ISSN: 2369-8543

NOV 2019 vol. 04 iss. 02

POCUS Journal

Journal of Point-of-Care Ultrasound

EMERGENCY MEDICINE. INTERNAL MEDICINE. CRITICAL CARE. CARDIOLOGY. PRIMARY CARE. ANESTHESIOLOGY. PULMONOLOGY

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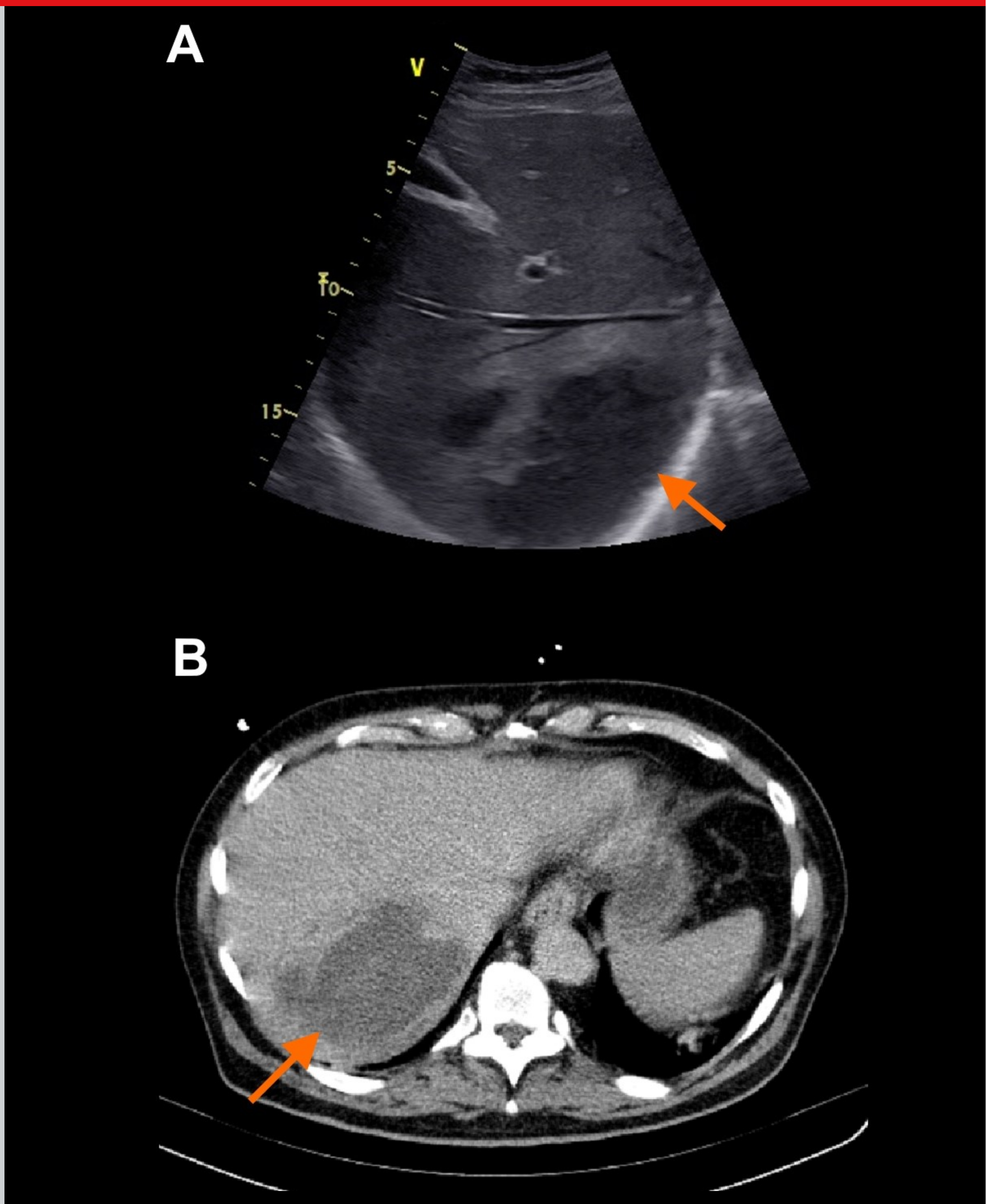

Shedding light on a hidden source of septic shock with POCUS

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Abstract

A 77-year old male was admitted in the emergency department for septic shock, yet no clear source of infection was noted upon physical examination and a portable chest x-ray. Due to his unstable condition, bedside ultrasound was performed. A heterogeneous mass in the liver was noted, hence a tentative diagnosis of liver abscess was made. This was latter confirmed by abdominal computed tomography. This case highlights that point-of-care ultrasound, when performed by expert physicians, can significantly decrease time to diagnosis for septic patients.

Case file

A 77-year old male presented to our hospital's emergency department complaining of acute shortness of breath and 1 week of malaise. He complained of nausea and vomiting in that period, without abdominal pain, diarrhea, cough, chest pain or dysuria. His past history included acute pulmonary thromboembolism 15 years prior and dyslipidemia.

Upon examination, he had a Glasgow Coma Scale of 15, was shivering, hypotensive (mean arterial blood pressure of 40 mmHg), tachycardic (140 beats per minute), hypoxic (peripheral oxygen saturation of 82% on room air) and febrile (temperature of 38.9 ºC). An arterial blood gas on 6L/min of oxygen through a simple face mask revealed a compensated acute metabolic acidosis, with a pH of 7.404, pCO2 15 mmHg, pO2 101 mmHg, HCO3 15.4 mmol/L and lactate of 10.4 mmol/L. He was admitted to the Emergency Room's Critical Care bay upon suspicion of septic shock. Sepsis protocols were immediately started and upon further examination, there still was no obvious source of infection: he had a clear lung exam, there was no abdominal or costovertebral angle tenderness and he had a normal prostate exam.

The chest x-ray had no visible consolidation. The patient's blood pressure improved only transiently after fluid therapy; because the patient continued to be unstable, a bedside ultrasound examination was performed to further look for a source of infection. It revealed a heterogeneous mass in the liver (Figure 1A). A liver abscess was suspected. An abdominal computed tomography scan was then performed, which revealed the aforementioned abscess located in the VI and VII liver segments, measuring 13x7x10 cm (Figure 1B) and signs of a contained perforated diverticulitis. Metronidazole and gentamicin were added to ceftriaxone that had already been administered. Percutaneous drainage revealed a thick purulent material; cultures later isolated an extended-spectrum beta-lactamase producer, *Morganella morganii*.

The patient's status rapidly deteriorated and he was started on vasopressor therapy, intubated and admitted to the Intensive Care Unit (ICU). Abscess drainage and appropriate antibiotic therapy led to steady improvement, both clinically and on repeat imaging exams (Figure 1C). He was later transferred to the intermediate care unit continuing on antibiotic therapy.

Septic shock has a high mortality rate, estimated to be higher than 40% [1], increasing as time passes without appropriate treatment. Hence, correct diagnosis of the cause of sepsis is essential to provide correct antibiotic coverage and, if necessary, drainage or removal of the infectious source. However, patients with septic shock are, by definition, hemodynamically unstable [1], hence it is reasonable that attempts at transportation of these patients for diagnostic tests should be keep at a minimum.

Pyogenic liver abscess is an uncommon entity in Western countries, yet clearly shows the need of quickly pinpointing the source of a septic shock, as it historically carried a high mortality rate, that is currently at 6.3% due to the generalized use of computed tomography and ultrasound [2]. There is usually a delay of 1 week between onset of symptoms and diagnosis, as most of them are non-specific and there are multiple occult sources of infection, such as diverticulitis [3].

Point-of-care ultrasound, when performed by expert physicians, significantly decreases time to diagnosis of septic patients [4], potentially decreasing time to control

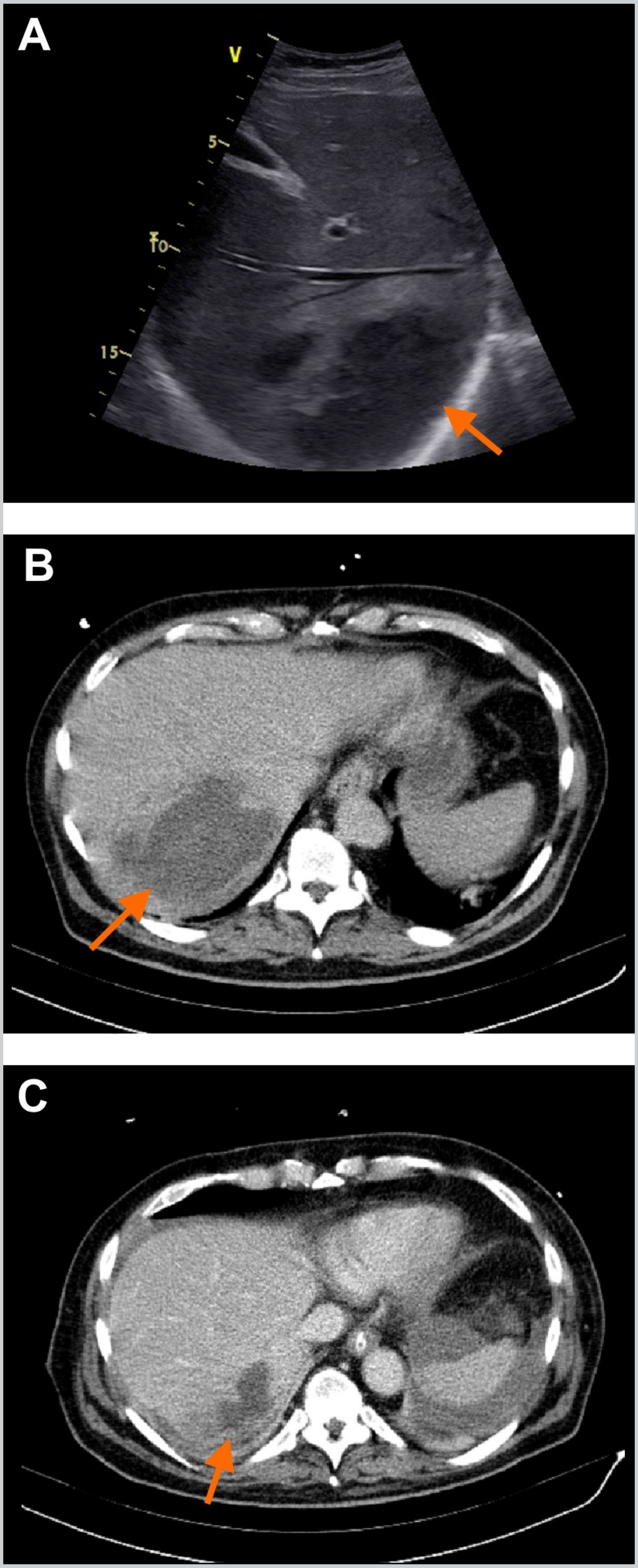

Figure 1. Abdominal point-of-care ultrasound showing an heterogeneous liver lesion (1A, arrow), confirmed as a liver abscess in the contrast-enhanced abdominal computed tomography (1B, arrow). There was significant decrease of the abscess after two weeks of therapy (1C, arrow).

of the septic source, while maintaining the patient in a more controlled environment and arranging for further testing. Also a quick identification of the septic source may help eliminate sepsis mimickers that could affect the differential diagnosis process. These advantages could be of benefit for patient outcomes, although, interestingly, patients with septic shock admitted to the ICU without a clear diagnosis at 24h had no difference in outcomes [5]. Studies to correlate use of point-of-care ultrasound in these patients with benefits in mortality are needed.

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Postpartum Hemorrhage Emergency Management Using Focused Assessment With Sonography For Obstetrics (FASO): A Case Report

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Abstract

Postpartum hemorrhage is the leading cause of maternal death around the world according to World Health Organization [1]. While cesarean delivery is a risk factor, uterine atony is the main etiology [2]. Cesarean delivery and concomitant tubal sterilization are a known risk of postoperative intra-abdominal bleeding, which can be insidious and difficult to diagnose in the recovery period. Furthermore, a late diagnosis can lead to a less than optimal management. Point-of-care ultrasonography is an available technique that can contribute to a prompt diagnosis and accurate decision-making [3]. We present a case of a patient in postoperative care after cesarean delivery and tubal sterilization who developed hypovolemic shock symptoms, without any sign of uterine atony or vaginal bleeding. Focused assessment with sonography for obstetrics (FASO) was quickly performed in the recovery room to diagnose intra-abdominal bleeding and decision-making to perform an emergency surgical intervention.

Introduction

The diagnosis and management of the Postpartum Hemorrhage (PPH) must be carried out in a multidisciplinary approach including the participation of gynecologists/obstetricians, anesthesiologists and nursing care. The evaluation of the hemodynamic status, as well as establishing a cause of hypovolemic shock, must be performed in a timely fashion, to provide early hemostatic control and adequate maternal resuscitation [4].

Within the field of emergency medicine, the intra-abdominal bleeding caused by trauma is initially diagnosed with point-of-care ultrasonography (POCUS) using the Focused Assessment with Sonography in Trauma (FAST) exam [5]. A modified version of this technique has been suggested in the Obstetrics field (FASO) [3] in order to evaluate patients in the postpartum period. This approach may facilitate an early diagnosis and an appropriate management, helping to establish the etiology of the bleeding. FASO provides an examination of the uterine and abdominal cavities with a safe, imaging technology at the bedside [6].

We followed the SCARE criteria and CARE guidelines [7,8] to report a case of an obstetric patient with severe hypovolemic shock using an emergency ultrasound to diagnose intra-abdominal hemorrhage post cesarean delivery and tube sterilization, in the context of a tertiary teaching hospital.

Case Report

A nineteen-year-old woman, underwent a cesarean delivery and tubal sterilization at 39 weeks of gestational age. The scheduled procedure was carried out under spinal anesthesia using hyperbaric bupivacaine 0.5% (12mg) and fentanyl 20 mcg. The surgery was uneventful, with 300 cc of estimated blood loss and normal hemodynamic throughout the case.

In the immediate post-operative period, the patient was found to have persistent low blood pressure with mean arterial pressures between 48-60 mmHg. She was tachycardic with heart rates 115 – 120 beats per minute. On examination, she appeared pale. There was minimal vaginal bleeding, a good uterine tonus, and no specific signs of peritoneal irritation. Fluid resuscitation was started.

After repeated intravenous fluid boluses totaling 2000 ml of volume resuscitation, the anesthesiologist performed a FASO examination with the patient in supine position using a convex-array transducer. First, the right upper quadrant was examined, evaluating for free fluid in Morison's pouch. Next, the left upper quadrant (splenorenal recess) was examined, followed by the suprapubic evaluation of the lower abdominal wall and the pouch of Douglas. The FASO examination found a large amount of free fluid in the abdominal cavity, mainly located in the hepatorenal recess and the pouch of Douglas.

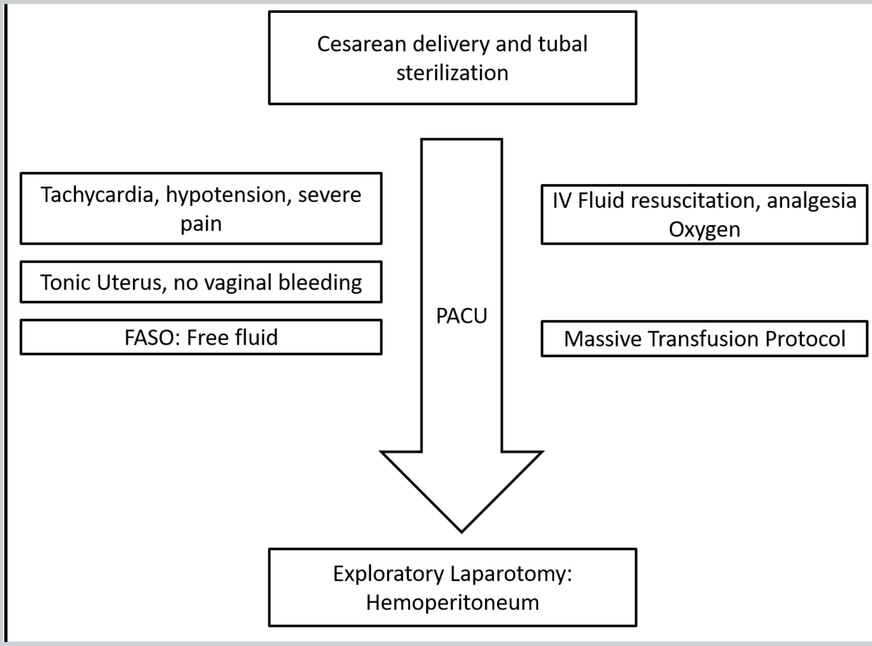

Figure 1. Timeline of the case: symptoms, clinical evaluation, performance of FASO and decision-making.

In this context, the diagnosis of a severe hemorrhagic shock was considered and the massive transfusion protocol was activated. The patient was immediately transferred to the operating room. After a rapid sequence induction for general anesthesia, an exploratory laparotomy was initiated. The surgical team drained 3,000 ml of hemoperitoneum with evidence of active bleeding through a small vessel in the left fimbriectomy stump, which was repaired with clamping and transfixation ligature (Figure 1).

Discussion

Postpartum hemorrhage is the leading cause of maternal death worldwide [4,9] , most commonly due to uterine atony [1]. The diagnosis is clinical and its management includes identifying the cause, emergency resuscitation and timely surgical intervention [10].

Tubal sterilization represents an important contraceptive method worldwide. Annually, more than 350,000 tubal sterilization procedures are held after vaginal birth or cesarean delivery in the United States, with a low rate of complications reported [11,12]. Unlike in uterine atony, in which vaginal bleeding occurs massively as an early sign of hemorrhage, the intra-abdominal bleeding from a vessel after tubal ligation can initially go undetected. Therefore, the diagnosis is usually delayed, increasing the risk of severe complications when definitive surgical treatment is not prompt [6]. Additionally, the interventions to manage uterine atony do not have a long lasting effect if the bleeding is intra-abdominal, increasing the risk of coagulopathy due to undetected bleeding [10]. POCUS assessment using the FASO exam might help in the process of emergency evaluation and result in a timely diagnosis and decrease maternal morbidity [3].

The gold standard imaging study to evaluate intra-abdominal bleeding is computerized tomography (CT). Currently, the use of FAST protocol in the emergency department allows the evaluation of intra-abdominal and pericardial bleeding caused by trauma. POCUS has the advantage of being inexpensive, repeatable, and rapid at the patient's bedside, with no exposure to radiation [6]. The modification of the technique for obstetrics patients (FASO examines the following anatomical areas: placenta and uterine cavity, bilateral hypochondria and the pouch of Douglas. Furthermore, it is useful to evaluate the diameter of the inferior vena cava in order to aid in the evaluation of volume status [13] (Figure 2).

Currently, the evaluation of uterine involution is done with a physical examination, but it can be influenced by the body-mass index, rigidity of the abdominal muscles, and the position of the umbilicus in relation to the symphysis pubis [14]. Given that clinical assessment can be variable, complementary methods like FASO are necessary. Proper training and clinical integration are required to use FASO safely given that postpartum patients can have physiologic intra-abdominal free fluid that is not pathological. In studies with CT [15] free fluid might be present in up to 73% of patients after Caesarian section. Nevertheless, if there is a large amount of free fluid, FAST has demonstrated an excellent sensitivity (69%–98%) and specificity (94%–100%) for detection of free fluid [5], with reported volume necessary to enable detection around 600mL in the Morison's pouch. This can be improved using the Trendelenburg position, in which smaller amounts of free fluid (100-400 mL) in the splenorenal and hepatorenal spaces can be identified

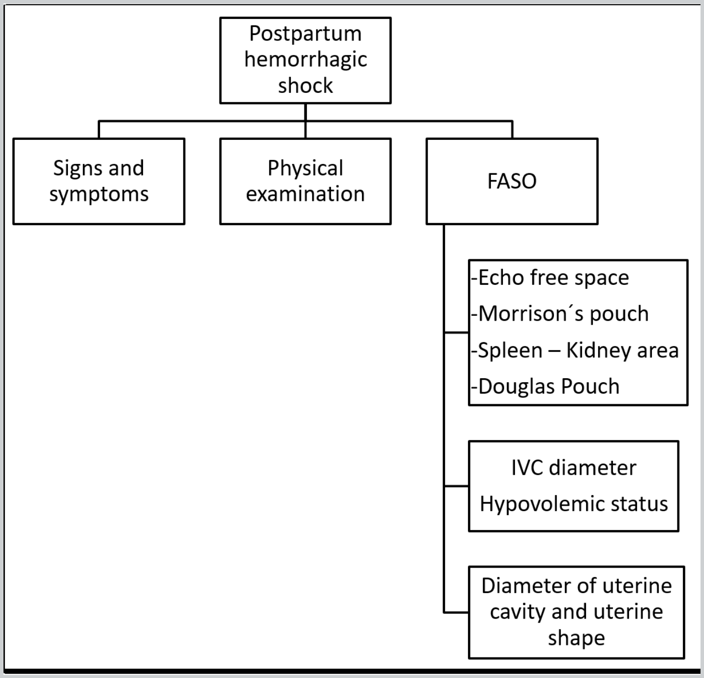

Figure 2. Diagnostic assessment used for postpartum hemorrhage shock. Combination of clinical evaluation with the FASO exam.

[16,17].

FASO examination in our patient showed free fluid in all the abdominal windows. This finding, in the clinical context of hemodynamic instability was highly suggestive of intra-abdominal hemorrhage. FASO proved helpful in the clinical decision-making process to proceed with surgical intervention.

Conclusions

In addition to the history and physical examination, POCUS should be considered in evaluating the post-partum patient for post-partum hemorrhage using the FASO exam. Combining clinical evaluation with the FASO exam might improve the decision-making process in patients with suspected post-partum hemorrhage.

Informed consent: The patient gave informed consent for publication.

Conflict of interest: There is not conflict of interest.

Statement of Ethics: Approved by the institutional ethical committee.

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Perceived Barriers and Facilitators to the use of Point-of-Care Ultrasound for Clinicians in Oregon

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Introduction

The use of Point-of-Care Ultrasound (POCUS) to provide clinical data beyond the history and physical examination is a relatively new practice for primary care providers and hospitalists. It takes many hours of dedicated ultrasound (US) training and practice to achieve POCUS proficiency; further, perceptions and attitudes of clinicians play a major role in adopting POCUS into daily clinical repertoire [1, 2]. Thus there are many possible barriers that could impede a clinician's ability to develop the skillset to use POCUS in clinical practice. The state of Oregon encompasses vast rural and underserved areas where POCUS could be a useful resource to improve local patient care [3,4]. For this reason, a qualitative survey study was conducted to assess the perceived barriers of clinicians to the clinical incorporation of POCUS.

Methods

A 20-question web-based survey was developed with input from local and national POCUS experts, including primary care, hospital medicine and emergency medicine physicians. This survey was administered on RedCap secure platform and approved by the Oregon Health & Science University (OHSU) Internal Review Board. Clinicians were invited to take the 5-10 minute electronic survey in-person on a provided tablet and volunteer participants included any clinician who provides direct medical care. Recruitment took place at four medical conferences in the state of Oregon, each of which served distinct audiences including hospitalists, primary care, general internal medicine, and clinicians interested in POCUS. In chronologic order these conferences were the American Institute of Ultrasound in Medicine & American College of Physicians co-sponsored workshop at OHSU in July, 2017, Northwest Regional Hospitalist Conference in September, 2017, American College of Physicians Oregon State Meeting in October, 2017, and OHSU Primary Care Review in February 2018.

Results

Thirty-six clinicians participated in the survey. Twenty were in Internal Medicine, 11 were in Family Medicine and five practiced in another specialty. Twenty-nine participants were attending physicians, in addition to three residents, three nurse practitioners, and one other clinician. Ten participants were either mostly or exclusively inpatient clinicians, 12 were both inpatient and outpatient and 14 were either mostly or exclusively outpatient clinicians. Eleven participants considered themselves Rural/Critical Access while 25 considered their practice setting to be Urban/Suburban. Eighteen (50%) participants were from teaching facilities. In terms of practice experience, 15 clinicians had less than ten years, nine had 10-20 years, and 12 had 20+ years of practice experience. Eleven surveyed clinicians currently use POCUS while 25 did not use POCUS.

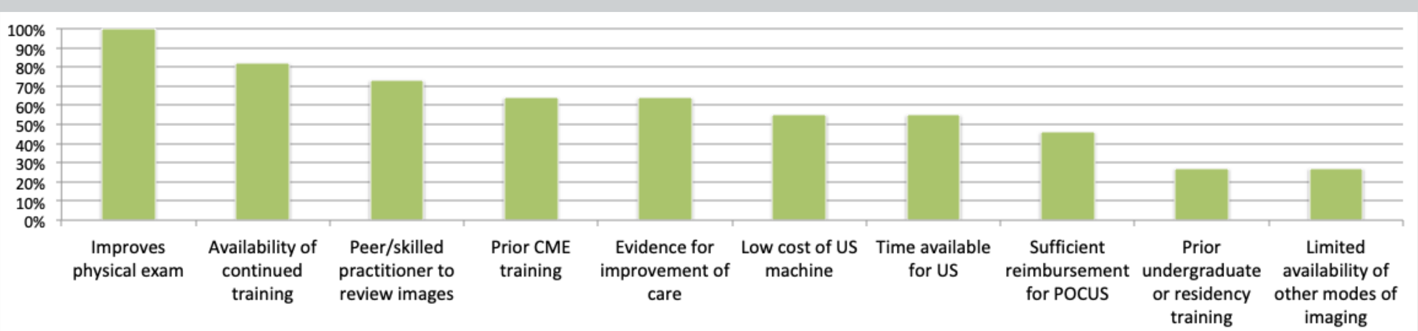

Figure 1. Percentage of current POCUS users indicating "most" or "very helpful" facilitators to incorporating of POCUS into clinical practice.

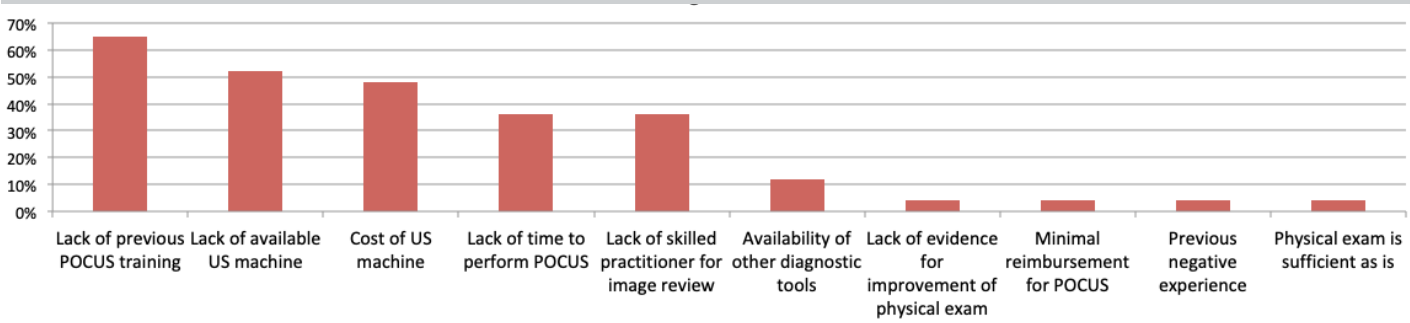

Figure 2. Percentage of non-POCUS users indicating "major" or "significant" barriers to incorporating POCUS into clinical practice.

Of the eleven respondents who use POCUS, the greatest facilitators were improvement of physical exam, availability of continued training, and peer/skilled practitioner to review US Images. These were given the highest ratings on a five-point Likert scale indicating they were the most helpful or very helpful attributes that facilitated POCUS in clinical practice (Figure 1).

Of the participants who indicated that they do not currently use POCUS in clinical practice, the most frequently reported barriers reported were lack of previous ultrasound training, lack of available ultrasound machine and high cost of ultrasound machine. These were given the highest rating on a five-point Likert scale indicating they were the major barrier or significant barrier that clinicians perceived impeding the ability to use POCUS in clinical practice (Figure 2).

Twenty-seven participants (75%) were either very likely or somewhat likely to take advantage of a regional training center if established in Portland, Oregon.

Discussion

Of clinicians surveyed, the greatest barriers to the use of POCUS were lack of previous ultrasound training, lack of available US machine, and cost of US machine. The most common facilitators included availability of continued training (CME), peer/skilled practitioner to review US images, and evidence of improvement of care. An overwhelming majority were at least at least somewhat likely to incorporate POCUS into their clinical practice if their noted barriers were removed, and also to take advantage of a regional ultrasound-training center if available in Portland, Oregon.

Participant recruitment was a major limitation to this project. Several attempts at obtaining participants through e-mails and newsletters first failed, thus only complete surveys that were completed in-person on electronic tablet were included in the final results. Half of those surveyed were from teaching facilities, likely a reflection of a higher proportion of academic clinicians attending surveyed conferences. However, despite small sample size, the demographics of those surveyed represented a relatively broad variety of practice types and experience levels.

Ethics

Statement of ethics approval/consent: OHSU IRB: 00016842

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Point-of-Care Ultrasound Training for Family Medicine Residents: Examining the outcomes and feasibility of a pilot ultrasound curriculum

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Introduction

It is estimated that 50% of deaths due to abdominal aortic aneurysms (AAA) could be prevented by a national screening program [1, 2, 3]. Thanks to technological advancements and cost reductions, point-of-care ultrasound (POCUS) in family medicine (FM) is becoming more prevalent [4, 5]. Despite the potential utility of POCUS in FM, of 224 FM residency programs surveyed, only 21% had developed a curriculum [6]. The main barriers identified to establishing a FM POCUS curriculum in Canadian FM residency programs were lack of trained faculty, lack of adequate equipment and lack of time in the curriculum [6].

Our study tested a pilot POCUS curriculum for first year FM residents which was developed to improve competency in screening for AAA using POCUS. To address the barrier of many learners, and few trained faculty, we incorporated a "train-the-trainer" model. The first set of two residents were trained by Canadian POCUS (CPOCUS)-certified faculty members [7] during a week of evening clinics. These two residents subsequently trained the next subset of two residents, tumbling forward over four weeks until eight residents were trained. This minimized direct faculty teaching time.

The confidence, knowledge, and clinical competence of trainees were assessed at various time points to assess the efficacy of our curriculum.

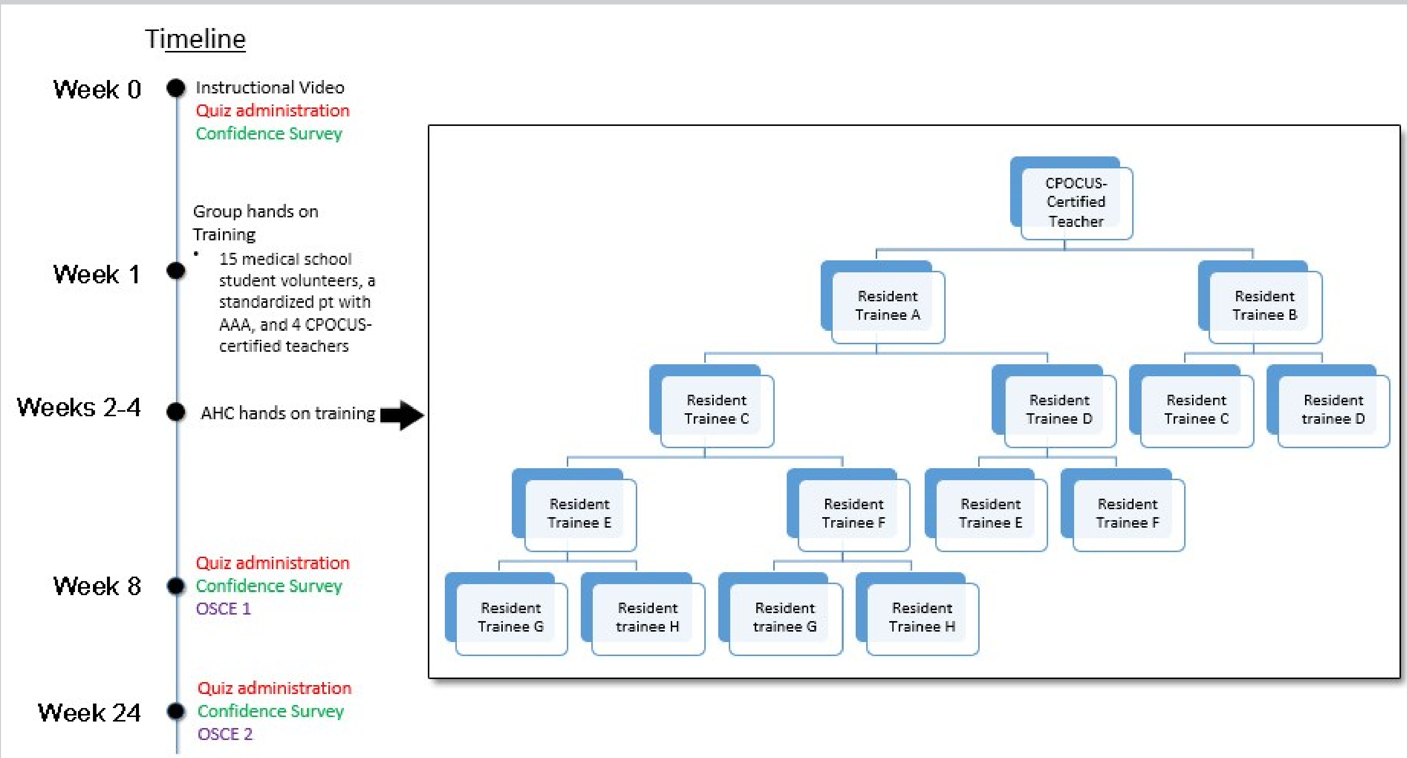


Figure 1. Pilot curriculum design with flow diagram depicting AHC rolling-forward structure of training and teaching.

Table 1. Prior experience of residents with US

Trainee	Formal US training prior to study	Number of AAA scans performed prior to study
1	Basic/introductory ultrasound course (e.g. EDE1)	4
2	Obstetrical US training - Biophysical profile, Estimated fetal weight	0
3	Ultrasound training at Queen's Family Clinic, ultrasound workshop as a medical student	0
4 to 8	None	0

Methods

Approval was obtained from the Queen's University Research Ethics Board. Eight FM residents were recruited on a voluntary basis and surveyed to obtain demographic information and prior exposure to POCUS (Table 1).

One week prior to hands-on training, trainees were given access to a 30-minute video teaching basic knobology and physics, POCUS techniques, and clinical integration related to AAA. Subsequently, they were quizzed on this information to assess knowledge and confidence. Confidence was rated on a 5-point Likert scale (1 = "Not confident at all", 5 = "Fully confident").

The first hands-on session was taught by four CPOCUS-certified faculty [7] and senior Emergency Medicine (EM) residents. Trainees practiced on fifteen medical student volunteers and one standardized patient (SP) with an AAA. All trainees obtained sixteen supervised scans during this session.

Further training took place in an after-hours walk-in-clinic (AHC) where patients were invited to volunteer to be scanned. Trainees were paired; Group 1 (trainees A and B) was trained by a POCUS certified instructor for 6 hours. Trainees A and B from Group 1 then trained Group 2 (trainees C and D) for 3 hours each. Group 2 then trained Group 3 and so forth. Using this rolling-forward structure, each trainee received 6 hours of training and provided 3 hours of teaching.

Trainees were assessed for competency using an objective structured clinical examination (OSCE) tool which targeted patient preparation, image acquisition/optimization, image interpretation, and clinical integration. Knowledge and confidence were assessed in the same domains using an electronic quiz and confidence survey. The same quiz was administered multiple times, but the answers were never provided.

For the OSCEs, two SPs (one with an AAA) were recruited. CPOCUS certified examiners blinded to the AHC training sessions scored trainees using an OSCE rubric created by the Queen's Department of Emergency Medicine (Table 2).

The quiz, confidence survey, and OSCE were administered once all residents completed AHC training, as well as four months later to assess retention. The quiz and confidence survey were also administered after trainees

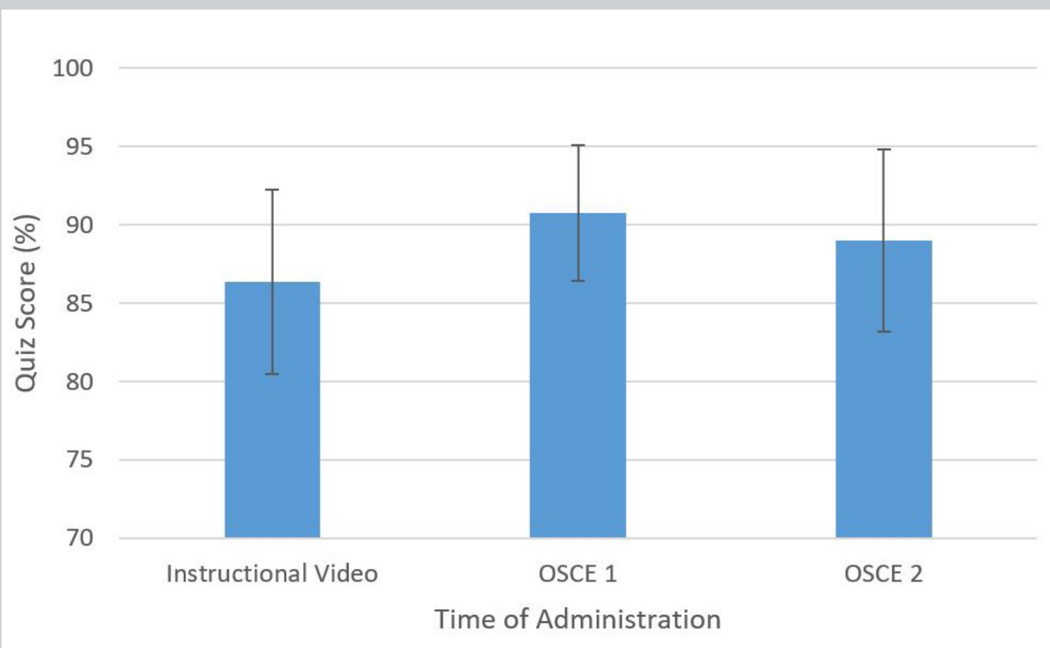


Figure 2. Quiz scores at different times of administration. "Instructional video" indicates quiz administration after watching the instructional video for the first time.

Table 2. OSCE Rubric with description of scores.

Domain	Criteria assessed
Preparation	• Ergonomics (bed height, arm reach, etc.) • Patient position • Probe Selection • Gel application • Draping • Initial settings (depth, preset) • Patient engagement
Image Acquisition	• Starting location • Hand and probe position • Identify appropriate landmarks • Aorta discriminators • Timing and economy of movement • Measurement
Image Optimization	• Centers area of interest • Appropriate gain • Frequency adjustment • Focal zone • Troubleshooting (gas, umbilicus, fat, artifacts)
Clinical Integration	• Interpretation (indeterminate, AAA, normal) • Understands limitations of US scan • Management priorities
Score	**Description**
1	Inferior - delayed or incomplete performance of all criteria. Entrustment decision: observation only, no execution
2	Novice - delayed or incomplete performance of many criteria. Entrustment decision: direct supervision required
3	Competent - delayed or incomplete performance of some criteria. Entrustment decision: indirect supervision required
4	Advanced - competent performance of most criteria. Entrustment decision: independent performance with remote supervision
5	Superior - efficient and rapid performance of all criteria. Entrustment decision: supervision of trainees

had watched the training video but before hands-on training. Formative group feedback was provided after the first OSCE. However, answers were never provided for the quiz or questions posed during OSCEs.

For quiz and confidence scores, single factor ANOVA was applied to the data to screen for significant differences in scores after watching the Instructional video and when OSCE 1 and 2 were administered. If F > Fcrit, paired t-tests were applied to identify where significant differences were present (i.e. between instructional video and OSCE 1, between instructional video and OSCE 2 and/or between OSCE 1 and OSCE 2). Paired t-tests were utilized to assess whether significant differences ($p<0.05$) were found in competency scores between OSCE 1 and OSCE 2. The same test was used to assess for significant differences between Group 1 vs. Group 4 OSCE scores. A summary of the study design is provided in Figure 1.

Results

Knowledge: quiz scores were 86.3%, 90.8% and 89.0% at Instructional video (i.e. after watching the video with no hands-on training), OSCE 1 and OSCE 2 respectively. There were no significant differences between scores (Figure 2).

Confidence: Between Instructional video and OSCE 1, all domains showed significant increase in confidence. Overall confidence after watching the instructional video averaged a score of 1.75, increasing to 4.50 by OSCE 1 and remaining high at 4.33 by OSCE 2. There was no significant difference in confidence in all domains between the two OSCEs (Figure 3).

Competency: There was no significant difference in OSCE scores between the two OSCEs, suggesting competency was retained after training for a minimum of four months. In both OSCEs, all trainees except for one had an entrustment decision score of 4, which meant independent performance with remote supervision. One trainee in both OSCEs scored a 3 for entrustment decision, which meant indirect supervision was required; however, this was not the same trainee for both OSCEs, and the two individuals were only rated a 3 by one of two POCUS evaluators. All residents reported performing POCUS less than once a month between OSCEs 1 and 2. The average score of all the domains were 3.75 and 3.70 for OSCE 1 and 2, respectively (Figure 4).

Effect of rolling-forward AHC training: OSCE scores for Group 1 (trainees A and B) in the AHC were not significantly different from OSCE scores for Group 4 (trainees G and H) in all competency domains (Figure 5).

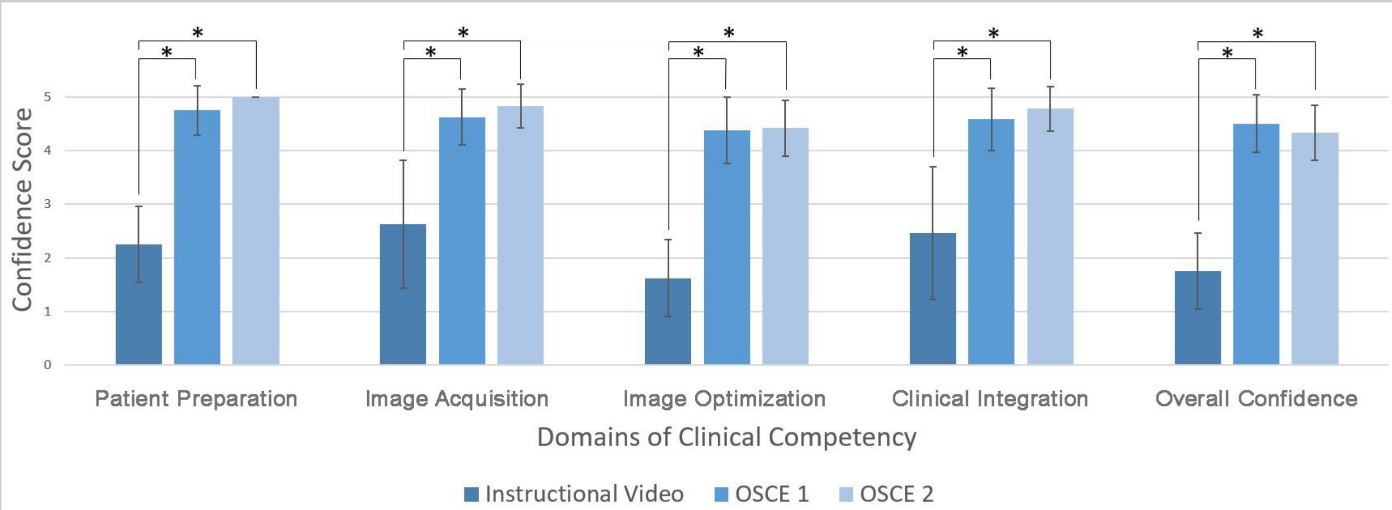


Figure 3. Confidence scores in each domain of clinical competency. Responses were gauged on a Likert scale where 1 = "Not confident at all" and 5 = "Fully confident." * $p < 0.05$.

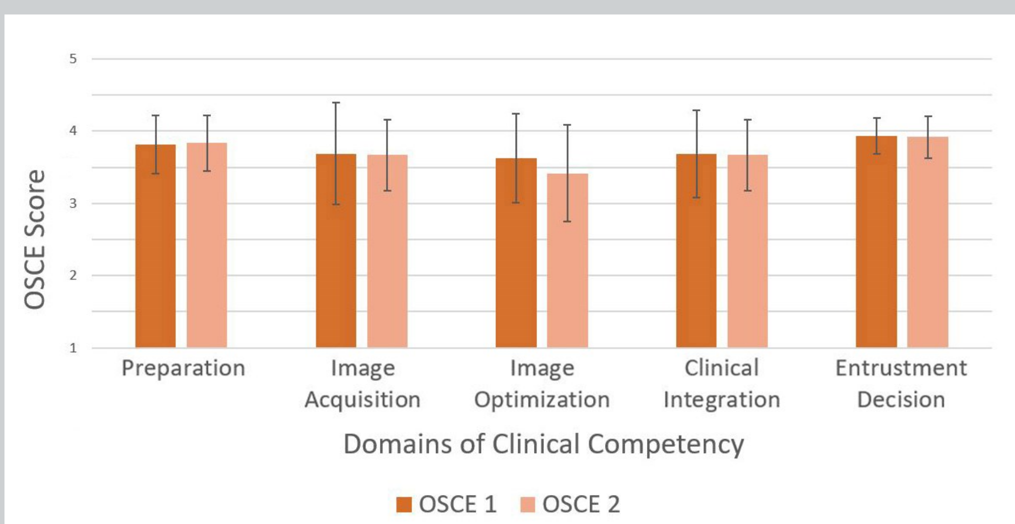
Conclusion

As part of the curriculum at Queen's university, FM residents participate in short horizontal experiences, each being an 8-16 hour commitment. The pilot POCUS curriculum had the same time commitment (total 12.5 hours) and ensured confidence, knowledge, and clinical competence that was retained at four months post-training. Our study had a small sample size, but most of our trainees had no prior US training, which is common amongst other first year FM residents.

The rolling-forward "train-the-trainer" curriculum encouraged professionalism and minimized demands on faculty to provide hands on training. There were no apparent differences in confidence, knowledge, or competency for trainees who were taught by faculty compared to trainees taught by other trainees.

During both OSCEs, the CPOCUS-certified examiner directly observed residents measure the aorta and assessed them using an established rubric in order to assess competence. However, one limitation is that the quantitative accuracy of the actual AAA measurements performed by the learner during training was not directly assessed by the instructor. This could have been achieved by comparing the trainee's measurements with a CPOCUS-certified trainer's findings on the same abdominal aorta. Accuracy is important because: 1) false negative measurements would mean that prevention of a life-threatening condition (AAA=related mortality, rupture and emergency repair) could have been avoided, and 2) false positive measurements generate unnecessary confirmatory imaging, follow-up care including emergency transfer and specialist referrals, and undue patient stress. Blois (2012) did demonstrate that a family physician could develop an accuracy with less than 0.2 mm discrepancy from official measurements but the physician in this study received significantly more training (i.e. 50 supervised scans) [1].

Figure 4. OSCE scores for each domain of clinical competency. Scores were gauged on a Likert scale where 1 = "Observation only, no execution", 2 = "Direct supervision required", 3 = "Indirect supervision required", 4 = "Independent performance with remote supervision", 5 = "Supervision of trainees."



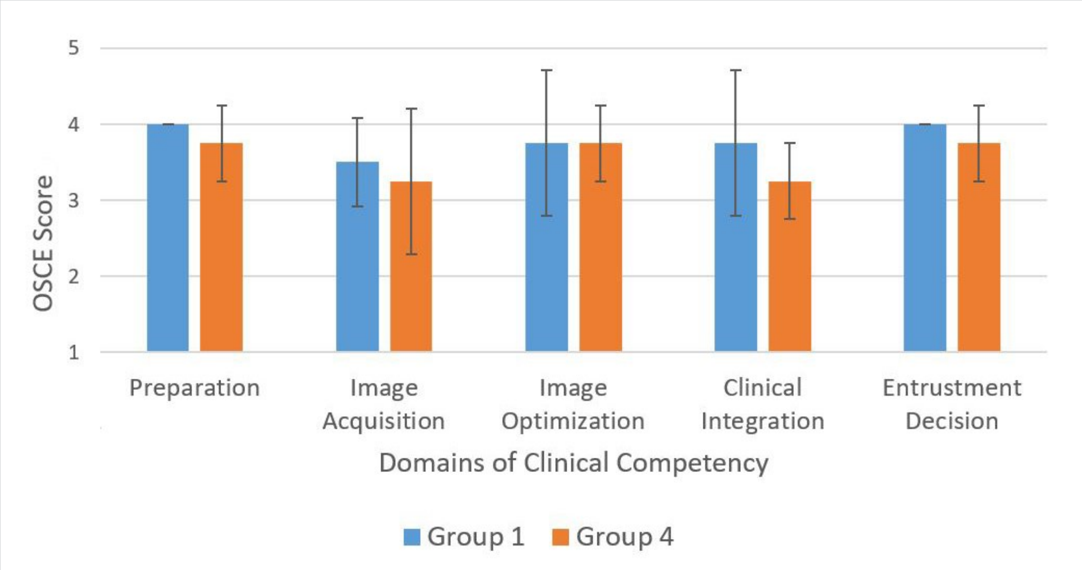


Figure 5. OSCE scores for each domain of clinical competency between Group 1 (Trainee A and B) and Group 4 (Trainee G and H) in rolling-forward AHC training.

In 2016, Wilkinson et al. also studied the effectiveness of a condensed POCUS curriculum but for the purposes of teaching cardiac scans [8]. Trainees were required to diagnose several pathologies, such as severe left ventricular dysfunction and ventricular septal defects. Of note, the curriculum was short and only provided 4 hours of either hands-on-training *or* simulation-based training taught by senior residents or ultrasound technicians [8]. This study raised a legitimate concern that condensed curriculums may have the undesired effect of increasing trainee confidence without the necessary increase in competency. Despite a significant increase in trainee confidence, there was an increase in the false positive rate after the training [8].

In contrast to these findings, our trainees exhibited concomitant increases in confidence, knowledge, and clinical competency. This was likely because our curriculum taught a single application, was longer in duration (12.5 hours), and utilized several different teaching modalities including a didactic online lecture, hands-on practice taught by POCUS-trained physicians, and peer-to-peer training. In incorporating POCUS training into an already overflowing medical curriculum, it is vital that the POCUS curriculums developed not only increase trainee confidence but also ensure clinical competency and improve patient care.

For FM residents interested in incorporating POCUS into their future practice, studying the efficacy of this teaching curriculum when applied to an entire FM residency program should be considered. The supplemental curriculum we have developed has the potential to teach them a life-saving scan which would be indicated for many patients seen in a typical FM practice [1, 2].

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Minding the Gap(s): Hospitalists Experience Aspirational, Safety, and Knowledge Deficits That Prevent Them From Practicing POCUS

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Abstract

Point-of-care ultrasound (POCUS) has been a mainstay of clinical decision-making in the intensive care unit and emergency department for more than a decade, but adoption into hospital medicine has lagged behind. Recently, internal medicine residency programs have started to develop POCUS curricula for trainees, though concurrent hospitalist training programs have been limited to date, with little consensus on what hospitalist-oriented curricula should entail. As such, there is wide variability amongst hospitalists with respect to utilization of, training in, and proficiency in POCUS. We conducted a two-part survey of internal medicine hospitalists at our institution: (1) *needs assessment* that focused on prior training, attitudes and perspectives, current practices, desired use, and barriers to clinical integration; and (2) *knowledge test* of exam indications, image interpretation, medical decision-making, and understanding of limitations. Our results demonstrate that a majority of hospitalists felt that POCUS was important for diagnostic purposes and that they would benefit from POCUS-specific education. Inadequate training was the most cited barrier to POCUS use. Hospitalist knowledge was lacking in all domains, particularly image interpretation and clinical integration. As a result, we created a three-tiered training program meant to engage: (1) *All* hospitalists in basic knowledge and appropriate use of POCUS, (2) *Some* hospitalists in hands-on skill acquisition and image interpretation, and (3) *Few* hospitalists in mastery of POCUS with resultant formal credentialing. A tiered approach to POCUS training for hospitalists ensures a fundamental cognitive understanding of POCUS for all, but also facilitates hands-on training for those who are committed to further skillset development.

Background

Point-of-care ultrasound (POCUS) is increasingly recognized as an important real-time diagnostic tool in hospital medicine for a variety of clinical indications, including dyspnea, hypotension, volume assessment, skin and soft tissue infections, and others [1-8]. The incorporation of POCUS into clinical decision-making has been shown to increase the speed and accuracy of initial diagnosis, decrease procedural complications, and increase patient satisfaction compared to usual care [9-11]. While POCUS has been adopted and studied within the emergency department and intensive care unit for nearly two decades, its integration into internal medicine practice has lagged behind.

In recent years, POCUS training for hospitalists has gained momentum. The American Medical Association (AMA) has stated that "ultrasound imaging is within the scope of practice of appropriately trained physicians," and the American College of Physicians (ACP) has announced that it "will collaborate with other professional societies to facilitate the implementation of appropriate uses of POCUS throughout internal medicine training and practice." [12, 13]. In 2018, the Society of Hospital Medicine (SHM) released a position statement defining elements of cardiac, pulmonary, abdominal, musculoskeletal, vascular, and procedural ultrasound as within the scope of the POCUS-trained hospitalist [14]. Additionally, there is increasing proliferation of institutionally supported faculty and residency curricula across academic medical centers [15-17].

Despite support from national societies and expansion of POCUS training programs, no consensus exists for what components a POCUS curriculum should include. Ma et al. proposed that the minimum requirements for a 3-year internal medicine residency program curriculum, based on conclusions from an expert consensus method, should consist of: inferior vena cava, lung b-lines, pleural effusion, abdominal free fluid, central venous catheterization, thoracentesis, and paracentesis [18]. Mathews et al. modeled a hospitalist-oriented curriculum after the American College of Chest Physicians (ACCP) Certificate of Completion (COC) program that included broader domains: machine controls ("knobology"), vascular, lung, abdominal, and cardiac ultrasound [19]. Alternatively, Bahner et al. have argued that while programs may need to vary in content in order to be specialty-specific, there should be a standard educational and clinical practice model that all programs follow: the I-AIM model [20]. This model focuses the learner on four domains for any POCUS application: Indication, Acquisition, Interpretation, and Medical Decision-Making. By applying this educational framework to a POCUS curriculum, physicians are guided towards appropriate educational and clinical use of any application.

We hypothesize that there has been wide variability of hospitalist exposure to POCUS training, leading to high variance with respect to competence, knowledge, and utilization of this skillset. Here, we describe the results of a two-part survey performed within our institution's three academic medical centers in an effort to better describe the current culture of POCUS understanding and education within hospital medicine.

Methods

We conducted a two-part survey in order to better understand present POCUS knowledge and practice amongst internal medicine hospitalists in order to create an educational program that is effective, accessible, and robust.

First, we created and disseminated a needs assessment within the Divisions of Hospital Medicine in three large, urban, academic hospitals. It involved a 13-item, web-based questionnaire focused on attitudes and perspectives, prior training, current practices and competencies, barriers to clinical integration, and aspirational goals.

Second, we conducted a web-based knowledge test to hospitalists within one of the three divisions. This test was comprised of 15 multiple choice questions that assessed different elements of the I-AIM model for a number of core POCUS applications: cardiac, IVC, lung, renal/bladder, skin and soft tissue ultrasound. Responses to the knowledge test were grouped by level of experience as a hospitalist (0-3 years, 4-6 years, 7-10 years, >10 years). Statistical analysis was performed using analysis of variance (ANOVA).

Both parts of the survey were reviewed by the institutional IRB and granted exemption status prior to dissemination.

Results

Needs Assessment

The response rate for the needs assessment was 64% (82/129). Most hospitalists had little formal training in POCUS with approximately four fifths of hospitalists reporting fewer than ten hours of training with respect to dedicated didactics (81%), supervised practice (85%) and image interpretation (84%). Key findings from this survey are summarized in Table 1.

Despite their limited experience with POCUS, the vast majority of hospitalists felt that it was important for diagnostic purposes in internal medicine (93%) and that it should be a formal part of residency training (88%). Furthermore, almost all hospitalists (93%) believed that they would benefit from a dedicated POCUS training program.

Table 1. Key Findings of the Hospitalist Needs Assessment

Importance:	
I believe POCUS is important for diagnostic purposes in internal medicine.	93%
I believe POCUS should be a formal part of residency training.	88%
Desired Use:	
Given proper training and access to equipment, I foresee myself using POCUS regularly to assist with clinical decision-making.	73%
Current Use:	
I currently use POCUS is some aspect of clinical care.	67%
Barriers:	
Inadequate training in POCUS	86%
Inconvenient/Lack of access to ultrasound machine	76%
Inadequate time to incorporate POCUS into clinical practice	52%
Future Directions:	
I believe faculty would benefit from faculty development in POCUS.	93%

With regard to current practice, a minority of hospitalists regularly incorporated POCUS into their clinical decision-making (16%). The five most important indications for POCUS identified by respondents included evaluation of volume status (using the inferior vena cava), left ventricular function, peritoneal fluid, pericardial effusion and pleural effusion. Yet, only a fraction of them felt highly competent to perform and interpret these examinations (5-47% depending on the indication, Figure 1). Moreover, a substantial proportion of hospitalists demonstrated knowledge deficits of the clinical applicability of POCUS. A fifth of respondents (20%) omitted widely accepted uses of POCUS in hospital medicine (e.g. lung ultrasound in a hypoxic patient) and another fifth (21%) endorsed POCUS for controversial, and generally non-recommended, indications (e.g. cardiac ultrasound to evaluate for aortic valvular disease).

The greatest barriers to POCUS use included inadequate training (86%), inconvenient and/or lack of access to

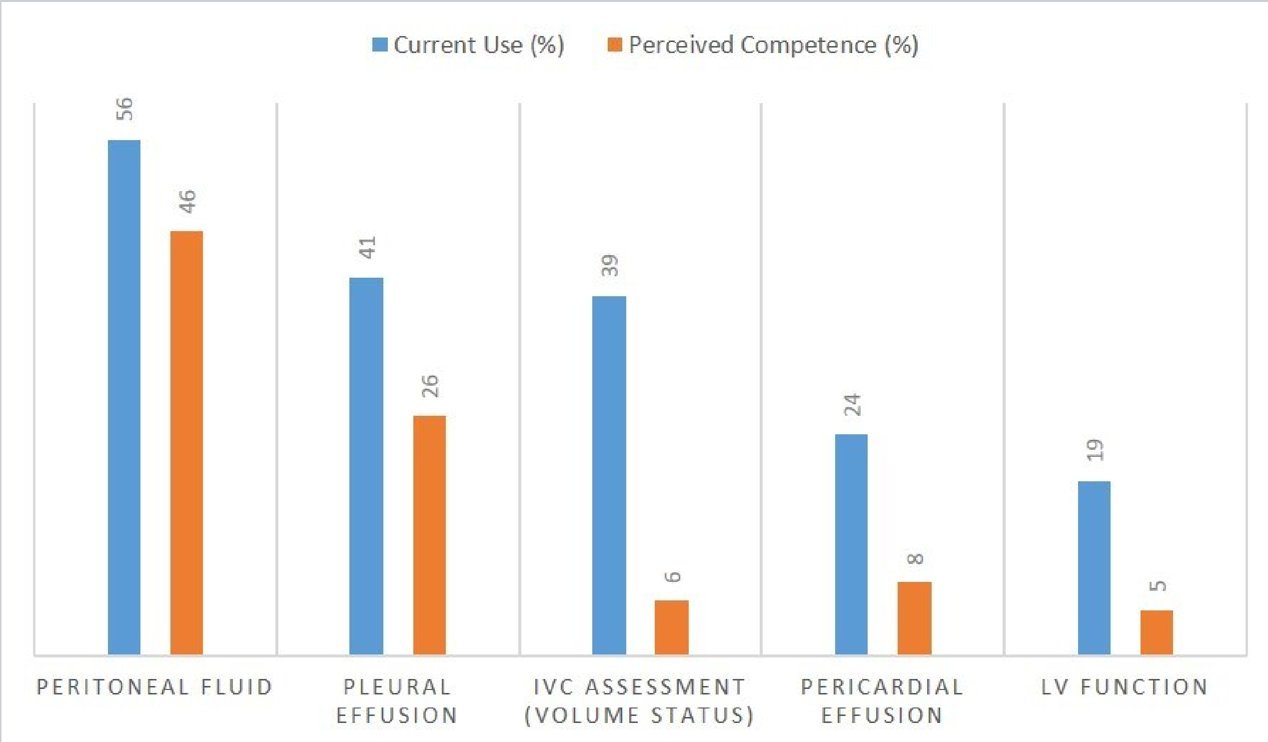

Figure 1. The Safety Gap Between Current Use and Perceived Competence. Survey respondents identified five domains of most frequent POCUS use in clinical practice: diagnostic evaluation of peritoneal fluid, pleural effusion, volume status (IVC), pericardial effusion, and LV function. However, hospitalists perceived competence in using POCUS for these five indications consistently fell below their reported use. We defined the gap between current use and perceived competence as the "safety gap" in faculty POCUS use.

ultrasound equipment (76%), and inadequate time to incorporate it into their clinical workflow (52%). If these barriers were addressed with proper training and access to equipment, most hospitalists could foresee themselves regularly incorporating POCUS into their clinical decision-making (73%).

Knowledge Test

The response rate for the knowledge test was 57% (55/97). The overall average score was 41% with a wide range in test performance (11-67.5%). Overall test scores and performance by I-AIM domain is summarized in Figure 2.

Test performance varied inversely based on level of experience with the most junior hospitalists (0-3 years since graduation from residency) scoring the highest (56%), the most senior hospitalists (>10 years since graduation from residency) scoring the lowest (22%), and mid-career hospitalists (4-6 and 7-10 years from residency graduation) scoring in between (37-43%, $p = <0.005$).

The significant difference in total score was driven primarily by two I-AIM domains – image interpretation and clinical integration – where junior hospitalists performed the best (54% and 58%, respectively) and senior hospitalists performed the worst (19% and 16.5%, respectively; both $p < 0.005$). Mid-career hospitalists performed consistently across all I-AIM domains (average scores ranging from 32-44%). There was no significant difference in scores assessing understanding of POCUS indications or limitations ($p = 0.75$ and 0.21, respectively), which appears to be driven by the relatively poor performance of all groups (range 33-44% and 25-46%, respectively).

Discussion

The results of our surveys reveal three major gaps in POCUS utilization in this hospital medicine population. These gaps are primarily driven by a lack of training and is a ready target for intervention.

First, our needs assessment identified an "aspirational gap," which we have defined as the difference between the current and desired states of POCUS adoption. This gap represents hospitalists who believe in the potential for POCUS to improve clinical care, but struggle with the hurdles that create a high barrier to entry, such as constraints on time, training and equipment availability, and financial support from their institution. As a result, these hospitalists may never have the opportunity to engage with POCUS education in its current modes of

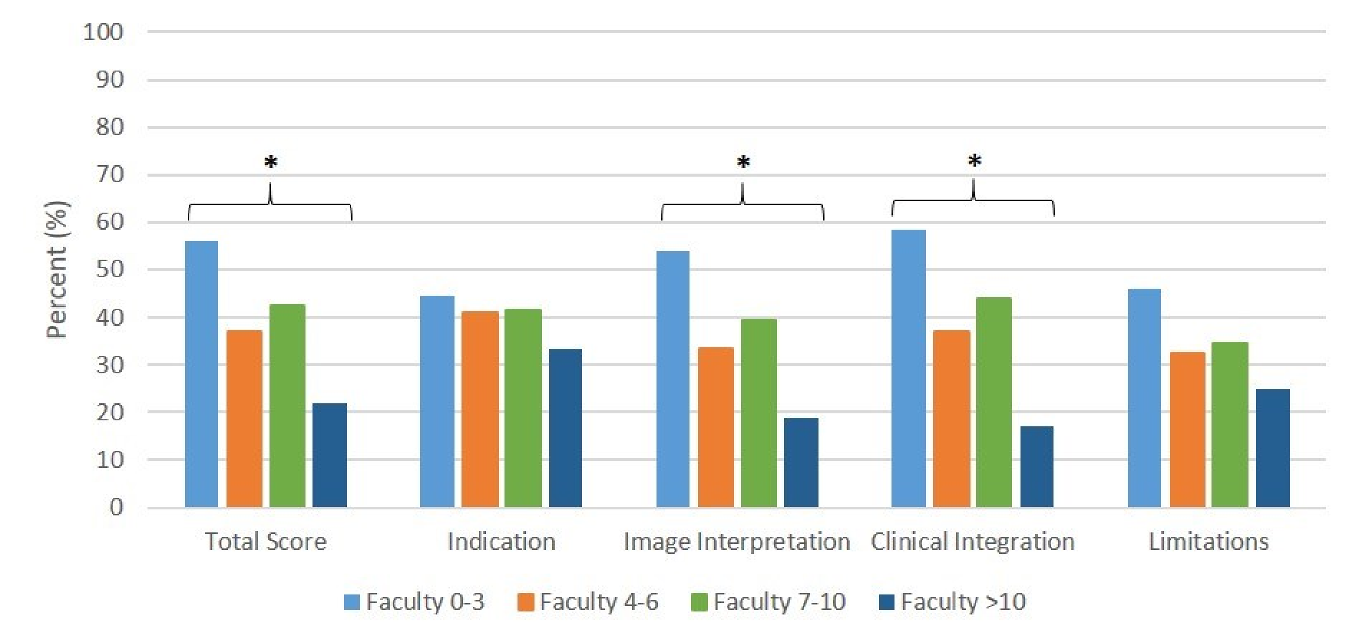

Figure 2. Knowledge Test Performance by Level of Hospitalist Experience. Hospitalist test scores varied significantly by level of experience (0-3 years, 4-6 years, 7-10 years, and >10 years) in the domains of total score (56, 37, 42.5, 22% respectively; $p = 0.0023$), image interpretation (54, 33.5, 39, 19% respectively; $p = 0.0015$), and clinical integration (58, 37, 44, and 17% respectively; $p = 0.0003$). There was no significant difference between groups in the domains of POCUS indication (44.5, 41, 41.5, 33% respectively; $p = 0.75$) or understanding of limitations (46, 32, 34.5, 25% respectively; $p = 0.21$). Legend: * = $p < 0.005$.

delivery. However, they still need to achieve a fundamental cognitive understanding of its basic principles, appropriate use, interpretation, and limitations in order to remain current given the growing body of physicians and trainees who have already integrated POCUS into their clinical practice.

Second, our needs assessment identified a "safety gap," which we have defined as the difference between current use and perceived competence in POCUS. This gap represents hospitalists who currently use POCUS without feeling confident in their abilities to accurately and reliably acquire and interpret ultrasound images with subsequent integration into their clinical decision-making. These hospitalists are more readily able to engage in POCUS education, but require additional training with emphasis on hands-on skill development and structured image review in order to promote high quality and safe clinical utilization of POCUS.

Third, our knowledge test revealed an overall deficit of understanding with respect to basic POCUS principles amongst all hospitalists, but particularly mid-career and senior hospitalists. These groups presumably had little-to-no POCUS education during their residency training and are at highest risk of being eclipsed by more junior hospitalists and trainees as POCUS use expands. This knowledge deficit was most significant in the domains of image interpretation and clinical integration, where junior hospitalists demonstrated higher levels of proficiency. However, it is notable that no hospitalist group achieved an average score >50% regarding POCUS indications or limitations, which is a concern for safety and appropriate POCUS use as this tool becomes more readily available.

Our survey had two major limitations. First, all data was collected from a single, academic center, which may limit its generalizability to all hospitalists. Secondly, our knowledge test questions were not previously validated. We believe that despite these limitations, our survey results reflect the current state of hospitalists with respect to their perspectives and knowledge of POCUS.

In order to address these gaps, we have developed a three-tiered POCUS curriculum that not only mandates cognitive competence for all hospitalists, but also offers expanded opportunities to engage up to their desired level of technical competence. Each tier is divided in order to achieve specific aims:

All hospitalists in basic knowledge and appropriate use of POCUS,

Some hospitalists in hands-on skill acquisition and image interpretation,

Few hospitalists in quality assurance and mastery of POCUS with resultant formal credentialing (Figure 3).

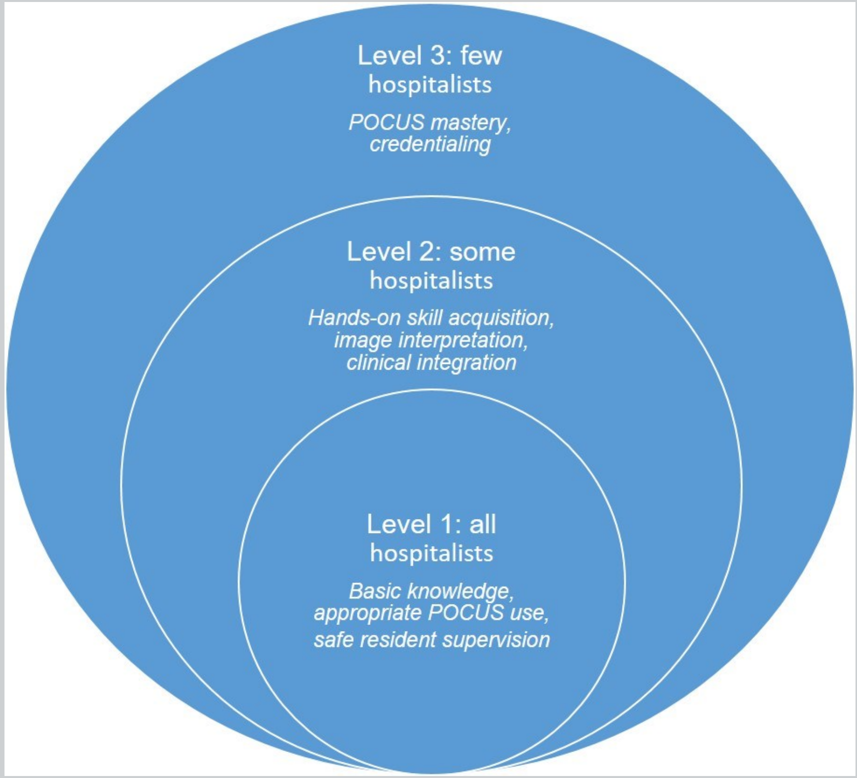

Figure 3. Schematic of Curricular Design and Learning Objectives. This novel, tiered approach to POCUS education engages all hospitalists in basic POCUS knowledge and safety principles designed to aide them in resident supervision and collaboration with other inpatient providers (EM, ICU). Levels 2 offers voluntary training for hospitalists who want to develop the technical skill necessary to incorporate POCUS into clinical practice. Level 3 is structured as mentored portfolio development and assessment in order for hospitalists to achieve mastery and meet requirements for credentialing.

The purpose of tiered training is pragmatic: all hospitalists must achieve a baseline knowledge and familiarity with fundamental concepts, while interested hospitalists must be empowered with a pathway for technical competence as well as comprehensive mastery. This is critical for hospitalists who have resident physicians under their supervision and collaborating specialists in emergency medicine and critical care who use POCUS routinely, as well as those who wish to incorporate POCUS into their own clinical practice. We aim to achieve tiered training by offering core didactics in an accessible format with online modules for cognitive competence, supervised practice through hands-on sessions and scanning shifts for technical competence, and mentored portfolio building and longitudinal image review sessions for mastery. Lastly, by providing ongoing educational opportunities and mentorship, we hope to expand the cohort of advanced POCUS practitioners within our hospitalist group that not only use POCUS to deliver high quality care for our patients, but also teach it to all levels of learners.

Conclusions

Point-of-care ultrasound is an important skillset that will be essential to the practice of hospital medicine in the near future. A needs assessment of the present state of POCUS within our institution has identified both an “aspirational” and a “safety” gap between current and desired use of POCUS as well as current use and perceived competence in POCUS, respectively. Furthermore, we identified significant knowledge gaps in all hospitalists, particularly amongst more senior hospitalists and in the domains of image interpretation and clinical integration. These gaps call for a novel, tiered curriculum that ensures a fundamental cognitive understanding of POCUS for all hospitalists, but also facilitates hands-on training for those who are committed to further skillset development ranging from technical competence for a limited set of indications to complete credentialing for the full spectrum of applications. We share a common concern that residents and other hospital-based providers will be using POCUS clinically to an extent that will eclipse the hospitalist’s ability to safely supervise them or integrate their findings without expanding training in a pragmatic and thoughtful manner that accounts for current barriers to learning.

Ethics Approval

Institutional IRB at USCF reviewed and approved the project under exempt certification: (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

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Simulator-Based Training in FoCUS with Skill-Based Metrics for Feedback: An Efficacy Study

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Abstract

Introduction: Focused Cardiac Ultrasound (FoCUS) is a relatively new technology that requires training and mentoring. The use of a FoCUS simulator is a novel training method that may prompt greater adoption of this technology by physicians at different levels of training and experience. The objective of this study was to determine if simulation training using an advanced echo simulator (Real Ultrasound®) is a feasible means of delivering training in FoCUS. **Methods:** Twenty-five residents and attending physicians participated in this study. After performing a pretest, training on the Real Ultrasound® was administered. Improvement was assessed immediately after simulator training. Additionally, some participants were retested six months after training to determine whether learned skills were retained. **Results:** Of the 25 participants recruited, all completed the pretest phase, and 17 completed the training and immediate posttest assessment. At pretest, the median angular deviation of acquired images from anatomically correct was 37°, which improved to 30° after training ($p<0.002$). Technical skill was largely maintained at six months of follow-up, with a median angle error of 27 and 31°, respectively ($p=0.093$) in 8 participants who completed the post and six-month retention assessments. The median pretest image interpretation score improved from 55% to 70% ($p=0.028$); median post and six month scores in the 8 participants were 72 and 68%, respectively ($p=0.735$). **Conclusions:** Simulation training in FoCUS significantly improves skills in image acquisition. These skills appear to be retained over time. This study adds support for the use of advanced echocardiographic simulators to enhance formal FoCUS training in a real-world setting.

Introduction

Point of care ultrasound (PoCUS) techniques, such as focused cardiac ultrasound (FoCUS), are useful adjuncts to the clinical examination of patients and are being rapidly adopted [1]. Currently, training in PoCUS is provided either during graduate medical education, at postgraduate educational conferences, or informally via online self-study. Much of the training being offered today is not hands-on, so skills consolidation requires that image acquisition and interpretation be learned under the direct supervision of a highly-trained instructor on live patient models. Although there is a growing need for formal training, it is both time and resource intensive [2].

The Real Ultrasound® cardiac ECHO simulator was developed to address these issues, as it can be utilized by physicians at any level of training and experience [3]. One advantage of simulators is that they allow clinicians to train on their own time and in a self-directed fashion. In this mode of training, clinicians benefit from real-time feedback regarding the anatomic accuracy with which they acquire standard views, which can be especially important early in the process of skills development [4-6].

We aimed to assess the utility of FoCUS simulation as a training aid for physicians at the graduate and postgraduate levels. In theory, by providing a freely accessible asynchronous mode of training via simulation, traditional time and cost limitations of PoCUS training can be largely overcome, while ensuring that training remains rigorous, reproducible, and effective. In this study, we assessed skills for cardiac image acquisition and interpretation, as well as improvement (short-term and long-term retention of skills) using a newly developed ultrasound simulator (Real Ultrasound®).

Methods

Study population

Invitations to participate in this study were sent to internal medicine residents, as well as internal medicine and emergency medicine attending physicians at Legacy Emanuel Medical Center (Portland, OR, USA). Twenty-five individuals (internal medicine residents, hospitalists, and emergency medicine physicians) gave their written consent to participate after being informed of the risks and benefits of study participation. This study was evaluated and approved by the Legacy Health Institutional Review Board.

Study design

The FoCUS simulator used in this study was developed at the University of Washington (UW) and has been validated in multiple studies for training and competency assessment [3,7,8]. Participants first completed a pre-training assessment (pretest), then a training curriculum

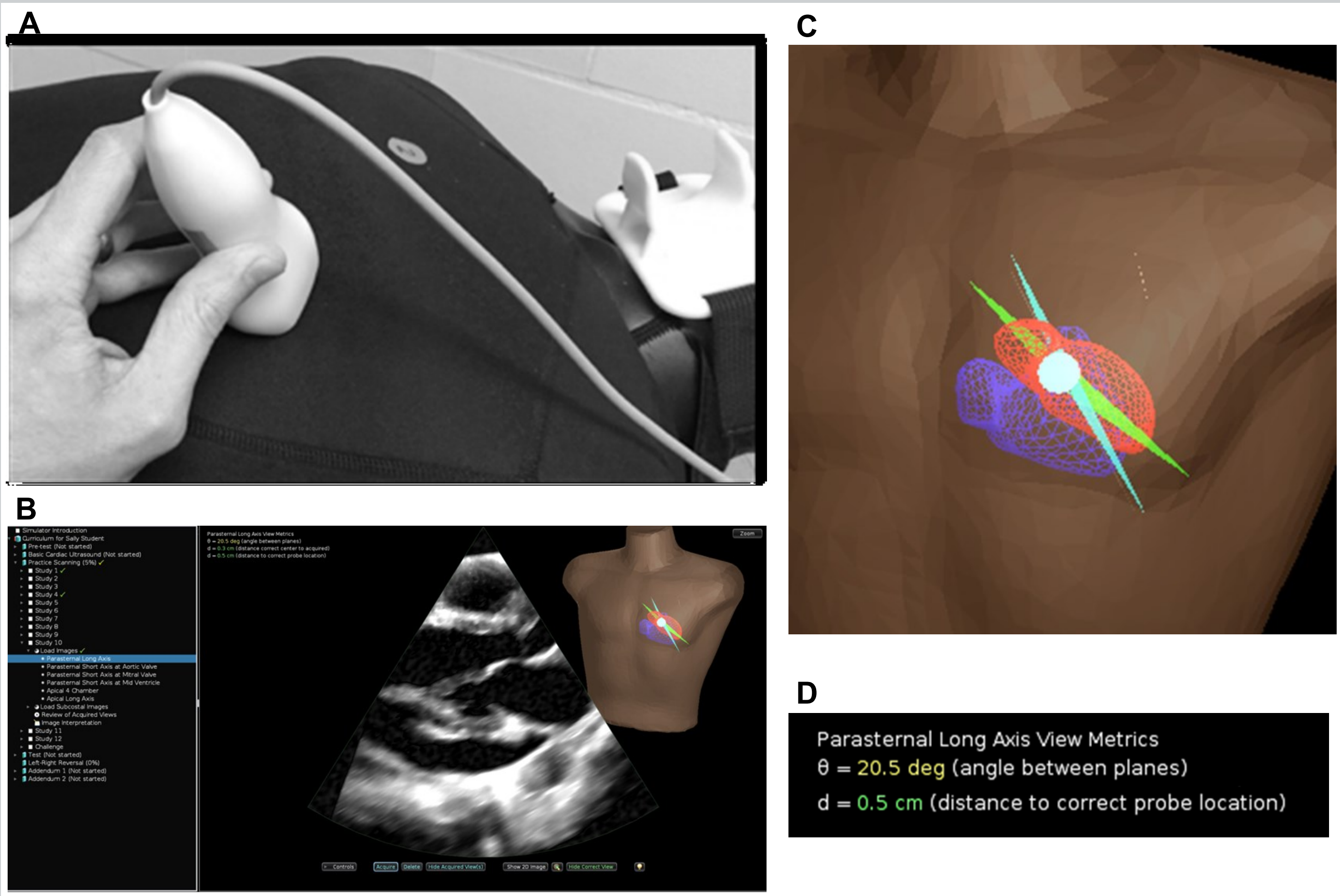

Figure 1. Simulator operation technique. **(A)** To operate the simulator, the participant places a reproduction of an ultrasound probe on a mannequin's chest. **(B)** User interface. **(C)** Enlargement of three-dimensional visual guidance indicator. The position and orientation of the acquired image (blue) and anatomically correct image (green) are displayed with the angle error (white arc). **(D)** Enlargement of numeric report of skill metrics. The angle error is above and the probe placement error is below.

of instructional modules, followed by six assigned interactive practice cases (with the option to complete all 10 available cases if the participant desired), and finally a post-training assessment test (posttest). The curriculum included instructional modules on focused cardiac ultrasound image acquisition and image interpretation in six standard views (parasternal long axis, parasternal short axis at the mitral valve, at the aortic valve, apical 4-chamber, apical long axis, and subcostal) of normal and commonly encountered abnormal pathology. To assess long-term skills and knowledge retention, a retention test was administered 6 months after training. The simulator hardware included tracking of the location and orientation of the mock transducer using a magnetic field system on mannequin's chest [3]. The tracking enabled assessment of participants' technical skill in terms of the angular deviation between the plane of a learner-acquired image and the plane of the anatomically correct image for a specified standard view (Figure 1). The correct view plane is defined geometrically from 3D reconstruction of each case's heart chambers and associated structures and verified by expert sonographers involved in training cardiology fellows at the UW 3. In addition the distance between the transducer locations for acquired and correct views was measured. In addition to image acquisition skills, participants were challenged to interpret the pathology (image interpretation skills). Cognitive skill in image assessment was our third skill metric; it was measured using multiple-choice examination of didactic knowledge. Skill was assessed using these three metrics during the pre, post and retention phases to gauge progress.

Simulation exercises

The simulator was available to participants 24 hours a day, seven days a week at the Legacy Emanuel Medical Center campus. Participants were tested on two skills: image acquisition and image interpretation. The transducer's position and orientation relative to the mannequin were used to generate and display a two

Table 1. Demographic characteristics of study participants.

Study participants		
	Total enrolled	25
	Completed survey	15
Age -- no. (%)	21-30	4 (26.7)
	31-40	5 (33.3)
	41-50	4 (26.7)
	51+	2 (13.3)
Gender -- no. (%)	Male	10 (66.7)
	Female	5 (33.3)
Level of training -- no. (%)	Medical Student	1 (6.7)
	Resident	6 (40.0)
	Attending	8 (53.3)
Specialty -- no. (%)	Medical Student	1 (6.7)
	Internal Medicine	13 (86.7)
	Emergency Medicine	1 (6.7)
Prior US training -- no. (%)	0-1 days	5 (33.3)
	1-2 days	4 (26.7)
	2+ days	6 (40.0)

dimensional image from a three dimensional data set in real-time on a monitor (Figure 1). All cases on the simulator display original transthoracic echocardiographic image data from normal subjects or from patients with pathologic findings such as reduced EF, pericardial effusions, valvular pathology, LVH etc.

During the training portion of the study, once the participants obtained what they felt was the optimal view, they were instructed to turn on a three-dimensional visual guidance indicator, which provided real-time feedback, to assist with manipulating the transducer into position to optimize the view. However, this guidance was not available during the testing portions of the study.

Six months after initial training and assessment (pretest, training, and posttest), participants were invited to repeat testing of their imaging skill and image interpretation to assess knowledge retention. Participants were also asked to complete an online survey to allow us to collect demographic and training/experience level data.

Statistical analysis

All statistical comparisons were performed using the Wilcoxon signed-ranks test with Bonferroni correction for multiple comparisons. Values are reported as the median. All statistical analyses were performed using the SPSS software package.

Results

Participants

Twenty-five individuals participated in this study and completed the pretest assessment. Of these, 17 of 25 (68%) completed some training modules and performed the posttest assessment. Only 8 of 25 (32%) participants completed the 6-month follow-up testing of their imaging skill and image interpretation knowledge in the retention phase of the study. Fifteen of 25 (60%) participants completed the online demographic survey, which captured data regarding age, sex, level of training, medical specialty, and amount of prior PoCUS training (Table 1). The participants were not receiving any other formal training during the study, other than self-directed learning

Assessment of immediate skills acquisition and knowledge

For image acquisition, the angle error decreased between pretest and posttest in the 17 participants who completed training and both tests (median 37° pretest to 30° posttest/ $Z=-3.385$, $p<0.002$). For knowledge assessment, participants answered a median of 55% of multiple choice questions correctly on the pretest and improved to an average of 76% on the posttest ($Z=-2.457$, $p=0.028$). There was no difference in probe placement error between the pre and post phases of the study, with median placement errors being 3.2 cm and 3.1 cm ($Z=-0.308$, $p=0.758$ compared to pretest) respectively.

Skills retention and knowledge after six months

In the 8 participants who completed the pretest, training and posttest session, angle error in image acquisition did not change significantly from median 27◦ pre to 31◦ post ($Z=-1.680$, $p=0.186$). Individual participants' angle error over time is shown in Figure 2. Didactic knowledge remained consistent, with participants answering 72% (median) of questions correctly on the pretest and 68% after 6 months ($Z=-0.339$, $p=0.735$). Probe placement error was also similar in the pre and retention phases of the study, with median placement errors being 2.9 and 3.1 cm, respectively ($Z=-1.680$, $p=0.186$.)

Discussion

Training on a FoCUS simulator can result in significant improvement in cognitive and motor skills that is largely sustained over time in physicians at the graduate and postgraduate levels. This study provides further support for the use of FoCUS simulation, in agreement with previously published studies [3]. There was a wide range of baseline skill levels among the study participants, but this variability narrowed following training on the simulator (Figure 2). Simulator training appeared to have the

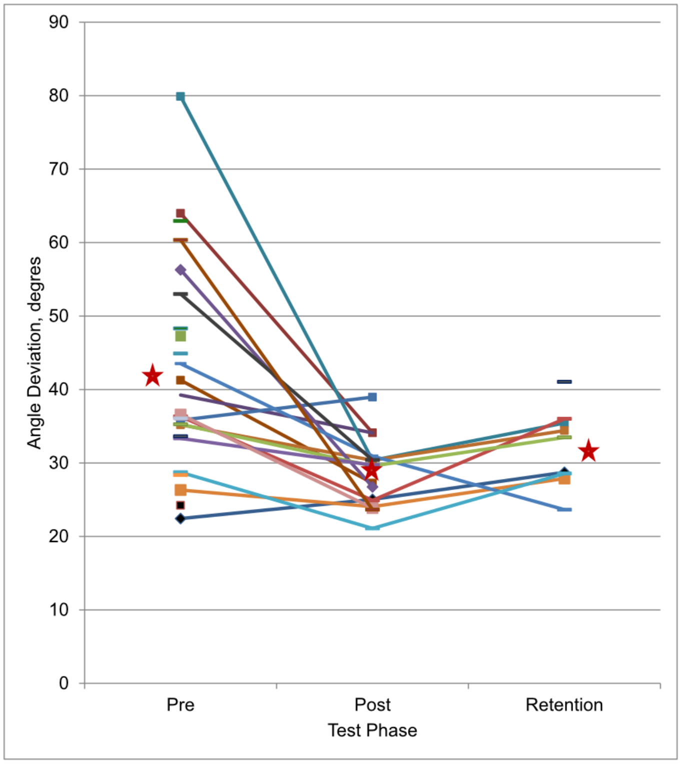

Figure 2. Angle error in image acquisition for all participants at pre, post, and retention phases. The red star indicates the median of all participants tested at each phase.

biggest impact on participants whose baseline scores were poorer, but improvement was more modest for those participants whose scores were good at the initial assessment.

The clinical utility and expanding presence of ultrasound in both graduate and postgraduate medical training generates increasing demands for continuing education [1]. Bedside ultrasound is increasingly becoming a useful adjunct to didactic lectures and hands-on training sessions with time and resource-intensive patient models [9]. In this study, we provided free, around-the-clock access to the simulator, which allowed participants to undergo self-directed, asynchronous learning with objectively measurable improvement in knowledge and skills across a wide range of participants at both graduate and postgraduate levels. As graduate medical education increasingly incorporates ultrasound into curricula, high-fidelity simulation can provide both training, and objective assessment of skills and knowledge, needed to ensure competency [10]. For postgraduates who trained before the PoCUS era, simulators also provide a means to become current in ultrasound techniques as well as increase proficiency in this important diagnostic modality.

This study's conclusions are limited by the size of the study population, particularly for those who returned for a third test at 6 months. The investigation was conducted with volunteers who participated during their limited nonclinical time, so enrollment and completion rates were relatively low. However, completion rates in previously published studies were also low, with Skinner et al [7] further voicing the need for protected training time for PoCUS and FoCUS. One study comparing clinical training alone vs. combined with simulator training for residents in obstetrics and gynecology had a much higher rate of follow-up, perhaps because the study was more formal than ours: it was a randomized trial conducted in three hospitals, and recruitment was continued until the number required for statistical analysis had completed the performance test [11]. Second, more studies are needed to assess the transferability of ultrasound skills and knowledge learned on simulators to real-world point of care ultrasound scenarios with patients. There is a large body of evidence to date, however, reporting that procedural skills learned on the simulator (T1) transfer to improved downstream patient care practices (T2) and improved patient and public health (T3) [12].

Conclusions

Training in FoCUS using a simulator with immediate feedback resulted in significant improvements in image acquisition and image interpretation skills. These skills appear to be sustained over time. Although participants displayed a wide range in their baseline skills, this range narrowed following training with the simulator. This study adds further support for the use of advanced echocardiographic simulators to enhance formal, reproducible, FoCUS training.

Acknowledgements

The authors would like to thank Dr. Florence Sheehan and her collaborators at the University of Washington for loaning us the Real Ultrasound® simulator used in this study and for their assistance with data extraction and aggregation from the simulator.

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