care Med.* 2022;28(4).
73. Borghesi A, Zigliani A, Masciullo R, et al. Radiographic severity index in COVID-19 pneumonia: relationship to age and sex in 783 Italian patients. *Radiol Med.* 2020;125(5):461–4.
74. Spogis J, Fusco S, Hagen F, et al. Repeated lung ultrasound versus chest X-ray: Which one predicts better clinical outcome in COVID-19? *Tomography.* 2023;9(2):706–16.
75. Docherty AB, Harrison EM, Green CA, et al. Features of 20133 UK patients in hospital with Covid-19 using the ISARIC WHO Clinical Characterisation Protocol: prospective observational cohort study. *BMJ.* 2020;369:m1985.

Nudge Theory: Effectiveness in Increasing Emergency Department Faculty Completion of Residency Assessments

Amelia Gurley, MD
Colin Jenkins, MD
Thien Nguyen, MD
Allison Woodall, MD
Jason An, MD

Riverside Community Hospital, Department of Emergency Medicine, Riverside, California

Section Editor: Jeffrey Love, MD, MHPE
Submission history: Submitted June 14, 2022; Revision received February 8, 2023; Accepted February 15, 2023
Electronically published December 6, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.57721

BACKGROUND

Assessments are a core component of residency training to assess development in the general competencies expected of all physicians.[1] Many methods are employed to evaluate performance, from checklists to computer-based questionnaires, as no single best practice exists.[2] Common to most, however, are barriers to the completion of assessments.[3] For example, residents and faculty often cite a perceived lack of time to perform assessments, which may lead to suboptimal compliance in completing assessments.[3] Some methods of assessment, such as providing narrative feedback to residents by faculty, may be seen as too burdensome.[3] The emergency department represents an especially challenging environment to overcome these barriers given the high cognitive demand placed on faculty and residents by default.

One possible strategy to enhance faculty compliance in completing assessments is to implement behavioral nudging into social and physical environments. Borrowed from behavioral economics, nudge theory involves use of evidence-based "nudges" that incorporate positive reinforcement and indirect suggestions to influence decisions and behavior.[4] Nudges can include use of the following: priming (environmental cues to subconsciously drive behavior); default options (desirable options are preselected as the default choice and thereby easiest for individuals to take); norm-based nudges (comparing individual behavior to peer practice); commitment (making a public promise to complete a task); and salience (drawing attention to a particular option through colors or a compelling story), among others.[4] For instance, in the surgical intensive care unit, hand hygiene compliance was enhanced when individuals were primed with a citrus-like fragrance that was dispensed into the environment.[5] In another example, medical student assessments were completed more often when faculty were prompted with electronic forms at the end of shifts, rather than relying on them to complete paper forms at their own discretion.[6] In this study, we evaluated the effectiveness of two priming nudges and one norm-based nudge in increasing compliance of faculty in completing assessments of emergency medicine residents.

OBJECTIVES

Our primary objective in the study was to assess the effectiveness of nudge interventions in increasing the number of resident performance assessments completed by attending physicians. This was assessed by comparing the number of assessments completed during the year prior to implementation of the nudge interventions with the years following their implementation. Our secondary objective was to identify which particular method was employed with the greatest frequency.

CURRICULAR DESIGN

This project qualified as a research study conducted in established or commonly accepted educational settings. The Research Oversight Committee approved the Institutional Review Board Exempt Review Form request for exemption. The study took place at Riverside Community Hospital, a tertiary-care referral academic/community medical center in Riverside, California. The residency program at Riverside Community Hospital is a three-year emergency medicine residency accredited by the Accreditation Council for Graduate Medical Education. Each class has 13 residents per year for a total of 39 residents. We had approximately 28–30 faculty during the study, and 28 faculty received prior training on completing end-of-shift assessments.

We collected pre-intervention data from July 1, 2019–June 30, 2020 with an email link sent to faculty at the beginning of the academic year. They were sent periodic email reminders to complete the survey. The intervention started on July 1, 2020. The post-intervention data was collected from July 1, 2020–May 11, 2021.

Table. Number of assessments completed over time charted against timeline of interventions.

Time frame	7/1/19–6/30/20 (pre-intervention)	7/1/20–6/20/21 (post-intervention)	7/1/21–6/1/22 (post-intervention)
Number of responses	3,663	4,243	4,534
Evaluations per month	305	354	453

Three primary nudges were used as the intervention to increase the number of end-of-shift assessments. We selected the nudges based on previous studies, which showed people change behavior based on social comparison.[7] People also tend to choose the most visible option.[8] The first nudge was to create a homepage on the faculty phone with a direct link to the end-of-shift assessment survey. The second nudge was a quick response (QR) code posted at the faculty work stations throughout the department: in the main ED; in the rapid care (lower acuity) zone; and in the faculty break room. The third nudge was based on a social proof heuristic. At the end of each block an email was sent to all faculty with the total number of assessments completed for the block, with comparisons to other faculty members' completion rate and a link to the survey.

At the end of the study period, all faculty received a survey asking which nudge was used the most often. Faculty were asked to rank each intervention, from used most often (weighted score of 3) to least often (weighted score of 1). The survey link in the email reminder was created in Surveymonkey.com (Momentive, San Mateo, CA). We created the QR code flyer on canva.com (Surry Hills, Australia).

We believe that the interventions in this study can be replicated at many other institutions. The QR code should be posted in highly visible locations near the faculty workspace in the ED. We discovered that many faculty members required detailed instructions on how to create a homepage on their mobile devices. However, the faculty reported that once the homepage was set up, it was the easiest way to complete the assessments. The end-of-the-block summary of the total number of assessments completed by faculty may be an administrative burden to some institutions.

IMPACT/EFFECTIVENESS

As shown in Table 1, there was a 15.8% increase in the number of assessments completed in the year after these interventions were implemented, with the number of completed assessments increasing from 3,663 (305 assessments per month) in the pre-intervention year to 4,243 (354 assessments per month) in the first post-intervention year. This increase was sustained in the following year, with 4,534 assessments (453 assessments per month) completed to date. This trend suggests that our "nudge" interventions may have been effective in producing a long-term change in faculty behavior patterns.

When surveying the 28 faculty to determine which nudge was most effective, there was an 85.7% (24) response rate. Of the respondents, 19 (79%) indicated that their most frequently used nudge was the survey link saved onto their phone, and that they completed over 75% of their assessments this way. Thirteen respondents (54%) reported that the nudge based on social heuristics—the link at the end of the monthly emails—was the second most frequently used. Only one respondent used the QR code flyers most frequently, and 20 (83%) stated they never used the QR code at all.

From our experimental design, we learned that nudges used online could be effective in increasing completion rates of assessments. A surprising limitation was the grouping of data into certain time frames, which could be delineated in future iterations to determine the impact that time of year has on response rates. We could also compare efficacies of different interventions, such as comparing a baseline rate of using home-screen survey links only to this baseline plus an added intervention, to assess the importance of each added variable and help determine which interventions truly provide benefit.

This assessment of our interventions' impact is limited by several factors. As the number and makeup of faculty changed during the intervention, it was not possible to determine whether a statistically significant number of faculty changed their practice as a result of this intervention. The increase in the assessment completion rate may also be due not only to our interventions but also to outside factors such as changing hospital policies, number of faculty, the impact of the COVID-19 pandemic, overall departmental shifts in attitude, or the Hawthorne effect, any of which may have played a role in influencing behavior. It is also difficult to distinguish which of the various interventions actually impacted attending behavior, as all were implemented simultaneously, and survey replies were anonymous and may be subject to recall bias. For example, it is possible that the presence of QR codes at workstations was responsible for the large increase in phone home-screen assessment completion.

Address for Correspondence: Allison Woodall, MD, Riverside Community Hospital, Department of Emergency Medicine, 4510 Brockton Avenue, Suite 223, Riverside CA 92501. Email: Allison.woodall@vituity.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. Gibbs T, Brigden D, Hellenberg D. Assessment and evaluation in medical education. *S Afr Fam Pract*. 2006;48(1):5–7.
2. Perkins SQ, Dabaja A, Atiemo H. Best approaches to evaluation and feedback in post-graduate medical education. *Curr Urol Rep*. 2020;21(10):36.
3. Malik MU, Diaz Voss Varela DA, Stewart CM, et al. Barriers to implementing the ACGME outcome project: a systematic review of program director surveys. *J Grad Med Educ*. 2012;4(4):425–33.
4. Yoong SL, Hall A, Stacey F, et al. Nudge strategies to improve healthcare providers' implementation of evidence-based guidelines, policies and practices: a systematic review of trials included within Cochrane systematic reviews. *Implement Sci*. 2020;15(1):50.
5. King D, Vlaev I, Everett-Thomas R, et al. "Priming" hand hygiene compliance in clinical environments. *Health Psychol*. 2016;35(1):96–101.
6. Tews MC, Treat RW, Nanes M. Increasing completion rate of an M4 emergency medicine student end-of-shift evaluation using a mobile electronic platform and real-time completion. *West J Emerg Med*. 2016;17(4).
7. Cheung TTL, Kroese FM, Fennis BM, et al. The Hunger Games: using hunger to promote healthy choices in self-control conflicts. *Appetite*. 2017;116:401–9.
8. Kroese FM, Marchiori DR, de Ridder DT. Nudging healthy food choices: a field experiment at the train station. *J Public Health (Oxf)*. 2016;38(2):e133–e137.

Emergency Medicine Resident Needs Assessment and Preferences for a High-value Care Curriculum

Bennett H. Lane, MD[*†°]
Simanjit K. Mand, MD[*°]
Stewart Wright, MD, MEd[*]
Sally Santen, MD, PhD[*]
Brittany Punches, PhD[‡]

[*]University of Cincinnati College of Medicine, Department of Emergency Medicine, Cincinnati, Ohio
[†]University of Cincinnati Health Air Care & Mobile Care, Cincinnati, Ohio
[‡]Ohio State University, Colleges of Nursing and Medicine, Department of Emergency Medicine, Columbus, Ohio
[°]Bennett H. Lane and Simanjit K. Mand contributed equally to this work

Section Editors: Sara Krzyzaniak, MD, and Jeffrey Love, MD
Submission history: Submitted December 13, 2022; Revision received October 3, 2023; Accepted November 3, 2023
Electronically published December 8, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.59622

Introduction: Consideration of the cost of care and value in healthcare is now a recognized element of physician training. Despite the urgency to educate trainees in high-value care (HVC), educational curricula and evaluation of these training paths remain limited, especially with respect to emergency medicine (EM) residents. We aimed to complete a needs assessment and evaluate curricular preferences for instruction on HVC among EM residents.

Methods: This was a qualitative, exploratory study using content analysis of two focus groups including a total of eight EM residents from a single Midwestern EM residency training program. Participants also completed a survey questionnaire.

Results: There were two themes. Within the overall theme of resident experience with and perception of HVC, we found five sub-themes: 1) understanding of HVC focuses on diagnosis and decision-making; 2) concern about patient costs, including the effects on patients' lives and their ability to engage with recommended outpatient care; 3) conflict between internal beliefs and external expectations, including patients' perceptions of value; 4) approach to HVC changes with increasing clinical experience; and 5) slow-moving, political discussion around HVC. Within the overall theme of desired education and curricular design, we identified four sub-themes: 1) limited prior education on HVC and health economics; 2) motivation to receive training on HVC and health economics; 3) desire for discussion-based format for HVC curriculum; and 4) curriculum targeted to level of training. Respondents indicated greatest acceptability of interactive, discussion-based formats.

Discussion: We conducted a targeted needs assessment for HVC among EM residents. We identified broad interest in the topic and limited self-reported baseline knowledge. Curricular content may benefit from incorporating resident concerns about patient costs and conflict between external expectations and internal beliefs about HVC. Curricular design may benefit from a focus on interactive, discussion-based modalities and tailoring to the learner's level of training. [West J Emerg Med. 2024;25(1)43–50.]

INTRODUCTION

A recent shift to focus on "value" in healthcare, often defined as health outcomes achieved per dollar spent, has emerged in response to persistently rising costs over decades.[1] Recent events have highlighted the cost of emergency care in the national spotlight, including federal legislation on surprise billing, insurer denials of claims for emergency department (ED) visits without a final emergent diagnosis, and regulations on payments for air ambulance transports.[2–5] Consistent with these developments, current

Accreditation Council for Graduate Medical Education (ACGME) guidelines state that "residents must demonstrate competence in … incorporating considerations of value, equity, cost awareness, delivery and payment, and risk-benefit analysis in patient and/or population-based care as appropriate."[6]

Despite the current ACGME guidelines and increasing demands for high-value care (HVC), the appropriate educational content and instructional methods have not been clearly established. Moriates and colleagues delineated 21 HVC competencies with beginning, proficient, and expert levels through an iterative process led by a multidisciplinary committee.[7] While rigorous and expert-led, this approach did not include a resident-focused needs assessment, and subsequent needs evaluations have been limited to surveys of internal medicine or pediatrics residents at a single site.[8–10] Similarly, evaluation of proposed internal medicine or pediatrics resident curricula have been limited to single-site pre-/post-surveys, with one study also including post-implementation focus groups.[10–13]

Within emergency medicine (EM), HVC and health economics educational resources are limited, as a 2010 systematic review of cost-effectiveness curricula identified only a single EM curriculum focused on the Ottawa ankle rules. Since that review, two additional contributions that we are aware of include 1) the Emergency Medicine Residents' Association *Residents' Advocacy Handbook* addressing policy-related topics in a textbook-like format and 2) a cost-conscious care curriculum developed by Lin and Laskowski at a single site in New York (personal communication, L. Laskowski).[14,15] There is a paucity of formal, resident-focused needs assessments across specialties, particularly in EM. Our objective was to perform a targeted needs assessment to assess EM residents' needs and interests in HVC and preferences for instructional modality.

Population Health Research Capsule

What do we already know about this issue?
Resident education guidelines now incorporate the topic of value in health care, but few resident-focused needs assessments for this concept are available.

What was the research question?
For high-value care, what are emergency medicine residents' needs, interests, and preferences for instructional modality?

What was the major finding of the study?
Residents self-report low knowledge but are interested in education on high-value care. They prefer discussion-based modalities.

How does this improve population health?
Addressing cost of care through graduate medical education may help address accessibility and affordability of care.

METHODS

Study Design

As part of a curriculum development process, we performed a problem identification and targeted needs assessment for EM residents, corresponding to Kern's six-step approach to curricular development.[16] To achieve our objective, we conducted a qualitative, exploratory study using conventional content analysis. This method allowed us to critically examine the participant responses to identify common categories and elucidate themes. Our secondary objective to determine preferences for instructional modality included a collection of respondents' self-assessments using a survey questionnaire. We obtained institutional review board (IRB) approval for all study procedures.

Setting and Participant Selection

The setting was a single Midwestern United States EM residency program with 56 total residents. Two physician authors were residents at the time of the data collection phase of the project (BHL, SKM). Recruitment of a convenience sample of eight EM residents was performed via email by one of the authors (SKM) to the remaining 54 residents. Nine residents responded. (One resident could not participate due to scheduling constraints.) No participant terminated their participation during the focus group.

Data Collection Procedures

We obtained documentation of informed consent prior to study procedures. A semi-structured interview guide for focus groups was primarily authored by a single author (BHL) and reviewed sequentially by additional authors for revision of content and phrasing (SKM, BP). The interview guide is included as Appendix 1. Focus groups were co-led by two physician authors who were residents at the time (BHL, SKM) following the interview guide. Both focus groups were audio recorded and subsequently transcribed. No field notes were made, nor were transcripts returned to participants for comment. The focus groups occurred during September 2020 in a medical school conference room with no other person present aside from focus group leaders and participants. After the focus group discussion was complete, participants independently completed a survey questionnaire using Likert scale and rank order questions on paper (Appendix 2). Each focus group included four participants with at least one intern (postgraduate year [PGY] 1) in each group. In total,

the first group included one PGY-1, one PGY-2, and two PGY-3 residents; the second focus group included two PGY-1 and two PGY-4 residents. Each focus group lasted between 75–85 minutes. No repeat interviews were completed. Participants received a $15 gift card for compensation, consistent with IRB guidelines.

Data Analysis

The transcripts were reviewed and conventional content analysis with line-by-line coding was completed by two independent coders (BHL, SKM). Using an open coding technique, important statements were identified (generally termed "the first cut").[17] Codes were developed in vivo and did not reference previous literature. (They are depicted in a coding tree in Appendix 3.) Significant redundancy in codes was identified, which was felt to be consistent with thematic saturation.[18] The analysis team came together with a third reviewer (BP) to categorize, refine, and cluster important statements, and subsequent themes and domains emerged. We used the consolidated criteria for reporting qualitative research (COREQ) as reporting guidelines (Appendix 5).[19] Descriptive statistics were performed in Microsoft Excel for questionnaire data, and we used Word (Microsoft, Redmond, WA) for transcripts and coding documentation. The use of independent coders and a team of three to categorize and develop themes enhanced credibility, and investigator triangulation aided confirmability of the results.[18]

Reflexivity Statement

Reflexivity of the research team included recognition that the focus group leaders and coders were known to the participants and identified their respective specific interests in HVC/health economics (BHL) and medical education (SKM) to the participants as part of the introduction. The focus group leaders identified as male (BHL) and female (SKM). BHL and SKM were residents at the time of the study. BP provided training to BHL and SKM regarding techniques in semi-structured, focus group facilitation; BHL had limited prior experience with focus group facilitation. A methodological limitation is that the same residents comprised the focus groups and completed survey questionnaires; survey questionnaire results may have been influenced by the preceding focus group discussion, although all questionnaires were completed independently by all participants without additional discussion.

RESULTS

A total of eight residents participated. With respect to the importance of education about HVC topics, residents endorsed the relevance of HVC topics to the resident physician (7/8, [88%]) and the importance of a HVC curriculum (8/8, [100%]) (Appendix 4, Figure 2). We identified two overarching themes: 1) experience with and perception of HVC; and 2) desired education and curricular design. For each overarching theme, component sub-themes summarized clusters of resident comments for which we include representative comments and (if identified) participant recommendations.

Overarching Theme 1: Experience with and Perception of High-value Care

Sub-theme 1: Understanding of high-value care focuses on diagnosis and decision-making.

Residents most frequently associated HVC with the activities that facilitate diagnosis and decision-making in the ED. For example, when asked whether they had a general definition for or had heard of the phrase "high-value care," one resident highlighted using the ED evaluation to "*appropriately figure out what is going on with this patient and decide where to send them*" (Resident #1, PGY-1). In this understanding, residents believe care activities are high value if they allow the clinician to make a diagnosis or disposition. Less commonly, other residents mentioned aspects of HVC such as resource use, stewardship (citing a specific example of a cost-savings initiative related to the use of combat gauze [Resident #7, PGY-4]), and the concept of cost-benefit analysis: "*clinical decision rules that … reduce unnecessary head CTs, not only from a radiation perspective, but also from a cost-savings perspective*" (Resident #8, PGY-4).

Sub-theme 2: Concern about patient costs.

In the focus group discussion, residents voiced uncertainty due to varying patient insurance reimbursement of care provided in the ED and concerns surrounding high patient costs, in large part due to a self-identified lack of knowledge. Because of this knowledge gap, residents felt inadequately prepared to have conversations surrounding cost and insurance coverage with patients. One of the participants recalled a patient encounter in which the resident felt uninformed to address the patient's reaction after the resident disclosed the presence of a new mass concerning for cancer:

> *How much is this going to cost me? How am I going to pay for this?' [and] I didn't know the answer. … It'd be nice if I actually had some data … like you're uninsured, it's ok, because it's going to be like this for the financial plan, if you're insured, this is what happens. I have no clue." (Resident #5, PGY-3)*

Other residents stated that they were unaware of the costs of commonly ordered diagnostics and therapeutics in the ED. They described being concerned and unaware of the financial and social ramifications of care activities on patients' lives outside of the hospital, and they particularly worried about the impact on patients' ability to engage with

recommended outpatient care: "*It's how much the patient gets charged that would actually matter from a social determinants of health perspective*" (Resident #2, PGY-1). Residents particularly cited feeling challenged by shared decision-making discussions when patients had financial concerns.

Sub-theme 3: Conflict between internal beliefs and external expectations.

Residents noted that there may be a conflict between a physician's personal beliefs and the external expectations and pressures they face. Some external expectations, such as those from systems-level "hurdles" placed in the electronic health record-ordering interface, are explicitly identifiable for residents: "*I try to order [intravenous acetaminophen] all the time. IT takes you through, you have to go through all these questions because they're trying to keep me from ordering [it]. … I know they're trying to keep me from ordering it, but I'm going to keep on ordering it*" (Resident #8, PGY-4). Other external expectations are perceived to be implicit within the medical community: *"Even though we talk about in an academic setting, or in a boardroom, it's OK to have a miss from a statistical perspective, I think culturally that's not acceptable. … It's just not playing out in the real world, in my opinion, accepting that there is a miss rate*" (Resident #4, PGY-2).

Residents particularly highlighted that patients are a source of external expectations and recognized that patients may view cost, quality, and value of care differently from the emergency physician. This difference in perception may lead to a disconnect in expectations: *"Value can really be in the eyes of the beholder … makes me think about what I think might be the best thing for the patient may not be at all the same as what the patient values"* (Resident #6, PGY-3). Moreover, the conflict between internal beliefs and external expectations can overshadow attempts to prioritize HVC. A context cited for this conflict were ED visits of patients who commonly frequent the ED. For these patients, the lack of community resources for patients can be frustrating and render a learner feeling helpless or unable to provide holistic patient care. For these patients, trainees noted feeling a disconnect between the care they felt expected to provide and the care they desired to provide.

Sub theme 4: Approach to high-value care changes with increasing clinical experience.

Residents shared anecdotes that demonstrate how the definition of and approach to optimize HVC changes with increasing clinical experience. One junior resident highlighted "wanting to know" as motivation for ordering testing: *"I'm as curious as [the patients] are, to be honest; so I want to know that this patient is perhaps a presentation of [a specific diagnosis]" (Resident #4, PGY-2)*. Similarly, as one non-intern resident reflected:

> *"And honestly, that's something that comes with time – like if you told me as an intern I could order a million-dollar test and get the answer that I need, I would 100% do it because it's easy, I'll be right, and I can help the patient. But as you practice medicine you realize … if you have a million-dollar test to answer if it's GERD … it's not going to change your management … As I'm progressing through residency I get more and more curious, and I'm more willing to accept information about [HVC]" (Resident #5, PGY-3)*

Sub-theme 5: Slow-moving, political discussion around high-value care in medicine.

In general, residents describe themselves as loosely aware of the political, academic, financial, and clinical implications of national discussions on HVC topics for future emergency physicians. For example, "*How you determine value? I remember back when Obama was still around and in office, I remember that was a big discussion, you know—what is real value and who determines that? That's sort of a black box" (Resident #8, PGY-4)*. Another resident reflected,

> *"There is always chatter out there in the … political and insurance world. And I'm not sure I know where like the landmark policy or … guiding foundation is for that conversation. So, certainly, outside there is a feeling that there is always this chatter happening*" (Resident #4, PGY-2).

When asked about proposed physician reimbursement models currently undergoing federal regulatory review, most residents did not know what those future policies entailed. In addition, many residents reported not being well versed in current reimbursement models, although non-intern residents reported more interest in current reimbursement information.

Overarching Theme 2: Desired Education and Curricular Design

Sub-theme 1: Limited medical education on health economics and high-value care.

When asked about their prior training in health economics and HVC topics, all residents noted minimal to no prior exposure during their medical training. In the survey questionnaire, all participants (8/8 [100%]) either strongly disagreed or disagreed with the statement "I feel confident that I know the cost of the care that I provide to patients in the emergency department" (Appendix 4). Much of the prior exposure described by residents was comprised of brief and infrequent didactic-based discussions that were described

as leading to limited information retention and limited application to clinical practice.

Beyond this, they voiced the belief that there were few opportunities for knowledge acquisition due to lack of available resources, particularly with respect to prices and costs of healthcare activities. Residents were not familiar with hospital-based or nationally based resources that could assist with day-to-day clinical healthcare questions such as patient cost: "*I think hospitals are mandated to have some sort of list, master list, of how much things costs, but it's also super hard to find … I have no idea where I would find that information*" (Resident #7, PGY-4).

Sub-theme 2: Motivated to receive training on high-value care and health economics.

The EM residents identified themselves as frontline healthcare workers. In their role, they interact directly with the community and patients with diverse backgrounds, particularly individuals facing financial barriers to accessing care. Because of this unique position in the medical field, residents believe that financial and insurance pressures may underlie patients' utilization of the ED and that clinicians should therefore understand these factors. One resident reflected

> "*I think when you … look … at healthcare as a gestalt, people are seeing primary care [clinicians] less and less and relying on the ED more for primary care. And assuming that that trend continues … I think as an emergency physician it is important to know those things [healthcare economics topics] because of that reason, just the utilization of the ED in general*" (Resident #1, PGY-1).

One resident also noted that the lack of health economics knowledge can put emergency physicians at a disadvantage in influencing and leading systems-based practice:

> *"I think not understanding [HVC and health economics topics] takes away a lot of our power to be a leader and makes us more pawns carrying out someone else's vision of how medicine should be practiced" (Resident #6, PGY-3).*

Residents recognized the importance of and need for further training on HVC topics to understand the impact that their decision-making has on patients and the healthcare system.

Sub-theme 3: Desire for discussion-based format for high-value care curriculum.

Residents were asked what the optimal format for HVC curriculum would be for residency-level learners, and the majority were in support of a discussion-based format.

> *"I like the idea of the case-based, small-group discussion. Especially when you have attendings there, and you have varied learner levels, and I kind of like that because you get varied sorts of inputs and that's interesting. And I just feel like this sort of stuff, these sorts of topics, are best, for me, explored verbally" (Resident #8, PGY-4).*

One resident noted that because this is not common knowledge among emergency clinicians, involving a content expert would be critical to a successful curriculum:

> *"Another part of incorporating this, is who is the content expert…. [HVC care is] a topic that … a typical academic [emergency] physician would [not] know about. It almost needs to be a collaboration… [someone] with health economic interest and knowledge and someone with an education background, too, to figure out how to incorporate this" (Resident #7, PGY-4).*

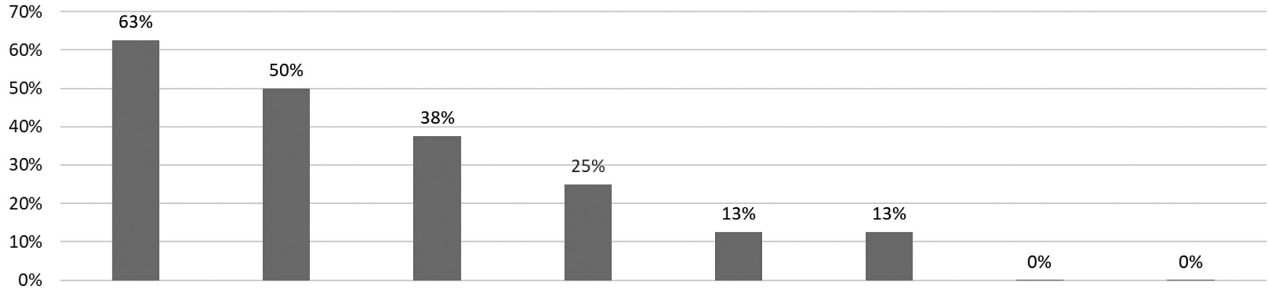
Consistent with this qualitative theme, the highest percentage of residents ranked modalities with the opportunity for interactive small-group discussion highly, whether as online apps or in person, on the survey questionnaire (Figure 1).

Sub-theme 4: Curriculum targeted to their level of training.

While most of the residents recognized the need for a formal HVC curriculum during medical training, there was variation in when they thought this curriculum should be introduced at the residency-training level. The PGY-1 and PGY-2 residents voiced desire to focus on clinical knowledge acquisition in lieu of health economics topics:

> *"As an intern, I'd rather be more towards the clinical aspect of things right now … I don't think I've developed that skill enough to want to sacrifice one of those journal clubs for health economics. I think as a later resident, I'd be on board …" (Resident #1, PGY-1).*
>
> *"My initial thought was that I would want something clinically relevant because I feel like [I am] earlier in training and just trying to build that foundation …" (Resident #4, PGY-2).*

A non-intern resident noted *"I feel like as I'm progressing through residency, I get more and more curious and I'm more willing to accept information about that stuff [HVC]"* (Resident #5, PGY-3). In reply to an intern indicating the topic of "[relative value units] *and physician-associated income … wouldn't appeal or apply to me right now when I would just forget it*" (Resident #3, PGY1), Resident #7 (a PGY-4) reflected that non-intern residents would be interested due to personal decision-making: *"I would say the PGY-3s because some of the PGYs would start signing contracts in the summer"*



Instructional modality	Online interactive app small groups	In-person interactive small groups	Online modules (self-paced asynchronous)	In-person large group didactic instruction	Secondary literature reading	Primary literature reading	Case-based in-person small group discussion	Optional resident interest group
Mean ranking (lower better)	2.75	3.125	4.625	4.375	5	6.375	4.875	5.125

Figure 1. Percentage of respondents ranking each instructional modality among top two choices and mean ranking within eight modality options ($n = 8$).

An interesting perspective raised by one of the non-intern residents was the potential to negatively influence junior learners' practice patterns if topics of HVC were introduced too early in medical training:

> *"I wonder from an education mission side, could you influence early trainees' . . . practice patterns because of knowledge of this. And I don't want that to happen . . . you need to see where you fall in that spectrum to develop your practice pattern. And I wonder if you find out that a test costs this amount of money, maybe you won't get to fully explore that spectrum and develop your own point on that spectrum" (Resident #7, PGY-4).*

Lastly, a couple of residents voiced concern about the integration of a novel curriculum in an EM training program given that EM's scope of practice already addresses many adjacent disciplines:

> *"We're all kind of in agreement that a baseline level of understanding you should have . . . but as far as about data and literature . . . I'd kind of reserve that for people that have an interest in it, similar to how we do with other things, like sports medicine" (Resident #3, PGY-1).*
>
> *"You have so many things to learn. Not only clinically, but also our non-clinical curriculum . . . is pretty impressive, so it's tough [to] add a whole other curriculum" (Resident #8, PGY-4).*

DISCUSSION

Residents recognized the importance of learning HVC principles for application in both patient care and to inform systems-based practice; however, they felt inadequately trained on the topic. Our needs assessment identified two main themes to inform EM-specific curricula addressing HVC topics: resident experience with and perception of HVC, and desired education and curricular design.

Consistent with studies in other disciplines and settings, the residents reported limited confidence in their knowledge of basic HVC principles, and the financial impacts of cost of care for individual patients and the healthcare system as a whole.[9,10,13] Sub-themes 1 (understanding of HVC focuses on diagnosis and decision-making) and 2 (resident concerns about patient costs) in this study were consistent with themes from focus groups completed with general pediatrics residents at two centers of "how an intervention changes management" and "thinking about the cost as a harm."[10]

Residents stated that early on in their training, HVC knowledge gaps are related to patient costs, patient insurance reimbursement, cost-benefit analysis, and resource stewardship. Later, self-identified knowledge gaps emerging as non-intern learners were primarily related to physician reimbursement. A review of the literature, including prior work within pediatrics and internal medicine, suggested no prior evidence of resident knowledge or interest varying by experience level; if validated in additional settings, such variations with learner experience would provide valuable guidance in the design of educational curricula.

The resident participants stated their lack of formal training in and basic knowledge of HVC was a barrier to providing high-value emergency care. They also reported limited awareness of national health policy yet were less interested in a detailed understanding of these topics. This finding suggests that a specialized elective may be better suited to education regarding health policy topics that do not directly tie into day-to-day emergency care, as in the example described by Greysen and colleagues.[21] Finally, the participants also indicated the need for more education on system-wide reimbursement and HVC policies. To meet this

need, prior national-level survey data from internal medicine residents and program directors suggests that institutional support for both HVC faculty development and provision of physician cost-of-care performance data are associated with an increase in resident reports of education on HVC.[22]

Unanticipated aspects of HVC that were viewed as learner obstacles included dynamic conflicts between internal learner beliefs and external expectations and the variability in value perception between patients and clinicians. These issues may complicate residents' perception of and implementation of HVC in the clinical setting; addressing these issues within HVC education is critical to avoid unintentional creation of anxiety, or even moral distress, in the training environment. In an intern-targeted curriculum in internal medicine, Hom and colleagues also discussed resident-perceived barriers surrounding intra-team, interdisciplinary, and patient and family dynamics and how they complicate understanding and implementation of HVC principles at an early learner stage.[14] Thus, future curricula will need to focus both on foundational knowledge dissemination and techniques on how to approach the above barriers.

An additional unexpected barrier raised by residents in the focus group was the concern that the existing EM training curriculum does not have the capacity to incorporate HVC; and, therefore, HVC training may not fit as a core element. While not addressed in these focus groups, a future direction for work in this area should include evaluation of how residents would weigh HVC training compared to other curricular elements and whether there would be opportunity to make potential "tradeoffs."

In terms of curricular design and format, themes emerged to optimize not only knowledge acquisition and understanding, but also timing during the residency training program. The resident participants were in support of an expert-led, discussion-based curriculum to learn the principles of HVC, consistent with the experiences of Hom and colleagues.[13] These findings also coincide with those of Stammen et al in their systematic review, concluding that reflective practice through feedback and group discussions incentivize physicians to think critically about medical decisions.[19]The residents also suggested that HVC topics should be targeted more toward non-intern residents who have mastered proficiency in basic clinical knowledge and skills and would be able to apply these new principles with more purpose than their junior counterparts, although some earlier knowledge base to supplement formative experiential growth throughout residency may be beneficial. They did voice concern that the introduction of HVC too early in residency could jeopardize early learners' practice pattern development.

LIMITATIONS

There are several limitations to consider with regard to our study. First, this study reflects a sample of residents from a single-center, large academic hospital and may not be applicable to all academic- and community-based training programs. Because it was a single-center study, we could not distinguish how three-year programs or four-year programs with different approaches to resident progression or "seniority" would differ from the findings identified here. Second, only a small subset of program residents participated in either focus group, leading to the possibility of selection bias with regard to the participants who volunteered to discuss their thoughts on HVC. These residents may have had a particular interest in medical education or HVC that may not be applicable to all EM residents across the country. The small subset of participating residents also likely limited the number of available perspectives to be collected and inform thematic saturation.

Third, the study included a mix of junior and senior residents. While the study allowed for a rich spectrum of experience to inform previous exposure to HVC principles, it may not have been as impactful as evaluating the perspectives of the most experienced residents in a program who had nearly completed the entire program curriculum and could identify areas for nuanced improvement. Fourth, while the use of focus groups (rather than one-on-one interviews) allowed emergent discussion between participants, the presence of peers may have led some participants to avoid making statements due to fear of being perceived as controversial. Fifth, due to transitions in roles, member checking could not be performed. While our study adds a critically necessary needs assessment to the current body of literature, further and more rigorous studies that include a larger number of residency programs and participating residents are needed to verify these findings to accurately inform future EM curricula.

CONCLUSION

Our targeted needs assessment indicates that residents currently face gaps in knowledge of high-value care topics pertaining to the medical care that they provide and may benefit from additional training during residency. Residents interviewed in this study identified several perceived barriers to understanding HVC, but they consistently expressed interest in a formal curriculum to address these challenges. We found a preference for interactive, small-group discussion-based formats with content adjusted by level of clinical training.

Address for Correspondence: Bennett H. Lane, MD, MS, University of Cincinnati College of Medicine, Department of Emergency Medicine, 231 Albert Sabin Way ML 0769, Cincinnati, OH 45267-0769. Email: lanebt@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. This work was supported by internal departmental funding from a designated Resident Research Fund. No author reports any related conflicts of interest. Bennett H. Lane reports receiving research grant support from the Society for Academic Emergency Medicine Foundation for investigator-initiated work on interhospital transfers by air. Bennett H. Lane also reports an equity interest and consulting fees from TriAxia Health for unrelated work.

REFERENCES

1. Porter ME. What is value in health care? *N Engl J Med*. 2010;363(26):2477–81.
2. Kliff S and Sanger-Katz M. For surprise medical bills, it's the beginning of the end. *The New York Times*. Published July 1, 2021. Available at: https://www.nytimes.com/2021/07/01/upshot/surprise-medical-bills-biden.html. Accessed July 19, 2021.
3. Chou SC, Gondi S, Baker O, et al. Analysis of a commercial insurance policy to deny coverage for emergency department visits with nonemergent diagnoses. *JAMA Netw Open*. 2018;1(6):e183731.
4. Kelly M. Sky-high air ambulance prices. *Ann Emerg Med*. 2020;76(5):A17–A20.
5. Mole Beth. Biggest health insurer plans to deny ER bills if it doubts you had an emergency. *ArsTechnica*. Published June 10, 2021. Available at: https://arstechnica.com/science/2021/06/biggest-health-insurer-plans-to-deny-er-bills-if-it-doubts-you-had-an-emergency/. Accessed July 19, 2021.
6. Accreditation Council for Graduate Medical Education. ACGME Common Program Requirements (Residency). Published online July 1, 2023. Available at: https://www.acgme.org/globalassets/pfassets/programrequirements/cprresidency_2023.pdf. Accessed October 2, 2023.
7. Moriates C, Dohan D, Spetz J, et al. Defining competencies for education in health care value: recommendations from the University of California, San Francisco Center for Healthcare Value Training Initiative. *Acad Med*. 2015;90(4):421–4.
8. Kohlwes RJ and Chou CL. A curriculum in medical economics for residents. *Acad Med*. 2002;77(5):465–6.
9. Dine CJ, Miller J, Fuld A, et al. Educating physicians-in-training about resource utilization and their own outcomes of care in the inpatient setting. *J Grad Med Educ*. 2010;2(2):175–80.
10. Dewan M, Herrmann LE, Tchou MJ, et al. Development and evaluation of high-value pediatrics: a high-value care pediatric resident curriculum. *Hosp Pediatr*. 2018;8(12):785–92.
11. Smith CD. Teaching high-value, cost-conscious care to residents: the alliance for Academic Internal Medicine–American College of Physicians Curriculum. *Ann Intern Med*. 2012;157(4):284–6.
12. Moriates C, Soni K, Lai A, et al. The value in the evidence: teaching residents to "choose wisely." *JAMA Intern Med*. 2013;173(4):308–10.
13. Hom J, Kumar A, Evans KH, et al. A high value care curriculum for interns: a description of curricular design, implementation and housestaff feedback. *Postgrad Med J*. 2017;93(1106):725–9.
14. Varkey P, Murad MH, Braun C, et al. A review of cost-effectiveness, cost-containment and economics curricula in graduate medical education: teaching cost-effectiveness. *J Eval Clin Pract*. 2010;16(6):1055–62.
15. Schlicher N, Haddock A, Solnick R, et al. *EMRA Emergency Medicine Advocacy Handbook*. 5th ed. Emergency Medicine Residents' Association; 2019.
16. Thomas PA, Kern DE, Hughes MT, et al. *Curriculum Development for Medical Education: A Six-Step Approach,* 3rd ed. Baltimore, MD: Johns Hopkins University Press; 2016.
17. Patton MQ.Qualitative research. In: *Encyclopedia of Statistics in Behavioral Science*; Hoboken, NJ; John Wiley & Sons, 2005.
18. Lincoln YS and Guba EG. *Naturalistic Inquiry*. Thousand Oaks, CA; Sage Publications, Inc. 1985.
19. Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *Int J Qual Health Care*. 2007;19(6):349–57.
20. Stammen LA, Stalmeijer RE, Paternotte E, et al. Training physicians to provide high-value, cost-conscious care: a systematic review. *JAMA* 2015;314(22):2384–400.
21. Greysen SR, Wassermann T, Payne P, et al. Teaching health policy to residents—three-year experience with a multi-specialty curriculum. *J Gen Intern Med*. 2009;24(12):1322–6.
22. Ryskina KL, Smith CD, Arora VM, et al. Relationship between institutional investment in high-value care (HVC) performance improvement and internal medicine residents' perceptions of HVC training: *Acad Med*. 2018;93(10):1517–23.

Integration of Geriatric Education Within the American Board of Emergency Medicine Model

Lauren T. Southerland, MD, MPH*
Lauren R. Willoughby, MD*
Jason Lyou, MD*
Rebecca R. Goett, MD†
Daniel W. Markwalter, MD‡§
Diane L. Gorgas, MD*

*The Ohio State University Wexner Medical Center, Department of Emergency Medicine, Columbus, Ohio
†Rutgers New Jersey Medical School, Department of Emergency Medicine, Newark, New Jersey
‡University of North Carolina School of Medicine, Department of Emergency Medicine, Chapel Hill, North Carolina
§University of North Carolina School of Medicine, UNC Palliative Care Program, Chapel Hill, North Carolina

Section Editors: Chris Merritt, MD, and Jeffrey Love, MD
Submission history: Submitted May 1, 2023; Revision received August 30, 2023; Accepted November 3, 2023
Electronically published December 22, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.60842

Background: Emergency medicine (EM) resident training is guided by the American Board of Emergency Medicine Model of the Clinical Practice of Emergency Medicine (EM Model) and the EM Milestones as developed based on the knowledge, skills, and abilities (KSA) list. These are consensus documents developed by a collaborative working group of seven national EM organizations. External experts in geriatric EM also developed competency recommendations for EM residency education in geriatrics, but these are not being taught in many residency programs. Our objective was to evaluate how the geriatric EM competencies integrate/overlap with the EM Model and KSAs to help residency programs include them in their educational curricula.

Methods: Trained emergency physicians independently mapped the geriatric resident competencies onto the 2019 EM Model items and the 2021 KSAs using Excel spreadsheets. Discrepancies were resolved by an independent reviewer with experience with the EM Model development and resident education, and the final mapping was reviewed by all team members.

Results: The EM Model included 77% (20/26) of the geriatric competencies. The KSAs included most of the geriatric competencies (81%, 21/26). All but one of the geriatric competencies mapped onto either the EM Model or the KSAs. Within the KSAs, most of the geriatric competencies mapped onto necessary level skills (ranked B, C, D, or E) with only five (8%) also mapping onto advanced skills (ranked A).

Conclusion: All but one of the geriatric EM competencies mapped to the current EM Model and KSAs. The geriatric competencies correspond to knowledge at all levels of training within the KSAs, from beginner to expert in EM. Educators in EM can use this mapping to integrate the geriatric competencies within their curriculums. [West J Emerg Med. 2024;25(1)51–60.]

INTRODUCTION

Emergency medicine (EM) residents have 3–4 years of training to learn an extensive array of skills. This includes the skills needed to care for older patients, who make up 16–20% of their patients.[1,2] The American Board of Emergency Medicine (ABEM) codifies the skills needed for competency in EM in the Model of the Clinical Practice of Emergency Medicine (EM Model) and the 2021 knowledge, skills, and abilities (KSA).[3,4] The EM Model lists clinical presentations and disease types and the KSAs are a list of skills and abilities integral to EM practice. Many residency programs base their curriculums on these documents. However, it is unclear how

best to integrate geriatric teaching within these complex curricula.

In 2010 Hogan et al published eight domains with 26 competencies of geriatric education derived from an expert consensus panel that are considered essential learning during EM residency for the care of older adults in the emergency department (ED).[5] These competencies are also used for categorizing geriatric continuing education for geriatric ED accreditation and have been pivotal to the development of geriatric EM as a subspecialty.[6,7] Despite this guidance, geriatric concepts are still only minimally integrated into resident education.[8] Without dedicated training, resident knowledge of geriatric competencies is poor.[9–11] But there is currently no guidance on how to integrate the geriatric competencies within an EM residency curriculum.

Our curriculum is based on the EM Model and KSAs. Our goal was to determine whether the geriatric competencies can be covered by an EM Model-based curriculum.

METHODS

This project is not human subjects research and did not require institutional board review. The study was a descriptive comparison of the 2019 EM Model and the 2021 KSAs to the 2010 geriatric competencies using a consensus-based process. The KSAs include both a description and a level. They are divided into overarching categories (eg, diagnosis, pharmacotherapy, reassessment) which are then divided into steps.[4] Each step is given a hierarchy in training (with A the highest and E the lowest). Level A is for advanced knowledge or skills. Level B is the minimal competency level for passing EM residency. Levels C, D, and E are skill steps to reach level B.

In the first phase of consensus mapping, two residents (a second-year EM resident and a fourth-year EM/internal medicine resident) and a geriatric fellowship-trained EM attending independently mapped geriatric competencies using Excel (Microsoft Corporation, Redmond WA). They were instructed to first use the search button to look for exact language and then go item by item through the EM Model and the KSAs to map similar language or concepts. For example, the concept of delirium could be described as altered mental status or encephalopathy. A clear association was defined by the team as 1) a keyword match or 2) consensus that it was likely that an emergency physician lecturing/teaching on the EM Model content item would, in normal teaching practices, teach the geriatric competency. If this was not the case, but the geriatric competency could be incorporated under this topic by someone *intentionally* teaching the competencies, this was listed as a suggested area for incorporation. Reviewers were instructed to be generous with mapping during this first round.

If all three or 2/3 agreed, this was considered initial consensus. Any remaining discrepancies were then independently reviewed by another emergency physician with expertise in resident education (former EM program director and current ABEM executive committee member). The full group met and reviewed the final discrepancies until consensus was reached. The consensus tables were then reviewed independently by two more emergency physicians at external residency programs for content validity. A similar process was used for mapping KSAs. Reviewers were blinded to the KSA level (A-E designation).

RESULTS

Incorporation into the 2019 EM Model

The EM Model has 963 items. On the first round, 126 items (13% of content) were identified as potential matches, including all of *17.1 Drug and Chemical Classes*. Round 1 consensus was 96.2% (927 items). Table 1 lists the 20 geriatric competencies (77%) included in the 2019 EM Model. Key word matches included competency #6: "*Demonstrate ability to recognize patterns of (physical/sexual, psychological, neglect/abandonment) that are consistent with elder abuse[,]"* which maps to "*Model Content 14.6.1.3 Patterns of Violence/Abuse/Neglect: Intrapersonal Violence: Elder*." Others were matched by concept, such as competency #11: "*Assess and correct (if appropriate) causative factors in agitated elders such as untreated pain, hypoxia, hypoglycemia, use of irritating tethers (defined as monitor leads, blood pressure cuff, pulse oximetry, intravenous access, and Foley catheter), environmental factors (light, temperature), and disorientation [,]"* which could be incorporated into teaching on *12.14 Nervous System Disorders: Delirium*.

Initial disagreements included whether signs and symptoms were meant to be used to formulate a differential diagnosis for that symptom or to describe management of the symptoms. There was also a question as to whether G11, which discusses "irritating tethers" as a cause of delirium, should be mapped to all procedures such as *19.4.1.4. Nasogastric tube*. The group decided that this would be better encompassed under the EM Model item for delirium. Table 2 lists the six geriatric competencies without a clear fit within the EM Model and suggestions from the team on where to include them.

Incorporation into the 2021 Knowledge, Skills, and Abilities

The initial independent mapping resulted in consensus on 84% of the items (179/214). Of the geriatric competencies, 216 (81%) mapped onto KSAs (Table 3). The most common categories were Communication & Interpersonal Skills (CS0), Pharmacotherapy (PT0), and Transitions of Care (TC0). Of the five competencies that did not map directly onto the KSAs, all had mapping items in the EM Model except one. The one competency that did not map directly to any EM Model or KSA was Effects of Comorbid Conditions (G24): "*Assess and document the presence of comorbid*

Table 1. The geriatric teaching competencies mapped onto the Emergency Medicine Model of Care.

Geriatric competency	Description	EM model item
G1	Generate a differential diagnosis recognizing that signs and symptoms such as pain and fever may be absent or less prominent in elders with acute coronary syndromes, acute abdomens, or infectious processes.	1.1 Abnormal vital signs 1.2 Pain
G2	Generate an age-specific differential diagnosis for elder patients presenting to the ED with general weakness, dizziness, falls, or altered mental status.	1.3.1 General- altered mental status 1.3.4 General- ataxia 1.3.19 General- fatigue/malaise 1.3.28 General- lightheadedness/dizziness 1.3.53 General- weakness 18.3.2 Multisystem trauma- falls
G3	Document consideration of adverse reactions to medications, including drug-drug and drug-disease interactions, as part of the initial differential diagnosis.	1.3.55 General- toxidromes 17.1 Drug and chemical classes: *entire section*
G4	In patients who have fallen, evaluate for precipitating causes of falls such as medications, alcohol use/abuse, gait or balance instability, medical illness, and/or deterioration of medical conditions.	1.3.4 General- ataxia 1.3.53 General- weakness 18.3.2 Multisystem trauma- falls
G5	Assess for gait instability in all ambulatory fallers; if present, ensure appropriate disposition and follow-up including attempt to reach primary care physician.	18.3.2 Multisystem trauma- falls
G6	Demonstrate ability to recognize patterns of trauma (physical/sexual, psychological, neglect/abandonment) that are consistent with elder abuse. Manage the abused patient in accordance with the rules of the state and institution.	14.6.1.3 Patterns of violence/abuse/neglect- elder
G7	Institute appropriate early monitoring and testing with the understanding that elders may present with muted signs and symptoms (eg, absent pain and neurologic changes) and are at risk for occult shock.	1.3.41 General- shock
G8	Assess whether an elder is able to give an accurate history, participate in determining the plan of care, and understand discharge instructions.	12.8.1 Other conditions of the brain-dementia 14.5.2 Organic psychoses- dementia 20.4.5.4 Regulatory/legal- consent, capacity and refusal of care
G9	Assess and document current mental status and any change from baseline in every elder, with special attention to determining whether delirium exists or has been superimposed on dementia.	1.3.1 General- altered mental status 12.8.1 Other conditions of the brain-dementia 12.14.1 Delirium- excited delirium syndrome 14.5.2 Organic psychoses- dementia
G10	Emergently evaluate and formulate an age-specific differential diagnosis for elders with new cognitive or behavioral impairment, including self-neglect; initiate a diagnostic workup to determine the etiology; and initiate treatment.	1.3.18 General- failure to thrive
G11	Assess and correct (if appropriate) causative factors in agitated elders such as untreated pain, hypoxia, hypoglycemia, use of irritating tethers (defined as monitor leads, blood pressure cuff, pulse oximetry, intravenous access, and Foley catheter), environmental factors (light, temperature), and disorientation.	12.14.1 Delirium- excited delirium syndrome

(*Continued on next page*)

Table 1. Continued.

Geriatric competency	Description	EM model item
G12	Recommend therapy based on the actual benefit to risk ratio, including but not limited to acute myocardial infarction, stroke, and sepsis, so that age alone does not exclude elders from any therapy.	12.11.1.1 Stroke- intracerebral hemorrhagic stroke 12.11.1.2 Stroke- subarachnoid hemorrhagic stroke 12.11.2.1 Stroke- embolic ischemic stroke 12.11.2.2 Stroke- thrombotic ischemic stroke 20.4.4.1 Health care coordination- advance directives
G14	Prescribe appropriate drugs and dosages considering the current medication, acute and chronic diagnoses, functional status, and knowledge of age-related physiologic changes (renal function, central nervous system sensitivity).	17.1 Drug and chemical classes: *entire section*
G15	Search for interactions and document reasons for use when prescribing drugs that present high risk either alone or in drug-drug or drug-disease interactions (eg, benzodiazepines, digoxin, insulin, NSAIDs, opioids, and warfarin).	17.1 Drug and chemical classes: *entire section*
G16	Explain all newly prescribed drugs to elders and caregivers at discharge, assuring that they understand how and why the drug should be taken, the possible side effects, and how and when the drug should be stopped.	20.1.1.3 Interpersonal skills- patient and family education
G19	With recognition of unique vulnerabilities in elders, assess and document suitability for discharge considering the ED diagnosis, including cognitive function, the ability in ambulatory patients to ambulate safely, availability of appropriate nutrition/social support, and the availability of access to appropriate follow-up therapies.	20.3.2.6 Ethical principles- care of vulnerable populations 20.4.4.3.1 Healthcare coordination- activities of daily living/functional assessment
G20	Select and document the rationale for the most appropriate available disposition (home, extended care facility, hospital) with the least risk of the many complications commonly occurring in elders during inpatient hospitalizations.	20.4.4.2.3 Healthcare coordination- hospice referral
G21	Rapidly establish and document an elder's goals of care for those with a serious or life-threatening condition and manage accordingly.	20.4.4.1 Healthcare coordination- advance directives 20.4.4.2.1 Healthcare coordination- patient identification for palliative care
G22	Assess and provide ED management for pain and key non-pain symptoms based on the patient's goals of care.	19.3.3 Anesthesia and acute pain management- analgesia
G23	Know how to access hospice care and how to manage elders in hospice care while in the ED.	20.4.4.2.3 Healthcare coordination- hospice referral

NSAID, non-steroid anti-inflammatory drug; *ED*, emergency department.

conditions (eg, pressure ulcers, cognitive status, falls in the past year, ability to walk and transfer, renal function, and social support) and include them in your medical decision-making and plan of care." Incorporating the potential consequences of comorbid conditions is included in KSA PR2: "*Perform the indicated procedure on an uncooperative patient, patient at the extremes of age (pediatric, geriatric), multiple co-morbidities, poorly defined anatomy, hemodynamically unstable, high risk for pain or procedural complications, sedation required, or emergent indication to perform procedure, and recognize the outcome and/or complications resulting from the procedure*" (KSA Level B). While the geriatrics competency addresses medical decision-making and the KSA address difficult procedures, there is some overlap in the training required.

Of the 63 matches within the KSA, five (8%) mapped onto advanced level A skills (*DX7, Identify obscure, occult, or rare patient conditions*; and *TI6, Develop protocols to avoid potential complications of interventions*). About half (31, 49%) mapped onto required competency skills (Level B), and the remaining 27 (43%) were developing skills (Level C, D or E, 27, 43%) (Table 3).

Table 2. Suggestions for teaching the geriatric competencies that do not fit clearly within the Emergency Medicine Model.

Geriatric competency	Description	Suggestions for teaching geriatric competencies without a clear association with EM Model items
G13	Identify and implement measures that protect elders from developing iatrogenic complications common to the ED including invasive bladder catheterization, spinal immobilization, and central line placement.	Could be discussed under *Procedure Domain* or *Practice-based Learning and Improvement: Patient safety and Medical errors*
G17	Document history obtained from skilled nursing or extended care facilities of the acute events necessitating ED transfer including goals of visit, medical history, medications, allergies, cognitive and functional status, advance care plan, and responsible PCP.	No transitions of care, nursing facility, or disposition areas. Could be taught under *Interpersonal and Communication Skills: Intra-departmental relations, teamwork, and collaboration skills*.
G18	Provide skilled nursing or extended care facilities and/or PCP with ED visit summary and plan of care, including follow-up when appropriate.	No transitions of care, nursing facility, or disposition areas. Could be taught under *Interpersonal and Communication Skills: Intra-departmental relations, teamwork, and collaboration skills*.
G24	Assess and document the presence of comorbid conditions (eg, pressure ulcers, cognitive status, falls in the past year, ability to walk and transfer, renal function, and social support) and include them in your medical decision-making and plan of care.	While individual elements listed are in the model (eg, ulcerative lesions: decubitus), the concept of comorbidity in older adults is distinct from disease-oriented items.
G25	Develop plans of care that anticipate and monitor for predictable complications in the patient's condition (eg, gastrointestinal bleed causing ischemia).	Could be discussed under *Practice-based Learning and Improvement: Patient safety and Medical Errors*.
G26	Communicate with patients with hearing/sight impairment	Could be discussed under *Interpersonal and Communication Skills: Cultural Competency.*

ED, emergency department; *PCP*, primary care physician.

DISCUSSION

The geriatric competencies for EM residency training integrate well within the EM Model and KSAs, with only one competency not having a direct match. Demonstrating this overlap between the suggested subspecialty curriculum and the EM model can help EM educators ensure that the geriatric competencies are incorporated into their curricula. This mapping could also guide the development of board exam questions, lectures, or simulation cases.

The EM Model is very brief, which can make directing education difficult. For instance, training on the EM Model item *18.3 Multi-system Trauma: Falls* is expounded upon in geriatric competency #4: "*In patients who have fallen, evaluate for precipitating causes of falls such as medications, alcohol use/abuse, gait or balance instability, medical illness, and/or deterioration of medical conditions*." Or another example, KSA *DX1 "Synthesize chief complaint, history, physical examination, and available medical information to develop a differential diagnosis*" can include a discussion of geriatric competency #3 "*Document consideration of adverse reactions to medications, including drug-drug and drug-disease interactions, as part of the initial differential diagnosis."* They both describe the initial generation of a differential diagnosis, but the geriatric competency adds pharmacology interactions and adverse reactions to be considered in the differential.

A second finding of this study was that the geriatric competencies align with elements required for minimal KSA competency. This implies that different aspects of geriatric care can (and we argue, should) be taught throughout a resident's training. It also suggests that the geriatric competencies were well developed for the residency level of training and should not be considered "too advanced" or "subspecialty training." While prior research has evaluated separate geriatric-specific curricula,[9–11] our work shows that geriatric competencies can be integrated throughout a curriculum based on the EM Model and KSAs. As of 2021, there were only 25 geriatric fellowship-trained emergency physicians, which is not enough for every residency program.[12] Programs without faculty who have no interest or training in geriatrics could also use external training resources such as the online learning modules at https://geri-em.com/ and at the Geriatric Emergency Department Collaborative (https://gedcollaborative.com/online-learning/).

LIMITATIONS

One limitation of this project was the consensus definitions used. We were unable to find any existing methods to help us

Table 3. The geriatric competencies were mapped onto the 2021 ABEM knowledge, skills, and abilities list.

Geriatric competency	Description	KSA code	Description	Level
G1	Generate a differential diagnosis recognizing that signs and symptoms such as pain and fever may be absent or less prominent in elders with acute coronary syndromes, acute abdomens, or infectious processes.	DX1	Synthesize chief complaint, history, physical examination, and available medical information to develop a differential diagnosis	C
		DX7	Identify obscure, occult, or rare patient conditions	A
		DX8	Construct a list of potential diagnoses based on the chief complaint	D
G2	Generate an age-specific differential diagnosis for elder patients presenting to the ED with general weakness, dizziness, falls, or altered mental status.	DX1	Synthesize chief complaint, history, physical examination, and available medical information to develop a differential diagnosis	C
		DX7	Identify obscure, occult, or rare patient conditions	A
		DX8	Construct a list of potential diagnoses based on the chief complaint	D
G3	Document consideration of adverse reactions to medications, including drug-drug and drug-disease interactions, as part of the initial differential diagnosis.	DX1	Synthesize chief complaint, history, physical examination, and available medical information to develop a differential diagnosis	C
		PT5	Recognize, monitor, and treat adverse effects of pharmacotherapy	B
G6	Demonstrate ability to recognize patterns of trauma (physical/sexual, psychological, neglect/abandonment) that are consistent with elder abuse. Manage the abused patient in accordance with the rules of the state and institution.	LI8	Adhere to processes and procedures to ensure that appropriate agencies are notified in situations that could pose a threat to individual or public health (eg, violence and communicable disease) in accordance with local legal standards	B
		LI10	Adhere to legal and ethical standards to assess and treat patients presenting to the ED	B
		LI11	Advocate for patients vulnerable to violence or abuse in accordance with legal and ethical standards	B
		LI13	Identify patients vulnerable to abuse or and/or neglect	C
G7	Institute appropriate early monitoring and testing with the understanding that elders may present with muted signs and symptoms (eg, absent pain and neurologic changes) and are at risk for occult shock.	DX7	Identify obscure, occult, or rare patient conditions	A
		DS1	Prioritize essential testing	D
		DS2	Determine necessity and urgency of diagnostic studies	E
G8	Assess whether an elder is able to give an accurate history, participate in determining the plan of care, and understand discharge instructions.	CS5	Communicate information to patients and families using verbal, nonverbal, written, and technological skills, and confirm understanding	B
		CS15	Solicit patient participation in medical decision-making by discussing, risks, benefits, and alternatives to care provided	C
		HP2	Prioritize essential components of a history and physical examination given limited (eg, altered mental status) or dynamic (eg, acute coronary syndrome) situations	B
		TC13	Ensure patient has resources and tools to comply with discharge plan, which may include modifying the plan or involving additional resources (ie, PCP, social work, financial aid) to optimize compliance	B

(*Continued on next page*)

Table 3. Continued.

Geriatric competency	Description	KSA code	Description	Level
		TC17	Explain clearly and ensure patient understanding of diagnosis, discharge instructions, and the importance of follow-up and compliance with treatments.	B
G9	Assess and document current mental status and any change from baseline in every elder, with special attention to determining whether delirium exists or has been superimposed on dementia.	HP6	Identify relevant historical and physical findings to guide diagnosis and management of a patient's presenting complaint in the context of their baseline condition	B
G10	Emergently evaluate and formulate an age-specific differential diagnosis for elders with new cognitive or behavioral impairment, including self-neglect; initiate a diagnostic workup to determine the etiology; and initiate treatment.	DX1	Synthesize chief complaint, history, physical examination, and available medical information to develop a differential diagnosis	C
		HP2	Prioritize essential components of a history and physical examination given limited (eg, altered mental status) or dynamic (eg, acute coronary syndrome) situations	B
G12	Recommend therapy based on the actual benefit to risk ratio, including but not limited to acute myocardial infarction, stroke, and sepsis, so that age alone does not exclude elders from any therapy.	CS14	Communicate risks, benefits, and alternatives to diagnostic and therapeutic procedures/interventions to patients and/or appropriate surrogates, and obtain consent when indicated	C
		DS4	Review risks, benefits, contraindications, and alternatives to a diagnostic study or procedure	C
		TI8	Assess indications, risks, benefits, and alternatives for the therapeutic intervention.	B
G13	Identify and implement measures that protect elders from developing iatrogenic complications common to the ED including invasive bladder catheterization, spinal immobilization, and central line placement.	DS4	Review risks, benefits, contraindications, and alternatives to a diagnostic study or procedure	C
		PR2	Perform the indicated procedure on an uncooperative patient, patient at the extremes of age (pediatric, geriatric), multiple comorbidities, poorly defined anatomy, hemodynamically unstable, high risk for pain or procedural complications, sedation required, or emergent indication to perform procedure, and recognize the outcome and/or complications resulting from the procedure	B
		PR7	Recognize the indications, contraindications, alternatives, and potential complications for a procedure	D
		TI8	Assess indications, risks, benefits, and alternatives for the therapeutic intervention.	B
G14	Prescribe appropriate drugs and dosages considering the current medication, acute and chronic diagnoses, functional status, and knowledge of age-related physiologic changes (renal function, central nervous system sensitivity).	PT2	Identify relative and absolute contraindications to specific pharmacotherapy	C
		PT5	Recognize, monitor, and treat adverse effects of pharmacotherapy	B
		PT6	Select and prescribe appropriate pharmaceutical agents based on intended e ect and patient allergies	C

(*Continued on next page*)

Table 3. Continued.

Geriatric competency	Description	KSA code	Description	Level
		PT9	Select, prescribe, and be aware of adverse effects of appropriate pharmaceutical agents based upon relevant considerations such as intended effect, financial considerations, possible adverse effects, patient preferences, institutional policies, and clinical guidelines.	B
G15	Search for interactions and document reasons for use when prescribing drugs that present high risk either alone or in drug-drug or drug-disease interactions (eg, benzodiazepines, digoxin, insulin, NSAIDs, opioids, and warfarin).	PT2	Identify relative and absolute contraindications to specific pharmacotherapy	C
		PT5	Recognize, monitor, and treat adverse effects of pharmacotherapy	B
		PT9	Select, prescribe, and be aware of adverse effects of appropriate pharmaceutical agents based upon relevant considerations such as intended effect, financial considerations, possible adverse effects, patient preferences, institutional policies, and clinical guidelines.	B
		PT10	Conduct focused medication review and identify agents including nutraceuticals and complementary medicines that may be causing an adverse effect	C
		TI6	Develop protocols to avoid potential complications of interventions	A
		TI8	Assess indications, risks, benefits, and alternatives for the therapeutic intervention.	B
G16	Explain all newly prescribed drugs to elders and caregivers at discharge, assuring that they understand how and why the drug should be taken, the possible side effects, and how and when the drug should be stopped.	CS5	Communicate information to patients and families using verbal, nonverbal, written, and technological skills, and confirm understanding	B
		TC17	Explain clearly and ensure patient understanding of diagnosis, discharge instructions, and the importance of follow-up and compliance with treatments.	B
G17	Document history obtained from skilled nursing or extended care facilities of the acute events necessitating ED transfer including goals of visit, medical history, medications, allergies, cognitive and functional status, advance care plan, and responsible PCP.	CS6	Elicit information from patients, families, and other healthcare members using verbal, nonverbal, written, and technological skills	D
		CS10	Communicate pertinent information to healthcare colleagues in effective and safe transitions of care	C
G18	Provide skilled nursing or extended care facilities and/or PCP with ED visit summary and plan of care, including follow-up when appropriate.	CS10	Communicate pertinent information to healthcare colleagues in effective and safe transitions of care	C
		TC14	Identify patients who will require transfer to a facility that provides a higher level of care and coordinate this transition of care by ensuring communication with the receiving provider, completion of transfer documentation, education of the patient or surrogate the reasons for transfer, consent for transfer, and arrangement of appropriate transportation.	B
		TC16	Use appropriate tools for transitions of care, discharge instructions, prescriptions, follow-up instructions, and any pending diagnostic studies to promote effective care and decrease error	B

(*Continued on next page*)

Table 3. Continued.

Geriatric competency	Description	KSA code	Description	Level
G19	With recognition of unique vulnerabilities in elders, assess and document suitability for discharge considering the ED diagnosis, including cognitive function, the ability in ambulatory patients to ambulate safely, availability of appropriate nutrition/social support, and the availability of access to appropriate follow-up therapies.	OB9	Reassess, manage, and prognosticate the course of patients in ED observation status to determine appropriate disposition.	B
		TC13	Ensure patient has resources and tools to comply with discharge plan, which may include modifying the plan or involving additional resources (ie, PCP, social work, financial aid) to optimize compliance	B
		TC18	Correctly determine the appropriate disposition	C
G20	Select and document the rationale for the most appropriate available disposition (home, extended care facility, hospital) with the least risk of the many complications commonly occurring in elders during inpatient hospitalizations.	CS10	Communicate pertinent information to healthcare colleagues in effective and safe transitions of care	C
		OB1	Identify patients appropriate for management in ED observation status	C
		OB9	Reassess, manage, and prognosticate the course of patients in ED observation status to determine appropriate disposition.	B
		TC12	Assign admitted patients to an appropriate level of care	B
		TC14	Identify patients who will require transfer to a facility that provides a higher level of care and coordinate this transition of care by ensuring communication with the receiving clinician, completion of transfer documentation, education of the patient or surrogate the reasons for transfer, consent for transfer, and arrangement of appropriate transportation.	B
		TC18	Correctly determine the appropriate disposition	C
G21	Rapidly establish and document an elder's goals of care for those with a serious or life-threatening condition and manage accordingly.	CS3	Elicit patients' reasons for seeking healthcare and their expectations from the ED visit	D
G22	Assess and provide ED management for pain and key non-pain symptoms based on the patient's goals of care.	ES15	Elicit the patient's goals of care prior to initiating emergency stabilization, including evaluating the validity of advanced directives	B
G25	Develop plans of care that anticipate and monitor for predictable complications in the patient's condition (eg, gastrointestinal bleed causing ischemia).	DS4	Review risks, benefits, contraindications, and alternatives to a diagnostic study or procedure	C
		TI6	Develop protocols to avoid potential complications of interventions	A
G26	Communicate with patients with hearing/sight impairment	CS5	Communicate information to patients and families using verbal, nonverbal, written, and technological skills, and confirm understanding	B
		CS7	Consider the expectations of those who provide or receive care in the ED and use communication methods that minimize the potential for stress, conflict, and miscommunication	B
		CS18	Demonstrate interpersonal and communication skills including adjustment of interactions to account for factors such as culture, gender, age, language, disability, that result in the effective exchange of information and collaboration with patients, families, and all other stakeholders.	B

KSA, knowledge, skills, abilities; *ED*, emergency department; *NSAID*, non-steroidal anti-inflammatory drug; *PCP*, primary care physician.

define curricular overlap. While we were strengthened by having representation from multiple EM residency programs, other education experts may have a different interpretation of the domains and competencies and how they are typically taught. Additionally, the reviewers were not all attendings and not all geriatric-fellowship trained. Despite this, first-round consensus was very high (84-96%), which suggests shared knowledge among the group. The EM residents involved in this project have since started fellowships in medical education and palliative medicine, demonstrating their passion and additional understanding in these areas.

CONCLUSION

The geriatric competencies are included within the EM Model and knowledge, skills, abilities list. The competencies provide more detail for education or board questions. We identified areas of overlap where these subspecialty competencies can be emphasized in EM residency curriculums.

ACKNOWLEDGMENTS

The authors thank Dr. Melissa Barton, ABEM Director of Medical Affairs, for her advice in designing this study. We also thank all the members of the Society of Academic Emergency Medicine's Academy of Geriatric Emergency Medicine.

Address for Correspondence: Lauren T. Southerland, MD, MPH, The Ohio State University Wexner Medical Center, Department of Emergency Medicine, 725 Prior Hall, 376 W 10th Ave, Columbus, OH 43210. Email: Lauren.Southerland@osumc.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. Diane L. Gorgas is a board member of the American Board of Emergency Medicine. Lauren T. Southerland has contributed to some of the free educational websites mentioned in the discussion.

REFERENCES

1. Kizziah MA, Miller KN, Bischof JJ, et al. Emergency medicine resident clinical experience vs. in-training examination content: a national database study. *AEM Educ Train.* 2022;6(2):e10729.
2. Ashman JJ, Schappert SM, Santo L. Emergency department visits among adults aged 60 and over: United States, 2014–2017. *NCHS Data Brief*, no 367. Hyattsville, MD: National Center for Health Statistics. 2020.
3. American Board of Emergency Medicine. The 2019 Model of the Clinical Practice of Emergency Medicine. Available at: https://www.abem.org/public/resources/em-model. Accessed September 9, 2020.
4. American Board of Emergency Medicine. 2022 Knowledge, Skills, & Abilities. Available at: https://www.abem.org/public/resources/emergency-medicine-milestones-ksas. Accessed August 9, 2022.
5. Hogan TM, Losman ED, Carpenter CR, et al. Development of geriatric competencies for emergency medicine residents using an expert consensus process. *Acad Emerg Med.* 2010;17(3):316–24.
6. ACEP Geriatric Emergency Department Accreditation Criteria. Version July 11, 2023. Available at: https://www.acep.org/siteassets/sites/geda/documnets/ged-criteria.pdf. Accessed February 21, 2023.
7. Magidson PD and Carpenter CR. Trends in geriatric emergency medicine. *Emerg Med Clin North Am.* 2021;39(2):243–55.
8. Ringer T, Dougherty M, McQuown C, et al. White paper–geriatric emergency medicine education: current state, challenges, and recommendations to enhance the emergency care of older adults. *AEM Educ Train.* 2018;2(Suppl 1):S5–16.
9. Hogan TM, Hansoti B, Chan SB. Assessing knowledge base on geriatric competencies for emergency medicine residents. *West J Emerg Med.* 2014;15(4):409–13.
10. Hesselink G, Sir Ö, Öztürk E, et al. Effects of a geriatric education program for emergency physicians: a mixed-methods study. *Health Educ Res.* 2020;35(3):216–27.
11. Biese KJ, Roberts E, LaMantia M, et al. Effect of a geriatric curriculum on emergency medicine resident attitudes, knowledge, and decision-making. *Acad Emerg Med.* 2011;18 Suppl 2:S92–6.
12. Thatphet P, Rosen T, Kayarian F, et al. Impact of geriatric emergency fellowship training on the careers of emergency physicians. *Cureus.* 2021;13(9):e17903.

The Accuracy of Predictive Analytics in Forecasting Emergency Department Volume Before and After Onset of COVID-19

Anthony M. Napoli, MD, MHL
Rachel Smith-Shain, MD
Timmy Lin
Janette Baird, PhD

Brown University, Alpert School of Medicine, Department of Emergency Medicine, Providence, Rhode Island

Section Editor: Gayle Galletta, MD
Submission history: Submitted May 16, 2023; Revision received October 16, 2023; Accepted October 20, 2023
Electronically published December 8, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.61059

Introduction: Big data and improved analytic techniques, such as triple exponential smoothing (TES), allow for prediction of emergency department (ED) volume. We sought to determine 1) which method of TES was most accurate in predicting pre-coronavirus 2019 (COVID-19), during COVID-19, and post-COVID-19 ED volume; 2) how the pandemic would affect TES prediction accuracy; and 3) whether TES would regain its pre-COVID-19 accuracy in the early post-pandemic period.

Methods: We studied monthly volumes of four EDs with a combined annual census of approximately 250,000 visits in the two years prior to, during the 25-month COVID-19 pandemic, and the 14 months following. We compared the accuracy of four models of TES forecasting by measuring the mean absolute percentage error (MAPE), mean square errors (MSE) and mean absolute deviation (MAD), comparing actual to predicted monthly volume.

Results: In the 23 months prior to COVID-19, the overall average MAPE across four forecasting methods was 3.88% ± 1.88% (range 2.41–6.42% across the four ED sites), rising to 15.21% ± 6.67% during the 25-month COVID-19 period (range 9.97–25.18% across the four sites), and falling to 6.45% ± 3.92% in the 14 months after (range 3.86–12.34% across the four sites). The 12-month Holt-Winter method had the greatest accuracy prior to COVID-19 (3.18% ± 1.65%) and during the pandemic (11.31% ± 4.81%), while the 24-month Holt-Winter offered the best performance following the pandemic (5.91% ± 3.82%). The pediatric ED had an average MAPE more than twice that of the average MAPE of the three adult EDs (6.42% ± 1.54% prior to COVID-19, 25.18% ± 9.42% during the pandemic, and 12.34% ± 0.55% after COVID-19). After the onset of the pandemic, there was no immediate improvement in forecasting model accuracy until two years later; however, these still had not returned to baseline accuracy levels.

Conclusion: We were able to identify a TES model that was the most accurate. Most of the models saw an approximate four-fold increase in MAPE after onset of the pandemic. In the months following the most severe waves of COVID-19, we saw improvements in the accuracy of forecasting models, but they were not back to pre-COVID-19 accuracies. [West J Emerg Med. 2024;25(1)61–66.]

INTRODUCTION

Forecasting emergency department (ED) volume is critical to determining staffing needs and operational planning. Forecasting methodologies for predicting future volume have historically relied on subjective predictions paired with historical volume. However, in recent years more sophisticated methods of forecasting have been employed by pairing large-scale data availability with newer predictive analytics techniques.[1,2] Variations in ED volume due to seasonal and day of the week fluctuation have a general

pattern that can be predicted based on advanced analytical techniques.[3–5] The benefits of advanced predictive capacity include calibrating staffing to volume needs, revising labor resources with operational demands, infrastructure planning, and informing financial planning.

Various methodologies exist for attempting to predict ED volume; however, linear regression models have shown the most promise.[4,6] Such methods have been shown to predict ED volumes with low mean absolute percentage errors (MAPE). One study of four hospitals in Paris, France, found a MAPE of 5%[6] while a Dutch study found a MAPE of 8.7%.[5] Another study that incorporated less conventional time-series techniques found a MAPE of 8–10%.[7] A fourth study in two Chinese EDs used a hybrid method to obtain MAPEs in the range of 5%.[8] Lastly, one study using internet search data showed improved model accuracy when including atmospheric data and weather patterns.[9]

Triple exponential smoothing (TES) has become one of the most recognized, reliable methods of predictive analytics for anticipating unknown volumes. While methods like TES are likely more accurate than subjective volume estimates, they are predicated on the assumption of similarity between recent experience and future expectations. Highly variable periods brought on by times of extreme uncertainty, such as the COVID-19 pandemic, raise questions about how predictive analytics based on historical results would perform. We sought to determine 1) which method of TES was most accurate in predicting pre-COVID-19, during COVID-19 and post COVID-19 ED volumes; 2) what would the effect of the pandemic be on exponential smooth accuracy; and 3) whether such models could regain their pre-COVID-19 accuracy after the disruptive influence of COVID-19.

Population Health Research Capsule

What do we already know about this issue?
Predictive analytics are more accurate than subjective expert opinion for forecasting future events. However, the accuracy may be compromised by large-scale, abrupt disruptive events.

What was the research question?
Was the accuracy of forecasting methods for ED volume disrupted by the COVID-19 pandemic?

What was the major finding of the study?
Predictive models accuracy changed from mean absolute percentage errors of 3.18% ± 1.65% pre-pandemic to 11.31% ± 4.81% after onset of COVID-19.

How does this improve population health?
While abrupt disruptive events such as a pandemic may affect the accuracy of models predicting ED volume, accuracy will improve over time.

METHODS

We examined data from four EDs between March 2018–April 2023 in three adult EDs (AED) and one pediatric ED (PED) with total pre-COVID-19 annual census >250,000 patients. Each ED provided data on monthly ED census during the time period of the study, 23 months of data pre COVID-19 (March 2018–January 2020), 25 months of data during COVID-19 (February 2020–February 2022), and 14 months after COVID-19 (March 2022–April 2023). This study included four EDs with similar patient populations but different organizational structures. One ED was a PED with nearly 55,000 visits per year prior to COVID-19. The three AEDs included a suburban community ED of approximately 33,000 visits pre-COVID-19 that is a primary stroke center with an admission rate of 18%; a mixed academic/community ED of nearly 75,000 visits pre-COVID-19 that is a primary stroke center/STEMI angiography center with an admission rate of 24%; and a Level I academic urban trauma center/comprehensive stroke center with over 100,000 visits pre-COVID-19 with an admission rate of 26%.

We compared four methods of monthly volume forecasting: simple exponential smoothing with a 24-month run-up (SES); Microsoft Excel's AAA version of the exponential smoothing (ES) algorithm seasonally adjusted with a 24-month run-up; and Holt-Winter TES using 12- and 24-month run-up, both seasonally adjusted. The SES and ES models use the Excel function FORECAST.ETS, which calls for a target date, historical values for forecasting, a timeline, and seasonality (for the ES model). Holt-Winter TES models use historical data, seasonally adjusted level, and seasonality from historical data to forecast ED volume. Holt-Winter has three smoothing constants: alpha (weighting of forecast placed on recent observations); beta (weighting of forecast placed on the trend slope of recent observations); and gamma (weighting of forecast placed on the seasonality of recent observations).

We assessed the comparison of the accuracy of all four models using the root mean squared errors (RMSE), which determines how well the forecasted values fit with the observed values, the lowest RMSE being the best fitting model. Accuracy of the model was assessed using the MAPE, mean square errors (MSE) and mean absolute deviation

(MAD), comparing actual to predicted monthly volume. An acceptable level of MAPE for this study was set within one standard deviation above the average MAPE for all forecasting models from the four sites. Using this approach the acceptable level of MAPE was 5.8%. Statistical analyses were conducted using Excel (Microsoft Corporation, Redmon, WA). Accuracy of the four forecasting models pre-, during, and post-COVID-19 was assessed by counting the number of months where the forecasting was at an acceptable level of MAPSE (5.8%) divided by the total of months' forecast. This was conducted for each AED and PED site and aggregated across all sites. This study received institutional review board approval with waiver of consent.

RESULTS

In the 23 months prior to COVID-19, the overall average MAPE across four forecasting methods was 3.88% ± 1.88% (range of 2.41% to 6.42% across the four ED sites). The overall average MAPE for the 25 months during COVID-19 pandemic was 15.21% ± 6.67% during COVID-19 (range of 9.97–25.18% across the four ED sites). In the 14 months following COVID-19, the overall average MAPE was 6.45% ± 3.92% after (range of 3.86–12.34% across the four ED sites). Due to the large difference in forecasting MAPE and accuracy across all time points of interest for the PED, performance was focused on the three AEDs.

Defining an acceptable limit to the MAPE as 1 SD above the upper range pre-COVID-19 MAPE (5.8%) resulted in the overall average of all forecasting models across the three AED sites being accurate was 49% of months *during* COVID-19 (range of 42–51% for overall forecasting model accuracy) and 71.43% *after* COVID-19 (range of 64.29–82.14% for overall forecasting model accuracy). (See Table 1). Following the COVID-19 pandemic, the overall Holt-Winter TES models indicated improvements trending toward pre-COVID-19 accuracy as observed with reductions in the MAPE and improvements in forecasting accuracy within the acceptable limits of the MAPE. Among all AEDs, the 12-month Holt-Winter had the greatest accuracy prior to COVID-19 (overall 2.36% ± 0.46%) and during the pandemic (8.92% ± 1.5%), while the 24-month Holt-Winter offered the best performance following the pandemic (3.98% ± 0.9%) (Table 1). Interestingly, for AED site 1 post COVID-19, a significantly larger accuracy was obtained using the Holt-Winter 24-month model (98.26%, 95% confidence interval (CI) 89.25–96.46%). This AED has the largest patient census. One example of this shift in the dynamic visualizing the different forecasting models for one AED site (site #1) is shown in Figure 1.

The PED was consistently less accurate than the AED, with an average MAPE of 6.42% ± 1.54% prior to COVID-19, 25.18% ± 9.42% during the pandemic, and 12.34% ± 0.55% after COVID-19. When combining all four EDs, Holt-Winter models accuracy decreased from 3.18% ± 1.65 pre-COVID-19, 11.31% ± 4.81 during the pandemic and 6.16% ± 4.02 after COVID-19 for the 12-month model and decreased from 3.37% ± 1.57 pre-COVID-19 11.51% ± 5.25 during the pandemic, and 5.91% ± 3.82 after COVID-19 for the 24-month model.

DISCUSSION

Large-scale healthcare institutional decisions have been substantially improved by the introduction of predictive analytics in healthcare. Until recently, forecasting ED volumes has been subjective and largely determined by consensus estimates of hospital and ED leadership.[2,10] Using consensus opinion for forecasting volumes is most applicable in settings where institutional leadership has some control over the volume estimates and the variability is lower. Predictive analytics improve accuracy when variability is too complex for subjective estimation, where volatility may be high, and when volume of services to be rendered is out of control of the institutional leadership. Therefore, predicting ED volumes should be ideally suited for these analytical methods. Recent work has demonstrated that predictive analytics can be used to forecast ED volumes with some degree of accuracy,[1–3,5–7,9] although a 5-9% mean absolute percentage error is unacceptable for financial and logistical planning.

Our study yields several interesting findings. First, we were able to find a forecasting methodology that was superior and yielded pre-COVID-19 forecasting accuracy better than was previously reported in the literature. Our 12-month Holt-Winter TES model had a MAPE of 3.18% ± 1.65% across all four EDs. This is nearly 2–3 times better than previously reported in the literature.[1,2,4–6] Our four EDs have a combined census of approximately 250,000 visits; prior to the pandemic this would have meant TES model accuracy within ±5,000 patients. One notable exception is that pre-, during and post-COVID-19 estimates using TES in the PED demonstrated MAPE twice that of the AED counterparts (Table 1).

Under normal circumstances, this model would be an excellent one to augment or perhaps supplant subjective consensus opinion. However, the COVID-19 pandemic disrupted normal assumptions about ED volume estimates and significantly altered the forecasting landscape using predictive analytics. After the onset of the pandemic, the accuracy of this model was significantly upended and resulted in substantial reductions in accuracy. Since onset of the pandemic, the MAPE is 4–5 times larger. A MAPE of about 10% would not be tolerated and would not be considered more accurate than subjective estimates by administrative leadership. This is particularly the case in the PED, which demonstrated a MAPE nearly twice that of the AEDs. COVID-19 hampered the ability of the TES model to accurately forecast ED volume, but post-COVID-19 has

Table 1. Four forecasting models mean average percentage error and accuracy across three adult emergency departments.

	Pre-COVID-19 MAPE[1]% (95% CI)	During COVID-19 MAPE[2]% (95% CI)	Accuracy during COVID-19 /25 months% (95% CI)	Post-COVID-19 MAPE[3]% (95% CI)	Accuracy post-COVID-19 /14 months% (95% CI)
Site 1					
SES	3.68 (3.67–3.69)	11.52 (11.46–11.59)	44 (40.11–47.89)	4.29 (4.27–4.31)	78.57 (72.83–84.32)
Excel AAA	1.62 (1.61–1.63)	13.85 (13.77–13.93)	36 (32.24–39.76)	4.14 (4.12–4.16)	78.57 (72.83–84.32)
HW 12 m	2.04 (2.03–2.05)	7.40 (7.36–7.45)	68 (64.34–71.66)	3.85 (3.84–3.87)	78.57 (72.83–84.32)
HW 24 m	2.31 (2.3–2.31)	7.09 (7.04–7.13)	56 (52.11–59.89)	3.14 (3.13–3.16)	92.86 (89.25–96.46)
Average	2.41 (1.54–3.29)	9.97 (6.75–13.18)	51 (47.08–54.92)	3.86 (3.35–4.36)	82.14 (76.78–87.5)
Site 2					
SES	3.72 (3.71–3.74)	14.51 (14.41–14.62)	44 (40.11–47.89)	5.23 (5.2–5.26)	57.14 (50.21–64.07)
Excel AAA	2.45 (2.44–2.47)	18.65 (18.53–18.78)	28 (24.48–31.52)	4.15 (4.13–4.16)	78.57 (72.83–84.32)
HW 12 m	2.21 (2.2–2.22)	9.84 (9.77–9.91)	52 (48.08–55.92)	4.12 (4.09–4.15)	78.57 (72.83–84.32)
HW 24 m	2.36 (2.35–2.37)	10.61 (10.53–10.68)	44 (40.11–47.89)	4.09 (4.07–4.12)	71.43 (65.1–77.75)
Average	2.69 (2.0–3.37)	13.4 (9.43–17.37)	42 (38.13–45.87)	4.4 (3.85–4.94)	71.43 (65.1–77.75)
Site 3					
SES	7.64 (7.61–7.68)	12.95 (12.84–13.07)	36 (32.24–39.76)	7.20 (7.16–7.24)	42.86 (35.93–49.79)
Excel AAA	2.46 (2.44–2.48)	17.58 (17.38–17.77)	36 (32.24–39.76)	4.50 (4.46–4.54)	71.43 (65.1–77.75)
HW 12 m	2.82 (2.81–2.83)	9.51 (9.41–9.62)	56 (52.11–59.89)	4.37 (4.34–4.41)	71.43 (65.1–77.75)
HW 24 m	3.09 (3.07–3.1)	9.08 (8.97–9.19)	56 (52.11–59.89)	4.72 (4.68–4.76)	71.43 (65.1–77.75)
Average	4.0 (1.61–6.39)	12.28 (8.42–16.14)	46 (42.09–49.91)	5.2 (3.88–6.51)	64.29 (57.58–70.99)
AED Average					
SES	5.01 (2.44–7.59)	12.99 (11.3–14.69)	32 (28.34–35.66)	5.57 (3.89–7.25)	57.14 (50.21–64.07)
Excel AAA	2.18 (1.63–2.72)	16.69 (13.84–19.54)	40 (36.16–43.84)	4.26 (4.03–4.5)	71.43 (65.1–77.75)
HW 12 m	2.36 (1.89–2.82)	8.92 (7.42–10.41)	64 (60.24–67.76)	4.11 (3.81–4.41)	78.57 (72.83–84.32)
HW 24 m	2.59 (2.09–3.08)	8.93 (6.93–10.92)	60 (56.16–63.84)	3.98 (3.08–4.88)	78.57 (72.83–84.32)
Average	3.03 (2.01–4.05)	11.89 (9.87–13.89)	49 (45.08–52.92)	4.48 (3.71–5.26)	71.43 (65.1–77.75)

[1]Pre-COVID-19: includes ED volume from March 2018–January 2020.
[2]During-COVID-19: includes ED volume from February 2020–February 2022.
[3]Post-COVID-19: includes ED volume from March 2022–April 2023.
COVID-19, coronavirus 2019; *CI*, confidence interval; *MAPE*, mean average percentage error; *AED*, adult emergency department; *SES*, simple exponential smoothing; *HW 12 m*, Holt-Winter 12 month; *HW 24*, Holt-Winter 24 month.

shown promise. Applying previous standards of accuracy (pre-COVID-19) demonstrates the models (post-COVID-19) were, on aggregate, able to accurately predict AED volume more than 70% of the time (71.43%). Although the three models with seasonal adjustment outperformed the SES model with no seasonal adjustment, this post-COVID-19 accuracy was an improvement from the 49% accuracy of the forecasting model during-COVID-19. On the contrary, overall PED volume accuracy remained poor during-COVID-19 (17%) and post-COVID (23.21%).

LIMITATIONS

There are several limitations to our study. While this study included four EDs in the same region, it includes four departments of varying size and demographics. However, each of these EDs demonstrated the same pattern, with pediatrics showing even greater changes in accuracy. While further stability in the model might be expected over time, recurrent COVID-19 surges have not shown a predictable pattern (Figure 1), making it doubtful that forecasting will substantially improve in the short term. The data abstractors were not blinded to the study hypothesis; however, they were abstracting objective data and were not involved in the data analysis. Lastly, although the changes brought on by the COVID-19 pandemic were similar across all four of our EDs, regional variations are likely to exist, particularly based on the effect that COVID-19 surges have had on ED volumes.

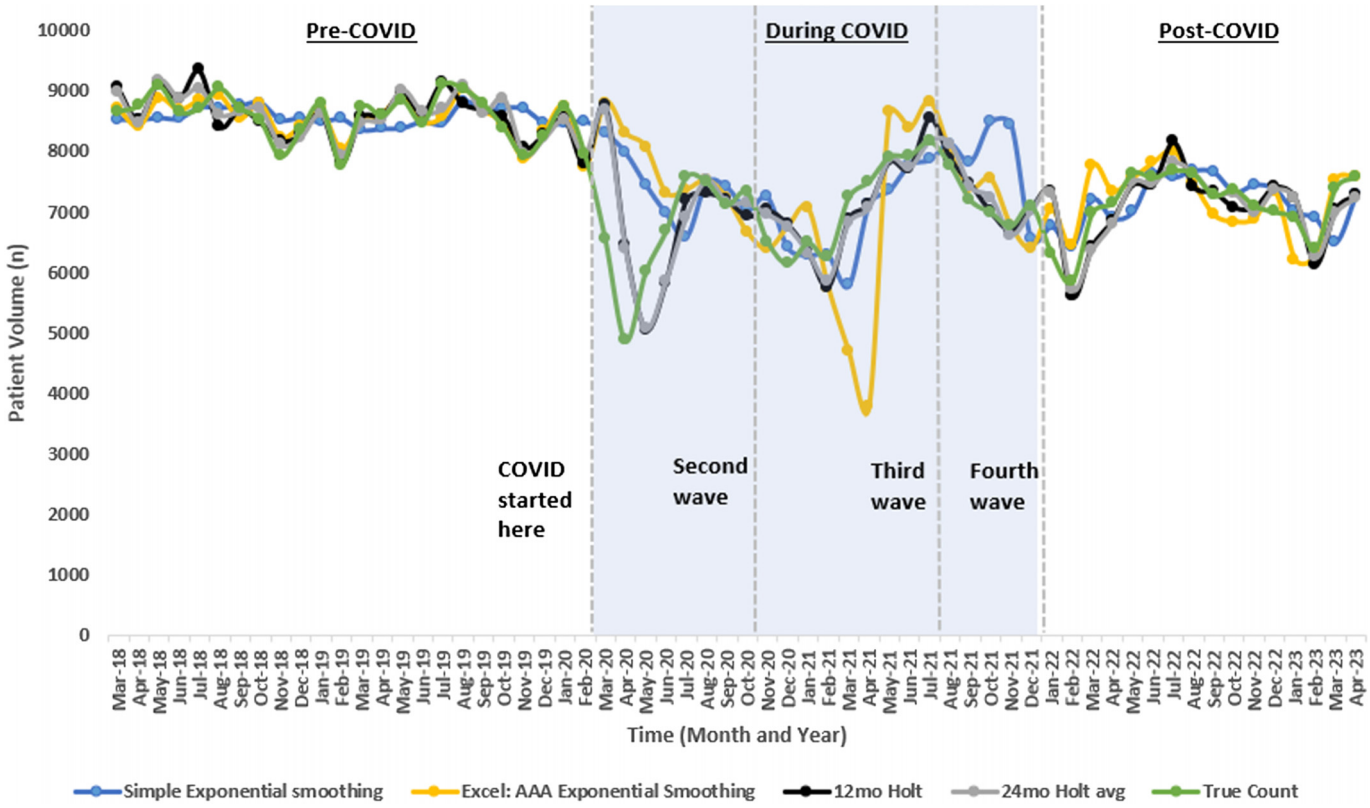


Figure 1. Adult emergency department #1 trend in actual and forecasted patient volume over time.
COVID-19, coronavirus 2019.

CONCLUSION

Under normal operating circumstances triple exponential smoothing represents an improvement in the accuracy of ED volume prediction. However, the COVID-19 pandemic significantly upset this balance, resulting in accuracy levels that are 4–5 times worse than they once were. During the pandemic, even the most accurate TES method was only able to meet pre-COVID-19 predictive accuracy levels approximately 64% of the time. Fortunately, after the pandemic, the forecasting ability did improve with predictive levels approximately 78.57% of the time. Hospital and ED operations leadership need to take this into account when forecasting budgetary needs. Future work is needed that confirms this decrease in forecasting accuracy and potentially forecast when these models will return to baseline levels of accuracy.

Address for Correspondence: Anthony Napoli, MD, Brown University, Alpert School of Medicine, Department of Emergency Medicine, 55 Claverick Street, Providence, RI 02903.
Email: anapoli@lifespan.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. Jones S, Thomas A, Evans RS, et al. Forecasting daily patient volumes in the emergency department. *Acad Emerg Medi.* 2008;15(2):159–70.
2. Tandberg D and Qualls C. Time series forecasts of emergency department patient volume, length of stay, and acuity. *Ann Emerg Med.* 1994;23(2):299–306.
3. Calegari R, Fogliatto FS, Lucini FR, et al. Forecasting daily volume and acuity of patients in the emergency department. *Comput Math Meth Med.* 2016;2016:3863268.
4. Etu EE, Monplaisir L, Masoud S, et al. A comparison of univariate and multivariate forecasting models predicting emergency department patient arrivals during the COVID-19 pandemic. *Healthcare (Basel).* 2022;10(6):1120.
5. Erkamp NS, van Dalen DH, de Vries E. Predicting emergency department visits in a large teaching hospital. *Int J Emerg.* 2021;14(1):34.
6. Wargon M, Casalino E, Guidet B. From model to forecasting: A multicenter study in emergency departments. *Acad Emerg Med.* 2010;17(9):970–8.

7. Sudarshan VK, Brabrand M, Range TM, et al. Performance evaluation of emergency department patient arrivals forecasting models by including meteorological and calendar information: A comparative study. *Comput Biol Med.* 2021;135:104541.
8. Xu Q, Tsui KL, Jiang W, et al. A hybrid approach for forecasting patient visits in emergency department. *Qual Reliab Eng.* 2016;32(8):2751–9.
9. Tideman S, Santillana M, et al. Internet search query data improve forecasts of daily emergency department volume. *J Am Med Inform Assoc.* 2019;26(12):1574–83.
10. Jones SS, Thomas A, Evans RS, et al. Forecasting daily patient volumes in the emergency department. *Acad Emerg Med.* 2008;15(2):159–70.

Development and External Validation of Clinical Features-based Machine Learning Models for Predicting COVID-19 in the Emergency Department

Joyce Tay, MD*
Yi-Hsuan Yen, MD†**
Kevin Rivera, MS‡**
Eric H Chou, MD†§**
Chih-Hung Wang, MD, PhD*‖**
Fan-Ya Chou, BS*‖**
Jen-Tang Sun, MD, MSc¶**
Shih-Tsung Han, MD, PhD#**
Tzu-Ping Tsai, MD**
Yen-Chia Chen, MD, PhD**
Toral Bhakta, DO†**
Chu-Lin Tsai, MD, ScD*‖**
Tsung-Chien Lu, MD, PhD*‖**
Matthew Huei-Ming Ma, MD, PhD*‖††

*National Taiwan University Hospital, Department of Emergency Medicine, Taipei, Taiwan
†Baylor Scott and White All Saints Medical Center, Department of Emergency Medicine, Fort Worth, Texas
‡Texas Christian University, School of Medicine, Fort Worth, Texas
§Baylor University Medical Center, Department of Emergency Medicine, Dallas, Texas
‖National Taiwan University, College of Medicine, Department of Emergency Medicine, Taipei, Taiwan
¶Far Eastern Memorial Hospital, Department of Emergency Medicine, New Taipei City, Taiwan
#Chang Gung Memorial Hospital at Linkou, Department of Emergency Medicine, Taoyuan, Taiwan
**Taipei Veterans General Hospital, Department of Emergency Medicine, Taipei, Taiwan
††National Taiwan University Hospital Yunlin Branch, Department of Emergency Medicine, Yunlin County, Taiwan

Section Editors: Stephen Liang, MD, and Elizabeth Burner, MD, MPH
Submission history: Submitted February 20, 2023; Revision received September 29, 2023; Accepted October 2, 2023
Electronically published December 22, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.60243

Introduction: Timely diagnosis of patients affected by an emerging infectious disease plays a crucial role in treating patients and avoiding disease spread. In prior research, we developed an approach by using machine learning (ML) algorithms to predict serious acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection based on clinical features of patients visiting an emergency department (ED) during the early coronavirus 2019 (COVID-19) pandemic. In this study, we aimed to externally validate this approach within a distinct ED population.

Methods: To create our training/validation cohort (model development) we collected data retrospectively from suspected COVID-19 patients at a US ED from February 23–May 12, 2020. Another dataset was collected as an external validation (testing) cohort from an ED in another country from May 12–June 15, 2021. Clinical features including patient demographics and triage information were used to train and test the models. The primary outcome was the confirmed diagnosis of COVID-19, defined as a positive reverse transcription polymerase chain reaction test result for SARS-CoV-2. We employed three different ML algorithms, including gradient boosting, random forest, and extra trees classifiers, to construct the predictive model. The predictive performances were evaluated with the area under the receiver operating characteristic curve (AUC) in the testing cohort.

Results: In total, 580 and 946 ED patients were included in the training and testing cohorts, respectively. Of them, 98 (16.9%) and 180 (19.0%) were diagnosed with COVID-19. All the constructed ML models showed acceptable discrimination, as indicated by the AUC. Among them, random forest (0.785, 95% confidence interval [CI] 0.747–0.822) performed better than gradient boosting (0.774, 95% CI

0.739–0.811) and extra trees classifier (0.72, 95% CI 0.677–0.762). There was no significant difference between the constructed models.

Conclusion: Our study validates the use of ML for predicting COVID-19 in the ED and demonstrates its potential for predicting emerging infectious diseases based on models built by clinical features with temporal and spatial heterogeneity. This approach holds promise for scenarios where effective diagnostic tools for an emerging infectious disease may be lacking in the future. [West J Emerg Med. 2024;25(1)67–78.]

INTRODUCTION

The global impact of the coronavirus 2019 (COVID-19) pandemic, caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has been far reaching.[1,2] Its clinical manifestations vary from mild to severe illness and even death, with a subset of those infected remaining asymptomatic.[3] The worldwide crisis has resulted in a significant loss of life and deeply affected global health. Effectively controlling disease transmission requires early recognition and quarantine measures; however, this was difficult before the identification of the causal pathogen and the advent of the molecular diagnostic tool during the early phase of the pandemic.

Taiwan had success in preventing COVID-19 outbreaks until mid-May 2021 when community transmission emerged and cases surged to over 3,100 in a week.[4] As of September 20, 2022, Taiwan has reported over six million cases and over 5,000 deaths. The sudden surge in cases, coupled with shortages of vaccine and testing, triggered a surge of patients seeking care in the emergency department (ED). This surge significantly impacted healthcare professionals, rendering them susceptible to burnout and emotional strain.[5–8] Tools to reduce workload and streamline processes for healthcare personnel are crucial to ease their mental health burden during a pandemic.

When facing an emerging infectious disease such as COVID-19, it is crucial to identify patients with the risk of infection and thus avoid spreading the disease into the community. For timely recognition of COVID-19 cases, various machine learning (ML) models were developed using a combination of clinical and laboratory reports,[9–12] with some requiring imaging data.[13–15] However, such data may not be readily available during ED triage, hindering early risk stratification. Moreover, any additional diagnostic tests further pose risk to healthcare personnel and require transport and movement of the patient, which should be minimized from an infection prevention and control perspective.[16] Hence, a persistent challenge remained: how to provide an accurate prediction of SARS-CoV-2 infection in suspected patients with limited modalities of data.

Population Health Research Capsule

What do we already know about this issue?
Timely diagnosis of an emerging infectious disease like COVID-19 is crucial for treatment and prevention.

What was the research question?
Can machine learning models predict COVID-19 based on features collected from different emergency departments?

What was the major finding of the study?
Random forest achieved good performance (AUC 0.785, 95% CI 0.747–0.822) for COVID-19 prediction.

How does this improve population health?
Machine learning can quickly predict COVID-19 in diverse EDs, holding promise for early diagnosis and control of emerging infectious diseases.

By employing clinical features ascertained during initial ED triage, we previously constructed ML models to create a preliminary screening mechanism that would effectively identify individuals with SARS-CoV-2 infection.[17] Based on the framework established in that earlier study, we sought external validation of our proposed methodology in the setting of an ED in a tertiary medical facility in Taiwan. Of note, this ED consists of a distinctive population of patients with dissimilar demographic characteristics (in contrast to the cohort used for the original model development). Our primary goal was to validate the feasibility of our approach, to expedite the process of risk stratification pertinent to emerging infectious diseases within the ED.

METHODS

Study Design and Setting

We previously conducted a retrospective cohort study by retrieving electronic health record (EHR) data of suspected COVID-19 patients from February 23–May 12, 2020 at the ED of Baylor Scott & White All Saints Medical Center (BAS) in Fort Worth, TX, a 574-bed, university-affiliated tertiary teaching hospital with ≈50,000 ED visits annually. In the current study, we retrospectively collected another set of patient records from suspected adult COVID-19 cases from 12 May 12–June 15, 2021 at the ED of National Taiwan University Hospital (NTUH), Taipei in Taiwan, a 2,400-bed university-affiliated tertiary teaching hospital with a daily census of ≈8,000 outpatients and 300 emergency visits. This study was approved by the Baylor Scott & White Research Institute Insitutional Review Board (No.: 344143), and by NTUH (No. 202009106RIPA), which waived the requirement for informed consent.

Study Population

In the retrospective study that served as the model development cohort, we identified all patients who presented at the ED of the study hospital with suspected COVID-19 and underwent testing for SARS-CoV-2 through the reverse transcription polymerase chain reaction (RT-PCR) method. In the current study, we also retrospectively collected clinical data for all adult (≥18 years) patients who were tested for SARS-CoV-2 using RT-PCR for suspected COVID-19 as the model's external validation cohort. The decision to perform RT-PCR tests was left to the discretion of the emergency physician or physician assistant of each patient.

Data Collection and Outcome Measures

Patient demographics, past medical histories (PMH), vital signs recorded at ED triage, and presenting symptoms were retrieved from the EHR. The comprehensive process of data collection was elaborated in our previous study.[17] A positive RT-PCR for SARS-CoV-2 confirms the diagnosis of COVID-19 (or SARS-CoV-2 infection) and was defined as the primary outcome in both cohorts. We used the model development cohort as the training/validation set to construct the ML models, and the external validation cohort was used as the testing set to evaluate the models' performance.

Data were entered, processed, and analyzed with SPSS Statistics for Windows version 27.0, (IBM Corp, Armonk, NY). We performed the assessment of data normality using the Shapiro-Wilk test for continuous variables. The results were subsequently reported as either the mean with standard deviation or the median with interquartile range. Categorical variables were denoted as proportions or percentages. To identify pertinent features, we used univariate analyses to discern disparities in outcomes among distinct groups. These analyses encompassed statistical methods such as the Student *t*-test, chi-squared test, Fisher exact test, or Mann-Whitney U test depending on the distribution. We subsequently selected variables with $P < 0.1$ on the training/validation set as the input features for the development of the ML models. We used K-fold cross-validation to train the model by setting k from 7 to 10, and the selection of k was based on the best area under the receiver operating characteristic curve (AUC) performance on the test set.

In our preceding study, we employed three distinct ML algorithms—specifically, gradient boosting, random forest, and extra trees classifiers—to construct prediction models for forecasting SARS-CoV-2 infection.[17] In the current study, we validated this approach in another ED population, wherein we replicated the predictive modeling methodology through the employment of the identical ML algorithms used in our prior research. These ML algorithms represent sophisticated ensemble techniques that amalgamate multiple individual models to enhance predictive accuracy and robustness for classification tasks. To deal with the intricate challenge posed by imbalanced data within our cohorts, we applied the synthetic minority oversampling technique (SMOTE), after technique to oversample the minority class, augmenting it by a factor of 0.6 times relative to the magnitude of the majority class. We undertook this measure to establish a more balanced representation, so that the ratio of COVID-19 positive to negative was 0.6 to 1.0 during the training phase. Subsequently, we assessed the performance metrics exhibited by the developed ML models used in the testing set.

To evaluate the performance of the models we built, we used different performance metrics, including the area under the receiver operating characteristic curve (AUC), accuracy, F1-score, precision (positive predictive value [PPV], recall (sensitivity), specificity, negative predictive value (NPV), and area under the precision-recall curve (AUPRC). We used the DeLong test for AUC and Boyd test for AUPRC for pairwise comparisons of the models' performances. All ML analyses were performed using Jupyter Notebook 6.0.3 (Project Jupyter) with Python 3.8.3 installed and the package scikit-learn 0.23.1 (Python Software Foundation).

RESULTS

The model development cohort (training/validation set) consisted of 580 cases from patients who presented to BAS, while the model validation cohort (testing set) comprised 946 cases from patients who presented to NTUH. Among them, 98 (16.9%) and 180 (19.0%), respectively, were diagnosed with COVID-19. The characteristics of the study population are shown in Table 1. The characteristics and univariate analyses of variables (features) between patients with COVID-19 are summarized in Table 2, for the training/validation and testing sets, respectively.

We selected 26 features by setting the *P*-value threshold of less than 0.1 from the model development

Table 1. Characteristics of the study population.

Variables (features)	Total (n = 1,526)	Training cohort (n = 580)	Testing cohort (n = 946)	*P* value
Demographics				
Age (years), mean (SD)	52.6 (19.4)	53.7 (18.9)	51.9 (19.6)	0.09
Gender				<0.001**
Male	670 (43.9)	213 (36.7)	457 (48.3)	
Female	856 (56.1)	367 (63.3)	489 (51.7)	
EMS transport	359 (23.5)	151 (26.0)	208 (22.0)	<0.001**
Triage				<0.001**
1	131 (8.6)	5 (0.9)	126 (13.3)	
2	315 (20.6)	149 (25.7)	166 (17.5)	
3	865 (56.7)	416 (71.7)	449 (47.5)	
4	140 (9.2)	9 (1.6)	131 (13.8)	
5	75 (4.9)	1 (0.2)	74 (7.8)	
Temperature, mean (SD)	37.3 (0.8)	37.2 (0.7)	37.4 (0.9)	<0.001**
Pulse rate, mean (SD)	96.6 (21.2)	92.8 (20.3)	99.0 (21.4)	<0.001**
Respiratory rate, mean (SD)	19.9 (4.8)	18.8 (3.6)	20.5 (5.3)	<0.001**
SBP, mean (SD)	132.6 (26.4)	137.9 (25.7)	129.3 (26.4)	<0.001**
DBP, mean (SD)	79.4 (16.4)	80.2 (16.7)	78.9 (16.2)	0.12
SpO_2, mean (SD)	96.7 (4.1)	97.4 (3.4)	96.3 (4.5)	<0.001**
Oxygen therapy	199 (13.0)	70 (12.1)	129 (13.6)	0.5
Weight, mean (SD)	73.1 (23.7)	88.9 (26.1)	63.4 (15.6)	<0.001**
Height, mean (SD)	1.7 (0.4)	1.7 (0.1)	1.7 (0.5)	0.16
BMI, mean (SD)	26.6 (7.8)	31.5 (9.0)	23.5 (4.9)	<0.001**
Smoking history				<0.001**
Yes	297 (19.5)	187 (32.2)	110 (11.6)	
No	773 (50.7)	376 (64.8)	397 (42)	
Unknown	456 (29.9)	17 (2.9)	439 (46.4)	
Travel history	348 (22.8)	36 (6.2)	312 (33.0)	<0.001**
Contact history	329 (21.6)	110 (19.0)	219 (23.2)	<0.001**
Duration, days, mean (SD)	4.1 (6)	5.7 (7.7)	3.1 (4.5)	<0.001**
AMS	123 (8.1)	30 (5.2)	93 (9.8)	0.001**
Seizures	15 (1.0)	4 (0.7)	11 (1.2)	0.36
Fever	673 (44.1)	266 (45.9)	407 (43.0)	0.42
Chills	130 (8.5)	84 (14.5)	46 (4.9)	<0.001**
Myalgia	218 (14.3)	131 (22.6)	87 (9.2)	<0.001**
Arthralgia	18 (1.2)	11 (1.9)	7 (0.7)	0.04**
Headache	199 (13.0)	116 (20.0)	83 (8.8)	<0.001**
Facial pain	9 (0.6)	4 (0.7)	5 (0.5)	0.69
Red eyes	6 (0.4)	5 (0.9)	1 (0.1)	0.02**
Otalgia	16 (1.0)	10 (1.7)	6 (0.6)	0.04**
Sore throat	332 (21.8)	81 (14.0)	251 (26.5)	<0.001**
Rhinorrhea	172 (11.3)	26 (4.5)	146 (15.4)	<0.001**
Stuffy nose	92 (6.0)	69 (11.9)	23 (2.4)	<0.001**
Sneezing	12 (0.8)	8 (1.4)	4 (0.4)	0.04**

(*Continued on next page*)

Table 1. Continued.

Variables (features)	Total (n = 1,526)	Training cohort (n = 580)	Testing cohort (n = 946)	*P* value
Postnasal drip	7 (0.5)	5 (0.9)	2 (0.2)	0.07
Hypogeusia/ageusia	14 (0.9)	3 (0.5)	11 (1.2)	0.2
hyposmia/anosmia	14 (0.9)	6 (1.0)	8 (0.8)	0.71
Hoarseness	6 (0.4)	1 (0.2)	5 (0.5)	0.28
Dysphagia	23 (1.5)	6 (1.0)	17 (1.8)	0.24
Cough	715 (46.9)	362 (62.4)	353 (37.3)	<0.001**
Sputum	197 (12.9)	47 (8.1)	150 (15.9)	<0.001**
SOB	535 (35.1)	334 (57.6)	201 (21.2)	<0.001**
Malaise	240 (15.7)	110 (19.0)	130 (13.7)	0.007**
Diarrhea	202 (13.2)	65 (11.2)	137 (14.5)	0.07
Vomiting	126 (8.3)	66 (11.4)	60 (6.3)	<0.001**
Nausea	154 (10.1)	115 (19.8)	39 (4.1)	<0.001**
Anorexia	52 (3.4)	26 (4.5)	26 (2.7)	0.07
Abdominal pain	132 (8.7)	62 (10.7)	70 (7.4)	0.03**
Chest pain	190 (12.5)	120 (20.7)	70 (7.4)	<0.001**
Hemoptysis	12 (0.8)	6 (1.0)	6 (0.6)	0.39
Skin lesion	9 (0.6)	5 (0.9)	4 (0.4)	0.28
Skin itch	9 (0.6)	3 (0.5)	6 (0.6)	0.77
Paresthesia	7 (0.5)	3 (0.5)	4 (0.4)	0.79
Back pain	51 (3.3)	38 (6.6)	13 (1.4)	<0.001**
Neuropathy	1 (0.1)	1 (0.2)	0 (0.0)	0.2
Renal colic/flank pain	18 (1.2)	15 (2.6)	3 (0.3)	<0.001**
Cormorbidities (if any)	906 (59.4)	450 (77.6)	456 (48.2)	<0.001**
Cormorbidities (>1)	646 (42.3)	355 (61.2)	291 (30.8)	<0.001**
COPD	87 (5.7)	66 (11.4)	21 (2.2)	<0.001**
Asthma	132 (8.7)	99 (17.1)	33 (3.5)	<0.001**
DM	281 (18.4)	149 (25.7)	132 (14.0)	<0.001**
HTN	497 (32.6)	276 (47.6)	221 (23.4)	<0.001**
CAD	115 (7.5)	55 (9.5)	60 (6.3)	0.02**
CHF	81 (5.3)	52 (9.0)	29 (3.1)	<0.001**
CVA	77 (5.0)	36 (6.2)	41 (4.3)	0.1
Hepatitis B	28 (1.8)	0 (0.0)	28 (3.0)	<0.001**
Hepatitis C	15 (1.0)	11 (1.9)	4 (0.4)	0.005**
Cirrhosis	20 (1.3)	14 (2.4)	6 (0.6)	0.003**
Cancer	213 (14.0)	74 (12.8)	139 (14.7)	0.29
Current chemotherapy	56 (3.7)	11 (1.9)	45 (4.8)	0.004**
CKD	102 (6.7)	76 (13.1)	26 (2.7)	<0.001**
ESRD	49 (3.2)	32 (5.5)	17 (1.8)	<0.001**
History of solid organ transplant	24 (1.6)	18 (3.1)	6 (0.6)	<0.001**
Immunodeficiency	132 (8.7)	5 (0.9)	127 (13.4)	<0.001**
HIV	11 (0.7)	4 (0.7)	7 (0.7)	0.91
Rheumatologic diseases	34 (2.2)	17 (2.9)	17 (1.8)	0.15
Dementia	24 (1.6)	11 (1.9)	13 (1.4)	0.43

(*Continued on next page*)

Table 1. Continued.

Variables (features)	Total (n = 1,526)	Training cohort (n = 580)	Testing cohort (n = 946)	*P* value
PUD	21 (1.4)	1 (0.2)	20 (2.1)	0.002**
Gastroparesis	5 (0.3)	4 (0.7)	1 (0.1)	0.05
Migraine	19 (1.2)	17 (2.9)	2 (0.2)	<0.001**
Fibromyalgia	8 (0.5)	4 (0.7)	4 (0.4)	0.48
Chronic pain syndrome	31 (2.0)	24 (4.1)	7 (0.7)	<0.001**
Alcohol use disorder	9 (0.6)	5 (0.9)	4 (0.4)	0.28
Substance use disorder	27 (1.8)	24 (4.1)	3 (0.3)	<0.001**
Depression	70 (4.6)	55 (9.5)	15 (1.6)	<0.001**
Psychiatric disease	73 (4.8)	52 (9.0)	21 (2.2)	<0.001**
Pregnancy	21 (1.4)	19 (3.3)	2 (0.2)	<0.001**

EMS, emergency medical services; *SBP,* systolic blood pressure; *DBP*, diastolic blood pressure; SpO_2, oxygen saturation; *BMI*, body mass index; *AMS*, altered mental status; *SOB*, shortness of breath; *COPD*, chronic obstruction pulmonary disease; *DM*, diabetes mellitus; *HTN*, hypertension; *CAD*, coronary artery disease; *CHF*, congestive heart failure; *CVA*, cerebrovascular accident; *CKD*, chronic kidney disease; *ESRD*, end stage renal disease; *PUD*, peptic ulcer disease.
Note: ** $P < 0.05$.

Table 2. Characteristics and univariate analyses of variables (features) between patients with or without COVID-19 on the training and testing cohorts.

	Training cohort (n = 580)			Testing cohort (n = 946)		
	COVID-19 (−) (n = 482)	COVID-19 (+) (n = 98)	*P* value	COVID-19 (−) (n = 766)	COVID-19 (+) (n = 180)	*P* value
Demographics						
Age (y), mean (SD)	54.4 (18.9)	50.3 (18.7)	0.05*	50.3 (20.3)	58.9 (14.6)	<0.001*
Gender			0.36			0.24
Female	309 (64.1)	58 (59.2)		403 (52.6)	86 (47.8)	
Male	173 (35.9)	40 (40.8)		363 (47.4)	94 (52.2)	
EMS transport	132 (27.4)	19 (19.4)	0.1	144 (18.8)	64 (35.6)	<0.001*
Triage			0.43			0.07*
1	3 (0.6)	2 (2.0)		98 (12.8)	28 (15.6)	
2	129 (26.8)	20 (20.4)		139 (18.1)	27 (15.0)	
3	342 (71.0)	74 (75.5)		352 (46.0)	97 (53.9)	
4	7 (1.5)	2 (2.0)		116 (15.1)	15 (8.3)	
5	1 (0.2)	0 (0.0)		61 (8.0)	13 (7.2)	
Temperature, mean (SD)	37.2 (0.7)	37.6 (0.7)	<0.001*	37.3 (0.8)	37.9 (0.9)	<0.001*
Pulse rate, mean (SD)	92.5 (20.7)	94.1 (18.1)	0.46	98.9 (22.2)	99.4 (18.0)	0.77
Respiratory rate, mean (SD)	18.7 (3.4)	19.5 (4.4)	0.05*	20.3 (5.4)	21.5 (4.9)	0.007*
SBP, mean (SD)	139.0 (26.2)	133.0 (22.2)	0.04*	128.9 (26.8)	130.7 (24.3)	0.42
DBP, mean (SD)	80.2 (17.2)	80.0 (13.7)	0.9	78.9 (16.7)	78.7 (14.1)	0.88
SpO_2, mean (SD)	97.6 (3.1)	96.3 (4.3)	<0.001*	96.6 (3.9)	94.9 (6.3)	<0.001*
Oxygen therapy	59 (12.2)	11 (11.2)	0.78	90 (11.7)	39 (21.7)	<0.001*
Weight, mean (SD)	87.6 (26.1)	95.0 (25.6)	0.01*	63.4 (16.3)	63.7 (12.5)	0.81
Height, mean (SD)	1.7 (0.1)	1.7 (0.1)	0.53	1.7 (0.6)	1.6 (0.1)	0.51
BMI, mean (SD)	31.1 (9.1)	33.7 (8.4)	0.009*	23.4 (5.1)	23.8 (3.8)	0.3

(*Continued on next page*)

Table 2. Continued.

	Training cohort (n = 580)			Testing cohort (n = 946)		
	COVID-19 (−) (n = 482)	COVID-19 (+) (n = 98)	*P* value	COVID-19 (−) (n = 766)	COVID-19 (+) (n = 180)	*P* value
Smoking history			<0.001*			<0.001*
Yes	169 (35.1)	18 (18.4)		80 (10.4)	30 (16.7)	
No	305 (63.3)	71 (72.4)		276 (36)	121 (67.2)	
Unknown	8 (1.7)	9 (9.2)		410 (53.5)	29 (16.1)	
Travel history	23 (4.8)	13 (13.3)	0.001*	204 (26.6)	108 (60.0)	<0.001*
Contact history	59 (12.2)	51 (52.0)	<0.001*	112 (14.6)	107 (59.4)	<0.001*
Duration, days, mean (SD)	5.9 (8.2)	5.1 (3.7)	0.35	2.9 (4.3)	3.7 (5)	0.04*
AMS	29 (6.0)	1 (1.0)	0.04*	82 (10.7)	11 (6.1)	0.06*
Seizures	4 (0.8)	0 (0.0)	0.37	10 (1.3)	1 (0.6)	0.4
Fever	197 (40.9)	69 (70.4)	<0.001*	287 (37.5)	120 (66.7)	<0.001*
Chills	72 (14.9)	12 (12.2)	0.49	36 (4.7)	10 (5.6)	0.63
Myalgia	98 (20.3)	33 (33.7)	0.004*	60 (7.8)	27 (15.0)	0.003*
Arthralgia	11 (2.3)	0 (0.0)	0.13	6 (0.8)	1 (0.6)	0.75
Headache	94 (19.5)	22 (22.4)	0.51	72 (9.4)	11 (6.1)	0.16
Facial pain	4 (0.8)	0 (0.0)	0.37	5 (0.7)	0 (0.0)	0.28
Red eyes	5 (1.0)	0 (0.0)	0.31	0 (0.0)	1 (0.6)	0.04*
Otalgia	8 (1.7)	2 (2.0)	0.79	6 (0.8)	0 (0.0)	0.23
Sore throat	70 (14.5)	11 (11.2)	0.39	205 (26.8)	46 (25.6)	0.74
Rhinorrhea	19 (3.9)	7 (7.1)	0.16	128 (16.7)	18 (10.0)	0.02*
Stuffy nose	55 (11.4)	14 (14.3)	0.42	21 (2.7)	2 (1.1)	0.2
Sneezing	7 (1.5)	1 (1.0)	0.74	4 (0.5)	0 (0.0)	0.33
Postnasal drip	4 (0.8)	1 (1.0)	0.85	2 (0.3)	0 (0.0)	0.49
Hypogeusia/ageusia	0 (0.0)	3 (3.1)	<0.001*	6 (0.8)	5 (2.8)	0.02*
hyposmia/anosmia	3 (0.6)	3 (3.1)	0.03*	6 (0.8)	2 (1.1)	0.67
Hoarseness	1 (0.2)	0 (0.0)	0.65	3 (0.4)	2 (1.1)	0.23
Dysphagia	6 (1.2)	0 (0.0)	0.27	16 (2.1)	1 (0.6)	0.16
Cough	285 (59.1)	77 (78.6)	<0.001*	248 (32.4)	105 (58.3)	<0.001*
Sputum	35 (7.3)	12 (12.2)	0.1	114 (14.9)	36 (20.0)	0.09*
SOB	277 (57.5)	57 (58.2)	0.9	141 (18.4)	60 (33.3)	<0.001*
Malaise	90 (18.7)	20 (20.4)	0.69	98 (12.8)	32 (17.8)	0.08*
Diarrhea	48 (10.0)	17 (17.3)	0.03*	114 (14.9)	23 (12.8)	0.47
Vomiting	57 (11.8)	9 (9.2)	0.45	57 (7.4)	3 (1.7)	0.004*
Nausea	92 (19.1)	23 (23.5)	0.32	36 (4.7)	3 (1.7)	0.07*
Anorexia	21 (4.4)	5 (5.1)	0.75	19 (2.5)	7 (3.9)	0.3
Abdominal pain	54 (11.2)	8 (8.2)	0.37	60 (7.8)	10 (5.6)	0.29
Chest pain	106 (22.0)	14 (14.3)	0.09*	55 (7.2)	15 (8.3)	0.59
Hemoptysis	4 (0.8)	2 (2.0)	0.28	4 (0.5)	2 (1.1)	0.37
Skin lesion	5 (1.0)	0 (0.0)	0.31	2 (0.3)	2 (1.1)	0.11
Skin itch	3 (0.6)	0 (0.0)	0.43	6 (0.8)	0 (0.0)	0.23
Paresthesia	2 (0.4)	1 (1.0)	0.45	4 (0.5)	0 (0.0)	0.33
Back pain	33 (6.8)	5 (5.1)	0.52	11 (1.4)	2 (1.1)	0.74
Neuropathy	0 (0.0)	1 (1.0)	0.03*	0 (0.0)	0 (0.0)	NA

(*Continued on next page*)

Table 2. Continued.

	Training cohort (n = 580)			Testing cohort (n = 946)		
	COVID-19 (−) (n = 482)	COVID-19 (+) (n = 98)	*P* value	COVID-19 (−) (n = 766)	COVID-19 (+) (n = 180)	*P* value
Renal colic/flank pain	12 (2.5)	3 (3.1)	0.75	3 (0.4)	0 (0.0)	0.4
Comorbidities (if any)	389 (80.7)	61 (62.2)	<0.001*	365 (47.7)	91 (50.6)	0.48
Comorbidities (>1)	304 (63.1)	51 (52.0)	0.04*	245 (32.0)	46 (25.6)	0.09
COPD	63 (13.1)	3 (3.1)	0.004*	18 (2.3)	3 (1.7)	0.58
Asthma	86 (17.8)	13 (13.3)	0.27	29 (3.8)	4 (2.2)	0.3
DM	125 (25.9)	24 (24.5)	0.77	101 (13.2)	31 (17.2)	0.16
HTN	236 (49.0)	40 (40.8)	0.14	170 (22.2)	51 (28.3)	0.08*
CAD	46 (9.5)	9 (9.2)	0.91	51 (6.7)	9 (5.0)	0.41
CHF	45 (9.3)	7 (7.1)	0.49	28 (3.7)	1 (0.6)	0.03*
CVA	35 (7.3)	1 (1.0)	0.02*	35 (4.6)	6 (3.3)	0.46
Hepatitis B	0 (0.0)	0 (0.0)	NA	23 (3.0)	5 (2.8)	0.87
Hepatitis C	10 (2.1)	1 (1.0)	0.49	4 (0.5)	0 (0.0)	0.33
Cirrhosis	14 (2.9)	0 (0.0)	0.09*	6 (0.8)	0 (0.0)	0.23
Cancer	66 (13.7)	8 (8.2)	0.13	123 (16.1)	16 (8.9)	0.01*
Current chemotherapy	9 (1.9)	2 (2.0)	0.91	43 (5.6)	2 (1.1)	0.01*
CKD	63 (13.1)	13 (13.3)	0.96	25 (3.3)	1 (0.6)	0.05*
ESRD	29 (6.0)	3 (3.1)	0.24	15 (2.0)	2 (1.1)	0.44
History of solid organ transplant	17 (3.5)	1 (1.0)	0.19	5 (0.7)	1 (0.6)	0.88
Immunodeficiency	5 (1.0)	0 (0.0)	0.31	112 (14.6)	15 (8.3)	0.03*
HIV	4 (0.8)	0 (0.0)	0.37	6 (0.8)	1 (0.6)	0.75
Rheumatologic diseases	16 (3.3)	1 (1.0)	0.22	14 (1.8)	3 (1.7)	0.88
Dementia	8 (1.7)	3 (3.1)	0.35	12 (1.6)	1 (0.6)	0.29
PUD	1 (0.2)	0 (0.0)	0.65	15 (2.0)	5 (2.8)	0.49
Gastroparesis	4 (0.8)	0 (0.0)	0.37	1 (0.1)	0 (0.0)	0.63
Migraine	15 (3.1)	2 (2.0)	0.57	2 (0.3)	0 (0.0)	0.49
Fibromyalgia	4 (0.8)	0 (0.0)	0.37	2 (0.3)	2 (1.1)	0.11
Chronic pain syndrome	20 (4.1)	4 (4.1)	0.98	5 (0.7)	2 (1.1)	0.52
Alcohol use disorder	5 (1.0)	0 (0.0)	0.31	3 (0.4)	1 (0.6)	0.76
Substance use disorder	21 (4.4)	3 (3.1)	0.56	3 (0.4)	0 (0.0)	0.4
Depression	54 (11.2)	1 (1.0)	0.002*	14 (1.8)	1 (0.6)	0.22
Psychiatric disease	47 (9.8)	5 (5.1)	0.14	17 (2.2)	4 (2.2)	1
Pregnancy	14 (2.9)	5 (5.1)	0.27	2 (0.3)	0 (0.0)	0.49

EMS, emergency medical services; *SBP*, systolic blood pressure; *DBP*, diastolic blood pressure; SpO_2, oxygen saturation; *BMI*, body mass index; *AMS*, altered mental status; *SOB*, shortness of breath; *COPD*, chronic obstruction pulmonary disease; *DM*, diabetes mellitus; *HTN*, hypertension; *CAD*, coronary artery disease; *CHF*, congestive heart failure; *CVA*, cerebrovascular accident; *CKD*, chronic kidney disease; *ESRD*, end stage renal disease; *PUD*, peptic ulcer disease.
Note: * $P < 0.1$.

cohort, encompassing six demographics, four triage data, 10 clinical symptoms, and six PMHs. Employing k as 7 for K-fold cross-validation, the classification outcomes for the three different ML models in the testing set are presented in Table 3 and Figure 1. The detailed performance metrics in terms of different k values on the training/validation and testing sets are shown in Supplementary Table 1.

Among the constructed ML models, random forest demonstrated superior performance with the highest AUC value (0.785, 95% CI 0.747–0.822), followed by gradient boosting (0.774, 95% CI 0.739–0.811) and extra trees

Table 3. Performance metrics of 7-fold cross validation for different machine learning algorithms on the testing set.

Models	AUC (95% CI)	AUPRC (95% CI)	Accuracy	F1	Sensitivity	Specificity	PPV	NPV
Gradient boosting	0.774 (0.739–0.811)	0.458 (0.381–0.534)	0.815	0.335	0.244	0.949	0.53	0.842
Random forest	0.785 (0.747–0.822)	0.497 (0.419–0.576)	0.827	0.427	0.339	0.941	0.575	0.858
Extra trees	0.72 (0.677–0.762)	0.42 (0.349–0.499)	0.792	0.426	0.406	0.883	0.448	0.863

CI, confidence interval; *AUC*, area under the receiver operating characteristic curve; *AUPRC*, area under the precision recall curve; *PPV*, positive predictive value; *NPV*, negative predictive value.

classifier (0.720, 95% CI 0.677–0.762). By fine-tuning the tradeoff between precision and recall for different thresholds to calculate the AUPRC, random forest (0.497. 95% CI 0.419–0.576) outperformed gradient boosting (0.458, 95% CI 0.381–0.534) and extra trees classifier (0.420, 95% CI: 0.349–0.499). The differences between each ML model in terms of AUC and AUPRC are not significant.

In evaluating additional performance metrics, all our ML models performed well in terms of accuracy, specificity, and NPV. Nevertheless, the performances of the F1 score, sensitivity, and PPV are suboptimal. Feature importance (presented as a heat map computed and ordered by median normalized importance across all models) is shown in

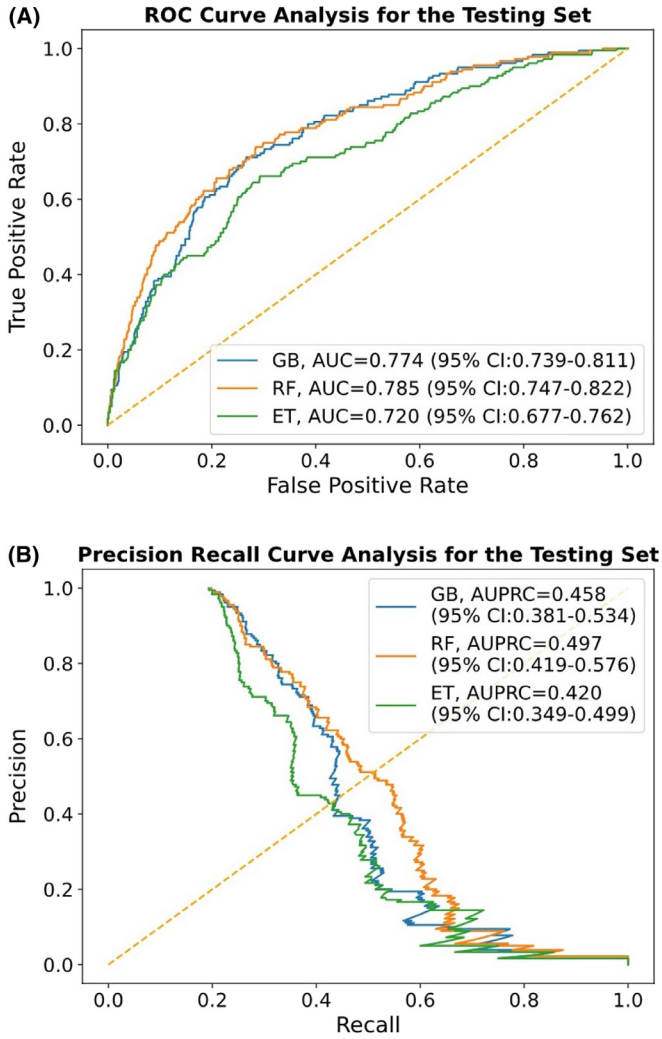


Figure 1. Results of the machine learning models on the test cohort. (A), Receiver operating characteristic (ROC) curves and the comparison of area under curve (AUC); (B), precision-recall curve and the comparison of area under the precision-recall curve (AUPRC) for three different machine learning models.
ET, extra trees; *RF*, random forest; *GB*, gradient boosting.

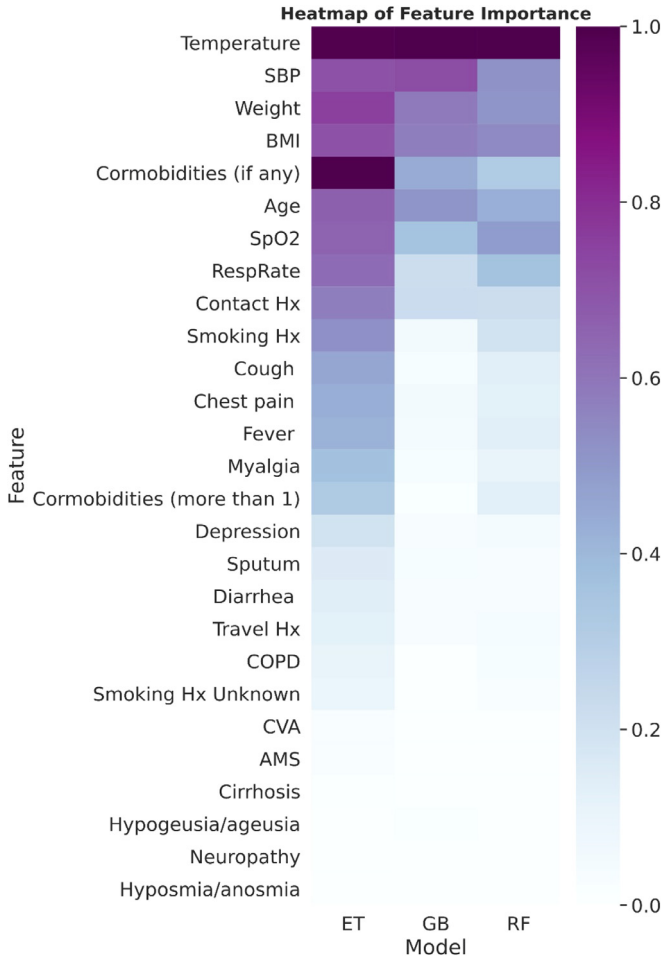


Figure 2. The heat map of computed features ordered by median normalized importance across all models.
SBP, systolic blood pressure; *BMI*, body mass index; *SPO_2*, oxygen saturation; *Hx*, history; *COPD*, chronic obstructive pulmonary disorder; *CVA, cerebrovascular accident; AMS*, altered mental state; *ET*, extra trees; *RF*, random forest; *GB*, gradient boosting.

Figure 2. The 9 most important features were temperature, systolic blood pressure, weight, body mass index, any co-morbidities, age, oxygen saturation, respiratory rate, and contact history.

DISCUSSION

The Main Findings of This Study

In our previous study, we constructed ML models designed to predict COVID-19 based on the clinical features documented during ED triage within a tertiary teaching hospital in the US during the first wave of the COVID-19 pandemic.[17] In the current study, our objective was to validate this approach externally in another ED population of a medical center located elsewhere in the world. By collecting a cohort of 946 consecutive ED patients visiting NTUH during the second wave of the COVID-19 pandemic in Taiwan, we found that the random forest model emerged as the best performer with acceptable discrimination performance in terms of AUC and AUPRC. However, the remaining two models also achieved close results without significant differences, and all models performed well in accuracy, specificity, and NPV. With only demographics, vital signs at triage, clinical symptoms, contact history and PMH collected at ED triage, this approach exemplifies the feasibility of predicting COVID-19 at triage even before patients go into the ED. The predictive results offer valuable assistance to emergency physicians in identifying patients at risk of the disease. This enables such patients to undergo further examination, testing, isolation, and appropriate treatment measures.

Comparison with Previous Studies

Since the inception of the disease, ML algorithms have been extensively applied in fighting COVID-19.[18] While certain applications targeted COVID-19 diagnosis as the primary outcome, others focused on morbidity and mortality for patients with confirmed SARS-CoV-2 infection.[10] Some investigations focused on the ED setting, while others focused on the general population.[19,20] Moreover, some reports used chest radiographs or computed tomography of the lung to exploit imaging characteristics to differentiate pneumonia caused by SARS-CoV-2 from that with other causes,[13,14,15] while others used routine blood test results.[9,11,12] Meanwhile, certain reports employed clinical data—including patient demographics, symptoms, vital signs, and PMH—as the input of prediction models similar to our study design.[21] Furthermore, there were studies that combined multiple modalities from the above-mentioned studies.[22] Although the source and size of the studies reported in the literature varied, our current study is the only one that uses only the clinical features collected from ED triage and provides promising external validation results.

In comparison to this study, our previous study yielded a stronger result with an AUC of 0.86, whereas the best-performing model in this study achieved only an AUC of 0.785. The decline in performance was anticipated since the test dataset in the previous study came from the same population as the training dataset, whereas in this study the two datasets came from different populations with different patient demographics. Additionally, certain features used in our previous study that rely on the model development cohort were not employed in this validation study due to different healthcare systems and ethnicity distribution in different populations. Nonetheless (with the exception of the study by Zoabi et al), the models we built in the current study showed competitive or even better performance in comparison to other studies that relied on clinical features for their models[19–22] (Supplementary Table 2).

Feasibility for Clinical Application

This study achieved acceptable predictive performances with metrics exceeding 0.7 in terms of AUC, specificity, and NPV, making these ML models a suitable screening tool to rule in patients in need of further attention. With the information readily accessible from the EHR during ED triage, our model may assist emergency clinicians to segregate patients with a high likelihood of COVID-19 infection from those at lower risk. By doing so, the risk of cross-infection may be minimized, and high-risk patients may receive appropriate care promptly. If effectively integrated into the system as an automated alert system during the initial ED encounter, it could exert substantial impact on clinical workflows while simultaneously reduce disease transmission and cross-infection in the ED setting. However, precision must be exercised to ensure the alerts provided by the predictive model are pertinent and timely, without disrupting the existing workflow.[23]

At present, a confirmed diagnosis of COVID-19 is made by direct detection of SARS-CoV-2 RNA using RT–PCR testing; however, it may take up to eight hours to obtain the test result after the sample is delivered.[24] Although several rapid antigen tests (RAT) have been developed as screening tools, their accuracy is strongly affected by the pretest probability and is less effective in the asymptomatic population.[25] Moreover, many regions worldwide still lack the capacity for RAT kits. As the COVID-19 pandemic persists and new variants emerge, a reliable ML prediction model could function as a rapid screening tool to quickly differentiate the suspicious cases from other patients and facilitate infection control even before patients enter the ED. Additionally, this study also provides a proof of concept for ML models capable of predicting an emerging infectious disease of an unknown pathogen based on models built by clinical features without the necessity of pathogen-specific tests. When faced with an emerging novel infectious disease in the future, this approach would be extremely valuable, particularly in situations where a dedicated diagnostic tool

has yet to be developed or encounters challenges related to supply and demand.

LIMITATIONS

This study does come with limitations. First, a class imbalance issue was evident. With only 16.9% and 19.0% being diagnosed with COVID-19 in our development and validation cohorts, the diagnostic performances in terms of sensitivity and PPV were suboptimal. However, the performance of AUPRC was acceptable given that the positivity rate of COVID-19 in the testing cohort was only 19%. Second, the study was conducted before widespread vaccination was available in the US (for the training/validation dataset) and in Taiwan (for the test dataset).[17] and prior to the emergence and dominance of the Omicron variant.[26] The difference in symptoms could affect the accuracy of the model when the models were trained with cases of different variants of SARS-CoV-2.[27] However, this approach could be aptly adapted in the future as the model is continuously trained and updated to reflect the new attributes of variant pathogens. It is essential that further prospective studies are undertaken to examine the feasibility of this model being applied to future patients.

CONCLUSION

Our machine learning approach exhibited acceptable discriminatory performance for screening patients with suspected COVID-19, based on models built in a different patient population characterized by temporal and spatial heterogeneity, and relying solely on clinical features captured during ED triage. This study offers a proof of concept, suggesting the applicability of an ML approach in diagnosing novel emerging infectious diseases within one region by drawing on clinical features collected from another region, especially in circumstances preceding the advent and availability of a rapid diagnostic tool.

Addresses for Correspondence: Tsung-Chien Lu, MD, PhD, National Taiwan University Hospital, Department of Emergency Medicine, No. 7, Zhongshan S. Rd., Zhongzheng Dist., Taipei City 100, Taiwan. Email: jonathanlu@ntu.edu.tw
Matthew Huei-Ming Ma, MD, PhD, National Taiwan University Hospital Yunlin Branch, Department of Emergency Medicine, No. 579, Sec. 2, Yunlin Rd., Douliu City, Yunlin County 640, Taiwan. Email: mattma.tw@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. This work was supported with grants from National Health Research Institutes (NHRI), Taiwan (NHRI-EX112-11137PI), and National Science and Technology Council (NSTC), Taiwan (109-2823-8-002-013-CV). The funders had no role in the design or conduct of the study; collection, management, analysis, or interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit the manuscript for publication. There are no conflicts of interest to declare.

REFERENCES

1. Zhu N, Zhang D, Wang W, et al. A novel coronavirus from patients with pneumonia in China, 2019. *N Engl J Med*. 2020;382(8):727–33.
2. Machhi J, Herskovitz J, Senan AM, et al. The natural history, pathobiology, and clinical manifestations of SARS-CoV-2 infections. *J Neuroimmune Pharmacol*. 2020;15(3):359–86.
3. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*. 2020;395(10223):497–506.
4. Zennie M, Tsai G: How a false sense of security, and a little secret tea, broke down Taiwan's COVID-19 defenses. *Time*, 2021. Available at: https://time.com/6050316/taiwan-covid-19-outbreak-tea/. Accessed July 7, 2022.
5. Cheng J and Wibawa T: Taiwan, once a COVID-19 success story, is now struggling with a spike in cases and vaccine shortages. *ABC News* 2021. Available at: https://www.abc.net.au/news/2021-05-27/taiwan-covid-19-rising-cases-vaccine-shortage-expensive-tests/100161458/. Accessed July 7, 2022.
6. Chiang S: Netflix Taiwan apologizes for meme mocking COVID rapid test 'shortage', *Taiwan News*, 2022. Available at: https://www.taiwannews.com.tw/en/news/4547537/. Accessed Jul 7, 2022.
7. Chen R, Sun C, Chen JJ, et al. A large-scale survey on trauma, burnout, and posttraumatic growth among nurses during the COVID-19 pandemic. *Int J Ment Health Nurs*. 2021;30(1):102–16.
8. Chang YT and Hu YJ. Burnout and health issues among prehospital personnel in Taiwan fire departments during a sudden spike in community COVID-19 cases: a cross-sectional study. *Int J Environ Res Public Health*. 2022;19(4):2257.
9. Brinati D, Campagner A, Ferrari D, et al. Detection of COVID-19 infection from routine blood exams with machine learning: a feasibility study. *J Med Syst*. 2020;44(8):135.
10. Heldt FS, Vizcaychipi MP, Peacock S, et al. Early risk assessment for COVID-19 patients from emergency department data using machine learning. *Sci Rep*. 2021;11(1):4200.
11. Banerjee A, Ray S, Vorselaars B, et al. Use of machine learning and artificial intelligence to predict SARS-CoV-2 infection from full blood counts in a population. *Int Immunopharmacol*. 2020;86:106705.
12. Soltan AAS, Kouchaki S, Zhu T, et al. Rapid triage for COVID-19 using routine clinical data for patients attending hospital: development and prospective validation of an artificial intelligence screening test. *Lancet Digit Health*. 2021;3(2):e78–87.
13. Wu Z, Li L, Jin R, et al. Texture feature-based machine learning classifier could assist in the diagnosis of COVID-19. *Eur J Radiol*. 2021;137:109602.

14. Qaid TS, Mazaar H, Al-Shamri MYH, et al. Hybrid deep-learning and machine-learning models for predicting COVID-19. *Comput Intell Neurosci*. 2021;2021:9996737.
15. Sedik A, Iliyasu AM, Abd El-Rahiem B, et al. Deploying machine and deep learning models for efficient data-augmented detection of COVID-19 infections. *Viruses*. 2020;12(7):769.
16. Centers for Disease Control and Prevention: Interim infection prevention and control recommendations for healthcare personnel during the coronavirus disease 2019 (COVID-19) pandemic. Available at: https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-control-recommendations.html. Accessed July 1, 2022.
17. Chou EH, Wang CH, Hsieh YL, et al. Clinical features of emergency department patients from early COVID-19 pandemic that predict SARS-CoV-2 infection: machine-learning approach. *West J Emerg Med*. 2021;22(2):244–51.
18. Mondal MRH, Bharati S, Podder P. Diagnosis of COVID-19 using machine learning and deep learning: a review. *Curr Med Imaging*. 2021;17(2):1403–18.
19. Zoabi Y, Deri-Rozov S, Shomron N. Machine learning-based prediction of COVID-19 diagnosis based on symptoms. *NPJ Digit Med*. 2021;4(1):3.
20. Martinez-Velazquez R, Tobón V, DP, Sanchez A, et al. A machine learning approach as an aid for early COVID-19 detection. *Sensors (Basel)*. 2021;21(12):4202.
21. Tostmann A, Bradley J, Bousema T, et al. Strong associations and moderate predictive value of early symptoms for SARS-CoV-2 test positivity among healthcare workers, The Netherlands, March 2020. *Euro Surveill*. 2020;25(16):2000508.
22. Mei X, Lee HC, Diao KY, et al. Artificial intelligence-enabled rapid diagnosis of patients with COVID-19. *Nat Med*. 2020;26(8):1224–8.
23. McGreevey JD3rd, Mallozzi CP, Perkins RM, et al. Reducing alert burden in electronic health records: state of the art recommendations from four health systems. *Appl Clin Inform*. 2020;11(1):1–12.
24. News 18: Know the result time of Covid-19 RT-PCR test and why it takes long. Available at: https://www.news18.com/news/india/know-the-result-time-of-covid-19-rt-pcr-test-and-why-it-takes-long-3142547.html. Accessed September 18, 2022.
25. Fernandez-Montero A, Argemi J, Rodríguez JA, et al. Validation of a rapid antigen test as a screening tool for SARS-CoV-2 infection in asymptomatic populations. Sensitivity, specificity and predictive values. *EClinicalMedicine*. 2021;37:100954.
26. Centers for Disease Control and Prevention: COVID Data Tracker: Variant Proportions," US Department of Health and Human Services, CDC. Available at: https://covid.cdc.gov/covid-data-tracker/#variant-proportions. Accessed September 18, 2022.
27. Menni C, Valdes AM, Polidori L, et al. Symptom prevalence, duration, and risk of hospital admission in individuals infected with SARS-CoV-2 during periods of omicron and delta variant dominance: a prospective observational study from the ZOE COVID Study. *Lancet*. 2022;399(10335):1618–24.

Pregnancy Complications After *Dobbs*: The Role of EMTALA

Kimberly Chernoby, MD, JD, MA*
Brian Acunto, DO, EJD†

*George Washington University School of Medicine and Health Sciences, Department of Emergency Medicine, Washington, D.C.
†Atlanticare Regional Medical Center, Department of Emergency Medicine, Galloway, New Jersey

Section Editors: Mark Langdorf, MD, MHPE, and Melanie Heniff, MD, JD
Submission history: Submitted June 27, 2023; Revision received November 2, 2023; Accepted November 14, 2023
Electronically published January 4, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.61457

In June 2023, the Supreme Court declared that there was no longer a right to abortion under the federal constitution. This decision has allowed states to promulgate different restrictions on abortion, many of which implicate the practice of emergency medicine. An abortion is defined as a "medical intervention provided to individuals who need to end the medical condition of pregnancy" and includes care such as termination of an ectopic pregnancy and induction of labor for previable preterm premature rupture of membranes—interventions that emergency physicians either perform or rely on the assistance of consultants to perform. State bans on abortion must be evaluated against duties under the Emergency Medical Treatment and Labor Act, a federal law that preempts state law. In this paper we examine the conflict between state and federal law as it applies to emergency abortion care and describe how emergency physicians can continue caring for patients. [West J Emerg Med. 2024;25(1)79–85.]

DISCLAIMER

This paper does not constitute legal advice nor should it be construed as such. Instead, this paper is for educational purposes only and identifies for physicians key legal points to consider when caring for patients with pregnancy complications in a state with abortion restrictions as a therapeutic option. Only an attorney licensed in the state you are practicing can give you legal advice on this matter.

PREGNANCY COMPLICATIONS AFTER *DOBBS*: THE ROLE OF EMTALA

Emergency physicians are trained to take care of patients with any complaint at any time of day. This core responsibility includes taking care of pregnant patients. However, what used to be routine medical care has devolved into a rapidly shifting paradigm after a US Supreme Court decision in June 2022 ended the federal constitutional protection of the right to abortion. Since *Dobbs v Jackson Women's Health Organization*, abortion restrictions have proliferated across states. These state laws are being interpreted in some instances as restricting the medical care that can be provided to pregnant patients—signaling a steep departure from the standard of care. However, despite changing state abortion laws, the Emergency Medical Treatment and Labor Act (EMTALA) still requires that emergency physicians provide stabilizing treatment for patients with emergency medical conditions. This federal law preempts conflicting state laws; so even in the face of state abortion restrictions, physicians need to be cognizant of their duties under EMTALA to render stabilizing medical care, which in some circumstances includes emergency abortion care.

PREGNANCY COMPLICATIONS IN THE EMERGENCY DEPARTMENT

Pregnancy complications are the fifth most common reason women between ages 15–64 visit emergency departments (ED) in the United States.[1] As many as 84% of pregnant people visit an ED during pregnancy.[2] While some emergency physicians have the benefit of an in-house obstetrician (OB), many do not. In the last 13 years, 217 rural hospitals have closed their labor and delivery units.[3] This means that an increasing number of emergency physicians are responsible for managing pregnancy complications, including discharging and transferring patients appropriately, without the support of an in-house OB.

THE LEGAL HISTORY OF THE RIGHT TO ABORTION IN THE UNITED STATES

In 1973, the US Supreme Court recognized a federal constitutional right to abortion in *Roe v Wade*.[4] In an earlier case related to the right to birth control, the Supreme Court found that people have a right to privacy in their intimate relationships.[5] In *Roe* the Court found that this right to privacy also included the right to abortion. This right was affirmed in several subsequent decisions and was said to extend to the point of fetal viability. Under the legal framework that emerged over the course of 50 years, states could pass restrictions on abortion such as waiting periods and mandatory ultrasounds unless the restriction posed an undue burden on abortion access, but patients ultimately still had a right to obtain an abortion up until the point of fetal viability. This meant that when pregnant patients presented with emergency medical conditions prior to fetal viability, physicians could offer abortions as part of emergency medical care.

In 2018, Mississippi enacted a 15-week abortion ban.[6] On its face, this law violated prior Supreme Court holdings, and usually such a law would be struck down as unconstitutional. However, the challenge to this law gave the Supreme Court the opportunity to revisit its decision in *Roe*. In *Dobbs v Jackson Women's Health Organization*, an abortion clinic in Mississippi challenged the state's 15-week abortion ban as unconstitutional. When this case made its way to the Supreme Court, the Court had to decide whether its prior decision related to abortion (*Roe*) should stand.

Stare decisis is the principal that courts will adhere to prior decisions, also known as precedents.[7] In this instance, it would mean that the Supreme Court would strike down the Mississippi law because it had already decided that the US Constitution protected the right to abortion up until the point of viability, which is well beyond 15 weeks of gestation. The Supreme Court has also held, however, that in very extraordinary circumstances it will not apply stare decisis, and instead it will overrule precedent. That is what happened in *Dobbs* when the Court overturned *Roe* and held that the right to privacy in the US Constitution does not protect the right to abortion.

The Tenth Amendment to the US Constitution says that if a power is not delegated to the federal government, then it is generally reserved to the states. Since there is no longer a right to abortion under the federal constitution, states have been able to make their own laws pertaining to abortion. Some states already had state constitutional protections for the right to abortion at the time of *Dobbs*, and others have since acted to protect the right to abortion, with three states enshrining the right to abortion in state constitutions. More commonly, though, *Dobbs* has led to state restrictions on abortion, including abortion bans. *Dobbs* allowed previously existing but not enforced bans to go into effect, while in other instances state legislatures have passed new abortion bans. There are currently 15 states with near-total bans (three of which are not in effect pending litigation) and four states with gestational bans that previously would have been unconstitutional.[8]

Some abortion bans that have been enacted since *Dobbs* are less restrictive than others. For example, some bans apply to all gestational ages while others only apply to later gestational ages. Some bans include an exception or affirmative defense in cases where the health and life of a pregnant person is in jeopardy, while others only include an exception or affirmative defense for the life of a pregnant person. Other exceptions may include rape, incest, or fetal anomalies. Shown in the Table are abbreviated examples of two state abortion bans and associated exceptions. State A illustrates a less restrictive ban and State B illustrates a more restrictive ban. These are excerpts and do not include the full scope of the abortion bans, such as language related to aiding and abetting in the provision of an abortion.

RELEVANCE OF ABORTION TO EMERGENCY MEDICINE

The term "abortion" has a clinical meaning that is very broad. However, the term has been stigmatized and so is often underused. Frequently, physicians provide care that is

Table. Examples of abortion bans.

Examples of abortion bans
State A
(a) It shall be unlawful for any person to intentionally perform or attempt to perform an abortion except as provided for by subsection (b).
(b) An abortion shall be permitted if an attending physician licensed in State A determines that an abortion is necessary in order to prevent a serious health risk to the unborn child's mother.
State B
(a) Every person who performs or attempts to perform an abortion as defined in this chapter commits the crime of criminal abortion.
(b) It shall be an affirmative defense to prosecution under ... this section ... that:
(i) The physician determined, in his good faith medical judgment and based on the facts known to the physician at the time, that the abortion was necessary to prevent the death of the pregnant woman.

technically an abortion, but they do not characterize the care as abortion care.[9] It is unclear whether this failure to accurately characterize care is deliberate, or because physicians do not know that the care they are providing is an abortion. This is problematic because physicians may not understand that they are potentially providing care that is banned under relevant state law. Additionally, patients also understand the term abortion to mean very different things, adding complexity to the dialogue between physicians and patients when managing pregnancy complications.[10]

Abortion is defined by the American College of Obstetricians and Gynecologists as "a medical intervention provided to individuals who need to end the medical condition of pregnancy."[11] State laws can be similarly broad. For example, one state defines abortion as "the termination of human pregnancy with an intention other than to produce a live birth or remove a dead fetus."[12] Many states specifically carve out procedures such as termination of an ectopic pregnancy with language that includes in its definition, for example, "an act is not an abortion if the act is done with the intent to . . . remove an ectopic pregnancy."[13] It is important that emergency physicians be aware of the broad technical definition of abortion, so that they can be cognizant of applicable laws.

Although not intuitive, these definitions includes interventions such as providing methotrexate for an ectopic pregnancy or induction of labor for previable preterm premature rupture of membranes (PPROM).As methotrexate terminates an ongoing pregnancy, this constitutes an abortion.[14] Similarly, management of previable PPROM can include either a dilation and evacuation (D&E) done in an operating room or an induction of labor (induction abortion), both of which are forms of abortion. In 2012, the American College of Emergency Physicians issued a clinical policy related to early pregnancy complications that included administration of methotrexate in the ED for ectopic pregnancies.[15] This means that emergency physicians may find themselves providing care that constitutes an abortion, or consulting colleagues for care that constitutes an abortion.

This is particulary important for emergency physicians to understand because there are instances in which a patient may present to an ED with an ectopic or PPROM and not yet be in extremis. In such a situation, an abortion ban with no exception for the health of a mother may be interpreted as banning an abortion for these patients, even though an abortion is considered the standard of care. Patients are being denied appropriate treatment and suffering as a result. A Texas hospital has stopped offering emergency abortion care for patients with previable pregnancy complications in response to the state's abortion ban, and the morbidity rate for patients has gone from 33% to 57%.[13] This is not limited to one state but is in fact happening across the country:

- In August 2022, a patient presented to hospitals in Missouri and Kansas with PPROM at 17 weeks gestation. She was denied emergency abortion care at both hospitals and was sent home to watch for signs of sepsis, hemorrhage, or active labor. She traveled across state lines to obtain the abortion she needed.[16] The Department of Health and Human Services (HHS) investigated two hospitals that did not provide abortion care (D&E or induction of labor) that she needed, and both hospitals were found to have violated EMTALA for not providing the stabilizing care (abortion) that the patient needed.[17,18,19]
- In December 2022, two women went to two separate Florida hospitals, both with previability PPROM. One patient was discharged without the emergency abortion she needed and delivered the fetus out of hospital the following day. She required emergency surgery and was subsequently admitted to the intensive care unit in critical condition. The other patient was repeatedly discharged with return precautions, including when she was four centimeters (cm) dilated, and was ultimately admitted for spontaneous delivery when she was in active labor. Both patients required subsequent surgeries that may limit their future fertility.[20]
- In February 2023, a patient presented to a hospital in Oklahoma and was diagnosed with a malignant molar pregnancy that required an abortion. She was not offered the abortion she needed but was told to wait in the parking lot until she decompensated so that she could receive life-saving care in a timely manner. She traveled across state lines to obtain the abortion she needed.[21]
- In March 2023, five women sued the state of Texas for their abortion ban in light of harms suffered from being denied critical abortion care. Two of the women suffered previable PPROM and were denied D&Es or inductions of labor.[22]

These cases are not happening in isolation. There are over 50 reports from across the country of patients receiving different iterations of sub-standard care because of state abortion bans, including being inappropriately discharged with PPROM only to return septic, or being discharged with ectopic pregnancies implanted in C-section scars only to later require a hysterectomy.[23] Emergency physicians may be liable for this care when they are the physician discharging the patient, especially given requirements under EMTALA.

EMERGENCY MEDICAL TREATMENT AND LABOR ACT

EMTALA is a federal law enacted in 1986 to ensure that patients have access to emergency medical care regardless of their ability to pay.[24] EMTALA requires that any patient who presents to an ED is offered a medical screening exam.[25]

The medical screening exam must be performed to determine whether an emergency medical condition exists.[26] An emergency medical condition is defined under EMTALA as "a condition manifesting itself by acute symptoms of sufficient severity (including severe pain) such that the absence of immediate medical attention could reasonably be expected to result in placing the individual's health (or the health of an unborn child) in serious jeopardy, serious impairment to bodily functions, or serious dysfunction of bodily organs."[27] If an emergency medical condition is present, then a physician must provide either stabilizing care within the capacity of the hospital or risk-minimizing medical treatment and an appropriate transfer to another medical facility if such stabilizing care is not available.[28] It is important to note that the Supreme Court has previously held that the motive behind a transfer does not matter when determining whether a transfer of care is within the bounds of EMTALA.[29]

If a physician, including an emergency physician or on-call consultant, fails to provide required stabilizing care under EMTALA, they can be personally liable for fines up to $119,942 for each violation.[30,31] This is in addition to fines levied on the hospital, as well as a personal civil action patients may initiate against hospitals. If an on-call physician is not available or refuses to provide the needed care, the emergency physician can discharge their EMTALA duty by arranging an appropriate transfer, although the on-call physician will still be liable for violating EMTALA. EMTALA is relevant to the care of pregnant patients experiencing complications because it requires stabilizing treatment and care, which in some cases is an abortion.

EMTALA AND STATE ABORTION BANS

Article VI, Clause 2 of the US Constitution establishes what is known as the Supremacy Clause.[32] The Supremacy Clause of the Constitution means that where there are conflicting federal and state laws, federal law controls. In other words, federal laws generally preempt conflicting state laws. In the instance of abortion bans, that means that the requirement to provide stabilizing treatment under EMTALA, including emergency abortion care, preempts conflicting state laws such as abortion bans. In July 2022, the HSS issued guidance to clarify that EMTALA requires abortion care despite contrary state laws.[33] Specifically, the guidance states:

> "If a physician believes that a pregnant patient presenting at an emergency department is experiencing an emergency medical condition as defined by EMTALA, and that abortion is the stabilizing treatment necessary to resolve that condition, the physician must provide that treatment. When a state law prohibits abortion and does not include an exception for the life of the pregnant person — or draws the exception more narrowly than EMTALA's emergency medical condition definition — that state law is preempted."

Shortly after this guidance was issued, two federal courts considered the relationship between EMTALA and state abortion bans.[34] A federal court in Idaho found that ETMALA preempted the state's abortion ban, and enjoined the state's abortion ban insofar as it conflicted with EMTALA, noting the role of the Supremacy Clause.[35] Specifically, the state had a narrow exception that only allowed abortions to be done to prevent death but did not provide an exception to protect the health of the pregnant person. The court found that this narrow exception conflicted with the requirements of EMTALA to provide emergency abortion care when the health or organ function of a patient was threatened and as such was preempted. The court issued an injunction against the state abortion ban.[36] However, the law was subsequently amended to exclude treatment of ectopic and molar pregnancies from the ban, and the state Supreme Court wrote in an opinion upholding the abortion ban that the law did not apply to nonviable pregnancies.[37,38] Subsequently, a panel of judges from the Ninth Circuit Court of Appeals reversed the original circuit court decision holding that the Idaho abortion ban as amended, and with the state Supreme Court's clarifying decision, did not conflict with EMTALA.[39]

Most recently, the Ninth Circuit Court of Appeals issued an order vacating the panel decision, and the case will be reheard in front of the entire Court (en banc).[40] In a challenge brought by the state of Texas, a federal court in Texas ruled that the Texas abortion ban was not in conflict with EMTALA and, therefore, the state law was not preempted. Consequently, the HHS guidance regarding emergency abortion care was enjoined in Texas and against members of certain medical societies that joined that lawsuit. Both the Idaho and Texas cases are on appeal.[41] As states choose to define medical emergencies differently, and have differing thresholds that trigger exceptions to abortion bans, this tension between state law and EMTALA will continue to be an issue for practicing physicians.

MANAGING PREGNANCY COMPLICATIONS AFTER *DOBBS*

Given the ongoing tension between state abortion bans and EMTALA, it is essential for physicians to be aware of any relevant laws in the geographic area they are practicing. When providing emergency medical care for a pregnant patient who needs an abortion, understanding that the term abortion may include care physicians don't routinely think of as an abortion, the first thing to consider is whether the state has an abortion ban and whether it applies to the gestational age of the pregnancy in question. If a physician is practicing in a state that does not have an abortion ban, then they can provide whatever care is indicated. If a physician is practicing

in a state that has an abortion ban and it applies to the patient's pregnancy based on gestational age, then the next question to consider is whether any exceptions or affirmative defenses apply. For example, if a patient who is seven weeks pregnant presents with a tubal ectopic pregnancy, and the state has a law banning abortion after 12 weeks, then the abortion ban does not apply to the patient and the physician can proceed normally. If there was a six-week abortion ban, then the physician would need to consider whether any of the exceptions apply.

To know if any exceptions to a state abortion ban apply to a patient, a physician will need to be familiar with the abortion laws in their state. Broadly, the two exceptions that are relevant to emergency physicians are exceptions for health and/or life of the pregnant person. Other exceptions that may be relevant would include exceptions for specific diagnoses such as ectopic pregnancy or PPROM. An example of applying an exception for the life of a pregnant person would be if a patient has a ruptured ectopic pregnancy and is unstable. Even if the pregnancy still has cardiac activity, that patient would meet an exception that allows for abortion to protect the life of the pregnant person. The above examples from State A and State B both illustrate such exceptions (A) or affirmative defenses (B).

The legality of management vis-à-vis state abortion bans becomes more unclear when the patient is stable. For example, if a patient has an early ectopic pregnancy that is not ruptured, some may argue that giving methotrexate (which will cause an abortion) would be permissible if there is an exception for both the health and life of a pregnant person, such as State A, but may not be permissible in a state with a narrow exception only to protect the life of the pregnant person, such as State B. In a state that only has a carve-out for the life of the pregnant person, like State B, the recommendation may be to discharge the patient until they become unstable and meet the criteria for an exception to protect the life of the pregnant person. However, state laws should be read broadly to protect abortion care when necessary to protect a pregnant person, and in any event EMTALA requires emergency abortion care in any state—even where the emergency medical provision in a state abortion ban appears narrower than EMTALA's definition of emergency medical condition.

This is where understanding EMTALA becomes critical. Even if a physician is practicing in a state with a narrow exception that only permits abortion when needed to save the life of a pregnant person, the physician is still obligated to comply with EMTALA. Under EMTALA, treatment is required if there is a threat to a patient's health, bodily functions, or the function of a bodily organ without treatment. Given that EMTALA preempts conflicting state abortion bans, that means that an abortion must be offered to patients, if indicated, when there is a threat to a patient's health, bodily function, or the function of a bodily organ even if such an abortion would be impermissible under state law. Failure to provide emergency abortion care in these situations would constitute an EMTALA violation.

PREPARATION IS KEY

Standard of care does not change across state lines, but we know that the care being offered to patients differs depending on local law because of the proliferation of abortion bans since *Dobbs*. Patients with pregnancy complications can present critically ill or with a condition that could rapidly deteriorate, such that immediate care us required. That is not the best occasion to be navigating a state abortion ban for the first time. Instead, preparation is critical. Emergency physicians working in states with abortion bans should meet with stakeholders including OB/GYN, whether in house or at the local hospital where pregnant patients are referred, hospital counsel, risk management and others to establish clinical policies that address the management of patients with emergent pregnancy complications. These clinical policies should be mindful of hospital and clinician obligations under EMTALA as well as state law.

Emergency physicians are compelled by EMTALA to provide stabilizing treatment, to engage consultants as needed to provide stabilizing treatment, and to transfer patients when needed. In cases of pregnancy complications, this often means consulting with in-house OB or transferring a patient to a hospital that has OB services. In the case of methotrexate therapy for ectopic pregnancies it can also mean directly providing the care. Emergency physicians must remember that if a consultant refuses to evaluate and treat a patient, or refuses transfer, based on a state abortion ban, then all parties involved may be violating EMTALA. Instead, patients should receive standard-of-care treatment including abortion care when indicated. Just as we would not accept recommendations from a surgeon to discharge a patient with an 8-cm, symptomatic aortic aneurysm and to instruct the patient to return for definitive treatment when the aorta is ruptured, emergency physicians should not accept recommendations to discharge patients with emergent pregnancy complications without treatment.

Address for Correspondence: Kimberly Chernoby, MD, JD, MA, George Washington University School of Medicine and Health Sciences, Department of Emergency Medicine, 2120 L. Street, NW, Suite 450, Washington, DC 20037.
Email: Kimi.chernoby@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. Centers for Disease Control and Prevention. National Hospital Ambulatory Medical Care Survey: 2011 Emergency Department Summary Tables. 2011. Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.cdc.gov/nchs/data/ahcd/nhamcs_emergency/2011_ed_web_tables.pdf. Accessed November 1, 2023.
2. Kilfoyle KA, Vrees R, Raker CA, Matteson KA. Nonurgent and urgent emergency department use during pregnancy: an observational study. *Am J Obstet Gynecol*. 2017;216(2):181.e1–181.e7.
3. Fleishman R. STAT. Rural hospitals are closing labor and delivery services. Babies' lives are in jeopardy. 2023. Available at: https://www.statnews.com/2023/04/18/neonatal-care-closure-rural-labor-delivery-services. Accessed November 1, 2023.
4. Roe v. Wade, 410 U.S. 113 (1973). Accessed November 1, 2023.
5. Griswold v Connecticut, 381 U.S. 479 (1965). Accessed November 1, 2023.
6. H.B.1510, Miss.Leg, Reg. Sess. (Miss. 2018). Accessed November 1, 2023.
7. Legal Information Institute. Cornell Law School. Stare Decisis. 2021. Available at: https://www.law.cornell.edu/wex/stare_decisis. Accessed June 1, 2023.
8. Nash E and Guarnieri I. Guttmacher Institute. Six months post-Roe, 24 US states have banned abortion or likely to do so: a roundup. https://www.guttmacher.org/2023/01/six-months-post-roe-24-us-states-have-banned-abortion-or-are-likely-do-so-roundup (Last visited June 1, 2023).
9. Ala. Code §26-23H-4 (2021). Accessed November 1, 2023.
10. Idaho Code §18-622 (2020). Accessed November 1, 2023.
11. Flink-Bochacki R, McLeod C, Lipe H, et al. Classification of periviable pregnancy-ending interventions for maternal life endangerment as induced abortion. *Contraception*. 2023;123:110011.
12. VandeVusse AJ, Mueller J, Kirstein M, et al. "Technically an abortion": understanding perceptions and definitions of abortion in the United States. *Soc Sci Med*. 2023;335:116216.
13. The American College of Obstetricians and Gynecologists. ACOG Guide to Language and Abortion. 2023. Available at: https://www.acog.org/contact/media-center/abortion-language-guide#:~:text=Abortion%20is%20a%20medical%20intervention,the%20medical%20condition%20of%20pregnancy. Accessed November 1, 2023.
14. Ind. Code § 16-18-2-1 (2022). Accessed November 1, 2023.
15. Tex. Health and Safety Code Ann. § 245.002 (2017). Accessed November 1, 2023.
16. Hahn SA, Lavonas EJ, Mace SE, et al. American College of Emergency Physicians. Clinical policy: critical issues in the initial evaluation and management of patients presenting to the emergency department in early pregnancy. *Ann Emerg Med*. 2012;60(3):381–390.
17. Nambiar A, Patel S, Santiago-Munoz P, et al. Maternal morbidity and fetal outcomes among pregnant women at 22 weeks' gestation or less with complications in 2 Texas hospitals after legislation on abortion. *Am J Obstet Gynecol*. 2022;227(4):648–650.
18. Seitz A. AP News. Feds: Hospitals that denies emergency abortion broke the law. 2023. Available at: https://apnews.com/article/emergency-abortion-law-hospitals-kansas-missouri-emtala-2f993d2869fa801921d7e56e95787567.
19. U.S. Department of Health and Human Services. HHS Secreatary Xavier Becerras Statement on EMTALA Enforcement. 2023. Available at: https://nwlc.org/wp-content/uploads/2022/11/Letter-to-Hospitals-FINAL.docx_Completed.pdf. Accessed November 1, 2023.
20. U.S. Department of Health and Human Services. Center for Medicare and Medicaid Services. OMB No. 0938-0391. 2023. Re: University of Kansas Hospital. Available at: https://nwlc.org/wp-content/uploads/2022/11/Freeman_260137-cms-form-2567-4-10-23-1.pdf. Accessed November 1, 2023.
21. U.S. Department of Health and Human Services. Center for Medicare and Medicaid Service. OMB No. 0938-0391. 2023. Re: Freeman Health System- Freeman West. Available at: https://nwlc.org/wp-content/uploads/2022/11/University-of-Kansas_170040-cms-form-2567-4-10-23.pdf. Accessed November 1, 2023.
22. Kitchener C. *The Washington Post*. Two friends were denied care after Florida banned abortion. One almost died. 2023. Available at: https://www.washingtonpost.com/politics/2023/04/10/pprom-florida-abortion-ban. Accessed November 1, 2023.
23. Simmons-Duffin S. NPR. In Oklahoma, a woman was told to wait until she's 'crashing' for abortion care. 2023. Available at: https://www.npr.org/sections/health-shots/2023/04/25/1171851775/oklahoma-woman-abortion-ban-study-shows-confusion-at-hospitals. Accessed November 1, 2023.
24. Zurawksi v State of Texas, D-1-GN-000968 (353rd Dist. Court). 2023. Available at: https://reproductiverights.org/wp-content/uploads/2023/03/Zurawski-v-State-of-Texas-Complaint.pdf. Accessed November 1, 2023.
25. Grossman D, Joffe C, Kaller S, et al. ANSIRH Deparments of Obstetrics, Gynecology and Reproductive Sciences, University of California, San Francisco. Care post-Roe: documenting cases of poor-quality care since the Dobbs decision. 2023. Available at: https://www.ansirh.org/research/research/how-post-roe-laws-are-obstructing-clinical-care. Accessed November 1, 2023.
26. Centers for Medicare & Medicaid Services. Emergency Medical Treatment & Labor Act (EMTALA). 2023. Available at: https://www.cms.gov/regulations-and-guidance/legislation/emtala. Accessed November 1, 2023.
27. EMTALA, 42 U.S.C. §1395dd(a) (1986).

28. Barber v Hospital Corp. of America, 977 F.2d 872 (1992). Accessed November 1, 2023.
29. EMTALA, 42 U.S.C. §1395dd(e)(3) (1986). Accessed November 1, 2023.
30. Cherukuri v Shalala, 175 F.3d 446 (1999). Accessed November 1, 2023.
31. Roberts v Galen of Va., Inc., 525 U.S. 249 (1999). Accessed November 1, 2023.
32. EMTALA, 42 U.S.C. §1395dd (1986). Accessed November 1, 2023.
33. 87 CFR 15107. Accessed November 1, 2023.
34. U.S. Const. art.VI,cl.2. Accessed November 1, 2023.
35. Tritz KL and Wright DR. U.S. Department of Health and Human Services. Center for Clinical Services and Quality. Reinforcement of EMTALA obligations specific to patients who are pregnant or are experiencing pregnancy loss. QSO-22-22-Hospitals. 2023. Available at: https://www.cms.gov/files/document/qso-22-22-hospitals.pdf. Accessed November 1, 2023.
36. Donley G, Chernoby K, Perryman S. *Time*. Two courts ruled on abortion in emergency situations. One got it right. 2022. Available at: https://time.com/6208656/abortion-emtala-texas-idaho-emergency-situations/.
37. United States v Idaho, No. 1:22-cv-00329-BLW. U.S Dist. Ct Idaho. 2022. Available at: https://storage.courtlistener.com/recap/gov.uscourts.idd.50547/gov.uscourts.idd.50547.95.0.pdf. Accessed November 1, 2023.
38. United States v Idaho, __F.Supp.3d__ (2022). Accessed November 1, 2023.
39. I.C. § 18-604(1), as amended effective 7/1/23. Accessed November 1, 2023.
40. Planned Parenthood v Idaho, Nos. 49615, 49817, 49899 (Idaho Jan. 5, 2023) at p. 88. Accessed November 1, 2023.
41. USA v Idaho, — F.4th ——, 2023 WL 6308107 (9th Cir. Sept. 28, 2023). Accessed November 1, 2023.
42. USA v Idaho, No. 23-35440 (9th Cir. Oct. 10, 2023) (order granting rehearing en banc). Accessed November 1, 2023.
43. Texas v Becerra. No. 5:22-CV-185-H. U.S. Dist. Ct. N.D.Tex. 2022. Available at: https://storage.courtlistener.com/recap/gov.uscourts.txnd.365015/gov.uscourts.txnd.365015.73.0.pdf. Accessed November 1, 2023.

Impact of Geriatric Consult Evaluations on Hospital Admission Rates for Older Adults

Stephen Meldon, MD*
Saket Saxena, MD†
Ardeshir Hashmi, MD†
Amanda Masciarelli McFarland, MHA*
McKinsey Muir, MHSA*
Fernando Delgado, MS*
Isaac Briskin, MA‡

*Cleveland Clinic Emergency Services Institute, Cleveland, Ohio
†Cleveland Clinic Center for Geriatric Medicine, Cleveland, Ohio
‡Cleveland Clinic, Department of Quantitative Health Sciences, Cleveland, Ohio

Section Editors: Luna Ragsdale, MD, MPH, and Danya Khoujah, MBBS
Submission history: Submitted April 11, 2023; Revision received September 8, 2023; Accepted November 15, 2023
Electronically published December 22, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.60664

Introduction: We examined the impact of a geriatric consult program in the emergency department (ED) and an ED observation geriatric care unit (GCU) setting on hospital admission rates for older ED patients.

Methods: We performed a retrospective case control study from June 1–August 31, 2019 (pre-program) to September 24, 2019–January 31, 2020 (post-program). Post-program geriatric consults were readily available in the ED and required in the GCU setting. Hospital admission rates (outcome) are reported for patients who received a geriatric consult evaluation (intervention). We analyzed probability of admission using a mixed-effects logistic regression model that included age, gender, recent ED visit, Charlson Comorbidity Index, referral to ED observation, and geriatric consult evaluation as predictor variables.

Results: A total of 9,663 geriatric ED encounters occurred, 4,042 pre-program and 5,621 post-program. Overall, ED admission rates for geriatric patients were similar pre- and post-program (44.8% vs 43.9%, $P = 0.39$). Of 243 geriatric consults, 149 (61.3%) occurred in the GCU. Overall admission rates post-program for patients receiving geriatric intervention were significantly lower compared to pre-program (23.4% vs 44.9%, $P < 0.001$). Post-program GCU hospital admission rates were significantly lower than pre-program ED observation unit admission rates (14/149, 9.4%, vs 111/477, 23.3%, $P < 0.001$). In the logistic regression model, admissions post-program were lower when a geriatric consult evaluation occurred (odds ratio [OR] 0.58, 95% confidence interval [CI] 0.41–0.83). Hospital admissions for older ED observation patients were also significantly decreased when a geriatric consult was obtained (GCU vs pre-program ED observation unit; OR 0.27, 95% CI 0.14–0.50).

Conclusion: Geriatric consult evaluations were associated with significantly lower rates of hospital admission and persisted when controlled for age, gender, comorbidities, and ED observation unit placement. This model may allow healthcare systems to decrease potentially avoidable hospital admission rates in older ED patients. [West J Emerg Med. 2024;25(1)86–93.]

INTRODUCTION

Background

Older adults have some of the highest rates of emergency department (ED) use in the United States.[1–4] Traditional ED models of care, however, are not ideally suited for the complex clinical presentation and healthcare needs of older adults.[5–7]

Importance

Older ED patients have higher admission rates than other age cohorts.[1,4] Hospitalizations in this group have significant adverse health outcomes including iatrogenic complications, delirium, functional decline, and loss of independence.[8–10] Hospitalizations also result in significant healthcare costs and inconsistent quality of care.[7] While several studies have evaluated subsequent ED use, subsequent hospitalizations and healthcare utilization following an index ED visit that included a geriatric-trained nurse or advanced practice nurse geriatric assessment,[11–14] few have evaluated the effect of a geriatric assessment program provided by an on-site, ED-imbedded geriatrician on admission rates during an index ED visit.

Goals of Investigation

Our objective in this study was to measure the impact of a geriatric consult program occurring in the ED setting or within an ED-based observation unit on hospital admission rates in older ED patients.

Population Health Research Capsule

What do we already know about this issue?
Older ED patients have higher admission rates than other age cohorts.

What was the research question?
Can an ED-based geriatrician assessment program impact admission rates in older ED and ED observation unit patients?

What was the major finding of the study?
Admission rates were lower for patients receiving a comprehensive geriatric assessment (23.4% vs. 44.9%). Geriatric assessment had the largest impact on ED observation patient admissions (9.4% v 23.3%; OR 0.27, 95% CI 0.14–0.50). Controlling for observation status, the odds of admission remained significantly decreased when a geriatric consult evaluation occurred (OR 0.58, 95% CI 0.4–0.83).

How does this improve population health?
An ED-based geriatric assessment program may allow healthcare systems to decrease potentially avoidable hospital admission rates in older ED patients.

METHODS

Study Design, Setting, and Selection of Participants

This was a retrospective case control study conducted from June 1–August 31, 2019 (pre-program) and September 24, 2019–January 31, 2020 (post-program) that examined the impact of a geriatric consultation program in the ED and ED observation setting on admission rates for older patients. The setting was an academic medical center with approximately 1,400 medical inpatient beds. The ED had 58 acute care beds and approximately 67,000 total annual visits, with 24% geriatric (age ≥65 years) encounters and a longstanding, ED-based observation unit (clinical decision unit [CDU]). The CDU was a short-stay (23 hours), 20-bed observation unit within the ED footprint, designed for additional condition-specific treatment or additional evaluation to determine the need for hospital admission. Clinical staffing of this unit consisted of acute care advanced practice nurses (APN) and unit-dedicated nurses. Emergency department pharmacists were available 24 hours per day, and case management roles were staffed for 14 hours (8 AM–10 PM) per day. Well-established CDU guidelines for short-stay ED observation patient selection were used throughout the study period.

A geriatric ED program was implemented with an imbedded geriatric consultant in the ED and ED-based observation unit (post-program) and became the basis for a subsequent geriatric ED accreditation application. As part of the geriatric ED program development, five CDU beds were designated as a geriatric care unit (GCU), although census could vary and was not limited by bed availability. Geriatric consult coverage was provided by the same geriatric physician four days per week and a single geriatric-trained APN one day per week. Geriatric consults were made available in the ED and required for all patients placed in the GCU. The geriatric consult typically included screening for dementia, depression, mobility, assessment of multi-morbidity and social support, and medication review. Case managers in the ED assisted with additional patient service needs such as mobility devices, home physical therapy, and home health services. Geriatric coverage was provided on weekdays from 9 AM–5 PM. Patients placed in the GCU off-hours were seen the following day, except on weekends.

As part of the geriatric ED program, emergency physician and advanced practice practitioner (physician assistants and APNs) education was provided that focused on the eight domains of geriatric care competencies model.[15] In addition, geriatric patient screening and nursing-driven delirium

screening were implemented. Although a number of geriatric ED screening instruments exist,[16,17] the performance of such instruments lacks sensitivity and specificity for predicting subsequent healthcare services.[18,19] In addition, it can be difficult to implement these instruments in a high-acuity and high-volume ED setting. For this reason, a modified Delphi approach (which included content experts in geriatrics, geriatric emergency medicine, case management, and pharmacy) was used to select electronic health record (EHR) screening criteria to identify high-risk elders.[20]

Characteristics chosen included age ≥80 years, positive delirium screen, fall presentation or history of falls on triage screening, dementia diagnosis noted in the EHR, polypharmacy (defined as greater than 10 medications), and more than five ED visits within the preceding year. Delirium screening consisted of a two-step process for patients aged 65-79 years. In this group, patients or family members/caregivers were asked whether there was concern for confusion, delirium, or a change in mental status; positive responses resulted in formal screening using the 4AT delirium screen.[21] In patients ≥80 years, this first-step screen was omitted, and patients in this age group were screened with the 4AT instrument.

To help notify emergency physicians of the geriatric screening results, an EHR-automated best practice alert alerted the physician to high-risk status upon entering the EHR. A positive delirium screen also resulted in an EHR banner informing physicians that the delirium screen was positive. An ED geriatric consult order populated a patient list for geriatric physician and APN use. Consultation and disposition decisions were at the discretion of the ED attending physician and based on their determination of the need for acute medical interventions that clearly required hospitalization, the need for further evaluation in the CDU because of patient complexity or additional investigation regarding safe disposition, or simple discharge. In the GCU/CDU setting, disposition decisions were made by the CDU APNs based on observation evaluation, test results, and consultations. This process was unchanged from prior practice and the pre-program period.

This study was institutional review board exempt.

Interventions

Geriatric consult evaluations, the intervention, used a standard comprehensive geriatric assessment with attention to medications, fall risk, depression, cognitive status, functional status, and social support, in addition to current and chronic medical issues. Geriatric consult evaluations were available in the ED at the discretion of the attending physician and required for all patients placed in the GCU. Geriatric patients placed in the ED observation unit who did not receive a geriatric consult evaluation were treated as routine CDU patients. We included all completed geriatric consult evaluations occurring in the ED and GCU in the intervention cohort. We used geriatric consult notes for confirmation of a completed consult.

Measurement and Outcomes

We included all geriatric ED visits for the pre- and post-program periods. Return visits by ED patients were considered a unique ED encounter with a subsequent disposition. Demographics (age, gender), frequency of prior ED visits within the preceding six months, Charlson Comorbidity Index (CCI),[22,23] and ED unit observation placement were recorded.

Hospital admission rates (the outcome) are reported for both pre- and post-program patient cohorts and for patients who had a geriatric consult evaluation (intervention). We developed a logistic regression model to control for patient variables (including placement in the ED observation unit) and evaluate the effect of geriatric consult evaluation on admission rates. Data was abstracted from the EHR (Epic Systems Corporation, Verona, WI).

Data Analysis

We summarized continuous measures with mean (+/− SD) or median [Q1, Q3] depending on skewness, and categorical variables were summarized with frequency (percentage). We analyzed the differences between pre- and post-intervention encounters with Kruskal Wallis tests for continuous variables and Pearson chi-square test for categorical variables. *P*-values less than 0.05 were considered significant. Odds of admission modeling was analyzed using a mixed-effects logistic regression model. Age at encounter, gender, recent visit, CCI, referral to ED observation, and geriatric evaluation were all included as predictor variables with hospital admission as the outcome. Odds ratios and 95% confidence intervals are reported. Analysis was done in SAS studio v9.4 (SAS Institute, Inc, Cary, NC).

RESULTS

There were 9,663 unique geriatric ED encounters, with 4,042 occurring pre-program and 5,621 occurring post-program. The overall median age was 73.0 years (68.0, 80.0) and 52.6% were female. Of these patients, 63% were Black and 35% White. Patient demographics and clinical characteristics are shown in Table 1. Emergency Severity Index (ESI) triage levels were similar between cohorts, with the exception of ESI-1. Eighteen (0.45%) patients received a geriatric consult evaluation in the pre-program cohort compared to 243 (4.3%) in the post-program period ($P < 0.001$). Out of 243 post-program interventions, 149 (61.3%) occurred in the GCU.

Overall, ED geriatric patient admission rates were similar pre- and post-program (44.8% vs 43.9%, respectively; $P = 0.39$). Case mix index was similar in both groups for those patients whose ED encounter resulted in admission (1.3 [0.91, 1.9] pre-program vs 1.2 [0.88, 1.8] post-program,

Table 1. Patient demographics and clinical characteristics.

Factor	Total (N = 9,663)	Pre-Program (N = 4,042)	Post-Program (N = 5,621)	*P*-value
Patient age at ED encounter	73.0[68.0,80.0]	73.0[68.0,80.0]	73.0[68.0,80.0]	0.01[b]
ED patient gender				*0.04*[c]
Female	5,079(52.6)	2,075(51.3)	3,004(53.4)	
Male	4,584(47.4)	1,967(48.7)	2,617(46.6)	
ESI triage level*				*<0.001*[c]
ESI-1	84(0.87)	20(0.50)	64(1.1)	
ESI-2	1,128(11.7)	456(11.3)	672(12.0)	
ESI-3H	5,993(62.1)	2,496(61.8)	3,497(62.3)	
ESI-3L	1,957(20.3)	843(20.9)	1,114(19.8)	
ESI-4	444(4.6)	209(5.2)	235(4.2)	
ESI-5	46(0.48)	12(0.30)	34(0.61)	
Seen by geriatrician (Intervention)	261(2.7)	18(0.45)	243(4.3)	*<0.001*[c]
ED encounter within prior 6 months?	4,767(49.3)	1,975(48.9)	2,792(49.7)	0.43[c]
Number of ED encounters in the previous 6 months	0.00[0.00,2.0]	0.00[0.00,2.0]	0.00[0.00,2.0]	0.62[b]
ED encounter associated with 10+ medications?	7,067(73.1)	2,966(73.4)	4,101(73.0)	0.65[c]
Charlson Comorbidity Index, mean ±SD	4.23 ± 3.75	4.16 ± 3.65	4.29 ± 3.82	0.09[a]
Medications at time of ED encounter (via Epic)*	15.0[10.0,21.0]	15.0[10.0,20.0]	15.0[10.0,21.0]	0.19[b]
Referred to CDU (Observation) within ED?	1,143(11.8)	493(12.2)	650(11.6)	0.34[c]
ED encounter resulted in admission?	4,278(44.3)	1,810(44.8)	2,468(43.9)	0.39[c]
Length of stay (minutes) in ED, not including time in CDU (observation)	304.0 [218.0,407.0]	306.0 [218.0,408.0]	303.0 [218.0,406.0]	0.75[b]

*Data not available for all subjects. Missing values: ESI triage level = 11 (Note: ESI 3H and 3L are internal triage classifications based on use of a fast-track ED model). Medications at time of ED encounter (via Epic) = 121; Statistics presented as mean ± SD, median [P25, P75], N (column %). -values: a = ANOVA, b=Kruskal-Wallis test, c = Pearson chi-square test.
ED, emergency department; *ESI*, Emergency Severity Index; *CDU*, clinical decision unit.

$P = 0.48$). In the post-program cohort, the overall admission rate for both ED and ED observation patients who received a geriatric consult evaluation was lower compared to those patients who did not receive one (23.4% vs 44.9%, $P < 0.001$). We also examined the impact of geriatric consult evaluations on ED observation patients by comparing GCU admission rates with pre-program ED observation unit (CDU) admission rates. Admission rates from the GCU were significantly lower than pre-program admissions from the CDU (14/149, 9.4% v 111/477, 23.3% respectively, $P < 0.001$). As a comparison, admission rates from the CDU in non-geriatric patients was 22.3% pre-program and 23.5% post-program (174/765 vs 226/958, respectively; $P = 0.74$).

The mixed-effects logistic regression model results are shown in Table 2. Odds of hospital admission for ED observation patients were significantly decreased when a geriatric consult evaluation occurred (GCU vs pre-program CDU, OR 0.27, 95% CI 0.14, 0.50, $P < 0.001$). Other predictors associated with admission included age, which had a surprisingly modest but negative effect, male gender, and comorbidity burden (increasing CCI score). Visits to the ED in the prior six months were not a predictor of admission. To assess the impact of the geriatric ED program development and account for possible emergency medicine practice and ED process changes, we examined admissions for the post-program period using the same mixed-effects logistic regression model (Table 3). Controlling for all variables, including ED observation status, the odds of hospital admission were significantly lower when a geriatric consult evaluation occurred (OR 0.58, 95% CI 0.40–0.83, $P = 0.003$). To further assess the effect of the geriatric ED implementation, we also looked at overall admission rates for ED observation patients. Pre-program ED observation (CDU) patients had a 69% higher odds of admission compared to all ED observation (both CDU patients who did not receive a geriatric evaluation and GCU patients) post-program patients (OR 1.686, 95% CI 1.26–2.34, $P = 0.002$).

Summed ED plus observation unit time length of stay (LOS) was higher in the GCU group vs the CDU group by

Table 2. Variables impacting hospital admission: logistic mixed-effects model results.

Factor	Estimate	95% Confidence Interval	*P*-value
Age at Encounter	0.979	(0.97,0.988)	*<0.001*
Gender (Male vs Female)	1.333	(1.170,1.518)	*<0.001*
Visit in prior 6 months? (No vs Yes)	0.995	(0.894,1.133)	0.94
CCI	1.461	(1.392,1.533)	*<0.001*
Seen by geriatrician, GCU (vs pre-CDU)	0.266	(0.142,0.500)	*<0.001*
Not referred to ED observation, post (vs pre)	0.756	(0.485,1.178)	0.22

CCI, Charlson Comorbidity Index; *GCU*, geriatric care unit; *CDU*, clinical decision unit; *ED*, emergency department.

Table 3. Variables impacting hospital admission: logistic mixed-effects model results (post-program patients only).

Factor	Estimate	95% Confidence Interval	*P*-value
Age at encounter	0.979	(0.97, 0.987)	*<0.001*
Gender (male vs female)	1.248	(1.113, 1.400)	*<0.001*
Visit in prior 6 months? (No vs Yes)	1.036	(0.925, 1.161)	0.54
CCI	1.513	(1.449, 1.580)	*<0.001*
Not Referred to ED observation	4.328	(3.413, 5.490)	*<0.001*
Seen by geriatrician (Intervention) (vs not seen by geriatrician)	0.579	(0.405, 0.828)	*0.003*

CCI, Charlson Comorbidity Index; *ED*, emergency department.

149 minutes (1,369.0 minutes [117.0–1587.0] vs 1220.0 minutes [936.0–1459.0], $P < 0.001$).

DISCUSSION

In this retrospective case control study, we demonstrated an associated decrease in hospital admission rates for older ED and ED observation patients who received a geriatric consult evaluation. This effect persisted when we controlled for age, gender, recent ED visits, CCI, and referral to an ED-based observation unit. The overall effect was a 42% reduction in odds of admission. For ED observation patients, the impact of the geriatric evaluation was even more significant with a 73% reduction in the odds of admission. Our results add to previous studies that have examined geriatric interventions and the impact on index ED visit hospital admission. Prior studies have shown a mixed-effect of ED geriatric intervention, with either decreased,[13,14,24] unchanged[25,26] or even increased subsequent healthcare utilization.[7] These discordant results likely reflect patient heterogeneity, availability of follow-up and community resources, and individual emergency physician practice and ED site-specific processes.

Hwang et al. examined the effect of an ED-based transitional care nurse (TCN) on inpatient admission during the index ED visit at three sites that used the Geriatric Emergency Department Innovations in Care through Workforce, Informatics, and Structural Enhancements (GEDI WISE) model of care. The GEDI WISE TCN intervention focused on facilitating transitions of care and avoiding inpatient admissions when possible. Admission reduction varied between 4.7–16.5%.[28] Another GEDI model reported 13% fewer admission following a GEDI Nurse Liaison assessment. An increased ED length of stay (LOS) and possibility of selection bias (ESI triage scores were used to compare cohorts) were noted by the authors.[29] Similar findings were noted in a pragmatic trial using the GEDI model. An increased likelihood of discharge (hazard ratio 1.19) and, conversely, a reduced ED LOS following GEDI team evaluation were noted.[30] A planned subgroup analysis of this study examining ED discharge for patients of residential aged care facilities showed similar results.[31]

A non-randomized prospective study using a geriatric allied health services care coordination team found a much more modest 2.4% absolute reduction in admissions in the intervention group, which was limited to a small number of common presenting problems, such as musculoskeletal conditions.[32] Keyes et al also examined admission rates following the opening of a geriatric ED and found a modest 3% reduction (47% pre-senior ED and 44% after).[33] This model included ED staff education and training and a case management approach but did not use geriatricians. Our geriatric ED program differs from these models because of an imbedded geriatric physician and APN. This integrated geriatric consultation intervention was thus available on-site and in real time during the ED and ED observation unit evaluation.

An important consideration, with both our program and others, is careful patient selection, with a focus on targeted

evaluation of older patients who do not obviously require hospital admission on initial ED evaluation. The concept of "high complexity, low acuity" is useful to describe this patient population. It seems likely that geriatric screening tools, combined with geriatric assessments and well-developed transitions of care programs, would have the greatest impact on potentially avoidable hospitalization rates in older patients.[34,35] A comprehensive geriatric assessment is designed to evaluate and address functional status, cognitive status, polypharmacy, falls assessment, social support, and other geriatric issues that are difficult to assess in the usual ED setting. Faced with these time-consuming, complex patients, emergency physicians often err on the side of admission.

Addressing these concerns with a comprehensive geriatric assessment and using safe transitions of care can potentially reduce hospital admissions for this high-complexity, vulnerable population. We believe our results are due to this direct geriatric physician/APN assessment, coupled with an existing transitions of care program and appropriate patient selection. This is supported by our data which showed a larger impact of geriatric intervention in our older ED-based observation (GCU) patients.

The advantages of an observation-based geriatric ED model are numerous, including use of existing ED space and staffing, easier use of defined geriatric protocols, decreased impact on ED throughput, and additional professional billing for both emergency physicians and geriatric consultants. [5,36] Our summed ED-observation unit LOS was higher in the GCU cohort, but the difference of 149 minutes, in our view, had no appreciable impact on operations of the ED observation unit. Neither was there significant ED operational or throughput impact since the observation unit is not used as additional ED clinical space.

Interestingly, our older post-program CDU observation patients who did not receive a geriatric evaluation (non-GCU) also had a lower admit rate; so it appears that our geriatric ED program had a positive overall effect on admission rates. Our institution does have a transitions of care program initially developed for accountable care organization (ACO) patients, which uses ED case management staff.[37] As this program has evolved, it has become increasingly payer-agnostic and has been applied to a broader number of insured patients. It is likely that as experience with the geriatric ED program developed, this existing transition of care pathway was used for non-ACO geriatric patients. In addition, additional education and experience around geriatric syndromes and domains likely increased the comfort level of APNs and physicians and allowed for discharge home with additional follow-up and services, thereby avoiding potential admissions.

In this analysis, we did not analyze the impact of geriatric intervention on subsequent ED visits or subsequent hospitalization following the index ED visit. Further evaluation is planned to determine whether this geriatric intervention also has an impact on subsequent ED visits or hospitalization and whether this geriatric ED program affected patient experience.

From a financial policy perspective, avoiding potentially avoidable hospitalizations can have important consequences for patients, insurers, and healthcare systems. This is especially relevant for value-based contracts and ACOs. We believe our compelling results can be attributed to our model, which included real-time geriatric consultation. However, we recognize that staffing model costs and cost effectiveness are important considerations when adopting a geriatric model of care.[5,38] As noted, other geriatric ED care models assess mobility and functional status, cognition, depression, and other geriatric syndromes using nursing or case management personnel and standardized screening tools. Future studies should compare the cost effectiveness of different geriatric ED models of care, examine healthcare outcomes and additional healthcare utilization, and measure financial impact from a healthcare system perspective.

LIMITATIONS

Limitations of this study include the single-site, academic medical center setting and patient selection bias for geriatric consults and GCU placement. Geriatric consults were not available on weekends and off-hours weekdays. The high-risk criteria were automated and EHR-driven and remained consistent during the post-program period; however, we did not perform independent verification of our selected high-risk criteria. In addition, delirium screening was not always completed. Neither did we compare ED clinical impressions or CDU admitting diagnosis for the pre- and post-program cohorts.

To help address selection bias and cohort differences, our logistic regression model controlled for age, gender, patient comorbidities, recent ED visits, and ED observation placement, in addition to geriatric intervention. We did not include other potentially important demographic variables such as race, education, or income level. We did examine admission rates for the similar populations of geriatric ED observation patients (GCU vs pre-program CDU patients) to help quantify the impact of the geriatric intervention on patients who did not initially require hospital admission. The effect of the intervention is also supported by the stable CDU hospital admission rates in non-geriatric CDU patients during the study periods. Even with these efforts, some selection bias in obtaining geriatric consult evaluations or placement in the ED-observation unit is likely present which may limit the magnitude of our results.

Emergency medicine practice or process changes between pre- and post-program also may account for some differences. Although our ED has a previously developed transitions of care program, case management staffing and transitions of care processes were unchanged during the

pre- and post-program periods. In addition, pre- and post-programs occurred at different times in the year and could reflect seasonal variability in illness patterns and subsequent admission rates.

Of note, the overall ED geriatric admission rates were similar pre- and post-program. This may reflect the small percentage of patients (4.3%) who received a geriatric consultation post-program intervention. While this is significantly greater than pre-program, it represents an opportunity to increase the scope and scale of the program in the future. Increasing the number of older patients who receive and benefit from the intervention would likely impact overall ED geriatric admission rates. Last, this program was part of a Geriatric ED accreditation application and used hospital resources (program managers, analytics) and philanthropic support, which could limit replication and generalizability.

CONCLUSION

Implementation of this novel geriatric consultation program in the ED and an ED-based observation unit was associated with significantly decreased odds of hospital admission in high-risk, lower-acuity older patients. Use of an ED or ED observation unit-based geriatric physician or advanced practice nurse consult program may allow healthcare systems to decrease potentially avoidable hospital admissions from the ED in older adults.

ACKNOWLEDGMENTS

We would like to thank the generosity of the Samuel H. and Maria Miller Foundation for supporting this work. We also want to acknowledge Luann Capone, Karen Guzi, Jeff Ruwe, MD, and our ED case managers Lauren Delaney and Sheila Haynes-Baisden.

Address for Correspondence: Stephen Meldon, MD, Cleveland Clinic Emergency Services Institute, 9500 Euclid Ave, E19, Cleveland, Ohio 44195. Email: meldons@ccf.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. Aminzadeh F and Dalziel WB. Older adults in the emergency department: a systematic review of patterns of use, adverse outcomes, and effectiveness of interventions. *Ann Emerg Med*. 2002;39(3):238–47.
2. Huang D, Kleiman S, Wasserman J. National trends in geriatric emergency department visits: demographics, morbidities, and hospital admission factors, 2011-2015. *Ann Emerg Med*. 2018:72(S83).
3. Pines JM, Mullins PM, Cooper JK, et al. National trends in emergency department use, care patterns, and quality of care of older adults in the United States. *J Am Geriatr Soc*. 2013;61(1):12–7.
4. Rui P and Kang K. National Hospital Ambulatory Medical Care Survey: 2017 emergency department summary tables. National Center for Health Statistics. Available at: https://www.cdc.gov/nchs/data/nhamcs/web_tables/2017_ed_web_tables-508.pdf. Accessed January 15, 2021.
5. Southerland LT, Lo AX, Biese K, et al. Concepts in practice: geriatric emergency departments. *Ann Emerg Med*. 2020;75(2):162–70.
6. Lo AX, Flood KL, Biese K, et al. Factors associated with hospital admission for older adults receiving care in U.S. emergency departments. *J Gerontol A Biol Sci Med Sci*. 2017;72(8):1105–9.
7. Lo AX and Biese K. Disseminating and sustaining emergency department innovations for older adults: Good ideas deserve better policies. *Acad Emerg Med*. 2018;25(1):83–4.
8. Covinsky KE, Palmer RM, Fortinsky RH, et al. Loss of independence in activities of daily living in older adults hospitalized with medical illnesses: increased vulnerability with age. *J Am Geriatr Soc*. 2003;51(4):451–8.
9. Wakefield BJ and Holman JE. Functional trajectories associated with hospitalization in older adults. *West J Nurs Res*. 2007;29(2):161–82.
10. Lakhan P, Jones M, Wilson A, et al. A prospective cohort study of geriatric syndromes among older medical patients admitted to acute care hospitals. *J Am Geriatr Soc*. 2011;59(11):2001–8.
11. Mion LC, Palmer RM, Meldon SW, et al. Case finding and referral model for emergency department elders: a randomized clinical trial. *Ann Emerg Med*. 2003;41(1):57–68.
12. McCusker J and Verdon J. Do geriatric interventions reduce emergency department visits? A systematic review. *J Gerontol A Biol Sci Med Sci*. 2006;61(1):53–62.
13. Foo CL, Siu VW, Tan TL, et al. Geriatric assessment and intervention in an emergency department observation unit reduced re-attendance and hospitalisation rates. *Australas J Ageing*. 2012;31(1):40–6.
14. Caplan GA, Williams AJ, Daly B, et al. A randomized, controlled trial of comprehensive geriatric assessment and multidisciplinary intervention after discharge of elderly from the emergency department–the DEED II study. *J Am Geriatr Soc*. 2004;52(9):1417–23.
15. Hogan TM, Losman ED, Carpenter CR, et al. Development of geriatric competencies for emergency medicine residents using an expert consensus process. *Acad Emerg Med*. 2010;17(3):316–24.
16. McCusker J, Bellavance F, Cardin S, et al. Detection of older people at increased risk of adverse health outcomes after an emergency visit: the ISAR screening tool. *J Am Geriatr Soc*. 1999;47(10):1229–37.
17. Meldon SW, Mion LC, Palmer RM, et al. A brief risk-stratification tool to predict repeat emergency department visits and hospitalizations in older

patients discharged from the emergency department. *Acad Emerg Med*. 2003;10(3):224–32.
18. Carpenter CR, Shelton E, Fowler S, et al. Risk factors and screening instruments to predict adverse outcomes for undifferentiated older emergency department patients: a systematic review and meta-analysis. *Acad Emerg Med*. 2015;22(1):1–21.
19. Heeren P, Devriendt E, Wellens NIH, et al. Old and new geriatric screening tools in a Belgian emergency department: a diagnostic accuracy study. *J Am Geriatr Soc*. 2020;68(7):1454–61.
20. Saxena S, Meldon S, Hashmi AZ, et al. Use of the electronic medical record to screen for high-risk geriatric patients in the emergency department. *JAMIA Open*. 2023;6(2): oad021.
21. Bellelli G, Morandi A, Davis DH, et al. Validation of the 4AT, a new instrument for rapid delirium screening: a study in 234 hospitalised older people. *Age Ageing*. 2014;43(4):496–502. Erratum in: Age Ageing. 2015;44(1):175.
22. Charlson ME, Pompei P, Ales KL, et al. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40(5):373–83.
23. Frenkel WJ, Jongerius EJ, Mandjes-van Uitert MJ, et al. Validation of the Charlson Comorbidity Index in acutely hospitalized elderly adults: a prospective cohort study. *J Am Geriatr Soc*. 2014;62(2):342–6.
24. Dresden SM, Hwang U, Garrido MM, et al. Geriatric emergency department innovations: the impact of transitional care nurses on 30-day readmissions for older adults. *Acad Emerg Med*. 2020;27(1):43–53.
25. Heeren P, Devriendt E, Fieuws S, et al. Unplanned readmission prevention by a geriatric emergency network for transitional care (URGENT): a prospective before-after study. *BMC Geriatr*. 2019;19(1):215.
26. Salvi F, Morichi V, Grilli A, et al. A geriatric emergency service for acutely ill elderly patients: pattern of use and comparison with a conventional emergency department in Italy. *J Am Geriatr Soc*. 2008;56(11):2131–8.
27. Arendts G, Fitzhardinge S, Pronk K, et al. Outcomes in older patients requiring comprehensive allied health care prior to discharge from the emergency department. *Emerg Med Australas*. 2013;25(2):127–31.
28. Hwang U, Dresden SM, Rosenberg MS, et al. Geriatric emergency department innovations: transitional care nurses and hospital use. *J Am Geriatr Soc*. 2018;66(3):459–66.
29. Aldeen AZ, Courtney DM, Lindquist LA, et al. Geriatric emergency department innovations: preliminary data for the geriatric nurse liaison model. *J Am Geriatr Soc*. 2014;62(9):1781–5.
30. Wallis M, Marsden E, Taylor A, et al. The Geriatric Emergency Department Intervention model of care: a pragmatic trial. *BMC Geriatr*. 2018;18(1):297.
31. Marsden E, Taylor A, Wallis M, et al. Effect of the Geriatric Emergency Department Intervention on outcomes of care for residents of aged care facilities: a non-randomised trial. *Emerg Med Australas*. 2020;32(3):422–9.
32. Arendts G, Fitzhardinge S, Pronk K, et al. The impact of early emergency department allied health intervention on admission rates in older people: a non-randomized clinical study. *BMC Geriatr*. 2012;12:8.
33. Keyes DC, Singal B, Kropf CW, et al. Impact of a new senior emergency department on emergency department recidivism, rate of hospital admission, and hospital length of stay. *Ann Emerg Med*. 2014;63(5):517–24.
34. Credé SH, O'Keeffe C, Mason S, et al. What is the evidence for the management of patients along the pathway from the emergency department to acute admission to reduce unplanned attendance and admission? An evidence synthesis. *BMC Health Serv Res*. 2017;17(1):355.
35. Hughes JM, Freiermuth CE, Shepherd-Banigan M, et al. Emergency department interventions for older adults: a systematic review. *J Am Geriatr Soc*. 2019;67(7):1516–25.
36. Southerland LT, Vargas AJ, Nagaraj L, et al. An Emergency department observation unit is a feasible setting for multidisciplinary geriatric assessments in compliance with the geriatric emergency department guidelines. *Acad Emerg Med*. 2018;25(1):76–82.
37. Meldon S, Hustey F, Brenner R, et al. Centers for Medicare and Medicaid. Skilled Nursing Facility 3-Day Waiver Pilot: evaluation of emergency department length of stay for direct admission to skilled nursing facilities. *Ann Emerg Med*. 2019; 74:S61.
38. Southerland LT, Savage EL, Muska Duff K, et al. Hospital costs and reimbursement model for a geriatric emergency department. *Acad Emerg Med*. 2020;27(10):1051–8.

Systematic Review, Quality Assessment, and Synthesis of Guidelines for Emergency Department Care of Transgender and Gender-diverse People: Recommendations for Immediate Action to Improve Care

Michael I. Kruse, MD, BSc*
Alexandra Clarizio, BSc, MSc†
Sawyer Karabelas-Pittman, BHSc, MBDC‡
Blair L. Bigham, MD, MSc§
Suneel Upadhye, MD, MSc¶

*McMaster University, Department of Family Medicine, Hamilton, Ontario, Canada
†McMaster University, Michael G. DeGroote School of Medicine, Hamilton, Ontario, Canada
‡Queen's University School of Medicine, Kingston, Ontario, Canada
§Scarbrough Health Network, Department of Critical Care, Toronto, Ontario, Canada
¶McMaster University, Division of Emergency Medicine, Hamilton, Ontario, Canada

Section Editors: Mandy Hill, DrPH, MPH, and Patrick Maher, MD, MS
Submission history: Submitted April 17, 2023; Revision received October 9, 2023; Accepted November 1, 2023
Electronically published December 20, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.60632

Introduction: We conducted this systematic review to identify emergency department (ED) relevant recommendations in current guidelines for care of transgender and gender-diverse (TGD) people internationally.

Methods: Using PRISMA criteria, we did a systematic search of Ovid Medline, EMBASE, and CINAHL and a hand search of gray literature for clinical practice guidelines (CPG) or best practice statements (BPS) published until June 31, 2021. Articles were included if they were in English, included medical or paramedical care of TGD populations of any age, in any setting, region or nation, and were national or international in scope.

Exclusion criteria included primary research studies, review articles, narrative reviews or otherwise non-CPG or BPS, editorials, or letters to the editor, articles of regional or individual hospital scope, non-medical articles, articles not in English, or if a more recent version of the guideline existed. Recommendations relevant to ED care were identified, recorded, and assessed for quality using the AGREE-II and AGREE-REX criteria. We performed interclass correlation coefficient for interrater reliability. Recommendations were coded for the relevant point of care while in the ED (triage, registration, rooming, investigations, etc.).

Results: We screened 1,658 unique articles, and 1,555 were excluded. Of the remaining 103 articles included, seven had recommendations relevant to care in the ED, comprising a total of 10 recommendations. Four guidelines and eight recommendations were of high quality. They included recommendations for testing, prevention, referral, and provision of post-exposure prophylaxis for HIV, and culturally competent care of TGD people.

Conclusions: This is the most comprehensive review to date of guidelines and best practices statements offering recommendations for care of ED TGD patients, and several are immediately actionable. There are also many opportunities to build community-led research programs to synthesize and inform a comprehensive dedicated guideline for care of TGD people in emergency settings. [West J Emerg Med. 2024;25(1)94–100.]

INTRODUCTION

Transgender and gender-diverse (TGD) patients comprise 0.3–0.6% of the North American population and may represent up to 1.2–4.1% of the adolescent population.[1–3] Care of this population presents unique challenges in many practice settings, including emergency departments (ED).[4] While ED avoidance has been high among TGD people due to systemic discrimination,[5,6] ED use has also been found to be higher because of a lack of access to TGD-competent health services in primary and specialist care.[7] As a result of these barriers and compounded by minority stress,[8–10] The TGD populations experience a higher disease burden throughout their lifespan, including much higher rates of mental illness, self-harm, and substance use disorders.[11–13] This has the potential to result in TGD people presenting with more severe illness when they come to the ED and requires an approach that does not recapitulate barriers they have experienced in the past to facilitate better care.

Clinical practice guidelines (CPG) have been defined by the Institute of Medicine as " . . . statements that include recommendations intended to optimize patient care that are informed by a systematic review of evidence and an assessment of the benefits and harms of alternative care options."[14] Best practice statements (BPS) are less evidence-driven and can include a consensus statement or practice advisory from an expert group, or a position statement or position paper from professional societies.[15] Both can present standardized approaches to evidence-informed clinical care and are often adapted to meet local needs in the form of clinical manuals targeted at front-line clinicians and healthcare workers. There have been several reviews of CPGs for the care of TGD people in the recent past.[16–18] Not all guideline recommendations can be successfully adopted/adapted into different clinical working environments, and there are none that focus on care in the ED. There are publications from the Emergency Medicine Residents' Association and the American College of Emergency Physicians that speak directly to care of TGD populations in the ED but they do not represent the more rigorous systematic process of a CPG. The former is a clinical training manual, and the latter was published after search for this current study was completed.[19,20]

Previous work has demonstrated a paucity of research relevant to ED care of TGD patients.[22] Our overall goal in conducting this systematic review was to identify and evaluate current practice recommendations that inform the care of TGD populations in ED settings.

METHODS

This was a PRISMA-based systematic review of guideline recommendations, followed by application of the AGREE II and REX assessment tools for recommendation quality and applicability (available at www.agreetrust.org). The trial was registered at the Open Science Foundation prior to commencement (https://doi.org/10.17605/OSF.IO/BWJQ5). We performed a comprehensive search of Medline, EMBASE, and CINAHL in collaboration with a medical librarian, and we included any article published through July 31, 2021, using keywords relating to the TGD population, emergency medicine, and guidelines (Appendix B). A gray- literature search of Google Scholar and a focused search of relevant EM and TGD health societies were also completed for that timeline. We included articles if they represented a CPG, BPS, consensus document or other structured guidance for medical care for TGD populations of any age, in any practice setting, any large region, or nation, and if they were available in English.

Articles were excluded if they were narrative or systematic reviews, offered unstructured/non-medical guidance, if they were of local/municipal or single institution in scope, or if they were replaced by a more recent version of the guideline (Appendix B, Box C). Three reviewers independently screened title/abstracts and full text, and conflicts were resolved by group consensus. Included studies were reviewed by two independent reviewers in Covidence (covidence.org) and were analyzed for ED-relevant recommendations using a keyword search for "emergency."

The individual recommendations relevant to the ED were coded as CPG or BPS using the criteria to be found in

Clinical Practice Guidelines are statements that include recommendations intended to optimize patient care that are informed by a systematic review of evidence and an assessment of the benefits and harms of alternative care options, and contain the following features:

Essential Features

1. Broad stakeholder involvement of all relevant parties.
2. Explicit conflict of interest statements presented.
3. Clear questions to specifically guide clinical practice.
4. Thorough transparent retrieval and assessment of evidence; may have an accompanying systematic review/meta-analysis to inform recommendations.
5. Structured grading of evidence and framing of recommendations using accepted framework (e.g, GRADE).
6. External review by relevant bodies.
7. Key recommendations highlighted in document.
8. Updating timelines presented.
9. Reporting using Agree-II framework.

Desirable Features

1. Implementation protocols/pathways provided for end-users.
2. Outcome Measurement tools provided; audit and feedback processes recommended.

Best Practice Statements are consensus statements, practice advisories, position statements, position papers, or frontline clinical manuals usually from professional societies or specialist groups that have the following features:

1. Current important topic for practice.
2. Attempt to seek and evaluate evidence.
3. Practical recommendations to guide practice.
4. High level of certainty that recommendations will improve patient care.

Figure 1. Key features of a clinical practice guideline or best practice statement.[14,15,19,21]

Figure 1 by country or region of origin. We defined "ED-relevance" as any recommendation pertaining to any process flow point during that ED visit: decision to come to ED; prehospital care; registration; triage; waiting room experience; rooming/initial nursing care; history and physical exam; investigations; diagnoses; treatment; disposition/discharge planning; and/or follow-up care. Three reviewers independently abstracted data with two reviewers per citation, and conflicts in coding were resolved by consensus. The data extraction template is available in Appendix B.

The methodological quality of included guidelines was evaluated using the AGREE-II instrument (four independent raters: AC, SKP, MK, SU), and individual EM-relevant recommendations with the AGREE-REX tool (three independent raters, AC, SKP, MK). Raters received training in instrument use via an online tutorial available through McMaster University, and from senior researchers on the project. We calculated rating tool scores using AGREE Trust calculator for AGREE-II (downloaded for free from the AGREE Trust website) and using Excel (Microsoft Corporation, Redmond, WA) for AGREE-REX using the calculations provided in the instrument manual. Using the interpretation suggestions in the original AGREE-II and AGREE-REX instruments[23,24] a domain score <30% was considered low quality, a score of 30-70% was considered moderate quality, and over 70% was considered high quality. We assessed interrater reliability through use of the intraclass correlation coefficient (ICC) statistic using SPSS Statistics for Windows version 28.0 (IBM Corporation. Armonk, NY). An ICC score < 0.5 is considered poor, from 0.5– <0.75 moderate, from 0.75 to <.90 good, and >0.90 excellent.[25]

RESULTS

The literature search identified 1,997 articles, and 339 duplicates were removed. We screened titles and abstracts of 1,658 articles, with 1,367 not meeting inclusion criteria. Of the 291 articles undergoing full text review, 190 were excluded. Of the 103 remaining (Appendix A), seven articles were found to have 10 ED-relevant recommendations, and these were analysed using AGREE-II and AGREE-REX instruments. The literature search is summarized in the PRISMA flow diagram (Figure 2).

A summary of the appraised articles can be found in Table 1, Appendix C.[26–32] Six of the articles met criteria as a CPG, and one as a BPS. Four of the articles were related to HIV care guidelines, one focused on comprehensive care of TGD populations, and two were focused on other minority populations, of which TGD people were a subset. The overall quality was judged by AGREE-II to be high in four of the articles.[26,29,30,32]

The 10 individual recommendations relevant to ED care are summarized in Figure 3. A more detailed list with AGREE-REX evaluations can be found in Table 2, Appendix C. Overall, eight recommendations were considered high quality using AGREE-REX, with two having no consensus.

Interclass correlations for AGREE-II showed good correlation for scope and purpose, rigor of development, applicability, and editorial independence (Table 3, Appendix C). Stakeholder involvement showed moderate correlations, while clarity of presentation had poor ICC. The Agree-REX ICC was poor for values and preferences and ease of implementability but had good and moderate correlations for clinical applicability and total score overall, respectively (Table 4, Appendix C).

DISCUSSION

This comprehensive systematic review of TGD patient care guidelines identified a small number of high-quality recommendations relevant to ED care. This represents the most comprehensive collection of guidance documents found to date, outpacing the previous guidelines (103 v 2–17).[16–18] Seven were identified as either BPSs or CPGs with recommendations relevant to the ED. These guidelines were a mixture of general, multinational studies that provided higher level recommendations and improvements to care, along with country-specific studies that provided more targeted recommendations within the context of their healthcare structures. While the individual recommendations will not seem novel, this paper synthesizes the current collection of consensus documents for the care of TGD populations and sets the stage for development of future guidance products. There are currently actionable items for every ED to enhance the care of TGD people (summarized in Figure 3).

No recommendations pertaining to prehospital care, triage, waiting room, nursing, or follow-up care were identified. Key ED-relevant guidance focused on domains of ED attendance decisions, investigations, treatments, and disposition or discharge.

The general recommendations highlighted in this study focused on 1) HIV prevention, recommending that testing and referral services should be available and offered to TGD people; 2) cultural-competence training and trauma-informed approaches for TGD care provision, including adolescents in crisis; and 3) non-occupational post-exposure prophylaxis, recommending medications that should be readily available and included in situations of physical violence (see Appendix C Tables 1 and 2 for the specific guidelines and quality review). The more general guidelines focused on training and an equitable approach to care for emergency clinicians, but beyond training mandates they were not very specific in their implementation goals or skills requirements. We did not find any guidelines specifically oriented to the care of TGD people in the ED. From a quality standpoint, the evaluators scored most of the CPG/BPSs as high quality and the recommendations as applicable.

The strength of these recommendations is in their clarity regarding the testing and treatment of HIV for TGD

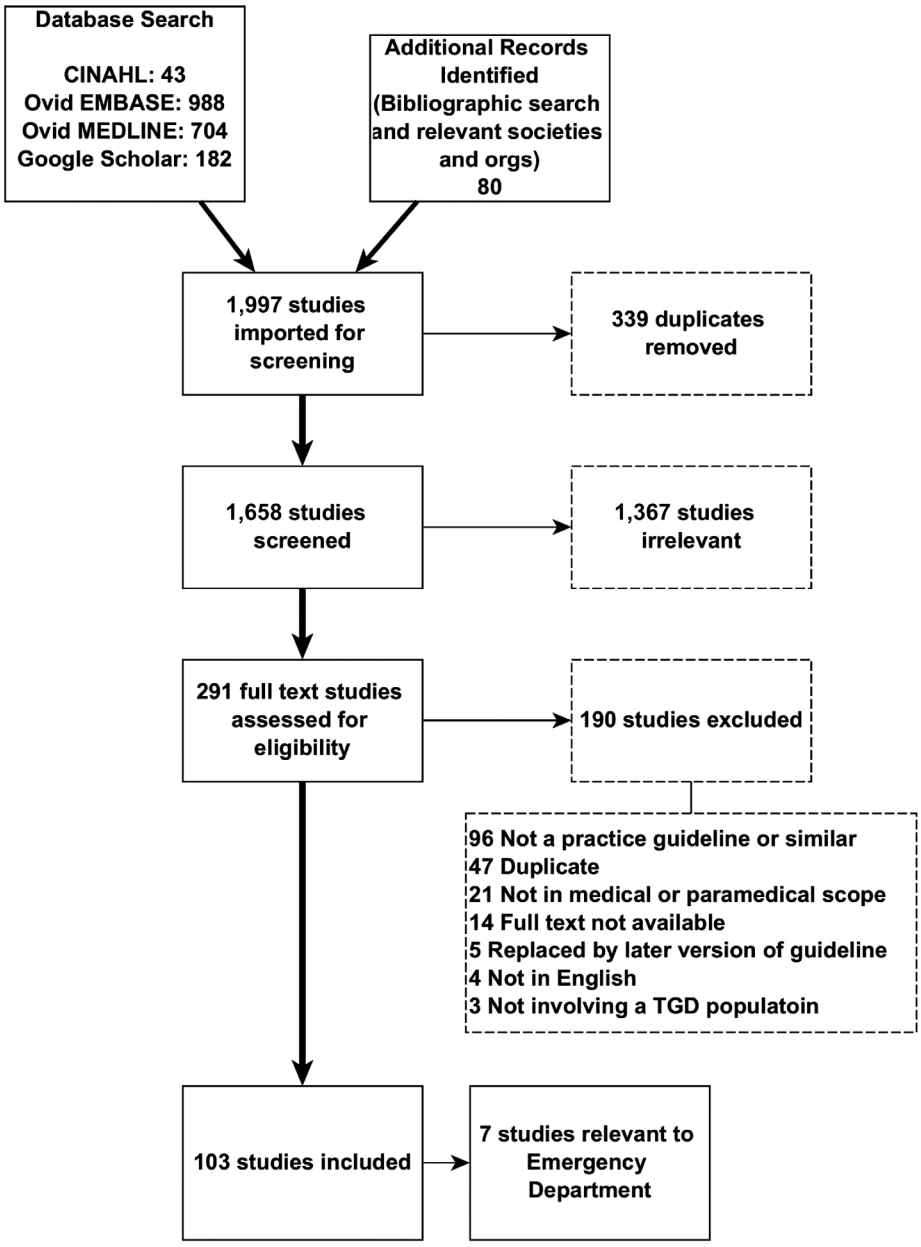


Figure 2. PRISMA diagram.

populations in the ED and the need for comprehensive cultural-humility training and proper referral. They highlight the need for creating effective and equitable referral pathways for TGD patients of all ages presenting to the ED, and an opportunity to remove the barriers to care experienced by this population.[5,6,33] The feasibility of HIV testing and referral from the ED is supported by recent systematic reviews, and universal implementation based on local prevalence is a reasonable goal.[34–36] Therefore, implementation of these recommendations with meaningful community engagement is something EDs could achieve right away. It is also true that these recommendations can be applied universally to TGD and non-TGD people alike, and implementation of population-based screening should be very careful not to recapitulate stigmatizing TGD people as having higher inherent risk for HIV exposure.[35] However, comprehensive clinical guidelines provide an opportunity to establish a standard of care in EDs and allow for TGD community stakeholder involvement to shape the urgent care this population needs.

The need for community engagement in primary research and knowledge translation, including guideline development, is critical for creating trustworthy and transparent guidance documents.[37] In general, TGD populations and queer people have found the ED to be a de-valuing and discriminatory space, like much of medicine,[38] and this has resulted in the

Summary of Recommendations

1. Transgender people in high-prevalence areas should be offered HIV testing if having blood tests for another reason. In very high prevalence areas, offer testing regardless of need for blood draw otherwise. (European Centre for Disease Prevention and Control et al 2018, Palfreeman et al 2020)
2. Using a trauma-informed approach, offer PrEP to TGD persons in the ED. (PanAm Health Org. et al 2014)
3. Offer non-occupational post-exposure prophylaxis (nPEP), STI, and pregnancy prevention counselling to TGD victims of sexual violence or if otherwise an urgent need is likely. (PanAm Health Org. et al 2014, Tan et al 2017
4. Immediate referral of a TGD person to HIV care is recommended following an HIV-positive diagnosis to improve linkage to anti-retroviral therapy. (Zuniga et al 2015)
5. Create a medical home for TGD children and create an equitable referral pathway from ED for those using it for primary care. (Bell et al 2021)
6. Health care providers in the ED must be trained in culturally competent care and have skills to treat TGD persons. (PanAm Health Org. et al 2014)
7. Using a trauma-informed approach, assess TGD people for substance use disorder symptoms and refer to TGD-focused treatment programs from the ED. (PanAm Health Org. et al 2014)
8. Risk-reduction and safety should be prioritized for TGD pts with acute gender dysphoria presenting to the ED. Consider hospitalization in extreme cases to prevent self-harm and consult TGD-competent care as needed. (Strang et al 2018)

Figure 3. Summary of recommendations.[26–32]
TGD, transgender diverse; *ED*, emergency department; *PrEP*, pre-exposure prophylaxis; *TGD*, transgender diverse; *nPEP*, non-occupational post-exposure prophylaxis; *STI*, sexually transmitted infections; *ED*, emergency department.

disconnection between the needs of the community and the guidelines for care that have been largely created in a researcher/clinician-oriented manner.[21] Purposeful community engagement models are needed to make any future guidelines relevant to the community and to remove barriers to ED care in all phases (decision to attend ED through discharge/follow-up). This comprehensive review identifies the current state of guidance literature for ED TGD care and highlights opportunities for improvement. For example, recommendations for equitable collection and use of gender identity information at triage,[39–41] the safe use of names and pronouns,[4] taking a sexual and gender history and organ inventory in TGD people,[42] and an approach to surgical and medical complications for gender-affirming care[43] are all ED-relevant questions that need to be integrated into good care for TGD populations.

To reinforce the need for community engagement, this review engaged members of the queer medical community in its production, and our group is developing one of the first diverse queer advisory panels to develop training systems for emergency clinicians. Our next step will be to broaden this into a national Delphi-type project to define the pathway for the next 10-year research program that will result in a comprehensive ED-focused guideline for all sexual and gender minorities, including TGD populations. This review, and ongoing similar reviews of sexual minorities and intersex populations, allows us to move onto community engagement so that we may draw patient-centered conclusions from these recommendations and produce more relevant community-focused recommendations in the form of a guideline.

LIMITATIONS

Limitations in this study include inclusion of only English-language articles and a reliance on gray literature where guidelines are not published in standard databases. Thus, it is possible that we did not find relevant BPSs that may have augmented this review. At the time of the literature search, the World Professional Association of Transgender Health Standards of Care version 8 had not been released and so were not included. An informal review of this document found no ED-focused recommendations. As we were concerned with the application of the evidence to clinical care, we excluded systematic and narrative reviews from our analysis. It is possible that by excluding these two sources from our review of guidelines we are missing valuable information for emergency care; however, it becomes a challenge to integrate the very specific but sometimes inconclusive results from a systematic review or the very general conclusions from a narrative review, into discrete clinical practice without a consensus document to give them proper context. For this reason, we felt the risk of exclusion was not outweighed by the benefits of inclusion.

During rating of CPGs/BPSs, the poor ICC of evaluations of methodological domains was affected by the lack of readily available supplementary material that had more details about the methods of the guideline development, and

if it was not included in the main paper it was judged as missing or not done. There was no ICC between assessments of values and preferences of stakeholders in the recommendations. This could be attributed to missing data in the main article, or due to differences in the understanding of the measure by the assessors. It may also be due to lack of overt statement of the values and preferences of the policy/decision makers and or guideline developers and the need to be inferred subjectively. As with the methods, the values and preferences statements were often published in supplemental material, leading to a more subjective assessment by reviewers.

Also, the absence of specific guidance for the ED is a strong limitation of this dataset and will require a more focused systematic review process to answer questions that arise out of the community consensus project mentioned above. The AGREE II process did include a risk of bias assessment (see section 9),[23] but a more subtle form of research bias representing how guidelines are developed in general may not have been captured by this process. Some of the guidelines did include community engagement after the question generation and systematic review process but did not appear to involve community members in question prioritization. This suggests that all the included studies have a researcher-oriented bias that is not captured by the AGREE-II tool. Finally, the AGREE-REX tool suggests that five reviewers review each recommendation to increase reliability of the individual assessments; we had three independent reviewers, which may have decreased the reliability of our quality assessments.

CONCLUSION

This is the most comprehensive review of clinical practice guidelines and best practice statements for ED care of transgender-diverse populations to date and reveals several important actionable recommendations for the care of TGD people in the emergency department. We identified opportunities for community-led development of a long-term research program and development of a comprehensive CPG for care of this population. Future endeavors should focus on creating ED-relevant guidance for culturally and medically competent care for TGD patients, with meaningful engagement of community members in all phases of developing guidance documents.

Address for Correspondence: Michael I. Kruse, MD, BSc, McMaster University, Department of Family Medicine, David Braley Health Sciences Centre, 100 Main Street West, 6th Floor, Hamilton, ON L8P 1H6. Email: michael.kruse@medportal.ca

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. Statistics Canada. Canada is the first country to provide census data on transgender and non-binary people. *The Daily*. 2022;(11):16.
2. Bonifacio JH, Maser C, Stadelman K, et al. Management of gender dysphoria in adolescents in primary care. *CMAJ*. 2019;191(3):E69–E75.
3. Flores AR, Herman JL, Gates GJ, et al. *How Many Adults Identify as Transgender in the U.S?* The Williams Institute, UCLA; 2016:1–13.
4. Hsiang E, Ritchie AM, Lall MD, et al. Emergency care of LGBTQIA+ patients requires more than understanding the acronym. *AEM Educ Train*. 2022;6(S1):S52–6.
5. Bauer GR, Scheim AI, Deutsch MB, et al. Reported emergency department avoidance, use, and experiences of transgender persons in Ontario, Canada: results from a respondent-driven sampling survey. *Ann Emerg Med*. 2014;63(6):713–20.e1.
6. Chisolm-Straker M, Jardine L, Bennouna C, et al. Transgender and gender nonconforming in emergency departments: a qualitative report of patient experiences. *Transgender Health*. 2017;2(1):8–16.
7. Abramovich A, de Oliveira C, Kiran T, et al. Assessment of health conditions and health service use among transgender patients in Canada. *JAMA Netw Open*. 2020;3(8):e2015036.
8. Meyer IH. Prejudice as stress: conceptual and measurement problems. *Am J Public Health*. 2003;93(2):262–5.
9. Delozier AM, Kamody RC, Rodgers S, et al. Health disparities in transgender and gender expansive adolescents: a topical review from a minority stress framework. *J Pediatr Psychol*. 2020;45(8):842–7.
10. Correro AN and Nielson KA. A review of minority stress as a risk factor for cognitive decline in lesbian, gay, bisexual, and transgender (LGBT) elders. *J Gay Lesbian Ment Health*. 2020;24(1):2–19.
11. Reisner SL, Poteat T, Keatley J, et al. Global health burden and needs of transgender populations: a review. *The Lancet*. 2016;388(10042):412–36.
12. Bauer GR, Scheim AI, Pyne J, et al. Intervenable factors associated with suicide risk in transgender persons: a respondent driven sampling study in Ontario, Canada. *BMC Public Health*. 2015;15:525.
13. Glynn TR and van den Berg JJ. A systematic review of interventions to reduce problematic substance use among transgender individuals: a call to action. *Transgender Health*. 2017;2(1):45–59.
14. Institute of Medicine, Board on Health Care Services, Committee on Standards for Developing Trustworthy Clinical Practice Guidelines, et al. *Clinical Practice Guidelines We Can Trust*. Washington, DC: National Academies Press; 2011.

15. Joshi GP, Benzon HT, Gan TJ, et al. Consistent definitions of clinical practice guidelines, consensus statements, position statements, and practice alerts: *Anesth Analg*. 2019;129(6):1767–70.
16. Ziegler E, Carroll B, Charnish E. Review and analysis of international transgender adult primary care guidelines. *Transgender Health*. 2021;6(3):139–47.
17. Dahlen S, Connolly D, Arif I, et al. International clinical practice guidelines for gender minority/trans people: systematic review and quality assessment. *BMJ Open*. 2021;11(4):e048943.
18. Bizub B and Allen B. A review of clinical guidelines for creating a gender-affirming primary care practice. *Wis Med J*. 2020;119(1):8–15.
19. Lech CA. EMRA Transgender Care Guide. Emergency Medicine Residents' Association; 2018.
20. American College of Emergency Physicians. Policy Statement: Caring for Transgender and Gender Diverse Patients in the Emergency Department. American College of Emergency Physicians; 2022:1. Available at: https://www.acep.org/siteassets/new-pdfs/policy-statements/caring-for-transgender-and-gender-diverse-patients-in-the-emergency-department.pdf. Accessed September 1, 2023.
21. Kruse MI, Bigham BL, Voloshin D, et al. Care of sexual and gender minorities in the emergency department: a scoping review. *Ann Emerg Med*. 2022;79(2):196–212.
22. Upadhye S. Key Features of a Clinical Practice Guideline and Best Practice Statement. Personal Communication, 2021.
23. AGREE Next Steps Consortium. The AGREE II Instrument [Electronic version]. Published 2017. Available at: http://www.agreetrust.org. Accessed October 3, 2021.
24. AGREE-REX Research Team. The Appraisal of Guidelines Research & Evaluation—Recommendation EXcellence (AGREE-REX) [Electronic version]. Published 2019. Available at: http://www.agreetrust.org. Accessed October 3, 2021.
25. Niven WGP, Wilson D, Goodacre S, et al. Do all HEART Scores beat the same: evaluating the interoperator reliability of the HEART Score. *Emerg Med J.* Published online September 14, 2018:emermed-2018-207540.
26. Palfreeman A., Sullivan A., Rayment M., et al. British HIV Association/ British Association for Sexual Health and HIV/British Infection Association adult HIV testing guidelines 2020. *HIV Med*. 2020;21(S6):1–26.
27. Pan American Health Organization. Bockting W, Keatley J, et al. Blueprint for the provision of comprehensive care for trans persons and their communities in the Caribbean and other Anglophone countries. Published online 2014. Available at: https://www.paho.org/hq/dmdocuments/2014/2014-cha-blueprint-comprehensive-anglo-countries.pdf. Accessed date.
28. Strang JF, Meagher H, Kenworthy L, et al. Initial clinical guidelines for co-occurring autism spectrum disorder and gender dysphoria or incongruence in adolescents. *J Clin Child Adolesc Psychol*. 2018;47(1):105–15.
29. Tan DHS, Hull MW, Yoong D, et al. Canadian guideline on HIV pre-exposure prophylaxis and nonoccupational postexposure prophylaxis. *Can Med Assoc J*. 2017;189(47):E1448–E1458.
30. Zuniga JM, Bekker LG, Montaner J, et al. IAPAC guidelines for optimizing the HIV care continuum for adults and adolescents. *J Int Assoc Provid AIDS Care*. 2015;14((Zuniga) International Association of Providers of AIDS Care, 1990 M Street NW, Washington, DC 20036, United States):S3–S34.
31. Bell S, Deen JF, Fuentes M, et al. Caring for American Indian and Alaska Native children and adolescents. *Pediatrics*. 2021;147(4).
32. European Centre for Disease Prevention and Control, Desai S, Hoekstra M, et al. *Public Health Guidance on HIV, Hepatitis B and C Testing in the EU/EEA : An Integrated Approach*. European Centre for Disease Prevention and Control; 2019.
33. Romanelli M., Lu W., Lindsey M.A. Examining mechanisms and moderators of the relationship between discriminatory health care encounters and attempted suicide among U.S. transgender help-seekers. *Adm Policy Ment Health*. 2018;45(6):831–49.
34. Bi L, Solnick RE, Merchant RC. A systematic review of HIV screening programs conducted in pediatric emergency departments in the United States. *BMC Emerg Med*. 2022;22:75.
35. González Del Castillo J, Fuentes Ferrer ME, Fernández Pérez C, et al. Efficiency of screening for human immunodeficiency virus infection in emergency departments: a systematic review and meta-analysis. *Emerg Rev Soc Espanola Med Emerg*. 2022;34(3):204–12.
36. Simmons R, Plunkett J, Cieply L, et al. Blood-borne virus testing in emergency departments – a systematic review of seroprevalence, feasibility, acceptability and linkage to care. *HIV Med*. 2022.
37. Carpenter CR, Morrill DM, Sundberg E, et al. Nothing about me without me: GRACE-fully partnering with patients to derive clinical practice guidelines. *Acad Emerg Med*. 2023;30(5):603–5. Epub 2022 Dec 7.
38. Casanova-Perez R, Apodaca C, Bascom E, et al. Broken down by bias: healthcare biases experienced by BIPOC and LGBTQ+ patients. *AMIA Annu Symp Proc*. 2022;2021:275–84.
39. Kodadek LM, Peterson S, Shields RY, et al. Collecting sexual orientation and gender identity information in the emergency department: the divide between patient and provider perspectives. *Emerg Med J*. 2019;36(3):136–41.
40. Leeies M, Collaborators, Hrymak C, et al. Equity-relevant sociodemographic variable collection in emergency medicine: a systematic review, qualitative evidence synthesis & recommendations for practice. *Acad Emerg Med*. Published online November 18, 2022: acem.14629.
41. Maragh-Bass A.C., Torain M., Adler R., et al. Is it okay to ask: transgender patient perspectives on sexual orientation and gender identity collection in healthcare. *Acad Emerg Med*. 2017;24(6):655–67.
42. Street B. Taking routine histories of sexual health: a system-wide approach for health centers. Published online November 2015. Available at: https://www.lgbtqiahealtheducation.org/wp-content/uploads/COM-827-sexual-history_toolkit_2015.pdf. Accessed November 23, 2020.
43. Hanley K, Wittenberg H, Gurjala D, et al. Caring for transgender patients: complications of gender-affirming genital surgeries. *Ann Emerg Med*. 2021;78(3):409–15.

Characteristics and Barriers of Emergency Department Patients Overdue for Cancer Screening

Sara W. Heinert, PhD, MPH*
Mohammed Ahmed*
Kelvin Guzman-Baez*
Ananya Penugonda*
Sarah Oh, PharmD*
Affan Aamir, PharmD*
Jeanne M. Ferrante, MD, MPH†

*Rutgers Robert Wood Johnson Medical School, Department of Emergency Medicine, New Brunswick, New Jersey
†Rutgers Robert Wood Johnson Medical School, Department of Family Medicine and Community Health, New Brunswick, New Jersey

Section Editor: Edward Michelson, MD
Submission history: Submitted March 13, 2023; Revision received October 19, 2023; Accepted November 1, 2023
Electronically published December 20, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.60400

Introduction: People without reliable access to healthcare are more likely to be diagnosed with late-stage cancer that could have been treated more effectively if diagnosed earlier. Emergency departments (ED) may be a novel place for cancer screening education for underserved patients. In this study we sought to determine patient characteristics and barriers to cancer screening for those patients who presented to a large, academic safety-net ED and were overdue for breast, cervical, and colorectal cancer screening since the coronavirus 2019 (COVID-19) pandemic.

Methods: Adult ED patients eligible for at least one cancer screening based on US Preventive Serivces Task Force guidelines completed a web-based survey. We examined the association of demographic characteristics and having a personal physician with being overdue on screening using chi-square or the Fisher exact test for categorical variables and *t*-tests for continuous variables.

Results: Of 221 participants, 144 were eligible for colorectal, 96 for cervical, and 55 for breast cancer screening. Of eligible patients, 46% (25/55) were overdue for breast cancer screening, 43% (62/144) for colorectal, and 40% (38/96) for cervical cancer screening. There were no significant characteristics associated with breast cancer screening. Being overdue for cervical cancer screening was significantly more likely for patients who were of Asian race ($P = 0.02$), had less than a high school diploma ($P = 0.01$), and were without a routine checkup within the prior five years ($P = 0.01$). Overdue for colorectal cancer screening was associated with patients not having insurance ($P = 0.04$), being in their 40s ($P = 0.03$), being Hispanic ($P = 0.01$), and not having a primary care physician ($P = 0.01$). Of 97 patients overdue for at least one screening, the most common barriers were cost (37%), lack of time (37%), and lack of knowledge of screening recommendations (34%). Only 8.3% reported that the COVID-19 pandemic delayed their screening.

Conclusion: The ED may be a novel setting to target patients for cancer screening education. Future work that refers patients to free screening programs and primary care physicians may help improve disparities in cancer screening and cancer mortality rates for underserved populations. [West J Emerg Med. 2024;25(1)101–110.]

INTRODUCTION

The World Health Organization estimates that 30–50% of cancer deaths could be prevented by modifying or avoiding key risk factors and implementing existing, evidence-based prevention strategies.[1] Early detection of cancer and management of patients who develop cancer can also reduce the cancer burden.[1] Over time, overall cancer death rates have decreased[2]; however, racial/ethnic and socioeconomic disparities exist. The rate of new cancer is higher for Whites than Blacks, yet cancer deaths are lower for Whites than Blacks.[3] Hispanic and Black women have higher rates of cervical cancer than other racial/ethnic groups, and Black women and women with less education have the highest rates of death from cervical cancer.[4] Additionally, people with less education are more likely to die from colorectal cancer (CRC) before the age of 65 than those with more education.[4]

While several factors contribute to cancer disparities, people without reliable access to healthcare are more likely to be diagnosed with late-stage cancer that could have been treated more effectively if diagnosed earlier.[4] Patients without insurance are significantly less likely to be up to date with mammography and CRC screening than patients with insurance.[5] Emergency departments (ED) tend to serve in a safety-net capacity for underserved patients.[6] Hispanic and Black patients are significantly more likely to report higher ED utilization and no usual source of care than White patients.[7] Visits to the ED for primary care needs are highest for uninsured and low-income patients, suggesting a lack of access to primary care for these patients.[8] Thus, many ED patients have no interaction with the healthcare system outside the ED, and they can be difficult to reach for cancer screening interventions.

Past studies of cancer screening adherence for eligible ED patients have found that 12–33% of women were overdue or had uncertain adherence with cervical cancer screening[9–11]; 12–46% of women were overdue for breast cancer screening[5,10–12]; and 17–46% were overdue for CRC screening.[5,12,13] The percentage of patients overdue for cancer screenings has been significantly higher for those who have no insurance[5,9,10,13] or a primary care physician,[9,13] and patients with less education,[5,9,13] with mixed findings on the role of race and ethnicity,[5,9,11–13] However, these studies occurred prior to the coronavirus 2019 (COVID-19) pandemic. Results from large national surveys showed that approximately 55% of respondents reported that they or someone in their household delayed or skipped routine medical care during the pandemic,[14,15] suggesting that rates of being overdue for cancer screening may be higher post-pandemic and/or more disparate for some groups of patients. Our objective in this study was to determine the proportion of patients in a large, diverse, academic safety-net ED who were eligible for and overdue on breast, cervical, and CRC screening, as well as to determine their characteristics and the barriers they faced to obtaining screening. We could find no other studies in the literature that explored patient characteristics since the COVID-19 pandemic or determined barriers to cancer screening among ED patients. Additionally, most past work has not included Spanish-speaking patients.

Population Health Research Capsule

What do we already know about this issue?
People without reliable access to healthcare are more likely to be diagnosed with late-stage cancer that could be treated more effectively if diagnosed earlier.

What was the research question?
What are the characteristics of and barriers faced by emergency department (ED) patients overdue for cancer screening?

What was the major finding of the study?
Patient characteristics were associated with being overdue for cervical and colorectal cancer screening. Cost (37%), lack of time (37%), and lack of knowledge (33%) were barrier.

How does this improve population health?
The ED may be a novel setting to target patients for cancer screening education. Our findings can inform future studies to improve cancer screening disparities.

METHODS

This was a cross-sectional survey study of patients seen from March–September 2022 at the Robert Wood Johnson University Hospital (RWJUH) ED in New Brunswick, New Jersey, a Level I trauma center and safety-net hospital. The ED treats approximately 71,000 adult (21+ years) patients annually and serves a population of approximately 54% women, 39% Black, and 17% Hispanic patients, with 23% having Medicaid and 16% with no insurance.

Survey Design

Survey questions included demographics, primary care physician and cancer screening questions from the 2020 Behavioral Risk Factor Surveillance System[18]; personal and family history of cancer and cancer information-seeking questions from the Health Information National Trends Survey 2020[19]; cancer screening barriers adapted from Akinlotan et al, 2017[20]; and delay of healthcare due to COVID-19 questions adapted from the National Health Interview Survey 2021.[21] The assessment consisted of 21 questions that all participants completed, followed by questions specific to each

cancer type (2–10 questions per section) that the participant was eligible for screening (based on age and gender). Additionally, 15 questions asked about barriers to cancer screening, including delays due to the COVID-19 pandemic. The survey was available in English and Spanish.

Survey Administration

Recruitment fliers were posted in the RWJUH ED, which included a quick response (QR) code and link to the survey on REDCap (Research Electronic Data Capture), a secure, web-based software platform designed to support data capture for research studies hosted at our institution.[16,17] Contact information for the study team was also listed on the flier if patients preferred to complete the survey via phone with a member of the study team. Surveys were initially available (March and April 2022) only through passive recruitment (posted fliers in the ED) due to the pandemic; research assistants (RA) actively recruited patients in the ED starting in May 2022. The RAs used convenience sampling to approach all patients during their recruitment shift and inform them about the study, assess eligibility, and direct eligible and interested patients to the survey. Most recruitment shifts were conducted during regular business hours. Several RAs were fluent in Spanish, aiding in communication with Spanish-speaking patients.

Interested patients had the option to follow the link to the survey on their own devices and complete the survey themselves or, if preferred, have the survey administered to them by the RA. Patients could participate if they were eligible for at least one cancer screening based on US Preventive Services Task Force recommendations for gender and age. [22–24] Patients self-reported their cancer screening status through the survey. Figure 1 provides details on patients approached by a RA in the ED. Of the three methods to complete the survey, 192 participants completed it when approached by an RA in the ED, 28 completed it on their own via link/QR code from a flier (six during passive recruitment only and 22 during a period of both active and passive recruitment), and one called the study team to complete the survey over the phone. Each participant completed only questions for each cancer type in which they were eligible for screening. All participants received a $15 gift card incentive. The study was approved by the Rutgers University Institutional Review Board.

Statistical Analysis

For our analytic samples, we excluded any patient who was eligible for screening questions for a cancer type but had previously been diagnosed with that cancer type. For example, if a participant was eligible for breast cancer screening questions, but they had previously been diagnosed with breast cancer then they were excluded from the breast cancer screening data analysis. We excluded women with a hysterectomy from the cervical cancer analysis. We used descriptive statistics to characterize the overall sample and the percentage of participants eligible for each cancer screening, as well as the percentage eligible who were overdue for each cancer screening. We examined bivariate associations of demographic and medical characteristics for participants overdue on screening for each cancer type, using chi-square and the Fisher exact test for categorical variables and *t*-tests for continuous variables. We analyzed data using Stata version 16.0 (StataCorp, College Station, TX). All *P*-values are two-tailed, and α was set at 0.05.

RESULTS

Characteristics for all 221 survey respondents are found in Table 1. Overall, 14.9% completed the survey in Spanish, 60.2% were women, 18.6% were Black, and 29.9% were Hispanic. The mean age was 51.6 years (SD 15.3), median 55.0. Over 22% and 10% had Medicaid or no insurance, respectively, and about half of participants had a high school education or less (51.2%). About 72% had a primary care physician, and 73% had seen a doctor for a routine checkup within the prior year. A quarter of the sample had a previous history of cancer, and 11% had delayed cancer screening due to the COVID-19 pandemic.

Table 2 shows the percentage of participants eligible for each cancer screening type. Most participants (144) were eligible for CRC screening, followed by 96 for cervical and 55 for breast cancer screening. Of eligible patients, 45.5% were overdue for breast, 39.6% for cervical, and 43.1% for CRC screening.

Table 3 shows demographic and medical characteristics of survey respondents who were overdue on cancer screening compared to the total eligible for cancer screening by cancer type. There were no significant characteristics associated with breast cancer screening. Being overdue for cervical cancer screening was significantly more likely for patients of Asian race ($P = 0.02$), patients who had less than high school diploma ($P = 0.01$), and those without a routine checkup within the prior five years ($P = 0.01$). Overdue for CRC screening was associated with not having insurance ($P = 0.04$), patients in their 40s ($P = 0.03$), being Hispanic ($P = 0.01$), and not having a primary care physician ($P = 0.01$). For the continuous age variable, patients overdue for CRC screening were significantly younger (mean 57.6, SD 8.6) compared to patients not overdue for CRC screening (mean 62.7, SD 7.4, not shown) ($P = <0.001$).

There were 97 unique participants who were overdue on at least one screening for which they were eligible. Table 4 summarizes cancer information-seeking and cancer screening barriers for these patients. Of patients overdue on screening, 35.1% had looked for information about cancer, and 77.3% were completely or very confident that they could get advice or information about cancer if they needed it. Most participants would first go to the internet (44.3%) or a doctor (42.3%) if they had a strong need to get information

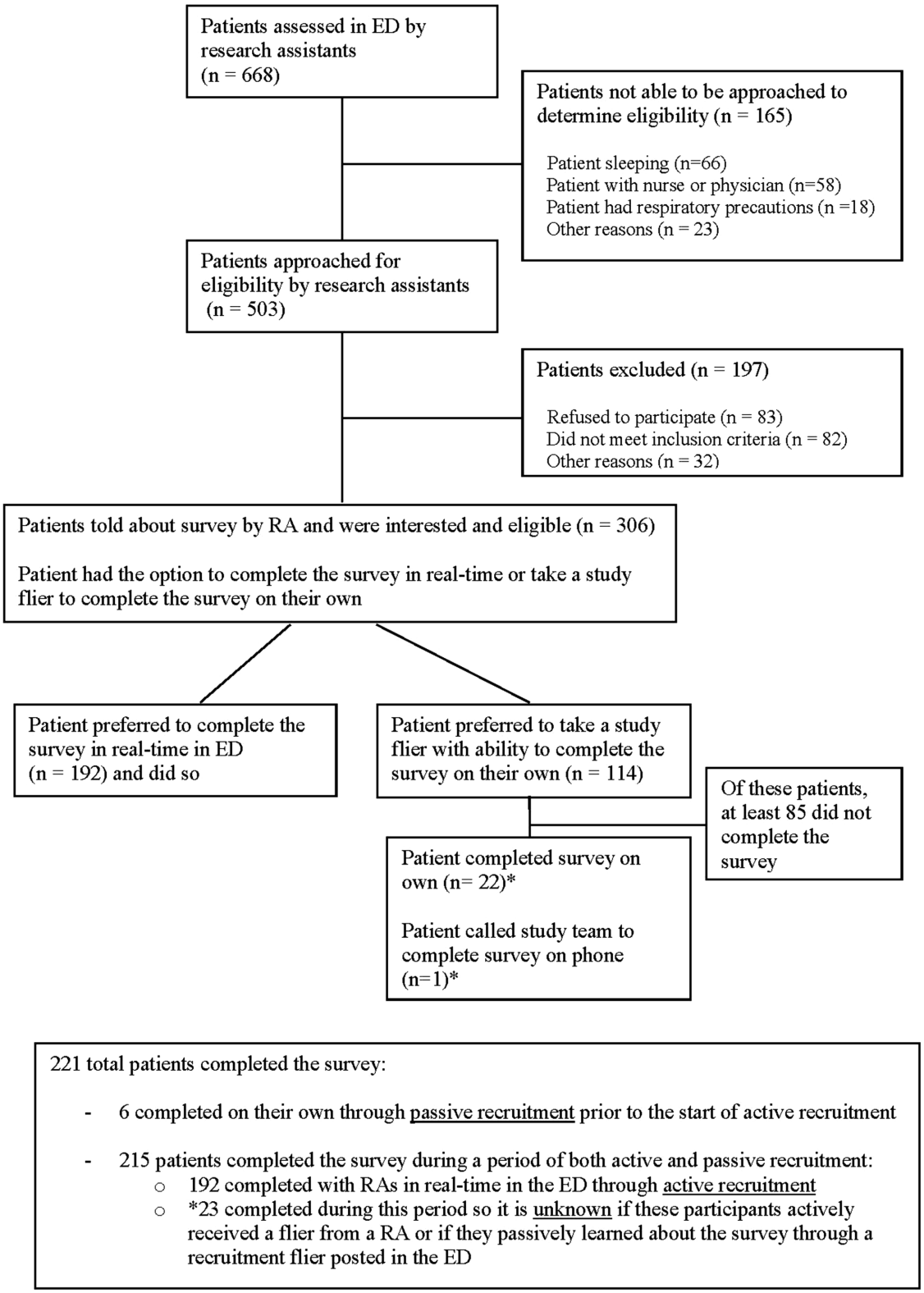


Figure 1. CONSORT diagram for patients approached by a research assistant in the emergency department. RA, research associate; ED, emergency department.

about cancer. The most common barriers to screening were cost (36.8%), lack of time (36.5%), and lack of knowledge regarding screening recommendations (34.4%). Of participants who were overdue on screening, only 8.3% reported that they delayed getting cancer screening because of the COVID-19 pandemic.

Table 1. Survey respondent demographics and health characteristics (N = 221).*

		N	%
Language	English	188	85.1
	Spanish	33	14.9
Gender	Men	88	39.8
	Women	133	60.2
Age (Years)	Mean (SD), median	51.6 (15.3), 55.0	
	18–45	72	32.6
	46–64	103	46.6
	≥65	46	20.8
Race^	Black	41	18.6
	Asian	16	7.2
	White	114	51.6
	American Indian/Alaskan Native	2	0.9
	Native Hawaiian or other Pacific Islander	1	0.5
	Other#	51	23.1
Ethnicity	Hispanic	66	29.9
	Non-Hispanic	155	70.1
Insurance type	Medicaid	49	22.4
	Medicare	56	25.6
	No insurance	23	10.5
	Private insurance	84	38.4
	Other	7	3.2
Highest level of education	Some high school	32	14.5
	High school degree	81	36.7
	College degree	68	30.8
	Postgraduate degree	25	11.3
	Trade school	15	6.8
Do you have one person you think of as your personal doctor or healthcare provider?	Yes, only one	158	71.5
	More than one	18	8.1
	No	44	19.9
	Not sure	1	0.5
About how long has it been since you last visited a doctor for a routine checkup?	Within the past year (any time less than 12 months ago)	162	73.3
	Within the past 2 years (1 year but less than 2 years ago)	19	8.6
	Within the past 5 years (2 years but less than 5 years ago)	14	6.3
	5 or more years ago	10	4.5
	Not sure	12	5.4
	Never	4	1.8
Have you ever been diagnosed as having cancer?	Yes (Any)	57	25.8
	Breast	7	3.2
	Cervical	3	1.4
	Colorectal	9	4.1

(*Continued on next page*)

Table 1. Continued.

		N	%
Have any of your first- or second-degree biological relatives ever had cancer? (N = 220)	Yes	126	57.3
	No	85	38.6
	Not sure	9	4.1
Was there any time when you delayed getting a cancer screening because of the coronavirus 2019 pandemic?	Yes	25	11.3
	No	194	87.8
	Not sure	2	0.9

*Percentages may not add to 100 due to missing data.
^Participants could choose all that apply.
#Other include the following: Hispanic (including Latino/a, Dominican, Mexican, Nicaraguan) (n = 37), more than one race (n = 4), Arabic (n=1), Egyptian (n = 1), and blank (n = 8).

Table 2. Percentage of participants eligible for and overdue on cancer screenings by cancer type

	Eligibility*	N of ED patients eligible for screening	N (%) of patients eligible who were overdue on screening
Breast	Women, 50–74 years+	55	25 (45.5)
Cervical	Women, 21–65 years	96	38 (39.6)
Colorectal (CRC)	Men and women, 45–75 years	144	62 (43.1)

Notes: *Based on US Preventive Services Task Force (USPSTF) recommendations.
+Survey was conducted prior to USPSTF changing its recommendation to begin breast cancer screening at age 40.

Table 3. Demographics and medical characteristics of survey respondents overdue on cancer screening compared to total eligible for cancer screening by type.

		Overdue on breast cancer screening N (%)[1] 25 (45.5)	*P*-value	Overdue on cervical cancer screening N (%)[2] 38 (39.6)	*P*-value	Overdue on colorectal cancer screening N (%)[3] 62 (43.1)	*P*-value
Language	English	25 (49.0)	0.12[e]	31 (36.5)	0.11[e]	51 (40.5)	0.10
	Spanish	0 (0.0)		7 (63.6)		11 (61.1)	
Gender	Men	-	-	-	-	35 (44.9)	0.63
	Women	-		-		27 (40.9)	
Age (years)	Mean (SD), Median (IQR)	60.8 (6.3), 60.0	0.15	44.7 (15.5), 48.0	0.17	57.6 (8.6), 57.0	<**0.001**
	21–39	-	0.45	14 (29.2)	0.06[e]	**-**	**0.03**
	40–49	-		5 (35.7)		13 (68.4)	
	50–65	19 (48.7)		19 (55.9)		36 (42.9)	
	66–75	6 (37.5)		-		13 (31.7)	
Race (Select all that apply)	Black	3 (30.0)	0.60[e]	4 (23.5)	**0.02[e]**	9 (33.3)	0.08[e]
	Asian	0 (0.0)		8 (72.7)		3 (42.9)	
	White	17 (51.5)		13 (30.2)		32 (39.0)	
	Other	5 (45.5)		13 (52.0)		18 (64.3)	

(*Continued on next page*)

Table 3. Continued.

		Overdue on breast cancer screening N (%)[1] 25 (45.5)	*P*-value	Overdue on cervical cancer screening N (%)[2] 38 (39.6)	*P*-value	Overdue on colorectal cancer screening N (%)[3] 62 (43.1)	*P*-value
Ethnicity	Hispanic	3 (30.0)	0.32[e]	12 (44.4)	0.54	21 (61.8)	**0.01**
	Non-Hispanic	22 (48.9)		26 (37.7)		41 (37.3)	
Insurance type	Medicaid	7 (70.0)	0.43[e]	12 (44.4)	0.06[e]	10 (40.0)	**0.04[e]**
	Medicare	8 (47.1)		2 (28.6)		19 (35.9)	
	No insurance	1 (33.3)		6 (75.0)		9 (69.2)	
	Private insurance	9 (37.5)		16 (31.4)		20 (40.8)	
	Other	0 (0.0)		2 (100.0)		4 (100.0)	
Highest level of education	Some high school	3 (42.9)	0.49[e]	5 (71.4)	**0.01[e]**	14 (58.3)	0.37[e]
	High school degree	13 (59.1)		15 (44.1)		25 (44.6)	
	College degree	6 (31.6)		16 (47.1)		16 (39.0)	
	Postgraduate degree[+]	1 (50.0)		2 (15.4)		3 (25.0)	
	Trade school	2 (40.0)		0 (0.0)		4 (36.4)	
Have a personal doctor or healthcare provider?	Yes, one or more	23 (45.1)	1.00[e]	27 (35.5)	0.11	48 (38.7)	**0.01**
	No	2 (50.0)		11 (55.0)		14 (70.0)	
About how long has it been since you last visited a doctor for a routine checkup?	Within the past year	16 (38.1)	0.22[e]	26 (36.1)	**0.01[e]**	41 (38.7)	0.30[e]
	Within the past 2 years (1–2 years ago)	2 (66.7)		2 (28.6)		8 (61.5)	
	Within the past 5 years (2–5 years ago)	2 (66.7)		2 (22.2)		4 (44.4)	
	5 or more years ago	3 (75.0)		6 (100.0)		3 (60.0)	
	Not sure	2 (100.0)		1 (100.0)		5 (71.4)	
	Never	0 (0.0)		1 (100.0)		1 (25.0)	
Past cancer diagnosis	Yes	8 (47.1)	0.87	9 (64.3)	0.07[e]	17 (37.8)	0.39
	No	17 (44.7)		29 (35.4)		45 (45.5)	
First- or second-degree biological relatives ever had cancer	Yes	15 (45.5)	0.77[e]	19 (32.2)	0.08[e]	34 (40.0)	0.55[e]
	No	9 (42.9)		18 (50.0)		24 (47.1)	
	Not Sure	1 (100.0)		1 (100.0)		4 (57.1)	

Notes: [+]Includes master's or doctorate degrees; e = Fisher exact test, [1]Of 55 total eligible for breast cancer screening, [2]Of 96 total eligible for cervical cancer screening. [3]Of 144 total eligible for colocrectal cancer screening.
IQR, interquartile range.

Table 4. Cancer information-seeking and barriers for patients overdue on breast, cervical, and/or colorectal cancer screening (N = 97)

	Response	Patients overdue on screening N (%)
Ever looked for information about cancer from any source	Yes	34 (35.1)
	No	63 (65.0)
Overall, how confident are you that you could get advice or information about cancer if you needed it?	Completely or very confident	75 (77.3)
Where you would you go first if you had a strong need to get information about cancer	Internet	43 (44.3)
	Doctor or health care provider	41 (42.3)
	Family	6 (6.2)
	Cancer organization	2 (2.1)
	Library	2 (2.1)
	Other	2 (2.1)
	Friends/Co-worker	1 (1.0)
	Books	0 (0.0)
Screening Barriers (Agree or Strongly Agree)	Lack of time	35 (36.5)
	Cost	35 (36.8)
	Not knowing screening recommendations	33 (34.4)
	Fear of finding cancer	32 (33.0)
	Forgetting to schedule appointment	30 (31.6)
	Anxiety	27 (27.8)
	Other health problems	25 (26.3)
	Transportation	22 (22.9)
	Anticipation of pain	21 (21.9)
	Embarrassment	21 (21.9)
	Language barriers	18 (18.8)
	Opposite sex physician	9 (9.4)
Was there any time when you DELAYED getting cancer screening because of the pandemic?	Yes	8 (8.3)
	No	89 (91.8)
Please share how the COVID-19 pandemic delayed you getting a cancer screening. (n=8)	Didn't want to leave house	3
	High-risk patient	1
	Increased fatigue, interest, forgetfulness	1
	"It just screwed up everything."	1
	Mammogram got rescheduled	1
	Process	1

COVID-19, coronavirus 2019.

DISCUSSION

We examined cancer screening adherence two years since the start of the COVID-19 pandemic and across three types of cancers: breast; cervical; and colorectal. It was not surprising that the highest percentage of ED patients responding to the survey were eligible for CRC screening since that group comprised both men and women. Approximately 40–45% of eligible patients were overdue on breast, cervical, or CRC screening.

Despite the fact that only 8.3% of participants reported that COVID-19 delayed their cancer screening, our findings found relatively high rates of patients overdue on screening compared to past studies conducted in the ED prior to the pandemic (overdue rates 12–33% for cervical,[9–11] 12–46% for breast,[5,10–12] and 17–46% for CRC screening[5,12,13]). Our higher rates of overdue screenings were probably due not to the pandemic but may have been related to the characteristics of our patient population. Our study had much higher percentages of Asian (7%) and Hispanic (30%) participants than other similar studies, which had 1–3%[5,9,10,13] and 7–18%,[5,10–13,25] respectively. Additionally, in our study Spanish-speaking patients represented 15% of all participants.

We could only find one previous study of screening adherence in ED patients that mentioned the availability of Spanish-speaking RAs for their survey, but no report of how many of the patients they surveyed spoke Spanish. [11]The study found 12% overdue for breast and 33% overdue for cervical cancer screening, and had higher rates of White and privately insured participants than our study.[11] Future research on culturally relevant cancer screening interventions that target Asian and Hispanic patients in the ED are warranted.

No significant characteristics were found for women overdue on breast cancer screening, suggesting that there may be existing programs that provide more equitable access to mammograms for all women. One prior study across five EDs found that being overdue for both breast and cervical cancer screenings was significantly higher for women with no insurance. [10] Our findings found similar results for cervical and CRC but not breast cancer screening. Our results suggest other patients who could be potentially targeted in the ED for cervical cancer screening: Asian women; those with less education; and patients not having a routine checkup within the prior five years. For CRC screening, potential populations to target in the ED include patients who are younger (40s), Hispanic, uninsured, and those without a primary care physician.

In addition to patient characteristics, our study also determined barriers to screening for overdue patients. To our knowledge, no other studies have explored barriers to cancer screening in patients presenting to the ED. Cost, lack of time, and lack of knowledge were the most prevalent screening barriers for patients overdue on cancer screenings. Future work can explore more in-depth explanations of these patient barriers and may be helpful for developing future interventions. For example, our findings suggest the ED may be a novel place to educate and refer patients for cancer screenings.

LIMITATIONS

This study has several limitations. First, it was conducted in one ED; however, the setting is probably similar to other academic safety-net hospitals in the Northeast US. Second, while recruitment fliers were displayed in the ED with a link for any patient interested in completing the survey, most participants (192/ 221) were recruited in person by a RA during business hours. In our convenience sample, Black patients were underrepresented and patients with previous cancer over-represented; thus, our cancer screening rates may be overestimated. Our hospital is affiliated with the only National Cancer Institute-designated cancer center in New Jersey, which could help explain our large percentage of participants with previous cancer diagnosis. It is possible that given their past history of cancer, they may have been more willing to participate in a cancer-related survey, more likely to get cancer screenings even during the pandemic, and may have had characteristics that are different than the general ED population, such as more connectedness to the healthcare system.

Additionally, our small sample precluded multivariable analyses; thus, our findings may have been confounded by other factors. Finally, we implemented both active and passive (fliers posted in the ED) recruitment, but we collected recruitment information only for participants during active recruitment. We do not know the percentage of total ED patients during our study period who were eligible for or received cancer screening, as chart review was beyond the scope of this study. Neither did we link recruitment method type to individual surveys, as all participants completed the survey through the same REDCap survey link. Thus, we were unable to determine whether participant characteristics differed between recruitment method types.

CONCLUSION

The ED may be a novel setting to target patients for cancer screening education. Our findings can inform future studies to create interventions that incorporate ways to improve cancer screening knowledge and support to improve disparities in cancer screening among ED patients. Referral to free screening programs and primary care physicians may help improve disparities in cancer screening and cancer mortality rates for underserved populations.

Address for Correspondence: Sara W. Heinert, PhD, MPH, Rutgers Robert Wood Johnson Medical School, Department of Emergency Medicine, One Robert Wood Johnson Place, New Brunswick, NJ 08901. Email: sara.heinert@rutgers.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. This study was supported by The Rutgers Cancer Institute of New Jersey (P30CA072720). During the study, Dr. Heinert was also supported by a KL2 career development award from the National Center for Advancing Translational Sciences (NCATS), a component of the National Institutes of Health (NIH) under award number KL2TR003018/ UL1TR003017. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

REFERENCES

1. World Health Organization. Cancer: Prevention. Available at: https://www.who.int/health-topics/cancer#tab=tab_2. Accessed October 11, 2021.

2. National Cancer Institute. Cancer Statistics. Available at: https://www.cancer.gov/about-cancer/understanding/statistics. Accessed October 11, 2021.
3. National Cancer Institute Surveillance E, and End Results Program. Cancer Stat Facts: Cancer Disparities. Available at: https://seer.cancer.gov/statfacts/html/disparities.html. Accessed October 11, 2021.
4. National Cancer Institute. Cancer Disparities. Available at: https://www.cancer.gov/about-cancer/understanding/disparities. Accessed October 11, 2021.
5. Miles RC, Flores EJ, Lopez DB, et al. Leveraging emergency department encounters to improve cancer screening adherence. *J Am Coll Radiol*. 2021;18(6):834–40.
6. Tang N, Stein J, Hsia RY, et al. Trends and characteristics of US emergency department visits, 1997-2007. *JAMA*. 2010;304(6):664–70.
7. Parast L, Mathews M, Martino S, et al. Racial/ethnic differences in emergency department utilization and experience. *J Gen Intern Med*. 2022;37(1):49–56.
8. Begley CE, Vojvodic RW, Seo M, et al. Emergency room use and access to primary care: evidence from Houston, Texas. *J Health Care Poor Underserved*. 2006;17(3):610–24.
9. Adler D, Abar B, Wood N, et al. An intervention to increase uptake of cervical cancer screening among emergency department patients: results of a randomized pilot study. *J Emerg Med*. 2019;57(6):836–43.
10. Abar B, Dalawari P, Ogedegbe C, et al. Identifying cancer screening adherence in the emergency department utilizing research associates. *J Emerg Med*. 2020;59(6):894–9.
11. Ginde AA, Millen JC, Love JS, et al. Compliance with recommended cancer screening among emergency department patients: a multicenter survey. *Acad Emerg Med*. 2008;15(5):483–6.
12. Pettit N, Ceppa D, Monahan P. Low rates of lung and colorectal cancer screening uptake among a safety-net emergency department population. *West J Emerg Med*. 2022;23(5):739–45.
13. Abar B, Park CS, Dalawari P, et al. Intervention during wait time: identification and referral of individuals non-adherent for colorectal cancer screening. *Emerg Cancer Care*. 2022;1(1):12.
14. Patel S, Lorenzi N, Smith T, et al. Critical insights from patients during the COVID-19 pandemic. *NEJM Catal Innov Care Deliv*. 2020;1(4).
15. Phillips Cate Jarrard and & Hancock , Strategies PO. *Executive Summary: Coronavirus and Its Impact on US Healthcare Providers*. April 2020.
16. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: building an international community of software platform partners. *J Biomed Inform*. 2019;95:103208.
17. 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.
18. Centers for Disease Control and Prevention. BRFSS Questionnaires: 2020 Survey Questions. 2020; Available at: https://www.cdc.gov/brfss/questionnaires/index.htm. Accessed November 21, 2022.
19. National Cancer Institute. Survey Instruments: HINTS 5, Cycle 4 (2020) Survey Materials. 2020; Available at : https://hints.cancer.gov/data/survey-instruments.aspx#H5C4. Accessed November 21, 2022.
20. Akinlotan M, Bolin JN, Helduser J, et al. Cervical cancer screening barriers and risk factor knowledge among uninsured women. *J Community Health*. 2017;42(4):770–8.
21. National Center for Health Statistics. NHIS Data, Questionnaires and Related Documentation: 2021 NHIS. 2021; Available at: https://www.cdc.gov/nchs/nhis/data-questionnaires-documentation.htm. Accessed November 21, 2022.
22. Siu AL. Screening for Breast Cancer: U.S. Preventive Services Task Force Recommendation Statement. *Ann Intern Med*. 2016;164(4):279–96.
23. US Preventive Services Task Force. Screening for Cervical Cancer: US Preventive Services Task Force Recommendation Statement. *JAMA*. 2018;320(7):674–86.
24. US Preventive Services Task Force. Screening for Colorectal Cancer: US Preventive Services Task Force Recommendation Statement. *JAMA*. 2021;325(19):1965–77.
25. Adler D, Abar B, Chiao EY. Emergency department-based cancer screening interventions. *Emerg Cancer Care*. 2022;1(1):3.

A Collaborative Approach to Mentored Peer Reviews Sponsored by the Council of Residency Directors in Emergency Medicine

Jeffrey N. Love, MD, MHPE, MSc*
Chris Merritt, MD, MPH, MHPE†
Jonathan S. Ilgen, MD, PhD‡
Anne M. Messman, MD, MHPE§
David P. Way, MEd‖
Douglas S. Ander, MD¶
Wendy C. Coates, MD#

*Georgetown University School of Medicine, Department of Emergency Medicine, Washington, DC
†Brown University, Alpert Medical School, Department of Emergency Medicine, Providence, Rhode Island
‡University of Washington, Department of Emergency Medicine, Seattle, Washington
§Wayne State University, Department of Emergency Medicine, Detroit, Michigan
‖Ohio State University College of Medicine, Department of Emergency Medicine, Columbus, Ohio
¶Emory University, Department of Emergency Medicine, Atlanta, Georgia
#University of California: Los Angeles, David Geffen School of Medicine, Department of Emergency Medicine, Los Angeles, California

Section Editor: Mark Langdorf, MD, MHPE
Submission history: Submitted July 2, 2023; Revision received August 21, 2023; Accepted August 23, 2023
Electronically published December 6, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.61488

Introduction: Historically, there have been no systematic programs for teaching peer review, leaving trainees to learn by trial and error. Recently, a number of publications have advocated for programs where experienced reviewers mentor trainees to more efficiently acquire this knowledge.

Objective: Our goal was to develop an introductory learning experience that intentionally fosters peer-review skills.

Methods: The Council of Residency Directors in Emergency Medicine (CORD) offered education fellowship directors the opportunity to mentor their fellows by reviewing submitted manuscript(s) supplemented by educational material provided by their journal. Reviews were collaboratively created. The decision letter that was sent to manuscript authors was also sent to the mentees; it included all reviewers' and editor's comments, as feedback. In 2022, fellows received a post-experience survey regarding prior experiences and their perspectives of the mentored peer-review experience.

Results: From 2020–2022, participation grew from 14 to 30 education fellowships, providing 76 manuscript peer reviews. The 2022 survey-response rate of 87% (20/23) revealed that fellows were inexperienced in education scholarship prior to participation: 30% had authored an education paper, and 10% had performed peer review of an education manuscript. Overall, participants were enthusiastic about the program and anxious to participate the following year. In addition, participants identified a number of benefits of the mentored experience including improved understanding of the scholarship process; informing fellows' scholarly pursuits; improved conceptualization of concepts learned elsewhere in training; and learning through exposure to scholarship.

Conclusion: This program's early findings suggest that collaboration between academic societies and interested graduate medical education faculty has the potential to formalize the process of learning peer review, benefitting all involved stakeholders. [West J Emerg Med. 2024;25(1)111–116.]

INTRODUCTION

The process of peer review has a longstanding history of providing both validity and credibility to published research.[1–3] Traditionally, peer reviewers achieved competence through trial and error with some receiving unstructured mentorship from experienced reviewers.[2] Although many have advocated for more rigorous and replicable processes for peer-review training, there remains a paucity of programs intentionally designed to achieve this goal.[2,4,5]

Over the last two decades, sporadic opportunities such as peer-review workshops, learning modules, and publications have been developed, yet these offerings have limited reach and variable content.[2,5,6] More recently, a few authors have shared their experiences, advocating for mentored peer reviews (MPR) based on one-to-one interactions with more experienced reviewers[7–9] and group peer reviews (GPR)[3,7,10,11] that incorporate a mix of reviewer experiences. These approaches provide opportunities to learn peer review from experienced role models and to practice and refine skills alongside peers. Some programs have begun to make progress in formalizing the process of MPRs. A GPR program involving blogs in academic emergency medicine (EM) reported increased confidence among participants who also felt the process was friendly, easy, efficient, and transparent.[8] The *Journal of the American College of Cardiology* similarly described a program in which fellows in a heart failure fellowship were nominated by an associate editor to learn the peer-review process through mentorship and group-based discussions.[7]

Although several editors in health professions education have expressed an interest in MPRs,[3,10,11] we are not aware of any formal, larger-scale educational opportunities to train novice reviewers.

OBJECTIVES

Cameron et al encouraged academic societies to sponsor professional development efforts related to education scholarship, including MPRs, which have the potential to "foster a pipeline of education scholars that reap benefits for an entire specialty."[12] In 2020 the Council of Residency Directors of Emergency Medicine (CORD) learned through a posting on the CORD listserv of a need among EM education fellowships for a learning opportunity related to peer review. A follow-up query on the CORD listserv yielded 14 education fellowships that were interested in having their fellows gain experience in this scholarly activity. As a result, CORD set about instituting learning communities around peer review, fostering MPR through the annual *Western Journal of Emergency Medicine Special Issue in Educational Research and Practice* (Special Issue). Consistent with CORD's mission to "lead the advancement of emergency medicine education,"[13] the objective of this opportunity was to develop an introductory, peer-review learning experience that would more intentionally foster peer-review skills. The data gathered as part of an observational study was used to provide a better understanding of the program's growth and potential value to the participants and journal.

CURRICULAR DESIGN

Fellowships in health professions education are becoming increasingly common as a means to provide junior faculty members with focused experiences in medical education practice and scholarship.[14–15] Education fellowships within EM can be either one or two years in duration, the latter tending to have a more scholarly focus.[16] Working closely with fellowship directors and other mentors, these programs offer an entrée into the community of practice of educators and education scholars through legitimate participation in teaching and education scholarship.[17]

Decision-making regarding curriculum development, program standards, and survey content were based on developing a consensus through an iterative process involving participating authors/editors. Mentored peer reviews were first offered to interested fellowship programs during the pilot phase in 2020. Fellowship directors received these offers as part of the normal rotation of reviewers, regardless of submission type or manuscript topic. Because education fellowships are not accredited by the Accreditation Council for Graduate Medical Education, they vary in structure and faculty support. Consequently, each fellowship director and mentee determined their own process of MPRs and negotiated how many reviews were appropriate each year.

At the end of every calendar year, editors solicited feedback from fellowship directors and fellows regarding how the program could be improved. This feedback informed editors' efforts to structure an enhanced program based on guiding principles of successful professional development initiatives including the following: 1) a basis in experiential learning; 2) the provision of feedback; 3) effective peer and colleague relationships; 4) well designed interventions following principles of teaching and learning; and 5) a diversity of educational methods within single interventions.[18] At the end of the 2022 submission cycle, a survey was initiated that included questions about participants' background and prior experience (Supplemental File 1).

As an experiential learning opportunity, the four components of Kolb's learning cycle were incorporated to maximize learning:[19]

- Concrete Learning: As a pre-interventional activity, we provided each mentee and their fellowship director with the following resources: three articles from varying perspectives on the principles of performing high quality peer review[20–22]; the scoring rubric editors used to assess reviews (Supplemental File 2);

and a blinded copy from the Special Issue archives previously recognized as a quality review.

- Experimentation: Mentorship is recognized as an important influence on learning, research, productivity, personal development, and satisfaction.[23,24] In our mentored peer-review process, novice peer reviewers play an authentic role in education scholarship under the guidance of a mentor, further incorporating them into a community of practice around shared values[25] while promoting their professional identify formation.[17,25–28]
- Reflection: There were multiple opportunities for novice reviewers to reflect on their review experiences. This began with their discussions with mentors regarding the merits and potential areas of improvement for each article and continued in their individual and collective efforts to convey this feedback in written form as they constructed their reviews. When editors rendered a disposition for each manuscript, reviewers were copied on the decision letter sent to the authors. This letter summarized the factors important in the editor's decision and included all reviewers' comments. This approach has been advocated to promote reflection through other reviewers' insights, and how the reviews were used collectively by the decision editor to render a decision.[20]
- Abstract Conceptualization: Professional development initiatives are most effective if they are integrated into a curriculum that allows for abstract conceptualization through reinforced learning and the opportunity to connect what was learned to related concepts.[11,25,29] Integration of the CORD MPR program into the fellowships' curricula enabled synergistic learning between the experiential learning afforded by the peer-review experience and underlying educational theory, best practices and research methodology, which are typical learning outcomes in education fellowships.

In the initial letter confirming acceptance of the review sent to mentor and mentee, we explicitly stated that the peer review was to be a mentored process with the final version representing a consensus perspective of those involved in the MPR. A single rating was provided for each MPR using our holistic editorial scoring rubric for reviews. Upon completing the initial peer review, participants were encouraged to perform additional mentored peer-reviews over the course of their fellowship training.

Our study of the Special Issue's MPR program was determined to be exempt by the George Washington School of Medicine Institutional Review Board.

IMPACE/EFFECTIVENESS

Over the three years of this intervention (2020–2022), participation grew from 14 to 30 education fellowships providing 58 fellows with the opportunity to participate in an MPR. The growth of the program over the first three years reflects a need among fellowship directors to provide a formalized educational experience in peer-review.

Twenty of the 23 (87.0%) participating fellows responded to the survey at the conclusion of the 2022 cycle regarding their background and prior experience (Table 1). Based on this survey, we learned that participants were novices with little experience in publishing or peer review. The fact that 80% of fellows were participating in a fellowship leading to a master's degree reflects a cohort committed to a career in education scholarship. The value of this experience to participants is supported by the fact that 100% of survey respondent affirmed that the inclusion of the decision letter was helpful to their education and remained interested in serving as a peer reviewer for the following year's Special Issue. We are in the process of contacting fellowship directors of graduating fellows to determine whether the mentors feel that their mentees are ready for independent peer review or whether they might benefit from additional mentored review experiences in the coming year.

Twenty of 23 participants also responded to the open-end question requesting suggested feedback for improving the program (Table 2). Although the suggestions made had little to do with improving the program, the responses provided were positive and enthusiastic regarding the value of the program. A number of these comments reflected potential benefits of the mentored peer-review experience including the following: learning content through critiquing articles with emerging questions and background information; better understanding of the peer-review process; improving the quality of the fellows'

Table 1. Background data of participating fellows who responded to the 2022 *Western Journal of Emergency Medicine Special Issue* call for participation in a mentored peer-review program.

Post-survey fellow questions	Yes/No #/Percentage
Have you authored a peer-reviewed publication related to education scholarship?	No 14/20 (70%)
Do you have prior experience performing peer reviews for publication?	No[a] 18/20 (90%)
Did you participate in a formal education scholar track in your residency?	No 14/20 (70%)
Have you participated in a postgraduate education scholarship program (other than your current fellowship)?	No[b] 17/20 (85%)
Will you be earning a master's degree with your fellowship?	Yes 16/20 (80%)

[a]The two fellows having prior experience with peer reviews were from previous participation with this program.
[b]The three fellows with prior experience in postgraduate education scholarship programs were all participants in the American College of Emergency Physicians Teaching Fellowship.

Table 2. Emergency Medicine fellows' responses on the 2022 post-program survey to the open-ended question, "Please provide any feedback that would improve the value of the mentored peer-review program as a learning experience".

I found the attached articles very helpful in supplementing my knowledge and aiding me in my review. I have referred to them when doing review for another journal since this experience.
This experience was extremely helpful in better understanding the role of peer-review in decision making regarding publication as well as likely improving the quality of my future scholarly submissions.
I thought the mentored peer review program was excellent. When the program started multiple materials including peer review guidelines and information on what to focus on during the review process were provided. There was easy communication to editors for clarification of questions. It gave me several opportunities to review current educational research articles, spend time to critically think about both the research itself, ensuring that research met the criteria to be high quality projects, that educational theory was used, and to identify whether the manuscripts were submitted within the guidelines required for the journal. I also appreciated being able to review a qualitative analysis manuscript. The only area for improvements I think may be useful is to provide some more opportunities to learn from the editors' perspective. For example, what do you prioritize in making a final decision on a manuscript? Are there any resources apart from those initially provided that are commonly referenced for specific educational themes or for certain kinds of studies? Just some ideas to get further insight into the thought process that goes into making a final decision on a submission. Thank you!
I anticipate working next year at a resident site in XXXX. They do not have a Med Ed Fellowship, but I would be happy to continue reviewing while there.
Really positive experience overall – really like this as an introduction to peer review!
This was an excellent formative activity. Thank you for this opportunity!
This was a great experience, thank you for the opportunity. I would be happy to review in either a mentored or independent fashion in the future.
The experience was valuable in getting experience performing peer review. I would love the opportunity to participate again!
Overall, a great experience and helped me to see the publication process from the inside-and think it will help me strengthen my own future publications.
Thank you for the chance to review.
I thought the process was very smooth! I found the attached documents on how to review a manuscript and tips very helpful especially as a first-time reviewer.

future scholarly submissions; and serving the role of abstract conceptualization in fellow learning.

Over the period of this study, the CORD MPR program provided 76 external peer reviews, 79% as mentor-mentee dyads and 21% as GPRs. The number of peer reviews provided by participating fellows from 2020–2022 ranged from 1–6 with an average of 1.6 reviews per fellow. A consensus discussion of the editors in each of the past three years concluded that the overall quality of the mentored peer reviews was very good to excellent, suggesting the value of this experience to the journal. This conclusion was substantiated by the fact that 50% (10/20) of those reviews recognized in 2020 as outstanding (editorial score of 5 on a 5-point scale used by the journal) were authored by 10 of the 14 (71.4%) fellowships participating in the mentored peer-review program.

The variability across programs in how the mentoring process was carried out limits what can be concluded regarding the appropriateness of the various approaches used.

Lessons Learned

Early in the 2022 submission cycle, the potential of this experience to serve as an introduction to the education scholarship community of practice as well as contribute the professional identify formation of fellows was apparent to the editors. With this in mind, in 2022 the fellow was made the point person for questions to the editor that had not been answered by advanced reading material or by the fellowship director as well as being responsible for submitting the review. This appeared to empower the fellows as they initiated appropriate questions about the peer-review process, expectations and outcomes to a greater degree than had previously been experienced with traditional reviewers.

Although overall the number of fellowships taking part in the program increased steadily over time, the editors noted that participation of interested fellowship programs appeared unpredictable. Through follow-up with the programs, we learned that this issue was often related to the timing of review offers, which did not always align with the fellows' training schedules. At the beginning of the 2022 cycle, we asked each fellowship director to provide optimal time periods to send requests. This appeared to significantly improve the number of programs that participated.

From an administrative standpoint, this program required a significant time commitment from the journal's editorial staff to track fellowship programs' availability, forward educational materials, and manage follow-up. Although this

commitment may be considered limiting, the editors viewed it as an investment in the future of our community, the journal, and as a service to the academic community at large to provide an enhanced pool of trained and qualified peer reviewers.

CONCLUSION

Early outcomes of the CORD mentored peer review program are encouraging, addressing a previously unmet need for sustainable reviewer training that could benefit academic journals and reviewers alike. Our cohort of novice reviewers reported multiple learning benefits across this experience, from a more scaffolded approach to peer reviewing as well as opportunities to reflect on their own scholarship. This suggests a climate that supports ongoing participation, more rigorous independent review, and rigorous education research.

Several studies of the program are currently underway to evaluate the value of the CORD MPR program to major stakeholders including the journal, editors, and authors. Although early outcomes of this work suggest several purported benefits of MPRs, a richer understanding of the value of this experience to the participants is needed, and qualitative explorations with mentees are underway.

Future studies are also needed to determine the long-term benefits of the program. Additional research will determine the degree to which the CORD MPR program may generalize to other journals, academic societies and graduate medical education in general. Although having an existing journal partnership facilitated our ability to shape and study this experience, recent interest in MPRs suggests the potential to develop such partnerships for others. This program's early findings suggest that collaboration between academic societies and interested graduate medical education faculty have the potential to formalize the process of learning peer review to the benefit of all involved stakeholders.

Address for Correspondence: Jeffrey N. Love, MD, MHPE, MSc, Georgetown University School of Medicine, Department of Emergency Medicine, 4917 Hine Dr, Shady Side, MD 20764. Email: Jlove01@georgetown.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. Kronick DA. Peer review in 18th century scientific journalism. *JAMA* 1990;263(10):1321–2.
2. Smith R. Peer review: a flawed process at the heart of science and journals. *J R Soc Med* 2006;99:178–82.
3. Dumenco L, Engle DL, Goodell K, et al. Expanding group peer review: a proposal for medical education scholarship. *Acad Med* 2017;92(2):147–9.
4. Evans AT, McNutt RA, Fletcher SW, et al. The characteristics of peer reviewers who produce good-quality reviews. *J Gen Intern Med* 1993;8(8):422–8.
5. Azer SA, Ramani S, Peterson R. Becoming a peer reviewer to medical education journals. *Acad Med* 2012;34:698–704.
6. Way DP, Bierer SB, Cianciolo AT, et al. Fundamentals of scholarly peer review: a workshop for health professions educators on practicing scholarly citizenship. *MedEdPORTAL*. 2021;17:11174.
7. Cooper LB, Bellam N, Vaduganathan M. Educating the next generation of peer reviewers. *J Am Coll Cardiol* 2016;67(17):2079–82.
8. Sidalak D, Purdy E, Luckett-Gatopoulos S, et al. Coached peer review: developing the next generation of authors. *Acad Med* 2016;92(2):201–4.
9. Wong VSS, Strowd RE, Aragon-García R, et al. Mentoring peer review of standardized manuscripts as a teaching tool for residents: a pilot randomized controlled multi-center study. *BioMed Central* 2017;2(6):1–9.
10. Ilgen JS, Artino AR, Simpson D, et al. Group peer review: the breakfast of champions. *J Grad Med Educ* 2016;8(5):646–9.
11. Richards BF, Cardell EM, Chow CJ, et al. Discovering the benefits of group peer review of submitted manuscripts. *Teach Learn Med* 2020;32(1):104–9.
12. Cameron MW, Crowther LN, Huang GC. Faculty development infrastructure to support educational scholarship: a scoping review on author development. *Acad Med* 2023;98(1):116.
13. Council of Residency Directors in Emergency Medicine. Available at: https://www.cordem.org/about-cord/mission–vision/mission–vision/. Accessed January 2nd, 2020.
14. Coates WC, Runde DP, Yarris LM, et al. Creating a cadre of fellowship-trained medical educators: a qualitative study of faculty development program leaders' perspectives and advice. *Acad Med* 2016;91(12):1696–704.
15. Jordan J, Yarris LM, Santen SA, et al. Creating a cadre of fellowship-trained medical educators, part ii: a formal needs assessment to structure postgraduate fellowships in medical education scholarship and leadership. *Acad Med* 2017;92(8):1181–8.
16. Society for Academic Emergency Medicine: Available at: https://member.saem.org/SAEMIMIS/SAEM_Directories/Fellowship_Directory/SAEM_Directories/P/FellowshipMap.aspx?hkey=573c442c-03ee-4c33-934a-5fda0b280835. Accessed March 2nd, 2023.
17. Lave J, Wenger EC. *Situated Learning: Legitimate Peripheral Participation*. Cambridge, UK: Cambridge University Press; 1991.
18. Steinert Y, Mann K, Centeno A, et al. A systematic review of faculty development initiatives designed to improved teaching effectiveness

in medical education: BEME Guide No 8. *Med Teach* 2006;28(6):497–526.
19. Kolb DA. *Experiential Learning: Experience as the Source of Learning and Development*. Englewood Cliffs, NJ: Prentice-Hall; 1984.
20. Watling C, Ginsburg S, Lingard L. Don't be reviewer 2! Reflections on writing effective peer review comments. *Perspect Med Educ* 2021;10:299–303.
21. Hayes MM, Fessler HE. How we review a medical education research manuscript. *ATS Scholar* 2022;3(1):38–47.
22. Roediger III, HL. Twelve tips for reviewers. *APS Obs* 2007;20:299–303.
23. Straus SE, Sackett D. Clinician-trialist rounds: 7. Mentoring: why every clinician-trialist needs to get mentored. *Clin Trials* 2011;8:765–7.
24. Farrell SE, Digioia N, Broderick KB, et al. Mentoring for clinician-educators. *Acad Emerg Med* 2004;11(12):1346–50.
25. Steinert Y. Faculty development: from workshops to communities of practice. *Med Teach* 2010;32:425–28.
26. Wald HS. Professional identity (trans)formation in medical education; reflection, relationship, resilience. *Acad Med* 2015;90(6):701–6.
27. Edmondson AC. Teamwork on the fly. *Harvard Bus Rev* 2012;90(4):72–80.
28. Mount GR, Kahlke R, Melton J, et al. A critical review of professional identity formation interventions in medical education. *Acad Med* 2022;97(115):S96–s106.
29. Garet MS, Porter AC, Desimone L, et al. What makes professional development effective? Result from a national sample of teachers. *Am Educ Res J* 2001;38(4):915–45.

The Development, Implementation, and Evolution of an Emergency Medicine Ultrasound-guided Regional Anesthesia Curriculum

Sally Graglia, MD, MPH[*†]
Derek Harmon, PhD[‡]
Barbie Klein, PhD[‡]

[*]University of California San Francisco, Department of Emergency Medicine, San Francisco, California
[†]Zuckerberg San Francisco General Hospital, San Francisco, California
[‡]University of California San Francisco, School of Medicine, Department of Anatomy, San Francisco, California

Section Editors: Jeffrey Druck, MD, and Danya Khoujah, MBBS
Submission history: Submitted January 3, 2023; Revision received May 19, 2023; Accepted October 18, 2023
Electronically published December 6, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.59793

Introduction: Despite the inclusion of both diagnostic and procedural ultrasound and regional nerve blocks in the original Model of the Clinical Practice of Emergency Medicine (EM), there is no recommended standardized approach to the incorporation of ultrasound-guided regional anesthesia (UGRA) education in EM training.

Methods: We developed and implemented a structured curriculum for both EM residents and faculty to learn UGRA in a four-hour workshop. Each Regional Anesthesia Anatomy and Ultrasound Workshop was four hours in length and followed the same format. Focusing on common UGRA blocks, each workshop began with an anatomist-led cadaveric review of the relevant neuromusculoskeletal anatomy followed by a hands-on ultrasound scanning practice for the blocks led by an ultrasound fellowship-trained EM faculty member, fellow, or a postgraduate year (PGY)-4 resident who had previously participated in the workshop. Learners identified the relevant anatomy on point-of-care ultrasound and reviewed how to conduct the blocks. Learners were invited to complete an evaluation of the workshop with Likert-scale and open-ended questions.

Results: In the 2020 academic year, six regional anesthesia anatomy and ultrasound workshops occurred for EM faculty (two sessions, N = 24) and EM residents (four sessions, N = 40, including a total of five PGY4s, 10 PGY3s, 12 PGY2s, and 13 PGY1s). Workshops were universally well-received by both faculty and residents. Survey results found that 100.0% of all responding participants indicated that they were "very satisfied" with the session. All were likely to recommend this session to a colleague and 95.08% of participants believed the session should become a required component of the EM curriculum.

Conclusion: The use of UGRA is increasing, and and it critical in EM. An interdisciplinary approach in collaboration with anatomists on an interactive, nerve block workshop incorporating both gross anatomy review and hands-on scanning was shown to be well-received and desired by both EM faculty and residents. [West J Emerg Med. 2024;25(1)117–121.]

BACKGROUND

There is currently no standardized educational approach to teaching ultrasound-guided regional anesthesia (UGRA) in emergency medicine (EM) training.[1] The use of point-of-care ultrasound (POCUS) is pervasive in EM, but novel POCUS applications are constantly challenging previously accepted "standards of care." The original 2001 Model of the Clinical Practice of Emergency Medicine included both

diagnostic and procedural ultrasound and regional anesthesia.[2] While POCUS use and regional anesthesia were recognized as critical components of EM training, the opioid epidemic and emergency department (ED) presentations surged.[3] Shown to decrease the use of opioids in pain management, UGRA has a potential role in combating the opioid pandemic.[4–8]

OBJECTIVES

Our goal was to create a standardized EM UGRA curriculum by providing a conceptual foundation, hands-on practice, and educational resource for common nerve blocks. The study was reviewed by the institutional review board and classified as exempt (Protocol #19-29811).

CURRICULAR DESIGN

We developed this curriculum following Kern's six-step approach:[9]

1. Problem identification

First, the need for UGRA training in EM was identified. Literature presents the utility of specific blocks or generalized need for UGRA education but not a comprehensive framework.

2. Targeted needs assessment

Exposure to UGRA by EM residents is dependent on the specific patients who present to the ED, whether the residents are on ultrasound rotation, and the comfort level of their supervising physician. We identified the need for a comprehensive UGRA curriculum, including the following nerve blocks:

- Superficial cervical plexus
- Interscalene
- Supraclavicular
- Radial
- Median
- Ulnar
- Serratus anterior
- Fascia iliaca (traditional and bowtie)
- Femoral
- Saphenous
- Sciatic
- Tibial nerve (ankle)

3. *Goals/Objectives*

For each nerve block, the learning objectives included the following:

- Common indications
- Anticipated area of anesthesia
- Anesthetic used
- Set-up
- Obtaining an accurate sonographic image to perform the block
- Critical anatomy
- Additional relevant anatomy
- Technique
- Associated risks

4. *Educational strategies*

This session used several evidence-based learning strategies. Coupling the visualization of anatomic structures through interactive cadaveric review with the corresponding sonographic identification, the three-dimensional anatomy was translated to the two-dimensional sonographic image. Repetition and review were embedded throughout the session as every learner had the opportunity to discuss and practice each specific block and observe their colleagues multiple times. Real-time discourse between anatomists (faculty within the Department of Anatomy who hold a doctoral degree in anatomical sciences) and emergency physicians ensured active learning. Finally, and perhaps most importantly, this session provided a comprehensive mental framework, equipping learners with the knowledge and preparation necessary to perform each block.

Objective Structured Clinical Examination (OSCE) Development

With the intention to assess competency of session attendees in the future, an OSCE was developed and piloted. While OSCEs exist for clinical skills in EM[10] and for ultrasound-guided procedures,[11,12] an OSCE specific for ultrasound-guided regional anesthesia had not been reported at the time of our research. The OSCE was developed by two of the authors combining their respective expertise in gross anatomy (DH) and clinical application of nerve blocks (SG). The OSCE was revised through an iterative consensus process after being reviewed by three ultrasound fellowship-trained EM faculty who are experts in regional anesthesia. The OSCE was used as a real-time reference sheet for learners during these sessions and provided as an educational resource for participants in the future. An example of the OSCE for a single block is presented in Figure 1 and is included entirely as Supplemental File A.

5. *Implementation*

The session was piloted during the 2019-2020 academic year with a cohort of EM residents rotating on the pain elective and implemented as a mandatory component of the EM curriculum in the 2020-2021 academic year. As a part of the mandatory EM curriculum, the session was offered separately to each residency class and twice to EM faculty.

Fascia Iliaca Block – Traditional View	Independently	Prompted	Unable
Identify common indications[8]: ● *Analgesia for hip fracture* ● *Femur fracture*			
Describe anticipated area of anesthesia: ● *Lateral thigh* ● *Anterior thigh* ● *Medial thigh* ● *Medial knee* ● *Medial leg* ● *Medial ankle*			
Describe anesthetic used: ● *Generally long-acting anesthesia* ● *~20cc of anesthesia combined with 20cc of sterile water or normal saline*			
Describe set-up: ● Machine positioning ● Patient positioning ● Describe which hand holds probe and which holds needle			
Obtain sonographic image & freeze:			
Identify critical anatomy: ● *Femoral nerve* ● *Femoral artery* ● *Femoral vein* ● *Fascia lata* ● *Fascia iliaca* ● *Iliopsoas muscle* ● *Sartorius muscle*[10]			
Describe additional relevant anatomy (not necessarily visualized): ● *Lateral femoral cutaneous nerve* ● *Obturator nerve*			
Describe technique: ● Needle approach ● Desired needle tip location ● Anticipated anesthesia hydrodissection			
Describe risks: ● *Vascular injection* ● *LAST*			

Figure 1. Example of the OSCE for a single block, the fascia iliaca block (traditional view), outlining common indications, anticipated area of anesthesia, anesthetic used, set-up, sonographic image, critical anatomy, relevant anatomy, technique, and risks.

6. *Evaluation of effectiveness*

Both residents and faculty were asked to evaluate the session. The evaluation included questions assessing participants' overall satisfaction with the session, likelihood of recommending the session to colleagues, interest in attending a similar session in the future, perceived length of the session, and whether the workshop should be a required component of the EM curriculum. Additionally, four open-ended questions asked what, if anything, participants learned during the workshop that could be applied to their clinical practice, what was most beneficial, how the workshop could be improved, and any other topics of interest to learn within the anatomy laboratory.

Implementation Phase

In the 2020 academic year, six regional anesthesia anatomy and ultrasound workshops occurred for EM residents (four sessions, N = 40, including a total of 5 PGY4s, 10 PGY3s, 12 PGY2s, and 13 PGY1s) and EM faculty (two sessions, N = 24). Each session was approximately four hours in length, followed the same format, and was led by an ultrasound-trained emergency physician and an anatomist.

The entire workshop was hosted in the anatomy laboratory and focused on the nerve blocks described in the *targeted needs assessment.* Workshops began with an anatomist-led review of the relevant upper extremity neuromusculoskeletal anatomy on a pre-dissected cadaveric donor followed by a

Table 1. Evaluation data for regional anesthesia anatomy and ultrasound workshops.

Question	Answers	Faculty (N = 22)	Residents (N = 39)	Combined (N = 61)
How would you rate your overall satisfaction with the session?	Very satisfied	100.0% (N = 22)	100.0% (N = 39)	100.0% (N = 61)
How likely are you to recommend this session to your colleagues?	Very likely	100.0% (N = 22)	100.0% (N = 39)	100.0% (N = 61)
Would you be interested in attending a session like this again?	Yes	95.45% (N = 21)	100.0% (N = 39)	98.36% (N = 60)
	No	4.55% (N = 1)	———	1.64% (N = 1)
Do you believe this session should be a required component of the EM curriculum?	Yes	95.45% (N = 21)	94.87% (N = 37)	95.08% (N = 58)
	No	———	5.13% (N = 2)	3.28% (N = 2)
	Offered, but not required*	4.55% (N = 1)	———	1.64% (N = 1)
How would you describe the length of this session?	Perfect	95.45% (N = 21)	82.05% (N = 32)	86.89% (N = 53)
	Too long	4.55% (N = 1)	12.82% (N = 5)	9.84% (N = 6)
	Between perfect/ too long*	———	5.13% (N = 2)	3.28% (N = 2)

*Some participants wrote in additional answers for questions that were between Likert scale units.
EM, emergency medicine.

hands-on ultrasound scanning practice session of the same blocks led by an ultrasound-trained emergency physician. For each specific nerve block, learners identified the relevant anatomy on POCUS and reviewed how to conduct an optimal scan and block. Learners repeated this process for each block until each learner felt comfortable.

Following the upper extremity section, the workshop repeated the format for the lower extremity nerve blocks listed in the *targeted needs assessment.* Following the anatomy review and ultrasound training for the lower extremity, learners were asked to complete an evaluation.

IMPACT/EFFECTIVENESS

Of 40 residents and 24 faculty who participated, 39 residents (97.5%) and 22 faculty (91.7%) completed an evaluation. The workshop sessions were universally well-received by both EM residents and faculty (Table 1). Open response comments noted several benefits of the session and areas for improvement.

LIMITATIONS

This study is not without limitations. This session focused on building foundational knowledge rather than motor skills; therefore, participants were unable to practice needle insertion necessary to perform ultrasound-guided procedures. Due to time constraints, assessment of learner competence in independently performing the procedures using a pre- and post-OSCE was not conducted. Additionally, because of the way residents log procedures, the number of times they had performed these procedures prior to and following this session were unavailable for analysis. Similarly, the effect of this session on clinical outcomes in patient care—the gold standard for any educational intervention targeting a specific clinical skill—was beyond the scope of this initial implementation. Finally, this session is dependent upon collaboration with anatomy educators with access to an anatomy laboratory and dissected cadavers demonstrating the relevant gross anatomy which may not be feasible for all EM residencies.

Future Directions

With regard to future iterations, most immediately we will make changes to the session based on collective feedback. The most consistent feedback from learners was the desire to practice needle visualization and anesthetic injection for these blocks on cadavers or phantoms. Going forward, sessions will employ hands-on manipulation of the ultrasound transducer and needle placement and insertion on either unembalmed cadavers or on phantom simulators to enable learners to build the skill of hand-eye coordination necessary to perform these procedures. Future sessions will incorporate additional innovative blocks as they emerge, such as the erector spinae plane block.[13] On a competency level, next steps will focus on evaluating the reliability and validity evidence for the OSCE as an assessment tool. On a program level, steps can be taken to incorporate the OSCE to assess learners' ability to independently perform these UGRA procedures. As this session has been incorporated into the structure of the EM residency curriculum, learners may be assessed longitudinally throughout their residency training, using this OSCE to demonstrate independence in performing these procedures.

CONCLUSION

Given the lack of an existing standardized UGRA curriculum in EM training, we chose to use Kern's six-steps of curriculum development to construct a curriculum that can be replicated at other institutions. A novel element to the success of our session was bringing clinicians back to the anatomy laboratory to visualize the gross anatomy and the corresponding sonographic identification for a comprehensive review of UGRA.

We attribute the success of this session to several factors. First, feedback was elicited after each session and considered to enhance session effectiveness. Implemented first as a pilot session in the 2019–2020 academic year, the OSCE was edited and the structure of the session was adapted for the 2020–2021 academic year. Second, by using Kern's model, we provided a level of structure to a previously unstructured skill that allowed learners to adopt a mental model through which they could approach UGRA in their own practice. The structure of the in-person session is directly reflective of the structure of the OSCE, reinforcing the framework. Third, this session was financially feasible. Because our institution's School of Medicine implements cadaveric-based instruction, this session capitalized on already having access to cadavers; thus, there was no additional cost to the ED to host this session. Additionally, the preservation of cadaveric tissue enabled the continued use of the prosections for subsequent workshops.

Address for Correspondence: Sally Graglia, MD, MPH, University of California San Francisco, Department of Emergency Medicine, 1001 Potrero Ave, Building 5, Room 6A, San Francisco, California 94110. Email: sally.graglia@ucsf.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. Wilson CL, Chung K, Fong T. Challenges and variations in emergency medicine residency training of ultrasound-guided regional anesthesia techniques. *AEM Education and Training.* 2017;1(2):158–64.
2. Hockberger RS, Binder LS, Graber MA, et al. The model of the clinical practice of emergency medicine. *Ann Emerg Med.* 2001;37(6):745–70.
3. Centers for Disease Control and Prevention. Understanding the Epidemic | Drug Overdose | CDC Injury Center [Internet]. 2021. Available at: https://www.cdc.gov/drugoverdose/epidemic/index.html. Accessed April 9, 2021.
4. Haines L, Dickman E, Ayvazyan S, et al. Ultrasound-guided fascia iliaca compartment block for hip fractures in the emergency department. *J Emerg Med.* 2012;43(4):692–7.
5. Casey S, Stevenson D, Mumma B, et al. Emergency department pain management following implementation of a geriatric hip fracture program. *West J Emerg Med.* 2017;18(4):585–91.
6. Groot L, Dijksman L, Simons M, et al. Single fascia iliaca compartment block is safe and effective for emergency pain relief in hip-fracture patients. *West J Emerg Med.* 2015;16(7):1188–93.
7. Miller GW, Godrey JJ, Sagmeister ML, et al. Provision of fascia iliaca compartment block in the acute management of proximal femoral fractures: a national observational study of UK hospitals. *Injury.* 2016;47(11):2490–4.
8. Herring AA. Bringing ultrasound-guided regional anesthesia to emergency medicine. *AEM Educ Train.* 2017;1(2):165–8.
9. Kern DE, Bass EB, Thomas PA, et al. *Curriculum Development for Medical Education: A Six Step Approach*. Baltimore, Maryland: Johns Hopkins University Press; 1988.
10. Bord S, Retezar R, McCann P, et al. Development of an objective structured clinical examination for assessment of clinical skills in an emergency medicine clerkship. *West J Emerg Med.* 2015;16(6):866–70.
11. Kissin EY, Grayson PC, Cannella AC, et al. Musculoskeletal ultrasound objective structured clinical examination: an assessment of the test. *Arthritis Care Res.* 2014;66(1):2–6.
12. Hofer M, Kamper L, Sadlo M, et al. Evaluation of an OSCE assessment tool for abdominal ultrasound courses. *Ultraschall in der Medizin - Eur J Ultrasound.* 2011;32(02):184–90.
13. Aydin ME, Tekin E, Ahiskalioglu EO, et al. Erector spinae plane block vs non-steroidal anti-inflammatory drugs for severe renal colic pain: a pilot clinical feasibility study. *Int J Clin Pract.* 2021;75(3):e13789.

Qualitative Study of Emergency Medicine Residents' Perspectives of Trauma Leadership Development

Antionette McFarlane, PhD*
Sarah M. Brolliar, MPH†
Elizabeth D. Rosenman, MD†
Joshua A. Strauss, MS‡
James A. Grand, PhD‡
Rosemarie Fernandez, MD*

*University of Florida, Department of Emergency Medicine, Gainesville, Florida
†University of Washington, Department of Emergency Medicine, Seattle, Washington
‡University of Maryland, Department of Psychology, College Park, Maryland

Section Editors: Mark Langdorf, MD, MHPE
Submission history: Submitted February 8, 2023; Revision received August 30, 2023; Accepted September 12, 2023
Electronically published December 20, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.60098

Background: Trauma team leadership is a core skill for the practice of emergency medicine (EM). In this study our goal was to explore EM residents' perception of their trauma leadership skill development through formal and informal processes and to understand factors that may impact the development and implementation of trauma leadership skills.

Methods: Using qualitative semi-structured interviews, we explored the leadership experiences of 10 EM residents ranging from second to fourth postgraduate year. Interviews were conducted between July 26–October 31, 2019 and were audio-recorded, transcribed, and de-identified. We analyzed data using qualitative content analysis.

Results: Residents discussed three main themes: 1) sources of leadership development; 2) challenges with simultaneously assuming a dual leader-learner role; and 3) contextual factors that impact their ability to assume the leadership role, including the professional hierarchy in the clinical environment, limitations in the physical environment, and gender bias.

Conclusion: This study describes the complex factors and experiences that contribute to the development and implementation of trauma team leadership skills in EM residents. This includes three primary sources of leadership development, the dual role of leader and learner, and various contextual factors. Research is needed to understand how these factors and experiences can be leveraged or mitigated to improve resident leadership training outcomes. [West J Emerg Med. 2024;25(1)122–128.]

INTRODUCTION

Leadership impacts the quality of patient care during trauma resuscitations.[1] Trauma team leaders coordinate care, manage and set priorities, and organize resources.[2] Such skills are critical under the dynamic, time-pressured conditions present during medical and trauma patient resuscitations. Failure to establish leadership in teams leads to suboptimal teamwork and threatens patient safety.[3] The medical education literature describes multiple training programs focused on developing trauma team leadership skills.[4] Research suggests that teaching residents to lead in high-stress environments is critical[5,6]; however, there remain gaps and challenges associated with developing critical leadership skills. Currently it is not known how residents experience trauma team leadership, nor is it well understood what factors may contribute to the development of leadership skills. Understanding these experiences and factors can help educators facilitate and optimize learning.

We conducted a qualitative study of emergency medicine (EM) residents with the objective of identifying how residents perceive their development of trauma leadership skills through formal and informal processes and what factors in

the clinical environment might support or inhibit development and reinforcement of trauma team leadership skills. This work will help address an important knowledge gap and inform future leadership development efforts.

Population Health Research Capsule

What do we already know about this issue?
Trauma team leadership is critical to patient care and an important part of physician development.

What was the research question?
Our goal was to identify how residents perceive their development of trauma leadership skills through formal and informal processes.

What was the major finding of the study?
This study reveals the importance of individual and team factors in the development of trauma team leadership skills.

How does this improve population health?
Understanding factors that influence trauma leadership development could help guide training and educational programming for junior physicians.

METHODS

Study Design

In this study we used an exploratory qualitative approach to examine EM residents' perception of trauma leadership skill development and understand factors that may impact the development and reinforcement of team leadership skills. We conducted semi-structured interviews between July 26–October 31, 2019. The University of Washington Institutional Review Board and the University of Florida Institutional Review Board approved this study as no greater than minimal risk. We used the Consolidated Criteria for Reporting Qualitative Research Checklist (COREQ) in preparation of this manuscript.

Setting and Study Population

We recruited a purposive sample of EM residents in their second through fourth years of postgraduate education because of their knowledge and experience as team leaders during trauma resuscitations. Participants were recruited from the University of Washington EM residency program. To recruit participants, we sent an email to the EM residency listserv containing the study description and a brief survey to elicit interest in study. The study coordinator (SMB) also conducted brief in-person informational sessions about the study during monthly EM residency conferences. Eleven EM residents were selected to participate in the study, with one resident declining due to a family emergency. Participation was voluntary. Recruitment concluded when data saturation[7] was reached, and no new insights were identified in the interview data. All participants were given a $25 gift card as compensation.

Interview Guide and Data Collection

Using an iterative process, we developed an interview guide to elicit participants' perspectives on trauma team leadership development. Question development was guided by a review of leadership and training literature.[4] Questions were pilot-tested with an EM resident and revised using feedback and suggestions from the resident and the research team. The interview guide underwent a second round of testing prior to implementation (See Supplemental Material [Interview Questions].) We did not include data from pilot-testing in the final results.

We collected data using semi-structured, face-to-face interviews that included probing questions and follow-up questions to gain more in-depth explanations and clarification. Participants answered questions regarding source of leadership skills, implementation of leadership skills, formal leadership training, and the dissemination of team leadership skills. All interviews were conducted in a private location with only the researcher and participant present. Interviews were conducted by SMB, who had prior experience conducting qualitative interviews and had no prior relationship with participants. Interviews ranged from 33–85 minutes, with a mean length of 43 minutes. Demographic information was collected through a secure online survey administered through REDCap, an electronic data capture tool hosted at the University of Washington. Interviews were audio-recorded, and recordings were transcribed verbatim by a professional service, followed by redactions of identifying information by the original interviewer. Transcripts were not returned to participants for review.

Data Analysis

Due to the limited research on leadership skill development, we used qualitative content analysis for data analysis.[8] Drawing on this method, researchers first immersed themselves in the data. Three members of the research team (AM, SMB, and JS) with previous qualitative experience served as coders and read through each of the transcripts several times. Then, using open coding[8,9] all three coders independently reviewed one of the interview transcripts and developed a set of initial codes to represent ideas and phrases revealed in the data. The coders met weekly to compare preliminary codes, discuss differences, and expand or collapse the codes as needed.

To ensure reliability of the codes, codes were further reviewed by the entire research team during bi-weekly meetings. These codes were used to construct a codebook, which included code names, definitions, and exemplar quotes. The codebook was then applied to two additional transcripts by all three coders, and the codes were refined through discussions with the entire research team. Using the finalized codebook, each remaining transcript was then coded by two of the coders. Coders met to review transcripts and discuss any disagreements until consensus was reached. Codes were analyzed across transcripts to identify categories and major themes, which were reviewed and modified by the larger research team. Coders summarized major themes and finalized results presented in this paper. Dedoose version 9.0.47[10] (SocioCultural Research Consultants, LLC, Manhattan Beach, CA) was used to assist in coding and organizing data. Participants did not provide feedback on the findings.

RESULTS

We conducted a total of 10 interviews. Participant demographics are described in the Table. This paper presents three primary themes that emerged from the data: 1) sources of leadership development; 2) dual learner-leader role; and 3) contextual factors impacting leadership. Supplemental Material (Central Themes and Exemplar Quotes) summarizes primary themes, subthemes, and representative quotations.

Table Participant demographics (N = 10).

Demographic	Participants (n = 10)
Age, year; mean (SD)	30(3)
Male, n(%)	5(50)
Race, n(%) [a]	
American Indian or Alaskan Native	0(0)
Black	0(0)
Native Hawaiian or other Pacific Islander	1(10)
Asian	2(20)
White	9(90)
Other	0(0)
Ethnicity n(%)	
Hispanic or Latino	0(0)
Not Hispanic or Latino	10(100)
Residency year, n(%)	
PGY 2	3(30)
PGY 3	3(30)
PGY 4	4(40)

[a]Participants were able to select more than one racial category.
PGY, postgraduate year.

Sources of Leadership Development

Drawing on life and work experiences, residents discussed the development of their leadership skills. Residents cited three primary sources: 1) observing senior residents and attendings; 2) supervised leadership practice; and (3) prior life experiences.

The observation of senior residents and attendings was cited as important to participants' leadership development. They noted that much of their time as junior residents was dedicated to observing others in the trauma leader role. The opportunity to observe senior residents and attendings provided exposure to multiple leadership styles that could inform their own leadership approach. One participant shared the following:

> "Two in particular, senior residents when I was an intern that I watched, that I took a lot of learning points from . . . like how they manage things. And I think what was helpful about those two senior residents in particular, was that I thought their leadership styles were something similar to what I wanted to emulate." (Participant 1)

Residents also pointed out that these opportunities diminished as they progressed in residency due to time constraints, scheduling factors (eg, not working at the same time as other senior residents), and a shift from being a team member to being the team leader.

Participants also emphasized the importance of closely supervised leadership opportunities in shaping their approach to leadership development, specifically, "low-stakes" supervised clinical practice. Junior residents were often encouraged by senior residents to take the leadership role in lower acuity trauma resuscitations, which provided an opportunity for them to practice their leadership responsibilities before applying them in a higher acuity, more complex situation. These opportunities were not a formalized process but rather depended on the residents' ability to free themselves from other clinical responsibilities and on their relationship with their senior resident.

In addition to on-the-job training, multiple residents described prior life experiences (eg, academic experience, sports team participation, etc) that provided a foundation of leadership skills and supported their role as trauma team leader. Participants described how these experiences helped to develop communication and team management skills, in addition to preparing them to acclimate to new or stressful environments. One resident stated,

> "I mean I guess leadership roles in your past life, like I was president of the [sports club] at my college and so had experience standing up in front of a group of people and like guiding things . . . there's a lot of leadership required there . . . " (Participant 9)

For a few participants, past experiences served to build their *confidence* as a team leader. One resident shared,

> "(my past experience impacts) ... my own personal confidence in telling other people what to do. Or like asking for help if I don't know what to do without feeling weird about it, I think more comes from like longer history of just being in those positions, leadership positions, kind of working with other people, teams, directing people, coaching." (Participant 11)

Dual Learner-Leader Role

Participants noted that the role of trauma team leader requires residents to simultaneously assume the role of a leader and a learner. As the leader of the resuscitation, the resident is seen as the "central figure" of the resuscitation. Participants indicated that trauma team leaders are responsible for information-sharing (collecting, synthesizing, and disseminating information) and role designation (assigning tasks to team members), as well as conducting the primary trauma survey. Participants shared that they established themselves as the team leader through their speech and their physical location in the room. They also exuded confidence by communicating frequently or by being "vocal," and in some instances by being "loud," when instructing the team.

Participants also acknowledged that they were still developing their medical knowledge and learning to manage the trauma team. Residents were not expected to have the expertise of their senior colleagues, and the senior residents were expected to provide supporting functions such as offering medical prompts ("code-whispering") or coaching. As a resident shared,

> "Well, you have your ED attending in there who will kind of bring things up that you may be missing ... there's a surgery senior, there's a surgery fellow, there's a surgery attending ... who are not going to allow you to kind of miss things. And so, while you should strive to be the person who's putting together all the plans, there's also a lot of people who will feed you things that you may have missed." (Participant 5)

Participants noted that embodying roles of both leader and learner may result in conflict. Specifically, residents suggested that their role as a learner may have impacted their success as trauma team leaders. As early learners, residents indicated that they were still developing their clinical knowledge and this may have overshadowed their focus on leadership responsibilities. A resident shared,

> "But it is really difficult, I think, as an early learner, especially as a second-year resident to be able to handle the mob that shows up and try to do good patient care when you're still trying to learn the clinical medicine." (Participant 1)

Residents perceived that the trauma leader's medical knowledge is necessary for effective leadership. As learners, residents are still questioning their medical knowledge and may not feel comfortable providing directions to team members. Additionally, residents' lack of experience leading trauma resuscitations shaped their confidence in their leadership abilities. A resident stated,

> "The other challenge, especially earlier on in training, is if you just don't have quite as much knowledge; so it's much easier to be in that role when you feel confident in the plan because you've done it a bunch of times and you kind of know what's supposed to happen next. But if you're still not quite totally sure about what is the right thing to do next, it becomes very difficult. I think, to kind of be in that more directive role ..." (Participant 11)

As learners, residents acknowledged that lack of experience leading trauma resuscitations and lack of medical knowledge directly affected their level of confidence and hindered their ability to lead. Further, a lack of knowledge undermines team members' confidence in the leader. Residents indicated that if team members thought the leader lacked confidence, a senior colleague could step in and assume leadership of the resuscitation.

Contextual Factors Impacting Leadership

Participants acknowledged that their leadership could have been impacted by numerous contextual factors including the professional hierarchy, the resident's gender, and physical workspace limitations. Several of the residents recognized how the professional hierarchy impacts their ability to lead a resuscitation. Although the resident is presumed to be the leader of the resuscitation, they are supervised by senior colleagues with more experience. Participants suggested that some supervision may be an impediment to leadership and deprive them of the opportunity to develop clinical and leadership skills. One resident revealed,

> "So for me I find it to be, it's hard for me to feel like I'm the person in charge when there's a lot of more senior people in the room that kind of want to butt in and make the decisions." (Participant 3)

When this occurred, residents shared that it was difficult to challenge the assertions of a senior colleague when team members were more likely to listen to the senior colleague. As a result, residents may adopt a more passive approach to leadership, where they are not assigning roles and tasks, but

rather they are receiving instructions from their senior colleagues who ultimately have more authority and experience.

Participants also discussed the impact of gender on their leadership efficacy. Residents mentioned that female trauma team leaders may face additional obstacles while leading. Female residents attributed these obstacles to their physical and vocal attributes such as stature or tone of voice. As one female resident shared,

> "You get the assumption that you are not the trauma doc running the resuscitation. Someone told me, 'I'm getting sick of being handed the oxygen when people walk in the room or being handed things like, 'Hey, can you throw this away,' when I need to really be focused on things." And I was like, 'Wow, that hasn't happened to me.' And then yesterday I got handed the oxygen." (Participant 8)

Participants of both genders suggested that male residents are assumed to be the leader due to their physical size or their ability to be "loud," while female trauma team leaders must work to establish themselves as the leader. The assumption that the female resident is not the leader of the resuscitation reinforces a gendered hierarchy where men are viewed as the "leader," and women are assumed to be in a supporting role.

Additionally, participants often discussed difficulties in leading the team due to limitations of the physical workspace and crowding. Smaller workspaces may obstruct trauma team leaders' ability to perform procedural tasks. Additionally, an increased number of observers and team members can lead to environmental noise and professional silos. Limited space in the trauma room and number of staff in the physical workspace may critically restrict the ability of the trauma team leader to perform their responsibilities.

DISCUSSION

Residents identified three primary sources that inform the development of leadership skills: 1) observation of senior residents and attendings during clinical care; 2) supervised leadership practice; and 3) prior life experiences. Interestingly, residents did not highlight formal leadership training delivered within the medical education curriculum, either as medical students or within residency. This may reflect the relative value residents place on various learning modalities and educational resources. These findings are in line with those of Quon et al (2022), which reflects the importance of informal curriculum in shaping the leadership development of EM residents.

Real-world experiences and practice may overshadow more passive learning experiences, such as lectures and online modules. In a prior qualitative review, EM residents reported employing different learning strategies for clinical skills vs leadership skills.[11] Simulation is frequently lauded as a modality for immersive, hands-on training without compromising patient safety.[12,13] While several residents mentioned simulation-based education, it was not a prominent theme relative to clinical exposure. This is supported by previous work indicating that simulation does not replicate the stress, anxiety, and other challenges encountered during actual clinical care.[14]

Understanding current sources of leadership development will help educators develop more effective leadership training programs. The importance of a needs assessment is highlighted in the training development literature. However, needs assessments in medical education generally evaluate gaps in training or knowledge and are not focused on the environmental, cultural, and organizational factors that directly impact learning.[15] This can result in failure to appreciate "hidden" educational opportunities and challenges. This study emphasizes the important role that other residents, particularly senior residents, play in shaping junior residents as they develop leadership skills. While the process of graduated responsibility from observation (via team membership) to low-acuity practice to team leadership is not novel, participants highlighted the critical role of their colleagues as facilitators of this process.

Peer and near-peer teaching has been effectively used in medical student education and has been shown to be as effective as faculty-led teaching.[16] Less is known about the efficacy of peer teaching in graduate medical education; however this work suggests that residents perceive peer teaching as a primary source of team leadership training. Explicitly involving senior residents and other resuscitation team members in the development and implementation of a leadership curriculum may improve post-training transfer and dissemination by reinforcing training principles, reducing the exposure to contradictory information, and removing barriers to team leadership practice. It is also important to be aware that while peer teaching was cited as an effective means of leadership development, this educational resource generally lacks standardization. This may lead to inequity in accessibility and opportunities for acquiring leadership experience for underrepresented groups in medicine and, therefore, deserves additional attention.[17]

In addition to understanding clinical and curricular factors, it is important to understand the learners themselves. Our study revealed that residents draw on previous life experiences in developing their leadership skills. The leadership development literature has examined the impact of past experiences on leadership development. Residents may bring diverse prior leadership experiences to the trauma team leader role, and these experiences can strengthen a person's belief in their own leadership abilities as well as influence leadership beliefs and practices. Incorporating previous leadership experiences into learning and on-the-job experiences may assist in leadership development.[18] To be more effective, leadership training could acknowledge these

residents' previous experiences and build upon residents' existing knowledge.

Residents acknowledged that the dual role of learner and leader had both advantages and disadvantages. Participants identified that support from the team was often very helpful in ensuring patient safety and their own success as a team leader. However, team involvement could at times be viewed as interference, undermining residents' ability to lead, as well as their self-efficacy. In fact, many of the challenges identified by residents related to the team, rather than clinical care. Given that team leadership and team performance are interdependent, the emphasis on team members' behaviors and relationships is not surprising. The importance of team followership is well recognized in the broader leadership and team science literature, but it has received comparatively little attention in healthcare.[19,20] Exemplary followers proactively contribute to team goals and support the team leader in a positive way, whereas other followership styles may be less supportive.[21]

While not a focus of this work, gender-based differences in the team leadership experience were mentioned. Female residents reported facing more challenges in getting the team to recognize them as the team leader. This is consistent with prior qualitative work exploring the role of gender and team leadership during medical resuscitations in both EM and internal medicine.[22,23] These findings highlight the importance of the team and team followership in promoting effective team leadership. Team leadership training programs could be supported through teamwork and team membership training for all members of the healthcare team, with a specific focus on eliminating disparate treatment of team leaders based on innate characteristics, such as gender.

In summary, this study identified individual and contextual factors that inform trauma leadership development among EM residents. An important consideration for leadership training is the impact of prior and current experiences on EM residents' leadership development. Educators should also consider the institutional factors that may inhibit or contribute to the leadership development of EM residents.

LIMITATIONS

This study had several limitations. First, the findings are from a small sample size at one urban, academic, Level 1 trauma center. Findings may not reflect the experiences of EM residents in other settings, as environmental factors (region, culture, resource availability) may have influenced responses. While qualitative studies aim to provide an in-depth understanding of specific contexts, future quantitative studies can expand on the aims of the current study to understand experiences of EM residents in other contexts. Selection bias is another potential limitation. Residents serving on non-EM rotations or who were off-site during the data collection period may have been less likely to participate. While the sample was balanced across men and women, only two participants (20%) reported a racial background other than White (Asian and multi-racial; native Pacific/Hawaiian Islander, White, and Asian descent)). However, this percentage is reflective of the average racial and ethnic makeup of EM residency classes over multiple years (2016–2022). Finally, reporting bias may have impacted the results. Coders had backgrounds in sociology, public health, and organizational psychology, but they did not have clinical expertise. The potential for bias was mitigated by having EM attending physicians review the findings throughout the coding process to provide context and interpret professional and institution-specific terminology.

CONCLUSION

Emergency medicine residents learn about and develop leadership skills through multiple sources and experiences, many of which are outside the formal medical education curriculum. Additionally, various individual and team factors can support and/or inhibit leadership development. We encourage the development of leadership training programs that incorporate diverse training strategies that take into consideration EM residents' prior leadership experiences and address some of the contextual factors that influence leadership development. More research is needed to identify the specific ways in which educators can leverage learners' prior experiences and existing informal educational processes to develop more effective leadership training programs.

Address for Correspondence: Rosemarie Fernandez, MD, University of Florida, Department of Emergency Medicine, HMEB 4th Floor, Rm 413, Gainesville, Florida 32610-0186. Email: fernandez.r@ufl.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 Department of Defense (W81XWH-18-1-0089; [RF]). The funding sources 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. RF reports research grant money to the University of Florida from the Department of Defense Congressionally Directed Medical Research Program to conduct research conceived and written by RF while at the University of Florida. RF reports grant money from the Defense Health Agency to the University of Florida to conduct research conceived and written by RF from the University of Florida. EDR reports research grant money to the University of Washington from the Department of Defense Congressionally Directed Medical Research Program to conduct research conceived and written by RF while at the University of Washington. JAG reports grant money to the University of Maryland to conduct research conceived and written by RF and JAG from the Department of Defense

Congressionally Directed Medical Research Program and the Army Research Institute for the Behavioral and Social Sciences to conduct research.

REFERENCES

1. Hoff WS, Reilly PM, Rotondo MF, et al. The importance of the command-physician in trauma resuscitation. *J Trauma Acute Care Surg*. 1997;43(5):772–7.
2. Fernandez R, Rosenman ED, Olenick J, et al. Simulation-based team leadership training improves team leadership during actual trauma resuscitations: a randomized controlled trial. *Crit Care Med*. 2020;48(1):73–82.
3. Joint Commission on Accreditation of Health Care Organizations. Update: sentinel event statistics. *Jt Comm Perspect Jt Comm Accreditation Healthc Organ*. 2006;26(10):14–5.
4. 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.
5. Hicks C and Petrosoniak A. The human factor: optimizing trauma team performance in dynamic clinical environments. *Emerg Med Clin North Am*. 2018;36(1):1–17.
6. Harvey A, Bandiera G, Nathens AB, et al. Impact of stress on resident performance in simulated trauma scenarios. *J Trauma Acute Care Surg*. 2012;72(2):497–503.
7. Hennink MM, Kaiser BN, Marconi VC. Code saturation versus meaning saturation: How many interviews are enough? *Qual Health Res*. 2017;27(4):591–608.
8. Hsieh HF and Shannon SE. Three approaches to qualitative content analysis. *Qual Health Res*. 2005;15(9):1277–88.
9. Strauss AL and Corbin JM. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*. 2nd ed. Thousand Oaks, CA: Sage Publications; 1998.
10. Dedoose 9.0.17, web application for managing, analyzing, and presenting qualitative and mixed method research data. www.dedoose.com
11. Goldman EF, Plack MM, Roche CN, et al. Learning clinical versus leadership competencies in the emergency department: strategies, challenges, and supports of emergency medicine residents. *J Grad Med Educ*. 2011;3(3):320–5.
12. Cook DA, Hatala R, Brydges R, et al. Technology-enhanced simulation for health professions education: a systematic review and meta-analysis. *JAMA*. 2011;306(9):978–88.
13. Zendejas B, Brydges R, Wang AT, et al. Patient outcomes in simulation-based medical education: a systematic review. *J Gen Intern Med*. 2013;28(8):1078–89.
14. Sachedina AK, Blissett S, Remtulla A, et al. Preparing the next generation of code blue leaders through simulation: What's missing? *Simul Healthc*. 2019;14(2):77–81.
15. Hannum W. Questioning needs assessment: some limitations and positive alternatives. *Educ Technol*. 2013;53(6):29–34.
16. Rees EL, Quinn PJ, Davies B, et al. How does peer teaching compare to faculty teaching? A systematic review and meta-analysis. *Med Teach*. 2016;38(8):829–37.
17. Samuelson HL, Levine BR, Barth SE, et al. Exploring women's leadership labyrinth: effects of hiring and developmental opportunities on gender stratification. *Leadersh Q*. 2019;30(6):101314.
18. DeRue DS and Workman KM. *Toward a Positive and Dynamic Theory of Leadership Development*. Oxford, United Kingdom: Oxford University Press; 2011.
19. Leung C, Lucas A, Brindley P, et al. Followership: a review of the literature in healthcare and beyond. *J Crit Care*. 2018;46:99–104.
20. Crossman B and Crossman J. Conceptualising followership – a review of the literature. *Leadership*. 2011;7(4):481–97.
21. Kelley RE. *The Power of Followership: How to Create Leaders People Want to Follow, and Followers Who Lead Themselves*. New York, NY: Broadway Business; 1992.
22. Kolehmainen C, Brennan M, Filut A, et al. "Afraid of being witchy with a 'B'": a qualitative study of how gender influences residents' experiences leading cardiopulmonary resuscitation. *Acad Med*. 2014;89(9):1276–81.
23. Linden JA, Breaud AH, Mathews J, et al. The intersection of gender and resuscitation leadership experience in emergency medicine residents: a qualitative study. *AEM Educ Train*. 2018;2(2):162–8.

Association Between Platelet-to-Lymphocyte Ratio and In-hospital Mortality in Elderly Patients with Severe Trauma

Ji Ho Lee, MD*
Dong Hun Lee, MD, PhD*†
Byung Kook Lee, MD, PhD*†

*Chonnam National University Hospital, Department of Emergency Medicine, Gwangju, Republic of Korea
†Chonnam National University Medical School, Department of Emergency Medicine, Gwangju, Republic of Korea

Section Editors: Eric Melnychuk, MD, and Gayle Galletta, MD
Submission history: Submitted June 11, 2023; Revision received October 5, 2023; Accepted November 16, 2023
Electronically published January 4, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.61343

Introduction: The platelet-to-lymphocyte ratio (PLR) is associated with the inflammatory response in various diseases. However, studies on the use of the PLR for the prognosis of elderly patients with severe trauma are lacking. In this study, we examined the relationship between the PLR and in-hospital mortality in elderly patients with severe trauma.

Methods: This retrospective observational study included elderly (≥65 years) patients who were admitted for severe trauma (as defined by an Injury Severity Score [ISS] ≥ 16) between January–December 2022. We conducted multivariate analysis to assess the association between the PLR and in-hospital mortality using logistic regression of relevant covariates. We also performed receiver operating characteristic curve analysis to examine the prognostic performance of the PLR for in-hospital mortality.

Results: Among the 222 patients included in the study, the in-hospital mortality rate was 19.4% (43). The PLR of non-survivors was lower than that of survivors (62.1 vs 124.5). The areas under the curve (AUC) of the Glasgow Coma Scale (GCS) score ≤12, ISS, hemoglobin level, and PLR for predicting in-hospital mortality were 0.730 (95% confidence interval [CI] 0.667–0.787), 0.771 (95% CI 0.710–0.824), 0.657 (95% CI 0.591–0.719), and 0.730 (95% CI 0.667–0.788), respectively. The AUC of the PLR was not significantly different from that of GCS score ≤12 and ISS for predicting in-hospital mortality. Multivariate analysis showed that the PLR was independently associated with in-hospital mortality (odds ratio: 0.993; 95% CI 0.987–0.999).

Conclusion: Low platelet-to-lymphocyte ratio is independently associated with in-hospital mortality in elderly patients with severe trauma. [West J Emerg Med. 2024;25(1)129–135.]

INTRODUCTION

Trauma is a leading cause of trauma-related death and disability worldwide. Indeed, a global burden of disease study showed that in 2019 8% of all deaths worldwide were due to injury.[1] Moreover, in 2019 109.7 million people were injured and 458,669 people died from injuries in all European countries.[2] Trauma also has a large economic burden resulting from hospitalization, time off work, and disability. In one study, the elderly showed worse outcomes, including mortality, hospitalization rate, hemodynamic instability criteria, and anatomical and biochemical parameters.[3] Another study showed higher mortality, longer hospital stays, and more severe complications in elderly patients with trauma than in younger patients with trauma.[4] Therefore, it is important to rapidly identify factors that can determine prognosis in elderly patients with trauma and to provide intensive treatment when a poor prognosis is predicted.

Many triage tools for trauma have been developed, and several studies have been conducted on the effectiveness of these tools in predicting patient outcome. Clinical

instruments, such as the National Early Warning Score, Modified Early Warning Score), and Acute Physiology and Chronic Health Assessment (APACHE II) score, used in critically ill patients can help predict prognosis in patients with trauma.[5,6] Additionally, the Injury Severity Score (ISS), Revised Trauma Score, and Trauma and Injury Severity Score are commonly used tools in trauma.[7–9] However, these tools often have cumbersome evaluation processes and subjective assessments; therefore, easier and more objective prognostic predictors should be considered.

The platelet-to-lymphocyte ratio (PLR) has good generalizability and can be calculated and obtained from routine laboratory tests at admission without further inconveniencing the patient. Studies have shown that the PLR is associated with the inflammatory response, with a higher PLR indicating poorer prognosis for patients with chronic obstructive pulmonary disease, myocardial infarction, and sepsis.[10–12] Moreover, a previous study showed that the PLR was associated with the neurologic outcome in intracranial hemorrhage.[13] As the PLR is routinely measured in clinical laboratories as a component of the complete blood count (CBC) and is available to most patients, it can be very useful for risk stratification in clinical decision-making. Therefore, the PLR would help to predict the outcome of elderly patients with severe trauma who visited the emergency department (ED). We examined the relationship between the PLR and in-hospital mortality in elderly patients with severe trauma.

Population Health Research Capsule

What do we already know about this issue?
Platelet to lymphocyte ratio (PLR) is part of complete blood count and is routinely implemented. Higher PLR is associated with poor prognosis of inflammatory conditions such as sepsis and intracranial hemorrhage.

What was the research question?
Could PLR help predict the outcome of elderly emergency department patients with severe trauma who visited the emergency department?

What was the major finding of the study?
a lower absolute PLR (in cells $\times 10^9$/L) was independently associated with in-hospital mortality (odds raito:0.993; 95% CI, 0.987–0.999). For survivors, PLR was 124.5, while those who died had PLR of 62.1.

How does this improve population health?
PLR alone could be helpful in predicting mortality of patients with severe trauma, but when combined with other factors, PLR can be more helpful in determining treatment direction.

METHODS

Study Design and Population

This was a retrospective observational study of elderly (≥65 years) patients with severe trauma (ISS ≥ 16) who visited the ED of Chonnam National University Hospital, a tertiary referral center in Gwangju, Korea, between January–December 2022. We collected and reviewed data from a prospectively collected trauma database at the hospital, which was nominated as a regional trauma center in South Korea in 2013. It corresponds to a Level I trauma center in the United States. Our 1,800-bed teaching hospital serves a population of three million people; and more than 500 patients with major trauma ((ISS >15) are admitted annually. Korea's regional trauma center consists of specialists in neurosurgery, thoracic surgery, trauma surgery, orthopedic surgery, and emergency medicine; ISS is evaluated by specialists in each department. The ISS is confirmed by each specialist of the trauma care center and mutually agreed upon in case of a conflict regarding the ISS determined through regular meetings. In addition, severe trauma cases are randomly selected every year and evaluated for ISS decisions by specialists in other hospitals.

The following exclusion criteria were applied: cardiac arrest following trauma before ED visit; and missing data. This paper complies with the STROBE guidelines for reporting observational studies (Appendix 1). The institutional review board of our hospital approved the study and waived the requirement for informed consent due to the retrospective nature of the study.

Data Collection

We obtained data on the following variables for each patient: age; gender; mechanism of trauma; systolic blood pressure (SBP, millimeters mercury); respiratory rate; pulse rate on ED arrival; initial Glasgow Coma Scale (GCS) score on ED arrival; laboratory results on arrival at the ED (CBC parameters, blood urea nitrogen [BUN], serum creatinine, and serum electrolytes); and in-hospital mortality. We calculated the PLR based on the lymphocyte and platelet counts of CBC parameters. The values of the abbreviated injury scale and ISS were evaluated based on the data from the patients' electronic health records. The primary outcome was in-hospital mortality.

Statistical Analysis

Continuous variables that did not satisfy the normality test are presented as median values with interquartile ranges.

Categorical variables are presented as frequencies and percentages. We assessed differences between the two groups using the Mann-Whitney U-test for continuous variables. The Fisher exact test or chi-square test was used to compare categorical variables, as appropriate. Furthermore, we conducted a multivariate analysis using logistic regression of relevant covariates to predict in-hospital mortality. Variables with *P*-values <0.20 in the univariate analysis were included in the multivariate regression model. We used a backward stepwise approach and sequentially eliminated variables with *P*-values >0.10 to build a final adjusted regression model.

The results of logistic regression analysis are presented as odd ratios (OR) and 95% confidence intervals (CI). Receiver operating characteristic curve (ROC) analysis was performed to examine the prognostic performance of GCS score ≤12, ISS, hemoglobin level, and PLR for in-hospital mortality. Comparison of dependent ROC curves was performed using the DeLong method.[14] We performed all analyses using PASW/SPSS software, version 18 (IBM Inc., Chicago, IL) and MedCalc version 19.0 (MedCalc Software, bvba, Ostend, Belgium). A two-sided significance level of 0.05 was defined as a statistically significant value.

RESULTS

Patient Selection and Characteristics

In total, 228 elderly patients with severe trauma met the inclusion criteria during the study period. After excluding patients based on the exclusion criteria, 222 patients were included in the study (Figure 1), comprising 151 men (68.0%), with a median age of 75.0 (70.0–80.8) years and an in-hospital mortality rate of 19.4% (43).

Prognostic Performance of the ISS, GCS <12, Hemoglobin Level, and PLR for Predicting In-hospital Mortality

The area under the curve (AUC) of GCS score ≤12, ISS, hemoglobin level, and PLR for predicting in-hospital mortality were 0.730 (95% confidence interval [CI] 0.667–0.787), 0.771 (95% CI 0.710–0.824), 0.657 (95% CI: 0.591–0.719), and 0.730 (95% CI 0.667–0.788), respectively. The AUC of the PLR was not significantly different from that of GCS score ≤12 and ISS for predicting in-hospital mortality (Figure 2).

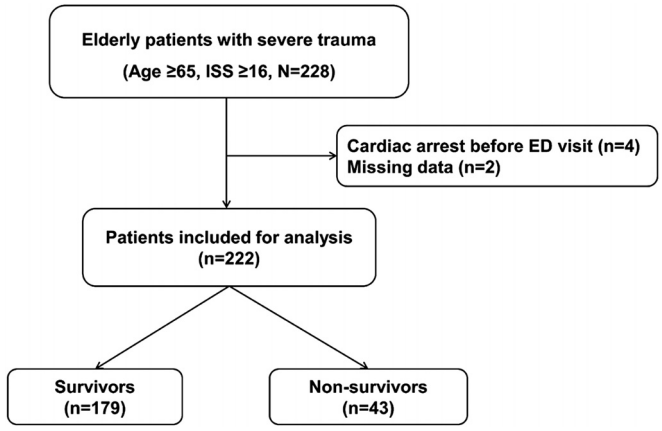


Figure 1. Schematic diagram showing the number of elderly patients with trauma included in the study.
ISS, Injury Severity Score; *ED*, emergency department.

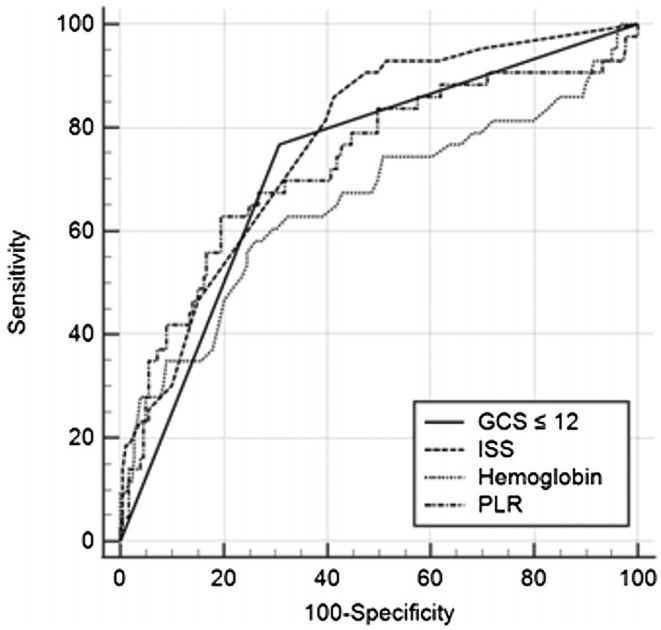


Figure 2. Graph showing the areas under the curves of Glasgow Coma Scale score ≤12, Injury Severity Score, hemoglobin level, and platelet-to-lymphocyte ratio for predicting in-hospital mortality.
GCS, Glasgow Coma Scale; *ISS*, Injury Severity Score; *PLR*, platelet-to-lymphocyte ratio.

Comparison of the Baseline and Clinical Characteristics Between Survivors and Non-Survivors

Table 1 shows the baseline and clinical characteristics of survivors and non-survivors. According to hospital data, non-survivors had a greater proportion of GCS scores ≤12, lower SBP, hemoglobin level, monocyte count, platelet count, and PLR, and higher ISS, lymphocyte count, red cell distribution width, and creatinine level than survivors.

Multivariate Analysis Using Logistic Regression for Predicting In-hospital Mortality

Table 2 shows the results of the multivariate analysis for predicting in-hospital mortality. After adjusting for confounders, GCS score ≤12 (OR 4.317, 95% CI 1.830–10.181), ISS (OR 1.103, 95% CI 1.033–1.177), hemoglobin level (OR 0.753, 95% CI 0.608–0.931), and PLR (OR 0.993, 95% CI 0.987–0.999) were independently associated with in-hospital mortality.

DISCUSSION

In this retrospective observational study, the PLRs of non-survivors were lower than those of survivors in elderly

Table 1. Comparison of the baseline characteristics of elderly patients with severe trauma according to in-hospital mortality.

Variables	Total patients (n = 222)	Survivors (n = 179)	Non-survivors (n = 43)	*P*-value
Age, years	75.0 (70.0–80.0)	74.0 (68.0–80.0)	76.0 (71.0–80.0)	0.159
Male, n (%)	151 (68.0)	120 (67.0)	31 (72.1)	0.648
Type, n (%)				1.000
Blunt	218 (98.2)	176 (98.3)	42 (97.7)	
Penetrating	4 (1.8)	3 (1.7)	1 (2.3)	
GCS score ≤12, n (%)	88 (39.6)	55 (30.7)	33 (76.7)	<0.001
Systolic blood pressure, mm Hg	130 (100–150)	130 (110–152)	90 (60–150)	<0.001
Respiratory rate, /min	20 (20–20)	20 (20–20)	20 (20–20)	0.816
Pulse rate, /min	84 (70–99)	85 (72–99)	78 (63–100)	0.140
Injury Severity Score	23 (16–25)	20 (16–25)	25 (25–30)	<0.001
Blood cell count				
White blood cell count, $\times10^9$/L	12.3 (9.1–15.8)	12.3 (9.1–15.9)	12.6 (9.0–15.8)	0.808
Hemoglobin, g/dL	12.0 (10.4–13.1)	12.2 (10.9–13.2)	10.6 (8.9–12.6)	<0.001
Neutrophil count, $\times10^9$/L	9.8 (6.3–12.8)	9.8 (6.3–13.0)	9.7 (6.8–12.6)	0.748
Lymphocyte count, $\times10^9$/L	1.6 (1.0–2.8)	1.4 (9.7–2.4)	2.6 (1.6–3.5)	<0.001
Monocyte count, $\times10^9$/L	0.7 (0.4–0.9)	0.7 (0.5–0.9)	0.5 (0.4–0.8)	0.031
Platelet count, $\times10^9$/L	183 (143–226)	194 (151–241)	153 (111–191)	<0.001
PLR	107.0 (66.2–181.0)	124.5 (75.7–204.6)	62.1 (36.2–104.8)	<0.001
Red cell distribution width, %	13.0 (12.4–13.7)	12.9 (12.4–13.6)	13.4 (12.6–13.8)	0.051
Kidney function				
Blood urea nitrogen, mg/dL	17.4 (13.8–21.3)	17.4 (13.9–21.4)	16.5 (13.4–21.1)	0.647
Creatinine, mg/dL	0.8 (0.7–1.0)	0.8 (0.6–1.0)	0.9 (0.8–1.1)	0.036
Serum electrolytes				
Sodium, mmol/L	139 (137–141)	139 (137–141)	139 (137–142)	0.530
Potassium, mmol/L	4.0 (3.6–4.3)	4.0 (3.6–4.2)	3.9 (3.6–4.3)	0.554
Chloride, mmol/L	105 (102–107)	105 (102–107)	106 (103–108)	0.078

GCS, Glasgow Coma Scale; *PLR*, platelet-to-lymphocyte ratio; *mm Hg*, millimeters of mercury; *g/dL*, grams per deciliter; *L*, liter; *mg*, milligrams; *mmol*, millimole.

patients with severe trauma. Additionally, the PLR showed similar predictive power to the GCS score and ISS for in-hospital mortality in elderly patients with severe trauma upon ED arrival. Lymphocyte and platelet counts of non-survivors were significantly different from those of survivors. Platelet activation results in endothelial damage and promotes neutrophil extracellular traps and microthrombus formation.[15,16] Several studies have reported that low platelet counts are related to multiorgan dysfunction syndrome in patients with trauma.[17,18] Platelets induce the secretion of inflammatory cytokines, which interact with neutrophils, T cells, and macrophages.[17,18] These platelet-induced complex inflammatory responses may contribute to in-hospital mortality in patients with trauma.

Several studies have reported that platelet function declines with age in elderly patients and that this relationship is associated with prognosis.[19–21] Lymphocytes, including T cells, B cells, and natural killer cells, are the major cellular component of the humoral and cell-mediated immune system.[22] Acute lymphocytosis in the early stages of trauma is related to the degree of injury and mortality.[23] In elderly patients, a high lymphocyte count has been shown to be associated with nutritional status or sepsis associated with delirium.[24,25] Thus, in the present study the effect of lymphocytes and platelets, which are related to prognosis, was further increased through the PLR in elderly patients with severe trauma. The PLR has many advantages and is widely used in the clinical field. The PLR is not only simple and easy to calculate, but the CBC test, which includes the PLR, is widely available and inexpensive, allowing it to be used in almost all EDs worldwide, including those in developing countries.

Table 2. Multivariate logistic regression analysis for predicting in-hospital mortality in elderly patients with severe trauma.

	Adjusted OR (95% CI)	*P*-value
Age, years	1.026 (0.966–1.089)	0.410
GCS score ≤12	4.317 (1.830–10.181)	<0.001
Systolic blood pressure, mm Hg	0.994 (0.984–1.004)	0.260
Pulse rate, /min	0.984 (0.964–1.004)	0.111
Injury Severity Score	1.103 (1.033–1.177)	0.003
Hemoglobin, g/dL	0.753 (0.608–0.931)	0.009
Monocyte count, $\times 10^9$/L	0.999 (0.998–1.000)	0.152
PLR	0.993 (0.987–0.999)	0.017
Red cell distribution width, %	1.153 (0.883–1.504)	0.295
Creatinine, mg/dL	0.671 (0.331–1.358)	0.267
Chloride, mmol/L	0.961 (0.879–1.050)	0.376

OR, odds ratio; *CI*, confidence interval; *GCS*, Glasgow Coma Scale; *PLR*, platelet-to-lymphocyte ratio; *mm Hg*, millimeters of mercury; *min*, minute; *g/dL*, grams per deciliter; *L*, liter; *mg*, milligram; *mmol*, millimole.

Several studies have reported that a low PLR is associated with mortality in patients with trauma, similar to the findings of the present study.[26–28] In the study by Ke et al, the PLRs of non-survivors were higher than those reported in the present study (124.3 vs 62.1).[26] However, in that previous study, the mean age of the included patients was <65 years, and there was also a proportion of patients with an ISS <16.[26] High PLRs have also been shown to be associated with prognosis in non-traumatic medical problems, including tumors, sepsis, and heart failure.[29,30] In the early stages of trauma, the response of various inflammatory or coagulation systems may be different from that of other diseases. Further studies are needed to clarify the relationship between PLR and disease or trauma.

Our results showed that a low hemoglobin level was associated with in-hospital mortality in elderly patients with severe trauma. The results of a previous study suggested that in patients with severe trauma without prehospital intravenous fluid administration, decreased hemoglobin levels on arrival may be associated with the severity of trauma and the need for hemostasis.[31] Another study reported that a low hemoglobin level was correlated with poor neurologic outcomes in patients with traumatic brain injury.[32] Low hemoglobin levels can be proportional to primary volume loss and result in secondary brain damage due to cerebral hypoxia.[32]

The GCS is a routine component of neurological examination for critically ill patients with trauma. Many studies have shown that a low GCS score is associated with poor prognosis in elderly patients with trauma, as shown in the present study.[33,34] However, it is difficult to predict prognosis with the GCS because it does not involve brainstem reflexes, nor does it accurately describe the verbal status of intubated patients. In particular, in elderly patients with trauma, the measurement of the GCS motor response can be inaccurate, requiring more careful measurement.[35]

Several studies have reported that a high ISS value is associated with mortality in elderly patients with trauma.[36,37] Indeed, one such study reported the predictive power of ISS for 30-day mortality as 0.66 (95% CI 0.59–0.74), which is lower than that reported in our study, as well as higher ISS values and mortality than in our study.[37] Additionally, as one of our inclusion criteria was patients with an ISS of ≥16, the relationship between ISS and mortality was more pronounced.

Elderly patients have more frequent loss of consciousness than non-elderly patient; this is often due to various metabolic causes as well as structural problems in the head. Thus, GCS score may be difficult to measure and less accurate in elderly patients than in non-elderly patients.[38] And GCS measurement is affected by sedatives or neuromuscular blockade, whereas PLR obtained by simple calculation through CBC can provide more objective information about patients than GCS measurement. In addition, PLR does not require imaging studies or related specialists, who are needed to determine ISS. However, in this study, PLR showed similar AUC values compared to GCS for predicting in-hospital mortality, which was not superior. The PLR alone cannot be a predictor of mortality; however, in combination with other factors, the PLR can be a warning sign or determine the direction of treatment.

LIMITATIONS

This study has several limitations that warrant discussion. First, it was a retrospective study performed at a single center; thus, our findings are not immediately generalizable to the overall population. Additional multicenter studies with larger samples and prospective designs are necessary to

substantiate our findings. Second, other inflammatory markers, such as cytokines and chemokines, were not investigated in this study. In particular, studies on the relationship between the lymphocyte subgroup and elderly trauma are needed. Third, as we investigated the relationship between the PLR at ED visit and prognosis, it is necessary to investigate the relationship between serial PLR and prognosis in elderly patients with trauma. Finally, because we are a small group, we played multiple roles of study designer, case identifier, data abstractor, data analyst, and author. There are limitations in blinding and monitoring because small groups carry out these roles by themselves. However, efforts were made to address the bias that could occur with a retrospective observational study and, fortunately, our hospital is constructing a dataset under the operation of a regional trauma center when a severely ill patient visits the hospital.

CONCLUSION

Low platelet-to-lymphocyte ratio is independently associated with in-hospital mortality in elderly patients with severe trauma. The association remained significant after adjustment for hospital risk factors and important laboratory variables.

Address for Correspondence: Dong Hun Lee, MD, PhD, Chonnam National University Medical School, Department of Emergency Medicine, 160 Baekseo-ro, Dong-gu, Gwangju, Republic of Korea. Email: ggodhkekf@hanmail.net

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. GBD 2019 Diseases and Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet*. 2020;396(10258):1204–22.
2. Haagsma JA, Charalampous P, Ariani F, et al. The burden of injury in Central, Eastern, and Western European sub-region: a systematic analysis from the Global Burden of Disease 2019 Study. *Arch Public Health*. 2022;80(1):142.
3. Savioli G, Ceresa IF, Macedonio S, et al. Major trauma in elderly patients: worse mortality and outcomes in an Italian trauma center. *J Emerg Trauma Shock*. 2021;14(2):98–103.
4. McKevitt EC, Calvert E, Ng A, et al. Geriatric trauma: resource use and patient outcomes. *Can J Surg*. 2003;46(3):211–5.
5. Yuksen C, Angkoontassaneeyarat C, Thananupappaisal S, et al. Accuracy of trauma on scene triage screening tool (Shock Index, Reverse Shock Index Glasgow Coma Scale and National Early Warning Score) to predict the severity of emergency department triage: a retrospective cross-sectional study. *Open Access Emerg Med*. 2023;15:79–91.
6. Li Q, Ren YQ, Qian YF, et al. The application value of the Modified Early Warning Score combined with age and injury site scores in the evaluation of injuries in emergency trauma patients. *Front Public Health*. 2022;10:914825.
7. Baker SP, O'Neill B, Haddon WJr, et al. The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*. 1974;14(3):187–96.
8. Champion HR, Sacco WJ, Carnazzo AJ, et al. Trauma score. *Crit Care Med*. 1981;9(9):672–6.
9. Boyd CR, Tolson MA, Copes WS. Evaluating trauma care: the TRISS method. Trauma Score and the Injury Severity Score. *J Trauma*. 1987;27(4):370–8.
10. Kumar P, Law S, Sriram KB. Evaluation of platelet lymphocyte ratio and 90-day mortality in patients with acute exacerbation of chronic obstructive pulmonary disease. *J Thorac Dis*. 2017;9(6):1509–16.
11. Mellick D, Gerhart KA, Whiteneck GG. Understanding outcomes based on the post-acute hospitalization pathways followed by persons with traumatic brain injury. *Brain Inj*. 2003;17(1):55–71.
12. Wang H, Li L, Ma Y. Platelet-to-lymphocyte ratio a potential prognosticator in acute myocardial infarction: a prospective longitudinal study. *Clin Cardiol*. 2023;46(6):632–8.
13. Shen Y, Huang X, Zhang W. Platelet-to-lymphocyte ratio as a prognostic predictor of mortality for sepsis: interaction effect with disease severity-a retrospective study. *BMJ Open*. 2019;9(1):e022896.
14. DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. *Biometrics*. 1988;44(3):837–45.
15. Wang Y, Ouyang Y, Liu B, et al. Platelet activation and antiplatelet therapy in sepsis: a narrative review. *Thromb Res*. 2018;166:28–36.
16. Nording HM, Seizer P, Langer HF. Platelets in inflammation and atherogenesis. *Front Immunol*. 2015;6:98.
17. Dewar DC, Tarrant SM, King KL, et al. Changes in the epidemiology and prediction of multiple organ failure after injury. *J Trauma Acute Care Surg*. 2013;74(3):774–9.
18. Nydam TL, Kashuk JL, Moore EE. Refractory postinjury thrombocytopenia is associated with multiple organ failure and adverse outcomes. *J Trauma*. 2011;70(2):401–6;discussion 406–7.
19. De Rosa R, Palmerini T, De Servi S, et al. High on-treatment platelet reactivity and outcome in elderly with non ST-segment elevation acute coronary syndrome - Insight from the GEPRESS study. *Int J Cardiol*. 2018;259:20–5.

20. Msaouel P, Lam AP, Gundabolu K, et al. Abnormal platelet count is an independent predictor of mortality in the elderly and is influenced by ethnicity. *Haematologica*. 2014;99(5):930–6.
21. van der Bom JG, Heckbert SR, Lumley T, et al. Platelet count and the risk for thrombosis and death in the elderly. *J Thromb Haemost*. 2009;7(3):399–405.
22. Balakrishnan K and Adams LE. The role of the lymphocyte in an immune response. *Immunol Invest*. 1995;24(1-2):233–44.
23. Lee DH, Lee BK, Lee SM, et al. Association of neutrophil-to-lymphocyte and platelet-to-lymphocyte ratios with in-hospital mortality in the early phase of severe trauma. *Ulus Travma Acil Cerrahi Derg*. 2021;27(3):290–5.
24. Leandro-Merhi VA, Bráz VN, Aquino JL. Is total lymphocyte count related to nutritional markers in hospitalized older adults? *Arq Gastroenterol*. 2017;54(1):79–82.
25. Li D, Zhang J, Bai G, et al. Lymphocyte and NK cell counts can predict sepsis-associated delirium in elderly patients. *Front Aging Neurosci*. 2021;12:621298.
26. Ke RT, Rau CS, Hsieh TM, et al. Association of platelets and white blood cells subtypes with trauma patients' mortality outcome in the intensive care unit. *Healthcare (Basel)*. 2021;9(8):942.
27. Jo S, Jeong T, Lee JB, et al. The prognostic value of platelet-to-lymphocyte ratio on in-hospital mortality in admitted adult traffic accident patients. *PLoS One*. 2020;15(6):e0233838.
28. Tekin YK. Are neutrophil-to-lymphocyte and platelet-to-lymphocyte ratios associated with mortality in pediatric trauma patients? A retrospective study. *Rambam Maimonides Med J*. 2019;10(4):e0022.
29. Liu J, Li S, Zhang S, et al. Systemic immune-inflammation index, neutrophil-to-lymphocyte ratio, platelet-to-lymphocyte ratio can predict clinical outcomes in patients with metastatic non-small-cell lung cancer treated with nivolumab. *J Clin Lab Anal*. 2019;33(8):e22964.
30. Chen T and Yang M. Platelet-to-lymphocyte ratio is associated with cardiovascular disease in continuous ambulatory peritoneal dialysis patients. *Int Immunopharmacol*. 2020;78:106063.
31. Kawai Y, Fukushima H, Asai H, et al. Significance of initial hemoglobin levels in severe trauma patients without prehospital fluid administration: a single-center study in Japan. *Trauma Surg Acute Care Open*. 2021;6(1):e000831.
32. Hifumi T, Nakamura K, Kuroda Y, et al. High early phase hemoglobin level is associated with favorable neurological outcome in patients with severe traumatic brain injury. *Am J Emerg Med*. 2021;44:373–7.
33. Lalwani S, Gera S, Sawhney C, et al. Mortality profile of geriatric trauma at a Level 1 trauma center. *J Emerg Trauma Shock*. 2020;13(4):269–73.
34. Scherer J, Kalbas Y, Ziegenhain F, et al. The GERtality score: the development of a simple tool to help predict in-hospital mortality in geriatric trauma patients. *J Clin Med*. 2021;10(7):1362.
35. Deeb AP, Phelos HM, Peitzman AB, et al. The whole is greater than the sum of its parts: GCS versus GCS-motor for triage in geriatric trauma. *J Surg Res*. 2021;261:385–393.
36. Pandya S, Le T, Demissie S, et al. The association of gender and mortality in geriatric trauma patients. *Healthcare (Basel)*. 2022;10(8):1472.
37. Egglestone R, Sparkes D, Dushianthan A. Prediction of mortality in critically ill elderly trauma patients: a single centre retrospective observational study and comparison of the performance of trauma scores. *Scand J Trauma Resusc Emerg Med*. 2020;28(1):95.
38. Salottolo K, Levy AS, Slone DS, et al. The effect of age on Glasgow Coma Scale score in patients with traumatic brain injury. *JAMA Surg*. 2014;149(7):727–34.

Pregnancy-adapted YEARS Algorithm: A Retrospective Analysis

Alden Mileto, BS*
Gina Rossi, MS*
Benjamin Krouse, BS*
Robert Rinaldi, MBS*
Julia Ma, MBS*
Keith Willner, MD†
David Lisbon, MD†

*Geisinger Commonwealth School of Medicine, Scranton, Pennsylvania
†Geisinger Wyoming Valley Health Center, Department of Emergency Medicine, Wilkes-Barre, Pennsylvania

Section Editors: Gabriel Wardi, MD, and Niels Rathlev, MD
Submission history: Submitted April 5, 2023; Revision received September 14, 2023; Accepted October 20, 2023
Electronically published December 8, 2023
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.60626

Introduction: Pulmonary embolism (PE) is an imperative diagnosis to make given its associated morbidity. There is no current consensus in the initial workup of pregnant patients suspected of a PE. Prospective studies have been conducted in Europe using a pregnancy-adapted YEARS algorithm, which showed safe reductions in computed tomography pulmonary angiography (CTPA) imaging in pregnant patients suspected of PE. Our objective in this study was 1) to measure the potential avoidance of CTPA use in pregnant patients if the pregnancy-adapted YEARS algorithm had been applied and 2) to serve as an external validation study of the use of this algorithm in the United States.

Methods: This study was a single-system retrospective chart analysis. Criteria for inclusion in the cohort consisted of keywords: pregnant; older than 18; chief complaints of shortness of breath, chest pain, tachycardia, hemoptysis, deep vein thromboembolism (DVT), and D-dimer—from January 1, 2019– May 31,2022. We then analyzed this cohort retrospectively using the pregnancy-adapted YEARS algorithm, which includes clinical signs of a DVT, hemoptysis, and PE as the most likely diagnosis with a D-dimer assay. Patients within the cohort were then subdivided into two categories: aligned with the YEARS algorithm, or not aligned with the YEARS algorithm. Patients who did not receive a CTPA were analyzed for a subsequent diagnosis of a PE or DVT within 30 days.

Results: A total of 74 pregnant patients were included in this study. There was a PE prevalence of 2.7% (two patients). Of the 36 patients who did not require imaging by the algorithm, seven CTPA were performed. Of the patients who did not receive an initial CTPA, zero were diagnosed with PE or DVT within a 30-day follow-up. In total, 85.1% of all the patients in this study were treated in concordance with the pregnancy-adapted YEARS algorithm.

Conclusion: The use of the pregnancy-adapted YEARS algorithm could have resulted in decreased utilization of CTPA in the workup of PE in pregnant patients, and the algorithm showed similar reductions compared to prospective studies done in Europe. The pregnancy-adapted YEARS algorithm was also shown to be similar to the clinical rationale used by clinicians in the evaluation of pregnant patients, which indicates its potential for widespread acceptance into clinical practice. [West J Emerg Med. 2024;25(1)136–143.]

INTRODUCTION

One of the challenges the emergency physician faces is the prompt diagnosis of pulmonary embolism (PE) in pregnant patients. Pulmonary embolism remains a significant cause of maternal mortality.[1–3] Studies show that approximately 9% of pregnancy-related deaths in the United States are due to a

PE.[2] Causes include physiologic changes in pregnancy that induce a hypercoagulable state, which predisposes patients to venous thromboembolism (VTE).[4–6] The normal physiologic changes in pregnancy substantially overlap with the clinical signs and symptoms of PE, which further complicates PE workups within this population. D-dimer testing, widely used in non-pregnant patients, is controversial in pregnancy because its accuracy varies by trimester.[3,7] Proposals for age-adjusted or trimester-adjusted cut-off values have been or are currently being considered.[8–10]

Reports show that the prevalence of PE in pregnant patients undergoing diagnostic workup in the emergency department (ED) is approximately 3.7%, whereas nonpregnant patients of childbearing age showing a PE prevalence of 6.0%.[11] Diagnostic workup, such as computed tomography pulmonary angiography (CTPA) or a V/Q scan, increases costs and evaluation times. These scans expose the fetus to radiation. Analyses have shown a 121% increase in radiologic examinations in pregnant women from the years 1997–2006.[12] While radiation poses potential teratogenic effects, these effects are dose-dependent and vary based on gestational age. Radiation exposures greater than 500 milligray (mGy) cause fetal damage, and exposure to less than 50 mGy has not been associated with differences in pregnancy outcomes.[13] While CTPA is associated with radiation exposure of <5 mGy, given the complexities of the effects of exposure based on gestational age and other radiation exposure during the pregnancy, it is recommended that the potential benefit of the radiologic study be weighed against the radiation exposure to the fetus.[12,13] Multiple criteria have been developed to aid clinicians in quickly assessing and diagnosing PE including Wells, PE rule-out criteria (PERC), and YEARS criteria. However, these criteria were originally developed excluding pregnant patients from their studies, which has resulted in a lack of consensus on PE workup in pregnant individuals.[14]

Recent studies have demonstrated greater efficacy of the YEARS criteria, in comparison to the traditionally used PERC and Wells criteria.[15–17] In 2019, an international study aimed to clinically evaluate PE in pregnant patients using a pregnancy-adapted YEARS algorithm.[14] Their conclusion was that a pregnancy-adapted YEARS algorithm proved viable in ruling out a PE without serious adverse consequences. The pregnancy-adapted YEARS algorithm is summarized in Figure 1.

Prior prospective studies applying the pregnancy-adapted YEARS algorithm took place in Europe.[14,18] Additionally, another study reviewed the prevalence of PE in North America and Europe in non-pregnant patients. The prevalence of patients tested for PE in Europe was 23% compared to 8% in North America. This study also reported both a lower rate of CTPA utilization (38% vs 60%) and a lower diagnostic yield from CTPA (13% vs 29%) in North America.[19] The objective of our study was to measure the potential avoidance of CTPA in pregnant patients being evaluated for a PE if the pregnancy-adapted YEARS algorithm had been applied and to serve as an external validation study of the use of this algorithm in the US.

Population Health Research Capsule

What do we already know about this issue?
Pulmonary embolism is challenging to diagnose in pregnant patients. In European studies the pregnancy-adapted YEARS algorithm has shown promise in simplifying this diagnosis.

What was the research question?
We investigated the reduction in computed tomography (CT) achieved by applying the YEARS algorithm to pregnant patients in two US hospitals.

What was the major finding of the study?
In our 74-patient sample, use of the YEARS algorithm could have safely avoided seven CTs (19.4% reduction).

How does this improve population health?
Adoption of the pregnancy-adapted YEARS algorithm could safely reduce CT imaging in pregnant patients, reducing their radiation exposure and streamlining ED workup.

METHODS

Study Design

This study was a retrospective chart analysis conducted on visits from January 1, 2019–May 31, 2022, spanning one Level I trauma center/tertiary care center and one urban community hospital in Pennsylvania. The cohort included pregnant patients ≥18 years of age who presented to the ED with chief complaints consistent with a suspected PE—shortness of breath, chest pain, tachycardia, hemoptysis, and clinical signs of deep vein thromboembolism (DVT). For the robustness of the dataset our search strategy also included pregnant patients for whom a D-dimer had been ordered. We excluded patients who did not receive a D-dimer test as part of their clinical workup. We also excluded patients who were worked up for a PE outside their pregnancy period. Procedures and protocols were approved by the institutional review board.

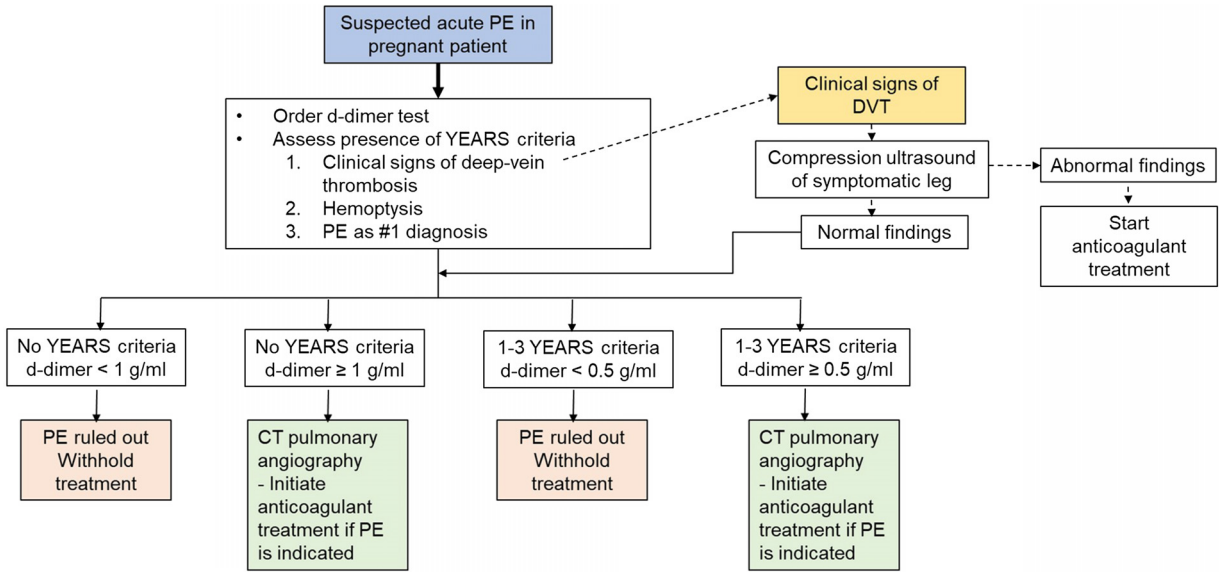


Figure 1. Pregnancy-adapted YEARS algorithm for management of suspected acute pulmonary embolism in pregnant patients. *DVT*, deep-vein thrombosis; *PE*, pulmonary embolism; *YEARS*, diagnostic algorithm for pulmonary embolism; *CT*, computed tomography; *g/mL*, grams per milliliter.

Procedures

Patients for this study were gathered by an initial search strategy that used the SlicerDicer feature in the Epic electronic health record (Epic Systems Corporation, Verona, WI). SlicerDicer is a validated tool within Epic that allows for the selection of patients given certain inclusion and exclusion data.[20] Trained medical student research assistants (RA) extracted patient data via retrospective chart review. The RAs were initially blinded to the study outcome. The two senior authors (KW, DL), both board-certified emergency physicians, reviewed a random sampling of each abstractor's charts for accuracy. Each chart was then tabulated by chief complaint and subsequent findings according to the YEARS algorithm summarized in Figure 1, regardless of whether the algorithm was used in patient workup. Any questionable cases were reviewed once more by an attending physician.

Clinical signs of a DVT included documented clinician suspicion of a DVT or documented unilateral or bilateral leg swelling, warmth, pain, or discoloration. Hemoptysis was deemed present if the patient reported hemoptysis during the visit, within 24 hours of a visit, or was determined by the evaluating clinician to be relevant. Pulmonary embolism as the most likely diagnosis was determined through thorough evaluation of health records. A detailed methodology of how "PE most or equally likely diagnosis" was determined is elucidated in the supplemental attachment. Any disagreement in the determination of PE as the "most or equally likely" diagnosis triggered review by a senior author and was resolved by consensus. The RAs evaluated charts independently, and ultimately all charts adjudicated as "PE most or equally likely diagnosis" were discussed by both senior authors; therefore, we did not calculate a kappa statistic. Missing historical or clinical exam findings were treated as absent.

If the CTPA showed a new filling defect in any pulmonary artery, PE was assumed to be present.[21] If the result of a compression ultrasonography showed noncompressibility of a proximal vein, a DVT was assumed to be present.[19] Patients were then further categorized as nonconcordant or concordant with the pregnancy-adapted YEARS algorithm (Figure 1).

Patients who did not receive a CTPA were assessed within a 30-day follow-up period. These visits included subsequent appointments in which the previous ED visit was addressed. Further analysis at the follow-ups included workup for suspected VTE, PE, or an additional ED visit as recommended by the treating clinician. All follow-up visits were within 30 days from the initial ED encounter for PE workup. Additionally, all patients in the study completed their pregnancy in the health system.

Analysis

We used Excel (Microsoft Corporation, Redmond, WA) to perform fundamental statistical calculations. To maintain data integrity and ensure ongoing data accuracy we implemented regular quality control procedures, including periodic reviews and spot-checking. This involved random sampling of entered data for extrinsic verification. We did not use data software to collect data.

RESULTS

A total of 323 patients were found via the initial search strategy. After removing duplicates and patients who were

not pregnant and did not have a D-dimer test performed, 67 cases remained. These cases were cross-referenced with the system's internal radiology database, which records pregnancy status of all patients who received ionizing radiation, yielding an additional seven cases for analysis. During the study period, 74 patients were evaluated for PE. The patients were 19–38 years old (mean age 27.85). The highest percentage (41.9%) of patients were in the third trimester of pregnancy at the time of their evaluation. The presenting complaints of the patients reviewed are summarized in Table 1.

Seven of the 74 patients reviewed did not have D-dimer testing completed, and thus were excluded from the analysis to determine the effectiveness of the pregnancy-adapted YEARS algorithm. Five of the excluded patients met at least one YEARS criteria, and two of those five patients were found to have a PE. These two patients comprise the 2.7% prevalence of PE in our study cohort. A breakdown of the range of D-dimer levels is represented in Table 2. Among the 67 patients included in the analysis, 47 patients (70.15%) met no YEARS criteria, and 20 patients (29.85%) met one or more YEARS criteria. Eighteen patients (90%) met the criteria of PE being considered the number one diagnosis, one patient (5%) had unilateral leg swelling, and one patient (5%) had both hemoptysis and PE considered as the number one diagnosis.

Among the 47 patients who did not meet any of the three YEARS criteria, 35 (74.47%) had a D-dimer below the threshold of 1.0 milligrams per liter (mg/L), and 12 (25.53%) had a D-dimer greater than 1.0 mg/L. Of those 35 patients who should not have undergone CTPA based on the pregnancy-adapted YEARS algorithm, seven (20%) had a CTPA performed. These seven patients represent the patients who could have avoided radiation exposure with application of the YEARS-adapted algorithm. Four of these patients had D-dimer levels between 0.5–1.0 mg/L, and three patients had a D-dimer level <0.5 mg/L. None of these seven patients were found to have a PE on imaging. Among the 28 patients who did not have a CTPA performed, 24 patients (85.71%) had a follow-up evaluation in the health system within 30 days, and none were found to have a VTE diagnosed. Four patients (14.29%) did not have a follow-up visit documented within 30 days of their PE workup in the ED. Of note, of the 28 patients who did not have a CTPA performed, 16 (67.14%) had D-dimer levels between 0.5–1.0 mg/L.

Of the 12 patients who met zero YEARS criteria and had a D-dimer of greater than 1.0 mg/L, 10 (83.33%) had a CTPA performed, all of which showed no PE. Two (16.67%) of these 12 patients did not have a CTPA performed. One of these did not have a follow-up visit documented within 30 days of their PE workup in the ED. However, this patient had no diagnosis of VTE or new anticoagulant medication listed on admission to labor and delivery.

Of the 20 patients with one or more YEARS criteria, 19 (95%) had a D-dimer >0.5 mg/L, and one patient (5%) had a D-dimer of <0.5 mg/L. The patient with a D-dimer of <0.5 mg/L did not have a CTPA performed and had no VTE at 30-day follow-up. Of the 19 patients with D-dimer levels of >0.5 mg/L, 17 (89.47%) had CTPA imaging performed and one (5.26%) had a VQ scan done, none of which were positive for PE. One patient (5.26%) did not have CTPA imaging done.

Our review indicated that 7 of 68 clinicians documented the use of the YEARS algorithm in their work-up. No clinician documented use of the pregnancy-adapted YEARS algorithm. However, 85.1% of the patients evaluated were treated in alignment with the pregnancy-adapted YEARS algorithm. Deviation from the YEARS criteria was observed

Table 1. Pregnancy demographics and chief complaints of patients suspected of pulmonary embolism.

	Total (%)
Population demographics	
Age Range	19–38 years
Mean Age	27.85 years
Age Standard Deviation	5.04 years
Trimester	
1st Trimester	16 (21.6%)
2nd Trimester	27 (36.4%)
3rd Trimester	31 (41.9%)
Patient Presentation	
Shortness of breath only	29 (39.2%)
Chest pain only	21 (28.4%)
Chest pain and shortness of breath	13 (17.6%)
Cold symptoms/COVID-19 symptoms	4 (5.4%)
Other	7 (9.5%)

Table 2. Breakdown of number of patients within certain ranges of D-dimer levels stratified by YEARS criteria met.*

D-dimer level	Number of patients
0 YEARS Criteria	
<0.5 mg/L	15
0.5–1.0 mg/L	20
>1 mg/L	12
≥1 YEARS Criteria	
<0.5 mg/L	1
>0.5 mg/L	19

*Below the standard cutoff of 0.5 mg/L, between the standard cutoff and the pregnancy-adapted YEARS algorithm level of 1.0 mg/L with no YEARS criteria, and above the algorithm's cutoff level (0.5 mg/L or 1.0 mg/L), depending on whether YEARS criteria were met.
mg/L, milligrams per lliter.

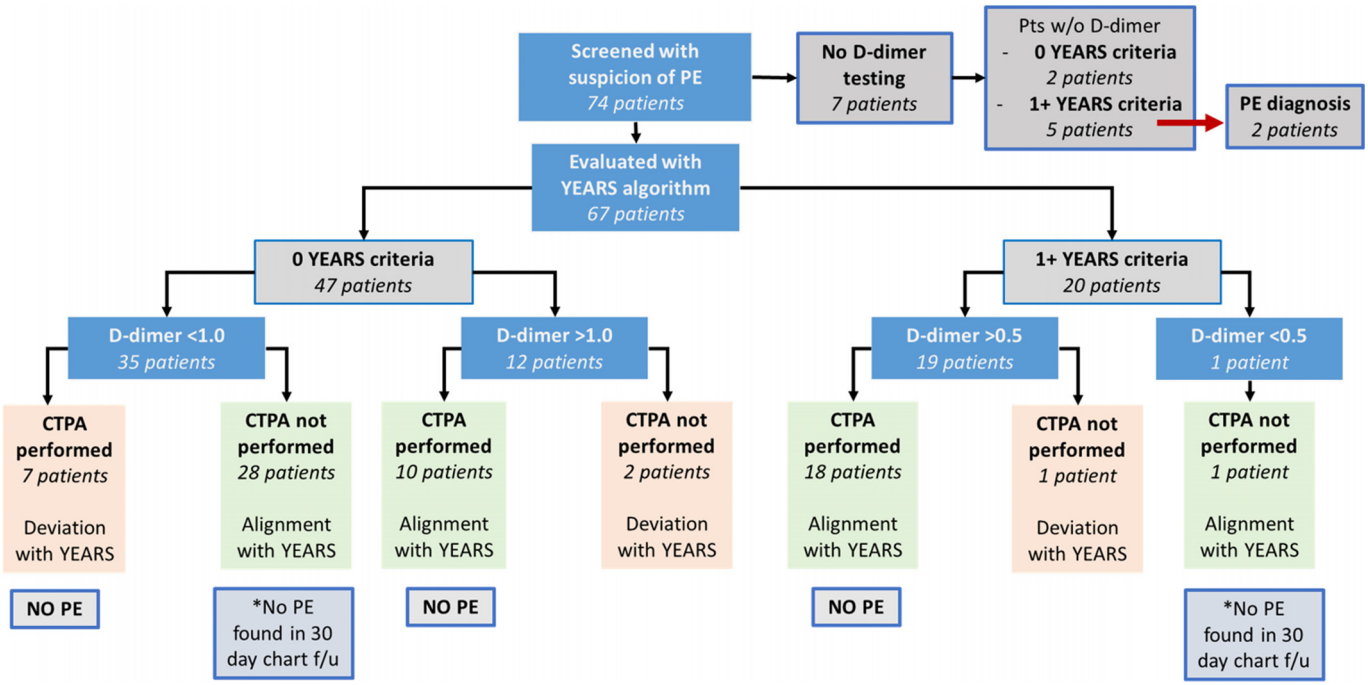


Figure 2. Flow chart of pregnancy-adapted YEARS algorithm in a retrospective diagnostic review. *PE*, pulmonary embolism; *CTPA*, computed tomography pulmonary angiography; *f/u*, follow-up.

with seven patients who received unnecessary CTPA imaging and three patients who did not undergo imaging, despite meeting criteria. Two (66.67%) of these three patients met no YEARS criteria and had D-dimer levels >1.0 mg/L, and one patient (33.33%) had one or more YEARS criteria and a D-dimer level of 0.5 mg/L.

The results of the pregnancy-adapted YEARS algorithm applied to our cohort are summarized in Figure 2. Additionally, 14 patients (20.89%) received a lower extremity Doppler, all of which were negative for DVT. Therefore, these patients followed the algorithm outlined in Figure 1. Outcomes of applying the pregnancy-adapted YEARS algorithm to our cohort are summarized in Table 3.

DISCUSSION

In March 2019, the ARTEMIS study was published demonstrating a 39% decrease in CTPA imaging among pregnant patients when using the pregnancy-adapted YEARS criteria.[14] The ARTEMIS study showed that the pregnancy-adapted YEARS algorithm was able to safely rule out PE in pregnant patients. Following the ARTEMIS study, Langlois et al published a study in May 2019 further applying the pregnancy-adapted YEARS algorithm. This study retrospectively assessed the data from the CT-PE pregnancy study to externally validate the accuracy and safety of the pregnancy-adapted YEARS algorithm. The CT-PE pregnancy study found a 14% decrease in the need for CTPA.[18] When the pregnancy-adapted YEARS algorithm was retrospectively applied to this data, 32 additional patients had PE excluded without the need for CTPA (78 in total, 21%). This resulted in almost twice as many patients being spared radiation exposure.[18]

The prospective ARTEMIS study and a subsequent retrospective study demonstrated the safety and efficacy of the pregnancy-adapted YEARS algorithm in pregnant patients in a European population. In our study we aimed to conduct an external validation study in the United States of those international studies. In our retrospective study, we found that 36 patients met no criteria to have a CTPA performed, but seven (19.4%) of these patients did receive a CTPA. None of these seven patients had PE detected via the imaging modality. This cohort represents the patients who could have avoided CTPA and radiation exposure if the pregnancy-adapted YEARS algorithm had been applied. Additionally, our cohort consisted of 28 patients who met zero YEARS criteria and had a D-dimer <1.0 mg/L. If a conventional D-dimer cutoff had been used, rather than the algorithm value, our patients would all have had a cutoff value of 0.5 mg/L.[16] By the intention to diagnose approach, this conventional cutoff would have resulted in an additional 16 patients meeting criteria to undergo CTPA imaging, as 16 of the 28 patients with zero YEARS criteria had a D-dimer level between 0.5–1.0 mg/L.

Combining these with the seven patients who received unnecessary CTPA imaging, our study showed retrospective application of the pregnancy-adapted YEARS algorithm would have resulted in a 34.3% decrease in CTPA utilization. This is consistent with prior prospective studies showing

Table 3. Outcomes of pregnancy-adapted YEARS algorithm retrospective utilization.

	Total (%)
Patients screened with suspicion of PE (N = 74)	
Patients with PE	2 (2.7%)
Patients with no PE	72 (97.3%)
Patients excluded from YEARS evaluation	7 (9.5%)
Patients available for YEARS evaluation	67 (90.5%)
YEARS algorithm (N = 67)	
Patients treated in concordance to YEARS	57 (85.1%)
Patients not treated in concordance to YEARS	10 (14.9%)
CTPA Use	
Patients who met criteria for CTPA	31 (46.3%)
Patients who did not receive CTPA*	3 (9.6%)
Patients who did not meet criteria for CTPA	36 (53.7%)
Patients who received unnecessary CTPA*	7 (19.4%)
Patients who received a CTPA (or V/Q)	36 (53.4%)
Patients with confirmed pulmonary embolism	2 (5.6%)
Patients with confirmed no pulmonary embolism	34 (94.4%)
Patients who did not receive a CTPA	31 (46.3%)
Failed to receive follow-up	5 (16.1%)
Patients diagnosed with PE or VTE upon 30-day follow-up	0 (0%)

*Patients who were treated non-concordant to the pregnancy-adapted YEARS algorithm.
PE, pulmonary embolism; *CTPA*, computed tomography pulmonary angiography; *VTE*, venous thromboembolism; *V/Q*, ventilation/perfusion scan.

21% and 32–65% reductions.[14,18] In other words, without actively following the pregnancy-adapted YEARS algorithm, the clinicians who evaluated the patients in our cohort used their clinical judgment to rule out a PE, despite an elevated D-dimer >0.5 mg/L in 16 patients. Given that a substantial percentage (85.1%) of the clinicians evaluated patients in concordance with the pregnancy-adapted YEARS algorithm, our study found that an additional 10.4% of CTPA utilization could have been avoided with active application of the algorithm because 7/67 patients underwent CTPA not in concordance with the algorithm. The ARTEMIS study featured 12 patients (6.2%) who underwent CTPA testing, despite no confirmed DVT and a D-dimer level below the threshold, which was defined as a protocol violation.[14] Our study showed a similar outcome with seven patients (10.4%) receiving a CTPA despite a D-dimer below the threshold. Therefore, our study validates the current body of research on the YEARS algorithm and the potential utility of the pregnancy-adapted YEARS algorithm in a rural-suburban setting.

Nevertheless, the results from this study have some notable differences compared to recent prospective studies. One difference was the number of patients in our study meeting any YEARS criteria, especially for hemoptysis or clinical signs of a DVT. Among the 67 patients included in the analysis, only 20 patients met one or more YEARS criteria (30%), and of those 20 patients one had unilateral leg swelling and one had both hemoptysis and PE considered as the number one diagnosis. This demonstrates the criterion of PE as the number one diagnosis being the largest contribution in our cohort, resulting in 40/67 (59.7%) patients with a negative YEARS algorithm. This criterion was subject to retrospective bias and may account for variation from previously published prospective studies. Notably, those previous prospective studies showed 49% and 75% of their cohort meeting one or more YEARS criteria.[14,18] Our study additionally featured a smaller sample size than previously published studies, with 67 patients included in the analysis compared to 510 in the ARTEMIS study and and 395 in the Langlois study.[14,18] However, despite our relatively small sample size, we were able to achieve a wide and relatively even spread of gestational ages across all trimesters.

To demonstrate the long-term applicability of the pregnancy-adapted YEARS algorithm, a 30-day chart follow-up was performed on the 36 patients who did not meet criteria for a CTPA. Five of these patients failed to follow up. None of the 31 patients who were reviewed demonstrated evidence of a PE or VTE upon follow-up. This further demonstrates consistency with other studies in the use of the

criteria in an acute diagnosis. All patients in the cohort were followed to completion of their pregnancy, and none had a new diagnosis of VTE or an anticoagulant listed on their medication list.

Our study also showed that three of the 31 patients should have received a CTPA according to the pregnancy-adapted YEARS algorithm but did not receive it. These patients are included in the cohort who received treatment that was non-concordant with the algorithm. The first of these patients was a 38-year-old woman in her first trimester with a D-dimer of 1.2 mg/L and no YEARS criteria, who was diagnosed with pneumonia. Literature suggests that pneumonia can cause an elevation of the D-dimer level.[22,23] Pneumonia may present similarly to a PE and represents a diagnosis that could require use of the YEARS algorithm and result in unnecessary CTPA utilization.

The second patient was a 28-year-old woman in her third trimester with a D-dimer of 0.76 mg/L and one YEARS criterion. The evaluating physician used a trimester-adjusted D-dimer and decided that CTPA was not necessary. Literature suggests that D-dimer values fluctuate during pregnancy, and its use alone is not sufficient in ruling out a PE regardless of trimester.[3,7] The third patient was a 28-year-old woman in her third trimester with a D-dimer of 1.48 mg/L with no YEARS criteria. The evaluating physician decided the patient had unspecified dyspnea of unclear origin and ruled that CTPA was not necessary. There were no PE diagnoses for these patients on 30-day follow-up. If counted against the efficacy of pregnancy-adapted YEARS algorithm, additional reduction would decrease from 7/67 (10.4%) to 4/67 (6%), and total reduction with application of the algorithm would decrease to 20/67 (29.85%), which is consistent with prior prospective studies.

Two patients in this study were diagnosed with a PE. Of note, neither of them had a D-dimer completed; therefore, they were excluded from the study. The first patient was 10 weeks pregnant. She presented with chest pain and shoulder pain that increased with inspiration. She had a complex superficial thrombosis of the lower extremity at the time of her workup and was being treated with low molecular weight heparin. Repeat duplex in the ED showed extension of the clot into the deep venous system. The patient's case was discussed with a maternal fetal medicine physician who recommended CTPA.

The second patient was 33 weeks pregnant. She presented with back pain and was known to be positive for COVID-19 prior to arrival. She also complained of increasing dyspnea and pleuritic chest pain. Given her symptoms and multiple risk factors for clots, the clinician felt that urgent CTPA was necessary. Although these patients were not included in the analysis, they were incorporated into our results for the prevalence of PE during our study period, which was 2.9%. The prevalence of PE in the ARTEMIS study was 5.4%, and in the Langlois study was 6.5%.[14,18] Therefore, our cohort had a lower prevalence of PE compared to the prior European studies. This is also consistent with literature demonstrating the prevalence of ED patients tested for PE in Europe to be 23% compared to 8% in North America.[19]

In total, 57 of the 67 patients (85.1%) in this study were treated in concordance with the pregnancy-adapted YEARS algorithm despite only seven physicians documenting the use of YEARS in their workup. This may indicate that there has already been an informal adoption of the pregnancy-adapted YEARS algorithm in clinical practice. The methodology used by clinicians in the workup of this patient population is similar to the proposed algorithm, which may demonstrate the pregnancy-adapted YEARS algorithm has a higher propensity to be used in clinical practice. However, additional studies are warranted to further elucidate the clinical significance of the pregnancy-adapted YEARS algorithm in different settings and populations Future research should be aimed at demonstrating safety of the algorithm applied to populations in the US.

LIMITATIONS

This retrospective study is not without its limitations. First, it introduced selection bias in the cohort that was reviewed. The reviewed charts were not originally designed for research; therefore, pertinent information may have been omitted. The criterion of PE as the number one diagnosis falls victim to retrospective bias. Unless explicitly stated, it was subjective in discerning whether the physician believed PE was a primary concern during the medical decision-making process. Another limitation was our small cohort of patients. This may limit the applicability of our results to larger populations. Therefore, the findings and conclusions drawn from this study should be interpreted with caution, recognizing the potential limitations associated with the small sample size. Finally, this study took place in a single health system in northeastern Pennsylvania and may not represent all populations.

CONCLUSION

Previous prospective studies applying the pregnancy-adapted YEARS algorithm in Europe found 21% and 32-65% reductions in CTPA imaging for pregnant patients with suspected pulmonary embolism.[8,18] Our retrospective study found similar conclusions of the pregnancy-adapted YEARS algorithm. Thus, this study serves as external validation for previous literature in Europe within the United States. Furthermore, this study demonstrated that most clinicians used clinical rationale concordant to the pregnancy-adapted YEARS algorithm, which indicates a potential for widespread adoption for the evaluation of pulmonary embolism in pregnant patients.

Address for Correspondence: Keith Willner, MD, Geisinger Wyoming Valley Health Center, Department of Emergency Medicine, 1000 E Mountain Dr., Wilkes-Barre, Pennsylvania 18711. Email: kwillner@geisinger.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. Simcox LE, Ormesher L, Tower C, et al. Pulmonary thrombo-embolism in pregnancy: diagnosis and management. *Breathe (Sheff).* 2015;11(4):282–9.
2. Abe K, Kuklina EV, Hooper WC, et al. Venous thromboembolism as a cause of severe maternal morbidity and mortality in the United States. *Semin Perinatol.* 2019;43(4):200–4.
3. Sadeghi S, Golshani M, Safaeian B. New cut-off point for D-dimer in the diagnosis of pulmonary embolism during pregnancy. *Blood Res.* 2021;56(3):150–5.
4. Heit JA, Kobbervig CE, James AH, et al. Trends in the incidence of venous thromboembolism during pregnancy or postpartum: a 30-year population-based study. *Annals of Internal Medicine.* 2005;143(10):697–706.
5. Maiello M, Torella M, Caserta L, et al. Trombofilia in gravidanza: evidenze clinico-sperimentali di uno stato trombofilico [Hypercoagulability during pregnancy: evidences for a thrombophilic state]. *Minerva Ginecol.* 2006;58(5):417–22.
6. James AH. Venous thromboembolism in pregnancy. *Arterioscler Thromb Vasc Biol.* 2009;29(3):326–31.
7. Hedengran KK, Andersen MR, Stender S, et al. Large D-dimer fluctuation in normal pregnancy: a longitudinal cohort study of 4,117 samples from 714 healthy Danish women. *Obstet Gynecol Int.* 2016;2016:3561675.
8. Erythropoulou-Kaltsidou A, Alkagiet S, Tziomalos K. New guidelines for the diagnosis and management of pulmonary embolism: Key changes. *World J Cardiol.* 2020;12(5):161–6.
9. Stals MAM, Takada T, Kraaijpoel N, et al. Safety and efficiency of diagnostic strategies for ruling out pulmonary embolism in clinically relevant patient subgroups: a systematic review and individual-patient data meta-analysis. *Ann Intern Med.* 2022;175(2):244–55.
10. Bates SM, Rajasekhar A, Middeldorp S, et al. American Society of Hematology 2018 guidelines for management of venous thromboembolism: venous thromboembolism in the context of pregnancy. *Blood Adv.* 2018;2(22):3317–59.
11. Kline JA, Richardson DM, Than MP, et al. Systematic review and meta-analysis of pregnant patients investigated for suspected pulmonary embolism in the emergency department. *Acad Emerg Med.* 2014;21(9):949–59.
12. Ratnapalan S, Bona N, Chandra K, et al. Physicians' perceptions of teratogenic risk associated with radiography and CT during early pregnancy. *AJR Am J Roentgenol.* 2004;182(5):1107–9.
13. Baysinger CL. Imaging during pregnancy. *Anesth Analg.* 2010;110(3):863–7.
14. van der Pol LM, Tromeur C, Bistervels IM, et al. Pregnancy-adapted YEARS algorithm for diagnosis of suspected pulmonary embolism. *N Engl J Med.* 2019;380(12):1139–49.
15. Kabrhel C, Van Hylckama Vlieg A, Muzikanski A, et al. Multicenter evaluation of the YEARS criteria in emergency department patients evaluated for pulmonary embolism. *Acad Emerg Med.* 2018;25(9):987–94.
16. Freund Y, Chauvin A, Jimenez S, et al. Effect of a diagnostic strategy using an elevated and age-adjusted D-dimer threshold on thromboembolic events in emergency department patients with suspected pulmonary embolism: a randomized clinical trial. *JAMA.* 2021;326(21):2141–9.
17. van der Hulle T, Cheung WY, Kooij S, et al. Simplified diagnostic management of suspected pulmonary embolism (the YEARS study): a prospective, multicentre, cohort study. *Lancet.* 2017;390(10091):289–97.
18. Langlois E, Cusson-Dufour C, Moumneh T, et al. Could the YEARS algorithm be used to exclude pulmonary embolism during pregnancy? Data from the CT-PE-pregnancy study. *J Thromb Haemost.* 2019;17(8):1329–34.
19. Germini F, Zarabi S, Eventov M, et al. Pulmonary embolism prevalence among emergency department cohorts: A systematic review and meta-analysis by country of study. *J Thromb Haemost.* 2021;19(1):173–85.
20. Saini V, Jaber T, Como JD, et al. 623 Exploring 'slicer dicer', an extraction tool in EPIC, for clinical and epidemiological analysis. *Open Forum Infect Dis.* 2021;8(Supp.1):S414–S5.
21. Blondon M, Martinez de Tejada B, Glauser F, et al. Management of high-risk pulmonary embolism in pregnancy. *Thromb Res.* 2021;204:57–65.
22. Martinelli I, Ferrazzi E, Ciavarella A, et al. Pulmonary embolism in a young pregnant woman with COVID-19. *Thromb Res.* 2020;191:36–7.
23. Trahan MJ, Malhamé I, Mitric C, et al. Severe and critical COVID-19 in pregnancy: A case series from Montreal. *Obstet Med.* 2021;14(3):170–6.

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
- Free and discounted registration to CAL/AAEM events
- 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

Join the CAL/AAEM Facebook Group to stay up-to-date:
www.facebook.com/groups/calaaem

www.aaem.org/calaaem

CALIFORNIA ACEP
AMERICAN COLLEGE OF EMERGENCY PHYSICIANS

MEDI-CAL RATE INCREASE

CALIFORNIA ACEP SECURED $200M ANNUALLY TO INCREASE MEDI-CAL REIMBURSEMENT FOR EMERGENCY PHYSICIANS!

EMERGENCY MEDICINE IS THE ONLY SPECIALTY WITH ITS OWN BUDGET ALLOCATION.

@CALIFORNIAACEP www.californiaacep.org