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Trans-hepatic Lung Ultrasound – A Window for Supine Patients

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Lung ultrasound has gained increasing use in the last few years, especially in the critically ill patients. By applying the probe on the thorax, much of the lung can be inspected and multiple conditions can be diagnosed and monitored, through anterior, lateral and posterior thoracic views [1].

However, the majority of ICU patients are supine, barring access to visualization of the lowest and most posterior portion of the lower lobe, as it extends through most of the posterior half of the lung and only little on the lateral surface [1,2]. Visualization of the lower lobe is important, as it occupies a significant portion of the right lung and it is usually affected in aspiration pneumonia [3].

We describe a novel approach to visualization of part of the lower lobe of the right lung, through a trans-hepatic approach. We first used this approach in a 72-year-old patient with dyspnea and severe hypoxemia, to diagnose a lower lobe pneumonia, which was ill-defined in the chest x-ray and later confirmed by looking at a computed tomography (CT) (Figure 1). This later exam had been performed in the same day, showing right lower lobe consolidation, as well as, left lower lobe consolidation.

![Figure 1. Chest x-ray of the patient (left) and CT scan of same patient (right), performed in the same day, showing right lower lobe consolidation, as well as, left lower lobe consolidation.](image)

![Figure 2. Positioning of the ultrasound probe in order to perform a trans-hepatic lung ultrasound (left panel); lung ultrasound findings in the same patient, showing the liver (L), diaphragm (D) and a consolidated lower lobe of the right lung (C), as shown by the shred sign (middle panel); lung ultrasound findings in another patient without pneumonia, with visible pleura (P) and lung sliding (right panel).](image)
ordered due to the suspicion of pulmonary embolism, since the initial chest x-ray had not revealed a condensation. Use of this novel trans-hepatic window could have made this diagnosis possible earlier. The lower lobe pneumonia was also not seen in the standard anterior and lateral views and a complete posterior view was not possible as the patient was supine and had difficulty in lateralizing.

This window can be obtained by placing a curvilinear probe transversely below the liver border and tilting the probe up until the liver and diaphragm can be seen (Figure 2, left panel); the diaphragm dome will be seen as an hyperechogenic line above the liver and, superior to it, the lowest portion of the inferior lobe will be presented (Figure 2, middle panel, and Video 1). The lower lobe will be visible in case a pneumonia or atelectasis is present. Identifying the shred sign will allow for the diagnosis of right lower lobe pneumonia. In patients without pneumonia, the pleura and lung sliding will be visible (Figure 2, right panel, and Video 2). In our brief experience, this window may not be attainable in obese patients, those with hepatomegaly or with ascitis, as the lowest portion of the lung becomes too deep relative to the liver border for the ultrasound to penetrate. Thus, this technique is not sensitive enough for excluding the diagnosis of right lower lobe pneumonia. A schematic showing the relative position to the ultrasound probe of the various organs is shown in Figure 3.

We believe this approach should be included in the standard approach to lung ultrasound, as it is quickly and easily obtained, without having to lateralize the potentially unstable patient.

Statement of Ethics
The requirement for informed consent was waived, as the information presented does not allow for patient identification.

Conflicts of interest
The authors declare no conflicts of interest.

References
Pseudoaneurysm of the Dorsalis Pedis Artery Diagnosed on Point-of-Care Ultrasound

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Abstract

A 46-year-old man presented with a painless mass on his dorsal right foot one week after striking it on a door. A traumatic hematoma was suspected, and needle aspiration of the mass is considered. However, point-of-care ultrasound performed by the emergency physician identified a pseudoaneurysm of the dorsalis pedis artery, a rare condition that can occur after minor trauma or iatrogenic intervention. This report demonstrates how point-of-care ultrasound can be used to identify a pseudoaneurysm of the lower extremity, thereby expediting emergency department workup and preventing potentially dangerous diagnostic procedures.

Introduction

Vascular aneurysms and pseudoaneurysms of the arteries of the foot are uncommon. Pseudoaneurysms form when a hematoma accumulates between the outer layers of the artery, the tunica media and tunica adventitia, usually following a trauma. Angiography, although traditionally the gold standard for diagnosis of lower extremity pseudoaneurysms, has largely been replaced by computed tomography angiography (CTA) or duplex sonography in the emergency department (ED). Our case demonstrates how emergency physicians can apply point-of-care ultrasound to diagnose a pseudoaneurysm of the dorsalis pedis artery, thereby preventing iatrogenic injury (e.g. diagnostic aspiration or incision) and expediting appropriate follow-up.

Case Report

A 46-year-old man presented to the ED with a soft tissue mass on his dorsal right foot one week after striking it on a door one week prior. He denied fevers, difficulty bearing weight, or associated pain or numbness in the area. On examination, he had a soft, non-tender, mobile, 3 cm x 3 cm mass on the dorsal right foot without overlying skin changes. Pulsations were felt over the dorsalis pedis artery but not the mass. The patient’s toes were well-perfused, and he had no sensory or motor deficits. Traumatic hematoma was suspected, and diagnostic aspiration was considered. However, point-of-care ultrasound performed by the emergency physician revealed a hypoechoic cystic mass, just lateral to the dorsalis pedis artery, with arterial waveforms. [Image 1A-B] The addition of color Doppler ultrasound revealed pulsatile flow within the mass, consistent with a pseudoaneurysm of the dorsalis pedis artery (Figure 1, online Video S1. The patient provided written consent for publication of the case.

Discussion

Pseudoaneurysms of the dorsalis pedis artery comprise less than 0.5% of all lower extremity aneurysms or pseudoaneurysms [1]. Foot pseudoaneurysms can occur days to years after a blunt or penetrating trauma, which may be minor [2]. Iatrogenic pseudoaneurysms of the dorsalis pedis artery have also been reported after ankle arthroscopy, Lisfranc operations, and arterial line placement [3-5]. Pseudoaneurysms are classically painless and pulsatile. However, compression of adjacent structures can cause pain, and thrombus formation within the pseudoaneurysm may prevent pulsatility, often making physical examination unreliable.

Angiography, despite being the gold standard imaging for patients with suspected lower extremity pseudoaneurysms, is often unavailable in the ED. CTA, although commonly performed in the workup of suspected pseudoaneurysms, is potentially nephrotoxic, limited by its resolution at the distal arteries, and has reconstruction-based artifacts [6]. Sonography with color Doppler, on the other hand, is radiation-free, readily available, and able to distinguish pseudoaneurysms from hematomas, abscesses, neoplasms, and other soft tissue masses [7]. On ultrasound, both a pseudoaneurysm and true aneurysm appears as a hypoechoic (dark) cystic mass adjacent to an artery. Application of color Doppler typically reveals pulsatile flow and, in some cases, swirling of the red and blue signals (i.e. the “yin-yang sign”) [8]. To best visualize flow in a pseudoaneurysm with color Doppler, the operator can tilt the probe slightly, thereby increasing the Doppler shift.
Patients with pseudoaneurysms or true aneurysms of the foot risk hemorrhage, distal thromboembolism, and compression neuropathy, and should be urgently referred to a podiatrist or vascular surgeon for operative repair [1, 9].

Conclusion
Emergency physicians should consider lower extremity pseudoaneurysms in patients presenting with soft tissue masses after trauma, even if minor. To our knowledge, this is the first reported case of a pseudoaneurysm of the dorsalis pedis artery diagnosed on point-of-care ultrasound performed by an emergency physician. The identification of a pseudoaneurysm of the dorsalis pedis artery should prompt urgent referral to a surgical specialist to avoid hemorrhage, distal thromboembolism, or neurovascular compromise.

Disclosures
The authors have no conflicts of interest to declare.

References

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Hematocrit Sign Elucidates Cause of Abdominal Pain

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Abstract
A 78-year-old male with chronic kidney disease on peritoneal dialysis developed unprovoked bilateral pulmonary embolisms. He was started on IV unfractionated heparin, but shortly thereafter developed severe pain and a small firm abdominal nodule near his dialysis catheter site. The diagnosis was unknown, and the initial plan was watchful waiting, until point-of-care ultrasound (POCUS) was used. POCUS revealed an ovoid mass with hyperdensity in the gravity dependent regions with spontaneous movement. This appearance was classic for the hematocrit sign. When combined with the clinical presentation, this was concerning for a rectus sheath hematoma. An urgent CT of the abdomen confirmed this several hours later. POCUS allowed for rapid bedside diagnosis, which expedited appropriate care in a potentially life-threatening situation.

Case File
A 78-year-old male with Stage V chronic kidney disease on peritoneal dialysis (PD), and numerous other cardiovascular co-morbidities, presented to the Emergency Department with a 4-day history of dyspnea. A ventilation/perfusion scintigraphy revealed bilateral unprovoked pulmonary emboli (PE). The patient was started on warfarin and IV unfractionated heparin as bridging anticoagulation. Three days after starting therapeutic anticoagulation, the patient developed severe pain located 5cm adjacent to his PD catheter insertion site. Palpation revealed a firm, 2cm, well-circumscribed, tender subcutaneous mass. The etiology was unclear, and the initial plan was to follow clinically.

Point-of-care ultrasound (POCUS) was performed to screen for an underlying etiology. POCUS revealed an unexpected finding. Within the subcutaneous tissue, outside of the peritoneum, there was a discrete ovoid visualized (Figure 1a, online Video S1). This structure was hyperechoic in the gravity dependent portion. Additionally, there appeared to be spontaneous movement within the ovoid. Taken together, these findings represent active extravasation forming a rectus sheath hematoma. The fluid-fluid layer, with the gravity dependent fluid being hyperechoic, is known as the hematocrit sign, which was the hallmark POCUS finding visualized.

Rectus sheath hematoma (RSH) is an uncommon clinical condition whereby blood accumulates in the rectus abdominus muscle sheath as a result of damaged muscle fibres or torn epigastric vessels [1]. This is typically due to blunt abdominal trauma, or overly forceful muscle

Figure 1. a) Point of Care Ultrasound of Left Lower Abdominal Quadrant mass showing the hematocrit sign. b) CT abdomen and pelvis showing a 11x11x5cm rectus sheath hematoma.
contraction, but can occur spontaneously particularly if patients are on anticoagulation [2]. Patients commonly present with acute abdominal pain and a palpable abdominal mass but may also have nausea, vomiting, fevers, and chills [2,3]. A high index of suspicion is required as abdominal wall pathology can mimic other causes of acute abdomen, making it a frequently overlooked diagnosis [4]. Appropriate investigations include monitoring for decreasing hemoglobin and imaging (ultrasound or CT of abdomen) [2]. Most patients with RSH are managed conservatively as they are often self-limiting but in hemodynamically unstable patients, embolization or surgical ligation may be required [2]. Complications associated with RSH include muscle necrosis, hypovolemic shock, abdominal compartment syndrome, myocardial infarction, and death [3,5].

The hematocrit sign is an imaging finding frequently associated with superficial hematomas or hemothorax [6-8]. The appearance of the hematoma varies depending on the duration of bleeding. Hematomas may appear heterogeneously hypoechoic initially and become increasingly hyperechoic over time [6]. The hematocrit sign (Figure 1a, Video S1) occurs as coagulated cells and debris collect in dependent areas due to gravity, forming a distinct line of separation between liquid and cellular components of blood [7,9]. There is no mimic for this sonographic finding; although the main differential could include a subcutaneous abscess, the contents of a subcutaneous abscess would not typically display a well-defined hyperechoic layer as seen in the hematocrit sign.

As the patient developed acute abdominal pain, the underlying cause was initially suspected to be due to peritoneal irritation from PD or a hernia. POCUS significantly expedited the diagnosis, allowing for rapid cessation of heparin, and initiation of close monitoring. Anticoagulation was indicated for his large unprovoked bilateral PE, but due to the RSH the decision was made to stop the IV heparin, and continue warfarin targeting an INR of 2.0. An urgent abdominal CT several hours later confirmed the diagnosis, showing at that time an 11x11x5cm rectus sheath hematoma in the left lower quadrant (Figure 1b). The patient required a transfusion of three units of packed red blood cells but otherwise improved clinically with no further complications.

**Statement of Ethics**

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.

**References**


Seven Year Old Male with Tricuspid Endocarditis

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Abstract

Pediatric endocarditis, a rare entity in developed countries, remains a challenging diagnosis to make in children. We present an uncommon etiology of shortness of breath on exertion (SOBOE) in a 7-year-old male presenting with two weeks of nocturnal fever, malaise and fatigue following a viral prodrome. Point of care ultrasound (POCUS) led to suspicion for a ventricular septal defect (VSD) with tricuspid valve (TV) endocarditis, which was ultimately confirmed by formal echocardiography. This ultrasound diagnosis allowed emergency clinicians to order blood cultures under the suspicion of endocarditis as well as expedited antibiotic treatment.

Case

Pediatric endocarditis, a rare diagnosis in developed countries [1]. Children from third world countries carry a unique set of risk factors that may predispose them to this rare and invasive infection with potential for severe sequelae [1]. Poor dentition, presence of a congenital cardiac abnormality (pre and post repair), foreign body, and being immunocompromised all carry independent risk for pediatric endocarditis [1]. This is a case of a previously healthy 7-year-old male who moved from Somalia to Canada 1 year prior to presentation in the ED. He took no medications, had no allergies, and his immunizations were up to date. He presented with a 2-week history of nocturnal fever, shortness of breath on exertion (SOBOE), malaise and fatigue. His mother described fever beginning at 1800 each night and persisting over the course of the evening. The fever did not respond to antipyretic treatment and would break in the morning. Cough and coryza preceded his nocturnal fevers. Over the 3 days prior to his presentation, he developed significant SOBOE to the point of dyspnea while drinking water or taking a few steps. His mother described him as fatigued but interactive. His oral intake was still maintained and he had no history of bowel or bladder symptoms. On review of systems, there was no rash, toxic ingestion, or trauma. He had no history of similar symptoms previously. He was seen in the community by a paediatrician and sent in with the presumptive diagnosis of myocarditis.

Upon arrival to the Alberta Children’s Hospital Emergency Department, he had a temperature of 37.9 for which he received an antipyretic at triage, heart rate of 118, blood pressure 94/45, respiratory rate of 35 and was saturating 94% on room air. On exam, he had an elevated JVP to the level of the tragus, grade III/VI holosystolic murmur at his left lower sternal border, hepatomegaly with his liver edge 5cm below the costal margin. His abdominal exam was otherwise benign. He had decreased breath sounds bilaterally, but no adventitia. He did not have stigmata of endocarditis. Point of care ultrasound (POCUS) showed normal contractility, normal left ventricular size, regurgitant flow at the basal aspect of the septum (Figure 1 and Figure 2/Video S1 and Video S2), a large mobile irregularly shaped mass at one leaflet of the tricuspid valve (TV) with evidence of regurgitant flow in the apical four chamber view (Figure 1, Figure 3/Video S3 and Video S4) as well as with doppler in the IVC indicating a basal ventricular septal defect (VSD – left to right shunt), TV endocarditis and evidence of tricuspid shrouding/tricuspid regurgitation at the level of the valve. There was

Figure 1. This is a still image of a parasternal long view of the heart. Overall, there are some irregularities in the basal aspect of the inter-ventricular septum and thickness to one of the leaflets of the tricuspid valve.
abnormal regurgitant doppler flow at the inferior vena cava.

Given the clinical history, presentation, physical exam and bedside ultrasound findings, the diagnosis of a TV endocarditis in the context of an undiagnosed basal VSD was entertained in the context of a preceding viral prodrome and poor dentition. This diagnosis was confirmed on formal echocardiography and blood cultures were positive for abiotrophia defectivia [2]. This bacteria is a variant of the viridans species of streptococcus, commonly known as the causative bug for endocarditis [2]. It is quite virulent and has a predisposition for affecting endovascular structures including heart valves [2]. It is also a common agent involved in culture negative endocarditis [2]. He received a total of 6 weeks of antibiotics prior to cardiovascular surgery. He underwent perimembranous VSD closure and tricuspid valve reconstruction. Post operatively, he was placed on an additional four weeks of antibiotics. Unfortunately, he also developed post-operative pericarditis confirmed by friction rub and diffuse ST segment elevation on his electrocardiogram.

Cardiac Ultrasound in Pediatric Emergency Departments

Bedside ultrasonography has become increasingly available across many adult and pediatric emergency departments [3]. It is utilized for many indications including: acute trauma, abdominal, cardiac, musculoskeletal and infectious presentations as well as for regional anesthesia, confirming fracture reduction, appraising ocular concerns, landmarking for central venous access. Point of care ultrasound is well described in adult literature. Applications to paediatrics remains simple and few. Hesitation regarding the use of bedside ultrasound in paediatrics remains strong in light of a rather small and slowly developing pool of literature [3]. In recent years, many centres across the world have recognized this gap and attempted to validate the use of bedside ultrasound in the appraisal of acute pediatric presentations within the emergency department[3–6]. A myriad of adult studies suggest skill acquisition over a short training module is possible for assessing left ventricular (LV) function and presence of pericardial effusion [7,8]. When appropriate training occurs, point of care cardiac ultrasound (POCUS) can be an accurate and fast way to make clinical decisions. Agreement between the trainee learning cardiac ultrasound and the cardiologist after a training session was seen in 93% of cases for visual estimated of global cardiac function, and 98% for detection of pericardial effusion [3]. For pericardial effusion, sensitivity of 60%, specificity of 100%, positive predictive value of 100% and negative predictive value of 97.9% is quoted [9]. The sensitivity of
cardiac POCUS in pediatric emergency physicians in detecting LV dysfunction is quoted as 95% and a specificity of 83% [3]. If one is well trained in cardiac POCUS, the results will be in line with a formal echo and can expedite care for patients [10]. Overall, adult and pediatric studies suggest bedside cardiac assessments are feasible, guide management, and inform disposition effectively [10].

Conclusion

Pediatric endocarditis, a rare entity in developed countries, remains a challenging diagnosis to make in children [11]. Point of care cardiac ultrasound can provide diagnostic information to increase comfort with clinical appraisal, management, and disposition. Without ultrasound, this child would still have been admitted and had undergone a formal echocardiogram. However, with the power of bedside ultrasound, we were able to facilitate early appraisal for endocarditis and empiric antibiotics. This is the first report we are aware of describing the diagnosis of a VSD and tricuspid valve endocarditis using POCUS from the pediatric emergency department.

Disclosures

The authors have no conflicts of interest to declare.

References

Diagnosing Early Cardiac Tamponade in Patient with JAK2+ Myeloproliferative Syndrome with Point of Care Ultrasound

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Background

Point of care ultrasound (POCUS) is a diagnostic modality growing in popularity and use in medicine in both the acute and chronic management settings. Its utility lies in its non-invasive application, direct user interface, and portability, especially in handheld devices, allowing for quick assessment and triage. Herein is a case of POCUS diagnosing life threatening cardiac tamponade in a patient with a new diagnosis of JAK2+ myeloproliferative syndrome prompting urgent intervention with pericardiocentesis. This case illustrates the utility of POCUS through its ability to serve as a quick diagnostic tool that can hasten intervention for potentially life-threatening conditions.

Case

A 69-year-old female presented to the emergency room with complaints of shortness of breath for 3 days. She has no known medical history and takes no prescription medications. On arrival she was noted to be in atrial flutter with rapid ventricular response with heart rate in the 160s. Initial management was targeted at controlling the heart rate with diltiazem and digoxin which did not resolve the rapid heart rate. On physical exam, she was tachycardic with bibasilar inspiratory crackles heard on auscultation and had significant hepatosplenomegaly. Her vitals were significant for a pulse of 162 beats per minute and systolic blood pressure >160 mmHg. Preliminary work up revealed significant leukocytosis of 78,000/uL and thrombocytosis of 2,000,000/uL. Bedside handheld ultrasound revealed a circumferential pericardial effusion with evidence of tamponade with right ventricular diastolic collapse, B-lines consistent with pulmonary edema, as well as hepatosplenomegaly (online Video S1). A formal STAT limited echocardiogram was done to further evaluate the extent of the effusion. The formal read stated the patient had a large circumferential pericardial effusion with a swinging heart, borderline diastolic right atrial and right ventricular collapse, as well as inflow variation across the AV valves, though minimal.

Cardiology service was consulted for intervention and the patient was admitted to the Cardiac Intensive Care Unit. Interventional Cardiology service performed a pericardiocentesis the same day of presentation removing 750cc of serosanguinous fluid with a pericardial effusion.
Cardiac tamponade carries a poor prognosis, especially in malignancy, which carries a 1-year mortality rate of 76% [6]. Characteristics of cardiac tamponade that can be seen with bedside ultrasound include diastolic collapse of the right ventricle and right atrium, exaggerated respiratory variations in flow across the tricuspid and mitral valves, as well as inferior vena cava plethora [7]. On exam and vital signs, patients can present with hypotension, jugular venous distension, and distant heart sounds, otherwise known as Beck’s Triad. Despite the low blood pressure that is characteristic of shock state, some patients with subacute progression of pericardial effusion can be hypertensive. One retrospective study characterizing the hemodynamics of patients with subacute pericardial effusion before and after pericardiocentesis showed that 27% of their study population presented hypertensive and blood pressure decreased after intervention [8]. This observation reflects the response that was seen in our patient in that her blood pressure trended towards more normal levels after intervention. Additionally, one systematic review of tamponade hemodynamics has shown that the pooled sensitivity of hypotension in tamponade is 26% [9]. Thus, hemodynamics alone are not suggestive of tamponade.

In the case described, POCUS revealed a circumferential pericardial effusion with evidence of cardiac tamponade and pulmonary edema. Though she was not in a florid obstructive shock-like state, the bedside echocardiogram did show evidence of early tamponade suggesting impending cardiovascular collapse. In Video S2, a subcostal 4 chamber view depicts the pericardial effusion with right ventricular collapse. Still-frame photos of the subcostal view show the collapsibility of the right ventricle through the heart cycle (Figure 1). Video S3 shows plethora of the inferior vena cava through the respiratory cycle with a fluttering right atrium. These findings were discussed with Interventional Cardiology which led to escalation of care and early intervention. In the absence of the bedside POCUS exam, the standard of care through the hospital system would have entailed ordering a formal full echocardiogram with reading, cardiology consultation, and hospital admission, all of which takes time that the patient may not have been able to afford clinically as these steps would not always be done in an urgent manner. This route would potentially result in adverse outcomes due to delay in intervention. In this case, the bedside POCUS exam revealed critical physiologic findings that resulted in a fastened escalation of care and intervention which may have saved the patient’s life. This case emphasizes the importance and utility of point of care ultrasound in diagnosis and triage of critical findings.

**Statement of Ethics**

The authors certify that verbal patient consent has been obtained for her images and anonymous clinical information to be reported for teaching or in a medical journal. The patient understands that her name, initials, or any identifying information will be kept anonymous and not be published.

**Disclosures**

The authors declare no conflicts of interest.

**References**


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Use of point-of-care ultrasound to diagnose spontaneous rupture of fibroid in pregnancy

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Abstract

Background: Complications of fibroids in pregnancy are well known, including postpartum hemorrhage, labor dystocia, and cesarean delivery. Outside of pregnancy and labor, the rare occurrence of spontaneous fibroid rupture has been documented.

Case: The current case report involves a woman who presented with acute abdominal pain in the third trimester of pregnancy and was found to have spontaneous rupture of a fibroid before the onset of labor. Her initial presentation, diagnosis through use of point-of-care ultrasound, acute surgical management, and postoperative course are described. Conclusion: When assessing acute abdominal pain in a pregnant patient, fibroid rupture should be considered despite the absence of prior uterine surgery. Bedside point-of-care ultrasonography is a useful tool for assessment of abdominal pain in the third trimester of pregnancy.

Introduction

Uterine fibroids are smooth muscle, benign tumors found in 12-25% of reproductive-age women [1]. Up to 10% of pregnancies are complicated by fibroids [2]. In pregnancy, the presence of fibroids has been associated with an increased risk of adverse pregnancy outcomes including labor dystocia, postpartum hemorrhage, abnormal fetal presentation and cesarean delivery [2-4]. Cumulatively, the presence of fibroids in pregnancy is associated with 10-40% incidence of obstetric complications [5,6].

Outside of pregnancy, spontaneous rupture of fibroid and subsequent hypovolemic shock necessitating emergency laparotomy for control of hemorrhage has been reported in young, nulliparous women as well as in postmenopausal women [7-10]. Rare case reports have described spontaneous rupture of fibroids occurring during pregnancy in women without prior myomectomies, notably in the second trimester as well as postpartum [11-14].

In both pregnant and non-pregnant patients presenting with abdominal pain and concern for active hemorrhage, point-of-care ultrasound (POCUS) has been utilized for triage and management decision making [8-10, 12]. In the present report, we describe the use of POCUS for the evaluation of a patient with a known fibroid and no prior surgical history presenting with acute abdominal pain and concern for active hemorrhage in the third trimester of pregnancy.

Case presentation

A 28-year-old, gravida 3 para 0, at 35 and 6/7 weeks of gestation presented to a triage unit with worsening abdominal pain. Her subjective history was notable for abdominal cramping the previous evening that progressively worsened through the morning of presentation. She described her pain as constant and sharp with radiation towards her back. She reported regular fetal movement and did not report any leakage of fluid or vaginal bleeding. Her review of symptoms was otherwise negative. Prior to pregnancy, her medical history was notable for a left-sided subserosal fibroid measuring 6.7 x 5.0 x 8.2 cm by transabdominal ultrasound that was identified in a workup for abnormal uterine bleeding. This fibroid then measured 8.4 x 10.2 x 6.1 cm at 20 weeks of gestation and 9.5 x 9.3 x 8.4 cm at 32 weeks of gestation (Figure 1). Her prenatal course was otherwise uncomplicated. Her medical history was unremarkable and prior to pregnancy she took no regular

Figure 1. Representative image of a fibroid in the third trimester of pregnancy.
medications. Her surgical history was notable for one prior surgical abortion via dilation and evacuation.

On initial presentation, her vital signs were as follows: pulse of 122 beats per minute, blood pressure of 146/67 mm Hg, respiratory rate of 22/min, and oxygen saturation of 96% on room air. On physical exam, the patient was alert and oriented and in mild distress. Cardiac exam was notable for regular rhythm tachycardia by manual pulse palpation and pulmonary exam was unremarkable. Abdominal exam demonstrated a firm and severely tender abdomen in all four quadrants with rebound tenderness. Cervical exam was 1cm dilation, 50% effacement, and -3 station. On electronic fetal heart monitoring, the fetus had a baseline heart rate of 140 beats per minute, moderate variability, and no accelerations or decelerations over a 20-minute period.

On external tocometry, there were regular contractions every 2 minutes. Transabdominal POCUS demonstrated a cephalic fetus and large, bilateral collections of free fluid in the maternal abdomen. Figure 2 (supplemental Video S1) and Figure 3 (supplemental Video S2) show representative findings in the right upper quadrant and pelvis, respectively. Laboratory evaluation showed a hematocrit of 37%, platelets of 415 x10^3/µL, serum creatinine of 0.7 mg/dL, AST/ALT 22/20 units/L, total bilirubin of 0.5 mg/dL, and LDH 195 U/L. Coagulation studies showed an INR of 0.9, PTT of 26 seconds, and fibrinogen of 700 mg/dL.

In the setting of worsening abdominal pain with positive rebound tenderness and significant free fluid concerning for hemoperitoneum, possible uterine rupture was suspected. The patient underwent an emergency cesarean delivery under general anesthesia. Upon entry into the peritoneum, light brown serosanguinous fluid and dark blood was visualized without evidence of an active hemorrhage. Inspection of the uterus and adnexal structures revealed an 8 to 10 cm uterine fibroid on the left side that distorted the lower uterine segment (Figure 4). No uterine dehiscence or rupture was identified. To avoid a low transverse hysterotomy extending into the fibroid, a midline vertical hysterotomy in a classical fashion was performed. A viable, male infant was then delivered through the hysterotomy. The placenta was removed intact. The uterus was exteriorized and the hysterotomy was then closed in three layers. The fibroid was again inspected and a rupture in the fibroid capsule was appreciated (Figure 4). The serosal capsule was entered and the contents within the fibroid were hemorrhagic, liquefied, and nearly entirely degenerated with minimal fibroid tissue remaining (Supplementary Image 1). Given these findings, the decision was made to proceed with a myomectomy. The fibroid was grasped with a tenaculum and the capsule was dissected from the underlying myometrium using a combination of blunt and electro surgical dissection to shell out the remaining contents of the fibroid. The defect was then repaired in three layers. The uterus was returned to the abdomen and the remainder of the surgery was completed without complications. The infant had APGAR scores of 3 and 8 at 1 and 5 minutes, respectively. Total estimated blood loss from the procedure was 1800 mL. Intraoperatively, the patient did not require any blood products or vasopressor therapy. Postoperatively, the patient was transferred to the postpartum floor in stable condition. Her postoperative course was notable for acute blood loss.
anemia with a Hgb nadir of 7.0 g/dL; the patient declined blood transfusion. Otherwise, her postoperative course was uncomplicated and she was discharged home on postoperative day #4 in stable condition. Final pathology resulted as benign leiomyoma.

Discussion

While it has been established that prior myomectomy is a risk factor for uterine rupture in pregnancy, there have been only a few reports of a ruptured fibroid complicating pregnancy. Spontaneous fibroid rupture postpartum at two days and nine weeks has been reported [13,14]. Similarly, there are also reports of spontaneous rupture of fibroid intrapartum and in the early second trimester at 15 and 20 weeks gestation [11, 12, 15]. To date, there is no report of a pregnant woman with known fibroids and no history of myomectomy presenting with spontaneous rupture of fibroid in the third trimester prior to the onset of labor, as we present here. In context of the rarity of this presentation, antepartum knowledge of fibroids is useful for management of abdominal pain in pregnancy.

In women with prior myomectomy and entry into the endometrial cavity, cesarean delivery at 37 weeks of gestation is recommended for the prevention of uterine rupture in labor [16]. However, in women without prior myomectomy, there is no consensus on the management of fibroids in pregnancy regarding size, number, and interval growth with the effects on pregnancy and labor outcomes. Concern for fibroids obstructing the birth canal is an indication for cesarean delivery [6]. In general, myomectomy in pregnancy is not recommended due to concern for pregnancy loss and hemorrhage [17]. Myomectomy in pregnancy has been reported for the treatment of intractable pain that has failed conservative management, torsion, renal compromise secondary to obstruction, and septic necrosis [17-21]. Limited retrospective studies have evaluated pregnancy outcomes in women who undergo first or second trimester myomectomies and while successful pregnancy outcomes have been reported conservative management is recommended and surgery is indicated only on a case-by-case basis [18, 22, 23].

While the rates of hemorrhage, fetal malpresentation, cesarean delivery, and other adverse obstetrical outcomes associated with fibroids are beginning to be understood, it is not definitively known to what effect myomectomy in pregnancy or planned cesarean delivery decreases the incidence of these outcomes. As this and other case reports suggest, the spontaneous rupture of fibroid in pregnancy is a very rare event. Thus, in a pregnant woman with fibroids, the risks associated with myomectomy in pregnancy or planned cesarean delivery likely outweigh the benefits of preventing spontaneous rupture of fibroid and other adverse obstetric outcomes associated with fibroids in labor.

Importantly, this case demonstrates the usefulness of point-of-care transabdominal ultrasonography (POCUS) in the evaluation and management of acute abdominal pain in pregnancy. Ultrasonography is a useful diagnostic tool for the detection of hemoperitoneum, visualized as free fluid in the abdomen or pelvis, especially in the setting of blunt and penetrating abdominal trauma [24-25]. In a patient with acute blunt or penetrating abdominal trauma, Focused Assessment with Sonography in Trauma (FAST) exam has a reported sensitivity of 69-98% for the detection of hemoperitoneum, with the higher ranges reported for patients with hypotension following trauma [26-27]. The specificity of FAST exam for free fluid in this patient population is reportedly 94-100% [26]. Follow up reviews have found that in hemodynamically stable patients the sensitivity may be as low as 22-28%, therefore serial exams and/or follow up imaging are recommended [28].

Among pregnant patients presenting with acute blunt or penetrating abdominal trauma, FAST exams have a sensitivity of 61-85% and specificity of up to 99% for the detection of intraperitoneal free fluid; this is similar to the
non-pregnant population [26, 27, 29-31]. For image acquisition, obtaining the pelvic views for evaluating free fluid in the pouch of Douglas may be more difficult secondary to the gravid uterus [26]. Nevertheless, there are no recommendations that the FAST exam be modified regarding how to obtain the standard FAST exam images when evaluating a pregnant patient with abdominal trauma. Compared to non-pregnant patients, ultrasound for the identification of hemoperitoneum may be associated with higher false positives secondary to increased physiologic free fluid [29]. However, specificity and negative predictive value for ruling out free fluid appear to be similar between pregnant and non-pregnant patients. Thus, while pregnant patients may have increased physiologic free fluid at baseline, when presenting with abdominal trauma and FAST scan is negative, this is reassuring for ruling out active bleeding and further diagnostic workup may be warranted pending overall maternal and fetal status.

In the present case, POCUS showed significant free fluid in the pelvis in the bilateral lower quadrants concerning for hemoperitoneum. The differential diagnosis included uterine rupture, placental abruption, fibroid rupture, fibroid necrosis, rupture of adnexal mass, as well as vascular and gastrointestinal etiologies. Although uterine rupture and placental abruption are not usually diagnosed with ultrasound, POCUS in the present case allowed for the rapid identification of intra-abdominal hemorrhage with reasonable certainty. Whereas POCUS did not rule in or out specific etiologies in this case, it appropriately identified a concerning intra-abdominal process necessitating urgent intervention. While the patient did not have a history of blunt or penetrating abdominal trauma, her overall clinical presentation was concerning for acute hemorrhage. In the context of tachycardia, rebound tenderness, and ultrasonographic signs of intra-abdominal bleeding, the decision was made to proceed with emergency exploratory laparotomy and delivery. With the use of FAST exam, intraabdominal bleeding was identified without requiring transport to CT scanning or serial lab monitoring, and she was transported to the operating room for stabilization, likely preventing further clinical deterioration. Ultrasound was therefore a useful tool in the present case for the urgent triage of a pregnant patient presenting with signs and symptoms of an acute abdomen potentially requiring surgical intervention.

Outside of obstetrics, the use of POCUS for the evaluation of unstable patients has been utilized in the fields of emergency medicine, anesthesia, and critical care. For example, the use and interpretation of bedside ultrasound are training requirements in these fields [32-34]. Additionally, the FAST exam skillset is readily taught in general surgery residency in order to appropriately evaluate patients with trauma/critical illness and formal training for POCUS has been developed by the American College of Surgery [35,36]. Furthermore, POCUS skillsets are becoming widely adopted throughout medicine as the American Association of Family Physicians, the American Board of Anesthesiology, the Society of Critical Care Medicine, the American College of Emergency Physicians, as well as the Society for Hospital Medicine have all developed formal training curricula for POCUS [37-41]. The American College of Physicians has also committed to developing curricula, guidelines, and training for POCUS, further demonstrating the rapid uptake of these skillsets throughout clinical medicine [42]. However to date, there are no formal training requirements for emergency POCUS skills for obstetrics and gynecology residents.

As the present case highlights, POCUS was vitally important for the evaluation and management of an obstetrical patient with an urgent clinical condition. Given that POCUS is a readily accessible and inexpensive imaging modality, formal training in these techniques like FAST exams should be included in obstetrics and gynecology residencies. Evaluation of obstetrical parameters like fetal growth and cervical length as well as gynecological assessment of the adnexa and endometrium are ultrasonographic skillsets taught during training. Combining basic familiarity in gynecological evaluation of fibroids, for example, along with emergency POCUS skills would allow for further ability to develop a differential and management plan for patients presenting with acute abdominal pain. With this basic familiarity in use of ultrasound, training in POCUS would not require significant burden regarding use of equipment or availability of machines. Obstetrics and gynecology residents will encounter patients with urgent clinical conditions in which POCUS may be helpful, such as in patients with ruptured ectopic pregnancy, postpartum hemorrhage, and abdominal trauma in pregnancy. Beyond the abdominal cavity, POCUS may be useful for the cardiothoracic systems as well for the evaluation of peripartum shortness of breath, post-operative hypoxia/fever, and other clinical presentations in which evaluation of the lung, pleura, and pericardial spaces may be beneficial for the triage of critically ill patients [43-44]. Given that obstetrics and gynecology residents already receive training in basic obstetrical ultrasound technique, the addition of formal training in selected emergency POCUS techniques will further serve their ability to appropriately triage patients with critical illness that they may encounter.

In review, this case highlights the importance of considering spontaneously ruptured fibroid when triaging a pregnant woman with acute onset of severe abdominal
pain, even without a history of prior myomectomy. The present case also highlights the usefulness of POCUS to aid in the medical decision making when evaluating a pregnant patient with severe abdominal pain. When an acute surgical abdomen is suspected in pregnancy the FAST exam is a quick and useful tool during triage. Obstetrics and gynecology residency programs should consider implementation of formal training in POCUS.

The patient consented to the use of de-identified information as well as the operative images. She provided full verbal consent for the publication with the understanding that while all information will be de-identified, absolute anonymity cannot be guaranteed.

Disclosures

The authors have no conflicts of interest to declare.

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The PEGASUS Games: Physical Exam, Gross Anatomy, physiology and UltraSound Games for Preclinical Medical Education

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Abstract

Introduction: Gamification engages learners and has successfully taught point-of-care ultrasound (POCUS) to residents and fellows. Yet ultrasound (US) curricula in undergraduate medical education remains limited. This study assessed a gamification model integrating US, anatomy, physiology, physical examination, and radiology created for preclinical medical students as compared with traditional didactic education. Methods: Twenty first-year medical students participated in a session on neck and thyroid material. Students were randomly assigned to a game or non-game group. Game students participated in games incorporating thyroid US with exam maneuvers, other imaging modalities, physiology, and pathology. Non-game students were taught the same material with an instructor. Students were assessed with a pretest and immediate and delayed post-tests. Group differences and scores were assessed using t-tests. A Likert scale evaluated learners’ opinions of the educational experience. Results: The game group performed better than the non-game group on the immediate post-test (p = 0.007, CI = [0.0305, ∞]). There was no significant difference between the groups on the delayed post-test (p = 0.726, CI = [-0.120, ∞]). Students in both groups felt more confident in their knowledge of the material, and all students in the game group agreed that the games encouraged teamwork. Most (9/10) stated the games allowed them to learn the material more effectively and would like to see more gamification (8/10). Conclusion: This US education model incorporating gamification for preclinical medical students promotes teamwork and is as effective for learning material than a traditional learning model. Students additionally convey a positive attitude towards gamification.

Background

In recent years, point of care ultrasound (POCUS) has been increasingly incorporated into the bedside evaluation of patients by many different medical specialties. POCUS does not replace formal ultrasound (US) studies, but it can quickly provide information that may be life-saving for patients [1]. Previous studies have demonstrated that intensivists and residents alike can be taught focused cardiac echocardiography with findings that consistently agree with those of experienced echocardiographers [2,3]. As POCUS increases in value as a safe and evidence-based tool, medical schools have begun to incorporate US into the physical examination, anatomy, and physiology curricula. Requirements for US education have been established at the graduate level, but integration of US into undergraduate medical education in the United States has varied across institutions [4]. Some have successfully piloted US training as early as the preclinical years of medical education [5,6], highlighting the applicability of US to physical examination and anatomy skills. Medical student response to US teaching has been enthusiastic with active student engagement [7,8], and students express interest in pursuing US education [9,10].

Gamification, defined as an approach to teaching and learning where educators design more motivational learning experiences by using methods from game design in non-game contexts [11,12], is an innovative method of instruction that increases learner engagement and aims to affect behaviors and learner attitudes. In a meta-analysis by Sailer and Homner, they reviewed the effect that gamification has had on different types of learning outcomes including cognitive, motivational, and behavioral learning as compared with conventional instructional methods and found a small but significant positive effect of gamification on each of these learning outcomes [13]. They also found that when a component of social interaction was included, motivational and behavioral learning outcomes can be positively influenced by creating an environment of competition and collaboration. Within medical education, gamification has been successfully used to teach POCUS to residents and fellows, demonstrating an increase in short-term learning and overall satisfaction [14,15]; however, gamification itself remains an emerging and controversial area of education [12]. Furthermore, when US education utilizing gamification is offered at events such as Ultrafest [17], students in all years of medical school are often required to complete the same games, although they have various levels of knowledge and clinical experience.
Additionally, some medical schools have started to incorporate various diagnostic modalities with the physical exam and physiology during the preclinical years [18,19]. US, in conjunction with other diagnostic studies and concepts drawn from physiology, can be used to reinforce students' anatomical knowledge and hone diagnostic skills [5,20]. This study was designed to create a method of education that caters to the knowledge base of preclinical students (first- and second-year medical students) and utilizes game design taken from POCUS education as a vector. This study sought to determine the role of gamification in preclinical education and integration of clinical US, anatomy, physiology, physical examination, and radiology, to compare gamification with traditional education through both short- and long-term recall of material, and to promote self-guided education and teamwork.

Methods

Twenty first-year medical students participated in a two-hour interactive session where they learned neck anatomy and radiology, reviewed thyroid physiology and pathology, and practiced physical exam maneuvers involving the neck as an adjunct to material already discussed in the medical school curriculum in the preceding weeks. All students were novices in POCUS having had less than 30 hours of prior US experience. Students were randomly assigned to a game or non-game group, and all students completed a pretest to gather demographic data, assess prior knowledge about neck and thyroid concepts, and determine if there were any group differences. This study was approved by the university’s Institutional Review Board.

Both groups were taught US basics – anatomical directions, probe selection, and image optimization – through a short instructional video created by study investigators. Students randomized to the game group were then split into teams to complete 3 game stations. At each station, they watched a video created by study investigators relating to the station topic and participated in a self-guided game with time for topic review with a senior medical student following game completion. Students randomized to the non-game group were also split into 3 groups and watched the same videos but were taught the station material through a traditional lecture format. Instructors were senior medical students or residents with significant prior US experience. They were provided with an instructor manual and advised to not deviate from the script in order to standardize the learner experience. The same educational objectives were used for both the game and non-game stations.

Game Stations

The first game station was called “Ball Toss”. Ten plastic cups were arranged in a pyramid shape. Each cup corresponded to a numbered question about thyroid physiology, clinical vignettes, or sonographic images for identification of structures. Each team member took turns attempting to throw a ball from a specified distance into the cups. When they landed a ball in a cup, they received the question assigned to that cup. Team members then worked together to provide a correct answer to the question.

The second game station was an image “taboo” game in which students identified structures in the neck such as the thyroid gland, sternocleidomastoid muscle, and internal jugular vein in CT and MRI images as well as hands-on US scans. One student was asked to describe the structure without using any of the listed “taboo” words while the remaining team members named the correct structure and identified the structure on the image or using a handheld US device. For example, to identify the internal jugular vein on ultrasound, students could not use the words “carotid”, “jugular”, “vessel”, “MRI”, “X-Ray”, “ultrasound”, or “CT”.

During the third game station, “Pin the Tail on the M2”, students were timed while completing 3 physical exam maneuvers: palpating the thyroid gland, drawing a line for the location of a tracheostomy incision, and using color doppler with a handheld US to assess the carotid pulse. Accuracy of thyroid gland palpation was determined using handheld US. Students were timed continuously until the task was completed correctly. Five minutes were reserved at the end of each station to review game answers. Points were awarded for each game.

Assessment and Analysis

Following completion of the interactive session, both groups took one version of two 15-question multiple choice post-tests that assessed the anatomy, physiology, physical exam, radiology, and US topics taught during the session. To ensure similar difficulty between the two post-test versions, medical students in their clinical years volunteered to complete both post-tests prior to the study session. A paired t-test was used to analyze the students’ differences in exam scores between post-test A and post-test B and demonstrated no difference between the two (p = 0.5467). The game group initially received post-test A, and the non-game group received post-test B. Two weeks following the session, both groups took a second post-test – the game group completed post-test B while the non-game group completed post-test A. Due to a mistake in post-test B, question #4 was thrown out of analysis. Three reminder emails were sent to all students.
to encourage completion of the second post-test.

Group demographics were analyzed descriptively. Group differences in pre- and post-test scores were assessed using paired t-tests as well as covariant analyses adjusting for prior US experience. Student experience was evaluated using Likert scales that was then assigned a numerical value for analysis (strongly disagree = 1, strongly agree = 5). Analysis was performed using Jamovi (The jamovi project (2019). jamovi (Version 0.9)).

**Results**

Demographics and prior US experience of the student in both the game and non-game group are depicted in Table 1.

There were 10 students in each group. The majority of students in both groups were male and had completed a degree related to science or healthcare. Most (19/20) students had less than 10 hours of prior US experience. One student listed 30 hours of prior US experience. Average US experience in the game group was 1.9 hours and 4.65 hours in the non-game group (p = 0.395).

Detailed information about individual student pretest and post-test scores can be found in Table 2.

There were no statistically significant group differences on the pretest when comparing prior knowledge of the session topics between two groups (p = 0.4313, CI = [-0.0966, 0.217]). The game group scored higher than the non-game group on the post-test immediately following the session (p = 0.007, CI = [0.0305, ∞]). There was no significant difference between the groups’ performances on the delayed post-test (p = 0.810, CI = [-0.110, ∞]). When controlling for prior US experience, the game group still did significantly better than the non-game group (p = 0.003) on the immediate post-test while there was still no difference between two groups on the delayed post-test (p = 0.265). Of note, all 10 students in the game group completed the second post-test while only 8 students in the non-game group completed it.

Students in both groups rated their confidence of their knowledge of the material higher following the session. When asked to rate the educational value of the activities the students participated in, those in the game group reported a higher educational value than those in the non-game group (p = 0.010, CI = [0.217, 1.18]). Figure 1 depicts the questions asked of students in both groups regarding overall satisfaction and compares the average response of each group.

All (10/10) of the students in the game group agreed or strongly agreed that the games encouraged teamwork. Most (9/10) felt the games taught the material more effectively than didactic educational methods and did not hinder their learning of the material. Most (8/10) also stated that they would like to see more gamification in their medical school curriculum.

**Discussion**

The preclinical years of medical education are undergoing rapid innovation as curricula shifts away from the classroom and towards online learning [21]. Nationally, nearly 25% of second-year medical students reported they almost never attended class during their preclinical years [22]. This educational model threatens

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**Table 1. Group Characteristics**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Game Group</th>
<th>Non-game Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender, n</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
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<tr>
<td>Female</td>
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<td>3</td>
</tr>
<tr>
<td>Prefer not to say</td>
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<td>23.4y</td>
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<tr>
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</tr>
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</tr>
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<td>9</td>
<td>5</td>
</tr>
<tr>
<td>No</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Ultrasound experience, mean hr*</td>
<td>1.9hr</td>
<td>4.65hr</td>
</tr>
</tbody>
</table>

*Most students (19/20) had <10 hours of previous ultrasound experience; 1 student in the non-game group reported 30 hours (p = 0.395)
important components of preclinical education such as hands-on physical exam techniques and diagnostic methods and undermines continued reinforcement of teamwork amongst peers. The ability to work on a team is essential for effective and efficient healthcare delivery. Creating a curriculum that integrates many clinical disciplines can help preclinical medical students synthesize concepts and better prepare for the wards. For example, Alerhand et al. demonstrated that it was feasible to create a POCUS curriculum which integrated anatomy, pathophysiology, and the physical exam for first-year medical students in their renal course and that students found it increased confidence in their understanding of the material [23]. This study similarly demonstrated that the integration of US, radiology, physical exam, and physiology is effective as a learning adjunct for preclinical medical students and also promotes teamwork amongst them. Unlike in Canada where The Canadian Ultrasound Consensus for Undergraduate Medical Education Group has recommended 85 US curricular elements for inclusion in all Canadian medical schools including the use of peer teachers, small-group scanning, simulation, and interprofessional training, medical education in the

<table>
<thead>
<tr>
<th>Group</th>
<th>Prior Ultrasound Experience (hr)</th>
<th>Pretest Score (%)</th>
<th>Immediate Post-test Score (%)</th>
<th>Delayed Post-test Score (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Game group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student 1</td>
<td>1.5</td>
<td>60.0%</td>
<td>93.3%</td>
<td>85.7%</td>
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<tr>
<td>Student 2</td>
<td>3.0</td>
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<td>80.0%</td>
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<tr>
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<td>93.3%</td>
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<td>80.0%</td>
<td>100.0%</td>
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<td>86.7%</td>
<td>78.6%</td>
</tr>
<tr>
<td>Student 7</td>
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<td>71.4%</td>
</tr>
<tr>
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<td>100.0%</td>
<td>85.7%</td>
</tr>
<tr>
<td>Student 9</td>
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<td>100.0%</td>
<td>92.9%</td>
</tr>
<tr>
<td>Student 10</td>
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<td>40.0%</td>
<td>93.3%</td>
<td>85.7%</td>
</tr>
<tr>
<td>Mean, SD</td>
<td>2.0, 2.9</td>
<td>64.0%, 12.6%</td>
<td>94.7%, 5.6%</td>
<td>86.4%, 8.9%</td>
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<tr>
<td>Non-game group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student 1</td>
<td>1.0</td>
<td>40.0%</td>
<td>78.6%</td>
<td>86.7%</td>
</tr>
<tr>
<td>Student 2</td>
<td>0.5</td>
<td>40.0%</td>
<td>85.7%</td>
<td>86.7%</td>
</tr>
<tr>
<td>Student 3</td>
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<td>60.0%</td>
<td>92.9%</td>
<td>93.3%</td>
</tr>
<tr>
<td>Student 4</td>
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<td>78.6%</td>
<td>78.6%</td>
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<tr>
<td>Student 5</td>
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<td>80.0%</td>
<td>92.9%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Student 6</td>
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<td>40.0%</td>
<td>78.6%</td>
<td>Did not complete</td>
</tr>
<tr>
<td>Student 7</td>
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<td>60.0%</td>
<td>100.0%</td>
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</tr>
<tr>
<td>Student 8</td>
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<td>40.0%</td>
<td>78.6%</td>
<td>73.3%</td>
</tr>
<tr>
<td>Student 9</td>
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<td>100.0%</td>
<td>92.9%</td>
<td>93.3%</td>
</tr>
<tr>
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<td>60.0%</td>
<td>85.7%</td>
<td>86.7%</td>
</tr>
<tr>
<td>Mean, SD</td>
<td>4.65, 9.1</td>
<td>58.0%, 19.9%</td>
<td>83.6%, 7.9%</td>
<td>87.3%, 8.5%</td>
</tr>
</tbody>
</table>

* The game group took post-test A immediately following the session and post-test B 2 weeks following the session. The non-game group took post-test B immediately following the session and post-test A 2 weeks later.
United States has no such consensus[24,25,26]. POCUS, particularly when taught using hand-held portable US devices, is well-suited to teaching US as an adjunct to the preclinical medical school curriculum. It can be incorporated easily through the use of trained senior medical student peer instructors[27] or interprofessional near-peers[28], especially when access to expert faculty is limited. While US education in the United States has no standardization, this study provides additional evidence to the increasingly growing body of research that medical students desire an US education prior to graduation[7,8,10].

Using gamification in this study increased student confidence, teamwork, autonomy, and motivation to learn by allowing for active learning to promote material retention. Yet the influence of gamification in education remains controversial [12]. Proponents of gamification in education believe the goal of gamification is to encourage an environment that supports learning and productive social interactions, and students seem to perceive this educational environment positively. On the other hand, gamification can be complex and competitive, something that may cater predominantly to learners who are proactive and intrinsically motivated. Other gamification models used in POCUS education have demonstrated a positive cognitive and behavioral effect for learners. Students in the SonoSlam national medical student US competition [16] and SonoGames resident competition[29] reported increased confidence and clinical performance. An US game to enhance learning of gastrointestinal anatomy and physiology for first-year medical students by measuring blood vessel velocity was successful in increasing student interaction [30]. This study, too, found that a game model is effective for material retention, at least in the short-term, increases student confidence in the material, and is positively received. But like prior studies, this study failed to demonstrate any differences in long-term retention of the material when comparing student knowledge for those who participated in the games with those who received traditional didactic education.

There is no one right way to incorporate POCUS into medical education. Students prefer small-group educational sessions as compared with large groups [31]. They also report that hands-on practice and the use of video clips in contrast to lectures and still images are more practical for learning [31]. The use of portfolios in higher education has also been shown to foster an improvement in knowledge and understanding of
material, increase personal responsibility for learning, emphasize reflection and engagement [32,33] and may be an additional adjunct to POCUS education. This study adds to the body of literature that demonstrates that gamification is a feasible and well-received method to incorporate POCUS into medical education.

Limitations
The major limitation of this study is the small sample size, though the strength of the study comes from being the first study to compare a group of students who participated in US games to those who participated in a traditional didactic format. The scope of this study was also narrow, as only thyroid and neck material were covered. Results of this study might not hold true for gamification models encompassing other organ systems or for POCUS education as a whole.

Additionally, the material covered in the session aligned with the information students were learning during regular curricular lectures and small group learning. Between the post-test immediately following the session and the delayed post-test, students may have studied the information in variable amounts, affecting retention of the material due to the session education alone. Selection bias may have also influenced results. It is conceivable that if the non-responders had completed the delayed post-test, this may have influenced the outcome.

Conclusions
This ultrasound education model incorporating gamification for preclinical medical students promotes teamwork amongst peers and is as effective, if not more effective, for learning material and retaining knowledge than a traditional learning model. Students appear to react positively towards gamification and feel that it improves their learning and understanding of concepts. Future research should continue to test the use of gamification and US to teach other organ systems and at other stages of medical education. Future studies should also create new games to compare effectiveness of different applications of gamification to education. Although our study did not find an impact of gamification on long-term material retention, future trials should continue to assess if gamification increases information retention in different settings.

Disclosures
The study authors have no disclosures or conflicts of interest to report.

Statement of Ethics Approval/Consent
All subjects who participated in this study gave informed consent. This study was approved by the IRB at Case Western Reserve University.

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References


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Focused Cardiac Ultrasound Curriculum for Internal Medicine Residents

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Abstract

Background: Focused cardiac ultrasound (FCU) is a safe and efficient diagnostic intervention for internal medicine physicians. FCU is a highly teachable skill, but is used in routine cardiac assessment in only 20% of surveyed training programs. We developed an FCU curriculum for internal medicine residents and an assessment tool to evaluate the impact of the curriculum on trainee knowledge and confidence. Methods: Internal medicine residents rotating through clinical cardiology services underwent 30 minutes of didactic and 60 minutes of hands-on teaching on acquisition and interpretation of FCU. A 20 item pre and post-curriculum online survey was administered (November 2018-December 2019) to assess confidence and knowledge in FCU. Results: 79 of 116 (68%) residents completed the pre-survey and 50 completed the post-survey, of whom 34 received the curriculum. The mean change in confidence score in those who received versus did not receive the curriculum was 0.99 versus 0.39 (p=0.046) on a 5-point Likert scale. Among 33 residents who had paired pre- and post-surveys the mean change in confidence score was 1.2 versus 0.85 (p=0.001) in those who received versus did not receive the curriculum. The mean increase in knowledge score was 13% versus 7% respectively (p=0.001). Conclusions: We instituted a novel curriculum for internal medicine residents to gain experience in image acquisition and interpretation. Both confidence and knowledge in FCU improved following the curriculum, indicating that this is a highly teachable skill. Additional analysis of the of the FCU study images will be useful for informing future interventions.

Background

Focused cardiac ultrasound (FCU) has gained immense traction within health systems as an opportunity for a safe, efficient, and cost-effective diagnostic tool [1-3]. In an era of digitization and speed, the physical examination is being complemented by a more comprehensive and accurate sonographic cardiovascular assessment [4].

Several studies show that FCU is a highly teachable skill at all educational levels including medical students, residents, and hospitalists [5-7]. Brief training modules can prepare residents sufficiently to diagnose left ventricular systolic dysfunction on images they obtain and interpret compared to transthoracic echocardiogram images interpreted by a level 3 trained echocardiographer [5]. Handheld ultrasounds allow physicians to detect pathology in a timely manner and potentially decrease downstream cost of unnecessary testing [6]. Interestingly, abnormalities detected on FCU have also been shown to predict readmission for heart failure better than any of the standard risk factors including patient comorbidities and biomarkers [7].

The Accreditation Council for Graduate Medical Education states that internal medicine residents should be exposed to sonography to develop competency in bedside sonography, however specific training methodologies are not published [8]. Trainees commonly miss critical cardiac pathological findings and misjudge volume status based on visual jugular venous pressure assessment [9]. Numerous studies, however, have shown that trainees can learn bedside ultrasonography to arrive at accurate clinical assessments [5,6,10-12]. Despite this, a recent national survey of medical education leaders revealed that in routine clinical practice cardiac and volume assessment using bedside sonography was done in 20% of training programs even though the perceived usefulness was rated 3.9 on a 5 point scale [13]. In that same study, only 25% of the programs reported having a formal curriculum [1].

Though several informal curriculums exist, there is sparse data demonstrating the quantitative impact of such curriculums on medical residents. [14,15] We developed an FCU curriculum for internal medicine residents and an assessment tool to evaluate resident knowledge of FCU as well as confidence in image acquisition and interpretation.

Methods

The inpatient cardiology rotations at our institution consist of the cardiac care unit and the cardiac intermediate care unit where four residents rotate on each of these services...
for two weeks at a time. Our FCU curriculum was embedded into the longitudinal cardiology curriculum already in existence for these rotations. The curriculum consisted of a 30-minute didactic session focusing on principles of cardiac ultrasound, instrumentation, image acquisition, optimization, and interpretation and a 60-minute precepted hands-on session where residents practiced image acquisition on patients admitted under their care guided by a facilitator. Two devices, the Sonosite Xporte and the Sonosite EDGE 2 (FUJIFILM, Washington, USA) were used to practice all image acquisition. The curriculum was administered or withheld on alternating 2-week blocks to generate two cohorts of residents: those who received and those who did not receive the curriculum.

Residents completed pre-curriculum and post-curriculum surveys that were developed by our research group assessing their confidence and fund of knowledge in image acquisition, interpretation, and clinical integration of findings (online supplementary Table S1). Confidence was assessed on a 5-point Likert scale (1-Not at all confident, 2-Only slightly confident, 3-Somewhat confident, 4-Moderately confident, 5-Very confident). If a resident received the curriculum more than once we used only the first paired pre- and post-curriculum surveys for analysis. In order to minimize contamination, we eliminated all duplicate unique identifiers and those who reported taking the curriculum chronologically before the pre-curriculum survey. Change in confidence and percent correct on the knowledge questions was analyzed via a paired t-test. P value was set at 0.05 for significance.

Results

Seventy-nine of 116 (68%) residents who rotated through cardiology between November 2018 and December 2019 completed the pre-curriculum survey and 50 residents completed the post-curriculum survey. Of those 50, 34 residents reported having received the didactic and hands-on curriculum. The residents were evenly distributed among PGY level. 58% (46/79) had never received any form of Point of Care Ultrasound (POCUS) curriculum prior to the study (Table 1). The mean confidence score increased by 0.80 on a 5-point Likert scale and the mean knowledge score increased by 7% in the total population. Among those who received the curriculum, the mean change in confidence score was 0.99 compared to 0.39 in those who did not receive the curriculum (p<0.05, Table 2). The mean change in knowledge score from pre- to post-survey was not significantly different in the two groups (8.7% in the group that did receive the curriculum compared to 9.2% in the group that did not receive the curriculum, p=0.88, Table 2).

Thirteen residents took both the pre and post-surveys, of whom 76% (25/33) stated that they had received the curriculum. There was a 13% mean increase in knowledge score in the group that received the curriculum compared to 7% increase in the group that did not receive the curriculum (p<0.001, Table 2). While confidence scores improved regardless of whether the resident had received the curriculum, there was a statistically significant greater increase in mean confidence scores among residents who received the curriculum versus not (1.20 vs 0.85, p<0.001, Table 2).

For the confidence assessment, two questions in the acquisition domain were identified as most able to discriminate whether the resident had received the curriculum. The mean confidence score in optimization of image quality with knob manipulation including gain and depth decreased (3.3 to 3.2) in those who did not receive the curriculum and increased in those who did (3.3 to 3.5). Residents who had the curriculum experienced a greater increase in confidence in correctly identifying cardiac anatomy compared to residents who did not receive the curriculum (3.0 to 3.5 vs 3.0 to 3.1).

Discussion

This study adds to the growing body of literature on the development and assessment of FCU curricula. Our results demonstrate that internal medicine residents at our institution have a high fund of knowledge in FCU interpretation, albeit with some heterogeneity. Confidence and skill in image acquisition were incrementally improved with the addition of a hands-on curriculum.

Although the mean knowledge score improved in all residents, the subset of residents who had matched pre-
and post-survey data showed that there was a statistically significant higher increase in score in the group that received the curriculum. This speaks to the benefit of an FCU curriculum to address specific knowledge gaps and provide a space in which to clarify questions with FCU experts on material residents may have learned through clinical practice. This may have also occurred because the didactic portion of the curriculum provided a dedicated space to learn the material in close proximity to the survey, increasing scores overall in that group. This is consistent with existing literature showing that bedside ultrasound (cardiac, lung abdomen, etc.) is a teachable skill to internal medicine residents [2,3].

It has been shown in several POCUS curricula that hands-on teaching improves competency and confidence in independent image acquisition and interpretation [2-4]. We re-demonstrated this in our study among a population of highly trained internal medicine residents already receiving clinical teaching on FCU. After a short didactic and hands-on session, residents felt substantially more comfortable in optimizing images with knob manipulation and identification of cardiac anatomy. Whether the skills acquired in the hands-on portion of the curriculum translate into improved FCU images acquired subsequently in clinical care is a worthwhile research question to pursue.

The pre- and post-curriculum assessment tool is a novel addition to existing literature as it provided a way of discriminating between those who did and did not receive the curriculum. While there exist competency assessments for individualized curriculums, our tool remains purposefully broad to encompass the basic tenets any FCU curriculum would cover thus enhancing its external validity.

Several limitations should be noted. This study was conducted at a large single center academic internal medicine residency program and thus repeated studies are warranted to ensure external validity. Importantly, high pre-curriculum knowledge scores indicate that residents who rotate through cardiology benefit from existing methods of ultrasound teaching on rounds and during clinical care. Thus, the benefit of the intervention in this study may be more attenuated than in other programs. Resident self-reporting may have limited the impact assessment of our curriculum. Residents who attended the curriculum were more likely to fill out a post-curriculum survey, and there was drop off in participation between the pre- and post-surveys. Despite these limitations, our study successfully demonstrated the additive benefit of a hands-on curriculum in teaching FCU to internal medicine residents. Future studies will help us understand the endurance of the curriculum, retention of knowledge and skill, and the effect it may have on clinical care.

**Conclusion**

We instituted a novel curriculum for internal medicine residents to learn FCU and gain experience in image acquisition and interpretation resulting in improvement in confidence and knowledge in FCU.

**Statement of ethics approval/consent:**

This study was approved by the Penn Institutional Review Board and each resident provided informed consent included in the online survey to participate in the study.

**Disclosures**

The authors declare no conflicts of interest.

**References**


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**Table 2. Confidence and Knowledge Scores**

<table>
<thead>
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<th>Total Study Population</th>
<th>Matched pre- and post-assessment Population</th>
</tr>
</thead>
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<tr>
<td></td>
<td>Curriculum (n=34)</td>
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<tr>
<td>Mean change in confidence score</td>
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</tr>
<tr>
<td>Mean change in knowledge score</td>
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Surgeon Performed Ultrasound for Diagnosis of Intussusception - A Pilot Study

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Abstract

Aim: To study the diagnostic accuracy of surgeon performed ultrasound (SPU) in the diagnosis of children presenting with clinical suspicion of intussusception to a tertiary paediatric facility in NSW, Australia. Methods: Children under the age of 16 presenting to the emergency department with clinical features suggestive of intussusception were recruited. After obtaining consent SPU was performed by a Paediatric surgeon. All patients subsequently had an ultrasound performed in radiology department (RPU) on which management was based. Diagnosis and images of SPU were reviewed by an independent radiologist blinded to results of the formal study. Results: Of 7 children enrolled 5 were male. Age ranged from 3 months to 7 years (mean 2.64, SD 2.282), weight from 5.2kgs to 25.2kgs (mean 13.69, SD 6.721). Five out of the 7 children presented during day hours i.e. 8a.m.-5 p.m. (mean 12.72, SD 4.049). Mean time to SPU was 6.3 hours (SD7.1) and RPU was 8.3 hours (SD 7.6). SPU was earlier by 2 hours and correlation between SPU and RPU was 100 percent. Conclusion: SPU for intussusception can be performed early and accurately. Surgeons should train and use ultrasound as a reliable tool in evaluating the child with suspected intussusception.

Introduction

Intussusception is an abdominal emergency that affects all ages but infants most commonly and can cause significant morbidity and mortality if missed [1, 2]. Clinical presentation of intussusception can be varied and non-specific and imaging (primarily ultrasound) is usually performed to confirm diagnosis [1]. Abdominal radiographs may be non-specific and contrast studies involve ionising radiation. Ultrasound (US) has evolved as the gold standard imaging for diagnosis because of its high accuracy [2]. It is also used to guide reduction of intussusception in some centres while in most institutions air enema under fluoroscopy is still the treatment of choice [3-5]. Surgery is reserved for failed pneumatic reductions, delayed presentations or complications such as perforation. We have anecdotally noticed many infants with intussusception present after hours, as have other authors [1], when sonographers may not be available and have to be recalled. This may contribute to delay in diagnosis, treatment and also has financial implications for the institution. A surgeon performed point of care ultrasound (POCUS) at the time of clinical examination should lead to earlier diagnosis and treatment. This pilot study sought to assess diagnostic accuracy and timeliness of SPU compared to Radiology Performed Ultrasound (RPU) in a tertiary paediatric hospital in NSW, Australia.

Methods

This was an ethics approved (HREC 11/CHW/27) study performed at The Children’s hospital at Westmead, a tertiary Paediatric hospital in New South Wales Australia. The hospital serves a population of 2.02 million (0-16) with 50,000 presentations to the emergency annually. Infants with a suspected diagnosis of intussusception referred to the surgical department were considered for the study. The surgical registrar offered the study to the families after assessing the infant. Ultrasound request for RPU was placed after surgical assessment and surgeon was also contacted at same time for SPU. US were performed by only one surgeon (first author) if the family agreed to participate in the study. RPU was performed by the sonographer who was on for the day. The first author has been performing FAST scans for 17 years and ultrasound guided central venous cannulation for 10 years. All enrolled children also had a RPU on which treatment was based. Study population was a convenience sample as we depended on the assessing doctor to contact the surgeon and it is likely the surgeon was not contacted for all eligible cases.

Technique: Sonosite M-Turbo mobile ultrasound (Sonosite Inc ,Washington, USA) was used for the studies. Three different probes were used as needed- C60 2-5MHz curved probe with 30cm scan depth for
older children (>6years), C11 5-8MHz curved probe with scan depth of 10cm for children under 6 and HFL38 6-13MHz linear transducer with scan depth 6cm (Figure 1). With the patient in supine position, curvilinear transducer was used to examine the whole abdomen looking for any masses of non-peristaltic bowel. If a mass suggestive of an intussusception was identified, a linear probe was used to demonstrate a target sign in the transverse axis and/or a pseudokidney sign in long axis and its dimensions measured. Presence or absence of fluid between bowel loops was documented. Doppler study was performed to document vascularity within the mass. RPU was performed with ultrasound equipment in radiology department not the Sonosite used by the surgeon.

A radiologist blinded to the results of RPU reviewed all SPU studies to assess adequacy of films and diagnosis. Gold standard was the result of RPU. Patient details and US findings were recorded on a predesigned data collection form and entered into an Excel file (Microsoft, Redmond, WA). Time to scan from referral time was documented. Patient outcomes were also recorded, including admission for observation, operative intervention or discharged (online Table S1). Readmissions and other investigations performed were recorded. Data was analysed using the IBM SPSS V22.0 statistical software. Descriptive analyses were applied to the data using means, standard deviations, median, range, frequencies, and percentages in accordance to the nature of the variables. Comparisons of means were conducted using paired t-tests for continuous variables.

Results
Over a one year period 7 children with suspected intussusception were recruited into the study. Five were boys. Age ranged from 3 months to 7 years (mean 2.64, SD 2.282), weight from 5.2kgs to 25.2kgs (mean 13.69, SD 6.721). Five out of the 7 children presented during day hours (mean 12.72, SD 4.049). Mean time of presentation of infant was midday. Mean hour of the day for SPU was 12.3 hours (SD 2.9) and RPU was 14.3 hours (SD 2.7). Mean time to SPU was 6.29 hours and RPU was 8.28 hours from time of presentation to ED. One child had a second presentation within a week of the initial presentation. Mean time difference was 2 hours in favour of SPU. Paired t-test comparing time of surgeon performed ultrasound and radiology performed ultrasound was significantly $p=0.003$ in favour of SPU.

Three out of the seven cases had intussusception (Figure 2) correctly diagnosed by both surgeon and radiology, with no false positives or false negatives. All three cases had target and pseudokidney sign demonstrated and were successfully reduced by air enema. The child with two presentations had both successful air enemas on both occasions. An independent radiologist agreed with the diagnosis of SPU in all cases (Kappa 1.00, $p=0.008$).

Discussion
Intussusception is the commonest surgical emergency in infancy [5]. US has emerged as the investigation of choice for diagnosis and has a sensitivity of 98-100% and specificity of 88-100% [1, 6, 7]. We compared SPU to RPU in this study and demonstrated SPU could be
performed earlier and was accurate in diagnosis when performed by an experienced consultant surgeon. False positive studies are uncommon and usually due to faecal matter mistaken for intussusception [7]. Only one of the previous studies on POCUS has been by Paediatric surgeons [10] and our study adds to the existing literature supporting POCUS for diagnosis of intussusception.

Over the last decade point of care ultrasound (POCUS) has become routine in many paediatric emergencies for a variety of clinical scenarios [6]. Paediatric surgeons however, have been slow to adopt POCUS and this study looked at use of SPU to diagnose intussusception. Inspite of the low numbers the surgeon’s interpretation of the studies matched the radiology diagnosis in all the cases. POCUS by clinician for diagnosis of intussusception has been shown to reduce time in making diagnosis aiding higher success of reduction[6, 7]. In our study SPU was performed 2 hours earlier than RPU. The time difference could have been longer if SPU was performed at the time of assessment by the surgical registrar. It was performed by a consultant amidst the rest of his clinical duties SPU is a natural extension of clinical examination and may decrease the need to call in a sonographer for diagnosis. Brian et al. retrospectively reviewed POCUS diagnosed intussusceptions over a five year period and demonstrated small bowel intussusceptions were more common than classical ileocolic intussusception [8]. In our study all cases were ileocolic intussusceptions. A recent meta-analysis analysed 30 studies on diagnosis of intussusception at all ages of which 7 were POCUS based studies. They concluded the diagnostic accuracy of POCUS was not significantly different from that of RPU [9].

Limitations of our study include the small numbers and scan being performed by a surgeon who performed them along with other clinical duties. This may have caused some delay in SPU. Diagnosis by SPU may avoid calling in a sonographer but a radiographer and radiologist would still need to be called in for the pneumatic reduction. An extension of the use of SPU would be ultrasound guided reduction that would obviate the need to call in radiology staff and reduce radiation exposure as demonstrated by S. Gfroerer and colleagues [10]. POCUS has demonstrated increased patient satisfaction as there is more interaction with the clinician, reduced patient movement and earlier diagnosis [7, 11].

This study is the first of its kind in Australasia demonstrating use of ultrasound by a surgeon in diagnosis of intussusception and we hope will stimulate use in emergency departments by emergency physicians and surgeons.

Disclosures
The authors have no conflicts of interest to declare.

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Measurement of the Applicability of Abdominal Point-of-Care Ultrasound to the Practice of Medicine in Saudi Arabia and the Current Skill Gaps

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Abstract

**Background:** Renal, gastrointestinal, and hepatic pathology, and the resources available for their management vary internationally. Whilst abdominal point-of-care ultrasound (APOCUS) should enhance management, uptake by physicians, worldwide, has been poor. So, the aim of this study was to explore the applicability of APOCUS to medical practice in Saudi Arabia, residents’ current ability to perform APOCUS, and the skill gaps. **Methods:** A validated questionnaire was distributed to the internal medicine residents at our institution to determine their ability to perform APOCUS (self-reported), and obtain their opinions on its applicability for the detection of hepatomegaly, splenomegaly, hydronephrosis, and ascites. **Statistical analysis:** Standard descriptive statistical techniques were used. Categorical data, presented as frequency, were compared using the χ² test. The Likert scale responses, presented as mean ± standard deviation, were compared with a t test or analysis of variance. **Results:** Ninety-eight residents participated (response rate 90.7%). Abdominal POCUS is very applicable to their practice. The use of APOCUS to detect ascites was the most applicable (mean 4.61 ± SD 0.69). However, proficiency in APOCUS was poor (mean 1.65 ± SD 1.11). **Conclusions:** The difference between internists’ self-reported ability to perform APOCUS and its perceived usefulness demonstrates a skill gap. Thus, whilst APOCUS is applicable to medical practice in Saudi Arabia, significant skill gaps exist.

Introduction

Diagnostic point of care ultrasound (POCUS) of the abdomen (APOCUS) is a fast, portable, non-invasive, diagnostic tool [1–4]. The diagnostic accuracy of APOCUS for the detection of many intra-abdominal pathologies (e.g., hepatomegaly [3], splenomegaly [4], hydronephrosis [1, 2], and ascites [3]) is excellent. Screening for hepatomegaly, splenomegaly, and ascites is amongst the commonest indications for APOCUS [3, 4], and the management of a patient with abdominal distension can be expedited if the treating physician uses APOCUS to answer the question: “does the patient have cirrhosis and portal hypertension leading to ascites?”

Thus, APOCUS is an invaluable adjunct to bedside diagnostic evaluation [1–6], that should be of great value to internists, nephrologists, gastroenterologists, and hepatologists. However, practicing physicians have been reluctant to integrate this paradigm-shifting technology into their routine practice [1].

It is argued that the availability of radiology services reduces the need for other physicians to perform imaging. However, this is in part because besides radiologists, most physicians lack of familiarity with the use of ultrasound [1]. As APOCUS is relatively new technology, most internists, nephrologists, gastroenterologists, and hepatologists have little or no experience of its use. Furthermore, POCUS is highly operator dependent [7]. To be effective, APOCUS must be performed by competent practitioners [1, 6]. Despite these limitations, there is increasing interest among internal medicine (IM) residents for additional training in ultrasound [8]. Safe, competent, and effective use of POCUS requires training to close gaps in learners’ knowledge and skills [9, 10]. Fortunately, recent data suggests that those keen to learn APOCUS can obtain adequate proficiency with minimal training [3, 11]. However, the integration of APOCUS into routine clinical practice still requires significant initial investment to cover the financial costs and train providers.

Many countries have developed APOCUS curricula for their internists [12–15], and nephrologists [6]. However, Saudi Arabia does not, as yet, have a syllabus for training IM residents or fellows in nephrology, gastroenterology or hepatology in APOCUS. As the Middle Eastern spectra of renal, gastrointestinal and hepatic pathologies differs...
from that in other regions [16], Western clinical practice may not be applicable to Saudi Arabia.

The high initial investment required to develop an APOCUS service must be justified. Thus, to confirm that APOCUS is applicable to the current practice of medicine in Saudi Arabia, an assessment of needs is required [9, 17].

The aim of this study was to determine IM residents’ perceptions on the applicability of APOCUS, and by quantifying their self-reported ability to perform APOCUS; define the skill gaps in tertiary healthcare in Saudi Arabia.

**Subjects and Methods**

**Ethical approval**

Ethical approval for the protocol for this study (RC19/213/R) was obtained from the institutional review board (IRB) of the King Abdullah International Medical Research Center, Riyadh, Saudi Arabia.

**Study design**

This cross-sectional survey of IM residents was performed in King Abdulaziz Medical City, Riyadh; an academic, tertiary referral centre in Saudi Arabia. Procedures followed were in accordance with the ethical standards of the responsible institutional committee on human experimentation and with the Helsinki Declaration of 1975, as revised in 2000.

**Survey development**

Studies describing the applications of APOCUS and the competencies required for its safe practice by internists, nephrologists, hepatologists and gastroenterologists were reviewed [1–6, 9, 12, 18, 19]. Two researchers with expertise in IM, APOCUS, and survey design (MS, and RR) used this literature data to develop a validated questionnaire to investigate the applicability of APOCUS to physicians. The questionnaire had three sections. The first section requested demographic data (i.e. gender, postgraduate year of training) The second section included questions on the applicability of four diagnostic applications of APOCUS (i.e. a needs assessment). The applicability of using APOCUS to detect hepatomegaly, splenomegaly, hydronephrosis, and abdominal free fluid was investigated. For each diagnostic application, participants were asked: How applicable is this indication for APOCUS to your practice? The third section asked participants to describe their ability to perform APOCUS (i.e. knowledge of APOCUS and proficiency in the interpretation of APOCUS findings). This section included a single self-reported question on their knowledge of APOCUS and their proficiency in the interpretation of APOCUS findings. This question was included to provide a summative overview of the respondents’ self-assessed ability to perform APOCUS.

<table>
<thead>
<tr>
<th>Grade</th>
<th>N (RR % PGY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PGY 1</td>
<td>31 (93.9%)</td>
</tr>
<tr>
<td>PGY 2</td>
<td>25 (89.3%)</td>
</tr>
<tr>
<td>PGY 3</td>
<td>23 (82.1%)</td>
</tr>
<tr>
<td>PGY 4</td>
<td>19 (100%)</td>
</tr>
<tr>
<td>Total</td>
<td>98 (90.7%)</td>
</tr>
</tbody>
</table>

After ethical approval, the survey (Appendix 1) was then pilot tested with three paediatric residents to obtain input on survey length, content, and clarity. It was universally agreed that no changes were required.

**Participants**

During the academic year 01/10/18 – 30/09/19 there were 108 IM residents (postgraduate year [PGY] 1–4). Assuming a response distribution of 50%, it was estimated that 85 residents would be required to participate to obtain a 5% margin of error at a level of confidence of 95%. All IM residents at our institution were invited to participate. The final paper questionnaire was distributed to IM residents in August 2019. No incentives were provided. Written informed consent was obtained before participation in the survey.

**Study outcomes**

A 5-point Likert scale (1 very poor, 2 poor, 3 fair, 4 good, 5 very good) was used to assess the perceived applicability of four indications for APOCUS in the practice of IM in Saudi Arabia. The same 5-point Likert scale was used to assess self-reported ability to perform APOCUS. The skill gap in APOCUS was determined from the difference between residents’ perception of the applicability of APOCUS to their practice and their self-reported ability to perform APOCUS.

**Statistical analysis**

The data were analysed using standard descriptive statistical techniques. The final analysis included all responses. The Cronbach’s alpha coefficient was used to determine the internal consistency of the subgroups of questions measuring applicability in the questionnaire. Residents’ responses were stratified by PGY. To facilitate the comparison of data, interval data, described on a 5-point Likert scale, were presented as both frequency and mean ± SD, as described previously. The data were compared using Student’s t-tests or analysis of variance.
(ANOVA) as appropriate. Categorical variables were compared using a Chi-squared test. All analyses were performed using Excel version 2016 (Microsoft, USA).

Results

Demographic data and response rates

The participants’ demographic details and response rates are shown in Table 1. The response rate (RR) was very high (90.7%) and exceeded that required to achieve the desired margin of error and level of confidence. Ninety-eight (male 73; female 25) of 108 (male 77; female 31) IM residents participated in our study. Although, female IM participants’ RR (80.6%) was significantly lower than that of the men (94.8%; \( \chi^2 = 5.27, P=0.022 \)); there were no statistically significant differences between the responses of male and female IM residents.

Applicability of APOCUS to IM practice in Saudi Arabia

The applicability of the four indications for diagnostic APOCUS to IM practice in Saudi Arabia are shown in Tables 2 and 3. Cronbach’s alpha was 0.79 suggesting that the internal consistency of the responses of these questions was good. There were no statistically significant differences between the groups’ means as determined by one-way ANOVA (F(3,388)=1.79, P=0.15). The combined applicability of all indications of APOCUS was very high (mean applicability 4.46 ± SD 0.85; 379 responses (96.7%) were fair, good or very good; 342 responses (87.2%) were good or very good).

Scanning to detect abdominal free fluid was the most applicable (mean applicability 4.61 ± SD 0.69). The participants considered scanning for hydronephrosis (mean applicability 4.33 ± SD 1.04), hepatomegaly (mean applicability 4.41 ± SD 0.83), and splenomegaly (mean applicability 4.42 ± SD 0.82) to be slightly less relevant.

IM residents’ ability to perform APOCUS and assessment for skill gaps.

The self-reported ability to perform APOCUS is displayed in Tables 2 and 3. The IM residents generally reported poor ability to perform APOCUS (mean 1.66 ± SD 1.11). When stratified by PGY (Table 2), no differences between residents’ abilities to perform APOCUS were identified (i.e. there were no statistically significant differences between the groups’ means as determined by one-way ANOVA (F(3,94)=0.18, P=0.91)). Thus, junior and senior residents’ self-reported abilities were similar and poor.

The self-reported ability to perform APOCUS was significantly lower than the IM residents’ perception of the applicability of APOCUS for detection of hydronephrosis (i.e. the indication for APOCUS perceived to be least useful; mean 4.33 ± SD 1.04; \( P < 0.0001 \)), suggesting the presence of a skill gap. The skill gaps did not differ between junior and senior residents (i.e. there were no statistically significant differences between the PGY groups’ means as determined by one-way ANOVA (F(3,94)=0.11, P=0.95)).

Discussion

Abdominal POCUS is an accurate tool for investigating abdominal disease.\(^{[1-4]}\) However, the spectra of abdominal diseases and facilities available within the Middle East varies significantly from that in other regions \(^{[16]}\).

To justify the high investment required to develop an APOCUS training program, it is important to confirm that IM residents in Saudi Arabia require this skill. The current study therefore describes IM residents’ perception of the applicability of four indications for APOCUS to their practice at a medical city in Saudi Arabia.
Residents’ perception of the applicability of APOCUS and their ability to perform APOCUS

The IM residents reported that APOCUS is very applicable to their practice (Figure 1 and Tables 2 and 3). All indications for APOCUS were thought to be highly applicable to IM practice, but scanning for abdominal free fluid was perceived to be the most applicable. However, the IM residents self-reported that their ability to perform APOCUS was poor. The assessment of the skill gaps can guide educational interventions to resolve this discrepancy.

Evaluation of the skill gaps

The difference between self-reported ability to perform a skill and the perceived usefulness of that skill can be used to measure a skill gap [9]. The applicability of APOCUS for detection of abdominal free fluid was reported as either good or very good by 93% of the sample. However, the sample’s self-reported ability to perform APOCUS (mean 1.66 ± SD 1.11; Figure 1 and Table 2) was significantly lower than their overall opinion of the least applicable indication for the use of APOCUS (mean 4.33 ± SD 1.04, P < 0.00001; Figure 1 and Table 2). These observations suggest the presence of significant skill gaps in APOCUS. This can only be addressed by institution of a training program.

We expected that the skills gap of junior residents (PGY1 and PGY2) would be greater than that of senior residents (PGY3 and PGY4). However, our data suggest there was no difference in their ability to perform APOCUS (Table 2). This may be because POCUS is a relatively new technology and very few trainers are available. Regardless, these observations reinforce the need for a POCUS training program.

Table 2. Residents’ perception of the applicability of APOCUS and their ability to perform APOCUS. This table presents residents’ perception of the applicability of APOCUS to their clinical practice and their self-reported ability to perform APOCUS. Applicability and proficiency are rated on a 5-point Likert Scale (1, Very Poor; 2, Poor; 3, Fair; 4, Good and 5, Very Good). Data are stratified by postgraduate year of training (PGY) and presented as mean ± standard deviation.

<table>
<thead>
<tr>
<th>Grade/Gender</th>
<th>Application of Abdominal Point of Care Ultrasound (Mean ± SD)</th>
<th>Ability (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hydronephrosis</td>
<td>Hepatomegaly</td>
</tr>
<tr>
<td>PGY 1</td>
<td>4.4 ± 1.2</td>
<td>4.4 ± 0.9</td>
</tr>
<tr>
<td>PGY 2</td>
<td>4.2 ± 1.2</td>
<td>4.2 ± 0.9</td>
</tr>
<tr>
<td>PGY 3</td>
<td>4.5 ± 0.7</td>
<td>4.6 ± 0.6</td>
</tr>
<tr>
<td>PGY 4</td>
<td>4.4 ± 0.9</td>
<td>4.5 ± 0.8</td>
</tr>
<tr>
<td>Overall</td>
<td>4.3 ± 1.0</td>
<td>4.4 ± 0.8</td>
</tr>
</tbody>
</table>

Table 3. Residents’ responses to questions on the applicability of APOCUS to their clinical practice and self-reported ability to perform APOCUS. This table presents residents’ responses to questions on the applicability of four indications for abdominal point of care ultrasound (APOCUS) and self-reported ability to perform APOCUS. Applicability and proficiency are rated on a 5-point Likert Scale (1, Very Poor; 2, Poor; 3, Fair; 4, Good and 5, Very Good). Data are presented as frequency.

<table>
<thead>
<tr>
<th>Response (Likert scale)</th>
<th>Application of Abdominal Point of Care Ultrasound</th>
<th>Ability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hydronephrosis</td>
<td>Hepatomegaly</td>
</tr>
<tr>
<td>Very Poor</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Poor</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Fair</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Good</td>
<td>22</td>
<td>27</td>
</tr>
<tr>
<td>Very Good</td>
<td>60</td>
<td>58</td>
</tr>
<tr>
<td>Total</td>
<td>98</td>
<td>98</td>
</tr>
</tbody>
</table>
Relevance of existing APOCUS training programs to Saudi Arabia

Perceptions of the applicability of APOCUS and the skill gaps reported by Canadian IM residency programs [9] are similar to our observations in Saudi Arabia (Figure 1 and Table 2). This may be because APOCUS findings, whilst useful, are relatively non-specific. Thus, although there are regional differences in the epidemiology of intra-abdominal pathology [16] and the availability of radiology services; the use of APOCUS to rapidly detect ascites at the bedside is universally applicable to the practice of medicine worldwide. This observation suggests that the international standardisation of basic APOCUS training may be possible and curricula developed in other countries may be relevant to internists in Saudi Arabia.

Strengths and Limitations

Whilst our study was conducted in IM residents, our observations and recommendations are likely to be relevant to nephrology, gastroenterology and hepatology fellows starting their fellowships. This is because the study was conducted towards the end of the academic year when the participating PGY4 IM residents had completed their residency training.

Whilst the response rate to the survey was very high, the study has some limitations. Our data include self-reported knowledge. There are many potential causes of bias in such data. [20] However, the ability to perform APOCUS was generally reported to be poor (Figure 1 and Tables 2 and 3). This finding is consistent with our personal observations.

Our study was conducted at only one institution in Riyadh, Saudi Arabia. So, its generalizability may be limited. However, our institution hosts one of the largest IM residency programs in Saudi Arabia. Our participants' views are therefore likely to represent residents training in IM throughout Saudi Arabia and indeed other countries with well-developed healthcare systems. Our observations and their views on APOCUS should therefore be taken into account when developing training programs to safely and effectively integrate APOCUS into the practice of IM.

Contribution to the existing literature

The presented data provide robust evidence that APOCUS is applicable to the practice of medicine in Saudi Arabia. However, our residents' ability to perform APOCUS is poor. This is likely to be true throughout Saudi Arabia. So, our data suggest that Saudi Arabian IM residents have statistically and clinically significant skill gaps in APOCUS.

Residency training programs must aim to provide tuition on the most clinically relevant knowledge and skills. Thus, IM residents clearly require a curriculum for training in APOCUS. Fellows in nephrology, gastroenterology and hepatology are also likely to benefit from formal training in APOCUS. Our observations can guide the development of a program that satisfies residents' and fellows' perceived needs.

Conclusions

Our data suggest that APOCUS is highly applicable to the practice of IM in Saudi Arabia. Existing programs for APOCUS training may be relevant to practice within the Middle East. Thus, international standardisation of APOCUS training may be possible and should be considered. Our findings will be of interest to those developing curricula to train residents and fellows in APOCUS.

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Conflicts of Interest: none declared.

References


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Point of Care Ultrasound First: An Opportunity to Improve Efficiency for Uncomplicated Pregnancy in the Emergency Department

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Abstract

Introduction: Research suggests emergency providers using point-of-care ultrasound (POCUS) to confirm an uncomplicated intrauterine pregnancy (IUP) can decrease emergency department (ED) length of stay (LOS) compared to a radiology department ultrasound (RADUS). The objective of this study was to compare the time to diagnosis and LOS between POCUS and RADUS patients. Methods: This was a retrospective study at one urban medical center. A standardized tool was used to abstract data from a random sample of pregnant patients diagnosed with uncomplicated IUP between January 2016 and December 2017 at a single tertiary care medical center. Microsoft Excel 2010 software was used to measure time intervals, prepare descriptive statistics, and perform Mann-Whitney U tests to compare differences. Results: A random sample of 836 (36%) of the 2,346 emergency department patients diagnosed with an IUP between 8-20 weeks’ gestation during the study period was evaluated for inclusion. Three hundred sixty-six met inclusion criteria and were included in the final analysis. Patients were divided into 2 groups based on which type of ultrasound scan they received first: POCUS (n=165) and RADUS (n=201). Patients who received POCUS were found to have an IUP identified in an average of 48 minutes (95% CI, 43 to 53), while the RADUS group’s mean time to diagnosis was 120 minutes (95% CI 113 to 127) with a difference of 72 minutes (95% CI, 63 to 80; p<0.001). The mean LOS for patients who received POCUS was 132 minutes (95% CI, 122 to 142), while that of the RADUS group was 177 minutes (95% CI 170 to 184) with a difference of 45 minutes (95% CI 32 to 56; p<0.001). The study is limited by its single-center, retrospective design and by lack of blinding of data abstractors. Conclusion: Pregnant emergency department patients diagnosed with an uncomplicated IUP between 8-weeks and 20-weeks’ gestation had statistically significant reduction in time to diagnosis and disposition from the ED if assessed with POCUS as compared to RADUS.

Background

According to the American College of Emergency Physicians (ACEP) clinical guidelines, emergency physicians should obtain a pelvic ultrasound for symptomatic pregnant patients with any β-hCG level to confirm an intrauterine pregnancy (IUP) [1]. However, sending a patient for a radiology department performed ultrasound and awaiting a radiologist interpretation can be time consuming, especially in hospitals that do not employ an ultrasound technician 24 hours per day. In the past two decades, mounting research suggests emergency providers can accurately use point-of-care ultrasound (POCUS) to confirm an uncomplicated intrauterine pregnancy (RADUS) while decreasing emergency department (ED) length of stay (LOS) [2-10].

The goal of our study was to measure and compare the time interval from ED arrival to ultrasound diagnosis and the LOS between patients who received initial POCUS or RADUS in our emergency department.

Methods

The study was approved by the hospital Institutional Review Board (Study ID: 2019-059). This was a retrospective study comparing time from ED arrival to ultrasound interpretation and time from ED arrival to ED departure between patients who received POCUS and patients who had a radiology department ultrasound (RADUS). The study took place at an urban tertiary care academic medical center with 99,900 ED visits per year during the study period. POCUS exams were performed by emergency medicine (EM) residents with attending supervision, ultrasound fellows, and board-certified or board-eligible EM attending physicians. All examinations were completed using transabdominal views in a structured format using Zonare Ultra or Pro models with either a P4-1c or C6-2 transducer (MINDRAY, Mountain View, CA) and digitally archived in QPath (Telexys Healthcare, Maple Ridge, British Columbia, Canada).

The study examined ED patients with an ultrasound confirmed IUP between January 2016 and December 2017. An honest broker service was used to generate a list of ED patients with international classification of disease (ICD) codes for intrauterine pregnancy of 8-20 weeks. The list of patients was randomized and a sample of 36% of the patients was selected for inclusion analysis. Only pregnant ED patients ≥18 years who received their initial diagnosis of an uncomplicated IUP between 8-20 weeks gestation were included in the final analysis. Uncomplicated was defined by the lack of exclusion criteria. Patients were excluded if they were taking fertility treatments, had BMI ≥40, had a known uterine anomaly, received an extended workup for a non-obstetric complaint, were admitted, were transferred in from an outside facility, had a new secondary diagnosis, or had...
prior ultrasound confirmed IUP. Patients with missing timestamp data were excluded from the final analysis as well. Missing data was not imputed. An ultrasound diagnosis of an IUP was defined by visualization of an intrauterine yolk sac or fetal pole. Arrival time was defined by the timestamp from the first recorded vital sign. Ultrasound time was defined either by the POCUS acquisition time or the radiologist interpretation timestamp, which are both digitally recorded. Departure time was defined by the patient departure timestamp.

There were consistent workflows in place during the study period by which these times were recorded in the electronic medical record (EMR). A standardized abstraction tool (Appendix 1) was used to guide data collection in a coded, systematic fashion. Each patient’s EMR was individually analyzed to abstract data points and timestamps for ED arrival, ultrasound scan(s), and ED departure. Data abstractors were initially trained and periodically audited for adherence to data collection protocols and were not blinded to the study hypothesis. In the case of patients with questionable inclusion or exclusion criteria, the record was reviewed independently by another researcher. In the case of disagreement, the record was reviewed for inclusion via research team conference, however interobserver reliability ratings were not performed. The time intervals were measured and compared between patients receiving POCUS and RADUS and descriptive statistics were prepared. Mann-Whitney U tests were performed to examine differences between the two groups with a p-value of <0.05 considered statistically significant. All calculations were performed using Microsoft Excel 2010 software.

Results
A random sample of 836 (36%) of the 2,346 emergency department patients diagnosed with IUP between 8-20 weeks’ gestation during the study period were evaluated for inclusion. Three hundred sixty-six met inclusion criteria and were included in the final analysis. Patients were divided into 2 groups for analysis based on which type of ultrasound scan they received first: POCUS (n=165) and RADUS (n=201). There were 8 patients who received POCUS first, followed by a RADUS that were included in the POCUS group for analysis. The average ages of the POCUS and RADUS groups were 25 and 26, respectively. Out of 366 included patients, 163 (45%) had vaginal bleeding and 264 (72%) reported abdominal pain. Other common complaints were vaginal discharge, nausea, and dysuria. When comparing the presenting complaints of abdominal pain between the POCUS and RADUS groups, 115 (70%) POCUS patients and 151 (75%) RADUS patients had a documented complaint of abdominal pain. A complaint of vaginal bleeding was recorded in 68 (41%) of POCUS patients and 92 (46%) of RADUS patients.

Patients who received POCUS were identified to have an IUP in an average of 48 minutes (95% CI, 43 to 53), while the RADUS group’s mean time to diagnosis was 120 minutes (95% CI 113 to 127) with a difference of 72 minutes (95% CI, 63 to 80; p<0.001) (Table 1).

The mean LOS of patients who received POCUS was 132 minutes (95% CI, 122 to 142), while that of the RADUS group was 177 minutes (95% CI 170 to 184) with a difference of 45 minutes (95% CI 32 to 56; p<0.001) (Table 1).

Discussion
This study is limited by its single-center, retrospective design which decreases generalizability and prevents group randomization to control for confounders. A systematic review performed by Beals et al in 2019 of 6 retrospective studies similar to this one demonstrated a mean decrease of 73.8 minutes in LOS in POCUS

<table>
<thead>
<tr>
<th></th>
<th>POCUS (n=165)</th>
<th>RADUS (n=201)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time interval between ED arrival and first scan (minutes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>48 (CI 43-53)</td>
<td>120 (CI 113-127)</td>
</tr>
<tr>
<td>Range</td>
<td>0-150</td>
<td>20-225</td>
</tr>
<tr>
<td>Difference</td>
<td>72 (CI 63-80)</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Time interval between ED arrival and departure (minutes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>132 (CI 122-142)</td>
<td>177 (CI 170-184)</td>
</tr>
<tr>
<td>Range</td>
<td>32-283</td>
<td>63-354</td>
</tr>
<tr>
<td>Difference</td>
<td>45 (CI 32-56)</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>
patients compared to RADUS patients [4]. A randomized controlled trial undertaken by Morgan et al found an average reduction of 49 minutes in time to diagnosis and 20 minutes in LOS for POCUS patients and provides an excellent design framework for future studies of this kind [5]. Our study, with an average decreased time to diagnosis of 72 minutes and average reduced LOS of 45 minutes, provides validation of prior findings. Variables such as institution-specific workflows, availability of ultrasound machines, POCUS skill level, and type of provider (fellowship-trained physician, non-fellowship trained physician, or advanced practice provider) may influence time to diagnosis and LOS metrics.

In our study and all referenced studies, there were a subgroup of patients who received POCUS, but needed additional radiology department ultrasound services. Our collaboration with the radiology department is critical to improving care and efficiency for our pregnant patients. Although POCUS has a nearly a 100% specificity rate for IUP, the radiology department scan is more comprehensive and a radiologist’s interpretation can be helpful in the evaluation of additional pathology. For all 8 patients in our study who received POCUS followed by RADUS, we noted that the physician wanted additional data that was not well-characterized with POCUS.

Other previous research has demonstrated additional benefits of using POCUS for patients with uncomplicated IUP, including increased accuracy, decreased length of stay (LOS), and improved patient satisfaction scores [2-9]. For example, Blaivas et al noted the reduced cost related to shorter length of stay and elimination of the need for transport out of the emergency department [10]. Despite growing awareness that POCUS has many patient-centered benefits, barriers such as lack of training and lack of access to equipment continue to prevent this from becoming a widely accepted practice. While it has been demonstrated that POCUS decreases time to diagnosis and LOS of our pregnant ED patients, additional work is needed to ensure pregnant ED patients everywhere are able to access this approach.

Conclusions

Pregnant emergency department patients diagnosed with an uncomplicated IUP between 8 and 20 weeks gestation had statistically significant lower times to diagnosis and departure if assessed with POCUS as compared to RADUS. Based on the agreement of our results with past research, we conclude that, for the confirmation of uncomplicated IUP in the ED setting, POCUS reduces time to diagnosis and LOS compared to RADUS.
Evaluation of Diagnostic Imaging Capacity and the Role for Point-of-Care Ultrasound (POCUS) within the Zanzibar Health System

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(3) Point-of-care Ultrasound in Resource-limited Environments, Philadelphia, PA USA
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(5) Department of Emergency Medicine, Thomas Jefferson University Hospital, Philadelphia, PA USA
(6) Department of Radiology, Mnazi Moja Hospital, Unguja Zanzibar

Abstract

Background: The Zanzibar Ministry of Health identified access to ultrasound (US) as a system priority due to limited diagnostic imaging capacity and consequent impact on patient care and requested a needs assessment in this regard. As a result, the objective of this study was to assess diagnostic imaging capacity focusing on ultrasound in Zanzibar, including health care providers’ (HCPs) current training, use, and barriers to implementation. Methods: A previously published ultrasound needs assessment survey was modified and administered on-site at the eight public hospitals in Zanzibar among a convenience sample of HCPs. Demographics, perceived US needs, current training and practice, and availability of specialty support were assessed. HCPs also completed focused personal interviews (FPIs) to explore experience with training, interests, and barriers to ultrasound. On-site diagnostic imaging modalities were assessed. Results: There were nine ultrasound machines present at six of the eight public hospitals assessed. All had x-ray, but only one had a CT scanner and a radiologist. There was no MRI capacity at the hospitals assessed at the time of the study. Survey data among 40 participants revealed that prior experience with POCUS was limited with only 10% reporting any prior ultrasound training or experience. The majority of those surveyed (72%), indicated a ‘high’ interest in learning ultrasound. Of those reporting interest in POCUS applications, obstetrics was the most often cited (70%). Lack of ultrasound machines (40%) and educators (28%) were identified as the greatest barriers. Conclusion: HCPs in Zanzibar have limited access to diagnostic imaging, including ultrasound, and expressed a high level of interest in learning point-of-care ultrasound. A shortage of machines and educators are the main barriers to widespread use. Obstetrics is the application for which ultrasound is currently most used and is the application HCPs are most interested in learning. Equipment and educational support for a POCUS program could improve care by increasing access to diagnostic imaging.

Background

Continually, diagnostic imaging is neglected when considering strategies for quality improvement in healthcare delivery in resource-limited settings. The World Health Organization has advocated for expanded global access to ultrasound teaching and technology for health providers [1, 2], as two-thirds of the world’s population currently has no access to imaging technologies. Supporting CT or MRI can be particularly challenging due to the cost of the initial equipment investment combined with infrastructure issues including maintenance and repair requirements, and training of technologists, thus the call for scale up of diagnostic ultrasound and x-ray capacity in particular in rural healthcare services [3].

Point-of-care ultrasound (POCUS) has been employed in resource-limited settings has demonstrated improvements in clinical decision-making and often leads to an immediate change in management [4, 5]. Purchase and maintenance costs of ultrasound machines are relatively inexpensive [5, 6], and are becoming more portable and affordable [7]. POCUS does not depend on specialized technologists or radiologists, both of which can be rare in resource-limited clinical settings[1]. There are savings of time and personnel engendered by the need for only one provider to acquire, interpret, and act on the test, and there may be direct cost savings associated [8].

Zanzibar is an archipelago consisting of two main islands which functions as a semi-autonomous region of the United Republic of Tanzania, with its own ministry of health. The Zanzibar Ministry of Health completed a preceding health system assessment and identified imaging as a major gap. Due to the very limited baseline radiology capacity (one radiologist in Zanzibar), they requested input of this research team to further evaluate the current role of ultrasound and suggest development of a POCUS training program thereafter.

There is an overall shortage of skilled clinicians in Zanzibar [9]. At the time of this study, there was one radiologist in Zanzibar for a population over one million. Subsequently, two radiologists have joined the staff at Mnazi Moja hospital bringing the total number of radiologists on the island to three. While there is access...
to public health facilities, the range of health care services provided is limited, including diagnostic imaging. At the same time, Zanzibar demographics reflect a young age structure with high birth, maternal mortality, and overall death rates, as well as low rates of contraceptive usage [10, 11]. The World Health Organization (WHO) estimates only half of Tanzanian women have regular antenatal care and deliver with a skilled birth attendant present [12], and overall access to comprehensive reproductive healthcare is limited [11]. Prior research shows one of the greatest impacts of ultrasound incorporated into clinical care is in obstetric conditions [6, 13-15]. POCUS has also proved useful in trauma, HIV/TB, pulmonary, cardiac, gynecology, hepatobiliary disease, genitourinary disease, mass casualty events, and tropical/infectious diseases [16-20].

The primary objective of this study was to evaluate diagnostic imaging capacity within the Zanzibar health system, with a focus on ultrasound availability, practitioners’ current use of ultrasound, knowledge of and interest in ultrasound use. The data collected from this assessment was collated into a needs assessment report to the Ministry of Health, and served as the background to a POCUS training program initiated in conjunction with the Zanzibar Ministry of Health.

Methods

This is a mixed methodology cross-sectional design using both a quantitative survey and focused personal interviews (FPIs). The needs assessment occurred between July and August of 2015 at eight public hospitals across Zanzibar. Diagnostic imaging capacity with a focus on ultrasound was evaluated at five rural and district hospitals on Pemba, two district hospitals on Unguja and also at Mnazi Mmoja Hospital (MMH), the referral hospital for Zanzibar (Figure 1). One day was spent at each site meeting clinical and administrative members of the hospital staff as well as imaging technicians. Where needed, follow up visits were made to meet previously unavailable respondents.

The protocol was deemed exempt by the Institutional Review Board at the University of Pennsylvania and approved by the Ministry of Health of Zanzibar. This was deemed exempt due to the focus on health system capacity assessment, limited risk to clinician participants in completing de-identified surveys, and no patient involvement in this study. Respondents were informed of the study objectives prior to completing the survey and provided verbal consent prior to participation. Survey and interview information collected from participants were done in a de-identified fashion, and participants did not receive any incentives.

This was a convenience sample of healthcare workers on duty at the time the investigator was at each site. Convenience sampling was utilized because apart from Mnazi Mjoja, these hospitals have a small number of clinical staff and it was possible to meet the majority of them within one to two visits. Targeted individuals included medical officers, assistant medical officers, physicians, nurses, midwives and imaging technicians in plain film radiography and ultrasound. After completing a self-administered quantitative ultrasound needs-assessment survey, respondents also completed a focused personal interview (FPI) with the principal investigator. The needs assessment tool was modeled on one previously published [21], used for similar purposes in Colombia [22]. It was modified to include items related to practice around management and transfer of patients to referral hospitals. The questionnaire was administered in English (the language of instruction at Zanzibar schools).

In addition to basic demographics, the survey tool included items in the following domains related to ultrasound: current practice patterns, integration into workflow, extent of prior exposure, desire for training and Figure 1. Map of Zanzibar’s 2 Islands.

This image ("Map_of_Zanzibar_Archipelago-en.svg" by Oona Räisänen) is reproduced under a CC BY-SA 4.0 license through Wikipedia Commons.
barriers to use. The questionnaire has 26 items grouped into themes and requires approximately fifteen minutes to complete [21, 22]. The first section focused on details of the individual practitioner’s practice location such as availability of specialist care and ultrasound as well as referral hospital transfer patterns. The second section focused on individual practice. The last section collected information regarding familiarity with ultrasound including any prior formal training.

Focused personal interviews (FPIs) were conducted by the principal investigator. At each site, a senior clinician or imaging technician, if available, was asked about all current imaging equipment and staff to create a detailed inventory of existing ultrasound machines, sonographers and radiologists. Imaging capacity for other modalities such as plain film radiography, computed tomography (CT), and MRI were also investigated. Information about training, most common applications of ultrasounds, methods of procurement of ultrasound equipment including gel and supplies, patient payment schemes for ultrasound scans and current capacity to manage acute conditions were assessed. Sessions occurred in English though an accompanying local coordinator, present during all interviews, occasionally assisted with interpreting difficult concepts in Swahili. On average, these sessions lasted fifteen minutes and were conducted in a private location convenient to the respondent to encourage open discussion.

The FPI administrator kept careful thematic notes during the sessions to capture qualitative data necessary to provide a programmatic context to the surveys. Qualitative data was analyzed using a simplified grounded theory approach in which specific themes were identified. Relevant thematic patterns emerged after analysis of the data collected to inform the results. The interview process was then finetuned over multiple iterations using a comparative method. Summary statistics such as frequencies and percentages were used to describe the survey data.

Results

At the time of the study, there were nine total ultrasound machines present at six of the eight public hospitals assessed. All had x-ray, but only Mnazi Mmoja had a CT scanner at the time of the study. At the time of the study, there was no MRI capacity in Zanzibar and twelve sonographers and one radiologist served all of the public hospitals in Zanzibar. Since then, Mnazi Moja hospital has acquired an MRI machine which is the only one available in Zanzibar. A private facility now also has a CT scanner. Two radiologists have joined the staff at Mnaza Moja Hospital bringing the total number of radiologists in Zanzibar up to three. A total of 40 ultrasound-focused surveys were collected, 37 in person and 3 electronically. All respondents worked at public hospitals across the two main islands of Zanzibar and were drawn from the full spectrum of healthcare workers at various stages professionally. Fifty-four percent of respondents were female and 32.5% were physicians (Table 1).

<table>
<thead>
<tr>
<th>Table 1. Study Population (N=40*)</th>
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<tr>
<td><strong>Demographic</strong></td>
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<tr>
<td>Gender</td>
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<tr>
<td>Female</td>
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<td>Physician</td>
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<td>Level of Training</td>
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<tr>
<td>Assistant Medical Officer</td>
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<td>Midwife</td>
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<td>Imaging Technician (XR or Ultrasound)</td>
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<td>Clinical Officer</td>
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<td>Clinical Health Nurse</td>
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<td>Medical Student</td>
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<td>Non-respondents</td>
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<td>Medical Specialty</td>
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<td>General Medicine</td>
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<td>Referral</td>
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<td>Reported Years of Clinical Experience</td>
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<td>1 to 5 years</td>
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<td>5 to 10 years</td>
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<td>&gt; 10 years</td>
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<td>Duration of Practice at Current Location</td>
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<td>0 to 6 months</td>
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<td>2 to 4 years</td>
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<tr>
<td>&gt;5 years</td>
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<tr>
<td>Some formal ultrasound training</td>
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<td>Prior Ultrasound Experience</td>
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There was limited prior experience with ultrasound among the healthcare workers surveyed. Only four (10%) respondents had prior formal ultrasound training and prior ultrasound experience. All respondents indicated interest in learning POCUS with 71.8% indicating a 'high' level of interest. Seventy percent of respondents expressed an interest in learning obstetric ultrasound. The second and third highest ranked modalities of interest were liver (22.5%) and trauma (17.5%) ultrasound. Respondents also indicated that when available, US is the initial imaging modality used for abdominal complaints. Twelve (30%) of respondents stated they would be willing to spend more than 10 hours weekly learning POCUS, while 19 (47.5%) respondents indicated they would be willing to spend 4–10 hours weekly. Five respondents (12.5%) indicated they would be available for less than 4 hours weekly. The remaining four respondents (10%) were split equally into two groups: two (5%) stated they had no time and two (5%) did not respond.

Respondents also indicated most common barriers to ultrasound use were a lack of teachers (40%), a lack of machines (28%), and no financial incentive (21%). HCW turnover was noted to be relatively low in this study; thirty-three (82.5%) of respondents had spent more than one year at their current practice location and 13 (32.5%) had spent more than five years at their current practice location. Of the thirty-six respondents who were clinicians, thirty-one (86.1%) reported that they were comfortable performing vaginal deliveries independently and sixteen (44.4%) reported that they were comfortable performing C-sections independently.

Sixteen respondents agreed to a focused personal interview. The most important themes that emerged from the FPIs were high demand for ultrasound services and limited ability to meet the need. Results from the survey administered indicated that 75% of HCPs had access to plain radiography and 80% to technologist-performed ultrasound. FPIs revealed persistent perceived difficulties with imaging services. The major themes from the FPIs were poor access to functioning machines and limited ability to maintain machines. The technicians and sonographers within the sample reported using old machines that break down frequently and a lack of access to replacement parts or skilled engineers to service existing machines. Radiology staff reported that there was high demand for ultrasound services without the necessary resources to meet the need in terms of available sonographers and machines. Lastly, the interviews revealed that delays within the system makes the procurement of gel and supplies as all such requests are processed through a central office at the MOH resulting in shortage of supplies. Respondents indicated that a patient cost-sharing scheme was started to mitigate this effect. With the patient cost-sharing scheme, every patient who benefitted from diagnostic ultrasound paid a small fee into a common pool of funds to maintain supplies such as ultrasound gel and gloves. Funds generated through this avenue are used to purchase supplies. Despite this, technicians still reported difficulty in maintaining ultrasound supplies.

HCPs reported poor access and delays particularly at night and on weekends. HCPs on Pemba reported less access at all times due to their distance from Mnazi Mmoja Hospital and the requirement for boat or flight transport due to their separate island location. Plain film radiography was available at all hospitals but two of the five hospitals on Pemba, (Micheweni and Vitongoji), had no ultrasound capability (see Appendix 2).

Discussion

This first detailed evaluation of diagnostic imaging capacity with a focus on the role of ultrasound within the Zanzibar public health demonstrates it to be extremely limited. Only plain films are regularly available outside of the referral hospital, and there was only one radiologist working in the public sector for a population of over one million, at the time of the study. Although ultrasound devices were available at some of the hospitals we evaluated, this study revealed overall limited prior experience and training with ultrasound among clinicians. Though there is a significant degree of interest in education, particularly obstetric applications, the study revealed limited opportunity to acquire formal training, as well as lack of teachers, machines, and financial incentive as barriers to use.

The World Health organization notes that 80-90% of all diagnostic problems could be solved by basic radiography (x-ray) and ultrasound (US) examinations [23]. POCUS has been shown to change clinical decision making in resource-limited settings, and some of the greatest utility appears to be in trauma and obstetrics[6, 24, 25]. The initial interest of this cohort in the obstetric and trauma ultrasound is consistent with the pattern seen in other studies in similar resource-limited settings, and may reflect greater familiarity with the use of ultrasound for these indications[14, 26, 27].

A study in Liberia showed the introduction of POCUS resulted in changes of management in 62% of cases seen at the tertiary teaching hospital in Monrovia[6]. The greatest impact was in cases of pregnancy, echocardiography and focused assessment of sonography in trauma (FAST). [6] Similar results were reported from Tanzania, Rwanda, and Ghana. [28]
Though a primary focus on obstetrics is of interest in this setting, trauma and abdominal POCUS applications, is of interest to this cohort and may prove useful given the scarcity of CT in this environment.

Several important barriers to ultrasound use were identified using this survey. The first was a lack of machines. With the exception of Mnazi Moja Hospital (MMH), ultrasound machines were frequently older and donated from abroad. Many were broken down or needed extensive service that was no longer possible due to their age or lack of warranty. Part of creating a sustainable program in POCUS in Zanzibar would involve acquiring durable ultrasound machines with a service plan for repair. Machine access for regular use is necessary to maintain and improve ultrasound skills and create a sustainable program.

The second identified barrier was the lack of teachers. Developing a sustainable ultrasound training program starts with longitudinal educator engagement, giving trainees the opportunity to practice under careful supervision. [21, 29] Then investing in POCUS trainees that become educators that longitudinally work toward capacity building with their colleagues and communities is ideal. A POCUS training program on Pemba Island in Zanzibar utilizes a ‘train the trainers’ model garnered considerable success. [30] Therein, establishing a stable cohort of local POCUS leaders/trainers is integral to achieve self-sustaining integration into a care setting.

Information from the FPIs revealed that while x-ray and ultrasound are present at most facilities, access to such equipment is poor. HCPs reported difficulty obtaining scans and sonographers reported prolonged turnaround times for ordered scans due to malfunctioning machines and inadequate staff to meet demand as the sonographers who perform the scans also interpret and report on them. This suggests that if POCUS training was provided, efficiency may be increased by clinicians performing and interpreting their own studies, within the relevant clinical context, in real-time.

This study was the initial assessment of ultrasound needs and capabilities within the Zanzibar health system. Data from this study was used to design a training program for HCPs in Zanzibar. Subsequently in 2016, fifteen HCPs from three hospitals on Pemba enrolled in a six-month training program with a special focus on obstetrics. Results from the training program with respect to training modalities, ultrasound skills acquisition and retention are published in a separate article.

Limitations

This study assessed a small convenience sample of HCPs encountered in public hospitals across Zanzibar. While every effort was made to interview and survey as many practitioners as possible, some sampling bias may exist and these practitioners may not be representative of the population of HCPs in Zanzibar or their practice patterns. This may also not be representative of resources and HCPs in private settings. This study was led by investigators from outside Zanzibar at the request of the Ministry of Health due to limited radiology capacity in Zanzibar so investigators’ lack of direct experience working in the healthcare system may be an additional limitation.

At the time of this needs assessment, CT was only available at Mnazi Moja hospital within the public sector and no public hospitals had MRI capability. Although English is the language of instruction in Zanzibar, HCPs have varying levels of comfort with the language. To minimize the effect of language barrier, an interpreter fluent in the native language was present during the FPI interviews. While effort was taken to make respondents feel that their survey answers and FPI discussions were confidential, it is possible responses were tempered or influenced by employment concerns. The scope of this investigation was limited to the survey questionnaire and FPIs. Both tools captured information related to self-reported use of ultrasound and not direct measurements of use or patient outcomes. Finally, this cross-sectional survey does not allow for an assessment of changing patterns of POCUS use over time.

Conclusions

Healthcare providers in Zanzibar have limited access to diagnostic imaging and express a high level of interest in learning and integrating point-of-care ultrasound. The lack of teachers and equipment were noted as main barriers to use. Equipment and educational support for a POCUS program could improve care by increasing access to diagnostic imaging.

Competing interests

The authors have no relevant financial or non-financial competing interests.

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References


An homage to Rembrandt's “The Anatomy Lesson of Dr. Nicolaes Tulp” for the modern physician (Acrylic on canvas).

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