Bedside Ultrasound Reduces Diagnostic Uncertainty and Guides Resuscitation in Patients With Undifferentiated Hypotension*

Hamid Shokoohi, MD, MPH, RDMS, RDCS, FACEP[1]; Keith S. Boniface, MD, RDMS, RDCS[1]; Ali Pourmand, MD, MPH, RDMS, FACEP[1]; Yiju T. Liu, MD, RDMS[2]; Danielle L. Davison, MD[3]; Katrina D. Hawkins, MD[3]; Rasha E. Buhumaid, MD, RDMS, RDCS[4]; Mohammad Salimian, MD[1]; Kabir Yadav, MDCM, MS, MSHS, FACEP[2]

Objectives: Utilization of ultrasound in the evaluation of patients with undifferentiated hypotension has been proposed in several protocols. We sought to assess the impact of an ultrasound hypotension protocol on physicians' diagnostic certainty, diagnostic ability, and treatment and resource utilization.

Design: Prospective observational study.

Setting: Emergency department in a single, academic tertiary care hospital.

Subjects: A convenience sample of patients with a systolic blood pressure less than 90 mm Hg after an initial fluid resuscitation, who lacked an obvious source of hypotension.

Interventions: An ultrasound-trained physician performed an ultrasound on each patient using a standardized hypotension protocol. Differential diagnosis and management plan was solicited from the treating physician immediately before and after the ultrasound. Blinded chart review was conducted for management and diagnosis during the emergency department and inpatient hospital stay.

Measurements and Main Results: The primary endpoints were the identification of an accurate cause for hypotension and change in physicians' diagnostic uncertainty. The secondary endpoints were changes in treatment plan, use of resources, and changes in disposition after performing the ultrasound. One hundred eighteen patients with a mean age of 62 years were enrolled. There was a significant 27.7% decrease in the mean aggregate complexity of diagnostic uncertainty before and after the ultrasound hypotension protocol (1.85–1.34; −0.51 [95% CI, −0.41 to −0.62]) as well as a significant increase in the absolute proportion of patients with a definitive diagnosis from 0.8% to 12.7%. Overall, the leading diagnosis after the ultrasound hypotension protocol demonstrated excellent concordance with the blinded consensus final diagnosis (Cohen $k = 0.80$). Twenty-nine patients (24.6%) had a significant change in the use of IV fluids, vasoactive agents, or blood products. There were also significant changes in major diagnostic imaging (30.5%), consultation (13.6%), and emergency department disposition (11.9%).

Conclusions: Clinical management involving the early use of ultrasound in patients with hypotension accurately guides diagnosis, significantly reduces physicians' diagnostic uncertainty, and substantially changes management and resource utilization in the emergency department. (*Crit Care Med* 2015; 43:2562–2569)

Key Words: diagnostic uncertainty; resuscitation; ultrasound; undifferentiated hypotension

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[1]Department of Emergency Medicine, The George Washington University Medical Center, Washington, DC.

[2]Department of Emergency Medicine, Harbor-UCLA Medical Center, Torrance, CA.

[3]Department of Critical Care Medicine and Anesthesiology, The George Washington University Medical Center, Washington DC.

[4]Department of Emergency Medicine, Shiekh Khalifa Medical City, Abu Dhabi, United Arab Emirates.

This study was performed at the George Washington University Hospital, Washington, DC.

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For information regarding this article, E-mail: shokoohi@gwu.edu

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Patients with sustained hypotension and shock are at high risk for developing serious adverse events, with an in-hospital mortality as high as 25% (1–3). The diagnosis and initial management of patients with hypotension in the emergency department (ED) must be prompt and accurate in order to optimize patient outcomes. History and physical examination may give an incomplete picture, and the diagnostic challenge is increased in complex patients (e.g., hemorrhage in a patient with preexisting cardiomyopathy). Sepsis and volume depletion are among the most common causes of shock, followed by cardiac-related pathologies. Mechanical factors, such as pericardial effusion and tamponade, pulmonary embolism, or tension pneumothorax, can also contribute (4–6). In addition, sustained hypotension can be developed in patients with internal bleeding, whether from occult gastrointestinal bleeding, ruptured ectopic pregnancy, abdominal aortic aneurysm (AAA) rupture, or other etiologies.

Understanding the cause of a patient's hypotension can expedite targeted interventions. But invasive monitoring techniques, comprehensive diagnostic testing, and imaging modalities can be time-consuming, costly, and are not always readily available to the ED clinician. Bedside ultrasound protocols have been proposed to identify the cause of shock and guide targeted therapy for patients with hypotension (7–19). While these protocols may prioritize the sequence of the components differently or include slightly different components, shock ultrasound guidelines are more similar than they are different. Most include cardiac evaluations to identify pericardial effusion, cardiac tamponade, left ventricular contractility, right ventricular (RV) strain, and inferior vena cava (IVC) size and collapsibility. Some include scanning for intra-abdominal free fluid, AAA, pneumothorax, and deep vein thrombosis. The majority of diagnostic evaluation studies using these protocols demonstrate accuracy, and a limited number of efficacy studies in ED (20–22) and ICU (23) settings have variously demonstrated improved diagnostic accuracy, resource utilization, or monitoring of resuscitative endpoints.

We sought to comprehensively assess the impact of an ultrasound hypotension protocol on ED clinicians' diagnostic certainty, diagnostic accuracy, treatment plans, and resource utilization in patients with undifferentiated hypotension. We hypothesized that a bedside ultrasound protocol in patients first presenting with undifferentiated hypotension would reduce diagnostic uncertainty and optimize management.

MATERIALS AND METHODS

Participants and Setting

This was a prospective, institutional review board–approved study using a convenience sample of patients with undifferentiated hypotension who presented to the ED in a single, academic tertiary care hospital over a 32-month period. Patients were enrolled based on the availability of physician research team members to perform the ultrasound protocol.

Patients were eligible for inclusion if they were 18 years old or older, had a systolic blood pressure less than 90 mm Hg after an initial fluid resuscitation (minimum of 1 L of normal saline), and lacked an obvious source of hypotension. Exclusion criteria included hypotensive patients with an obvious source (including hemorrhage or myocardial infarction requiring urgent revascularization) and trauma-related hypotension. Patients who had a "do-not-resuscitate" order or whose treating physician was not intending to use comprehensive resuscitation were also excluded.

No departmental protocols incorporating ultrasound in the evaluation of patients in shock were in place at the time of the study, and the management of the study patients was at the discretion of the treating clinician.

Ultrasound Protocol

An ultrasound-trained attending physician (including ultrasound fellows) with extensive experience in emergency and critical care ultrasound performed a standardized hypotension ultrasound protocol on each enrolled patient. Real-time ultrasonographic examinations were performed using a Sonosite M-Turbo (SonoSite, Bothell, WA) with a 5-1 MHz phased array transducer and a Zonare z.one ultra (Zonare Medical Systems, Mountain View, CA) using a 4-1 MHz phased array transducer. In all cases, the clinician sonographer was not directly involved in patient care and was not provided the patient's history or physical examination findings. The ultrasound variables and findings were systematically categorized, documented, and reported to the treating attending physician in charge of patient care (**Appendix 1**, Supplemental Digital Content 1, http://links.lww.com/CCM/B398). The duration of ultrasound examinations was not recorded.

The ultrasound hypotension protocol consisted of a focused cardiac scan to assess cardiac contractility, RV size, and the presence of pericardial effusion/tamponade; IVC scan (diameter and collapsibility); abdominal scan (detection of free fluid or AAA); and transthoracic scan (evaluation for pneumothorax).

The cardiac scan included subxiphoid, parasternal long and short axis, and apical four-chamber views when technically feasible. Cardiac contractility of the left ventricle (LV) was categorized as normal, moderately depressed, or severely depressed. RV dilation was assessed from the apical and subcostal four-chamber views. An RV/LV ratio greater than one was reported as abnormal RV dilation. The presence of pericardial effusion was categorized as mild, moderate, or large, with signs of cardiac tamponade being diastolic collapse of the right heart and simultaneous IVC dilation with the lack of respiratory variations. IVC measurements were obtained in the sagittal plane just distal to the junction of the right hepatic vein and the IVC. The IVC was reported as collapsed (diameter < 1.5 cm), normal (1.5–2.5 cm), or dilated (> 2.5 cm). The Focused Assessment with Sonography for Trauma protocol was performed with the patient in the supine position, looking for intra-abdominal free fluid. Aorta scans measured the maximum anteroposterior diameter at proximal, midabdominal, and distal aorta just proximal to its bifurcation. An aortic diameter greater than 3 cm was defined as an aneurysmal enlargement. The thoracic ultrasound protocol consisted of three views of anterior chest bilaterally in the midclavicular line, looking for the presence of lung sliding, as well as one view of lateral costophrenic angle bilaterally looking for pleural effusion.

Outcome Measures

Primary outcome measures consisted of change in the treating physician's diagnostic certainty before and after the ultrasound protocol and the concordance of postultrasound ED diagnosis with the chart review final diagnosis. Secondary outcome measures included changes in patients' treatment plans, use of diagnostic imaging, and changes in disposition.

The treating clinician completed a pretest questionnaire immediately before receiving the results of ultrasound hypotension protocol and completed the posttest portion immediately after receiving the results of ultrasound hypotension protocol. The questionnaires collected diagnostic certainty for each category of shock, including distributive (sepsis), cardiogenic, obstructive (pericardial effusion), obstructive (pulmonary embolism), and hypovolemic shock (Appendix 1, Supplemental Digital Content 1, http://links.lww.com/CCM/B398). Diagnostic certainty for each distinctive category of hypotension was recorded as one of five ordinal categories: 0%, 1–25%, 26–50%, 51–75%, and 76–100%. A definitive diagnosis was defined as the treating physician reaching high certainty in only one category. The survey also evaluated treatment plans, diagnostic imaging, and anticipated disposition. Treatment plans included the administration of IV fluids, resuscitative pharmacotherapy, and blood products. Diagnostic imaging included abdominal and/or chest CT scans and comprehensive echocardiography in the ED. Disposition included surgical, cardiology, or critical care consultations and location of planned admission.

Trained research assistants conducted chart review on all enrolled patients using a standardized data abstraction form to collect diagnostic testing, treatments, and diagnoses related to hypotension/shock. Two board-certified intensivists (D.L.D., K.D.H.) independently reviewed each patient chart to determine final diagnosis. The intensivists performed structured chart review using explicit criteria for the final diagnosis and, by consensus, assigned each encounter to the most plausible category of shock. Both intensivists were blinded to the results of ultrasound hypotension protocols and the treating clinician's differential diagnosis rank list. All other clinical, laboratory, and imaging results during ED and hospital admissions were available to them.

Statistical Analysis

The primary analysis consisted of measuring certainty of diagnosis and accuracy of diagnosis. The first analysis was a quantification of physicians' certainty on differential diagnosis before and after the ultrasound protocol using methods previously defined for Shannon Information Theory and its binary entropy function (**Appendix 2**, Supplemental Digital Content 2, http://links.lww.com/CCM/B399) (24, 25). This approach quantifies uncertainty, or information entropy, in a differential diagnosis by creating a summation score of each probability-weighted diagnosis, with a higher score representing greater uncertainty. By using the binary entropy function, a log base 2 transformation, each diagnosis is considered a "bit" of probability-weighted information, with both 0% and 100% probability contributing the least to uncertainty. The score is dependent on the number of differential diagnosis possibilities and the relative distribution of probabilities. If all diagnoses have similar probabilities, the uncertainty increases rapidly as the number of differential diagnoses increases. If one diagnosis is given a high probability and the others are given a low probability, the average uncertainty is greatly reduced and much less dependent on the total number of diagnoses in the list. Thus, the uncertainty is high for a broad and equally likely differential before the ultrasound protocol but decreases if one or a few diagnoses are favored after the ultrasound protocol has helped the physician rule out alternative diagnoses.

We performed analyses of interrater agreement on chart review final diagnoses between two intensivists and between post-ultrasound and consensus final diagnoses by calculating the Cohen κ statistic (k) and raw agreement (R_a). The baseline characteristics, changes in diagnosis, use of resources, and disposition before and after the ultrasound protocol were analyzed using Stata 12.1 (Stata Corp, College Station, TX) to perform parametric and nonparametric tests of association and descriptive statistics as appropriate.

RESULTS

One hundred eighteen patients with a mean age of 62 years were enrolled. The demographic profile and clinical characteristics of the study subjects are presented in **Table 1**. Overall in-hospital mortality for the cohort was 14.4% (95% CI, 8.0–20.8), with one death occurring on the first day of hospital admission.

Using the paired t test for normally distributed changes, there was a significant 27.7% decrease in the mean aggregate complexity of diagnostic uncertainty before and after the hypotension protocol (1.85–1.34; –0.51 [95% CI, –0.41 to –0.62]). There was a significant increase in the absolute proportion of patients with a definitive diagnosis from 0.8% to 12.7% (+11.9%; 95% CI, 5.6–18.1). **Table 2** summarizes the findings of the ultrasound protocols. **Table 3** categorizes, by type of shock, the changes in diagnostic certainty.

There was a change in treatment plan for 29 patients (24.6%; 95% CI, 16.7–32.5), including changes in fluid resuscitation, vasoactive medications, or blood transfusions (**Table 4**). Plan for further diagnostic imaging changed for 36 patients (30.5%; 95% CI, 22.1–38.9). The total number of chest and abdominal CT scan orders increased from 48 CT scans before to 51 CT scans after the ultrasound protocol ($p = 0.03$), but a change in the type of CT scans was observed for 29 patients (25%), both from abdominal to chest and vice versa (Table 4). Treating physicians changed the plan for consultation with ICU, cardiology, surgery, and other subspecialty teams for 16 patients (13.6%; 95% CI, 8.4–21.1). They changed the admission level of care in 14 patients (11.9%; 95% CI, 7.1–19.1) after receiving the ultrasound findings.

In a subgroup of cases, performing ultrasound identified serious and time-sensitive pathologies that led to significant changes in the patient's ED course. **Figure 1** provides original ultrasound images from a sample of cases with a marked shift in the patients' management.

TABLE 1. Demographic and Clinical Characteristics of the Study Subjects

Characteristics	Measurement
Age, mean, yr (95% CI)	61.6 (58.7–64.5)
Gender, % male	61.0
BP	
Systolic BP, mean, mm Hg (95% CI)	74.6 (72.7–76.4)
Diastolic BP, mean, mm Hg (95% CI)	44.8 (43.1–46.5)
Mean arterial pressure, mean, mm Hg (95% CI)	54.7 (53.1–56.3)
Shock index, mean, beat min^{-1} mm Hg^{-1}	1.29 (1.22–1.37)
Temperature, mean, °F (95% CI)	98.0 (97.7–98.4)
Heart rate, mean, beats/min (95% CI)	94.9 (89.4–100.4)
WBCs, median, count/mm^3 (IQR)	9.26 (6.5–13.89)
Plasma lactate, median, mmol/L (IQR) ($n = 88$)	2.3 (1.5–3.5)
Preexisting conditions, *n* (%)	
Hypertension	56 (47.5)
Congestive heart failure	33 (28.0)
End-stage renal disease and hemodialysis	25 (21.2)
Diabetes	19 (16.1)
History of cancer	17 (14.4)
Chronic obstructive pulmonary disease	17 (14.4)
Cerebrovascular disease	14 (11.9)
HIV/AIDS	12 (10.2)
History of liver disease	7 (5.9)
Emergency department disposition, *n* (%)	
Home	5 (4.2)
Medical/surgical admission	3 (2.5)
Telemetry admission	48 (40.7)
ICU/coronary care unit admission	54 (45.8)
Operating room and catheterization laboratory	4 (3.4)
Against medical advice and transfer	4 (3.4)
In-hospital length of stay, median, d (IQR)	5 (2–11)
In-hospital mortality, %, mean (95% CI)	14.4 (8.0–20.8)

BP = blood pressure, IQR = interquartile range.

TABLE 2. Bedside Ultrasound Measures and Findings ($n = 118$)

Ultrasound Finding	*n* (%)
Ejection fraction	
Normal	61 (52)
Depressed	40 (34)
Severely depressed	13 (11)
Undetermined	4 (3)
Right ventricular size	
Normal	93 (79)
Dilated	20 (17)
Inconclusive	5 (4)
Pericardial effusion	
None	91 (78)
Mild	17 (14)
Moderate to large	5 (4)
Inconclusive	5 (4)
Inferior vena cava size	
Normal	37 (31)
Collapsed	55 (47)
Dilated	19 (16)
Not visualized	7 (6)
Abdominal free fluid	
None	89 (75)
Mild	14 (12)
Moderate to large	9 (8)
Inconclusive	6 (5)
Abdominal aortic aneurysm	
No	107 (91)
Yes	4 (3)
Nonvisualized	7 (6)
Pneumothorax	
No	110 (93)
Yes	3 (3)
Inconclusive	5 (4)
Other findings[a]	
No	91 (77)
Yes	27 (23)

[a]The main noncontributory ultrasound findings include pleural effusion, renal cyst, ovarian cyst, and lung consolidation.

Final diagnosis was determined with substantial to excellent interrater reliability with a Cohen κ of 0.78 (95% CI, 0.64–0.85) and raw agreement (R_a) of 84.8%. When compared with the final diagnosis, the leading diagnosis after the hypotension protocol matched the final discharge diagnosis 86% of the time, with an excellent Cohen κ of 0.80 (95% CI, 0.73–0.88). When the ultrasound protocol led to a definitive diagnosis, it was concordant with the final diagnosis in 13 of 15 cases (87%), with ultrasound matching inpatient CT and ultrasound scans in both discrepant cases.

TABLE 3. Changes in Physicians' Diagnostic Uncertainty Before and After the Ultrasound Hypotension Protocol ($n = 118$)

	Partial Complexity (C_i), Mean (95% CI)		% Changes	
Category of Shock	Pre Ultrasound	Post Ultrasound	Pre-Post Ultrasound	p
Distributive (sepsis)	0.402 (0.372–0.432)	0.317 (0.275–0.358)	−21.1	< 0.0001
Cardiogenic (depressed ejection fraction)	0.347 (0.314–0.380)	0.256 (0.215–0.298)	−26.2	< 0.0001
Obstructive (pericardial effusion)	0.289 (0.255–0.322)	0.097 (0.065–0.129)	−66.4	< 0.0001
Obstructive (pulmonary embolism)	0.264 (0.228–0.300)	0.200 (0.161–0.239)	−24.2	< 0.0001
Hypovolemic and hemorrhagic	0.418 (0.390–0.445)	0.340 (0.301–0.378)	−18.7	< 0.0001
Others	0.133 (0.094–0.172)	0.129 (0.090–0.168)	−3.0	0.6444
	Aggregate Complexity (C), Mean (95% CI)		**% Changes**	
	Pre Ultrasound	**Post Ultrasound**	**Pre-Post Ultrasound**	**p**
All diagnoses	1.852 (1.754–1.951)	1.339 (1.214–1.463)	−27.7	< 0.0001

TABLE 4. Changes in Physicians' Plan for Further Diagnostic Imaging, Treatment, Consultation, and Admission Before and After the Ultrasound Hypotension Protocol ($n = 118$)

Management	Pre Ultrasound	Post Ultrasound	Pre-Post Ultrasound Decision Changes (%) (Cancel or New Order)	95% CI
Change in treatment[a]			29 (24.6)	17.5–33.3
IV fluids	108	103	11 (9.3)	5.2–16.2
Transfusion	12	12	8 (6.8)	3.4–13.1
Vasopressor	25	36	17 (14.4)	9.1–22.1
Diagnostic imaging[a]			36 (30.5)	22.8–39.5
Abdominal CT scan[b]	27	26	15 (12.7)	7.8–20.1
Chest CT scan[b]	21	25	14 (11.9)	7.1–19.2
2D echocardiography[b]	21	22	23 (19.5)	13.2–27.8
Consultation			16 (13.6)	8.4–21.1
Cardiology	32	27	11 (9.3)	5.2–16.2
Intensivist	43	45	12 (10.2)	5.8–17.2
Surgeon	2	3	1 (0.8)	0.1–5.9
Other	14	15	6 (5.1)	2.3–11.0
Admission location			14 (11.9)	7.1–19.2
ICU	63	65	11 (9.3)	5.2–16.2
Coronary care unit	12	12	6 (5.1)	2.3–11.0
Telemetry	35	34	9 (7.6)	4.0–14.1
Ward	8	7	1 (0.8)	0.1–5.9

[a]If a patient had more than one change in a category (treatment and diagnostic imaging), the patient was only counted once.
[b]Chart review revealed that no cancelled diagnostic imaging led to delayed/missed findings or adverse events.

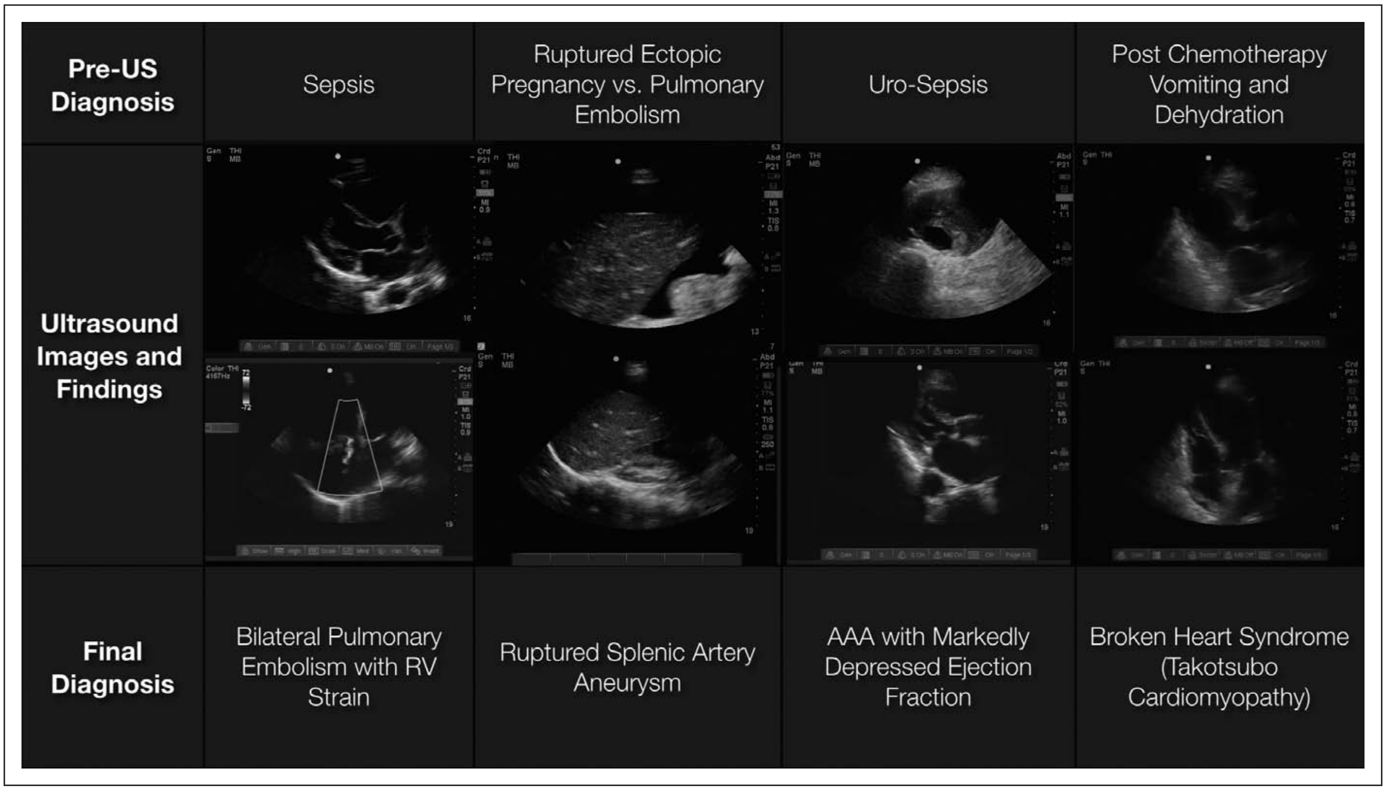

Figure 1. A sample of cases with a drastic diagnostic change after ultrasound (US) hypotension protocol with significant impact on the management of patients. AAA = abdominal aortic aneurysm, RV = right ventricle.

DISCUSSION

In this prospective study, performing a bedside ultrasound hypotension protocol in patients with undifferentiated hypotension resulted in a statistically significant reduction in physicians' diagnostic uncertainty, with the leading diagnosis after ultrasound being highly concordant with the final diagnosis. There were also significant postultrasound changes in physicians' treatment plans, diagnostic imaging utilization, consultations, and disposition.

Performing an ultrasound hypotension protocol was associated with an increase in the identification of a definitive cause of hypotension. In those cases, the posttest diagnosis was concordant with the final diagnosis. In the two cases with discordance, the bedside ultrasound imaging matched comprehensive imaging obtained during hospitalization. The discordant cases highlight the importance of integrating ultrasound findings into the complete clinical picture. For example, a patient with a preexisting cardiomyopathy can present with shock caused by pulmonary embolism or a patient with sepsis can have a coexisting but noncontributing AAA. Therefore, the results support the appropriate use of the ultrasound protocol, as it discovered diagnoses that otherwise may have been missed, yet it did not lead physicians astray.

The efficacy of utilizing ultrasound in patients with undifferentiated hypotension and shock has been demonstrated by a few similar prospective studies (20–23). The most comparably robust study is by Jones et al (20), which demonstrated that goal-directed ultrasound in the first 15 minutes of evaluation of patients with undifferentiated shock can shorten the differential diagnosis list compared with a group that received delayed ultrasound (median of 4 vs 9 items) and improve the accuracy of the top-ranked correct diagnosis on the differential (from 50% at baseline to 80% post ultrasound). Although our primary analytic approach quantified the combined change in narrowing a differential diagnosis and identifying a high-probability diagnosis, we did note comparably high concordance between the leading diagnosis post ultrasound and final diagnosis (86.4%). In our study, we primarily looked for increasing (or decreasing) certainty across the differential diagnosis, and a "definitive diagnosis" required a single diagnosis remaining on the differential. As a result of our strict criteria, our rate of postprotocol definitive diagnosis was 12.7%.

In the study by Haydar et al (21), treating physicians were queried before and after bedside ultrasound of the heart and IVC on 74 patients with suspected sepsis about treatment plans and certainty about volume status. Bedside ultrasound led to a change in treatment plan in about half of the cases. They also reported that the physician certainty about the cause of clinical findings increased in 71% and decreased in 29% of the cases (21). Although ruling in or ruling out a disease is desirable, the study by Haydar et al (21) highlights the challenge of studying diagnostic certainty with a broad differential, as judging the impact of ultrasound by the increase or decrease in diagnostic certainty of one etiology in isolation is difficult. Our measurement of diagnostic uncertainty captures both directions of improvement across the differential diagnosis, noting a 21.1% decrease in diagnostic uncertainty when specifically considering sepsis (Table 3).

In another study by Volpicelli et al (22), the physician sonographers followed a protocol of sequential examinations of the heart, IVC, abdomen, and lower extremities for deep vein thrombosis with an additional lung ultrasound in 108 ED patients with undifferentiated hypotension. Based on the ultrasound findings, the physicians were queried on the probable causes for the hypotension. A good concordance between ultrasound diagnosis and final diagnosis with Cohen κ of 0.71 was found (22). In addition to looking at diagnostic certainty and multiple other management outcomes, our study demonstrated similarly strong concordance between ultrasound diagnosis and final diagnosis with a Cohen κ of 0.80.

Manno et al (23) also reported that performing a bedside ultrasound protocol in all admitted ICU patients changed the admitting diagnosis in 25.6% of patients, prompted further testing in 18.4% of patients, and altered medical therapy in 17.6% of patients (23). Although in a different practice setting, we found similar substantial changes in diagnosis and management of patients.

LIMITATIONS

The results of this study must be interpreted in the context of some limitations. This study is from a single urban tertiary care teaching hospital and from an ED population, the latter group likely being at a different volume status compared with an ICU population who may already have had their volume status optimized. The study ultrasound examinations were performed by experienced physician sonographers, which might preclude generalizing these study results to clinicians without proper ultrasound training. We sought to minimize this limitation, however, by carefully selecting components of the hypotension protocol that have been shown to be accurately performed by ED clinicians. We feel that, as a result, the ultrasound protocol may hold broad applicability to emergency and critical care physicians.

The primary data analysis for diagnostic uncertainty is based on the use of Shannon Information Theory and its binary entropy function, which has been extensively used in the fields of applied mathematics, computer science, and electrical engineering. Although previously applied to quantifying the uncertainty inherent in a broad differential diagnosis and measuring the reduction in uncertainty from stages of the diagnostic workup (24, 25), it has not been used widely, and there are no generally accepted thresholds for clinically significant changes. That said, differential lists with 7–9 items have ranges of complexity from 1.920 to 2.405, and sequential reductions in uncertainty have been shown from taking a history and physical examination (2.890) to laboratory testing (1.446) to confirmatory special studies (0.065) (24). In our study, we detected significant improvements in uncertainty for categories of shock amendable to ultrasound evaluation and did not detect significant change in categories of shock not suitable for ultrasound evaluation. This indirectly supports the appropriateness of using the binary entropy function for our analysis of diagnostic certainty. A commonly used alternative medical approach is to simply look at the change in leading diagnosis based on a diagnostic test; however, we did not feel that this truly addresses the breadth of impact on diagnostic uncertainty in undifferentiated hypotension.

Finally, our study design limits the ability to directly measure patient-oriented outcomes. Beyond the compelling discovery of heretofore unexpected diagnoses that otherwise would have been missed (Fig. 1), it was not possible to measure how the changes in physician decision making or resource utilization led to decreased patient morbidity and mortality.

CONCLUSIONS

We found that early utilization of bedside ultrasound using a hypotension protocol had a clinically significant impact on physicians' differential diagnosis as well as leading to significant changes in patients' management in the ED. In a small minority of cases, ultrasound dramatically changed the diagnosis and identified pathology that required a complete shift of management and immediate interventions. A prospective study focusing on clinical outcomes is the logical next step to validate the observed benefits of this protocol among the patients with undifferentiated hypotension and shock.

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