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Original Contribution

Impact of point-of-care ultrasonography on ED time to disposition for patients with nontraumatic shock☆,☆☆

M. Kennedy Hall, MD [a,*], R. Andrew Taylor, MD [b], Seth Luty [c], I. Elaine Allen, PhD [d], Chris L. Moore, MD [b]

[a] Division of Emergency Medicine, University of Washington School of Medicine, Harborview Medical Center, Box 359702, Mailstop 3EC-24, 325 9th Ave, Seattle, WA 98104, USA
[b] Department of Emergency Medicine, Yale University School of Medicine, 464 Congress Ave, Suite 260, New Haven, CT 06519, USA
[c] Yale Center for Clinical Investigation, Yale University School of Medicine, Yale Center for Clinical Investigation, 2 Church St South, Suite 404, New Haven, CT 06519, USA
[d] Department of Epidemiology & Biostatistics, University of California, Global Health & Clinical Sciences Building, 550 16th St, 2nd Floor, Box #0560, San Francisco, CA 94158-2549

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ABSTRACT

Study objective: Nontraumatic shock in the emergency department (ED) has multiple causes and carries in-hospital mortality approaching 20%, underscoring the need for prompt diagnosis and treatment. Diagnostic ultrasonography at the point of care is one method that may improve the ability of ED physicians to quickly diagnose and treat. This study assesses the effect of the use and timing of point-of-care (POC) ultrasonography on time to disposition request.
Methods: This retrospective study across 4 Connecticut EDs compared propensity score matched shock patients who did and did not receive POC ultrasonography. Two propensity score matches were performed: the first using covariates of time to disposition from previous literature and the second using 25 novel covariates identified from electronic health records using machine learning to reduce variable selection biases.
Results: A total of 3834 unique patients presented with shock during an 18-month period, and 703 (18.3%) patients received POC ultrasonography. Mean time to disposition for all patients was 255.4 minutes (interquartile range, 163.8). After propensity score matching, patients had a mean reduction of 26.7 minutes (95% confidence interval [CI], 2.8-58.3) in time to disposition when POC ultrasonography was performed within 1 hour of ED arrival and a lesser reduction of 16.7 minutes (95% CI, −2.8 to 35.5) when POC ultrasonography was performed within 2 hours. There was no evidence of reduction in time to disposition when ultrasonography was performed after 2 hours (16.7 minutes; 95% CI, −14.3 to 29.9). Propensity score models using machine learning–selected variables yielded similar results.
Conclusion: Performance of POC ultrasonography likely improves time to disposition when performed early on ED patients with shock.

1. Introduction

1.1. Background

Hypotension and shock are late-stage manifestations of injury and disease characterized by tissue hypoperfusion and abnormal cellular metabolism [1–3]. Within the emergency department (ED), hypotension increases the probability of in-hospital death by 3- to 6-fold depending on nadir systolic blood pressures (SBPs) and how long patients remain hypotensive [4]. Although there are multiple etiologies of shock with overlapping definitions [5], all types have significant morbidity and mortality [3,5].

Unfortunately, management of underlying causes of shock can be inhibited by diagnostic uncertainty because more than one type of shock may be present in a single patient [6–9] and clinical features of shock can be highly variable [3,10]. However, point-of-care (POC) ultrasonography may help improve and expedite diagnosis.

1.2. Importance

Previous randomized trials have demonstrated that POC ultrasonography can accelerate emergency care for traumatic presentations in idealized situations [11], but no studies have yet examined the effect of POC ultrasonography on ED length of stay in the setting of nontraumatic hypotension. In both settings, management of the cause of hypotension is crucial and may involve lifesaving procedures [6].

One randomized controlled trial by Jones and colleagues [9] examining 184 patients with nontraumatic hypotension showed that POC ultrasonography performed in the first 15 minutes decreased number of differential diagnoses within that time vs POC ultrasonography performed at 30 minutes, highlighting the possibility that POC ultrasonography use

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* Corresponding author. Division of Emergency Medicine, University of Washington School of Medicine, Harborview Medical Center, Box 359702, Mailstop 3EC-24, 325 9th Ave, Seattle, WA 98104, USA.

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may improve diagnostic accuracy. Although the study of Jones et al. was promising, there has been an absence of supporting, definitive, and real-world data.

POC ultrasonography is used infrequently [12] and in a nonstandardized way, with more than 15 hypotensive POC ultrasonography protocols currently available [13–28]. It is unknown whether standardization, adoption, and relevant training should be increased. However, because of general acceptance of POC ultrasonography, it would likely be unethical to randomize its use [29]. Instead, a data-driven approach using retrospective data may be the only option for further investigation. With such an approach, treatment groups may vary from control groups in terms of baseline characteristics, obscuring inference due to covariate imbalance [30]. Propensity score analysis is a helpful method to account for covariate imbalance by collapsing the probability of receiving a treatment into a single score, conditional on a set of observed covariates, thereby creating a control group with similar characteristics to allow for meaningful comparison [31]. For example, because sicker patients are likely to receive POC ultrasonography and sicker patients are more likely to have a faster time to disposition request (TTD), being able to account for severity of illness and match patients who did and did not receive POC ultrasonography via propensity scoring is key to performing meaningful and unbiased comparisons.

1.3. Goals of this investigation

Our goal for this study is to determine the effect of POC ultrasonography on the TTD in patients with nontraumatic hypotension. We build upon previous work by (1) assessing effects of POC ultrasonography in a real-world setting across multiple hospital sites, (2) increasing study sample size via large-scale electronic health record (EHR) data, and (3) examining the effect size when POC ultrasonography is performed within specific time windows beginning from ED arrival: <15 minutes, 15 minutes–1 hour, 1–2 hours, and 2–4 hours.

2. Methods

2.1. Study design, setting, and population

This was a retrospective analysis of admitted adult patients presenting to 1 of 4 EDs over a 19-month period (March 2013 through September 2014). All EDs are part of a single health care system. One is an urban, academic, level 1 trauma center with 85,000 annual visits and 5 POC ultrasonography machines available for ED use; the second ED is an urban level 2 trauma center without emergency medicine residents that sees approximately 70,000 patients per year and has 3 POC ultrasonography machines; the third ED is a community-based, urban, and an auxiliary training site for emergency medicine residents with an annual census of approximately 77,000 patients per year and 2 POC ultrasonography machines; the fourth ED is a suburban free-standing community-based center with an annual census of approximately 30,000 patients per year and 1 POC ultrasonography machine. All 3 hospital-based EDs have intensive care units (ICUs) capable of providing advanced care for hypotensive patients. All hospitals used the same POC ultrasonography machine (Philips Sparq; Royal Philips Electronics, Amsterdam, the Netherlands), an Epic (Verona, Wisconsin)-based EHR, and an electronic POC ultrasonography image archival and storage system (QPATH Telexy Healthcare, Everett, WA).

2.2. Selection of participants

We included all adult (age ≥ 18 years) patients meeting shock criteria who were admitted to the hospital. Shock criteria were as follows: first measurements of SBP less than 90 mm Hg or a shock index (heart rate/SBP) > 1 with a concurrent SBP < 121. These criteria are in line with previously reported values for circulatory shock [6]. For patients with multiple encounters, only 1 visit was included (selected at random). Patients were excluded in the cases of trauma activation during the ED visit, death during ED visit, discharge from the ED, or missing ED disposition timestamp.

2.3. Interventions

Point-of-care ultrasonography was performed by attendings, residents, interns, and medical students in a hospital system with a mature POC ultrasonography program and 11 POC ultrasonography fellowship-trained attendings. Diagnostic POC ultrasonography procedures performed were any combination of abdominal aorta, focused assessment with sonography in trauma examination, echo, or thoracic ultrasonography.

2.4. Methods and measurements

All data elements for each patient were obtained from the enterprise data warehouse CLARITY (Epic). Structured Query Language queries were used to abstract all demographic information (age, sex, insurance status, employment and marital status, race), previous health status (medical and surgical history, outpatient medications), ED health status (triage emergency severity index, chief concern, vital signs, mental status, laboratory result values, code status, ED clinical impression, and hospital discharge diagnosis), ED services rendered (supplemental oxygen type and electrocardiogram performance), and operational details (ED time of initial presentation, weekend presentation, ED arrival method).

International Classification of Diseases, Ninth Revision, diagnosis codes were recoded using Agency for Healthcare Research and Quality Clinical Classification Software (http://www.hcup-us.ahrq.gov/toolssoftware/ccs/ccs.jsp), and prior medication use was recategorized using the Anatomical Therapeutic Chemical Classification System 9. Repeated measurements of vitals and lactate values were recoded into variables indicating first, last, mean, minimum, maximum, and trend values. All continuous variables were discretized via k-means clustering into 6 levels including a missing value indicator to facilitate machine learning [32]. Data were stored in a centralized database (Filemaker Pro 13.0; Filemaker Inc, Santa Clara, CA), and Stata 13 (StataCorp, College Station, TX) was used for descriptive analyses and data recoding.

The primary outcome in this study was time to ED disposition, calculated from EHR timestamps of ED arrival and time of admission request. This study was approved by the institutional review board.

2.5. Analysis

2.5.1. Power and sample size calculation

Predictions of TTD and effect size were drawn from 2 previous studies: In 1 study of all-comers to an ED, the TTD was 75 minutes (interquartile range [IQR], 58-89) [33]; in a randomized trial of POC ultrasonography for traumatic presentations, there was a 40% reduction in time [11,34]. Using a robust estimation for SD where SD = IQR/1.35 [35], a conservative predicted decrease in disposition time of approximately of 8 minutes (a 10% reduction), 81-87 treated subjects, and 784-2426 control subjects would be needed to detect a difference with power at 0.8 and significance level at .05, with a 5% rate of exclusion.

2.5.2. Propensity score matching

Propensity score analyses were performed to evaluate the effect of POC ultrasonography on TTD using multivariate models on each of the following time periods: (1) the first 15 minutes, 2) 15 minutes–1 hour, (3) 1–2 hours, and (4) 2–4 hours, using traditional covariates drawn from the literature as detailed in Appendix A. Kernel matching (also known as kernel weighting) was performed in Stata 13 (package: *psmatch2*, kernel bandwidth = 0.06, probit regression) [31]. Covariate balance was evaluated using the absolute standardized difference of bias between treated and untreated groups. Average treatment effects of POC ultrasonography were calculated along with bootstrapped 95% confidence intervals (CIs) (2500 iterations).