

POCUS Journal

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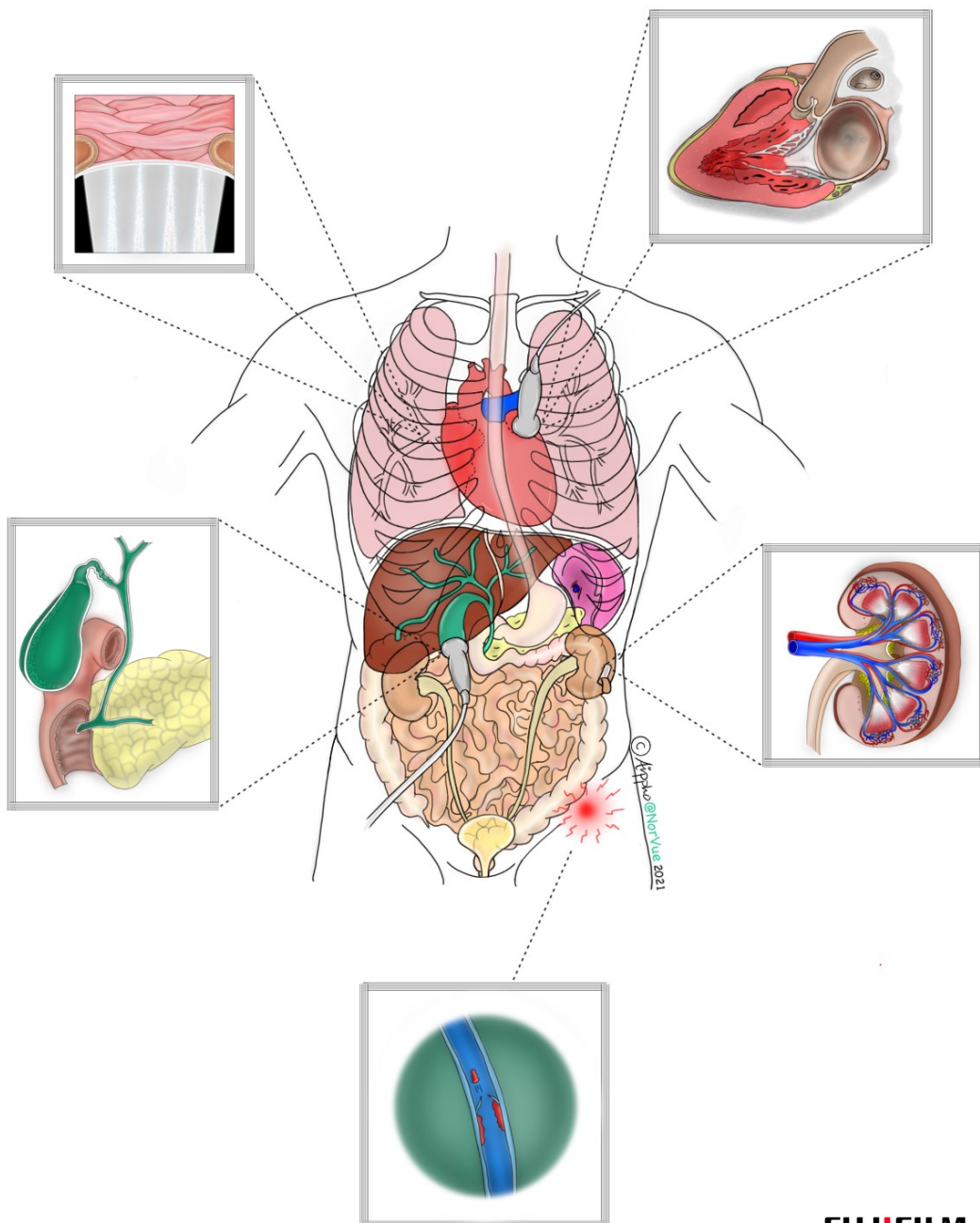


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Incidental Findings in POCUS: “Chance favors the prepared mind”

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Point of Care Ultrasound (POCUS) has the potential to rapidly aide in diagnostic algorithms at the bedside, however POCUS users are often faced with the dilemma of appropriate management of incidental findings [1]. Incidental findings in POCUS are defined as any indeterminate, benign, or potentially concerning finding found unexpectedly that is not related to the patient's chief complaint [2]. Increased use of POCUS has driven the increased discovery of incidental findings, with a reported frequency between 1.6% to 26% depending on the institution, frequency of documentation, and level of experience [1,2]. While many incidental findings are benign, some are not and benefit from follow-up. This raises important concerns regarding the need for systematic, evidence-based guidelines to ensure necessary follow-up while avoiding unnecessary additional imaging, patient anxiety and increased healthcare costs [1,3].

In some instances, incidental findings can lead to diagnoses that significantly alter patient treatments. In this issue of *POCUS Journal*, Melissa Bouwsema and Colin Bell report a case of a patient with a history of nephrolithiasis presenting with renal colic symptoms who was found to have both recurrent nephrolithiasis and an iliac artery aneurysm on POCUS exam [4]. While it is difficult to know if the aneurysm was truly incidental or contributing to the patient's presentation, this rare entity has a high mortality rate and the astute POCUS user made a life-saving diagnosis that could easily have been missed [5].

Louis Pasteur is credited with the quote “chance favors the prepared mind.” In POCUS this would suggest that users should be trained to identify incidental findings and to triage their approach to managing them. Triage is required, especially when performing “contextualized scanning” and POCUS during emergencies [6]. Yet operationalizing this practice is challenging, as it is hard

to anticipate and manage the triage behaviors of providers who encounter a finding they are often neither looking for nor trained to evaluate. Lack of systematic, organized approaches to incidental findings with non-standard ultrasound views can lead to erroneous interpretation of acquired images and either under or over-referral to additional care. For instance, serious harm could have resulted if the aneurysm in Bouwsema and Bell's case had been noted but not acted upon rapidly. On the other hand, in a similar theoretical case of abdominal pain where large para-aortic nodes were confused with the aorta and or aortic abdominal aneurysm, unnecessary imaging could have been done, resulting in increased health care costs and patient anxiety, which is of particular importance for vulnerable and marginalized patients who experience frequent interruptions in care [1-3,7]. Furthermore, incidental findings must be communicated to the patient and subsequent care team to ensure proper documentation and assessment [8]; and failure to do this appropriately may lead to medical legal claims [9].

Optimal management of incidental findings in all types of medical imaging / radiology requires concrete, evidence based, uniformly practiced protocols and standardized image acquisition to improve inter-rater reliability and cost-effective treatment as outlined by the American College of Radiology (ACR) and Fleischer Society [1,10]. The burden of uniform application of guidelines for both practitioners and trainees falls on each individual institution and requires targeted training and ongoing discussion [11]. While the case by Melissa Bouwsema and Colin Bell in this issue of *POCUS Journal* demonstrated a clear benefit to recognizing an unexpected or potentially incidental finding, developing a robust system to manage all types of incidental findings in POCUS is complicated. Further study of incidental findings by POCUS are required to inform guidelines in this area.

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Consensus Terminology for Point of Care Ultrasound Studies with Incomplete Documentation and Workflow Elements

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To the Editor:

Point of Care Ultrasound (POCUS) use by emergency physicians has grown in both breadth and depth of clinical use [1-3]. POCUS workflow is different from a traditional imaging-based specialist workflow because a single clinician orders, obtains images, interprets, and reports the exam results. Traditionally, multiple individuals participate in the workflow: the clinician places the order; an ultrasound technologist reconciles order and identifiers and acquires images; lastly an imaging specialist interprets the exam and creates a report. These contrasting approaches has led to unique challenges in streamlining POCUS workflows and identifying disruptions, errors and potential corrections given the differences from radiology focused workflow and resources.

There have been limitations in institutional support and resources to create infrastructure to support POCUS exams and documentation workflows [4,5]. This has also not been a primary focus of research and the literature has a variety of terminology to describe workflow and documentation errors [6]. Enhancing the availability of POCUS images and the dissemination of reporting is an essential component for continuity of patient care and will continue to gain importance as POCUS continues to grow in Emergency Medicine and other specialties outside of traditional imaging specialties.

The objective of this study was to develop a standard terminology for workflow related errors in POCUS documentation. Standardizing terminology is important because it serves as the basis for future research to address and prevent workflow disruptions which can affect data transparency impacting patient safety and quality of care. Standardized terminology in technical standards such as the Systematized Nomenclature of Medicine – Clinical Terms (SNOMED-CT), Integrating the Healthcare Enterprise (IHE), and Health Level Seven (HL7) projects is becoming more pervasive with increased use of technology. Standardized terminology for research topic areas is also increasing to enhance the

reproducibility and implementation of research findings [7]. This protocol was approved by the ChristianaCare Institutional Review Board. This study was initially part of a Society of Clinical Ultrasound Fellowships (SCUF) workshop on POCUS workflow with respondents solicited from SCUF through the membership listserv.

Respondents were presented with the premise that a completed POCUS exam needs to have the following elements: images; patient identifiers; an identified operator, and a report interpretation. We did not specify the number of identifiers or the elements needed in an interpretation report as this can vary by institution, software, and type of study.

An electronically distributed modified Delphi process was used to define standard terminology for POCUS studies with missing elements due to workflow errors. The first phase presented current terminology utilized by the authors and colleagues for selection and requested any additional terminology used by participants. As an example question, for studies with images and documentation, but missing patient identifiers respondents were initially given the options of “incomplete study missing patient identifiers”, “partial study missing patient identifiers”, “phantom study”, “ghost study”, or “unlabeled study” or to submit other potential terms. A particular error, with many names, that can occur during POCUS utilization is the performance of an examination without captured images or documentation making it a difficult error to identify and quantify as the exam does not exist in either the medical record or image archiving software.

During phase 2 the respondents chose to endorse the most common terms from phase 1 or selected from other potential terminology in a First-Pass-the-Post or an Instant-Runoff voting methodology, depending on the number of options to speed agreement. Phase 3 presented the consensus terminology to the volunteer group and then the broader SCUF membership for acceptability.

Table 1. Consensus Terminology for Point of Care Ultrasound Examinations with Missing Documentation and Workflow Elements.

Term	Definition
Incomplete study, missing operator	Study does not contain information on who performed the study
Incomplete study, missing documentation	Study does not have a complete interpretation report
Incomplete study, missing images	Study does not have complete images
Incomplete study, missing patient identifiers	Study does not contain patient identifiers
Phantom scan	A study that has not been documented in the medical record or have archived images; when audited it does not exist.

Volunteers were solicited from the 122 ultrasound fellowship programs included in the SCUF listserv. The listserv consists of the 122 program directors and any faculty that become SCUF members, the total membership is not publicly available. Phase 1 had 53 respondents who agreed to participate in the modified Delphi process. The group included 28 Ultrasound Directors, 31 Fellowship Directors, 24 Core US Faculty, 9 Associate or Assistant Directors; positions are not mutually exclusive, representing 43 unique programs or 35% of fellowships at the time of the survey. The 2nd and third phases were only distributed to the volunteer group of 53 faculty from phase 1. Thirty of the original 53 (57%) volunteers replied to the 2nd phase. All but three (90%) chose to use the term “incomplete or partial study” with a qualifier. Of those 27 individuals 25 (93%) chose “incomplete” as the preferred term. Those that did not choose “incomplete” as their first choice ranked it as their 2nd. For studies that have no retained images or documentation, and by electronic means does not exist, the term “phantom scan” was the primary choice by 21 respondents (70%) over “ghost scan”. The terminology was then presented to the volunteer group for review, with 37 responses (70% of volunteer group) unanimously agreeing that the terminology presented in Table 1 was acceptable as consensus terminology. This was then presented to the SCUF membership via listserv with an additional 70 respondents (37 Ultrasound Directors, 41 Fellowship Directors, 15 Associate or Assistant Directors and 25 Core Faculty, categories not mutually exclusive), for a total of 107 unique respondents who unanimously voted that the terminology was acceptable consensus. Respondents represented 63 separate programs or 52%

of fellowships at the time of the survey. The final agreed upon terms are not currently delineated in published literature or technical standards. Terminology in published research has some similarities as the study population may have included those authors and they were able to suggest terminology, however the consensus terms have not been previously published.

Our study presents an agreed upon list of consensus terms to identify POCUS studies that are missing key elements for documentation and archiving as an imaging study. The use of standardized terminology for workflow errors can be utilized for research in point of care ultrasound workflow to find solutions to prevent and correct errors. Use of standard terminology will improve communication to assist in the implementation and interoperability of workflows between institutions, programs and specialties. Consistent terminology can also facilitate the reproducibility, implementation, and expansion of point of care ultrasound workflow research and operational practices across different POCUS programs and specialties. We suggest that these terms be utilized when performing point of care ultrasound workflow research to facilitate understanding of problems, potential solutions and application of interventions.

Disclosures

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Point-of-Care Ultrasound for Physicians in Practice – A Training Model for Specialty Specific and Clinically Relevant Skill Development

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Point-of-care Ultrasound (POCUS) skills are required competencies for emergency medicine and paediatric emergency medicine training [1,2,3,4]. Over time, more specialties will require these skills of their graduates. Experienced physicians who completed their training before POCUS requirements may ask: How can I gain POCUS skills training and competency? In this perspective piece we describe in-person and asynchronous training programs available to these clinicians in practice. We highlight these programs due to their person-centred design: they maximise the needs of the learner, provide personalised education, and expose them to respected and established POCUS faculty and training centers.

POCUS learning revolves around 4 principles: image acquisition techniques, image interpretation, understanding of the clinical context, and integration into the patient care at the bedside. Some of these principles can be practised asynchronously, or exclusively online. Image interpretation programs such as ImageSim or Core Ultrasound providing large banks of practice images [5,6]. Short course workshops can create a foundation of acquisition skills. This is not enough as many physicians will need to supplement these with bedside skill development. Programs for physicians in practice allow training for physicians who lack local opportunities. While these programs vary in cost, scholarships and price reductions are possible and available depending on the practice location or specialty of the trainer.

There are many free open access medical education (FOAMed) resources available; however, experienced clinicians are often seeking hands-on training, and deeper expertise to gain hospital privileges and competency. Short duration workshops are widely available in the form of pre-courses at conferences, or free-standing POCUS courses [7,8]. Some of these brief trainings even offer credentialing in core applications, however this may not translate directly to hospital privileges [7]. It must be said that there is no evidence that these asynchronous and brief in person POCUS

education offerings establish competency.

A longitudinal and in-person POCUS program has many advantages. Physicians in practice can gain confidence and experience in specific POCUS applications, can learn administrative skills on topics such as hardware, software, workflow, and quality improvement, and can gain a mentor and coach for hands-on POCUS skill competency.

The Hospital for Sick Children in Toronto offers paediatricians the opportunity to train in person for 1-3 months. Trainers come from across Canada and around the world. The program's relationship with its International Recruitment office allows provision of this program to learners globally. An existing paediatric emergency medicine POCUS framework serves as the core curriculum. The trainer is asked to provide specific objectives and goals. There is no clinical shift component or expectation. The focus is in developing POCUS skills and competency. As part of their time in the program, trainees have access to digital learning materials, to an asynchronous image interpretation program, and to participate fully in the training and educational schedule of the POCUS fellows and resident rotators. Focus is also placed on how to build local capacity at their home site, and in developing relationships across specialties or with hospitals in the trainer's region [9].

The UC Irvine Sabbatical Program offers a one month program that is integrated into the existing POCUS curriculum. Final year medical students who have participated in a transformational ultrasound-prioritised medical education curriculum serve as the instructors for the physicians in practice [10,11]. Wilson et al published a sample four week POCUS curriculum mini-fellowship for physicians in practice [11]. This was offered at the University of Colorado and now at Thomas Jefferson in Philadelphia [11].

The Ultrasound Leadership Academy offers an asynchronous and remote learning option. This model allows clinicians to scan in their home environment. The

12-month remote learning curriculum includes one-on-one virtual support and quality assurance. There are in-person workshop opportunities. Models such as this offer training without requiring the participant to relocate [12].

Physicians currently in practice can learn POCUS skills specific to their clinical needs. A longitudinal education program can support their needs in a more accessible and sustainable fashion.

Disclosures

REL serves on the medical advisory board of Echonous. REL is the director of POCUS at Thomas Jefferson University. LJM is the Director of POCUS at the Hospital for Sick Children. Both have taught and collaborated with directors and instructors of other programs mentioned.

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A Point-of-Care Ultrasound Rotation for Medical Education Fellows in Emergency Medicine

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Background

A Medical Education (MedEd) fellowship provides emergency medicine (EM) residency graduates the structured and rigorous training to develop skills as educators. Although not accredited by the Accreditation Council for Graduate Medical Education (ACGME), MedEd fellowships have established minimum curriculum standards [1]. Our institution's MedEd fellowship curriculum incorporates an innovative opportunity for fellows: two 3-week rotations in Point-of-Care Ultrasound (POCUS). Here we describe the rationale for using this POCUS rotation to reinforce key MedEd concepts that benefit the MedEd fellows, the POCUS trainees, and the Ultrasound section. Ultimately, we believe this addition in training helps further develop MedEd fellows' teaching skills, with specific attention to kinesthetic and visual-spatial content.

Curricular Design

All MedEd fellows graduate from an ACGME accredited EM residency. Consequently, MedEd fellows hold hospital privileges in POCUS [2]. That being said, the POCUS training and competency assessment for graduation vary by residency. The POCUS skills of each MedEd fellow also vary. Our institution's rotation began as a proof of concept -- an educational intervention that would provide fellows with the clinical context to develop the ability to teach highly-kinesthetic procedural skills. Although there was anecdotal evidence to suggest this was a valuable educational experience, there was a need to trial the rotation with developmental milestones to capture its impact better [3]. We established goals and objectives for each 3-week rotation and outlined experiences within the rotation that would support the stated objectives. We also developed self-directed learning assignments and integrated teaching roles aligned with graduated roles and responsibilities.

Each MedEd fellow completes two 3-week POCUS rotations over the course of a 12-month fellowship. They attend weekly POCUS section meetings during the rotation, review POCUS images with faculty during the

Quality Improvement (QI) segment, and lead journal club discussions. They assist with didactics focused on MedEd theory, employ educational techniques, and conduct competency-based assessments of residents and students. MedEd didactics mostly take the form of a Monday journal club with articles and roundtable discussions centered on a journal article that anchors the conversation around the intersection of POCUS and MedEd. During the rotation, the MedEd fellows organize and teach a weekly scan shift: a bedside POCUS examination and skill day in the Emergency Department for rotation trainees. At this time, they employ education techniques learned over the course of the MedEd fellowship, several of which are described in Table 1. While the applications they teach may be more basic than the advanced applications of a POCUS fellow, they focus on framework, technique, and competency assessments.

Impact/Effectiveness

Benefits to the MedEd Fellow

Seven MedEd fellows have completed the POCUS rotations to date. All have shared similar perceived benefits of the rotation. The MedEd fellows found that the scanning shifts provide opportunities to apply MedEd educational models while reinforcing POCUS skills (Table 1). The rotation emphasizes reviewing the specific examination technique immediately before performing it in real-time at the bedside [4]. Just-in-time training also serves as a refresher of POCUS content that the MedEd fellows may have learned in residency. Through repetition in performing POCUS, microskills are reinforced, and teaching the application to trainees further allows the fellows to demonstrate progress from novice to a master in skill acquisition [5]. The fellows also apply Miller's pyramid [6] as a competency-based assessment framework to evaluate the resident and medical student learners from "knowing how" to demonstrating a specific POCUS skill. Fellows can also use educational theories, such as cognitive apprenticeship, to frame their procedural teaching [7]. Lastly, as an expectation of the POCUS rotation, MedEd fellows are assessed in their

Table 1. A Framework for MedEd Fellows to Deliberately Practice their Teaching Skills through POCUS. (con't on next page).

	Theory / Model	Theory / Model Explained	Example in Practice
Teaching and Learning			
	Dreyfus Model of Skill Acquisition [12]	Dreyfus describes a stepwise progression for learning specific skills, proceeding through <i>novice</i> , <i>advanced beginner</i> , <i>competent</i> , <i>proficient</i> , and eventually to <i>expert</i> . Levels have anchors in four domains, including <i>components</i> , <i>perspective</i> , <i>decision</i> , and <i>commitment</i> . The time period through which one achieves expert status can last months or years.	The fellow can intentionally choose the POCUS skills to be taught to the learner based on where the learner falls on the Dreyfus model. For novice learners, the fellow can focus on knobology and fundamental principles in probe manipulation. In contrast, for more competent and proficient learners, the fellow can challenge the learner with more advanced ultrasound applications (e.g., examining the vitreous chamber of a patient with acute vision loss). This provides the fellow with the scaffolding to guide learner instruction.
	Miller's Pyramid of Skill Acquisition [13]	Miller walks through several levels of assessment of skills acquisition: <i>knows</i> (demonstrates knowledge), <i>knows how</i> (demonstrates competence), <i>shows how</i> (demonstrates performance), and <i>does</i> (demonstrates action). Depending on the skill, progression may be completed over a variable time period.	The MedEd fellow can apply Miller's Pyramid throughout a shift with a learner for a specific skill. When teaching a learner how to perform a Focused Assessment with Sonography in Trauma (FAST) exam for the first time, the fellow can ask the learner to explain the FAST and its indications and then progress to how it is performed. Throughout the shift, the fellow can prompt the learner to demonstrate the FAST with supervision, and over time perform the FAST independently with remote review by the fellow. This approach prompts the fellow to consider a scaffolded, step-wise approach to teaching a procedural skill.
	Kolb's Experiential Learning Cycle [14]	Kolb suggests that learners progress through four separate, but related phases, by which learners experience and process their learning. Phases include: <i>concrete experience</i> , <i>reflective observation</i> , <i>abstract conceptualization</i> , and <i>active experimentation</i> . As phases are non-linear, educational experiences can focus on one phase (i.e., either in series or in parallel).	The MedEd fellow can use the Kolb model to identify ways to better support learning. For learners who prefer concrete experiences, the fellow can identify undifferentiated patients on whom POCUS examinations are performed as a starting point for teaching. For learners who prefer abstract conceptualizations, the fellow can begin instruction by discussing specific scenarios requiring imaging and identifying the best course of action to obtain those POCUS examinations. For learners who prefer active experimentation, the fellow can use a task trainer to practice image acquisition before imaging a patient. And for learners who prefer reflective observation, the fellow can begin a teaching session by asking the learner to reflect on previous experiences with imaging a patient and exploring aspects on previous performance.

Table 1 (con't). A Framework for MedEd Fellows to Deliberately Practice their Teaching Skills through POCUS.

	Theory / Model	Theory / Model Explained	Example in Practice
Instruction			
	Just-in-Time Training [15]	Web-based assignments designed to complete before giving and receiving instruction on POCUS examinations.	The fellow can prompt the learner to review the necessary steps to successfully perform POCUS-guided fascia iliaca nerve block in a patient with a hip fracture immediately preceding the procedure. This may take the form of watching a FOAMed video and/or verbally describing critical steps of the procedure with the learner.
	Microskills Teaching	Specific and discrete actions that can be observed and repeatedly practiced into understandable and repeatable skills.	When performing a cardiac POCUS examination, the fellow can break down the procedure into its steps and specifically teach those steps. For example, position the patient, drape the patient, and manipulate the phased-array ultrasound probe for a subxiphoid view.
	Hands-on Bedside Teaching	Perform POCUS procedure, interpret images, integrate into patient care.	The fellow instructs trainees on Heart/Lung/ Inferior Vena Cava (IVC) POCUS examinations in a patient with undifferentiated dyspnea and periodically steps-in to optimize image acquisition and/or quality. This may be in the form of literal hands-on assistance or verbal coaching during the scan.
Assessment of Learners			
	Standardized Direct Observational Assessment Tool (SDOT) [6]	Checklist of steps to complete the POCUS examination.	The fellow can use the SDOT to assess students and residents during a scanning shift.
	Direct Observation	The trainer observes the trainee performing the assessment and assesses the ability to perform it accurately and properly.	Fellows can be prompted to directly observe the learners' POCUS skills. They would be prompted to not interfere with scanning or image acquisition and only observe skills, which would be referenced during the debriefing that follows the scan.
	Quality Improvement	A systematic approach to the analysis of practice performance and efforts to improve performance.	During Quality Improvement sessions with ultrasound section faculty, fellows can provide feedback on recent ultrasound studies performed in the ED for clinical care. They learn to give remote feedback to the clinicians on improving future ultrasound examinations, such as optimizing depth and gain or re-educating on how to differentiate the IVC from the aorta.

technical skills for performing the procedures and demonstrating the ability to teach these skills to other learners. They are also immersed in opportunities to complete workplace-based assessments of learners' POCUS skills [8]. An application of this assessment is using the standardized direct observation tool (SDOT) [9]. The POCUS SDOT is designed as an example of a competency-based checklist and provides a snapshot of a resident's clinical performance that can be repeated longitudinally to document the progression of competency over time. Incorporating learning theories through POCUS theory and skills acquisition, supplemented by bedside hands-on training, provides a framework to expand teaching POCUS skills to teaching other EM procedures, e.g., central venous catheter placements.

Benefits to the Ultrasound Fellowship and Section

The EM Ultrasound faculty and fellows have responded positively to the MedEd fellow POCUS rotation. The MedEd fellows contribute to the Monday journal club discussions and provide an evidence-based MedEd perspective to the analysis. EM Ultrasound faculty and fellows learn the education theory behind the POCUS skills they teach thanks to this collaboration. MedEd fellows develop confidence in integrating POCUS into their clinical practice more than other new faculty and fellows. This enhances the EM department's commitment to coding and billing for POCUS diagnostic and procedural examinations. Additionally, as part of the second 3-week rotation, the MedEd fellows can serve as the first reviewer for a portion of the weekly POCUS Quality Improvement (QI) patient examinations. This offers the POCUS section assistance with reviewing all POCUS examinations performed in the ED [10,11].

Limitations

There are several limitations we would highlight. The benefits are anecdotal and have not yet been studied using rigorous program evaluation methods. The efficiency and confidence that the MedEd fellows report after the POCUS rotation have not been measured. Future studies should evaluate the impact of the curricular addition of POCUS to the MedEd Fellowship program objectives, the trainees, the POCUS section, and the department.

Conclusions

The POCUS rotation for MedEd fellows provides an opportunity for fellows to develop the skills and confidence in POCUS while applying the MedEd theories they are studying. MedEd fellowship programs may consider the addition of a POCUS rotation to their core curriculum to help meet program learning objectives.

Disclosures

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REL serves on the medical advisory board of Echonous

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A Brisk and Life-Saving Diagnosis of Pericardial Effusion as the Cause for Recurrent Dyspnea

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Abstract

Point of care ultrasound (POCUS) is a reliable diagnostic tool for the evaluation of a patient with dyspnea. This case provides an example of an acutely dyspneic patient in which standard evaluation failed to elucidate the true etiology of the patient's dyspnea. The patient was initially diagnosed with pneumonia but returned to the emergency department with acute worsening of his symptoms despite empiric antibiotics leading to the presumption of antibiotic failure. POCUS revealed a large pericardial effusion requiring pericardiocentesis ultimately leading to the accurate diagnosis. This case highlights the importance of POCUS in evaluating patients with shortness of breath.

Introduction

Acute dyspnea is a common presentation typically requiring a rapid and thorough evaluation [1, 2]. Given myriad etiologies of dyspnea, finding the potential cause for presentation poses a challenge as the underlying cause could be life-threatening. Point of care ultrasound (POCUS) has been noted to expedite a precise diagnosis for the etiology of acute dyspnea, especially in uncertain scenarios [3]. The American College of Physicians (ACP) developed guidelines for the appropriate use of POCUS in patients with acute dyspnea in emergent settings. The rationale for these guidelines was based on several considerations including increased proportion of correct diagnosis by 32% when used in addition to the standard diagnostic pathway, improved test accuracy (particularly sensitivity) and no known serious harms [4]. In the present report, we describe a clinical scenario of patient presenting with acute dyspnea at the heels of acute hospitalization due to community acquired pneumonia and the use of POCUS that completely changed the diagnostic pathway.

Case

A 59-year-old man with diabetes mellitus, hypertension, obstructive sleep apnea, dyslipidemia, cerebrovascular disease, and end stage renal disease on hemodialysis presented to the emergency department with progressive dyspnea. He was hospitalized one week earlier and diagnosed with community acquired pneumonia based on his symptoms of exertional dyspnea and chest tightness as well as chest x-ray findings of obscuration of left hemidiaphragm and left heart border and possible infiltrate (Figure 1). He was discharged on empiric oral antibiotics, however his dyspnea continued to progress

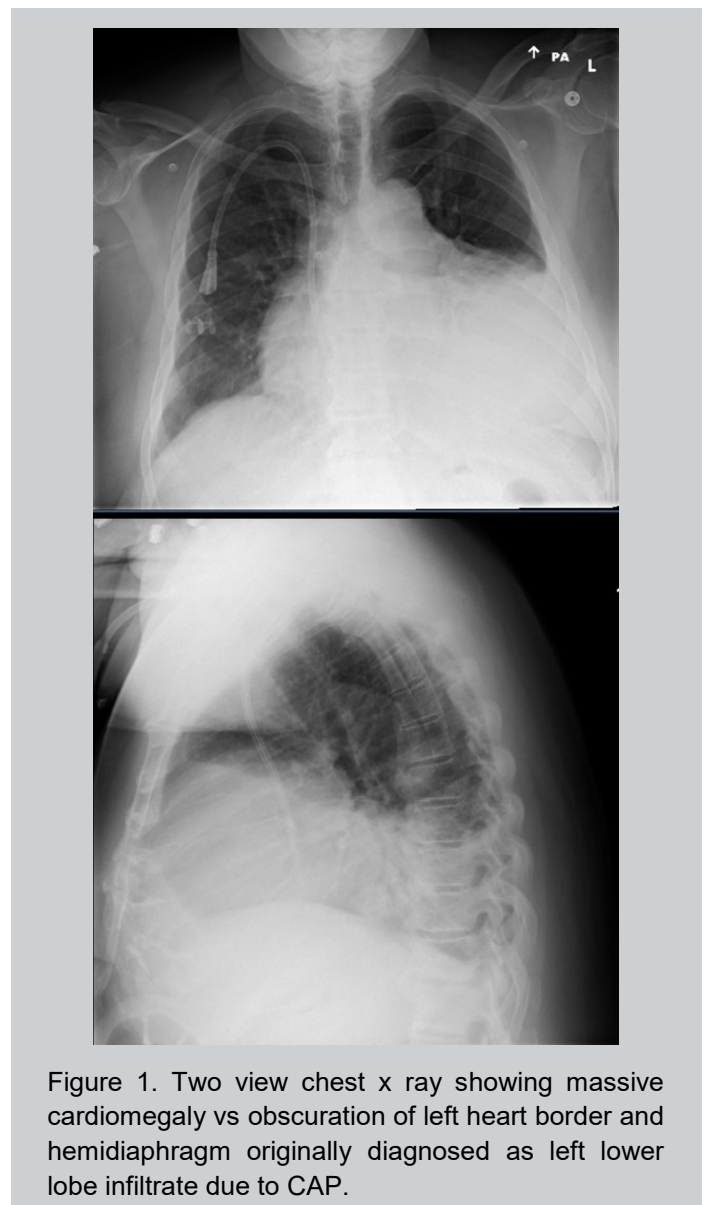


Figure 1. Two view chest x ray showing massive cardiomegaly vs obscuration of left heart border and hemidiaphragm originally diagnosed as left lower lobe infiltrate due to CAP.

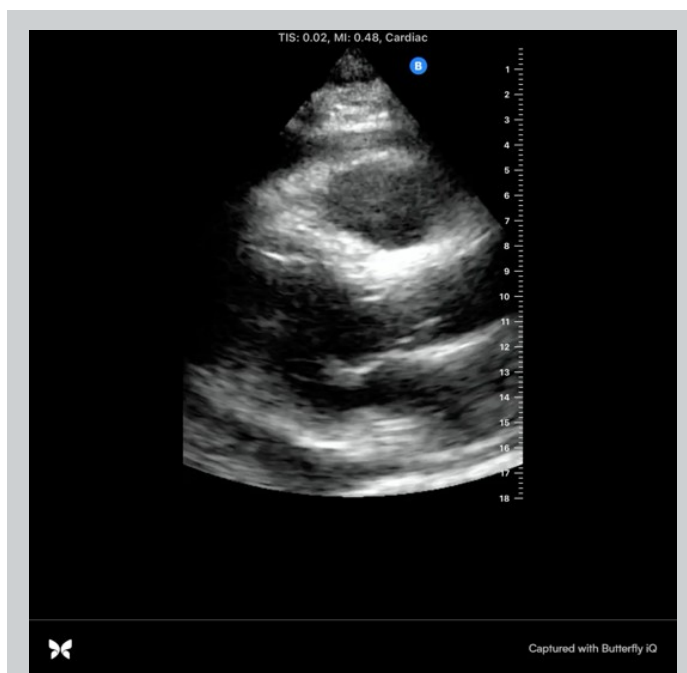


Figure 2. Parasternal long axis view by point of care cardiac ultrasonography revealing moderate to large pericardial effusion.

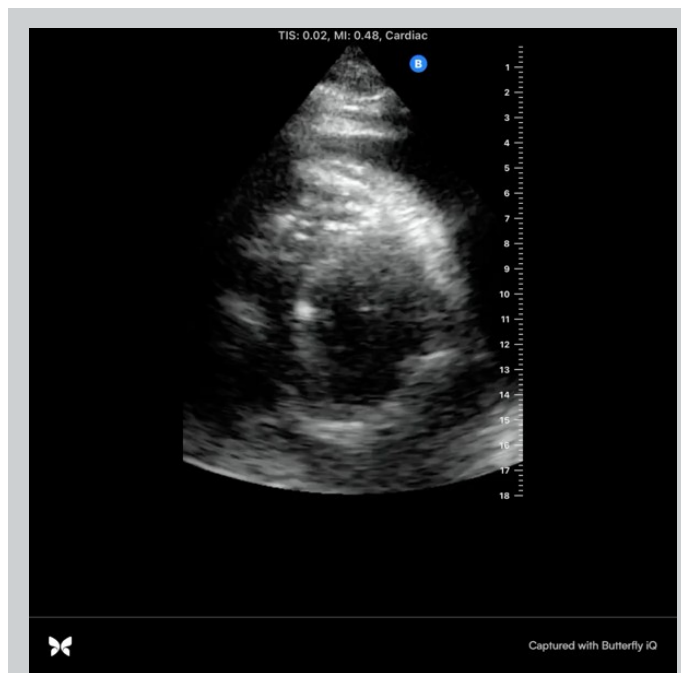


Figure 3. Parasternal short axis view by point of care cardiac ultrasonography revealing moderate to large pericardial effusion.

along with the interval development of dry cough. At baseline he was active, working as a mason, and could easily walk a mile or take a few flights of stairs. Upon return to the emergency department, he was struggling to walk across the room due to dyspnea and exertional chest tightness. He denied nausea, light-headedness, lower extremity swelling, or paroxysmal nocturnal dyspnea. His vital signs were within normal limits. He had no supplemental oxygen needs. He was afebrile with no leukocytosis along with normal troponin and electrocardiogram. He was negative for COVID-19. There was an apparent worsening of left lower lobe infiltrate on chest x-ray. Of note, his last hemodialysis run was shortened to 3 hours due to clotted access. The patient was presumed to have the diagnosis of pneumonia with empiric antibiotic failure. POCUS was performed at the time of admission and revealed moderate to large pericardial effusion (Figures 2-4, online Video S1-3) with redemonstration of consolidation on the left side lung ultrasound with bilateral A profile. His inferior vena cava (IVC) showed considerable respiratory variation (Figure 5). This essentially ruled out tamponade physiology, as IVC plethora is a quite sensitive echocardiographic sign of cardiac tamponade [5,6].

A STAT echocardiogram and cardiology consultation was ordered which confirmed the findings of the POCUS study. IVC respiratory variation was reassuring in ruling out tamponade physiology and an emergent need for intervention. Therefore, the patient was taken for pericardiocentesis the following morning whereby 870

milliliters of bloody fluid was drained. Pericardial fluid was negative for bacterial and fungal cultures, acid fast bacilli, and cytology for malignancy. His anti-nuclear antibody was noted to be positive ($>1:640$) along with an elevated C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR). During the hospital course, he unfortunately developed rapid accumulation of the pericardial effusion necessitating a pericardial window. Rheumatology was consulted and further studies including myeloperoxidase and serum proteinase 3 antibodies (MPO/PR3), rheumatoid factor (RF), cyclic citrullinated peptide antibody (anti-CCP), complements (C3/C4), and double stranded DNA antibodies (anti-dsDNA) were sent. These studies were subsequently noted to be negative. The differential diagnosis for this patient's pericardial effusion remains uremia related vs an autoimmune etiology. His dyspnea improved and the patient was discharged to home with close cardiology and rheumatology follow up.

Discussion

The present case highlights the vital role of POCUS in diagnosing a patient accurately with a symptomatic pericardial effusion. POCUS is a diagnostic tool that has increasingly been used for rapid evaluation of the acutely dyspneic patient, especially in emergent settings. It is particularly useful given its wide applicability to assist with the rapid diagnosis and treatment for a patient with shortness of breath [7,8]. Multiple studies have validated its diagnostic accuracy and possible superiority to standard work up performed in these patients [9,10]. A



Figure 4. Apical four chamber view by point of care cardiac ultrasonography revealing moderate to large pericardial effusion. This view is foreshortened and unable to completely visualize the atria therefore limiting interpretation.

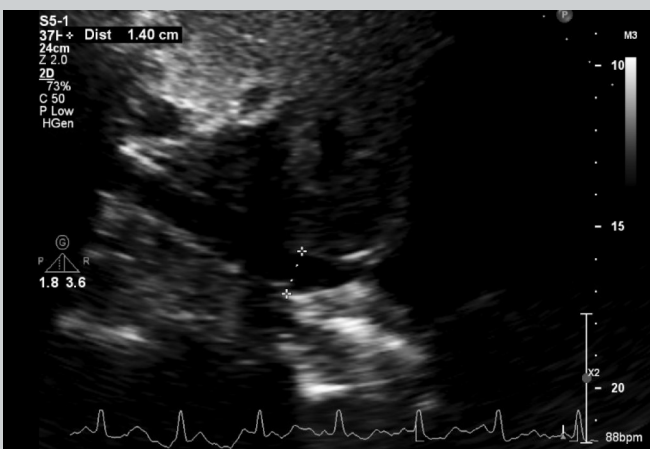


Figure 5. A small caliber IVC with significant respirophasic variation. This provided reassurance that this was not tamponade physiology.

study of patients presenting with dyspnea or chest pain demonstrated that the POCUS exam revealed clinically relevant findings among 79% of patients and led to alteration of the primary diagnosis among 28% of patients. Additionally, time to diagnosis was significantly shorter among patients in the POCUS group compared with the control group with median time of 5 hours vs. 24 hours [3]. In this case, POCUS changed the plan of care

rapidly and diagnosed a potentially life-threatening acute condition that required early intervention. This further supports the benefits of early and often use of bedside ultrasonography for management of patients presenting with shortness of breath.

Statement of Ethics

Informed consent was obtained from the patient by the authors. The patient has consented to the use of de-identified images, video clips, and health information to be published within the journal.

Disclosures

The authors have no conflicts of interest to declare.

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Hickam's Dictum Incarnate: A Case of Simultaneous Left-Sided Urolithiasis and Ruptured Iliac Artery Aneurysm

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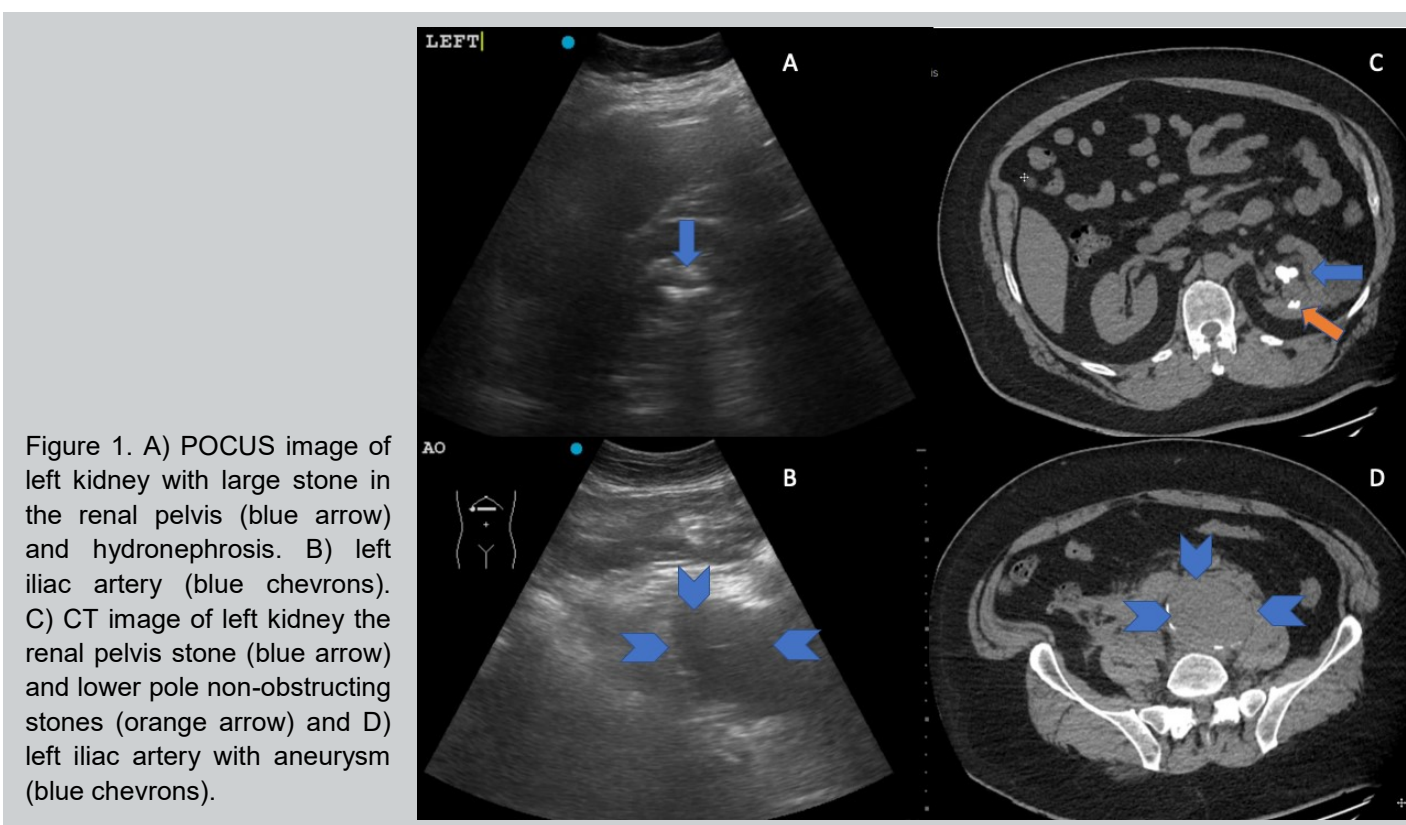
Abstract

A 51-year-old man with a history of nephrolithiasis presented to the Emergency Department after a sudden onset of left-sided groin pain and syncope. At presentation, he described his pain as similar to prior renal colic episodes. At his initial assessment, point of care ultrasound (POCUS) was used, which revealed findings consistent with obstructive renal stones, as well as a substantially enlarged left iliac artery. Computed tomography (CT) imaging confirmed the comorbid diagnoses of left-sided urolithiasis and a ruptured isolated left iliac artery aneurysm. POCUS facilitated expedited definitive imaging and operative management. This case highlights the importance of performing related POCUS studies in reducing anchoring and premature closure bias.

Case File

A 51-year-old man with a previous history of renal stones and gout presented to the emergency department after sudden onset severe 10/10 left-sided groin pain accompanied by a syncopal episode. His triage vitals were BP 126/87, HR 92, RR 20, SpO₂ 97% on room air, T 36.5°C. On assessment, the pain had improved, and the patient was complaining of 2/10 left groin pain, stating the discomfort was similar to previous renal colic episodes.

Point of care ultrasound (POCUS) was performed, with targeted views of the kidneys and bladder given the patient's history of nephrolithiasis, as well as complete visualization of the aorta to the iliac bifurcation given the patient's presentation with undifferentiated flank pain in accordance with emergency medicine POCUS recommendations [1-3]. The ultrasound revealing a large left renal stone with associated hydronephrosis (Figure 1A), a non-aneurysmal aorta, and an enlarged left iliac artery (Figure 1B, online Video S1). The presence of the dilated left iliac artery prompted immediate consultative



imaging rather than the common diagnostic pathway of next day outpatient consultative imaging. A CT scan confirmed the presence of multiple left-sided renal stones with hydronephrosis including a 2cm cluster in the renal pelvis (Figure 1C) and a 6.7cm ruptured left isolated iliac artery aneurysm (IAA; Figure 1D).

IAA typically presents in conjunction with abdominal aortic aneurysm [4], commonly mimicking renal colic [5], and can present with hydronephrosis without renal stones [6]. Isolated IAA is a rare diagnosis accounting for approximately 0.4% to 1.9% of all arterial aneurysms [7]. Isolated IAA are at a particular high risk for rupture [6]. Rupture of an isolated IAA carries a mortality risk of 50-75% [4,6].

IAA is an uncommon, but important diagnosis that might mimic other more frequently encountered disease processes. IAA should be considered for patients with histories incongruous with their physical exam findings. Abdominal pain, dysuria, urinary frequency or urgency, constipation, hydronephrosis, pelvic masses are common historical features and findings for IAA [4]. Most IAAs are discovered incidentally on imaging ordered for other indications [7]. The aorta and renal studies are typically performed together as both renal colic and symptomatic ruptured AAA are relatively common causes of severe acute flank and abdominal pain [1-3]. POCUS is typically performed in a targeted manner to the patient's symptoms in contrast to comprehensive consultative radiology studies. In our patient there was a real possibility that his pain was caused by a ruptured AAA, or in this case an IAA as well as renal colic.

This case highlights the importance of systematically performing related POCUS studies. Here, the operator systematically searched for AAA in spite of already having identified urolithiasis and hydronephrosis correlating with the patient's symptoms. The systematic use of POCUS, prevented the pitfall of anchoring bias and premature closure bias, both recognized as common sources of bias in diagnosis [8]. AAA is a life-threatening diagnosis, with a varied presentation, of which physical exam is particularly unreliable in detection [9].

As POCUS presents a rapid, sensitive, and accurate assessment tool for examination of the abdominal aorta, particularly in the symptomatic population [3], it is a useful test for avoiding premature closure in patients with undifferentiated severe flank or abdominal pain, particularly in patients >50 years old who have a higher risk of aneurysm compared to younger populations [2,3].

The patient was transferred to the operating room and underwent an uncomplicated endovascular repair. He was discharged home on post-operative day 2. Of note, he also underwent laser lithotripsy and basket retrieval of

nephrolithiasis. The use of POCUS in this patient facilitated the diagnoses of dual conditions warranting subspecialty intervention.

Statement of Patient Consent

The authors certify that informed consent was obtained from the patient. The patient has consented to the use of images, video clips, and information regarding his condition and treatment to be published within the journal.

Disclosures

The authors have no conflicts of interest to declare.

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Sonographic Crepitus, a Point-of-Care Ultrasound Finding

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Introduction

Necrotizing fasciitis is a life-threatening polymicrobial skin and soft tissue infection that requires prompt diagnosis and treatment. Delays in diagnosis and treatment can result in an increase in morbidity and mortality [1]. Necrotizing fasciitis has historically been a clinical diagnosis. Patients with a high clinical suspicion for necrotizing fasciitis generally receive antibiotics and undergo emergent surgical debridement. In some cases, necrotizing fasciitis may be clinically difficult to differentiate from other skin and soft tissue infections such as severe cellulitis and abscesses. In such cases, POCUS may assist in diagnosis and has been shown to have a positive impact in expediting care [2,3]. Below, we describe a unique sonographic finding in a patient diagnosed with necrotizing fasciitis.

Presentation and Discussion

A 62-year-old male with no reported past medical history presented with worsening left foot swelling after cutting his toenail. Abnormal vital signs included a blood pressure of 166/99 mmHg, heart rate of 121 beats per

minute, and a fingerstick blood glucose of 500 mg/dL. On physical examination, his left foot was swollen, warm, erythematous, and tender to palpation. There was a poorly healing wound on the plantar surface of his left foot. Of note, crepitus was not felt. A point-of-care ultrasound (POCUS) of the left foot was performed which showed extensive cobblestoning without a discrete fluid collection, and deeper “dirty” shadowing suggestive of subcutaneous air (Figure 1). When gentle pressure was applied with the transducer, the subcutaneous air mobilized, confirming our suspicion that the “dirty” shadowing visualized was indeed subcutaneous air (Video S1). We call this novel sonographic finding “sonographic crepitus.” This dynamic visualization of subcutaneous air movement with transducer pressure application ultimately raised our suspicion for necrotizing fasciitis, in an otherwise equivocal physical examination of the wound. Prior studies have described sonographic findings consistent with necrotizing fasciitis such as subcutaneous thickening, air, and fascial fluid as well as an approach to early POCUS screening in these patients [2,3]. We hope that sonographic crepitus may be added

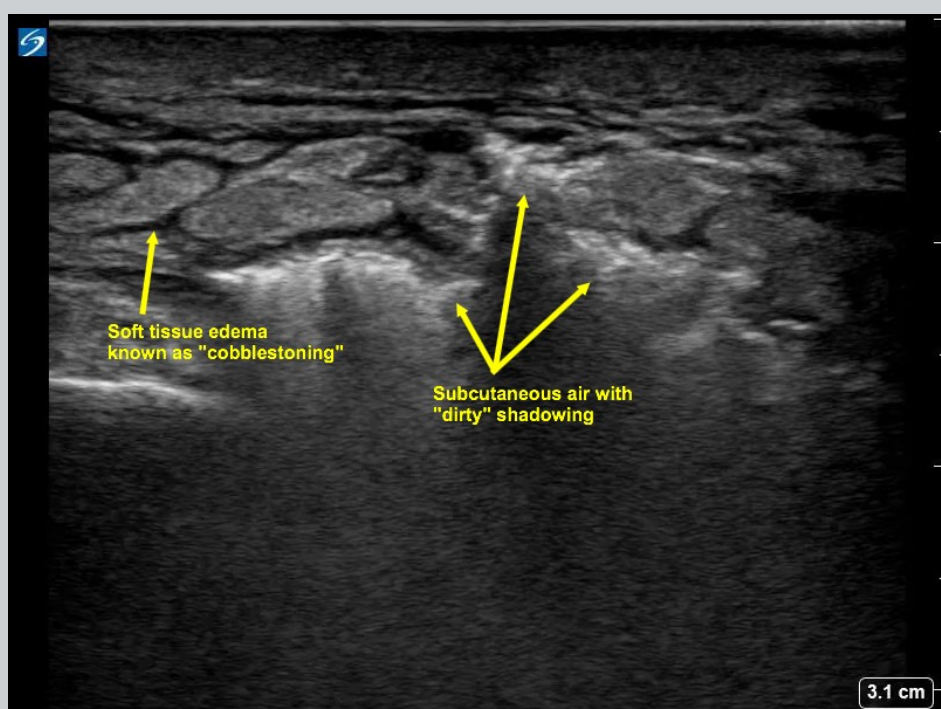


Figure 1. Cobblestoning and hyperechoic subcutaneous air with “dirty” shadowing, suggestive of necrotizing fasciitis.



Figure 2. Lateral view of a plain radiograph showing extensive subcutaneous air concerning for necrotizing fasciitis.

to the continuum of sonographic findings associated with necrotizing fasciitis and further assist diagnosis in ambiguous cases.

Clinical follow up

In the emergency department, an X-ray of the patient's foot was performed revealing diffuse soft tissue gas (Figure 2). From the emergency department, he was taken to the operating room for a transmetatarsal amputation. A surgical wound culture grew multiple organisms including *Enterococcus faecalis*, *Bacteroides fragilis*, *Streptococcus mitis*, *Streptococcus oralis*, and *Streptococcus constellatus*. Four days later, he was discharged to an acute rehabilitation facility with a wound vacuum. One month after the initial presentation to the emergency department, he was discharged to home care. He was recently discharged from home care services and currently follows with general surgery and wound care specialists as an outpatient, with improvement in his wound healing.

Limitations

The POCUS for this patient was performed by an emergency ultrasound-trained physician, who was able to identify the abnormal sonographic findings seen in necrotizing fasciitis. The ability to properly operate POCUS and identify these findings requires additional training that may not be ubiquitous.

Future

We hope this sonographic finding sparks interest to obtain additional data on sensitivities, specificities, positive predictive value, and negative predictive value of sonographic crepitus.

Conclusion

Sonographic crepitus, or mobilization of dirty air shadowing with application of probe pressure to the affected area, is a sonographic finding we describe here, in a patient diagnosed with necrotizing fasciitis. Questions still remain regarding the clinical utility and efficacy of POCUS in the diagnosis of patients with necrotizing fasciitis, an historically clinical diagnosis. We emphasize that obtaining a POCUS should not delay definitive treatment, though, in equivocal cases, it can serve as an additional diagnostic tool.

Disclosures

None.

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Diagnosing Paget-Schroetter Syndrome Using Point of Care Ultrasound (POCUS)

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Abstract

Paget-Schroetter Syndrome, or effort thrombosis, is a relatively rare disorder. It refers to axillary-subclavian vein thrombosis (ASVT) that is associated with strenuous and repetitive activity of the upper extremities [1]. Anatomical abnormalities at the thoracic outlet and repetitive trauma to the endothelium of the subclavian vein are key factors in its initiation and progression. Doppler ultrasonography is the preferred initial test, but contrast venography is the gold standard for diagnosis [1,2]. Early diagnosis coupled with a multimodal treatment strategy is crucial for optimal outcomes. We present a case of a 21-year-old male in which point of care ultrasound (POCUS) expedited the diagnosis and subsequent early treatment of right subclavian vein thrombosis. He presented to our Emergency Department with acute swelling, pain and erythema of his right upper limb. He was promptly diagnosed to have thrombotic occlusion of the right subclavian vein using POCUS in our Emergency Department.

Case Report

A 21-year-old male who is an avid sportsman presented to the emergency department with a 3-day history of pain and swelling of the right upper limb. He had joined a gym club three months prior where he partakes in weightlifting. His only past medical history was COVID-19 12 months prior. He had no family history of thromboembolic disease.

His examination revealed a swollen and erythematous right upper limb. His peripheral pulses were palpable and comparable to the opposite side. His range of movements were intact. The left upper limb and both lower limbs were normal. He had no symptoms of pulmonary embolism.

Right upper limb POCUS was concerning for subclavian vein thrombus with a distended right subclavian vein. The findings are demonstrated in Figures 1-3 and corresponding Videos S1-S3. Blood work up revealed a non-negative D-dimer at 0.93 mg/l (reference range <0.50mg/l). His chest x-ray showed no obvious abnormalities, and no evidence of an accessory rib. Once the diagnosis of subclavian vein thrombosis was made, low-molecular-weight heparin was initiated, and he was admitted under General Medicine. An urgent formal ultrasound confirmed an acute 6 cm thrombus within the right subclavian vein. Furthermore, it showed normal compressibility and colour flow within the right basilic vein, brachial vein, cephalic vein and axillary vein without any evidence of thrombosis. The patient underwent

thrombectomy and venoplasty by Interventional Radiology the next day due to severity of symptoms, followed with anticoagulation. These are demonstrated in



Figure 1. Transverse view with linear probe over the right medial end of the clavicle shows the right subclavian vein being noncompressible with an echogenic thrombus inside.

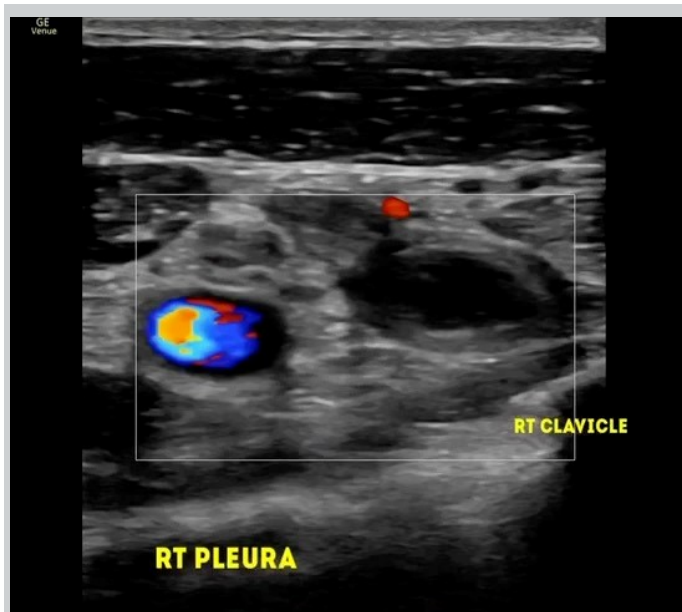


Figure 2. Transverse view with linear probe over the right medial end of the clavicle shows good colour flow within the right subclavian artery but the right subclavian vein lying above the medial end of the right clavicle shows no colour flow with same echogenic thrombus inside.

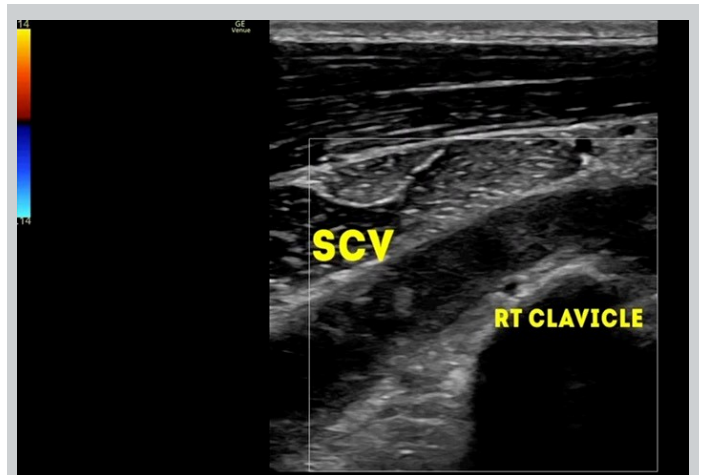


Figure 3. In long axis view with linear probe over the right medial end of the clavicle, POCUS colour doppler demonstrates the right subclavian vein above the right clavicle which is non-compressible.

Figures 4-6. Video S4 shows the initial digital subtraction venogram from the right arm which demonstrates thrombotic occlusion of the right subclavian vein with collateralization.

He was initially treated with Low Molecular Weight Heparin (LMWH), then switched to Apixaban. The IR venogram showed an acute thrombotic occlusion of the right subclavian vein with a high-grade stenosis at the junction of the first rib and clavicle. The findings were consistent with Paget-Schroetter Syndrome, with venous thoracic outlet obstruction. He was discharged on anticoagulation and is being followed up for consideration of a first rib resection. The importance of POCUS in this case is demonstrated through the 1-day turnaround between diagnosis and interventional treatment.

Discussion

Paget-Schroetter Syndrome, or effort thrombosis, usually follows vigorous sporting activities, such as wrestling, playing ball, gymnastics and swimming, which involve upper extremity movements. Hyperabduction and extension of the arm involved with these activities cause undue strain on the subclavian vein leading to micro trauma of the endothelium and activation of the coagulation cascade. Paget-Schroetter Syndrome is categorized as a venous variant of thoracic outlet syndrome and accounts for 30–40% of spontaneous

axillary-subclavian vein thrombosis (ASVT) and for 10–20% of all upper extremity deep venous thrombosis (UEDVT) [2, 5, 6]. Patients can present in different ways, ranging from asymptomatic to acute, intense pain and swelling. POCUS has been instrumental in diagnosing cases promptly in the emergency department. Emergency physicians using POCUS as initial line of investigation is important for the early diagnosis and treatment of this disorder. CT Venogram can be used in ultrasound negative cases which have high index of suspicion.

Common complications of Paget-Schroetter syndrome are pulmonary embolism and post thrombotic syndrome [2]. PE due to Paget-Schroetter Syndrome is now thought to have an incidence of 10–25% [4]. Post-thrombotic syndrome has a high morbidity associated with chronic pain, swelling, discoloration, edema, ulcers and varicose vein formation. Its incidence varies between 7% and 46% [4]. Management is with anticoagulation, systemic thrombolysis, or catheter directed thrombolysis. A survey conducted in UK regarding the most favored approaches to treat Paget-Schroetter Syndrome revealed that most surgeons favored a combined interventional radiology and surgical approach; 17% favored conservative management and 86.7% favored thrombolysis followed by elective thoracic outlet decompression procedure; 65% did not favor stenting. First rib resection was the most favored surgical procedure (74%) and trans-axillary approach was favored by majority (55%) [5]. Importance of prompt diagnosis within the emergency department is crucial to prevent these complications and emergency physicians must be vigilant to not miss such rare cases of upper limb thrombosis.

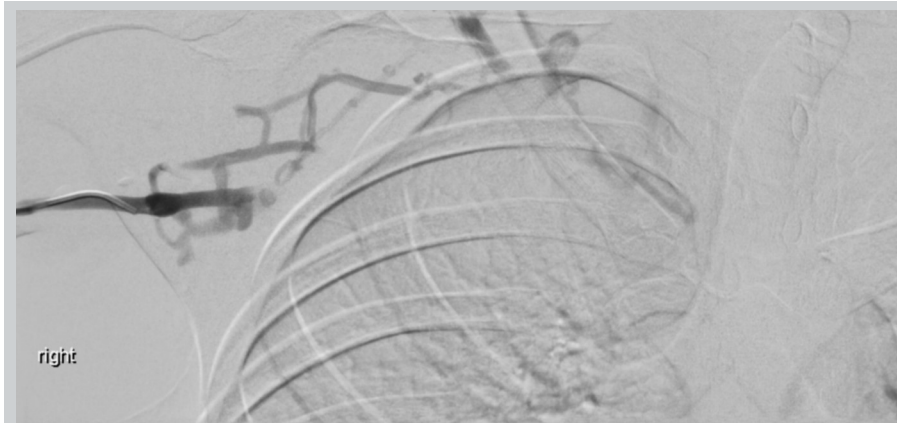


Figure 4. Digital subtraction venogram from the right arm demonstrates thrombotic occlusion of the right subclavian vein with collateralization.

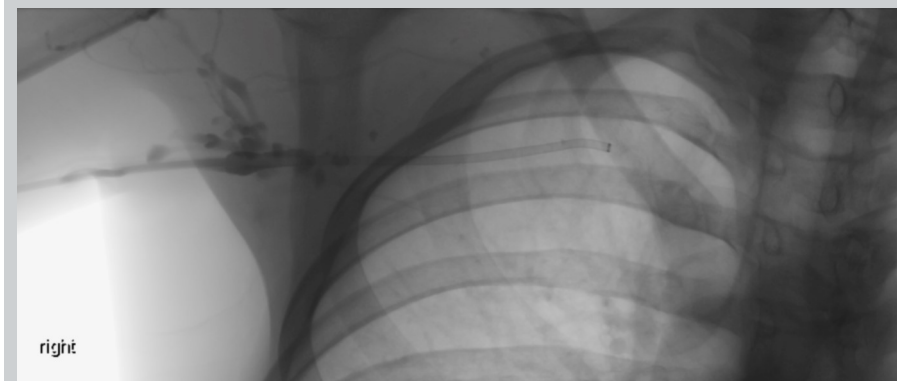


Figure 5. Aspiration thrombectomy performed with Penumbra Indigo Cat 8 device.

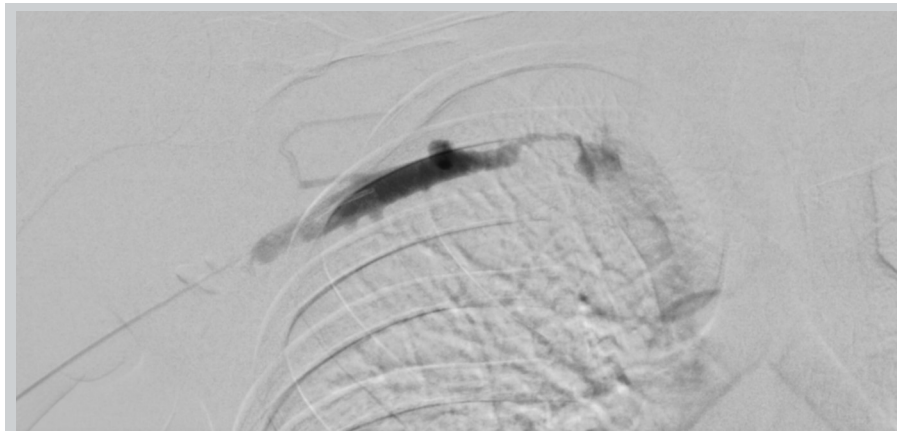


Figure 6. Completion venography demonstrating high grade stenosis of the right subclavian vein with due to compression by the clavicle and first rib, consistent with Thoracic Outlet Syndrome (TOS). No residual thrombus is identified.

Conflict of interest

JMM has professional links to Angiodynamics, Boston Scientific, Penumbra, Medtronic, Retriever, Pavmed, Inquis, Innova Vascular. The other authors have no disclosures to declare.

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Patient consent

The authors gained consent from the patient to publish.

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Point of Care Ultrasound (POCUS) in Bedside Diagnosis of Pyomyositis

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Abstract

A 43 year old man with a history of IV drug use, and presenting with three days of painful and swollen left calf, was referred to exclude deep vein thrombosis (DVT). Ultrasound showed no evidence of DVT. An area of localised warm, erythematous, which was disproportionately tender, prompted a point of care ultrasound (POCUS) assessment. POCUS confirmed a hypoechoic area in the underlying tissue, likely representing a collection because of no recent trauma. It led to prompt antibiotic therapy for the treatment of his pyomyositis. The patient surgical team reviewed the patient and recommended a conservative approach with a satisfactory clinical outcome that led to a safe discharge. Overall, this case demonstrates the versatility of POCUS as an efficient diagnostic tool in the acute setting, and it also helped to differentiate cellulitis from pyomyositis.

Introduction

Pyomyositis is an acute bacterial infection of skeletal muscle that results in localised abscess formation presenting with symptoms, including pain, swelling, erythema, and fever. It is usually associated with tropical climates; however, there has been an increasing number of cases presenting with pyomyositis in patients with a history of intravenous drug use [1-3].

The imaging modalities for the diagnosis of pyomyositis include ultrasound (US), computed tomography (CT) and magnetic resonance imaging (MRI). However, in the acute setting and after hours, point of care ultrasound (POCUS) is favoured most among Acute physicians and trainees who are skilled in using POCUS [4]. It uses a portable ultrasound scanner at the bedside to help clinicians answer binary questions promptly. It is beneficial during out-of-hours and acute emergencies. POCUS is relatively inexpensive, provides real-time images at the bedside and has the added benefit of being radiation free. In the acute setting, POCUS is used for the assessment of fluids in cavities (ascites, pleural or pericardial effusions), guidance for invasive procedures (ultrasound-guided vascular access) and identifying collections [5]. Kumar et al. [6] demonstrated the effectiveness of using POCUS to diagnose and treat pyomyositis without resorting to formal imaging techniques.

The role of POCUS in arriving at a positive early diagnosis and prompt initiation of intravenous antibiotics is a strong affirmation of one of the benefits of POCUS in an acute setting. Furthermore, the clarity of the diagnosis

also facilitated early discussion with the orthopaedic team if an invasive intervention had been necessary. POCUS played a significant role in diagnosing pyomyositis during out-of-hours. The subsequent events led to a positive diagnosis (not merely a negative diagnosis) and a satisfactory patient outcome.

Case Report

A 43-year-old gentleman presented to the acute medical initial assessment unit with a three-day left calf swelling and pain history. He had a history of intravenous drug use, and was recently discharged from the respiratory ward two weeks prior with a right-sided empyema that required a chest drain and a course of IV Co-amoxiclav. Upon discharge, he had completed a two-week course of oral Co-amoxiclav.

The patient had a medical history of past intravenous drug use on a methadone program; previous right-sided lower limb deep vein thrombosis (DVT), chronic viral Hepatitis C, asthma and duodenitis. On admission to the acute medical initial assessment unit, he denied any recent intravenous drug use.

The patient was clinically well but complained of constant pain in the left calf on examination. The left calf was swollen and warm to the touch, with mild erythema over the lateral aspect (Figure 1). The calf was tender on palpation with no evidence of recent trauma.

The patient had a Well's score for DVT of 4 (Calf Swelling >3 cm compared to other leg, collateral superficial veins, localised tenderness in the deep venous system and previously documented DVT). In line with NICE



Figure 1. Left lateral lower limb with erythematous skin overlying gastrocnemius muscle bulk

guidelines [7], a wells score equal or greater than two points should trigger a Doppler ultrasound scan to assess the leg veins (between the groin and the popliteal fossa) for deep vein thrombosis. He went straight for US Doppler Veins Leg Lt, which was negative for a DVT.

During the Consultant rounds, he happened to be reviewed by the Acute Physician, who also happened to be a Focused Acute Medicine Ultrasound (FAMUS) Supervisor, who noted that there was mild erythema in the lateral aspect of the lower limb with severe tenderness on palpation. This area would not be routinely scanned when assessing the deep vein distribution during a DVT Ultrasound.

POCUS of the lateral aspect of the patient's left leg demonstrated a 1.6x1.1cm non-compressible, non-pulsatile hypoechoic area with irregular borders likely represents a collection using bedside ultrasound (Figure 2). After that, intravenous flucloxacillin, Benzylpenicillin and Clindamycin were started to treat the collection (abscess) within the muscle as per local guidelines.

The patient's presentation was discussed with the plastic surgery team, who noted that the current presentation is unlikely to require incision and drainage due to low inflammatory markers and the patient appearing clinically stable. They recommended continuing IV antibiotics and drainage under interventional radiology if he deteriorated.

Overnight, the lateral aspect of gastrocnemius muscle bulk (of the patient's left leg) become increasingly inflamed. The orthopaedic team reviewed the patient, who found the range of movement at the knee and ankle joints was restricted due to pain with altered sensation around the sole of the left foot. They queried a

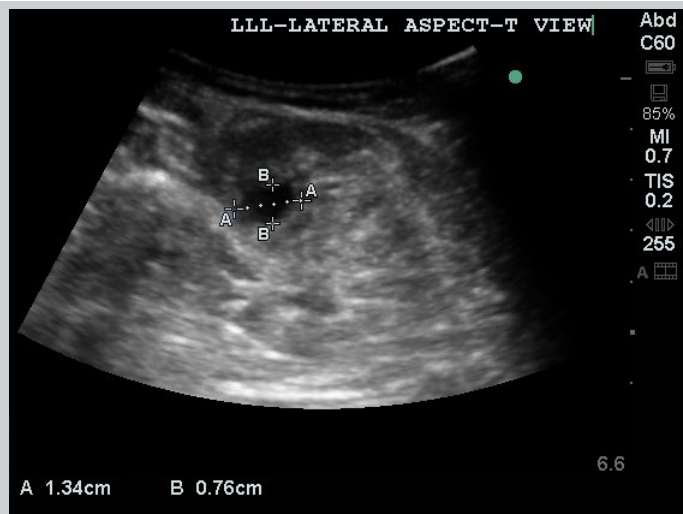


Figure 2. 1.6x1.1cm non-compressible, non-pulsatile hypoechoic area with irregular borders within left lateral gastrocnemius muscle confirming presence of fluid.

developing compartment syndrome and commenced Gentamicin, keeping the patient nil by mouth overnight for a potential surgical intervention the next day.

The following morning the patient had improved, and on assessment, there were no convincing features of necrotising fasciitis or compartment syndrome. Therefore, the patient was deemed not to require surgical intervention.

The following day the patient was well and discharged with a seven-day course of Flucloxacillin and for follow-up in the community.

Discussion

This case demonstrates the usefulness of POCUS for quick and accurate diagnosis of soft tissue collections, especially in a busy hospital environment where the number of ultrasound scans that can be carried out each day is limited, especially after hours. POCUS can also improve patient outcomes. Patients can be scheduled for incision and drainage or guided aspiration in a timelier manner rather than prolong wait for requested scans.

A retrospective study by Trusen et al. [8] on imaging modalities revealed that both ultrasound and MRI showed characteristic changes of pyomyositis. Ultrasound features of pyomyositis include altered echogenicity of the affected muscles and fluid collection. This was consistent with the ultrasonographic findings in our patient. However, MRI displays hyperintensity on the T2-weighted images, diffuse borders and contrast enhancement. They recommended ultrasound being the first imaging modality of choice in the extremities.

Although Kumar et al. [6] and Soler et al. [9] did recommend MRI and CT scanning as the gold standard

for diagnosing pyomyositis, ready access to these modalities are not always accessible in a timely fashion on a busy shift after hours. However, POCUS provides rapid diagnosis for initiation of antibiotics while MRI and CT scanning can be used for confirmation and surgical planning [6,10]. Additionally, it was noted that POCUS measurements of collections were often understated compared with MRI. Furthermore, unlike MRI, different types of fluid are difficult to distinguish from one another using ultrasound (pus, haematoma or other fluid).

Fortunately for this patient, his clinical presentation was not as catastrophic as expected because he was on oral antibiotics from his recent discharge from the respiratory ward. This is consistent with Wang et al. [11] work suggesting that antibiotics in the skin and soft tissue infections ameliorate the severity of inflammatory markers and clinical picture of skin and soft tissue infection.

It is also important to note that although our patient did not require incision and drainage because of his stable clinical state, Fitch et al. [12] recommend that most cutaneous abscesses are appropriate for incision and drainage when greater than 5 mm in diameter and accessible location.

Conclusion

This case report echoes the importance of maintaining a broad differential diagnosis when a positive diagnosis is not immediately in sight. It also illustrates how easy diagnosis like mild cellulitis can be differentiated from a more challenging diagnosis like pyomyositis with the aid of POCUS.

The bedside diagnosis of pyomyositis with the aid of POCUS in the hands of clinicians and trainees skilled in using POCUS is an invaluable skill. It will help prompt diagnosis of soft tissue collections (abscess) and expedite treatment in the acute setting, especially in out-of-hours.

Statement of Consent: A written informed consent was obtained from the patient before this case was written and submitted.

Disclosures

None.

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The Takotsubo Syndrome: Clinical Diagnosis Using POCUS

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Abstract

Takotsubo syndrome is a cardiomyopathy that can mimic an acute heart attack, in terms of clinical presentation, electrocardiographic changes, and findings on echocardiogram. Point-of-care-ultrasound (POCUS) can be used to detect this condition, even though the definitive diagnosis is made angiographically. We present the case of an 84-year-old woman with a subacute coronary syndrome and high levels of myocardial ischemia markers. The POCUS performed on admission showed characteristic left ventricular dysfunction involving the apex but sparing the base. The coronary angiography ruled out significant arteriosclerotic in the coronary arteries. The wall motion abnormalities were partially corrected in the 48 hours after admission. POCUS might be a useful tool to establish an early diagnosis of Takotsubo syndrome at time of admission.

Clinical Case

The patient is an 84-year-old woman with a medical history of hypertension and hypercholesterolemia on a type II angiotensin receptor antagonist (ARAI) and ezetimibe, who presented with an episode of mid-thoracic pain which radiated to her neck. The pain lasted for two hours and persisted as a slight to moderate discomfort until the patient finally went to the Emergency Room 24 hours later. The electrocardiogram (ECG) done at admission showed sinus rhythm of 61 beats per minute (bpm), with an axis of 30°, the PR segment of 0.19 milliseconds (ms), the QRS duration of 100 ms and a 0.1 mV elevation of the ST segment in II and aVF, and a 0.2 mV elevation in the V3, V4, V5 and V6 (Figure 1). The markers for myocardial injury were positive, with an ultrasensitive TnI of 3832 ng/l (nanograms per liter).

Since the patient was completely asymptomatic at this point, the case was interpreted as an anterolateral infarction in its subacute phase. Acetylsalicylic acid (ASA) and clopidogrel were administered and anticoagulant treatment with heparin of a low molecular weight was started. The patient was admitted to the Intensive Care Unit.

Upon arrival, the patient was still asymptomatic, with a stable sinus rhythm and without a sign of cardiac failure. In the physical exploration an audible systolic heart murmur that radiated to the neck could be heard.

An advanced cardiac POCUS was performed (Video S1) and revealed the following:

- Non-dilated left ventricle, with an eccentric hypertrophy affecting the basal part of the interventricular septum.

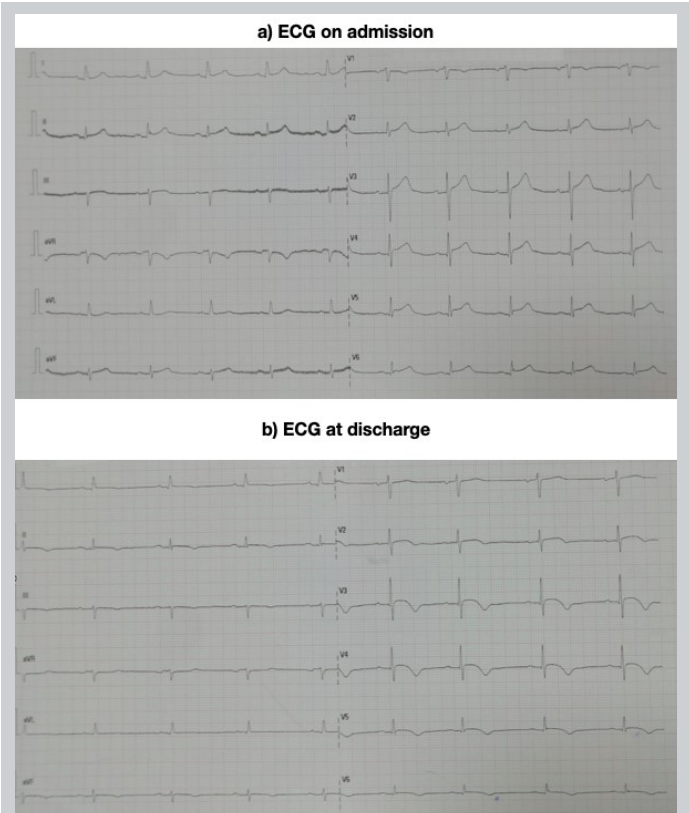


Figure 1. ECG at admission and at 24 hours. A) ECG on admission: sinus rhythm with a frequency of 61 beats per minute (bpm), the axis was 30°, the PR segment lasted for 0.19 milliseconds (ms), the QRS complex for 100 ms and there was a 0.1 mV elevation of the ST segment in the II and aVF derivations, and a 0.2 mV elevation in the V3, V4, V5 and V6 derivations. B) ECG at discharge: the elevation of the ST segment was still present and the T waves in the V3, V4, V5 and V6 derivations were beginning to become negative.



Figure 2. Dynamic systolic gradient in the exit tract of the left ventricle. At admission and 24 hours later. A) When it was studied using pulsed-doppler the spectral analysis had the characteristic keel shape of the subvalvular dynamic stenosis. The gradient peak was 63 millimeters of mercury (mmHg). B) In the control echocardiography 24 hours later, there was a substantial decrease of the dynamic systolic gradient of the exit tract of the left ventricle, this was attributed to the beta-blocker treatment.

- Severe hypokinesia of the apex and most apical segments of the anterior and lateral surfaces of the heart.
- Compensating hyperkinesia in the basal segments.
- Slightly depressed ejection fraction.
- Sclerosis and calcification of the mitral-aortic ring and of the valves.
- Abnormal pattern of relaxed diastolic filling.
- Moderate mitral regurgitation.
- Slight aortic regurgitation.
- In the study done with color-doppler, a turbulent flux appeared in the left ventricular outflow tract. When pulsed-doppler was applied, it had the characteristic knife shape of sub-valvular dynamic stenosis. The gradient peak was about 63 millimeters of mercury (mmHg). (Figure 2).
- In the two-dimensional image (2D) the movement of the anterior valve towards the septum during the systole (systolic anterior movement, SAM) could be clearly seen (Video S2).

The maximum peak of ultrasensitive TnI was reached at 5298 ng/l. In the ICU, anticoagulants, antiplatelets and beta-blockers (bisoprolol) were started. The following morning coronary angiography did not show any coronary lesions (Figure 3). Incidentally, the descending anterior

artery was abnormally long, and wrapped around the apex and continued along the diaphragmatic surface. The diagnosis of Takotsubo syndrome was made, and the clopidogrel was stopped, while continuing the AAS and the bisoprolol.

On the ECG done prior to discharge, 18 hours after the coronary angiography, elevation of the ST segment was still present while the T waves in V3, V4, V5 and V6 were beginning to become negative. The follow up echocardiography showed evidence of a substantial decrease of the dynamic systolic gradient of the left ventricular outflow tract (LVOT) which was attributed to the beta-blockers.

Conclusions

The Takotsubo syndrome was first described in 1990 by Sato et al. [1,2] and included in the American Heart Association's (AHA) classification of myocardopathies for the first time in 2006 under the name acquired primary stress cardiomyopathy [3].

The usual clinical presentation is indistinguishable from that of an acute coronary syndrome, since it produces the typical central thoracic pain, elevation of the ST segment in the ECG and an elevation of the markers for myocardial ischemia [4].

The echocardiographic image is very characteristic. The severe apical hypokinesia appears together with hyperkinesia in the basal segments which gives the heart the appearance of an inverted vase, the type traditional

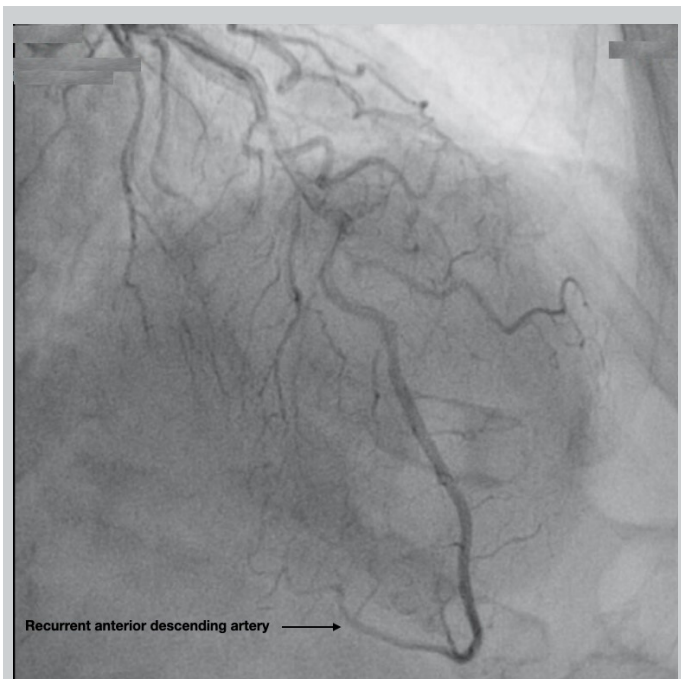


Figure 3. Redundant anterior descending artery. In some series of coronarography the anterior descending artery has shown a longer than average length and a longer recurrent diaphragmatic segment.

Japanese fishermen used to capture octopuses (takotsubo) [5].

The hallmark of Takotsubo syndrome is that on coronary angiography the coronary arteries will show no significant lesions.

The etiology of the syndrome is still not definitively known. It has been observed that often the symptoms are triggered by a situation which causes emotional distress, and it has been postulated that the syndrome might be explained by the toxic effect of catecholamines amidst the excessive local sympathetic response [4]. Given that Takotsubo predominantly affects postmenopausal women, lack of estrogens could be contributory since it is known that sex hormones exert an important influence over the sympathetic neurohormonal axis and coronary vasoreactivity [5].

On the echocardiography, a dynamic obstruction of the LVOT with systolic anterior movement of the mitral valve (SAM) can be seen in 20% of cases, generating an intraventricular gradient greater than 30 mmHg [6].

This gradient could be important in the genesis of the syndrome, because the obstruction elevates the intraventricular pressures of the apical area and diminishes myocardial perfusion (Video S2). In some series of coronarography the anterior descending artery has shown a longer than average length with a longer diaphragmatic course (Figure 3) [7].

After diagnosing Takotsubo and confirming it angiographically, antiplatelet treatment can be stopped, but beta-blockers must still be used, specially, in cases where an LVOT obstruction exists.

Even though alterations in the left ventricular ejection fraction are characteristically transitory and functional recovery is the norm, some patients can present very severe cases of heart failure and even cardiogenic shock and death.

For the emergency or ICU physician that uses POCUS, it is important to know the cardiac POCUS and echocardiographic characteristics of Takotsubo cardiomyopathy in order to raise the index of suspicion in patients presenting with chest pain.

Disclosures

None

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Avulsion Fracture of the Anterior Superior Iliac Spine in a Young Athlete Detected by Point-Of-Care Ultrasound

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Abstract

Pelvic avulsion fractures (PAFs) are common in adolescents. X-ray is commonly used to diagnose PAF, but the use of point-of-care ultrasound (POCUS) for this purpose in pediatric emergency departments has yet to be published. We reported herein a pediatric case of anterior superior iliac spine (ASIS) avulsion fracture detected by POCUS. A 14-year-old male patient visited our emergency department for groin pain he experienced during a game of baseball. POCUS of the right ilium demonstrated a hyperechoic structure anterolaterally displaced towards the ASIS, suggesting an ASIS avulsion fracture. X-ray of the pelvis confirmed the findings and led to the diagnosis of ASIS avulsion fracture.

Introduction

Pelvic avulsion fractures (PAFs) are rare and specific to adolescents and young athletes [1, 2]. Owing to their stage of musculoskeletal development, forceful contractions of muscles or tendons during sports activities frequently cause a PAF to occur in any of four anatomical sites, including the iliac crest, anterior superior iliac spine (ASIS), anterior inferior iliac spine (AIIS), and ischial tuberosity [1, 2]. X-ray is normally used to diagnose PAFs, but the condition can be misdiagnosed if the fragments of the fractured bones are small [3]. Computed tomography (CT) or magnetic resonance imaging (MRI) may also be used but they are expensive to perform. Point-of-care ultrasound (POCUS) is an alternative modality for diagnosing long bone fractures or ruptured tendons, [4, 5] but the reports of its use for this purpose in the pediatric emergency care setting are scarce. We herein reported a pediatric case of ASIS avulsion fracture detected by pediatric emergency physicians using POCUS.

Case Report

A previously healthy, 14-year-old male patient visited our emergency department for right groin pain which occurred when he suddenly changed course while running during a game of baseball. The pain prevented him from walking. He denied paresthesia or testicular pain. His vital signs were appropriate for his age. Physical examination revealed tenderness in the ASIS area but denied tenderness in the iliac crest or femoral head. His right leg was slightly flexed, and the range of motion of his right pelvic joint was limited because of the pain.

An attending pediatric emergency physician with five years' experience using pediatric POCUS performed a scan using LOGIQ™ e (GE Healthcare, Japan) with a high-frequency linear transducer (8-13 MHz). The patient was placed in a supine position, and a transducer was placed transversely and longitudinally from the iliac crest to the ischium (Figure 1). POCUS normally allows visualization of the ASIS and its apophysis as hyperechoic structures with an acoustic shadow, with the apophysis overlying the ASIS (Figure 2). In the present patient, the apophysis appeared hyperechoic with an acoustic shadow on the anterolateral side of the ASIS with an anterior and lateral displacement of 3.6 mm and 3.8 mm, respectively, suggesting an ASIS avulsion fracture (Figure 3).

Based on the findings, an ASIS avulsion fracture was

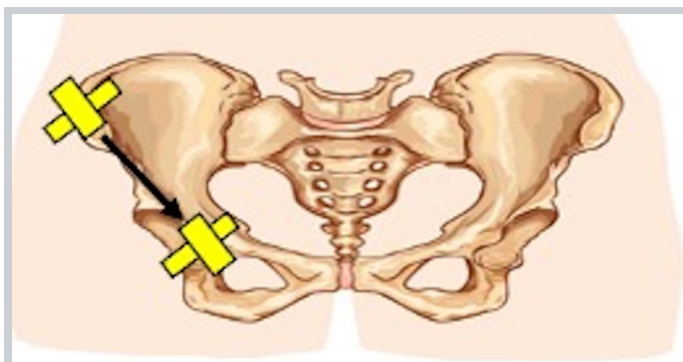


Figure 1. POCUS protocol. A high-frequency linear transducer (8-13 MHz) was placed transversely on the pelvis to scan the area from the iliac crest to the ischium.

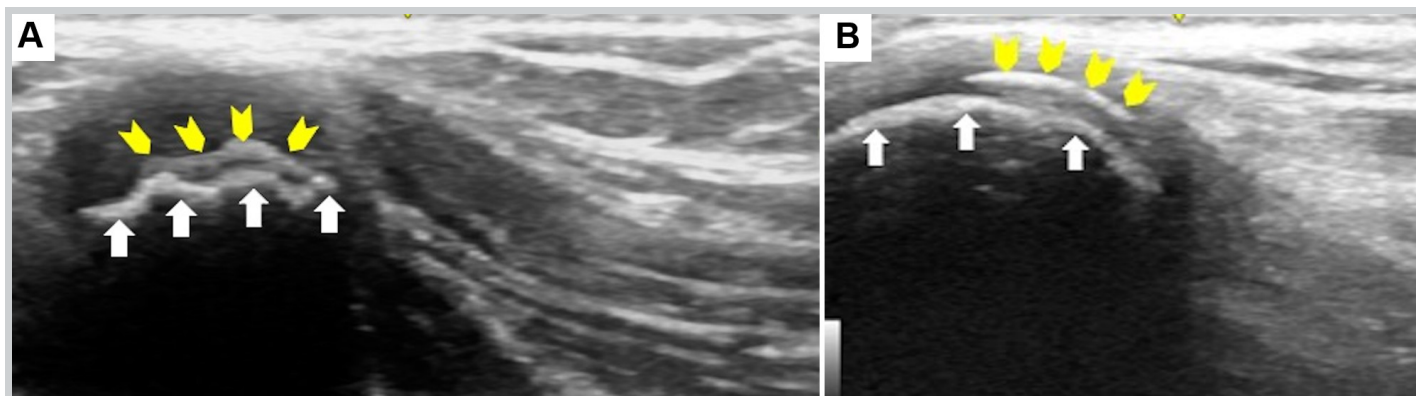


Figure 2. POCUS findings (ASIS view). Transverse (A) and longitudinal view (B) of the ASIS showed two hyperechoic structures with acoustic shadows. POCUS visualized ASIS as an uneven structure (indicated by the arrow), and the apophysis as a curved structure (indicated by the arrow head). The apophysis normally overlies the ASIS when not displaced.



Figure 3. POCUS findings (ASIS view). Transverse (A) and longitudinal view (B) of the ASIS showed two hyperechoic structures with acoustic shadows. The uneven structure is the ASIS (arrow), and the curved structure is the apophysis (arrow head). In the present patient, the apophysis was anterolaterally displaced.

suspected. X-ray of the pelvis confirmed the diagnosis of ASIS avulsion fracture (Figure 4). The displacement of the fragment was calculated for surgical fixation but was found to be 3.8 mm (< 20 mm), allowing conservative management. The patient was discharged with conservative treatment with non-weight bearing and had no complications at one month after discharge.

Discussion

To the best of our knowledge, the present report is the first to describe the use of POCUS to identify an ASIS avulsion fracture in an adolescent in the pediatric emergency department setting. Reports of ultrasound use in diagnosing PAFs are scarce. A previous case report from a rehabilitation department showed the utility of ultrasound for detecting an ASIS avulsion fracture in adolescent male although the technique was performed after a pelvic X-ray finding led to suspicion of a fracture [6]. A previous case-series study demonstrated that ultrasound performed by a radiologist was useful in detecting ASIS and AIIS avulsion fractures [7]. Furthermore, several studies demonstrated the usefulness of ultrasound used by orthopedists evaluating pelvic stability in adult patients with traumatic pelvic fractures [8]. However, there are no previous studies of

POCUS use by pediatric emergency physicians to detect PAF.

PAF comprises 4% of pelvic fractures and only 1.4% of all fractures. It mainly occurs in adolescents with a mean age of around 14 years [1, 2] most commonly at one of four sites, including the origin of the rectus femoris at the anterior inferior iliac spine (AIIS); the sartorius; the tensor fasciae latae at the ASIS; the hamstring at the ischial tuberosity; and the tensor fasciae latae at the iliac crest [1]. The frequency of avulsion fractures at the ischial tuberosity, ASIS, AIIS, and iliac crest is 31.9%, 33.9%, 25.2%, and 5.9%, respectively [2, 9]. Both direct forces, such as a hard tackle, and indirect forces, such as those involved in kicking a ball, running or sprinting may cause an ASIS fracture [9, 10]. However, lack of awareness about PAFs often leads to its misdiagnosis as muscle strain, ligament injury or apophysitis [2]. A previous case-series study discussed five cases of ASIS fracture that were initially misdiagnosed only by physical examination as muscle strain [3]. Therefore, when adolescent patients present with pelvic pain, especially engaging in specific, sports-related movements like those mentioned above, POCUS can be effective in differentiating PAF from other pathologies.



Figure 4. X-ray of the pelvis. A slightly displaced radiopaque structure was detected on the lateral side of the ASIS, suggesting an ASIS avulsion fracture (arrow).

Treatment of PAFs is mainly conservative, involving non-weight bearing and analgesics. Surgery is indicated only if the displacement of the fracture is > 20 mm [2]. A retrospective study demonstrated that 97% of PAF patients were treated conservatively [9]. A meta-analysis showed no statistically significant difference in clinical outcomes in PAFs without a severe displacement > 15 mm [11].

X-ray is normally used to diagnose PAF and is useful as long as the site of injury is first correctly identified. A retrospective study of 228 cases of pelvic apophyseal avulsion fractures in adolescents revealed that x-ray was able to diagnose 99% of PAF cases correctly and to identify the fracture displacement and fracture accurately [9], demonstrating a level of usefulness comparable to that of CT or MRI, which are only performed for PAF diagnosis when the radiographic findings are in doubt.

POCUS has the potential to be a screening method for diagnosing PAFs in adolescents. First, understanding of the unique mechanism of injury and the PAF presentations will help the treating physicians focus on scanning the most likely sites of PAF occurrence. POCUS allows these areas to be scanned, increasing the likelihood of identifying the site of injury rapidly. Second, as discussed by Martinoli et al. [12], unlike x-ray, POCUS can demonstrate the anatomical details of the pelvis, including the bones, muscles, and tendons, to help differentiate of PAF from other pathologies, enabling PAF to be differentiated from muscle or tendon injuries. Furthermore, POCUS enables a correct measurement of the displacement size, clarifying the need for surgical fixation, while avoiding CT and MRI. While the quality of its findings are operator-dependent with adult avulsion

fractures of the ischial tuberosity sometimes being misidentified as a hematoma [13], and a certain amount of training is required to obtain an adequate image [14], pediatric emergency physicians can be trained to use POCUS as an useful modality to diagnose PAFs in the same way they use it to diagnose long bone fractures [15]. Although further research is needed, the current report demonstrated that a pediatric emergency physician can readily use POCUS to diagnose an ASIS avulsion fracture.

Acknowledgements

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Conflicts of Interest

Takaaki Mori, Takateru Ihara, and Osamu Nomura have no financial relationships relevant of this article to disclose.

Ethical consideration

Written informed consent to publish details of this case was obtained from the patient.

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Impact of Point-of-Care Ultrasound in Medical Decision Making: Informing the Development of an Internal Medicine Global Health POCUS Curriculum

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Abstract

Background: Point-of-care Ultrasound (POCUS) is particularly useful in low-middle income countries (LMICs) where advanced imaging modalities and diagnostics are often unavailable. However, its use among Internal Medicine (IM) practitioners is limited and without standard curricula. This study describes POCUS scans performed by U.S. IM residents rotating in LMICs to provide recommendations for curriculum development. **Methods:** IM residents within a global health track performed clinically-indicated POCUS scans at two sites. They logged their interpretations and whether or not the scan changed diagnosis or management. Scans were quality-assured by POCUS experts in the US to validate results. Using the criteria of prevalence, ease of learning, and impact, a framework was developed for a POCUS curriculum for IM practitioners within LMICs. **Results:** A total of 256 studies were included in analysis. 237 (92.5%) answered the clinical question, 107 (41.8%) changed the diagnosis, and 106 (41.4%) changed management. The most frequently used applications were the Focused Assessment for Sonography for HIV associated TB (FASH) exam, finding fluid (pericardial effusion, pleural effusion, ascites), qualitative assessment of left ventricular function, and assessment for A-lines/B-lines/consolidation. The following scans met ease of learning criteria: FASH-basic, assessment of LV function, A-lines vs. B-lines, and finding fluid. Finding fluid and assessment of LV function changed diagnosis and management most frequently, greater than 50% of the time for each category. **Discussion/Conclusion:** We recommend the following applications as highest yield for inclusion in a POCUS curriculum for IM practitioners within LMICs: finding fluid (pericardial effusion, pleural effusion, ascites) and assessment of gross LV function.

Background

Point-of-care ultrasound (POCUS) is increasingly used as a powerful diagnostic tool for bedside assessment and procedures [1]. Unlike complete ultrasound (US) examinations performed by technicians and interpreted by radiologists, POCUS is performed by the clinician at the bedside to answer focused, clinical questions and integrate findings into decision making and management [1,2]. With brief training, ultrasound practitioners can rapidly diagnose and treat [3]. Particularly in low and middle income countries (LMICs), POCUS is more readily available and accessible than other imaging modalities [4–6]. While the use of POCUS has been well-established in Emergency Medicine, there is growing recognition of its value among other medical fields, including Internal Medicine (IM) [7,8].

POCUS has a variety of clinical applications. Lung ultrasound has been shown to be more accurate than chest radiography for consolidation, pleural effusion, and pneumothorax [9,10]. Focused cardiac ultrasound can

improve qualitative bedside assessment of left ventricular (LV) systolic function, volume responsiveness [11–16], chamber enlargement and pericardial effusion [17–21]. POCUS can also improve diagnosis of extrapulmonary TB using the Focused Assessment with Sonography for HIV-associated TB (FASH) [2,22]. The FASH exam identifies potential ultrasound findings in six abdominal locations that may be indicative of extrapulmonary TB (EPTB) in patients with HIV coinfection and is most sensitive for those with a CD4 count less than 100. Prior studies suggest that specifically in LMICs, POCUS may change clinical management in greater than 60% of cases [3,6,23–26]. These smaller studies depict some of the novel uses of POCUS in LMICs, but there is still limited research on the highest-yield applications of POCUS by IM physicians in LMICs.

No standardized POCUS curriculum within IM in LMICs has been established, as clinical applications are still being studied and can be region and resource specific [6]. Other studies aimed at teaching POCUS in

LMICs have taught various US applications and measured trainees' competencies pre- and post-training [27]; however, to our knowledge, our study is the first to collect data on which US applications are highest yield to teach and include in an IM-based curriculum in LMICs. In considering applications to include in a POCUS curriculum, a few different criteria have been proposed. Two studies used the following three criteria: prevalence, impact, and difficulty [2,28]. The Canadian Internal Medicine Ultrasound (CIMUS) group published consensus-based recommendations for an IM POCUS curriculum that agreed upon four principles: 1) applications should be selected based on clinical and/or education needs; 2) applications should be educationally feasible (cognitive and technical components); 3) content should have clinical and/or educational evidence to support its use; and 4) any unintended consequences should pose minimal risks to patients [8]. Finally, a Netherlands review describes a curriculum with applications that are easy to learn, rapid to perform, frequently encountered, and preferably have a dichotomous yes/no question. Utilizing this literature, we have chosen the following criteria to model our curriculum: prevalence, ease of learning, and impact on diagnosis and management.

We describe the highest impact POCUS applications by investigating the ability of POCUS to answer a clinical question, assist with diagnosis, and change management when used by U.S. IM residents in two LMICs. Using these results, we quantified the prevalence, impact, and ease of learning from our study and prior literature to guide curriculum development. Furthermore, we implemented a quality assurance (QA) program to validate the use of POCUS in these settings.

Methods

This was a descriptive study to assess the frequency and clinical utility of various POCUS applications by IM residents in LMICs. The study was conducted by residents in the Internal Medicine/Global Health track at the University of Pittsburgh Medical Center (UPMC).

Prior POCUS Training

At UPMC, Pulmonary and Critical Care faculty provide POCUS training to IM residents in the Global Health track. This includes a 20-hour didactic and hands-on training in image acquisition and interpretation, including education on cardiac, lung, abdominal, and lower extremity deep vein thrombosis (DVT) assessment. Training also includes instruction on logging images and the Quality Assurance (QA) system.

Data Collection

POCUS scans were performed in two different clinical settings: Kamuzu Central Hospital (KCH) in Lilongwe,

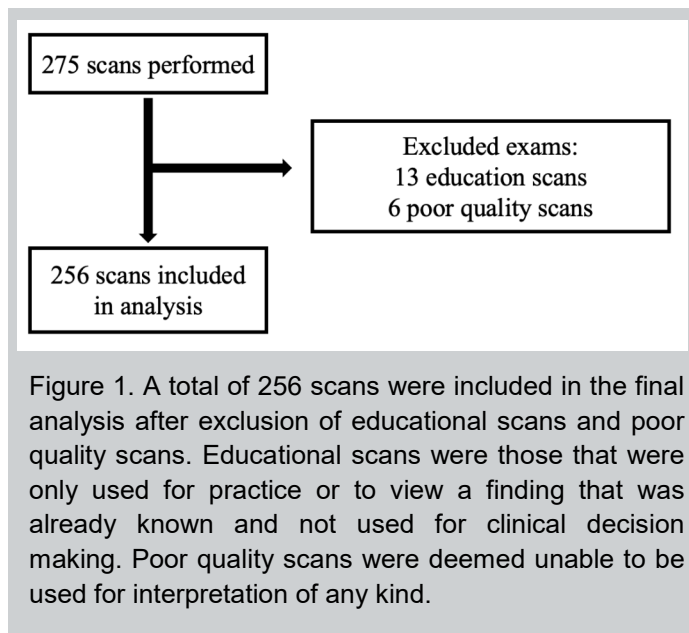
Table 1. Log and QA Spreadsheet. Residents completed this spreadsheet for each POCUS scan that was performed and uploaded corresponding images. QA faculty completed their component of the spreadsheet for images requesting review.

User	Data Entries
Image Uploader (GH resident)	<ul style="list-style-type: none">• Unique Study ID• Type of Study (Abdominal, Cardiopulmonary, Vascular, MSK/ Soft Tissue)• Country• Brief description of patient's problem• Primary Clinical Question• POCUS findings• Did POCUS answer your clinical question? (Yes, No)• Did POCUS change diagnosis? (Yes, No)• Did POCUS change management? (Yes, No)• Category (For Urgent QA, For non-urgent QA, No additional QA needed, poor quality images (do not QA), Educational Scan)

Malawi, and Georgetown Public Hospital Corporation (GPHC) in Georgetown, Guyana. These are two international clinical sites for IM residents training at UPMC. KCH is a very low-resource environment with limited access to radiography and formal ultrasound with substantial delay; it does not have a functional CT scan. GPHC has access to radiology-performed ultrasound and radiography and CT scan in some cases. Residents performed clinically-indicated POCUS scans at their respective clinical sites. Each scan was labeled with a unique, non-protected health information (PHI) identifier. Residents documented their interpretation in Google Sheets as outlined in Table 1. The images were uploaded to Google Drive and were remotely evaluated for QA by a POCUS expert in the United States within one week. This QA process is described in detail separately [29].

Ethics

Approval was obtained from the University of Pittsburgh Medical Center Institutional Review Board with educational exemption, IRB #PRO18040339. This project evaluated an initiative that was already being implemented for educational purposes. This was not human subjects research, as we were studying diagnostic reasoning rather than patients or human subjects



themselves. Approval was obtained from leadership at international partner sites.

Data Analysis

Data were analyzed using Stata/IC version 15.1 and Microsoft Excel. Studies were excluded from the analysis if they were labeled as an “Educational scan” or “Poor quality images” (Figure 1). An educational scan was a scan performed for academic purposes only and not for clinical decision making. Outcomes measured included the total number of studies performed and the number and percentage of studies that answered the clinical question, changed the diagnosis, and changed management. This was further stratified by type of study performed, location, and clinical question. Based on a prior pilot and existing literature [30] it was felt that applications involving “finding fluid”, including assessment for ascites, pleural effusion, and pericardial effusion, may be the highest yield. Given similar technique and potential for procedural application, these applications were grouped together in analysis. Finally, study validity was assessed by measuring the number of studies that underwent QA and the frequency of concordance between the reviewer and resident interpretations.

Defining prevalence, ease of learning, and impact on diagnosis and management

We defined the most prevalent applications of our study as those that were performed >10 times or >5% of all scans performed by all residents. To assess the ease of learning for a particular POCUS application, we sought to answer the following question: “Can providers learn and perform this application reliably in a limited time period?” We considered a “limited” time period to be a few hours of training per application, followed by 10-25 supervised

Table 2. Total number of studies stratified by location and type of study.

Exams performed	n (%)
Total	256 (100)
Malawi	225 (88)
Guyana	31 (12)
Type of Study	
Abdominal	117 (46)
Cardiopulmonary	126 (50)
Vascular	8 (3)
MSK / Soft tissue	3 (1)

clinical exams. A literature review was performed to answer the questions of prevalence and ease of learning, as outlined further in the results section. After narrowing down the POCUS applications based on prevalence and ease of learning, we utilized the results of our study to assess the impact of each POCUS application. Diagnosis and management change are frequently studied measures of the utility of POCUS in the clinical setting [3,23,31,32], thus these parameters were used to measure the impact of each POCUS application. For each exam, the examiner directly answered the questions “Did this exam change the diagnosis?” and “Did this exam change management?”. For each application, percent of “yes” answers was calculated for each question to quantify change in diagnosis and management.

Results

A total of 256 studies were included in the analysis (Table 2). 225 (88%) studies were performed in Malawi and 31 (12%) studies were performed in Guyana. The most frequent study type was cardiopulmonary with 126 (50%) studies followed by abdominal with 117 (46%) studies. Of all studies included in the analysis, 237 (92.5%) answered the clinical question, 107 (41.8%) changed the diagnosis, and 106 (41.4%) changed management (Figure 2). The majority of clinical questions were reliably answered by POCUS, however POCUS was less frequently able to answer clinical questions pertaining to: evaluation for malignancy (55.6%), assessment of RV function (77.8%), etiology of

Figure 2. Percentage of POCUS scans that answered the clinical question, changed diagnosis, and changed management, out of 256 total scans. This was collected by survey that asked for subjective report of the individual performing the scan.

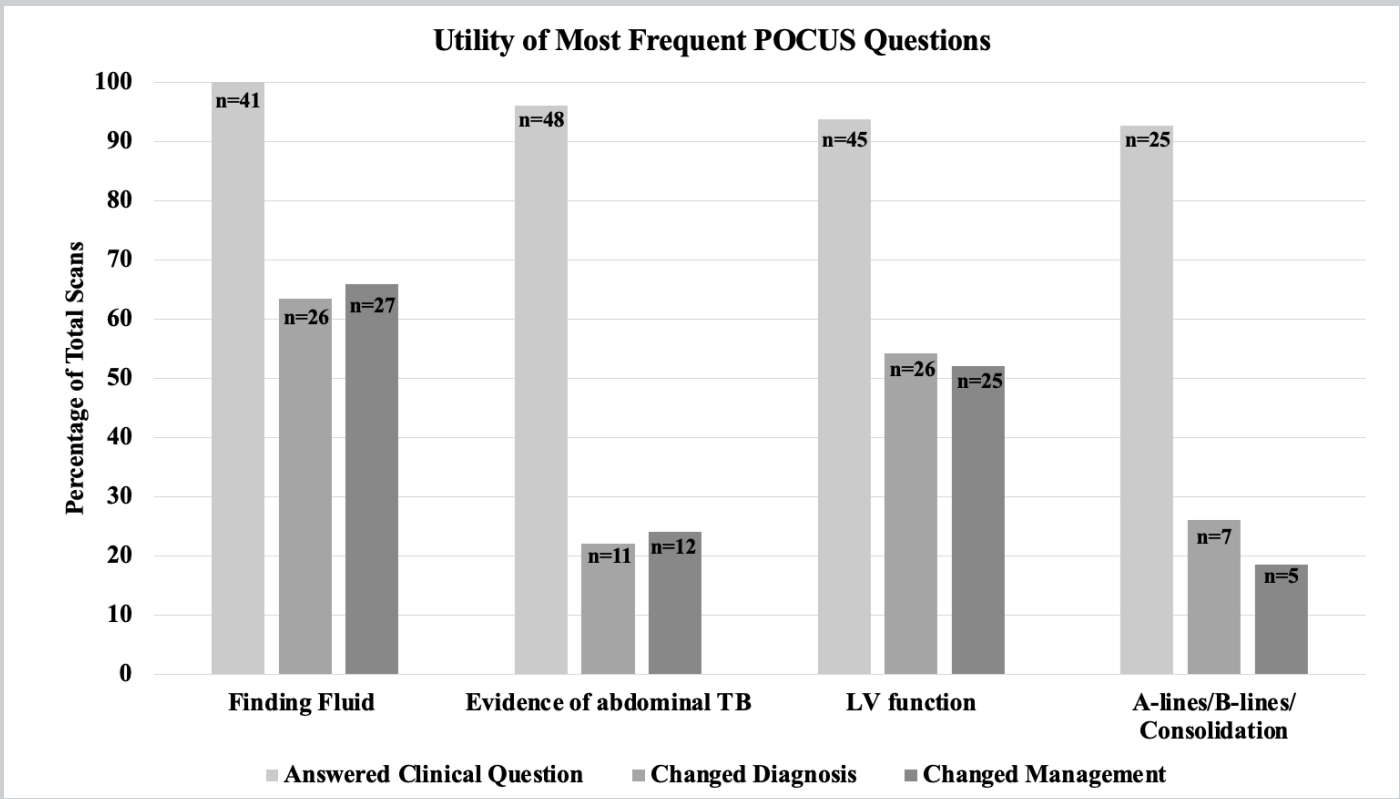
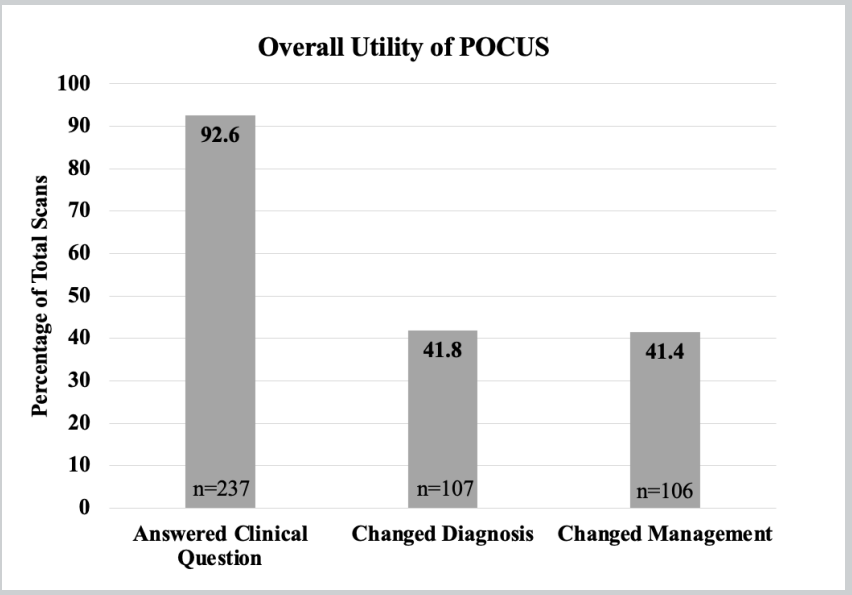


Figure 3. The four most frequent applications of POCUS stratified by how often each answered the clinical question, changed the diagnosis, and changed management, as subjectively reported by the individual performing the scan. The number of scans in each category is noted on top of each bar.

undifferentiated abdominal pain (66.7%), and assessment for vegetations (33.3%). Of the four most frequently asked questions, qualitative assessment of LV function and finding fluid changed the diagnosis and management more often than assessment for TB and A-lines/B-lines/consolidation (Figure 3). Other notable clinical questions for which POCUS frequently changed the diagnosis and management were evaluation for kidney size/assessment of chronic kidney disease (CKD), and

assessment of bladder or Foley catheter, though these were performed less frequently. All clinical questions and their ability to answer the clinical question, change diagnosis, and change management can be seen in Table 3.

Prevalence

The most prevalent applications in our study were the FASH study for abdominal TB, qualitative assessment of

Table 3. Clinical questions in order of frequency, broken down by how often POCUS was able to effectively answer the question, how often POCUS changed the diagnosis, and how often POCUS changed management. Items excluded from Table 4 were: "Other" and those with <3 scans which included gallbladder pathology, abscess and lung sliding.

	Total	Answered Clinical Question Answered	Changed Diagnosis	Changed Management
	n	n (%)	n (%)	n (%)
Total	256	237 (92.6)	107 (41.8)	106 (41.4)
Is there evidence of abdominal TB?	50	48 (96)	11 (22)	12 (24)
What is the qualitative LV function?	48	45 (93.8)	26 (54.2)	25 (52.1)
Finding Fluid	41	41 (100)	26 (63.4)	27 (65.9)
Pleural effusion	24	24 (100)	19 (79)	20 (83.3)
Pericardial effusion	7	7 (100)	2 (38.6)	2 (28.6)
Ascites	3	3 (100)	2 (66.7)	3 (100)
Abdominal free fluid (i.e.FAST)	7	7 (100)	3 (42.9)	2 (28.6)
Are there a-lines, b-lines or consolidation?	27	25 (92.6)	7 (26)	5 (18.5)
Is there evidence of cirrhosis?	16	15 (93.8)	7 (43.8)	5 (31.3)
Evaluation for malignancy	9	5 (55.6)	5 (55.6)	4 (44.4)
Is there evidence of DVT?	9	9 (100)	4 (44.4)	5 (55.6)
Is there hepatosplenomegaly?	9	9 (100)	2 (22.2)	1 (11.1)
Is there right ventricular (RV) strain?	9	7 (77.8)	4 (44.4)	4 (44.4)
Is there evidence of CKD? (or assessment of kidney size)	8	8 (100)	5 (62.5)	5 (62.5)
What is the volume status?	6	6 (100)	1 (16.7)	4 (66.7)
Assessment of bladder or foley	4	4 (100)	3 (75)	3 (75)
Is there hydronephrosis?	4	4 (100)	1 (25)	1 (25)
What is the etiology of abdominal pain?	3	2 (66.7)	2 (66.7)	1 (33.3)
Are there vegetations?	3	1 (33.3)	1 (33.3)	1 (33.3)

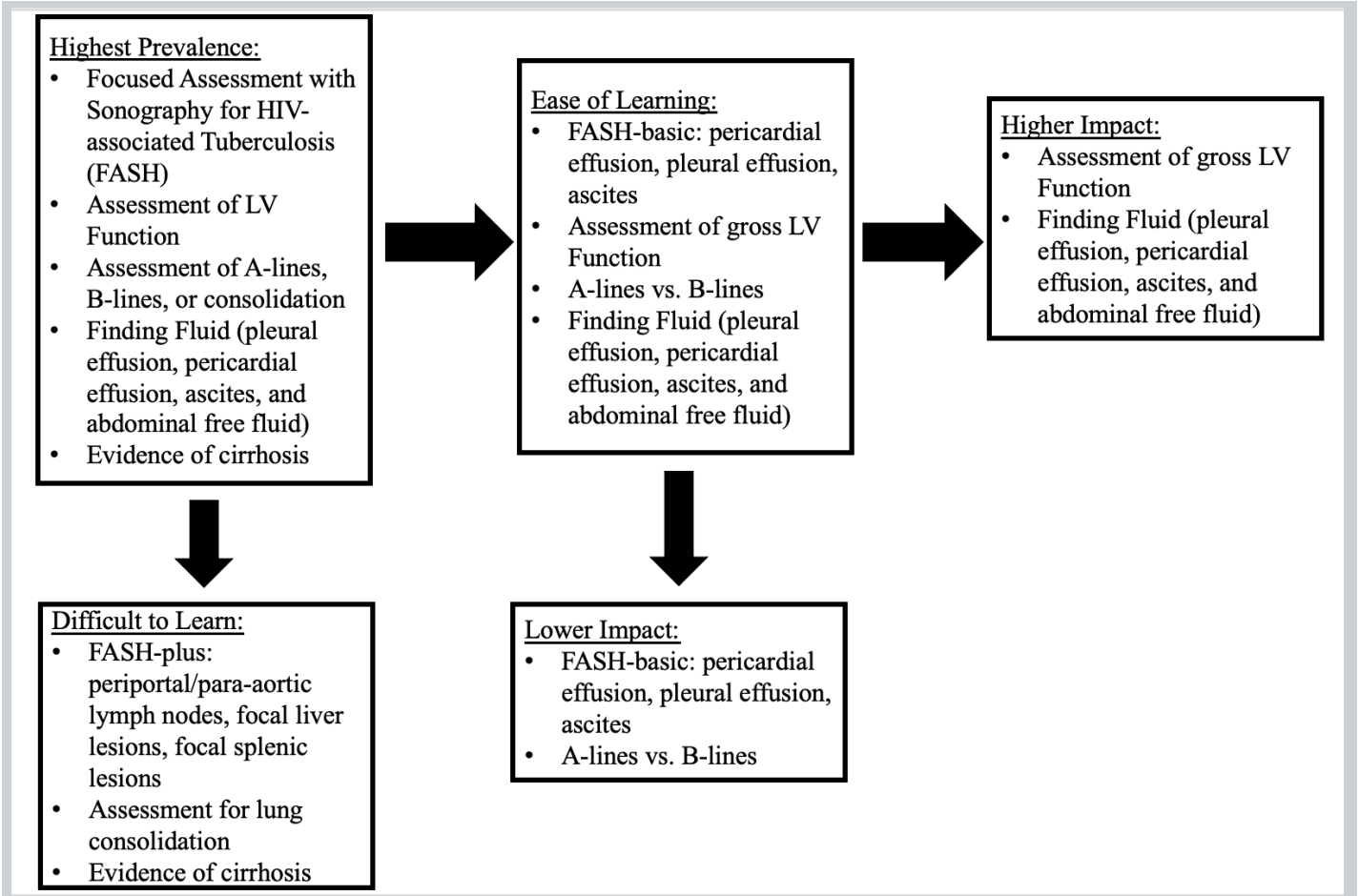


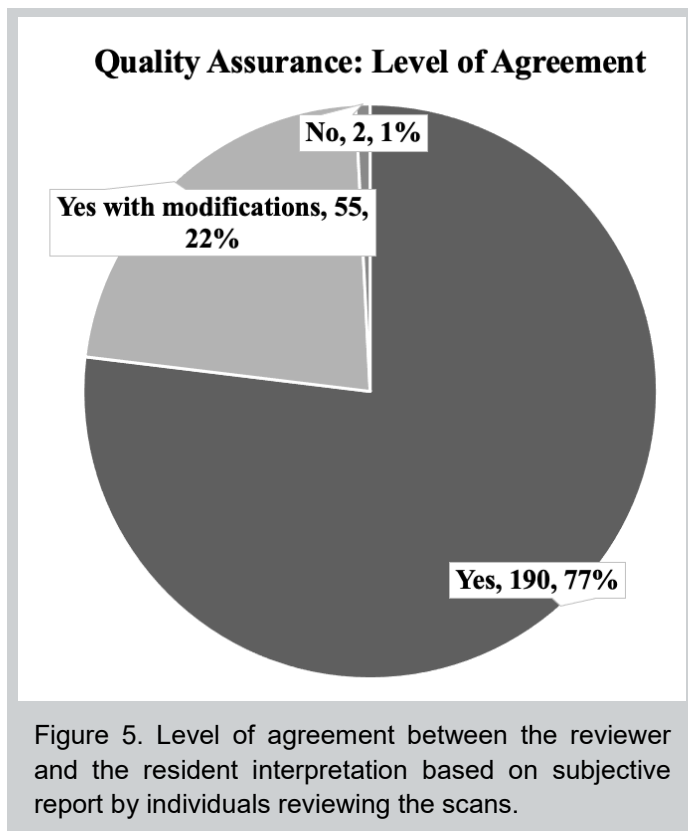
Figure 4. Proposed Curriculum for POCUS Education of Internal Medicine Curricula in Resource-limited Settings using Prevalence, Ease of Learning, and Impact as criteria for inclusion.

LV function, finding fluid (included ascites or abdominal free fluid, pleural effusion, or pericardial effusion), assessment for A-lines/B-lines/consolidation, and evidence of cirrhosis. This is in relative agreement with other studies from LMICs [33–35] with the exception of OB/GYN ultrasound being one of the most common applications in each of these studies. Both of our clinical sites had separate OB/GYN departments that performed ultrasound exams which likely explains this discrepancy. In addition, according to the CDC, HIV/AIDS and TB are among the top ten causes of mortality in Malawi [36], which supports the high use of the FASH exam in our study population. Figure 4 outlines our process for developing a POCUS curriculum, starting with the applications from our study that we have included as the “highest prevalence.”

Ease of Learning

As far as ease of learning, our literature review revealed data behind the following being easy to learn: qualitative assessment of LV function (i.e. > or < EF 40%) [37,38], hydronephrosis [39], DVT [40], finding fluid [30], and assessment for B-lines or A-lines [30]. In contrast, there

is data to support that biliary and gallbladder pathology may be more difficult to learn [23,41]. In our study, this is less relevant as there was a very low prevalence of biliary ultrasound; however, we have applied these results to any complex hepatobiliary application such as evaluation for cirrhosis or hepatomegaly, as these often require more technique and skill. In a Malawian study, DVT exams were considered “easy”; FASH, heart, and renal exams were considered “moderate”; and liver and gynecology exams were considered “difficult” [2]. In that study, the FASH exam is considered moderate difficulty likely due to the inclusion of the assessment of splenic abscesses and abdominal lymphadenopathy. In a separate paper, the study authors outlined the “FASH-basic” which focuses only on finding fluid in the pleural and abdominal spaces and likely requires significantly less skill [22]. Thus, the following applications have met the criteria of “easy to learn”: 1) FASH-basic or finding fluid, both of which include pericardial effusion, pleural effusion, ascites/abdominal free fluid, 2) qualitative assessment of LV function, and 3) A-lines vs. B-lines. Contrarily, we determined that FASH-plus, assessment for consolidation, and evidence of cirrhosis would be



more challenging to perform, and thus we recommend excluding these applications from the initial curriculum (Figure 4).

Impact on Diagnosis and Management

Of the remaining indications (Figure 4), finding fluid changed the diagnosis and management 63.4% and 65.9% of the time, respectively, and qualitative assessment of LV function did so 54.2% and 52.1% of the time, respectively. Contrarily, the FASH exam changed the diagnosis and management 22% and 24%, respectively, and A-lines/B-lines/Consolidation did so 26% and 18.5% of the time, respectively. Thus, the following applications have been defined as higher impact: qualitative assessment of LV function and finding fluid. The following have been excluded as lower impact: FASH basic and A-lines vs. B-lines. All clinical questions and their respective impact can be seen in Table 3.

Quality Assurance and Validation of Data

A total of 243 (94.9%) of scans were reviewed by experts for quality assurance. Of those that were reviewed, 76.9% had complete agreement between the resident and reviewer and 22.3% noted agreement but with modifications (Figure 5). In 2 (0.8%) cases the reviewer did not agree with the interpretation, though this did not change the clinical management in either case. Of note, reviewer agreement with the interpretation did not significantly differ between clinical questions. The 13 scans that were not reviewed either had local quality

assurance by a radiologist or were not uploaded correctly to the Google Drive and were thus unable to be reviewed. More detailed analysis of the quality assurance of these scans can be seen in Fox et al [29].

Discussion

In our study, POCUS was able to answer the clinical question 92% of the time and changed diagnosis and management 41.8% and 41.4% of the time, respectively. This is comparable to other studies that have been done in LMICs [23,32–34,42]. Questions that were more difficult to answer with POCUS were more open-ended, such as “etiology of abdominal pain” and “evaluation for malignancy.” Binary questions such as “is there evidence of a pleural effusion?” were more likely to answer the question. This is consistent with prior literature discussing the most effective use of POCUS [2,33,43,44].

Proposed Indications to Include in GH POCUS Curriculum

Based on the results above (Figure 4), we have outlined a recommended curriculum for POCUS education of IM practitioners in LMICs settings similar to those in this study (Table 4). This includes assessment for free fluid and qualitative assessment of LV function. One important note is that the FASH exam is most sensitive when utilized in patients with HIV and CD4 counts less than 100. It is possible that in our study the FASH exam was performed in a broader population, which may have decreased its sensitivity and specificity [22]. Thus, in settings where there is a high prevalence of HIV-TB coinfection, we recommend including the FASH-basic exam into the curriculum as well, which would mainly consist of teaching how finding fluid can be applied to the diagnosis of TB in patients with HIV, particularly those with CD4 counts less than 100. In such settings, changing the diagnosis and management even 15-20% of the time would arguably be worthwhile.

For assessment of LV function, we recommend emphasizing that the goal of this assessment is to evaluate general, or qualitative, heart function rather than measuring ejection fraction or assessing more complex valvular pathology. We recommend still obtaining a formal echocardiogram in most cases with the knowledge that this may take several days to get done in these settings, or patients may not be able to be transported for it at all. Depending on skill level, assessment of LV function may be incorporated with the assessment of B-lines and pleural effusions to form the Cardiac Limited Ultrasound (CLUE) exam [45] to determine overall volume responsiveness or need for diuresis, though this may be too nuanced for basic learners.

Two applications that we did not include in our proposed curriculum but may be useful are assessment of

Table 4. Proposed Basic Curriculum for Internal Medicine practitioners in LMICs.

POCUS Application	Clinical questions	Scanning locations
Finding fluid *Including FASH-basic exam in areas of high HIV/TB prevalence	Is there a pericardial effusion? Is there evidence of a pleural effusion? Is there evidence of ascites or abdominal free fluid?	Subxyphoid view Bilateral lung bases Right upper quadrant Left upper quadrant Suprapubic
LV function	What is the qualitative left ventricular function?	Parasternal long axis Apical 4 chamber view Subxyphoid view

hydronephrosis and assessment for DVT. We did not include these because the prevalence in our study sites was quite low, but in areas where the prevalence is higher, these applications may be worthwhile to include and would meet the ease of learning criteria. One additional application that was found to be useful in Malawi was the assessment of kidney size. Often, it is difficult to obtain lab results in a timely manner, so kidney size and character was often used as a surrogate marker for possible chronic kidney disease.

Role of Quality Assurance

It is worth briefly discussing the role of QA both for our study and for future potential curricula. For our study, QA served two purposes: 1) to validate the results of our study, and 2) to increase the quality of our residents' education while abroad, as described in our other paper [29]. Ideally, QA would be incorporated into any POCUS curriculum, but we recognize this may not be possible in many centers. Whenever possible, learners should be encouraged to review their deidentified images with a more expert individual, whether that be in person or electronically via mobile applications.

Limitations

Our study has several limitations. First, our study discusses POCUS applications in LMICs; however, there is of course substantial heterogeneity of clinical setting within LMICs, including different disease prevalence/epidemiology and resource availability. It should be noted that a significant majority of scans in our study were performed in Malawi over Guyana, likely due to a decreased number of rotators in Guyana as well as more formal imaging resources available in Guyana. As such, it is worth emphasizing that the study may have limited generalizability to all LMICs.

Second, the data collected was subjective report. While we attempted to standardize this by providing criteria for

diagnosis and management change, there is still potential for variation in what constitutes "changed diagnosis" and "changed management" per participant.

Third, we did not pre-define clinical questions that were appropriate for POCUS, which resulted in some open-ended questions, such as "etiology of abdominal pain" and "evaluation for malignancy" that were more difficult to answer with POCUS. In the future, we would standardize these to include more specific, binary questions. We suspect this may be due to the fact that in settings with limited availability of alternative imaging, POCUS frequently is used to answer more broad questions rather than the binary clinical questions that are answered in high-resource settings.

Finally, while we validated our findings with QA, we did not measure patient outcomes in our study, nor did we measure the feasibility of this curriculum being implemented among local practitioners. Next steps for this project would be to teach and include local practitioners, measuring the feasibility and applicability not only with US-trained IM residents but with local IM practitioners, allowing for capacity building and sustained integration of POCUS, which would be the gold standard for assessing whether the diagnostic and management change was valid.

Conclusions and Next Steps

In this study, we recommend that an initial POCUS curriculum for inpatient medicine practitioners in LMIC settings similar to those in this study include the following applications: finding fluid (pericardial effusion, pleural effusion, and ascites) and qualitative assessment of LV function. This novel educational model describes POCUS applications that are highest yield to include in an IM POCUS curriculum based on prevalence, impact, and ease of use, and could improve the way POCUS is taught and used in these settings.

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Disclosures

The authors declare no conflicts of interest.

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Ultrasound Image Quality Comparison Between a Handheld Ultrasound Transducer and Mid-Range Ultrasound Machine

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Abstract

Objectives: Not all labor and delivery floors are equipped with ultrasound machines which can serve the needs of both obstetricians and anesthesiologists. This cross-sectional, blinded, randomized observational study compares the image resolution (RES), detail (DET), and quality (IQ) acquired by a handheld ultrasound, the Butterfly iQ, and a mid-range mobile device, the Sonosite M-turbo US (SU), to evaluate their use as a shared resource. **Methods:** Seventy-four pairs of ultrasound images were obtained for different imaging purposes: 29 for spine (Sp), 15 for transversus abdominis plane (TAP) and 30 for diagnostic obstetrics (OB) purposes. Each location was scanned by both the handheld and mid-range machine, resulting in 148 images. The images were graded by three blinded experienced sonographers on a 10-point Likert scale. **Results:** The mean difference for Sp imaging favored the handheld device (RES: -0.6 [(95% CI -1.1, -0.1), $p = 0.017$], DET: -0.8 [(95% CI -1.2, -0.3), $p = 0.001$] and IQ: -0.9 [95% CI -1.3, -0.4, $p = 0.001$]). For the TAP images, there was no statistical difference in RES or IQ, but DET was favored in the handheld device (-0.8 [(95% CI -1.2, -0.5), $p < 0.001$]). For OB images, the SU was favored over the handheld device with RES, DET and IQ with mean differences of 1.7 [(95% CI 1.2, 2.1), $p < 0.001$], 1.6 [(95% CI 1.2, 2.0), $p < 0.001$] and 1.1 [(95% CI 0.7, 1.5), $p < 0.001$], respectively. **Conclusions:** Where resources are limited, a handheld ultrasound may be considered as a potential low-cost alternative to a more expensive ultrasound machine for point of care ultrasonography, better suited to anesthetic vs. diagnostic obstetrical indications.

Introduction

In a dynamic labor and delivery floor, a handheld/portable device is crucial for assessing fetal heart rate, placental position, and for procedural guidance in a timely and efficient manner. For the obstetrician, the ultrasound has been a vital diagnostic tool since its introduction in 1958 [1]. More recently, the use of ultrasound (US) technology has gained significant traction in anesthesiology as a clinical and diagnostic tool. However, not all labor and delivery floors are equipped with ultrasound machines which can serve the needs of both obstetricians and anesthesiologists, nor can all afford two different machines to suit their different needs. Limitations to ultrasound use include financial constraints to obtain a device, limited time, limited HIPAA compliant storage space, synchronization with electronic medical records, lack of portability, and steep learning curves for both obtaining and interpreting images [1-6]. Advances in technology have made possible the creation of pocket-sized ultrasound machines that aim to increase ultrasound accessibility by addressing these limitations [1]. The increase in accessibility can benefit

both patients and trainees as ultrasounds can be utilized in routine care of parturients. Yet, the question remains, does improved portability and access compromise image quality?

In this study, we evaluate the image characteristics of a handheld device against our standard mobile ultrasound machine. Our study's primary aim was to compare the quality of images obtained by a handheld ultrasound machine (the Butterfly iQ) and our current mobile mid-range ultrasound system, the Sonosite M-turbo US. Given that obstetricians and anesthesiologists routinely use ultrasound, we designed a comparison study utilizing shared resources. This cross-sectional, blinded, and randomized observational study aims to compare the image characteristics acquired by the two ultrasound machines herein described for both obstetric and anesthesiologic purposes.

Methods

This prospective observational study was carried out in a tertiary care labor and delivery unit and an outpatient maternal-fetal medicine office. The protocol was approved by the Yale University Institutional Review

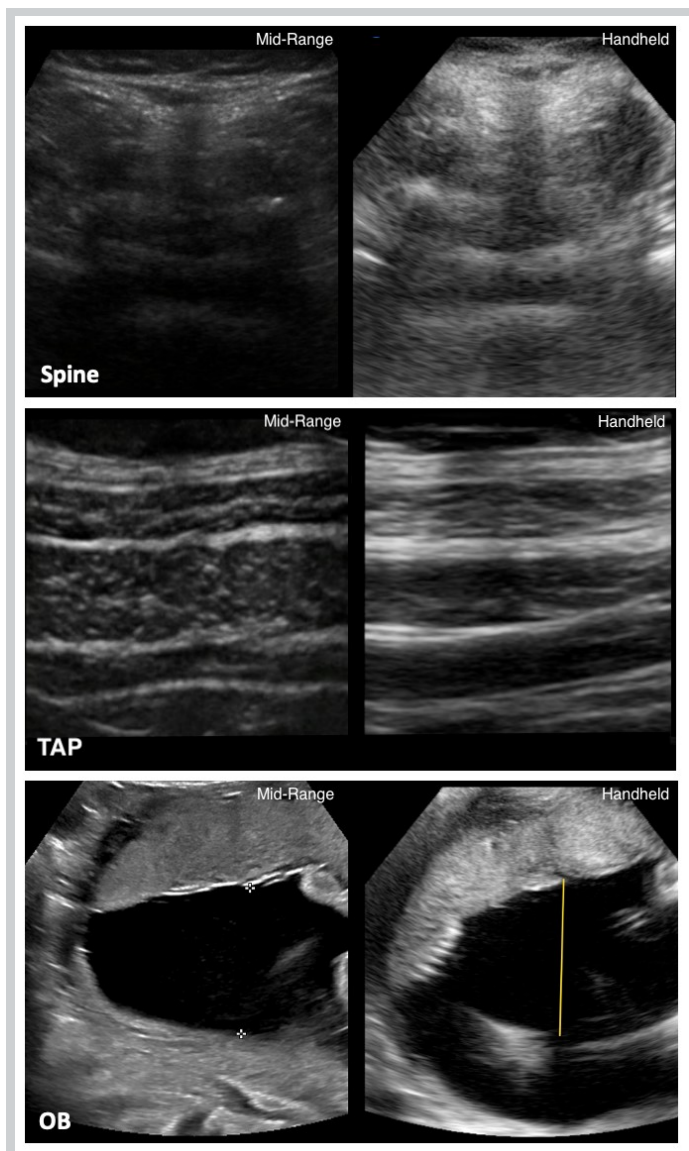


Figure 1. Examples of paired images. Images were unlabeled, cropped, masked, deidentified, and presented in randomized pairs to experienced sonographers for grading. Images were presented by group (Sp, TAP and OB) and graded on a Likert scale from 1-10 on image resolution (RES), detail (DET) and quality (IQ).

Board (IRB) and registered on ClinicalTrials.gov (ClinicalTrials.gov Identifier: NCT03764111). The outpatient maternal-fetal medicine office was chosen over the labor and delivery floor and triage due to the differences in acuity to minimize interruptions to patient care and any interference with image acquisition. A total of 75 patients were approached to obtain 30 ultrasound spine (Sp) images, 15 transverse abdominis plane (TAP) images and 30 obstetric (OB) images by each the handheld US (Butterfly iQ; Guilford, CT, USA), and the mid-range Sonosite M Turbo (Bothell, WA, USA). Clinically, the Sp images were obtained to aid with neuraxial anesthesia placement, the TAP images to aid in

regional anesthesia nerve blocks for post-cesarean pain, and the OB images for a variety of diagnostic indications, including assessing fetal heart rate, placental position, various measurements of fetal growth, and more.

Pairs of ultrasound images were obtained for the Sp, TAP and diagnostic OB purposes. Each patient was scanned in one of the respective locations by both the handheld and mid-range devices. Images were acquired by two experienced sonologists in their respective fields (AG-F for the Sp and TAP and SA-R for obstetric images). The sonographers were instructed to adjust the gain, depth, and frequency of each probe to optimize the best picture on each machine.

Spine and TAP images were acquired on the day of a patient's scheduled cesarean delivery. The 30 obstetric images were obtained as part of the parturients' prenatal care. All participants agreed to have images taken with both US devices. When utilizing the mid-range US, two types of probes were utilized: a linear array transducer (5 – 11 MHz) for the TAP imaging, and a curvilinear transducer (up to 5 MHz) was utilized for the Sp and OB imaging. On the contrary, the handheld Butterfly iQ relies on capacitive micro-machined ultrasound transducers (CMUTs), allowing for changes in MHz as a preset function (a single probe can scan at different MHz). The images on the handheld Butterfly iQ were performed in the abdomen imaging preset for Sp and OB and on the musculoskeletal preset for TAP images.

Once the images were obtained, they were transferred to a computer, where they were cropped, deidentified, and masked to leave only gray-scale images. The pairs were then randomized for grading (see Figure 1). Three experienced sonologists from each specialty (six raters total) reviewed and rated the images. Sp and TAP images were graded by anesthesiologists familiar with ultrasound use for neuraxial and regional blockade. OB images were graded by experienced physicians from the section of Maternal-Fetal Medicine. Each reviewer rated every pair of images for its resolution (RES), detail (DET), and image quality (IQ).

- RES was defined as the sharpness and crispness of the image and a lack of haziness/blurriness.
- DET was defined as clarity of bone/tissue outlines and ease with which boundaries of structures are seen.
- IQ was an overall assessment encompassing contrast of solid and fluid-filled structures and the absence of noise.

Each of these three qualities was rated using a ten-point Likert scale, as described by Blaivas et al. [7], where 1-3 was defined as “poor”, 4-7 was “good” and 8-10 was “very good” image scores.

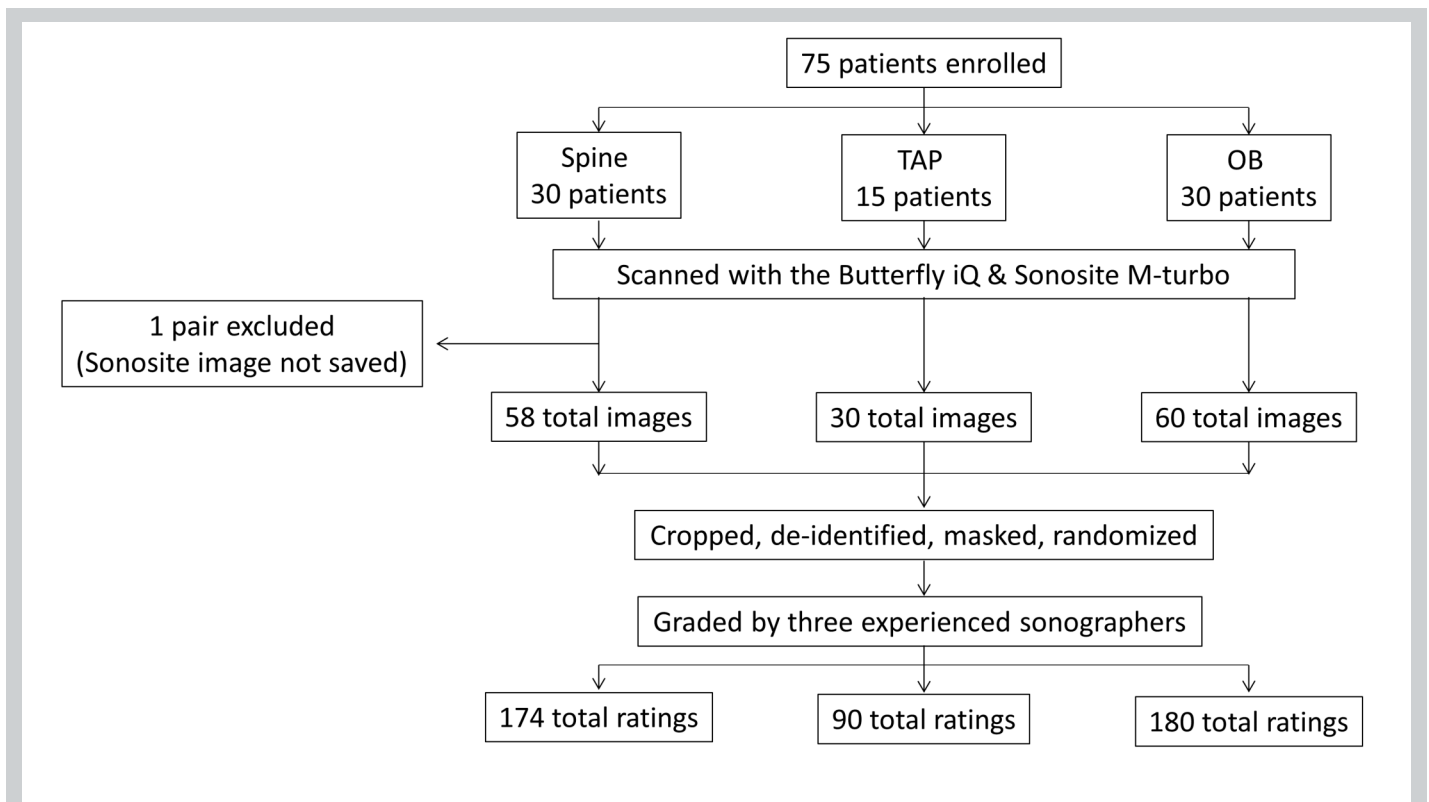


Figure 2. Flow chart of the methods. Patients were enrolled and imaged in one of three groups. Images were obtained by both the handheld Butterfly iQ and mid-range Sonosite M-turbo and the image pairs were cropped, de-identified, masked and randomized before being given to raters. One pair of images from the Spine group was excluded because the image on the mid-range device was not saved. Total images is the number of images that were graded for each: image resolution, detail, and quality. Graders were experienced sonographers in their respective fields. Spine and TAP blocks were graded by anesthesiologist who routinely use ultrasound in their practice, OB images were graded by experienced obstetricians. TAP = Transversus abdominis plane, OB = obstetric.

Statistical Analysis. Our design yielded three rating scores for each image and six rating scores for each patient's image pairs. We used generalized estimating equation models (GEE) to account for patient-level correlated data to model these data and perform statistical inference. We estimated mean rating scores for RES, DET, and IQ in separate models. We tested for differences in the mean rating scores between the device types using Wald statistics. Hypothesis tests, p-values, and confidence intervals were two-sided. We stratified our analyses by image type: Spine (Sp), the transversus abdominis plane (TAP) and OB images. All analyses were performed with the Stata software package (version 16.1). Measures of inter-rater agreement were computed using the overall percent agreement and intra-rater kappa statistics. The kappa statistics are intra-rater because we computed agreement within rater for the two devices.

Results

A total of 74 image pairs were evaluated by three raters from each specialty: 29 for the Sp, 15 for the TAP, and 30 for OB, for a total of 148 images and 444 ratings for each the handheld and the mid-range US. One of the images

from the spine group was not saved to the mid-range device, hence we were unable to compare it (Figure 2). Please see Table 1 for a summary of the mean ratings for Sp, TAP, and OB. Mean differences are with the mid-range US as our reference; positive mean differences indicate that the mid-range unit had a higher rating and negative mean differences indicate that the handheld device had a higher rating (Table 2).

Overall percent agreements were relatively high at 0.71 (0.05); 0.69 (0.05) and 0.67 (0.05) for image RES, DET and IQ. Kappa statistics for RES, DET and IQ were 0.12 (0.09) [95% CI=(-0.06, 0.30)]; 0.10 (0.09) [95% CI=(-0.07, 0.27)] and 0.19 (0.7) [95% CI=(0.04, 0.33)], respectively.

Spine

There were 174 rating scores for the spine images for each of the three imaging criteria. Overall, the mean differences in scores for the handheld device and mid-range unit favored the handheld device. Our analyses of the spine sonoanatomy showed a mean RES rating score of 6.6 (95% CI [6.2, 7.0]) for the handheld and a mean score of 6.0 (95% CI [5.5, 6.5]) for the mid-ranged US with a mean difference of -0.6 (95% CI [-1.1, -0.1],

Table 1. Mean ratings of the Sp, TAP and OB images. Ratings were on a ten-point Likert scale, where 1-3 was defined as “poor”, 4-7 was “good” and 8-10 was “very good” image scores.

	Mid-Range Ultrasound		Handheld Ultrasound	
	Mean	95% CI	Mean	95% CI
Spine (n = 174)				
Resolution	6.0	5.5 - 6.5	6.6	6.2 - 7.0
Detail	6.0	5.5 - 6.4	6.8	6.4 - 7.1
Quality	5.9	5.3 - 6.4	6.8	6.5 - 7.1
TAP (n = 90)				
Resolution	5.9	5.3 - 6.5	6.0	5.5 - 6.5
Detail	6.0	5.5 - 6.5	6.8	6.5 - 7.1
Quality	5.9	5.5 - 6.3	6.4	6.0 - 6.7
OB (n = 180)				
Resolution	8.4	8.2 - 8.6	6.7	6.3 - 7.1
Detail	8.6	8.4 - 8.8	7.0	6.6 - 7.4
Quality	8.2	7.9 - 8.4	7.1	6.7, 7.5

p = 0.017). The mean DET score for the handheld was 6.8 (95% CI [6.4, 7.1]), and a mean score for the mid-ranged US images was 6.0 (95% CI [5.5, 6.4]) with a mean difference of -0.8 (95% CI = [-1.2, -0.3], p = 0.001). For the spine total image quality scores, the mean rating score for the handheld device was 6.8 (95% CI [6.5, 7.1]) and 5.9 (95% CI [5.3, 6.4]) for the mid-range US, with a mean difference of -0.9 (95% CI [-1.3, -0.4], p = 0.001). For neuraxial imaging, the image characteristics of the handheld device may be preferable compared to the mid-ranged unit.

TAP

There were 90 rating scores for the TAP images for the imaging criteria. Ratings of image characteristics were much more mixed when looking at this image category. The mean RES scores were 6.0 (95% CI = [5.5, 6.5]) for the handheld device and 5.9 (95% CI = [5.3, 6.5]) for the mid-range unit. The difference was -0.1 (95% CI = [-1.1, -0.1]). The size of the mean difference is typical of what one might expect to observe if there was no true difference (p-values > 0.868). The mean DET scores for the TAP images were 6.8 (95% CI = [6.5, 7.1]) for the handheld and 6.0 (95% CI = [5.5, 6.5]) for the mid-range US. The difference in scores was -0.8 (95% CI = [-1.2, -0.5]), indicating the handheld scores were significantly higher (p < 0.001). For the TAP IQ scores, the mean rating for the handheld US was 6.4 (95% CI = [6.0, 6.7]) and 5.9 (95% CI = [5.5, 6.3]) for the mid-range. The difference was -0.4 (95% CI = [-0.9, 0.04]), with a non-statistically significant comparison (p = 0.072). For TAP imaging, there does not seem to be one device that is consistently rated as having better image characteristics.

OB

There were 180 rating scores for the OB images each of the three imaging criteria. Unlike the last two image groups, there seemed to be a preference for the mid-range US in these images. The mean RES scores were 6.7 (95% CI = [6.3, 7.1]) for the handheld US and a mean score of 8.4 (95% CI = [8.2, 8.6]) for the mid-range device and a difference of 1.7 (95% CI = [1.2, 2.1], p < 0.001). The mean DET score for the handheld was 7.0 (95% CI = [6.6, 7.4]) and a mean score for the mid-range US images was 8.6 (95% CI = [8.4, 8.8]), with a mean difference of 1.6 (95% CI = [1.2, 2.0], p < 0.001). For the OB IQ scores, the mean rating score for the handheld device was 7.1 (95% CI = [6.7, 7.5]), while the mean score for the mid-range machine was 8.2 (95% CI = [7.9, 8.4]) for a mean difference of 1.1 (95% CI = [0.7, 1.5], p < 0.001).

Discussion

Our study was geared towards the assessment and functionality of a handheld ultrasound device that could be shared amongst both obstetricians and anesthesiologists in a dynamic labor and delivery floor. The main outcome of this study was to compare the image characteristics of these devices, focusing on image RES, DET and IQ.

The obstetric providers preferred the mid-range machine over the handheld device. The results for the handheld device mostly on the high spectrum of a “good image” (4-7 score) while the mid-range unit scored on the “very good image” (8-10) range. That is, the obstetric images for both devices were rated mainly between the 7-8.6, which accounts for good and very good images. Overall

Table 2. Mean differences of the Sp, TAP and OB images. Mean differences are with the SU as our reference; positive mean differences indicate that the SU had a higher rating and negative mean differences indicate that the BU had a higher rating.

Mid-Range vs. Handheld Ultrasound Mean Difference			
	Spine (n = 174)	TAP (n = 90)	OB (n = 180)
Resolution	-0.6 95% CI = (-1.1, -0.1) p = 0.017	-0.1 95% CI = (-1.1, -0.1) p > 0.868	1.7 95% CI (1.2, 2.1) p < 0.001
Detail	-0.8 95% CI = (-1.2, -0.3) p = 0.001	-0.8 95% CI = (-1.2, -0.5) p < 0.001	1.6 95% CI = (1.2, 2.0) p < 0.001
Quality	-0.9 95% CI = (-1.3, -0.4) p = 0.001	-0.4 95% CI = (-0.9, 0.04) p = 0.072	1.1 95% CI = (0.7, 1.5) p < 0.001

percentage agreement and Kappa statistics show good agreement between and amongst raters. When evaluating the anesthesia-related imaging, our study showed that the handheld device provided better RES, DET, and IQ when evaluating neuraxial or Sp imaging than the mid-range device. Similarly, when comparing the TAP block images, there was a tendency towards better RES, DET and IQ from the handheld device. Yet, the only one that achieved statistical significance was the detail of the image.

There are several plausible explanations as to why there was a difference in the rating scores of the obstetricians and anesthesiologists. One may have to do with the ultrasound technology used in each of the respective ultrasounds. As described earlier, traditional US technology, as in the mid-range US, depends on ultrasound waves emitted from piezoelectric crystals, while new technology in the handheld device utilizes CMUTs for this purpose [8,9]. There may be a difference in how these technologies produce images on different wave-structure interfaces (e.g., bone, soft tissue, or fascial planes). Additionally, obstetricians, more than anesthesiologists, are trained by evaluating images from high end consoles and are therefore conditioned to notice even small differences in image quality. Despite the differences, all evaluators agreed that the images from both devices were good, and sufficient for performing routine bedside scans in the maternity ward. The small difference in scores should be accounted for when considering the 20 times price difference between devices (\$2,000 vs. \$40,000). The addition of handheld devices at our institution has increased the availability of

ultrasound from 2 to 6 devices with a moderate investment.

Increased availability of a handheld device may improve both faculty and trainees' scanning skills. Ultrasonography skill acquisition and retention require practice and constant feedback given that imaging is very operator dependent [3,6]. Some authors have proposed that the number of examinations and competence may not be linearly correlated [6]. Both the obstetric and anesthesiology literature coincides with the need for more hands-on US time and curriculum that address its use and correct interpretation [6,10,11]. For programs to be able to provide such a curriculum, more ultrasound devices are needed in the hands of trainees with live feedback readily relayed. Independent of the technology utilized, the image should be reliable, and the US should be affordable and portable. A handheld device improves the availability to quickly deploy resources to the needed location without carrying cumbersome heavy equipment that requires draping or disinfection after each patient use. In our study, the handheld US weighs in at 0.69 lbs vs. 6.7 lbs for our mid-range unit— not including traveling cart. Smaller size may especially be of use when evaluating parturients outside of the labor and delivery floor as well, such as in the emergency department or perioperative areas for fetal heart rate.

At our institution, the increased availability of US devices has improved the hands-on experience for trainees and increased the frequency at which ultrasound is used. Although not evaluated in our study, the increased availability and trainee's ability to share de-identified images via encrypted emails, increases the amount of

images available for review and improves the feedback they receive. The ability of providers to remotely review an image could not only help to facilitate and expedite care for their patients, but also to increase *ad hoc* teaching opportunities.

One of this study's strengths is the number of images reviewed by three graders from each specialty. Additionally, we compared the capabilities of the handheld Butterfly iQ vs. our current mid-ranged US by testing both the linear and curvilinear presets. We considered this an important addition since most obstetric anesthesiology divisions with financial restrictions would use labor and delivery resources. In general, this means that anesthesiologists would have access to a curvilinear probe, but not a linear probe. Linear probes are essential for anesthesiologists to perform US-guided intravenous, arterial insertions, central line insertions, and transversus abdominis plane (TAP) blocks. There is evidence that the use of liposomal bupivacaine for TAP block for post-caesarean pain may improve patient satisfaction and overall narcotic consumption and having an accessible linear probe for providing this procedure seemed prudent [12-14]. Another advantage of our study is that we did not rely on volunteers; rather, we recruited patients with various body mass indexes.

One of our study's limitations was that the handheld US images' acquisition was directly acquired from the Butterfly network cloud, whereas the imaging from our current US was extracted from the machine hard drive and then imported into a PowerPoint presentation. The latter could have resulted in the degradation of images during the transfer as described by Blaivas et al. [15]. Since the images from the handheld device were already in a digital format, they may have been affected the least by the transfer.

Conclusions

When comparing ultrasounds on image characteristics alone, the handheld US was rated lower when used for obstetrical purposes. However, RES, DET and IQ of the handheld device was still rated as being "good". The ideal ultrasound in the inpatient setting should be affordable and portable while maintaining comparable image quality to high-end ultrasound machines [15,16]. Secondary to advancements in technology, both the cost and portability (size) of US machines have been reduced over the last decade. A handheld ultrasound may be considered as a potential low-cost alternative to a more expensive ultrasound machine for point of care ultrasonography, better suited to anesthetic vs. diagnostic obstetrical indications.

Statement of Ethics Approval: The protocol was approved by the Yale University Institutional Review Board (IRB) and registered on ClinicalTrials.gov (ClinicalTrials.gov Identifier: NCT03764111).

Disclosures

None.

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E-Point Septal Separation Accuracy for the Diagnosis of Mild and Severe Reduced Ejection Fraction in Emergency Department Patients

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Abstract

Introduction: In the Emergency Department (ED), a thorough cardiovascular evaluation cannot be accomplished only with physical examination. E-Point Septal Separation (EPSS) measure through Point-of-Care Ultrasound (POCUS) has been used to evaluate systolic function in echocardiography. We analyzed EPSS for diagnosis of Left Ventricle Ejection Fraction $<50\%$ and $\leq 40\%$ in ED patients. **Methods:** Retrospective analysis of a convenience sample of patients presenting to ED with chest pain or dyspnea who underwent admission POCUS evaluation by Internal Medicine Specialist unaware of Transthoracic Echocardiogram. Accuracy was assessed with sensitivity, specificity, likelihood ratios (LR) and Receiver operating characteristics (ROC) curve. The best cut off point was calculated using Youden Index. **Results:** Ninety-six patients were included. Median EPSS and LVEF were 10mm and 41% respectively. Area Under the ROC Curve (AUC-ROC) to diagnose a LVEF $<50\%$ was 0.90 (IC95% 0.84-0.97). Youden Index was 0.71 with cut off point EPSS at 9.5mm, performing with a sensitivity of 0.80, a specificity of 0.91, a positive LR of 9.8 and a negative LR of 0.2. AUC-ROC to diagnose a LVEF $\leq 40\%$ was 0.91 (IC95% 0.85-0.97). Youden Index was 0.71 with a cut off point EPSS at 9.5mm, performing with a sensitivity of 0.91 and specificity of 0.80, a positive LR of 4.7 and a negative LR of 0.1. **Conclusion:** EPSS can reliably diagnose reduced LVEF in a set of ED patients with cardiovascular symptoms. A cut off point at 9.5 mm has good sensitivity, specificity and Likelihood ratios.

Introduction

Chest pain, dyspnea and syncope are among the most common reasons to seek care in the Emergency Department (ED). Chest pain accounts for more than a thousand visits per year [1], dyspnea and syncope represent approximately 7 to 8% of ED consults [2,3]. At this moment, a thorough cardiovascular evaluation cannot be accomplished only with physical examination. Valvular disease and systolic dysfunction diagnosis improve when evaluated with a physical exam along with cardiac ultrasound [4].

For the past decade, Point-Of-Care-Ultrasound (POCUS) has become a widely available tool to evaluate ED patients and discriminate high-risk diagnosis and initiate appropriate treatment [5]. One of the most sensitive evaluations is cardiac function, specifically the assessment of systolic function. For a complete cardiovascular evaluation, it is important to establish Left Ventricular Ejection Fraction (LVEF), given that it represents prognosis, medical treatment and eventually invasive interventions according to clinical presentation. LVEF of less than 40% represent reduced systolic dysfunction, thus poorer outcomes and worse prognosis, with the need of specific medications such as mineralocorticoid receptor antagonists (MRA), Angiotensin Receptor Neprilysin Receptor Inhibitor

(ARNI) among others [6]. Recently, LVEF of less than 50% has been defined as a mildly reduced ejection fraction, becoming an issue to evaluate in cardiovascular patients in the Emergency Department [7].

E-Point Septal Separation (EPSS) measure has been used to evaluate systolic function in echocardiography [8]. The strong correlation of EPSS and LVEF has been assessed with adequate results. Its limitations are known and include mitral stenosis, hypertrophic cardiomyopathy, and aortic regurgitation. There are studies evaluating the accuracy of EPSS to predict a LVEF $<30\%$ in dyspneic patients and $<50\%$ in perioperative elective patients [9,10], but there is scarce information about accuracy of EPSS for the diagnosis of LVEF less than 50% and 40% in ED patients consulting for cardiovascular symptoms.

We analyzed ED patients presenting with chest pain and dyspnea who received a formal transthoracic echocardiogram (TTE) and POCUS at admission. This study aimed to evaluate the diagnostic accuracy of EPSS to predict reduced (LVEF $\leq 40\%$) and mildly reduced Ejection Fraction (LVEF $< 50\%$).

Methods

This is a retrospective study including Emergency Room patients older than 18 years with cardiovascular symptoms in a Tertiary University-based Hospital which

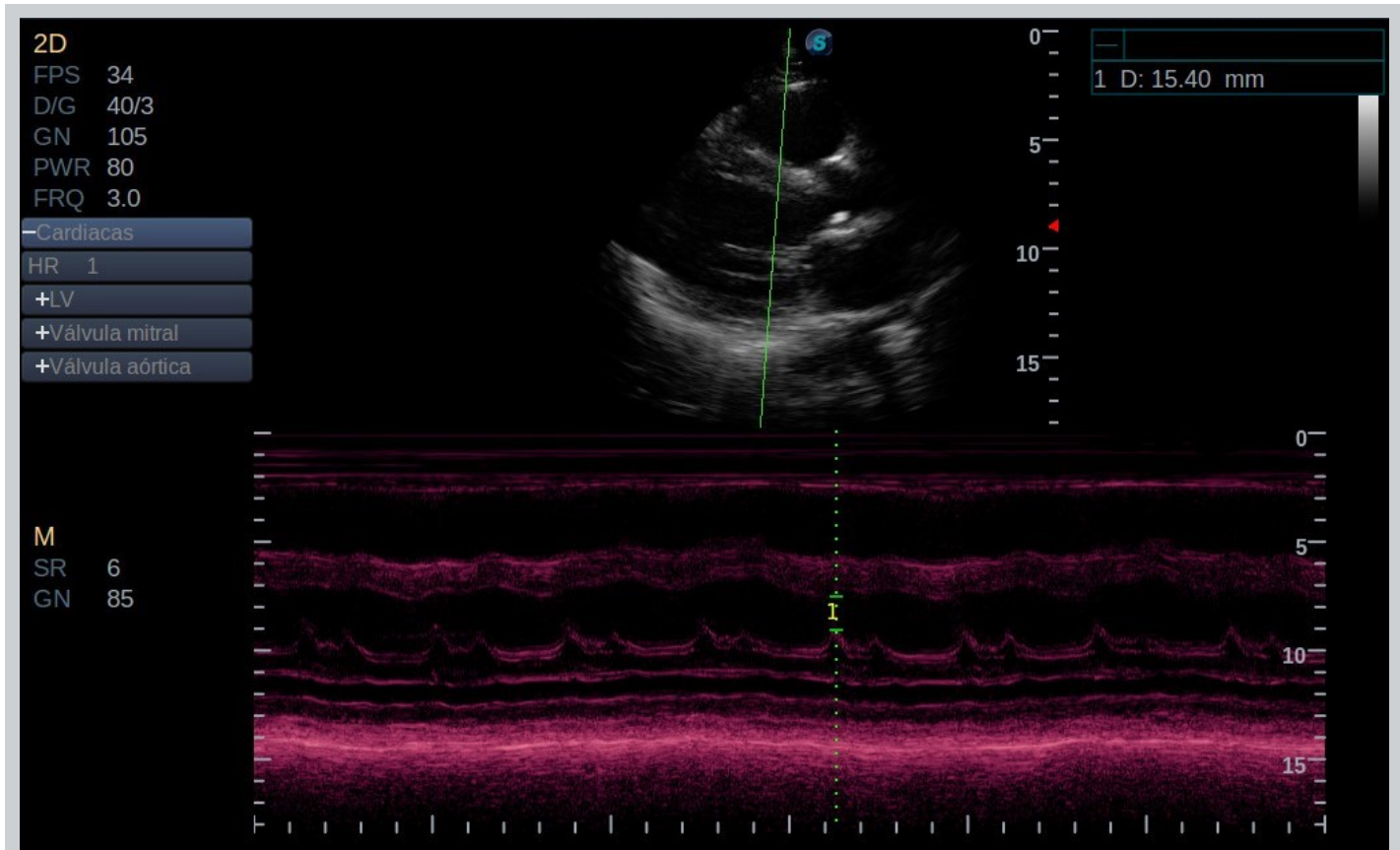


Figure 1. E-Point Septal Separation Measure. The E-Point Septal Separation measure was taken in early diastole, using Parasternal Long Axis View (PLAX) M-Mode, between the tip of the anterior mitral valve leaflet and the interventricular septum.

receives approximately 70.000 emergency visits per year. The Ethics Committee and Institutional Board approved this protocol (Act 244 July 2021).

Patients with chest pain or dyspnea as chief complaint and consulting our Emergency Room from July 2019 to March 2021 were identified through chart review. Those who received POCUS evaluation at admission and a transthoracic echocardiogram during the hospitalization were eligible. Patients with shock or hypotensive at admission were excluded, as well as patients in cardiac arrest at admission or those who received inotropes and/or vasopressors.

POCUS evaluation was performed at admission by the attending Internist as part of usual care. The equipment used was a Sonoscape S2 Ultrasound Machine with a 2.5MHz Phased Array (Sonoscape Corp. Guangdong, China. 2016-3). The E-Point Septal Separation measure was taken in early diastole, using Parasternal Long Axis View (PLAX) M-Mode, between the tip of the anterior mitral valve leaflet and the interventricular septum (Figure 1).

Only one ED Internist with formal POCUS training and 3 years of experience performed ultrasound evaluations. The Internal Medicine (IM) specialist was the treating

clinician of this group of patients during their stay in the ED. At admission, IM clinician was aware of chief complaint (chest pain, dyspnea) and the clinical background of patients (Heart Failure, Hypertension, Acute Coronary Syndrome) but was unaware of previous LVEF.

Transthoracic echocardiogram was performed by a cardiologist with a subspecialty in echocardiography and more than 10 years of experience. LVEF was calculated through Simpson Biplane formula. Given the patient flow in our hospital, IM Clinician performed POCUS evaluation before TTE, therefore Cardiologist and IM POCUS performing were unaware of each other evaluation.

Main outcome was diagnostic accuracy of EPSS for LVEF in a formal echocardiogram performed by an experienced Cardiologist. We evaluated sensitivity, specificity, likelihood ratios and we performed a receiver operating characteristics curve to establish the best cut off point for a LVEF $\leq 40\%$ and $< 50\%$.

Statistical analysis

All clinical characteristics were collected from electronic records. Qualitative variables were analyzed using frequencies and percentages. Quantitative variables were

Table 1. Basal Characteristics.

	n=96
Demographics and Medical History	
Age	61 (52-76)
Male	59 (61,5)
Hypertension	58 (60,4)
Type 2 Diabetes	23 (24)
Heart Failure	16 (16,7)
Acute Coronary Syndrome	12 (12,5)
Admission Diagnosis	
Acute Coronary Syndrome	24 (25)
Acute Decompensated Heart Failure	60 (62,5)
COVID-19 Pneumonia	9 (9,5)
Others (Pleural Effusion and Pulmonary Embolism)	3 (3)
Clinical Variables	
Systolic Blood Pressure	140 (119-167)
Median Blood Pressure	99 (88-122)
Heart Rate	94 (78-110)
Pulse Oximetry	97 (92-98)
Creatinine	1,2 (1-2)
B-Type Natriuretic Peptide	1076 (98-2550)
Positive Troponin I	43 (44,8)
Normal EKG	45 (46,9)
ST Segment Elevation / Depression	17 (17,7)
*Categorical variables are expressed in absolute frequency and (%) percentages. Quantitative variables are expressed in median (interquartile ranges).	

reported as median with interquartile ranges due to non-parametric distribution. EPSS measurements were reported as a continuous variable in millimeters. Diagnostic accuracy was evaluated with sensitivity, specificity, likelihood ratios and Youden Index (YI). Receiver operating characteristics (ROC) curves were obtained for the prediction of an Ejection Fraction (EF) $\leq 40\%$ and $< 50\%$. The best cut off point was calculated through the YI. All analyses were performed using SPSS Software Version 25.

Results

A total of 96 patients were included in the analysis. Basal characteristics are shown in Table 1. Median age was 61

Table 2. POCUS and Transthoracic Echocardiogram Findings.

	n=96
POCUS	
EPSS measure (mm)	10 (6-17)
Qualitative Depressed Systolic Function	43 (44,8)
Dilated Right Cavities	9 (9,4)
Pericardial Effusion	15 (15,6)
B lines	72 (75)
Transthoracic Echocardiogram	
LVEF (%)	41 (27-56)
EF $< 50\%$	59 (61,5)
EF $\leq 40\%$	44 (45,8)
Time to TTE	5,5 (2-24)
*Categorical variables are expressed in absolute frequency and (%) percentages. Quantitative variables are expressed in median (interquartile ranges).	

years, most patients (61.5%) were male. The most common comorbid condition was hypertension (60.4%) followed by type 2 diabetes mellitus (24%). The main chief complaint at admission was dyspnea and chest pain (96%). A total of 24 (25%) patients had Acute Coronary Syndrome as admission diagnosis and 62.5% were diagnosed with acute decompensated heart failure. The 51.2% of individuals had myocardial injury (positive troponin I test). Among all patients included, 46.9% had a normal ECG, 5.2% ST-segment elevation, 12.5% ST-segment depression, 5.2% atrial fibrillation and 14.6% any bundle-branch block.

The median for EPSS and LVEF was 10 mm and 41% respectively. The prevalence of reduced systolic function (LVEF $\leq 40\%$) was 45.8% and prevalence for mildly reduced ejection fraction (LVEF $< 50\%$) was 61.5%. The median time between POCUS evaluation and TTE was 5.5 hours (Interquartile range 2 - 24 hours). Table 2 presents ultrasound findings for POCUS and TTE.

The Area Under the Curve (AUC) of the ROC Curve (AUC-ROC) for EPSS to diagnose a LVEF $< 50\%$ was 0.90 (IC95% 0.84-0.97). The highest Youden Index was 0.71 with a cut off point EPSS at 9.5 mm, performing with a sensitivity of 0.80, a specificity of 0.91, a positive LR of 9.8 and a negative LR of 0.2. (Figure 2)

The Area Under the Curve (AUC) of the ROC Curve (AUC-ROC) for EPSS to diagnose a LVEF $\leq 40\%$

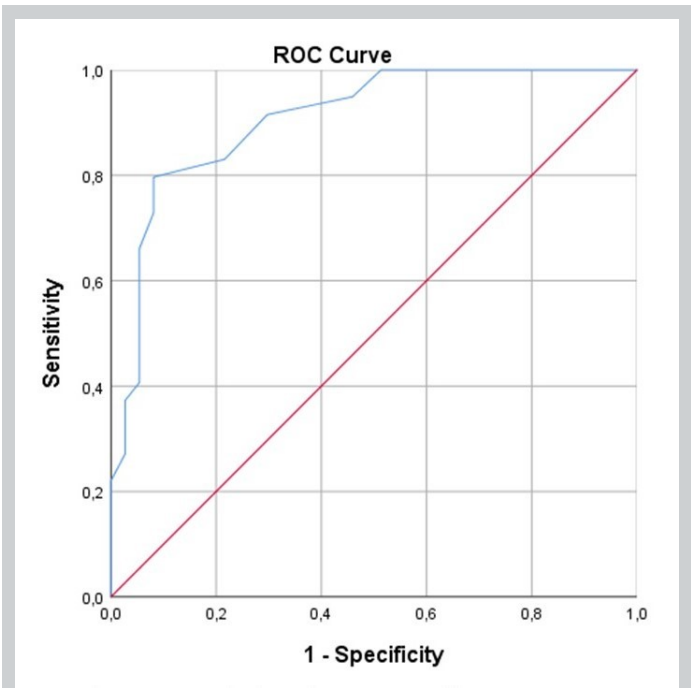


Figure 2. ROC Curve of EPSS for diagnosis of LVEF <50%. ROC Curve showing the Area Under the Curve calculated 0.90 (IC95% 0.84-0.97) for EPSS to diagnose LVEF <50%.

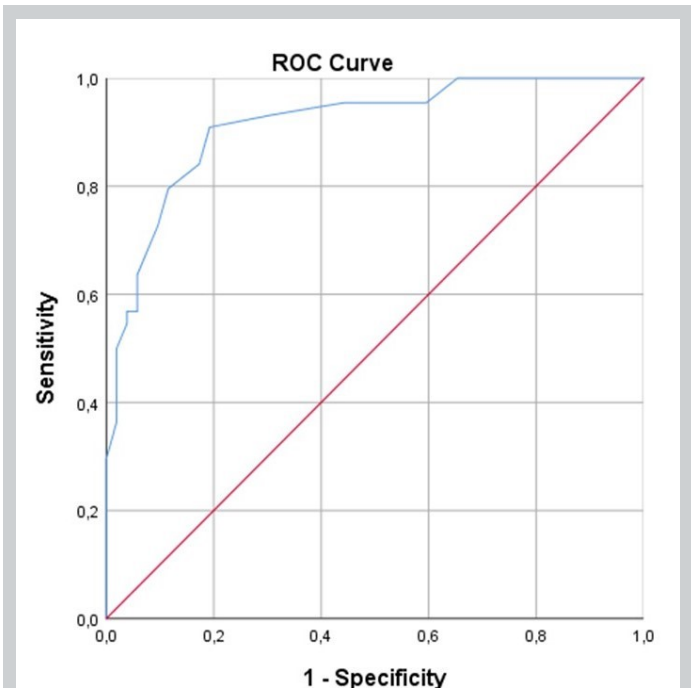


Figure 3. ROC Curve of EPSS for diagnosis of LVEF ≤40%. ROC Curve showing the Area Under the Curve calculated 0.91 (IC95% 0.85-0.97) for EPSS to diagnose LVEF ≤40%.

was 0.91 (IC95% 0.85-0.97). The highest Youden Index was 0.71 with a cut off point EPSS at 9.5mm, performing with a sensitivity of 0.91 and specificity of 0.80, a positive LR of 4.7 and a negative LR of 0.1 (Figure 3).

In Table 3 and 4 are displayed the different EPSS measures with each sensitivity, specificity, Likelihood Ratios and Youden Index.

Discussion

In this retrospective diagnostic study, we found a good accuracy of E-Point Septal Separation for the diagnosis of mildly reduced and reduced ejection fraction with Echocardiography in patients with cardiovascular symptoms in the Emergency Department.

A cut off point of 9.5 mm allowed sensitivities of 80% and 91% for mildly reduced EF and reduced EF respectively, along with specificities of 91% and 80% for mildly reduced and reduced EF. Positive likelihood Ratios were 9.8 for mildly reduced EF and 4.7 for reduced EF.

There are several studies analyzing the accuracy of EPSS for left ventricle dysfunction according to LVEF. McKaigney et al [10] published in 2014 a prospective study with unselected ambulatory patients with any indication for TTE. This study used a LVEF classification according that moment, and Teichholz Method for LVEF calculation. The cut-off point used was 7 mm with a sensitivity of 100% and specificity of 51% for ≤ 30%

LVEF. Our study chose emergency room patients with specific cardiovascular complaints, thus selecting a punctual population very common in emergency rooms. Additionally, we used the most recent LVEF classification and Simpson's Biplane formula for calculating LVEF, which is the recommended method in guidelines [11]. Another study in 2021 evaluated elective preoperative patients [9]. A low prevalence (22%) of LVEF <50% was found. EPSS cut off point was 6mm with an AUC-ROC 0.89, sensitivity 86% and specificity 88%. This population is in many ways different from ours, including the low prevalence of left ventricle dysfunction and the use of a different cut off point for the analysis. There is a registered systematic review in PROSPERO database, which is an ongoing review for the level of agreement between emergency physicians and expert echocardiographers, consequently there are no results yet and it is not aimed to evaluate diagnostic accuracy as it was in our study [12].

We found a similar proportion of patients having depressed left ventricle function in POCUS evaluation (44.8%) compared to TTE of LVEF <40% (45.8%) which could represent the consistency in ultrasound findings between POCUS and TTE formal evaluation. Youden Index and AUC-ROC for LVEF <50% and ≤40% were the same, this reflects the fact that differentiating these two types of patients could be challenging. The EF 40-50% “gray-zone” of mildly reduced EF represents patients in

Table 3. Diagnostic Accuracy of EPSS for LVEF<40%.

Cut off Point	Sensitivity	Specificity	Youden Index	Positive Likelihood Ratio	Negative Likelihood Ratio
4.5	1.000	0.346	0.346	1.529	0.000
5.5	0.955	0.404	0.358	1.601	0.113
6.5	0.955	0.481	0.435	1.838	0.095
7.5	0.955	0.558	0.512	2.158	0.082
8.5	0.932	0.692	0.624	3.028	0.098
9.5	0.909	0.808	0.717	4.727	0.113
10.5	0.841	0.827	0.668	4.859	0.192
11.5	0.795	0.885	0.680	6.894	0.231
12.5	0.727	0.904	0.631	7.564	0.302
13.5	0.636	0.942	0.579	11.030	0.386

Table 4. Diagnostic Accuracy of EPSS for $\leq 50\%$.

Cut off Point	Sensitivity	Specificity	Youden Index	Positive Likelihood Ratio	Negative Likelihood Ratio
4.5	1.000	0.486	0.486	1.947	0.000
5.5	0.949	0.541	0.490	2.066	0.094
6.5	0.932	0.622	0.554	2.464	0.109
7.5	0.915	0.703	0.618	3.079	0.121
8.5	0.831	0.784	0.614	3.841	0.216
9.5	0.797	0.919	0.716	9.825	0.221
10.5	0.729	0.919	0.648	8.989	0.295
11.5	0.661	0.946	0.607	12.229	0.358
12.5	0.593	0.946	0.539	10.975	0.430
13.5	0.492	0.946	0.437	9.093	0.538

an intermediate stage of HF sharing clinical characteristics of reduced and preserved EF patients [7]. We consider patients in the ED do not have specific need for identification mildly reduced or normal EF. In contrast, identifying patients with an EF <40% in the context of Acute Coronary Syndrome or new-onset Heart Failure is important to promote the rapid initiation of treatment and interventions. There are other methods to assess LVEF through POCUS as qualitative evaluation, which focuses on myocardial thickening and fractional shortening, based on calculating left ventricle end-diastole and end-systole diameter. These two methods have limitations such as subjective visual-based estimation for the first and complex formula with no direct correlation with LVEF for the second.

We actively excluded unstable patients requiring vasopressors or inotropes to control confounding on EF calculation after administering inotropes. In this one-center experience, the median time to TTE was 5.5 hours, which could represent the time one attending saves for the diagnosis and treatment initiation. The interquartile range between 2 hours and 24 hours (sometimes even 96 hours) gives an idea of the long time a patient must wait for a formal echocardiographic evaluation.

The insights of AUC-ROC allow us to consider an EPSS of less than 5.5 mm to rule-out an EF <50% and consequently EF <40% (Negative LR 0.09, Sensitivity 95%). On the other hand, an EPSS ≥ 13.5 confirms EF <40% (Positive LR 11, Specificity 95%) and an EPSS

≥11.5 confirms EF <50% (Positive LR 12, Specificity 95%).

Our limitations include a small sample size and the fact that only one ED Internist was capable of performing ultrasound evaluations due to lack of staff training; moreover one cardiologist did all transthoracic echocardiograms. This limitation could positively impact results considering there is no inter-observer variability. At the same time, the situation may reflect a lack of POCUS use among ED specialists. There is a need to promote and ensure access to Point-Of-Care Ultrasound training for healthcare professionals. This study was carried out in one center, thus reducing inference of its results. Our population had a higher prevalence of reduced EF than many other publications, so care must be taken in extrapolating results in other institutions.

Our study has several strengths. We analyzed an emergency room set of cardiovascular patients in need to be evaluated thoroughly to confirm or rule-out left ventricle dysfunction. Our patients would have taken a different treatment and diagnosis path if they would have had or not a depressed LVEF. Patients with dyspnea or chest pain and LVEF less than 40% have different prognosis and management, involving a different decision-making process. The blinding of health-care professionals performing ultrasound evaluations allowed an unbiased evaluation of the test and the gold-standard. All patients included in our analysis underwent POCUS and echocardiogram evaluations (test and gold-standard) as is the recommendation for diagnostic accuracy studies.

These results impulse the use of EPSS in ED patients, allowing ED Physicians and internists to perform POCUS evaluation with more certainty of establishing accurate Left Ventricle Function and making decisions more appropriate in each case. We also provide a table with cut off values and its sensitivities, specificities and likelihood ratios so every clinician could use the best cut off point according to low-probability or high-probability clinical scenario. EPSS measures should become the standard of care in focused cardiac assessment for patients with chest pain and dyspnea in the emergency room.

Conclusion

EPSS is a reliable tool to diagnose reduced LVEF in a set of ED patients with cardiovascular symptoms. A cut off point at 9.5mm has reasonable sensitivity and specificity to diagnose reduced LVEF.

Statement of ethics approval

At a meeting of the Research Ethics Committee in the

Health Area of the University del Norte, made on July 29, 2021, and legalized by act No. 244, the consensus of its members approve the research protocol and waved the informed consent considering this observational research.

Disclosures

None.

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Near Peer POCUS Education Evaluation

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Abstract

Objective: At Texas College of Osteopathic Medicine (TCOM), point of care ultrasound (POCUS) is taught to medical students in conjunction with trained medical student teaching assistants (TAs). The purpose of our study is to evaluate the effectiveness of near peer teaching in the setting of ultrasound education. We hypothesized that this would be the preferred learning technique among TCOM students and TAs. **Methods:** To evaluate our hypotheses about the value of near peer instruction, we created two comprehensive surveys for students to share their experiences with the ultrasound program. One survey was for general students and the other survey was for students designated as TAs. The surveys were sent via email to second and third-year medical students. **Results: General Student Population Survey Results:** Of the 63 students who took the survey, 90.4% agreed that ultrasound is an integral part of medical education, 79.4% of students either agreed or strongly agreed that ultrasound improves their understanding of systems-based course material, 53.9% of students prefer near peer techniques over other teaching methods, while only 38.7% of students would prefer faculty-led sessions. 73% of students agreed that their ultrasound skills have improved with peer-led sessions, 71.4% of students agreed that peer-led sessions have made them want to pursue additional ultrasound training, and 96.8% of students report that they are very likely or somewhat likely to use POCUS in their future practice. **Ultrasound Teaching Assistant Survey Results:** Nineteen TAs responded to the survey, of which 78.9% assisted with more than 4 teaching sessions, 84.2% attended more than 4 TA training sessions, 94.7% reported spending additional time practicing ultrasound outside of TA activities each week, 100% agreed or strongly agreed that being an ultrasound TA has helped their medical education, and 78.9% either agreed or strongly agreed that they feel competent in their ultrasound skills. Among TAs, 78.9% preferred near peer techniques over other teaching methods, 100% agreed or strongly agreed that being a TA has helped develop their ultrasound skills, and 100% were likely or very likely to use POCUS in their future practice. **Conclusions:** Based on the results of our surveys, we were able to conclude that near peer teaching is the preferred learning method among students at our institution, and TCOM students found ultrasound to be a beneficial adjunct to systems courses in medical school education.

Introduction

Point of care ultrasound (POCUS) is a diagnostic tool that is growing in both use and accessibility. Clinicians are no longer weighed down by a bulky machine when pocket ultrasound devices that connect to your phone or tablet are available. Due to its increased ease, POCUS is more widely applied across medical specialties. Some specialties require training in POCUS, and this training should begin in undergraduate medical education [4]. Several professional societies advocate for the addition of ultrasound into undergraduate medical coursework, including the American Academy of Emergency Medicine, among others [4,5]. Early exposure to ultrasound has many potential benefits, including improved understanding of anatomy, physiology, pathology, and the physical exam [6].

An increasing number of medical schools are incorporating ultrasound into their curricula [4]. At Texas College of Osteopathic Medicine (TCOM), students are exposed to ultrasound beginning in Year One. Training sessions are led primarily by Year Two students designated as ultrasound teaching assistants (TAs) via

the near peer teaching model. The purpose of our study is to look at the effectiveness of near peer teaching in the setting of POCUS education. Near peer teaching occurs when material is taught to students by their peers. This has been proven to be an effective teaching technique in other settings and its utility in ultrasound continues to be explored [1,2,3]. With each new class, POCUS education at TCOM has grown both in exposure time and clinical application. Ultrasound is implemented in the first year as part of the physical exam course and in the second year as part of the simulation lab course, both to correlate with the anatomy and physiology course material. To help facilitate this learning, POCUS TAs were introduced in 2019. The program was born out of necessity, as there was a limited number of POCUS-trained faculty available. Initially, sessions were taught by one faculty member using one POCUS device to large groups of students at a time. After recognizing that students had very little hands-on training with this teaching technique, near peer training was discussed. This allowed for smaller group sessions, even with few POCUS-trained faculty. This is a common problem faced by institutions when adding POCUS to the curriculum [6]. In a recent survey of

medical schools with ultrasound programs, 68.4% had 10 or fewer faculty involved with ultrasound, and most participated as volunteers [4].

At TCOM, the TA program started with about 10 students from the class of 2022 who volunteered to help with student instruction. As more POCUS was added to the curriculum, student interest also grew. At the time of our project, the program had close to 30 TAs who were responsible for about 4 hours of instruction per week. After a year of implementation, curriculum staff decided to evaluate the efficacy of POCUS TAs and how near peer teaching may benefit both student teachers and learners.

Methods

Teaching assistants are second-year TCOM students who volunteered to lead the instruction of their peers. For the class of 2022 and 2023, TAs were selected informally and trained through both online modules (Sonosim™, Santa Monica, CA) and additional teaching sessions. The TAs then lead small group POCUS instruction during the physical exam or simulation courses under the supervision of POCUS faculty. Teaching assistants were responsible for approximately four hours of simulation lab teaching time each week. Prior to each new POCUS topic, students participated in a one-hour training session with faculty. Additional training time was not required but encouraged. While the TAs completed the majority of instruction, some students were occasionally placed in small groups led by faculty.

There was no risk associated with participating and students were consented to being part of the study prior to filling out the survey. To evaluate the effectiveness of TAs, TCOM students were surveyed on their experiences with the near peer teaching technique. At the time the survey was sent, both classes had experienced at least one year of near peer education. The class of 2022 was participating in clinical rotations and the class of 2023 was starting their second year of near peer teaching. Students were sent a survey that was fourteen questions in length. They were presented with a variety of phrases about their POCUS training and asked to rank their agreement with each phrase. The available options were strongly disagree, disagree, neutral, agree and strongly agree, or not likely, somewhat likely and very likely. Students who were identified as POCUS TAs were asked to complete a separate survey, in which they were asked about their experiences as both teachers and learners. The TA survey utilized a similar format previously mentioned and was fifteen questions in length. The surveys were limited to one response per student. Data from both surveys was collected and stored anonymously using an electronic survey system (Qualtrics™, Seattle, WA). This project was reviewed and approved through the North Texas Regional Institutional Review Board.

Results

For the general student population of approximately four-hundred students, sixty-three students respond to the survey, for a response rate of about 15.75%. We learned that 90.4% of these students either agreed or strongly agreed that POCUS is an integral part of medical education, and 79.4% of the students either agreed or strongly agreed that POCUS improves their understanding of systems-based course material. When looking at near peer preference versus other teaching methods, we found that 53.9% of the students prefer near peer techniques, while only 38.7% of the students would prefer faculty-led sessions. In terms of the effectiveness of this teaching style, 73% of the students agreed that their POCUS skills have improved with peer-led sessions. Finally, when assessing the lasting impact of POCUS education, 71.4% of the students agreed that peer-led sessions have made them want to pursue additional POCUS training, and 96.8% of the students reported that they are very likely or somewhat likely to POCUS in their future practice (Table 1).

Among the TA group of forty-one students, nineteen students responded to the survey, for a response rate of 46.3%. Of the respondents, 78.9% had assisted with more than four teaching sessions, 84.2% attended more than four TA training sessions, and 94.7% of students also reported spending additional time practicing POCUS outside of TA activities each week. When looking at how being an POCUS TA impacted the students, we found that 100% of them either agreed or strongly agreed that being a TA has helped their medical education. Of the TAs, 78.9% either agreed or strongly agreed that they feel competent in their POCUS skills. When comparing different education methods, 78.9% of the TAs prefer near peer techniques over other teaching methods. Ultimately, we can conclude that being an POCUS TA had a large impact on the students, where 100% of TAs agreed or strongly agreed that being a TA has helped develop their POCUS skills and 100% of TAs are likely or very likely to use point of care POCUS in their future practice (Table 2).

Discussion

There are many potential benefits to the integration of POCUS into undergraduate medical education [6]. As reflected in our survey results, medical students feel that POCUS enhances their learning of traditional systems-based courses. When looking at how ultrasound is taught to medical students, there is a wide range of methods and approaches [4,6]. Based on our data, we propose that near peer instruction is a valuable method to teach POCUS for several reasons. First, when taught by their peers, students succeed in learning POCUS. 73% of our students agreed that their skills have improved through

Table 1. General Student Responses to the Near Peer Ultrasound Evaluation Survey.

General Student Population					
Survey Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Ultrasound training has improved my understanding for system based courses.	0%	4.8%	15.9%	23.8%	55.6%
Ultrasound training is an integral part of medical education.	0%	3.2%	6.3%	33.3%	57.1%
I prefer near peer teaching techniques over other teaching techniques.	1.6%	12.7%	31.7%	28.6%	25.4%
I effectively learn during ultrasound peer taught sessions.	1.6%	9.5%	25.4%	44.4%	19.0%
I believe the ultrasound TAs are effective teachers and I have confidence in their skills.	1.6%	9.5%	23.8%	44.4%	20.6%
I would prefer faculty solely taught ultrasound skills.	4.8%	24.2%	32.3%	25.8%	12.9%
I feel my ultrasound skills have improved with near peer ultrasound training.	0%	6.3%	20.8%	49.2%	23.8%
I feel competent in my point of care ultrasound skills.	7.9%	22.2%	31.7%	25.4%	12.7%
Near peer ultrasound training has made me want to pursue more ultrasound training.	1.6%	6.3%	20.6%	44.4%	27.0%
Survey Question	Not likely	Somewhat likely		Very Likely	
How likely are you to pursue a residency with an ultrasound emphasis?	19.4%	53.2%		27.4%	
How likely are you to use point of care ultrasound in your future?	3.2%	57.1%		39.7%	

peer-led sessions. Teaching assistants improve their skills, as well; 78.9% of them agreed or strongly agreed that they are competent in POCUS. This success may be due, in part, to the fact that students explain concepts at a level that their peers can easily understand, as discussed in Naeger et al [2]. Not only is near peer teaching effective, but students enjoy being taught by their classmates. We have found that a larger number of student respondents prefer peer-led POCUS sessions compared to other, more traditional teaching methods. Reasons for this may include better relationships with their colleagues and the low-stress environment of being taught by other students [6]. Learners may feel more inclined to ask questions or participate when being instructed by someone who is academically their equal [2]. Not only do these factors make the experience more enjoyable, but more conducive to learning. Our results also suggest that near peer instruction helps foster an interest in POCUS amongst students, where 96.8% of the students indicate that they are somewhat or very likely to

use POCUS in their future practice. As mentioned previously, students may be more apt to participate in hands-on learning in front of their peers, which could lead to a more positive experience overall with POCUS.

Lastly, we believe that students who participate in our program as TAs have an even greater learning experience. 100% of them agreed or strongly agreed that being a TA has helped improve their POCUS abilities. Not only do they participate in POCUS as a learner, but they have the opportunity to develop their teaching skills, which will inevitably be used throughout their careers in medicine [6]. In previous studies on peer-led teaching, student teachers reported improvements in their clinical, communication, and teaching skills [3].

This study had several limitations, including the low response rate for the general student population and the fact that it was conducted at a single site. With a response rate of only 15.75%, there is the possibility of selection bias, as only the students with strong opinions

Table 2. Teaching Assistant Responses to the Near Peer Ultrasound Evaluation Survey.

Teaching Assistant Population Survey					
Survey Question	Class of 2022		Class of 2023		
Select your current year of training.	21.1%		78.9%		
Survey Question	1	2	3	4	More than 4
How many 2-hour simulation lab sessions have you helped with?	0%	5.3%	5.3%	10.5%	78.9%
How many practice sessions have you attended?	0%	5.3%	5.3%	5.3%	84.2%
Survey Question	0 hours	Up to 1 hour	1-2 Hours	3 or more hours	
On average, how much additional time weekly do you spend practicing ultrasound outside of TA activities?	5.3%	57.9%	36.8%	0%	
Survey Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Being an ultrasound TA has helped with my medical education.	0%	0%	0%	5.3%	94.7%
Being an ultrasound TA has hindered my medical education.	0%	0%	0%	26.3%	73.7%
I feel competent in my point of care ultrasound skills.	0%	5.3%	15.8%	52.6%	26.3%
I would recommend others to be an ultrasound TA.	0%	0%	0%	21.1%	78.9%
I prefer near peer teaching techniques over other techniques.	0%	0%	21.2%	47.4%	31.6%
Ultrasound TA training sessions prepare me to teach other students.	0%	0%	0%	42.1%	57.9%
Being an ultrasound TA has helped to develop my teaching skills overall.	0%	0%	0%	21.1%	78.9%
Survey Question	Not Likely	Somewhat Likely		Very Likely	
How likely are you to pursue a residency with an ultrasound emphasis?	5.3%	52.6%		42.1%	
How likely are you to use point of care ultrasound in your future practice?	0%	26.3%		73.7%	
How likely are you to pursue a career in which teaching is part of your clinical responsibilities?	5.3%	42.1%		52.6%	

on POCUS may have responded to the survey. There is a similar risk of bias with the TAs. Since TAs are volunteers, many of them had significant interest in POCUS beforehand and thus their positive survey results may reflect that. Other considerations include the challenge of standardizing TA skills. Despite training sessions, we recognize that there may be discrepancies in TA ability, which may impact the student experience. This issue was highlighted in Smith et al, in which some of the student teachers had varying levels of preparedness and confidence [3]. Furthermore, many of our survey questions were subjective. For example, we did not formally assess whether students improved with near peer instruction. Lastly, there may be variations in the amount of exposure to other, different teaching modalities. While the class of 2023 has experienced other teaching techniques throughout their time at TCOM, they only briefly were exposed to purely faculty-led POCUS instruction. This is because the TA program was already established by the time they entered medical school. Strengths to the study include the anonymity of the surveys, as it allowed for students to share their thoughts without concern for repercussions. Similarly, the surveys were easily accessible via email and could be completed on any device. We must also consider that the positive response to the near peer model may be a reflection of the TCOM student population. A large portion of students at TCOM tend to be driven towards specialties such as primary care, internal medicine, and emergency medicine, where POCUS is of growing interest.

The results of our surveys not only have implications for medical education, but for clinical medicine, as well. Many of TCOM's students plan to train and practice in rural or underserved areas. The skills they have learned through our POCUS program will help them bring POCUS to their communities and beyond. With added teaching experience, our TAs are prepared to instruct fellow physicians, advanced practice providers, and other members of their community in POCUS. This demonstrates how the near peer model of teaching is incredibly sustainable. As students gain more experience, they themselves become teachers and can disseminate information and skills to others.

Moving forward, the POCUS leadership has developed an evaluation process to standardize TA skills and further standardize the POCUS experience at TCOM. When discussing standardization, a question that was presented was how to quantify and qualify POCUS as a learned skill. Currently in the development and trial phase is a credentialing program to train and test third and fourth-year medical students on their POCUS abilities. Teaching assistants will be an integral part of this program, as students, providers, and other community

members earn certifications in POCUS. We also hope this program will provide another opportunity to learn about how POCUS can best be integrated into medical education

Conclusion and Future Directions

Our study has shown that it is possible to develop and implement a near peer POCUS curriculum that is well received and beneficial for students. To further expand this study, it would be valuable to survey how other medical schools have implemented POCUS education and how it was received. Future directions also include obtaining feedback on TA abilities from practicing physicians.

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Disclosures

None.

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Can Medical Students Learn and Perform POCUS in the Pediatric Emergency Department? Implementation of a Short Curriculum

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Abstract

Purpose: To determine medical student ability to accurately obtain and interpret POCUS exams of varying difficulty in the pediatric population after a short didactic and hands-on POCUS course. **Methods:** Five medical students were trained in four POCUS applications (bladder volume, long bone for fracture, limited cardiac for left ventricular function, & inferior vena cava collapsibility) and enrolled pediatric ED patients. Ultrasound-fellowship-trained emergency medicine physicians reviewed each scan for image quality and interpretation accuracy using the American College of Emergency Physicians' quality assessment scale. We report acceptable scan frequency and medical student vs. Ultrasound-fellowship-trained emergency medicine physician interpretation agreement with 95% confidence intervals (CI). **Results:** Ultrasound-fellowship-trained emergency medicine physicians graded 51/53 bladder volume scans as acceptable (96.2%; 95% CI 87.3-99.0%) and agreed with 50/53 bladder volume calculations (94.3%; 95% CI 88.1-100%). Ultrasound-fellowship-trained emergency medicine physicians graded 35/37 long bone scans as acceptable (94.6%; 95% CI 82.3-98.5%) and agreed with 32/37 medical student long bone scan interpretations (86.5%; 95% CI 72.0-94.1%). Ultrasound-fellowship-trained emergency medicine physicians graded 116/120 cardiac scans as acceptable (96.7%; 95% CI 91.7-98.7%) and agreed with 111/120 medical student left ventricular function interpretations (92.5%; 95% CI 86.4-96.0%). Ultrasound-fellowship-trained emergency medicine physicians graded 99/117 inferior vena cava scans as acceptable (84.6%; 95% CI 77.0-90.0%) and agreed with 101/117 medical student interpretations of inferior vena cava collapsibility (86.3%; 95% CI 78.9-91.4%). **Conclusions:** Medical students demonstrated satisfactory ability within a short period of time in a range of POCUS scans on pediatric patients after a novel curriculum. This supports the incorporation of a formal POCUS education into medical school curricula and suggests that novice POCUS learners can attain a measure of competency in multiple applications after a short training course.

Introduction

Point-of-care ultrasound (POCUS) is used by emergency physicians to make rapid critical diagnoses in the emergency department (ED) [1]. POCUS is now being incorporated into medical student patient assessment curricula [2, 3]. Several studies have demonstrated the feasibility of medical students using POCUS and have included teaching multiple POCUS applications to medical students simultaneously [2,4,5]. However, there are few studies demonstrating medical students' ability to accurately perform POCUS on pediatric patients and these studies have typically included one POCUS application taught at a time [6-9].

POCUS is particularly well suited to aid the evaluation of pediatric patients [10]. When it comes to POCUS, children are not little adults: their smaller body size, higher ratio of cartilage to bone and decreased fat to lean

body mass are suitable to ultrasound. However, their fear of clinical interactions and lack of cooperation can make physical and POCUS exams more difficult, and it is often beneficial to utilize distraction technique to facilitate the exam [11]. It has been demonstrated that POCUS training has a positive effect on medical student anatomic and physiologic knowledge, clinical decision making, and development of clinical skills [12-14]. It has also been suggested that early medical student ultrasound training may prevent future diagnostic mistakes by maximizing their ability to obtain accurate ultrasound images [15]. However, it has not been shown that medical students could achieve the level of competency needed to obtain and accurately interpret quality POCUS images in pediatric patients across a spectrum of POCUS exams.

Emergency medicine (EM) and pediatric EM ultrasound curricula generally teach a wide variety of POCUS scans,

ranging from easy-to-master scans, such as bladder volume assessment, to moderately difficult scans, such as for long bone fractures, to more difficult scans, such as limited echocardiography and vascular scans.

Bladder volume measured with the use of POCUS is more reliable than automated bladder scans [16]. The two main benefits of teaching bladder volume scans to medical students include teaching an easy to learn scan, paving the way for more advanced applications, and teaching a useful clinical adjunct that can help decide the timing of bladder catheterization in young pediatric patients.

POCUS has been successfully used by emergency physicians to diagnose pediatric extremity fractures. A study by Barata [17] demonstrated a high sensitivity (95.3%) and specificity (85.5%) for identifying suspected pediatric long bone fractures with ultrasound performed by physicians trained via a brief didactic session and video review of normal and fractured long-bones. This was similar to results from a study by Poonai [18] showing a sensitivity of 94.7% and specificity of 93.5% in ultrasound performed by physicians with at least 2 years POCUS experience who also reviewed a video and performed 25 practice scans prior to the study. The minimal training and satisfactory results in both novice and experienced POCUS users suggest that it is an application that could be included in medical student POCUS curricula.

Vomiting, diarrhea, and volume depletion are common presentations of pediatric ED patients. POCUS assessment of inferior vena cava (IVC) diameter and respiratory variation and left ventricular (LV) function have been used to determine responsiveness in clinically hypovolemic patients and in the assessment of unexplained hypotension or shock [19-21]. The benefits of teaching IVC and cardiac POCUS to medical students include earlier detection of patients with clinically relevant volume depletion and shock.

The purpose of this study was to demonstrate the ability of medical students with limited training in POCUS to accurately obtain and interpret ultrasound exams across a spectrum of exam difficulty in pediatric patients. For this study, we chose to examine medical students' ability to perform POCUS examinations for bladder volume assessment, long bone fracture identification, LV function assessment, and IVC collapsibility in pediatric patients.

Methods

Study Approval

This study was approved by the institutional review boards of the University of Texas Southwestern and Children's Medical Center of Dallas. All subjects underwent informed consent in either English or Spanish.

Medical Student Recruitment and Training

Five medical students with no prior ultrasound experience were recruited from the medical student emergency medicine interest group and underwent informed consent to participate. Training was scheduled over the two weeks following the completion of their first year of medical school and included lectures in ultrasound physics, bladder assessment, long bone fracture assessment, limited echocardiography, and IVC assessment given by ultrasound-fellowship-trained emergency physicians (USEMP). The medical students also observed two 4-hour quality assurance (QA) sessions that were part of the EM resident ultrasound rotation which included image review of these ultrasound techniques and related topics. Medical students also received training in obtaining informed consent and hands on practice with volunteers on all US techniques in this study. The investigators also created a simulated bone model as all volunteers for the bone ultrasound did not have fractures. The students were required to complete one Standardized Direct Observational Tool (SDOT) of patient enrollment and study technique for each study application on a patient or medical student volunteer at the end of the training period with a faculty investigator. Any students with unsatisfactory completion of one or more steps completed additional SDOTs until all steps were completed satisfactorily.

Patient Inclusion and Exclusion Criteria

Inclusion criteria for bladder ultrasound exam subjects included all patients under age 18 years requiring urethral catheterization with an English or Spanish speaking parent or guardian present. Exclusion criteria included patients unable to tolerate the POCUS exam and patients not consenting to participate.

Inclusion criteria for long bone ultrasound exams subjects included all patients under age 18 years presenting with traumatic extremity pain with an English or Spanish speaking parent or guardian. Exclusion criteria included patients unable to tolerate the POCUS exam, patients with concern for open fracture, patients with radiology department imaging already performed, and patients not consenting to participate.

Inclusion criteria for cardiac & IVC exams subjects were clinically stable ED patients under 14 years old with clinical euvolemia as determined by the treating physician (ED attending or pediatric EM fellow) with an English or Spanish speaking parent or guardian present. Exclusion included: 1. recent vomiting, diarrhea, or decreased oral intake, 2. clinical impression of volume depletion or shock, 3. Inability to lay supine for the study procedure, 4. patient history of congenital heart disease, renal disease, liver cirrhosis, heart transplant, liver transplant, Marfan

syndrome, or complex care (e.g. tube feedings or parental nutrition), 5. patients not consenting to participate.

Patient enrollment

Medical students staffed an urban tertiary pediatric ED 24 hours a day for 5 weeks in 12 hour shifts from late June - early August 2019. The medical student searched the ED track board for patients meeting inclusion criteria. The ED attending or fellow approved patients for study enrollment. The patient's parent/guardian underwent informed consent via a standard script. Spanish speaking parents/guardians were consented in person with the hospital-based interpreter when available or via telephone by an on-call Spanish speaking study staff member. Patients over age 10 years gave assent to participate.

Ultrasound examination procedures

Patient demographics including age, sex, and ethnicity, as well as the medical student performing the scan were recorded. All scans were completed using a Mindray TE 7 ultrasound with a 2.9-10.5 mHz phased array transducer (younger patients undergoing IVC/cardiac/bladder scans) or 2-4 mHz phased array transducer (typically for older patients undergoing IVC/cardiac/bladder scans) or 2-8 mHz linear array transducer (long bone scans) as deemed appropriate by the medical student performing the scan. All relevant still images and clips were reviewed by ultrasound trained faculty.

Bladder volume study: Patients were placed supine. Still images of the bladder were obtained in longitudinal and transverse views pre- and post-catheterization. Anterior-posterior, transverse and head-to-toe measurements were obtained, and bladder volume was calculated by the ultrasound machine.

Fracture study: Patients were placed in a position of optimal comfort. The ultrasound transducer was placed over the point of maximal tenderness (determined by patient indication in verbal patients and by treating physician exam in nonverbal patients) with enough ultrasound gel to limit contact of the transducer with the skin. Eight second video clips were obtained in longitudinal and transverse views in the area of interest. Location of pain, medical student interpretation of fracture presence or absence, and presence or absence of fracture on radiology department imaging, were recorded.

Cardiac/IVC scans: Patients were placed supine. The medical student obtained 8 second ultrasound clips of the longitudinal IVC and parasternal long and apical 4 chamber cardiac views. medical student qualitative assessment of LV function (hyperdynamic, normal function or hypodynamic [mild, moderate or severe]) and

Table 1. Practice Scans Completed by Medical Students.

Ultrasound exam	Average number of practice scans per medical student (Range)
Bladder	5.2 (4-7)
Bone	4.4 (3-6)
IVC	9.4 (8-11)
Cardiac	6.8 (5-8)

IVC collapsibility (greater than or less than 50%) were recorded.

Review of ultrasound scans

Recorded information was entered into a REDCap database by three study team EM residents. Each clip and still image was securely downloaded by the Principal Investigator and given directly to the USEMP responsible for reviewing the images. Each scan was reviewed by one of four USEMPs for image quality and accuracy of medical student interpretation. Each scan was reviewed by a second USEMP if the first disagreed with the medical student interpretation. Quality was graded based on the American College of Emergency Physician's (ACEP) emergency ultrasound standard reporting guidelines' 5-point quality assurance (QA) scale with a score of 3 or above meeting minimum criteria for diagnosis. The scale is as follows:

- 1: No recognizable structure, no objective data can be gathered
- 2: Minimally recognizable structures but insufficient for diagnosis
- 3: Minimal criteria met for diagnosis, recognizable structures but with some technical or other flaws
- 4: Minimal criteria met for diagnosis, all structures imaged well and diagnosis easily supported
- 5: Minimal criteria met for diagnosis, all structures imaged with excellent image quality and diagnosis completely supported

Data Analysis

All data from the REDCap database were transferred to Microsoft Excel 365. We report the frequency of acceptable scans obtained by the medical student as determined by the USEMP and the agreement between the medical student interpretation and the USEMP interpretation, both with 95% confidence intervals (CI).

Table 2. Patient Demographics.

	Bladder	Fracture	IVC/CV
Number of Patients	53	37	120
Age Range (mean years)	4d – 15 yrs (1.37 yrs)	1.5 yrs – 17 yrs (8.5 yrs)	1 wk – 15 yrs (6.6 yrs)
Male, # (%)	22 (40%)	20 (51%)	64 (53.3%)
Race, # (%)			
• African American	17 (31%)	8 (20.5%)	36 (30%)
• Caucasian	26 (47%)	25 (64.1%)	71 (59.1%)
• More than one	2 (4%)	0	1 (0.8%)
• Unknown/not reported	10 (18%)	6 (15.4%)	12 (10%)
Hispanic, # (%)	26 (47%)	21 (53.8%)	54 (45%)
BMI range, (median)	N/A	N/A	10.9-33 (17.7)
Location of extremity pain, # (%)	N/A		N/A
Upper arm		5 (13.5 %)	
Forearm		11 (29.7 %)	
Thigh		8 (21.6 %)	
Lower leg		13 (35.1 %)	

Results

Each medical student completed an average of 25.8 practice scans during the training period (Table 1).

During the study period, 323 scans on 210 ED patients age 1 week to 17 years (Table 2) were completed by the medical students. Each medical student performed between 22 to 143 scans.

Bladder Volume

Fifty-three ED patients age 1 week to 15 years had bladder scans completed during the study. Two additional patients were approached and consented for enrollment but did not complete the study and were excluded from analysis. Each medical student performed an average of 10.6 bladder scans (range 3-17). The USEMP graded 51/53 scans as QA 3 or above (96.2%; 95% CI 87.3-99.0%). One scan of poor quality was graded as QA 2 by the USEMP, consistent with the student's interpretation and the second USEMP. The second scan of poor quality was graded QA 1 by the USEMP, consistent with the student's interpretation and the second USEMP. Bladder volumes were measured in 50/53 subjects and the

USEMP agreed with all of the measurements submitted, yielding an accuracy of 94.3% based on bladder volume scans attempted. Of the 3 studies without volume measurements, the USEMP stated that 2 of the studies had inadequate images to calculate bladder volumes and that 1 of the studies appeared to have adequate images to calculate bladder volume. The medical students' mean self-reported image quality was 3.25, while the faculty perception of students' image quality was 4.10 ($p < .001$; Table 3).

Bladder catheterization volumes were available for 49 of the 53 patients undergoing bladder volume assessment. Four patients did not undergo in and out (I&O) catheterization. Bladder volume adequate for urinalysis and urine culture was defined as greater than or equal to 2.5 mL [22, 23]. Of the 49 patients, 47 had bladder volumes that measured ≥ 2.5 mL, and 42 of those patients had > 2.5 mL collected by I&O catheterization. Two patients had bladder volumes measured as less than 2.5 mL. One of those patients had a measured volume of 1.43 mL with 0.2 mL collected, the other had a measured volume of less than 1 mL with 5 mL collected. The

Table 3. Percentage of acceptable scans and accuracy of interpretation of POCUS scans completed by Medical Students.

Scan	QA ≥ 3 / Total (%)	Accurate medical student interpretation per USEMP (%)
Bladder	51/53 (96.2%)	50/53 (94.3%)
Long Bone	35/37 (94.6%)	32/37 (86.5%)
Cardiac	116/120 (96.7%)	111/120 (92.5%)
IVC	99/117 (84.6%)	101/117 (86.3%)

POCUS bladder volume measurement of > 2.5 mL predicting adequate volume for I&O cath yielded a sensitivity of 97.7%, similar to prior studies in bladder volume measurement [22, 23], though the specificity was much lower at 16.7%. The measured bladder volumes in the I/O caths yielding inadequate urine volume were 5.82 mL, 7.4 mL, 10.34 mL, 10.54 mL, and 18.92 mL. The overall accuracy compared to I&O cath volume was 87.8%.

Long Bone Scans for Presence/absence of Fracture

During the study, 37 ED patients aged 18 months to 17 years had long bone scans for the presence/absence of fracture (fracture scans) completed. An additional 2 patients were enrolled but did not complete the study and were excluded from analysis. Each medical student performed an average of 7.4 long bone scans (range 4-14). Medical students completed 5 humerus scans, 11 radius/ulna scans, 8 femur scans, and 13 tibia/fibula scans. USEMP graded 35/37 long bone scans as able to be interpreted with image quality QA 3 or above (94.6%; 95% CI 82.3-98.5%). USEMP agreed with 32/37 medical student interpretations (presence or absence of fracture) of long bone fracture scans (86.5%; 95% CI 72.0-94.1%). Of the 5 scans in which the USEMP did not agree with the medical student interpretation, both USEMP stated that 2 of the study images were of too poor quality to support an interpretation. On the three other scans in disagreement, the USMEP both stated that fractures were present on ultrasound when the medical student stated no fracture was present (Table 2).

Radiograph results were available for 35 of 37 patients who completed the fracture US scans. Medical students identified 12 of 16 fractures detected by radiograph and

stated no fracture was present on 17 of 19 negative radiographs. This yielded a sensitivity of 75.0% (95% CI 47.6-92.7%), specificity of 89.5% (95% CI 66.9-98.7%), positive predictive value of 85.7% (95% CI 61.1-95.8%), and negative predictive value of 82.9% (95% CI 64.2-91.0%) when compared to radiographs, with an overall accuracy of 82.9% (95% CI 66.4-93.4%; Table 3).

Cardiac 2 view: parasternal long axis and apical 4 chamber

Cardiac scans were completed in 120 ED patients age 1 week to 13 years. An additional 15 patients were enrolled but did not complete the study and were excluded from analysis. Each medical student performed an average of 24 cardiac scans (range 8-57). USEMP graded 116/120 cardiac scans 3 or above (96.7%; 95% CI 91.7-98.7%). USEMP agreed with medical student interpretation of LV function on 111/120 scans (92.5%; 95% CI 86.4-96.0%). In 3 of the 9 scans in which the USEMP did not agree with the medical student interpretation, the medical student stated there was moderately diminished LV function (1 scan) or mildly diminished function (2 scans) and both USEMP stated the LV function was normal. Of the other 6 scans in which there was disagreement, the medical student stated there was normal LV function whereas both faculty stated the images were of too poor quality to support an interpretation (Table 3). As there were no scans with diminished function by USEMP interpretation, sensitivity and positive predictive value for LV failure cannot be calculated. However, the medical students' specificity was 97.3% and negative predictive value was 94.9%, with an accuracy of 92.5%.

IVC

There were 117 ED patients, aged 1 week to 13 years who had IVC scans completed during the study. An additional 18 patients were enrolled but did not complete the study and were therefore excluded from analysis. Each medical student performed an average of 23.4 IVC scans (range 5-56). USEMP graded 99/117 IVC scans as a 3 or above (84.6%; 95% CI 77.0-90.0%). The USEMP agreed with 101/117 medical student interpretations of IVC collapsibility of greater or less than 50% (86.3%; 95% CI 78.9-91.4%; Table 3).

Of the 99 scans of sufficient quality for interpretation, the medical student and USEMP agreed on > 50% collapse in 16 subjects and agreed on < 50% collapse in 81 subjects. There were 2 patients that the medical student interpreted as > 50% collapse where the USEMP disagreed. There were no disagreements where the medical student stated < 50% collapse. This yielded a sensitivity of 100%, specificity of 88%, positive predictive value of 88.9%, and negative predictive value of 100%, with an accuracy of 98%.

Discussion

Medical schools are increasingly integrating ultrasound into their curriculum, which has been encouraged by the American Academy of Emergency Medicine [2, 24-28, 29]. Teaching POCUS along with fundamental clinical examination skills may improve both skill sets [28]. Multiple studies have shown that combined didactic and hands-on learning improves learning outcomes, and that medical students with limited training can identify pathologies and possibly affect patient outcomes [30-32]. Udrea, et al., demonstrated that POCUS performed by second year medical students in an adult ED demonstrated a 94.7% agreement between treating physicians and the medical student performed studies and led to a newly discovered diagnosis in 12.4% of scans, changed the initial management plan in 17.3% of scans, reduced time to disposition 33.5% of the time, and led to an avoidance of additional imaging studies 53% of the time [33]. However, despite the expanding use of POCUS and its incorporation into medical school education, there are few studies examining the diagnostic accuracy of medical student-performed POCUS [33-35].

In this study, we studied the proficiency achieved by medical students through a short ultrasound course covering clinical ultrasound scans of varying difficulty (similar to our approach in teaching EM residents during their clinical ultrasound rotation), comparing the diagnostic accuracy of the medical students' interpretations with the USEMP's QA review of the scan. Current expert guidelines for credentialing pediatric EM faculty in clinical ultrasound recommend a minimum of 5 bladder volume scans, 10 IVC scans, 25 musculoskeletal scans and 25 cardiac scans as part of a competency assessment [36], with an increased number of required scans reflecting a greater difficulty to achieve competency.

Medical students demonstrated adequate competency in ultrasound acquisition with regard to the organ of interest with a QA grade 3 or better in 96.2% of bladder scans, 94.6% of long bone scans, 96.7% of cardiac scans, and 84.6% of IVC scans. Medical students also displayed a satisfactory ability to arrive at an accurate diagnosis compared to the gold standard USEMP interpretation of 94.3% for bladder scans (87.8% vs I&O cath volume), 86.5% for long bone scans (82.9% vs radiograph), 92.5% for cardiac scans, and 86.3% for attempted IVC scans (97.9% of interpretable IVC scans). The most likely reason for a USEMP to disagree with an medical student interpretation was an interpretation submitted for a scan of QA 1 or 2. We report the results in this format to give a more realistic view that scans should be of sufficient quality in order to make a diagnosis. The degree of accuracy is similar to a study by Andersen et al [35], who

examined medical students' use of pocket-sized POCUS devices on hospitalized adult patients after a POCUS curriculum in identification of LV function, pericardial effusion (on an apical 4-chamber view only), pleural effusion, lung comets, hydronephrosis, bladder distention, gallstones, abdominal free fluid, cholecystitis, and aorta and IVC diameters. Twenty-five medical students self-selected 1151 scans which were reviewed by unblinded radiologists or cardiologists. Given the self-selection bias, the scans were determined to have an acceptable organ presentation (similar to our QA ≥ 3) in 73.8% of cardiovascular scans and 88.4% of radiologic scans, with a diagnostic accuracy of 93.5% of acceptable cardiac scans and 93.2% of acceptable radiologic scans. In our study, the overall diagnostic accuracy was similar despite the inclusion of nondiagnostic QA 1 or 2 scans.

The medical students' ability to rule-in or rule-out long bone fractures had a lower sensitivity of 75% but a specificity of 89.5%, PPV of 85.7% and NPV of 82.9%. A prior meta-analysis of long-bone fracture diagnosis by POCUS showed a pooled sensitivity of 64.7-100% and specificity of 79.2-100% placing the medical student performance in the current investigation well within the previously documented ranges of long bone fracture diagnosis with POCUS [37]. Additional possibilities explaining the lower sensitivity of medical students to detect lone bone fractures may be that this was the least practiced scan during the practice scanning portion of the educational course, with medical students practicing on average 4.4 long bone scans vs 5.2 bladder scans, 6.8 LV cardiac scans, and 9.4 IVC scans. Additionally, lone bone scan practice was done on healthy volunteers, and the practice scans were all normal, at least suggesting that seeing pathology during training may be beneficial to the development of POCUS skills.

It has been previously demonstrated that incorporation POCUS education into existing medical student education improves knowledge of anatomy and physiology, and physical exam skills [37,38]. The knowledge is retained [39]. Additionally, it has been demonstrated that increased POCUS use leads to increased proficiency [40-42]. This study shows that a good measure of competency can be achieved after a short course in POCUS. Extrapolating from the previous studies mentioned above [37-42], it would be expected that the image acquisition ability and diagnostic accuracy demonstrated by the medical students on a wide range of POCUS scans in this study would only improve with continued education and practice, supporting the incorporation of formal POCUS education into medical school curricula.

Limitations

This study has several limitations. First, it was a small

sample size of medical students who were recruited from an EM interest group who may have been more motivated to learn POCUS than the typical medical student.

Two bladder, 2 fracture, 15 cardiac and 18 IVC subjects were enrolled but unable to complete the study. Because the subjects were recruited during their stay in the pediatric emergency department with the goal of not interfering with patient care, it was assumed that the subjects could not complete the study due to ED care and not a medical student inability to obtain an image. We recognize, however, the possibility of a selection bias. Though unlikely, assuming all of the incomplete exams were due to an inability to obtain a proper image, the acceptable scan rate would decrease from 96.2% to 92.7% for bladder scans, 94.6% to 89.7% for the long bone scans, 96.7% to 85.9% for the cardiac scans, and from 84.6% to 73.3% for the IVC scans.

The subjects undergoing cardiac and IVC scans were recruited from a group with low likelihood for pathology, with only 26/120 being at risk for volume depletion due to decreased oral intake, fever, vomiting, diarrhea, moderate anemia and orthostatic hypotension. This creates a potential interpretation bias that cardiac function would be expected to be normal and the IVC expected to not significantly collapse.

Potential long bone scan subjects with fractures may have been less likely to consent for enrollment due to increased pain, and it is assumed, though not recorded by the medical student, that several subjects enrolled for long bone scans had radiographs completed and interpreted prior to enrollment in the POCUS study, thereby potentially affecting blinding of the medical student.

Conclusions

Medical students demonstrated proficiency in a range of POCUS scans on pediatric patients after a relatively short curriculum. This study provides more support for the feasibility of a successful short medical student POCUS curriculum, which should include pediatric patients. Future studies are needed to recommend a standardized medical student POCUS curriculum, as well as to evaluate for minimum numbers for competency and integration of medical student POCUS use in clinical practice.

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validated data entry; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for importing data from external sources.

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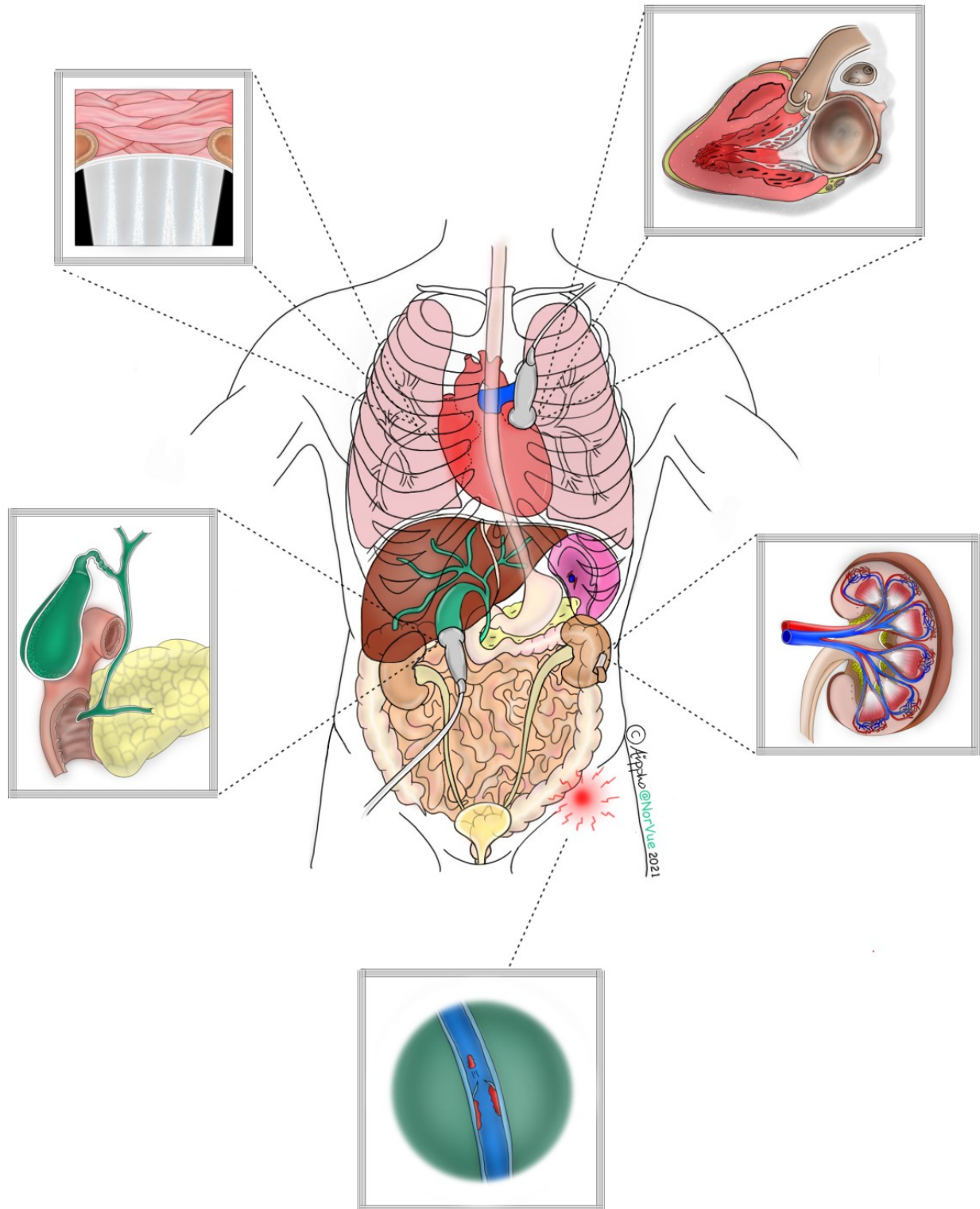
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The Beauty of Sound Waves

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“The Beauty of Sound Waves” is an artwork representing the anatomy of various organs in the human body that can be detected by ultrasound, either as normal findings or pathology. Made by Ai Phi Thuy Ho. Disclosures: none.

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