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Ultrasound in Emergency Medicine

EFFECTS OF STUDENT-PERFORMED POINT-OF-CARE ULTRASOUND ON PHYSICIAN DIAGNOSIS AND MANAGEMENT OF PATIENTS IN THE EMERGENCY DEPARTMENT

Daniel S. Udrea, BS,* Andrew Sumnicht, BS,* Deanna Lo, BS,* Logan Villarreal, BS,* Stephanie Gondra, BS,* Richard Chyan, BS,* Audra Wisham, MD,† and Vi Am Dinh, BS, RDMS, RDCS†‡

*School of Medicine, Loma Linda University, Loma Linda, California, †Department of Emergency Medicine, Loma Linda University, Loma Linda, California, and ‡Department of Medicine, Division of Pulmonary and Critical Care, Loma Linda University, Loma Linda, California

Corresponding Address: Vi Am Dinh, MD, RDMS, RDCS, Loma Linda University Medical Center, 11234 Anderson Street, A108, Loma Linda, CA 92354

☐ Abstract—Background: Despite the increasing integration of ultrasound training into medical education, there is an inadequate body of research demonstrating the benefits and practicality of medical student–performed point-of-care ultrasound (SP-POCUS) in the clinical setting. Objectives: The primary purpose of this study was to evaluate the effects that SP-POCUS can have on physician diagnosis and management of patients in the emergency department, with a secondary purpose of evaluating the diagnostic accuracy of SP-POCUS. Methods: SP-POCUS examinations were performed in the emergency department by medical students who completed year one of a 4-year medical school curriculum with integrated ultrasound training. Scans were evaluated by an emergency physician who then completed a survey to record any changes in diagnosis and management. Results: A total of 641 scans were performed on the 482 patients enrolled in this study. SP-POCUS resulted in a change in management in 17.3% of scans performed. For 12.4% of scans, SP-POCUS discovered a new diagnosis. SP-POCUS reduced time to disposition 33.5% of the time. Because of SP-POCUS, physicians avoided ordering an additional imaging study for 53.0% of the scans performed. There was 94.7% physician agreement with SP-POCUS diagnosis. Conclusions: This study showed that SP-POCUS is feasible and may potentially have a meaningful impact on physician diagnosis and management of patients in the emergency department. In addition, the implementation of SP-POCUS could serve as an ideal method of developing ultrasound skills in medical school while positively impacting patient care. © 2017 Elsevier Inc. All rights reserved.

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INTRODUCTION

Since the 1970s, ultrasound has become less expensive and increasingly portable, leading to the growth of point-of-care ultrasound (POCUS) in clinical medicine, otherwise defined as clinician-delivered ultrasonography at the patient's bedside (1,2). Ultrasound is nonionizing, noninvasive, and portable, and therefore a patient's anatomy can safely be assessed in real-time using focused ultrasonographic examinations to systematically rule in or out certain diagnoses (1,3,4). POCUS is currently a well-established practice and has proven to be an essential diagnostic modality in many settings (5–12). Moreover, some specialties now require a certain level of education in ultrasound before completion of residency because of mandates set forth by the American College of Graduate Medical Education (ACGME) (13–20).

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In an effort to prepare students for residency, medical schools across the nation have begun to incorporate ultrasound training into their respective 4-year curricula (21). Current medical school teaching curricula expose students to ultrasonography mostly through didactic education and hands-on training sessions using healthy human models or cadavers (19,22–25). Recent studies have shown that an active, hands-on learning approach is superior to classroom didactic education and that medical students with limited training can identify pathologies and possibly impact patient outcomes from their findings (24,26,27).

Despite the growing popularity of POCUS and its incorporation into medical school curricula, there has not been an adequate evaluation of the diagnostic accuracy and utility of medical student–performed POCUS (SP-POCUS) in the clinical setting. Previous studies have focused on how physician-performed POCUS can change diagnosis and management (28,29). However, it is unclear what effect SP-POCUS can have on the management of patients. This study was designed to expand upon the feasibility and utility of SP-POCUS performed on a diverse patient population in the emergency setting using an array of ultrasonographic applications. To achieve this goal, a protocol was developed that would assess the correlation between a student's ultrasound scan and the physician's delivery of patient care. The primary purpose of this study was to evaluate the effects that SP-POCUS can have on physician diagnosis and management in the emergency department (ED). The secondary purpose of this study was to assess the diagnostic accuracy of SP-POCUS examinations, measured by physician agreement.

METHODS

Study Design

This was a prospective observational study. Data were collected in the ED of a single tertiary academic level I trauma center. Patients included in the study were a convenience sample of adult patients (≥18 years of age) in the ED who required POCUS (indicated scans) or would consent to receive a scan for educational purposes (training scans). Patients excluded were patients with psychiatric disorders, pediatric patients, and patients who already had an ultrasound examination performed in the same visit. All patient data were accessible only to research personnel. The local institutional review board approved this study.

Ultrasound Machines

Ultrasound scans were performed with the following machines: SonoSite M-Turbo (SonoSite, Inc, Bothell, WA), GE Logiq E (General Electric Company, Fairfield, CT), and Ultrasonix SonixTouch (Ultrasonix Medical Corporation, Richmond, BC).

Data Collection Forms

Two forms were created for data collection. The first form was created for students to record their findings and diagnoses of each patient. Students were able to perform the following 10 scans: aorta, biliary, cardiac, inferior vena cava (IVC), extended focused assessment with sonography for trauma (eFAST), renal, pulmonary, obstetrics, ocular, and soft tissue (Appendix A). The student would then report an ultrasound finding of "normal" or "abnormal." If the student could not visualize the structures needed to complete the examination, then they would report "nonvisualized" and these were considered nondiagnostic by the physicians. The second form was created for physicians to complete after reviewing the students' ultrasound images and diagnoses. Physicians evaluated and reported agreement with the students' findings of "normal" vs. "abnormal," and whether the scan performed resulted in a change of their initial diagnosis, management, or amount of time needed to make a decision about a patient's disposition (Appendix B).

Student Preparation

Five medical students from a 4-year U.S. medical school participating in a summer ultrasound elective were selected for this study. All students had just completed year one of medical school that included a year-long physical examination course with integrated hands-on ultrasonography using normal human models. The ultrasound curriculum gave students a basis for the normal anatomic appearance of soft tissue, vasculature, lungs, heart, liver, kidneys, spleen, aorta, and bladder. All students were exposed to an average of 10 h of ultrasound during their first year, including 3 h of online didactics and approximately 30 hands-on scans. In addition, the students fulfilled approximately 15 h of online didactics by completing 13 required SonoSim modules prior to data collection. The 13 SonoSim modules were: fundamentals of ultrasound, aorta/IVC, bladder scanning, cardiology, eFAST, intestinal/biliary, musculoskeletal, obstetrics/gynecology, ocular, pulmonary, rapid ultrasound in shock and hypotension (RUSH), renal, and soft tissue. The modules provided didactic training through instructional videos and quizzes that required passing scores of >75%. The purpose of these modules was for students to learn standard scanning protocols and techniques for pathologies that can be reliably detected by POCUS, and to serve as a basis for standardizing the way each student performed scans on each respective organ system. Students then spent 6 h of hands-on training with a licensed ultrasonographer who familiarized students with specific ED ultrasound protocols and machine use.

Study Protocol

Data collection occurred between 9:00 AM and 5:00 PM for 56 consecutive days between June 2015 and August 2015. Three students were present each day, with two of the students scanning patients while the third student acted as the research coordinator. The research coordinator did not perform scans but recorded patient demographic data, kept data organized, acquired bedside ultrasound orders from emergency clinicians, and assigned scans to the other two students. The chief complaint was autopopulated from the electronic medical system. The chief complaint was then classified into several categories (Table 1). For example, if the patient came in with chest pain, it was categorized as cardiac. If a patient came in with primary complaint of joint pain, it was categorized as musculoskeletal. If a patient came in with any complaint and met criteria for sepsis, they were categorized as infectious. The roles of research coordinator and scanning patients were equally divided among the five medical students throughout the study period.

Emergency clinicians designated scans as either training or indicated. Training scans were assigned when the clinician believed that performing an ultrasound on a patient would serve as a beneficial learning experience for students. Indicated scans were assigned when a clinician would ordinarily perform POCUS as part of a patient's diagnostic workup. Indicated scans were further subdivided into indicated-unstable or indicated-stable. Indicated-unstable scans were defined as indicated scans in patients with altered mental status, intubation on mechanical ventilation, hemodynamic instability (systolic blood pressure <90 mm Hg), trauma, or those who were otherwise unresponsive. Indicated-stable patients were all other indicated scans not meeting criteria for indicated-unstable scans. Students obtained verbal informed consent prior to performing an examination. All scans were saved in video clip format to improve accuracy. Standard views were obtained for each examination, per the American College of Emergency Physicians recommendations (30).

After obtaining images of the assigned scan(s) and making a preliminary interpretation, the student filled out the data form and showed their results and diagnoses to the ordering emergency physician credentialed in point of care ultrasonography, according to American College of Emergency Physicians guidelines (30). The physician would review the ultrasound clips directly on the ultrasound machine within 1 h of the scan being performed. That clinician would then complete the physician form and all data collection forms were returned to the research coordinator for recordkeeping and data input. All scans performed were reviewed by the ordering emergency physician.

Data Analysis

Data from surveys was input into Qualtrics (version August 2015; Qualtrics, LLC, Provo, UT). Data were exported from Qualtrics to Microsoft Excel (version 14.4.2; Microsoft, Redmond, WA), and averages, standard deviations, and percentages were analyzed with STATA software (version 12.1; StataCorp, LLC, College Station, TX).

Table 1. Patient Demographics

	Training (n = 145)	Indicated-Stable (n = 236)	Indicated-Unstable (n = 101)	All (n = 482)
Mean age, years ± SD	52.5 ± 19.4	46.6 ± 18.3	51.2 ± 20.6	49.3 ± 19.3
Male sex (%)	63 (43.4%)	83 (35.2%)	58 (56.9%)	204 (42.3%)
Mean weight, kg ± SD	79.0 ± 21.4	79.4 ± 24.5	79.6 ± 21.0	79.3 ± 22.9
Mean LOS, min ± SD	300.3 ± 286.3	254.3 ± 215.8	126.2 ± 129.5	241.5 ± 234.0
Presenting chief complaint from EMR, n (%)				
Cardiac	50 (34.5)	54 (22.9)	22 (21.8)	126 (26.1)
GI/GU	50 (34.5)	90 (38.1)	2 (2.0)	142 (29.5)
Respiratory	10 (6.9)	15 (6.4)	5 (5.0)	30 (6.2)
Neurologic	10 (6.9)	13 (5.5)	12 (11.9)	35 (7.3)
Endocrine	1 (0.7)	0 (0.0)	0 (0.0)	1 (0.2)
MSK	5 (3.4)	18 (7.6)	1 (1.0)	24 (5.0)
Infectious	1 (0.7)	5 (2.1)	0 (0.0)	6 (1.2)
Hematologic	1 (0.7)	6 (2.5)	2 (2.0)	9 (1.9)
OB	1 (0.7)	6 (2.5)	1 (1.0)	8 (1.7)
Trauma	6 (4.1)	8 (3.4)	55 (54.5)	69 (14.3)
Other	9 (6.2)	9 (3.8)	1 (1.0)	19 (3.9)
Ocular	1 (0.7)	12 (5.1)	0 (0.0)	13 (2.7)
Total	145	236	101	482

EMR = electronic medical record; GI = gastrointestinal; GU = genitourinary; MSK = musculoskeletal; OB = obstetrics; LOS = length of stay; SP-POCUS = student-performed point-of-care ultrasound; SD = standard deviation.

Table 2. Changes in Management and Diagnosis by Patient Scan Type

	Training (n = 194)	Indicated-Stable (n = 313)	Indicated-Unstable (n = 134)	Total (n = 641)
Change in management, n (%)	19 (9.8)	60 (19.2)	32 (23.9)	111 (17.3)
Rule in/out diagnosis, n (%)	97 (50.0)	195 (62.3)	90 (67.2)	382 (59.6)
New diagnosis, n (%)	24 (12.4)	42 (13.4)	14 (10.5)	80 (12.4)
Reduced time to patient disposition, n (%)	38/194 (19.6)	120/313 (38.3)	57/134 (42.5)	215/641 (33.5)
Confirmatory study avoided, n (%)	120/194 (61.9)	159/313 (50.8)	61/134 (45.5)	340/641 (53.0)

RESULTS

There were 482 patients enrolled, with a mean duration of stay of 241.5 min at the time the patients were enrolled (Table 1). A total of 641 SP-POCUS scans were performed with 194 training scans, 313 indicated-stable scans, and 134 indicated-unstable scans (Table 2). Twelve scans yielded a "not visualized" result, with 75% physician agreement. Overall change in management for all scans was 17.3% with indicated-unstable scans having the most change in management of 23.9%. SP-POCUS ruled in or out a diagnosis for 59.6% of all scans, and was more likely to benefit patients in the indicated-stable and indicated-unstable groups (62.3% and 67.2% respectively), compared to 50% in the training group. There was a new diagnosis found with SP-POCUS in 12.4% of all scans. Physicians reported that SP-POCUS helped reduced time to disposition in 33.5% of cases.

Table 3 shows changes in management by the four most commonly ordered SP-POCUS scans: cardiac, renal/bladder, eFAST, and IVC. The most common scan type was cardiac (n = 165, 25.7% of all scans). The next most common scan types included renal/bladder (n = 99, 15.4% of all scans), eFAST (n = 81, 12.6% of all scans), and IVC (n = 70, 10.9% of all scans). Renal/bladder scans found the greatest frequency of new diagnoses (14.1%). IVC scans ruled in or out diagnoses most frequently (72.9%) and resulted in the most frequent change in management (30.0%). IVC SP-POCUS yielded the lowest frequency of expected results (65.7%) whereas eFAST yielded the highest frequency of expected results (91.4%). Physicians had an overall agreement of 94.7% with the diagnoses students made on SP-POCUS (Table 4). There were no physician comments noted.

DISCUSSION

This study sought to evaluate the effects that SP-POCUS has on physician diagnosis and management in the ED. Our results demonstrate that with limited training and use of ultrasound in the ED, novice junior medical students can yield new diagnoses, assist in ruling in or out diagnoses, influence physician management of patients, reduce disposition time, and reduce the need for confirmatory imaging studies.

Our study aims to address the gap in research between medical students and physicians in the clinical setting. There is a well-established body of research that supports the utility of POCUS by graduate medical education trainees and attending physicians in various specialties (5,10,18,20,28,31–37). A parallel set of studies focuses on the implementation, analysis, and development of novel training methodologies for medical school curricula (4,19,22,23,25,38–43). Multiple studies have shown that physicians can change management with POCUS in the clinical setting, but we are unaware of a prior study that evaluates the potential effects that SP-POCUS can have on patient management, particularly in the ED (26,34,44,45).

SP-POCUS ruled in or out a diagnosis in a majority of unstable patients. Out of the top four most performed scans, SP-POCUS of the IVC changed management, ruled in/out diagnoses, and avoided confirmatory studies most often. IVC ultrasound was most commonly ordered for hypotensive patients to evaluate for fluid tolerance. If the IVC was collapsible in a hypotensive patient, this allowed the physician to be able to give fluids with low risk for adverse side effects, such as pulmonary edema or fluid overload (46). On the other hand, SP-POCUS scans occasionally

Table 3. Changes in Management and Diagnosis by Top Four Most Performed Point-of-Care Ultrasound Types

	Cardiac (n = 165)	Renal/Bladder (n = 99)	eFAST (n = 81)	IVC (n = 70)
Change in management, n (%)	21 (12.7)	18 (18.2)	11 (13.6)	21 (30.0)
Able to rule in/out diagnosis, n (%)	90 (54.5)	57 (57.6)	54 (66.6)	51 (72.9)
New diagnosis, n (%)	20 (12.1)	14 (14.1)	6 (7.4)	5 (7.1)
Expected result, n (%)	139 (84.2)	77 (77.8)	74 (91.4)	46 (65.7)

eFAST = extended focused assessment with sonography for trauma; IVC = inferior vena cava.

Table 4. Physician Agreement and Confirmatory Study Agreement With Student Diagnosis

Scan Type	Agreement/No. of Scans Performed (%)
Aorta	39/41 (95.1)
Biliary	59/60 (98.3)
Cardiac	152/165 (92.1)
IVC	68/70 (97.1)
eFAST	80/81 (98.8)
Renal/bladder	91/99 (91.9)
Pulmonary	45/47 (95.7)
Obstetrics	29/31 (93.5)
Ocular	15/16 (93.8)
Soft tissue	29/31 (93.5)
All scans	607/641 (94.7)

eFAST = extended focused assessment with sonography for trauma; IVC = inferior vena cava.

demonstrated a fluid-overloaded state with a noncollapsible IVC, depressed ejection fraction, and pulmonary interstitial edema, in which case a physician would be prompted to cease the delivery of intravenous fluids (47). Interestingly, training scans occasionally yielded results that gave new information to the physician or led to a change in management of patients. This may indicate that scanning ED patients may lead to incidental findings that may affect their care. Further study into the significance of incidental POCUS findings remains unclear.

The level and legitimacy of student diagnoses is considerable when using physician agreement (94.7%) as a surrogate. This provides support for the potential use of SP-POCUS in academic hospitals for both teaching and for patient management. This concept is further supported by the utility of SP-POCUS in potentially narrowing down differential diagnoses, discovering new diagnoses, reducing the time to determine a patient's disposition, and avoiding the use of other costly imaging modalities at times.

This study provides evidence that a medical school curriculum that includes formal ultrasound training and experience in the clinical setting can provide students with sufficient abilities to influence diagnosis and management of patients. In addition, this study shows that it is feasible for a medical student to gain ultrasound experience under physician supervision in the clinical setting while aiding in patient care. This study also shows that certain types of scans have varying utility when performed by students. For example, indicated patient scans were often useful for clinicians, whereas training scans were helpful to students but would take time from clinicians, rarely leading to a change in patient outcomes. In addition, certain scan types, such as cardiac, are innately more useful in the ED and will be used more often, whereas potentially helpful scans, such as biliary, were often limited by the level of difficulty of the scan.

Ideally, this study can serve as a model for future research analyzing the impact SP-POCUS can have on patient disposition. A study by Kontos et al. found that "the greatest limitation to [echocardiography's] widespread adoption is the logistical difficulty of supplying highly skilled personnel for around-the-clock image acquisition and interpretation" (48). Implementing a robust 4-year undergraduate ultrasound curriculum that includes elective ultrasound rotations can help fill this need. An ultrasound elective also provides an excellent opportunity for medical students to become more comfortable interacting with both patients and physicians (49). Future research is needed to elucidate the specific impacts that SP-POCUS has on patient outcomes, student development, and hospital costs. Both the implementation of SP-POCUS in medical school curricula and the results from this study help to bridge the use of POCUS by medical students as they transition to residency and consequent specialty fields. These results may be used to justify the implementation of ultrasound in the clinical training of undergraduate medical students before they transition to residency.

Limitations

Physicians may have had varying levels of trust in the students' scanning proficiency. If they trusted the students scanning proficiency, they may have been more confident in using the results to affect patient diagnosis and management. On the other hand, if they did not trust the students scanning proficiency, they may have gotten a confirmatory study. Additional research is needed to determine the effect on decisions made regarding a patient's treatment plan, hospital admission, discharge, duration of stay, delay in care, adverse management decisions, or incorrect diagnoses. In future studies, modifications to the physician survey (Appendix B) could be made to more adequately address whether SP-POCUS negatively impacted patient care. Oftentimes physicians would not comment on which new diagnoses were made or diagnoses that were ruled in/out, which led to a deficit in that data.

In addition, for even the most experienced ultrasonographers, some patients were difficult to scan for a variety of reasons. Some patients had a larger body habitus, exhibited distress, or had comorbidities that made a particular scan difficult to obtain. Scans with a "not visualized" result were not compared to a scan on the same patient by an experienced sonographer, so it is difficult to determine whether these scans were limited by student proficiency or by typical limitations of ultrasound. Physicians agreed with the results of "not visualized" scans 75% of the time, which could mean that 25% of the time, physicians may have felt that the student's scan actually did show meaningful images even though the student may not have been confident in the quality of their scan. These factors, compounded with the relative inexperience of students, made collecting ideal ultrasound images more difficult.

This research provided the five students with a great deal of hands-on experience. However, the students' skills did not necessarily progress at the same rate. The students reported that the different ultrasound applications had differing levels of difficulty. For example, the students found biliary scans to have a steeper learning curve than renal/bladder scans. Students were assigned scans at random, and therefore some students had completed more scans of a certain type than the other students. In addition, each student scanner had naturally different abilities and comfort levels, which may account for some variation in both scan quality and physician trust level. Past research has demonstrated that hands-on ultrasound training is preferred to didactics (24,27). Using this study as the framework, additional research could be designed to examine the exact benefits or detriments to a student's ability to learn ultrasound effectively. This study only included five students at one medical center, so repeating this model using more students at various other medical centers would ideally yield more generalizable data as it pertains to the impact on students.

CONCLUSIONS

SP-POCUS is feasible in the ED. It can lead to changes in management, reduced time to disposition, and avoidance of confirmatory studies. Implementation of SP-POCUS in the clinical setting could serve as a method of developing hands-on ultrasound skills in medical school while possibly improving patient care.

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SUPPLEMENTARY DATA

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ARTICLE SUMMARY

1. Why is this topic important?

An increasing number of medical schools are starting to integrate ultrasound into their curricula. The clinical benefits of such ultrasound curricula are still largely unknown.

2. What does this study attempt to show?

This study attempts to explore the effects of novice medical student–performed point-of-care ultrasound in the emergency department setting.

3. What are the key findings?

Student-performed point-of-care ultrasound can have impact on physician management in the emergency department. Physicians usually agree with the results of student-performed point-of-care ultrasound.

4. How is patient care impacted?

Student-performed point-of-care ultrasound may change patient management by reducing the time to patient disposition and reducing the number of formal radiographic tests ordered in the emergency department.