
WestJEM

Volume 20, Number 4, July 2019 Open Access at *West*JEM.com ISSN 1936-900X

# *Western Journal of Emergency Medicine:*

## Integrating Emergency Care with Population Health

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VOLUME 20, NUMBER 4, July 2019

PAGES 538-689


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Integrating Emergency Care with Population Health

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





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

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Editorial and Publishing Office: *West*JEM/Depatment of Emergency Medicine, UC Irvine Health, 333 City Blvd, West, Rt 128-01, Orange, CA 92868, USA
Office: 1-714-456-6389; Email: Editor@westjem.org

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Editorial and Publishing Office: *West*JEM/Depatment of Emergency Medicine, UC Irvine Health, 333 City Blvd, West, Rt 128-01, Orange, CA 92866, USA

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

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**VITAL STATISTICS**

*Western Journal of Emergency Medicine* (*West*JEM): Integrating Emergency Care with Population Health (*West*JEM) is the premier open-access Medline-indexed EM journal in the world. As the official journal of the California Chapter of the American College of Emergency Physicians (ACEP), American College of Osteopathic Emergency Physicians (ACOEP), and the California chapter division of the American Academy of Emergency Medicine (AAEM), the journal focuses on how emergency care affects health and health disparities in communities and populations. Additionally, *West*JEM focuses on how social conditions impact the composition of patients seeking care in emergency departments worldwide. *West*JEM is distributed electronically to 19,000 emergency medicine scholars and 2,800 in print. This includes 83 academic department of emergency medicine subscribers and 8 AAEM State Chapters.

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# We Need Our Village: CORD's Response to the ACGME's Common Program Requirements

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*Section Editor:* Mark I. Langdorf, MD, MHPE
Submission history: Submitted June 15, 2019; Revision received Accepted July 1, 2019; Accepted July 1, 2019
Electronically published July 3, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.7.44138
[West J Emerg Med. 2019;20(4)538-540.]

"It takes a village to raise a child," is a common colloquialism referring to the immense amount of time and support required to develop a contributing member of society. In residency education, it takes collaboration amongst multiple individuals to run a program, educate within the standard of graded responsibility, and mentor residents with differing needs and interests. This village of educators (Residency Leadership and Core Faculty), allows for exposure to different ways of thinking, approaches to patient care, and methods of teaching, creating a rich environment for the exponential growth of learners. It is the responsibility of these individuals to assure excellence in education, inside and outside the clinical setting, to develop high quality emergency physician (EP) graduates for our society.

Until 2019, the Emergency Medicine ACGME (Accreditation Council for Graduate Medical Education) program requirements stated that institutions were required to provide protected non-clinical time for core faculty. Specifically, core faculty could not be required to generate clinical or other income to support that protection. These core faculty could not average more than 28 clinical hours per week, or 1344 clinical hours per year. In the new proposed program requirements, the requirement to ensure this non-clinical time has been removed. This will undoubtedly have a negative effect on the quality of resident education and the physician wellness of the faculty.

While we can certainly understand the ACGME's desire to create uniformity in processes among training in all specialties, there are unique qualities of each specialty that merit individualization. Specifically, EM has shift scheduling challenges, increasing patient volumes with frequent emergency department (ED) crowding, and an increased burden of clerical work. These factors pose unique challenges in educating and training EM residents that will create serious consequences without the provision for protected time for clinician-educators. Additionally, changes in other specialties and decreased availability of specialists has led to increased workload on EPs, and increased need for education in areas that were previously not in the purview of our specialty.

The ED is open and available 168 hours per week, all weekends and all holidays. An EP's work is compounded when other specialists are less or not available at all. It has been demonstrated that when EDs are busy, EPs need to be able to distribute the work of procedures to admitting services to continue to serve the patients.[1] Current ED trends demonstrate increasing volumes and complexity each year, which further challenge EM educators to teach during clinical shifts.[2]

Several changes in other specialty requirements have been focused on controlling the learning environment to comply with ACGME rules. These, have, in turn, negatively impacted EM residents by increasing workload. Patient capping (limits for inpatient residents to accept further patients for care), decrease in non-EM specialty procedural requirements (creating need for EM residents to perform procedures prior to admission), and changes in rotational requirements (removing off-service residents from ED rotations) have all impacted the ED. The effect of capping patient volumes to admitting services has increased ED crowding, which increases the cognitive load on EPs.[3] When other specialties decrease their scope of practice, the EP's must necessarily expand, increasing the workload and complexity of the learning environment. As an example, the removal from the ACGME requirement for nephrology fellows to be trained to place dialysis catheters has shifted that responsibility to critical care or ED teams. With the decrease in other specialties rotating through the ED, the understanding of the ED environment by consultants and admitting teams declines as well. This lack of exposure and understanding can lead residents to delay writing admitting orders until it is either convenient, or the patient has been seen by more senior residents and supervisors, or even other possible admitting services. This leads to delay in patient care, increased cognitive load on the EP, and patient dissatisfaction. Additional stress may decrease EP empathy, the faculty's ability to educate, and

residents' openness to learning.[4]

The scope of EM practice is very broad. One of the critical aspects of EM training is preparing learners for low frequency, high stakes clinical scenarios and procedures. As the scope of practice for procedures done in the ED continues to expand, the burden of education that occurs outside the clinical environment increases. Peri-mortem c-sections, emergent cricothyrotomies, acute resuscitations of massive gastrointestinal bleeds, and ruptured ectopic pregnancies are not very common scenarios, but an excellent EM resident must be prepared and competent to perform these rare clinical cases. What allows training residents to achieve competence is the increased use of high and low fidelity simulators and task trainers. Proper preparation of learners for these cases requires innovative teaching strategies that leverage technology, simulation, blended learning, and traditional teaching. To guarantee exposure of all residents, procedural experiences and other teaching must be scheduled outside of the ED clinical environment. EM education "beyond the shift" has been identified as a best practice, given common ED crowding, which limits time available to teach due to immediate patient care needs.[5] Suggestions include that faculty send articles after shifts and create teaching files outside the shifts to best educate EM residents. For procedural training, simulation is increasingly necessary to ensure patient safety and a standardized training environment. The number of procedures done and self-report of comfort does not equate to procedural competence.[6] "Rigorous simulation-based education is a natural fit with the ACGME milestone framework because it provides standardization, deliberate practice, feedback, translation of outcomes to improved patient care, and reliable formative evaluation until a mastery standard is met."[6]

While EM faculty are committed to providing these blended teaching methods and experiential learning environments, they require protected non-clinical time for preparation and teaching. Such examples from EM educational faculty in ultrasound and simulation demonstrate the time commitment of these training modalities outside of the clinical environment.

- Benchmarking surveys performed by The Society for Clinical Ultrasound Fellowships determined that clinical ultrasound faculty spend, on average, 590 hours per year on ultrasound activities, with 288 hours spent on ultrasound education alone. This translates to more than 6 hours per week per faculty member. An additional 124 hours per year is spent on quality assurance of ultrasound examinations performed by residents, fellows, and faculty as part of the education mission.
- Data from the Society for Academic Emergency Medicine's Simulation Academy demonstrates that, on average, 300 hours of simulation are taught every year to students, EM residents, and fellows by each EM simulation faculty. This survey also demonstrated that most programs are using simulation to educate EM residents with up to 30% of curriculum being taught via simulation and faculty report spending up to 50 hours per month on simulation education.

EM has been on the forefront of innovative teaching solutions using sound andragogical theory. Without clear delineation of protected educational time for faculty, we will necessarily decrease educational innovation and effort in order to accommodate increased clinical expectations. This will degrade the educational experience for the residents and adversely affect patient safety and the clinical learning environment. The quality of the training environment impacts patient outcomes during training, and this effect remains stable after graduation.[7] ,Without the explicit requirement of protected time for EM faculty to teach, this time will be lost due to the market forces described below. It is clear that the inability to train EM residents for rare, but high-risk clinical situations will have a profound negative impact on training, and will be transmitted to the public, as the population of inadequately-prepared residents grows.

We must also consider how the proposed rule changes will impact physician burnout. According to Medscape's Annual National Burnout and Depression Report 2018, [8] EM has one of the highest burnout rates. A study published in *Archives of Internal Medicine* in 2012 reported that EM physicians were three times more likely to develop burnout than the average physician.[9] The following factors have been identified as drivers of burnout and decreased engagement: workload/job demands, efficiency/resources, meaning in work, culture/values, control/flexibility, social support/community work, and work-life integration.[10] The changes in support for faculty time in academic settings will have significant impact on the workload/job demands and meaning in work categories. Increasing ED volumes, charting demands, and emphasis on throughput metrics have negatively impacted the teaching environment.[11] Faculty at institutions with residency programs consider it part of their mission to educate the next generation of EM physicians. If the balance of clinical service and education is shifted by increasing workload and decreasing time to educate, there will be a negative impact on faculty physician wellness and an increase in burnout.

Additionally, EM practice is becoming ever-more privatized and consolidated into large contracted medical groups (CMG). These corporations are large, for-profit companies that are incentivized to have their employees (EM physicians) see patients and generate revenue rather than spend time on educational or academic pursuits. This market pressure will begin to force CMGs that wish to remain lean and competitive to disincentivize academic and education time. This will absolutely and inevitably degrade the high standards to which EM educators hold their learners, and endanger patients both at those training sites and beyond.[7]

Results from a recent internal CORD survey queried Program Directors, Assistant Program Directors, and Core Faculty in US EM training programs. With almost 200 respondents, 95% reported that removal or decrease of core faculty protected time would be "job threatening" or "career threatening." Likewise, over 96% of respondents reported that a loss of protected time would impede their ability to perform their

academic duties to a large extent. Additionally, more than 99% of core faculty responding felt there would be a distinct negative impact from the loss of academic protected time.

With increasing volumes and charting demands, greater range of responsibilities, and no protected non-clinical time to teach outside of the clinical setting for Core Faculty, education outside of the clinical setting will be left solely to Program Directors and Associate/Assistant Program Directors without provisions for additional protected time for them. This will further erode resident education as well as Core Faculty and Program Director wellness. Additionally, it will have a negative impact on academic scholarship, when that is no longer seen as something worth time to cultivate.

Changes in requirements of dedicated non-clinical time for EM education faculty will lead to decreased scholarship, diminished exposure of residents to varied ways of thinking and practice, and a workforce of EPsthat are only incentivized by how fast patients can be moved through an ED. While external forces have decreased the amount of time available to teach during clinical shifts, removing protected time for Core Faculty to engage in education away from the bedside will diminish the amount and quality of that education. We need to protect our village to innovate and continue to advance EM education, creating the leaders of the future.

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



**REFERENCES**

1. Atzema CL, Stefan RA, Saskin R, et al. Does ED crowding decrease the number of procedures a physician in training performs? A prospective observational study. *Am J Emerg Med.* 2012;30(9):1743-8.
2. Lin MP, Baker O, Richardson LD, et al. Trends in Emergency Department Visits and Admission Rates Among US Acute Care Hospitals. *JAMA Intern Med.* 2018;178(12):1708-10.
3. Wagner MJ, Wolf S, Promes S, et al. Duty hours in emergency medicine: balancing patient safety, resident wellness, and the resident training experience: a consensus response to the 2008 institute of medicine resident duty hours recommendations. *Acad Emerg Med.* 2010;17(9):1004-11.
4. Panagioti M, Geraghty K, Johnson J, et al. Association Between Physician Burnout and Patient Safety, Professionalism, and Patient Satisfaction: A Systematic Review and Meta-analysis. *JAMA*. 2018;178(10):1317-30.
5. Lin M, Taira T, Promes S, et al. Educational excellence in a crowded emergency department: consensus recommendations from the council of emergency medicine residency directors 2010. *J Grad Med Educ.* 2011;3(2):249-52.
6. Barsuk JH, Cohen ER, Feinglass J, et al. Residents' Procedural Experience Does Not Ensure Competence: A Research Synthesis. *J Grad Med Educ.* 2017;9(2):201-8.
7. Asch DA, Nicholson S, Srinivas S, et al. Evaluating obstetrical residency programs using patient outcomes. *JAMA*. 2009;302(12):1277-83.
8. Survey MNBaD. 2018. Available at: https://www.medscape.com/slideshow/2018-lifestyle-burnout-depression-6009235#3. Accessed July 1, 2019.
9. Shanafelt TD, Boone S, Tan L, et al. Burnout and satisfaction with work-life balance among US physicians relative to the general US population. *Arch Intern Med*. 2012;172(18):1-9.
10. Shanafelt TD, Noseworthy JH. Executive Leadership and Physician Well-being: Nine Organizational Strategies to Promote Engagement and Reduce Burnout. *Mayo Clin Proc.* 2017;92(1):129-46.
11. Lin M, Battaglioli N, Melamed M, et al. High Prevalence of Burnout Among US Emergency Medicine Residents: Results From the 2017 National Emergency Medicine Wellness Survey. *Ann Emerg Med*. 2019;pii:S0196-0644(19)30064-2.

# Resource Utilization in Non-Academic Emergency Departments with Advanced Practice Providers

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*Section Editor:* David Lee, MD
Submission history: Submitted January 22, 2019; Revision received May 9, 2019; Accepted May 17, 2019
Electronically published July 1, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.5.42465

**Introduction:** Advanced practice providers (APP), including physicians' assistants and nurse practitioners, have been increasingly incorporated into emergency department (ED) staffing over the past decade. There is scant literature examining resource utilization and the cost benefit of having APPs in the ED. The objectives of this study were to compare resource utilization in EDs that use APPs in their staffing model with those that do not and to estimate costs associated with the utilized resources.

**Methods:** In this five-year retrospective secondary data analysis of the Emergency Department Benchmarking Alliance (EDBA), we compared resource utilization rates in EDs with and without APPs in non-academic EDs. Primary outcomes were hospital admission and use of computed tomography (CT), radiography, ultrasound, and magnetic resonance imaging (MRI). Costs were estimated using the 2014 physician fee schedule and inpatient payments from the Centers for Medicare and Medicaid Services. We measured outcomes as rates per 100 visits. Data were analyzed using a mixed linear model with repeated measures, adjusted for annual volume, patient acuity, and attending hours. We used the adjusted net difference to project utilization costs between the two groups per 1000 visits.

**Results:** Of the 1054 EDs included in this study, 79% employed APPs. Relative to EDs without APPs, EDs staffing APPs had higher resource utilization rates (use per 100 visits): 3.0 more admissions (95% confidence interval [CI], 2.0–4.1), 1.7 more CTs (95% CI, 0.2–3.1), 4.5 more radiographs (95% CI, 2.2–6.9), and 1.0 more ultrasound (95% CI, 0.3–1.7) but comparable MRI use 0.1 (95% CI, -0.2–0.3). Projected costs of these differences varied among the resource utilized. Compared to EDs without APPs, EDs with APPs were estimated to have 30.4 more admissions per 1000 visits, which could accrue $414,717 in utilization costs.

**Conclusion:** EDs staffing APPs were associated with modest increases in resource utilization as measured by admissions and imaging studies. [West J Emerg Med. 2019;20(4)541-548.]

## INTRODUCTION

Advanced practice providers (APP), including physicians' assistants (PA) and nurse practitioners (NP), have been increasingly incorporated into emergency department (ED) staffing over the past decade. According to the Emergency Department Benchmarking Alliance (EDBA), ED APP staffing increased from 23% of EDs in 2010 to 62% in 2016.[1] This rise is in response to increased ED visits, a shortage

of emergency medicine (EM)-trained physicians,[2] and cost constraints. In addition to providing direct ED patient care, APPs serve as transitional providers between the ED and inpatient units as patients wait for beds to become available.[3] About 10.5% of PAs identify EM as their primary specialty.[4,5] Another 10% specialize in urgent care medicine, according to a North Carolina study.[3] Proficiency with procedural skills such as laceration repairs and abscess drainage make APPs particularly suitable to ED and urgent care practice.[6]

Data have demonstrated the cost effectiveness of APPs. Their involvement in urgent care settings decreases costs and waiting room time.[7] APPs on trauma services have been associated with significantly decreased intensive care unit length of stay.[8] One of the benefits APPs are thought to provide to the overall staffing structure is the ability to free emergency physicians to see higher acuity patients. Phillips and colleagues found that over 90% of APPs see low-acuity patients defined as Emergency Severity Index (ESI) levels 3-5 while 36% of APPs report caring for high acuity (ESI levels 1 and 2) patients.[9] The variation in ESI levels seen by APPs might be due to differing physician supervision requirements across states that can also influence diagnostic study and admission ordering privileges.

*Population Health Research Capsule*

What do we already know about this issue?
*Emergency departments (ED) with advanced practice providers (APP) have increased from 23% in 2010 to 62% in 2016, but little is known about resource use as measured by admissions and imaging studies.*

What was the research question?
*Does resource use differ in EDs staffed with attending physicians only vs EDs with APPs in the staffing mix?*

What was the major finding of the study?
*Non-academic EDs staffing APPs were associated with modest increases in admissions and imaging studies.*

How does this improve population health?
*Optimizing resources is essential for population health. Better understanding of resource utilization can help ED staffing decisions and health system costs.*

**Importance**

There is scant literature examining resource utilization and the cost-benefit of APPs in the ED setting. In a cross-sectional study surveying American College of Emergency Physician council members, NPs were perceived as using significantly more resources than their PA counterparts. In addition, the survey revealed concern for over-testing by all APPs, which abated with experience.[9] Despite these concerns, APP use in EDs is increasing incrementally over time.[1]

**Goals of This Investigation**

The objectives of this study were twofold: 1) to compare resource utilization in EDs that use APPs in their staffing model with those that do not; and 2) to estimate costs associated with the utilized resources.

## METHODS

**Study Design and Setting**

We conducted a five-year retrospective secondary data analysis of non-academic EDs that reported data to the EDBA. EDBA is a national, non-profit ED-level database of member organizations that was created to collate and monitor trends of ED performance metrics on an annual basis.[10,11] The EDBA contains data from more than 1100 EDs in the United States, representing over 40 million patient visits.[12] The data is accessible to member institutions that voluntarily submit their ED demographics and performance metrics to the organization. Member organizations use the data to benchmark performance against similar EDs, identify best practices, conduct research, and collaborate to improve quality. EDBA contains annual ED aggregate data including hospital demographics, annual visit volumes, provider hours, patient acuity, length of stay, hospital admissions, computed tomography (CT), radiographs, ultrasounds, and magnetic resonance imaging (MRI). Definitions of metrics in the report are standardized by the EDBA Board of Directors. Data are blinded at the hospital level but clustered by state. EDBA data is completely free from commercial influence and solely reported for purposes of benchmarking quality. The database has been used for numerous studies published in peer-reviewed journals.[13-17]

We compared resource utilization in EDs that included APPs in their staffing mix with EDs that did not. We then analyzed the cost implications of those differences using the 2014 Centers for Medicare and Medicaid Services (CMS) physician fee schedule and inpatient Diagnoses Related Group (DRG) payments to estimate utilization cost. The term *cost* is used strictly to represent CMS average admission and prospective resource utilization payments. The University of Maryland institutional review board (IRB) exempted this study from IRB review since only de-identified data were examined.

The study included patient encounters that occurred between 2012 and 2016 in 1092 EDs located in 44 states

and the District of Columbia. Because data reporting was voluntary, reporting compliance varied among EDs: some reported data for the entire five-year study period while others reported one, two, three, or four years. The use of APP staffing was unchanged for most EDs during the study period as departments either used or did not use APPs in the staffing matrix. This consistency facilitated a two-group comparative panel in which EDs staffing APPs constituted the comparison group while EDs without APPs became the control group.

All EDs reporting data to the EDBA were examined for inclusion in the study. Inclusion criteria were non-teaching general and adult EDs. We excluded EDs classified as "academic" or "teaching" because they have different resource utilization patterns than non-teaching facilities. EM resident physicians have been shown to increase the hospitalization percentage and use of imaging studies relative to attending physicians practicing alone.[18,19] Similar utilization patterns were observed during our data screening leading to exclusion of academic EDs or EDs with residents. We also excluded EDs classified as free-standing, urgent care, or pediatric, as the former two lack admission capabilities while the latter focuses on a pediatric population, which differs in practice from EDs that treat adults. Thirty-eight EDs changed their staffing patterns from one year to the next, adding or eliminating APPs from their staffing matrix. To avoid biasing the findings by the 38 EDs that would appear in both study arms, we excluded these facilities. We used a first-percentile Winsorization approach[20] for the primary outcomes to identify the highest and lowest outcome outliers, which were flagged and removed from the analysis.

**Outcome Measures**

The primary outcome variables used to reflect resource utilization were hospital admission, CT, radiography, ultrasound, and MRI. All outcome variables were reported as rates (number of uses per 100 ED visits). Of the 1054 EDs included in the study, 144 reported zero use of MRI and 11 reported zero use of ultrasound for an entire year. We converted zero values to missing because we could not discern if "zero" meant lack of use, lack of equipment, or lack of accurate reporting. EDBA defines *ED volume* as the total number of annual patient visits; it defines *high acuity* as the percentage of total visits assigned Current Procedural Terminology (CPT) code levels (four, five, or critical care), and defines *provider hours* as the number of staffed hours in an average day. These three potential confounders—annual ED volume, high acuity, and attending hours—that could influence resource utilization were also examined and included in our analytical models.

Cost estimates were obtained from two CMS sources: inpatient admission charge data and Physician Fee Schedule payments. First, we used the inpatient charge data for fiscal year 2014 to compute the average admission cost. The charge file lists average total payments for each Medicare Severity Diagnosis Related Group (MS-DRG). We summed the total payments for all MS-DRGs and averaged them to obtain a grand overall mean for admission cost. The average admission cost was inflation adjusted by 3.5%[21] to account for rising healthcare costs. Second, we used the CMS Physician Fee Schedule to estimate resource utilization payments. Because these payments vary according to CPT codes, we estimated usage cost by averaging payment for common radiology CPT codes of each imaging study. The supplemental eTable 1 lists the CPT codes that we used with their prospective payments as derived from the CMS Physician Fee Schedule and includes the summed total and average resource payments.

We calculated the estimated resource utilization cost as follows: the utilization difference between EDs with and without APPs was projected per 1000 patients, which was then multiplied by the average resource payment to reflect the estimated resource cost per 1000 patients. For example, if CT use was increased, hypothetically, by 10 scans per 1000 visits in EDs with APPs compared with those without APPS, and if the average payment of one CT is $276, then the total cost for the extra CTs per 1000 patients would be $2,760 (10 x $276). The supplemental eFigure 1 presents a condensed graphical summary of the average cost per single use and the estimated utilization difference.

**Data Analysis**

Descriptive statistics are presented as overall means and standard deviations. Mean comparisons using Student's t-test were employed to compare resource utilization in EDs with and without APPs. The number of EDs reporting data for each variable was also recorded to reflect variations in reporting patterns. We generated adjusted estimates for each outcome using a linear mixed regression with repeated measures. The multivariable model results were presented as means and 95% confidence intervals (CI) adjusted for ED volume, high acuity, and attending hours. All tests were two sided, with a $p$-value <0.05 considered statistically significant. We performed all analyses with SAS 9.4 statistical package (SAS Institute Inc., Cary, North Carolina).

## RESULTS

**Characteristics of Study Population**

The five-year study period contained 6033 total ED records, of which 4631 were for non-academic ED records. After applying our exclusion criteria, the final working sample consisted of 2699 ED records representing 1054 unique EDs (Figure 1).

Of the 1054 distinct EDs, 79% (n=830) had APPs on staff and 21% (n=224) did not. Resource utilization rates by APP status are shown in Table 1. EDs with APPs had higher crude resource utilization rates in all assessed measures compared with EDs without APPs ($p < 0.05$). EDs with APPs also had a higher prevalence of high-acuity visits (66.6% vs 61.3%) and

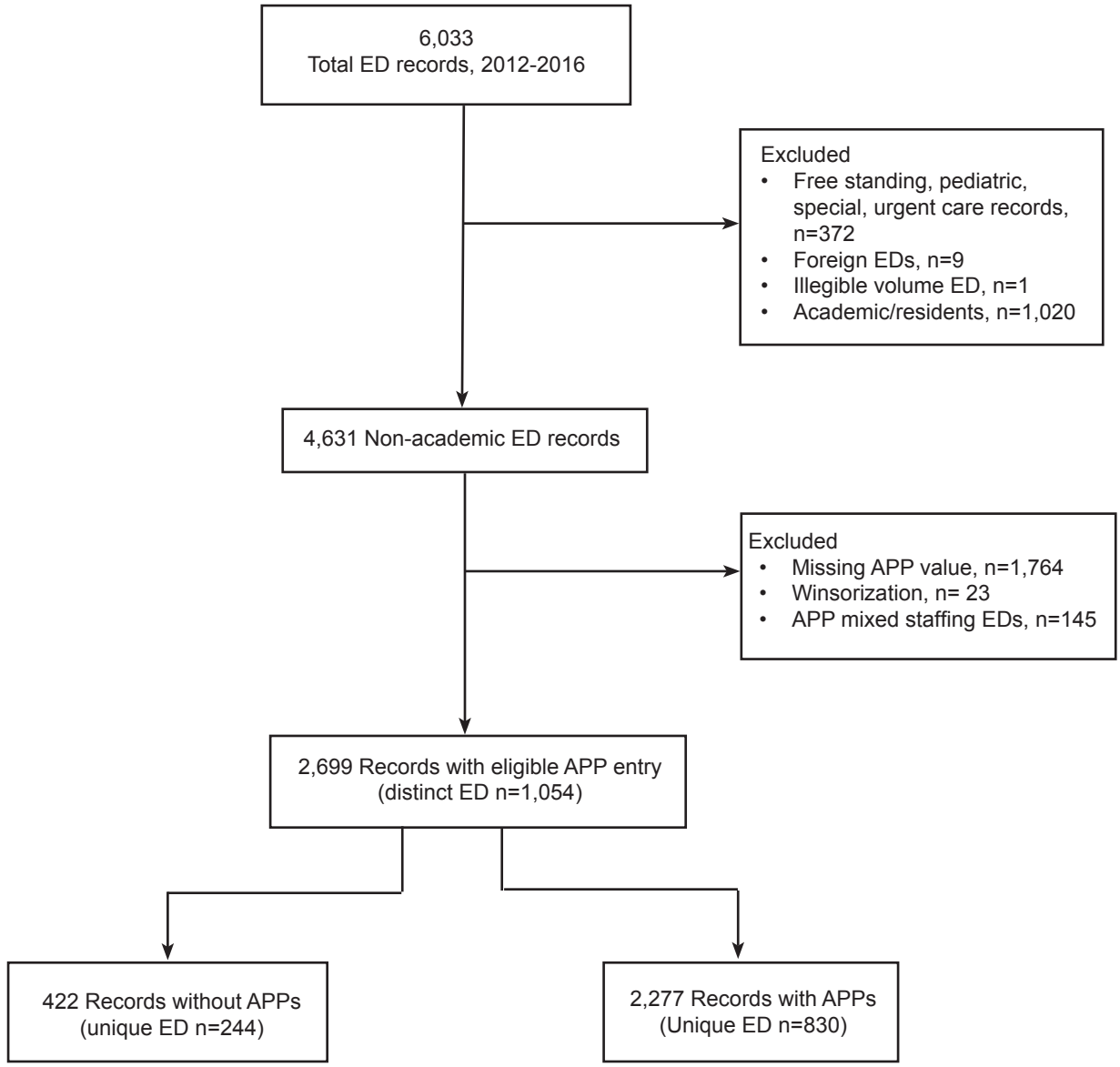


**Figure 1.** Study population.
*ED,* emergency department; *AAP,* advanced practice provider.

more average attending hours (39.3 vs 28.0 per day) than EDs without APPs.

Adjusted regression estimates comparing resource utilization between EDs with and without APPs are displayed in Table 2. Relative to EDs without APPs, resource utilization increased by 3.04 per 100 visits (95% CI, 2.0–4.1) for admission, by 1.7 per 100 (95% CI, 0.2–3.1) for CT, by 4.5 per 100 (95% CI, 2.2–6.9) for radiography, and by 1.0 per 100 (95% CI, 0.3–1.7) for ultrasound in EDs with APPs. There was no statistical difference in MRI utilization between the two study groups (1.0 vs 0.9 per 100 visits [p=0.58]). The supplemental eTable 2 provides the adjusted coefficient outputs and regression estimates of the controlled covariates for each model.

Figure 2 presents the projected costs associated with increases in resource utilization in EDs with APPs based on 1000 patient visits. The average inflation-adjusted costs were $13,642 for a single hospital admission, $276 for a CT, $82 for a radiograph, $214 for an ultrasound, and $486 for an MRI. EDs with APPs were estimated to have 30.4 more admissions per 1000 patients, which would accrue $414,717 (30.4 x $13,642. While not as substantial, the approximated costs per 1000 for CT, radiography, ultrasound, and MRI were $4692, $3690, $2140, and $486, respectively.

**Table 1.** Descriptive statistics of emergency departments (ED) by advanced practice provider (APP) status (per 100 patient visits), EDBA 2012–2016.[1]

| | All EDs (n=1,054) | | | EDs With APPs (n=830) | | | EDs without APPs (n=224) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Resource | n | Mean | (SD) | n | Mean | (SD) | n | Mean | (SD) | p value |
| Hospital admission | 1021 | 15.4 | ±(7.0) | 809 | 16.5 | ±(6.7) | 212 | 11.3 | ±(6.6) | <0.01 |
| CT scan | 762 | 20.7 | ±(7.7) | 615 | 21.4 | ±(7.7) | 147 | 17.8 | ±(7.0) | <0.01 |
| Radiography | 784 | 45 | ±(12.3) | 635 | 46.2 | ±(12.3) | 149 | 40.1 | ±(11.5) | <0.01 |
| Ultrasound | 450 | 4.8 | ±(3.1) | 366 | 5.2 | ±(3.1) | 84 | 3.1 | ±(2.5) | <0.01 |
| MRI | 610 | 1.1 | ±(1.1) | 531 | 1.1 | ±(1.1) | 79 | 0.8 | ±(1.0) | 0.03 |
| High acuity | 938 | 65.6 | ±(11.2) | 763 | 66.6 | ±(10.8) | 175 | 61.3 | ±(11.6) | <0.01 |
| Attending hours | 1053 | 36.9 | ±(17.3) | 830 | 39.3 | ±(17.8) | 223 | 28 | ±(11.7) | <0.01 |
| Volume | 1054 | 35052 | ±(21281) | 830 | 40285 | ±(19908) | 224 | 15661 | ±(13616) | <0.01 |

[1]Data presented are overall (distinct ED) means and standard deviation (SD); attending hours are average hours on an average day; volume is average per year.
*EDBA,* Emergency Department Benchmarking Alliance; *CT,* computed tomography; *MRI,* magnetic resonance imaging.

## DISCUSSION

APPs are providing increasing numbers of hours to cover ED shortages in the United States. Using EDBA data, Augustine noted that 39% of hours were worked by PAs or NPs in 2016.[1] We believe that our study is the first examining the potential impact of this change by comparing resource utilization and cost in the ED setting. Our findings do not conclude that APPs are causing the increase in resource utilizations. We found that EDs staffing APPs were associated with increased resource utilization, as measured by hospital admissions and the use of CT, radiography, and ultrasound studies. Although our study could not directly compare ED attendings to ED APPs due to data limitations, our aggregate analysis demonstrated correlation between APP ED setting and modest increases in utilization. This comparison can be a starting point for future discussions and a call for more robust research on this important topic.

In past studies, other practices outside the ED have shown increased utilization among APPs compared to physicians as well. Studies done in primary care practices demonstrated increased utilization of resources when comparing physician practice with that of APPs. Everett et al. found that patients whose usual primary care provider was an APP had 2.4-3 times the odds of having five or more annual primary care visits (compared with the typical 2-4 visits) if seen primarily by a physician.[22] In an office-based setting, another study found that new and established patients seen by APPs were significantly more likely to have more imaging studies ordered than those seen by primary care physicians.[23] Additionally, studies examining quality of care and comparing resource-ordering patterns between APPs and physicians for patients with diabetes or cardiovascular disease found that APPs ordered slightly more tests, imaging studies, and referrals.[24-26]

In our study, ultrasound and MRI studies had the smallest adjusted differences, 1 and 0.1 per 100 visits respectively. To evaluate if converting the zero values for 144 MRI and 11 ultrasound records to "missing" biased our model estimates, we included these zero records, re-estimated the models, and compared the findings. We found no sizeable differences between the two models when zero value records were included. Including zero values caused the adjusted differences for ED with APPs to be marginally larger (1.0 vs 1.2 per 100 visits) for ultrasound, and (0.1 vs 0.2 per 100 visits) for MRI, with no change in statistical significance.

Although our findings demonstrate correlation between EDs staffing APPs and increased resource utilization and cost, we cannot assume causation. Our results simply demonstrate that average resource utilization rates increased in EDs with APPs of comparable volume, acuity, and doctor hours relative to EDs without APPs. A valid argument is that resource utilization increases are caused by increases in volume and acuity in EDs staffing APPs. We adjusted for the effect of acuity and volume in our models, and we separately examined if volume or acuity moderated the effect seen on hospital admission. The interaction between acuity and APPs was not statistically significant, which means that EDs with APPs had higher hospital admission rates regardless of acuity levels. On the other hand, patient volume showed a partial moderation effect on hospital admission in that hospital admission differences between EDs with vs those without APPs were larger at EDs with smaller annual volume (<40,000) but the utilization differences were smaller in EDs with larger volume. The direct effect of EDs with APPs was still about three more admissions per 100 visits for EDs with APPs even if the interaction term was adjusted for in the model.

Even with modest differences, the financial impact on the healthcare system can be large. Hospital admission is one of the

**Table 2.** Adjusted resource utilization rates (number of uses per 100 patient visits) for emergency departments (ED) with and without advanced practice providers (APP), EDBA 2012–2016.[1]

| Resource | With APPs | | Without APPs | | Difference | | p value |
|---|---|---|---|---|---|---|---|
| Hospital admission | 16.5 | (16.1–16.9) | 13.5 | (12.5–14.4) | 3.04 | (2.0–4.1) | <0.01 |
| CT scan | 20.8 | (20.2–21.4) | 19.1 | (17.8–20.5) | 1.7 | (0.2–3.1) | 0.03 |
| Radiography | 45.5 | (44.6–46.4) | 40.9 | (38.8–43.1) | 4.5 | (2.2–6.9) | <0.01 |
| Ultrasound | 4.9 | (4.6–5.2) | 3.9 | (3.2–4.5) | 1.0 | (0.3–1.7) | 0.01 |
| MRI | 1.0 | (0.9–1.1) | 0.9 | (0.7–1.1) | 0.1 | (-0.2–0.3) | 0.58 |

[1]Data are means and 95% confidence intervals adjusted for high acuity, volume, and attending hours.
*EDBA,* Emergency Department Benchmarking Alliance; *CT,* computed tomography; *MRI,* magnetic resonance imaging.

most prominent factors driving cost. An increase in the rate by 30.4 admissions per 1000 visits in a single hospital could have a projected cost of $414,717. CT, radiography, and ultrasound have projected increases in cost as well, but certainly not as large as hospital admission.

In light of the study limitations, we cannot conclude that APPs are causing the noted increases in resource utilization because multiple factors can influence utilization patterns. Among those factors are clinical experience, medical judgment, and APP scope of practice. Studies examining resource utilization demonstrated that ordering patterns varied among emergency physicians.[27,28] Physicians who ordered more radiography, CTs, ultrasounds, and MRIs were more likely to have higher admission rates than physicians with lower resource utilization rates.[28] Hence, utilization variations might be due to physician heterogeneity between the two comparative groups.

Scope of practice is another complex factor that can influence resource utilization. While NPs mostly function independently, physician supervision is required for PAs in 43 states.[29] The level of APPs' practice is specified by the practice site, which can vary greatly even within the same state. Hence, privileges to order imaging studies or admission independently are diverse among APPs. Some practice sites require co-signature of a physician,[29] while others do not allow APPs to write admission orders. Our study did not consider the level of attending supervision[19] in our analysis of resource utilization in EDs staffed with APPs.

This study did not assess quality or patient safety. We do not know if increased utilization represents over-utilization of resources in EDs that staffed APPs or under-utilization in EDs that do not. Further work is needed to delineate and track ordering practices in EDs with and without APPs as well as examine the value of increased testing and hospitalization.

## LIMITATIONS

This study has several limitations. First, it was a retrospective observational study of aggregate data. Control of confounders was limited to aggregate variables available in the data, which included high acuity, annual volume, and average attending hours. The data lacked patient-level (demographic) factors that could influence resource utilization, such as age and comorbidity. ED-specific factors were also limited to those used in the model. Second, we could determine neither the provider who ordered imaging studies or hospitalization, nor the type of APP-physician supervision. Hence, our findings reflect only the overall association between these resources and EDs with APPs. Finally, the CMS cost figures are estimates; actual costs would depend on the specific geographic location and payer mix of the ED patient population.

## CONCLUSION

Within the context of this study's limitations, we found that EDs staffing APPs are associated with modest increases in resource utilization, as measured by admissions and imaging studies. Studies are needed to track resource utilization prospectively in a more granular ED sample and to incorporate a broader spectrum of diagnoses.

## ACKNOWLEDGEMENTS

The authors acknowledge the Emergency Department Benchmark Alliance (EDBA) for use of their data for this study. The authors thank Jennifer Fishe, MD, from the University of Florida College of Medicine for manuscript review and constructive feedback. The manuscript was copyedited by Linda J. Kesselring, MS, ELS.

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

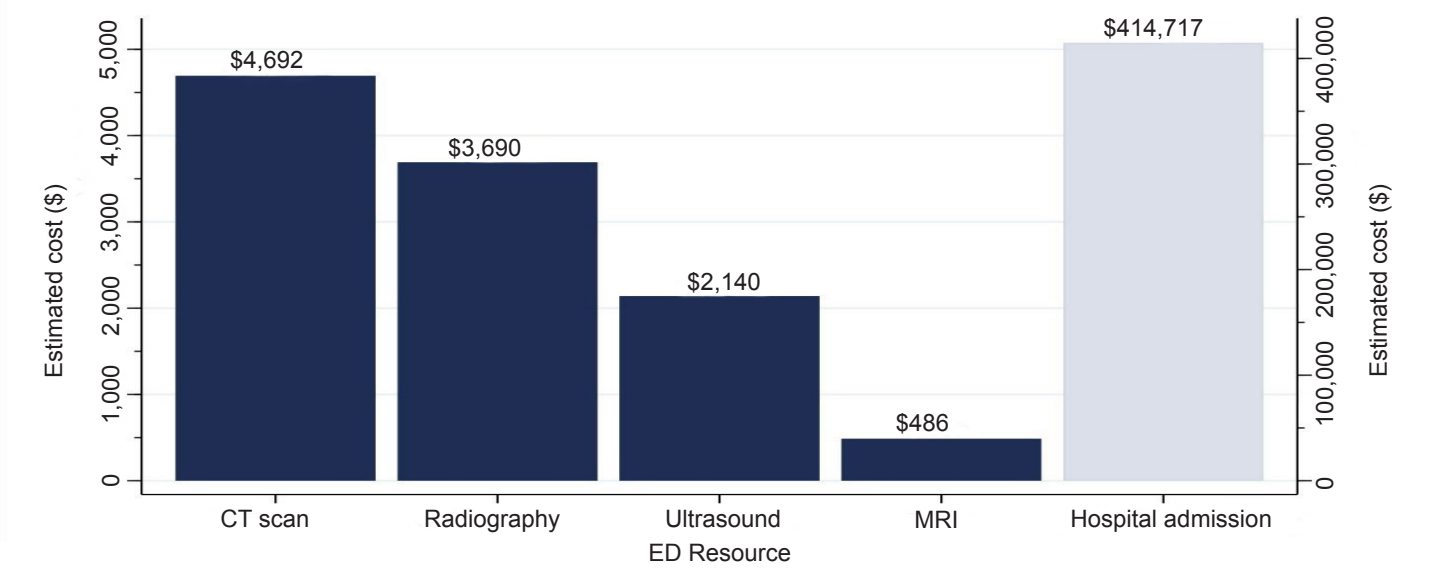


**Figure 2.** Projected additional costs of emergency departments (ED) with advanced practice providers per 1000 visits, Emergency Department Benchmarking Alliance 2012–2016.
*CT,* computed tomography; *MRI,* magnetic resonance imaging.

## REFERENCES


1. Augustine JJ. More advanced practice providers working in emergency departments. 2017. Available at: http://www.acepnow.com/article/advanced-practice-providers-working-emergency-departments/?singlepage=1. Accessed August 2, 2018.
2. Hooker RS, Cipher DJ, Cawley JF, et al. Emergency medicine services: interprofessional care trends. *J Interprof Care*. 2008;22(2):167-78.
3. Fraher EP, Morgan P, Johnson A. Specialty distribution of physician assistants and nurse practitioners in North Carolina. *JAAPA*. 2016;29(4):38-43.
4. American Academy of Physician Assistants. History of the PA profession. 2010. Available at: https://www.aapa.org/about/history/. Accessed August 15, 2018.
5. American Academy of Physician Assistants. PA prescribing. 2017. Available at: https://www.aapa.org/wp-content/uploads/2017/03/f-833-4-8256527_dk6DMjRR_Prescribing_IB_2017_FINAL.pdf. Accessed August 15, 2018.
6. Hooker RS, Klocko DJ, Luke Larkin GL. Physician assistants in emergency medicine: the impact of their role. *Acad Emerg Med*. 2011;18(1):72-7.
7. Memmel J, Spalsbury M. Urgent care medicine and the role of the APP within this specialty. *Dis Mon*. 2017;63(5):105-14.
8. Gillard JN, Szoke A, Hoff WS, et al. Utilization of PAs and NPs at a level I trauma center: effects on outcomes. *JAAPA*. 2011;24(7):34, 40-3.
9. Phillips AW, Klauer KM, Kessler CS. Emergency physician evaluation of PA and NP practice patterns. *JAAPA*. 2018;31(5):38-43.
10. Welch S, Augustine J, Camargo CA, et al. Emergency department performance measures and benchmarking summit. *Acad Emerg Med*. 2006;13(10):1074-80.
11. Wiler JL, Welch S, Pines J, et al. Emergency department performance measures updates: Proceedings of the 2014 emergency department benchmarking alliance consensus summit. *Acad Emerg Med*. 2015;22(5):542-53.
12. Emergency Department Benchmarking Alliance. About us. 2012. Available at: https://www.edbenchmarking.org/about-us. Published 2018. Accessed August 11, 2018.
13. Welch SJ, Augustine JJ, Dong L, et al. Volume-related differences in emergency department performance. *Jt Comm J Qual Patient Saf*. 2012;38(9):395-402.
14. Welch SJ. Using data to drive emergency department design: a metasynthesis. *HERD*. 2012;5(3):26-45.
15. Handel DA, Sun B, Augustine JJ, et al. Association among emergency department volume changes, length of stay, and leaving before treatment complete. *Hosp Top*. 2015;93(3):53-9.
16. Anderson D, Pimentel L, Golden B, et al. Drivers of ED efficiency: a statistical and cluster analysis of volume, staffing, and operations. *Am J Emerg Med*. 2016;34(2):155-61.
17. Quaday KA, Salzman JG, Gordon BD. Magnetic resonance imaging and computed tomography utilization trends in an academic ED. *Am J Emerg Med*. 2014;32(6):524-8.
18. Chiu IM, Syue YJ, Kung CT, et al. The influence of resident seniority on supervised practice in the emergency department. *Med (Baltimore)*. 2017;96(4):e5987.
19. Pitts SR, Morgan SR, Schrager JD, et al. Emergency department resource use by supervised residents vs attending physicians alone. *JAMA*. 2014;312(22):2394-2400.
20. Wilcox RR. (2010). *Fundamentals of Modern Statistical Methods:*

*Substantially Improving Power and Accuracy*. (second ed). New York, New York: Spinger Science +Business Media, LLC.

21. Bureau of Labor Statistics. Databases, Tables & Calculators by Subject. Available at: https://www.bls.gov/data/. Accessed August 10, 2018.
22. Everett CM, Morgan P, Jackson GL. Primary care physician assistant and advance practice nurses roles: Patient healthcare utilization, unmet need, and satisfaction. *Healthc (Amst)*. 2016;4(4):327-33.
23. Hughes DR, Jiang M, Duszak R Jr. A comparison of diagnostic imaging ordering patterns between advanced practice clinicians and primary care physicians following office-based evaluation and management visits. *JAMA Intern Med*. 2015;175(1):101-7.
24. Virani SS, Maddox TM, Chan PS, et al. Provider type and quality of outpatient cardiovascular disease care insights from the NCDR PINNACLE registry. *J Am Coll Cardiol*. 2015;66(16):1803-12.
25. Virani SS, Akeroyd JM, Ramsey DJ, et al. Health care resource utilization for outpatient cardiovascular disease and diabetes care delivery among advanced practice providers and physician providers in primary care. *Popul Health Manag*. 2018;21(3):209-16.
26. Tavarez MM, Ayers B, Jeong JH, et al. Practice variation and effects of e-mail-only performance feedback on resource use in the emergency department. *Acad Emerg Med*. 2017;24(8):948-56.
27. Levine MB, Moore AB, Franck C, et al. Variation in use of all types of computed tomography by emergency physicians. *Ann Emerg Med*. 2012;60(4):S104-5.
28. Hodgson NR, Saghafian S, Mi L, et al. Are testers also admitters? Comparing emergency physician resource utilization and admitting practices. *Am J Emerg Med*. 2018;36(10):1865-9.
29. American Medical Association. Physician assistant scope of practice. 2018. Available at: https://www.ama-assn.org/sites/default/files/media-browser/public/arc-public/state-law-physician-assistant-scope-practice.pdf. Accessed August 11, 2018.

# How a Bill Becomes a Law, or How a Truly Terrible Bill Becomes Less Awful

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*Section Editor:* Mark I. Langdorf, MD, MHPE
Submission history: Submitted May 6, 2019; Accepted May 6, 2019
Electronically published July 1, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.5.43666
[West J Emerg Med. 2019;20(4)549-551.]

It started slowly. On February 12, 2013, James Flavy Coy Brown arrived in downtown Sacramento after being placed on a three-day Greyhound ride on discharge from a Nevada psychiatric hospital. Less than three months later the story was exposed by the *Sacramento Bee*[1] and ultimately led to a class action lawsuit on behalf of the patients, and a Pulitzer nomination for the paper. The following year brought a lawsuit against a hospital in Los Angeles for discharging a patient to a local shelter. In late 2016, an outbreak of Hepatitis A in San Diego's homeless population again highlighted the poor health conditions of California's growing homeless population. The following years brought a flood of news stories highlighting the plight of California's homeless populations, culminating in a general sense that something should be done.

On February 14, 2018, we learned what that something was. California Senate Bill (SB) 1152 was introduced by Senator Ed Hernandez, an optometrist representing the San Gabriel Valley. At the time, while he was serving the final year of his Senate term, he was still the powerful chair of the Senate Health Committee and he was running for lieutenant governor. With the support of powerful state unions, the bill proposed limits on both hospital and emergency department (ED) homeless patient discharges.

As introduced, the bill essentially prohibited discharging homeless patients from hospitals and EDs. Homeless patients could not be discharged at night, or into inclement weather. Homeless patients could only be released to a care facility or social services agency that had agreed in writing to accept that patient. Prior to discharge, homeless patients were to receive a meal, appropriate clothing, a 30-day supply of all medications, all necessary durable medical equipment, infectious disease screening, all appropriate vaccinations, a source of regular follow-up care, a psychiatric evaluation, and transportation to any place of their choosing. Remember this was not a guideline or a recommendation for best practice. There was no room for clinical decision-making or variation in practice patterns; it would be a crime not to comply. Yes, it was intended to include patients seen only in the ED.

The fundamental challenge is that our policymakers and legislators do not share our understanding or experiences. Their contact with emergency medicine (EM) is as a patient and family member, or through news stories of sympathetic patients. The concept of the Emergency Medicine Treatment and Active Labor Act (EMTALA) which is so embedded into our daily practice and fundamental to our mission as a specialty, is poorly understood by policymakers. Those of us on the frontlines inherently understood that SB 1152 would decimate California EDs' ability to treat patients. But from the outside it looks like basic human decency, backed by the most powerful players in California politics.

California's Chapter of the American College of Emergency Physicians (ACEP) is almost as old as ACEP itself. At 47, the California chapter has a track record of fighting for our specialty and our patients. California ACEP is the voice of EM in the California State Capitol. The chapter has invested in our state policymakers for years. The work of explaining the unique challenges of an ED and building champions has to begin long before there is a need. Relationships and trust must also be built with other stakeholders in the political process, not just with legislators . It's the years of building relationships and a reputation as a patient advocate that gives California ACEP influence.

California ACEP's opposition letter to SB 1152 outlined the bill's impact on crowding and patient care in the ED. Throughout the remainder of the spring, the California Chapter continued to meet with legislators to educate them on the impact on our ED patients. The first stop for SB 1152 was the Senate Health Committee chaired by its author Senator Hernandez.

We relied on the background work educating legislators

that happens every year when our members go to Sacramento for lobby day and take policymakers on ED tours in their communities. We also worked with the sponsors of the bill to help them understand the unintended consequences of their proposal and to make changes to the bill.

Lobbying against a bill always begins with the author and their staff in the hopes that, if you can provide a better understanding of the policy and its potential impact, they will be willing to make modifications. If that doesn't work, or they aren't willing to make enough changes, the next step is to lobby the committee chair and the committee consultant – the staff person assigned to analyze the bill. The chair of each committee has tremendous power to reshape legislation that is heard in his or her committee. And while each committee has many members, they often defer to the chair, and they are certainly reluctant to oppose the chair. Unfortunately for us, in this instance the chair was also the author, so we weren't going to be able to rely on the committee making changes for us. We lobbied each of the nine members of the committee, and many of them raised questions and gave voice to our concerns during the committee hearing. However, they ultimately voted for the bill. It passed out of committee with all seven Democrats voting in favor, one Republican voting no, and the other Republican abstaining.

The Chapter reached out to the California Medical Association, the California Hospital Association, and our public hospital partners to keep up pressure on our state legislators to negotiate the provisions of the bill. Throughout this process there was a continual back-and-forth conversation of potential changes and amendments. California ACEP worked hard to get to a place that we felt could provide for the needs of the homeless population, while allowing EDs the space and resources to continue to provide emergency care.

Usually bills that have a potential cost to the state are referred to the Appropriations Committee in each house for a fiscal analysis. Costs to the state are estimated for each bill, and those with a cost of more than $150,000 are placed on the "suspense file" to be considered at the end of the fiscal committee deadline. This is meant to be a thoughtful, deliberative process to maintain fiscal accountability, while various new programs/initiatives are considered each year. However, this process is often also used as a political tool to kill a bill without voting it down. It is not a stretch to estimate SB 1152 would increase costs to the state through the Medi-Cal program and increase costs to public and University of California hospitals. However, with a senator as its author and powerful political winds behind SB 1152, it bypassed the Senate Appropriations Committee process entirely and went straight to the Senate floor to be voted on by all senators.

It passed out of the Senate on a straight party line vote: all 26 Democrats voted in favor and all 13 Republicans voted against. After passing the California Senate a bill goes through a mirror process in the California Assembly before going to the Governor. The Assembly gave us another opportunity to express our concerns with lawmakers and seek amendments. Since we had a more objective committee chair in the Assembly, and because the bill was sent to the Appropriations Committee in the Assembly, there were more opportunities for our lobbying to be fruitful. It was in this process that we were able to impact the outcome of the bill.

As a result of California ACEP's work, six sets of amendments were made to SB 1152, each lessening the impact on care provided to all patients in the ED. For example, homeless patients could be discharged when clinically appropriate, and the rest of the bill's mandates could take place in an area of the hospital that does not provide clinical care. Homeless patients could be given transportation to a place of their choosing, rather than only to social service providers that may or may not exist or have available capacity. On August 28, SB 1152 passed out of the Senate and landed on Governor Jerry Brown's desk.

Governor Brown was always a wild card in this debate. His passion has always been for California's infrastructure and climate change, rather than healthcare. Also at play was Governor Brown's style of governing. While not anti-government, he has been thoughtful and judicious when considering imposing new state requirements. While more unpredictable than most governors, he was more likely to veto legislation that places mandates on private businesses and local governments than most Democratic governors. He often said he saw the unintended consequences of the mandates he signed during his first gubernatorial terms from 1975-1983 both as a private citizen and then as mayor of Oakland.

Again, we mobilized, this time calling upon our members who sent over 700 messages to the Governor urging him to veto the bill.

Yet late in the evening on Sunday September 29, 2018, just hours before his deadline to act, Governor Brown signed SB 1152 into law. At the time it felt like a crushing defeat. However, looking back at the original bill, the efforts of California ACEP are clear. Even in defeat, I am reminded how important it is for every emergency physician to stay engaged for the health of our specialty and our patients. Recall that the original bill did not allow discharge of a homeless patient in inclement weather. Another of the many requirements was that a homeless patient be "permitted to remain in the facility for the time necessary to ensure that he or she is released during daytime hours where the receiving social services or other agency is open and available to receive the patient." The final version of the bill requires the hospital to identify a post-discharge destination, which could include a patient's "home." As far as the requirements on the treating physicians before patient discharge, there were only

three in the final bill, and none of them are substantially different from what we already do. They are as follows:

- The treating physician has provided a medical screening examination and evaluation. If the treating physician determines that the results of the medical screening examination and evaluation indicate that follow-up behavioral healthcare is needed, the homeless patient shall be treated or referred to an appropriate provider.

- The treating physician has determined the homeless patient's clinical stability for discharge, including, but not limited to, an assessment as to whether the patient is alert and oriented to person, place, and time, and the physician or designee has communicated post-discharge medical needs to the homeless patient.

- The homeless patient has been provided with a prescription if needed, and for a hospital with an onsite pharmacy licensed and staffed to dispense outpatient medication and an appropriate supply of all necessary medication, if available.

Thousands of bills are introduced each year in the state legislature. In 2018 the California state legislature considered over 2,000 bills. California ACEP takes a broad look for any potential impact on our patients and our healthcare system. Each of the bills are reviewed by California ACEP staff. Several hundred bills are reviewed by California ACEP's Government Affairs Committee and selected for either support, oppose or "watch" positions. Many bills are written poorly, and we must try to seek amendments to them to avoid unintended consequences. This process, while seemingly simple, is very resource-intensive. Additionally, California ACEP carefully watches hundreds of relevant bills during the process in case one is amended in a harmful way for our patients or practice. Well-intentioned ideas can be unworkable in the busy 24/7 pace of EM. One example is the requirement for prescribers in California to check the state Prescription Drug Monitoring Program prior to prescribing controlled substances. In recognition of our practice environment, California ACEP successfully lobbied for an exemption for prescriptions for less than seven days duration, saving untold hours of precious practice time, while protecting patients in pain.

In addition, each year, critical issues for our patients and our practice lead to chapter-sponsored bills. Currently California ACEP is sponsoring an effort to support ED patient navigators for substance use and behavioral health disorders, as well as legislation to allow emergency physicians to continue to operate as independent contractors despite a Supreme Court ruling that threatens this long-term practice. The Chapter typically sponsors four bills each year. Some take multiple attempts over several years to be enacted, while others are successful on the first try. We have sponsored at least one bill each year for the last several years to improve our ability to care for patients with mental illness. While that has been a consistent theme, our sponsored legislation has covered a wide variety of practice topics. For example, we sponsored and successfully enacted legislation that allows health information technology such as the Emergency Department Information Exchange to access information from the CURES (Controlled Substance Utilization Review and Evaluation System) database. Prior to our bill, this was prohibited by California law.

While we do not have a perfect track record, our record defeating, fixing, supporting, and sponsoring legislation is stellar. This is even more true when you consider the resources available to us. In 2017, the *Sacramento Bee* published a list of the top 500 lobbyist employer spenders. The California Hospital Association ranked sixth, the California Medical Association ranked 19th, the Service Employees International Union (the sponsors of SB 1152) ranked third, and California ACEP ranked 215th. Much like the emergency physicians we represent, California ACEP is adept at doing more with less and producing impressive outcomes. We owe much of it to the passionate voices of our members working across the state. We hope you will join us and add your voice to the fight.

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



## REFERENCES

1. Hubert C. Cast out of Nevada, mentally ill man tells story of finding kindness in Sacramento. The Sacramento Bee. 2013. Available at: https://www.sacbee.com/news/investigations/nevada-patient-busing/article2577125.html. Accessed October 26, 2018.

# Preferences for Firearm Locking Devices and Device Features Among Participants in a Firearm Safety Event

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*Section Editor:* Mark Faul, PhD, MA
Submission history: Submitted February 11, 2019; Revision received May 19, 2019; Accepted May 17, 2019
Electronically published July 1, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.5.42727

**Introduction:** Safe firearm storage is associated with a lower risk of firearm-related injury and death. Although providing firearm locking devices is a key component of firearm safety interventions, little is known about the types and characteristics of devices preferred by firearm users or others who make decisions about firearm storage. The aim of this study was to describe preferences for firearm locking devices and device features among firearm safety event participants.

**Methods:** We conducted a cross-sectional survey in the State of Washington in 2016 that assessed participants' preferences for five firearm locking devices (eg, trigger lock) and seven device features (eg, quick access). We categorized respondents (n=401) as adults in households with 1) all firearms locked, 2) at least one unlocked firearm, and 3) no firearms. We analyzed data in 2017.

**Results:** Device ownership and feature preferences varied substantially but were similar across the three household categories. Of those residing with unlocked firearms, 84% reported they would consider using or definitely use a lock box, whereas 11% reported they would never use a trigger lock. Additionally, of those residing with unlocked firearms, 80% and 89% reported that the ability to lock a firearm while loaded and unlock it quickly were, respectively, "very important" or "absolutely essential."

**Conclusion:** Participants had differing preferences for firearm locking devices and device features, although preferences were largely similar across households with locked, unlocked, or no firearms. At least eight in ten participants reported "great importance" regarding the ability to lock a firearm while loaded and unlock it quickly, which is likely related to perceptions about the utility of safely stored firearms for household protection. Designing firearm safety interventions to match the needs and preferences of those who make firearm storage decisions may improve their effectiveness. [West J Emerg Med. 2019;20(4)552-556.]

## INTRODUCTION

Safe firearm storage (i.e., storing firearms locked and unloaded) is associated with a lower risk of firearm-related suicide as well as firearm-related unintentional injury and death.[1-3] Several interventions have been shown to be effective in promoting safe firearm storage.[4,5] The provision of firearm locking devices appears to be a key component of successful interventions.[4] However, little is known about preferences for different, commercially-available locking devices, including external locking mechanisms (e.g.,

trigger, cable, and Life Jacket™ locks) or storage containers in which firearms can be secured (e.g., firearm safes, lock boxes) (Appendix A). A recent community-based firearm safety intervention found that 96% of participants elected to receive a free firearm lock box rather than a trigger lock.[6] This finding is consistent with a small study among rural Alaskan households in which participants preferred firearm safes instead of trigger locks and were much less likely at follow-up to use trigger locks than safes to store their firearms.[7]

These findings are concerning given that most interventions have relied on distributing cable or trigger locks to promote changes in firearm storage behaviors, largely due to their relatively low cost and ease of distribution.[4,5] Such a "one size fits all" approach may be ineffective in promoting population-level changes in storage practices given the diversity in characteristics of firearm owners, types of firearms owned, and firearm uses.[8-10] A majority of firearm owners in the U.S. report that protection is a primary reason for their firearm ownership.[8,10] Storage preferences (e.g., ease of access) may differ among those owning firearms for hunting or target shooting rather than protection. Aligning intervention characteristics with the needs and preferences of those who make decisions on firearm storage practices is necessary. The aims of this study were to provide a detailed description of preferences for multiple, available firearm locking devices and the first description of preferences for locking device features among firearm safety event participants.

## METHODS

### Study Design

We conducted a cross-sectional survey among participants in two community-based, firearm safety events in the State of Washington in 2016. We included participants who were 18 years or older, spoke English or Spanish, signed a legal release form necessary for event participation, and returned a completed survey. This evaluation was exempted from review by the human subjects divisions of the University of Washington and Seattle Children's Hospital. We analyzed the data in 2017.

### Firearm Safety Event and Survey Procedure

Events were held at community retail locations where participants received a brief safety message and their choice of a free firearm trigger lock or lock box. Additional details have been published previously.[6] Prior to event participation, participants completed a voluntary, 23-item survey assessing firearm storage practices, reported and considered use of specific firearm storage devices, and perceived importance of specific device features. Pictures of specific storage devices and their approximate costs were presented to participants using a visual placard that showed a trigger lock ($5-15), cable lock ($5-15), Life Jacket™ ($20-30), lock box ($20-100), and a firearm cabinet/safe ($100 or more) (Appendix A).

### Statistical Analysis

We classified respondents into three categories, namely those who reported the following: 1) all household firearms were stored locked; 2) at least one household firearm was unlocked; and 3) no firearms were kept in their homes. We described device ownership and use across these groups and compared device feature preferences between them using chi-squared tests.

## RESULTS

Of 583 participants, 401 returned completed surveys (68.8% response proportion). Demographic characteristics and storage practices are shown in the supplemental table. Prevalence of device ownership and reported device use or consideration of use was similar across the three groups (Table 1). A greater proportion of respondents within each household category reported that they would never use a trigger lock (4.2-8.9%), cable lock (7.7-11.4%), or Life Jacket™ (7.6-14.4%) compared to a lock box (0.6-2.8%) or firearm safe (0-4.3%). Large proportions within each household category reported they would consider using, or definitely use, each of the devices if they owned it (51.9-85.5%). Those reporting at least one unlocked household firearm were most likely to report that they would consider using, or definitely use, a lock box if owned (84.0%), followed by the Life Jacket™ (82.4%), trigger lock (78.6%), firearm safe (76.5%), and cable lock (68.9%).

Preferences for device features were generally similar across the three groups (Table 2). Eighty percent and 89% reported that the ability to lock a firearm while loaded and to unlock it quickly, respectively, was "*very important"* or "*absolutely essential*," whereas 12% and 26% reported that device appearance and device cost of less than $15, respectively, was "*very important"* or "*absolutely essential*." Of those who responded to the survey, 80-90.2% reported that ease of transfer between vehicle and home, ability to use the device on both handguns and long guns, and recommendation of the device by a law enforcement agency or firearm advocacy group were at least "*moderately important*."

## DISCUSSION

In this study we found that firearm safety event participants had differing preferences for firearm locking devices and device features, although preferences were largely similar among households with locked, unlocked, or no firearms. To our knowledge, no prior work has assessed preferences for firearm locking devices or device features in such detail.

**Table 1.** Device use and considered use by household firearm ownership and storage practices (n=401)*^

| | Firearm-owning household, all firearms locked | | | | | Firearm-owning household, at least one unlocked firearm | | | | | Non-firearm owning household | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n=185 | | | | | n=141 | | | | | n=75 | | | | |
| | Would never use if owned | Would consider using if owned | Would definitely use if owned | Owns and uses | Owns but does not use | Would never use if owned | Would consider using if owned | Would definitely use if owned | Owns and uses | Owns but does not use | Would never use if owned | Would consider using if owned | Would definitely use if owned | Owns and uses | Owns but does not use |
| Trigger lock | 13 (7.2%) | 19 (10.5%) | 100 (55.3%) | 39 (21.6%) | 10 (5.5%) | 12 (8.9%) | 38 (28.2%) | 68 (50.4%) | 14 (10.4%) | 3 (2.2%) | 3 (4.2%) | 10 (13.9%) | 49 (68.1%) | 7 (9.7%) | 3 (4.2%) |
| Cable lock | 14 (7.7%) | 33 (18.2%) | 79 (43.7%) | 43 (23.8%) | 12 (6.6%) | 15 (11.1%) | 35 (25.9%) | 58 (43.0%) | 18 (13.3%) | 9 (6.7%) | 8 (11.4%) | 13 (18.6%) | 40 (57.1%) | 6 (8.6%) | 3 (4.3%) |
| Life Jacket™ | 13 (7.6%) | 60 (34.9%) | 87 (50.6%) | 10 (5.8%) | 2 (1.2%) | 18 (14.4%) | 39 (31.2%) | 64 (51.2%) | 4 (3.2%) | 0 (0%) | 8 (11.6%) | 13 (18.8%) | 45 (65.2%) | 2 (2.9%) | 1 (1.5%) |
| Lock box | 1 (0.6%) | 11 (6.0%) | 112 (61.5%) | 40 (22.0%) | 18 (9.9%) | 3 (2.2%) | 9 (6.5%) | 107 (77.5%) | 12 (8.7%) | 7 (5.1%) | 2 (2.8%) | 5 (6.9%) | 54 (75.0%) | 7 (9.7%) | 4 (5.6%) |
| Firearm safe | 0 (0%) | 11 (6.0%) | 84 (45.9%) | 61 (33.3%) | 27 (14.8%) | 3 (2.2%) | 9 (6.6%) | 95 (69.9%) | 22 (16.2%) | 7 (5.2%) | 3 (4.3%) | 5 (7.1%) | 50 (71.4%) | 9 (12.9%) | 3 (4.3%) |

* Cell data are frequencies and corresponding row percentages. Row frequencies may not sum to totals due to missing data.
^ Participants were able to report ownership of more than one device.

These findings have important implications for safe firearm storage interventions. Most interventions have focused on distributing single devices (usually cable or trigger locks).[4,5] Having only offered trigger locks during these events would not have addressed the 8% of those in firearm households who reported they would never use this device and the 4% who already owned but did not use them. There are many variations in what storage options might work best for gun owners given the variety of firearms available and reasons for ownership and use. Participant-centered interventions designed to address this variation are likely to be more effective.

At least eight in ten participants reported "great importance" regarding the ability to lock a firearm while loaded and unlock it quickly. This is likely related to the fact that two-thirds of firearm owners keep firearms for protection and perceptions that the time required to unlock a firearm may interfere with that purpose.[8,10] Such strong preferences should be considered in deciding what types of devices are distributed in safety device promotion interventions. However, those who develop interventions with the aim of preventing firearm suicides must also consider that delaying access to a firearm during an emotional crisis is precisely one of the purposes of the locking device. In this scenario, there may be a role for developing communication strategies to be incorporated into firearm safety interventions that address risk misperceptions (e.g., balancing the risk of harm to oneself and household members vs harm from others).

## LIMITATIONS

This study was conducted among event participants in the State of Washington, and specific findings on device preferences may not apply elsewhere. What is generalizable, however, is that gun owners have preferences that must be addressed if they are to be expected to use a product – a concept that has yet to be applied broadly to firearm safety interventions. A small proportion who identified themselves as living in non-firearm owning households also reported owning and using firearm safety devices. This finding can be explained if respondents were reluctant to report firearm ownership, completed this item in error, used devices on firearms stored outside the home, if devices were used to store non-firearm items (e.g., valuables stored in locked safe), or if they intended to give the storage device to someone else.

## CONCLUSION

This study provides the first detailed insights into preferences for firearm safety devices among adults in both firearm and non-firearm owning households. Determining whether the consideration of these preferences in the design of firearm safety interventions improves their effectiveness is warranted.

## ACKNOWLEDGMENTS

We would like to acknowledge the substantial contributions of the Seattle Children's Hospital Firearm Injury Prevention Research Team in the planning and implementation of these events and data collection for this study.

**Table 2.** Importance of specific firearm locking device features by household firearm ownership and storage practices (n=401).* Question stem: "Please tell us how important each of these features is to you in a gun locking device.

| | Total | Firearm-owning household, all firearms locked | Firearm-owning household, at least one unlocked firearm | Non-firearm owning household | p value |
|---|---|---|---|---|---|
| | n=401 | n=185 | n=141 | n=75 | |
| Can unlock the device quickly | | | | | 0.67 |
| Not at all/little importance | 9 (2.3%) | 3 (1.6%) | 5 (3.6%) | 1 (1.3%) | |
| Moderate importance | 34 (8.5%) | 14 (7.6%) | 12 (8.6%) | 8 (10.7%) | |
| Very important | 150 (37.5%) | 66 (35.7%) | 54 (38.6%) | 30 (40.0%) | |
| Absolutely essential | 207 (51.8%) | 102 (55.1%) | 69 (49.3%) | 36 (48.0%) | |
| Device costs less than 15 United States dollars | | | | | 0.09 |
| Not at all/little importance | 164 (41.4%) | 81 (44.3%) | 55 (39.6%) | 28 (37.8%) | |
| Moderate importance | 128 (32.3%) | 56 (30.6%) | 51 (36.7%) | 21 (28.4%) | |
| Very important | 69 (17.4%) | 24 (13.1%) | 25 (18.0%) | 20 (27.0%) | |
| Absolutely essential | 35 (8.8% | 22 (12.0%) | 8 (5.8%) | 5 (6.8%) | |
| Can lock firearm while it is loaded | | | | | 0.52 |
| Not at all/little importance | 28 (7.0%) | 15 (8.2%) | 8 (5.7%) | 5 (6.8%) | |
| Moderate importance | 51 (12.8%) | 27 (14.7%) | 15 (10.7%) | 9 (12.2%) | |
| Very important | 131 (32.9%) | 51 (27.7%) | 57 (40.7%) | 23 (31.1%) | |
| Absolutely essential | 188 (47.2%) | 91 (49.5%) | 60 (42.9%) | 37 (50.0%) | |
| Appearance of locking device | | | | | 0.03 |
| Not at all/little importance | 283 (71.1%) | 137 (74.9%) | 105 (75.0%) | 41 (54.7%) | |
| Moderate importance | 67 (16.8%) | 30 (16.4%) | 20 (14.3%) | 17 (22.7%) | |
| Very important | 32 (8.0%) | 9 (4.9%) | 10 (7.1%) | 13 (17.3%) | |
| Absolutely essential | 16 (4.0%) | 7 (3.8%) | 5 (3.6%) | 4 (5.3%) | |
| Easy transfer between vehicle and home | | | | | 0.66 |
| Not at all/little importance | 39 (9.8%) | 21 (11.4%) | 14 (10.0%) | 4 (5.3%) | |
| Moderate importance | 94 (23.6%) | 38 (20.7%) | 33 (23.6%) | 23 (30.7%) | |
| Very important | 156 (39.1%) | 70 (38.0%) | 57 (40.7%) | 29 (38.7%) | |
| Absolutely essential | 110 (27.6%) | 55 (29.9%) | 36 (25.7%) | 19 (25.3%) | |

*Rows may not sum up to total population due to missing data.

**Table 2.** Continued.
Question stem: "Please tell us how important each of these features is to you in a gun locking device.

| | Total | Firearm-owning household, all firearms locked | Firearm-owning household, at least one unlocked firearm | Non-firearm owning household | p value |
|---|---|---|---|---|---|
| | n=401 | n=185 | n=141 | n=75 | |
| Can use on both long guns and handguns | | | | | 0.18 |
| Not at all/little importance | 79 (19.8%) | 29 (15.7%) | 37 (26.4%) | 13 (17.3%) | |
| Moderate importance | 126 (31.5%) | 61 (33.0%) | 46 (32.9%) | 19 (25.3%) | |
| Very important | 114 (28.5%) | 52 (28.1%) | 37 (26.4%) | 25 (33.3%) | |
| Absolutely essential | 81 (20.3%) | 43 (23.2%) | 20 (14.3%) | 18 (24.0%) | |
| Device recommended by law enforcement agency or firearm advocacy group | | | | | 0.24 |
| Not at all / little importance | 50 (12.5%) | 16 (8.7%) | 24 (17.3%) | 10 (13.3%) | |
| Moderate importance | 105 (26.3%) | 49 (26.5%) | 38 (27.3%) | 18 (24.0%) | |
| Very important | 143 (35.8%) | 63 (34.1%) | 50 (36.0%) | 30 (40.0%) | |
| Absolutely essential | 101 (25.3%) | 57 (30.8%) | 27 (19.4%) | 17 (22.7%) | |

*Rows may not sum up to total population due to missing data.

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



**REFERENCES**

1. Grossman DC, Mueller BA, Riedy C, et al. Gun storage practices and risk of youth suicide and unintentional firearm injuries. *JAMA.* 2005;293(6):707-14.
2. Shenassa ED, Rogers ML, Spalding KL, et al. Safer storage of firearms at home and risk of suicide: a study of protective factors in a nationally representative sample. *J Epidemiol Community Health.* 2004;58(10):841-8.
3. Conwell Y, Duberstein PR, Connor K, et al. Access to firearms and risk for suicide in middle-aged and older adults. *Am J Geriatr Psychiatry.* 2002;10(4):407-16.
4. Rowhani-Rahbar A, Simonetti JA, Rivara FP. Effectiveness of Interventions to promote safe firearm storage. *Epidemiol Rev.* 2016;38(1):111-24.
5. U.S. Government Accountability Office. Personal firearms: programs that promote safe storage and research on their effectiveness. 2017. Available at: https://www.gao.gov/products/GAO-17-665. Accessed May 19, 2019.
6. Simonetti JA, Rowhani-Rahbar A, King C, et al. Evaluation of a community-based safe firearm and ammunition storage intervention. *Inj Prev.* 2018;24(3):218-23.
7. Horn A, Grossman DC, Jones W, et al. Community-based program to improve firearm storage practices in rural Alaska. *Inj Prev.* 2003;9(3):231-4.
8. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Ann Intern Med*. 2007;147(8):573-7.
9. Simonetti JA, Azrael D, Rowhani-Rahbar A, et al. Firearm storage practices among American veterans. *Am J Prev Med*. 2018;55(4):445-54.
10. Cleveland EC, Azrael D, Simonetti JA, et al. Firearm ownership among American veterans: findings from the 2015 National Firearm Survey. *Inj Epidemiol.* 2017;4(1):33

# Legalized Cannabis in Colorado Emergency Departments: A Cautionary Review of Negative Health and Safety Effects

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*Section Editor:* Mark I. Langdorf, MD, MHPE
Submission history: Submitted July 20, 2018; Revision received April 2, 2019; Accepted April 8, 2019
Electronically published June 3, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.4.39935

Cannabis legalization has led to significant health consequences, particularly to patients in emergency departments and hospitals in Colorado. The most concerning include psychosis, suicide, and other substance abuse. Deleterious effects on the brain include decrements in complex decision-making, which may not be reversible with abstinence. Increases in fatal motor vehicle collisions, adverse effects on cardiovascular and pulmonary systems, inadvertent pediatric exposures, cannabis contaminants exposing users to infectious agents, heavy metals, and pesticides, and hash-oil burn injuries in preparation of drug concentrates have been documented. Cannabis dispensary workers ("budtenders") without medical training are giving medical advice that may be harmful to patients. Cannabis research may offer novel treatment of seizures, spasticity from multiple sclerosis, nausea and vomiting from chemotherapy, chronic pain, improvements in cardiovascular outcomes, and sleep disorders. Progress has been slow due to absent standards for chemical composition of cannabis products and limitations on research imposed by federal classification of cannabis as illegal. Given these factors and the Colorado experience, other states should carefully evaluate whether and how to decriminalize or legalize non-medical cannabis use. [West J Emerg Med. 2019;20(4)557–572.]

## INTRODUCTION

As of January 2018 in the United States, nine states have legalized cannabis for recreational use, with another 29 legalizing it for medical use. These policy changes have created broad interest in understanding the effects on public health and the healthcare system.

The Colorado Department of Public Safety report, "*Impacts of Marijuana Legalization in Colorado: A Report Pursuant to Senate Bill 13-283,"* includes a timeline for marijuana legalization in Colorado with five distinct periods in both the legal status and commercial availability of marijuana in Colorado.[1] These include the following:

- Prior to 2000: It is illegal to possess or grow marijuana.
- 2000-2009: Amendment 20 is approved and medical marijuana is legalized. The Colorado Department of Public Health and Environment (CDPHE) issues registry identification cards to individuals who have received recommendations from a doctor that marijuana will help a debilitating medical condition. No regulated market exists. Individual grow operations or caregiver grow operations limited to five patients are allowed.
- 2010-2012: Medical marijuana is commercialized and regulated with licensed dispensaries, grow operations, and product manufacturers open in jurisdictions allowing these types of businesses. This corresponded with the Ogden memorandum issued in October 2009, which instructed U.S. Attorneys not to "focus federal resources in your States on individuals whose actions are in clear and unambiguous compliance with existing state laws providing for the medical use of marijuana."[2] The commercialization of medical marijuana followed and the number of patients registered with CDPHE increased dramatically from about 5000 in 2009 to almost 119,000 in 2011.
- 2013: Amendment 64 takes effect. Personal possession and grow limits for recreational marijuana are in place but sales are not commercialized. Medical continues as a regulated, commercial market.
- 2014 to present: Recreational and medical marijuana is fully regulated and commercialized. Licensed retail

stores open January 1, 2014. This corresponded with the Cole memorandum, which gave further guidance to U.S. Attorneys: "[I]n jurisdictions that have enacted laws legalizing marijuana in some form and that have also implemented strong and effective regulatory and enforcement systems to control the cultivation, distribution, sale, and possession of marijuana, conduct in compliance with those laws and regulations is less likely to threaten federal priorities… [E]nforcement of state law by state and local law enforcement and regulatory bodies should remain the primary means of addressing marijuana-related activity."[3] This memorandum was widely interpreted to mean that the federal government would not interfere with state marijuana laws;[4] however, in January 2018 the Cole memorandum was rescinded by then U.S. Attorney General Jeff Sessions.[4]

Changes in past-month cannabis use by year and age group for Colorado and Kansas (non-legalized state) are shown in Figures 1 and 2. (Kansas was chosen for proximity; other non-legalized states in proximity, including Wyoming and Idaho, had similar graphs to Kansas.)[5]

Over this time span cannabis potency has increased. Current commercialized cannabis is near 20% tetrahydrocannabinol (THC), the primary psychoactive constituent of cannabis, while in the 1980s concentration was <2%. This 10-fold increase in potency does not include other formulations such as oils, waxes, and dabs, which can reach 80-90% THC.[6]

This general increase in cannabis use and increase in cannabis potency has led to cannabis-related presentations to emergency departments (ED) and hospitalizations across the state. This review will focus on negative health and safety effects Colorado has experienced with inclusion of relevant peer-reviewed literature. It will conclude with a short review of the medicinal use of cannabis products.

*Population Health Research Capsule*

What do we already know about this issue?
*Legalized cannabis has led to increased cannabis related presentations to emergency departments (ED).*

What was the focus of this review?
*The negative impacts to EDs, particularly in the state of Colorado, following cannabis legalization.*

What was the conclusion of this review?
*Cannabis legalization has been correlated with multiple adverse outcomes that impact EDs.*

How does this improve population health?
*Healthcare policy makers may take the adverse outcomes described into consideration when considering if and/or how to legalize cannabis.*

**Cannabis Effects on Healthcare Resources in Colorado**

ED visits and hospitalizations with marijuana-related billing codes have increased following legalization. Mental

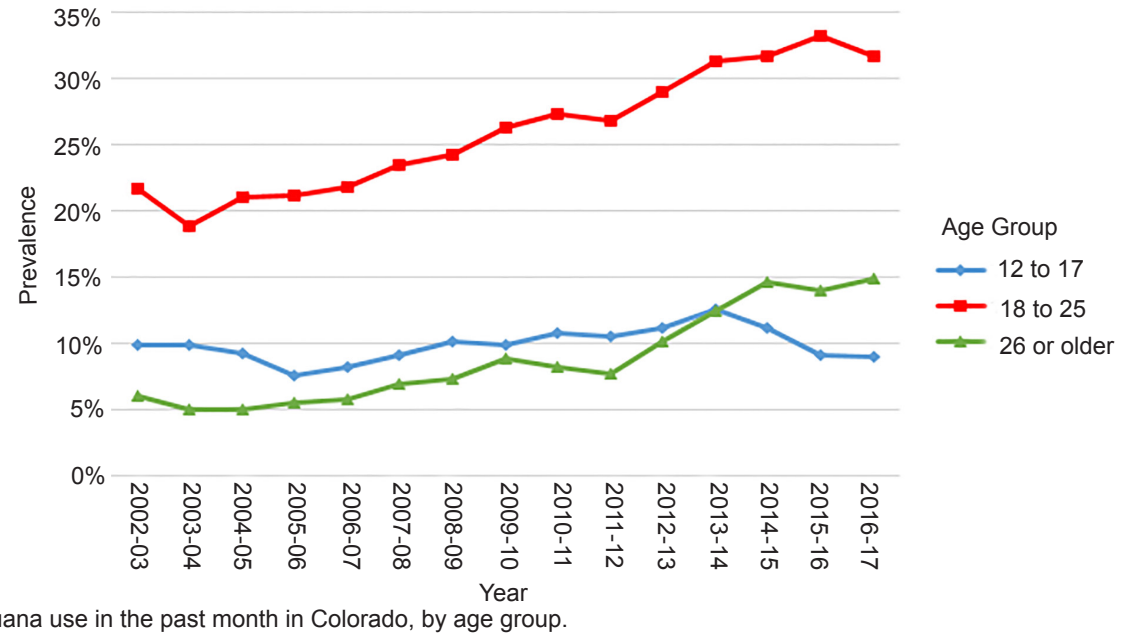


**Figure 1.** Marijuana use in the past month in Colorado, by age group.
Reproduced from Substance Abuse and Mental Health Services Administration National Survey on Drug Use and Health: State Estimates. Available at: https://pdas.samhsa.gov/saes/state. Accessed November 2018.

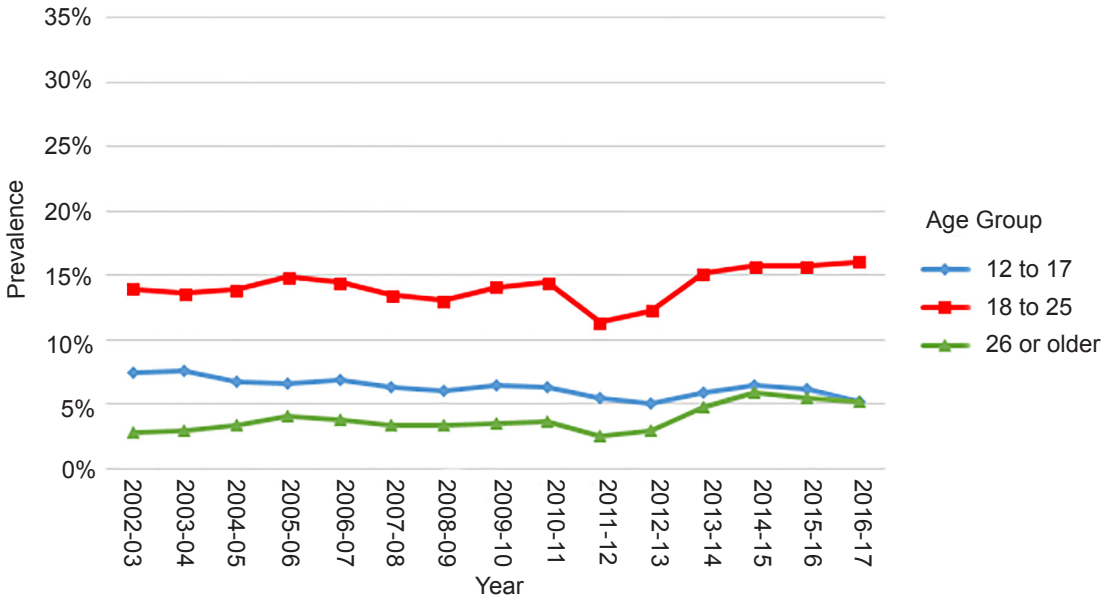


**Figure 2.** Marijuana use in the past month in Kansas, by age group.
Reproduced from Substance Abuse and Mental Health Services Administration National Survey on Drug Use and Health: State Estimates. Available at: https://pdas.samhsa.gov/saes/state. Accessed November 2018.

illness represents a concerningly large number of marijuana-related visits. A retrospective review by Wang et al. reported Colorado Hospital Association hospitalizations and ED visits with marijuana-related billing codes. Between 2000 and 2015, hospitalization rates increased 116% from 274 to 593 per 100,000 hospitalizations. For primary diagnosis categories, the prevalence of mental illness was five-fold higher (5.07; 95% confidence interval [CI], 4.96 - 5.09) for ED visits and nine-fold higher (9.67; 95% CI, 9.59 - 9.74) for hospital admissions for patients with marijuana-related billing codes compared to those without.[7] This data compared diagnostic categories between patients with a marijuana-related diagnostic code and those without.

Subsequent data by the CDPHE show significant increases in hospitalizations in each phase of marijuana legalization, increasing from 575 per 100,000 hospitalizations in 2000 to 2413 in the 2014–June 2015 period, as displayed in Figure 3.[8] There are differences in incidence between the Wang study and the CDPHE report because the Wang study only included a patient's healthcare event if a marijuana code was among the first three diagnostic codes, while the CDPHE study included marijuana diagnostic codes within the top 30.

ED and urgent care (UC) visits with cannabis-associated International Classification of Diseases (ICD) codes or positive urine drug screens for teenagers and young adults have increased since legalization, and the majority require behavioral health evaluation. A subsequent retrospective review by Wang et al. from 2005-2015 identified 4202 such visits for patients 13 to <21 years old to a tertiary-care children's hospital system. Behavioral health evaluation was obtained for 2813 (67%) and a psychiatric diagnosis was made for the majority (71%) of the visits. ED/UC visits with cannabis-associated ICD codes or positive urine drug screens of all types increased 2.7-fold from 1.8 per 1000 in 2009 to 4.9 per 1000 in 2015 (N = 161 in 2005 to 777 in 2015). Behavioral health consultations increased 2.7-fold from 1.2 per 1000 in 2009 to 3.2 per 1000 in 2015 ( N = 84 in 2005 to 500 in 2015). These data indicate that despite national survey data suggesting the rate of adolescent marijuana use is flat, there has been a significant increase in adolescent ED/UC visits with cannabis-associated ICD codes or positive urine drug screens.[9] Figure 4 displays these visits by year.

## Cannabis Effects on Mental Health

### *Psychosis and Schizophrenia*

Previous studies, including large reviews by the World Health Organization (WHO) and the National Academies of Sciences, Engineering, and Medicine (NASEM), have found substantial evidence of a statistical association between cannabis use and the development of schizophrenia or other psychoses, with the highest risk among the most frequent users.[6,10] In a study of 45,570 Swedish men drafted into the military, the authors found that the men who had tried cannabis by age 18 were 2.4 times (95% CI, 1.8-3.3) more likely to be diagnosed with schizophrenia over the next 15 years than those who had not.[11] A follow-up study found a dose-response relationship between frequency of cannabis use at the age of 18 and the risk of schizophrenia. This effect persisted after controlling for confounding factors such as psychiatric diagnosis at enlistment, IQ score, personality variables concerned with interpersonal relationships, place of upbringing, paternal age, cigarette smoking, disturbed behaviors in childhood, history of alcohol misuse, family history of psychiatric illness, financial situation of the family, and father's occupation. (The enlistment procedure

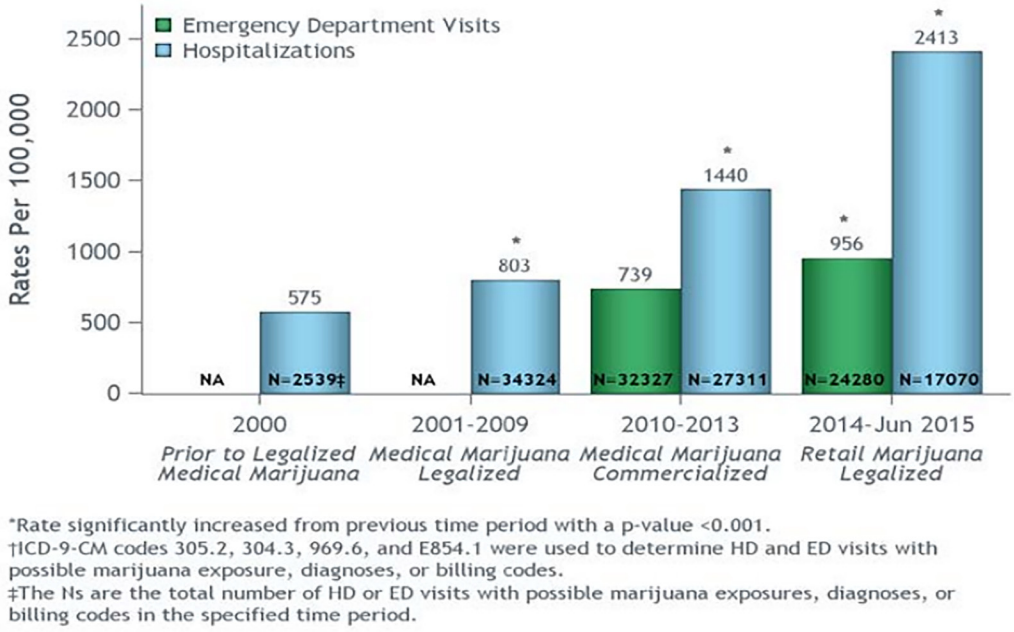


**Figure 3.** Rates of hospitalizations (HD) and emergency department (ED) visits per year with possible marijuana exposures, diagnoses, or billing codes per 100,000 HD and ED visits, by legalization eras in Colorado.
*NA*, Data not available.
Data provided by Colorado Hospital Association with analysis provided by Colorado Department of Public Health and Environment.
Note: Data for 2015 covers January 1, 2015 – June 30, 2015. An individual can be represented more than once in the data; therefore, the rate is HD or ED visits with marijuana codes per 100,000 total HD or ED visits.
Reproduced from Marijuana Legalization in Colorado: Early Findings. A Report Pursuant to Senate Bill 13-283. Colorado Department of Public Safety. 2016. Available at: http://cdpsdocs.state.co.us/ors/docs/reports/2016-SB13-283-Rpt.pdf. Accessed March 2018.

included intelligence tests and non-anonymous, self-reported questionnaires on family, social background, behavior during adolescence, and substance use – including first drug used, drug most commonly used, frequency of use, and direct questions regarding use of a list of specified drugs.) The researchers estimated that 13% of cases of schizophrenia could have been averted if no one in the cohort had used cannabis.[12] These findings have been reproduced repeatedly and across the world.[13-20]

*Depression, Anxiety, and Suicide*

Cannabis use is associated with increased rates of depression, anxiety, and suicide. The NASEM found that there is a moderate statistical association between cannabis use and an increased risk for the development of depressive disorders (odds ratio [OR] = 1.17; 95% CI, 1.05-1.30) and this increases with increased frequency of use (OR = 1.62; 95% CI, 1.21-2.16).[10,21] There was also moderate evidence of a statistical association between regular cannabis use and increased incidence of social anxiety disorder (OR = 1.28; 95% CI, 1.06–1.54).[10,22] The NAESM found that there was moderate evidence of a statistical association between cannabis use and the incidence of suicidal ideation (OR = 1.43; 95% CI, 1.13-1.83 with any cannabis use, OR = 2.53; 95% CI, 1.00-6.39 with heavy cannabis use) and suicide attempts (OR = 2.23; 95% CI, 1.24-4.00 for any cannabis use, OR = 3.20; 95% CI, 1.72–5.94 with heavy cannabis use), and increased incidence of suicide completion (OR = 2.56; 95% CI, 1.25–5.27 for any cannabis use).[10,23]

The NASEM reviewed multiple studies to come to the summary conclusions, and the odds ratios represent the most compelling systematic review for the conclusions. However, there were many more studies used to reach the stated conclusions. The data reviewed by the World Health Organization also demonstrate similar results for depression, anxiety, and suicide.[6] Both the NASEM and the WHO reviews acknowledge that reverse causation and shared risk factors cannot be ruled out as explanations of these statistical associations and acknowledge that further research is needed.

In the most recent data on Colorado adolescent suicides, marijuana was the most common substance present for ages 10-19 in 2016. Of 62 suicides with toxicology data available, marijuana was present in 30.6% (n = 19) compared to 9.7% (n = 6) for alcohol.[24] This trend has been increasing since liberalization of marijuana policy in 2010. This is more concerning as suicide is currently the leading cause of death of adolescents in Colorado.[25] For all age groups in Colorado, in the five-year period from 2004-2009 there were 4822 suicides and 7.1% (n

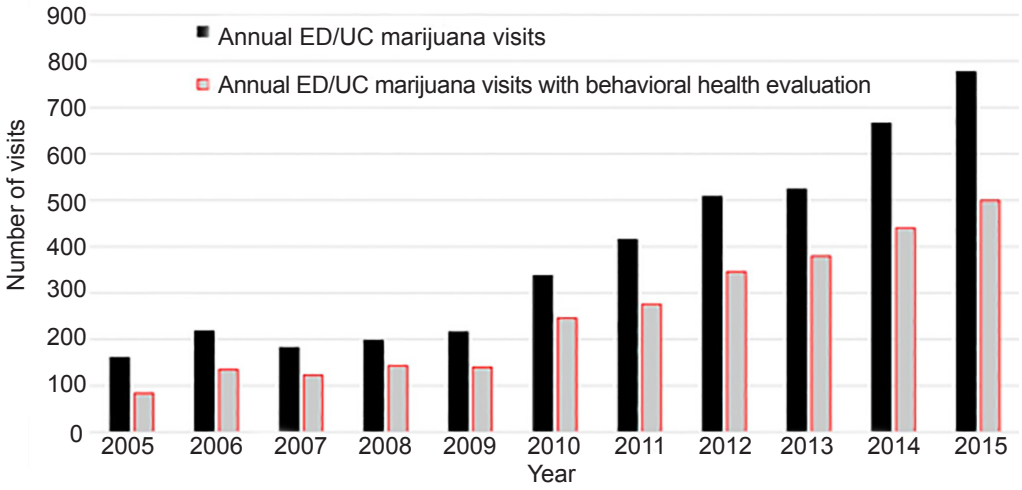


**Figure 4.** Number of emergency department (ED)/urgent care (UC) visits with cannabis-associated International Classification of Diseases codes or positive urine drug screens by adolescents aged 13 to < 21 to a tertiary-care children's hospital system in Colorado by year.[105]

= 303) of those were marijuana positive on toxicology analysis (538 did not have toxicology data available). In the subsequent five-year period of marijuana legalization, 2010-2015, there were 5880 total suicides (22% increase), and 12.6% had a positive toxicology for marijuana (n = 601; 1,120 did not have toxicology data available). This represents a statistically significant 77.5% increase in the proportion of suicide victims with toxicology positive for marijuana (an absolute difference of 5.5%) for which toxicology data were reported (chi square 77.2884, p<0.0001). Suicides with marijuana toxicology by year and overall suicide by year data are displayed in Figure 5.

*Social Outcomes*

Cannabis has been associated with adverse social outcomes which may impact EDs and patient health. The large (N = 49,321) cohort study of Swedish men drafted at age 18-20 and followed to age 40 showed increased risk of unemployment and need for welfare assistance in those using cannabis greater than 50 times (risk ratio [RR]=1.26; 95% CI, 1.04–1.53 for unemployment), (RR = 1.38; 95% CI, 1.19–1.62 for welfare assistance).[26] These results were repeated in a longitudinal birth cohort study in New Zealand to 25 years old, which found high levels of cannabis use correlated with statistical significance to poorer educational outcomes, lower income, greater welfare dependence and unemployment, and lower relationship and life satisfaction. This cohort was classified into six levels of cannabis use, and found that as cannabis use increased, the odds ratio of adverse outcome increased.[27,28] Both of these studies adjusted for confounding factors including socioeconomic background of the family, family functioning and exposure to adversity, exposure to child sexual and physical abuse, childhood and adolescent adjustment, academic achievement in early adolescence, comorbid mental health disorders, and other substance use.

A prospective cohort study from upstate New York (N = 548) found that, compared with cannabis nonusers or minimal users (a few times a year or less), chronic users and users who began use in early adulthood and then tapered off use into later adulthood, had a significantly higher likelihood of unemployment at mean age 43 (adjusted OR=3.51; 95% CI, 1.13–10.91), even after controlling for covariates.[29] The NASEM review stated that there was a limited level of evidence of impaired academic achievement and education outcomes, increased rates of unemployment and/or low income, and impaired social functioning or engagement in developmentally appropriate social roles.[10] The report stated that although there was evidence to suggest these outcomes, it was difficult to document a direct link between cannabis use and these outcomes because other variables played a role. Social outcome data for cannabis users specifically in Colorado are currently unavailable and could be an area for further research.

*Structural, Functional, and Chemical Brain Changes in Cannabis Users*

A number of review articles on cannabis have described adverse effects on brain imaging.[6,30-33] These findings may help establish a mechanistic link between the epidemiological studies on the adverse effects of cannabis. Structural, functional, and chemical changes to the brain have been established. These include both the gray matter (neuronal cells) and white matter (nerve axons responsible for communication).[34,35] Structural changes to the brain include reductions in the hippocampus[34-38] (12.1% in the left and 11.9% in the right, relative to controls)[38] and amygdala[37,38] (6.0% in the left and 8.2% in the right, relative to controls)[38] volumes in cannabis users.

Several studies also identified reductions in volume of

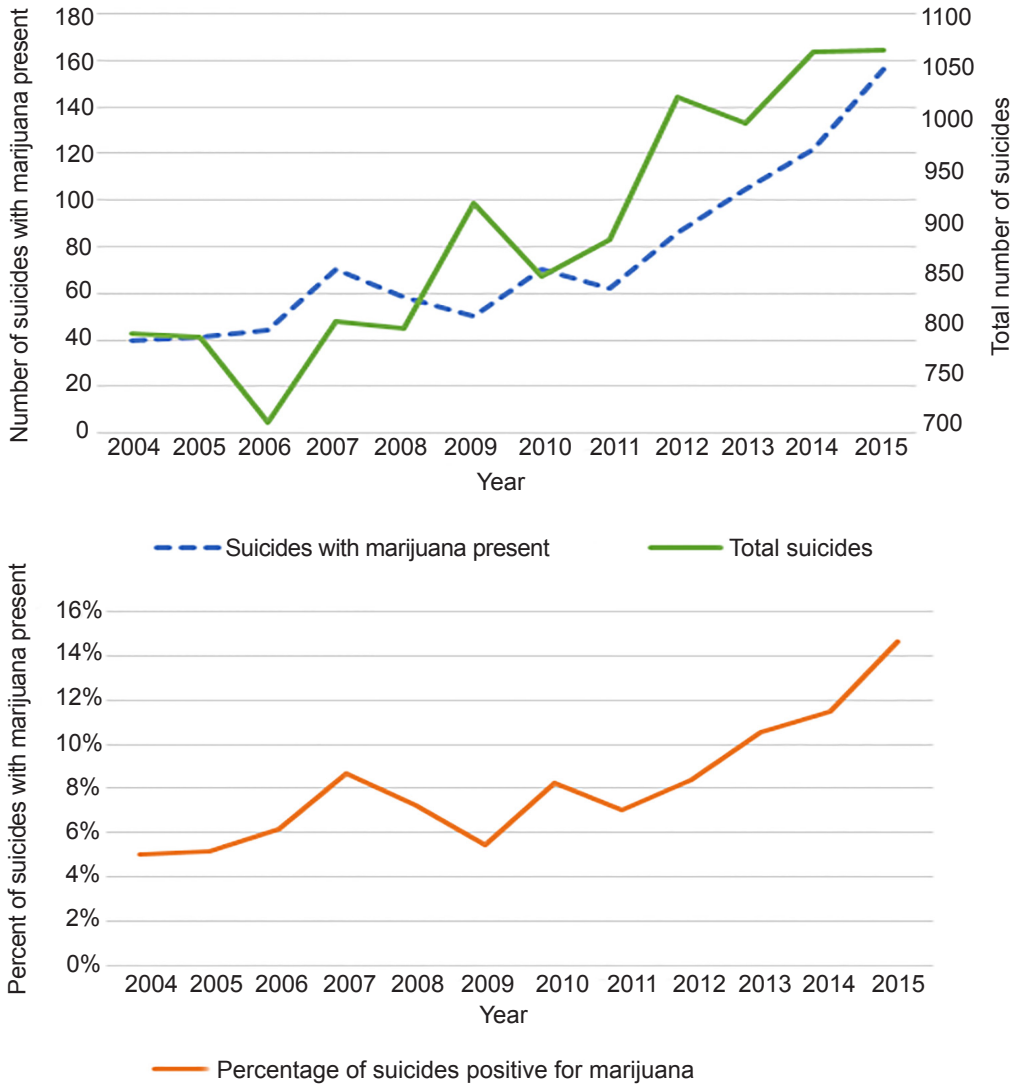


**Figure 5.** Suicides with marijuana toxicology by year and total suicides by year in Colorado (A). Percent of suicides with marijuana present by year (B).[24]

specific areas of the prefrontal cortex,[39-41] as well as functional magnetic resonance imaging (fMRI) studies demonstrating reduced functional connectivity in the prefrontal networks responsible for executive function (including inhibitory control) and the subcortical networks, which process habits and routines.[30,42-25] Other fMRI studies show reduced connectivity in the fimbriae of the hippocampus and commissural fibers extending to the precuneus, and suggest that this disturbed brain connectivity in cannabis users may underlie cognitive impairment and vulnerability to psychosis, depression, and anxiety disorders.[46] Multiple other areas of the brain have also been shown to demonstrate changes on fMRI studies in response to cannabis and include the orbitofrontal cortex, anterior cingulate cortex, striatum, amygdala, hippocampus, and cerebellum.[37] In general, these changes on both structural and functional MRI studies corresponded with frequency of use and earlier age of onset of use (although several studies identified these changes in adult users as well).[34,35]

Changes to neurotransmitters in the brain have also been well described in systematic reviews and include disruptions in glutamate,[47] dopamine,[48] N-acetylaspartate,[49] myo-inositol,[49] choline,[49] and γ-aminobutyric acid (GABA).[33,49]

Taken together, these changes may underlie the clinical features being observed in observational and epidemiological studies demonstrating increases in psychosis, impulsivity, depression, anxiety, suicidality, decreases in cognition, IQ, and executive function, abnormalities in habits, routines, decision-

making capacity, and deficits in learning, memory, attention, and social interaction.[6,30,31]

*Link to Other Substance Abuse*

Cannabis use has also been associated with abuse of other illicit substances. According to the NASEM report, there is a moderate level of evidence of a statistical association between cannabis use and the development of substance dependence and/or substance abuse disorder for alcohol, tobacco, and illicit drugs.[10] Multiple cohort studies have demonstrated these results.[50-52] Four separate discordant twin studies have found that the twin who used marijuana was more likely to use other substances even after controlling for environmental and genetic influences.[53-56] Although some studies reported that medical cannabis has resulted in improvements in opiate-related deaths,[57,58] Colorado has had an increase in poisoning and deaths from opiates and methamphetamines since 2010, with the highest in 2017. These rates have increased nationwide as well and the influence of cannabis in Colorado is difficult to discern. Nevertheless, the increase in overdose deaths in Colorado is alarming. These data are shown in Figure 6.[25]

Although animal studies do not consistently translate to human effects, rat studies can provide some mechanistic clues. After exposure to tetrahydrocannabinol (THC), rats have an increased behavioral sensitization response to not only THC but also opiates and nicotine.[59-61] Studies also demonstrate that these behavioral changes in rats correspond to neuronal activity changes in mesolimbic dopamine neurons in the ventral tegmental area and nucleus accumbens and that cross-tolerance results with exposure to morphine, amphetamines, and cocaine.[61,62] Repeat morphine self-administration has been shown to be significantly lower in $CB_1$ knockout mice ($CB_1$ receptors are the among the most predominant G protein-coupled receptors in the brain and mediate most of the psychotropic effects of THC) and opiate withdrawal symptoms significantly less when the knockout mice are administered naloxone.[63]

*Cannabis Dependence/Withdrawal Symptoms*

Cannabis use may result in dependence and cessation may result in withdrawal symptoms. Dependence rates are reported at one in 10 among those who ever use cannabis, one in six among adolescent users, and one in three among daily users.[6,64-67] Withdrawal symptoms may include anxiety, insomnia, appetite disturbance, and depression. These symptoms are sufficient to impair everyday functioning and are markedly attenuated by doses of an oral cannabis extract.[6]

**Other Relevant Physiological and Safety Concerns with Cannabis**

*Cannabinoid Hyperemesis Syndrome*

Cannabinoid hyperemesis syndrome (CHS) has been well described in the literature.[68-70] The symptoms of CHS include significant nausea, violent vomiting, and abdominal pain in the setting of chronic cannabis use. Cardinal diagnostic characteristics include regular cannabis use, cyclic nausea and vomiting, and compulsive hot baths or showers with resolution of symptoms after cessation of cannabis use.[69] CHS patients present similarly to cyclic vomiting syndrome patients with the exception that cannabis use is required to make the diagnosis.[69] Following legalization, the prevalence of cyclic vomiting presentations to Denver Health and the University of Colorado Hospital increased 1.92-fold (95% CI, 1.33 to 2.79) from 41 per

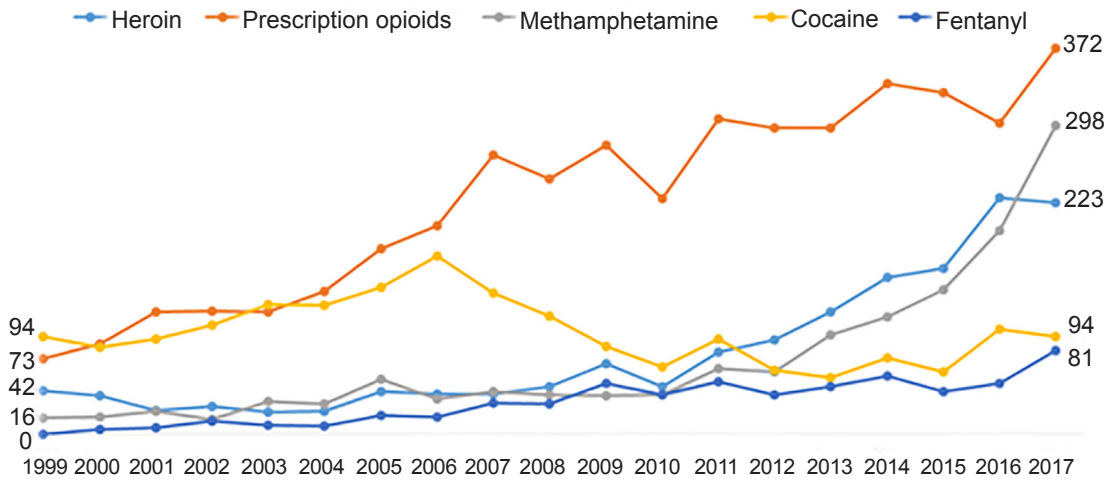


**Figure 6.** Drug poisoning/overdose deaths in Colorado by involvement of specific drug type: Colorado residents, 1999-2017.* Reproduced from: Vital Statistics Program, Colorado Department of Public Health and Environment. Available at: https://drive.google.com/file/d/1vfi4kL9eD9rib7aEboteiGw67gOxXFpf/view.
*Drug categories are not mutually exclusive; a death involving more than one type of specific drug will be counted in each applicable category. "Fentanyl" is a subset of "prescription opioid."

113,262 ED visits from a year prior to marijuana liberalization (November 1, 2008–October 31, 2009) to 87 per 125,095 ED visits a year following marijuana liberalization (June 1, 2010–May 31, 2011). Patients with cyclic vomiting in the post-liberalization period were more likely to have marijuana use documented than patients in the pre-liberalization period (OR = 3.59; 95% CI, 1.44 to 9.00).[71] These patients often are evaluated with multiple imaging studies, lab work, endoscopies, and admissions to the hospital as well as antiemetic treatment. These studies are often non-diagnostic and treatment is often ineffective. This may also influence ED crowding.[68,72]

*Motor Vehicle Collisions*

Traffic fatalities with blood or urine drug screens positive for cannabinoids have sharply risen across Colorado.[73,74] Total fatal motor vehicle collisions (MVC) in Colorado had been decreasing from a high of 677 in 2002 to a low of 407 in 2011 but then began increasing each year since then to 600 in 2017. Total MVCs mirror this trend. The NASEM review found substantial evidence of a statistical association between cannabis use and increased risk of MVCs.[10] CDPHE found substantial evidence that recent marijuana use by a driver increases his or her risk of a MVC and that the higher the blood THC level, the higher the risk of MVC. The use of alcohol and marijuana together increases risk of impairment and MVC more than either substance alone. For less-than-weekly marijuana users, using marijuana containing 10 milligrams (mg) of THC is likely to impair the ability to safely drive, bike, or perform other safety-sensitive activities. A typical marijuana cigarette, or joint, contains 60-115 mg of THC.[75]

A systematic review of observational studies and meta-analysis for acute cannabis consumption and MVC risk found that driving under the influence of cannabis was associated with a significantly increased risk of MVCs compared with unimpaired driving (OR = 1.92; 95% CI, 1.35 to 2.73), especially for fatal collisions (OR = 2.10; 95% CI, 1.31 to 3.36).[76] However, a recent study of crash fatality rates after recreational marijuana legalization in Washington and Colorado found changes in motor vehicle crash fatality rates were not statistically different from those in similar states without recreational marijuana legalization. This was, however, only after further statistical regression analysis (for population, gender, spending on road construction and maintenance, annual gross domestic product, per capita income, unemployment rate, per capita alcohol consumption, seatbelt laws, road density, traffic density, and rurality). Initial data demonstrated that after legalization, motor vehicle crash fatality rates increased by a mean of +0.1 (± 0.4) fatalities per billion vehicle miles traveled in Washington and Colorado, and decreased by a mean of -0.5 (± 0.9) fatalities per billion vehicle miles traveled in the control states each year.[77]

*Cardiovascular Effects*

The effect of cannabinoids on the cardiovascular system is complex and an area of ongoing research.[78] Of concern to practicing emergency physicians is ST-segment elevation myocardial infarctions and acute stroke presentations with a close temporal relationship with cannabis use, which have been documented in multiple case reports in otherwise young, healthy, male patients.[79-82] The NASEM summary found there was a limited level of evidence of a statistical association between acute cannabis use and triggering an acute myocardial infarction (AMI), ischemic stroke, or subarachnoid hemorrhage.[10] The WHO review states: "There is evidence that cannabis use can trigger coronary events. Recent case reports and case series suggest that cannabis smoking may increase cardiovascular disease risk in younger cannabis smokers who are otherwise at relatively low risk."[6]

CDPHE found moderate evidence that marijuana use increases risk of ischemic stroke in individuals younger than 55 years of age and limited evidence that acute marijuana use increases risk of myocardial infarction.[75] The main case crossover study cited for the AMI findings demonstrated that the risk for AMI associated with cannabis use during the hour preceding symptoms of AMI was elevated 4.8 times over baseline (95% CI, 2.9-9.5). This risk was substantially reduced following that hour.[83]

A review of nationwide inpatient sample data from 2010 to 2014 demonstrated a 32% increase in inpatient admissions for primary diagnosis of myocardial infarction and secondary diagnosis of cannabis use disorder (increasing from 2198 to 2900 cases). The overall mean age of patients was 41 years old. These patients also had longer lengths of stay, higher hospitalization costs, and higher levels of morbidity due to AMI following hospitalization than non-cannabis users.[84]

In a study reviewing secondhand marijuana smoke exposure, the authors found that one minute of exposure substantially impaired endothelial function in rats for at least 90 minutes, considerably longer than comparable impairment by tobacco secondhand smoke.[85]

The pathophysiological basis of these events is not fully understood and a full discussion is beyond the scope of this review. In short summary, it may encompass a complex interaction between exogenous cannabinoids and the endocannabinoid system, autonomic nervous system, oxidative stress, direct cellular effects on the endothelium, and pro-coagulant effects.[86] Exposure to THC causes activation of the sympathetic nervous system and inhibition of the parasympathetic nervous system.[87] These effects include elevated heart rate, serum norepinephrine levels, elevated supine blood pressure, and increases in left ventricular systolic function[87-89] Smoking results in decreasing oxygen delivery to the heart and other vital organs and may be further compromised by increasing carboxyhemoglobin levels.[90] The impaired myocardial oxygen demand-to-supply ratio following cannabis smoking has been shown to reduce the time to onset of symptoms during exercise in patients with stable angina.[91]

Direct effects of cannabis on blood vessels are complex due to the differing compounds in cannabis and the functional properties of the blood vessels examined.[92] Studies are

inconsistent regarding the effects on vasoconstriction and dilation. Cannabis has been consistently shown to produce vasodilation with resultant orthostatic hypotension,[92,93] but it has also been implicated in vasoconstrictive arteritis mechanisms.[94,95] A large review article suggested that there are three phases in cardiovascular parameters affected by the endocannabinoid system and that different chemical constituents of the cannabis plant have varying effects at different target organs, which may account for the differences.[93] Transient vasospasm and reduction in cerebral blood flow are well described and may underlie changes in coronary, cerebral, and peripheral arterial systems leading to end organ ischemia.[86,96,97] Myocardial blood flow has been shown to correlate inversely with circulating plasma levels of endocannabinoids.[86,98] Cannabis has also been shown to be a potent source of cellular oxidative stress through formation of reactive oxygen species, and this may contribute to endothelial dysfunction and promote regional arterial vasospasm.[86,99]

THC has also recently shown a dose-dependent pro-coagulant effect.[100] This ex vivo observation has been supported by reports of thrombotic coronary artery occlusion in young individuals without underlying atherosclerosis.[86] There are also cannabinoid receptors on the surface of platelets and THC has been shown to increase the surface expression of glycoprotein IIb–IIIa and P selectin in a concentration-dependent manner resulting in platelet activation.[86,101] Figure 7 summarizes these effects.

*Respiratory Effects*

Marijuana smoking leads to adverse pulmonary outcomes. The NASEM, CDPHE, and WHO reports state there is substantial evidence of a statistical association between marijuana smoking and worse respiratory symptoms and more frequent chronic bronchitis episodes.[6,10,75] These data were based primarily on a systematic review by Tetrault et al. from 14 studies that assessed the association between long-term cannabis smoking respiratory symptoms including chronic cough (OR = 1.7–2.0), increased sputum production (OR = 1.5–1.9), and wheezing (OR = 2.0–3.0).[102] There is also evidence of a statistical association between the cessation of cannabis smoking and improvements in respiratory symptoms.[10] Cannabis smoking may also lead to increased rates of pneumonia and upper respiratory infections. On histology, this is associated with a reduction in ciliated cells and increase in mucus secretion from the larger number of mucus-secreting cells.[6,30,103]

*Exposures to Children*

Reported exposures to children less than age 10 have sharply increased in Colorado following recreational marijuana legalization. A retrospective cohort study of hospital admissions and regional poison control center (RPC) cases between January 1, 2009–December 31, 2015 at a tertiary-care children's hospital found that the mean rate of marijuana-related visits to the children's hospital (ages 0-9) increased from 1.2 per 100,000 population in the two years prior to legalization to 2.3 per

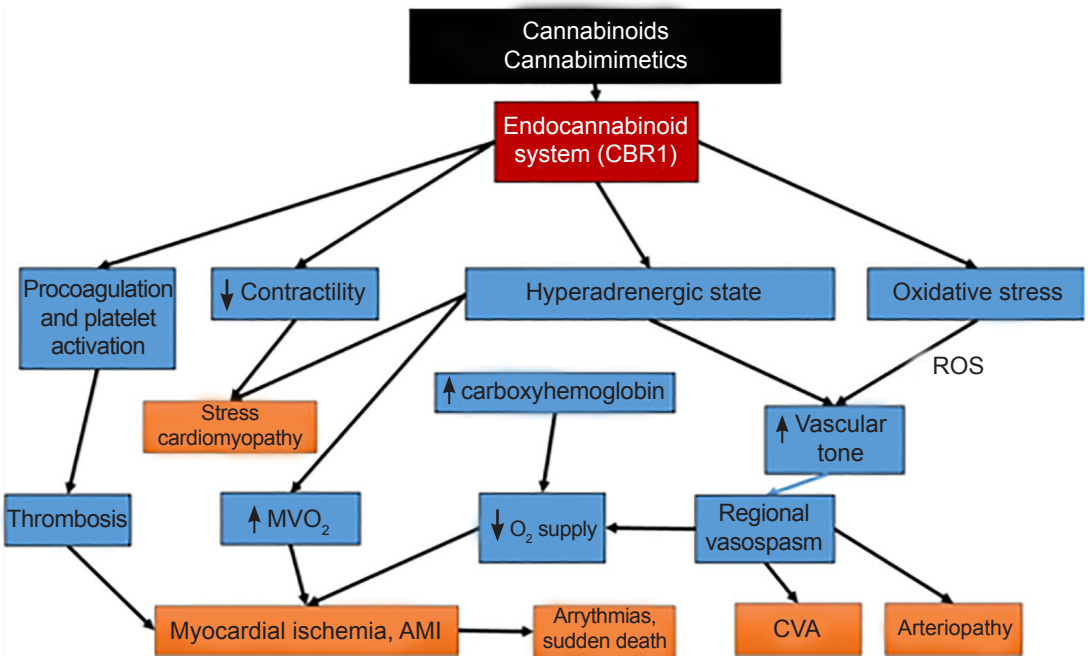


**Figure 7.** Flow diagram demonstrating pathophysiologic pathways to common major adverse cardiovascular events reported in users of cannabis and related chemicals.[86]
*AMI*, acute myocardial infarction; *CBR1*, cannabinoid receptor 1; *CVA*, cerebrovascular accident; *$MVO_2$* myocardial oxygen consumption (demand); *$O_2$*, oxygen; *ROS*, reactive oxygen species.

100,000 after (P=.02). The median age of exposure was 2.4 years. The majority were exposure to an infused edible product (48%, n = 30); 65% (n = 40) were observed in the ED or UC; 21% (n = 13) were admitted to an inpatient ward; and 15% (n = 9) were admitted to the intensive care unit. Two of these children required respiratory support. The median length of stay for all patients was 11 hours, and the median length of stay for admitted patients was 26 hours.

Annual RPC pediatric marijuana cases increased more than five-fold from 2009 (nine cases) to 2015 (47 cases).[104] Colorado had an average increase in RPC cases of 34% (P < .001) per year while the remainder of the United States had an increase of 19% (P < .001).[104] In a follow-up study in October 2018, the same author found that despite multiple public health interventions in legislation after 2014 (child-resistant packaging, dose limitations, opaque packaging, limiting marketing campaigns, and banning specific edibles), the incidence of children's hospital visits and RPC calls has continued to rise in Colorado with an observed doubling of children's hospital visits in 2017 compared to 2016[105] (Figure 8). Edibles are sold as cookies, candies, and sodas with advertising that appeals to children.[104,106]

*Cannabis Contaminants, Cannabis Concentrates, and Hash-oil Burns*

Varying cultivation techniques and end-product alterations further complicate the understanding of the physiological effects of cannabis. Cannabis plants can be altered to achieve higher growth rates, changes in potency, and increased bud production. These techniques can include use of varying soil types, fertilizers, and pesticides that can result in physiological effects. These changes may also result in exposures to possible fungal agents such as powdery mildew and botrytis; budworm or mite infestations have been reported in the literature. Historically, there have been reports of bacterial contamination with salmonella, enterobacter, streptococcus, and klebsiella, as well as case reports of fungal spore contaminants, including mycotoxin-producing strains of aspergillus.[107]

There are three pathways through which cannabis may be contaminated with heavy metal substances. Firstly, cannabis is able to remove heavy metals from substrate soils and deposit these in its tissues by virtue of its bioaccumulative capacity. Secondly, cross-contamination may occur during processing (eg, during drying). Thirdly, post-processing adulteration may occur, whereby metals may be added to the preparation to increase weight and thereby appreciate its street value. There are case reports of lead and arsenic poisoning from cannabis.[107] Pesticides are also commonly used in cannabis cultivation. In a report from Washington State, laboratory analysis revealed that 84.6% (N = 26 samples) of legalized cannabis products contained significant quantities of pesticides including insecticides, fungicides, miticides, and herbicides. These comprised a wide array of different substances and encompassed proven carcinogens (carbaryl, diuron, ethoprophos, permethrin, and propargite), endocrine disruptors, as well as a variety of developmental, reproductive, and neurological toxins.[107,108]

There are also changes in end-product concentrations through post-processing of the plant. These changes include creation of oils, waxes/shatter, and dabs. Oils are created by removing the hydrophobic components such as THC with a heated butane solvent. THC concentrations may reach up to 55.7%.[109] Waxes and shatter are concentrated and solidified oil with THC concentration reaching up to 90% THC.[110,111] Dabs are composed of heated wax and are inhaled off of an

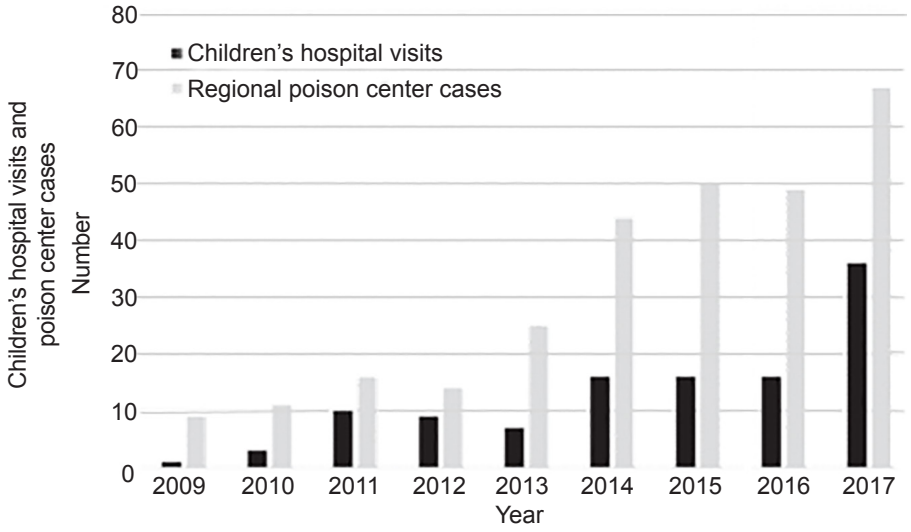


**Figure 8:** Colorado pediatric marijuana exposures (ages 0-9) to a tertiary-care children's hospital, and regional poison control center cases by year.[105]

object such as a nail, which even further concentrates THC content over 90%.[112]

Preparation of these concentrated products has also led to fires and explosion injuries in amateur production attempts in garages, tool sheds, and vacant homes.[113,114] In Colorado 29 patients with butane hash-oil burns were admitted to the University of Colorado Burn Center from 2008-2014. Zero cases presented prior to medical liberalization, 19 during medical liberalization (October 2009–December 2013), and 12 from January–June 2014 at the study's conclusion. (Two patients had four total visits.) The median total body surface area (TBSA) burn size was 10% (TBSA range 1-90%). Median length of hospital admission was 10 days. Six required intubation for airway protection while 19 required skin grafting.[115]

*Marijuana Shop Employees Providing Medical Advice*

Marijuana shop employees not trained in medicine or pharmacology are giving medical advice that may be harmful to patients. A recent study in Colorado found that employees are giving medical advice 70% of the time to use cannabis for treatment of nausea and vomiting in pregnancy and few dispensaries encouraged discussion with a healthcare provider without prompting.[116] The author has personally had patients bring in products recommended by dispensary workers with a recommended potency and frequency of use and report being advised to stop their usual medications and use the cannabis product instead. Cannabis dispensaries provide medical advice and offer treatment without medical training even when this may harm the patient.

**Potential Medicinal Uses of Cannabis**

There are potential therapeutic intervention targets for cannabinoids. In general, these therapeutic targets require a high ratio of cannabidiol compounds (CBD- cited to decrease or eliminate the psychoactive effects of THC), and are from products that significantly differ from those found in commercial dispensaries. The NASEM report found substantial evidence that cannabis or cannabinoids are effective for the treatment of chronic pain in adults, as an antiemetic for chemotherapy-induced nausea and vomiting, and for improving patient-reported multiple sclerosis spasticity symptoms. They also found moderate evidence that cannabis or cannabinoids are effective for improving short-term sleep outcomes associated with obstructive sleep apnea, fibromyalgia, chronic pain, and multiple sclerosis.[10] Studies have also demonstrated that cannabinoids may improve cardiovascular outcomes.[92,117]

Likely the most significant treatment implication has been in patients with refractory epilepsy, most commonly in patients with Dravet's syndrome and Lennox-Gestault syndrome, but also in other patients. This has led to the U.S. Food and Drug Administration approving Epidiolex (a high concentration CBD cannabinoid treatment) in June 2018 for the treatment of Dravet's syndrome and Lennox-Gestault syndrome.[118-120] Despite these potential medicinal uses, current Colorado legal distribution of cannabis products goes through an intermediary budtender before making it to the patient which may not consistently promote therapeutic benefit; there is insufficient training of dispensary staff to serve this purpose.

**Variations in Potency, Bias in Studies, and Conflicting Laws Confuse Consumers and Impair Research**

The potential positive health effects of cannabis rest on which of the multiple species and hybrids are studied and their specific chemical composition. One of the difficulties in determining the physiological effects of cannabis is that "marijuana," or "cannabis," can refer to multiple species of plants with widely varying chemical compounds and corresponding variable physiological effects. The cannabis genus includes multiple species, most commonly *Cannabis sativa* and *Cannabis indica*, and within those are hybrids specifically developed by growers to achieve a specific effect. For example, the commonly used term, hemp, refers to a variety of *Cannabis sativa* that is fast growing and can be spun into usable fiber for paper, textiles, clothing, biofuel, animal feed, and other industrial uses. Hemp has low concentrations of THC (less than 0.3%) and higher concentrations of CBD.

The differences in composition offer different potential treatment effects. For example, the effect for pain control cited in the NASEM review was primarily found with nabiximols (Sativex), a cannabis extract mouth spray that delivers a dose of 2.7 mg of THC and 2.5 mg of CBD.[121] For comparison, a typical marijuana cigarette or joint contains 0.5 g of marijuana and THC content ranges from 12-23%; therefore, a typical joint contains 60-115 mg of THC, 20-40 times the medicinal dose. The NASEM cautioned that many of the cannabis products sold in state-regulated markets bear little resemblance to those available for research at the federal level in the U.S.[10] This is further complicated in that commonly sold cannabis products are often mislabeled for CBD and THC content. One study showed only 17% of dispensary products were accurately labeled.[122,123] Scientific studies, particularly for treatment of pain, have been limited by a substantial bias, and results have varied.[124,125] Some demonstrate improvement in pain[10] with coinciding decreases in opiate abuse,[10,57,126] while others show the opposite.[123,125,127,128]

The conflict between federal and state laws on the medical use of cannabis products, the lack of consistency among state laws, and the availability of artisanal products in dispensaries, with high variability between composition of products, have caused significant confusion for researchers and limited the ability to fully and accurately research the true effects of commonly available dispensary cannabis products.[129]

## LIMITATIONS

This was not a systematic review of the literature but rather a summary of selected research including several large reviews from the NASEM, the WHO, and the CDPHE. There is undoubtedly much literature, some of it conflicting, not cited here. However, as other states and countries wrestle with decriminalization and legalization of cannabis for personal use and sale, it is crucial to report the Colorado experience as a cautionary tale. This review summarizes a large body of research for practicing emergency physicians who are increasingly confronted with questions and patients who use cannabis. Although the author practices in Colorado, the information is likely generalizable. This review clearly reflects the author's biases, yet its composition was motivated by alarming experience in everyday practice.

Discussions of cannabis' effects are relevant not only to the healthcare system, but to legal, business, environmental, legislative, and other branches within a public health framework. This article does not address those other facets. Neither have numerous other physiological effects of cannabis been reviewed here. Many of the previous research studies have focused on cannabis with a much lower THC level limiting applicability to cannabis sold at dispensaries today. Finally, the words "marijuana" and "cannabis" were used interchangeably throughout the article. This was done to maintain the wording from the studies cited consistent with their original language. No difference should be implied with the alternating use of these terms.

## CONCLUSION

Cannabis legalization has led to significant health consequences, particularly to EDs and hospitals in Colorado. The most concerning include psychosis, suicide, and other substance abuse. There are deleterious effects on the brain and some of these may not be reversible with abstinence. Other significant health effects include increases in fatal motor vehicle collisions, adverse effects on cardiovascular and pulmonary systems, inadvertent pediatric exposures, cannabis contaminants exposing users to infectious agents, heavy metals, and pesticides, and hash-oil burn injuries due to preparation of concentrates. Finally, cannabis dispensary workers not trained in medicine are giving medical advice that could be harmful to patients.

Cannabis research may offer opportunities for novel treatment of seizures, spasticity from multiple sclerosis, nausea and vomiting from chemotherapy, chronic pain, improvements in cardiovascular outcomes, and sleep disorders. However, progress has been difficult due to absent standardization of the chemical composition of cannabis products and limitations on research secondary to federal classification of cannabis. Given these factors and the Colorado experience, other states should carefully evaluate whether and how to decriminalize or legalize non-medical cannabis use.

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*Conflicts of Interest*: By the WestJEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. 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. Colorado Division of Criminal Justice Department of Public Safety. Impacts of marijuana legalization in colorado: A report pursuant to senate bill 13-283 2018. Available at: https://cdpsdocs.state.co.us/ors/docs/reports/2018-SB13-283_Rpt.pdf. Accessed November 2018.
2. Ogden Memo: Investigations and Prosecutions in States Authorizing the Medical Use of Marijuana 2009. Available at: https://www.justice.gov/archives/opa/blog/memorandum-selected-united-state-attorneys-investigations-and-prosecutions-states. Accessed November 2018.
3. Cole, Memo: Guidance Regarding Marijuana Enforcement 2013. Available at: https://www.justice.gov/iso/opa/resources/305201382913275685746 7.pdf. Accessed November 2018.
4. Sessions nixes Obama-era rules leaving states alone that legalize pot 2018. Available at: https://www.cnn.com/2018/01/04/politics/jeff-sessions-cole-memo/index.html. Accessed January 2018.
5. Interactive NSDUH State Estimates: Substance Abuse & Mental Health Data Archives 2015. Available at: https://pdas.samhsa.gov/saes/state. Accessed November 2018.
6. The health and social effects of non-medical cannabis use 2016. Available at: http://apps.who.int/iris/bitstream/10665/251056/1/9789241510240-eng.pdf?ua=1. Accessed March 2016.
7. Wang GS, Hall K, Vigil D, et al. Marijuana and acute health care contacts in Colorado. *Prev Med*. 2017;104:24-30.
8. Marijuana legalization in Colorado: early findings. A report pursuant to Senate Bill 13-283 2016. Available at: https://cdpsdocs.state.co.us/ors/docs/reports/2016-SB13-283-Rpt.pdf. Accessed August 6, 2018.
9. Wang GS, Davies SD, Halmo LS, et al. Impact of Marijuana Legalization in Colorado on Adolescent Emergency and Urgent Care Visits. *J Adolesc Health.* 2018;63(2):239-41.
10. National Academies of Sciences, Engineering, and Medicine. The Health Effects of Cannabis and Cannabinoids: Current State of Evidence

and Recommendations for Research. Washington, DC: The National Academies Press 2017.

11. Andréasson S, Allebeck P, Engstrom A, et al. Cannabis and schizophrenia. A longitudinal study of Swedish conscripts. *Lancet*. 1987;330(8574):1483-6.
12. Zammit S, Allebeck P, Andreasson S, et al. Self reported cannabis use as a risk factor for schizophrenia in Swedish conscripts of 1969: historical cohort study. *BMJ*. 2002;325(7374):1199.
13. van Os J, Bak M, Hanssen M, et al. Cannabis use and psychosis: a longitudinal population-based study. *Am J Epidemiol*. 2002;156(4):319-27.
14. Henquet C, Krabbendam L, Spauwen J,et al. Prospective cohort study of cannabis use, predisposition for psychosis, and psychotic symptoms in young people. *BMJ*. 2004;330(7481):11.
15. Arseneault L, Cannon M, Poulton R, et al. Cannabis use in adolescence and risk for adult psychosis: longitudinal prospective study. *BMJ*. 2002;325(7374):1212-3.
16. Fergusson DM, Horwood LJ, Swain-Campbell NR. Cannabis dependence and psychotic symptoms in young people. *Psychol Med*. 2003;33(1):15-21.
17. Stefanis NC, Dragovic M, Power BD, et al. The effect of drug use on the age at onset of psychotic disorders in an Australian cohort. *Schizophr Res*. 2014;156(2–3):211-6.
18. Moore TH, Zammit S, Lingford-Hughes A, et al. Cannabis use and risk of psychotic or affective mental health outcomes: a systematic review. *Lancet*. 2007;370(9584):319-28.
19. Libuy N, Angel V, Ibáñez C. Risk of schizophrenia in marijuana users: findings from a nationwide sample of drug users in Chile. 2015. *National Institute on Drug Abuse*.
20. Di Forti M, Sallis H, Allegri F, et al. Daily use, especially of high-potency cannabis, drives the earlier onset of psychosis in cannabis users. *Schizophr Bull*. 2014;40(6):1509-17.
21. Lev-Ran S, Roerecke M, Le Foll B, et al. The association between cannabis use and depression: a systematic review and meta-analysis of longitudinal studies. *Psychol Med*. 2014;44(4):797-810.
22. Kedzior KK, Laeber LT. A positive association between anxiety disorders and cannabis use or cannabis use disorders in the general population - a meta-analysis of 31 studies. *BMC Psychiatry*. 2014;14:136.
23. Borges G, Bagge CL, Orozco R. A literature review and meta-analyses of cannabis use and suicidality. *J Affect Disord*. 2016;195:63-74.
24. Suicides in Colorado: methods, circumstances, and toxicology. Colorado Violent Death Reporting System 2016. Available at: https://cohealthviz.dphe.state.co.us/t/HSEBPublic/views/CoVDRS_12_1_17/Story1?:embed=y&:showAppBanner=false&:showShareOptions=true&:display_count=no&:showVizHome=no#4. Accessed August 2018.
25. Implications of legalized cannabis in Colorado emergency departments, Colorado Department of Public Health and Environment. Available at: https://drive.google.com/file/d/126A5GxdZWp2375pU14iXFq2T3s9ubZSl/view. Accessed July 11, 2018.
26. Danielsson A, Falkstedt D, Hemmingsson T, et al. Cannabis use among Swedish men in adolescence and the risk of adverse life course outcomes: results from a 20-year follow-up study. *Addiction.* 2015;110(11):1794-802.
27. Fergusson DM, Boden JM. Cannabis use and later life outcomes. *Addiction*. 2008;103(6):969-76.
28. Fergusson DM, Boden JM, Horwood LJ. Psychosocial sequelae of cannabis use and implications for policy: findings from the Christchurch Health and Development Study. *Soc Psychiatry Psychiatr Epidemiol*. 2015;50(9):1317-26.
29. Zhang C, Brook JS, Leukefeld CG, et al. Trajectories of marijuana use from adolescence to adulthood as predictors of unemployment status in the early forties. *Am J Addict*. 2016;25(3):203-9.
30. Volkow ND, Baler RD, Compton WM, et al. Adverse health effects of marijuana use. *N Engl J Med*. 2014;370(23):2219-27.
31. Hall W, Degenhardt L. Adverse health effects of non-medical cannabis use. *Lancet*. 2009;374(9698):1383-91.
32. Sagar KA, Gruber SA. Marijuana matters: reviewing the impact of marijuana on cognition, brain structure and function, & exploring policy implications and barriers to research. *Int Rev Psychiatry*. 2018;30(3):251-67.
33. Memedovich KA, Dowsett LE, Spackman E, et al. The adverse health effects and harms related to marijuana use: an overview review. *CMAJ Open*. 2018;6(3):E339-46.
34. Batalla A, Bhattacharyya S, Yücel M, et al. Structural and functional imaging studies in chronic cannabis users: a systematic review of adolescent and adult findings. *PLoS One*. 2013;8(2):e55821.
35. Lorenzetti V, Lubman DI, Whittle S, Solowij N, et al. Structural MRI findings in long-term cannabis users: what do we know? *Subst Use Misuse*. 2010;45(11):1787-808.
36. Rocchetti M, Crescini A, Borgwardt S, et al. Is cannabis neurotoxic for the healthy brain? A meta-analytical review of structural brain alterations in non-psychotic users. *Psychiatry Clin Neurosci*. 2013;67(7):483-92.
37. Cousijn J, Wiers RW, Ridderinkhof KR, et al. Grey matter alterations associated with cannabis use: results of a VBM study in heavy cannabis users and healthy controls. *NeuroImage*. 2012;59(4):3845-51.
38. Yücel M, Solowij N, Respondek C, et al. Regional brain abnormalities associated with long-term heavy cannabis use. *Arch Gen Psychiatry*. 2008;65(6):694-701.
39. Churchwell J, Lopez-Larson M, Yurgelun-Todd D. Altered frontal cortical volume and decision making in adolescent cannabis users. *Front Psychol.* 2010;1:225.
40. Gruber SA, Yurgelun-Todd DA. Neuroimaging of marijuana smokers during inhibitory processing: a pilot investigation. *Brain Res Cogn Brain Res.* 2005;23(1):107-18.
41. Wrege J, Schmidt A, Walter A, Smieskova R, et al. Effects of cannabis on impulsivity: a systematic review of neuroimaging findings. *Curr Pharm Des.* 2014;20(13)2126-37.
42. Blanco-Hinojo L, Pujol J, Harrison BJ, et al. Attenuated frontal and sensory inputs to the basal ganglia in cannabis users. *Addict Biol.* 2017;22(4):1036-47.
43. Filbey F, Yezhuvath U. Functional connectivity in inhibitory control networks and severity of cannabis use disorder. *Am J Drug Alcohol.* Abuse 2013;39(6):382-91.

44. Camchong J, Lim KO, Kumra S. Adverse effects of cannabis on adolescent brain development: a longitudinal study. *Cerebral Cortex.* 2017;27(3):1922-30.
45. Fischer AS, Whitfield-Gabrieli S, Roth RM, et al. Impaired functional connectivity of brain reward circuitry in patients with schizophrenia and cannabis use disorder: Effects of cannabis and THC. *Schizophr Res*. 2014;158(1):176-82.
46. Zalesky A, Solowij N, Yücel M, et al. Effect of long-term cannabis use on axonal fibre connectivity. *Brain.* 2012;135(7):2245-55.
47. Colizzi M, McGuire P, Pertwee RG, et al. Effect of cannabis on glutamate signalling in the brain: a systematic review of human and animal evidence. *Neurosci Biobehav Rev*. 2016;64:359-81.
48. Sami MB, Rabiner EA, Bhattacharyya S. Does cannabis affect dopaminergic signaling in the human brain? A systematic review of evidence to date. *Eur Neuropsychopharmacol*. 2015;25(8):1201-24.
49. Sneider JT, Mashhoon Y, Silveri MM. A review of magnetic resonance sepctroscopy studies in marijuana using adolescents and adults. *J Addict Res Ther*. 2013;4(10).
50. Swift W, Coffey C, Degenhardt L, et al. Cannabis and progression to other substance use in young adults: Findings from a 13-year prospective population-based study. *J Epidemiol Community Health.* 2012;66(7):e26.
51. Silins E, Swift W, Slade T, et al. A prospective study of the substance use and mental health outcomes of young adult former and current cannabis users. *Drug Alcohol Rev*. 2017;36(5):618-25.
52. Taylor M, Collin SM, Munafò M,R., et al. Patterns of cannabis use during adolescence and their association with harmful substance use behaviour: findings from a UK birth cohort. *J Epidemiol Community Health*. 2017;71(8):764-70.
53. Agrawal A, Neale M, Prescott C, et al. A twin study of early cannabis use and subsequent use and abuse/dependence of other illicit drugs. *Psychol Med.* 2004;34(7)1227-37.
54. Grant JD, Lynskey MT, Scherrer JF, et al. A co-twin control analysis of drug use and abuse/dependence risk associated with early-onset cannabis use. *Addict Behav*. 2010;35(1):35-41.
55. Lynskey MT, Heath AC, Bucholz KK, et al. Escalation of drug use in early-onset cannabis users vs co-twin controls. *JAMA*. 2003;289(4):427-33.
56. Lynskey MT, Vink JM, Boomsma DI. Early onset cannabis use and progression to other drug use in a sample of Dutch twins. *Behav Genet*. 2006;36(2):195-200.
57. Bachhuber M, Saloner B, Cunningham C, et al. Medical cannabis laws and opioid analgesic overdose mortality in the United States, 1999-2010. *JAMA Intern Med*. 2014;174(10):1668-73.
58. Livingston MD, Barnett TE, Delcher C, et al. Recreational cannabis legalization and opioid-related deaths in Colorado, 2000–2015. *Am J Public Health*. 2017;107(11):1827-9.
59. Cadoni C, Pisanu A, Solinas M, et al. Behavioural sensitization after repeated exposure to Î”9-tetrahydrocannabinol and cross-sensitization with morphine. *Psychopharmacology (Berl).* 2001;158(3):259-66.
60. Panlilio LV, Zanettini C, Barnes C, et al. Prior exposure to THC increases the addictive effects of nicotine in rats. *Neuropsychopharmacology*. 2013;38(7):1198-208.
61. Pistis M, Perra S, Pillolla G, et al. Adolescent exposure to cannabinoids induces long-lasting changes in the response to drugs of abuse of rat midbrain dopamine neurons. *Biol Psychiatry.* 2004;56(2):86-94.
62. Cadoni C, Valentini V, Di Chiara G. Behavioral sensitization to Δ9-tetrahydrocannabinol and cross-sensitization with morphine: Differential changes in accumbal shell and core dopamine transmission. *J Neurochem.* 2008;106(4):1586-93.
63. Ledent C, Valverde O, Cossu G, et al. Unresponsiveness to cannabinoids and reduced addictive effects of opiates in $CB_1$ receptor knockout mice. *Science.* 1999;283(5400):401-4.
64. van der Pol P, Liebregts N, de Graaf R, et al. Predicting the transition from frequent cannabis use to cannabis dependence: a three-year prospective study. *Drug Alcohol Depend*. 2016;133(2):352-9.
65. Swift W, Coffey C, Carlin JB, et al. Adolescent cannabis users at 24 years: trajectories to regular weekly use and dependence in young adulthood. *Addiction*. 2008;103(8):1361-70.
66. Lopez-Quintero C, Perez de los Cobos J, Hasin DS, et al. Probability and predictors of transition from first use to dependence on nicotine, alcohol, cannabis, and cocaine: results of the National Epidemiologic Survey on Alcohol and Related Conditions (NESARC). *Drug Alcohol Depend.* 2010;115(1-2):120-30.
67. Hasin DS, Saha TD, Kerridge BT, et al. Prevalence of marijuana use disorders in the United States between 2001-2002 and 2012-2013. *JAMA Psychiatry.* 2015;72(12):1235-42.
68. Lapoint J, Meyer S, Yu CK, et al. Cannabinoid hyperemesis syndrome: public health implications and a novel model treatment guideline. *West J Emerg Med.* 2017;19(2):380-6.
69. Sorensen C, DeSanto K, Borgelt L, et al. Cannabinoid hyperemesis syndrome: diagnosis, pathophysiology, and treatment—a systematic review. *J Med Toxicol*. 2017;13(1):71-87.
70. Parekh JD, Wozniak SE, Khan K, et al. Cannabinoid hyperemesis syndrome. *BMJ Case Rep*. 2016;bcr2015213620.
71. Kim HS, Anderson JD, Saghafi O, et al. Cyclic vomiting presentations following marijuana liberalization in Colorado. *Acad Emerg Med.* 2015;22(6):694-9.
72. Hernandez JM, Paty J, Price IM. Cannabinoid hyperemesis syndrome presentation to the emergency department: a two-year multicentre retrospective chart review in a major urban area. *CJEM*. 2018;20(4):550-5.
73. Salomonsen-Sautel S, Min S, Sakai JT, et al. Trends in fatal motor vehicle crashes before and after marijuana commercialization in Colorado. *Drug Alcohol Depend*. 2014;140:137-44.
74. Drugged driving statistics [Internet]; c2016 [cited 2018 07/11]. Available at: https://www.codot.gov/safety/alcohol-and-impaired-driving/druggeddriving/drugged-driver-statistics/view. Accessed July 2018.
75. Monitoring health concerns related to marijuana in Colorado: 2016 changes in marijuana use patterns, systematic literature review, and possible marijuana-related health effects [Internet]; c2016 [cited 2018 August 8]. Available at: https://www.colorado.gov/pacific/cdphe/retail-

marijuana-public-health-advisory-committee. Accessed August 2018.
76. Asbridge M, Hayden JA, Cartwright JL. Acute cannabis consumption and motor vehicle collision risk: systematic review of observational studies and meta-analysis. *BMJ*. 2012;344:e536.
77. Aydelotte JD, Brown LH, Luftman KM, et al. Crash fatality rates after recreational marijuana legalization in Washington and Colorado. *Am J Public Health.* 2017;107(8):1329-31.
78. Alfulaij N, Meiners F, Michalek J, et al. Cannabinoids, the heart of the matter. *J Am Heart Assoc*. 2018;7(14):e009099.
79. Hodcroft CJ, Rossiter MC, Buch AN. Cannabis-associated myocardial infarction in a young man with normal coronary arteries. *J Emerg Med.* 2014;47(3):277-81.
80. Velibey Y, Sahin S, Tanık O, et al. Acute myocardial infarction due to marijuana smoking in a young man: guilty should not be underestimated. *Am J Emerg Med*. 2015;33(8):1114.e1-3.
81. Caldicott DGE, Holmes J, Roberts-Thomson K, et al. Keep off the grass: marijuana use and acute cardiovascular events. *Eur J Emerg Med*. 2005;12(5):236-44.
82. Hackam DG. Cannabis and stroke: systematic appraisal of case reports. *Stroke*. 2015;46(3):852-6.
83. Mittleman MA, Lewis RA, Malcolm M, et al. Triggering myocardial infarction by marijuana. *Circulation*. 2001;103(23):2805-9.
84. Patel RS, Katta SR, Patel R, et al. Cannabis use disorder in young adults with acute myocardial infarction: trend inpatient study from 2010 to 2014 in the United States. *Cureus.* 2018;10(8):e3241.
85. Wang X, Derakhshandeh R, Liu J, et al. One minute of marijuana secondhand smoke exposure substantially impairs vascular endothelial function. *J Am Heart Assoc*. 2016;5(8).
86. Singh A, Saluja S, Kumar A, et al. Cardiovascular complications of marijuana and related substances: a review. *Cardiol Ther.* 2018;7(1):45-59.
87. Benowitz NL, Rosenberg J, Rogers W, et al. Cardiovascular effects of intravenous delta-9-tetrahydrocannabinol: autonomic nervous mechanisms. *Clin Pharmacol Ther.* 1979;25(4):440-6.
88. Gash A, Karliner JS, Janowsky D, et al. Effects of smoking marihuana on left ventricular performance and plasma norepinephrine: studies in normal men. *Ann Intern Med.* 1978;89(4):448-52.
89. Jones RT. Cardiovascular system effects of marijuana. *J Clin Pharmacol*. 2002;42(S1):58S-63S.
90. Wu T, Tashkin DP, Djahed B, et al. Pulmonary hazards of smoking marijuana as compared with tobacco. *N Engl J Med*. 1988;318(6):347-51.
91. Aronow WS, Cassidy J. Effect of marihuana and placebo-marihuana smoking on angina pectoris. *N Engl J Med.* 1974;291(2):65-7.
92. Goyal H, Awad HH, Ghali JK. Role of cannabis in cardiovascular disorders. *J Thorac Dis*. 2017;9(7):2079-92.
93. Malinowska B, Baranowska-Kuczko M, Schlicker E. Triphasic blood pressure responses to cannabinoids: Do we understand the mechanism? *Br J Pharmacol.* 2012;165(7):2073-88.
94. Ducros A, Boukobza M, Porcher R, et al. The clinical and radiological spectrum of reversible cerebral vasoconstriction syndrome. A prospective series of 67 patients. *Brain*. 2007;130(Pt 12):3091-101.
95. Disdier P, Granel B, Serratrice J, et al. Cannabis arteritis revisited: ten new case reports. *Angiology.* 2001;52(1):1-5.
96. Thomas G, Kloner RA, Rezkalla S. Adverse cardiovascular, cerebrovascular, and peripheral vascular effects of marijuana inhalation: what cardiologists need to know. *Am J Cardiol*. 2014;113(1):187-90.
97. Herning RI, Better WE, Tate K, et al. Cerebrovascular perfusion in marijuana users during a month of monitored abstinence. *Neurology.* 2005;64(3):488-93.
98. Quercioli A, Pataky Z, Vincenti G, et al. Elevated endocannabinoid plasma levels are associated with coronary circulatory dysfunction in obesity. *Eur Heart J*. 2011;32(11):1369-78.
99. Lipina C, Hundal HS. Modulation of cellular redox homeostasis by the endocannabinoid system. *Open Biol.* 2016;6(4):150276.
100. Williams JC, Klein TW, Goldberger BA, et al. Delta(9)-tetrahydrocannabinol (THC) enhances lipopolysaccharide-stimulated tissue factor in human monocytes and monocyte-derived microvesicles. *J Inflamm (Lond)*. 2015;12:39.
101. Deusch E, Kress HG, Kraft B, Kozek-Langenecker SA. The procoagulatory effects of delta-9-tetrahydrocannabinol in human platelets. *Anesth Analg*. 2004;99(4):1127,30.
102. Tetrault JM, Crothers K, Moore BA, et al. Effects of marijuana smoking on pulmonary function and respiratory complications: a systematic review. *Arch Intern Med*. 2007;167(3):221-8.
103. Aldington S, Williams M, Nowitz M, et al. Effects of cannabis on pulmonary structure, function and symptoms. *Thorax*. 2007;62(12):1058-63.
104. Wang G, Le Lait M, Deakyne SJ, et al. Unintentional pediatric exposures to marijuana in Colorado, 2009-2015. *JAMA Pediatr.* 2016;170(9):e160971.
105. Wang GS, Hoyte C, Roosevelt G, et al. The continued impact of marijuana legalization on unintentional pediatric exposures in Colorado. *Clin Pediatr (Phila)*. 2019;58(1):114-6.
106. Vo KT, Horng H, Li K, et al. Cannabis Intoxication Case Series: The dangers of edibles containing tetrahydrocannabinol. *Ann Emerg Med.* 2018;71(3):306-13.
107. Dryburgh LM, Bolan NS, Grof CPL, et al. Cannabis contaminants: sources, distribution, human toxicity and pharmacologic effects. *Br J Clin Pharmacol.* 2018;84(11):2468-76.
108. Russo EB. Current therapeutic cannabis controversies and clinical trial design issues. *Front in Pharmacol*. 2016;7:309.
109. Chandra S, Radwan MM, Majumdar CG, et al. New trends in cannabis potency in USA and Europe during the last decade (2008-2017). *Eur Arch Psychiatry Clin Neurosci.* 2019;269(1):5-15.
110. Raber JC, Elzinga S, Kaplan C. Understanding dabs: contamination concerns of cannabis concentrates and cannabinoid transfer during the act of dabbing. *J Toxicol Sci.* 2015;40(6):797-803.
111. Pierre JM, Gandal M, Son M. Cannabis-induced psychosis associated with high potency "wax dabs." *Schizophr Res.* 2016;172(1-3):211-2.
112. Cinnamon Bidwell L, YorkWilliams SL, Mueller RL, et al. Exploring cannabis concentrates on the legal market: user profiles, product

strength, and health-related outcomes. *Addict Behav Rep*. 2018;8:102-6.
113. Al-Zouabi I, Stogner JM, Miller BL, et al. Butane hash oil and dabbing: insights into use, amateur production techniques, and potential harm mitigation. *Subst Abuse Rehabil*. 2018;9:91-101.
114. Romanowski KS, Barsun A, Kwan P, et al. Butane hash oil burns: a 7-year perspective on a growing problem. *J Burn Care Res.* 2017;38(1):e165-71.
115. Bell C, Slim J, Flaten HK, et al. Butane hash oil burns associated with marijuana liberalization in Colorado. *J Med Toxicol*. 2015;11(4):422-5.
116. Dickson B, Mansfield C, Guiahi M, et al. Recommendations from cannabis dispensaries about first-trimester cannabis use. *Obstet & Gynecol.* 2018;131(6)1031-8.
117. Eid BG. Cannabinoids for treating cardiovascular disorders: putting together a complex puzzle. *J Microsc Ultrastruct.* 2018;6(4):171-6.
118. Devinsky O, Cross JH, Laux L, et al. Trial of cannabidiol for drug-resistant seizures in the Dravet syndrome. *N Engl J Med.* 2017;376:2011-20.
119. Thiele EA, Marsh ED, French JA, et al. Cannabidiol in patients with seizures associated with lennox-gastaut syndrome (GWPCARE4): a randomised, double-blind, placebo-controlled phase 3 trial. *Lancet.* 2018;391(10125):1085-96.
120. Medical marijuana and epilepsy 2018. Available at: https://www.epilepsy.com/learn/treating-seizures-and-epilepsy/other-treatment-approaches/medical-marijuana-and-epilepsy. Accessed July 2018.
121. Sativex oromucosal spray 2015. Available at: https://www.medicines.org.uk/emc/product/602/smpc. Accessed July 11, 2018.
122. Bonn-Miller MO, Loflin ME, Thomas BF, et al. Labeling accuracy of cannabidiol extracts sold online. *JAMA*. 2017;318(17):1708-9.
123. Vandrey R, Raber JC, Raber ME, et al. Cannabinoid dose and label accuracy in edible medical cannabis products. *JAMA*. 2015;313(24):2491-3.
124. Mücke M, Phillips T, Radbruch L, et al. Cannabis-based medicines for chronic neuropathic pain in adults. *Cochrane Database Syst Rev.* 2018;3:CD012182.
125. Hall W, West R, Marsden J, et al. It is premature to expand access to medicinal cannabis in hopes of solving the US opioid crisis. *Addiction.* 2018;113(6):987-8.
126. Wen H, Hockenberry JM. Association of medical and adult-use marijuana laws with opioid prescribing for Medicaid enrollees. *JAMA Intern Med.* 2018;178(5):673-9.
127. Campbell G, Hall WD, Peacock A, et al. Effect of cannabis use in people with chronic non-cancer pain prescribed opioids: findings from a 4-year prospective cohort study. *Lancet Public Health*. 2018;3(7):e341-50.
128. Olfson M, Wall MM, Liu S, et al. Cannabis use and risk of prescription opioid use disorder in the United States. *Am J Psychiatry.* 2017;175(1):47-53.
129. Mead A. The legal status of cannabis (marijuana) and cannabidiol (CBD) under U.S. law. *Epilepsy Behav*. 2017;70(Pt B):288-91.

# Evidence-Informed Practice: Diagnostic Questions in Urinary Tract Infections in the Elderly

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*Section Editor:* Kathleen Walsh, DO
Submission history: Submitted December 27, 2018; Revision received May 6, 2019; Accepted May 1, 2019
Electronically published June 11, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.5.42096

**Introduction:** Routine interventions in the practice of medicine often lack definitive evidence or are based on evidence that is either not high quality or of only modest-to-marginal effect sizes. An abnormal urinalysis in an elderly patient presenting to the emergency department (ED) with non-specific symptoms represents one condition that requires an evidence-informed approach to diagnosis and management of either asymptomatic bacteriuria or urinary tract infection (UTI). The emergency provider often will not have access to urine cultures, and the risks associated with antibiotic use in the elderly are not without potentially significant side effects.

**Methods:** We performed a historical and clinical review of the growing body of literature suggesting measurable differences in the systemic immune response manifest among patients with asymptomatic pyuria and UTI, including increases in the pro-inflammatory cytokine interleukin-6 and the acute phase reactant procalcitonin.

**Results:** Serum procalcitonin, a peptide that undergoes proteolysis into calcitonin, has been demonstrated to quickly and reliably rise in patients with severe bacterial infections, and may serve as a potentially sensitive and specific marker for identification of bacterial illness.

**Conclusion:** In the absence of validated risk scores for diagnosing UTI in elderly patients presenting to the ED, there may be a role for the use of procalcitonin in this patient population. [West J Emerg Med. 2019;20(4)573-577.]

## INTRODUCTION

### Evidence-Based to Evidence-Informed Practice: The Clinical Reality

The evolution from eminence-based to evidence-based care has come to define bedside emergency medicine (EM), with rigorous skepticism and scholarly consideration accelerated by the power of global connectivity.[1] Where anecdote and opinion once drove therapy, clinicians now approach clinical conundrums with deliberate reflection, expecting – and at times demanding – ever-higher proof of perfection prior to implementing or incorporating therapies, tests, or approaches into their own practice. Such cogitation ensures excellence and safety and avoids pitfalls of over-adoption or confounding. Sackett originally defined this approach as evidence-based medicine, or the "use of current best evidence in making decisions about the care of individual patients...integrating individual clinical expertise" and honoring patients' values and preferences.[2] Unfortunately,

many of our daily decisions are made in a space devoid of definitive data.[3-8]

We thus are required to transition from the ideals of evidence-*based* medicine into the real and pragmatic world of evidence-*informed* medicine. It is at this precipice of real-world practice—where often studies and statistics do not exist, are not of high quality, or are of modest-to-marginal effect sizes—that we change, where we push forward the boundaries of care, and develop not only experience but the very questions that will define the next advances in EM. With this in mind, we sought to explore the clinical realities of the assessment and treatment of abnormal urinalyses in the elderly patient presenting with non-specific symptoms to the emergency department (ED).

## METHODS

We performed a historical and clinical review of the current literature on urinary tract infection (UTI) focusing on identifying and summarizing key trends relevant to the diagnosis of abnormal urinalyses in elderly patients with non-specific symptoms with a specific emphasis on the biomarker procalcitonin.

## RESULTS

### Asymptomatic Bacteriuria: Historical Perspective

Asymptomatic bacteriuria was first identified in the mid-1950s, when a series of autopsy reports identified chronic pyelonephritis as a common cause of renal failure, despite the fact that none of the deceased individuals had been diagnosed with a urinary tract infection while alive.[9] Such findings led researchers to declare, "there is now clear evidence that bacteriuria is one of the commonest human infections, that it may be chronic and persistent, that it may influence structure and function outside of the urinary tract, and that it plays an important role in disease from the cradle to the grave—from prematurity to hypertension and renal failure."[10] Since these observations, decades of antibiotics have been administered with frequency through the mouths, veins, and bladders of asymptomatic patients, all while several studies conclusively demonstrated that treatment of asymptomatic bacteriuria not only lacks benefit, but likely increases the short-term risk of pyelonephritis.[11]

### Asymptomatic Bacteriuria: Clinical Pearls in the Emergency Department

Asymptomatic bacteriuria is a microbiologic diagnosis defined as $>10^5$ colony-forming units per milliliter (cfu/mL) bacteria identified in two consecutive voided urine specimens (only one specimen needed for males).[12] It is incredibly common, affecting greater than 20% of healthy, elderly, community-dwelling women, and reaching a prevalence as high as 50% in institutionalized elderly females, and 100% in patients with indwelling catheters.[13] In the ED, without access to culture information, emergency providers are thus not confronted with asymptomatic bacteriuria, but rather asymptomatic *pyuria*, an even more prevalent and low-yield urinalysis usurper.

The clinical conundrum of the abnormal urinalysis in an elderly patient presenting with non-specific symptoms is a common occurrence.[14] While it is well-known that UTIs can cause malaise and mental status changes in elderly populations,[15] consistent clinical data suggest that the overwhelming percentage of "positive" urinalyses (UA) represent asymptomatic bacteriuria, and are neither truly indicative of UTI nor related to the patient's non-specific complaints.[16] Additionally, fixating on the "positive" UA can often cause clinicians to reach premature diagnostic closure and stop further investigations. Unfortunately, determining which UAs represent constitution-influencing infection and which are simple asymptomatic presentations is a difficult task in the ED, particularly when the patient lacks the cognitive or physical ability to relay typical symptoms such as dysuria, urinary frequency, or hesitancy.

Knowing that antibiotic treatment is of no value in non-pregnant patients with simple asymptomatic bacteriuria,[11,12] we strive to limit such unnecessary antimicrobials, which also bring risk of allergic reaction, increased antibiotic resistance, and iatrogenic injury ranging from *Clostridium difficile* colitis to renal injury.

Despite compelling data that treatment of asymptomatic bacteriuria lacks benefit, and growing evidence that non-specific symptoms in the elderly are generally *not* caused by UTIs,[16] these patients are overwhelmingly exposed to broad spectrum agents initiated in the ED or upon admission to the hospital.[17,18] It can be difficult for the emergency provider to avoid incorporating into the diagnostic framework the need for antibiotic stewardship with the real concerns of disease progression or missed infection treatment metrics. Even when restraint wins out in the ED, diagnostic equipoise often drives inpatient teams to start antibiotics. Strikingly, well-done surveys demonstrate that nearly half of physician respondents prescribe antibiotics for asymptomatic bacteriuria despite *knowing* a UA demonstrates asymptomatic bacteriuria and not true infection.[19] When clinicians are unable to elicit information on lower urinary tract symptoms from elderly patients with dementia, advanced cerebrovascular disease, or other impairments resulting in communication barriers, they are likely to initiate antimicrobial therapy in a well-intentioned effort to prevent progression and worsening infectious outcomes with anecdote of improvement perpetuating such practice.[20]

### Systemic Immune Response

Recognizing the difficulty in distinguishing true infection from asymptomatic bacteriuria, multiple authors have attempted to investigate differences in systemic immune response among these cohorts. In 2011, a group of researchers compared the levels of various inflammatory markers in urine samples before and after inoculation with *Escherichia coli*, noting a substantial increase in both white blood cells and polymorphonuclear neutrophils, a not uncommon

phenomenon in lab results seen in the ED.[21] Interestingly, however, levels of interleukin-6 (IL-6), a pro-inflammatory cytokine that is not only an acute phase reactant but also one of the major regulators of acute phase protein synthesis,[22,23] remained unchanged in this study.[21] The authors suggested that these findings support the hypothesis that a less-robust host immune response occurs among patients with asymptomatic bacteriuria compared to those with symptomatic infection.

A subsequent study exploring the role of IL-6 and heparin binding-protein (HBP), a protein released from activated neutrophils during infection[24] and previously shown to be associated with UTIs,[25] a 2016 investigation enrolled asymptomatic, elderly, nursing home residents and matched them with patients living in the community or at nursing homes with symptomatic UTI.[26] In this study, urinary IL-6, but not HBP, reliably distinguished between patients with cystitis or asymptomatic bacteriuria, adding further to the growing observational literature that there is a fundamental *and measurable* difference in the body's immune reaction in cases of true infection compared to colonization.[26]

**Procalcitonin and Urinary Tract Infection**

Perhaps one of the most hotly debated acute phase reactants, procalcitonin, is the latest diagnostic darling in inpatient circles. Procalcitonin (the biologic precursor to calcitonin) reaches measurable serum concentrations quickly and reliably in the setting of bacterial infection.[27-29] Dozens of trials have reliably demonstrated procalcitonin's strong performance in decision support for antibiotic initiation or cessation; however, in the most salient ED investigation—the Procalcitonin Consensus Trial (ProACT) —procalcitonin failed miserably in limiting unnecessary antibiotic use.[30] Notably, however, such failure seemed more a function of clinician fears of untreated infection rather than a shortcoming of the test itself, an idiosyncrasy noted many times over in a myriad of editorials following publication of ProACT. The recently published HI-TEMP trial, however, applied PCT across a heterogeneous population and found no benefit in decreasing antibiotic use or significantly decreasing patient-oriented endpoints.[31] As many respondents to ProACT argued, though – and the trial authors seemed to agree with – the combination of this reassuring objective test with a concerted effort to limit unnecessary antibiotic use, or an antibiotic stewardship program, could be more effective in harnessing the diagnostic value of procalcitonin.[32-34]

**DISCUSSION**

We suggest that a considered and nuanced synthesis of this inflammatory marker in a well-defined clinical context is supported by a vibrant body of literature suggesting a role for procalcitonin in the diagnosis of true UTI. In one bench study, procalcitonin reliably increased with worsening urinary tract disease.[35] Additionally, one comprehensive review found procalcitonin to be a "key marker" in children with UTI.[36] When operationalized, serum procalcitonin was a good predictor of disease severity in a meta-analysis of prospective pediatric clinical trials of UTIs.[37] More recently, a randomized controlled trial (RCT) out of Switzerland randomized patients presenting to the ED with a UTI to a procalcitonin-pyuria-based (PCT-pyuria) algorithm or current guidelines (control group) for initiation and duration of antibiotic therapy.[38] In the intention-to-treat analysis, cumulative 90-day exposure to antibiotics was shorter in the PCT-pyuria group compared to the control, although with no changes in mortality and reinfections. In a 2015 *Cochrane* review assessing procalcitonin for diagnosing acute pyelonephritis in pediatric patients,[39] there were limited studies at the time of the review and marked heterogeneity of the included studies to recommend it for daily practice, although procalcitonin performed significantly better for ruling-in pyelonephritis compared to erythrocyte sedimentation rate or C-reactive protein.

It is important to note that procalcitonin can be elevated in any acute infectious circumstance and is not specific to a UTI. Therefore, an elevated procalcitonin level should not be equated to UTI and does not clinch the diagnosis of UTI. Pyuria in the setting of an elevated procalcitonin level may still represent asymptomatic bacteriuria with an alternate infectious process (i.e., meningitis, bacteremia, etc.). Clinicians should be cautious to avoid premature diagnostic closure in this circumstance. Furthermore, it should be noted that PCT levels may not rise with localized infections (septic arthritis, localized abscess, etc.), steroid use, and atypical bacteria,[40,41] and decisions regarding antimicrobial therapy should not be based solely on procalcitonin serum concentrations.

**Procalcitonin for Urinary Tract Infection in the Emergency Department**

The management morass of abnormal urinalyses in the elderly patient with nonspecific symptoms may represent an excellent opportunity for utilization of procalcitonin testing using an evidence-informed approach, ie, efforts undertaken in the absence of strict guiding data but supported and shepherded by complementary knowledge. Given the ambiguity of asymptomatic bacteriuria, a de-facto antibiotic stewardship effort is already underway in every hospital across the country, as well-meaning physicians strive to separate true infection from asymptomatic distractors. Where clinical complacency exists—an afebrile, non-toxic-appearing patient in whom the desire to spare unnecessary antibiotic use conflicts with the compulsion to not allow an indolent infection run rampant—a procalcitonin-augmented strategy might satisfy both imperatives.

This recommended strategy is not novel. As recently reported in the *American Journal of Emergency Medicine*, one retrospective analysis of UTIs found a negative predictive value of 91% for a low procalcitonin further bolstering the argument in favor of its use as an adjunct in the non-initiation of empiric antibiotics.[42] Even more compelling, a RCT of nearly 200 ED patients found that a procalcitonin-

based algorithm reduced antibiotic exposure by 30% without negative effects on clinical outcomes.[38] The introduction of procalcitonin in these departments served as a reliable and objective diagnostic marker and limited costly, harmful, and unnecessary exposure to antibiotics.

## LIMITATIONS

The use of procalcitonin in the work-up of UTI in elderly patients with an abnormal urinalysis presenting with non-specific symptoms requires further investigation ideally through a multicenter, RCT. Furthermore, this historical and clinical review was not systematic in its goal to describe the entirety of the use of procalcitonin; however, the purpose of this paper was to provide a succinct, narrative update of the latest research related to the use of biomarkers for diagnosing UTI for this patient population in the ED setting.

## CONCLUSION

Where definitive studies are lacking, nuance and rational integration of the literature is not only an option, but an imperative. The application of evidence-based medicine is at its easiest after large RCTs and rigorous analyses are popularized and widely disseminated. A true test of bedside Bayesianism, however, comes when the clinician is presented with clinical conundrums not yet thoroughly vetted and extensively analyzed. When no clear answer exists in the literature, we are forced to faithfully apply the best available knowledge to answer critical questions in real time in an ongoing attempt to correct shortcomings and pursue better care. No current rigorous trial has yet examined procalcitonin's performance in this narrow and nuanced framework, but the collated and considered information available suggests that adding this simple test likely provides a much-needed diagnostic beacon and can safely lead to better care in real-world applications.

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



## REFERENCES

1. Pescatore R, Salzman M, Cassidy-Smith T, et al. The benefits and risks of asynchronous education. *Acad Med*. 2015;90(9):1183.
2. Sackett DL, Rosenberg WM, Gray JA, et al. Evidence based medicine: what it is and what it isn't. *BMJ*. 1996;312(7023):71-2.
3. Ioannidis JP. Why most published research findings are false. *PLoS Med*. 2005;2(8):e124.
4. Ioannidis JP. Contradicted and initially stronger effects in highly cited clinical research. *JAMA*. 2005;294(2):218-28.
5. Prasad V, Vandross A, Toomey C, et al. A decade of reversal: an analysis of 146 contradicted medical practices. *Mayo Clin Proc*. 2013;88(8):790-8.
6. Pereira TV, Horwitz RI, Ioannidis JP. Empirical evaluation of very large treatment effects of medical interventions. *JAMA*. 2012;308(16):1676-84.
7. Fleming PS, Koletsi D, Ioannidis JP, et al. High quality of the evidence for medical and other health-related interventions was uncommon in Cochrane systematic reviews. *J Clin Epidemiol*. 2016;78:34-42.
8. Prasad V, Gall V, Cifu A. The frequency of medical reversal. *Arch Intern Med*. 2011;171(18):1675-6.
9. Freedman LR. Chronic pyelonephritis at autopsy. *Ann Intern Med*. 1967;66(4):697-710.
10. Kass EH. Pyelonephritis and bacteriuria. A major problem in preventive medicine. *Ann Intern Med*. 1962;56:46-53.
11. Nicolle LE. The paradigm shift to non-treatment of asymptomatic bacteriuria. *Pathogens*. 2016;5(2).
12. Nicolle LE, Bradley S, Colgan R, et al. Infectious Diseases Society of America guidelines for the diagnosis and treatment of asymptomatic bacteriuria in adults. *Clin Infect Dis*. 2005;40(5):643-54.
13. Nicolle LE. Asymptomatic bacteriuria. *Curr Opin Infect Dis*. 2014;27(1):90-6.
14. Frazee BW, Enriquez K, Ng V, et al. Abnormal urinalysis results are common, regardless of specimen collection technique, in women without urinary tract infections. *J Emerg Med*. 2015;48(6):706-11.
15. Gupta K, Grigoryan L, Trautner B. Urinary tract infection. *Ann Intern Med*. 2017;167(7):ITC49-64.
16. Caterino JM, Kline DM, Leininger R, et al. Nonspecific symptoms lack diagnostic accuracy for infection in older patients in the emergency department. *J Am Geriatr Soc*. 2019;67(3):484-92.
17. Gandhi T, Flanders SA, Markovitz E, et al. Importance of urinary tract infection to antibiotic use among hospitalized patients. *Infect Control Hosp Epidemiol*. 2009;30(2):193-5.
18. Khawcharoenporn T, Vasoo S, Ward E, et al. Abnormal urinalysis finding triggered antibiotic prescription for asymptomatic bacteriuria in the ED. *Am J Emerg Med*. 2011;29(7):828-30.
19. Lee MJ, Kim M, Kim N-H, et al. Why is asymptomatic bacteriuria overtreated?: A tertiary care institutional survey of resident physicians. *BMC Infect Dis*. 2015;15:289.
20. Miller J. To treat or not to treat: managing bacteriuria in elderly

people. *CMAJ*. 2001;164(5):619-20.
21. Grönberg-Hernández J, Hernández JG, Sundén F, Connolly J, Svanborg C, Wullt B. Genetic control of the variable innate immune response to asymptomatic bacteriuria. *PloS One*. 2011;6(11):e28289.
22. Castell JV, Gómez-Lechón MJ, David M, et al. Interleukin-6 is the major regulator of acute phase protein synthesis in adult human hepatocytes. *FEBS Lett*. 1989;242(2):237-9.
23. Gruys E, Toussaint MJ, Niewold TA, et al. Acute phase reaction and acute phase proteins. *J Zhejiang Univ Sci B*. 2005;6(11):1045-56.
24. Linder A, Christensson B, Herwald H, et al. Heparin-binding protein: an early marker of circulatory failure in sepsis. *Clin Infect Dis*. 2009;49(7):1044-50.
25. Kjölvmark C, Påhlman LI, Åkesson P, et al. Heparin-binding protein: a diagnostic biomarker of urinary tract infection in adults. *Open Forum Infect Dis*. 2014;1(1):ofu004.
26. Kjölvmark C, Tschernij E, Öberg J, et al. Distinguishing asymptomatic bacteriuria from urinary tract infection in the elderly - the use of urine levels of heparin-binding protein and interleukin-6. *Diagn Microbiol Infect Dis*. 2016;85(2):243-8.
27. Quadir AF, Britton PN. Procalcitonin and C-reactive protein as biomarkers for neonatal bacterial infection. *J Paediatr Child Health*. 2018;54(6):695-9.
28. Memar MY, Varshochi M, Shokouhi B, et al. Procalcitonin: the marker of pediatric bacterial infection. *Biomed Pharmacother*. 2017;96:936-43.
29. Taggart K, Nielsen S. Procalcitonin as a biomarker of bacterial infection. *S D Med*. 2016;69(8):370-1.
30. Huang DT, Yealy DM, Filbin MR, et al. Procalcitonin-guided use of antibiotics for lower respiratory tract infection. *N Engl J Med*. 2018;379(3):236-49.
31. van der Does Y, Limper M, Jie KE, et al. Procalcitonin-guided antibiotic therapy in patients with fever in a general emergency department population: a multicentre non-inferiority randomized clinical trial (HiTEMP study). *Clin Microbiol Infect*. 2018;24(12):1282-9.
32. Bremmer DN, Shively NR, Walsh TL. Procalcitonin-guided antibiotic use. *N Engl J Med*. 2018;379(20):1972.
33. Spellberg B, Gaffin N. Procalcitonin-guided antibiotic use. *N Engl J Med*. 2018;379(20):1972-3.
34. Pulia MS, Schulz LT, Fox BC. Procalcitonin-guided antibiotic use. *N Engl J Med*. 2018;379(20):1971-2.
35. Xu RY, Liu HW, Liu JL, et al. Procalcitonin and C-reactive protein in urinary tract infection diagnosis. *BMC Urol*. 2014;14:45.
36. Leroy S, Gervaix A. Procalcitonin: a key marker in children with urinary tract infection. *Adv Urol*. 2011;2011:397618.
37. Mantadakis E, Plessa E, Vouloumanou EK, et al. Serum procalcitonin for prediction of renal parenchymal involvement in children with urinary tract infections: a meta-analysis of prospective clinical studies. *J Pediatr*. 2009;155(6):875-81.e1.
38. Drozdov D, Schwarz S, Kutz A, et al. Procalcitonin and pyuria-based algorithm reduces antibiotic use in urinary tract infections: a randomized controlled trial. *BMC Med*. 2015;13:104.
39. Shaikh N, Borrell JL, Evron J, et al. Procalcitonin, C-reactive protein, and erythrocyte sedimentation rate for the diagnosis of acute pyelonephritis in children. *Cochrane Database Syst Rev*. 2015;1:CD009185.
40. Jereb M, Kotar T. Usefulness of procalcitonin to differentiate typical from atypical community-acquired pneumonia. *Wien Klin Wochenschr*. 2006;118(5-6):170-4.
41. Butbul-Aviel Y, Koren A, Halevy R, et al. Procalcitonin as a diagnostic aid in osteomyelitis and septic arthritis. *Pediatr Emerg Care*. 2005;21(12):828-32.
42. Levine AR, Tran M, Shepherd J, et al. Utility of initial procalcitonin values to predict urinary tract infection. *Am J Emerg Med*. 2018;36(11):1993-7.

# The Surgical Intervention for Traumatic Injury Scale: A Clinical Tool for Traumatic Brain Injury

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*Section Editor:* Pierre Borczuk, MD
Submission history: Submitted December 10, 2018; Revision received March 25, 2019; Accepted April 5, 2019
Electronically published June 18, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.4.41802

**Introduction:** There is no widely used method for communicating the possible need for surgical intervention in patients with traumatic brain injury (TBI). This study describes a scoring system designed to communicate the potential need for surgical decompression in TBI patients. The scoring system, named the Surgical Intervention for Traumatic Injury (SITI), was designed to be objective and easy to use.

**Methods:** The SITI scale uses radiographic and clinical findings, including the Glasgow Coma Scale Score, pupil examination, and findings noted on computed tomography. To examine the scale, we used the patient database for the Progesterone for the Treatment of Traumatic Brain Injury III (ProTECT III) trial, and retrospectively applied the SITI scale to these patients.

**Results:** Of the 871 patients reviewed, 164 (18.8%) underwent craniotomy or craniectomy, and 707 (81.2%) were treated nonoperatively. The mean SITI score was 5.1 for patients who underwent surgery and 2.5 for patients treated nonoperatively ($P<0.001$). The area under the receiver operating characteristic curve was 0.887.

**Conclusion:** The SITI scale was designed to be a simple, objective, clinical decision tool regarding the potential need for surgical decompression after TBI. Application of the SITI scale to the ProTECT III database demonstrated that a score of 3 or more was well associated with a perceived need for surgical decompression. These results further demonstrate the potential utility of the SITI scale in clinical practice. [West J Emerg Med. 2019;20(4)578–584.]

## INTRODUCTION

In the United States, traumatic brain injury (TBI) leads to significant morbidity and mortality with recent data showing that patients reaching a hospital with TBI account for more than 250,000 hospital admissions and more than 50,000 deaths.[1] While there are no approved pharmacotherapeutic agents for the treatment of TBI, timely management at an appropriate institution may improve outcomes.[2] One method for potentially facilitating communication and management of this patient population is the use of a clinical decision tool.

When designed and used appropriately, clinical decision tools have been shown to improve clinical practice.[3] Currently, there are no widespread clinical decision tools for the evaluation and surgical treatment of TBI. The Glasgow Coma Scale (GCS) has been extensively used to classify TBI patients by injury severity and is a well-defined and reproducible system;[4] however, this scale does not provide information to indicate whether a surgical intervention is necessary.[5] We previously described the Surgical Intervention for Traumatic Injury (SITI) scale as a possible clinical decision tool for evaluating a patient's potential need for surgical decompression (craniotomy or craniectomy) for treatment of TBI.[6]

Our currently presented findings expand on that original study by using the database from a recent multicenter study for TBI. The Progesterone for Traumatic Brain Injury, Experimental Clinical Treatment (ProTECT III) trial was a prospective, randomized clinical trial that examined the effect of treatment with intravenous progesterone vs placebo in patients with nonpenetrating, moderate or severe TBI.[7] We used the emergency department (ED) admission data, head computed tomography (CT) findings at presentation, and the surgical treatment data from the ProTECT III trial to determine if the patient's score on the SITI scale correlated with whether they received a surgical decompression within the first 24 hours of admission. Our hypothesis was that the SITI score, at the time of admission, would be significantly higher in patients who went on to have surgical decompression.

*Population Health Research Capsule*

What do we already know about this issue?
*The Glasgow Coma Scale is widely used to classify severity of traumatic brain injury (TBI). It does not measure potential need for surgery in patients with TBI.*

What was the research question?
*Does the Surgical Intervention for Traumatic Injury [SITI] scoring system correlate with the decision to perform a craniotomy for TBI?*

What was the major finding of the study?
*When applied to the database of ProTECT III (a clinical trial of progesterone to treat TBI), scores on the SITI scale correlated with a perceived need for craniotomy*

How does this improve population health?
*While our results need prospective evaluation, the SITI scale may be a clinical decision tool that can efficiently communicate potential surgical urgency in TBI patients.*

## METHODS

The ProTECT III trial met institutional requirements for the conduct of human subjects research and was registered on http://www.ClinicalTrials.gov (identifier, NCT00822900). The currently presented study used de-identified data from the ProTECT III database; nonetheless, we sought approval by the institutional review board (IRB). The IRB determined that review was not necessary.

### Patient Data

This was a retrospective study that used an existing database from the ProTECT III trial.[7] The ProTECT III trial was a phase III, multicenter, double-blind, clinical trial examining the efficacy of progesterone for the treatment of TBI. Inclusion criteria for the ProTECT III trial were adults with blunt force TBI and an initial GCS combined score of 4-12 who were able to initiate treatment within four hours of injury. Exclusion criteria included the following: an injury deemed nonsurvivable; a clinical exam demonstrating bilateral dilated and unresponsive pupils; clinical evidence of hypoxemia, hypotension, spinal cord injury, or status epilepticus; a history of cardiopulmonary resuscitation following the injury; a current pregnancy; a history of reproductive cancer or a blood clotting disorder; a current diagnosis of active myocardial infarction, ischemic stroke, pulmonary embolism, or deep vein thrombosis; allergy to either progesterone or the pharmacological delivery vehicle; severe alcohol intoxication (defined as having an ethanol level greater than 249 milligrams per deciliter); or being a ward of the state (e.g., a prisoner). In addition, for analysis for the current study, patients were removed if they presented with intraparenchymal hemorrhage in the posterior fossa or if surgical intervention was not considered (eg, the family decided to withdraw care, or surgery was excluded as an option by the treating physicians).

We reviewed the patient report forms from the ProTECT III trial to ensure that the data collected would be sufficient for calculating the SITI score. The variables needed to determine the SITI score were mapped to the data elements from the original ProTECT III public-use data set, and a single database was created using SPSS (IBM, Armonk, New York). Specifically, the data used for this study included demographic information, mechanism of injury, timing from injury to arrival to the ED, the combined GCS score on arrival, pupillary response on arrival, data obtained from the radiologist's interpretation of the admission head CT, and information regarding surgical interventions. All patients

included and randomized to the ProTECT III study had a calculated GCS performed in the ED. For intubated patients, the verbal response was graded 1T. None of the patients included in the ProTECT III trial were found to have a history of prior eye surgery that would have prevented performance of a pupillary light reflex.

For patients with midline shifts that were not clear from the ProTECT III database, a radiologist (Jason W. Allen) blinded to the patient's background information determined the degree of midline shift. In cases where the patient's operative status was unclear (ie, whether the patient had an operation in the first 24 hours after admission), individual case reviews were performed to determine whether the patient received surgical intervention. We defined patients as "operative patients" if they had craniotomies or craniectomies within 24 hours of arrival to the hospital. In ProTECT III, craniectomy and craniotomy were considered third-tier therapy. Surgeons were advised to perform surgical intervention, at their discretion, for refractory intracranial pressure and were referred to the most recent surgical guidelines.[5]

**SITI Scale**

The SITI scale was previously described (Table 1),[6] and its design was influenced by published surgical guidelines.[5] Briefly, the scale has five components: the combined GCS score on initial evaluation in the ED; eye findings; midline shift on head CT; presence of blood within or near the temporal lobe on head CT; and presence of an epidural hematoma on head CT.

To calculate the SITI score, we obtained the GCS combined score from the patient's initial evaluation in the ED, Patients with total GCS scores of 9-12 received 1 point, and patients with total GCS scores of <9 received 2 points. On the initial eye exam, a unilateral enlarged pupil added 2 points. (Bilateral enlarged and/or unreactive pupils did not add points.) Findings on head CT were also used: we measured midline shift of the septum pellucidum (measured at the level of the foramen of Monro), and patients received 2 points for midline shift measuring 5-10 millimeters (mm) and 4 points for midline shift >10 mm. Pathology (defined as hemorrhage or edema) localized to the middle cranial fossa added 1 point. An epidural hematoma with a width ≥ 10 mm added 2 points. The minimum score was zero, and the maximum possible score was 11.

**Table 1.** Components of the Surgical Intervention for Traumatic Injury Scale.[6]

| Feature | Finding | Points |
|---|---|---|
| GCS | >12 | 0 |
| | 9-12 | 1 |
| | <9 | 2 |
| Eyes | | |
| Unilateral enlarged pupil | yes | 2 |
| | no | 0 |
| Head CT | <5 mm | 0 |
| Midline shift | 5-10 mm | 2 |
| | >10 mm | 4 |
| Temporal blood | yes | 1 |
| | no | 0 |
| Epidural hematoma >10 mm | yes | 2 |
| | no | 0 |

*GCS*, Glasgow Coma Scale; *CT*, computed tomography; *mm*, millimeter.

**Statistical Analysis**

The statistical analyses were performed by a statistician (Junxin Shi), and the software Statistical Analysis System 9.3 (SAS Institute, Cary, North Carolina) was used. We compared operative and nonoperative patient groups using t-tests for means and chi-squared tests for percentages (statistical significance was defined as $P<0.05$). We built logistic models to examine the odds of surgery with varied combinations of the five SITI score components as independent variables. For each of these models, we constructed area under the receiver operating curves (AUC) to evaluate the SITI scale's performance.[8] For the final chosen model, using all five SITI score components, we report sensitivity, specificity, positive predictive value, and negative predictive value.

## RESULTS

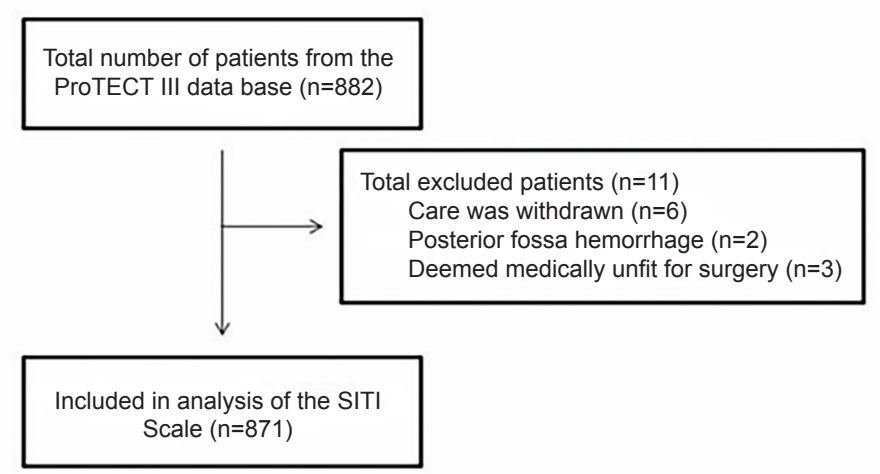
**Characteristics of Study Subjects**

Of the 882 patients enrolled in the ProTECT III trial, 871 patients were assessed. Eleven patients were not assessed for this retrospective analysis: six of the patients had care withdrawn; two had a posterior fossa hemorrhage; and three were deemed medically unfit for surgery by their treating physician (Figure 1). Patient characteristics were examined by univariate analysis (Table 2). Comparing the operative and nonoperative patients, we found no difference in gender or intubation status. Operative patients were, on average, six years older than nonoperative patients ($P<0.001$), and operative patients were transported from the location where the injury took place to the admitting hospital, on average, eight minutes earlier than nonoperative patients ($P<0.001$). For the components of the SITI score, operative patients had a slightly higher GCS combined score ($P= 0.047$), a higher rate of a unilateral enlarged pupil on initial exam ($P=0.015$), and higher rates of midline shift, temporal pathology, and epidural hematoma ($P<0.001$, for each variable). Treatment with progesterone for the ProTECT study was similar between the two groups ($P=0.82$).

**Main Results**

Comparing the percentages of patients who had certain

**Figure 1.** Flowchart of retrospective patient selection from the ProTECT III database.




*ProTECT III*, Progesterone for the Treatment of Traumatic Brain Injury III Trial; *SITI*, Surgical Intervention for Traumatic Injury.

**Table 2.** Patient characteristics.

| | Nonoperative | Operative |
|---|---|---|
| Total number of patients, n | 707 | 164 |
| Mean age, years‡ | 37.8 | 44.2 |
| Female patients, n[a] | 184 (26.0) | 44 (26.8) |
| Mechanism, n[a‡] | | |
| MVC/ATV/Scooter | 425 (60.1) | 62 (37.8) |
| Fall | 101 (14.3) | 33 (20.1) |
| Assault | 38 (5.4) | 16 (9.8) |
| Bicycle | 38 (5.4) | 8 (4.9) |
| Other/unknown | 23 (3.2) | 13 (7.9) |
| Pedestrian struck by vehicle | 82 (11.6) | 32 (19.5) |
| Mean time from injury to ED intake (minutes)‡ | 55.1 | 47.2 |
| Intubation, n[a‡] | 169 (23.9) | 41 (25) |
| Mean GCS† | 7.6 | 8.1 |
| Enlarged pupul, n[a‡] | 94 (13.2) | 34 (20.7) |
| Midline shift, n[a‡] | | |
| 0-5 millimeters | 688 (97.3) | 61 (37.2) |
| 5-10 millimeters | 19 (2.7) | 68 (41.5) |
| > 10 millimeters | 0 | 35 (21.3) |
| Temporal pathology, n[a‡] | 245 (34.7) | 143 (87.2) |
| Epidural hematoma, n[a‡] | 56 (7.9) | 49 (29.8) |
| Treatment with progesterone, n[a‡] | 352 (49.8) | 80 (48.7) |

*MVC*, motor vehicle collision; *ATV*, all-terrain vehicle, *ED*, emergency department; *GCS*, Glasgow Coma Scale score.
[a]Parentheses indicate percentage of total
†Indicates difference between the non-operative and operative groups is P<0.05
‡Indicates difference between the non-operative and operative groups is P<0.001

SITI scores, approximately 66.5% of the nonoperative patients had SITI scores between of 0 and 2, as compared with 6.7% of the operative patients (Figure 2). To determine the potential usefulness of setting the threshold of a positive SITI score at 3 or above, we performed retrospective analysis. The sensitivity for the SITI score with the decision to perform a craniotomy or craniectomy was 0.93, and the specificity was 0.66 (Table 3). The positive predictive value was 0.39, and the negative predictive value was 0.97 (Table 3). The AUC was also examined and was found to be 0.89 (Figure 3).

## DISCUSSION

As was shown in the initial publication describing the SITI score,[6] our results indicate that there is a strong association between the SITI score and a neurosurgeon's perceived need to perform a craniotomy or craniectomy for treatment of TBI. Our work represents an initial effort to create such a tool, and there is no gold standard to use for comparison. To further examine the SITI score,we used AUC analysis, which is a well-recognized method of evaluating a diagnostic test.[9]

The AUC for the SITI score was found to be 0.89, indicating that higher SITI scores were associated with patient presentations that neurosurgeons perceived as requiring surgical intervention.[10] For comparison, in a multicenter study the commonly used Acute Physiology, Age, Chronic Health Evaluation (APACHE III) methodology was found to have an AUC of 0.89 for prediction of mortality in trauma patients admitted to the intensive care unit.[1] In addition, the SITI score had a high sensitivity and a high negative predictive value, suggesting that it would have a higher tendency to identify patients who potentially need surgery and would have a lower tendency to mislabel potentially operative patients as nonoperative.

**Figure 2.** The Surgical Intervention for Traumatic Injury (SITI) score at admission for operative and nonoperative patients.

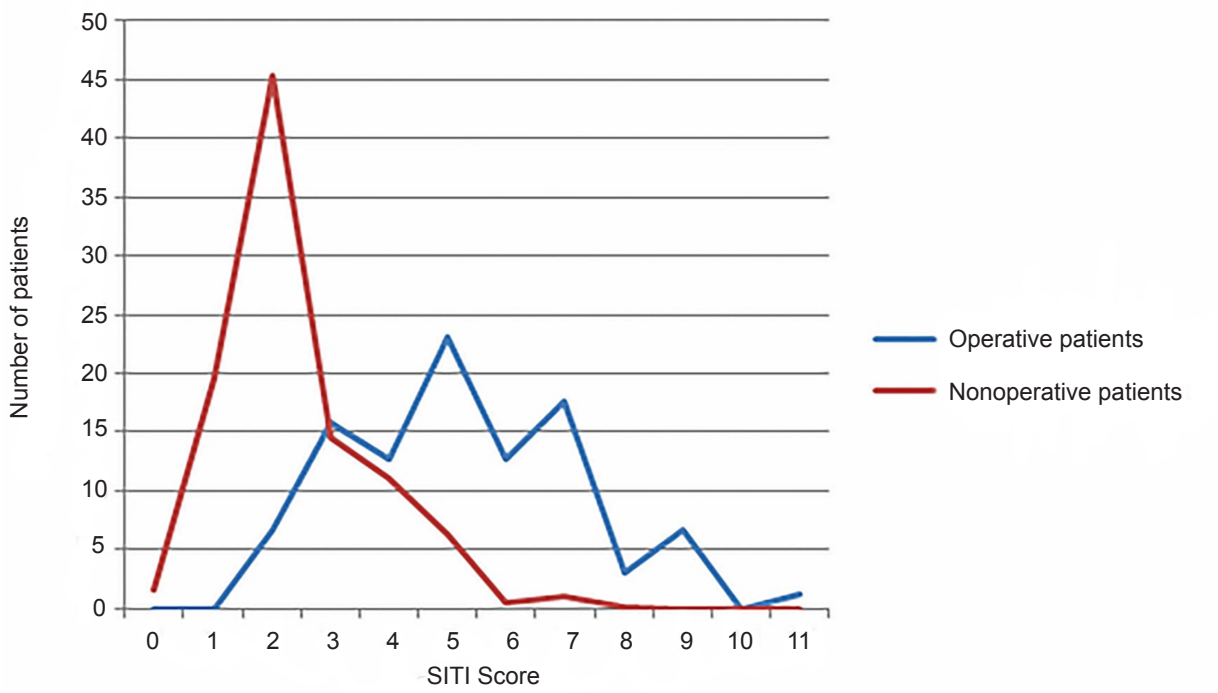


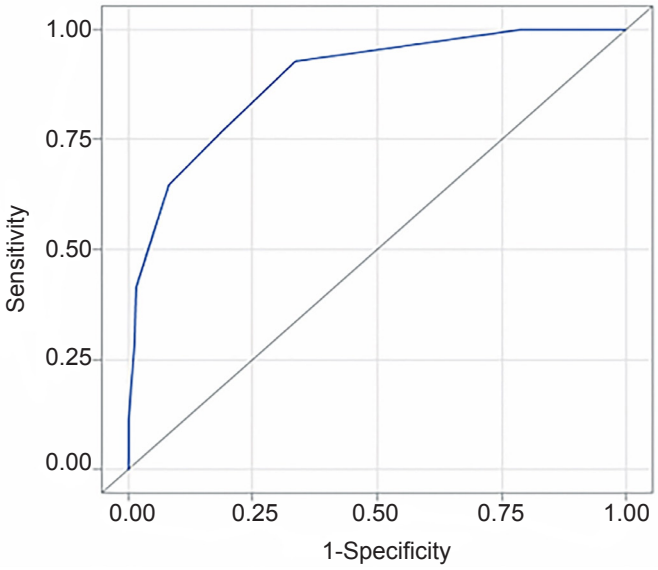

**Table 3.** Using a threshold of 3 for the SITI (Surgical Intervention for Traumatic Injury) score, the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) are shown.

| | Operative patients | Nonoperative patients | | |
|---|---|---|---|---|
| SITI Score > 3 | 152 | 327 | PPV | 0.39 |
| SITI Score < 3 | 12 | 470 | NPV | 0.97 |
| | Sensitivity | Specificity | | |
| | 0.93 | 0.66 | | |

The clinical implications of such a scale are several-fold. A validated numerical scale could promote clear and efficient communication between clinicians in the manner similar to how the GCS is used to rapidly communicate a neurological assessment.[12] The SITI score could be used in interdepartmental communication (e.g., between the ED and the neurosurgery consultant) or for hospital-to-hospital transfer (e.g., between a referring hospital and an accepting trauma center). Increasing efficiency in communication for patient transfers may translate into improved outcomes, as earlier operative intervention may improve functional outcome.[13]

The current study advances our research of the SITI scale as a clinical tool. Our initial retrospective study[6] did show a possible association between the SITI score and the surgeon's decision to perform a surgical decompression, but that study had several limitations, including that it was limited to a single-center, retrospective design, a limited number of patients, and had a high potential for observer bias. While the current study was also retrospective, the data were from a Phase III, multicenter trial where TBI patient treatment and outcome data were collected for a completely separate purpose; thus, observer bias was not likely introduced. Nonetheless, future work on the SITI scale will need to include prospective analysis.

**Figure 3.** The area under the receiver operating characteristic (ROC) curve using a Surgical Intervention for Traumatic Injury (SITI) score of 3 as the threshold.
Area under the curve = 0.8866.



Determining the utility of the SITI score in clinical practice will require prospective testing and, ultimately, clinician acceptance. Nonetheless, prior research has identified several aspects of a clinical decision tool that were predictive of usefulness: the SITI scoring system is automated; it provides information at the time of clinical decision making; and it provides a recommendation that can result in a clinical intervention.[3] The SITI scoring system is based on information that should already have been gathered for the TBI patient. It would easily lend itself to a handheld device (e.g., tablet or smartphone). Additionally, the information provided by the score would arrive at the time a decision needs to be made and would support a clinical action.

For a scoring system to be effective, it must define a specific clinical scenario and population to be addressed. For instance, the commonly used Subaxial Cervical Spine Injury Classification (SLIC) is not applicable to the entire cervical spine, as injuries involving the atlas, axis, and craniocervical junction are distinct injuries that do not lend themselves to the SLIC scale.[14] Finally, a clinical scale should be used to suggest a clinical response, not to dictate it. The over-riding point of the scale is not to replace clinical judgment but to highlight a patient population in which timely surgical action may be warranted.

## LIMITATIONS

A limitation to the SITI scale is that it is not intended to be used for all forms of TBI. It only covers closed head injury; skull fractures do not factor into the score, and it does not address posterior fossa injuries. Guidelines for the surgical management of penetrating head injury[15] and depressed skull fracture[16] exist and have additional considerations, such as infection prevention, that also must be taken into account when deciding on surgical management. Injuries to the posterior fossa have their own indications and are rare.[17-19] The current study uses data obtained from the ProTECT III trial; thus, any exclusion criteria from that study (e.g., severe alcohol intoxication) influenced the present study and limit its applicability. Future work will need to be more inclusive to demonstrate the utility of this clinical tool.

## CONCLUSION

In summary, this study used the multicenter ProTECT III database to examine whether the previously described SITI scoring system correlates with TBI patients who received surgical intervention for their injury. Our findings show a strong association between a SITI score of 3 or greater and the treating neurosurgeon's perceived need to perform an operative intervention. Our findings potentially have significant clinical implications. Utility of the SITI score in clinical practice and future clinician acceptance require further prospective evaluation.

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



## REFERENCES

1. Centers for Disease Control and Prevention. Injury in the United States: epidemiology and rehabilitation. Atlanta: National Center for Injury Prevention and Control. 2015. Available at: https://www.cdc.gov/traumaticbraininjury/pdf/tbi_report_to_congress_epi_and_rehab-a.pdf. Accessed May 20, 2019.
2. Joosse P, Saltzherr TP, van Lieshout WA, et al. Impact of secondary transfer on patients with severe traumatic brain injury. *J Trauma Acute Care Surg*. 2012;72(2):487-90.
3. Kawamoto K, Houlihan CA, Balas EA, et al. Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. *BMJ*. 2005;330(7494):765.
4. Rimel RW, Giordani B, Barth JT, et al. Moderate head injury: completing the clinical spectrum of brain trauma. *Neurosurgery*. 1982;11(3):344-51.
5. Bullock MR, Chesnut R, Ghajar J, et al. Guidelines for the surgical management of traumatic brain injury. *Neurosurgery*. 2006;58:S1-62.
6. Sribnick EA, Hanfelt JJ, Dhall SS. A clinical scale to communicate surgical urgency for traumatic brain injury: A preliminary study. *Surg Neurol Int*. 2015;6:1.
7. Wright DW, Yeatts SD, Silbergleit R, et al. Very early administration of progesterone for acute traumatic brain injury. *N Engl J Med*. 2014;371(26):2457-66.
8. Zou KH, O'Malley AJ, Mauri L. Receiver-operating characteristic analysis for evaluating diagnostic tests and predictive models. *Circulation*. 2007;115(5):654-7.
9. Hanley JA and McNeil BJ. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology*. 1982;143(1):29-36.
10. Xia J, Broadhurst DI, Wilson M, et al. Translational biomarker discovery in clinical metabolomics: an introductory tutorial. *Metabolomics*. 2013;9(2):280-99.

11. Vassar MJ, Lewis FR, Chambers JA, et al. Prediction of outcome in intensive care unit trauma patients: a multicenter study of Acute Physiology and Chronic Health Evaluation (APACHE), Trauma and Injury Severity Score (TRISS), and a 24-hour intensive care unit (ICU) point system. *J Trauma*. 1999;47(2):324-9.
12. Teasdale G, Maas A, Lecky F, et al. The Glasgow Coma Scale at 40 years: standing the test of time. *Lancet Neurol*. 2014;13(8):844-54.
13. Lee EJ, Hung YC, Wang LC, et al. Factors influencing the functional outcome of patients with acute epidural hematomas: analysis of 200 patients undergoing surgery. *J Trauma*. 1998;45(5):946-52.
14. Vaccaro AR, Hulbert RJ, Patel AA, et al. The subaxial cervical spine injury classification system: a novel approach to recognize the importance of morphology, neurology, and integrity of the disco-ligamentous complex. *Spine (Phila Pa 1976)*. 2007;32(21):2365-74.
15. Kazim SF, Shamim MS, Tahir MZ, et al. Management of penetrating brain injury. *J Emerg Trauma Shock*. 2011;4(3):395-402.
16. Bullock MR, Chesnut R, Ghajar J, et al. Surgical management of depressed cranial fractures. *Neurosurgery*. 2006;58(3 Suppl):S56-60; discussion Si-iv.
17. Bullock MR, Chesnut R, Ghajar J, et al. Surgical management of posterior fossa mass lesions. *Neurosurgery*. 2006;58(3 Suppl):S47-55; discussion Si-iv.
18. Heros RC. Cerebellar hemorrhage and infarction. *Stroke*. 1982;13(1):106-9.
19. Tsai FY, Teal JS, Itabashi HH, et al. Computed tomography of posterior fossa trauma. *J Comput Assist Tomogr*. 1980;4(3):291-305.

# Daylight Saving Time is not Associated with an Increased Number of Trauma Activations

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*Section Editor:* Mark I. Langdorf, MD, MHPE
Submission history: Submitted Feburary 18, 2019]; Revision received May 23, 2019; Accepted May 29, 2019
Electronically published July 2, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.5.42780
[West J Emerg Med. 2019;20(4)585-586.]

## INTRODUCTION

Prior studies have reported that during the period of Daylight Saving Time (DST) adjustment, there are a greater number of motor vehicle collisions.[1-3] These studies noted that the increase in collisions occurs mainly on the following Monday after the time change. We hypothesize that changes in sleep patterns may be one of the reasons for this increase. Although the number of fatal accidents increases, it is unclear whether there is an increased need for hospital-based trauma services. We hypothesized that there may be an increased number of trauma activations during DST changes that may indicate a need for increased resources.

## METHODS

We performed a retrospective chart review at an academic, tertiary care hospital identified as a Level 1 trauma center. This hospital serves multiple counties and has an emergency department annual census of 83,000 patients. There are no other trauma centers in the primary county. Data, including dates and total number of trauma activations for those respective dates, were extracted from the hospital's trauma registry. We compared the number of trauma activations occurring on the Mondays of DST change to those occurring on the Mondays one week before and one week after the DST changes, over a 20-year span. Mann-Whitney U tests were employed for all analyses.

## RESULTS

At the start of DST, the median number of trauma activations (N = 40) on the Mondays of DST (median = 2, range = 7) did not differ significantly (U = 190.5; p = 0.41) from the Mondays one week before (median = 2.5, range = 7), nor did it significantly differ (U = 184; p = 0.34) from the Mondays one week after (median = 2.5, range = 7). Likewise, at the end of DST, the median number of total trauma activations for the Mondays of DST (median = 2, range = 7) did not differ significantly (U = 167; p = 0.19) from the Mondays one week before (median = 3, range = 7), nor did it significantly differ (U = 161.5; p = 0.15) from the Mondays one week after (median = 2, range = 7).

## DISCUSSION

We did not identify an increase in the number of trauma activations associated with DST changes during the study period. Our hospital is located in the Mid-Atlantic area of the United States and our data might differ from other sites by experiencing greater lighting changes during DST. Furthermore, with a relatively low sample size of trauma activations per day, there may not be enough variability to detect changes associated with DST. Although this site provides care to multiple counties with the nearest Level 1 trauma center over 20 miles away, we did not find a significant increase in activations. Currently, there are no indications for increasing trauma services during DST changes at our single site.

**Table 1.** Trauma activations on Mondays.

| | Median Number of Activations | Range | P |
|---|---|---|---|
| Mondays 1 week before start of DST | 2.5 | 7 | 0.41 |
| Mondays of start of DST | 2.0 | 7 | |
| Mondays 1 week after start of DST | 2.5 | 7 | 0.34 |
| Mondays 1 week before end of DST | 3.0 | 7 | 0.19 |
| Mondays at end of DST | 2.0 | 7 | |
| Mondays 1 week after end of DST | 2.0 | 7 | 0.15 |

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

**REFERENCES**

1. Varughese J, Allen RP. Fatal accidents following changes in daylight savings time: the American experience. *Sleep Med*. 2001;2(1):31-6.
2. Lambe M, Cummings P. The shift to and from daylight savings time and motor vehicle crashes. *Accid Anal Prev*. 2000;32(4):609-11.
3. Carey RN, Sarma KM. Impact of daylight saving time on road traffic collision risk: a systematic review. *BMJ Open*. 2017;7(6):e014319.

# Evaluation and Management of Angioedema in the Emergency Department

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*Section Editor:* Kenneth Whitlow, DO
Submission history: Submitted February 3, 2019; Revision received May 9, 2019; Accepted May 28, 2019
Electronically published July 2, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.5.42650

Angioedema is defined by non-dependent, non-pitting edema that affects several different sites and is potentially life-threatening due to laryngeal edema. This narrative review provides emergency physicians with a focused overview of the evaluation and management of angioedema. Two primary forms include histamine-mediated and bradykinin-mediated angioedema. Histamine-mediated forms present similarly to anaphylaxis, while bradykinin-mediated angioedema presents with greater face and oropharyngeal involvement and higher risk of progression. Initial evaluation and management should focus on evaluation of the airway, followed by obtaining relevant historical features, including family history, medications, and prior episodes. Histamine-mediated angioedema should be treated with epinephrine intramuscularly, antihistaminergic medications, and steroids. These medications are not effective for bradykinin-mediated forms. Other medications include C1-INH protein replacement, kallikrein inhibitor, and bradykinin receptor antagonists. Evidence is controversial concerning the efficacy of these medications in an acute episode, and airway management is the most important intervention when indicated. Airway intervention may require fiberoptic or video laryngoscopy, with preparation for cricothyrotomy. Disposition is dependent on patient's airway and respiratory status, as well as the sites involved. [West J Emerg Med. 2019;20(4)587-600.]

## INTRODUCTION

Angioedema is a condition defined by non-dependent, non-pitting, transient edema lasting up to seven days due to the accumulation of vasoactive substances.[1-5] These substances increase vascular permeability, resulting in swelling in the deep dermal, submucosal, and subcutaneous tissues of the face, lips, neck, extremities, and gastrointestinal (GI) system.[1,2,6-9] Urticaria may be present in up to 50% of cases, depending on the underlying process.[1,2,6-9]

Angioedema accounts for 80,000 to 112,000 emergency department (ED) visits per year, with a hospitalization rate of 4.0 per 100,000 population.[10-12] For patients taking angiotensin-converting enzyme inhibitors (ACEi), the incidence of angioedema ranges from 0.1-0.7% over a patient's lifetime, while the prevalence of hereditary angioedema (HAE) ranges from 1 in 10,000 to 1 in 50,000 persons.[6,10-15] Over 50% of patients with HAE require ED management, with over half of patients admitted to the hospital.[1-3] ACEi-mediated angioedema accounts for 30% of angioedema cases. Of the cases of ACEi-mediated angioedema, one study found 18% of patients were admitted to observation, 12% to the inpatient setting, and 11% to the intensive care unit.[1,16] Due to risk of airway involvement and death, the emergency physician (EP) plays a key role in assessment and management of angioedema.[1,2,17,18]

## METHODS

We searched PubMed and Google Scholar for articles in English from 1966 to October 2018 using a combination of the keyword and medical subject heading "angioedema" for production of this narrative review. Our search included case reports and series, retrospective and prospective studies, systematic reviews and meta-analyses, narrative reviews, and clinical guidelines. Two authors decided by consensus which studies to include for the review. Initial literature search revealed

over 500 articles, of which 185 were selected for inclusion, focusing on ED evaluation and management.

## DISCUSSION

### Etiology

Angioedema can be defined as either hereditary (bradykinin) or acquired (bradykinin or histamine) (Table 1).[1-5,7,15,19-24] The underlying pathophysiology (ie, bradykinin- vs histamine-mediated) influences the clinical presentation and treatment recommendations.[1,2,7,8] Bradykinin-mediated forms are generally more severe, longer lasting, and frequently involve the upper airway and gastrointestinal (GI) system.[1,20-24]

### Histamine-mediated

Histamine-mediated angioedema is the most common form, accounting for 40-70% of all cases, and is associated with immunoglobulin E resulting in degranulation of mast cells and basophils.[1-5] H1 and H2 receptors are primarily responsible for the swelling that leads to angioedema.[1,4,5] Histamine-mediated angioedema, such as anaphylaxis, occurs rapidly after an allergen exposure (type I hypersensitivity reaction).[5,25-30] Histamine-mediated angioedema and anaphylaxis present similarly, as they are along the same clinical spectrum, although diagnosis of anaphylaxis requires specific clinical criteria.[1-5] Importantly, therapy for histamine-mediated angioedema and anaphylaxis is the same, which will be discussed later. Histamine-mediated angioedema typically resolves within 24-48 hours. This form can result from food allergens, medications, exercise, bites, stings, or latex exposure.[31-33] There is also a form of physically-induced angioedema from cold exposure, heat pressure, physical activity, ultraviolet radiation, and vibration, which is most likely due to histamine release.[34-36]

*Population Health Research Capsule*

What do we already know about this issue?
*Angioedema is defined by non-dependent, non-pitting edema that affects several different sites and is potentially life-threatening due to laryngeal edema.*

What was the research question?
*This narrative review evaluates the pathophysiology, evaluation, and management of angioedema.*

What was the major finding of the study?
*There are two forms of angioedema. Management must focus on the airway, although several medications are promising.*

How does this improve population health?
*Evidence is controversial for the efficacy of several medications, and airway management is the most vital intervention if indicated. Disposition depends upon airway and respiratory status.*

### Bradykinin-mediated

Bradykinin-mediated pathways involve this vasoactive nonapeptide that activates endothelial cells.[5,14,37] Several systems regulate bradykinin, including the coagulation, complement, and contact pathways.[4,38] Excess bradykinin is due to production, release, or inhibition of its breakdown.[39-41] This form comprises drug-induced angioedema (ie, ACEi-mediated), HAE

**Table 1.** Types of angioedema.

| Types | Characteristics |
|---|---|
| Histamine-mediated (with urticaria) | - Allergy to food, venom, latex, medication<br>- Acute or chronic spontaneous urticaria<br>- Urticaria/angioedema associated with cold urticaria, vasculitis, exercise, episodic angioedema, vibration-induced, drug reaction |
| Bradykinin-mediated (without urticaria) | - Type I HAE: defective C1-INH level/function<br>- Type II HAE: defective C1-INH function<br>- Type III HAE: normal C1-INH<br>-Acquired C1-INH deficiency: Type I associated with increased catabolism of C1-INH (lymphoproliferative disorder, autoimmune disease); Type II associated with autoantibody to C1-INH<br>- ACEi-mediated angioedema<br>- Medication associated: dipeptidyl peptidase-IV inhibitor (gliptins for diabetes mellitus), angiotensin II receptor blockers, recombinant tissue plasminogen activator, sirolimus, tacrolimus, everolimus |
| Idiopathic (unknown etiology) | - Histaminergic<br>- Nonhistaminergic |

*HAE*, hereditary angioedema; *C1-INH*, C1 inhibitor; *ACEi*, angiotensin-converting enzyme inhibitor.

types I and II, and several forms of acquired and idiopathic angioedema.[13,20,42,43]

ACEi-mediated angioedema accounts for up to 30% of ED visits for angioedema of all types.[16,21,44-49] ACEis prevent the conversion of angiotensin I to angiotensin II and reduce bradykinin metabolism, which increases the risk of angioedema. Most cases are localized to the lips and tongue.[14,15] Patients at greatest risk for developing ACEi-mediated angioedema include African Americans and those taking immunosuppressants or dipeptidyl peptidase-IV inhibitors (a class of diabetic medications) in addition to the ACEi.[14,15,49] The rate of angioedema is highest within the first 30 days of starting an ACEi, although the risk of angioedema remains for the duration of the ACEi use, with cases of ACEi-mediated angioedema documented in patients with prolonged courses of multiple years.[50-52] If a patient continues taking an ACEi after developing ACEi-mediated angioedema, the average time to recurrence is approximately 10 months.[50,53] Angiotensin II receptor blockers (ARB) and renin antagonists can also cause angioedema, but this is not due to bradykinin.[1-5] If angioedema develops in a patient on an ACEi, the ACEi should be discontinued and a different antihypertensive class used.

HAE is thought to be autosomal dominant with abnormal C1-INH amounts and/or function. HAE affects approximately 1 in 10,000–50,000 people.[1,2,54,55] Type 1 is due to decreased and defective C1-INH and is the most common (85%) form of HAE, followed by type II which is caused by dysfunctional C1-INH.[13,55-59] A third form of HAE with normal C1-INH has also been described.[60-62] Most patients present by age 10 with recurrent episodes of edema.[1-4,58] HAE is often associated with prodromal symptoms, such as erythema marginatum, but not urticaria.[1,4,16,61,63] HAE occurs more commonly in females and causes more severe swelling with significant face and tongue involvement when compared with males.[1-5,13] Estrogen-containing medications and pregnancy increase the attack frequency in female patients.[7,61,64]

Acquired angioedema appears similar to HAE with C1-INH deficiency, but this is not hereditary and more commonly affects those > 40 years.[1,65-71] This form is most commonly due to catabolism of C1-INH, although some patients may have a lymphoproliferative or autoimmune disorder.[1,65-71]

A less common cause of non-histaminergic angioedema is associated with medications, including nonsteroidal anti-inflammatory drugs (NSAID), antibiotics, and ARB.[72-75] NSAID-associated angioedema results from inhibition of cyclooxygenase and accumulation of leukotriene mediators, and occurs in 0.1-0.3% of patients taking an NSAID.[56] Exposure to recombinant tissue plasminogen activator therapy in acute ischemic stroke is also associated with angioedema, occurring in 1.2-5.1% of patients, with increased risk in patients taking an ACEi.[76-80] Most of these cases are mild and resolve in 24 hours.[1,2,7,8]

**Idiopathic**

Idiopathic angioedema is diagnosed by failure to determine the etiology with ≥ 3 attacks in a 6-12 month period.[2,5,81-83] Most patients with idiopathic angioedema will demonstrate a response to standard therapies for anaphylaxis (eg, epinephrine, antihistamines, steroids), although a small group will not improve with these therapies.[1-4,84] This latter group is more commonly bradykinin-associated.[1-4,84]

**Presentation, History, and Physical Examination**

Initial evaluation requires assessing vital signs, airway, and cardiovascular systems. Asphyxiation is the leading cause of mortality in these patients, necessitating airway evaluation.[17,18,85] At least one episode of laryngeal edema occurs in over half of all patients with HAE and accounts for over 30% of deaths in HAE.[17,18] Emergency physicians (EP) must inquire about lip swelling, tongue swelling, and GI symptoms (nausea, vomiting, diarrhea, and pain). Additional information to gather includes prior personal or family history of angioedema, medications, and related symptoms (eg, pruritis, dyspnea, syncope, lightheadedness).[85-93] Patients with a known history of HAE should also be asked about recent trauma, which can trigger an episode.[1-5] Most patients with HAE report prodromal symptoms prior to swelling, such as fatigue and rash.[94]

The presentation can vary depending upon the subtype but is primarily dependent upon whether the etiology is histaminergic or non-histaminergic (Table 2).[1-5,13] The most commonly involved areas include the head and neck (eg, eyelids, lips, tongue, larynx), extremities (eg, hands and feet), external urogenital system, and abdomen.[1-5,9,13,28] However, involvement of these sites is often non-contiguous, with no specific pattern.[1-5,7,8] Histaminergic forms display faster onset, while HAE and acquired forms have a slower, progressive onset occurring over several hours.[1,2,7,8] GI tract submucosal involvement occurs in up to 93% of patients with HAE and can cause symptoms that mimic bowel obstruction.[13,55,90,91] Non-pitting edema is present in both histaminergic and non-histaminergic forms.[1,4,7,8] Pruritic, localized, urticarial lesions may be present in histamine-mediated forms with involvement

**Table 2**. Comparison of features between non-histaminergic and histaminergic angioedema.

| Features | Histaminergic | Non-histaminergic |
|---|---|---|
| Onset | Minutes | Hours |
| Duration | 12-24 hours | 48-72 hours |
| Hypotension | Common | Atypical |
| Urticaria | Common | Atypical |
| Bronchospasm; wheezing | Common | Atypical |
| Laryngeal edema | Possible | Possible |
| Abdominal pain | Possible | Possible |
| Therapy with epinephrine, antihistamines, steroids | Effective | Not effective |

of the deep dermis, but these are rare in non-histaminergic forms.[13,95,96] Urticaria occurs in approximately 50% of patients with histamine-mediated angioedema.[13,95,96]

Findings suggestive of the need for a definitive airway include stridor, hoarseness, dyspnea, and voice changes.[86-92] The patient should be asked to phonate "E" with a high pitch, as a patient able to complete this maneuver is unlikely to have laryngeal edema.[1,7,8] Auscultation of the lungs to determine the presence of wheezing is recommended.

Differentiating histamine and bradykinin-mediated angioedema can be difficult. One retrospective study evaluated 188 patients, with one point assigned to age > 65 years, dyspnea, no itching or erythema, laryngeal involvement, and intake of ACEi/AT-II antagonist, and two points assigned if there was no response to steroid therapy.[97] If the score was ≥ 3 points, the patient was treated with C1-INH or B2 receptor antagonist for suspicion of bradykinin-mediated angioedema. This resulted in a sensitivity of 96% and specificity of 84% for the diagnosis of bradykinin-mediated angioedema.[97] While this tool can help to differentiate the underlying etiology, it requires further validation before routine use.

**Diagnostic Testing**

Angioedema is a clinical diagnosis, with no required testing in the ED.[1,2,4] Leukocyte counts cannot reliably differentiate if an infection is present, as leukocytosis over 30,000 per cubic millimeter has been observed.[98] C-reactive protein may be elevated in ACEi-mediated angioedema.[1,4] Determining the specific type of angioedema involves specialized laboratory testing not available in the ED, including tryptase, C4, and C1-INH.[1-4] These tests can be obtained in the outpatient setting and should not be routinely obtained in the ED, as they do not guide management. Histamine-mediated forms can display elevated tryptase levels during attacks, while patients with HAE will display normal tryptase levels.[3] C4 levels serve as a sensitive screening test for C1-INH deficiency.[1,3] Serum C4 levels will typically be < 30% of normal in acute episodes of angioedema from HAE types I and II, although the laboratory values may be normal between attacks.[23,100,101] Type I HAE often involves low C1-INH levels and decreased function, while type II HAE includes normal levels but decreased function.[13,19,102] C1q levels, a component of the complement system, can be used to differentiate acquired and hereditary forms, as C1q is decreased in acquired angioedema and normal in HAE.[1,3,4,100,103] Type III HAE has normal levels and function of C1-INH but is usually identified by a positive family history.[1-4,7,8] No tests can confirm ACEi-mediated angioedema.[1,7,19,23]

Patients with abdominal symptoms may demonstrate segmental bowel wall edema, straightening of intestinal segments, and ascites on computed tomography (CT).[4,104,105] Ultrasound may similarly reveal bowel wall thickening or ascites.[106] Ultrasound can be used to evaluate for laryngeal edema, although this requires further study.[4] Chest radiography, if obtained, is typically normal. Neck radiographs and CT of the neck with intravenous (IV) contrast can evaluate for mimics of angioedema, but they should not be ordered routinely for patients with suspected angioedema.[104] Fiberoptic visualization of laryngeal and airway structures is recommended if concern for laryngeal or airway involvement is present.

**Management**

The primary focus of ED management is assessment of the airway and evaluation for anaphylaxis, which is the most common mimic.[1-4,7,8] Figure 1 depicts an algorithm for management. Vital signs should not be relied upon in isolation to determine the need for airway intervention.

*Airway Management*

Patients with angioedema involving the tongue or larynx require consideration of definitive airway management. Angioedema can progress rapidly within hours, and airway obstruction occurs in up to 15% of patients with angioedema.[1,4,17,18] For patients with angioedema who require a definitive airway, cricothyrotomy or tracheostomy is needed in up to 50% of cases.[17,87,105] Prior history of intubation or severe angioedema should raise the concern for a difficult airway which may require early airway intervention.[1,4,107] Evidence of upper airway involvement on examination includes stridor, change in patient voice, and hoarseness. If physical examination reveals swelling of the tongue, floor of the mouth, or soft palate, directly visualize the tongue base and airway with fiberoptics. The presence of epiglottic, aryepiglottic, or laryngeal edema suggests need for definitive airway.[1,2] If the angioedema exclusively involves structures anterior to the teeth such as the lips, intubation is generally not needed.[85-92]

Noninvasive positive pressure ventilation can also assist with temporization; however, this is not a definitive therapy for patients with airway involvement. Supraglottic and extraglottic airway devices are common rescue devices; however, they are not recommended in patients with angioedema, as the device will remain above the site of airway obstruction.[1,4,7,8,85] If placed, these devices may also worsen edema due to the associated trauma with placement.

Physical manipulation of the airway may worsen edema, especially in bradykinin-mediated angioedema.[1,4,7,8] In patients with history or evidence on examination of a difficult airway, video laryngoscopy or fiberoptic awake intubation is recommended, as this allows the patient to maintain his/her airway reflexes during airway visualization and the intubation attempt.[1,4,107-109] Topical anesthetics and ketamine are optimal agents for awake intubation. Severe edema may prohibit passage of an endotracheal tube through the glottis, even with the use of fiberoptic or video laryngoscopy guidance. Thus, the resuscitation team must prepare for cricothyrotomy before an attempt at intubation is started, known as a double setup.[1-5] If the patient does not require immediate airway intervention, transfer to the operating room may be beneficial with anesthesia and otolaryngology consultation, similar to pediatric epiglottitis.

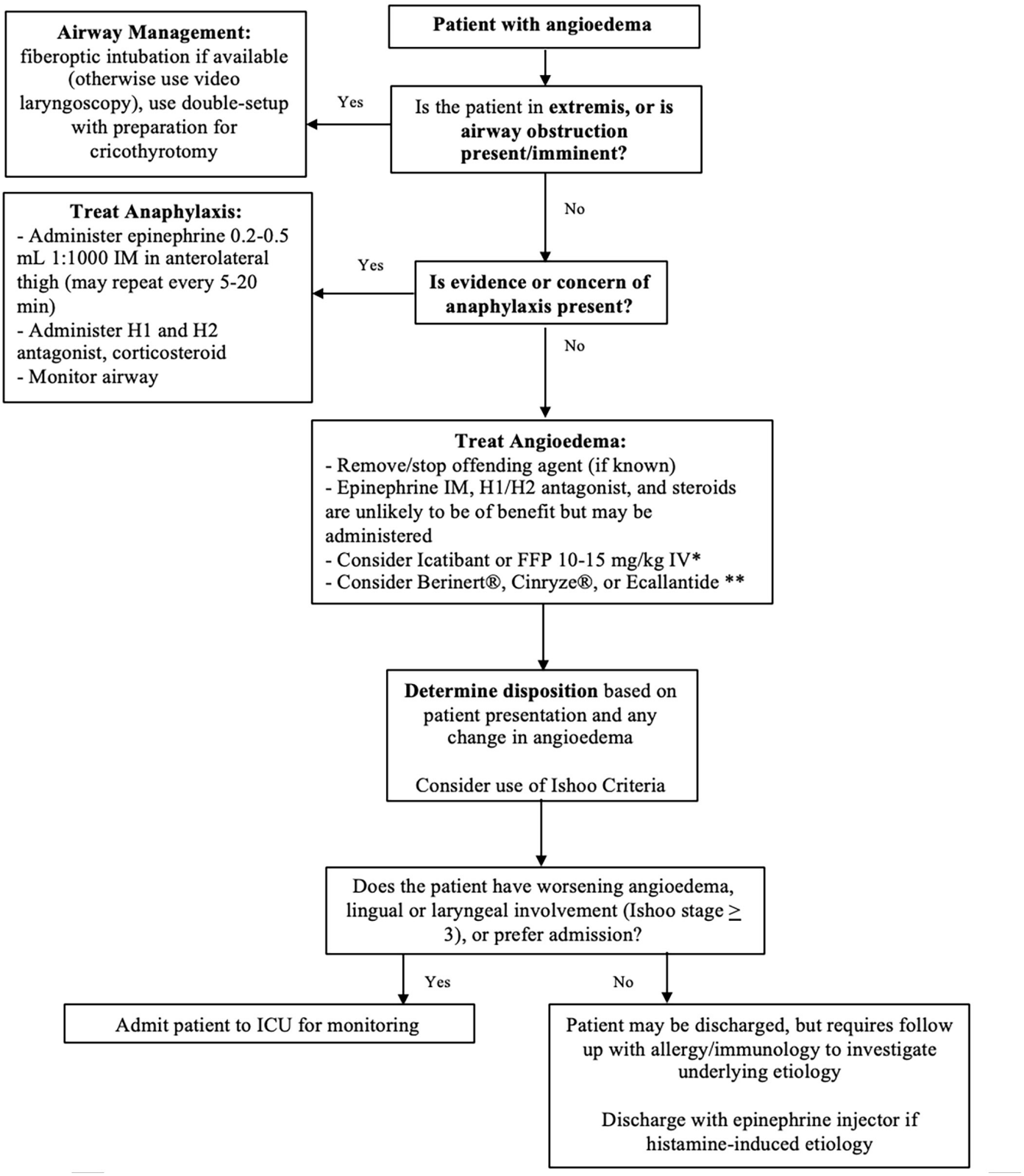


**Figure 1.** Algorithm for angioedema management.
*IV*, intravenous; *IM,* intramuscular; *ACEi*, angiotensin converting enzyme inhibitor; *FFP*, fresh frozen plasma; *ICU,* intensive care unit.
*ACEi-mediated, Hereditary, or Acquired Angioedma only.
**Hereditary or Acquired Angioedema only.

*Medications*

Medication management focuses on three aspects: acute episode management, short-term prophylaxis, and long-term prophylaxis, with ED management focusing on the acute episode.[1,4,7,8] If the suspected etiology is drug- or allergic-induced, the trigger must be removed.[1-5] In histamine-mediated forms of angioedema, standard therapy for anaphylaxis is recommended. However, in other forms of angioedema including bradykinin-mediated forms, standard therapies for anaphylaxis should not be effective.[110,111]

Patients with evidence of histaminergic forms of angioedema and concern for airway involvement should receive epinephrine, steroids, antihistamines, and IV fluids.[1-5,7,8,112] If there is any suspicion of anaphylaxis, urticaria-associated angioedema, or if the exact underlying cause of the angioedema is unknown, histamine-mediated edema should be assumed. Epinephrine should be administered via the intramuscular route into the anterolateral middle third of the thigh, with initial dose 0.3-0.5 milliliter (mL) (0.3-0.5 milligram [mg]) of 1:1000 dilution (1 mg/mL), which can be repeated every 5-20 minutes.[1,4] Subcutaneous administration is not recommended.[112-114] IV epinephrine should be considered in patients requiring multiple doses of intramuscular epinephrine and should begin at doses of 1-4 micrograms (mcg) per minute.[112,115,116] Epinephrine can be administered peripherally by injecting 1 mg of epinephrine into 1 L of normal saline, resulting in a final concentration of 1 mcg/mL. If administered wide-open through an 18-gauge IV, this provides 20-30 mL/minute (20-30 mcg/minute) of epinephrine.

Adjunctive therapies for histamine-mediated angioedema include antihistamines and steroids.[1-5,7,8,112] Antihistamines have a slower onset of action and should only be used as an adjunctive therapy.[1-5,7,8,112,117] Diphenhydramine is an H1 antagonist that can be used in doses of 25-50 mg IV to reduce swelling in combination with a second- or third-generation antihistamine agent (eg, cetirizine, loratadine, fexofenadine, levocetirizine, desloratadine).[1-5,112,117-127] The addition of an H2 antagonist is beneficial in decreasing urticaria, as 15% of cutaneous histamine receptors are H2.[117-128] Steroids such as methylprednisolone 125 mg IV decrease inflammatory mediators in histamine-mediated angioedema and anaphylaxis but, similar to other medications, there is little to no evidence for their use in non-histaminergic angioedema.[1,4,7,8,112] The onset of action after administration is delayed, typically requiring 4-6 hours to take effect.[1-5,7,8,14,15]

Fresh frozen plasma (FFP) has been recommended for use in angioedema based on case reports demonstrating improvement in HAE and ACEi-mediated angioedema,[129-133] as FFP contains varying amounts of C1-INH.[1-4,7,8,14,15,134-136] Several of the first case reports suggested FFP can be used as prophylaxis for HAE in patients undergoing dental procedures.[129,135,137] A retrospective study suggests efficacy in decreased intubation frequency and intensive care unit (ICU) length of stay.[137] However, type II HAE may worsen with FFP due to the presence of an autoantibody responsible for decreased C1-INH.[134] Limited literature has described FFP in ACEi-mediated angioedema, primarily case reports and series demonstrating improved symptoms at four hours.[132,133,136,138-145] Its use in acquired forms has not demonstrated efficacy, and a major limitation is the need to thaw FFP for use. The literature is inconsistent with regard to preferred dosing, with most studies giving 1-4 units (250–1000 cubic centimeters).[1-5,135,136] FFP requires close to 50 times the volume of other medications with C1INH to obtain the same serum levels of enzyme.[135] Risks include potential volume overload, transmission of bloodborne infection, and hypersensitivity reaction.[1-4,7,8,136] FFP also contains substrates such as kallikrein and kininogen that may paradoxically worsen angioedema.[1-4,7,8,14] Despite this theoretical effect, worsening of angioedema with FFP administration has not been found in cases of ACEi-mediated angioedema.[1,4,134-136] There is no support for FFP in other acquired forms of angioedema.[1-4,135]

Prothrombin complex concentrate (PCC) has also been used for ACEi-mediated angioedema.[1,4,146] However, the data is limited to one case report in which 1500 units were administered. Symptoms began to improve in 20 minutes, with resolution in eight hours.[146] Four-factor PCC contains C1-INH, which may explain the improved symptoms.

**Targeted Therapies for Bradykinin-mediated Angioedema**

Bradykinin-mediated forms of angioedema are typically resistant to therapies effective in histamine-mediated reactions.[1,4,7,8,13,135,136,147] At the time of construction for this review, several medications have been FDA approved for treatment of acute bradykinin-mediated angioedema: three C1-INH concentrates (two plasma-derived and one recombinant), one kallikrein inhibitor, and one bradykinin-2-receptor antagonist (Table 3).[1,4,7,8,13,135,136]

*C1 Inhibitor Concentrate*

C1-INH concentrate for HAE episodes was first described in 1973, and there are two plasma-derived formulations currently available (Berinert and Cinryze), as well as one recombinant form (Ruconest), all administered intravenously.[1-5,7,8,135,136,148] They are currently approved for acute HAE, although these medications have been used for ACEi-mediated forms.[1-5,7,8,135,136,148] Berinert and Cinryze provide native plasma protein that regulates kallikrein and Factor XII activity, reducing bradykinin production. Bork et al. published a study based on 18 patients with 193 episodes of HAE, finding that the mean time to reversal was 42.2 minutes.[149] The IMPACT trials (funded by CSL Behring, manufacturer of Berinert) evaluated Berinert vs placebo for acute episodes of HAE. IMPACT-1 found 20 units per kilogram (kg) improved time to symptom relief (0.5 hours vs 1.5 hours), but 10 units/kg did not.[150,151] IMPACT-2 evaluated 1085 episodes of HAE in 57 patients, with a median time to symptom relief of 0.46 hours in patients receiving open-label Berinert.[151] Cinryze has also been evaluated in HAE, with a double-blind placebo-controlled trial of 68 patients finding no statistically significant improvement in time to relief, although a double-blind crossover trial of 21 patients demonstrated decrease in attack number, duration, and severity.[4,136,152] A study that was

**Table 3.** Angioedema medications.

| Medication (trade name) | Mechanism | Route | Dose | Time to onset | Minor side effects | Serious side effects |
|---|---|---|---|---|---|---|
| Plasma derived C1-INH (Berinert, Cinryze) | C1-INH protein replacement | IV | Berinert 20 units/kg; Cinryze 1000 units | Median 30-48 minutes | Dysgeusia | Hypersensitivity, thrombosis, blood-borne infection |
| Recombinant C1-INH (Ruconest) | C1-INH protein replacement | IV | 50 units/kg | Median 90 minutes | Pruritis, rash, sinusitis | Hypersensitivity, anaphylaxis |
| Ecallantide (Kalbitor) | Kallikrein inhibitor | SQ | 30 mg | Median 67 minutes | Headache, injection site reactions, nausea, fever | Hypersensitivity, anaphylaxis |
| Icatibant acetate (Firazyr) | Bradykinin B2 receptor antagonist | SQ | 30 mg | Median 2 hours | Elevated LFTs, injection reaction, dizziness, headache, nausea, fever | Theoretical worsening of an ongoing ischemic event |
| Fresh frozen plasma | C1-INH protein replacement (various amounts) | IV | 15 mg/kg | Minutes to hours | | Hypersensitivity, worsening angioedema, transfusion infection |

*C1-INH*, C1 inhibitor; *IV*, intravenous; *SQ*, subcutaneous; *LFTs*, liver function tests; *mg*, milligram; *kg*, kilogram.

not placebo controlled found 68% of patients had improvement at one hour, while 87% experienced relief at four hours.[153] Other trials evaluating Berinert and Cinryze for HAE and ACEi-mediated angioedema have found that the time to symptom improvement from administration varies from 0.5-5 hours, with complete resolution occurring within 1-10 hours.[136] Ruconest is a recombinant form of C1INH. One open-label study with no placebo control found time to symptom relief of 30 minutes.[154] A double-blind, placebo-controlled trial found time to symptom relief of 66 minutes in patients receiving 100 units/kg, vs 495 minutes in controls.[155] Another randomized trial found time to symptom relief of 75 minutes in treated patients vs 303 minutes in patients receiving placebo.[156]

*Kallikrein Inhibitor*

Ecallantide (Kalbitor) is a recombinant plasma inhibitor of kallikrein provided subcutaneously and approved for use in HAE.[1,4,7,8,136] This agent reduces bradykinin synthesis by preventing the cleavage of kininogen.[1,4,7,8,136] It is associated with up to a 3% risk of anaphylaxis, necessitating close observation during administration and for up to one hour after.[1,4,7,8] The EDEMA trials evaluated ecallantide for HAE.[157-160] The EDEMA1 trial evaluated ecallantide at various doses vs placebo, finding the 40 mg/m$^2$ dose improved symptoms at four hours, although other doses did not.[157] The phase 2 EDEMA2 trial found subcutaneous dosing had improved outcomes vs IV dosing.[158] EDEMA3 was an open label and double-blind phase 3 trial evaluating ecallantide vs placebo, with improvement in treatment score at four hours in patients receiving ecallantide.[159] EDEMA4 found improved symptom scores vs placebo.[160] A triple-blind phase 2 randomized controlled trial compared ecallantide at three different subcutaneous doses with placebo for ACEi-mediated angioedema and found no difference in patients meeting criteria for discharge.[161] Lewis et al. conducted a double-blind phase 2 study with patients randomized to placebo or ecallantide.[162] Most patients received therapy for histamine-mediated angioedema as well. The study found no difference in patients meeting criteria for discharge within six hours with ecallantide administration.[162]

*Bradykinin B2 Receptor Antagonist*

Icatibant acetate (Firazyr) is a selective and competitive bradykinin B2 receptor antagonist.[1,4,7,8,136] Icatibant was evaluated in three clinical trials: FAST-1, FAST-2, and FAST-3.[136,163,164] FAST-1 was a double-blind, placebo-controlled trial that demonstrated faster symptom relief (0.8 vs 16.9 hours) but no difference in the degree of symptom relief.[4,163] The FAST-2 study demonstrated improved time to symptom relief in a double-blind study comparing icatibant to oral tranexamic acid (onset of symptom improvement 0.9 vs 7.8 hours).[4,163] FAST-3 was a phase 3 double-blind, randomized, placebo-controlled trial that found a decrease in the time to primary symptom relief (2.0 vs 19.8 hours) and complete symptom relief (median 8.0 vs 36 hours).[4,164] The literature suggests that the time to symptom improvement ranges from several minutes up to seven hours for icatibant. Of studies reporting improvement, approximately half of patients improve within 30 minutes, while time to complete symptom resolution ranges from 0.5-16 hours.[136,165-174] Importantly, 40% of cases have complete resolution under four hours.[136,165-173] A phase 2 multicenter, randomized controlled trial by Bas et al. evaluated icatibant vs steroids plus antihistamines, finding a shorter time to symptom relief with icatibant (2 hours vs 11.7 hours).[174] More patients receiving icatibant also demonstrated resolution of edema at four hours. However, there was no difference in the degree of patient-reported symptom relief.[4,136]

A systematic review published in 2017 evaluating medication use in ACEi-mediated angioedema concluded icatibant possessed the highest level of evidence due to better study quality, while FFP has limited evidence demonstrating benefit and inconsistent dosing strategies for ACEi-mediated angioedema.[136] This systematic review incorporated case reports, case series, a prospective observational study, and one randomized controlled trial. However, the recommendations were limited by low quality evidence and significant heterogeneity with respect to the severity of angioedema and clinical outcomes.[175] Most of the included studies evaluated time to discharge and time to symptom relief, rather than the need for definitive airway, peak symptoms severity, duration of mechanical ventilation, and hospital/ICU admission.[136,175] Publication bias was also severe, limiting conclusions. Studies following the publication of this systematic review from 2017 suggest no difference in time to discharge with icatibant.[175] Sinert et al. evaluated icatibant vs placebo in a phase III, double-blind clinical trial.[176] Time to discharge was four hours in both groups, with similar time of symptom relief.[176] A second prospective, randomized study published by Straka et al. compared icatibant and placebo, finding no difference in symptom severity or duration.[177]

The current literature evaluating targeted therapy for bradykinin-mediated angioedema suffers from several limitations, including significant heterogeneity in patient selection, outcomes, comparators, dosing, and study design, as well as low numbers of included patients and high risk of bias.[1,4,136,175] Medication efficacy is controversial with delayed onset of action, variable relief of symptoms, and limited availability depending on the institution.[136,175] Rather than primarily focus on administering medications that may or may not improve symptoms in bradykinin-mediated forms of angioedema, EPs should focus on managing the patient's airway.[1,4,175]

**Disposition**

Disposition is mainly determined by airway involvement. Several studies have sought to predict airway compromise in patients with acute angioedema.[1-5,85,178] Ishoo et al. performed a retrospective study of 80 patients with 93 acute episodes of angioedema.[85] Wheezing, voice change, hoarseness, and stridor predicted the need for airway intervention. This study categorized patients based on the anatomic location of angioedema (Table 4).[85] A subsequent study published one year later found the same factors predict need for definitive airway.[178] Importantly, these factors require further validation and laryngeal visualization for staging.

Patients with respiratory or airway distress require ICU admission, as well as those with stage III and IV edema due to risk of progression.[1-5,7,8,89] Patients with stable or improving stage I or II edema of the face, lip, or soft palate should be monitored for several hours to evaluate for worsening of the angioedema.[1-5,7,8,89,102] Patients with stage I angioedema can be discharged with follow-up after evaluation for progression. Patients with stage II angioedema are often discharged home within 24 hours, and ED observation units provide an optimal setting for monitoring of these patients.[1,4] However, if edema involves ≥ 3 sites (lips, tongue, mouth floor, soft palate, and larynx), admission is recommended due to greater risk of airway involvement.[89]

Patients with acute and recurrent angioedema may benefit from consultation with allergy/immunology specialists to discuss laboratory testing and arrange follow-up, particularly in patients with HAE.[1-5,7,8,102] Patients with a first episode of angioedema, no response to anaphylaxis treatment, or family history of HAE require follow-up with an allergy/immunology specialist. These specialists can help diagnose a specific cause, evaluate and educate the patient concerning triggers, and provide prophylactic medications, which may prevent the need for ED care.[1,4,179,180] Patients with known HAE and a recurrent attack may present with an action plan and recommended therapies, which should be followed when possible.[102,181,182]

Patients discharged from the ED with histamine-mediated angioedema and those with unclear etiology or first-time episode should be prescribed epinephrine autoinjectors and educated on potential triggers.[69,102] Family and friends should also be educated on these factors. Patients with respiratory distress or airway swelling after discharge should use the epinephrine autoinjector and immediately return to the ED. The patient with ACEi-mediated angioedema must discontinue his or her medication, and an alternative agent should be discussed with the patient's primary care provider.[1-5,7,8,102] Most patients can use calcium channel blockers or angiotensin receptor blockers without developing a recurrence of their angioedema.[1,183,184] The literature suggests the incidence of angioedema with ARB is 0.11%, which is not statistically different than placebo.[185]

**Table 4.** Predicting airway compromise based on anatomic location of angioedema.[85]

| Stage | Site | Frequency | Discharge | Inpatient | ICU | Intervention |
|---|---|---|---|---|---|---|
| I | Face, lip | 31% | 48% | 52% | 0% | 0% |
| II | Soft palate | 5% | 60% | 40% | 0% | 0% |
| III | Tongue | 32% | 26% | 7% | 67% | 7% |
| IV | Larynx | 31% | 0% | 0% | 100% | 24% |

*ICU,* intensive care unit.

## CONCLUSION

Angioedema is non-dependent, non-pitting edema at a variety of sites. Its forms can be divided into histamine-mediated and bradykinin-mediated types. Histamine-mediated forms can present similarly to anaphylaxis, while bradykinin-mediated angioedema is slower in onset, presents with greater face and oropharyngeal involvement, and has higher risk of progression. Initial evaluation and management should focus on the airway, followed by an evaluation for family history, medications, and prior episodes. Histamine-mediated angioedema is treated like anaphylaxis with epinephrine, antihistamines, and steroids. These medications are not effective for the bradykinin-mediated forms, although they can be attempted in the absence of effective therapy. Other medications include C1-INH protein replacement, kallikrein inhibitor, and bradykinin receptor antagonists. Several studies have evaluated these for angioedema, but the evidence is lacking for efficacy. The focus should be on airway management rather than medications in bradykinin-mediated angioedema. This may require fiberoptic or video laryngoscopy, with preparation for cricothyrotomy. Disposition depends on patient's airway and respiratory status, as well as the involved sites.

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*Conflicts of Interest*: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. No author has professional or financial relationships with any companies that are relevant to this study. This review does not reflect the views or opinions of the U.S. government, Department of Defense, U.S. Army, U.S. Air Force, or SAUSHEC EM Residency Program. There are no conflicts of interest or sources of funding to declare.



## REFERENCES

1. Moellman JJ, Bernstein JA, Lindsell C, et al. A consensus parameter for the evaluation and management of angioedema in the emergency department. *Acad Emerg Med.* 2014;21(4):469–84.
2. Bork K. An evidence based therapeutic approach to hereditary and acquired angioedema. *Curr Opin Allergy Clin Immunol.* 2014;14(4):354-62.
3. Bork K. Angioedema. Immunol Allergy Clin North Am. 2014;34(1):23-31.
4. Wilkerson RG. Angioedema in the emergency department: an evidence-based review. *Emerg Med Pract.* 2012;14(11): 1-21.
5. Frigas E, Nzeako UC. Angioedema. Pathogenesis, differential diagnosis, and treatment. *Clin Rev Allergy Immunol.* 2002;23(2):217-3.
6. Kim SJ, Brooks JC, Sheikh J, et al. Angioedema deaths in the United States, 1979-2010. *Ann Allergy Asthma Immunol.* 2014;113(6):630-4.
7. Bernstein JA, Moellman J. Emerging concepts in the diagnosis and treatment of patients with undifferentiated angioedema. *Int J Emerg Med.* 2012;5(1):39.
8. Bernstein JA, Cremonsei P, Hoffman TK, et al. Angioedema in the emergency department: a practical guide to differential diagnosis and management. *Int J Emerg Med.* 2017;10(1):15.
9. Gill P, Betschel SD. The clinical evaluation of angioedema. *Immunol Allergy Clin N Am.* 2017;37(3):449-66.
10. Gaeta TJ, Clark S, Pelletier AJ, et al. National study of US emergency department visits for acute allergic reactions, 1993 to 2004. *Ann Allergy Asthma Immunol.* 2007;98(4):360-5.
11. Zilberberg MD, Jacobsen T, Tillotson G. The burden of hospitalizations and emergency department visits with hereditary angioedema and angioedema in the United States, 2007. *Allergy Asthma Proc.* 2010;31(6):511-9.
12. Lin RY, Anderson AS, Shah SN, et al. Increasing anaphylaxis hospitalizations in the first 2 decades of life: New York State, 1990-2006. *Ann Allergy Asthma Immunol.* 2008;101(4):387-93.
13. Zuraw BL. Clinical practice. Hereditary angioedema. *N Engl J Med.* 2008;359(10):1027-36.
14. Bas M, Adams V, Suvorava T, et al. Nonallergic angioedema: role of bradykinin. *Allergy.* 2007;62(8):842-56.
15. Bernstein JA. Update on angioedema: evaluation, diagnosis, and treatment. *Allergy Asthma Proc.* 2011;32(6):408-12.
16. Banerji A, Clark S, Blanda M, et al. Multicenter study of patients with angiotensin-converting enzyme inhibitor induced angioedema who present to the emergency department. *Ann Allergy Asthma Immunol.* 2008;100(4):327-32.
17. Bork K, Hardt J, Witzke G. Fatal laryngeal attacks and mortality in hereditary angioedema due to C1-INH deficiency. *J Allergy Clin Immunol.* 2012;130(3):692-7.
18. Bork K. Recurrent angioedema and the threat of asphyxiation. *Dtsch Arztebl Int.* 2010;107(23):408-14.
19. Craig T, Pursun EA, Bork K, et al. WAO Guideline for the Management of Hereditary Angioedema. *World Allergy Organ J.* 2012;5(12):182-99.
20. Hoyer C, Hill MR, Kaminski ER. Angio-oedema: an overview of differential diagnosis and clinical management. *Contin Educ Anaesth Crit Care Pain.* 2012;12(6):307-11.
21. Bluestein HM, Hoover TA, Banerji AS, et al. Angiotensin-converting enzyme inhibitor-induced angioedema in a community hospital emergency department. *Ann Allergy Asthma Immunol.* 2009;103(6):502-7.
22. Bernstein JA, Moellman JJ. Progress in the emergency management of hereditary angioedema: focus on new treatment options in the United States. *Postgrad Med.* 2012;124(3):91-100.
23. Lang DM, Aberer W, Bernstein JA, et al. International consensus on hereditary and acquired angioedema. *Ann Allergy Asthma Immunol.* 2012;109(6):395-402.

24. Moellman JJ, Bernstein JA. Diagnosis and management of hereditary angioedema: an emergency medicine perspective. *J Emerg Med.* 2012;43(2):391-400.
25. Ghably J, Saleh H, Vyas H, et al. Paul Ehrlich's mastzellen: a historical perspective of relevant developments in mast cell biology. *Methods Mol Biol.* 2015;1220:3-10.
26. Krishnaswamy G, Ajitawi O, Chi DS. The human mast cell: an overview. *Methods Mol Biol.* 2006;315:13-34.
27. Krishnaswamy G, Kelley J, Johnson D, et al. The human mast cell: functions in physiology and disease. *Front Biosci.* 2001;6:D1109-27.
28. Grigoriadou S, Longhurst HJ. Clinical Immunology Review Series: an approach to the patient with angio-oedema. *Clin Exp Immunol.* 2008;155(3):367-77.
29. Abbas AK, Pober JS, Lichtman AH. (2010). Cellular and Molecular Immunology, 2nd ed. Philadelphia, Pennsylvania: Saunders/Elsevier.
30. Morgan BP. Hereditary angioedema-therapies old and new. *N Engl J Med.* 2010;363(6):581-3.
31. Saleh H, Embry S, Nauli A, et al. Anaphylactic reactions to oligosaccharides in red meat: a syndrome in evolution. *Clin Mol Allergy.* 2012;10(1):5.
32. Miller CW, Guha B, Krishnaswamy G. Exercise-induced anaphylaxis: a serious but preventable disorder. *Phys Sportsmed.* 2008;36(1):87-94.
33. Ismail S, Cheng L, Grigoriadou S, et al. Lesson of the month 2: the limitations of steroid therapy in bradykinin-mediated angioedema attacks. *Clin Med (Lond).* 2015;15(1):101-3.
34. Lawlor F, Black AK, Breathnach AS, et al. Vibratory angioedema: lesion induction, clinical features, laboratory and ultrastructural findings and response to therapy. *Br J Dermatol.* 1989;120(1):93-9.
35. Rose RF, Bhushan M, King CM, et al. Solar angioedema: an uncommonly recognized condition? *Photodermatol Photoimmunol Photomed.* 2005;21(5):226-8.
36. Bentley B 2nd. Cold-induced urticaria and angioedema: diagnosis and management. *Am J Emerg Med.* 1993;11(1):43-6.
37. Cicardi M, Zingale L, Zanichelli A, et al. C1 inhibitor: molecular and clinical aspects. Springer Semin Immunopathol. 2005;27(3):286-98.
38. Maurer M, Bader M, Bas MB, et al. New topics in bradykinin research. *Allergy.* 2011;66(11):1397-406.
39. Kaplan AP, Joseph K. Complement, kinins, and hereditary angioedema: mechanisms of plasma instability when C1 inhibitor is absent. *Clin Rev Allergy Immunol.* 2016;51(2):207-15.
40. Kaplan AP, Joseph K. The bradykinin-forming cascade and its role in hereditary angioedema. *Ann Allergy Asthma Immunol.* 2010;104(3):193-204.
41. Kaplan AP, Joseph K. Pathogenesis of hereditary angioedema: the role of the bradykinin-forming cascade. *Immunol Allergy Clin North Am.* 2017;37(3):513-25.
42. Gompels MM, Lock RJ, Morgan JE, et al. A multicentre study of the diagnostic efficiency of serological investigations for C1 inhibitor deficiency. *J Clin Pathol.* 2002;55(2):145-7.
43. Tarzi MD, Hickey A, Forster T, et al. An evaluation of tests used for the diagnosis and monitoring of C1 inhibitor deficiency: normal serum C4 does not exclude hereditary angio-oedema. *Clin Exp Immunol.* 2007;149(3):513-6.
44. Gang C, Lindsell CJ, Moellman J, et al. Factors associated with hospitalization of patients with angiotensin-converting enzyme inhibitor-induced angioedema. *Allergy Asthma Proc.* 2013;34(3):267-73.
45. Holm JP, Ovesen T. Increasing rate of angiotensin-converting enzyme inhibitor-related upper airway angio-oedema. *Dan Med J.* 2012;59(6):A4449.
46. Williams-Johnson JA, Hemmings S, Williams EW, et al. Six years experience of angioedema at the University Hospital of the West Indies. *West Indian Med J.* 2007;56(3):278-81.
47. Brown NJ, Ray WA, Snowden M, et al. Black Americans have an increased rate of angiotensin converting enzyme inhibitor-associated angioedema. *Clin Pharmacol Ther.* 1996;60(1):8-13.
48. Wilkin JK, Hammond JJ, Kirkendall WM. The captopril-induced eruption. A possible mechanism: cutaneous kinin potentiation. *Arch Dermatol.* 1980;116(8):902-5.
49. Nussberger J, Cugno M, Amstutz C, et al. Plasma bradykinin in angio-oedema. *Lancet.* 1998;351(9117):1693-7.
50. Miller DR, Oliveria SA, Berlowitz DR, et al. Angioedema incidence in US veterans initiating angiotensin-converting enzyme inhibitors. *Hypertension.* 2008;51(6):1624-30.
51. Lin RY, Levine RJ, Lin H. Adverse drug effects and angioedema hospitalizations in the United States from 2000 to 2009. *Allergy Asthma Proc.* 2013;34(1):65-71.
52. Kostis JB, Kim HJ, Rusnak J, et al. Incidence and characteristics of angioedema associated with enalapril. *Arch Intern Med.* 2005;165(14):1637-42.
53. Byrd JB, Adam A, Brown NJ. Angiotensin-converting enzyme inhibitor-associated angioedema. *Immunol Allergy Clin North Am.* 2006;26(4):725-37.
54. Blanch A, Roche O, Urrutia I, et al. First case of homozygous C1 inhibitor deficiency. *J Allergy Clin Immunol.* 2006;118(6):1330-5.
55. Bork K, Meng G, Staubach P, et al. Hereditary angioedema: new findings concerning symptoms, affected organs, and course. *Am J Med.* 2006;119(3):267-74.
56. Berges-Gimeno MP, Martin-Lazaro J. Allergic reactions to nonsteroidal anti-inflammatory drugs: is newer better? Curr Allergy Asthma Rep. 2007;7(1):35-40.
57. Zuraw BL, Christiansen SC. Pathophysiology of hereditary angioedema. *Am J Rhinol Allergy.* 2011;25(6):373-8.
58. Frazer-Abel A, Giclas PC. Update on laboratory tests for the diagnosis and differentiation of hereditary angioedema and acquired angioedema. *Allergy Asthma Proc.* 2011;32(Suppl 1):S17-21.
59. Yamamoto T, Horiuchi T, Miyahara H, et al. Hereditary angioedema in Japan: genetic analysis of 13 unrelated cases. *Am J Med Sci.* 2012;343(3):210-4.
60. Warin RP, Cunliffe WJ, Greaves MW, et al. Recurrent angioedema: familial and oestrogen-induced. *Br J Dermatol.* 1986;115(6):731-4.
61. Bork K, Barnstedt SE, Koch P, et al. Hereditary angioedema with normal C1-inhibitor activity in women. *Lancet.* 2000;356(9225):213-7.
62. Binkley KE, Davis A 3rd. Clinical, biochemical, and genetic characterization of a novel estrogen-dependent inherited form of

angioedema. *J Allergy Clin Immunol.* 2000;106(3):546- 50.

63. Prematta MJ, Kemp JG, Gibbs JG, et al. Frequency, timing, and type of prodromal symptoms associated with hereditary angioedema attacks. *Allergy Asthma Proc.* 2009;30(5):506-11.
64. Baeza ML, Rodriguez-Marco A, Prieto A, et al. Factor XII gene missense mutation Thr328Lys in an Arab family with hereditary angioedema type III. *Allergy.* 2011;66(7):981-2.
65. Caldwell JR, Ruddy S, Schur PH, et al. Acquired C1 inhibitor deficiency in lymphosarcoma. *Clin Immunol Immunopathol.* 1972;1(1):39-52.
66. Jackson J, Sim RB, Whelan A, et al. An IgG autoantibody which inactivates C1-inhibitor. *Nature.* 1986;323(6090):722-4.
67. Chevailler A, Arlaud G, Ponard D, et al. C-1-inhibitor binding monoclonal immunoglobins in three patients with acquired angioneurotic edema. *J Allergy Clin Immunol.* 1996;97(4):998-1008.
68. D'Incan M, Tridon A, Ponard D, et al. Acquired angioedema with C1 inhibitor deficiency: is the distinction between type I and type II still relevant? *Dermatology.* 1999;199(3):227-30.
69. Busse PJ. Angioedema: differential diagnosis and treatment. *Allergy Asthma Proc.* 2011;32(Suppl 1):3-11.
70. Cicardi M, Zingale LC, Pappalardo E, et al. Autoantibodies and lymphoproliferative diseases in acquired C1-inhibitor deficiencies. *Medicine (Baltimore).* 2003;82(4):274-81.
71. Fremeaux-Bacchi V, Guinnepain MT, Cacoub P, et al. Prevalence of monoclonal gammopathy in patients presenting with acquired angioedema type 2. *Am J Med.* 2002;113(3):194-9.
72. Bertazzoni G, Spina MT, Scarpellini MG, et al. Drug-induced angioedema: experience of Italian emergency departments. *Intern Emerg Med.* 2014;9(4):455-62.
73. Toh S, Reichman ME, Houstoun M, et al. Comparative risk for angioedema associated with the use of drugs that target the renin-angiotensin-aldosterone system. *Arch Intern Med.* 2012;172(20):1582-9.
74. Strom BL, Carson JL, Morse ML, et al. The effect of indication on hypersensitivity reactions associated with zomepirac sodium and other nonsteroidal antiinflammatory drugs. *Arthritis Rheum.* 1987;30(10):1142-8.
75. Settipane GA. Aspirin and allergic diseases: a review. *Am J Med.* 1983;74(6A):102-9.
76. Beavers CJ, Dunn SP, Macaulay TE. The role of angiotensin receptor blockers in patients with angiotensin-converting enzyme inhibitor-induced angioedema. *Ann Pharmacother.* 2011;45(4):520-4.
77. Kidney Disease Outcomes Quality Initiative (K/DOQI). K/DOQI clinical practice guidelines on hypertension and antihypertensive agents in chronic kidney disease. *Am J Kidney Dis.* 2004;43(Suppl 1):S1-290.
78. Bas M, Greve J, Strassen U, et al. Angioedema induced by cardiovascular drugs: new players join old friends. *Allergy.* 2015;70(10):1196-200.
79. Bezalel S, Mahlab-Guri K, Asher I, et al. Angiotensin converting enzyme inhibitor-induced angioedema. *Am J Med.* 2015;128(2):120-5.
80. Baş M, Hoffmann TK, Kojda G. Icatibant in ACE-inhibitor-induced angioedema. *N Engl J Med.* 2015;372(19):1867-8.
81. Sala-Cunill A, Björkqvist J, Senter R, et al. Plasma contact system activation drives anaphylaxis in severe mast cell mediated allergic reactions. *J Allergy Clin Immunol.* 2015;135(4):1031-43.e6.
82. US Hereditary Angioedema Association. Comprehensive angioedema typology and description. Available at: http://www.haea.org/professionals/angioedema/. Accessed November 3, 2015.
83. Cicardi M, Aberer W, Banerji A, et al. Classification, diagnosis, and approach to treatment for angioedema: consensus report from the Hereditary Angioedema International Working Group. *Allergy.* 2014;69(5):602-16.
84. Zingale LC, Beltrami L, Zanichelli A, et al. Angioedema without urticaria: a large clinical survey. *CMAJ.* 2006;175(9):1065-70.
85. Ishoo E, Shah UK, Grillone GA, et al. Predicting airway risk in angioedema: staging system based on presentation. *Otolaryngol Head Neck Surg.* 1999;121(3):263-8.
86. Agah R, Bandi V, Guntupalli KK. Angioedema: the role of ACE inhibitors and factors associated with poor clinical outcome. *Intensive Care Med.* 1997;23(7):793-6.
87. Al-Khudari S, Loochtan MJ, Peterson E, et al. Management of angiotensin-converting enzyme inhibitor-induced angioedema. *Laryngoscope.* 2011;121(11):2327-34.
88. Gannon TH, Eby TL. Angioedema from angiotensin converting enzyme inhibitors: a cause of upper airway obstruction. *Laryngoscope.* 1990;100(11):1156-60.
89. McCormick M, Folbe AJ, Lin HS, et al. Site involvement as a predictor of airway intervention in angioedema. *Laryngoscope.* 2011;121(2):262-6.
90. Pigman EC, Scott JL. Angioedema in the emergency department: the impact of angiotensin-converting enzyme inhibitors. *Am J Emerg Med.* 1993;11(4):350-4.
91. Saxena S, Gierl B, Eibling DE. Supraglottic swelling may not correlate with tongue swelling in angiotensin converting enzyme inhibitor-induced angioedema. *Laryngoscope.* 2010;120(1):62-4.
92. Stojiljkovic L. Renin-angiotensin system inhibitors and angioedema: anesthetic implications. *Curr Opin Anaesthesiol.* 2012;25(3):356-62.
93. Bork K, Staubach P, Eckardt AJ, et al. Symptoms, course, and complications of abdominal attacks in hereditary angioedema due to C1 inhibitor deficiency. *Am J Gastroenterol.* 2006;101(3):619-27.
94. Khan DA. Hereditary angioedema: Historical aspects, classification, pathophysiology, clinical presentation, and laboratory diagnosis. *Allergy Asthma Proc.* 2011;32(1):1-10.
95. Champion RH, Roberts SO, Carpenter RG, et al. Urticaria and angio-oedema. A review of 554 patients. *Br J Dermatol.* 1969;81(8):588-97.
96. Vazquez Nava F, Almeida Arvizu VM, Sanchez Nuncio HR, et al. [Prevalence and potential triggering factors of chronic urticaria and angioedema in an urban area of northeastern Mexico]. [Article in Spanish]. *Rev Alerg Mex.* 2004;51(5):181-8.
97. Lenschow M, Bas M, Johnson F, et al. A score for the differential diagnosis of bradykinin- and histamine-induced head and neck swellings. *Eur Arch Otorhinolaryngol.* 2018;275(7):1767-73.
98. Calbo L, Quattrocchi P, Ferlazzo B. Abdominal attack of hereditary angioedema associated with marked leucocytosis. A case report. *Ital J Gastroenterol.* 1992;24(8):464-5.
99. Zuraw BL, Bernstein JA, Lang DM, et al. A focused parameter update: hereditary angioedema, acquired C1 inhibitor deficiency, and

angiotensin-converting enzyme inhibitor-associated angioedema. *J Allergy Clin Immunol.* 2013;131(6):1491-3.

100. Markovic SN, Inwards DJ, Phyliky RP. Acquired C1 esterase inhibitor deficiency. *Ann Intern Med.* 2000;133(10):839.
101. Li H, Busse P, Lumry WR, et al. Comparison of chromogenic and ELISA functional C1 inhibitor tests in diagnosing hereditary angioedema. *J Allergy Clin Immunol Pract.* 2015;3(2):200-5.
102. Bowen T, Cicardi M, Farkas H, et al. 2010 International consensus algorithm for the diagnosis, therapy and management of hereditary angioedema. *Allergy Asthma Clin Immunol.* 2010;6(1):24.
103. Alsenz, J, Bork K, Loos M. Autoantibody-mediated acquired deficiency of C1 inhibitor. *N Engl J Med.* 1987;316(22):1360-6.
104. Scheirey CD, Scholz FJ, Shortsleeve MJ, et al. Angiotensin-converting enzyme inhibitor-induced small-bowel angioedema: clinical and imaging findings in 20 patients. *AJR Am J Roentgenol.* 2011;197(2):393-8.
105. Jaiganesh T, Wiese M, Hollingsworth J, et al. Acute angioedema: recognition and management in the emergency department. *Eur J Emerg Med.* 2013;20(1):10-7.
106. Sofia S, Casali A, Bolondi L. Sonographic findings in abdominal hereditary angioedema. *J Clin Ultrasound.* 1999;27(9):537- 40.
107. Walls R, Murphy M. (2012). Manual of Emergency Airway Management. Philadelphia, PA: Lippincott, Williams, and Wilkins, Wolters Kluwer.
108. Kramer A, Müller D, Pförtner R, et al. Fibreoptic vs videolaryngoscopic (C-MAC(®) D-BLADE) nasal awake intubation under local anaesthesia. *Anaesthesia.* 2015;70(4):400-6.
109. Simmons ST, Schleich AR. Airway regional anesthesia for awake fiberoptic intubation. *Reg Anesth Pain Med.* 2002;27(2):180-92.
110. Bramante RM, Rand M. Images in clinical medicine. Angioedema. *N Engl J Med.* 2011;365(2):e4.
111. Richman MJ, Talan DA, Lumry WR. Treatment of laryngeal hereditary angioedema. *J Emerg Med.* 2012;42(1):44-7.
112. James C, Bernstein JA. Current and future therapies for the treatment of histamine-induced angioedema. *Expert Opin Pharmacother.* 2017;18(3):253-62.
113. Simons FE, Roberts JR, Gu X, et al. Epinephrine absorption in children with a history of anaphylaxis. *J Allergy Clin Immunol.* 1998;101(1 Pt 1):33-7.
114. Simons FE, Gu X, Simons KJ. Epinephrine absorption in adults: intramuscular versus subcutaneous injection. *J Allergy Clin Immunol.* 2001;108(5):871-3.
115. Johnston SL, Unsworth J, Gompels MM. Adrenaline given outside the context of life threatening allergic reactions. *BMJ.* 2003;326(7389):589-90.
116. ECC Committee, Subcommittee and Task Forces of the American Heart Association. 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation.* 2005;112(24 Suppl):IV1-203.
117. Runge JW, Martinez JC, Caravati EM, et al. Histamine antagonists in the treatment of acute allergic reactions. *Ann Emerg Med.* 1992;21(3):237-42.
118. Lin RY, Curry A, Pesola GR, et al. Improved outcomes in patients with acute allergic syndromes who are treated with combined H1 and H2 antagonists. *Ann Emerg Med.* 2000;36(5):462-8.
119. Breneman DL. Cetirizine versus hydroxyzine and placebo in chronic idiopathic urticaria. *Ann Pharmacother.* 1996;30(10):1075-9.
120. Goh CL, Wong WK, Lim J. Cetirizine vs placebo in chronic idiopathic urticaria--a double-blind randomized cross-over study. *Ann Acad Med Singapore.* 1991;20(3):328-30.
121. Finn AF Jr, Kaplan AP, Fretwell R, et al. A double-blind, placebo-controlled trial of fexofenadine HCl in the treatment of chronic idiopathic urticaria. *J Allergy Clin Immunol.* 1999;104(5):1071-8.
122. Nelson HS, Reynolds R, Mason J. Fexofenadine HCl is safe and effective for treatment of chronic idiopathic urticaria. *Ann Allergy Asthma Immunol.* 2000;84(5):517-22.
123. Kapp A, Wedi B. Chronic urticaria: clinical aspects and focus on a new antihistamine, levocetirizine. *J Drugs Dermatol.* 2004;3(6):632-9.
124. Monroe EW, Bernstein DI, Fox RW, et al. Relative efficacy and safety of loratadine, hydroxyzine, and placebo in chronic idiopathic urticaria. *Arzneimittelforschung.* 1992;42(9):1119-21.
125. Monroe EW. Relative efficacy and safety of loratidine, hydroxyzine, and placebo in chronic idiopathic urticaria and atopic dermatitis. *Clin Ther.* 1992;14(1):17-21.
126. Handa S, Dogra S, Kumar B. Comparative efficacy of cetirizine and fexofenadine in the treatment of chronic idiopathic urticaria. *J Dermatolog Treat.* 2004;15(1):55-7.
127. Kaplan AP. Clinical practice. Chronic urticaria and angioedema. *N Engl J Med.* 2002;346(3):175-9. Review.
128. Sampson HA, Muñoz-Furlong A, Campbell RL, et al. Second symposium on the definition and management of anaphylaxis: summary report--second National Institute of Allergy and Infectious Disease/Food Allergy and Anaphylaxis Network symposium. *Ann Emerg Med.* 2006;47(4):373-80.
129. Pickering RJ, Good RA, Kelly JR, et al. Replacement therapy in hereditary angioedema. Successful treatment of two patients with fresh frozen plasma. *Lancet.* 1969;1(7590):326-30.
130. Hill BJ, Thomas SH, McCabe C. Fresh frozen plasma for acute exacerbations of hereditary angioedema. *Am J Emerg Med.* 2004;22(7):633.
131. Pekdemir M, Ersel M, Aksay E, et al. Effective treatment of hereditary angioedema with fresh frozen plasma in an emergency department. *J Emerg Med.* 2007;33(2):137-9.
132. Warrier MR, Copilevitz CA, Dykewicz MS, et al. Fresh frozen plasma in the treatment of resistant angiotensin-converting enzyme inhibitor angioedema. *Ann Allergy Asthma Immunol.* 2004;92(5):573-5.
133. Bolton MR, Dooley-Hash SL. Angiotensin-converting enzyme inhibitor angioedema. *J Emerg Med.* 2012;43(4):e261-2.
134. Prematta M, Gibbs JG, Pratt EL, et al. Fresh frozen plasma for the treatment of hereditary angioedema. *Ann Allergy Asthma Immunol.* 2007;98(4):383-8.
135. Longhurst HJ. Emergency treatment of acute attacks in hereditary angioedema due to C1 inhibitor deficiency: what is the evidence? *Int J Clin Pract.* 2005;59(5):594-9.
136. Riha HM, Summers BB, Rivera JV. Novel therapies for angiotensin-converting enzyme inhibitor-induced angioedema: a systematic review

of current evidence. *J Emerg Med.* 2017;53(5):662-79.

137. Jaffe CJ, Atkinson JP, Gelfand JA, et al. Hereditary angioedema: the use of fresh frozen plasma for prophylaxis in patients undergoing oral surgery. *J Allergy Clin Immunol.* 1975;55(6):386-93.
138. Saeb A, Hagglund KH, Cigolle CT. Using fresh frozen plasma for acute airway angioedema to prevent intubation in the emergency department: a retrospective cohort study. *Emerg Med Int.* 2016;2016:6091510.
139. Hassen GW, Kalantari H, Parraga M, et al. Fresh frozen plasma for progressive and refractory angiotensin-converting enzyme inhibitor-induced angioedema. *J Emerg Med.* 2013;44(4):764-72.
140. Karim MY, Masood A. Fresh-frozen plasma as a treatment for life threatening ACE-inhibitor angioedema. *J Allergy Clin Immunol.* 2002;109(2):370-1.
141. Stewart M, McGlone R. Fresh frozen plasma in the treatment of ACE inhibitor induced angioedema. *BMJ Case Rep.* 2012;2012. pii: bcr2012006849.
142. Lipski SM, Casimir G, Vanlommel M, et al. Angiotensin-converting enzyme inhibitors-induced angioedema treated by C1 esterase inhibitor concentrate (Berinert ®): about one case and review of the therapeutic arsenal. *Clin Case Rep.* 2015;3(2):126-30.
143. Tharayil AM, Chanda AH, Shiekh HA, et al. Life threatening angioedema in a patient on ACE inhibitor (ACEI) confined to the upper airway. *Qatar Med J.* 2014;2014(2):92-7.
144. Shiber J. Lingual Angioedema due to ACE-Inhibitor. *Trop Med Surg.* 2014;2(1):161.
145. Atalay E, Özdemir MT, Çiğsar G, et al. Angiotensin Converting Enzyme Inhibitor-related Angioedema: A Case of an Unexpected Death. *Iran J Allergy Asthma Immunol.* 2015;14(6):642-5.
146. Millot I, Plancade D, Hosotte M, et al. Treatment of a life-threatening laryngeal bradykinin angio-oedema precipitated by dipeptidylpeptidase-4 inhibitor and angiotensin-I converting enzyme inhibitor with prothrombin complex concentrates. *Br J Anaesth.* 2012;109(5):827-9.
147. Henry Li H, Riedl M, Kashkin J. Update on the use of C1-esterase inhibitor replacement therapy in the acute and prophylactic treatment of hereditary angioedema. *Clin Rev Allergy Immunol.* 2019;56(2):207-18.
148. Brackertz D, Kueppers F. Hereditary angioneurotic oedema. *Lancet.* 1973;2(7830):680.
149. Bork K, Barnstedt SE. Treatment of 193 episodes of laryngeal edema with C1 inhibitor concentrate in patients with hereditary angioedema. *Arch Intern Med.* 2001;161(5):714-8.
150. Craig TJ, Levy RJ, Wasserman RL, et al. Efficacy of human C1 esterase inhibitor concentrate compared with placebo in acute hereditary angioedema attacks. *J Allergy Clin Immunol.* 2009;124(4):801-8.
151. Craig TJ, Bewtra AK, Bahna SL, et al. C1 esterase inhibitor concentrate in 1085 hereditary angioedema attacks--final results of the I.M.P.A.C.T.2 study. *Allergy.* 2011;66(12):1604-11.
152. Zuraw BL, Busse PJ, White M, et al. Nanofiltered C1 Inhibitor concentrate for treatment of hereditary angioedema. *N Engl J Med.* 2010;363(6):513-22.
153. Riedl MA, Hurewitz DS, Levy R, et al. Nanofiltered C1 esterase inhibitor (human) for the treatment of acute attacks of hereditary angioedema: an open-label trial. *Ann Allergy Asthma Immunol.* 2012;108(1):49-53.
154. Choi G, Soeters MR, Farkas H, et al. Recombinant human C1-inhibitor in the treatment of acute angioedema attacks. *Transfusion.* 2007;47(6):1028-32.
155. Zuraw B, Cicardi M, Levy RJ, et al. Recombinant human C1-inhibitor for the treatment of acute angioedema attacks in patients with hereditary angioedema. *J Allergy Clin Immunol.* 2010;126(4):821-7.
156. Riedl MA, Bernstein JA, Li H, et al. Recombinant human C1-esterase inhibitor relieves symptoms of hereditary angioedema attacks: phase 3, randomized, placebo-controlled trial. *Ann Allergy Asthma Immunol.* 2014;112(2):163-9.e1.
157. Schneider L, Lumry W, Vegh A, et al. Critical role of kallikrein in hereditary angioedema pathogenesis: a clinical trial of ecallantide, a novel kallikrein inhibitor. *J Allergy Clin Immunol.* 2007;120(2):416-22.
158. Lumry W, Li H, Schneider L, et al. Results of a repeat-dosing study of intravenous and subcutaneous administration of ecallantide (DX-88), a recombinant plasma kallikrein inhibitor, in patients with hereditary angioedema. *Ann Allergy Asthma Immunol.* 2007;98(Suppl 1):A29.
159. Levy R, McNeil D, Li H, et al. Results of a 2-stage, phase 3 pivotal trial, EDEMA3: a study of subcutaneous DX-88 (ecallantide), a plasma kallikrein inhibitor, in patients with hereditary angioedema (HAE). *J Allergy Clin Immunol.* 2008;121(2 Suppl 1):S231.
160. Levy RJ, Lumry WR, McNeil DL, et al. EDEMA4: a phase 3, double-blind study of subcutaneous ecallantide treatment for acute attacks of hereditary angioedema. *Ann Allergy Asthma Immunol.* 2010;104(6):523-9.
161. Bernstein JA, Moellman JJ, Collins SP, et al. Effectiveness of ecallantide in treating angiotensin-converting enzyme inhibitor-induced angioedema in the emergency department. *Ann Allergy Asthma Immunol.* 2015;114(3):245-9.
162. Lewis LM, Graffeo C, Crosley P, et al. Ecallantide for the acute treatment of angiotensin-converting enzyme inhibitor-induced angioedema: a multicenter, randomized, controlled trial. *Ann Emerg Med.* 2015;65(2):204-13.
163. Cicardi M, Banerji A, Bracho F, et al. Icatibant, a new bradykinin receptor antagonist, in hereditary angioedema. *N Engl J Med.* 2010;363(6):532-41.
164. Lumry WR, Li HH, Levy RJ, et al. Results from FAST-3: A Phase III Randomized, Double-Blind, Placebo-Controlled, Multicenter Study of Subcutaneous Icatibant in Patients with Acute Hereditary Angioedema (HAE) Attacks. *J Allergy Clin Immunol.* 2011;127(2 Suppl):AB1.
165. Bartal C, Zeldetz V, Stavi V, et al. The role of icatibant-the B2 bradykinin receptor antagonist-in life-threatening laryngeal angioedema in the ED. *Am J Emerg Med.* 2015;33(3):479.e1-3.
166. Charmillon A, Deibener J, Kaminsky P, et al. Angioedema induced by angiotensin converting enzyme inhibitors, potentiated by m-TOR inhibitors: successful treatment with icatibant. *Intensive Care Med.* 2014;40(6):893-4.
167. Crooks NH, Patel J, Diwakar L, et al. Icatibant in the treatment of angiotensin-converting enzyme inhibitor-induced angioedema. *Case Rep Crit Care.* 2014;2014:864815.
168. Gallitelli M, Alzetta M. Icatibant: a novel approach to the treatment of angioedema related to the use of angiotensin-converting enzyme

inhibitors. *Am J Emerg Med.* 2012;30(8):1664.e1-2.

169. Mahajan H, Thynne T, Gabb GM, et al. Drug safety in Aboriginal Australians: three cases of angiotensin-converting enzyme inhibitor angioedema. *Intern Med J.* 2015;45(2):231-3.
170. Bas M, Greve J, Stelter K, et al. Therapeutic efficacy of icatibant in angioedema induced by angiotensin converting enzyme inhibitors: a case series. *Ann Emerg Med.* 2010;56(3):278-82.
171. Bova M, Guilarte M, Sala-Cunill A, et al. Treatment of ACEI-related angioedema with icatibant: a case series. *Intern Emerg Med.* 2015;10(3):345-50.
172. Jacob J, Bardes I, Palom X, et al. Angiotensin converting enzyme inhibitor-induced angioedema and icatibant: a new hope. *Intern Med J.* 2015;45(10):1093-4.
173. Volans A, Ferguson R. Using a bradykinin blocker in ACE inhibitor associated angioedema in the emergency department. *BMJ Case Rep.* 2013;2013. Pii:bcr2012008295.
174. Bas M, Greve J, Stelter K, et al. A randomized trial of icatibant in ACE-inhibitor-induced angioedema. *N Engl J Med.* 2015;372(5):418-25.
175. Wilkerson RG, Martinelli AN, Oliver WD. Treatment of angioedema induced by angiotensin-converting enzyme inhibitor. *J Emerg Med.* 2018;55(1):132-3.
176. Sinert R, Levy P, Bernstein JA, et al. Randomized trial of icatibant for angiotensin-converting enzyme inhibitor-induced opper airway angioedema. *J Allergy Clin Immunol Pract.* 2017;5(5):1402-9.e3.
177. Straka BT, Ramirez CE, Byrd JB, et al. Effect of bradykinin receptor antagonism on ACE inhibitor-associated angioedema. *J Allergy Clin Immunol.* 2017;140(1):242-8.
178. Bentsianov BL, Parhiscar A, Azer M, et al. The role of fiberoptic nasopharyngoscopy in the management of the acute airway in angioneurotic edema. *Laryngoscope.* 2000;110(12):2016-9.
179. Kreuz W, Rusicke E, Martinez-Saguer I, et al. Home therapy with intravenous human C1-inhibitor in children and adolescents with hereditary angioedema. *Transfusion.* 2012;52(1):100-7.
180. Cicardi M, Bork K, Caballero T, et al. Evidence based recommendations for the therapeutic management of angioedema owing to hereditary C1 inhibitor deficiency: consensus report of an International Working Group. *Allergy.* 2012;67(2):147-57.
181. Wahn V, Aberer W, Eberl W, et al. Hereditary angioedema (HAE) in children and adolescents--a consensus on therapeutic strategies. *Eur J Pediatr.* 2012;171(9):1339-48.
182. Epstein TG, Bernstein JA. Current and emerging management options for hereditary angioedema in the US. *Drugs.* 2008;68(18):2561-73.
183. Cicardi M, Zingale LC, Bergamaschini L, et al. Angioedema associated with angiotensin-converting enzyme inhibitor use: outcome after switching to a different treatment. *Arch Intern Med.* 2004;164(8):910-3.
184. Haymore BR, Yoon J, Mikita CP, et al. Risk of angioedema with angiotensin receptor blockers in patients with prior angioedema associated with angiotensin-converting enzyme inhibitors: a meta-analysis. *Ann Allergy Asthma Immunol.* 2008;101(5):495-9.
185. Makani H, Messerli FH, Romero J, et al. Meta-analysis of randomized trials of angioedema as an adverse event of renin-angiotensin system inhibitors. *Am J Cardiol.* 2012;110(3):383-91.

# Skill Proficiency is Predicted by Intubation Frequency of Emergency Medicine Attending Physicians

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*Section Editor:* Gabriel Wardi, MD
Submission history: Submitted March 3, 2019; Accepted June 5, 2019
Electronically published July 2, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.6.42946

**Introduction:** Airway management is a fundamental skill of emergency medicine (EM) practice, and suboptimal management leads to poor outcomes. Endotracheal intubation (ETI) is a procedure that is specifically taught in residency, but little is known how best to maintain proficiency in this skill throughout the practitioner's career. The goal of this study was to identify how the frequency of intubation correlated with measured performance.

**Methods:** We assessed 44 emergency physicians for proficiency at ETI by direct laryngoscopy on a simulator. The electronic health record was then queried to obtain their average number of annual ETIs and the time since their last ETI, supervised and individually performed, over a two-year period. We evaluated the strength of correlation between these factors and assessment scores, and then conducted a receiver operator characteristic (ROC) curve analysis to identify factors that predicted proficient performance.

**Results:** The mean score was 81% (95% confidence interval, 76% - 86%). Scores correlated well with the mean number of ETIs performed annually and with the mean number supervised annually ($r = 0.6$, $p = 0.001$ for both). ROC curve analysis identified that physicians would obtain a proficient score if they had performed an average of at least three ETIs annually (sensitivity = 90%, specificity = 64%, AUC = 0.87, $p = 0.001$) or supervised an average of at least five ETIs annually (sensitivity = 90%, specificity = 59%, AUC = 0.81, $p = 0.006$) over the previous two years.

**Conclusion:** Performing at least three or supervising at least five ETIs annually, averaged over a two-year period, predicted proficient performance on a simulation-based skills assessment. We advocate for proactive maintenance and enhancement of skills, particularly for those who infrequently perform this procedure. [West J Emerg Med. 2019;20(4)601-609]

## INTRODUCTION

Endotracheal intubation (ETI) is a high-stakes, life-saving, procedural skill. However, little is understood regarding maintenance of proficiency for this procedure. Although airway skills are known to decline without continuous practice,[1,2] factors influencing the maintenance of proficiency for this procedure are poorly understood. Patients requiring ETI for impending respiratory failure are at high risk of death or permanent cognitive impairment when the procedure is improperly performed. Prior studies demonstrate that patients undergoing multiple attempts at intubation (three or more) have significantly higher adverse event rates as compared with patients undergoing fewer attempts.[3,4]

The Accreditation Council of Graduate Medical Education (ACGME) mandates that resident physicians, prior to graduation, perform a specific number of intubations, which varies across specialties, in order to achieve proficiency for this skill.[5] However, once acquired, the best way to maintain this skill is unclear,[6,7] and evidence is lacking regarding the

minimum experience needed to maintain proficiency. Pusic et al. suggested that there is a rate for both gaining and losing skills, and that deliberate practice was the method of choice for avoiding losses.[8]

The Agency for Healthcare Research and Quality, The Joint Commission, and the American Board of Medical Specialties (ABMS) have increased efforts on quality improvement initiatives that facilitate the maintenance of proficiency and adherence to evidence-based standards. In 2004, the American Board of Emergency Medicine (ABEM) implemented a maintenance of certification (MOC) program to improve the quality of care delivered by emergency physicians.[9] It consists of the four components proposed by ABMS: 1) lifelong learning and self-assessment; 2) improvement in medical practice; 3) the ConCert examination (assessment of knowledge, judgment and skills); and 4) professionalism and professional standing. Despite these efforts, there is no evidence-based guideline for maintaining proficiency in procedural skills such as ETI.

The purpose of this study was to identify factors relating to intubation frequency that correlate with proficiency for ETI.

*Population Health Research Capsule*

What do we already know about this issue?
*Intubation skill is associated with frequency of performance and deliberate practice, not years of experience. Formal skill assessment after residency is uncommon.*

What was the research question?
*How does the frequency of endotracheal intubation correlate with measured performance in attending physicians?*

What was the major finding of the study?
*Performing at least three or supervising at least five intubations annually predicted proficient skill.*

How does this improve population health?
*Evidence-based guidelines regarding intubation frequency help inform the need for proactive training to maintain proficiency in this critical skill.*

## METHODS

### Study Design

This was a cross-sectional study to determine factors related to intubation frequency that correlated with assessed skill of ETI via direct laryngoscopy (DL) on an airway simulator. We performed a subsequent analysis on factors with good correlation to identify intubation frequencies that could predict assessment scores below a defined proficiency level. The study was classified as "exempt" by the local institutional review board.

### Study Setting and Sample

The study was conducted at a private urban hospital in the Northeast with an annual emergency department census of 115,000 patients, and an associated emergency medicine (EM) residency program. Subjects assessed for ETI proficiency included a convenience sample of all employed full-time attending physicians over a three- month time period. All participants were board certified or board eligible in EM, pediatric EM, or both. Participation was mandated as part of a departmental skills advancement initiative conducted between November 2011 and January 2012.

### Measurements

The primary outcome measures were the strength of correlation between DL ETI assessment scores and the following: 1) the time since last performing an intubation; 2) the time since last supervising an intubation; 3) the mean number of intubations performed annually; and 4) the mean number of intubations supervised annually. The secondary outcome measure was the identification of intubation frequencies that predict a physician score below the established proficiency score on the airway assessment. We performed a post hoc analysis to measure the strength of correlation with years of experience and ETI assessment score.

*ETI Assessment - Score Calculation*

Each attending physician was individually administered a skills assessment of ETI by DL on a TruCorp Airsim Advance mannequin, which was a model replicating the airway from DICOM library images of an actual patient's computed tomography. We assessed physicians for successful completion of 11 checklist items (Table 1), as well as their overall psychomotor adeptness using a rating scale of 0-10,

**Table 1.** 11-item intubation checklist.

| |
|---|
| Assembly of equipment: |
| □ Suction |
| □ Correct-sized endotracheal tube and blade |
| □ Back-up tube and blade |
| □ Rescue device |
| □ Stylet |
| □ Confirmation device (EDD, $EtCO_2$ detector, etc.) |
| Discrete actions: |
| □ Evaluates airway anatomy and mobility |
| □ Positions appropriately |
| □ Articulates RSI meds |
| □ Does not rock laryngoscope handle backwards on insertion |
| □ Inserts tube to correct depth |

*EDD*, esophageal detector device; *$EtCO_2$*, end-tidal carbon dioxide; *RSI,* rapid sequence intubation.

with 0 representing significant "struggle" and 10 representing "no struggle." The construct of "struggle" was defined by characteristics such as coordination, grace, dexterity, and timing. Of note, time itself was not discretely measured as we aimed for the assessment to reward quality over speed. At least two of three pre-trained raters were present during each evaluation, and performance scores were recorded by consensus on a standardized evaluation form. Successful performance for each checklist item was grounded in common best practices. For example, the item "inserts tube to correct depth" would be considered acceptable if a 7.5 tube was placed at a level anywhere from 21-24 cm at the lips. Regarding tube and blade size, a variety of common options available in the clinical space were provided, and any reasonable choice appropriate to the size of the airway simulator was deemed acceptable. The binary evaluation for procedural step completion and the overall psychomotor adeptness scale were similarly weighted such that the total assessment had a maximal potential score of 21 points. The total score was ultimately represented as a percentage of the total possible points (ie, 18/21 would be 86%).

*ETI Assessment - Instrument Validity*

There is no well-established, validated tool for measuring ETI skill via the DL approach for experienced providers who served as our population group. Furthermore, few previously published tools provide validity evidence in accordance with its contemporary conceptualization embodied by the current Standards of Educational and Psychological Testing.[10] Thus, the authors chose to develop a novel assessment tool. Content validity of the tool is supported in that checklist items were crafted after triangulation of multiple sources for best practices in EM and anesthesiology textbooks and discussion with experienced emergency physicians.[11,12]

Due to the inherent limitations in an assessment rooted purely in checklist items,[13] we also used a psychomotor scale to evaluate other characteristics of procedural skill such as coordination, grace, dexterity, and timing. Checklists alone have been criticized for rewarding thoroughness rather than competence,[14] and do not differentiate the novice who performs all steps (poorly) from the expert. They do add an objective component to the evaluation that allows assessors a standardized report of critical actions. Global rating scales may be more appropriate for assessment on performance-based evaluations,[15] and have been shown to have good psychometric characteristics when used in conjunction with a checklist.[16,17]

Response process was supported in that all three raters (authors BG, DS, and AA) were involved in developing the instrument and had come to consensus on how to employ the tool a priori. Raters also familiarized themselves with equipment and testing conditions in advance of assessments, and they deliberated upon ratings for each step, with disagreements discussed in real time until there was consensus. As the scores were shared with the department chair as part of Ongoing Professional Practice Evaluations, care was taken to ensure that scores were an accurate representation of performance on the simulator. This was made explicitly transparent to participants, thus providing an impetus to make their best attempt at intubating as if it were a real patient. Further consequences validity evidence was provided in that low assessment scores resulted in protected time to attend an airway skills refresher course at the expense of the department, additional mannequin training in the simulation center, and repeat assessment (with improved results). Validity evidence based on internal structure of the tool was supported by demonstration of good internal consistency between checklist items and psychomotor adeptness (Cronbach's $\alpha = 0.8$).

*ETI Assessment - Proficiency Cut Score*

We used a borderline methods approach to determine a cut score for proficient skill performance.[18] The construct of proficient performance was defined as a physician demonstrating requisite skill such that he or she is likely to successfully intubate patients via DL in the emergent setting, consistent with the definition of proficiency as provided by Dreyfus.[19] After participants completed their assessment, each rater independently identified attendings whose performance was not clearly proficient or clearly not proficient, ie, on the borderline. We used the median score from this cohort as the cut off for proficient skill performance.

**Data Analysis**

We presented assessment scores and intubation frequencies with descriptive statistics and 95% confidence intervals (CI). Intubation frequencies were obtained by querying the electronic health record over the previous two years, concluding on the date of each physician's assessment. Factors relating to intubation frequency were 1) the time interval between a physician's assessment and their last performance of an ETI; 2) the time interval between a physician's assessment and their last supervision of an ETI; 3) the total number of ETIs performed; and 4) the total number of ETIs supervised. We performed a post hoc analysis to measure the strength of correlation with years of experience and ETI assessment score.

The strength of correlation between assessment scores and each of these factors was calculated using Pearson's correlation coefficient. Factors that demonstrated good correlation with assessment scores ($r \geq 0.6$) were plotted on a receiver operating characteristic (ROC) curve to identify specific values that would predict ETI assessments below the proficiency cut score. We evaluated internal consistency of the assessment tool with Cronbach's alpha for its two overarching aspects, psychomotor adeptness and completion of procedural steps. Data was analyzed with SPSS version 20 (IBM, Armonk, New York).

**RESULTS**

We assessed all full-time employed EM attending physicians (n = 44, 33 general EM trained and pediatric EM (PEM) trained). From this initial cohort, 12 were excluded as they were not present for the entirety of the two-year, look-back period,

leaving 24 EM-trained and 8 PEM-trained physicians (n = 32). The mean years of professional practice for the physician group, defined as years practiced since graduating from residency, was 10.3 years (95% CI, 7.4-13.3) (Table 2).

General emergency physicians on staff during the look-back period performed an average of 4.2 intubations per year (95% CI, 2.8-5.6) and supervised an average of 5.3 per year (95% CI, 4.4-6.2). PEM physicians on staff during the two-year, look-back period performed an average of 0.2 intubations per year (95% CI, 0-0.4) and supervised an average of 0.3 per year (95% CI, 0.1-0.6). There was significant heterogeneity between physicians regarding the number of days elapsed between taking the assessment and last performing an intubation (mean = 405, median = 74, standard deviation = 687) or last supervising an intubation (mean = 83, median = 35, standard deviation = 144). A summary of EM and PEM assessment scores is provided in Table 3.

We identified 14 participants as borderline performers (10 EM and 4 PEM) relating to the construct of clearly evident proficient performance. The median assessment score for the borderline group was 79% (lower quartile = 75%; upper quartile = 86%,; interquartile range = 11%).

Scores correlated well with the average number of intubations performed per year ($r = 0.6$, $p < 0.001$) and with the average number of intubations supervised per year ($r = 0.6$, $p = 0.001$). Scores did not correlate as well with the time passed since last supervising or performing an intubation, or with years of experience ($r = -0.5$, $p = 0.002$; $r = -0.3$, $p = 0.07$; and $r = -0.4$, $p = 0.004$; respectively).

ROC analysis identified, with good accuracy, that physicians

**Table 2.** Summary of practice setting and provider characteristics.

| Practice setting | Faculty specialty | Physician | Total supervised | Total performed | Years post-residency |
|---|---|---|---|---|---|
| Academic urban | General EM | 1 | 11 | 14 | 4.5 |
| | | 2 | 16 | 16 | 4.5 |
| | | 3 | 18 | 20 | 3.5 |
| | | 4 | 6 | 10 | 0.5 |
| | | 5 | 7 | 6 | 8.5 |
| | | 6 | 10 | 12 | 8.5 |
| | | 7 | 8 | 0 | 8.5 |
| | | 8 | 10 | 2 | 10.5 |
| | | 9 | 16 | 21 | 3.5 |
| | | 10 | 5 | 0 | 30.5 |
| | | 11 | 5 | 9 | 0.5 |
| | | 12 | 10 | 13 | 16.5 |
| | | 13 | 6 | 1 | 12.5 |
| | | 14 | 16 | 7 | 5.5 |
| | | 15 | 20 | 23 | 4.5 |
| | | 16 | 10 | 8 | 2.5 |
| | | 17 | 4 | 6 | 2.5 |
| | | 18 | 7 | 2 | 6.5 |
| | | 19 | 8 | 1 | 9.5 |
| | | 20 | 15 | 7 | 7.5 |
| | | 21 | 8 | 1 | 15.5 |
| | | 22 | 13 | 5 | 3.5 |
| | | 23 | 13 | 13 | 2.5 |
| | | 24 | 12 | 4 | 4.5 |
| | Pediatric EM | 25 | 1 | 0 | 3.5 |
| | | 26 | 1 | 0 | 17.5 |
| | | 27 | 0 | 0 | 12.5 |
| | | 28 | 1 | 2 | 3.5 |
| | | 29 | 0 | 0 | 33.5 |
| | | 30 | 2 | 0 | 3.5 |
| | | 31 | 0 | 1 | 7.5 |
| | | 32 | 0 | 0 | 10.5 |

| | Total precepted | Total performed | Years post-residency |
|---|---|---|---|
| General EM mean (n=24) | 10.6 | 8.4 | 7.4 |
| Pediatric EM mean (n=8) | 0.6 | 0.4 | 11.5 |
| Total mean (n=32) | 8.1 | 6.0 | 8.4 |

*EM*, emergency medicine.

**Table 3.** Comparison of emergency medicine and pediatric emergency medicine providers' assessment scores in intubation skills.

| ETI Assessment Score | Mean | Median | IQR | Standard Deviation | Range (min) | Range (max) |
|---|---|---|---|---|---|---|
| All EM Attendings (n=44) | 81% | 86% | 76-91% | 16% | 33% | 100% |
| Adult EM Attendings (n=33) | 85% | 86% | 81-95% | 14% | 33% | 100% |
| PEM Attendings (n=11) | 69% | 76% | 60-79% | 17% | 33% | 86% |

*ETI*, endotracheal intubation; *IQR,* interquartile range; *EM,* emergency medicine; *PEM*, pediatric emergency medicine.

would score at or above the proficiency cut score if they performed an average of at least three intubations annually (sensitivity = 90%, specificity = 64%, area under the curve [AUC] = .87, p = .001) or supervise an average of at least five intubations annually (sensitivity = 90%, specificity = 59%, AUC = .81, p = .006) over a period of two years (Figures 1 and 2).

## DISCUSSION

It is the public trust that gives physicians their status as professionals. When polled, 95% of respondents rated MOC for physicians as "important," with a majority stating that regular testing to assess physician medical knowledge and periodically testing clinical performance and quality of care as being "very important."[20] Leach described skill acquisition and competence as a process, not a destination, with professional development needing to be a lifelong habit.[21] This is because skill decay (the loss or degradation of acquired skills after periods of non-use) is a well-known phenomenon.

We ultimately identified two factors that correlated well with ETI performance– the number of intubations performed and the number of intubations supervised (on average per year for both). Specifically, physicians were at risk to fall below proficiency if they performed fewer than three or supervised fewer than five intubations per year on average. The ROC analysis allowed us to establish an optimal cut point for intubation frequency to predict proficient performance on the assessment. We chose cut points with higher sensitivity to avoid misclassification of "true positives," ie, those who actually scored below the proficiency cut score on the assessment. We were unable to parse out the relative importance of performing vs supervising intubations as these metrics were exceedingly interconnected. It is unclear exactly how supervising intubations contributes to maintaining proficiency in the actual performance of ETI. However, neuroscience research on mirror neurons does suggest a physiologic basis for this phenomenon.[22,23]

Several studies have shown decay of critical cognitive and psychomotor skills in managing cardiopulmonary arrest.[24,25,26] Major factors that influence the rate of decay are length of retention interval; degree of overlearning; task characteristics (closed loop vs open loop, cognitive vs physical, speed vs accuracy); methods of testing for original learning and retention; conditions of retrieval; instructional strategies or training methods; and individual differences in abilities.[27] Historically, ETI was taught in the same place it needed to be performed – on patients in the clinical setting. While this method may positively influence some of the listed factors (original learning methods and conditions of retrieval), it is unlikely to provide the kind of experience that will lead to overlearning.

Ericsson et al. demonstrated that deliberate practice (rigorous practice with assessment and feedback) is the method of choice to gain expertise and avoid decay of a skill.[28] For ETI, this would be most easily accomplished and assessed with simulation. Simulation-based assessments are increasingly integrated into medical education and have been proposed as the modality of choice to develop and assess procedural skill acquisition.[29] Our study demonstrates replicable methodology using an airway simulator to assess performance. Obviously, simulation is not "real life"; however, it is the ethical alternative in which patient safety is not at risk and where confounding variables may be tightly controlled. Additionally, a simulation-based assessment carries greater face validity than the current practice of no assessment at all for this procedure. That said, the strong correlation between assessment scores and intubation experience suggests further construct validity of the assessment platform used in this study.

Similar to other sites,[30] the PEM physicians in our cohort averaged less than one intubation per year, which is well below the threshold identified in our study. Not surprisingly, a prior survey of PEM directors revealed that 62% felt the number of ETIs performed were inadequate to maintain competency, and nearly half (48%) of the respondents reported that they use simulation to remediate or maintain competency.[31] Ultimately, we chose not to exclude the PEM attendings, just as we chose not to exclude other cohorts that intubate less frequently (eg, physician administrators, researchers, or those working predominantly in less- acute zones), since the population of providers that infrequently perform ETI was specifically the group we were most concerned with regarding potential skill decay.

Board-certified EM and PEM physicians are expected to be able to perform airway management in adult and pediatric patients with requisite skill. Furthermore, the ACGME mandates the development of such skill as part of program requirements.

| Intubations performed per year (n=32) | | |
|---|---|---|
| Cut Off | Sensitivity | Specificity |
| 0 | 0% | 100% |
| 0.5 | 60% | 91% |
| 1 | 80% | 82% |
| 2 | 80% | 68% |
| 2.5 | 80% | 64% |
| 3 | 90% | 64% |
| 3.5 | 100% | 59% |
| 4 | 100% | 50% |
| 4.5 | 100% | 46% |
| 5 | 100% | 41% |
| 6 | 100% | 36% |
| 6.5 | 100% | 32% |
| 7 | 100% | 23% |
| 8 | 100% | 18% |
| 10 | 100% | 14% |
| 10.5 | 100% | 9% |
| 11 | 100% | 5% |

ROC curve with cutoff at 3 ETIs performed per year

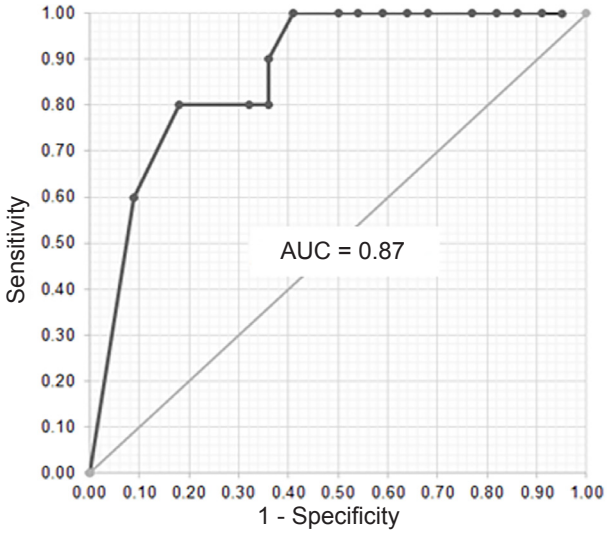


**Figure 1.** Sensitivity and specificity for various cut points represented as the number of endotracheal intubations performed annually.
*ROC*, receiver operator characteristic; *ETI,* endotracheal intubation; *AUC,* area under the curve.

| Intubations performed per year (n=32) | | |
|---|---|---|
| Cut Off | Sensitivity | Specificity |
| 0 | 0% | 100% |
| 0.5 | 40% | 100% |
| 1 | 50% | 91% |
| 2 | 60% | 91% |
| 2.5 | 60% | 86% |
| 3 | 60% | 77% |
| 3.5 | 60% | 68% |
| 4 | 70% | 64% |
| 5 | 90% | 59% |
| 5.5 | 90% | 41% |
| 6 | 90% | 36% |
| 6.5 | 90% | 32% |
| 7.5 | 100% | 27% |
| 8 | 100% | 23% |
| 9 | 100% | 9% |
| 10 | 100% | 5% |
| 10.5 | 100% | 0% |

ROC curve with cutoff at 5 ETIs performed per year

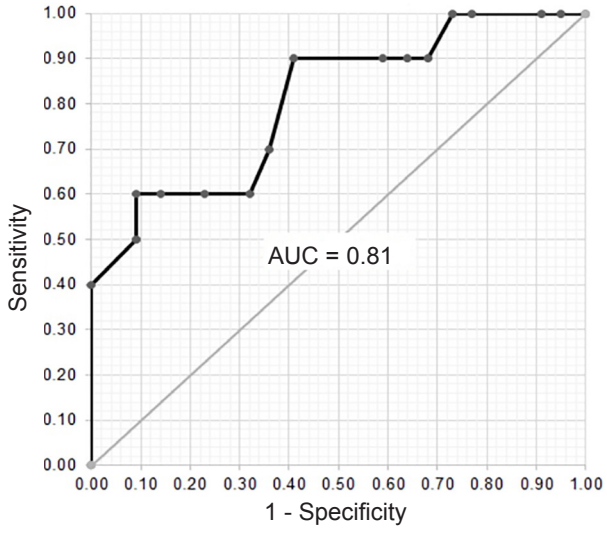


**Figure 2.** Sensitivity and specificity for various cut points represented as the number of ETIs supervised annually and the ROC curve for a cut point of five intubations supervised/year.
*ROC*, receiver operator characteristic; *ETI,* endotracheal intubation; *AUC,* area under the curve.

Thus, we chose to include all providers who might be expected to perform an intubation on a patient with an adult-sized airway. Most dedicated pediatric emergency physicians treat patients with an upper age range from 18-25. We felt it would be inconsistent with the public trust placed in EDs for us to remove PEM providers from our cohort because they less frequently perform intubations. There is no published data showing PEM attendings have explicitly been assessed for procedural skill, and no data comparing their skill to general EM attendings. That said, in our cohort EM and PEM providers performed at both ends of the spectrum with a similar distribution of borderline performers to the overall cohort. Furthermore, in support of competency-based education, the expectation of educators is to train to a set standard regardless of subspecialty.[32]

Procedural re-credentialing is essentially automatic in our specialty, typically in two-year intervals, which is why we chose a two-year interval to analyze. Given the high-stakes nature of ETI, the results of this study may be used to help identify physicians

who may benefit from refresher training in conjunction with re-credentialing. In our department, attendings who performed poorly were required to complete an airway refresher course at the department's expense as well as local, simulation-based training. This approach was well received, and when re-assessed their scores dramatically improved.

It is well accepted that psychomotor skill acquisition and maintenance requires repetition. The surgical literature demonstrates this principle. Patient outcomes after surgical procedures have a clear association with the number of times that the surgeon has performed the procedure.[33-35] Even when attempts to control for other factors have been considered, the number of times that a surgeon has performed a procedure remains strongly correlated to outcomes. This stands to reason: practice makes perfect.

Experience in years alone, however, does not predict a higher level of functioning. Our study showed a weak negative correlation between years of experience and assessed skill. Multiple previous studies have also shown that provider experience has an inverse relationship to many measures of clinical performance,[36] and specifically in complex airway management.[37] This implies that skills must be practiced with some minimal frequency. We cannot ethically dictate how many of our patients will need ETI, and so alternative methods of experience must be sought. Computer screen-based simulation may be an acceptable method for teaching some skills, but high-fidelity simulation has shown to assist in the retention of complex airway skills for up to one year.[38]

It is possible that the level of skill demonstrated by physicians on the airway simulator used in this study does not translate to a similar level of competence in the clinical arena. The use of simulation requires a "suspension of disbelief," and there has been some concern raised that task trainers do not accurately replicate human anatomy.[39-41] Using simulation for the assessment of competence needs to be authentic if it is to imply that the practitioner would perform similarly with real patients.[42] However, research demonstrates that assessment in simulated environments can be reliable and valid.[43,44] Specifically in airway management, studies have shown that assessment of competence corresponds to operational performance in the clinical setting.[45,46] In addition, there is evidence supporting the use of mannequins for training, assessment, and maintaining competency.[47,48]

While faculty development may be ubiquitous in training institutions, generally it is focused on the domains relevant to career advancement such as teaching, administration, and research. The focus of developing more generalized knowledge, skills, and attitudes is limited to resident trainees. In our department, this initiative led to the formalization of an ongoing, robust, simulation-based faculty skills advancement curriculum that encompasses procedural (both novel and established), clinical, and cognitive skills. This has been well received by our faculty,[49,50] and we hope this skills advancement curriculum will serve as a model for other organizations.

## LIMITATIONS

We abstracted intubation data from the electronic health record, making it possible that uncharted intubations may have been missed. Assessors and participants were both employed by the same department. This meant that although the assessors had no prior access to each provider's intubation record, absolute blinding was impossible. It is unknown if this contributed to unconscious bias. Additionally, for ethical reasons assessments were conducted on an airway simulator as opposed to live patients. However, the strong correlation observed between physicians' assessment scores and their average numbers of annual intubations suggests construct validity for this assessment, and internal consistency for the tool was very good.

Although general EM and PEM providers are expected to be able to intubate both adult and pediatric patients, we only tested providers on the adult-equivalent manikin. This study was performed at a single center with a small sample size and may reflect factors not found at other institutions. Lastly, the study was conducted at an academic ED, where the majority of intubations are supervised rather than performed by attending physicians. As such, there was significant variance among physicians with regard to the time between last performing an intubation and taking the assessment. This likely relates to why the assessment scores correlated particularly poorly with the time interval since last performing an intubation at our institution.

## CONCLUSION

Performing at least three or supervising at least five ETIs per year correlated with proficient performance on a skills assessment in our cohort. Our methodology is easily replicable and can be extrapolated across a wide range of procedures in future studies. Since simulation training has become widely available, we advocate for this modality as a platform for active maintenance and advancement of procedural skills. This approach was well received in our department.

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

## REFERENCES


1. Kovacs G, Bullock G, Ackroyd-Stolarz S, Cain E, Petrie D. A randomized controlled trial on the effect of educational interventions in promoting airway management skill maintenance. Ann Emerg Med. 2000;36(4):301-9.
2. Youngquist ST, Henderson DP, Gausche-Hill M, Goodrich SM, Poore PD, Lewis RJ. Paramedic self-efficacy and skill retention in pediatric airway management. Acad Emerg Med. 2008;15(12):1295-303.
3. Hasegawa K, Shigemitsu K, Hagiwara Y, et al. Association between repeated intubation attempts and adverse events in emergency departments: an analysis of a multicenter prospective observational study. Ann Emerg Med. 2012;60(6):749-54.
4. Sakles JC, Chiu S, Mosier J, Walker C, Stolz U. The importance of first pass success when performing orotracheal intubation in the emergency department. Acad Emerg Med. 2013;20(1):71-8
5. Emergency medicine defined key index procedure minimums. Accreditation Council for Graduate Medical Education website. 2017. Available at: https://www.acgme.org/Portals/0/PFAssets/ProgramResources/EM_Key_Index_Procedure_Minimums_103117.pdf?ver=2017-11-10-130003-693. Accessed Sept 7, 2018.
6. Nolan J, Clancy M. Airway management in the emergency department. Br J Anaesth. 2002;88(1):9-11.
7. Graham CA. Advanced airway management in the emergency department: What are the training and skills maintenance needs for UK emergency physicians? EMJ. 2004;21(1):14-9.
8. Pusic MV, Kessler D, Szyld D, Kalet A, Pecaric M, Boutis K. Experience curves as an organizing framework for deliberate practice in emergency medicine learning. Acad Emerg Med. 2012;19(12):1476-80.
9. MOC overview. American Board of Emergency Medicine website. Available at: https://www.abem.org/public/stay-certified. Accessed August 31, 2018
10. Validity.1999. In: American Educational Research Association, American Psychological Association, National Council on Measurement in Education. Standards for Educational and Psychological Testing. Amer Educational Research Assn.
11. Brown CA, Walls RM. Airway. In: Marx JA, Hockberger RS, Walls RM, eds. Rosen's Emergency Medicine: Concepts and Clinical Practice. 7th ed. Philadelphia: Mosby/Elsevier; 2010:3-22
12. Hagberg, CA, Artime, CA. 2015. Airway Management in the Adult. In Miller RD (Ed.), Miller's Anesthesia, 8th ed. (1647-1683). Philadelphia, Pennsylvania: Saunders/Elsevier.
13. Streiner DL, Norman GR, Cairney J. 2015. Validity. In Streiner DL, Norman GR, Cairney J. Health Measurement Scales: A Practical Guide to Their Development and Use, 5th ed. (227-253). Oxford, United Kingdom: University Press.
14. Norman G. Editorial - Checklists vs. ratings, the illusion of objectivity, the demise of skills and the debasement of evidence. Adv Health Sci Educ Theory Pract. 2005;10(1):1-3.
15. Regehr G, MacRae H, Reznick RK, Szalay D. Comparing the psychometric properties of checklists and global rating scales for assessing performance on an OSCE-format examination. Acad Med. 1998;73(9):993-7.
16. Martin JA, Regehr G, Reznick R, et al. Objective structured assessment of technical skill (OSATS) for surgical residents. Br J Surg. 1997;84(2):273-8.
17. Cohen R, Rothman AI, Poldre P, Ross J. Validity and generalizability of global ratings in an objective structured clinical examination. Acad Med. 1991;66(9):545-8.
18. Streiner DL, Norman GR, Cairney J. 2015. From items to scales. In Streiner DL, Norman GR, Cairney J. Health Measurement Scales: A Practical Guide to Their Development and Use. 5th ed. (131-158). Oxford, United Kingdom: University Press.
19. Dreyfus SE. The five-stage model of adult skill acquisition. Bull. Sci. Technol. Soc. 2004;24(3):177-81.
20. Facts about the ABMS consumer survey: Lifelong learning and other qualities in choosing a doctor. 2011. American Board of Medical Specialties website. Available at: https://www.abms.org/media/1319/abms_2010_consumer_survey_fact_sheet.pdf. Accessed August 31,2018.
21. Leach DC. Competence is a habit. JAMA. 2002;287(2):243-4.
22. Keysers C, Gazzola V. Social neuroscience: mirror neurons recorded in humans. Curr Biol. 2010;20(8):R353-R354
23. Keysers C. Mirror neurons. Curr Biol. 2009;19(21):R971-R973.
24. Stross JK. Maintaining competency in advanced cardiac life support skills. JAMA. 1983;249(24):3339-41.
25. Palese A, Trenti G, Sbrojavacca R. Effectiveness of retraining after basic cardiopulmonary resuscitation courses: A literature review. Assist Inferm Ric. 2003;22:68-75.
26. Kaye W, Wynne G, Marteau T, et al. An advanced resuscitation training course for preregistration house officers. Clin Med (Lond).1990;24(1):51-54.
27. Arthur W, Bennett W, Stanush PL, McNelly TL. Factors that influence skill decay and retention: a quantitative review and analysis. Human Performance. 1998;11(1):57-101.
28. Ericsson KA. Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. Acad Med. 2004;79(10):S70-S81
29. Wang EE, Quinones J, Fitch MT, et al. Developing technical expertise in emergency medicine - the role of simulation in procedural skill acquisition. Acad Emerg Med. 2008;15(11):1046-57.
30. Mittiga MR, Geis GL, Kerrey BT, Rinderknecht AS. The spectrum and frequency of critical procedures performed in a pediatric emergency department: implications of a provider-level view. Ann Emerg Med. 2013;61(3):263-70.
31. Losek JD, Olson LR, Dobson JV, Glaeser PW. Tracheal intubation practice and maintaining skill competency - survey of pediatric emergency department medical directors. Pediatr Emerg Care. 2008;24(5):294-9.
32. McGaghie WC, Siddal VJ, Mazmanian PE, et al. Lessons for continuing medical education from simulation research in undergraduate and graduate medical education: effectiveness of continuing medical education: American College of Chest Physicians Evidence-Based Educational Guidelines. Chest. 2009;135(3):62S-68S.
33. Birkmeyer JD, Siewers AE, Finlayson EVA, et al. Hospital

volume and surgical mortality in the United States. N Engl J Med. 2002;346(15):1128-37.

34. Birkmeyer JD, Stukel TA, Siewers AE, Goodney PP, Wennberg DE, Lucas FL. Surgeon volume and operative mortality in the United States. N Engl J Med. 2003;349(22):2117-27.
35. Hannan EL, Kilburn H, Racz M, Shields E, Chassin MR. Improving the outcomes of coronary artery bypass surgery in New York State. JAMA. 1994;271(10):761-6.
36. Siu LW, Boet S, Borges BCR, et al. High-fidelity simulation demonstrates the influence of anesthesiologists' age and years from residency on emergency cricothyroidotomy skills. Anesth Analg. 2010;111(4):955-60.
37. Nyssen AS, Larbuisson R, Janssens M, Pendeville P, Mayne A. A comparison of the training value of two types of anesthesia simulators: computer screen-based and mannequin-based simulators. Anesth Analg. 2002;94(6):1560-5.
38. Boet S, Borges BCR, Naik VN, et al. Complex procedural skills are retained for a minimum of 1 yr after a single high-fidelity simulation training session. Br J Anaesth. 2011;107(4):533-9.
39. Schebesta K, Hupfl M, Rossler B, Ringl H, Muller MP, Kimberger O. Degrees of reality airway anatomy of high-fidelity human patient simulators and airway trainers. Anesthesiology. 2012;116(6):1204-9.
40. Klock PA. Airway simulators and mannequins: a case of high infidelity? Anesthesiology. 2012;116(6):1179-80.
41. Schebesta K, Hupfl M, Ringl H, Machata AM, Chiari A, Kimberger O. A comparison of paediatric airway anatomy with the SimBaby high-fidelity patient simulator. Resuscitation. 2011;82(4):468-72.
42. Ker J, Bradley P. Simulation in medical education. In: Swanwick T, ed. Understanding Medical Education: Evidence, Theory, and Practice. Chichester, United Kingdom: Wiley-Blackwell; 2010:164-80.
43. Newble D. Techniques for measuring clinical competence: objective structured clinical examinations. Med Educ. 2004;38(2):199-203.
44. Nishisaki A, Keren R, Nadkarni V. Does simulation improve patient safety? Self-efficacy, competence, operational performance, and patient safety. Anesthesiology Clinics. 2007;25:225-36.
45. Mayo PH, Hackney JE, Mueck JT, Ribaudo V, Schneider RF. Achieving house staff competence in emergency airway management: Results of a teaching program using a computerized patient simulator. Crit Care Med. 2004;32(12):2422-7.
46. Overly FL, Sudikoff SN, Shapiro MJ. High-fidelity medical simulation as an assessment tool for pediatric residents' airway management skills. Pediatr Emerg Care. 2007;23(1):11-5.
47. Friedman Z, You-Ten KE, Bould MD, Naik V. Teaching lifesaving procedures: the impact of model fidelity on acquisition and transfer of cricothyrotomy skills to performance on cadavers. Anesth Analg. 2008;107(5):1663-9.
48. Chandra DB, Savoldelli GL, Joo HS, Weiss ID, Naik VN. Fiberoptic oral intubation: the effect of model fidelity on training for transfer to patient care. Anesthesiology. 2008;109(6):1007-13.
49. Saloum D, Gillett B, Aghera A et al. A mechanism to promote faculty involvement in nonclinical activities. Ann Emerg Med. 2013;62(5):S174-S175
50. Saloum D, Aghera A, Gillett B. A simulation-based video laryngoscopy course for maintenance of board certification. Ann Emerg Med. 2013;62(5):S179.

# Improvement in the Safety of Rapid Sequence Intubation in the Emergency Department with the Use of an Airway Continuous Quality Improvement Program

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*Section Editor:* Matthew Prekker, MD, MPH
Submission history: Submitted January 14, 2019; Revision received April 6, 2019; Accepted April 20, 2019
Electronically published June 3, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.4.42343

**Introduction:** Airway management in the critically ill is associated with a high prevalence of failed first attempts and adverse events which negatively impacts patient care. The purpose of this investigation is to describe an airway continuous quality improvement (CQI) program and its effect on the safety of rapid sequence intubation (RSI) in the emergency department (ED) over a 10-year period.

**Methods:** An airway CQI program with an ongoing airway registry was initiated in our ED on July 1, 2007 (Academic Year 1) and continued through June 30, 2017 (Academic Year 10). Data were prospectively collected on all patients intubated in the ED during this period using a structured airway data collection form. Key data points included method of intubation, drugs and devices used for intubation, operator specialty and level of training, number of intubation attempts, and adverse events. Adult patients who underwent RSI in the ED with an initial intubation attempt by emergency medicine (EM) resident were included in the analysis. The primary outcome was first pass success which was defined as successful tracheal intubation with a single laryngoscope insertion. The secondary outcome was the prevalence of adverse events associated with intubation. Educational and clinical interventions were introduced throughout the study period with the goal of optimizing these outcomes. Data were analyzed by academic year and are reported descriptively with 95% confidence intervals (CI) of the difference of means.

**Results:** EM residents performed RSI on 342 adult patients during Academic Year 1 and on 445 adult patients during Academic Year 10. Over the 10-year study period, first pass success increased from 73.1% to 92.4% (difference = 19.3%, 95% CI 14.0% to 24.6%). The percentage of patients who experienced an adverse event associated with intubation decreased from 22.5% to 14.4% (difference = -7.9%, 95% CI -13.4% to -2.4%). The percentage of patients with first pass success without an adverse event increased from 64.0% to 80.9% (difference = 16.9%, 95% CI 10.6% to 23.1%).

**Conclusion:** The use of an airway CQI program with an ongoing airway registry resulted in a substantial improvement in the overall safety of RSI in the ED as evidenced by an increase in first pass success and a decrease in adverse events. [West J Emerg Med. 2019;20(4)610–618.]

## INTRODUCTION

Critically ill patients frequently require airway management in the emergency department (ED) and this is usually accomplished with rapid sequence intubation (RSI).[1] Emergency airway management has been shown to be associated with a high prevalence of failed first attempts and adverse events, both of which can negatively affect patient care.[2,3,4,5,6,7,8,9,10,11] Multiple intubation attempts are associated with an increase in adverse events, many of which can be life-threatening.[3,12,13] When adverse events occur during emergency intubation, the effect on patient outcomes are much more severe compared to elective intubation.[9,14] To maximize the safety of intubation in the ED, the goal should be to achieve first pass success without any adverse events. Without measuring important outcomes like first pass success and adverse events, it is difficult to improve patient care with emergency airway management. In our ED we developed an airway continuous quality improvement (CQI) program that incorporated an ongoing airway registry with the aim of improving the safety of emergency airway management. This study describes our airway CQI program and its associated effect on the safety of airway management in our ED.

*Population Health Research Capsule*

What do we already know about this issue?
*Airway management is frequently performed in the emergency department (ED) and is associated with a high prevalence of adverse events.*

What was the research question?
*Could monitoring of airway performance in conjunction with an airway continuous quality improvement (CQI) program improve the safety of rapid sequence intubation in the ED?*

What was the major finding of the study?
*Over a 10-year period the airway CQI program was associated with a 19.3% absolute increase in first pass success and a 7.9% absolute decrease in adverse events.*

How does this improve population health?
*By monitoring airway management practices in the ED and making iterative clinical adjustments, the safety of this high-risk procedure can be improved.*

## METHODS

### Study Design and Setting

This study was conducted at an urban academic ED with a Level 1 trauma center and includes data over the 10-year period from July 1, 2007 (Academic Year 1) to June 30, 2017 (Academic Year 10). Since this project was a CQI initiative it was granted an exemption by the University of Arizona Institutional Review Board.

This institution serves as the training site for two Accreditation Council for Graduate Medical Education (ACGME) accredited three-year emergency medicine (EM) residency programs, one of which is a university hospital-based program and the other which is a community-hospital based program. In addition, the institution supports a five-year combined emergency medicine/pediatrics (EM/PEDS) residency program. There are currently a total of 79 residents in these three training programs. Intubations in this ED are performed primarily by the EM and EM/PEDS residents under direct supervision by the EM attending.

Throughout the study period, multiple airway devices were stocked in the ED, with clinical availability of the devices varying somewhat. The availability of these devices were based on hospital considerations and manufacturer issues and were not the result of the CQI program. The direct laryngoscope (DL) with Macintosh and Miller blades was available in the ED throughout entire study period. One or more video laryngoscopes (VL) were also available throughout the study period. The hyperangulated GlideScope® was available from Academic Year 1 continuously through the second month of Academic Year 10, and the standard geometry GlideScope® (MAC T3 and T4) was available from Academic Year 8 continuously through the second month of Academic Year 10. The standard geometry C-MAC® was available from the eighth month in Academic Year 3 continuously through Academic Year 10 and the hyperangulated C-MAC® (D-blade) was available from the tenth month in Academic Year 4 continuously through Academic Year 10. Other VLs such as the McGrath®, the Pentax Airway Scope® and the Res-Q-Scope® were available sporadically on a trial basis for brief periods of time. Rescue devices available during the study period included a supraglottic device (LMA Fastrach®) and a commercially available surgical airway kit (Cook Universal Emergency Cricothyrotomy Catheter Set®).

This study included all adult patients 18 years of age and older that underwent RSI in the ED by an EM resident as the first operator.

### Airway CQI Program and Airway Registry

The airway CQI program and airway registry was started on July 1, 2007. A single page (double sided) paper-based airway data collection form was developed to capture important clinical information regarding intubations in the ED (Appendix: https://escholarship.org/uc/item/8tv7v5nz#supplemental). The form was

housed in the physician charting area of the ED. After each intubation the resident was expected to fill out the airway form. The senior investigator reviewed all airway forms on a weekly basis and cross-referenced them with the electronic medical record and the hospital admission log. If any intubations were identified without a corresponding airway form, a blank form was given to the resident for completion. If any of the airway forms had incomplete or contradictory information, the resident was interviewed by the senior author and the form updated as appropriate. Timeliness of completion of the airway forms was recorded during the last two years of the study period. 70% of the forms were filled out on the day of the intubation, 86% were filled out within two days of the intubation, and 94% were filled out within seven days of the intubation. Ultimately, 100% of airway forms were completed.

The airway form was designed to capture important information about the patient, the operator and the characteristics of the procedure. This included data such as patient age and sex, diagnosis, operator post-graduate year (PGY), operator specialty, reason for intubation, method of intubation, difficult airway characteristics, drugs used for intubation, device used on each attempt, outcome of each attempt, and adverse events associated with intubation. Adverse events and their definitions are presented in Table 1. An intubation attempt was defined as the insertion of the laryngoscope blade into the mouth of the patient, regardless of whether an attempt was made to insert a tracheal tube. First pass success was defined as successful tracheal intubation on a single laryngoscope insertion. First pass success without an adverse event was defined as successful tracheal intubation on the first attempt without the occurrence of any adverse events.

The airway training program for the EM and EM/PEDS residents consisted of multiple educational components. Residents in the university-based EM and EM/PEDS program complete a four-week rotation on the anesthesia service to learn fundamental aspects of airway management. Residents in the community-based EM program do not participate in an anesthesia rotation. During the intern year there is a full day airway orientation that includes three hours of didactics and three hours of hands-on experience in the simulation laboratory. Each year there is a difficult airway lab in the simulation lab. The difficult airway lab has been expanded over the study period and currently includes the following six hands-on stations: 1. Rigid laryngoscopy including both DL and VL, 2. Flexible laryngoscopy, 3. Face mask ventilation and supraglottic insertion, 4. Surgical airway techniques, 5. Pediatrics, and 6. Ultrasound assessment of the airway and hemodynamics. Airway lectures and cases are presented on an ongoing basis at the regularly scheduled conference time throughout the academic year. Based upon ongoing data analysis from the airway registry, these educational programs have been modified and expanded to address varying clinical concerns. For example, use of a VL for the initial attempt has been increasingly promoted over the entire study period due to the beneficial effects observed with the CQI program. Even if DL was the primary approach to be performed, use of a standard geometry VL was strongly encouraged.[15] In the last four years of the study, heavy emphasis was placed on the importance of physiologic optimization prior to intubation.[16] Appropriate preoxygenation strategies were emphasized and non-invasive ventilation (NIV) for hypoxemic patients with shunt physiology was encouraged.[17] The use of apneic oxygenation and high flow nasal oxygen (HFNO) was also encouraged for patients at high risk of oxygen desaturation. Hemodynamic optimization before intubation, with crystalloids, blood products, vasopressors or inotropes, as clinically indicated, was also strongly emphasized. Pre-intubation point-of-care cardiovascular ultrasonography was promoted as a means to identify patients at risk of hemodynamic collapse and to allow proactive management with appropriate resuscitation strategies. Operators

**Table 1.** Definitions of adverse events.

| Adverse event | Definition |
|---|---|
| Aspiration | Presence of vomit at the glottic inlet visualized during intubation in a previously clear airway |
| Cardiac arrest | Pulseless dysrhythmia occurring during intubation |
| Cuff leak | Air leak around a cuffed ETT requiring replacement of the ETT |
| Dental trauma | Fracture or avulsion of tooth during intubation |
| Dysrhythmia | Bradycardia or any ventricular dysrhythmia during intubation |
| Esophageal intubation | Inadvertent placement of the ETT in the esophagus requiring removal and reintubation |
| Extubation | Accidental removal of the ETT requiring reintubation |
| Hypotension | Decrease in systolic blood pressure to <90 mmHg |
| Hypoxemia | A decrease in oxygen saturation below 90% |
| Laryngospasm | Adduction of vocal cords preventing passage of the ETT through the glottic inlet |
| Mainstem intubation | Radiographic identification of the tip of the ETT in a mainstem bronchus |

*ETT*, endotracheal tube; *mmHg*, millimeters of mercury.

were encouraged to use their assessment of cardiac function and evaluation of the inferior vena cava (IVC) to determine the need for intravenous fluids or vasoactive drugs in the peri-intubation period.

### Outcome Measures

The primary outcome measure was first pass success. The secondary outcome measure was the number of patients who experienced an intubation associated adverse event. Other important variables such as first pass success without an adverse event and procedural characteristics are reported as well.

### Data Analysis

Data from the collected paper forms was entered into Excel® for Windows 2013 (Microsoft, Redmond, Washington) and transferred in to STATA 13® (StataCorp, College Station, Texas) for analysis. Data was analyzed by academic year (July 1, 2007–June 30, 2017). The first year of the study was the academic year 2007-2008 (Academic Year 1), and the last year of the study was academic year 2016-2017 (Academic Year 10). Data are reported descriptively with 95% confidence intervals (CIs) or the 95% CI of the difference of the means, as appropriate.

## RESULTS

### Characteristics of Study Subjects

There were 5,229 total intubations performed in the ED over the 10-year study period. Of these, 4,362 were performed using an RSI technique. The number of adult patients who underwent RSI by an EM resident was 3,763, and these were included in this analysis. The mean age in years of patients intubated was 46.1 (range 18-98). 1,307 (34.7%) were women and 1,431 (38.0%) were trauma patients.

### First Pass Success

First pass success by academic year is listed in Table 2. Over the 10-year period, first pass success increased from 73.1% to 92.4% (difference = 19.3%, 95% CI 14.0% to 24.6%). Intubation was successful within two attempts in 88.6% of patients in Academic Year 1 and 99.3% of patients in Academic Year 10. Intubation was successful within three attempts in 94.7% of patients in Academic Year 1 and in 100% of patients in Academic Year 10.

### Adverse Events

The number of patients who experienced an adverse event are listed in Table 3. Over the 10-year period, the percentage of patients who experienced an adverse event decreased from 22.5% to 14.6% (difference = -7.9%, 95% CI -13.4% to -2.4%).

Specific adverse events are listed in Table 4. Hypoxemia ($SpO_2$<90%) was the most common adverse event and occurred in 76.6% (59/77) of the patients with adverse events in Academic Year 1 and in 76.9% (50/65) of the patients with adverse events in Academic Year 10. The percentage of patients who had hypoxemia decreased from 17.3% to 11.2% (difference = -6.0%, 95% CI -11.0% to -1.1%).

Complete oxygen saturation data was available in 73.4% (251/342) of patients in Academic Year 1 and in 86.3% (384/445) of patients in Academic Year 10. Oxygen desaturation to <80% occurred in 8.8% of patients in Academic Year 1 and in 3.6% of patients in Academic Year 10 (difference = -5.2%, 96% CI -8.7% to -1.7%). Oxygen desaturation to <70% occurred in 5.0% of patients in Academic Year 1 and in 1.6% of patients in Academic Year 10 (difference = -3.4%, 95% CI -6.0% to -0.8%).

The percentage of patients who had a recognized esophageal intubation decreased from 4.4% in Academic Year 1 to 0% in Academic Year 10 (difference = -4.4%, 95% CI -6.4% to -2.2%).

### First Pass Success without an Adverse Event

First pass success without an adverse event increased over the 10-year period from 64.0% to 80.9% (difference = 16.9%, 95% CI 10.6% to 23.1%).

### Procedural Characteristics

Procedural characteristics are listed in Table 5. VL use on the initial attempt increased from 44.7% to 97.8% (difference = 53.0%, 95% CI 47.6% to 58.5%) over the 10-year period. GlideScope ® use decreased from 86.9% in Academic Year 1 to 5.5% in Academic Year 10 and C-MAC® use increased in

**Table 2.** First pass success by year over the 10-year period.

| Academic Year | First Pass Success % (n) | 95% CI |
|---|---|---|
| 1 (2007-2008) | 73.1% (250/342) | 68.2% to 77.5% |
| 2 (2008-2009) | 73.9% (260/352) | 69.0% to 78.2% |
| 3 (2009-2010) | 75.3% (220/292) | 70.1% to 79.9% |
| 4 (2010-2011) | 79.8% (257/322) | 75.1% to 83.9% |
| 5 (2011-2012) | 82.5% (320/388) | 78.4% to 86.0% |
| 6 (2012-2013) | 85.2% (351/412) | 81.4% to 88.3% |
| 7 (2013-2014) | 86.2% (367/426) | 82.5% to 89.1% |
| 8 (2014-2015) | 89.1% (352/395) | 85.6% to 91.8% |
| 9 (2015-2016) | 92.1% (348/378) | 88.9% to 94.4% |
| 10 (2016-2017) | 92.4% (410/445) | 89.5% to 94.5% |

*CI,* confidence interval.

**Table 3.** Patients with adverse intubation events by year over the 10-year period.

| Academic Year | Patients with Adverse Events % (n) | 95% CI |
|---|---|---|
| 1 (2007-2008) | 22.5% (77/342) | 18.4% to 27.2% |
| 2 (2008-2009) | 29.3% (103/352) | 24.8% to 34.2% |
| 3 (2009-2010) | 25.0% (73/292) | 20.4% to 30.3% |
| 4 (2010-2011) | 22.9% (74/322) | 18.7% to 27.9% |
| 5 (2011-2012) | 23.5% (91/388) | 19.5% to 27.9% |
| 6 (2012-2013) | 20.6% (85/412) | 17.0% to 24.8% |
| 7 (2013-2014) | 22.8% (97/426) | 19.0% to 27.0% |
| 8 (2014-2015) | 15.4% (61/395) | 12.2% to 19.4% |
| 9 (2015-2016) | 15.3% (58/378) | 12.0% to 19.3% |
| 10 (2016-2017) | 14.6% (65/445) | 11.4% to 18.0% |

*CI,* confidence interval.

Academic Year 1 from 0% to 94.5% in Academic Year 10, reflecting clinical availability of the two devices. In Academic Year 9, when the GlideScope® and C-MAC® were both available, clinical use was very similar (GlideScope® 48.6% and C-MAC® 51.4%).

Use of succinylcholine increased from 40.4% to 53.9% (difference = 13.6%, 95% CI 6.6% to 20.5%) and use of ketamine increased from 2.0% to 14.6% (difference = 12.6%, 95% CI 9.0% to 16.2%). Senior residents (PGY ≥3) performed 43.6% of the intubations in Academic Year 1 and 51.2% in Academic Year 10 (difference = 7.7%, 95% CI 6.6% to 14.7%). The need for a device switch after a failed intubation attempt decreased from 17.8% to 0.5% (difference = -17.4%, 95% CI -21.5% to -13.3%), and the need for an EM attending to rescue an EM resident decreased from 5.8% to 0.2% (difference = -5.6%, 95% CI -8.1% to -3.1%).

Over the entire study period there were 6 adult patients (0.16%) with a failed RSI by an EM resident that ultimately went on to receive a surgical airway (one in Academic Year 2, one in Academic Year 5, two in Academic Year 6, one in Academic Year 7, and one in Academic Year 9).

## DISCUSSION

Airway management in the critically ill is known to be associated with a high prevalence of failed intubation attempts and serious adverse events, which can negatively impact patient care. To maximize patient safety, the goal of airway management in the ED should be first pass success without adverse events. Just over a decade ago we developed an airway CQI program with an ongoing airway registry to monitor our airway performance in the ED. We found over the 10-year period that first pass success increased from 73% to 92% and adverse events decreased from 23% to 15%. Patients that had first pass success without an adverse event increased by 17%. While it is difficult to say exactly which components of our program were responsible for this improvement, we believe there were a couple of key factors. One is the adoption of near universal VL use for initial intubation attempts. Over the 10-year period VL use increased from 45% to 98%. Since the operators in this study were EM residents, they had variable and limited experience with intubation. When using a DL, the supervising attending had virtually no ability to assist the resident with laryngoscopy and identification of the airway, thus increasing the risk of a failed intubation attempt or esophageal intubation. On the other hand, when using a VL, the EM attending could see everything the resident was seeing during laryngoscopy and thus could assist with navigation to and identification of the airway. This would have the effect of improving first pass success and avoiding inadvertent misplaced tubes in the esophagus. This notion is supported by the fact that with essentially universal VL use, the esophageal intubation rate fell to 0% and the need for the EM attending to rescue the resident fell to 0.2%. The CQI program allowed us to realize the beneficial effect of VL in our ED and thus was largely responsible for the promotion of increased VL use.

The other factor that we believe played an important role in the improvement we observed was greater emphasis on pre-intubation physiologic optimization during the latter half of the study period.[16] Greater attention was given to optimization of preoxygenation and hemodynamics before intubation. Appropriate preoxygenation methods were emphasized to maximize oxygen stores before RSI.[17] NIV was encouraged for preoxygenation in patients with shunt physiology who remained hypoxemic with conventional preoxygenation techniques.[18] The use of apneic oxygenation and HFNO was encouraged for patients at great risk of oxygen desaturation. Point-of-care ultrasound was encouraged prior to intubation to evaluate cardiovascular function and to guide decision making for appropriate hemodynamic support in the peri-intubation period.

There were some minor changes in procedural characteristics over the 10-year period. There was a small increase (8%) in the number of intubations performed by senior residents. This may also have contributed to the increase in first pass success observed in the study, as previous work in our ED has demonstrated an increase in first pass success with VL with increasing post-graduate level.[19] Other notable differences over the study period

**Table 4.** Adverse intubation events in Academic Year 1 versus Academic Year 10.

| Specific Adverse Events | Academic Year 1 (2007-2008) %, (n = 342) | Academic Year 10 (2016-2017) %, (n = 445) | % Difference (95% CI) |
|---|---|---|---|
| Aspiration | 1.8% (6) | 0% (0) | -1.8% (-3.1% to -0.4%) |
| Cardiac arrest | 0.6% (2) | 0% (0) | -0.6% (-1.4% to 0.2%) |
| Cuff leak | 0.6% (2) | 0% (0) | -0.6% (-1.4% to 0.2%) |
| Dental injury | 0.3% (0) | 0% (0) | -0.3% (0.9% to 0.3%) |
| Dysrhythmia | 0.3% (1) | 0.2% (1) | -0.07% (-0.8% to 0.7%) |
| Esophageal intubation | 4.4% (15) | 0% (0) | -4.4% (6.6% to 2.2%) |
| Extubation | 0.6% (2) | 0.7% (3) | 0.1% (-1.0% to 1.1%) |
| Hypoxemia | 17.3% (59) | 11.2% (50) | -6.0% (-11.0% to -1.1%) |
| Hypotension | 0% (0) | 2.9% (13) | 2.9% (1.4% to 4.5%) |
| Laryngospasm | 0% (0) | 0.45% (2) | 0.5% (-0.2% to 1.1%) |
| Mainstem intubation | 2.6% (9) | 0.9% (4) | -1.7% (-3.6% to 0.2%) |
| Total patients with adverse events | 22.5% (77) | 14.6% (65) | -7.9% (-13.4% to -2.4%) |
| Patients with 1 adverse event | 17.5% (60) | 12.8% (57) | -4.7% (-9.8% to 0.4%) |
| Patients with 2 adverse events | 3.5% (12) | 1.8% (8) | -1.7% (-4.0% to 0.6%) |
| Patients with ≥3 adverse events | 1.5% (5) | 0% (0) | -1.5% (-2.7% to 0.2%) |

*CI,* confidence interval.

involved the use of pharmacologic agents for RSI. Succinylcholine use increased by 14%, likely representing a shift away from the use of long acting neuromuscular blocking agents in trauma patients with traumatic brain injuries to allow ongoing neurologic assessment. Ketamine use increased by 13%, likely reflecting an increased awareness of ketamine's safety in head injured patients and its beneficial hemodynamic profile in shocked patients. Based on previous studies it is unlikely that any of these pharmacologic changes we observed would have significantly affected first pass success.[20,21]

Many other programs have also attempted to improve the safety of emergency airway management with a variety of clinical interventions. In a university affiliated ED, Hwang and colleagues reported on their experience with an airway CQI initiative over a three-year period.[22] With procedural standardization, airway education and equipment preparation they found that they were able to increase their first pass success from 68% to 79%. They also observed a decrease in adverse events from 16% to 8%. It is of interest that in their study, they also had a significant increase in VL use for first intubation attempts, from 9% in year 1 to 60% in year 3. In an academic pediatric ED, Kerrey and colleagues instituted a CQI program with the goal of reducing the prevalence of oxygen desaturation during emergency intubation.[23] With the use of an RSI checklist, the use of VL, and the restriction of intubation to specific providers, they observed a reduction of intubation associated hypoxemia from a historical control of 33% to 16%. In the intensive care unit (ICU) setting, Jaber and colleagues instituted an intubation bundle in an attempt to decrease complications associated with emergency intubation.[24] Their intubation bundle had 10 components and included such things as pre-intubation fluid loading, early vasopressor use, and NIV for preoxygenation. They found a reduction in life-threatening complications from 34% to 21% in the six-month period after the introduction of this bundle. Mayo and colleagues reported on their results from a CQI program in their intensive care unit (ICU), where emergency intubations were performed by pulmonary/critical care fellows.[25] Their CQI program incorporated a combined team approach, mandatory checklist use, crew resource management techniques and scenario-based training using computerized patient simulators. Over a three-year period, they observed a first pass success of 62%. Of note, their standard approach for emergency intubation was not RSI, but rather sedative only intubation. In the prehospital setting, Olvera and colleagues reported on their experience with the introduction of a CQI program in a large aeromedical transport service.[26] They implemented an elaborate CQI program across 160 helicopter bases and over a three-year period found an improvement in first pass success from 85% to 95%. First pass success without desaturation was found to increase from 84% to 94%. In another prehospital study, Jarvis and colleagues described their experience with an intubation bundle designed to reduce the occurrence of peri-intubation hypoxemia.[27] Their

**Table 5.** Procedural characteristics in Academic Year 1 versus Academic Year 10.

| Procedural characteristic | Academic Year 1 (2007-2008) %, (n = 342) | Academic Year 10 (2016-2017) %, (n = 445) | % Difference (95% CI) |
|---|---|---|---|
| Device used | | | |
| Direct laryngoscope | 52.6% (180) | 2.0% (9) | -50.6% (-56.1% to -45.2%) |
| Video laryngoscope | 44.7% (153) | 97.8% (435) | 53.0% (47.6% to 58.5%) |
| Hyperangulated VL | 100% (153/153) | 7.4% (32/435) | -92.6% (-95.1% to -90.2%) |
| Standard Geometry VL | 0% (0/153) | 92.6% (403/435) | 92.6% (90.2% to 95.1%) |
| GlideScope® | 86.9% (133/153) | 5.5% (24/435) | -81.4% (-87.2% to -75.7%) |
| C-MAC® | 0% (0/153) | 94.5% (411/435) | 94.5% (92.3% to 96.6%) |
| Other VL | 13.1% (20/153) | 0% (0/435) | -13.1% (-18.4% to -7.7%) |
| Paralytic used | | | |
| Succinylcholine | 40.3% (138) | 54.0% (240) | 13.6% (6.6% to 20.5%) |
| Rocuronium | 59.1% (202) | 45.8% (204) | -13.2% (-20.2% to -6.3%) |
| Sedative used | | | |
| Etomidate | 90.4% (309) | 81.6% (363) | -8.8% (-13.5% to -4.0%) |
| Ketamine | 2.0% (7) | 14.6% (65) | 12.6% (9.0% to 16.2%) |
| Propofol | 2.6% (9) | 2.2% (10) | -0.4% (-2.6% to 1.8%) |
| Operator PGY | | | |
| PGY 1 | 17.3% (59) | 13.7% (61) | -3.5% (-8.7% to 1.6%) |
| PGY 2 | 39.2% (134) | 35.0% (156) | -4.1% (-10.9% to 2.7%) |
| PGY ≥3 | 43.6% (149) | 51.2% (228) | 7.7% (0.7% to 14.7%) |
| Rescue maneuvers | | | |
| Device switch | 17.8% (61) | 0.5% (2) | -17.4% (-21.5% to -13.3%) |
| Resident rescue | 3.2% (11) | 0.9% (4) | -2.3% (-4.4% to -0.3%) |
| Attending rescue | 5.8% (20) | 0.2% (1) | -5.6% (-8.1% to -3.1%) |
| SGD rescue | 1.2% (4) | 0% (0) | -1.2% (-2.3% to 0%) |
| CRIC rescue | 0% (0) | 0% (0) | 0% |

Other VL=McGrath®, Pentax Airway Scope®, Res-Q-Scope®.
*CI,* confidence interval; *VL,* video laryngoscope; *SGD*, supraglottic device; *CRIC,* cricothyrotomy; PGY, postgraduate year.

intubation bundle included goal directed preoxygenation, apneic oxygenation, and the use of delayed sequence intubation. They found that implementation of this bundle in their ground ambulance service resulted in a decrease in intubation associated hypoxemia from 44% to 3.5%. As a whole, the results of these studies consistently show a temporal relationship between monitoring airway performance with iterative clinical adjustments and improved procedural safety.

**Limitations**

There are several important limitations in this study. First, this is single center observational study at an academic center where EM residents perform most of intubations in the ED, so these results might not be generalizable to EDs with fully trained practitioners at non-teaching hospitals. In particular, the value of VL may be overstated when extrapolated to these clinicians and environments. Second, the data collected was all self-reported by the operator and collected at varying times after the intubation. It is thus highly subject to recall bias. Studies on emergency airway management have demonstrated that operators tend to over-report first pass success and under-report adverse events in the chart compared to what is found on recorded videos of the intubation.[28,29] In one study it was found that intubation associated desaturation events were only documented in the chart in 16% of the cases, when video review of those same cases identified a 33% prevalence of oxygen desaturation.[29] While video review of ED intubations would be ideal to obtain the highest quality data, this was not possible given the structure of our ED. Additionally, video review is

expensive and very labor intensive, and while important for research projects, it is simply impractical for widespread adoption of airway CQI programs in the ED. Third, the definitions used for adverse events in our study were not very specific and could be subject to varying interpretation by the operators. For example, if hypotension or a cardiac arrest occurred shortly after intubation, the operator may not believe or document this as a complication of the procedure. Finally, numerous educational and clinical changes were made throughout the 10-year study period, so it is impossible to ascertain which of these interventions were responsible for the clinical improvements we observed. While increased use of VL and greater emphasis on physiologic optimization appear to be associated with the improvement we have observed, this is not evidence of causation.

## CONCLUSION

To maximize the safety of airway management in the ED, the goal should be first pass success without adverse events. We developed an airway CQI program in our ED that incorporated an ongoing airway registry to monitor and improve the safety of emergency intubation. With this approach we were able to substantially increase first pass success and decrease adverse events associated with intubation. We recommend that all EDs monitor their airway performance and attempt to improve upon it so that patent safety can be maximized.

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*Conflicts of Interest*: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. Dr. Sakles has reported that he serves as a consultant to Verathon. There are no other conflicts of interest or sources of funding to declare.



## REFERENCES

1. Brown CA, Bair AE, Pallin DJ, et al. Techniques, success, and adverse events of emergency department adult intubations. *Ann Emerg Med*. 2015;65(4):363-70.
2. Mort TC. The incidence and risk factors for cardiac arrest during emergency tracheal intubation: A justification for incorporating the ASA Guidelines in the remote location. *J Clin Anesth*. 2004;16(7):508-16.
3. Mort TC. Emergency tracheal intubation: Complications associated with repeated laryngoscopic attempts. *Anesth Analg*. 2004;99(2):607-13.
4. Heffner AC, Swords D, Kline JA, et al. The frequency and significance of postintubation hypotension during emergency airway management. *J Crit Care*. 2012;27(4):417.
5. Heffner AC, Swords DS, Neale MN, et al. Incidence and factors associated with cardiac arrest complicating emergency airway management. *Resuscitation*. 2013;84(11):1500-4.
6. Bodily JB, Webb HR, Weiss SJ, et al. Incidence and duration of continuously measured oxygen desaturation during emergency department intubation. *Ann Emerg Med*. 2016;67(3):389-95.
7. Perbet S, De Jong A, Delmas J, et al. Incidence of and risk factors for severe cardiovascular collapse after endotracheal intubation in the ICU: A multicenter observational study. *Crit Care*. 2015;19:257.
8. De Jong A, Rolle A, Molinari N, et al. Cardiac Arrest and Mortality Related to Intubation Procedure in Critically Ill Adult Patients. *Crit Care Med*. 2018;46(4):532-9.
9. Cook TM, Woodall N, Harper J, et al. Major complications of airway management in the UK: Results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: Intensive care and emergency departments. *Br J Anaesth*. 2011;106(5):632-42.
10. Walker RG, White LJ, Whitmore GN, et al. Evaluation of physiologic alterations during prehospital paramedic-performed rapid sequence intubation. *Prehospital Emerg Care*. 2018;22(3):300-11.
11. Park L, Zeng I, Brainard A. Systematic review and meta-analysis of first-pass success rates in emergency department intubation : creating a benchmark for emergency airway care. 2017; *Emerg Med Australas.* 2017;Feb;29(1):40-4.
12. Hasegawa K, Shigemitsu K, Hagiwara Y, et al. Association between repeated intubation attempts and adverse events in emergency departments: an analysis of a multicenter prospective observational study. *Ann Emerg Med*. 2012;60(6):749-54.
13. Sakles JC, Chiu S, Mosier J, et al. The importance of first pass success when performing orotracheal intubation in the emergency department. *Acad Emerg Med*. 2013;20(1):71-8.
14. Cook TM and MacDougall-Davis SR. Complications and failure of airway management. *Br J Anaesth*. 2012;109(Suppl1):i68-85.
15. Sakles JC, Mosier JM, Patanwala AE, et al. The utility of the C-MAC as a direct laryngoscope for intubation in the emergency department. *J Emerg Med*. 2016;51(4):349-57.
16. Mosier J, Joshi R, Hypes C, et al. The physiologically difficult airway. *West J Emerg Med*. 2015;16(7):1109-17.
17. Weingart SD, Levitan RM. Preoxygenation and prevention of desaturation during emergency airway management. *Ann Emerg Med*. 2012;59(3):165-75.
18. Mosier JM, Hypes CD, Sakles JC. Understanding preoxygenation

and apneic oxygenation during intubation in the critically ill. *Intensive Care Med*. 2017;43(2):226-8.

19. Sakles J, Mosier J, Patanwala A, et al. Learning curves for direct laryngoscopy and GlideScope® video laryngoscopy in an emergency medicine residency. *West J Emerg Med*. 2014;15(7):930-7.
20. Patanwala AE, Stahle SA, Sakles JC, et al. Comparison of succinylcholine and rocuronium for first-attempt intubation success in the emergency department. *Acad Emerg Med*. 2011;18(1):11-4.
21. Patanwala AE, McKinney CB, Erstad BL, et al. Retrospective analysis of etomidate versus ketamine for first-pass intubation success in an academic emergency department. *Acad Emerg Med*. 2014;21(1):87-91.
22. Hwang SY, Park JH, Yoon H, et al. Quality improvement program outcomes for endotracheal intubation in the emergency department. *J Patient Saf*. 2018;14(4):e83-8.
23. Kerrey BT, Mittiga MR, Rinderknecht AS, et al. Reducing the incidence of oxyhaemoglobin desaturation during rapid sequence intubation in a paediatric emergency department. *BMJ Qual Saf*. 2015;24(11):709-17.
24. Jaber S, Jung B, Corne P, et al. An intervention to decrease complications related to endotracheal intubation in the intensive care unit: A prospective, multiple-center study. *Intensive Care Med*. 2010;36(2):248-55.
25. Mayo PH, Hegde A, Eisen LA, et al. A program to improve the quality of emergency endotracheal intubation. *J Intensive Care Med*. 2011;26(1):50-6.
26. Olvera DJ, Stuhlmiller DFE, Wolfe A, et al. A continuous quality improvement airway program results in sustained increases in intubation success. *Prehospital Emerg Care*. 2018;22(5):602-7.
27. Jarvis JL, Gonzales J, Johns D, et al. Implementation of a clinical bundle to reduce out-of-hospital peri-intubation hypoxia. *Ann Emerg Med*. 2018;72(3):272-9.
28. Kerrey BT, Rinderknecht AS, Geis GL, et al. Rapid sequence intubation for pediatric emergency patients: Higher frequency of failed attempts and adverse effects found by video review. *Ann Emerg Med*. 2012;60(3):251-9.
29. Rinderknecht AS, Dyas JR, Kerrey BT, et al. Studying the safety and performance of rapid sequence intubation: data collection method matters. *Acad Emerg Med*. 2017;24(4):411-21.

# Thromboembolic Risk of 4-Factor Prothrombin Complex Concentrate versus Fresh Frozen Plasma for Urgent Warfarin Reversal in the Emergency Department

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*Section Editor:* Gabriel Wardi, MD
Submission history: Submitted November 14, 2018; Revisions received April 25, 2019; Accepted April 26, 2019
Electronically published June 11, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.4.41649

**Introduction:** Warfarin is a potent anticoagulant used for the prevention and treatment of venous and arterial thrombosis. Occasionally, patients require emergent warfarin reversal due to active bleeding, supratherapeutic international normalized ratio, or emergent diagnostic or therapeutic interventions. Various agents can be used for emergent warfarin reversal, including fresh frozen plasma (FFP) and 4-factor prothrombin complex concentrate (4F-PCC). Both FFP and 4F-PCC are generally considered safe; however, both agents contain coagulation factors and have the potential to provoke a thromboembolic event. Although clinical trials have compared the efficacy and safety of FFP and 4F-PCC, data are limited comparing the risk of thromboembolism between the two agents.

**Methods:** A retrospective chart review was performed at a single, urban, academic medical center comparing the incidence of thromboembolism with FFP or 4F-PCC for warfarin reversal during a three-year period in the emergency department (ED) at Massachusetts General Hospital. Patients were included in the study if they were at least 18 years of age and were on warfarin per electronic health records. Patients were excluded if they had received both FFP and 4F-PCC during the same visit. The primary outcome was the frequency of thromboembolism within 30 days of 4F-PCC or FFP. Secondary outcomes included time to thromboembolic event and in-hospital mortality.

**Results:** Three hundred and thirty-six patients met the inclusion criteria. Thromboembolic events within 30 days of therapy occurred in seven patients (2.7%) in the FFP group and 14 patients (17.7%) in the 4F-PCC group (p=<0.001). Death occurred in 39 patients (15.2%) who received FFP and 18 patients (22.8%) who received 4F-PCC (p=0.115). Since the 4F-PCC group was treated disproportionately for central nervous system (CNS) bleeding, a subgroup analysis was performed including patients requiring reversal due to CNS bleeds that received vitamin K. The primary outcome remained statistically significant, occurring in four patients (4.1%) in the FFP group and nine patients (14.1%) in the 4F-PCC group (p=0.02).

**Conclusion:** Our study found a significantly higher risk of thromboembolic events in patients receiving 4F-PCC compared to FFP for urgent warfarin reversal. This difference remained statistically significant when controlled for CNS bleeds and administration of vitamin K. [West J Emerg Med. 2019;20(4)619-625.]

## INTRODUCTION

Warfarin is a potent anticoagulant used for the prevention and treatment of venous and arterial thrombosis. As a vitamin K antagonist, warfarin prevents the post-translational carboxylation of coagulation factors II, VII, IX, and X, along with protein C and S, by 30-50%.[1] Warfarin is one of the top medications implicated in emergency department (ED) visits due to bleeding events. Annually, bleeding complications associated with over-anticoagulation with warfarin occur in 15-20% of patients, with fatal bleeds accounting for 1-3%.[2]

Occasionally, patients require emergent warfarin reversal due to life-threatening bleeds or the need for emergency diagnostic or therapeutic intervention. The risk of bleeding is directly related to the degree of international normalized ratio (INR) elevation.[3] It is important to note, however, that half of all major bleeding episodes associated with warfarin occur when the INR is less than 4.0.[4] The degree and rapidity of reversal are dependent upon not only the absolute value of the INR, but also the clinical indication for reversal. Prior to the approval of 4-factor-prothrombin complex concentrate (4F-PCC) in 2013, fresh frozen plasma (FFP) was the preferred therapy for reversing warfarin in the United States. However, 4F-PCC reduces the INR more quickly and is now preferred as a first-line agent for warfarin reversal in intracranial hemorrhage, the most disabling form of major bleeding.[5,6,7,8,9] Both FFP and 4F-PCC are generally considered safe; however, both agents contain coagulation factors and have the potential to provoke a thromboembolic event. Although clinical trials have compared the efficacy and safety of FFP and 4F-PCC, there is sparse data comparing the risk of thromboembolism between the two agents outside the clinical trial setting, using "real world" data. [6,7,10,11,12,13,14]

The primary objective of this study was to assess the incidence of thromboembolic events in patients who received either 4F-PCC or FFP for emergent warfarin reversal.

*Population Health Research Capsule*

What do we already know about this issue?
*Despite clinical trials of fresh frozen plasma (FFP) vs. 4-factor prothrombin complex concentrate (4F-PCC), few data compare thromboembolism risk for warfarin reversal.*

What was the research question?
*What is the incidence of thromboembolism using FFP compared to 4F-PCC for urgent warfarin reversal?*

What was the major finding of the study?
*There was a higher risk of thromboembolic events in patients receiving 4F-PCC compared to FFP for urgent warfarin reversal.*

How does this improve population health?
*While 4F-PCC is the preferred agent for warfarin reversal, providers must weigh the risks and benefits when using it in patients already at high risk of thromboembolism.*

## METHODS

We performed a retrospective chart review at a single, urban, academic medical center. Consecutive patients receiving 4F-PCC in the ED between April 20, 2016 – October 28, 2017, or FFP in the ED between January 1, 2010 – January 30, 2011, were identified from the electronic health record (EHR). During the FFP period, 4F-PCC was not available for use at our institution, and FFP was used for all emergent warfarin reversal. In April 2013, 4F-PCC became available for warfarin reversal, although its use was restricted to patients with central nervous system (CNS) and intrapulmonary bleeds on warfarin. Any other indications required hematology approval. A report from the hospital's EHR identified patients who received an order for FFP or 4F-PCC while in the ED.

Patients were included in the current study if they were at least 18 years of age and were on warfarin as per EHR, including outpatient medication lists, previous prescriptions, and prescriber notes. We excluded patients if they had received both FFP and 4F-PCC during the same visit. Collected data included initial INR on presentation to the ED, indication for warfarin, indication for warfarin reversal, administration and dose of FFP or 4F-PCC, administration of vitamin K, thromboembolic events, and mortality. Age, gender, and race were also collected for demographic purposes. Thromboembolic events were identified by reviewing provider notes, discharge summaries, follow-up notes, imaging, and medication administration records.

We used the search function of the EHR to ensure that no thromboembolic events occurring at our hospital were overlooked. This search function identifies the searched term in the EHR, as well as any other medically related terms. For example, when searching for the term "clot," similar search terms such as thromboembolism and thrombus are also identified. Patients in the FFP group were originally collected for a separate analysis of pulmonary complication rates after FFP administration and time to INR reversal.[15]

Abstractors were trained in clinical research and quality assurance. There was an initial review of study variables, standard operating procedures for data abstraction,

and the data abstraction form (which was electronic, using REDCap). Each abstractor then reviewed a set of practice records, with variables verified for accuracy and discrepancies adjudicated. After training, regular meetings occurred to review data collection and address questions and discrepancies.

The primary outcome was the frequency of thromboembolism within 30 days of 4F-PCC or FFP administration. Secondary outcomes included time to thromboembolic event and in-hospital mortality.

**Statistical Analysis**

This study was approved by the institutional review board. We collected and analyzed data using RedCap and Excel. We used chi-square tests to compare the rate of thromboembolic events and mortality between patients who received 4F-PCC and FFP. The method by Cohen was used to determine power since there were no previous studies on which to base our power analysis.[16] In order to detect a medium effect size difference ($d = 0.5$ where $d = (mean_a\text{-}mean_b)/\alpha$) and $\alpha = 0.05$), it was estimated that 64 patients would be required for each group. We also calculated Cohen's kappa to assess for inter-rater reliability. This number was based on 10% of our data chosen at random to be reabstracted by an independent reviewer for our primary endpoint.

**RESULTS**

Table 1 shows patients' baseline characteristics. The most common reason for patients to receive 4F-PCC was CNS bleed (82.3%), while the indications for FFP were more varied, including CNS bleed (38.1%), urgent surgery (25.7%), and gastrointestinal bleed (19.8%). The median amount of FFP administered was 3 units (interquartile range [IQR] 1-3) with the average dose being 9.4 milliliters per kilogram (mL/kg). The mean dose of 4F-PCC administered was 2168 units (standard deviation [SD] 723 units). All patients included in the 4F-PCC group received a dose within 10% of their calculated dose based on their initial INR and weight, consistent with U.S. Food and Drug Administration (FDA)-approved dosing. Inclusion and exclusion criteria are described in Figure 1.

The primary outcome, thromboembolic events within 30 days, occurred in seven patients (2.7%) in the FFP group and 14 patients (17.7%) in the 4F-PCC group (p=<0.001). We calculated a Cohen's kappa score of 0.84 based on 10% of the data reabstracted by an independent reviewer. The mean time to thromboembolic event was 4.1 days (SD 5.4) in the FFP group and 8.9 days (SD 8.7) in the 4F-PCC group (p=0.20). We also evaluated thromboembolic events based on type and indications for warfarin use, as seen in Tables 2 and 3. Two patients in the FFP group and four patients in the 4F-PCC group had superficial clots, all of which were cephalic vein thromboses. When these less dangerous and non-life-threatening clots were removed from the analysis, the difference in thromboembolic events remained statistically significant (p=<0.001) between the two groups.

Vitamin K was administered in 209 of 257 (81.3%) patients in the FFP group and 78 of 79 (98.7%) patients in the 4F-PCC group (p=0.0002). Death occurred in 39 patients (15.2%) who received FFP and 18 patients (22.8%) who received 4F-PCC (p=0.115). Cause of death in the FFP group was attributed to a bleeding event in 20 patients and thromboembolic event in two patients, while 17 patients had other, non-related or unclear causes of death. In the 4F-PCC group, death was attributed to a bleeding event in 10 patients and thromboembolic event in two patients, while six patients had other, non-related or unclear causes of death. All bleeding events resulting in death were attributed to the presenting event.

As the 4F-PCC group was treated disproportionately for CNS bleeding (due to the hospital guideline restricting 4F-PCC use to high-risk conditions such as this), we performed a subgroup analysis including only patients requiring warfarin reversal due to CNS bleeds and those that received vitamin K in the ED. There were 98 patients included in the FFP group and 65 patients included in the 4F-PCC group. The median amount of FFP administered was 4 units (IQR 1-3), while the mean dose of 4F-PCC administered was 2148 units (SD 698 units). The primary outcome, thromboembolic events within 30 days, remained statistically significant occurring in four patients (4.1%) in the FFP group and nine patients (14.1%) in the 4F-PCC group (p=0.02). Death occurred in 30 patients (30.6%) who received FFP and 17 patients (26.2%) who received 4F-PCC (p=0.54).

**DISCUSSION**

According to the American College of Cardiology (ACC) and the Neurocritical Care Society guidelines on anticoagulation reversal, 4F-PCC is currently recommended as the preferred method for emergency warfarin reversal.[8,9] Although patients receiving warfarin have pre-existing thromboembolic risk factors that may be unmasked with reversal, it is not clear whether different warfarin reversal options carry different thromboembolic risks. Phase 2 and 3 clinical trials evaluating thromboembolic events between FFP and 4F-PCC for vitamin K antagonist reversal found no difference between these options.[5,6,7,17] However, our study of real-world data suggests the thromboembolic risk of 4F-PCC may be higher than FFP. Importantly, the thromboembolic events in the 4F-PCC group, on average, occurred much later in the clinical course and therefore may be less related to the initial reversal administered. Although this difference was not statistically significant, it could have clinically significant implications.

Several factors may have contributed to the difference in thromboembolic risk in our study, the first of which is the differences in baseline characteristics. Patients who received 4F-PCC had a significantly higher rate of atrial fibrillation requiring warfarin therapy, while more

**Table 1.** Baseline characteristics.

| | 4F-PCC (n=79) | FFP (n=257) | p-value |
|---|---|---|---|
| Sex | | | |
| Male | 59.5% | 59.1% | 0.96 |
| Female | 40.5% | 40.9% | 0.96 |
| Age (years) | 75.2 | 73.0 | 0.09 |
| Race | | | |
| Hispanic/Latino | 2 (2.5%) | 4 (1.6%) | 0.57 |
| Not Hispanic/Latino | 76 (96.2%) | 252 (98.0%) | 0.35 |
| Unavailable | 1 (1.3%) | 1 (0.4%) | 0.38 |
| Weight (kg) | 78.3 | 79.8 | 0.26 |
| Baseline INR | 3.65 | 3.86 | 0.37 |
| Indication for Warfarin* | | | |
| Atrial fibrillation | 60 (75.9%) | 162 (63.0%) | 0.03 |
| Mitral valve replacement | 4 (5.1%) | 7 (2.7%) | 0.31 |
| Aortic valve replacement | 6 (7.6%) | 13 (5.1%) | 0.39 |
| Deep vein thrombosis | 7 (8.8%) | 41 (15.9%) | 0.12 |
| Pulmonary embolism | 4 (5.1%) | 36 (14.0%) | 0.03 |
| Hypercoagulable state | 5 (6.3%) | 11 (4.3%) | 0.45 |
| Other | 3 (3.8%) | 57 (22.1%) | <0.001 |
| Indication for Warfarin reversal* | | | |
| CNS bleed | 65 (82.3%) | 98 (38.1%) | <0.001 |
| GI bleed | 5 (6.3%) | 51 (19.8%) | 0.005 |
| Musculoskeletal bleed | 3 (3.8%) | 2 (0.8%) | 0.05 |
| Intra-abdominal bleed | 0 (0%) | 10 (3.9%) | 0.13 |
| Hematuria | 0 (0%) | 4 (1.6%) | 0.58 |
| Hemoptysis | 0 (0%) | 3 (1.2%) | 1.0 |
| Epistaxis | 0 (0%) | 2 (0.8%) | 1.0 |
| Hematoma | 4 (5.1%) | 4 (1.6%) | 0.07 |
| Hemothorax | 0 (0%) | 1 (0.4%) | 1.0 |
| Other bleeding** | 0 (0%) | 7 (2.7%) | 0.21 |
| Surgery | 4 (5.1%) | 66 (25.7%) | <0.001 |
| Other indications for reversal | 0 (0%) | 7 (2.7%) | 0.21 |
| Average dose | 28 IU/kg | 9.4 mL/kg | |
| Concomitant vitamin K | 78 (98.7%) | 209 (81.3%) | <0.001 |

*Numbers do not add up to 100% as some patients had more than one indication for warfarin or warfarin reversal.
**Other bleeding includes vaginal bleeding, catheter site bleeding, arteriovenous fistula, hemorrhagic ovarian cyst, hemorrhagic goiter, bleeding associated with multi-trauma, and hemathrosis.
*FFP*, fresh frozen plasma; *4F-PCC*, 4-factor prothrombin complex concentrate; *kg*, kilogram; *INR*, international normalized ratio; *CNS*, central nervous system; *GI*, gastrointestinal; *mL/kg*, milliliters per kilogram; *IU/kg*, international unit per kilogram.

FFP patients were under treatment for thromboembolic disorders such as pulmonary emboli. Patients in the FFP group had an overall higher risk of venous thromboemboli, potentially putting them at higher risk of thromboembolic events with warfarin reversal. Our results demonstrated the opposite, suggesting that the patients in the 4F-PCC group may have an increased risk of thromboembolic events despite their indication for warfarin.

The dose of FFP administered and differences in vitamin K administration may also have contributed.

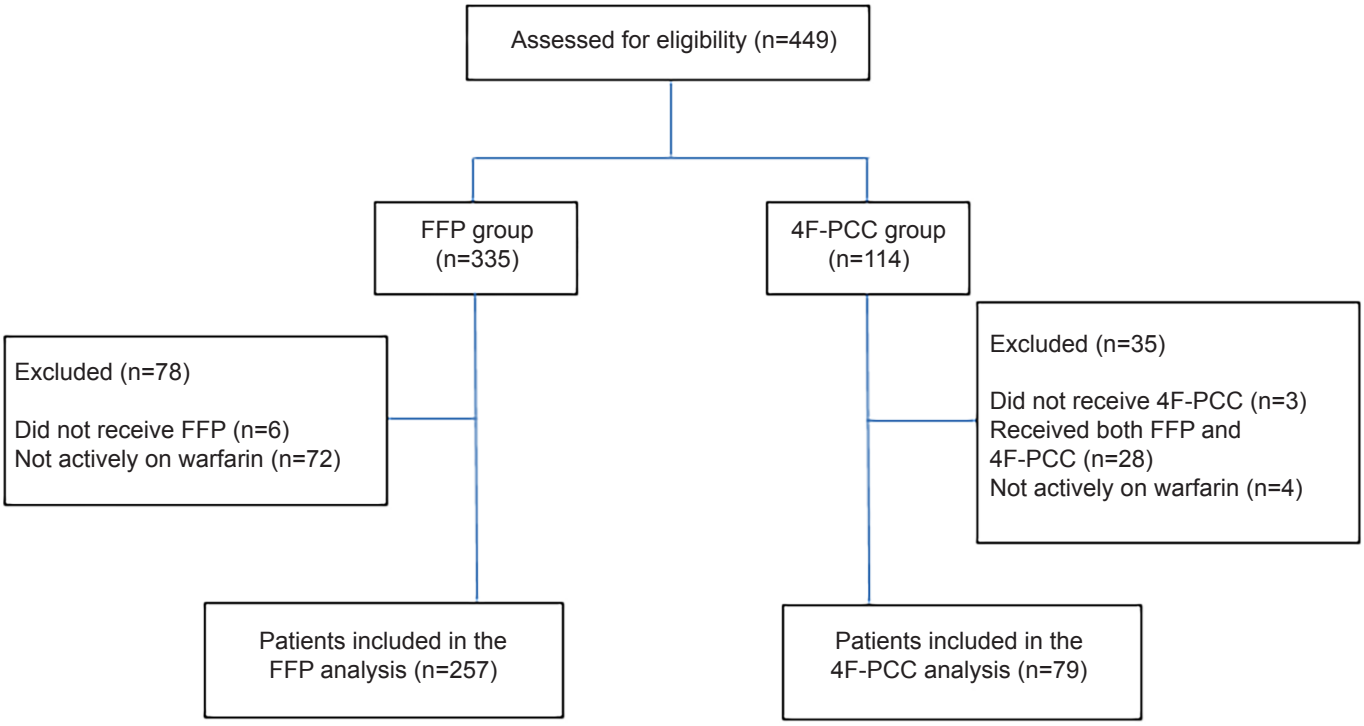


**Figure 1.** Study inclusion and exclusion.
*FFP,* fresh frozen plasma; *4F-PCC*, 4-factor prothrombin complex concentrate.

When using FFP for the emergency reversal of warfarin, 10-15mL/kg is recommended.[9] Most adults will need an average dose of 3-6 units to replace enough coagulation factors to reverse warfarin. In our study, the median amount of FFP given was 3 units, with the group having a mean weight of 79.8 kg. On average, patients in our study received a subtherapeutic dose of FFP at 9.4 mL/kg, while all patients in the 4F-PCC group received the recommended dose based on their weight and INR. For comparison, the FFP arms of clinical trials include doses that are substantially higher than those used in our center during the study period;[6,7,17] therefore, our FFP patients may have been exposed to lower thromboembolic risk. Although the average FFP dose administered in our study was subtherapeutic according to the guidelines, it was within 10% of the lower limit of the recommended dose of 10 mL/kg, which suggests that the lower end of the dosing range may be safer.

**Table 2.** Thromboembolic events within 30 days of warfarin reversal.

| | 4F-PCC (14) | FFP (7) | p-value |
|---|---|---|---|
| Myocardial infarction | 0 (0%) | 1 (14.3%) | 0.33 |
| Cerebral vascular accident | 2 (14.3%) | 0 (0%) | 0.53 |
| Pulmonary embolism | 2 (14.3%) | 1 (14.3%) | 1 |
| Deep venous thrombosis | 4 (28.6%) | 3 (42.9%) | 0.64 |
| Superficial thrombosis* | 4 (28.6%) | 2 (28.6%) | 1 |
| Other** thromboembolic event | 2 (14.3%) | 0 (0%) | 0.53 |

*Superficial thrombosis includes cephalic vein thrombus.
**Other events include left ventricular thrombus and right atrial thrombus.
*FFP,* fresh frozen plasma; *4F-PCC*, 4-factor prothrombin complex concentrate.

The difference in Vitamin K administration might also have contributed to the difference in thromboembolic events. The FFP group received vitamin K significantly less often than the 4F-PCC group (81% vs.99%, respectively; p = <0.001), a difference that was not seen in most other studies.[5,6,7]

Another difference identified between the two groups was the number of CNS bleeds. Our hospital guideline allows 4F-PCC to be ordered without specialist approval for patients with CNS bleeds; however, most other uses require hematology approval. To control for this, we performed a subgroup analysis examining only those with CNS bleeds who received vitamin K. The thromboembolic event rate remained higher in the 4F-PCC group. However, there was no difference in mortality. It remains possible that providers selected more severely injured patients for 4F-PCC.[18]

Several studies examined the difference between thromboembolic events as a secondary outcome, but only a few have looked at this occurrence as a primary outcome.[5,6,7,17] A post

**Table 3.** Warfarin indications for patients with thromboembolic events after reversal with 4-factor prothrombin complex concentrate (4F-PCC) or fresh frozen plasma (FFP).

| Thromboembolic event | Warfarin Indication* | |
|---|---|---|
| | 4F-PCC | FFP |
| Cerebral vascular accident (n=1 in 4F-PCC) | Atrial fibrillation (n=1)<br>Cerebral vascular accident (n=1) | None |
| Myocardial infarction (n=1) | None | Atrial fibrillation (n=1) |
| Pulmonary embolism (n=2 in 4F-PCC and 1 in FFP) | Atrial fibrillation (n=2)<br>Deep venous thrombosis (n=1) | Deep venous thrombosis (n=1)<br>Hypercoagulable state (n=1) |
| Deep venous thrombosis (n=4 in 4F-PCC and 4 in FFP) | Atrial fibrillation (n=4)<br>Deep venous thrombosis (n=1)<br>Factor V Leiden (n=1) | Atrial Fibrillation (n=3)<br>Deep venous thrombosis (n=1)<br>Hypercoagulable state (n=2) |
| Superficial thrombosis (n= 4 in 4F-PCC and 2 in FFP) | Mechanical valve (n=2)<br>Atrial fibrillation (n=3) | Pulmonary embolism (n=1)<br>Deep venous thrombosis (n=1)<br>Hypercoagulable state (n=1) |
| Other thromboembolic event (n=2 in 4F-PCC) | Atrial fibrillation (n=1)<br>Mechanical valve (n=1)<br>Deep venous thrombosis (n=1) | None |

*Warfarin indications were not mutually exclusive.
*FFP,* fresh frozen plasma; *4F-PCC*, 4-factor prothrombin complex concentrate.

hoc exploratory analysis of two randomized controlled trials found that most thromboembolic events in the 4F-PCC group occurred >7 days after reversal, clustering around the two-week mark while thromboembolic events in the FFP group occurred within seven days of reversal, with nearly 50% occurring within the same day. This difference may be due to the increased amount of vitamin K and non-vitamin K dependent coagulation factors being loaded over a short period but also raises the question of whether the thromboembolic events were caused by the administration of 4F-PCC or a consequence of prolonged hospitalizations and delayed anticoagulation initiation after a major bleeding event.

The ACC published an expert consensus on the management of bleeding in patients on oral anticoagulants, in which they recommend the use of either variable dosing of 4F-PCC based on INR and weight or fixed dose.[9] There are few data to suggest that the rate of thromboembolic events with 4F-PCC is dose dependent. However, giving a fixed dose of 1000-1500 international units may theoretically reduce the risk of thromboembolic events. Since our study used the variable FDA dosing of 4F-PCC based on INR and weight, further studies are needed to determine if the risk of thromboembolic events would remain significant between FFP and 4F-PCC when using fixed dose 4F-PCC.

## LIMITATIONS

Limitations of this study include its retrospective, single-center design, which only included patients seen and followed up at our hospital. Although we were able to identify all patients that followed up at hospitals within our healthcare system, patients may have been missed if they had thromboembolic events or died at hospitals outside of our system. Another limitation is the difference in time periods in which the data were collected and the difference in baseline characteristics between the two groups. Although 4F-PCC was FDA approved in 2013, its distribution was managed by the blood bank at our institution until 2016, when it was transferred to the pharmacy department.[18] Due to this timing, we were unable to obtain any data for 4F-PCC use before this time. To ensure inter-rater reliability an independent abstractor conducted quality assurance using the Cohen's kappa score by reabstracting 10% of the data. Despite the difference in abstractors and time periods, a kappa score of 0.84 suggested almost perfect agreement between the abstractors. In addition, clinical care of patients requiring warfarin reversal may have changed during the study period, and data capture for thromboembolic events may have improved, artificially increasing the frequency of thromboembolism over time. Lastly, we are unable to comment on the long-term morbidity and mortality between the two groups as this study only analyzed data up to 30 days after patients received 4F-PCC and FFP.

## CONCLUSION

Our study found a higher risk of thromboembolic events in patients receiving FDA-approved doses of 4F-PCC compared to FFP for urgent warfarin reversal. This difference remained when controlled for CNS bleeds and administration of vitamin K. Thromboembolic events, on average, developed several days later in the 4F-PCC group compared to the FFP group. Although 4F-PCC is the preferred agent for emergent warfarin reversal, it is important for providers to weigh the risks and benefits when using this agent in patients already at high risk of thromboembolic events.

**ACKNOWLEDGMENTS**

Portions of data collection were funded by CSL Behring.

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



**REFERENCES**

1. Majerus PW, Tollefsen DM. Blood anticoagulation and anticoagulant, thrombolytic, and antiplatelet drugs. In *Goodman and Gillman's The Pharmacological Basis of Therapeutics, 11th Ed.* 2006:1467-88.
2. Zareh M, Davis A, Henderson S. Reversal of warfarin-induced hemorrhage in the emergency department. *West J Emerg Med.* 2011;12(4):386-92.
3. Palareti G, Leali N, Coccheri S, et al. Bleeding complications of oral anticoagulant treatment: an inception-cohort, prospective collaborative study (ISCOAT). *Lancet*. 1996;348(9205):423-8.
4. Campbell P, Gallus A. Managing warfarin therapy in the community. *Aust Prescr.* 2001;24:86-9.
5. Sarode R, Milling TJ Jr, Refaai MA, et al. Efficacy and safety of a 4-factor prothrombin complex concentrate in patients on vitamin K antagonists presenting with major bleeding: a randomized, plasma-controlled, phase IIIb study. *Circulation*. 2013;128(11):1234-43.
6. Goldstein JN, Refaai MA, Milling TJ Jr, et al. Four-factor prothrombin complex concentrate versus plasma for rapid vitamin K antagonist reversal in patients needing urgent surgical or invasive interventions: a phase 3b, open-label, non-inferiority, randomised trial. *Lancet.* 2015;385(9982):2077-87.
7. Steiner T, Poli S, Griebe M, et al. Fresh frozen plasma versus prothrombin complex concentrate in patients with intracranial haemorrhage related to vitamin K antagonists (INCH): a randomised trial. *Lancet Neurol.* 2016;15(6):566-73.
8. Frontera JA, Lewin JJ, Rabinstein AA, et al. Guidelines for reversal of antithrombotics in intracranial hemorrhage: a statement for healthcare professionals from the Neurocritical Care Society and Society of Critical Care Medicine. *Neurocrit Care.* 2016;24(1):6-46.
9. Tomaselli GF, Mahaffey KW, Cuker A, et al. 2017 ACC expert consensus decision pathway on management of bleeding in patients on oral anticoagulants: a report of the American College of Cardiology Task Force on Expert Consensus Decision Pathways. *J Am Coll Cardiol.* 2017;70(24):3042-67.
10. Rowe AS, Mahbubani PS, Bucklin MH, et al. Activated prothrombin complex concentrate versus plasma for reversal of warfarin-associated hemorrhage. *Pharmacotherapy*. 2016;36(11):1132-7.
11. Chai-Adisaksopha C, Hillis C, Siegal DM, et al. Prothrombin complex concentrates versus fresh frozen plasma for warfarin reversal. A systematic review and meta-analysis. *Thromb Haemost*. 2016;116(5):879-90.
12. Johansen M, Wikkelsø A, Lunde J, et al. Prothrombin complex concentrate for reversal of vitamin K antagonist treatment in bleeding and non-bleeding patients. *Cochrane Database Syst Rev*. 2015;(7):CD010555.
13. Agarwal P, Abdullah KG, Ramayya AG, et al. A retrospective propensity score-matched early thromboembolic event analysis of prothrombin complex concentrate vs fresh frozen plasma for warfarin reversal prior to emergency neurosurgical procedures. *Neurosurgery*. 2018;82(6):877-6.
14. Rowe AS, Dietrich SK, Phillips JW, et al. Activated prothrombin complex concentrate versus 4-factor prothrombin complex concentrate for vitamin K-antagonist reversal. *Crit Care Med*. 2018;46(6):943-8.
15. Marshall AL, Levine M, Howell ML, et al. Dose-associated pulmonary complication rates after fresh frozen plasma administration for warfarin reversal. *J Thromb Haemost*. 2016;14(2):324-30.
16. Cohen J. A power primer. *Psychol Bull*. 1992;112:155–9.
17. Milling TJ Jr, Refaai MA, Goldstein JN, et al. Thromboembolic events after vitamin K antagonist reversal with 4-factor prothrombin complex concentrate: exploratory analyses of two randomized, plasma-controlled studies. *Ann Emerg Med*. 2016;67(1):96-105.
18. Corio JL, Sin JH, Hayes BD, et al. Impact of a pharmacist-driven prothrombin complex concentrate protocol on time to administration in patients with warfarin-associated intracranial hemorrhage. *West J Emerg Med*. 2018;19(5):849-54.

# Radiograph Interpretation Discrepancies in a Community Hospital Emergency Department

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*Section Editor:* Kenneth Whitlow, DO
Submission history: Submitted October 22, 2018; Revision received December 18, 2018; Accepted January 20,2019
Electronically published July 2, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.1.41375

**Introduction:** In many hospitals, off-hours emergency department (ED) radiographs are not read by a radiologist until the following morning and are instead interpreted by the emergency physician (EP) at the time of service. Studies have found conflicting results regarding the radiographic interpretation discrepancies between EPs and trained radiologists. The aim of this study was to identify the number of radiologic interpretation discrepancies between EPs and radiologists in a community ED setting.

**Methods:** Using a pre-existing logbook of radiologic discrepancies as well as our institution's picture archiving and communication system, all off-hours interpretation discrepancies between January 2012 and January 2015 were reviewed and recorded in a de-identified fashion. We recorded the type of radiograph obtained for each patient. Discrepancy grades were recorded based on a pre-existing 1-4 scale defined in the institution's protocol logbook as Grade 1 (no further action needed); Grade 2 (call to the patient or pharmacy); Grade 3 (return to ED for further treatment, e.g., fracture not splinted); Grade 4 (return to ED for serious risk, e.g., pneumothorax, bowel obstruction). We also recorded the total number of radiographs formally interpreted by EPs during the prescribed time-frame to determine overall agreement between EPs and radiologists.

**Results:** There were 1044 discrepancies out of 16,111 EP reads, indicating 93.5% agreement. Patients averaged 48.4 ± 25.0 years of age and 53.3% were female; 25.1% were over-calls by EPs. The majority of discrepancies were minor with 75.8% Grade 1 and 22.3% Grade 2. Only 1.7% were Grade 3, which required return to the ED for further treatment. A small number of discrepancies, 0.2%, were Grade 4. Grade 4 discrepancies accounted for two of the 16,111 total reads, equivalent to 0.01%. A slight disagreement in finding between EP and radiologist accounted for 8.3% of discrepancies.

**Conclusion:** Results suggest that plain radiographic studies can be interpreted by EPs with a very low incidence of clinically significant discrepancies when compared to the radiologist interpretation. Due to rare though significant discrepancies, radiologist interpretation should be performed when available. Further studies are needed to determine the generalizability of this study to EDs with differing volume, patient population, acuity, and physician training. [West J Emerg Med. 2019;20(4)626-632.]

## INTRODUCTION

In many emergency departments (ED) across the United States and throughout the world, plain radiographic studies are initially interpreted by an emergency physician (EP) without the immediate interpretation of a trained radiologist. While EP interpretation aids in ED flow and prompt treatment, interpretation errors can potentially place a patient at unnecessary risk of adverse outcome and the treating physician at risk for litigation.[1,2] Studies in the literature have suggested that immediate radiology interpretation has potential to reduce

errors that would require call-back to the ED.[3,4]

Several studies have examined radiologic interpretation discrepancies between EPs and radiologists.[5-18] These studies report a wide range of agreement between the two specialties in regard to plain radiograph interpretation in the ED. Two existing studies found agreement rates as high as 97-99% between EPs and radiologists.[15,16] In contrast, other studies have found agreement rates as low as 52-66%.[5,7] The large variability in the reported range of radiographic interpretation discrepancies suggests the need for further study in relation to this clinically relevant topic encountered on a day-to-day basis in many EDs without 24-hour radiologist coverage.

The aim of this study was to identify the number of radiologic interpretation discrepancies between EPs and radiologists in a community ED setting. We also sought to determine the frequency and nature of treatment- changing discrepancies to determine whether plain radiographs can be safely interpreted by EPs without immediate radiologist interpretation. A secondary aim was to examine the agreement in radiology reads based on age as well as the specific body area imaged. We hypothesized that radiographs interpreted by EPs would have a high level of agreement with final radiologist interpretation. Furthermore, we hypothesized that discrepancies presenting serious risk to the patient would be rare.

*Population Health Research Capsule*

What do we already know about this issue?
*Existing studies have found conflicting agreement rates between emergency physicians (EP) and radiologists regarding plain radiograph interpretations.*

What was the research question?
*Can EPs accurately interpret plain radiographs without the immediate aid of a radiologist?*

What was the major finding of the study?
*EPs can accurately interpret commonly obtained radiographs with a very low rate of treatment-changing misses.*

How does this improve population health?
*While EPs interpret common films well, this study can improve emergency department care by stimulating EPs to be more cautious interpreting pediatric and less common radiographs.*

## METHODS

The setting for this study was a community hospital ED with an emergency medicine (EM) residency program in which "off-hours," plain radiographs are not read by a radiologist until the following morning. These off-hours are generally 5-6 PM to 6:30 AM. The number of hours without radiologist coverage of plain radiographic reads varies per day based on the radiologist shift schedule, which generally ranges from 8-12 hours without coverage of radiograph interpretation. During times without radiologist coverage, initial interpretations, determined by the attending, board-certified EP, are logged into our picture archiving and communication system (PACS) and a board-certified general radiologist provides final interpretations in the morning.

Radiographic discrepancies are charted in the morning after radiology read in a discrepancy logbook by the day-shift attending EP. The degree of discrepancy, as explained below, is also determined and documented by the attending physician. Necessary callbacks are made by nursing based on the clinical judgment of the documenting, not interpreting, EP. No formal training is specifically given to the EP on discrepancy grading, although the grading follows straightforward guidelines. If in the clinical judgment of the documenting EP, a callback or return to ED was warranted this was directly reflected in the discrepancy grading.

Degree of discrepancy is graded on a 1-4 scale. Grade 1 is a minor discrepancy with no additional action needed, eg, an infiltrate read on radiologist interpretation of chest radiograph (CXR) but not seen overnight by the EP even though the patient was started on an antibiotic at the time of service. Minor "over-calls" by the EP that were not appreciated in the final radiology interpretation would also be considered Grade 1. For example, an EP interprets, "questionable fracture," and instructs the patient to follow-up although the radiologist interprets, "no fracture." Grade 2 is a minor discrepancy in which the patient was contacted and did not require return to the ED. For example, a radiologist interprets infiltrate on CXR, not appreciated on overnight read, which required an antibiotic to be called in to the pharmacy. An additional example would be informing a patient via phone call regarding a pulmonary nodule that was appreciated by the radiologist, which requires primary care follow-up. Grade 3 is a major discrepancy in which the patient was required to return to the ED for further treatment. An example would be calling a patient back to the ED to splint a fracture that was not appreciated on overnight EP read. Grade 4 discrepancies are major discrepancies that risk serious harm to the patient. Examples are a missed pneumothorax, free air under the diaphragm, small bowel obstruction, etc.

Following institutional review board approval, we retrospectively reviewed all radiologic discrepancies

recorded in our logbook and PACS between January 1, 2012 and January 1, 2015, regardless of patient age, gender, or presenting complaint. No discrepancies were excluded. Age and gender of the patient were documented. We also recorded the initial diagnosis, final diagnosis, body area of radiographic study, nature of discrepancy, grade of discrepancy, modified treatment, and disposition. The total number of EP radiographic reads during the time period studied were obtained from our PACS to determine overall EP and radiologist agreement. In addition, we queried our PACS and categorized EP reads by body area to determine if certain types of radiographs had a higher or lower level of agreement in interpretation. Radiographs were separated into groups as follows: chest, abdomen, lower extremity, upper extremity, cervical spine, thoracic-lumbar-sacral-coccygeal spine, pelvis, soft tissue neck, or other. Upper extremity included any radiograph performed at the level of the shoulder or distal to the shoulder. Lower extremity included any radiograph at the level of the hip or distal to the hip. The category of "other" included radiographs of the scapula, clavicle, sternum, nose, face, orbits, mandible, and ribs. We further categorized patients into the age groups of 0-6 years, 7-12 years, 12-17 years, and 18 years or greater to determine if discrepancy rates were higher in a particular age group.

Data were entered into, organized, and analyzed with PASW statistics (version 17.0, SPSS Inc., Chicago, IL). We determined frequency counts for all categorical variables, and measures of central tendency and dispersion were performed on continuous variables. Agreement percentages were calculated as 100 - [(number of discrepancies/ number of reads) x 100].

## RESULTS

In our ED between January 2012 and January 2015, 16,111 radiographs were interpreted by an EP without the aid of immediate radiologist interpretation. Of these interpretations, there were 1044 discrepancies indicating an overall 93.5% agreement rate between EP and radiologist. The average age of patients with radiographic discrepancies was 48.4 ± 25.0 years, and 53.3% of patients were female. The age of patients with discrepancies ranged from 0.03 years to 98.3 years. Of patients with radiographic discrepancies, 28.8% were admitted to the hospital from the ED.

The majority of discrepancies, 75.8%, were very minor and required no further action after radiologist interpretation. Grade 2 discrepancies, which required a phone call to the patient, patient's physician, pharmacy, and/or to the hospital floor accounted for 22.3% of discrepancies. Less than 2% of discrepancies required the patient to return to the ED and/ or risked serious harm to the patient (Table 1). Based on the total number of EP radiology interpretations, discrepancies in radiograph interpretation led to 20 ED return visits, which is approximately 0.1% of the entire cohort studied. Based on the total 16,111 interpretations, Grade 1 discrepancies occurred in 4.9%, Grade 2 in 1.4%, Grade 3 in 0.1%, and Grade 4 in 0.01%.

**Table 1.** Discrepancies in radiograph read (n=1044).

| | |
|---|---|
| Not appreciated by EP (%) | 66.6 |
| Over-call by EP (%) | 25.1 |
| Conflict in read (%) | 8.3 |
| Discrepancy grade (%) | |
| Grade 1 | 75.8 |
| Grade 2 | 22.3 |
| Grade 3 | 1.7 |
| Grade 4 | 0.2 |

*EP,* emergency physician.
Grade 1 - No action needed; Grade 2 - Call to patient or pharmacy; Grade 3 - Major discrepancy, return to ED; Grade 4 - Major discrepancy, serious risk to patient.

Both of the Grade 4 discrepancies encountered in this study were small pneumothoraces. Patient 1 had a 3.5 centimeter (cm) pneumothorax as well as a rib fracture interpreted on rib radiographs by the radiologist that were not appreciated by the EP. This patient was previously discharged from the ED and required callback for further treatment. No additional significant morbidity was encountered as a result of the missed pneumothorax based on review of the patient's hospital course. Patient 2 had a CXR performed in the ED that was initially interpreted as "effusion" by the EP. On radiology interpretation in the morning, a 2.5 cm pneumothorax was appreciated. This patient was admitted following his ED course; therefore, the medicine team was contacted and prompt surgical consultation was initiated. This patient experienced no obvious significant morbidity due to the missed pneumothorax.

Of the 1044 discrepancies studied, 66.6% were attributed to findings that were not originally appreciated by the EP at the time of service. Over-calls by the EP accounted for 25.1% of discrepancies, while 8.3% of discrepancies were based on a conflict in finding between the EP and radiologist (Table 1). For example, an EP interprets pneumonia on CXR while radiologist interprets vascular congestion or vice versa. CXRs accounted for 45.1% of the total number of radiographs interpreted by an EP, followed by 20.9% lower extremity, 17.7% upper extremity, and 6.2% abdominal. The remainder of body areas accounted for 10% of the total number of radiographs interpreted. Analysis of the various body areas revealed greater than 90% agreement in all types of radiographs except for those grouped into the category "other." Only 31 radiographs were interpreted in this "other" category, with an agreement rate of only 35.5% (Table 2) . Of the 695 abnormalities not appreciated by the EP, the most common were the following, in descending order: 22.9%

**Table 2.** Radiographs and discrepancies by body area (n=16111).

| Type of radiograph read by EP | % of total interpretations |
|---|---|
| Chest | 45.1 |
| Lower extremity | 20.9 |
| Upper extremity | 17.7 |
| Abdominal | 6.2 |
| TLS spine | 5.2 |
| Pelvis | 2.5 |
| Cervical spine | 1.7 |
| Soft tissue neck | 0.4 |
| Other | 0.2 |
| Discrepancy by radiograph type | # discrepancies/ # reads (% Agreement) |
| Chest | 616/7261 (91.5) |
| Lower extremity | 165/3371 (95.1) |
| Upper extremity | 135/2858 (95.3) |
| Abdominal | 50/999 (95.0) |
| TLS spine | 19/844 (97.8) |
| Pelvis | 25/400 (93.7) |
| Cervical spine | 8/278 (97.1) |
| Soft tissue neck | 6/69 (91.3) |
| Other | 20/31 (35.5) |

*EP*, emergency physician; *TLS*, thoracic, lumbar, and/or sacrum coccyx; #, number.
Other includes scapula, clavicle, sternum, nasal, facial, orbital, mandible, ribs.

infiltrate; 16.5% fracture; 15.7% pulmonary nodule; 10.9% extremity finding other than fracture; 9.9% nonspecific lung density. In terms of possible or definite missed fractures, they were well distributed throughout the body areas with the highest percentages found in the forefoot including fifth metatarsal (13.0%), scaphoid (8.7%), rib (7.8%), triquetral (6.1%), ankle (6.1%), and thoracic or lumbar fractures (6.1%). Of the 262 findings that were over-called by the EP, the most common were as follows, in descending order: 35.5% fracture; 33.6% infiltrate; 9.2% pulmonary vascular congestion; 7.3% other lung finding; 5.3% extremity finding other than fracture. In terms of the over-called fractures, they were well distributed with the most frequent being forefoot (15.1%), ankle (10.8%), distal radius (9.7%), metacarpals/phalanges (6.5%), and rib (6.5%).

In subgroup analysis based on categorized age, radiographs of patients 0-6 years of age had an agreement rate of 70.8%. Radiographs of patients 7-12 years had an agreement rate of 92.1%, patients 13-17 years 89.4%, and those aged 18 or greater had an agreement rate of 94.1% (Table 3). Of the discrepancies in patients aged 0-6 years, 60% were EP misses and 35.7% were EP over-calls, with the remainder being a conflict in read. Of the EP misses in those 0-6 years, 64.3% were possible or definite infiltrates. Of the EP over-calls, 72.0% were possible or definite infiltrates.

**Table 3.** Radiographic discrepancies by patient age (n=16111).

| Age categorized | # discrepancies/ # reads (% Agreement) |
|---|---|
| 0 to 6 years | 70/240 (70.8) |
| 7 to 12 years | 37/467 (92.1) |
| 13 to 17 years | 51/479 (89.4) |
| 18 years and greater | 886/14925 (94.1) |

#, number.

## DISCUSSION

In this study we sought to examine discrepancies in plain radiographic reads between EPs and radiologists over a three-year period in our community hospital ED. While similar studies have been performed, data adding to the existing body of evidence are necessary as there are conflicting reports in the literature with agreement rates as low as 52%[7] and as high as 97%-99%.[15,16] We hypothesized that agreement would be high between the specialties. Our results support this hypothesis as we found a 93.5% agreement rate out of 16,111 total radiographic reads. We also hypothesized that discrepancies that place a patient at significant risk would be rare. Again, our results support this hypothesis, as only 0.01% of the total 16,111 reads were deemed to place a patient at serious risk. In total, only 0.1% of the total reads were determined to require return to the ED for further treatment.

Similar studies at academic institutions have found results comparable to ours. In a 1996 study performed at two academic EDs, Nitowski et al. performed an analysis of 14,046 radiographic studies interpreted by EP attending and radiologist and found a 0.95% disagreement rate with only 0.2% of the total being of clinical significance.[15] While our overall disagreement rate was higher at 6.5% we found a similar rate of serious discrepancies: 2/16,111 in our study, compared to 3/14,046 in Nitowski et al.[15] In a 1990 study performed by Gratton et al. at an emergency medicine residency program, the radiographic error rate between various EPs, including residents, with radiologist interpretation was reported as 3.4% overall with 2.8% of the total being of clinical significance.[10] A 2011 study also found a very low rate of major discrepancies requiring emergent treatment, 85/151,693 (0.056%). In total, the authors found 4605 discrepant studies out of 151,693 radiographs.[16]

The findings of these studies, in combination with our data,

suggest that plain radiographs can be interpreted by EPs with a very low occurrence of discrepancies that would place a patient at serious risk. A potential caveat is that two of the above-mentioned studies are over 20 years old and were performed in a time period with lesser technology in relation to electronic PACS. A more recent study performed in Iran in 2014 studied 105 trauma CXRs and found identical interpretation between EPs and radiologists in 89.5% of cases.[18] The authors reported subcategories for differing traumatic injuries and found that EPs and radiologists had an agreement rate of 99% for hemothorax and 98.1% for pneumothorax.[18]

On the contrary, other studies have found conflicting results with much higher discrepancy rates than reported in our study. In a 2009 study by Al Aseri, 312 CXRs were studied and a 34% disagreement rate was reported between EPs and radiologists.[5] In a 2005 study examining the agreement in pneumonia diagnosis on CXR between EPs and radiologists, the authors reported only a 52.3% agreement rate when combining reads of pneumonia or possible pneumonia.[7] Of the 817 CXRs the EP read as pneumonia or possible pneumonia, the radiologist read normal in 21.2%, and 26.5% were interpreted as a process different from pneumonia. The authors explicitly mentioned that neither the EP nor the radiologist was held to blame as CXR is prone to significant inter- and intra-observer variability, even among radiologists. The authors also noted that EPs have the benefit of making a diagnosis on clinical grounds rather than just a static image and, therefore, the EP treatment may have been appropriate.[7] In a 2018 study performed in Switzerland the authors examined discrepancies in interpretations for various imaging modalities, and in subgroup analysis of radiographs they found a discrepancy rate of 17.9% with a clinically significant disagreement rate of 5.67%.[13]

In conflict with the above studies, our data suggest that discrepancy rates in EDs may be much lower than the rather high discrepancy rates reported by these three studies. Regardless, data reported by these studies should alert an EP that discrepancies do in fact occur; and to minimize risk to a patient, an EP must not discount the value of radiologist interpretation.

While we reported discrepancies for all types of radiographs, the majority were CXRs and musculoskeletal extremity films. Facial, sternal, clavicular, orbital, nasal, and rib radiographs are obtained much less frequently in our ED; only 31 total as a group were interpreted first by an EP and the overall interpretation agreement was extremely low at 35.5%. This is in stark contrast to the greater than 90% agreement for films of frequently encountered body areas. Gratton et al. found a 9% disagreement rate when looking specifically at facial films, while they found lower rates of disagreement in more frequently encountered radiographs.[10] Despite the low subgroup sample size we believe this suggests that EPs must exercise caution when interpreting films in which experience is lacking as this may lead to an increasing number of interpretive errors. In addition, while extremities films and CXRs are commonly encountered by the EP, our results may suggest the need for a more broad radiographic education for EPs as additional imaging modalities may not always be available to the EP.

In adult EDs, pediatric radiographs are generally encountered less frequently than those of older teenagers and adults. In our study only 1186/16,111 radiographs were in patients 17 years and younger. Furthermore, only 1.5% of the 16,111 radiographs were in patients six years and younger. Given the fact that radiographs of the very young are a small subset of day-to-day practice in an adult ED, experience can play a factor in radiographic interpretative error. Our agreement rate for those six years and younger was 70.8%, which is approximately 20% less than any other age group studied. In addition, the vast majority of misses and over-interpretations in this age group were infiltrates on CXRs. This common finding in our study could suggest the need for better education regarding interpretation of pediatric CXRs.

In a 2010 study, Johnson and Kline studied the intra- and inter-observer reliability of radiologists, senior pediatric EPs, and junior pediatric EPs in interpreting pediatric CXRs in patients aged 1-4 years.. Even in these pediatric-trained EPs, interpretative variability was considerably higher than among pediatric radiologists.[19] Our subgroup analysis indicates that adult EPs must be vigilant when interpreting radiographs in the very young patient as interpretative discrepancies are more likely to occur than in adults presenting to a non-pediatric ED.

## LIMITATIONS

This was a single-site study in a community hospital ED with a limited number of practicing EPs and radiologists. This could negatively influence the overall generalizability of the study to sites with a greater or lesser number of physicians with differing levels of experience and/or training. Also, we were unable to determine whether an EP's or radiologist's number of years in practice had any correlation with interpretation accuracy. While all EPs interpreting radiographs in this study were board-certified, this is an area that warrants future research with well-designed prospective studies. In addition, we were unable to obtain an accurate gauge of the total number of radiographs with serious pathology such as abdominal free air, pneumothorax, bowel obstruction, etc. that were correctly interpreted by the EP over the studied time period. While our ED evaluates patients with pneumothorax, perforated viscus, and small bowel obstructions on a regular basis, we were unable to ascertain whether or not the percentage of treatment-changing discrepancies would be influenced if a higher incidence of serious pathology were encountered during off-hours.

The retrospective nature of this study did lead to weaknesses that should be addressed in future studies. Based on the documentation method used in our logbook as well

as in our PACS, we were unable to determine the number of true-positives vs true-negatives. Agreements were simply documented as no deficiency whether they were a positive or negative study. As such, more robust measures of inter-rater reliability such as the kappa coefficient could not be calculated. Also as mentioned above, we were unable to determine the influence of the raters' experience due to the method in which the deficiencies were documented. Prospective studies comparing the interpretation of more than one EP with more than one radiologist could account for these limitations. Despite this, our findings as well as our limitations suggest that despite the study of this topic in the past, more research is needed.

While we used the radiologist interpretation as the gold standard of diagnosis, it should be mentioned that there are potential issues with this design. There was more than one radiologist interpreting images in this study and radiologists can differ in their opinion or interpretation. It has been found that overall error rates between experienced radiologists is potentially around 3-9% in a mixture of negative and positive plain radiograph studies.[20-23] Studies have abstracted from these data that if normal studies were excluded, error rates between radiologists could be as high as 30% in a grouping of abnormal studies.[20] While this could have influenced our discrepancy percentage in a positive or negative direction, we feel it is unlikely to have skewed the results by more than a few percentage points based on the potential 3-9% radiologist disagreement rate reported above. In addition, the EP is more likely to have clinical clues, eg, pinpoint tenderness over the distal radius leading to an EP over-call of "possible fracture" while a radiologist is only provided a small history without aid of physical examination. This can introduce bias, mainly in regard to discrepancies in which an EP over-calls a specific radiographic study. While this may contribute to patient safety in a positive manner, it could potentially lead to overtreatment with antibiotics, immobilization, etc.

Finally, radiologists at our institution are not blinded to the overnight EP interpretation, and therefore this potentially introduces bias to the radiologist interpretation. Unfortunately in our PACS, the EP interpretation appears immediately when a radiologist opens the radiographic study. In general, radiologists at our institution do attempt to formulate their own interpretation of a study before fully reviewing the EP interpretation to determine if there are any conflicts. A project with blinding of the radiologist to the EP interpretation warrants further study in the future to determine if the radiologist interpretation is actually influenced by EP read.

## CONCLUSION

We found that plain radiographic studies can be interpreted by EPs with a low incidence of clinically significant discrepancies when compared to the final radiologist interpretation. While conflicting reports exist regarding disagreement in plain radiographic reads between EPs and radiologists, our study suggests that discrepancy rates are most consistent with studies reporting lower rather than higher discrepancy rates. Although serious discrepancies were rare in our study, radiologist interpretation should be performed immediately when available to limit the small number of treatment-changing discrepancies that could potentially place patients at risk of adverse outcome. Furthermore, while we found greater than 90% agreement in the most commonly obtained radiographs in the ED, infrequently obtained radiographs such as facial and rib films had a very poor agreement rate among EPs and radiologists. Increasing discrepancy rates were also found in patients aged six and younger when compared to adults and older pediatric patients. In the best interest of patient care, an EP should be hesitant to make treatment decisions based on their interpretation of infrequently obtained radiographs as well as in the very young if immediate radiologist interpretation is not available. Future prospective studies are needed to determine the generalizability of this study to EDs with differing volume, patient population, acuity, and physician training.

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



## REFERENCES

1. Guly HR. Diagnostic errors in an accident and emergency department. *Emerg Med J*. 2001;18(4)263-9.
2. Pinto A, Reginelli A, Pinto F, et al. Errors in imaging patients in the emergency setting. *Br J Radiol*. 2016;89(1061):20150914.
3. Benger JR, Lyburn ID. What is the effect of reporting all emergency department radiographs? *Emerg Med J*. 2003;20(1):40-3.
4. Hardy M, Snaith B, Scally A. The impact of immediate reporting on interpretive discrepancies and patient referral pathways within the emergency department: a randomized controlled trial. *Br J Radiol*.

2013;86(1021):20120112.
5. Al aseri Z. Accuracy of chest radiograph interpretation by emergency physicians. *Emerg Radiol*. 2009;16(2):111-4.
6. Brunswick JE, IIkhanipour K, Seaberg D, et al. Radiographic interpretation in the emergency room. *Am J Emerg Med.* 1996;14(4):346-8.
7. Campbell SG, Murray DD, Hawass A, et al. Agreement between emergency physician diagnosis and radiologist reports in patients discharged from an emergency department with community-acquired pneumonia. *Emerg Radiol.* 2005;11(4):242-6.
8. Espinosa JA, Nalan TW. Reducing errors made by emergency physicians in interpreting radiographs: longitudinal study. *BMJ.* 2000;320(7237):737-40.
9. Gatt ME, Spectre G, Paltiel O, et al. Chest radiographs in the emergency department: is the radiologist really necessary? *Postgrad Med J*. 2003;79(930):214-7.
10. Gratton MC, Salomone JA 3rd, Watson WA. Clinically significant radiograph misinterpretations at an emergency medicine residency program. *Ann Emerg Med*. 1990;19(5):497-502.
11. Klein EJ, Koenig M, Diekema DS, et al. Discordant radiograph interpretation between emergency physicians and radiologists in a pediatric emergency department. *Pediatr Emerg Care*. 1999;15(4):245-8.
12. Lufkin KC, Smith SW, Matticks CA et al. Radiologist's review of radiographs interpreted confidently by emergency physicians infrequently leads to changes in patient management. *Ann Emerg Med.* 1998;31(2):202-7.
13. Mattssson B, Ertman D, Exadaktylos AK, et al. Now you see me: a pragmatic cohort study comparing first and final radiological diagnosis in the emergency department. *BMJ Open*. 2018;8(1):e020230.
14. Mayhue FE, Rust DD, Aldag JC, et al. Accuracy of interpretation of emergency department radiographs: effect of confidence levels. *Ann Emerg Med*. 1989;18(8):826-30.
15. Nitowski LA, O'Connor RE, Reese CL 4th. The rate of clinically significant plain radiograph misinterpretation by faculty in an emergency medicine residency program. *Acad Emerg Med*. 1996;3(8):782-9.
16. Petinaux B, Bhat R, Boniface K, et al. Accuracy of radiographic readings in the emergency department. *Am J Emerg Med*. 2011;29(1):18-25.
17. Preston CA, Marr JJ, Amaraneni KK, et al. Reduction of "callbacks" to the ED due to discrepancies in plain radiograph interpretation. *Am J Emerg Med*. 1998;16(2):160-2.
18. Safari S, Baratloo A, Negida AS, et al. Comparing the interpretation of traumatic chest x-ray by emergency medicine specialists and radiologists. *Arch Trauma Res*. 2014;3(4):e22189.
19. Johnson J, Kline JA. Intraobserver and interobserver agreement of the interpretation of pediatric chest radiographs. *Emerg Radiol*. 2010;17(4):285-90.
20. Berlin L. Accuracy of diagnostic procedures: has it improved over the past five decades. *AJR Am J Roentgen*. 2007;188(5):1173-8.
21. Geijer H, Geijer M. Added value of double reading in diagnostic radiology, a systematic review. *Insights Imaging*. 2018;9(3)287-301.
22. Robinson PJ, Wilson D, Coral A, et al. Variation between experienced observers in the interpretation of accident and emergency radiographs. *Br J Radiol*. 1999;72(856):323-30.
23. Soffa DJ, Lewis RS, Sunshine JH, Bhargavan M. Disagreement in interpretation: a method for the development of benchmarks for quality assurance in imaging. *J Am Coll Radiol*. 2004;1(3):212-7.

# Modification of the Emergency Severity Index Improves Mortality Prediction in Older Patients

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*Section Editor:* Mark I. Langdorf, MD, MHPE
Submission history: Submitted September 26, 2018; Revision received April 5, 2019; Accepted April 12, 2019
Electronically published July 2, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.4.40031

**Introduction:** Older patients frequently present to the emergency department (ED) with nonspecific complaints (NSC), such as generalized weakness. They are at risk of adverse outcomes, and early risk stratification is crucial. Triage using Emergency Severity Index (ESI) is reliable and valid, but older patients are prone to undertriage, most often at decision point D. The aim of this study was to assess the predictive power of additional clinical parameters in NSC patients.

**Methods:** Baseline demographics, vital signs, and deterioration of activity of daily living (ADL) in patients with NSC were prospectively assessed at four EDs. Physicians scored the coherence of history and their first impression. For prediction of 30-day mortality, we combined vital signs at decision point D (heart rate, respiratory rate, oxygen saturation) as "ESI vital," and added "ADL deterioration," "incoherence of history," or "first impression," using logistic regression models.

**Results:** We included 948 patients with a median age of 81 years, 62% of whom were female. The baseline parameters at decision point D (ESI vital) showed an area under the curve (AUC) of 0.64 for predicting 30-day mortality in NSC patients. AUCs increased to 0.67 by adding ADL deterioration to 0.66 by adding incoherence of history, and to 0.71 by adding first impression. Maximal AUC was 0.73, combining all parameters.

**Conclusion:** Adding the physicians' first impressions to vital signs at decision point D increases predictive power of 30-day mortality significantly. Therefore, a modified ESI could improve predictive power of triage in older patients presenting with NSCs. [West J Emerg Med. 2019;20(4)633-640.]

## INTRODUCTION

Over 15% of the visits to emergency departments (EDs) can be attributed to patients older than 65 years in the United States.[1] Compared to younger patients, this population has a higher risk of death or development of a functional decline leading to institutionalization.[2,3] Moreover, atypical symptoms in prevalent diseases are common, and older patients often present with nonspecific complaints (NSC), such as weakness or acute functional decline.[4,5] Previous studies showed that patients presenting with NSCs have a 30-day mortality reaching 6%–13%.[6,7] However, individual prediction of mortality is difficult due to the broad differential diagnosis including a wide span of reasons ranging from lack of social support to acute life-threatening disease.[4,8] Therefore, disease-specific risk scores (such as the HEART score) are not used at presentation; instead, general risk stratification tools to identify patients at risk should be developed. Although various parameters and clinical tools for the prediction of mortality in the general ED population exist,[9] risk stratification tools for older patients with NCSs have not yet been developed. This is an unmet need in one

of the largest groups that requires several external resources during work-up presenting to the ED.[10]

The main tool used for the prediction of mortality in ED "all-comers" population is triage.[11] Triage is the categorization of patients according to urgency and prognosis at presentation. A reliable and valid triage instrument is the Emergency Severity Index (ESI), which uses a five-level classification system.[11,12] ESI levels can be used to predict six-month and one-year mortality in an older ED population.[13,14] Four decision points (A to D) are used to triage patients into the five ESI levels. Patients with ESI level 1 are in need of an immediate life-saving intervention (decision point A). Stable patients in a high-risk situation are designated to ESI level 2 (decision point B). At decision point C, patients are assigned according to the expected use of resources, reaching from none (ESI 5) to more than one (ESI 3). To ultimately classify a patient as ESI level 3, vital signs must be assessed. If they exceed defined limits, re-assignment to ESI level 2 is to be considered (decision point D).[11,15] Obviously, vital sign assessment is important for the identification of patients with a poorer prognosis requiring urgent attention.

One of the main problems of triage in older patients is undertriage.[10] Undertriage describes a phenomenon where patients are misclassified into a lower urgency group. It occurs most commonly at decision point D separating ESI 3 from ESI 2.[10] This highlights that decision point D may be crucial to avoiding undertriage and could, therefore, be a weakness of this triage tool.

The aim of this study was to assess the effectiveness of vital sign assessments at decision point D ("ESI vital") for the prediction of 30-day mortality in patients presenting with NSCs. We further evaluated the predictive power at decision point D with additional parameters such as the deterioration in activity of daily living (ADL) ("ESI A"), the incoherence of history ("ESI H"), and the first impression by the physician ("ESI F"). We focused on older patients with NSCs as a highly prevalent and vulnerable population.

*Population Health Research Capsule*

What do we already know about this issue?
*Patients presenting with nonspecific complaints (NSCs) in the emergency department (ED) are older than average and show an increased risk of adverse outcomes.*

What was the research question?
*The aim was to assess the effectiveness of parameters for the prediction of 30-day mortality in NSCs patients.*

What was the major finding of the study?
*The parameters of respiratory rate and the physician's "gesalt" are most efficient in predicting 30-day mortality.*

How does this improve population health?
*The parameters can help improve the effectiveness of triaging patients according to their risk and assign the appropriate resources for each patient.*

## METHODS

### Study Design and Setting

This study was part of a prospective, observational multicenter study with a 30-day follow-up. Data collection was conducted from May 24, 2007 to July 26, 2011. The study was performed at three EDs: a 700-bed tertiary care hospital, a 600-bed tertiary care hospital, and a 400-bed secondary care hospital. The local ethics committee approved the study protocol. The study is registered at ClinicalTrials.gov.

### Selection of Participants

We used a validated German version of the Emergency Severity Index (ESI) for triage.[11,16] All non-trauma patients older than 18 years with an ESI of 2 or 3, whose vital signs were not extremely out of range, (see Table 1) and who presented to the ED with NSCs were eligible for this study. Patients were included by the study team after recording of the patient's medical history and focused clinical examination, but before laboratory results were available. Exclusion criteria are shown in Table 1.

### Screening for Nonspecific Complaints (NSCs)

NSCs are symptoms that are not part of the set of specific complaints. Patients with specific complaints or a clinical presentation suggestive of a working diagnosis can be managed using evidence-based management protocols for emergency physicians. Patients for whom the physicians could name a specific complaint or a specific working diagnosis were excluded from the study. Any patients presenting with recent external laboratory results or specific electrocardiogram (ECG) changes on admission were not eligible.[4] This definition for NSCs by exclusion has a major advantage, as there is not an endless list of nonspecific presenting complaints. Furthermore, patients with NSCs as defined above are comparable to patients with weakness and fatigue regarding demographics and outcomes.[17]

### Measurements

Previously trained study physicians recorded the

**Table 1.** Exclusion criteria in study assessing the predictive power of triage in older patients presenting with non-specific complaints.

| Criteria | Examples |
|---|---|
| ESI 1, 4, or 5 | |
| Specific complaints | Chest pain, dyspnea, abdominal pain |
| Clinical presentation suggestive of a working diagnosis to be managed by evidence based protocols | Jaundice |
| Vital signs markedly out of range | Systolic blood pressure < 90mmHg<br>Heart rate > 120 beats/min<br>Tympanic body temperature > 38.4°C or <35.6°C<br>Respiratory rate > 30 breaths/min<br>Oxygen saturation < 92% |
| Recent external laboratory results, or referral | Documented anemia |
| Specific electrocardiogram changes on ED presentation | ST-segment elevation |
| Moribund patients with terminal conditions | End-stage cancer |
| Incomplete data | Missing values for activity of daily living (ADL) |
| Lack of informed consent | |

*ESI*; emergency severity index; *mmHg*, millimeters of mercury; *°C*, degrees Celcius; *min*, minute.

following data shortly after ED presentation: demographic (age, sex); ESI level; vital signs (heart rate, blood pressure, oxygen saturation, and body temperature); ECG; ADL deterioration within the prior two weeks; evaluation of the coherence of the patient's history; and the physician's first impression of the patient. The mode of presentation was extracted from the patient's electronic health records (EHR) and included two modes: "ambulance transport" (including hospital transfer) or "walk-in."

To assess the parameter "ADL deterioration," the study physician asked the patient about a decline of independence in the prior two weeks regarding "bathing," "dressing," "mobility," "feeding," "toilet hygiene," and "incontinence." For the parameter "coherence of history," the study physicians provided a subjective judgment (yes/no), whether they considered the history given by the patient as coherent (no discrepancy to other information, such as health records or histories by proxies). For "first impression by the physician," every physician assigned points to the question, "how ill does this patient look?," using a scale ranging from 0 (patient looks very healthy) to 10 (patient looks critically ill). Mortality at 30 days was obtained from the EHR, the patient's primary care physicians (by questionnaires), and from hospital discharge reports.

**Emergency Severity Index**

Specifically trained triage nurses used the German version of the ESI.[11] The first of the four decision points (decision point A) distinguishes patients in need of an immediate life-saving intervention and allocates them to ESI level 1. ESI level 2 is assigned to patients who should not wait due to high-risk situations, such as new onset of confusion, lethargy, disorientation, and severe pain or distress (decision point B). ESI levels 5 to 3 are assigned according to the expected use of resources. Patients who need no resources are categorized as level ESI 5, while those who need one or more resources are classified as ESI 4 or ESI 3, respectively (decision point C). If patients are to be assigned to ESI level 3, vital signs must be assessed. If vital signs exceed the defined limits (heart rate higher than 100 beats per minute (min), respiratory rate higher than 20/min, or oxygen saturation lower than 92%), re-assignment to ESI level 2 should be considered (decision point D).[11,15]

**Additional Parameters Assessed at Decision Point D**

For prediction of outcome, we compared the following predictors: all parameters in the set of vital signs at decision point D (heart rate, respiratory rate, and oxygen saturation ["ESI vital"]). Additional possible outcome predictors were a decline in ADL ("ESI A"), an incoherent medical history ("ESI H"), and the first impression by the physician of 9 or higher ("ESI F"). Moreover, we added the additional parameters pairwise to obtain "ESI AH," "ESI AF," and "ESI HF," as well as all additional parameters combined to obtain "ESI AHF" as an outcome predictor.

**Statistical Analyses**

We tested the following 12 parameters to predict 30-day mortality in the NSCs population: age (years); sex (male); heart rate (per min); respiratory rate (per min); oxygen saturation (% on room air); systolic blood pressure (mmHg); low temperature (<35°C); ECG changes (all findings except tachycardia, bradycardia, and pacemaker rhythm); "ambulance transport" mode of presentation; "incoherence of history"; "ADL deterioration"; and "first impression by the physician." In order to detect the effect of various parameters on the 30-day mortality, we used univariate logistic regression models. Results are expressed as odds ratios (OR) with corresponding 95% confidence intervals (CI) and p-values. Further, the AUC of a receiver operating characteristic (ROC) curve was calculated with corresponding 95% CIs for each parameter.

To compare the different scores (eg, "ESI vital," "ESI A," etc.), AUCs of the different scores were calculated and compared pairwise using a non-parametric approach model.[18] We computed descriptive statistics with frequencies or median and interquartile range (IQR). Overall p-values correspond to t-test (for means), Kruskall-

Wallis test (for median), and chi-square test or Fisher's exact test if the expected frequencies were less than 5. A p-value <0.05 was considered significant. We did all analyses using R version 3.0.1 (The R Foundation for Statistical Computing, Vienna, Austria).

## RESULTS

### Characteristics of Study Subjects

A total of 1401 non-trauma patients who presented with NSCs to the ED were screened for eligibility. Of these, 1278 patients fulfilled the inclusion criteria. The data were retrospectively reviewed for completeness of all clinical parameters. In 330 patients one or more clinical parameters was missing, and these patients were subsequently excluded (Figure 1). To exclude selection bias, we compared the 948 patients with complete data and the 330 patients with incomplete data. The two groups were comparable with respect to age, sex, and vital signs (heart rate, respiratory rate, oxygen saturation, and systolic blood pressure), and regarding the occurrence of the parameters "ADL deterioration," "incoherence of history," "first impression by the physician," and 30-day mortality (Supplementary Data 1).

Table 2 shows the baseline characteristics of all 948 patients included. A total of 589 patients (62.1%) were female; the median age was 81 years with an IQR from 74-87 years, and 835 (88.1%) patients were older than 65 years. A total of 57 (6.01%) patients were not alive 30 days after presentation to the ED.

### Prediction of Mortality

To determine predictors of mortality, we analyzed the effectiveness of 12 clinical parameters including the vital sign parameters assessed at decision point D. We performed univariate logistic regression analysis for all parameters (Table 3). We found the following parameters to predict mortality: sex (male); respiratory rate; "ADL deterioration"; "incoherence of history"; and "first impression by the physician >8 points." Of these, the physician's first impression had the best predictive performance regarding 30-day mortality with an OR of 1.250 per 10% increase and an AUC of 0.67. The second most reliable parameter was respiratory rate with an OR of 2.667 and an AUC of 0.56. Respiratory rate is one of the vital signs assessed at decision point D. The other two vital signs recorded at decision point D (ie, heart rate and oxygen saturation had low predictive power) (Table 3).

To test the predictive power of vital signs at decision point D, we combined all three vital signs (respiratory rate, heart rate, and oxygen saturation) and calculated the "ESI vital" score. This score yielded an AUC of 0.64 for predicting the 30-day mortality in patients with NSCs.

To further increase the predictive power of "ESI vital," we added the three remaining best-performing parameters (accessory parameters) to the score: "ADL deterioration" for "ESI A"; "incoherence of history" for "ESI H"; and "first impression by

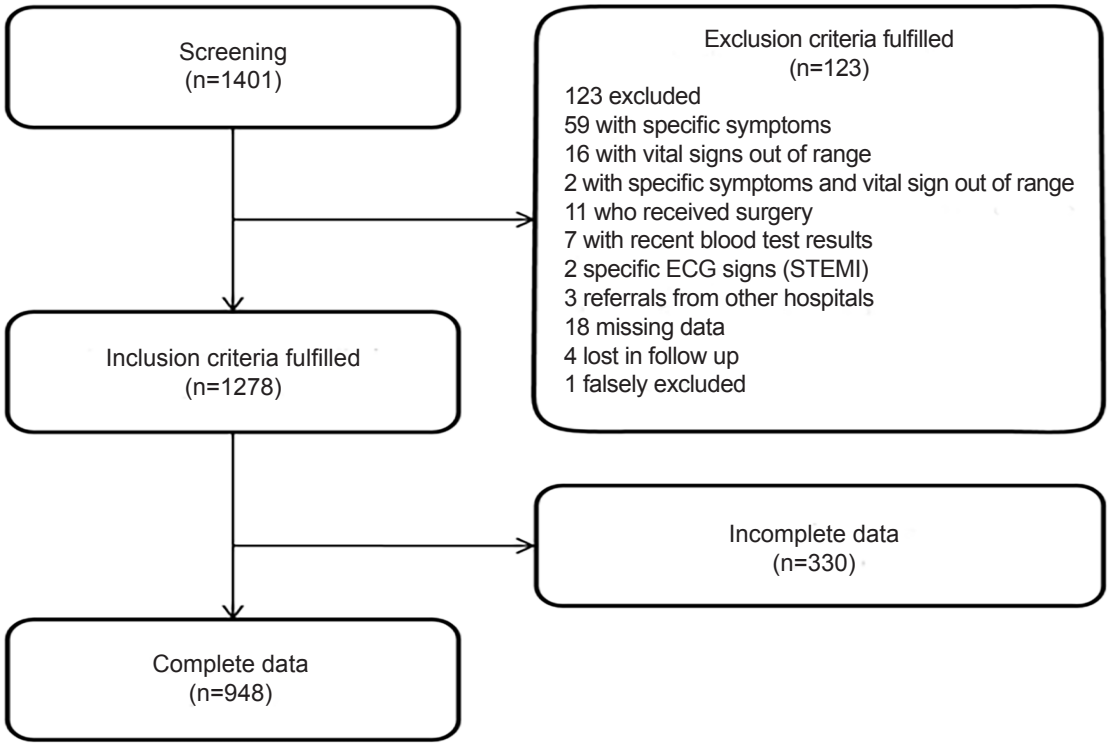



**Figure 1.** Patient enrollment chart.
*ECG*, electrocardiogram; *STEMI*; ST-elevation myocardial infarction.

**Table 2.** Baseline and demographic variables.

| Variables | Number |
|---|---|
| Total [n] | 948 |
| Sex | |
| Male [n (%)] | 359 (37.9%) |
| Female [n (%)] | 589 (62.1%) |
| Age [median years (IQR)] | 81 (74-87) |
| < 65 years [n (%)] | 113 (11.9%) |
| ≥ 65 years [n (%)] | 835 (88.1%) |
| ESI Level at Triage | |
| 2 | 41 (4.7%) |
| 3 | 836 (95.3%) |
| Mortality (30 days) | |
| Non-survivors [n (%)] | 57 (6.0%) |
| Living situation | |
| Nursing home [n (%)] | 81 (8.5%) |
| Vital signs at triage | |
| Heart rate > 100/min [n (%)] | 104 (11.0%) |
| Respiratory rate > 20/min / < 8/min [n (%)] | 93 (9.8%) |
| $O_2$ saturation < 92% [n (%)] | 23 (2.4%) |
| Systolic blood pressure < 100 mmHg [n (%)] | 38 (4.0%) |
| Other parameters at triage [n (%)] | |
| Incoherence of history [n (%)] | 436 (46.0%) |
| ADL deterioration [n (%)] | 544 (57.4%) |
| First impression > 8 points [n (%)] | 75 (7.9%) |
| Temperature < 36.5°C [n (%)] | 6 (0.6%) |
| ECG changes [n (%)] | 447 (47.2%) |
| Ambulance transport [n (%)] | 615 (64.9%) |

$O_2$, oxygen; *mmHg*, millimeters of mercury; *IQR*, interquartile range; *°C*, degrees Celcius; *min*, minute; *ESI*, emergency severity index. Incoherence of history: physician's judgment, whether he or she considered the patient's history as coherent. Activity of daily living (ADL) deterioration: deterioration of any ADL within the prior two weeks. First impression: rating by the physician using a scale ranging from 0 (patient looks very healthy) to 10 (patient looks critically ill). Electrocardiogram (ECG) changes: all findings except tachycardia, bradycardia, and pacemaker rhythm and specific changes.

the physician >8 points" for "ESI F." We calculated the predictive power of the different scores and compared it to the power of "ESI vital." The AUC increased from 0.64 to 0.67 for "ESI A" and to 0.66 for "ESI H." A significant increase to 0.71 was observed for "ESI F" (p=0.004), if >8 points was chosen as cut-off. Figure 2 shows the ROC curves for 30-day mortality based on the scores "ESI vital," "ESI A," "ESI H," and "ESI F." This shows that the prediction of the 30-day mortality could be increased by adding the parameters "ADL deterioration," "incoherence of history," or "first impression by the physician" to the basic model "ESI vital."

To further increase the predictive power, we added the additional parameters pairwise to "ESI vital": "ADL deterioration" and "incoherence of history" for "ESI AH;" "incoherence of history" and "first impression by the physician" for "ESI HF"; and "ADL deterioration" and "first impression by the physician" for "ESI AF." We compared the AUC of these scores with the AUCs of "ESI vital" and observed an increase in the predictive power, whereby "ESI AH" had an AUC of 0.68, "ESI HF" of 0.72, and "ESI AF" of 0.72. Moreover, we added all three parameters to "ESI vital" ("ESI AHF"). By combining all three parameters, the predictive power further increased to an AUC of 0.73. This shows that the predictive power of "ESI vital" can be increased by addition of multiple accessory parameters, whereby the combination "ESI AHF" performed best, but not significantly better than ESI F.

## DISCUSSION

We analyzed the parameters determined in ESI triage at decision point D separately and found that first, respiratory rate alone can efficiently predict 30-day mortality in patients presenting with NSCs. This result is in line with previous studies, showing that abnormal respiratory rate (<8/min and >30/min) can be used to predict in-hospital mortality.[19,20] Tachycardia and hypoxia, the other two parameters assessed at decision point D, were found previously to be associated with an increased risk of death in the ED.[20] However, these two parameters alone were not useful for risk prediction in our population of elderly patients with NSCs. This discrepancy can be attributed to the a priori exclusion of patients with severe tachycardia and hypoxia (Table 1).

Second, the combination of all three vital sign parameters measured at decision point D (heart rate, respiratory rate, and oxygenation), predicted 30-day mortality moderately well. This result is also in line with previous studies.[21,22] Yet undertriage occurs most often at decision point D.[10] The reasons for this are probably multifactorial. However, it appears that vital sign assessment at decision point D is often performed incompletely, and this lack of adherence to the algorithm (e.g., lack of measurement of respiratory rate) contributes to the occurrence of undertriage.[22] Hence, we have shown that vital signs are predictive for the patients' outcomes, and our findings support the importance of a complete assessment of vital signs, including respiratory rate, to avoid undertriage.

Older patients are particularly at risk of undertriage.[10] This might be explained by the age-related changes of vital signs in the elderly.[23] Moreover, the measurement of vital signs tends to be less sensitive in patients with severe illness or injury who are older than 75 years. Thus, the use of age-adapted vital sign cut-offs at decision point D for the

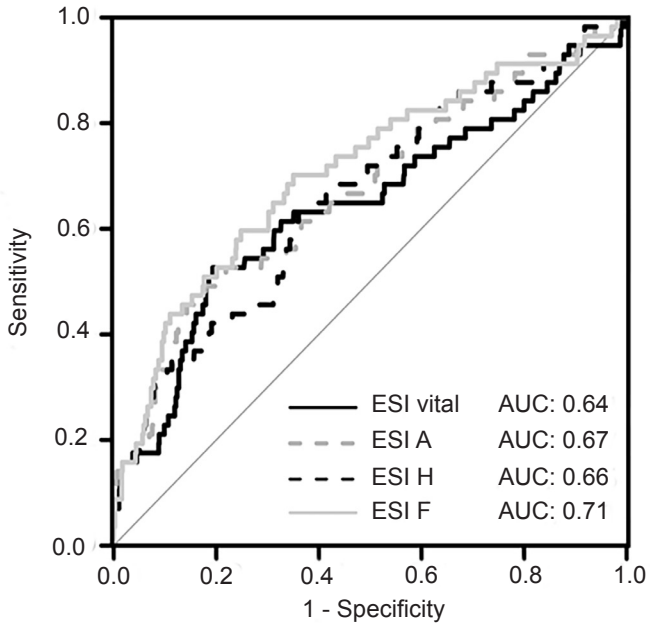
**Table 3.** Odds ratios (OR) for all parameters tested for an association with 30-day mortality.

| Parameters | AUC | Lower | Upper |
|---|---|---|---|
| Age (years) | 0.54 | 0.47 | 0.62 |
| Sex (male) | 0.63 | 0.57 | 0.70 |
| Vital signs at triage | | | |
| Heart rate > 100/minute | 0.57 | 0.48 | 0.66 |
| Systolic blood pressure < 100 mmHg | 0.61 | 0.54 | 0.68 |
| Respiratory rate > 20/minute | 0.56 | 0.51 | 0.61 |
| $O_2$ saturation > 92% | 0.50 | 0.42 | 0.57 |
| Other parameters at triage | | | |
| Incoherence of history | 0.55 | 0.49 | 0.62 |
| ADL deterioration | 0.59 | 0.53 | 0.65 |
| First impression > 8 points | 0.67 | 0.60 | 0.74 |
| Temperature < 36.5°C | 0.56 | 0.48 | 0.65 |
| ECG changes | 0.55 | 0.48 | 0.61 |
| Ambulance transport | 0.50 | 0.44 | 0.56 |
| Scores | | | |
| "ESI vital" | 0.64 | 0.56 | 0.73 |
| "ESI A" | 0.67 | 0.59 | 0.75 |
| "ESI H" | 0.66 | 0.58 | 0.74 |
| "ESI F" | 0.71 | 0.63 | 0.79 |
| "ESI AH" | 0.68 | 0.60 | 0.76 |
| "ESI HF" | 0.72 | 0.65 | 0.79 |
| "ESI AF" | 0.72 | 0.64 | 0.79 |
| "ESI AHF" | 0.73 | 0.65 | 0.80 |

*mmHg*, millimeters of mercury; *$O_2$*, oxygen; *°C*, degrees Celcius; *ESI*, Emergency Severity Index; *ESI A,* decline in activity of daily living (ADL); *ESI H*, incoherence of history; *ESI F*, first impression of physician; *ESI AH*, decline in ADL plus incoherence of history; *ESI AF*, decline in ADL plus first impression of physician; *ESI HF,* incoherence of history plus first impression of physician; *ESI AHF*, decline in ADL plus incoherence of history plus first impression of physician.

Incoherence of history: physician's judgment, whether he or she considered the patient's history as coherent. Activity of daily living (ADL) deterioration: deterioration of any ADL within the prior two weeks. First impression: rating by the physician using a scale ranging from 0 (patient looks very healthy) to 10 (patient looks critically ill). Electrocardiogram (ECG) changes: all findings except tachycardia, bradycardia, and pacemaker rhythm and specific changes.

**Figure 2.** Comparison of area under the receiver operating characteristic (ROC) curve of the different modifications of the emergency severity index (ESI) vital, ESI A, ESI H, and ESI F. The black continuous line shows the ESI vital including pulse, respiratory rate, and oxygen-saturation. The grey dotted line shows the ESI A including ESI vital and activity of daily living deterioration. The black dotted line shows ESI H including ESI vital and accuracy of medical history. The grey continuous line shows ESI F including ESI vital and the first impression by the physician.




*AUC*, area under the curve; *ESI A*, decline in activity of daily living (ADL); *ESI H*, incoherence of history; *ESI F*, first impression of physician.

geriatric patient population has been suggested.[24] Adapting vital sign cut-offs for specific age groups has been applied in the pediatric version of the ESI (e.g., heart rate > 140 [3-8 years], respiratory rate > 30 [3-8 years]).[25] Adapting cut-offs for vital signs in older patients may increase the power of mortality prediction, but has not been used for any triage tool as of yet.

Third, we could show that a further improvement of mortality prediction can be achieved by adding parameters to the baseline model of vital signs at ESI decision point D. The best-performing additional parameters were "ADL deterioration" and "first impression by the physician." Consistent with this, adding these parameters to "ESI vital" increased the predictive power of the tool. The increased predictive power of "first impression by the physician" is consistent with the findings of a recent study, which showed that physicians may identify patients at risk of in-hospital mortality.[26] Adding the parameter "ADL deterioration" also increased the prediction power over the baseline model of vital signs. This is in line with a previous study showing that the decrease of the ADL is a risk factor for in-hospital death in older patients.[20]

The predictor analysis also showed an increased (yet not significant) risk of mortality for patients with an incoherent history (OR 1.53). This is in agreement with other studies which showed that an inaccurate medical history might lead to delayed or missed diagnoses.[27,28]

The combination of all three parameters improved the predictive power of "ESI vital." However, the improvement was comparable to adding "first impression by the physician" only. Additionally adding so many variables into the ESI while testing may limit the external validity. Therefore, we believe that "ESI F" should be preferred over other modifications as it performs best while keeping triage using the ESI as fast and simple as possible.

## LIMITATIONS

Various parameters were needed for the calculation of the different scores. Since data were not available for all patients, 334 patients could not be included to the analysis. This, however, increases the risk of a selection bias. Nonetheless, both included and excluded populations are comparable regarding baseline demographics and regarding the prevalence of the parameters. Therefore, we assume that lack of data had most likely a random effect. Yet excluding patients with vital parameters extremely out of range in the first place could limit the performance of the different scores. Moreover, other tools such as the PARIS score, which is based on blood pressure, age, respiratory rate, loss of independence and oxygen saturation[29] were not evaluated but could be tested in future studies.

Generally, mortality may not be the ideal outcome parameter in a population of patients with a median age of 82 years. In future studies, the performance of scores should be tested on other outcomes such as acute morbidity or institutionalization.

## CONCLUSION

Patients with NSCs may need a triage system using additional information. At triage, it is important to use easily available parameters requiring no further equipment. We have shown that adding the first impression by the physician increased the prediction of mortality in patients presenting with NSC. Thus, in addition to vital signs out of the defined range, a score of 9 or 10 for "looking ill" may be considered for re-assignment to ESI level 2. With this modification, the use of "gestalt," which was suggested in the original ESI score, could be specified concisely at decision point D. Improving the predictive power of triage in elderly patients presenting with nonspecific complaints is of importance due to their high vulnerability. This additional specification of decision point D should be prospectively validated in patients older than 65 years.

## ACKNOWLEDGEMENTS

The authors acknowledge the emergency nurses and emergency physicians who were involved in the data collection. We thank Christian Millar and Andy Schtzau (EUDOX, Basel, Switzerland) for statistical analysis. We thank L. Malinovska for writing assistance.

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



## REFERENCES

1. Albert M, McCaig LF, Ashman JJ, et al. Emergency department visits by persons aged 65 and over: United States, 2009-2010. *NCHS Data Brief*. 2013;(130):1-8.
2. McCusker J, Verdon J, Tousignant P, et al. Rapid emergency department intervention for older people reduces risk of functional decline: results of a multicenter randomized trial. *J Am Geriatr Soc.* 2001;49(10):1272-81.
3. 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.
4. Nemec M, Koller MT, Nickel CH, et al. Patients presenting to the emergency department with non-specific complaints: the Basel Non-specific Complaints (BANC) study. *Acad Emerg Med.* 2010;17(3):284-92.
5. Vanpee D, Swine C, Vandenbossche P, et al. Epidemiological profile of geriatric patients admitted to the emergency department of a university hospital localized in a rural area. *Eur J Emerg Med.* 2001;8(4):301-4.
6. Safwenberg U, Terent A, Lind L, et al. The emergency department presenting complaint as predictor of in-hospital fatality. *Eur J Emerg Med.* 2007;14(6):324-31.
7. Nickel CH, Ruedinger J, Misch F, et al. Copeptin and peroxiredoxin-4 independently predict mortality in patients with nonspecific complaints presenting to the emergency department. *Acad Emerg Med.* 2011;18(8):851-9.
8. Gordon M. Differential diagnosis of weakness--a common geriatric symptom. *Geriatrics.*1986;41(4):75-80.
9. Brabrand M, Folkestad L, Clausen NG, et al. Risk scoring systems for adults admitted to the emergency department: a systematic review. *Scand J Trauma Resusc Emerg Med.* 2010;18:8.
10. Grossmann FF, Zumbrunn T, Frauchiger A, et al. At risk of undertriage? Testing the performance and accuracy of the

Emergency Severity Index in older emergency department patients. *Ann Emerg Med.* 2012;60(3):317-25.e3.

11. Grossmann FF, Nickel CH, Christ M, et al. Transporting clinical tools to new settings: cultural adaptation and validation of the Emergency Severity Index in German. *Ann Emerg Med.* 2011;57(3):257-64.
12. Gilboy N, Tanabe P, Travers D, et al. Emergency Severity Index (ESI): A Triage Tool for Emergency Department Care, Version 4. Implementation Handbook, 2012;12-14.
13. Wuerz, R. Emergency Severity Index triage category is associated with six-month survival. ESI Triage Study Group. *Acad Emerg Med.* 2001;8(1):61-4.
14. Baumann, MR, Strout TD. Triage of geriatric patients in the emergency department: validity and survival with the Emergency Severity Index. *Ann Emerg Med.* 2007;49(2):234-40.
15. Gilboy, N, Tanabe P, Travers D, et al. Emergency Severity Index, Version 4: Implementation Handbook. Rockville, MD: Agency for Healthcare Research and Quality. 2005:1-72.
16. Gilboy N, Tanabe P, Travers D, et al. Emergency Severity Index (ESI) A Triage Tool for Emergency Department Care, Version 4. Implementation Handbook. Rockville: Agency for Healthcare Research and Quality, 2012.
17. Nickel CH, Malinovska A, Bingisser R, et al. Should weakeness be subsumed to nonspecific complaints?-Correspondence in response to Bhalla et al. *Am J Emerg Med.* 2015;33(5):722-3.
18. DeLong ER, DeLong DM, Clarke-Pearson DL, et al. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. *Biometrics.* 198844(3):837-45.
19. Buist, M, Bernard S, Nguyen TV, et al. Association between clinically abnormal observations and subsequent in-hospital mortality: a prospective study. *Resuscitation.* 2004;62(2):137-41.
20. LaMantia MA, Stewart PW, Platts-Mills TF, et al. Predictive value of initial triage vital signs for critically ill older adults. *West J Emerg Med.* 2013;14(5):453-60.
21. Prytherch DR, Smith GB, Schmidt PE, et al. ViEWS--Towards a national early warning score for detecting adult inpatient deterioration. *Resuscitation.* 2010;81(8):932-7.
22. Grossmann FF, Zumbrunn, Ciprian S, et al. Undertriage in older emergency department patients--tilting against windmills? *PLoS One.* 2014;9(8):e106203.
23. Chester JG, Rudolph JL, et al. Vital signs in older patients: age-related changes. *J Am Med Dir Assoc.* 2011;12(5)337-43.
24. Platts-Mills TF, Travers D, Biese K, et al. Accuracy of the Emergency Severity Index triage instrument for identifying elder emergency department patients receiving an immediate life-saving intervention. *Acad Emerg Med.* 2010;17(3):238-43.
25. Travers DA, Waller AE, Katzneison J, et al. Reliability and validity of the Emergency Severity Index for pediatric triage. *Acad Emerg Med.* 2009;16(9):843-9.
26. Brabrand, M, Hallas J, Knudsen T, et al. Nurses and physicians in a medical admission unit can accurately predict mortality of acutely admitted patients: a prospective cohort study. *PLoS One.* 2014;9(7):e101739.
27. Han JH, Bryce SN, Ely EW, et al. The effect of cognitive impairment on the accuracy of the presenting complaint and discharge instruction comprehension in older emergency department patients. *Ann Emerg Med.* 2011;7(6):662-71.
28. Peng A, Rohacek M, Ackermann S, et al.The proportion of correct diagnoses is low in emergency patients with nonspecific complaints presenting to the emergency department. *Swiss Med Wkly.* 2015;145:w14121.
29. Brabrand M, Lassen AT, Knudsen T, et al. Seven-day mortality can be predicted in medical patients by blood pressure, age, respiratory rate, loss of independence, and peripheral oxygen saturation (the PARIS score): a prospective cohort study with external validation. *PLoS One.* 2015;10(4):e0122480.

# Is National Resident Matching Program Rank Predictive of Resident Performance or Post-graduation Achievement? 10 Years at One Emergency Medicine Residency

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*Section Editor:* Jeffrey Druck, MD
Submission history: Submitted August 12, 2018; Revision received April 3, 2019; Accepted April 16, 2019
Electronically published June 13, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.4.40602

**Introduction:** Each year residency programs expend considerable effort ranking applicants for the National Residency Matching Program (NRMP). We explored the relationship between residents' NRMP rank list position as generated at our institution and their performance in residency and post-graduation to determine whether such efforts are justified.

**Methods:** Faculty who were present for the 10 consecutive study years at an allopathic emergency medicine residency retrospectively evaluated residents on their overall performance, medical knowledge, and interpersonal skills. Residency graduates were surveyed regarding their current position, hours of clinical practice, academic, teaching and leadership roles, and publications. We compared match position to performance using graphical techniques as the primary form of analysis.

**Results:** Ten faculty evaluated the 107 residents who graduated from the program during these 10 years by class year. Eighty-four residents responded to the survey. In general, we found little correlation between NRMP rank and faculty rank of resident performance. There was also little correlation between position in the NRMP rank list and the probability of having an academic career, publishing research, or having a teaching or leadership role.

**Conclusion:** We found that the position on our NRMP rank list was of little value in predicting which residents would do best in residency or take on academic or leadership roles once graduated. Residencies should evaluate the processes they use to generate their rank list to determine whether the ranking process is sufficiently predictive to warrant the effort expended. [West J Emerg Med. 2019;20(4)641-646.]

## INTRODUCTION

Each year residencies across the United States participate in a time-intensive application process with three principal purposes: 1) to educate graduating medical student applicants about the residency program in a way that is both positive and realistic; 2) to identify applicants who would be a poor fit with the program and should not be ranked in the match; and 3) to differentiate highly desirable applicants from less desirable ones. While the first two objectives are necessary and feasible, the third objective poses a challenge and, in our experience, is very time intensive. Existing evidence suggests that programs are not particularly successful at determining which of their best performing medical student applicants will continue to be top performers in residency and ordering their rank lists accordingly.[1-3] However, to our knowledge no study has explored the ability of the National Residency Matching

Program (NRMP) rank to predict post-residency performance.

Our goal was to determine whether the NRMP applicant ranking process correlated with resident clinical performance, which has been studied on a few occasions,[1-7] and post-graduation outcomes. This study was based on the ranking process currently conducted at a dual site emergency medicine (EM) residency program. We believe that if programs are unable to show that the energy expended ranking residents in a detailed manner produces important benefits to the program, then the faculty hours freed up by a less time-consuming method of ranking applicants could be redirected toward activities that improve the resident experience.

*Population Health Research Capsule*

What do we already know about this issue?
*Residency programs expend considerable faculty time developing their National Residency Matching Program (NRMP) rank list. The value of fine tuning this list is unknown.*

What was the research question?
*Does NRMP rank order predict performance during residency or as a practicing physician?*

What was the major finding of the study?
*NRMP rank order did not predict performance during residency or career path in a meaningful way.*

How does this improve population health?
*This may motivate residencies to streamline their match list creation process.*

## METHODS

The overall design of our study was to compare the NRMP rank list generated for each class over a 10-year period to residency and post-graduation performance of the residents. This was achieved via the comparison of the rank-list position by class with attending evaluation and post-graduation survey data.

### Residency Recruitment Process

This two-part retrospective survey study took place in a dual site, four-year, allopathic EM residency program. The residency has been in place since 1978 with the mission of producing future leaders of EM in clinical research, academia, and public health administration. Our program has the luxury of having many more applicants (≈750) than positions (≈11 at the time of the study), so an applicant's position on the rank list greatly influences his or her likelihood of joining our program.

During the time of this study, our selection process began with a crude screening of applications using objective criteria such as medical school attended and United States Medical Licensing Exam test scores to reduce the pool to 300-400 applicants. The residency recruitment committee reviewed these dossiers to identify the roughly 100 applicants who were offered an on-site interview. Each interviewee spent one of 10 interview days at the program, participating in activities that included three, 30-minute interviews with faculty members. The interviews were used to assess characteristics difficult to ascertain from an application dossier including interpersonal and communication skills, ambition, commitment to a career in EM, and humanitarian beliefs. Interviewing faculty members completed a standardized scoring form that included a global assessment placing the applicant in a rank list quintile or "do not rank."

Additional faculty, residents, or staff (i.e., residency coordinators) who met the applicants during the interview day also submitted written comments. Based on the dossier, the interview ratings, and other comments, the program directors (PD) placed applicants in a tentative order. After each interview day they interdigitated additional applicants into the growing rank list. After concluding the interviews, PDs, faculty, and residents involved with recruitment reconsidered all applicants and held two full-day meetings to determine the final rank list submitted to the NRMP.

### Study Design

In part 1 of this study, we obtained performance data for 10 years of residents using an electronically administered survey to elicit the opinions of longstanding, full-time faculty members who were present for the entire residency experience of these classes. Each faculty member independently ranked all of the residents within a graduating class from highest to lowest on three distinct measures based on residency milestones – overall performance, medical knowledge, and interpersonal skills – generating three rankings per resident per graduating class. The residents within a class were presented in random order, as were the classes, using software that allowed the faculty to move icons containing each resident's name and photograph into the desired order. Ties were not permitted.

In part 2 of this study, we electronically surveyed former residents in the 10 graduating classes regarding clinical, leadership, and academic outcomes post-residency (Appendix 1). This survey was designed to capture various pathways of career advancement in EM based on promotion guidelines at local academic and community institutions. This study was approved by the institutional review board (IRB) at our home institution. All participants read an IRB-approved description of the study;

their participation was deemed evidence of consent.

**Selection of Participants**

All categorical EM residents who graduated from the program during 10 consecutive years were included. To maintain confidentiality of our participants, the specific years are not reported, but the 10-year period was within the time frame 1998-2013. We excluded residents who participated in our combined EM/pediatrics or EM/internal medicine training programs.

Faculty were eligible to participate if they were present for all years when these residents were in training, were not part of the study team, and were not involved in preparing the final NRMP rank order list, meaning that they were not a PD or an associate PD intimately involved in producing the final list. Faculty who interviewed applicants, met them at social events, or attended the rank meetings were eligible to participate provided they did not meet exclusion criteria.

**Outcome Measures and Analysis**

We defined our outcomes as follows:

1. Faculty rank: For each resident attribute (overall performance, medical knowledge, interpersonal skills), we created an overall rank order for each class using the mean of the faculty ranks. We broke ties using the mode and, if there were still ties, the median.

2. Assessment of self-reported, post-residency professional activities: Based on their responses to the survey, residency graduates were classified into the mutually exclusive categories "Major Academic," "Minor Academic," "Community Practice," and "Out of Emergency Medicine" with those in "Community Practice" further divided into "Leader," "Teacher," "Leader and Teacher," or "Clinical Practice Only" using rules described in Appendix 2. These categories have not been previously described but were intended to group graduates by their general type of involvement in EM and, as such, have face validity.

Our independent variable was NRMP rank. Residents were assigned ranks first to Nth based on their position in the residency's NRMP rank list relative to the other matched residents in their class. Residents taken outside the match were analyzed separately.

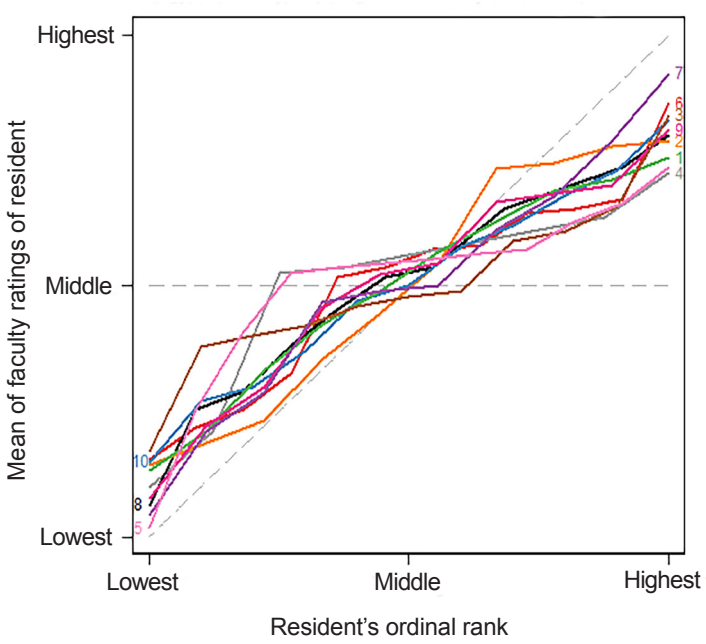
Our analysis was descriptive with the intention of visually depicting the degree of correlation between the NRMP rank order list, the faculty raters' impression of each resident, and the graduates' self-reported professional activities. Detailed graphics are used for this purpose as a method for visually assessing correlation. We examined the inter-rater reliability of the faculty rankings graphically, examining the distribution of deviations of each ranking from the average by rater and also examining the total squared deviations of each rater. We performed data management, analytics, and graph creation using Stata 14.2 (Stata Corp., College Station, Texas).

**RESULTS**

Of the 14 eligible faculty members, 10 agreed to participate. The 10 classes had 107 categorical EM residency graduates, 95 of whom entered the residency through the match and had an NRMP rank. Class size varied from 9-12 residents over the 10 years, primarily due to variations in the number of residents participating in our combined EM/pediatrics and EM/internal medicine programs. Eighty-four (79%) residency graduates completed the survey of post-residency activity, 77 of whom entered the program through the NRMP match. Residents entering the program outside the match did so when the size of the residency increased or to replace residents lost to attrition.

There was general agreement among faculty raters when ranking residents. Figure 1 provides support for the notion that faculty were generally consistent in the ratings of the residents. For most classes there was more agreement about who were the lowest- and highest-performing residents in a class, as the leftward and rightward sections of the curves are parallel to the 45° (perfect agreement) line, and the middle section of the curve parallels the horizontal (no agreement) line. There was no evidence that raters were more consistent for more recent graduating classes (Figure 1 and Supplementary Figure 1). While there was variation in

**Figure 1.** Faculty rating of residents' mean rank vs ordinal rank by year.

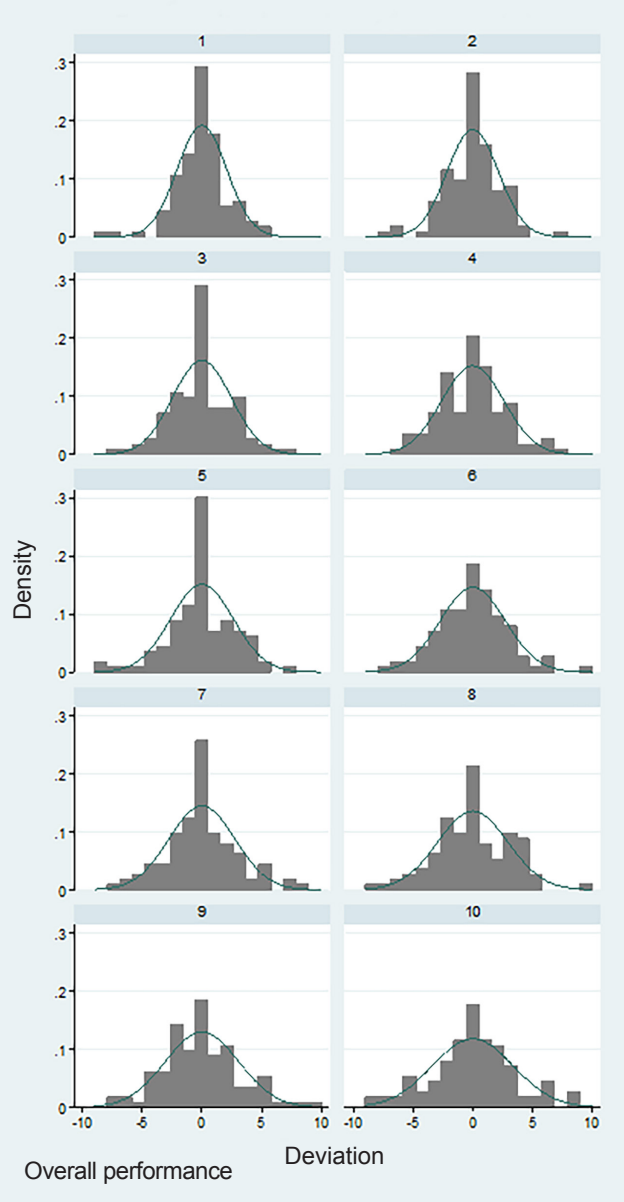



This graph illustrates inter-rater reliability for the faculty with regard to the overall performance question by class. The x-axis indicates the resident's overall rank (See text for explanation). The y-axis is the mean of that resident's faculty rankings. For each class (colored/numbered line), perfect agreement among faculty would result in a line that superimposes the 45° dashed line, as all faculty members would have ranked the overall highest ranked resident as 1, the next as 2, etc. Conversely, if there were perfect disagreement the lines would fall on the horizontal dashed gray line. Classes are labeled 1=earliest to 10=most recent.

rankings among the faculty, no faculty member was an obvious outlier (Figure 2 and Supplementary Figure 2). Together these analyses suggest that the faculty were able to rank resident performance within each class with sufficient reliability to make these rankings meaningful.

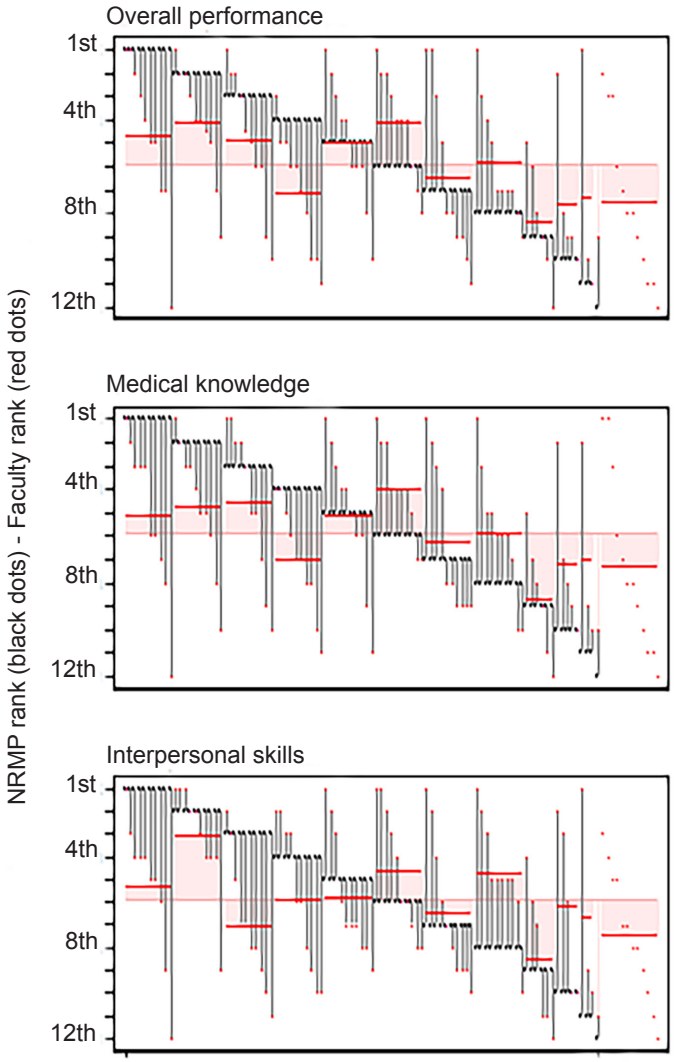
While there is some evidence that residents taken higher in the NRMP match received higher performance ratings from the faculty, the association was quite weak. Figure 3 shows that top faculty-rated residents came from all parts of the rank order list and from residents taken outside the match. The same is true for residents with low faculty ratings. While there is some evidence that being in the top half of the NRMP match predicts having an above-average faculty rating for overall performance and medical knowledge (top two panels of Figure 3), there appears to be no correlation between NRMP

**Figure 2.** Deviation of faculty raters' scores from average, by rater.




Each histogram represents one faculty rater and shows the distribution of deviations between his or her rank and the mean rank of each of the 107 residents they ranked on overall performance. Raters are sorted from lowest (1) to highest (10) deviator, but there is no strong evidence that any raters were particularly better or worse than other raters. Histograms for the other questions are in the Appendix.

**Figure 3.** National Residency Matching Program (NRMP) rank and average faculty rank by resident, 1998-2013.




This figure illustrates the NRMP rank order for each matched resident (black dot) and their average faculty rating (red dot) sorted by their NRMP rank. Faculty ratings for residents taken outside the match are shown on the far right. For each NRMP rank, the solid red bar segment represents the mean faculty rating of the residents who had that NRMP rank across all years, while the horizontal is the overal mean rank. The pink shading represents the divergence of the mean rating for the group of residents with that NRMP rank and the mean faculty mean rating for all residents.

rank order and faculty rating of interpersonal skills. This is confirmed by analysis of the distribution of deviations of NRMP rank and faculty rank (Supplementary Figure 3).

We observed a similar pattern when we compared self-reported professional activity with NRMP rank order (Figure 4). Over the 10 years included in the study, the program produced 36% academics (30 of the 84 graduates who responded to the survey), 33% of whom came from the top three positions in the NRMP rank order for their residency class. Interestingly, another 17% of academics came from residents taken outside of the match; 71% (5 of 7) of residents taken outside of the match went into academics. While the average NRMP rank of "major academics" was highest (4.0), the next highest average NRMP rank (4.6) was for those graduates who no longer play an active role in academics, teaching, or leadership (n=8) or are no longer practicing EM (n=1). Those in clinical teaching and leadership roles tended to come from the middle NRMP ranks. Academics came from all parts of the rank order list, as did those who appear to have minimal continuing involvement in the specialty.

## DISCUSSION

Despite our institution's rigorous applicant evaluation process, this study demonstrates that the relative position of a resident on our NRMP rank list was not meaningfully predictive of clinical performance during residency and participation in professional activities post-residency (Figures 3 and 4). While higher NRMP rank was somewhat predictive of a career in academics, this trend was not strong (Figure 4).

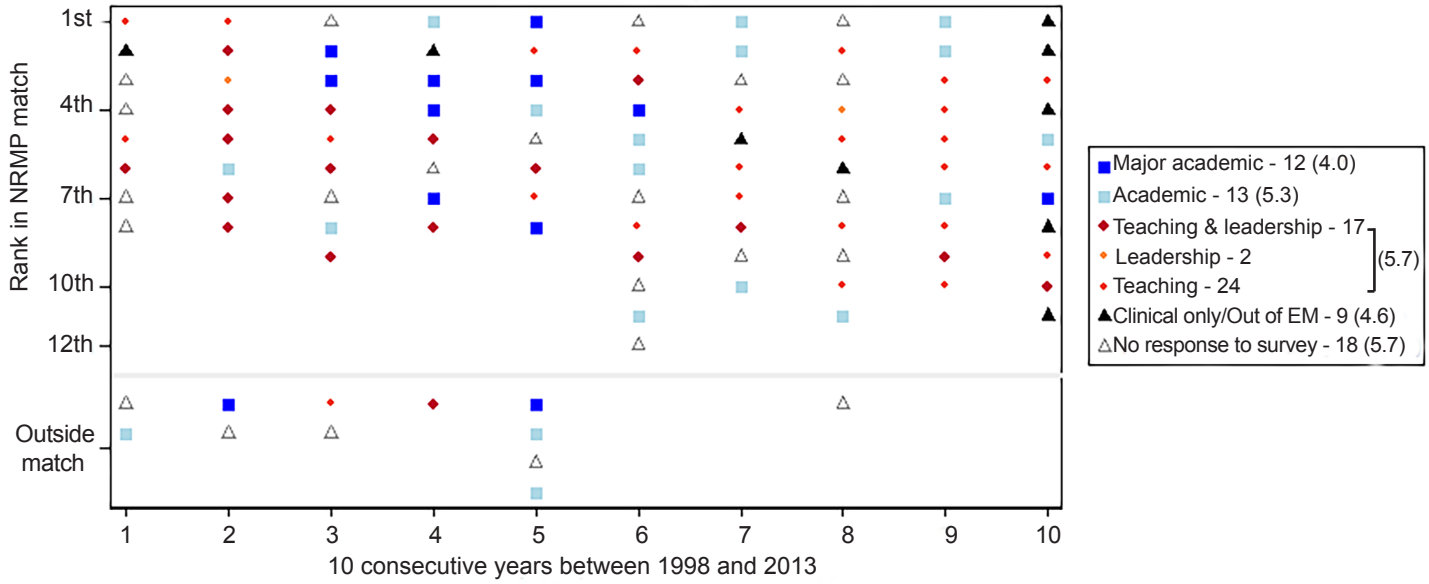
Our results reinforce the results of other investigations into the predictive value of the NRMP rank list. The majority of studies have shown that NRMP relative rank order correlates poorly with residency performance.[1-3] Only one study found a positive correlation.[7] Sklar and Tandberg (1996) demonstrated a positive correlation between NRMP relative rank order and faculty perception of 20 EM residents who graduated over a four-year period and found a positive correlation. Their results may differ from ours because they had smaller graduating classes (five per year) and ranked the four years of graduates together. Given the limited data and discrepant results, further investigation is warranted.

Many faculty hours are expended to determine the final rank order list. Given our findings, the time dedicated to a carefully ordered rank list appears to have low utility in predicting resident performance in residency and post-graduation, and less faculty-intensive methods should be considered.

## LIMITATIONS

Our study had notable limitations. We used a resident's relative order from the rank list and relative class performance ranking by faculty to assess the predictive value of the rank order list. It is possible that other methods of analyzing NRMP rank would produce different results. Faculty evaluations of resident clinical performance were retrospective and thus subject to recall bias and recency bias. Our method for categorizing post-residency professional outcomes has not been previously described and only captures gross categories of activity. Prior studies have focused on in-residency performance

**Figure 4.** Professional outcome of graduates by year and National Resident Matching Program (NRMP) rank.




Scatter plot of NRMP rank vs residency class based on post-graduation survey responses. Legend categories are defined in the text and Appendix 1. Following each category is the number in that category and the average rank in the NRMP match for that category. Parentheses in rightward box denote average class rank (of 12 positions).

and not categorized post-residency performance.

Fortunately, or unfortunately, there is no absolute definition or measure of "success." Furthermore, there was an error with our post-graduate survey that had non-mutually exclusive choices (e.g., "0-5 publications" and "5-10 publications"), which would have been ambiguous for those with exactly five publications (Appendix 1). Finally, to protect anonymity, we did not take into account years since graduation with regard to publications; thus, residents from more recent graduating classes may not have the time to develop the criteria required to be considered a "major academic" or "leader."

This study only investigated the performance and professional outcomes of the applicants who matched with us. Since we start with an applicant pool of approximately 750, interview roughly 100, and fill our 12 positions by an average of 50-60 on our rank list, we can only assess what the recruitment committee considered to be the top 8% of our applicants. We cannot address the utility of faculty time consumed determining who should be interviewed, nor the utility of time devoted to determining which applicants should be placed in the top vs the bottom half of our rank list, as we did not include those who were not matched at our program.

## CONCLUSION

In summary, there was a lack of strong correlation between our NRMP rank order and clinical performance during an EM residency, a finding similar to the majority of literature on the topic. Correlation between NRMP rank order and post-residency outcomes was also not strong. Given these findings, each residency will need to determine the appropriate amount of faculty labor used to formulate the NRMP rank order list while seeking ways to improve the predictive value of their rank lists and to identify and eliminate low-productivity faculty hours. We suspect that the process is insufficiently predictive to warrant current levels of expenditure of faculty time, which could be used more productively on other activities.

## ACKNOWLEDGMENTS

The authors thank Thomas Chen, BS, for assistance with programming the resident rating software and the survey of residents.

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*Conflicts of Interest*: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. Dr. Schriger's time on this paper was supported in part by an unrestricted grant from the Korein Foundation.



## REFERENCES

1. Papp KK, Polk HC, Richardson JD. The relationship between criteria used to select residents and performance during residency. *Am J Surg*. 1997;173(4):326-9.
2. Borowitz SM, Saulsbury FT, Wilson WG. Information collected during the residency match process does not predict clinical performance. *Arch Pediatr Adolesc Med*. 2000;154(3):256-60.
3. Adusumilli S, Cohan RH, Marshall KW, et al. How well does applicant rank order predict subsequent performance during radiology residency? *Acad Radiol*. 2000;7(8):635-40.
4. Calhoun KH, Hokanson JA, Bailey BJ. Predictors of residency performance: a follow-up study. *Otolaryngol Head Neck Surg*. 1997;116(6):647-51.
5. Metro DG, Talarico JF, Patel RM, et al. The resident application process and its correlation to future performance as a resident. *Anesth Analg*. 2005;100(2):502-5.
6. Olawaiye A, Yeh J, Withiam-Leitch M. Resident selection process and prediction of clinical performance in an obstetrics and gynecology program. *Teach Learn Med*. 2006;18(4):310-5.
7. Sklar DP, Tandberg D. The relationship between National Resident Match Program rank and perceived performance in an emergency medicine residency. *Am J Emerg Med*. 1996;14(2):170-2.

# Trials and Tribulations in Implementation of the Emergency Medicine Milestones from the Frontlines

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*Section Editor:* Jeffrey Druck, MD
Submission history: Submitted December 20, 2018; Accepted April 29, 2019
Electronically published June 3, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.4.42061
West J Emerg Med. 2019;20(4)647-650.

## INTRODUCTION

As part of medical education's shift toward competency-based education (CBE), the Accreditation Council for Graduate Medical Education (ACGME) announced the Milestones Project in 2008 to create an outcomes-based model of competency development. The goal was to characterize specific accomplishments or behaviors demonstrated by physician trainees as they progressed toward independent practice. Since then, multiple specialties, with emergency medicine (EM) at the forefront, have developed and incorporated competency-based assessment of residents using specialty-specific Milestones. The development of EM Milestones by the Emergency Medicine Milestone Working Group (EMMWG) has been well-described.[1] The EMMWG identified 23 subcompetencies within the six core competencies, and within each subcompetency, five different levels of proficiency. Each level has one or more Milestones of competency to mark the level of proficiency. As part of the Next Accreditation System (NAS) implemented by the ACGME in July 2013, each Milestone subcompetency has to be reported for every resident at six-month intervals by individual residency clinical competency committees (CCC).[1]

While well-intended, methodically planned and developed, these standards have been met with various levels of exasperation and confusion by medical educators seeking to implement the new requirements.[2] It is not my goal to push back against the Milestones approach, as it represents an iterative, dynamic process to continually advance medical education to provide safer and higher quality patient care. However, I aim to describe some frontline challenges for clinician educators attempting to implement these recommendations.

Ankel et al. predicted that "the future of CBE will require significant changes in the learning environment, resident assessment frequency, and faculty development."[3] Such changes have not happened in many programs, including my own. As a result, the sources of the trials and tribulations in the implementation of EM Milestones can be similarly categorized into issues with the Milestones themselves, resident assessment, direct observation, educational infrastructure, and limited resources.

### The EM Milestones

The all-encompassing nature of EM Milestones, lacking specificity to any case, disease, or context, prevents educators from reaching consensus when evaluating and assigning Milestone rankings. I frequently notice one faculty describing a trainee performing well on a Milestone behavior, ranking them highly on a particular subcompetency, while another faculty might feel differently regarding the trainee's performance on the same subcompetency or even the same Milestone. This is because skills and behaviors in one setting may not translate to another. Trainees' performances on tests of general constructs are known to be highly case-dependent.[4-6] A resident might be fully capable of developing and narrowing down a differential diagnosis (PC4), ordering the right test (PC3), and choosing the optimal disposition (PC7) for a presentation that he or she is familiar with and be completely clueless without prior experience with such a case. Some have suggested the linking of Entrustable Professional Activities (EPA), defined as "units of physician practice in which the goal is unsupervised competent practice by a trainee" with EM Milestones.[7] Because EPAs are based on clinical descriptions rather than individual physician descriptions, there may be less faculty development needed for Milestone subcompetency assessment.[7] Often, EPAs are presentation or diagnosis specific, which may mitigate concerns regarding conflicting reports of trainee competency in different contexts. However, creation of EPAs for every single disease within the Model of the Clinical Practice of EM is likely too overwhelming to develop, evaluate, implement, and measure. Developers of EM Milestones would likely point out that the optimal solution is the use of multiple assessment tools to measure Milestone subcompetencies. And this leads us to my next point.

**Resident Assessment**

Beeson et al. accurately anticipated the need for EM to develop multiple, valid and reliable objective measures of Milestone competency assessments.[1] However, our field has yet to meet this challenge raised by the developers of EM Milestones.

The EM Milestones include suggested methods of evaluation that vary with subcompetency but may include direct observation, simulation, chart review, standardized patients, global ratings, multi-source feedback, and end-of-shift evaluations. However, none has been sufficiently validated to effectively evaluate a trainee's progression through the EM Milestones. In fact, EM Milestones have been shown to possess poor inter-rater reliability between various stakeholders, such as resident self-assessment, faculty, and CCC, in various clinical settings and in simulation.[8-11] Furthermore, EM Milestone ranking determined by CCC in this early stage of implementation is hardly a gold standard of comparison. Similarly, multiple assessment tools of Milestone competency failed to demonstrate significant utility.[8,12] Specifically, end-of-shift evaluations of EM Milestones resulted in grade inflation compared to CCC results.[8] A multicenter, prospective, observational study to develop a direct observation assessment of Milestones in the form of the Critical Care Direct Observation Tool demonstrated low inter-rater reliability.[12] The authors expressed concerns for the reliability of other EM Milestone assessment tools that are currently in use.[12]

Despite mandating the semiannual review and update of the progression of EM Milestones of every resident, the EMMWG never released specific guidelines on the ideal administration and format of a CCC. Therefore, the way each CCC is run differs between residency programs.[13] Program directors and faculty are often left to their own devices in terms of what assessment tools to use and how to assign Milestone rankings. Even though my program's CCC uses multiple assessment tools (shift evaluations, off-service evaluations, monthly EM rotation evaluations, in-service scores, procedure, ultrasound, and simulation logs), none have been shown to be valid in the assessment of Milestone subcompetencies. After diving deeply into all available assessment data, my colleagues and I in the CCC meet in person in an attempt to build consensus in assigning Milestone rankings. Despite our best efforts, my fellow faculty and I are still left with the best "educated guess" of where each resident lies on most subcompetencies.

My department has trainees who are known to be less clinically competent but somehow consistently rank higher on EM Milestones year after year compared to their more capable peers. Much like a meta-analysis, the utility of the combined evidence depends on the strengths of the studies analyzed. The soundness and credibility of our CCC Milestone rankings leave much to be desired. My residents and faculty recognize the lack of reliability and validity in the assessment tools we use. This is demotivating to learners and educators alike, leading to less incentive for both parties to complete more assessments. The shortage of assessment data erodes faith in the Milestone evaluation process. This in turn feeds into the cycle of decreased validity and reliability of our Milestone ranking in the CCC, which further disincentivizes our residents and faculty to complete additional assessments.

**Direct Observation**

The intention of using objective behaviors for EM Milestones requires direct observation to occur. Assessment of professional competence will need to be based on multiple assessment methods, each with a minimum of 8-10 observations to ensure reliable inferences.[3] This is unrealistic for many frontline EM educators who work with limited departmental and institutional resources for faculty time for direct observation. A previous report has suggested that the overall faculty-EM resident interaction time accounts for only 20% of a resident's time spent on a clinical shift. Direct observation time of EM residents interacting with patients by faculty in the emergency department was only 3.6% of the time.[14] This is exacerbated by our specialty's distinct workflow, where trainees frequently work with multiple faculty on a single shift without opportunities for sustained contact and direct observation. A monthly EM Milestone evaluation is likely low-yield since sporadic short periods of observation by multiple faculty will not illuminate a consistent picture of trainee performance. Although video precepting can be a helpful adjunct to direct observation, it is not a panacea and can be time- and resource-intensive.[15] The same could be said of simulation programs and standardized patients.

**Educational Infrastructure**

One of the advantages of CBE is that the ability to progress is not based on time. Yet in graduate medical education (GME), no system exists that allows for the residents who attain Level 4 or 5 Milestone rankings to graduate early. There's no reward for thinking critically or to excel.[16] Level 5 "reach" Milestones are not important goals for trainees, as EM Milestones are no longer relevant for emergency physicians after residency graduation. Academic institutions have become overly dependent on trainees to provide patient care. Any change in the rate of progression for trainees can wreak havoc on the learners' ability to meet their service requirements and therefore disrupt the current funding model for GME.[2] After all, "the American public is both the consumer and the financier of the United States residency training system."[1]

Policymakers are demanding educational reform in light of healthcare inequality, cost pressures, the aging of populations, emerging diseases, and the advent of personalized medicine.[2] Considering the need for public accountability, the main drive for the shift toward CBE has been described as political because it affects the way our government allocates

resources.[16] Quality and patient safety is an example of an area where significant resources have been allotted. However, if Milestone data are to be used to provide assurance to the public, payers, and policymakers that residency programs are providing sufficient training in targeted areas of healthcare delivery as suggested by Beeson et al.,[1] departmental and institutional resources have to be allocated for the proper implementation and assessment of EM Milestones.

**Limited Resources**

However, despite mandating the implementation of EM Milestones, resources have not been made available to individual programs for execution or medical education research to support their use. None of my fellow CCC members have been given additional protected time or administrative support to dedicate to the observation, evaluation, discussion, and assignment of EM Milestone rankings. Beeson et al. warned against the potential threats to validity of EM Milestones in the form of too few observation and bias in rankings.[1] Given the constraints imposed by finite time and resources, it will not be possible to reliably measure more than a minute fraction of all the behaviors and scenarios that would be required to effectively evaluate a trainee's competence. Furthermore, resources for faculty development to "ensure consistent and appropriate evaluations" deemed as important by the developers of EM Milestones have yet to materialize.[1,17]

Despite all this, residencies are still required by the ACGME to evaluate each resident using Milestones during CCC on a semiannual basis.[18] The amount of time and energy, as well as faculty resources, may be inadvertently diverted away from other important educational interventions in order to facilitate this requirement. So far for my program, the efforts have not come to fruition. I hope that, through open discussion of my department's barriers to implementation, I can encourage further dialogue to develop best practices to improve Milestone assessment and CCC administration, at my own and other programs.

## CONCLUSION

The Milestone Project is a noble, longitudinal endeavor in medical education reform that I hope will lead to improved patient outcomes. However, its implementation requires dedicated resources for research and execution at all levels. Unfortunately, those on the frontlines of EM resident education lack valid assessment tools, opportunities for direct observation, proper educational infrastructure and resources to fulfill the mandate effectively at a program level.

## ACKNOWLEDGEMENTS

The author humbly acknowledges Jeff Markuns, MD, MEd and Lindsay Demers, MS, PhD for their inspiration, support, and invaluable input during the writing of this editorial.

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



## REFERENCES

1. Beeson MS, Carter WA, Christopher TA, et al. The development of the emergency medicine milestones. *Acad Emerg Med*. 2013;20(7):724-9.
2. Holmboe ES, Sherbino J, Englander R, et al. A call to action: the controversy of and rationale for competency-based medical education. *Med Teach*. 2017;39(6):574-81.
3. Ankel F, Franzen D, Frank J. Milestones: quo vadis? *Acad Emerg Med*. 2013;20(7):749-50.
4. Hodges B, Turnbull J, Cohen R, et al. Evaluating communication skills in the OSCE format: reliability and generalizability. *Med Educ*. 1996;30(1):38-43.
5. Lurie SJ. History and practice of competency-based assessment. *Med Educ*. 2012;46(1):49-57.
6. Miller GE. The assessment of clinical skills/competence/performance. *Acad Med*. 1990;65(9 Suppl):S63-7.
7. Beeson MS, Warrington S, Bradford-Saffles A, et al. Entrustable professional activities: making sense of the emergency medicine milestones. *J Emerg Med*. 2014;47(4):441-52.
8. Dehon E, Jones J, Puskarich M, et al. Use of emergency medicine milestones as items on end-of-shift evaluations results in overestimates of residents' proficiency level. *J Gr Med Educ*. 2015;7(2):192-6.
9. Tichter AM, Mulcare MR, Carter WA. Interrater agreement of emergency medicine milestone levels: resident self-evaluation vs clinical competency committee consensus. *Am J Emerg Med*. 2016;34(8):1677-9.
10. Goldflam K, Bod J, Della-Giustina D, et al. Emergency medicine residents consistently rate themselves higher than attending assessments on ACGME milestones. *West J Emerg Med*. 2015;16(6):931-5.
11. Wittels KA, Abboud ME, Chang Y, et al. Inter-rater reliability of select

emergency medicine milestones in simulation. *J Emerg Intern Med*. 2017;1(2:12):1-4.

12. Schott M, Kedia R, Promes S, et al. Direct observation assessment of milestones: problems with reliability. *West J Emerg Med*. 2015;16(6):871-6.
13. Doty CI, Roppolo LP, Asher S, et al. How do emergency medicine residency programs structure their clinical competency committees? A survey. *Acad Emerg Med*. 2015;22(11):1351-4.
14. Chisholm CD, Whenmouth LF, Daly EA, et al. An evaluation of emergency medicine resident interaction time with faculty in different teaching venues. *Acad Emerg Med*. 2004;11(2):149-155.
15. Quillen DM. Challenges and pitfalls of developing and applying a competency-based curriculum. *Fam Med*. 2001;33(9):652-4.
16. Leung WC. Learning in practice competency based medical training: review. *BMJ*. 2002;325(7366):693-6.
17. Beeson MS, Holmboe ES, Korte RC, et al. Initial validity analysis of the emergency medicine milestones. *Acad Emerg Med*. 2015;22(7):838-44.
18. Andolsek K, Padmore J, Hauer KE, et al. Accreditation Council for Clinical Competency Committees: *A Guidebook for Programs* (2nd ed). 2015:1-53.

# Design Your Clinical Workplace to Facilitate Competency-Based Education

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*Section Editor:* Mark I. Langdorf, MD, MHPE
Submission history: Submitted March 27, 2019; Revision received May 10, 2019; Accepted April 29, 2019
Electronically published June 11, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.4.43216
[West J Emerg Med. 2019;20(4)651-653.]

Competency-based education (CBE) is a criterion-referenced, outcomes-based framework used for curriculum design and assessment in medical education.[1] The goals of CBE are to define and assess provider competence along a trajectory, from novice to expert, using objective performance measures.[2]

CBE requires five key design features to be successful.[3] (1) The first requirement is an outcomes-based competency framework. The Accreditation Council for Graduate Medical Education (ACGME) developed the ACGME Milestones Project to operationalize competency domains for postgraduate trainees.[4] (2) The second expectation is that competencies and their developmental markers must support learner progression along a continuum. The Milestones represent just such a developmental model, with defined behavioral outcomes for residents as they progress through training. The remaining key features of CBE include (3) individually-tailored learning experiences within an authentic workplace environment that are sequenced or designed in response to each resident's developmental trajectory; (4) coaching for individual resident growth and achievement; and (5) programmatic assessment using multiple methods of data collection. High-quality data is sourced from numerous assessors, at a high frequency, mapped to the chosen framework, and used for robust summative entrustment and promotion decision-making by a clinical competency committee (CCC).[5-6] This approach to assessment is labor-intensive but results in publicly-defensible decisions about the training and competence of our physician workforce.

## The Challenges of Competency-based Education in Emergency Medicine

The ACGME Milestones can be operationalized to meet each of the CBE design features listed above. However, Sheng et al. identified significant challenges in their local implementation and utilization of this framework.[7] The true intent of the ACGME Milestones is to represent the developmental trajectory of a resident over time. The variability in faculty ratings, which may initially seem frustrating, are instead intentionally important to the process of monitoring development in our trainees. There is no perfect assessment tool and there will be variability in assessments. And that's okay.

The attainment of competence is rarely a linear path for a resident, just as developmental progression is not the same for children.[5,8] Residents learn at different rates, have different strengths, and different areas for improvement. These areas for improvement are rarely stable throughout three or four years of residency training. The lack of inter-rater consistency among faculty is normal and expected. The beauty of the Milestones is that the vast array of "dots" on the submission form – or assessment data points – will eventually provide a general understanding of each resident's trajectory. The greater number of data points, the clearer the trajectory, especially if data points are sourced from a wide range of supervisory perspectives.

"Does context matter?" The answer is clearly yes, for each separate data point. It is thus up to the trained group of faculty members who comprise the CCC to interpret those data and the context from which they arose. The Committee may then provide an *educated decision* about a trainee's progress and propose an individually-tailored learning plan to address any areas of deficiency. An educated decision is *not a random guess* if the decision is based on adequate data; if there are inadequate data, then your CCC has simply identified an *assessment gap* for which the program needs to obtain more or better data.[9]

Optimizing this process is difficult without first changing our approach to obtaining Milestones data. Aggregate evaluations at the end of each rotation generally lack the necessary timeliness, granularity, or approachability to provide learners with truly actionable feedback.[10] Residents often do not understand the Milestones themselves and simply look to any narrative comments on their evaluations to obtain insight

into their performance.[11] We need to rethink our process of data collection and separate that process from decisions about the Milestones.

CBE is successful when there is a substantial emphasis on workplace-based assessment of trainees.[5,12] True workplace-based assessment requires at least some direct observation.[5,11] Unfortunately, there are abundant barriers to conducting planned observations in our workplaces. Emergency departments (ED) are fraught with interruptions, high volumes of patients, and competing priorities for faculty members' attention. These practice realities can distract faculty members and trainees from seeking opportunities for lengthy, formal observations during a clinical shift.

Failure to optimize workplace-based assessments in the ED is often blamed on the complexity of the Milestones rather than the workplace itself. We can design impressive assessments, but if our learning environments have barriers to performing observations or providing timely feedback, these assessments may be rendered useless to all stakeholders. The inability to obtain quality data about our learners may result from misalignment of our assessment methods and our workplaces. This lack of data ultimately impairs the work of the CCC, which leads to suboptimal group processes, uninformed promotion decisions, and a poor functional understanding of CBE by our residency core faculty members.

**Strategies for Success**

The ED can be deliberately designed to facilitate CBE. Emergency medicine faculty members make frequent subconscious decisions about entrustment and trainee supervision throughout each shift. We regularly allow residents to perform procedures with on-demand supervision, or we step back to observe senior residents as they direct a resuscitation team. Simply "recording" these moments and providing direct feedback to trainees operationalizes workplace-based assessment without necessitating the use of the Milestones in real time. It is the responsibility of the CCC to map the documentation of these assessments back to the Milestones for aggregate decision-making and reporting purposes. Such frontline documentation does not need to include any Milestones language. We do not need to train every faculty member to deeply understand the Milestones framework; rather we need to train our CCC members to interpret available data.[13-14]

Desired outcomes must drive assessments. If you want your senior residents to perform a tube thoracostomy with only indirect supervision, then you need to optimize the learning environment to ensure adequate opportunities for them to practice this task. Learning outcomes are workplace-based *tasks*; outcomes are not the Milestones themselves. If your workplace environment does not support your current assessment methods, redesign the workplace or change the assessment method. Augment data collection with other modalities such as multisource feedback and simulation. Then design faculty development and resident training that follows your redesigned assessment process.

Faculty development is one of the most frequently identified challenges to assessment, particularly as it relates to the Milestones.[15] Many faculty development challenges may be ameliorated by simplifying frontline assessments to more intuitive forms that use task-based evaluations and supervisory language. Data from these forms can then be mapped back to the Milestones by the CCC. The Milestones were not designed to be copied onto evaluation forms directly as they are written; they were also not designed for use by frontline faculty.[16,17] By making workplace assessment tools more usable by the general faculty, you minimize your need for intensive faculty development. Use digital assessment tools rather than paper, if available; smartphone apps are more convenient than desktop portals for frontline evaluations. In addition, encourage residents to seek feedback using simply designed, self-assessment tools. These changes will reduce the burden of day-to-day assessment for faculty members, creating a shared responsibility to generate feedback for both faculty members and residents.

The value of the CCC can be maximized through better group processes for summative decision-making. The guiding purpose of the CCC may in fact be twofold: to make decisions about each resident's progress using the Milestones, and to critically appraise the assessment data available to the committee on a regular basis.[18] Identify gaps in assessment that are preventing the CCC from making informed decisions about learner development and progression. Use available data to develop individualized learning plans and coach the residents accordingly.

To ensure that CCC decisions are defensible and accurate, there must be a structured format for committee meetings so that all stakeholder viewpoints are represented. This is often best accomplished by a having faculty "expert" for each postgraduate year (PGY) class.[13,18] Involve each CCC member in the pre-review process of trainees in their assigned PGY class and allow them to lead the discussion of these trainees during the meetings. Provide CCC members with early access to high-quality assessment data and conduct regular training of the CCC members. Finally, stakeholder output is a key mandate of the CCC. While Milestone ratings are the necessary administrative outcome, individualized learning plans may be the more important CCC goal.[18] These learning plans should document areas for improvement to be reviewed with trainees by their assigned faculty coaches.

**SUMMARY**

Challenge your residency leadership and CCC to design a workplace that facilitates CBE. Create simpler frontline assessments that avoid the direct use of Milestone language and supplement with multisource feedback and simulation

to address assessment gaps. Map frontline assessment tools to the Milestones behind the scenes. Be deliberate about what you intend to assess, ensuring that assessment reflects key learning outcomes of the curriculum. Schedule time for direct observation of learners. Use faculty development and resident training to create a shared understanding of CBE and its application in your ED. Resolve any disconnect between obtaining data and using data. Empower residents to seek feedback during clinical shifts, to review self-assessments with their faculty coaches, and to fully engage in the assessment process at your institution. Finally, focus the outcomes of CCC meetings not simply on the assignment of Milestones, but on the creation of individual learning plans that promote trainee development.

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



## REFERENCES

1. Carraccio CL, Englander R. From Flexner to competencies: reflections on a decade and the journey ahead. *Acad Med*. 2013;88(8):1067–73.
2. Frank JR, Snell LS, Cate OT, et al. Competency-based medical education: theory to practice. *Med Teach*. 2010;32(8):638–45.
3. International Competency-Based Medical Education Collaborators. Five Core Components of CBME. Available at: http://gocbme.org/icbme-site/five-core.html. Accessed March 16, 2019.
4. Accreditation Council for Graduate Medical Education. Milestones. Available at: https://www.acgme.org/What-We-Do/Accreditation/Milestones/Overview. Accessed March 16, 2019.
5. Ten Cate O, Hart D, Ankel F, et al. Entrustment decision making in clinical training. *Acad Med*. 2016;91(2):191-8.
6. van der Vleuten CP, Schuwirth LW, Driessen EW, et al. A model for programmatic assessment fit for purpose. *Med Teach*. 2012;34(3):205-14.
7. Sheng AY. Trials and Tribulations in the Implementation of the Emergency Medicine Milestones from the Frontlines. *West J Emerg Med*. 2019;20(4):
8. Ten Cate O. Entrustment as assessment: recognizing the ability, the right, and the duty to act. *J Grad Med Educ*. 2016;8(2):261-2.
9. Ten Cate O, Regehr G. The power of subjectivity in the assessment of medical trainees. *Acad Med*. 2019;94(3):333-7.
10. Gruppen LD, Ten Cate O, Lingard LA, et al. Enhanced requirements for assessment in a competency-based, time-variable medical education system. *Acad Med*. 2018;93(3S Competency-based, time-variable education in the health professions):S17-21.
11. Holmboe ES, Sherbino J, Long DM, et al. The role of assessment in competency-based medical education. *Med Teach*. 2010;32(8):676-82.
12. Norcini J, Burch V. Workplace-based assessment as an educational tool. AMEE Guide No. 31. *Med Teach*. 2007;29(9):855-71.
13. Hauer KE, Chesluk B, Iobst W, et al. Reviewing residents' competence: a qualitative study of the role of clinical competency committees in performance assessment. *Acad Med*. 2015;90(8):1084-92.
14. Hauer KE, Cate OT, Iobst W, et al. Ensuring resident competence: a narrative review of the literature on group decision making to inform the work of clinical competency committees. *J Grad Med Educ*. 2016;8(2):156-64.
15. Hawkins RE, Welcher CM, Holmboe ES, et al. Implementation of competency-based medical education: Are we addressing the concerns and challenges? *Med Educ*. 2015;49(11):1086-102.
16. Beeson MS. The emergency medicine Milestones: with experience comes uggestions to improve. *Acad Emerg Med*. 2016;23(12):1434-6.
17. Dehon E, Jones J, Puskarich M, et al. Use of emergency medicine Milestones as items on end-of-shift evaluations results in overestimates of residents› proficiency level. *J Grad Med Educ*. 2015;7(2):192-6.
18. Kinnear B, Warm EJ, Hauer KE. Twelve tips to maximize the value of a clinical competency committee in postgraduate medical education. *Med Teach*. 2018;40(11):1110-5.

# SurgeCon: Priming a Community Emergency Department for Patient Flow Management

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*Section Editor:* Kenneth S. Whitlow, DO
Submission history: Submitted January 10, 2019; Revision received May 21, 2019; Accepted May 17, 2019
Electronically published July 5, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.5.42027

**Introduction:** Canadian emergency departments (ED) are struggling to provide timely emergency care. Very few studies have assessed attempts to improve ED patient flow in the rural context. We assessed the impact of SurgeCon, an ED patient-management protocol, on total patient visits, patients who left without being seen (LWBS), length of stay for departed patients (LOSDep), and physician initial assessment time (PIA) in a rural community hospital ED.

**Methods:** We implemented a set of commonly used methods for increasing ED efficiency with an innovative approach over 45 months. Our intervention involved seven parts comprised of an external review, Lean training, fast track implementation, patient-centeredness approach, door-to-doctor approach, performance reporting, and an action-based surge capacity protocol. We measured key performance indicators including total patient visits (count), PIA (minutes), LWBS (percentage), and LOSDep (minutes) before and after the SurgeCon intervention. We also performed an interrupted time series (ITS) analysis.

**Results:** During the study period, 80,709 people visited the ED. PIA decreased from 104.3 (±9.9) minutes to 42.2 (±8.1) minutes, LOSDep decreased from 199.4 (±16.8) minutes to 134.4(±14.5) minutes, and LWBS decreased from 12.1% (±2.2) to 4.6% (±1.7) despite a 25.7% increase in patient volume between pre-intervention and post-intervention stages. The ITS analysis revealed a significant level change in PIA – 19.8 minutes ($p<0.01$), and LWBS – 3.8% (0.02), respectively. The change over time decreased by 2.7 minutes/month ($p< 0.001$), 3.0 minutes/month ($p<0.001$) and 0.4%/month ($p<0.001$) for PIA, LOSDep, and LWBS, after the intervention.

**Conclusion:** SurgeCon improved the key wait-time metrics in a rural ED in a country where average wait times continue to rise. The SurgeCon platform has the potential to improve ED efficiency in community hospitals with limited resources. [West J Emerg Med. 2019;20(4)654-665.]

## INTRODUCTION

Emergency department (ED) crowding is a perennial Canadian healthcare concern.[1] Misdiagnosis, declining patient confidentiality and satisfaction, and bed-block (when all available beds are occupied and patients are left in corridors and ambulances) are only some of the resulting issues.[1,2] Amidst a perfect storm of recent Canadian Association of Emergency Physician national targets,[1] increasing financial

and resource pressures,[3] loss of full-care community providers,[4] and aging populations,[5] Canadian EDs are grappling with some of the longest wait times compared to peer industrialized countries.[6] The Newfoundland and Labrador (NL) Department of Health and Community Services has referred to EDs as the "front door" to the province's healthcare system.[7] After missing its own wait time benchmarks in 2016,[8] NL's Eastern Regional Health Authority joined the chorus of emergency care providers across Canada hunting for a solution to crowded ED care.[7,9-13] Large-scale process improvement is effective at urban facilities,[14,15] but NL is predominately rural[16] with many small EDs facing crowding,[17] increasing hospital occupancy rates,[18] and restrictive department sizes.[19]

A key problem with the literature related to ED quality improvement is the focus on urban tertiary/quaternary centers rather than smaller, rural EDs where the factors affecting patient flow may be different. In many rural communities, the ED is often the first and only choice to receive care.[20,21] Our team from the rural NL community of Carbonear created SurgeCon as a way to counteract these challenges. Rural EDs are an ideal setting to implement innovative models since they are more agile and have the potential to improve healthcare delivery and patient outcomes for a considerable portion of the population.[22] The ED in Carbonear represents a new frontier for the assessment of ED quality improvement interventions given the size of the communities it serves and the resources at its disposal, while facing the same challenges as larger centers.

SurgeCon is a pragmatic, ED management platform that includes a series of interventions acting together to improve ED efficiency and patient satisfaction. More specifically, the interventions target three key areas: 1) ED organization and workflow; 2) action-based ED management, and 3) the establishment of a patient-centric environment. SurgeCon is a term derived from the concepts of patient surge and defense readiness condition (DEFCON), which is a military escalation system. It is explicitly designed to address ED crowding by implementing commonly used methods for increasing ED efficiency in concert with technological innovation. The 45-month, proof-of-concept investigation described in this paper assessed the impact of SurgeCon on key, patient-flow and wait-time indicators in a rural community ED strained by a large volume of lower acuity patients. Specifically, we examined 1) time until physician initial assessment (PIA), 2) the proportion of patients who registered but left without being seen by a physician or his/her delegate (LWBS), and 3) mean length of stay for departed patients (LOSDep).

*Population Health Research Capsule*

What do we already know about this issue?
*Emergency department (ED) wait times continue to rise annually in Canada with a significant increase in crowding and cost to the healthcare system.*

What was the research question?
*How does the new initiative "SurgeCon" impact patient flow and wait times in a rural community ED?*

What was the major finding of the study?
*SurgeCon resulted in significant improvements in key wait-time metrics in a rural community ED.*

How does this improve population health?
*Decreasing wait times and crowding in the ED increases quality of care and improves patient health outcomes.*

## METHODS

### Study Design and Time Period

We used a quasi-experimental research design to assess the impact of the SurgeCon intervention. The data used in this study considered a period of 15 months before the intervention (July 1, 2013, to September 30, 2014, inclusive) and 30 months after the intervention (October 1, 2014, to March 31, 2017, inclusive).

### Study Setting

Carbonear General Hospital is an 80-bed hospital located on the southeastern coast of Newfoundland, the island portion of Canada's easternmost province Newfoundland and Labrador.[23] Carbonear is located approximately 75 minutes (~100 kilometers) from the only two provincial, tertiary referral hospitals, which are located in the capital city of St. John's. The community of Carbonear has a population of approximately 5,000, and the Carbonear Hospital provides services to a catchment population of approximately 40,000.[24] There are four full-time and four part-time emergency physicians (EP), one full-time nurse practitioner, two dedicated paramedics, and a maximum of three nurses at one time allocated to the ED.

### Data Collection and Integration

Routinely collected data provided by the Eastern Regional Health Authority included patient ED wait times from the point of registration to patient departure from the ED (eg, discharge, hospital admission). We used IBM Cognos Analytics (Armonk, New York), a business intelligence analytics platform, to provide monthly reviews from July 1, 2013, to March 31, 2017. A 45-month retrospective review of ED patient flow metrics was completed and compiled in May 2017. Values for each of these metrics were captured each month for 15 months prior

to initiation, 15 months in the early intervention period, and 15 months in the late intervention period. This quality improvement initiative was conducted exclusively for ED improvement purposes and did not require ethics approval from the provincial Health Research Ethics Authority.

**Intervention**

Our intervention is composed of seven parts, which were implemented sequentially as described below.

1. *Independent External Review:* In October 2014 we contracted an ED quality improvement (QI) consulting firm to conduct a comprehensive assessment of the organization and function of the Carbonear ED. This review formally quantified performance, clarified key improvement issues, and prepared staff members to begin the improvement process.

2. *Lean*[25]: Studies indicate that Lean strategies have been associated with improved ED performance and patient satisfaction.[26,27] Frontline staff attended two days of Lean training to facilitate the implementation of improvement initiatives and encourage ED staff to become active participants in the improvement process. The course was formulated to directly improve the flow of patients at the frontline of operational EDs by using simulation exercises, innovative surge-management software tools, and inventive approaches to real-life ED flow problems.

3. *Rapid Assessment "Fast Track" Zone:* Fast-track areas staffed by midlevel providers can improve patient flow and reduce ED crowding, wait times, LOSDep, and LWBS rates without affecting quality of care.[28-32] We created a rapid assessment zone by re-designating an underused waiting area adjacent to the ED triage area, enabling a 20% increase in physical ED space. Adding two new short examination tables and a chair in this area and using it for patient assessment, blood tests, electrocardiograms, and other minor procedures, maximized accessibility and ambulatory patient throughput. By removing competition for assessment space, this area also doubled for early reassessments and discharges, and as an independent nurse practitioner area.

4. *Patient Centeredness:* ED staff often believe that lower acuity patients should not seek care in an ED setting while also distinguishing patients based on "their legitimacy to be treated within the ED."[33] This belief system can create a culture of apathy and disregard toward patients who require primary and non-urgent care. Based on evidence that promoting a culture of patient "worthiness" improves patient satisfaction and ED efficiency,[33,34] we initiated multiple 30-minute staff educational sessions reinforcing the following three main topics: 1) providing quality ED care to all patients regardless of urgency; (2) treating all patients with respect; and (3) always considering the patient's visit to an ED to be necessary as they may have no other option. We also provided strategies to get the patient to the provider in a timelier manner (eg, physicians going to triage, moving patients from clinical assessment spaces back to waiting room/alternate waiting room, faster admitted patient extraction, efficient use of fast track areas, etc.). Patient-centeredness was also addressed through improving the ED environment, as a patient's waiting environment is a better predictor of patient satisfaction than wait times.[35] We removed all wall postings not pertinent to ED staff and patients, and all subsequent postings required departmental approval before being placed in a central location. We also redecorated the ED waiting room and patient examination rooms with framed photographs of coastal communities from the hospital's rural catchment area.

5. *Physician Initial Assessment "Door to Doctor" Focus:* A number of studies have found a strong correlation between patient satisfaction and PIA; the shorter the PIA, the more satisfied the patient.[36-38] To reduce the time to PIA we used the following strategies

a. ED staff briefly assessed patients even when formal assessment space was not immediately available.

b. EPs were provided with the option of triaging with nursing staff with the potential goal of patient discharge directly from the triage room without waiting.

c. Triage nurse-driven orders (eg, symptom management, laboratory testing, diagnostic imaging, etc.) were only applied on patients who would be waiting longer than one hour to see a physician. If the patient could have been seen by a physician within an hour, waiting for potentially unnecessary test results could delay the PIA.

d. If there were no available beds, EPs assessed patients arriving on ambulance stretchers in the hallway to initiate investigations instead of waiting for a bed to be free.

e. Staff attempted to offer short physician assessments prior to ordering diagnostic tests that could have potentially delayed discharge.

6. *Performance Data and Patient Flow*: Regular performance reporting enhances ED functioning and assists with improvement strategies.[27,38] Previously, the Carbonear EPs, nurses, managers, and staff infrequently reviewed ED performance data; however, as part of SurgeCon, our team circulated and clearly posted data in a prominent area of the department on a monthly basis. Individual physicians were informed of their monthly PIA times compared to the ED average.

7. *Action-based Surge Capacity Protocol:* We created and implemented a unique frontline, action-based tool that helps ED staff (paramedics, nurses and physicians) manage their actions to actively reduce patient surges and wait times and increase patients' access to emergency medical care. This tool uses algorithms to prompt the appropriate and timely use of volume-based staffing and management and overcapacity protocols, which may otherwise be overlooked by distracted frontline ED staff. When the ED is at overcapacity, ED staff require additional external support and resources, which are obtained by calling management. The prescribed actions included in the protocol when patient demand exceeds capacity in an optimal flow environment (eg, SurgeCon 4 & 5) are designed to find ways to remediate systemic issues that exist outside the ED and require managerial-level interventions that contribute to holistic operating conditions. This protocol converts key performance indicators into instructions for ED providers using a three-step process:

i. An EP, nurse, or administrator enters counts of specific indicators every two hours (eg, number of beds available, number of admitted patients, number of patients not seen) onto a whiteboard as part of their regular workflow.

ii. As a result of step (i), the team gains awareness of workload that can be shared with key stakeholders both internal and external to the ED. External stakeholders could determine bed availability, extract patients from the ED to an assigned inpatient bed, temporarily increase nurse and physician staffing, contact admitting consultants, and contact primary care paramedics for assistance.

iii. Using the visual board, the team adds the scores to get a total. This total score falls in one of five graduated levels, each with a set of prescribed actions. For example, a total score of 40 or more is level 5, with associated actions such as "Send all lower acuity patients to the waiting room." This scoring algorithm provides clarity for frontline staff in real time (Appendix II). Moving stable patients or visitors from clinical assessment spaces back to a primary or alternate waiting room is in line with our objective of creating a patient-centered environment as this allows for more non-assessed patients to become the center of care.[39,40]

**Outcome Measures**

The ED team (EP, nurses, and nursing management) manually collected data for PIA, LOSDep, and LWBS from Carbonear's hospital records, and reviewed it monthly from July 1, 2013–March 31, 2017. In May 2017, we retrospectively reviewed PIA, LOSDep, and LWBS in each study period and compiled the data for analysis.

An ED team (clinical manager, site clinical physician chief, nurse practitioner, nursing-appointed chairperson, and various other frontline staff) identified the following as outcome measures before the intervention began:

- PIA: mean time (in minutes) from patient triage to first assessment by a physician or their delegate (nurse practitioner, trainee, etc.). PIA is also referred to as "arrival to provider" or "door to doctor."[1,41,43]
- LWBS: percentage of patients who leave the ED without an assessment by a physician or their delegate. LWBS is also referred to as "left before being seen."[1,43,44]
- LOSDep: mean time interval (in minutes) between patient being triaged and discharged from the ED (in minutes). LOSDep is also referred to as "ED length of stay for discharged patient."[1,43]

Senior ED management send out scorecards with PIA, LOSDep, and LWBS data to local ED management for their review. To get PIA and LOSDep times, they take the earliest of three time stamps (arrival time, triage time, or registration time) and use that as the patient's time of arrival.

**Data Analysis**

Interrupted time series (ITS) analysis is an effective statistical approach to assess the impact of an intervention in a quasi-experimental research design.[45] To design a robust ITS analysis, we used guidelines introduced by Bernal, Cummins, and Gasparrini,[46] and selected a single-group, segmented time-series regression model. Time series analyses calculate the change in an outcome over time before an intervention is introduced, and then assess the immediate (month after introduction) and long-term (change in trend over time) effects of the intervention after adjusting for this pre-intervention trend. Thus, an immediate effect is significant if there is a statistically significant change in outcome in the month after program introduction from what would have been expected if the pre-intervention trend had continued. The long-term effect of the intervention is assessed by determining if there is a difference between the rates of change in outcome over time (slope) from the pre- to post-intervention periods.

For the purpose of this study, we initially conducted a segmented time-series regression model with two segments (pre-intervention and post-intervention) to identify whether there was any significant change in outcomes after implementation of the intervention. Then, we graphed the data and visualized two breakpoints occurring after the intervention. Therefore, we used a three-segment ITS model to more accurately represent our data. To identify the optimum breakpoints, we visually estimated that the breakpoints would be somewhere between months 15 and 30 of our 45-month study period. We looked for any sign changes and big swings in the values of the estimated coefficients as well as the model fitness criterion.

The analyses suggested that the estimates of the early

intervention become significant after six months of the intervention and remained so until 15 months of intervention with no variation in the magnitude or direction of the estimated coefficients. The analyses also suggested that the estimates of the late intervention become significant after 15 months. Increasing the duration of the late intervention period did not show any significant change in model fitness, magnitude and direction of the estimated coefficients of the late intervention until 30 months after initiation of the intervention. For this reason, the three-segmented linear regression model with segments including before intervention (July 1, 2013 to September 30, 2014, inclusive), early intervention (October 1, 2014 to December 31, 2015, inclusive), and late intervention (January 1, 2016 to March 31, 2017, inclusive) have been fitted to the data.

Finally**,** we added the number of visits per month as a covariate in the model to reassess the model fitness and any statistically significant changes in the estimated coefficients. We also conducted seasonality analysis to see whether the data experienced regular and predictable changes, and found no periodic fluctuations in all calendar seasons. Details about the parameters in the model are available in Appendix I. We used Stata version 14.2 (StataCorp, College Station, Texas) for statistical analyses.

## RESULTS

Over the entire study period, there were 80,709 patient visits to the Carbonear ED. Table 1 shows the characteristics of ED visits.

Overall, in this 45-month study PIA decreased from a mean of 104.3 minutes (±9.9 standard deviations) to 42.2 (±8.1) minutes, LOSDep decreased from 199.4 (±16.8) minutes to 134.4(±14.5) minutes, and LWBS decreased from 12.1% (±2.2) to 4.6% (±1.7). The results of a segmented time series analysis are as follows:

### Physician Initial Assessment

As described in Table 2, the ITS regression with two segments shows an immediate effect (level change) of -19.8 minutes ($p<0.01$; 95% confidence interval [CI], -33.68 to -5.89] ) drop in PIA and a long-term effect (slope change) of -2.72 ($p< 0.001$; 95% CI, -3.97 to -1.48) after the intervention.

Using the three-segment model, the level change shows a reduction in both early and late intervention by -5.59 ($p=0.186$; 95% CI, -13.99 to -2.81) and -13.99 ($p<0.004$; 95% CI, -23.35 to -4.63), respectively. The change in PIA slope was mainly due to changes in the early intervention period where the PIA significantly decreased every month by -4.45 minutes on average ($p<0.001$; 95% CI, -5.59 to -3.32). A monthly increase of 5.12 minutes (slope change) in PIA can be seen during the late-intervention period ($p<0.001$; 95% CI, 4.19 to 6.05) compared to early intervention. However, considering the linear trend of -3.80 ($p< 0.001$; 95% CI, -4.45 to -3.15) in the early intervention vs l.3 ($p< 0.001$; 95% CI, 0.60 to 2.05) in the late intervention and the level change of 13.99 ($p<0.004$; 95% CI, -23.35 to -4.63) in the late intervention, there was an overall decline over the entire post-intervention period. This can be verified upon visual inspection of Figure 1.

**Table 1.** Characteristics of patient visits to the Carbonear emergency department.

| | Pre-intervention | Post-intervention | |
|---|---|---|---|
| | | Early-intervention | Late-intervention |
| Total number of patients | 23898 | 26780 | 30031 |
| Total number of months | 15 | 15 | 15 |
| Total number of days | 457 | 457 | 456 |
| Mean PIA, minutes (SD) | 104.3 (9.9) | 77.3 (18.3) | 42.2 (8.1) |
| Mean LOSDep, minutes (SD) | 199.4 (16.8) | 170.6 (25.4) | 134.4 (14.5) |
| Mean LWBS, % (SD) | 12.1 (2.2) | 8.2 (3.2) | 4.6 (1.7) |
| CTAS 1, n (%) | 83 (0.3%) | 56 (0.2%) | 44 (0.1%) |
| CTAS 2, n (%) | 1212 (5.1%) | 1063 (4.0%) | 1157 (3.9%) |
| CTAS 3, n (%) | 7148 (29.9%) | 9590 (35.8%) | 8981 (29.9%) |
| CTAS 4, n (%) | 10459 (43.8%) | 13201 (49.3%) | 16820 (56.0%) |
| CTAS 5, n (%) | 1315 (5.5%) | 1756 (6.6%) | 1660 (5.5%) |
| Unspecified CTAS | 3688 (15.4%) | 1069 (4.0%) | 1236 (4.1%) |

*PIA*, time until physician initial assessment; *SD*, standard deviation; *LOSDep*, length of stay for departed patients; *LWBS*, patients who left without being seen; *CTAS*, the Canadian Triage and Acuity Scale.

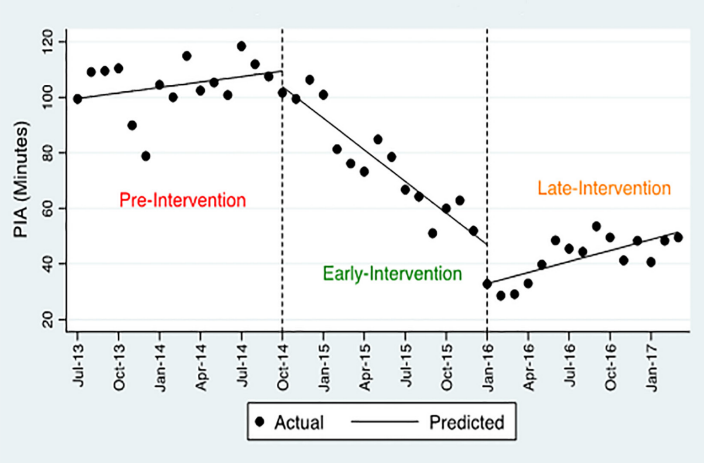
*Note that patient numbers reported by CTAS level will not match patient numbers reported by patient visits to the Carbonear emergency department (ED). This discrepancy is the result of a combination of an oversight in Eastern Health's internal reporting system, patients who visit the ED for reasons not requiring a CTAS score (e.g., intravenous specialist assessment), and omissions in paper charts.

**Table 2.** Interrupted time-series analyses showing effects of intervention on time to physician initial assessment, patient length of stay and left without being seen rates.

| Emergency department efficiency indicator | Coefficient | 95% confidence interval Lower band, Upper band | P value |
|---|---|---|---|
| Average physician initial assessment | | | |
| Baseline slope | 0.66 | -0.35, 1.66 | 0.20 |
| Level change | -19.80 | -33.68, -5.89 | 0.01* |
| Slope change | -2.72 | -3.97, -1.48 | 0.001* |
| Average length of stay until departure from emergency department | | | |
| Baseline slope | 0.63 | -0.96, 2.22 | 0.43 |
| Level change | -17.52 | -41.63, 6.59 | 0.15 |
| Slope change | -3.00 | -4.87, -1.14 | 0.001* |
| Percent of patients left without being seen | | | |
| Baseline slope | 0.20 | -0.06, 0.46 | 0.13 |
| Level change | -3.81 | -6.87, -0.75 | 0.02* |
| Slope change | -0.44 | -0.73, -0.15 | 0.0014* |

* P value < 0.05.

**Figure 1.** Physician Initial Assessmen (PIA).




Visual depiction of the overall declining trend in time to physician initial assessment over entire post-intervention period.

### Length of Stay Until Departure from Emergency Department

According to the two-segment model, the immediate effect of the intervention was a 17.5-minute decrease in LOS for departed patients, but this difference is not statistically significant (p<0.150). The long-term effect (slope change) on LOSDep is statistically significant (p<0.002) with a reduction of three minutes per month after implementation of the intervention.

The three-segment model reports a statistically non-significant level change in both early intervention (1.93, p=0.82) and the late intervention period (0.43, p=0.97) (Table 3). It also reveals a significant decrease of 5.7 minutes in LOSDep (slope change) during the early period (p<0.001) and 5.7 minutes increase (slope change) in the late period (p<0.001). By looking at the linear trend results for the early intervention period (-5.1, p<0.001, 95% CI, -6.64 to -3.59) and late intervention period (0.6, p=0.43, 95% CI, -0.92 to 2.12), the overall diminishing trend seems to be preserved during the post-intervention period (-3, p<0.002; 95% CI, -4.87 to -1.14). This also can be verified upon visual inspection of Figure 2.

### Left Without Being Seen

Applying a two-segment model shows an immediate effect of 3.8% decrease (p<0.02; 95% CI, -6.87 to -0.75) and the long-term effect of decrease by 0.4 % (p<0.004; 95% CI, -0.73 to -0.15) on LWBS after the implementation of the intervention. Using the three-segment model, a statistically non-significant level change of -1.42% (p=0.340) in the early period and 0.41% (p=0.718) in the late period is seen (Table 3). This model also shows a drop in the long-term effect of 0.78% (p<0.001; 95% CI, -1.14 to – 0.43) and then an increase of 0.68% during the late intervention (p<0.001; 95% CI, 0.41 to 0.95). The linear trend in the early intervention period shows a significant decrease by 0.58 (p<0.001; 95% CI, -077 to -0.40) and a non-significant trend of 0.09 (p=0.38). Since the overall slope change is declining (Table 2), the slope of linear trend in the early-intervention period is decreasing by 0.58 (p<0.001) and the positive slope of linear trend is not statistically significant (0.09, P=0.38), the overall long-term effect (trend) is diminishing over the post-intervention period (Figure 3).

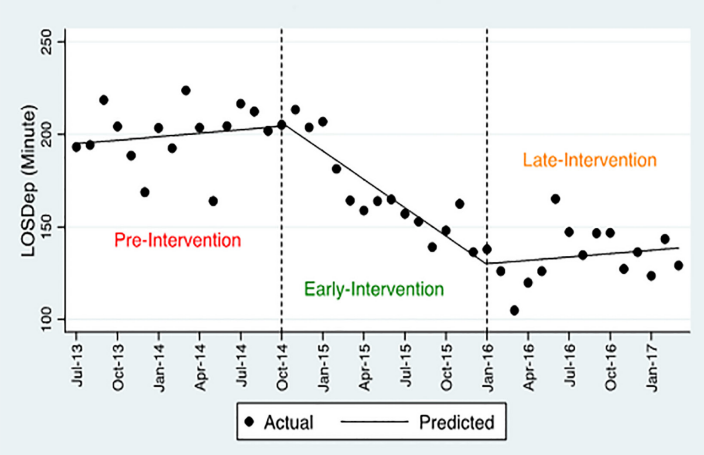
To control for the effect of patient volume, we adjusted the model by adding number of visits per month ("Visits")

**Table 3.** Three-segment statistical model showing a statistically non-significant level change in both early intervention and late interventions.

| Emergency department efficiency indicator | Coefficient | 95% confidence interval Lower band, Upper band | P value |
|---|---|---|---|
| Average physician initial assessment | | | |
| Baseline slope | 0.66 | -0.30, 1.61 | 0.17 |
| EI: Level change | -5.59 | -13.99, 2.81 | 0.19 |
| EI: Slope change | -4.45 | -5.59, -3.32 | 0.001* |
| LI: Level change | -13.99 | -23.35, -4.63 | 0.001* |
| LI: Slope change | 5.12 | 4.19, 6.06 | 0.001* |
| EI: Linear trend | -3.80 | -4.45, -3.15 | 0.001* |
| LI: Linear trend | 1.32 | 0.60, 2.05 | 0.001* |
| Average length of stay until departure from emergency department | | | |
| Baseline slope | 0.63 | -0.58, 1.84 | 0.30 |
| EI: Level change | 1.93 | -15.35, 19.20 | 0.82 |
| EI: Slope change | -5.74 | -7.69, -3.79 | 0.001* |
| LI: Level change | 0.43 | -19.60, 20.45 | 0.97 |
| LI: Slope change | 5.71 | 3.48, 7.95 | 0.001* |
| EI: Linear trend | -5.11 | -6.64, -3.58 | 0.001* |
| LI: Linear trend | 0.60 | -0.92, 2.12 | 0.43 |
| Percent of patients left without being seen | | | |
| Baseline slope | 0.20 | -0.09, 0.49 | 0.17 |
| EI: Level change | -1.42 | -4.22, 1.37 | 0.31 |
| EI: Slope change | -0.78 | -1.14, -0.43 | 0.001* |
| LI: Level change | 0.41 | -2.23, 3.04 | 0.76 |
| LI: Slope change | 0.68 | 0.41, 0.95 | 0.001* |
| EI: Linear trend | -0.58 | -0.77, -0.40 | 0.001* |
| LI: Linear trend | 0.09 | -0.12, 0.31 | 0.38 |

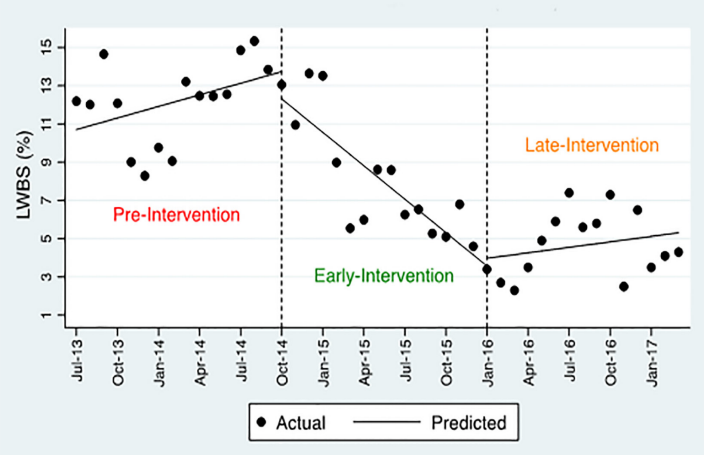
*EI*, early intervention (October 1, 2014 to December 31, 2015); *LI*, late intervention (January 1, 2016 to March 31, 2017).
* P value < 0.05.

**Figure 2.** Length of stay for departed patients (LOSDep).




Visual depiction of the overall diminishing trend during the entire post-intervention period.

**Figure 3.** Patients left without being seen (LWBS).




Visual depiction showing overall long-term trend diminshing over the post-intervention period.

to the three-segment model. The results (Table 4) show visits to be associated with PIA (0.02, 95% CI, 0.00 to 0.04; p<0.05) and LWBS (0.01, 95% CI, 0.00 to 0.01; p<0.04).

Overall, the adjusted model (Table 4) is consistent with the primary model (Table 3). No abnormal changes in the direction/sign of coefficients were seen, except the magnitude of coefficients, which have partially changed between the early- and late-intervention periods. Comparing the primary and adjusted models, the only difference is that the baseline slopes become statistically significant in PIA ([0.66, p=0.17] vs ([0.76, p<0.03]) and LWBS ([0.20, p=017] vs. [0.23, p<0.03]), respectively.

## DISCUSSION

Before implementing SurgeCon, there was anecdotal evidence that the Carbonear ED was not achieving national benchmarks and had the highest LWBS rate relative to similar-sized EDs in NL.[8] This study provides evidence that EDs can be adapted to efficiently provide urgent and non-urgent care in rural communities. All of our analyses showed an upward trend (ie, worsening) in outcomes over time in the pre-intervention period. After the implementation of the SurgeCon platform at the Carbonear ED, all outcomes showed a significant improvement. While the trend change was reversed in the late-intervention period, the rate of change was either non-significant or slower compared to immediate and long-term effects of the intervention in the early intervention period. The worsening trend from the early- to late-intervention period is likely a combination of an increase in ED volume and sustaining the gains long term. A refresher session may improve the results after the first 15 months.

**Table 4.** Number of visits per month and time to physician initial assessment and left without being seen rates.

| Emergency department efficiency indicator | Coefficient | 95% confidence interval Lower band, Upper band | P value |
|---|---|---|---|
| Average physician initial assessment | | | |
| Visits | 0.02 | 0.00, 0.04 | 0.05* |
| Baseline slope | 0.76 | 0.07, 1.46 | 0.03* |
| EI: Level change | -6.16 | -13.39, 1.07 | 0.09 |
| EI: Slope change | -5.19 | -6.60, -3.78 | 0.001* |
| LI: Level change | -11.69 | -22.85, -0.52 | 0.04* |
| LI: Slope change | 5.48 | 4.30, 6.65 | 0.001* |
| EI: Linear trend | -4.43 | -5.55, -3.30 | 0.001* |
| LI: Linear trend | 1.05 | 0.18, 1.93 | 0.02* |
| Average length of stay until departure from emergency department | | | |
| Visits | 0.00 | -0.04, 0.04 | 0.96 |
| Baseline slope | 0.64 | -0.62, 1.89 | 0.31 |
| EI: Level change | 1.90 | -15.56, 19.36 | 0.83 |
| EI: Slope change | -5.77 | -8.42, -3.12 | 0.001* |
| LI: Level change | 0.53 | -22.67, 23.72 | 0.96 |
| LI: Slope change | 5.73 | 3.46, 8.00 | 0.001* |
| EI: Linear trend | -5.14 | -7.25, -3.03 | 0.001* |
| LI: Linear trend | 0.59 | -1.22, 2.40 | 0.51 |
| Percent of patients left without being seen | | | |
| Visits | 0.01 | 0.00, 0.01 | 0.04* |
| Baseline slope | 0.23 | 0.02, 0.44 | 0.03* |
| EI: Level change | -1.57 | -3.93, 0.80 | 0.19 |
| EI: Slope change | -0.97 | -1.37, -0.57 | 0.001* |
| LI: Level change | 1.00 | -2.16, 4.16 | 0.53 |
| LI: Slope change | 0.77 | 0.44, 1.09 | 0.001* |
| EI: Linear trend | -0.74 | -1.05, -0.43 | 0.001* |
| LI: Linear trend | 0.03 | -0.23, 0.28 | 0.84 |

*EI*, early intervention (October 1, 2014 to December 31, 2015); *LI*, late intervention (January 1, 2016 to March 31, 2017).
* P Value < 0.05.

Sensitivity analyses did not show any significant change in the model's fitness or estimated coefficients where we applied the three-segment models to different subsets of the data. Moreover, repeating these processes by adding the variable number of visits per month did not show any significant change in the model's fitness or estimated coefficients.

It is worth highlighting that the dramatic improvements in outcomes demonstrated here occurred despite a 25.7% increase in patient visits from the pre- to the late-intervention periods. Moreover, no additional staff were hired during the study period. The increased volume were predominantly patients who were categorized as Canadian Triage and Acuity Scale (CTAS) 4 or non-urgent visits, which are often considered to be those that are amenable to treatment in primary care. The ability to provide care to a larger volume of patients without increasing wait times may be due in part to improved team awareness. The mechanisms that lead to improved "team awareness" in the context of the SurgeCon platform are a result of the tasks and goals set by the protocol. The protocol addresses issues related to harmful assumptions, establishes a common decision-making process, improves communication, and sets expectations for everyone on the ED team through role assignment. This is achieved via the protocol by defining the problem, the strategies to overcome them, and the overall goals of the department depending on the level of demand at any given time.

Our study does not suggest EDs can replace traditional means of accessing primary care; however, they can be relied upon as a secondary alternative approach to providing primary care in communities where access to a family physician may be challenging. In the community surrounding the Carbonear Hospital there has been a large loss of primary care physicians who retired in recent years. Recent studies have found evidence that rural patients are more likely to use EDs for non-urgent reasons when compared to their urban counterparts.[47,48] Geographic proximity to EDs and the likelihood of being seen by a regular family physician were found to be important factors influencing this discrepancy.[48-50]

In recent years many studies have evaluated Lean initiatives,[51-53] fast-track areas in the ED,[54-6], physicians in triage,[57] and full capacity protocols,[58] although the vast majority of these studies took place in urban centers. Furthermore, most studies examine just one initiative while our study included a large initiative with seven parts. The biggest strength to this study is that the initiatives were developed and implemented by a team of frontline practitioners (physicians and registered nurses) who have experienced firsthand the inefficiencies of the ED.

## LIMITATIONS

There are a few limitations that should be taken into consideration when interpreting the findings from this study. First, the generalizability of our results is limited given that implementation occurred at a single site. That said, the nature of a proof-of-concept initiative is to test a novel process on a small scale for feasibility and impact. The scoring system as shown in Appendix II also has limited generalizability because it is not normalized against ED size, and gives exact numbers (e.g., number of occupied beds) instead of proportions of beds that are full. Another limitation encountered during the study is particular to the hospital setting, where we could only call the inpatient unit for the immediate extraction from the ED during SurgeCon 5, instead of proactively calling. This was due to a negotiation between busy units, when ideally the unit would be called prior to this level of overcapacity.

Second, once patients had been seen by ED staff they were sorted using the CTAS. This triaging was not considered in our analysis because for this QI initiative, we used data aggregated on a monthly basis. We did not have data at the individual level to assess the associations with CTAS. Visits based on CTAS shows slight fluctuations in CTAS I and II during the study period and increasing number of visits with CTAS III and IV. The percentage of unclassified CTAS patients was also higher in the pre-intervention period than in the post-intervention period. Third, we did not measure 72-hour return to ED rate; however, a 2016 study by Cheng et al.[59] found that this often-cited measure is not reliably indicative of ED quality. Another potential limitation is that we only used 45 time points and it is known that power in ITS analyses increases with a larger number of time points.[46] The decision to use mean instead of median might be viewed as a limitation within the context of this study. Although median may perform better for a skewed distribution such as length of stay in hospital and wherever the goal is to represent a typical length of stay, mean is more sensitive to magnitude and is a more representative statistic from the point of view of assessing health system costs and efficiency.[60-62]

One may question the decision to use segmented regression instead of autoregressive integrated moving average (ARIMA).[63] Although ARIMA models inherently account for autocorrelation, non-stationarity and seasonality, they require a sufficient number of data points and observations in the pre- and post-intervention periods (a minimum of nine data points and over 100 observations).[64] Segmented regression on the other hand is one of the most common interrupted time series methods used in health sciences research.[64] It is similar to linear regression and is suggested for functions that cut segments of time particularly for studies such as the one described here where the points of switching segments are known. They are also more flexible for multivariate analysis.[46,65] To ensure elements covered through ARIMA models were included in our analysis, we checked for autocorrelation, non-stationarity, and seasonality before running the model (Appendix). With this in mind, due to the flexibility and applicability in the context of a proof of concept study we conducted a segmented regression analysis.[66]

As there is a trend toward increasing PIA, LOSDep, and LWBS between the early- and late- intervention stages, it

is possible some of the measures may have returned to pre-intervention levels if the study had continued for longer. It is possible that a "refresher" training session may be needed to combat this. It is also possible that a decrease in LWBS will result in a slight increase in the number of patients leaving before treatment is completed as some patients will not want to wait for test results regardless of how quickly the doctor sees them. Unfortunately, the routinely collected data used in this study did not include the number of patients who left before completing treatment. Another possible limitation of this study is the Hawthorne effect in which individuals behave differently when they know they are being observed. This may have led to ED staff modifying their behavior over the course of this study. Finally, physicians and nurse practitioners manually entered PIA, which may have impacted data quality.

## CONCLUSION

Our team recognized the necessity of a hospital-wide response from the outset, and designed and implemented SurgeCon accordingly. We took careful stock of existing resources in the ED and developed the comprehensive SurgeCon strategy around them. This was achieved by aligning the ED team around performance gains and approaching other key stakeholders in the system to help with output issues. This study provides evidence that interventions such as SurgeCon can result in significant gains with regard to key wait-time metrics in a rural community hospital with limited resources.

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*Conflicts of Interest*: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. Funding was received from the Canadian Institutes for Health Research Rewarding Success Phase II Grant. There are no conflicts of interest or sources of funding to declare.



## REFERENCES

1. Affleck A, Parks P, Drummond A, et al. Emergency department overcrowding and access block. *CJEM.* 2013;15(6):359-84.
2. Stoklosa H, Scannell M, Ma Z, et al. Do EPs change their clinical behaviour in the hallway or when a companion is present? A cross-sectional survey. *Emerg Med J.* 2018;35(7):406-11.
3. Canadian Institute for Health Information. National Health Expenditure Trends, 1975 to 2016. 2016. Available at: https://www.cihi.ca/sites/default/files/document/nhex-trends-narrative-report_2016_en.pdf. Accessed July 11, 2018.
4. Collaborative Working Group on the Future of Emergency Medicine in Canada. Emergency Medicine Training & Practice in Canada: Celebrating the Past & Evolving for the Future. 2016. Available at: http://www.cfpc.ca/uploadedFiles/CWG0001_CWG-EM_Report-FINAL_WEB_Final_2.pdf. Accessed July 11, 2018.
5. Statistics Canada. Population projections for Canada, provinces and territories. 2015. Available at: https://www150.statcan.gc.ca/n1/pub/91-520-x/2010001/aftertoc-aprestdm1-eng.htm. Updated 2015. Accessed July 11, 2018.
6. The Commonwealth Fund. The Commonwealth Fund 2010 International Health Policy Survey in Eleven Countries. 2010. Available at: http://www.commonwealthfund.org/~/media/files/publications/chartbook/2010/pdf_2010_ihp_survey_chartpack_full_12022010.pdf. Accessed July 11, 2018.
7. Department of Health and Community Services. A strategy to reduce emergency department wait times in Newfoundland and Labrador. 2012. Available at: https://www.health.gov.nl.ca/health/wait_times/pdf/emergency_department_strategy.pdf. Accessed July 11, 2018.
8. Eastern Health. Annual performance report 2015-2016. 2016. Available at: https://issuu.com/easternhealth/docs/rpt_eastern_health_apr_2015-16_fina. Accessed January 9, 2017.
9. Campbell SG, Sinclair DE; Canadian Association of Emergency Physicians flow management contributors. Strategies for managing a busy emergency department. *CJEM.* 2004;6(4):271-6.
10. Health Quality Ontario. Under pressure: emergency department performance in Ontario. 2016. Available at: https://www.hqontario.ca/portals/0/Documents/system-performance/under-pressure-report-en.pdf. Accessed January 7, 2019.
11. Canadian Institute for Health Information. Health care in Canada, 2012: A focus on Wait Times. 2012. Available at: https://secure.cihi.ca/free_products/HCIC2012-FullReport-ENweb.pdf. Accessed January 7, 2019.
12. Rotteau L, Webster F, Salkeld E, et al. Ontario's emergency department process improvement program: the experience of implementation. *Acad Emerg Med.* 2015;22(6):720-9.
13. Johnson M, Capasso V. Improving patient flow through the emergency department. *J Healthc Manag.* 2012;57(4):236-43.
14. Leung AK, Whatley SD, Gao D, et al. Impact of process improvements on measures of emergency department efficiency. *CJEM.* 2017;19(2):96-105.
15. Whatley SD, Leung AK, Duic M. Process improvements to reform patient flow in the emergency department. *Healthcare Q.* 2017;19(1):29-35.
16. Simms A, Greenwood R. State of rural Canada: Newfoundland and Labrador. 2015. Available at: http://sorc.crrf.ca/nl/. Accessed January 7, 2019.
17. Van Vonderen ML. Managing rural emergency department

overcrowding. *J Trauma Nurs.* 2008;15(3):112-7.
18. Auditor General of Newfoundland and Labrador. Report to the House of Assembly on Performance Audits of Departments and Crown Agencies November 2016. 2016. Available at: http://www.ag.gov.nl.ca/ag/annualReports/2016AnnualReport/Annual%20Report%202016.pdf. Accessed July 11, 2018.
19. Eitel DR, Rudkin SE, Malvehy MA, et al. Improving service quality by understanding emergency department flow: a White Paper and position statement prepared for the American Academy of Emergency Medicine. *J Emerg Med.* 2010;38(1):70-9.
20. Callen JL, Blundell L, Prgomet M. Emergency department use in an rural Australian setting: Are the factors prompting attendance appropriate? *Aust Health Rev.* 2008;32(4):710-20.
21. Nelson J. Why patients visit emergency units rather than use primary care services. *Emerg Nurse.* 2011:19(1):32-6.
22. Pong R, Atkinson A, Irvine A, et al. Rural health research in the Canadian Institutes of Health Research. A position paper prepared for Canadian Health Services Research Foundation and Social Sciences and Humanities Research Council. 2000. Available at: https://www.academia.edu/13598913/Rural_health_research_in_the_Canadian_Institutes_of_Health_Research. April 25, 2018.
23. Eastern Health. Carbonear General Hospital. 2018. Available at: http://www.easternhealth.ca/AboutEH.aspx?d=3&id=766&p=724. Accessed July 12, 2018.
24. Statistics Canada. Census Profile, 2016 Census: Carbonear, Town [Census subdivision], Newfoundland and Labrador and Newfoundland and Labrador [Province]. 2016. Available at: https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=1001370&Geo2=PR&Code2=10&Data=Count&SearchText=Carbonear&SearchType=Begins&SearchPR=01&B1=All&GeoLevel=PR&GeoCode=1001370&TABID=1. Accessed July 12, 2018.
25. Hines P, Holweg M, Rich N. Learning to evolve: A review of contemporary lean thinking. *Int J Oper & Prod Manag.* 2004;24(10):994-1011.
26. Bucci S, de Belvis AG, Marventano S, et al. Emergency department crowding and hospital bed shortage: Is lean a smart answer? A systematic review. *Eur Rev Med Pharmacol Sci.* 2016;20(20):4209-19.
27. Dickson EW, Singh S, Cheung DS, et al. Application of lean manufacturing techniques in the emergency department. *J Emerg Med.* 2009;37(2):177-82.
28. Swedish Council on Health Technology Assessment. Triage methods and patient flow processes at emergency departments: a systematic review. 2010. Available at: https://www.sbu.se/contentassets/79b7a8f6aaad46dcbc988cffed33339f/eng_smf_triage_110520.pdf. Accessed June 14, 2018.
29. Laker LF, Froehle CM, Lindsell CJ, et al. The flex track: flexible partitioning between low- and high-acuity areas of an emergency department. *Ann Emerg Med.* 2014;64(6):591-603.
30. Cooke MW, Wilson S, Pearson S. The effect of a separate stream for minor injuries on accident and emergency department waiting times. *Emerg Med J.* 2002;19(1):28-30.
31. Ieraci S, Digiusto E, Sonntag P, et al. Streaming by case complexity: evaluation of a model for emergency department fast track. *Emer Med Australas.* 2008;20(3):241-9.
32. Sanchez M, Smally AJ, Grant RJ, et al. Effects of a fast-track area on emergency department performance. *J Emerg Med.* 2006;31(1):117-20.
33. McConnell D, McCance T, Melby V. Exploring person-centredness in emergency departments: a literature review. *Int Emerg Nurs.* 2016;26:38-46.
34. Pham JC, Trueger NS, Hilton J, et al. Interventions to improve patient-centered care during times of emergency department crowding. *Acad Emerg Med.* 2011;18(12):1289-94.
35. Pruyn A, Smidts A. Effects of waiting on the satisfaction with the service: beyond objective time measures. *Int J Res Mark.* 1998;15(4):321-34.
36. Pang PS, McCarthy D, Schmidt M, et al. 440 Factors associated with perfect Press Ganey satisfaction scores for discharged emergency department patients. *Ann Emerg Med.* 2011;58 (4 Supplement):S327-8.
37. El Sayed MJ, El-Eid GR, Saliba M, et al. Improving emergency department door to doctor time and process reliability: a successful implementation of Lean methodology. *Medicine (Baltimore).* 2015;94(42):e1679.
38. Lean-driven solutions slash ED wait times, LOS. *ED Manag.* 2012;24(12):139-41.
39. Davis K, Schoenbaum SC, Audet AM. A 2020 vision of patient-centered primary care. *J Gen Intern Med.* 2005;20(10):953-7.
40. NEJM Catalyst. What Is Patient-Centered Care? 2017. Available at: https://catalyst.nejm.org/what-is-patient-centered-care/. Accessed April 26, 2019.
41. Canadian Institute for Health Information. Emergency department wait time for physician initial assessment (90% spent less, in hours). 2017. Available at: http://indicatorlibrary.cihi.ca/pages/viewpage.action?pageId=5111829. Accessed January 16, 2018.
42. Chartier L, Josephson T, Bates K, et al. Improving emergency department flow through Rapid Medical Evaluation unit. *BMJ Qual Improv Rep.* 2015;4(1):pii: u206156. w2663.
43. Wiler JL, Welch S, Pines J, et al. Emergency department performance measures updates: proceedings of the 2014 emergency department benchmarking alliance consensus summit. *Acad Emerg Med.* 2015;22(5):542-53.
44. Sørup CM, Jacobsen P, Forberg JL. Evaluation of emergency department performance – a systematic review on recommended performance and quality-in-care measures. *Scand J Trauma Resusc Emerg Med.* 2013;21:62.
45. Zhang F, Wagner AK, Ross-Degnan D. Simulation-based power calculation for designing interrupted time series analyses of health policy interventions. *J Clin Epidemiol.* 2011;64(11):1252-61.
46. Bernal JL, Cummins S, Gasparrini A. Interrupted time series regression for the evaluation of public health interventions: a tutorial. *Int J Epidemiol.* 2017;46(1):348-55.

47. Roberge D, Larouche D, Pineault R, et al. Hospital emergency departments: substitutes for primary care. Results of a survey among the population of Montréal and Montérégie. 2007. Available at: https://www.researchgate.net/publication/237397422_Hospital_Emergency_Departments_Substitutes_For_Primary_Care_Results_Of_A_Survey_Of_The_Population_Of_Montreal_AND_Monteregie. Accessed January 7, 2019.
48. McCusker J, Roberge D, Tousignant P, et al. Closer than you think: linking primary care to emergency department use in Quebec. 2013. Available at: http://www.aiiuq.qc.ca/images/articles/25.pdf. Accessed January 7, 2019.
49. Greenwood-Ericksen MB, Tipirneni R, Abir M. An emergency medicine-primary care partnership to improve rural population health:eExpanding the role of emergency medicine. *Ann Emerg Med.* 2017;70(5):640-7.
50. Palmer E, Leblanc-Duchin D, Murray J, et al. Emergency department use: Is frequent use associated with a lack of primary care provider? *Can Fam Physician.* 2014;60(4):e223-9.
51. Allaudeen N, Vashi A, Breckenridge JS, et al. Using Lean management to reduce emergency department length of stay for medicine admissions. *Qual Manag Health Care.* 2017;26(2):91-6.
52. Arbune A, Wackerbarth S, Allison P, et al. Improvement through small cycles of change: lessons from an academic medical center emergency department. *J Healthc Qual.* 2017;39(5):259–69
53. Balfour ME, Tanner K, Jurica PJ, et al. Using Lean to rapidly and sustainably transform a behavioral health crisis program: impact on throughput and safety. *Jt Comm J Qual Patient Saf.* 2017;43(6):275-83.
54. Aksel G, Bildik F, Demircan A, et al. Effects of fast-track in a university emergency department through the National Emergency Department Overcrowding Study. *J Pak Med Assoc.* 2014;64(7):791-7.
55. Celona CA, Amaranto A, Ferrer R, et al. Interdisciplinary design to improve fast track in the emergency department. *Adv Emerg Nurs J.* 2018;40(3):198-203.
56. Gardner RM, Friedman NA, Carlson M, et al. Impact of revised triage to improve throughput in an ED with limited traditional fast track population. *Am J Emerg Med.* 2018;36(1):124-7.
57. Abdulwahid MA, Booth A, Kuczawski M, et al. The impact of senior doctor assessment at triage on emergency department performance measures: Systematic review and meta-analysis of comparative studies. *Emerg Med J.* 2016;33(7):504-13.
58. Villa-Roel C, Guo X, Holroyd BR, et al. The role of full capacity protocols on mitigating overcrowding in EDs. *Am J Emerg Med.* 2012;30(3):412-20.
59. Cheng J, Shroff A, Khan N, et al. Emergency department return visits resulting in admission: Do they reflect quality of care? *Am J Med Qual.* 2016;31(6):541-51.
60. Lee AH, Fung WK, Fu B. Analyzing hospital length of stay: mean or median regression? *Med Care.* 2003;41(5):681-6.
61. OECD. Average length of stay in hospitals. In: Health at a glance 2017: OECD Indicators. OECD Publishing, Paris; 2017.
62. Fletcher J. Comparing length of stay. *BMJ.* 2009;338:b1280.
63. Kontopantelis E, Doran T, Springate DA, et al. Regression based quasi-experimental approach when randomisation is not an option: interrupted time series analysis. *BMJ.* 2015;350:h2750.
64. Jandoc R, Burden AM, Mamdani M, et al. Interrupted time series analysis in drug utilization research is increasing: systematic review and recommendations. *J Clin Epidemiol.* 2015;68(8):950-6.
65. Taljaard M, McKenzie JE, Ramsay CR, et al. The use of segmented regression in analysing interrupted time series studies: an example in pre-hospital ambulance care. *Implement Sci.* 2014;9:77.
66. Linden A. Conducting interrupted time-series analysis for single- and multiple-group comparisons. *Stata J.* 2015;15(2):480-500.

# Decreasing the Lag Between Result Availability and Decision-Making in the Emergency Department Using Push Notifications

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*Section Editor:* David Lee, MD
Submission history: Submitted February 14, 2019; Revision received April 12, 2019; Accepted May 11, 2019
Electronically published July 1, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.5.42749

**Introduction:** Emergency department (ED) patient care often hinges on the result of a diagnostic test. Frequently there is a lag time between a test result becoming available for review and physician decision-making or disposition based on that result. We implemented a system that electronically alerts ED providers when test results are available for review via a smartphone- and smartwatch- push notification. We hypothesized this would reduce the time from result to clinical decision-making.

**Methods:** We retrospectively assessed the impact of the implementation of a push notification system at three EDs on time-to-disposition or time-to-follow-up order in six clinical scenarios of interest: chest radiograph (CXR) to disposition, basic metabolic panel (BMP) to disposition, urinalysis (UA) to disposition, respiratory pathogen panel (RPP) to disposition, hemoglobin (Hb) to blood transfusion order, and abnormal D-dimer to computed tomography pulmonary angiography (CTPA) order. All ED patients during a one-year period of push-notification availability were included in the study. The primary outcome was median time in each scenario from result availability to either disposition order or defined follow-up order. The secondary outcome was the overall usage rate of the opt-in push notification system by providers.

**Results:** During the study period there were 6115 push notifications from 4183 ED encounters (2.7% of all encounters). Of the six clinical scenarios examined in this study, five were associated with a decrease in median time from test result availability to patient disposition or follow-up order when push notifications were employed: CXR to disposition, 80 minutes (interquartile range [IQR] 32-162 minutes) vs 56 minutes (IQR 18-141 minutes), difference 24 minutes ($p<0.01$); BMP to disposition, 128 minutes (IQR 62-225 minutes) vs 116 minutes (IQR 33-226 minutes), difference 12 minutes ($p<0.01$); UA to disposition, 105 minutes (IQR 43-200 minutes) vs 55 minutes (IQR 16-144 minutes), difference 50 minutes ($p<0.01$); RPP to disposition, 80 minutes (IQR 28-181 minutes) vs 37 minutes (IQR 10-116 minutes), difference 43 minutes ($p<0.01$); and D-dimer to CTPA, 14 minutes (IQR 6-30 minutes) vs 6 minutes (IQR 2.5-17.5 minutes), difference 8 minutes ($p<0.01$). The sixth scenario, Hb to blood transfusion (difference 19 minutes, $p=0.73$), did not meet statistical significance.

**Conclusion:** Implementation of a push notification system for test result availability in the ED was associated with a decrease in lag time between test result and physician decision-making in the examined clinical scenarios. Push notifications were used in only a minority of ED patient encounters. [West J Emerg Med. 2019;20(4)666-671.]

## INTRODUCTION

Decreasing emergency department (ED) length of stay and wait times is an ongoing effort in emergency medicine.[1-3] ED crowding is a challenge, and increasing throughput is an objective for many institutions. Improvements in ED flow and crowding are associated with higher quality of care.[4,5] Crowding is associated with higher stress levels among healthcare providers, longer wait times, increased boarding of admitted patients, and a higher rate of adverse events and poor outcomes.[6,7] While many factors are associated with ED crowding, ED patients are often awaiting test results to affect a clinical disposition. This is an element of ED throughput that may be a target for quality improvement.[8]

Emergency physicians typically manage several patients simultaneously and make clinical decisions based on information that becomes serially available as tests result. Tracking the timing of resulting patient studies while caring for multiple patients is difficult and managed idiosyncratically by most physicians. Delays in responding to newly resulted test information (due to task-switching, interruptions, and other challenges of the ED clinical environment) likely impact patient throughput.[9,10] Electronic systems that wirelessly alert providers about timed events have been shown to improve throughput in ED patients evaluated for chest pain.[11,12] These alerts also increase the likelihood of the result reaching the provider and help avoid potential errors in communication of test results.[13]

At our institution we implemented the ability for providers to receive an electronic alert when the result of any selected test has been entered in the system. Providers are able to indicate their choice to receive such an alert at the point of order entry in the electronic health record (EHR). This alert is sent in the form of a push notification to handheld devices (smartphones and smartwatches) that have the mobile version of the EHR installed. The notification signals to the provider that a test result is available for viewing on either the smartphone or computer.

We chose to examine four commonly ordered tests in the ED to evaluate whether a push notification about the availability of these results reduced the time to a disposition decision being made about patients (discharge vs admission). Additionally, we examined two clinical scenarios to evaluate whether the time to ordering a follow-up intervention was reduced by the new alerting mechanism. The first scenario evaluated the time from a critically low hemoglobin result (<7 grams per deciliter) was entered into the system and a blood transfusion was ordered; the second scenario was the time from an abnormal D-dimer result to the time when a computed tomography pulmonary angiogram (CTPA) was ordered. These scenarios were chosen a priori by the study investigators as clinical decisions most clearly related to the result of a single preceding test result. Our hypothesis was that the new alerting system would reduce the lag time between result availability and physician decision-making.

*Population Health Research Capsule*

What do we already know about this issue?
*Electronic health records can push notification of results to smartphones; this strategy has been shown to reduce time to disposition in chest pain patients.*

What was the research question?
*Does a push notification system decrease lag time to decision-making in several clinical scenarios of interest?*

What was the major finding of the study?
*Use of result push notifications was associated with decreased time to decision-making in several clinical scenarios.*

How does this improve population health?
*Push notifications are a strategy that busy emergency departments may consider to help address issues of crowding and improve throughput.*

## METHODS

### Study Setting and Population

New York University (NYU) Langone Health is an integrated health network in New York City with three EDs that collectively evaluate 150,000 patients per year. NYU Tisch Hospital is a tertiary care academic medical center with approximately 75,000 visits per year, NYU Cobble Hill is a free-standing ED with approximately 24,000 visits per year, and NYU Brooklyn Hospital is a Level 1 trauma center with approximately 52,000 visits per year. We collected data on patients from July 1, 2017, when the push notification functionality was made available, through June 30, 2018. In that time period, 78 ED providers subscribed to at least one push notification (37 attending physicians, 24 resident physicians in emergency medicine, and 17 physician assistants).

### Study Design

This was a retrospective, multicenter study to evaluate a quality improvement initiative. ED providers were free to subscribe to push notifications on whatever studies they chose and on whichever patients they chose. Providers were notified of this new functionality via departmental email update. Any order not yet resulted after being placed could be selected for a result push notification. This included orders placed by nursing or any other provider. Providers were not blinded as blinding in

this setting would have been infeasible. Providers were never prevented from accessing result data via the traditional log-in, computer-based EHR (Epic Systems Corporation, Verona, Wisconsin), even if they were using push notifications. EHR data was queried from the Epic Systems Clarity database with the use of Oracle SQL Developer (Oracle Corporation, Redwood City, California) and exported for data analysis; the queried data included encounter ID, notification type, notification time, order time, order-resulted time, and disposition time (defined as order to either admit or discharge the patient from the ED). The study was approved by the institutional review board of the NYU School of Medicine.

**Table 1.** Characteristics of the no push notification and push notification cohorts.

| Characteristcs | No Notifications Cohort, n = 148,391 | Notifications Cohort, n = 4,183 |
|---|---|---|
| Age, median | 41 | 51 |
| Women (%) | 50.6% | 51.8% |
| Admission rate (%) | 17.2% | 21.9% |
| ESI* | 3.87 | 3.35 |

*ESI*, Emergency Severity Index (lower values signify higher patient acuity).

**Outcomes**

The outcomes of interest in this study included the following: time from the result of a chest radiograph (CXR) being made available to the time of disposition; time from basic metabolic panel (BMP) result available to disposition; time from urinalysis (UA) result available to disposition; time from respiratory pathogen panel (RPP) result available to disposition; time from hemoglobin (Hb) result available to time blood transfusion was ordered; and time from D-dimer result available to time of CTPA order. Point-of-care laboratory tests (eg, troponin, lactate) – the results of which are communicated directly from the test performer (the nurse) to the test orderer (physician or physician assistant) – were excluded from analysis because the results of these tests are available prior to being entered in the EHR. We also excluded advanced imaging studies from analysis because providers are frequently informed of critical results by radiology telephone call prior to their being entered into the EHR.

**Data Analysis**

Median time with interquartile ranges (IQR) is reported in each scenario, and we used the Mann Whitney (Wilcoxon) test for unpaired data to assess whether the difference in medians between the two groups was statistically significant, defined as two-tailed p-values < 0.05 (R Statistics, version 3.3.3). For each of the measured scenarios we constructed a clustered boxplot comparing the median times with IQRs in the push notification and no push notification groups; minimum/maximum value whiskers were not displayed for visual scaling purposes (Excel, Microsoft Corporation, Redmond, Washington).

## RESULTS

During the study period there were 152,574 ED encounters: 148,391 ED encounters without a push notification (no notifications cohort), and 4183 ED encounters with a push notification (notifications cohort). There were 6115 push notifications generated from the notifications cohort, comprised of 4102 distinct patients. The median age, admission rate, average Emergency Severity Index, and gender percentages for the two patient cohorts are presented in Table 1. Overall, 32% (78/241) of ED providers subscribed to at least one notification during the study period: 28% (37/136) of attending physicians, 38% (17/45) of physician assistants, and 53% (24/45) of resident physicians. Fifteen of the 78 providers (19.2%) accounted for 79.7% of the notifications. Providers received result notifications about 320 unique lab/imaging studies. Of the 320 studies, 37 (11.6%) accounted for 79.8% of the total. There were four lab or imaging tests on average ordered per encounter in the push notification cohort. Push notifications were employed in 2.7% of all ED encounters during the study period. The overall rate of push notification subscriptions rose slightly over the study period, from 2911 push notifications during the first six months to 3204 push notifications in the second six months.

Of the six diagnostic tests we examined in this study, five were associated with a decrease in median time from test result availability to provider decision-making (Figure 1); the sixth scenario did not meet statistical significance. The largest improvements in median time from result to disposition were seen with the UA and RPP result notifications (50 and 43 minutes, respectively), whereas the improvement in time from result to disposition for the CXR and BMP results was more modest (24 and 12 minutes, respectively) (Table 2). In the follow-up order scenarios, the time from abnormal D-dimer to CTPA order was eight minutes faster in the push notification group; the time from critically low Hb result to blood transfusion was 19 minutes faster, but this finding was not statistically significant.

## DISCUSSION

This study's findings demonstrate a correlation between employment of test-result push notifications to smart devices and improved patient care efficiency. Of the six diagnostic test types examined, all were associated with a decrease in lag time from result availability to the next clinical step – either patient disposition, or defined follow-up order. A larger magnitude of effect was observed for UA and RPP results than for CXR and BMP results. Both UA and RPP require specific collection (urine sample or nasopharyngeal swab), which commonly leads to delays, and both tests typically take longer to result than blood tests; result notifications may be more efficacious in the setting of tests that are slow to result. The improved time from D-dimer result to CTPA order was modest (eight minutes). In the setting of cascading delays in ED patients who first wait for

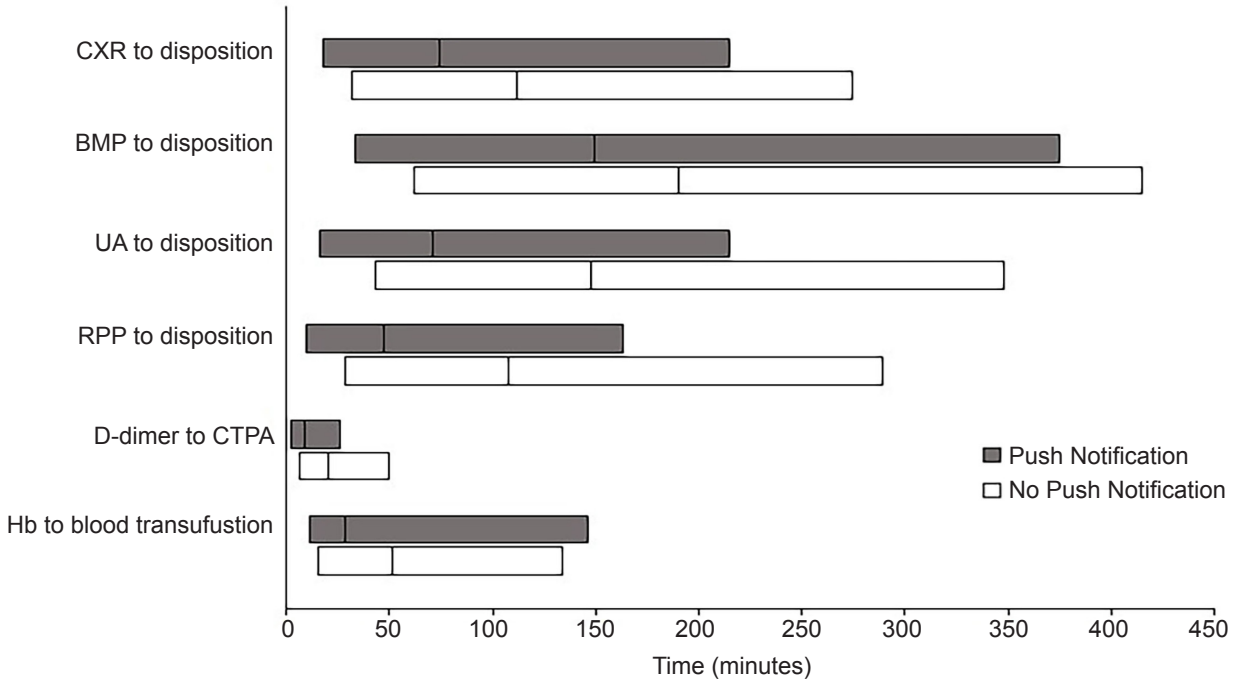


**Figure 1.** Boxplot of median minutes and interquartile ranges for time to disposition or time to follow-up order in each clinical scenario studied. *CXR*, chest radiograph; *BMP*, basic metabolic panel; *UA*, urinalysis; *RPP*, respiratory pathogen; *CTPA*, computed tomography pulmonary angiography; *Hb*, hemoglobin.

blood test results and then imaging study results, even this small improvement in lag time may be relevant. Similarly, for the time from Hb result to blood transfusion, an improvement of 19 minutes would also be clinically meaningful, even though due to the small sample size of push notifications in this scenario (18 notifications) this finding did not meet statistical significance.

The result push-notification functionality described is inherent to the EHR used at our institution, and therefore any institution using this EHR can potentially use this functionality. At this time, however, there is no ability to default result push notifications for all providers, or for a given provider conditionally for a specific test (for example, to always push CXR result notifications). The requirement to manually opt-in each time a test is ordered may have limited the magnitude of effect and depressed the usage rate of the push notification functionality in our study. While the overall rate of push notification usage did rise slightly during the study period, and a large number of physicians and physician assistants used the push notification system at least once, there was a low overall percentage of patient encounters in which push notifications were employed by the provider (2.7% during the study period). A notably larger percentage of resident physicians opted to use the push notifications than attending physicians, which may be due to role-related workflows (residents primarily managing the patient flow) as well as age-related factors (younger resident physicians may be more likely to adopt smart device technology).[14] System improvements for ease-of-use and customizability might increase provider use and limit the potential for user frustration or overuse; too many notifications would likely prove counterproductive to ED flow.

The overall magnitude of improvements observed in our study is similar to a trial of smartphone, troponin- result push notifications, in which Verma et al. found a 26-minute improvement in lag time from troponin result to patient disposition.[11] Our institution almost exclusively uses a point-of-care troponin test in the ED and thus we could not study the specific clinical scenario of troponin to disposition in our study. A study of radiologic critical test results reported via text message to physicians similarly showed improved response time in ED patients.[15]

Our study specifically examined clinical scenarios in which the authors felt knowledge of a test result would most clearly lead to either a disposition decision or an additional test order, and hence a measurable effect. These specific clinical situations represent only a small proportion of the total ED volume and clinical caseload during the study period. While prolonged length of stay and ED crowding are multifactorial in etiology and the lag time between result availability and physician action is a small contributor,[8] these results suggest that push notifications were potentially effective in modestly decreasing time to decision-making for providers opting-in for push notifications. This is also likely true in more complex clinical situations that were not

| Clinical scenario | Number of studies | | Median minutes (IQR) | | p value |
|---|---|---|---|---|---|
| | No Notifications Cohort | Notification Cohort | No Notifications Cohort (IQR) | Notification Cohort (IQR) | |
| CXR result to disposition | 31592 | 516 | 80 (32-162) | 56 (18-141) | p<0.01 |
| BMP result to disposition | 82946 | 354 | 128 (62-225) | 116(33-226) | p<0.01 |
| UA result to disposition | 39510 | 397 | 105 (43-200) | 55 (16-144) | p<0.01 |
| RPP result to disposition | 2991 | 168 | 80 (28-181) | 37 (10-116) | p<0.01 |
| D-dimer result to CTPA order | 863 | 35 | 14 (6-30) | 6 (2.5-17.5) | p<0.01 |
| Hb result to transfusion order | 852 | 18 | 36 (15-83) | 17 (11-118) | p=0.73 |

IQR, interquartile range; CXR, chest radiograph; BMP, basic metabolic panel; UA, urinalysis; RPP, respiratory pathogen panel; CTPA, computed tomography pulmonary angiography; Hb, hemoglobin.

studied. Further investigation is needed to identify and measure the impact of push notifications more broadly in the ED.

## LIMITATIONS

There are multiple limitations to this study. Our retrospective study was only able to show a correlation between result push notifications and improved time to decision-making. In addition, because each provider independently made the decision on whether or not to subscribe to a given test push notification, there may have been a potential selection bias: it is possible that providers who were motivated to subscribe to such alerts may also be those who are more efficient in general. It's also possible providers subscribed to push notifications more often in situations in which they could quickly disposition a patient pending that single result.

The admission rate for the notification cohort was slightly higher than that for the encounters without a push notification. It is possible that slight differences in patient characteristics between the two groups may explain part of the difference in efficiency. We attempted to limit this shortcoming by also studying two scenarios in which patient factors would not affect efficiency (time to CTPA and time to transfusion).

The study only examined six different test results and clinical scenarios. It is possible that we chose scenarios that showed an improvement, whereas tests not studied (eg, extremity radiograph results) may not have demonstrated an effect. The finding of decreased lag time in every scenario studied suggests that the efficiency observed is likely generalizable to other types of studies.

## CONCLUSION

Implementation of a push notification system for test result availability in the ED was associated with a decrease in lag time between test result and provider decision-making in several clinical scenarios. However, push notifications were used in only a minority of all ED patient encounters during the study period. The use of push notifications may play a role in improving the timeliness of care delivered in the ED.

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



## REFERENCES

1. Mullins PM, Pines JM. National ED crowding and hospital quality: results from the 2013 Hospital Compare data. *Am J Emerg Med*. 2014;32(6):634-639.
2. Stang AS, Crotts J, Johnson DW, Hartling L, Guttmann A. Crowding measures associated with the quality ofrEmergency department care: a systematic review. Zehtabchi S, ed. *Acad Emerg Med*. 2015;22(6):643-656.
3. Hoot NR, Aronsky D. Systematic review of emergency department crowding: causes, effects, and solutions. *Ann Emerg Med*. 2008;52(2):126-136.e1.
4. Pines JM, Hollander JE, Localio AR, Metlay JP. The association between emergency department crowding and hospital performance on antibiotic timing for pneumonia and percutaneous intervention for myocardial infarction. *Acad Emerg Med*. 2006;13(8):873-878.
5. Bernstein SL, Aronsky D, Duseja R, et al. The effect of emergency department crowding on clinically oriented outcomes. *Acad Emerg Med*. 2009;16(1):1-10.
6. Bond K, Ospina MB, Blitz S, et al. Frequency, determinants and impact of overcrowding in emergency departments in Canada: a national

survey. *Healthc Q*. 2007;10(4):32-40.

7. Guttmann A, Schull MJ, Vermeulen MJ, Stukel TA. Association between waiting times and short term mortality and hospital admission after departure from emergency department: population based cohort study from Ontario, Canada. *BMJ*. 2011;342:d2983.
8. Paul JA, Lin L. Models for improving patient throughput and waiting at hospital emergency departments. *J Emerg Med*. 2012;43(6):1119-1126.
9. Blocker RC, Heaton HA, Forsyth KL, et al. Physician,interrupted: workflow interruptions and patient care in the emergency department. *J Emerg Med*. 2017;53(6):798-804.
10. Fong A, Ratwani RM. Understanding emergency medicine physicians' multitasking behaviors around interruptions. Yadav K, ed. *Acad Emerg Med.* 2018;25(10):1164-1168.
11. Verma A, Wang AS, Feldman MJ, Hefferon DA, Kiss A, Lee JS. Push-alert notification of troponin results to physician smartphones reduces the time to discharge emergency department patients: a randomized controlled trial. *Ann Emerg Med*. 2017;70(3):348-356.
12. M. Feldman, BDeMendonca, D Hefferon et al. An electronic system reduces waiting time to disposition in emergency department patients with chest pain. *Can J Emerg Med*. 2014;16 (S1):S23.
13. Piva E, Sciacovelli L, Zaninotto M, Laposata M, Plebani M. Evaluation of effectiveness of a computerized notification system for reporting critical values. *Am J Clin Pathol*. 2009;131(3):432-441.
14. Richards JD, Harris T. Beam me up, Scotty! Impact of personal wireless communication devices in the emergency department. *Emerg Med J.* 2011;28(1):29-32.
15. Lim WH, Shin C-I, Chang JM, Sohn C-H, Park CM. Critical test result notification via mobile phone-based automated text message system in the radiologic field: single institutional experience. *J Am Coll Radiol*. 2018;15(7):973-979.

# Transportation Preferences of Patients Discharged from the Emergency Department in the Era of Ridesharing Apps

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*Section Editor:* Nikhil Goyal, MD
Submission history: Submitted February 19, 2019; Revision received May 7, 2019; Accepted May 12, 2019
Electronically published July 2, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.5.42762

**Introduction:** Patients discharged from the emergency department (ED) may encounter difficulty finding transportation home, increasing length of stay and ED crowding. We sought to determine the preferences of patients discharged from the ED with regard to their transportation home, and their awareness and past use of ridesharing services such as Lyft and Uber.

**Methods:** We performed a prospective, survey-based study during a five-month period at a university-associated ED and Level I trauma center serving an urban area. Subjects were adult patients who were about to be discharged from the ED. We excluded patients requiring ambulance transport home.

**Results:** Of 500 surveys distributed, 480 (96%) were completed. Average age was 47 ± 19 years, and 61% were female. There were 33,871 ED visits during the study period, and 67% were discharged home. The highest number of subjects arrived by ambulance (27%) followed by being dropped off (25%). Of the 408 (85%) subjects aware of ridesharing services, only eight (2%) came to the ED by this manner; however, 22 (5%) planned to use these services post-discharge. The survey also indicated that 377 (79%) owned smartphones, and 220 (46%) used ridesharing services. The most common plan to get home was with family/friend (35%), which was also the most preferred (29%). Regarding awareness and past use of ridesharing services, we were unable to detect any gender and/or racial differences from univariate analysis. However, we did detect age, education and income differences regarding awareness, but only age and education differences for past use. Logistic regression showed awareness and past use decreased with increasing patient age, but correlated positively with increasing education and income. Half the subjects felt their medical insurance should pay for their transportation, whereas roughly one-third felt ED staff should pay for it.

**Conclusion:** Patients most commonly prefer to be driven home by a family member or friend after discharge from the ED. There is awareness of ridesharing services, but only 5% of patients planned to use these services post-discharge from the ED. Patients who are older, have limited income, and are less educated are less likely to be aware of or have previously used ridesharing services. ED staff may assist these patients by hailing ridesharing services for them at time of discharge. [West J Emerg Med. 2019;20(4)672-680.]

## INTRODUCTION

Emergency department (ED) visits continue to grow steadily each year, with roughly 137 million per year based on the most recent data from the National Center for Health Statistics.[1] ED crowding remains a serious problem despite progressive measures aimed at improving patient flow, especially with regard to inpatient admissions.[2] One factor that has received less recognition as a potential variable for ED crowding is time spent arranging transportation home for patients discharged from the ED, which adds to overall

length of stay.[3] Discharged patients may experience difficulty finding family or friends to pick them up from the ED, may not be able to use public transportation, or may have physical or mental limitations on their ability to get home on their own. Patients who have driven themselves to the ED may have received sedating medications and be unsafe to drive. The onus of finding appropriate transportation home for discharged patients frequently falls on ED staff, who may be overextended during periods of crowding.

The advent and rapid growth of ridesharing services, such as Lyft and Uber, represents a potential solution for timely patient discharges from the ED.[4] Once available only to those with smartphone or internet access, ridesharing services may now be arranged by telephone and arrive expeditiously and reliably via real-time global positioning system tracking via an application (app) or webpage. These services are usually paid for by patients but may be covered by medical insurance or individual EDs contracting with ridesharing companies. As this technology is relatively new, the impact of ridesharing services on patient transportation to and from the ED is not yet known.

To determine how much patients know about and use ridesharing services, we conducted a survey study in the ED. We also queried ED patient demographics, their preferences regarding transportation home, and their opinion of how it should be paid for. Our findings may be of interest to hospital and ED leadership, administration, and nursing. As ridesharing services expand and become more accessible to those without smartphone access, we believe ED patients may prefer this mode of transportation to and from the ED, especially if the hospital and/or their medical insurance cover its cost.

*Population Health Research Capsule*

What do we already know about this issue?
*Patients discharged from the emergency department (ED) may encounter difficulty obtaining a ride home, especially the elderly and disabled.*

What was the research question?
*What are patients' preferences regarding transportation home, and what is their awareness and use of ridesharing services?*

What was the major finding of the study?
*Transportation home with family or friend is preferred. Awareness and use of ridesharing services is limited.*

How does this improve population health?
*Ridesharing services are underutilized, and ED staff may arrange rides for patients without smartphones. This may improve time to discharge, patient satisfaction, and ED crowding.*

## METHODS

We performed a prospective, survey-based study during the five-month period September 1, 2017– January 31, 2018, at a university-associated ED and Level 1 trauma center serving an urban population of two million in central California. The study coincided with the advent of a hospital policy of arranging and paying for ridesharing service to certain patients discharged from the ED with financial or social hardships; the service was provided at the discretion and sanction of the ED charge nurse. This new policy was not publicized, did not apply to taxi services, and was granted on a case-by-case basis upon patient request. Subjects were a convenience sample of randomly-chosen adult patients 18 years of age or older, or adult parents of patients under 18, who were about to be discharged from the ED. The survey questions (Supplement 1) were only provided in the English language, requiring subjects to be able to read English or have their accompanying family and/or friends translate for them. Exclusion criteria were patients requiring ambulance transport home.

The survey was voluntary and anonymous, and potential subjects could decline participating in the study prior to receiving the survey instrument. Surveys were distributed to subjects in paper form and collected immediately after completion by collaborators from our Emergency Medicine Research Associate Program (EMRAP). The EMRAP collaborators clarified any questions subjects may have had regarding the survey and also checked the surveys for completeness. If any surveys were incomplete or had multiple responses checked, the EMRAP collaborators worked with the subject to resolve any discrepancies at the time of collection. The time period of distribution in the ED was from 5 AM to midnight, seven days a week. This study was approved by our institutional review board as an exemption, and patient consent was waived. We performed univariate and multiple logistic regression analyses using MedCalc™ version 18.11.3 (Ostend, Belgium). Statistical significance was assumed at $P \leq 0.05$.

## RESULTS

A total of 500 surveys were distributed; 480 (96%) subjects completed the survey and 20 subjects (4%) declined to participate after receiving the survey. The average age of the study subjects was 46.4 ± 18.7 years, and 291 (61%) were female. In contrast, the overall ED population during the study period had an average age of 40.0 ± 23.8 years, and 16,553 (49%) were female. Further demographics, including

race, education, income, and smartphone/internet usage are displayed in table 1.

**Table 1.** Demographics of respondents to a survey of transportation preferences post discharge from the emergency department.

| | |
|---|---|
| Age (years) | 46.4 ± 18.7 |
| Gender | |
| Female | 291 (60.6%) |
| Male | 186 (38.8%) |
| Undisclosed | 3 (0.6%) |
| Race | |
| White | 214 (44.6%) |
| Black | 91 (19.0%) |
| Hispanic | 80 (16.7%) |
| Asian | 48 (10%) |
| Other | 40 (8.3%) |
| Prefer not to disclose | 7 (1.4%) |
| Education | |
| College | 207 (43.1%) |
| High school or GED | 172 (35.8%) |
| Graduate | 47 (9.8%) |
| Vocational school | 25 (5.2%) |
| Up to Grade 8 | 18 (3.7%) |
| Prefer not to disclose | 11 (2.4%) |
| Income | |
| Less than $20,000 | 191 (39.7%) |
| $20,001 to $50,000 | 98 (20.4%) |
| $50,001 to $100,000 | 69 (14.4%) |
| Prefer not to disclose | 85 (17.8%) |
| greater than $100,000 | 37 (7.7%) |
| Internet | |
| Own smartphone | 377 (78.5%) |
| Text messages per day | 21.9 ± 35.7 |
| Emails sent per day | 8.3 ± 20.1 |
| Aware of rideshare apps? | 408 (85%) |
| Used rideshare apps? | 220 (45.8%) |

*GED,* general educational development.

Of the 33,871 ED visits during the study period, 22,833 (67%) were discharged home. The most frequent mode of transportation to the ED was by ambulance (n = 127, 27%) followed by being dropped off by a family member or friend (n = 119, 25%) (Table 2).

Although 408 (85%) were aware of ridesharing services, only eight (2%) came to the ED by this manner, but 22 (5%) planned to use such a service post-discharge. There were 377 (79%) who indicated they possessed a smartphone, and 220 (46%) had previously used these ridesharing services. The highest number of subjects planned to get home with a family member or friend (n = 167, 35%), which was also the most preferred method (n = 141, 29%) (Table 2). Regarding the awareness of ridesharing services, we found significant age, education, and income differences from univariate analysis (Table 3). For prior use of ridesharing services, significant differences were found for only age and education (Table 4).

Logistic regression analysis of ridesharing awareness and use also revealed differences by age, education, and income, but not gender or race (Table 5). In general, both awareness and use decreased with age (Odds ratio (OR) less than one) and increased with rising education and income levels (OR greater than one). The model for predictors of ridesharing awareness was statistically significant ($P < 0.0001$, $\chi 2 = 58.48$, df = 17, Nagelkerke $R^2 = 0.20$, and area under the receiver operating characteristic (ROC) curve 0.77 (95% confidence interval (CI), 0.72 to 0.80). Awareness predictor variables reaching statistical significance were age (OR = 0.96, $P < 0.0001$) education level up to 8$^{th}$ grade (OR = 0.33, P = 0.03), income less than $20,000 per year (OR = 0.52, P = 0.02), and income $50,000 - $100,000 per year (OR =3.7, P = 0.01). The regression model for predictors of ridesharing use was also significant ($P < 0.0001$, $\chi 2=86.11$, df = 17, Nagelkerke $R^2 = 0.22$, and area under the ROC curve 0.73 (95% CI, 0.69 to 0.77). Ridesharing use predictor variables reaching significance were age (OR = 0.95, $P < 0.0001$), high school or general educational development (GED) education level (OR = 2.05, P = 0.03), and college (OR = 2.77, P = 0.002). Income greater than $100,000 per year approached significance (OR = 2.09, P = 0.06).

Half the subjects (n = 241, 50%) felt their medical insurance should pay for their transportation home, whereas 148 (31%) felt the ED staff should arrange and pay for it. The average estimated distance home was 16.4 ± 22.0 miles, with most being less than 10 miles from the ED. There were 589 (2.6%) ridesharing transports arranged by ED staff and paid for by the hospital during the study period for a total cost of $8,731. Average cost and distance per ride was $15.70 ± 14.10 and 9.1 ± 10.1 miles, respectively. The majority were hailed during the day (7 AM - 7 PM) (n = 339, 57.6%) and 250 (42.4%) were hailed overnight (7 PM - 7 AM).

## DISCUSSION

Transportation to and discharge home from the ED is an essential need, especially for elderly, disabled, and economically disadvantaged patients. It is estimated roughly four million individuals fail to receive medical care annually due to transportation barriers.[5] Delays in the diagnosis and treatment of patients with chronic diseases often results in

**Table 2.** Transportation to the emergency department, and plans/preferences for discharge transportation.

| | |
|---|---|
| How did you come to the emergency department? | |
| Ambulance | 127 (26.5%) |
| Dropped off by family member or friend | 119 (24.8%) |
| Your personal vehicle driven by someone else | 101 (21.0%) |
| Your personal vehicle alone | 93 (19.4%) |
| Walk | 16 (3.3%) |
| Public transportation (Bus/Light Rail) | 12 (2.5%) |
| App-based rideshare service (Uber/Lyft) | 8 (1.7%) |
| Taxi | 3 (0.6%) |
| Bike | 1 (0.2%) |
| How do you plan to get home? | |
| Pick-up by family or friend | 167 (34.8%) |
| Your personal vehicle driven by someone else | 119 (24.8%) |
| Your personal vehicle alone | 89 (18.6%) |
| Not sure yet | 28 (5.8%) |
| App-based rideshare services (Uber/Lyft) | 22 (4.6%) |
| Walk | 17 (3.5%) |
| Public transportation (Bus/Light Rail) | 15 (3.1%) |
| Ambulance transport | 11 (2.3%) |
| Taxi | 8 (1.7%) |
| Other | 3 (0.6%) |
| Bike | 1 (0.2%) |
| Ideally, what is your top preference of transportation home? | |
| Pick-up by family or friend | 141 (29.3%) |
| Your personal vehicle alone | 140 (29.1%) |
| Your personal vehicle driven by someone else | 105 (21.9%) |
| App-based rideshare services (Uber/Lyft) | 26 (5.4%) |
| Public transportation (Bus/Light Rail) | 19 (4.0%) |
| Taxi | 13 (2.7%) |
| Free, hospital-provided shuttle | 10 (2.1%) |
| Ambulance transport | 8 (1.7%) |
| Other | 8 (1.7%) |
| Walk | 7 (1.5%) |
| Bike | 3 (0.6%) |

destabilization and progression of those diseases, ED crowding, excessive use of inpatient resources, and poor outcomes.[6-8] According to a 2016 report of the United States Government Accountability Office, the cost of medical transportation for Medicare and Medicaid patients exceeded $2.7 billion, with the Medicaid segment rising significantly in the past decade.[9] This does not include estimates on the cost of missed and/or unused clinic appointments and negative downstream health effects, which is estimated at $150 billion.[10]

For the next several decades, the number and percentage of older adults are expected to increase, particularly the "oldest-old" (those 85 years and older). This subgroup will number roughly seven million (2% of the population) in 2020 but will grow to 18 million (4.5%) by 2050.[11] Coupled with this aging population and rising Medicaid enrollment, government spending on medical transportation will continue to increase. Thus, the need for more cost-efficient ways to provide transportation for patients has become an important issue in healthcare and consumer spending.

Prior to the ridesharing app era, patients discharged from the ED who had no family/friends/self to drive them had to rely on taxis or private medical shuttle companies. At present, ridesharing companies such as Lyft and Uber have begun to offer programs that address this need at a lower cost than traditional taxi services, which have been shown to be more expensive in all major cities except New York.[12] According to the Lyft business website, 80% of patients prefer Lyft for transportation, with a cost reduction of 32%.[13] The chief business officer of Lyft wrote that the company's goal is to reduce the healthcare transportation gap by 50% by 2020.[10] Of 30,000 Lyft riders surveyed, 29% reported they have used the ridesharing app for healthcare transportation, according to the company's 2019 economic impact report.[14] Lyft has recently partnered with nine health systems and 10 medical transportation firms to provide patients with more extensive transportation options.[15]

Uber, the other major ridesharing app provider, launched Uber Health in 2015 for medical transportation.[16,17] Uber Health, so far available only in the U.S., allows ED staff to book rides for discharged patients who do not have a smartphone. It has been used by more than 100 health facilities, many of which pay for the service to avoid the downstream health and personnel costs of delayed discharges and missed appointments. One issue that has arisen from the use of ridesharing apps for post-discharge transportation is that elderly and/or disabled patients may have unique needs and preferences, such as help getting into and out of the vehicle or a slower ride. Uber has responded to this need with Uber Assist, in which drivers are specifically trained to assist seniors and those with disabilities.[18] Lyft has partnered with CareMore to provide similar services, and preliminary survey data from this program showed decreased transportation wait time and cost and increased patient satisfaction.[18,19] Other novel programs aimed at reducing the transportation burden of older and disabled patients discharged from the ED include GoGoGrandparent, ITNAmerica, and Liberty Mobility Now.[20]

Despite the obvious cost and access advantages to the use of ridesharing services for medical transportation, the authors of one study found the impact of these services on

**Table 3.** Patient awareness of ridesharing services.

| | Aware | Not aware | P |
|---|---|---|---|
| Age (years) | 44.8 ± 18.1 | 55.7 ± 19.2 | < 0.0001* |
| Gender | | | |
| Female | 253 (86.9%) | 38 (13.1%) | |
| Male | 153 (82.3%) | 33 (17.7%) | 0.2 |
| Race | | | |
| Asian | 36 (75.0%) | 12 (25.0%) | |
| Black | 80 (87.9%) | 11 (12.1%) | |
| Hispanic | 63 (78.7%) | 17 (21.3%) | |
| White | 186 (86.9%) | 28 (13.1%) | |
| Other | 37 (92.5%) | 3 (7.5%) | 0.06 |
| Education | | | |
| Up to Grade 8 | 11 (61.1%) | 7 (38.9%) | |
| High School or GED | 144 (83.7%) | 28 (16.3%) | |
| Vocational School | 19 (76.0%) | 6 (24.0%) | |
| College | 183 (88.4%) | 24 (11.6%) | |
| Graduate | 43 (91.4%) | 4 (8.6%) | 0.009 |
| Income/year | | | |
| Less than $20,000 | 155 (81.1%) | 36 (18.9%) | |
| $20,001 to $50,000 | 86 (87.7%) | 12 (12.3%) | |
| $50,001 to $100,000 | 65 (94.2%) | 4 (5.8%) | |
| Greater than $100,000 | 34 (91.8%) | 3 (8.2%) | 0.03 |

* Student's t-test; otherwise $X^2$.
*GED,* general educational development.

medical appointment attendance may be minimal, even when offered for free. In their prospective clinical trial, Chaiyachati and colleagues offered gratis Lyft rides to 786 patients to and from their clinic appointments. The rate of missed appointments was 36.5% compared to 36.7% for study participants not offered free transportation.[21] More than half of patients contacted with offers of a free ridesharing service responded they weren't interested. Some theories on this finding were that those most in need of ridesharing, such as elderly and/or low-income patients, were the least technology-savvy and unlikely to own smartphones. Skepticism of ridesharing services and concern over privacy issues were also cited.

The findings of our survey with regard to age, income, and education parallel other studies conducted in non-healthcare settings. According to the Pew Research Center, 33% of adults in the U. S. have never heard of ridesharing services, and only 15% have ever used them.[22] From the same survey, ridesharing users tended to be younger and college-educated, with higher than average incomes. Vivoda et al. surveyed older Americans and found 74% reported no knowledge of ridesharing services, and only 1.7% had used them.[20] Younger age, male gender, and higher education were all independently associated with greater knowledge of ridesharing services in their study.

In the past, Lyft and Uber required the use of a smartphone and/or internet to hail a ride. It is estimated only 42% of older adults own a smartphone, and only 64% use the internet.[23] Further survey findings have shown those with higher educations and incomes are likely to have more disposable income to spend on smartphones and internet access.[24] In our study we did not ascertain differences between gender and race with regard to ridesharing service awareness and use. However, the authors of previously published studies have highlighted gender differences. Men, particularly in older adulthood, have been shown to take more trips per day than women and to have more favorable attitudes toward technology than women.[25-27] Women may be less inclined to use ridesharing services, as it involves taking a ride with a stranger in an environment perceived as less regulated than a taxi.[28]

The use of immediately-available ridesharing services

**Table 4.** Prior use of ridesharing services by emergency department patients.

| | Used before | Never used | P |
|---|---|---|---|
| Age (years) | 40.2 ± 17.4 | 51.6 ± 18.2 | < 0.0001* |
| Gender | | | |
| Female | 140 (48.1%) | 151 (51.9%) | |
| Male | 79 (42.7%) | 106 (57.3%) | 0.3 |
| Race | | | |
| Asian | 27 (56.3%) | 21 (43.7%) | |
| Black | 42 (46.1%) | 49 (53.9%) | |
| Hispanic | 32 (40.0%) | 48 (60.0%) | |
| White | 93 (43.4%) | 121 (56.6%) | |
| Other | 22 (55.0%) | 18 (45.0%) | 0.2 |
| Education | | | |
| Up to Grade 8 | 4 (22.2%) | 14 (77.8%) | |
| High School or GED | 72 (41.8%) | 100 (58.2%) | |
| Vocational School | 6 (24.0%) | 19 (76.0%) | |
| College | 102 (49.3%) | 105 (50.7%) | |
| Graduate | 32 (68.1%) | 15 (31.9%) | 0.0004 |
| Income/year | | | |
| Less than $20,000 | 79 (41.3%) | 112 (58.7%) | |
| $20,001 to $50,000 | 49 (50.0%) | 49 (50.0%) | |
| $50,001 to $100,000 | 35 (50.7%) | 34 (49.3%) | |
| Greater than $100,000 | 22 (59.4%) | 15 (40.6%) | 0.1 |

*Student's t-test; otherwise $X^2$.
GED, general educational development.

for transportation to and from the ED has several benefits. The first is eliminating the need for arranging a ride, driving to the ED, negotiating traffic, and finding parking. These actions add additional stressors upon the patient and their accompanying family and friends. Patients often receive sedating medications during their ED stay, such as antihistamines, antiemetics, benzodiazepines, and opioids. Ridesharing services may mitigate the risk associated with patients driving themselves home, especially the elderly, and these services have been shown to decrease substance-impaired driving after socialization.[29,30] ED crowding may be favorably affected, as patient discharges from the ED no longer rely on finding a ride, which can take hours based on the availability of acquaintances or public transportation schedules.

When ridesharing services are hailed by the ED staff for a patient, as in our ED, there is no longer a need for patient ownership of a smartphone. Reduction of pollution, traffic congestion, and fuel use are further benefits. The transportation sector is the largest source (29%) of greenhouse gas emissions in the U.S., leading to serious air pollution and negative health effects, with cars alone accounting for the largest share (41.6%).[31] Furthermore, over three-quarters of Americans drive alone to work, while 9.0% use ridesharing services and 5.1% use public transit.[32] In heavily congested and polluted cities, such as Beijing, China, ridesharing has been shown to improve greenhouse gas emissions and energy savings.[33]

## LIMITATIONS

There are some limitations to this study that must be acknowledged. It is a survey study that relied on voluntary responses from subjects, although a high percentage (96%) completed the survey. Surveys were not distributed during the hours of midnight to 5 AM, and some differences in subject response may have been missed, especially during a time period of limited public and private transportation options. Recall bias may have been a factor, especially in the elderly subgroup. Some subjects may have been in discomfort or upset at ED crowding conditions while taking the survey, which may have affected their responses. Regarding the survey instrument (Supplement 1), response options were not alphabetized, which may have led some subjects to preferentially choose the first one or two options. There was overlap of income range on the fifth

**Table 5.** Multiple logistic regression analysis of ridesharing service awareness and use.

| | B | SE | Wald | OR | 95% CI | P |
|---|---|---|---|---|---|---|
| Awareness | | | | | | |
| Age | -0.04 | 0.01 | 23.5 | 0.96 | 0.94 to 0.97 | <0.0001 |
| Education | | | | | | |
| Up to Grade 8 | -1.1 | 0.53 | 4.28 | 0.33 | 0.11 to 0.94 | 0.03 |
| Vocational school | -0.56 | 0.97 | 0.33 | 1.18 | 0.23 to 5.96 | 0.83 |
| High School/GED | -0.23 | 0.84 | 0.07 | 1.92 | 0.48 to 7.72 | 0.35 |
| College | 0.11 | 0.85 | 0.01 | 2.85 | 0.70 to 11.52 | 0.13 |
| Graduate school | 0.51 | 1 | 0.25 | 4.03 | 0.75 to 21.55 | 0.1 |
| Income/year | | | | | | |
| < $20,000 | -0.64 | 0.27 | 5.4 | 0.52 | 0.30 to 0.90 | 0.02 |
| $20,001 - $50,000 | 0.29 | 0.45 | 0.4 | 1.34 | 0.54 to 3.28 | 0.15 |
| $50,001 - $100,000 | 1.31 | 0.62 | 4.42 | 3.7 | 1.09 to 12.51 | 0.01 |
| > $100,000 | 1.08 | 0.72 | 2.25 | 2.95 | 0.71 to 12.16 | 0.11 |
| Constant | 3.26 | 1.42 | 5.22 | | | 0.02 |
| Use | | | | | | |
| Age | -0.04 | 0.01 | 45.64 | 0.95 | 0.94 to 0.97 | <0.0001 |
| Education | | | | | | |
| Up to Grade 8 | -1.03 | 0.93 | 1.24 | 0.35 | 0.05 to 2.19 | 0.26 |
| Vocational school | -1.02 | 0.87 | 1.38 | 0.35 | 0.06 to 1.97 | 0.23 |
| High School or GED | 0.72 | 0.34 | 4.32 | 2.05 | 1.04 to 4.06 | 0.03 |
| College | 1.02 | 0.34 | 9 | 2.77 | 1.42 to 5.40 | 0.002 |
| Graduate school | 1.8 | 0.44 | 16.81 | 6.09 | 2.56 to 14.46 | <0.0001 |
| Income/year | | | | | | |
| < $20,000 | 0.01 | 0.26 | 0.001 | 1.01 | 0.59 to 1.69 | 0.97 |
| $20,001 - $50,000 | 0.35 | 0.29 | 1.42 | 1.42 | 0.79 to 2.56 | 0.23 |
| $50,001 - $100,000 | 0.38 | 0.32 | 1.39 | 1.47 | 0.77 to 2.78 | 0.23 |
| > $100,000 | 0.73 | 0.4 | 3.4 | 2.09 | 0.95 to 4.59 | 0.06 |
| Constant | 2.12 | 1.17 | 3.25 | | | 0.07 |

*B,* coefficient; *CI,* confidence interval; *GED,* general educational development; *SE,* standard error; *OR,* odds ratio.

question, and the last question may have been misinterpreted by those subjects without medical insurance. Our ED serves an urban geographic area serving a population of over two million, and this may not reflect other urban or rural settings with different racial and ethnic proportions.

Another limitation is that our study subjects differed from the overall ED population with regard to gender and age, which may affect the generalizability of our findings. The proportion of females responding to the survey was significantly different from the overall ED population (60% vs 49%, $X^2 = 17.9$, $P < 0.0001$). One potential explanation for this gender difference is that females are more likely than males to complete surveys.[34] The average age of the study population was higher than the overall ED population (46.4 ± 18.7 versus 40.0 ± 23.8 years, $P < 0.0001$, unpaired t-test), which likely reflects that patients less than 18 years of age were excluded. Finally, this study was only able to determine demographics, preferences, and rates of knowledge and/or use of ridesharing services; it did not assess underlying socioeconomic or medical reasons for any observed differences.

## CONCLUSION

Patients prefer to be driven home by a family member or friend after discharge from the ED. There is ample awareness of ridesharing services, but only 5% use these services to get home after discharge from the ED. Patients who are older, have less income, and have less education are less likely to be aware of or

have previously used ridesharing services. ED staff may suggest or even contact a ridesharing service for patients at time of discharge to assist in their transportation home. The on-demand and expeditious nature of ridesharing services may have a positive impact on patient satisfaction and ED crowding. Further studies are needed to assess these variables as the prevalence and success of ridesharing services continues to grow.

**ACKNOWLEDGMENTS**

The authors would like to thank our colleagues from our university's Emergency Medicine Research Associate Program for their invaluable assistance in this study.

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*Conflicts of Interest*: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. 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. Emergency department visits. 2017. Available at: https://www.cdc.gov/nchs/fastats/emergency-department.htm. Accessed February 10, 2019.
2. Chang AM, Cohen DJ, Lin A, et al. Hospital strategies for reducing emergency department crowding: a mixed-methods study. *Ann Emerg Med.* 2018;71(4):497-505.e4.
3. Patel H, Morduchowicz S, Mourad M. Using a systematic framework of interventions to improve early discharges. *Jt Comm J Qual Patient Saf.* 2017;43(4):189-96.
4. Hathaway I, Muro M. Ridesharing hits hyper-growth. 2017. Available at: https://www.brookings.edu/blog/the-avenue/2017/06/01/ridesharing-hits-hyper-growth/. Accessed February 10, 2019.
5. Syed ST, Gerber BS, Sharp LK. Traveling towards disease: transportation barriers to health care access. *J Community Health.* 2013;38(5):976-93.
6. Erskine NA, Waring ME, McManus DD, et al. Barriers to healthcare access and long-term survival after an acute coronary syndrome. *J Gen Intern Med.* 2018;33(9):1543-50.
7. Euceda G, Kong WT, Kapoor A, et al. The effects of a comprehensive care management program on readmission rates after acute exacerbation of COPD at a community-based academic hospital. *Chronic Obstr Pulm Dis.* 2018;5(3):185-92.
8. Chan KE, Thadhani RI, Maddux FW. Adherence barriers to chronic dialysis in the United States. *J Am Soc Nephrol.* 2014;25(11):2642-8.
9. Government Accountability Office. Nonemergency medical transportation: updated Medicaid guidance could help states. 2016. Available at: https://www.gao.gov/assets/680/674934.pdf. Accessed February 10, 2019.
10. Baga D. Nobody's health should suffer because they can't find a ride. 2018. Available at: https://medium.com/@justbaga/nobodys-health-should-suffer-because-they-can-t-find-a-ride-b69e8338f372. Accessed February 10, 2019.
11. Ortman JM, Velkoff VA, Hogan H. An aging nation: the older population in the United States. 2014. Available at: http://www.census.gov/prod/2014pubs/p25-1140.pdf. Accessed February 10, 2019.
12. Ride Guru. Uber vs. Lyft vs. taxi: cost analysis across the United States. 2017. Available at: https://ride.guru/content/newsroom/uber-vs-lyft-vs-taxi-cost-analysis-across-the-united-states. Accessed February 10, 2019.
13. Lyft Concierge. 2018. Available at: https://www.lyftbusiness.com/healthcare. Accessed February 10, 2019.
14. Cohen JK. 29% of Lyft riders use the app for healthcare trips, survey finds. 2019. Available at: https://www.beckershospitalreview.com/patient-flow/29-of-lyft-riders-use-the-app-for-healthcare-trips-survey-finds.html. Accessed February 10, 2019.
15. Lyft. New solutions to keep seniors moving. 2016. Available at: https://blog.lyft.com/posts/new-solutions-to-keep-seniors-moving. Accessed February 10, 2019.
16. Uber Health. 2018. Available at: https://www.uberhealth.com/. Accessed February 10, 2019.
17. Collier R. Uber enters medicine but disrupting health care may prove difficult. *CMAJ.* 2018;190(24):E756-7.
18. Powers BW, Rinefort S, Jain SH. Nonemergency medical transportation: delivering care in the era of Lyft and Uber. *JAMA.* 2016;316(9):921-2.
19. Joszt L. CareMore finds success using Lyft to transport Medicare beneficiaries to appointments. 2018. Available at: https://www.ajmc.com/focus-of-the-week/caremore-finds-success-using-lyft-to-transport-medicare-beneficiaries-to-appointments. Accessed February 10, 2019.
20. Vivoda JM, Harmon AC, Babulal GM, et al. E-hail (Rideshare) knowledge, use, reliance, and future expectations among older adults. *Transp Res Part F Traffic Psychol Behav.* 2018;55:426-34.
21. Chaiyachati KH, Hubbard RA, Yeager A, et al. Association of rideshare-based transportation services and missed primary care appointments: a clinical trial. *JAMA Intern Med.* 2018;178(3):383-9.
22. Smith A. On-demand: ride-hailing apps. 2016. Available at: http://www.pewinternet.org/2016/05/19/on-demand-ride-hailing-apps/.

Accessed February 10, 2019.

23. Anderson M, Perrin A. Technology use among seniors. 2017. Available at: http://www.pewinternet.org/2017/05/17/technology-use-among-seniors/. Accessed February 10, 2019.
24. Elliot AJ, Mooney CJ, Douthit KZ, et al. Predictors of older adults' technology use and its relationship to depressive symptoms and well-being. *J Gerontol B Psychol Sci Soc Sci.* 2014;69(5):667–77.
25. Zhang Y, Zhang Y. Exploring the relationship between ridesharing and public transit sse in the United States. *Int J Environ Res Public Health.* 2018;15(8).Pii:E1763.
26. Cai Z, Fan X, Du J. Gender and attitudes toward technology use: a meta-analysis. *Computers & Education.* 2017;105:1-13.
27. Goswami A, Dutta S. Gender differences in technology usage—a literature review. *Open J Business Management.* 2016;4(01):51-9.
28. Rogers B. The social costs of Uber. *University of Chicago Law Review Dialogue.* 2017;82(1):85-102.
29. Dickerson AE, Molnar LJ, Bédard M, et al. Transportation and aging: an updated research agenda to advance safe mobility among older ddults transitioning from driving to non-driving. *Gerontologist.* 2019;59(2):215-21.
30. Whitehill JM, Wilner M, Rataj S, Moreno MA. College students' use of transportation networking companies: An opportunity to decrease substance-impaired driving. *J Am Coll Health.* 2018:1-4. In press.
31. United States Environmental Protection Agency. Sources of greenhouse gas emissions. 2019. Available at: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions. Accessed February 10, 2019.
32. Tomer A. America's commuting choices: 5 major takeaways from 2016 census data. 2017. Available at: https://www.brookings.edu/blog/the-avenue/2017/10/03/americans-commuting-choices-5-major-takeaways-from-2016-census-data/. Accessed February 10, 2019.
33. Yu B, Ma Y, Xue M, et al. Environmental benefits from ridesharing: a case of Beijing. *Appl. Energy.* 2017;191:141–52.
34. Slauson-Blevins K, Johnson KM. Doing gender, doing surveys? Women's gatekeeping and men's non-participation in multi-actor reproductive surveys. *Sociol Inquiry*. 2016;86(3):427-49.

# Impact of Emergency Department Phlebotomists on Left-Before-Treatment-Completion Rates

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*Section Editor:* Gary Johnson, MD
Submission history: Submitted November 21, 2018; Revision received March 11, 2019; Accepted May 11, 2019
Electronically published July 2, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.5.41736

**Introduction:** The emergency department (ED) serves as the primary access point to the healthcare system. ED throughput efficiency is critical. The percentage of patients who leave before treatment completion (LBTC) is an important marker of department efficiency. Our study aimed to assess the impact of an ED phlebotomist, dedicated to obtaining blood specimen collection on waiting patients, on LBTC rates.

**Methods:** This study was conducted as a retrospective observational analysis over approximately 18 months (October 5, 2015-March 31, 2017) for patients evaluated by a triage provider with a door-to-room (DtR) time of > 20 minutes (min). LBTC rates were compared in 10-min DtR increments for when the ED phlebotomist collected the patient's specimen vs not.

**Results:** Of 71,942 patient encounters occurring during the study period, 17,349 (24.1%) met study inclusion criteria. Of these, 1842 (10.6%) had blood specimen collection performed by ED phlebotomy. The overall LBTC rate for encounters included in the analysis was 5.26% (95% confidence interval [CI], 4.94%-5.60%). Weighting the LBTC rates for each 10-min DtR interval using the fixed effects model led to an overall LBTC rate of 2.74% (95% CI, 2.09%-3.59%) for patient encounters with ED phlebotomist collection vs 5.31% (95% CI, 4.97%-5.67%) in those which did not, yielding a relative reduction of 48% (95% CI, 34%-63%). The effect of the phlebotomist on LBTC rates increased as DtR times increased. The difference in the rate of the rise of LBTC percentages, per 10-min interval, was 0.50% (95% CI, 0.19%-0.81%) higher for non-ED phlebotomist encounters vs phlebotomist encounters.

**Conclusion:** ED phlebotomy demonstrated a significant reduction in ED LBTC rates. Further, as DtR times increased, the impact of ED phlebotomy became increasingly significant. Adult EDs with increased rates of LBTC patient encounters may want to consider the implementation of ED phlebotomy. [West J Emerg Med. 2019;20(4)681-687.]

## INTRODUCTION

The emergency department (ED) serves as the primary access point to the healthcare system for more than 117 million patient encounters in the United States (U.S.) annually.[1] Prolonged wait times, extended lengths of stay (LOS), and crowding negatively impact the patient experience and quality of care.[2,3] To meet patient and community healthcare needs, efficient ED throughput and patient flow is critical. Patients who leave the ED prior to completing assessment, treatment, and formal disposition by an ED provider have been identified as a potential marker of systemwide inefficiency.[4]

Patients who leave the ED before treatment completion

(LBTC) represent the total number of patients who leave early.[5] Overall, approximately 0.36%–15% of all patients presenting to an ED in the U.S. LBTC.[5-8] Of these, approximately two-thirds leave before being seen (LBBS) by a physician or physician extender, with the remaining one-third leaving subsequent to being seen (LSBS).[6] LBTC encounters increase ED recidivism, potentially damage the reputation and trust of the healthcare institution with the community, and result in lost revenue.[6,9,10-13] These encounters are considered "missed opportunities" for the healthcare system.[9,14] Accordingly, the proportion of LBBS encounters is used by the Centers for Medicare & Medicaid Services (CMS) as a hospital quality indicator, with previous investigators estimating the desirable LBBS goal at <2%.[4,15]

Excessive wait time, due to crowding and fluctuating patient volumes beyond ED capacity, is the most powerful LBTC predictor.[9,10,12,15-18] The mean time a patient spends in the ED before they leave without being seen is between 102.4–171 minutes (min).[9,19] Initiatives aimed at reducing ED LBTC rates commonly target the patient arrival process in order to reduce the time from patient arrival to room and formal evaluation.[12] A target wait time of fewer than 45 mins, for patients who do not require the most immediate intervention or evaluation as characterized by an Emergency Severity Index (ESI) 3, and 60 mins for ESI 4 patients, has been demonstrated to result in an overall LBBS rate of < 2%.[15] Further, a door-to-room (DtR) time of <20 mins increases the likelihood of obtaining a LBBS rates of <1%.[20]

We predict early patient engagement in a meaningful and tangible way increases the patient's investment in the encounter and will therefore make them less likely to leave early. Our study aimed to describe the impact of blood specimen collection performed by a dedicated ED phlebotomist on patients waiting to be roomed, on LBTC rates as DtR times increase.

*Population Health Research Capsule*

What do we already know about this issue?
*Increased emergency department (ED) wait times, lengths of stay, and patients who leave prior to completing treatment (LBTC) are a potential marker of systemwide inefficiency.*

What was the research question?
*Do dedicated ED phlebotomists decrease LBTC rates on patients waiting to being roomed as door-to-room (DtR) times increase?*

What was the major finding of the study?
*The LBTC rate for encounters with ED phlebotomy was 2.74% vs 5.31% in those without. The effect increased as DtR times increased.*

How does this improve population health?
*ED phlebotomy reduced LBTC rates as DtR times increased. EDs should consider the implementation of ED phlebotomy to reduce LBTC rates.*

## METHODS

The study protocol was reviewed and approved by the Maricopa Integrated Health System institutional review board. The study did not involve human subjects.

### Study Setting and Population

The study ED is a large, urban, single-center, adult Level 1 trauma center at a primary academic training institution and is part of a safety net healthcare system. The annual ED census includes approximately 50,000 patient encounters, with a 14% admission rate and approximately 2000 hours of ED boarding of admitted patients per month. The ED is staffed by emergency medicine (EM)-boarded physicians, advanced practice providers (APPs), and EM residents in a postgraduate year (PGY) 1-3 program.

Upon arrival, patients are triaged by a registered nursing provider before moving to a bedded location in fast track (five beds), the main ED (32 beds), or a designated critical care area (five beds). Patients arriving via emergency medical services (EMS) are offloaded to a hallway bed before being moved to a room. For 12 hours a day, the triage encounter also includes a brief physician-in-triage screening assessment. Stable patients, unable to be roomed immediately due to ED saturation, wait in the ED external waiting room after triage is completed. The ED employs a single ED technician as a phlebotomist eight hours per day (1 PM-9 PM), four days a week (Monday, Tuesday, Thursday, Friday), in overlap with the physician-in-triage. The ED phlebotomist is tasked with blood specimen collection on orders placed during the triage process for patients waiting in the external waiting room prior to being roomed. For encounters occurring when ED phlebotomy is not available, a nurse collects a blood specimen collection after the patient has been roomed.

### Study Protocol

This study was conducted as a retrospective observational analysis over approximately 18 months (October 5, 2015-May 31, 2017). We extracted the following from the ED electronic health record for all patient encounters that occurred during the study window: 1) patient demographics, including gender, age and ESI; 2) whether blood specimen collection was ordered and performed by ED phlebotomy or nursing; 3) encounter throughput metrics, including arrival time to triage, room, blood specimen collection, provider and disposition; and 4) whether the patient completed treatment. Data extraction was performed by a blinded programmer and then reviewed by study authors who were not blinded to the study hypothesis.

LBTC rates for patient encounters when the ED phlebotomist

collected the patient's blood specimen were compared to encounters with nursing collection after the patient was roomed or when the patient did not require collection. We included for analysis only patient encounters with a screening evaluation by a triage physician and a DtR time of >20 mins for analysis. Encounters with undocumented or DtR time of <20 mins were excluded as previous studies have demonstrated very few patients roomed within 20 mins of arrival leave early.[20] We also excluded encounters without a physician-in-triage screening encounter as ED phlebotomy was only available when the physician-in-triage was present, and it has previously been shown that a physician-in-triage screening encounter increases the number of patients who are willing to complete treatment.[21] For analysis, encounters were stratified into 10-min DtR time increments (starting with DtR of >20-≤30 mins). Patient encounters with DtR times beyond six hours were grouped into a single stratum for analysis. Patient encounters without blood specimen collection orders were included, as the patient was unlikely to be aware of whether collection orders were placed when deciding to leave early.

**Data Analysis**

Proportions are described with confidence intervals (CI) using Wilson method with continuity correction. To determine the overall percentage change in LBTC rates, we used a fixed effects model and calculated CIs using the law of propagation of uncertainty (and confirmed them using Monte Carlo simulation of the binomial distribution). Linear regression was performed to evaluate and compare the rate of LBTC increase as DtR times rose. We evaluated significance of the rate increase trend using Cochrane Armitage test. Statistical analysis was performed in Microsoft Excel (Microsoft Corp., Redmond, WA) and R version 3.5.1.

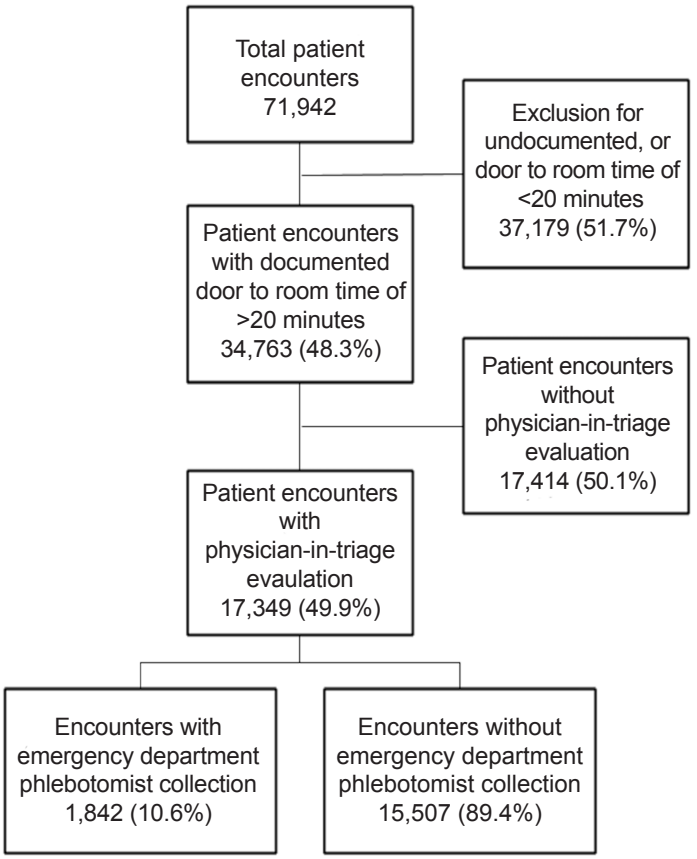


**Figure 1.** Study population inclusion for comparison of throughput with and without ED phlebotomy.

## RESULTS

A total of 71,942 patient encounters occurred during the study period, of which 17,349 (24.1%) met study inclusion criteria (Figure 1). Additionally, one encounter was removed prior to analysis due to incomplete data. Of these, 1842 (10.6%) had blood specimen collection performed by ED phlebotomy prior to being roomed. Patient encounter demographics and throughput characteristics are described in Table 1. Encounters with ED phlebotomist collection were found to have a similar ESI (ESI 3), with an overall lower rate of admission (10.7%) as compared to those without (14.1%). The ED phlebotomist encounter group was found to have similar door to triage (17.98 mins vs. 18.48 mins), shorter door to blood specimen collection (66.16 mins v. 152.26 mins), and longer DtR (122.71 mins vs 74.12 mins), primary physician evaluation (207.10 mins vs 149.21 mins), and disposition times (343.76 mins vs 286.76 mins) as compared to the non-ED phlebotomist encounter group.

The overall LBTC rate for encounters included in the analysis was 5.26% (95% CI, 4.94%-5.60%). Weighting the LBTC rates for each ten-min DtR interval using the fixed effects model demonstrated an overall LBTC rate of 2.74% (95% CI, 2.09%-3.59%) for patient encounters with ED phlebotomist collection vs 5.31% (95% CI, 4.97%-5.67%) in those that did not, yielding a relative reduction of 48% (95% CI, 34%-63%). For encounters with DtR of <20 mins, which were excluded from the primary analysis, we found a significant difference in the LBTC rate for encounters with blood specimen collection performed by ED phlebotomy, as compared to ED nursing collection (1.68% vs. 2.57%, $p < .001$).

Figure 2 demonstrates the LBTC rate at each 10-min interval between patients who had ED phlebotomist-collected specimens as compared to those who did not between DtR times of 20 mins to 240 mins. The effect of the phlebotomist on the LBTC rate increased as DtR times increased. (Cochrane Armitage test for trend was $p < 0.01$.) The difference in the rate of the rise of the LBTC percentage, per ten-min interval, was 0.50% (95% CI, 0.19%-0.81%) higher for non-ED phlebotomist encounters vs phlebotomist encounters. For encounters with DtR of >240 mins, which were excluded from the primary analysis, the LBTC rate for encounters with blood specimen collection performed by ED phlebotomy was found to be 15.8% (95% CI, 10.4%-23.1%), and 36.2% (95% CI, 31.0%-41.7%) for collections performed by ED nursing. Due to smaller sample sizes, larger LBTC rate variability was noted in the phlebotomy group as the DtR time increased.

## DISCUSSION

In addition to prolonged wait times, patient-specific and departmental factors have been shown to predict LBTC rates. Patients of younger age, male gender, a lower socioeconomic status group (including being uninsured or covered by Medicaid), non-English speaking or from a minority group, and with lower acuity presentations are at a higher risk of incomplete visits.[6,11,12,17,18,22-26] Additionally, department specific- predictors include visits in a metropolitan or urban area, encounters at a teaching institution, and a lack of department management by an EM-trained physician.[12,15,22,23] While ED providers have little control over patient-specific or institution-location predictors, at the departmental level changes can be implemented to identify and retain patients at higher risk for leaving early.

Initiatives aimed at reducing ED LBTC rates often target the "bottleneck" effect created during the patient arrival process.[12] A variety of approaches directed at disrupting the arrival bottleneck, through increased operational efficiency and reduction in the time from patient arrival to provider evaluation, have been successfully demonstrated in the literature.[12,27-29] Approaches include the implementation of an ED fast track for lower acuity patients, a "team" approach to patient triage including a physician-in-triage screening evaluation, the initiation of patient treatments during the triage process, and dedicated ED technicians performing minor procedures on waiting patients.[21,30-32] Such approaches have demonstrated significant reduction in patient wait times, door to physician evaluation, and total LOS.[21,32-42] Further, such approaches have been demonstrated to reduce LBTC rates.[21,32,36,38,39,42,43,46] Unfortunately, deployment of extensive changes to the ED arrival process and triage system may not be feasible due to significant development time, effort, and expense.

To our knowledge, the impact of an ED phlebotomist encounter on premature departure rates has not been previously evaluated. In the study population, the ED phlebotomist group demonstrated a significant reduction in LBTC rates as compared to encounters when ED phlebotomy was not involved in the patient care process. This reduction in LBTC occurred despite an overall longer time from DtR, physician assessment, and disposition for encounters that included ED phlebotomy. Further, the impact on LBTC rates increased by half a percent for every 10-min increase in DtR, representing a population of encounters increasingly difficult to maintain in the ED. While the reason for the reduction in LBTC rates is unclear, it is reasonable to infer that patients who perceive their care has begun or is ongoing may be more inclined to wait longer to completion. Departments with limited ability to significantly change the patient arrival process may want to consider deployment of an ED phlebotomist in triage to reduce LBTC rates.

Dedicated ED phlebotomists offer additional advantages to patient care. Prior studies have demonstrated an increase in the rate of effective phlebotomy, improved patient satisfaction, a reduction in hemolysis, contamination, and specimen-misidentification rates. Further, phlebotomy utilization has been shown to result in a reduction in cost to the patient and hospital system, decreased needle-stick injury rates among providers, and a potential reduction in ED LOS.[44-50] In addition to the reduction in ED LBTC rates, institutions should

**Table 1.** Patient demographic and throughput characteristics.

| Demographics and throughput characteristics | Encounters with ED phlebotomist collection | Encounters without ED phlebotomist collection |
|---|---|---|
| Total encounters | 1842 | 15507 |
| Age (median) | 42.03 | 42.29 |
| Female (%) | 1288 (69.92%) | 8243 (53.16%) |
| Admissions (%) | 91 (4.94%) | 1158 (7.47%) |
| Emergency Severity Index (ESI) (Median) | 3.0 (IQR 3-4) | 3.0 (IQR 3-4) |
| Median door to (minutes): | | |
| Triage | 17.98 | 18.48 |
| Room | 122.71 | 74.12 |
| Blood draw | 66.16 | 152.26 |
| Primary physician evaluation* | 207.10 | 149.21 |
| Disposition | 343.76 | 286.76 |

*IQR*, interquartile range; *ED*, emergency department.
*Primary physician evaluation subsequent to physician-in-triage screening.

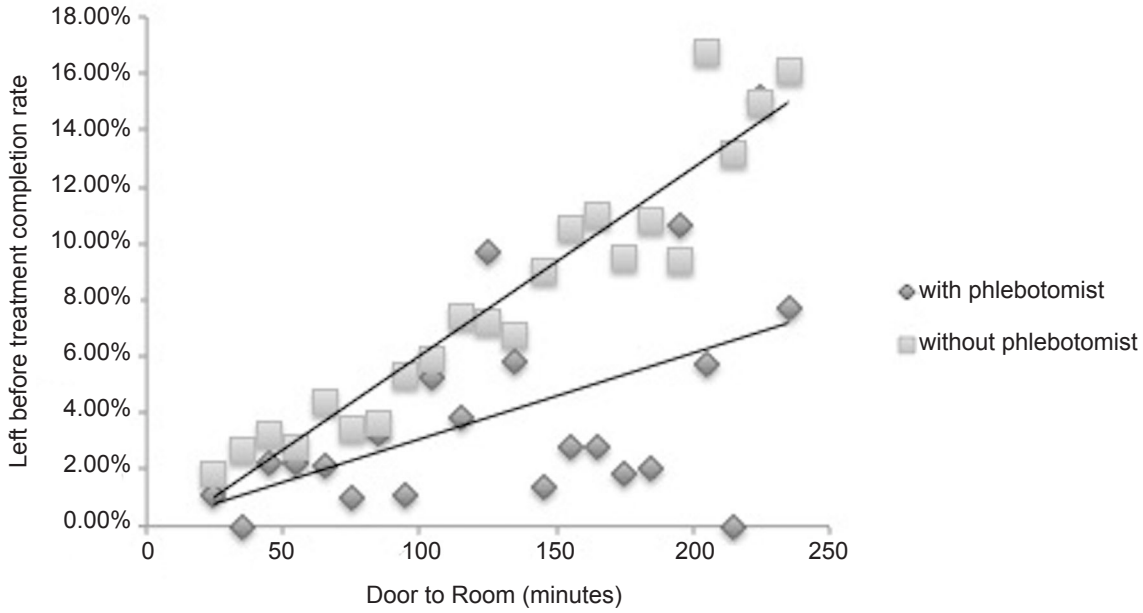


**Figure 2.** Left-before-treatment-completion percentage between time intervals 20 and 240 miutes.

consider these additional advantages when considering the implementation of ED phlebotomists.

## LIMITATIONS

During study development and implementation, we identified several potential limitations. During the study window, a dedicated ED fast track was implemented, which altered patient flow. However, the lack of a formal ED fast track would likely have amplified study findings, as most ED fast track patients are of lower acuity, do not get blood drawn, and therefore are more likely to leave sooner.[12] This study was conducted retrospectively in a single, adult ED that uses a provider-in-triage, fast track, and ED technicians. Generalizability to dissimilar departments may be limited.

While ESI (ESI 3) and patient age (42.03 vs. 42.29) were similar, additional patient demographics, including chief complaint, were not obtained and may limit comparison of the study groups. There was a predominance of female patients in the group that received ED phlebotomy collection. Previous studies have demonstrated a lower LBTC rate among female patients, which may have impacted the study results. Additionally, patients without blood specimen-collection orders after a physician-in-triage evaluation, by definition, were grouped with the patients without phlebotomy. This may have confounded the study results, as these patients were potentially lower risk, and as a result, more likely to LBTC. However, the distribution of patients by ESI in both study groups was similar.

Median DtR, primary physician encounter, and disposition was prolonged in the ED phlebotomy group. We believe that this was the result of ED crowding during the ED phlebotomist shift timeframe rather than a negative effect of ED phlebotomy. Patient disposition, including LBTC designation, is assigned by nursing providers in real time. Nursing is trained to assign the correct disposition designation, but it is possible that the incorrect disposition type may have been applied at times, as it was not possible to review each chart for confirmation. When not performing blood specimen collections, the ED phlebotomist was tasked with assisting with other department tasks, including stocking and performing electrocardiograms. While the impact of the performance of these tasks was not quantifiable as part of this study, it is possible that utilization of dedicated ED phlebotomists would also increase the impact on LBTC rates.

## CONCLUSION

The utilization of ED phlebotomy in waiting patients resulted in a significant reduction in ED LBTC rates. Further, as DtR times increased, the impact of ED phlebotomy became increasingly significant. Adult EDs with increased LBTC rates may want to consider the implementation of ED phlebotomy.

## ACKNOWLEDGEMENTS

The study authors would like to acknowledge WenShan Lin for assistance with data collection and Bikash Bhattarai, PhD, for contributions to study design planning and data analysis.

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*Conflicts of Interest*: By the WestJEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. Murtaza Akhter has a career development grant from the Emergency Medicine Foundation for his basic science research in traumatic brain injury. There are no other conflicts of interests to disclose.



## REFERENCES

1. Niska R, Bhuiya F, Xu J. National Hospital Ambulatory Medical Care Survey: 2007 emergency department summary. *Natl Health Stat Report*. 2010;26:1-31.
2. Barish RA, McGauly PL, Arnold TC. Emergency room crowding: a marker of hospital health. *Trans Am Clin Climatol Assoc*. 2012;123:304-10.
3. Arab M, Movahed Kor E, Mahmoodi M. The effect of time-to-provider, left-without-treatment and length-of-stay on patient satisfaction in training hospitals' emergency department, Iran. *Iran J Public Health*. 2015;44(10):1411-7.
4. Artenstein AW, Rathlev NK, Neal D, et al. Decreasing emergency department walkout rate and boarding hours by improving inpatient length of stay. *West J Emerg Med.* 2017;18(6):982-92.
5. Wiler JL, Welch S, Pines J, et al. Emergency department performance measures updates: proceedings of the 2014 Emergency Department Benchmarking Alliance Consensus Summit. *Acad Emerg Med*. 2015;22(5):542-53.
6. Moe J, Belsky JB. Comparing patients who leave the ED prematurely, before vs after medical evaluation: a National Hospital Ambulatory Medical Care Survey analysis. *Am J Emerg Med.* 2016;34(5):830-3.
7. Bindman AB, Grumbach K, Keane D, et al. Consequences of queuing for care at a public hospital emergency department. *JAMA*. 1991;266(8):1091-6.
8. Arendt KW, Sadosty AT, Weaver AL, et al. The left-without-being-seen patients: What would keep them from leaving? *Ann Emerg Med.* 2003;42(3):317-23.
9. Carron P-N, Yersin B, Trueb L, et al. Missed opportunities: evolution of patients leaving without being seen or against medical advice during a six-year period in a Swiss tertiary hospital emergency department. *Biomed Res Int*. 2014;2014:690368.
10. Rowe BH, Channan P, Bullard M, et al. Characteristics of patients who leave emergency departments without being seen. *Acad Emerg Med.* 2006;13(8):848-52.
11. Tropea J, Sundararajan V, Gorelik A, et al. Patients who leave without being seen in emergency departments: an analysis of predictive factors and outcomes. *Acad Emerg Med.* 2012;19(4):439-47.
12. Clarey AJ, Cooke MW. Patients who leave emergency departments without being seen: literature review and English data analysis. *Emerg Med J*. 2012;29(8):617-21.
13. Pines JM, Batt RJ, Hilton JA, et al. The financial consequences of lost demand and reducing boarding in hospital emergency departments. *Ann Emerg Med*. 2011;58(4):331-40.
14. Sørup CM, Jacobsen P, Forberg JL. Evaluation of emergency department performance - a systematic review on recommended performance and quality-in-care measures. *Scand J Trauma Resusc Emerg Med*. 2013;21:62.
15. Lucas J, Batt RJ, Soremekun OA. Setting wait times to achieve targeted left-without-being-seen rates. *Am J Emerg Med.* 2014;32(4):342-5.
16. Polevoi SK, Quinn J V, Kramer NR. Factors associated with patients who leave without being seen. *Acad Emerg Med*. 2005;12(3):232-6.
17. Kennedy M, MacBean CE, Brand C, et al. Review article: leaving the emergency department without being seen. *Emerg Med Australas.* 2008;20(4):306-13.
18. Fernandes CM, Daya MR, Barry S, et al. Emergency department patients who leave without seeing a physician: the Toronto Hospital experience. *Ann Emerg Med.* 1994;24(6):1092-6.
19. Fayyaz J, Khursheed M, Mir MU, et al. Missing the boat: odds for the patients who leave ED without being seen. *BMC Emerg Med*. 2013;13:1.
20. Pielsticker S, Whelan L, Arthur AO, et al. Identifying patient door-to-room goals to minimize left-without-being-seen rates. *West J Emerg Med.* 2015;16(5):611-8.
21. Rogg JG, White BA, Biddinger PD, et al. A long-term analysis of physician triage screening in the emergency department. *Acad Emerg Med.* 2013;20(4):374-80.
22. Pham JC, Ho GK, Hill PM, et al. National study of patient, visit, and hospital characteristics associated with leaving an emergency department without being seen: predicting LWBS. *Acad Emerg Med.* 2009;16(10):949-55.
23. Hsia RY, Asch SM, Weiss RE, et al. Hospital determinants of emergency department left without being seen rates. *Ann Emerg Med.* 2011;58(1):24-32.
24. Ding R, McCarthy ML, Li G, et al. Patients who leave without being seen: their characteristics and Hhstory of emergency department use. *Ann Emerg Med.* 2006;48(6):686-93.
25. Hall J, Jelinek GA. Characteristics and outcomes of patients who "did not wait" after attending Perth public hospital emergency departments, 2000-2003. *Med J Aust.* 187(11-12):626-9.
26. Stang AS, McCusker J, Ciampi A, et al. Emergency department conditions associated with the number of patients who leave a pediatric emergency department before physician assessment. *Pediatr Emerg Care.* 2013;29(10):1082-90.
27. McHugh M, Van Dyke KJ, Howell E, et al. Changes in patient flow among five hospitals participating in a learning collaborative. *J Healthc*

*Qual.* 2013;35(1):21-9.
28. Sayah A, Rogers L, Devarajan K, et al. Minimizing ED waiting times and improving patient flow and experience of care. *Emerg Med Int.* 2014;2014:981472.
29. Sharieff GQ, Burnell L, Cantonis M, et al. Improving emergency department time to provider, left-without-treatment rates, and average length of stay. *J Emerg Med.* 2013;45(3):426-32.
30. Fernandes CM, Price A, Christenson JM. Does reduced length of stay decrease the number of emergency department patients who leave without seeing a physician? *J Emerg Med.* 1997;15(3):397-9.
31. Grouse A, Bishop R. Non-medical technicians reduce emergency department waiting times. *Emerg Med (Fremantle).* 2001;13(1):66-9.
32. Chan TC, Killeen JP, Kelly D, et al. Impact of rapid entry and accelerated care at triage on reducing emergency department patient wait times, lengths of stay, and rate of left without being seen. *Ann Emerg Med.* 2005;46(6):491-7.
33. Terris J, Leman P, O'Connor N, et al. Making an IMPACT on emergency department flow: improving patient processing assisted by consultant at triage. *Emerg Med J.* 2004;21(5):537-41.
34. Choi YF, Wong TW, Lau CC. Triage rapid initial assessment by doctor (TRIAD) improves waiting time and processing time of the emergency department. *Emerg Med J.* 2006;23(4):262-5.
35. Travers JP, Lee FCY. Avoiding prolonged waiting time during busy periods in the emergency department: Is there a role for the senior emergency physician in triage? *Eur J Emerg Med*. 2006;13(6):342-8.
36. Abdulwahid MA, Booth A, Kuczawski M, et al. The impact of senior doctor assessment at triage on emergency department performance measures: systematic review and meta-analysis of comparative studies. *Emerg Med J.* 2016;33(7):504-13.
37. Subash F, Dunn F, McNicholl B, et al. Team triage improves emergency department efficiency. *Emerg Med J.* 2004;21(5):542-4.
38. Burström L, Engström M-L, Castrén M, et al. Improved quality and efficiency after the introduction of physician-led team triage in an emergency department. *Ups J Med Sci.* 2016;121(1):38-44.
39. Holroyd BR, Bullard MJ, Latoszek K, et al. Impact of a triage liaison physician on emergency department overcrowding and throughput: a randomized controlled trial. *Acad Emerg Med.* 2007;14(8):702-8.
40. Han JH, France DJ, Levin SR, et al. The effect of physician triage on emergency department length of stay. *J Emerg Med.* 2010;39(2):227-33.
41. Partovi SN, Nelson BK, Bryan ED, et al. Faculty triage shortens emergency department length of stay. *Acad Emerg Med*. 2001;8(10):990-5.
42. Elder E, Johnston AN, Crilly J. Review article: systematic review of three key strategies designed to improve patient flow through the emergency department. *Emerg Med Australas* 2015;27(5):394-404.
43. Oredsson S, Jonsson H, Rognes J, et al. A systematic review of triage-related interventions to improve patient flow in emergency departments. *Scand J Trauma Resusc Emerg Med.* 2011;19:43.
44. MacPhee M, Venous Access Task Force. Using evidence-based practice to create a venous access team: the Venous Access Task Force of the Children's Hospital of Denver. *J Pediatr Nurs.* 2002;17(6):450-4.
45. Bologna LJ, Mutter M. Life after phlebotomy deployment: reducing major patient and specimen identification errors. *J Healthc Inf Manag.* 2002;16(1):65-70.
46. McGuff J, Popovsky MA. Needlestick injuries in blood collection staff. A retrospective analysis. *Transfusion.* 1989;29(8):693-5.
47. Self WH, Talbot TR, Paul BR, et al. Cost analysis of strategies to reduce blood culture contamination in the emergency department: sterile collection kits and phlebotomy teams. *Infect Control Hosp Epidemiol.* 2014;35(8):1021-8.
48. Gander RM, Byrd L, DeCrescenzo M, et al. Impact of blood cultures drawn by phlebotomy on contamination rates and health care costs in a hospital emergency department. *J Clin Microbiol*. 2009;47(4):1021-4.
49. Dinh MM, Green TC, Newsome D, et al. Impact of technical assistants for venepuncture and intravenous cannulation on overall emergency department performance. *Emerg Med Australas.* 2011;23(6):726-31.
50. Tintinalli J, Hayden S, Larson J. Emergency department phlebotomist: a failed experiment. *Ann Emerg Med.* 2004;44(2):185-6.

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

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Electronically published July 2, 2019
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2019.4.44160

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

Erratum in
*West J Emerg Med*. 2019 July;20(4):688-689. There was a dosing error in Table 2 regarding haloperidol dosing in pediatric agitation. The dose is listed as 0.55 mg/kg/dose and should be corrected to 0.05-0.1 mk/kg/dose.

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

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

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

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

PMCID: PMC6404720 [PubMed - indexed for MEDLINE]

**Table 2.** Medication reference.

| Medication | Dose | Peak effect | Max daily dose | Notes/monitoring |
|---|---|---|---|---|
| Diphenhydramine (antihistaminic) | PO/IM: 12.5-50mg<br>1 mg/kg/dose | PO: 2 hours | Child: 50-100 mg<br>Adolescent: 100-200 mg | Avoid in delirium.<br>Can be combined with haloperidol or chlorpromazine if concerns for EPS.<br>Can cause disinhibition or delirium in younger or DD youth. |
| Lorazepam (benzodiazepine) | PO/IM/IV/NGT: 0.5 mg-2 mg<br>0.05 mg-0.1 mg/kg/dose | IV: 10 minutes<br>PO/IM: 1-2 hours | Child: 4 mg<br>Adolescent: 6-8 mg<br>Depending on weight/proir medication exposure | Can cause disinhibition or delirium in younger or DD youth.<br>Can be given with haloperidol, chlorpromazine or risperidone.<br>Do not give with olanzapine (especially IM due to risk of respiratory suppression. |
| Clonidine (alpha2 agonist) | PO: 0.05 mg-0.1 mg | PO: 30-60 minutes | 27-40.5 kg: 0.2 mg/day<br>40.5-45 kg: 0.3 mg/day<br>>45 kg: 0.4mg/day | Monitor for hypotension and bradycardia.<br>Avaoid giving with BZD or atypicals due to hypotension risk. |
| Chlorpromazine (antipsychotic) | PO/IM: 12.5-60 mg (IM should be half PO dose)<br>0.55 mg/kg/dose | PO: 30-60 minutes<br>IM: 15 minutes | Child <5 years: 40mg/day<br>Child >5 years: 75mg/day | Monitor hypotension.<br>Monitor for QT prolongation. |
| Haloperidol (antipsychotic) | PO/IM: 0.5 mg-5 mg (IM should be half a dose of PO)<br>0.05-0.1 mg/kg/dose | PO: 2 hours<br>IM: 20 minutes | 15-40 kg: 6mg<br>>40 kg: 15 mg<br>Depending on prior antipsychotic exposure | Monitor hypotension.<br>Consider EKG or cardiac monitoring for QT prolongation, especially for IV administration.<br>Note EPS risk with MDD > 3mg/day, with IV dosing having very high EPS risk.<br>Consider AIMS testing. |
| Olanzapine (antipsychotic) | PO/ODT or IM: 2.5-10 mg (IM should be half or 1/4 dose of PO) | PO: 5 hours (range 1-8 hours)<br>IM: 15-45 minutes | 10-20 mg Depending on antipsychotic exposure | Do not give with or within 1 hour of any BZD given risk for respiratory suppresion |
| Risperidone (antipsychotic) | PO/ODT: 0.25-1mg<br>0.005-0.01mg/kg/dose | PO: 1 hour | Child: 1-2 mg<br>Adolescent: 2-3 mg Depending on antipsychotic exposure | Can cause akathisia (restlessness/agitaion) in higher doses. |
| Quetiapine (antipsychotic) | PO: 25-50 mg<br>1-1.5 mg/kg/dose (or divided) | PO: 30 minutes-2 hours | >10 years: 600 mg<br>Depending on prior antipsychotic exposure | More sedating at lower doses<br>Monitor hypotension. |

*PO,* by mouth; *IM*, intramuscular; *IV*, intravenous; *NGT*, nasogastric tube; *mg*, milligram; *EPS*, extrapyramidal symptoms; *DD*, developmental disability; mg/kg, milligrams per kilogram; *BZD*, benzodiazepines; *EKG*, electrocardiogram; *AIMS*, Abnormal Involuntary Movement Scale; *MDD*, major depressive disorder; *ODT*, orally dissolving tablet.

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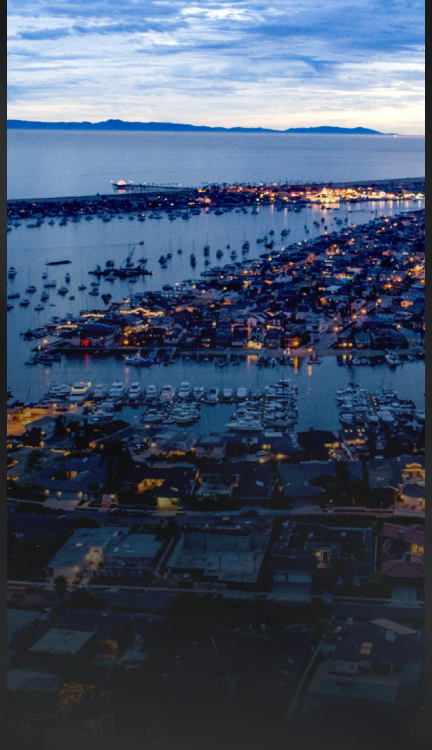

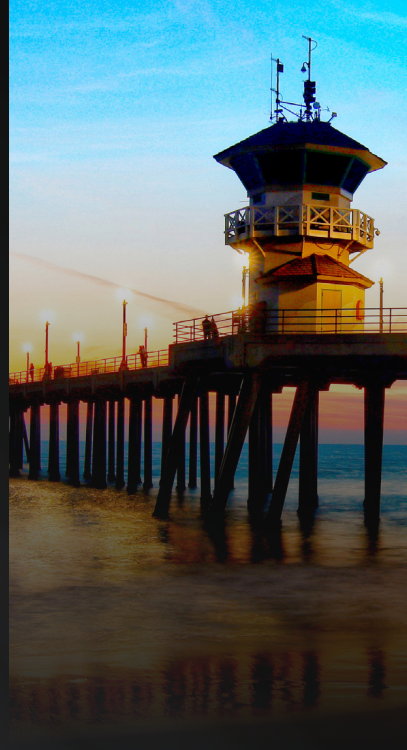

# ADVANCED›

## YOUR LIFE IN EMERGENCY MEDICINE

› CALIFORNIA ACEP'S ANNUAL CONFERENCE 2019

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

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

CALIFORNIA ACEP
AMERICAN COLLEGE OF EMERGENCY PHYSICIANS