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Point-of-Care Ultrasound is Having Its Moment

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Ultrasound performed at the point of care (POCUS) is having its moment. The COVID-19 pandemic has seemingly caused the acceleration of POCUS acceptance by hospital leaders, and POCUS examinations are increasingly performed by specialists outside of emergency medicine. What is driving this rapid culture change?

POCUS simply makes sense. This technology has been deemed essential to the safe management of patients amidst the COVID-19 pandemic [1]. The clinical examination and imaging can be accomplished at the same time and by the same physician. The conditions of the pandemic have favored imaging modalities that can be rapidly deployed to the bedside, are quick to complete, involve easily disinfected instruments, and do not require multiple personnel. To date, there are no large outcome data on the use of POCUS for COVID-19, but published reports support that POCUS is time efficient and can accurately demonstrate clinical diagnoses, such as viral pneumonia [2,3].

Cardiologists and radiologists have shown unprecedented support for POCUS during COVID-19. In fact, the pandemic has inspired non-emergency medicine specialties to write POCUS-related policies and guidelines. For example, the American Society of Echocardiography stated that clinicians caring for COVID-19 positive patients and those under investigation (PUI) should perform cardiac POCUS as a first-line imaging tool for cardiovascular findings. Doing so potentially replaces or delays the need for comprehensive transthoracic echocardiography or other imaging [4]. This approach reduces the number of healthcare workers potentially exposed to an infected patient while improving efficiency. Similarly, an expert panel of radiologists from academic institutions in the United States and the American College of Radiology have discouraged the routine and first line use of computed tomography (CT) for diagnostic purposes in COVID-19 [3,4]. Studies of COVID-19 pneumonia patients have shown similar test characteristics between lung POCUS and CT. There is growing support that lung POCUS is an accurate initial imaging tool for the early diagnosis of COVID-19 pneumonia, particularly in patients with flu-like symptoms [5,6]. The immediate imaging results and interpretation lead to more efficient care and better throughput from the ED to inpatient care areas. On the inpatient side, clinicians who use POCUS have less need for consultative services to perform diagnostic imaging and ultrasound-guided procedures, such as paracentesis or thoracentesis.

Machines designed for POCUS applications range in size from cart-based machines that are wheeled directly to the patient bedside, to handheld units which attach to smartphones and fit in a pocket. Machine screens, surfaces and transducers can be covered using translucent sheaths, and cleaned directly with viricidal wipes to be made ready for the next patient. On the other hand, obtaining a CT scan on a COVID-19 positive or PUI patient requires a more time-consuming cleaning and disinfection process, as well as adequate room ventilation and passive air exchange [7]. The impact to workflow may be trivial at a hospital with multiple CT scanners, but significant to a hospital that has few.

Hospital leaders working closely with Information Systems and Technology (IS&T) are prioritizing POCUS projects so that emergency and critical care physicians can digitally archive images to reduce duplication of imaging studies and enable image sharing with all consulting services. Archiving of POCUS studies has been historically difficult to achieve, but hospitals have increasingly engaged their IS&T departments during the pandemic.

As POCUS use increases, there is a concomitant need for physician training. While dedicated proctored training is optimal, this may not be possible in a time of social distancing and course cancellations. Fortunately, novel teleguidance and augmented reality platforms have emerged on various handheld POCUS devices [7]. Tele-ultrasound is being used by experienced faculty to deliver remote hands-on education for students and trainees including teaching proper scanning technique and demonstrating pathologic findings. POCUS teleguidance technologies may also aid frontline clinicians in remotely managing critical COVID-19 patients or discharged patients who are self-monitoring at home.
COVID-19 is rapidly changing the paradigm of how clinicians diagnose and manage patients at the bedside. Hospital leaders should embrace POCUS and ensure that proper equipment, training, and credentialing are readily available to frontline clinicians.

References


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Orbital Mass Detected with POCUS

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Case File

A previously healthy 46-year-old female patient presented to the Emergency Department (ED) with a primary complaint of binocular diplopia worsening over the past 48 hours. Physical exam revealed minor left inferior lid ecchymosis and was significant for proptosis (Figure 1a). There was no pain on extraocular movements, erythema of either lid, induration, chemosis, ophthalmoplegia, relative afferent pupillary defect, or other features of orbital cellulitis. Point of care ultrasound (POCUS) of the globe and orbit was performed and demonstrated a hypoechoic mass within the left lateral rectus muscle (Figure 1b; online Video S1). The patient had orbital CT and MRI imaging revealing, “Two enhancing masses within the left orbit adjacent to or arising from the left lateral rectus muscle causing mild medial displacement of the left optic nerve and mild left proptosis. No evidence of extra orbital extension or perineural spread. Imaging findings nonspecific....”

Orbital masses are rare presentations outside of specialized clinics, and typically involve a comprehensive imaging and laboratory evaluation. Periorbital or orbital cellulitis, thyroid ophthalmopathy, orbital malignancies, systemic autoimmune conditions, and idiopathic orbital inflammation are possible causes of orbital mass [1]. Periorbital and orbital cellulitis typically have different physical exam features including discomfort with extraocular motions. On POCUS a periorbital or orbital cellulitis typically has an irregular cobblestone appearance of the edematous subcutaneous tissues with increased echogenicity of the affected tissue [2]. Thyroid ophthalmopathy is bilateral in 95% of cases is usually accompanied by laboratory evidence of hyperthyroidism. POCUS findings for thyroid ophthalmopathy include

Figure 1. a) Appearance of the patient’s eyes on presentation to the Emergency Department; b) and c) Sonographic appearance of orbit with left lateral rectus muscle. Mass denoted in 1C by red arrow and red outline.
symmetrical thickening of the ocular muscles without discrete mass[3]. Finally, orbital malignancy and localized presentations of systemic autoimmune conditions can be expected to have a wide variety of POCUS findings representative of their underlying pathology.

A diagnosis of idiopathic orbital inflammation (IOI) was suspected based on the clinical history, physical examination and initial imaging findings. IOI, previously known as orbital pseudotumor, is a mass or enlargement in orbital structures as a result of inflammation due to an unknown cause. IOI poses difficulty in diagnosis due to the heterogeneity of clinical presentation, lack of rigid diagnostic criteria, unknown etiology, and similarity to other conditions [4]. Thus, it is considered a diagnosis of exclusion once other similarly appearing diseases have been ruled out [5]. While there are no sonographic pathognomonic features of IOI, POCUS confirmed the presence of a unilateral asymmetric orbital mass affecting the left lateral rectus muscle, thereby refining the differential diagnosis and streamlining the subsequent advanced imaging studies.

POCUS is being routinely employed for visualization of intraocular pathology including retinal detachment, vitreous hemorrhage, globe rupture, and intraocular foreign bodies [6]. Moreover POCUS is increasingly employed for extraorbital pathology such as optic nerve sheath diameter to assess for intracranial pressure assessment. This case demonstrates that POCUS can be used to not only diagnose intraocular, but also extraocular, intraorbital pathology. The POCUS findings in this case streamlined advanced imaging studies and allowed for rapid oculoplastic surgery referral.

The patient underwent an orbital mass biopsy performed by the oculoplastic surgery team which may not have obtained a sufficient tissue sample and was ultimately non-diagnostic, being thought not to represent the lesion in question. After observation, serial imaging and repeat ophthalmology follow up for over 1 year, the working diagnosis became orbital venous lymphatic malformation. The sonographic features of orbital venous lymphatic malformations are smooth well circumscribed lesions with high echogenicity [7, 8], and not consistent with the POCUS images obtained. If orbital venous lymphatic malformation is the true diagnosis, the images here may represent a particular subtype or a lesion that matured, subsequently taking on different sonographic findings. The patient’s clinical status has improved; however, a tissue diagnosis has not been obtained.

Disclosures: The authors declare no conflicts of interest.

Statement of Consent: Signed consent from the patient for photographic documentation and publication of the findings was obtained at the time of diagnosis at Denver Health Medical Centre.

References

Interscalene Block in an Anesthetized Adult with Hypertrophic Obstructive Cardiomyopathy Undergoing Clavicle Fracture Reduction

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Abstract
Whether regional anesthesia procedures should be performed in heavily sedated/anesthetized adults remains controversial. One of the purported advantages of performing regional nerve blocks in conversant patients is early warning against major nerve injury and, arguably, early detection of local anesthetic systemic toxicity (LAST). A 60-year-old man with hypertrophic obstructive cardiomyopathy (HOCM) underwent a clavicle fracture repair under general anesthesia. Intraoperative transesophageal echocardiography revealed dynamic left ventricular outflow track obstruction and systolic anterior motion of the posterior mitral valve leaflet. In part based on such echo findings, he received an ultrasound-guided interscalene plus a superficial cervical plexus block for postoperative analgesia prior to emergence from general anesthesia. Given the lack of robust data on the safety of ultrasound-guided regional techniques in heavily sedated/anesthetized adults, we use the example of echographic evidence of significant HOCM to argue for a pragmatic and individualized approach when faced with unusual situations in which the pros of such an approach may outweigh the cons – in this case for performing an interscalene block on an anesthetized adult.

Introduction
One of the purported advantages of performing regional nerve blocks in awake patients is early warning against major nerve injury and, arguably, early detection of local anesthetic systemic toxicity (LAST). For example, a needle tip positioned within the epineurium of a nerve may elicit severe paresthesia, alerting the care provider to potential intraneural injection. Specifically, interscalene block (ISB) was singled out as the one block that should be performed only in awake/lightly sedated patients, including children (Class I recommendation), in the first American Society of Regional Anesthesia (ASRA) practice advisory [1]. Even though this recommendation is no longer present in the society’s second practice advisory [2] the controversy on whether ISB should be performed in heavily sedated/anesthetized adults continues [3].

Case Report
A 60-yr-old man was scheduled for a right clavicle fracture internal fixation. Preoperatively, his pain level at rest was adequately managed with acetaminophen, ibuprofen, and oral hydromorphone.

His past medical history consisted of echocardiographic evidence of hypertrophic obstructive cardiomyopathy (HOCM). The cardiac investigation was triggered by a syncopal episode when he was dehydrated. He did not normally engage in prolonged strenuous activity and had no other major co-morbidities.

Given the proximity of the surgical site to the head, an estimated surgical time of 2½ hours, and the possibility of intraoperative breakthrough pain, we opted for general anesthesia (GA) which also allowed intraoperative transesophageal echocardiography, in addition to standard monitors and an arterial line. The patient had agreed to an interscalene block (ISB) plus a superficial cervical plexus block (SCPB) but was anxious and was reluctant to have the block while awake. Given the risk of an anxiety-driven sympathetic surge, and after discussing the risks of performing an ISB under GA, the patient was open to the idea of receiving a block prior to emergence from GA, or receiving the block after emergence from GA and if other means of pain control have failed. He was given a 500 mL-crystalloid bolus prior to induction. Perioperative hemodynamic goals included maintaining euvoelemia and avoiding excessive sympathetic stimulation. Phenylephrine and esmolol were on standby. The procedure proceeded uneventfully. HOCM, systolic anterior motion (SAM) of the mitral valve leaflet, and severe concentric left ventricular hypertrophy (Figure 1) with preserved systolic function were evident on intraoperative transesophageal echocardiography. SAM was from a redundant posterior mitral leaflet moving across the left ventricular outflow tract (LVOT) during systole (Figure 2A and Video S1). Intraoperative echocardiogram found an LVOT gradient of 24 mm Hg, and colour Doppler across the LVOT demonstrated flow acceleration and turbulence associated with dynamic outflow obstruction (Figure 2B). Prior to emergence from
GA, a single-shot ISB (30 mL) and SCPB (10 mL) were performed under ultrasound (US) guidance with ropivacaine 0.5%. An in-plane technique was used, and caution taken to ensure that the needle was advanced only with the tip in view, and that the injections did not require excessive pressure and were preceded by negative aspirations. The use of ultrasound provided visualization of the spread of local anesthetic in real time. The patient was then allowed to emerge and transferred to the recovery room, where he reported 0/10 pain. He had a hoarse voice but no Horner’s syndrome or dyspnea. He started to feel discomfort at the surgical site 15 hours later. From there onwards, his pain was adequately controlled with low doses of acetaminophen and hydromorphone. He was discharged the next morning and did not report any neurologic symptoms postoperatively.

Discussion

Anesthesiologists generally consider patient wakefulness to be a good, albeit not always reliable, monitor against nerve injury during regional anesthesia [3]. At our institution, most shoulder surgeries are done under GA with an ISB performed typically before the awake/slightly sedated patient is taken to the operating room, or in the recovery room following surgery. In this instance, we considered the presence of hemodynamically significant HOCM (the presence of intraoperative SAM and LVOT dynamic obstruction with significant gradient under near-ideal general anesthetized and well hydrated state) justification for ISB and SCPB under GA. In HOCM, the higher velocity of blood travelling across a hypertrophied LVOT generates a Venturi effect that may draw a floppy mitral valve leaflet into the LVOT, exacerbating the dynamic obstruction. The vast majority of SAM involves the anterior leaflet, only occasionally the posterior leaflet, as in our patient. The loss of mitral valve leaflet apposition usually leads to mitral regurgitation, further compromising forward flow. SAM can be triggered by reduced ventricular filling and/or exaggerated ventricular emptying [4]. Unexpected perioperative circulatory deterioration can occur in the setting of HOCM [4]; and cardiac events are common in patients with septal hypertrophy [5]. In patients with HOCM, maintenance of adequate cardiac preload and avoiding increased sympathetic stimulation are cornerstones of perioperative management. In our patient, the pain level at rest from his fracture was low before surgery, and performing the blocks awake in an anxious and reluctant patient could potentially trigger a sympathetic surge. During nerve blocks in anxious patients, a vasovagal response is not uncommon, which may mimic circulatory collapse in HOCM. Furthermore, several extra hours of postoperative analgesia could be gained by blocking at the end of the case. Performing the regional blocks after the patient had emerged from GA would increase the risk of severe postoperative pain and associated sympathetic stimulation on the one hand. A heavily narcotized patient, on the other hand, may have CO₂ retention with increased catecholamine output and may be an unreliable monitor against nerve injury and LAST, may have airway obstruction, and may not be able to maintain adequate positioning for the block. Furthermore, a decision had to be made at the end of the case whether surgeon administered local infiltration should be used. From experience, local infiltration of the operative field by surgeon is not very effective; it also reduces the amount of LA that could be used during a subsequent rescue nerve block. As a result, performing the US-guided blocks under GA in our case appeared to be prudent after detailed consideration of the risks and benefits.

The dated ASRA Class I recommendation for ISB to be performed only in awake/lightly sedated patients was based in part on case reports, including 4 patients with spinal cord injuries who had ISB while under GA [6]. Three of those cases were guided by electrical stimulation and 1 patient’s block was performed by walking the needle tip off the C6 transverse process [6]. A case of inadvertent intrathecal placement of an interscalene catheter has also been described [7]: A Tuohy needle was inserted using landmark technique guided by electrical simulation while the patient was unconscious; subsequent intrathecal injection of bupivacaine via a catheter which had been threaded 7 cm beyond the Tuohy tip led to death. In such cases, it was assumed that had the patients been awake during the block or catheterization, pain would have been elicited. This assumption is reasonable, as other authors...
reporting cases of inadvertent subarachnoid/subdural injections during non-US guided ISB in wakeful patients had all reported paresthesia or severe pain [8]. Although no subarachnoid injection has apparently appeared in the literature using US in ISB in anesthetized patients, it can occur if the operator loses track of the tip of the block needle. Fortunately, visualizing the entire needle is easy in ISB and SCPB using an in-plane approach because of the near-orthogonal orientation between the needle and the US beam. As for the argument that a wakeful patient might reduce the risk of intraneuronal injection, the intuitive answer is ‘yes’ but there is no experimental data to confirm this assumption. Given the low incidence of serious nerve injury [9], and the general acceptance of blocks in conversant adults, such data are unlikely to become available. Whether to block someone awake or anesthetized must therefore be considered on an individual basis, and one must not be dogmatic by shutting the door on any option. In weighing the pros/cons, the following factors need to be considered. First, the incidence of major nerve injury and LAST after ISB in anesthetized children (mostly US-guided and between 10-18 years of age) is low (0/518 ISBs) [10]. Second, postoperative neurologic symptoms (PONS) have occurred after blocks in wakeful patients who did not report paresthesia [1]. Indeed, Perlas et al. have found that paresthesia in wakeful patients was reported in only 38% of needle-to-nerve contacts in axillary blocks [11], bearing in mind that needle-to-nerve contact is less traumatic than intraneuronal injection. Third, not all paresthesia leads to PONS [12]. For example, Candido et al. prospectively collected PONS data after 693 ISBs in conversant patients using nerve stimulation [12]. There were 29 patients with 31 post-ISB PONS that lasted up to several months, but only 7 of those were blocks in which paresthesia was elicited [12]. Fourth, current US probes lack the resolution to detect intraneuronal injury [13], and the operator must rely on injection pressure and current intensity to help prevent nerve injury. Fifth, the overall success rate of ISB in anesthetized patients in experienced hands using nerve stimulation alone was 97%; PONS occurred in 4.4% (40 of 910) of patients, and long-term neurologic complications occurred in 0.8% (8 of 910) [14]. One might expect similar results from US-guided ISB as a randomized controlled trial comparing US- and nerve stimulation-guided ISB had observed no significant differences in block failures, patient satisfaction, or incidence and severity of PONS [15].

**Conclusion**

Given the lack of robust data on the safety of US-guided ISB in anesthetized patient, we use the example of symptomatic HOCM to argue for a pragmatic and individualized approach when faced with unusual situations in which the pros of such an approach may outweigh the cons.

**Declaration of patient consent**

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient (s) has/have given his/her/their consent for his/ her/their images and other clinical information to be reported in

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**Figure 2.** A) Midesophageal 5-chamber view at end-systole showing significant myocardial hypertrophy at the level of the LVOT, and the mitral valve posterior leaflet being drawn into the LVOT. B) Midesophageal 5-chamber view at end-systole with color Doppler showing turbulent flow through a constricted LVOT. LA = left atrium, LV = left ventricle, RV, right ventricle, LVOT = left ventricular outflow tract, IVS = interventricular septum, MV = mitral valve.
the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed. This study was approved by the Queen’s University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board.

Disclosures

None

References


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The Hybrid POCUS-to-Echo Feasibility Study: Provision of Expedited Cardiac Point of Care Ultrasound Service (e-POCUS) by the Echocardiography Lab

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Abstract

Background: Comprehensive transthoracic echocardiography (CTE) provides information vital to the care of acutely ill and unstable patients, but may not be readily available. Cardiac point of care ultrasound (POCUS) is well suited to providing key information at the bedside to expedite decision making. Our objective was to evaluate the feasibility of expedited-POCUS (e-POCUS) provided by the echo lab for internal medicine, cardiology and intensive care services. Methods: A new e-POCUS service was developed by the Kingston Health Sciences Center Echo Lab, whereby focused information relevant to 4 clinical situations (acute heart failure, tamponade, shock and suspected acute valvulopathy) would be provided urgently at the bedside. Requests were acquired over a 4 month period. Sonographers were immediately deployed on request and followed a standard POCUS protocol for each scenario. Staff echocardiographers provided immediate interpretation and arranged for further imaging at their discretion. The response time, diagnostic accuracy and clinical utility of e-POCUS was assessed. Results: A total of 18 patients were evaluated. The average time of an e-POCUS exam was 10 minutes and the average e-POCUS to formal CTE timing was 1.3 days. The agreement between e-POCUS and CTE for the presence of segmental wall motion abnormalities was 83% (Kappa=0.61, p=0.009) and 72% for the detection of right ventricular dilatation (Kappa =0.44, p=0.058). The e-POCUS results altered the working diagnosis in 72% of cases. Conclusion: The provision of an e-POCUS service by the Echo Lab is a feasible workflow solution meeting the demands of a new practice pattern.

Background

Echocardiography is not consistently available to acutely ill patients. The barriers include scheduling, availability of a limited number of full-service units, and the need to follow strict protocol driven procedures to ensure a full-standardized study. These barriers have recently resulted in the proliferation of cardiac point of care ultrasound devices (POCUS) to allow for decision-making immediately at the bedside. However, concerns about the quality of cardiac POCUS acquired by non-traditional operators remains, in addition to concerns related to interpretation and archiving [1]. To address these concerns while simultaneously meeting the demand for immediate decision-making, expedited POCUS (e-POCUS) sonographers in an echocardiography lab may be a solution to providing high quality imaging that is rapidly delivered at the bedside. In our study, we identified four clinical scenarios where e-POCUS would be useful: 1) suspicion of acute heart failure, 2) tamponade, 3) shock of unknown aetiology and 4) Clinical suspicion of a significant valvulopathy. Our objective was to evaluate the feasibility of e-POCUS provided by the Echo Lab for the cardiology, internal medicine and intensive care services.

Methods

Education of the sonographers and referring physicians: Six experienced sonographers were given thirty-minute hands on session on the use of the e-POCUS machine (Mindray TE 7) [2] and on how to transfer the images to a digital storage and reporting system (Philips Healthcare). The Mindray TE 7 machine has a 15-inch anti-glare touch screen with image optimization options such as zoom and gain adjustments, which can be selected with a single touch.

No electrocardiogram is required during image acquisition. For the comprehensive transthoracic echocardiogram (CTE), a Vivid E9 (GE Healthcare) was used. The cardiology, internal medicine and intensive care unit (ICU) department heads and chief residents were informed that the Echo Lab was providing an e-POCUS service in the evaluation of these four clinical scenarios.

Clinical Care Pathway (Figure 1)

The e-POCUS service was available from Monday to Friday, 8:00 to 16:00. When a call was made to the e-POCUS service, the assigned sonographer would immediately proceed to the bedside to answer the immediate question following a pre-specified protocol for
each clinical situation. The images were then transferred to the cardiologist reader of the day who would make an immediate interpretation following the American Society of Echocardiography (ASE) guidelines [3]. The interpretation of valvular lesions from the e-POCUS scan was based on qualitative visual assessment and was only reported as significant if it appeared moderate to severe visually. The results were then communicated to the referring service by phone and/or pager. The referring physician was also asked whether the e-POCUS confirmed or changed the pre-POCUS working diagnosis, which was always documented before the e-POCUS protocol was initiated. If no initial abnormality was found on the ‘scout’ exam, the study was triaged as per normal routine protocol. If an initial concerning abnormality was found, treatment decisions were at the discretion of the referring physician, and a full-service echocardiogram was urgently performed to supplement the ‘scout’ images. The longest delay allowed between the e-POCUS and CTE was 48 hours. Both the e-POCUS scout images and CTE study were archived and reported individually in the hospital electronic medical record. The time to respond and to acquire the e-POCUS and CTE were recorded.

**Statistical analysis**

The continuous data are expressed as mean ± one standard deviation and categorical variables as number (%) of the total group. Results from the CTE were considered the gold standard. The agreement between e-POCUS and CTE was assessed using the Kappa statistics. Comparisons between continuous variables were done using Student t test.

**Results**

A total of 18 cases were collected over a 4-month period. Fifteen cases were requested from the internal medicine department, two cases from the ICU and one case from the cardiology department. Diagnostic imaging was collected in 17 cases. There was one patient where imaging was not diagnostic because of difficult positioning and clinical instability with the use of non-invasive ventilation (BiPAP). Most of the requests were for acute heart failure (50%) followed by shock (22%), tamponade (17%) and acute valvulopathy (11%). There were four calls made to the e-POCUS service that were not appropriate. Three of these requests were made to rule out vegetation in patients without any physical findings of acute valvulopathy. The other case was a patient who had elevated troponins and the requesting service wanted to rule out any regional wall motion abnormality.

The average scan duration was 10 minutes. The average of stored images was 26 ± 8 and 82 ± 26 for the e-POCUS and CTE respectively. The difference in the number of stored images between e-POCUS and CTE was statistically significant (p <0.0001). The time from the request to the start of the POCUS exam was 43 minutes. The results of the POCUS were communicated to the treating team within 70 minutes of the request. The CTE was done within 1.3 days. There was one patient that was inadvertently discharged from hospital before having his CTE. However, he was called back for it within 7 days of the e-POCUS. No major finding was missed in this patient. The agreement between e-POCUS and CTE for the presence of regional wall motion abnormalities (RWMA) was 83% (Kappa=0.61, p=0.009) and 72% for the detection of right ventricular dilatation (Kappa =0.44, p=0.058). In one case, the grading of tricuspid regurgitation was upgraded from mild to moderate. Overall, no major finding was missed. The e-POCUS altered the working diagnosis of the referring physicians in 72% of cases (13/18 cases). For example, one of the cases was a 75 year-old woman presenting to emergency room (ER) with acute shortness of breath and desaturation (Figure 2). The CXR showed interstitial lung markings. The working diagnosis was acute heart failure. She was treated with intravenous furosemide in the ER without any improvement. E-POCUS was requested by the internal medicine in the following 24 hours. The main findings were significant right ventricular dilatation with severe systolic dysfunction. The left ventricular function was normal. Consequently, the treating team stopped diuretics and started investigations for pulmonary hypertension.

![Flowchart of the e-POCUS service with the average timing of each step starting from the time of the requisition (time 0).](Image)
Discussion

Our study was designed to assess the feasibility of providing an expedited POCUS (e-POCUS) evaluation by experienced sonographers to the cardiology, internal medicine and ICU departments in a busy tertiary care Echo Lab. We found that it was easily feasible and useful because the working diagnosis of the referring physicians was altered by e-POCUS exam in 72% of the cases.

E-POCUS diagnostic limitation: The fact that e-POCUS missed subtle RWMA is in keeping with previous work. Other studies have shown that RWMA with POCUS are more likely to be missed compared to the CTE [4]. On the other hand, POCUS and CTE have a good correlation for LV function assessment [4]. The Kappa and percent of agreement for the presence of RWMA in our study was good and it was statistically significant (Kappa=0.61, p=0.009). The cases where RWMA was missed were all identified on the CTE where in one case Definity contrast had to be used for better evaluation.

The detection of RV dilatation was more in the moderate inter-rater agreement range and the p-value was just short of significance due the small sample size (Kappa =0.44, p=0.058). In fact, it is sometimes challenging to assess the RV size due to the limited views of the RV that are obtained. In our study, the cases where there was disagreement were mostly patients where RV dilatation was subsequently seen on CTE where more views of the RV are usually obtained. On the other hand, the assessment of RV systolic function was the same with e-POCUS (visual estimate) and CTE (visual estimate supported by more objective measurements). Lastly, the case where mild tricuspid regurgitation was upgraded to moderate is in keeping with the limitations of POCUS to grade valvular lesion severity. However, it has been shown that there is a good agreement between POCUS and the CTE for the detection of significant valvulopathy [5].

Study limitations

Our study is a single institution project that included a small number of patients. The interpreter of the CTE was not blinded to the POCUS results, which may affect their interpretation. The interpretation of the e-POCUS and CTE were completed by the same reader in 55% of the cases (10 out of 18 cases), which may introduce an element of bias. On the other hand, this approach reflects the day-to-day practice where the echocardiographers rotate through the Echo Lab and don’t have control over which case they can read.

Conclusion

The provision of an expedited cardiac POCUS (e-POCUS) service by the echocardiography lab is feasible and potentially a rapid workflow solution meeting the demands of care providers. The new workflow model offers a potentially new organizational approach to the Echo Lab of the near future, providing rapid imaging, education, and guidance to various hospital departments in a “hub-and-spoke”, centered around a high quality, accredited Unit.

References


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The Master Clinician’s Elective: Integrating Evidence-Based Physical Examination and Point of Care Ultrasonography in Modern Clinical Medicine

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Abstract

Background: Many internal medicine residency programs have incorporated ultrasonography into their curriculum; however, its integration with physical examination skills teaching at a graduate medical level is scarce. The program’s aim is to create a reproducible elective that combines physical exam and bedside ultrasound as a method for augmenting residents’ knowledge and competence in these techniques with the ultimate goal of improving patient care. Methods: We designed and implemented a two-week elective rotation for senior internal medicine residents, combining evidence-based physical examination with diagnostic bedside ultrasonography. The rotation took place in an inpatient setting at Denver Health Hospital. Program evaluation data was collected data between February 2016 and March 2019. IRB approval was waived. Results: Since its inception in 2016, 19 residents completed the rotation. Residents performed a pre-test and a post-test under direct observation by course faculty. Each resident was measured on the ability to perform pre-determined physical exam and point-of-care ultrasound (POCUS) skills. In the pre-test, participants correctly performed an average of 40% of expected physical exam maneuvers and 32% of expected POCUS skills. At elective conclusion, all participants were effectively able to demonstrate the highest yield physical exam and ultrasound maneuvers. Discussion and Conclusion: An elective designed specifically to integrate POCUS and physical exam modalities improves the ability of resident physicians to utilize both diagnostic modalities.

Background

Medical schools and training programs in the United States have shifted emphasis away from physical exam teaching [1, 2]. A recent study identified that students perform worse on the physical examination components of the United States Medical License Examination Step 2 Clinical Skills relative to the history taking components [3]. While modern medical imaging positively impacts patient care in many ways, its widespread availability has decreased practitioners’ reliance on the physical exam for establishing diagnoses, reduced the confidence of trainees and practitioners in their physical examination skills, and eroded their perceived value of the physical examination [4, 5]. In turn, faculty feel unqualified and less motivated to teach these skills, further perpetuating their deterioration [4, 5].

A review by Oliver et. al. [1] revealed a decline of 31.2% from 1975 to 2011 in the number of total body systems documented as examined by house-staff and junior faculty alike. In its Choosing Wisely® campaign, the American Board of Internal Medicine highlights the downstream effects of blind reliance on technological innovation in the practice of medicine: increased healthcare expenditures, medically unnecessary interventions, and adverse patient outcomes [6,7]. Within this context, our elective provides learners with a more tempered integration of a new imaging modality—Point of Care Ultrasonography (POCUS)—into clinical practice with specific goals: to answer a focused clinical question, improve procedural safety, minimize complications, and augment the accuracy of the physical examination.

Additional motivators for our elective include: 1) the expansion of POCUS into inpatient medicine; 2) a national trend to incorporate ultrasound Internal Medicine residency training programs [8]; 3) a growing body of literature supporting the value of POCUS in improving accuracy of the physical exam [9-15]; and 4) technological improvements in POCUS technology that make it accessible and affordable for individual practitioners.

Acknowledging the persistent value of the physical exam while recognizing the need to teach ultrasound skills to future physicians, we sought to synthesize the subjects into a two-week “Master Clinician” elective.

Methods

We designed and implemented a two-week elective, offered yearly since 2016, combining teaching of EBPE skills with POCUS. In order to perform the program evaluation, we collected and analyzed data between February 2016 and March 2019. Six faculty members from the division of Hospital Medicine at Denver Health
Hospital Authority (DHHA), an Internal Medicine Residency Program (IMRP) affiliated site for the University of Colorado, School of Medicine (CUSOM) facilitated the curriculum and taught the content at DHHA. The elective was offered for up to six PGY-2 and PGY-3 categorical Internal Medicine residents in the CUSOM IMRP per course iteration. Since inception, 19 residents have participated. On average, 20 were on the waitlist each year.

**Program’s Development**

The program’s main objective was to create a reproducible and effective elective rotation combining evidence-based physical exam (EBPE) and POCUS as a method for cultivating resident’s knowledge and competence in these techniques, ultimately leading to improved quality of care and patient safety.

The program’s aims included: 1) use of case-based-learning to identify gaps in residents’ skills; 2) employ direct observation to provide learners real-time, targeted feedback; 3) analyze published literature on discussed topics; 4) correlate ultrasound with physical examination findings; 5) provide guidance on how to integrate this information into clinical practice 6) test newly acquired knowledge and skills through near-peer teaching.

By the end of the elective rotation, participants were able to: 1) understand the utility, importance, and evidence

**Table 1. Topic pairs for BPE and POCUS didactics**

<table>
<thead>
<tr>
<th>Evidence-Based Physical Exam Sessions (and some examples of didactic descriptions)</th>
<th>Topics for Point-of-Care Ultrasonography Didactics and Hands-on Skills Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to the use of likelihood ratios and evidence based bedside medicine</td>
<td>Introduction to POCUS and use of an US machine (Knobology)</td>
</tr>
<tr>
<td>Clinical case: Pneumonia (with review of differential diagnosis and introduction to EBPE). Discussion of diagnostic utility of physical exam components in establishing a diagnosis of pneumonia and pleural effusions, with particular focus on egophony and percussion. Includes review of basic pulmonary auscultation, description of abnormal findings, and their clinical implications. Additional discussion on clinical predictors of pneumonia and radiographic findings as they relate to underlying infectious organism.</td>
<td>Lung: Protocolized approach to hypoxia assessment, normal and pathologic profiles.</td>
</tr>
<tr>
<td>Clinical case: Chest Pain (Acute Coronary Syndrome, Venous Thromboembolism)</td>
<td>DVT: Rule-in assessment using two-zone approach</td>
</tr>
<tr>
<td>Clinical cases: Syncope</td>
<td>Shock Assessment (IVC measurement, RUSH protocol, assessment for cardiac tamponade)</td>
</tr>
<tr>
<td>Clinical case: Congestive Heart Failure. Discussion of diagnostic utility of physical exam components in establishing heart failure, with particular focus on JVP assessment, PMI, predictors of valvular pathology based on murmur characteristics, and discussion of the Valsalva maneuver.</td>
<td>Focused Cardiac Ultrasound (FOCUS) using four views to assess for pericardial effusion, gross assessment of left ventricular function, and right ventricular size</td>
</tr>
<tr>
<td>Clinical Case: Cirrhotic Liver Disease</td>
<td>Abdominal US: RUQ, LUQ, Abdominal Aorta</td>
</tr>
<tr>
<td>Clinical Case: Gastrointestinal Bleeding</td>
<td>Procedures: Paracentesis, Thoracentesis, Joint Aspiration</td>
</tr>
<tr>
<td>Clinical Case: Abdominal Pain. Discussion of diagnostic utility of physical exam components (isolated maneuvers vs. diagnostic scores) in establishing a diagnosis of hepatomegaly, acute cholecystitis and acute appendicitis.</td>
<td>Abdominal US: Renal and Bladder</td>
</tr>
<tr>
<td>Clinical Case: Chronic Obstructive Pulmonary Disease</td>
<td>Scanning Workshop: Hands-on skills improvement and introduction to quality assessment and online free and open access medical education resources (FOAMed)</td>
</tr>
<tr>
<td>Clinical Case: Soft tissue pathology</td>
<td>Soft tissue and Musculoskeletal</td>
</tr>
</tbody>
</table>
Table 2. Primary and Secondary Resources for Course development.

<table>
<thead>
<tr>
<th>Primary Resources</th>
<th>Selected Secondary Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POCUS topics</strong></td>
<td></td>
</tr>
</tbody>
</table>

behind common and uncommon physical exam maneuvers; 2) demonstrate the ability to apply likelihood ratios (LR) to modify diagnostic probability; 3) exhibit the aptitude to implement an EBPE by correctly performing high-yield physical exam maneuvers, accurately identifying the presence of pathology during examination, and synthesizing signs with clinical decision making; 4) confirm or challenge clinical diagnosis by skillfully performing high yield POCUS maneuvers; 5) utilize POCUS to increase success rates and decrease complications of medical bedside procedures. Institutional Review Board approval was not required for this study.

Program’s Implementation
To ensure integration, each instructional day provided EBPE teaching and POCUS training sessions focused on a single content area. We organized each day as follows: one hour of independent reading and literature review, followed by one-hour long interactive EBPE didactic. This was followed by two hours of EBPE bedside-rounding led by faculty on prescreened patients with pathology relating to that day’s topic. In the afternoon, interactive pedagogies continued with a one-hour POCUS didactic session, followed by two and a half hours of POCUS rounding, led and supervised a trained faculty.

Session topics (Table 1) and clinical cases were selected based on the relevance to hospital medicine (commonly encountered diagnosis) and on published literature in EBPE and POCUS (Table 2). During EBPE didactics faculty highlighted the limited diagnostic value of commonly performed exam maneuvers, subsequently discussing and demonstrating specific exam maneuvers with the highest diagnostic yield. Course participants practiced these maneuvers under direct observation of faculty while receiving feedback. POCUS content focused on: image acquisition, identification of pathologic findings,
and integration into clinical reasoning. Image acquisition was taught systematically for each application and can be deconstructed as follows: 1) visualization during a short didactic lecture; 2) hands-on guided scanning with one of the two POCUS content faculty; 3) practicing during unguided free-scanning; 4) quality assessment guided by POCUS faculty. Integration of POCUS into clinical reasoning aimed to supplement the EBPE using systematic approaches to scanning in each content area and body region. Course participants then demonstrated POCUS knowledge acquisition at course end by preparing and presenting key concepts to their peers during a noon conference, with POCUS faculty on-hand to guide discussion and ensure accuracy. Enrollment was capped to optimize the participant to attending ratio, which was maintained at a 5:1 ratio.

To overcome a common challenge of identifying patients with relevant pathology, our faculty developed reporting tools within our Electronic Medical Record (EMR - Epic) to identify patients with diagnoses relevant to the course.

Program’s Assessment

We combined quantitative and qualitative measures. Beginning in 2016, all participants underwent a pre-test and post-test which involved direct observation of learners conducting the physical exam, followed by real-time feedback with the goal of motivating them to improve their physical examination skills. For the pre-test, participants were asked to perform a comprehensive cardiac examination for a patient with suspected heart failure, a comprehensive pulmonary exam for a patient with suspected pneumonia, a targeted exam for cirrhotic patients, and a focused neurologic examination. They were directly observed using a standardized checklist (Figure 1) to assess whether they correctly perform physical exam maneuvers recognized in the literature to have good predictive value for heart failure, pneumonia, and complications of cirrhosis.

Results

In 2019, the three participants that completed both pre- and post-tests (because of illness and scheduling conflicts, only 3 of 5 participants were observed pre and post)—correctly performed an average of 3.3 of 9 (range 0-7) components related to visual assessment of JVP in the pre-test and 4.7 in the post-post (range 4-6). Only 1 of 3 assessed the point of maximal impulse (PMI) in the pre-test; all 3 assessed PMI in the post-test. In the pre-test, no participant correctly assessed for egophony or asymmetric pulmonary expansion; all 3 assessed both in the post-test. Cirrhosis inspection and palpation scores improved from 0.67 (range 0-2) to 4.67 (range 3-6) (of 6) and 2 (range 1-3) to 4 (range 3-5) (of 5) pre- to post-test, respectively (Table 3). A twenty-six point checklist created by the POCUS faculty was used to perform a pre-elective hands-on cardiac and lung POCUS skills assessment. The US skill checklist is shown in Figure 2. This assessment tested knowledge and performance of ultrasound probe and machine functions, relevant anatomy focused on standard views of the heart and lungs, and basic diagnostic POCUS assessments of these organs. The median pre-test score was 9 out of 26 possible points.

At the conclusion of the elective, participants prepared and delivered small group teaching sessions to junior learners, discussing the evidence-based elements of the cardiac and pulmonary examinations. They also demonstrated and led learners in the proper examination techniques on actual patients. Their teaching was directly observed, and they received feedback on their teaching techniques. All participants were effectively able to describe the pathophysiology underlying abnormal exam findings, demonstrate the highest yield physical exam maneuvers, and explain the method of acquisition and clinical implications of basic cardiac and pulmonary POCUS. At the end of the elective the POCUS hands-on skills assessment was repeated with an improvement of the median to 26 of 26 points.

We also included components not covered in the course (neurologic examination) to serve as a control measure for our pre- and post-test exams. The average score on the neurologic pre-assessment was 3.67 (range 3-5) and the post course assessment average score was 2.67 (range 2-3).

The Master Clinician Elective underwent continuous comprehensive evaluation following the Plan-Do-Check-Act (PDCA) format, widely known as a strategic planning modality. Learners were asked to provide constructive feedback on rotation structure, individual didactic sessions, and faculty at course end.

Discussion

In the era of high value care, we believe it imperative for
Because faculty and ultrasound resources are limited, we are working to expand our ability to teach this important content through both internal faculty development and partnering with other IMRP clinical sites. Our data clearly shows a marked improvement of learners in both their physical exam and POCUS skills. While our elective is a collaboration of four physical exam-focused providers and two POCUS providers, it could feasibly be run with as few as 1 of each with enrollment limited to four participants. One of the challenges for our faculty and for faculty at other programs is limited protected time for POCUS education. Our study demonstrates the value of this elective, which should support decisions regarding allocation of protected time for faculty to dedicate to POCUS education.

This elective requires the availability of bedside ultrasound technology and faculty with a level of expertise to accurately teach bedside ultrasound applications. In our experience, learners require approximately 1 machine for every 2 to 3 learners to have adequate scanning time to achieve course ultrasound goals. Our POCUS expert faculty collaborated in the curriculum design and reflected their experience as hands-on educators at a national level. All future practitioners should master EBPE and POCUS skills. Because faculty and ultrasound resources are limited, we are working to expand our ability to teach this important content through both internal faculty development and partnering with other IMRP clinical sites. Our data clearly shows a marked improvement of learners in both their physical exam and POCUS skills.

<table>
<thead>
<tr>
<th>Points</th>
<th>Total Points Pre-Test: /26</th>
<th>Total post-test: /26</th>
</tr>
</thead>
</table>

Figure 2. Checklist for Bedside Ultrasound Skills- Chest (heart and lung) POCUS. Used for both Pre and Post Test.

**POCUS Skills**  
Heart and Lung Bedside Ultrasonography

<table>
<thead>
<tr>
<th>A</th>
<th>Preparation for Cardiac US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choose appropriate probe. Low frequency 3-5 MHz, cardiac probe</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B</th>
<th>Long axis view</th>
</tr>
</thead>
<tbody>
<tr>
<td>Place probe over left 3rd to 4th intercostal space along cardiac long axis.</td>
<td></td>
</tr>
<tr>
<td>Visualize RV, LV, MV, AV, pericardium and descending aorta.</td>
<td></td>
</tr>
<tr>
<td>Evaluating Ejection Fraction (EF): Visual Assessment Anterior MV leaflet movement toward IVS</td>
<td></td>
</tr>
<tr>
<td>LV thickness visual assessment</td>
<td></td>
</tr>
<tr>
<td>Pericardial effusion</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C</th>
<th>Short axis view</th>
</tr>
</thead>
<tbody>
<tr>
<td>Place probe over 3rd intercostal space perpendicular to cardiac axis</td>
<td></td>
</tr>
<tr>
<td>Visualize LV, LA, RV, papillary muscles</td>
<td></td>
</tr>
<tr>
<td>Visual assessment of EF: Wall motion toward center of LV</td>
<td></td>
</tr>
<tr>
<td>Assess septal wall motion</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>D</th>
<th>Sub-xiphoid View</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visualize all 4 chambers</td>
<td></td>
</tr>
<tr>
<td>Rule out pericardial effusion</td>
<td></td>
</tr>
<tr>
<td>Move to IVC successfully</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>E</th>
<th>Four-chamber Apical View</th>
</tr>
</thead>
<tbody>
<tr>
<td>Able to visualize all 4 chambers and apex</td>
<td></td>
</tr>
<tr>
<td>Assess septal wall motion</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>F</th>
<th>IVC evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient in supine position</td>
<td></td>
</tr>
<tr>
<td>Place probe over xiphoid in long axis over IVC</td>
<td></td>
</tr>
<tr>
<td>Visualize IVC passing through the liver</td>
<td></td>
</tr>
<tr>
<td>Distinguishing IVC vs. Aorta (arriving into RA, respiro-phasic variation, non-pulsatile)</td>
<td></td>
</tr>
<tr>
<td>Obtaining appropriate image (IVC, hepatic vein and RA in same window)</td>
<td></td>
</tr>
<tr>
<td>Evaluating volume tolerance by: [] Static measure at either 3cm from RA insertion or 1cm behind hepatic vein takeoff, [] Sniff test, [] respiro-phasic variation</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>G</th>
<th>Lung ultrasound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify all lung Zones (4 per hemi-thorax)</td>
<td></td>
</tr>
<tr>
<td>Identify lung sliding</td>
<td></td>
</tr>
<tr>
<td>Identify A lines</td>
<td></td>
</tr>
<tr>
<td>Identify B lines vs. diffuse B profile pattern</td>
<td></td>
</tr>
<tr>
<td>Use M Mode to identify “Seashore Sign”</td>
<td></td>
</tr>
</tbody>
</table>

**Abbreviations:**  
level. They are invited speakers and faculty at annual conferences for the American College of Physicians, Society of Hospital Medicine (SHM), American College of Chest Physicians (CHEST), and Society of General Internal Medicine. A low number of learners per machine is a design tool used at the national level to maintain learner engagement and maximize individual teachable moments for this hand-eye skill. The incorporation of unguided scanning time with post-image acquisition quality review mimics on a small-scale the portfolio building processes used by both CHEST and SHM certification programs.

Our study is single-center and, by design, small in size. We believe it would be easily reproduced at other institutions, with limitations. The limitations are, in order of anticipated impact, a requirement of faculty skilled and capable of teaching POCUS and assessing skill and image acquisition of novice learners, access to ultrasound devices, faculty capable and skilled in teaching EBPE. While there are standards for what constitutes quality image acquisition and interpretation, there is inherent subjectivity in a bedside assessment of the learner. Furthermore, the assessment of learners was not blinded and was conducted by course faculty, leading to a possible bias of skills assessment and is a limitation of our findings.

Other considerations include the fact that we did not assess skill decay. The optimal frequency of “refresher” courses that would allow knowledge and skill retention is yet to be determined.

We recognize that many GME programs offer POCUS training [8-10]. The University of Toronto has published the only other curriculum available specifically combining physical exam and POCUS, but with only subjective evaluations available [11]. We believe our elective is novel in its integration of EBPE and POCUS and its focus on objectively demonstrating skills acquisition that can impact the provision of timely, high-value care for patients at a safety net hospital. This educational model allows us to utilize our limited resources effectively, rekindles enthusiasm for using the physical exam, improves physical exam skills and POCUS among medical trainees, and fosters their interest and ability to teach these important tools.

**Conclusion**

An elective designed specifically to integrate POCUS and physical exam modalities improves the ability of resident physicians to utilize both diagnostic modalities. This elective enhances clinical reasoning by weaving traditional EBPE with novel POCUS, however little is known regarding the clinical impact of this training paradigm. How would this change medical imaging ordering practices? Will the positive yield of these orders increase? Will this process decrease or increase length of stay and overall hospital cost? These are amongst some of our high priority questions.

**References**


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Demonstration of a Longitudinal Medical Education Model (LMEM) Model to Teach Point-of-Care Ultrasound in Resource-Limited Settings

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Abstract

Background: Short-term medical missions prevail as the most common form of international medical volunteerism, but they are ill-suited for medical education and training local providers in resource-limited settings. Objective: The purpose of this study is to evaluate the effectiveness of a longitudinal educational program in training clinicians how to perform point-of-care ultrasound (POCUS) in resource-limited clinics. Design: A retrospective study of a four-month POCUS training program was conducted with clinicians from a rural hospital in Haiti. The model included one-on-one, in-person POCUS teaching sessions by volunteer instructors from the United States and Europe. The Haitian trainees were assessed at the start of the program and at its conclusion by a direct objective structured clinical examination (OSCE), administered by the visiting instructors, with similar pre- and post-program ultrasound competency assessments. Results: Post-intervention, a significant improvement in POCUS competency was observed across six different fundamental areas of ultrasound (p < 0.0001). According to our objective structured clinical examination (OSCE), the mean assessment score increased from 0.47 to 1.68 out of a maximum score of 2 points, and each trainee showed significant overall improvement in POCUS competency independent of the initial competency pre-training (p < 0.005). There was a statistically significant improvement in POCUS application for five of the six medically relevant assessment categories tested. Conclusion: Our results provide a proof-of-concept for the longitudinal education-centered healthcare delivery framework in a resource-limited setting. Our longitudinal model provides local healthcare providers the skills to detect and diagnose significant pathologies, thereby reducing avoidable morbidity and mortality at little or no addition cost or risk to the patient. Furthermore, training local physicians obviates the need for frequent volunteering trips, saving costs in healthcare training and delivery.

Background

Point-of-care medicine is a rapidly emerging field in diagnostic imaging that allows clinicians to administer acute care at the bedside in emergent situations [1]. Namely, point-of-care ultrasound (POCUS) is a reliable diagnostic tool that affords clinicians the ability to examine patients in real time and make clinical assessments without the expense, delay, or radiation associated with other imaging modalities [2]. Given its profound versatility, usability, and low training requirements, POCUS is emerging as an increasingly important tool for bedside diagnosis [3-9].

With reduced costs and a user-friendly portable interface, POCUS holds promise for application in resource-limited settings that often suffer from a lack of access to diagnostic imaging technologies [13]. Previous studies have shown POCUS to be effective in developing countries. For instance, Shah et al. showed that in two district rural hospitals the utilization of ultrasound changed the course of patient care up to 43% of the time [14], while Kotlyar et al. reported a ultrasound-driven change in patient management in 62% of cases in a tertiary care center in Liberia [15]. Furthermore, POCUS education was shown to improve patient care by Mathews et. al., who developed a standardized protocol of POCUS education that resulted in long-term retention of ultrasound image acquisition and interpretation skills [16].

Given the well-documented benefits of POCUS, applying this technology to resource-limited areas would be opportune. Traditionally, international volunteering trips to resource-limited settings are centered around ‘short-term
medical missions’ (STMMs), which are largely considered to be cost-ineffective and limited in timespan [17]. One primary driver of this low efficacy is that many pathologies, especially in resource-limited areas, cannot be detected and/or treated in the duration of a single medical mission. Most medical interventions in these settings often require delivery of delayed lab results or treatment of complications secondary to initial treatment, which precludes clinical follow-up especially in the timeframes of typical STMMs [17]. As a result, the existing medical infrastructure is left to bear the consequences of treating an acute influx of patients with already limited resources. Given these drawbacks, follow-up post-STMM treatment may potentially adversely affect the existing patient population as a result of a diversion and dilution of limited medical resources [17]. Specifically, the use of POCUS in medical volunteering trips requires additional training that many clinicians practicing in low-resource medical institutions lack, making incorporating POCUS into medical practice challenging.

In this study, we propose a novel educational model, ‘longitudinal medical education model’ (LMEMs), and discuss how this model transcends many of the limitations faced by traditional STMMs. The LMEM model provides a unique framework for sustained medical education while minimizing costs and burden on the instructors. This was accomplished through an extended program that emphasizes hands-on training at the bedside, as opposed to the traditional patient care-oriented model of STMMs. Traditional short courses can get trainees familiar with POCUS, but their skills can often decay overtime as a result of a lack of longitudinal repetition. Alternatively, trainees are more likely to retain skills and continue utilizing POCUS as part of their standard practice with a longitudinal training program over months, rather than an intensive, traditional two- or four-day course. However, many volunteer POCUS experts are unable to dedicate many months away from their respective practices to teach such longitudinal courses.

To address this limitation, we created multiple teams of two to three instructors where each team visits the low-resource medical clinic for one week, spread out over a four-month period. This provided continuous mentorship for the POCUS trainees over the course of many months and allows for longitudinal hands-on training and evaluation. Furthermore, utilizing an array of instructors from Europe and the United States provides a broad perspective in teaching POCUS. The objective of the bedside training sessions is to work with the trainees individually and teach them fundamental POCUS skills through real-time clinical scenarios. Training local physicians reduces the need for frequent volunteering trips in the long run and has the potential to save tremendous costs in healthcare delivery. We show that by equipping and training Haitian physicians with state-of-the-art diagnostic tools, such as POCUS, we can correctly diagnose many prevalent pathologies that often go misdiagnosed due to a lack of training and resources.

Methods

We retrospectively evaluated the efficacy of the proposed LMEM model implemented over the span of four months. Study participants were clinicians from the 68-bed Alma Mater Hospital in Gros-Morne, Haiti, a small rural community on the north side of the Caribbean island. The program consisted of 12 local Haitian physicians, with 4 of the 12 completing the full 4-month training program while the remaining 8 engaged in a fraction of the training program. Our POCUS educators were practicing physicians across a wide variety of specialties including radiology, internal medicine, family practice, and emergency medicine.

Program Description

The goal of our hospital-based POCUS training program was to demonstrate a proof-of-concept methodology in incorporating the usage of POCUS in resource-limited settings to ultimately improve the accuracy and timeliness of diagnoses and safety of procedures by utilizing ultrasound guidance. Our POCUS training program consisted of nine weeks of in-person training sessions spread over the course of four months. There were two week-long sessions for a general introduction to ultrasound, followed by seven weeks of POCUS training with one- to two-week separation periods interspersed throughout the training program. The overall training program consisted of a total of six ultrasound fundamentals: neck, lung, abdomen, cardiac, lower extremity, and soft tissue (Table 1). The curriculum was tailored to the individual specialties of the volunteer POCUS instructors on each week-long trip; collectively, they were able to cover a variety of hands-on concepts, as detailed in Table 1. Our pre- and post-training program objective structured clinical examination (OSCE) assessments were designed to assess the basics of POCUS, and were adapted from the Comprehensive Hospitalist Assessment and Mentorship with Portfolios (CHAMP) ultrasound program from Mathews et al [16]. All volunteer instructors followed a standard set of ultrasound education principles to guide the in-person training of participants.

Online Modules and Supplemental Reading

Online training modules were provided by SonoSim, Inc. and featured a handheld probe simulator for interactive feedback. We asked the study participants to review the relevant online modules prior to the weekly group
sessions that focused on a particular POCUS topic. For example, the participants were asked to review the echocardiography online module from SonoSim, Inc. prior to a week-long, in-person didactic sessions with the echocardiography specialist. This online module-based training was supplemented with Point-of-Care Ultrasound POCUS-training textbook from Soni et al, which also acted as a reference guide for the study participants [18].

**Bedside POCUS Training**

As aforementioned, the core of our POCUS training program involved a series of nine week-long, hands-on training sessions that together formed a single LMEM. The program utilized the Philips Lumify portable ultrasound system consisting of their S4-1 cardiac, C5-2 curvilinear, and L12-4 linear transducers. The Lumify system remained on-site indefinitely for continued usage by the trainees after the conclusion of the training program.

**Reacts-enabled Tele-ultrasound Training and Collaboration**

In addition to the in-person training provided by volunteer POCUS experts, we used the Lumify with Reacts (Remote Education, Augmented Communication, Training and Supervision) integrated tele-ultrasound software developed in collaboration by Philips ultrasound and Innovative Imaging Technologies (IIT), Inc. in order to work with the study participants remotely in real-time. Reacts is a collaborative platform developed by IIT that allows for real-time remote medical education and consultation. The hand-held ultrasound system simultaneously streams ultrasound images along with video and audio in real-time. The system was used to continue ultrasound education during the limited number of weeks where POCUS educators were not available to travel to Haiti. These remote training sessions were conducted approximately three times over the course of the four-month data collection period using a reliable cellular or Wi-Fi connection.

**Assessments**

Trainees were assessed in six core areas of ultrasound in terms of imaging and interpretation: neck, lung, abdomen, cardiac, lower extremity, and soft tissue. In each of these areas of assessment, there were multiple skills, and participants were evaluated on a scale of 0 to 2 for each skill. A score of 0 represents the inability to generate the ultrasound image, 1 represents the ability to generate the ultrasound image but an inaccurate interpretation of the image, and 2 represents the ability to both generate and interpret the ultrasound image. This ultrasound skills assessment was adapted from the CHAMP ultrasound program [16].

**Statistical Analysis**

Assessment scores per core area with multiple skills were reported as the average of values, with the minimum possible score being 0 and the maximum being 2. Comparisons of assessment scores were performed using paired-samples t-test. Differences were considered statistically significant when p-value was less than 0.05. Statistical Package for the Social Sciences (SPSS) (IBM SPSS Statistics for Mac, Version 26.0. Armonk, NY: IBM Corp) was used for analysis.

**Results**

The assessment score data for our sample of n = 4 physicians that completed the training program is shown in Fig. 1. The mean score across all assessments in the fundamental areas of POCUS are shown in Fig. 1(a);
prior to our program, the average score per assessment was 0.47, which improved to 1.68 (p < 0.0001) after the training program. Furthermore, each physician showed substantial overall improvement in POCUS competency (Fig. 1(b)), independent of the initial competency pre-training (p < 0.004). Finally, there was an overall improvement in POCUS application for five of the six medically relevant assessment categories tested: neck, lung, abdomen, cardiac, and lower extremity imaging (Fig. 1(c)).

Discussion

The LMEM model demonstrates a statistically significant trend of improvement in most categories of assessment. Given that our sample population consisted of Haitian physicians, the baseline assessment scores shown in Fig. 1(b) is expected, as the Haitian medical education covers many of the fundamentals of neck, lung, abdomen, and cardiac anatomy. In contrast, trainees exhibited no prior knowledge regarding image acquisition and interpretation with respect to lower extremities/DVTs and soft tissue ultrasonography, which are often considered to be more advanced ultrasound techniques. Improvements in assessment scores were observed in all categories of ultrasound image acquisition and interpretation regardless of previous experience.

One limitation to this study was the trainee dropout rate. The dropout of eight out of twelve clinicians could have led to attrition bias in the assessment scores. Compared to other ultrasound training programs reported in the literature [19, 20], our dropout rate is expected. Follow-up with the clinicians who did not complete the program would be informative to understand the attitudinal, psychomotor-skill related, cultural, language, and/or clinical barriers to learning POCUS in a resource-limited setting. Despite this dropout rate, the longitudinal nature of this ultrasound training program resulted in highly skilled POCUS trainees, a few of which extended their clinical employment with the Alma Mater Hospital to continue their POCUS training of the remaining clinicians, including some that did not finish the training program described herein. These new POCUS-trained clinicians serve as evidence for the efficacy of the longitudinal model over the traditional short-term trips—by continually training local physicians, they are reducing the need for future volunteer trips.

Qualitatively, Physician C in Fig. 1(b) reported to have studied textbook ultrasound training material prior to the beginning of the program, while the other physicians reported no such self-studying [18]. The data suggests that self-study, even without hands-on practice, could be beneficial for improved assessment scores both during the pre-study assessment and post-study assessment. Indeed, among all the study participants that completed

Figure 1. Mean assessment score of physicians pre- and post-training program with 95% confidence level. (a) The average POCUS competency score per assessment (trainees were given a 0, 1, or 2) pre- and post-training. Paired t-test, df=66, p < 0.0001. (b) The average POCUS competency score per assessment pre- and post-training for each physician that completed the entirety of the training program. Paired t-test, df=14, 17, 18, and 14 for Physicians A, B, C, and D, respectively, p = 0.0032 for Physician A, p < 0.0001 for Physicians B - D. (c) The average POCUS competency score per assessment pre- and post-training for each of the six medically relevant categories, as per the delineated categories in our assessment. Paired sample t-test, df=8, 11, 19, 15, and 8 for neck, lung, abdomen, cardiac, and lower extremity/DVT, respectively. p = 0.0207, p < 0.0001, p < 0.0001, p = 0.0002, and p < 0.0001, for neck, lung, abdomen, cardiac, lower extremity/DVT, respectively. Due to limited data in soft tissue category, no statistical testing could be conducted in this category. Vertical lines above each bar indicate one standard error of the mean on either side of the mean; absence of a bar indicates a mean of 0, and absence of a line above a bar indicates no reportable standard error. PRE-ASMT = Pre-assessment; POST-ASMT = Post-assessment.
this training program, Physician C performed the best in both the pre-training and post-training assessments conducted. Further randomized studies are needed with a larger number of study participants in order to better investigate if pre-program studying is beneficial to physician competency both during and following the program.

During this study, remote tele-ultrasound education was explored using the Reacts software integrated into the Philips Lumify ultrasound system. We found the Lumify with Reacts tele-ultrasound to be user-friendly and convenient even in this resource-limited setting. This suggests that Lumify with Reacts tele-ultrasound is a viable option for continued education and training even in resource-limited settings. In general, Lumify with the Reacts integration used in this study presents an exemplifying instance of the growing field of healthtech advancements, enabling long-term cost reductions and the ability to pursue sustainable LMEMs. This platform has the potential to empower local POCUS leaders to scale up training of other nearby communities with the support and expertise of international volunteer instructors, circumventing language/cultural barriers and high transportation costs, and reducing the target communities’ dependence on foreign involvement in the long run. This concept of self-sustainability is a particularly promising feature of the LMEM, as evidenced by the trainees training additional Haitian clinicians.

We envision the potential for many long-term benefits of pursuing LMEM as opposed to STMMs in terms of cost, sustainability, and self-reliability. As discussed previously, the primary limitation with most STMMs is that they are unable to build on previous work done with the communities of interest; every medical mission is essentially conducted independently of adjacent ones. Thus, while current STMMs can provide temporary relief with varying efficacy, they are not appropriately structured to provide medical assistance in the form of specialized medical education, technical training, and other forms of aid that cannot feasibly be accomplished within the mission’s short time frame. LMEM is a feasible solution to address this problem, and we have demonstrated its use in bringing POCUS education and technology to an under-resourced setting.

Conclusions

The proposed LMEM model successfully demonstrates a pragmatic method of incorporating POCUS into an existing medical infrastructure in a resource-limited setting. Our POCUS training program significantly improved the clinician study participants’ ultrasound acquisition skills, and thereby patient care. By training local physicians through a longitudinal model and equipping them with state-of-the-art technology, we transcend many of the limitations suffered by short-term volunteering projects and promote self-sustainability. This eliminates the need for on-going volunteering trips thereby saving healthcare costs. Additional technological advancements, such as real-time tele-ultrasound training platforms and lower-cost ultrasound transducers will synergistically allow for more effective changes to community healthcare systems and improvements to differential diagonoses and patient treatments over the long term.

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Conflicts of Interest

The authors have no conflicts of interest to disclose.

Ethics Approval

This study was deemed exempt and approved by the Legacy Emanuel Institutional Review Board (IRB) (Portland, OR) under exempt certification for research conducted in established or commonly accepted educational settings, involving normal educational practices.

References


Can the Use of Bedside Lung Ultrasound Reduce Transmission Rates in The Case of The COVID-19 Patient? - A Narrative Review

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Abstract
Novel Corona Virus Disease-19 (nCov-19, COVID-19) was recognised as a pandemic by the World Health Organization on March 11, 2020. As of June 14, 2020, this contagious viral disease has afflicted 188 out of 195 countries in the world with 7,893,700 confirmed cases and 432,922 global deaths. Canada has 98,787 people infected and 8,146 deaths. COVID-19 is thought to transmit through contact, droplets and aerosolization. A rapid review showed limited information on the benefits of conducting lung ultrasound (LUS) versus chest radiograph (CXR) or studies correlating lung ultrasound to chest computed Tomography (CT) in patients positive for Covid-19. The literature review confirmed that CT and LUS cannot diagnose this disease, but that both can help in the management and staging of this disease. There is no literature to prove that LUS at the bedside may be beneficial from the view of decreased transmission to other health care workers and bystanders due to reduced transit but comparing the transit pathway and contact leads one to propose that this would be so. Pregnant patients with COVID-19, young children and patients in the reproductive stage would also benefit from LUS since there is no radiation dose and the critical patient in distress will benefit from testing at the bedside.

Introduction
On March 11, 2020, the World Health Organization (WHO) declared Corona Virus Disease 2019 (COVID-19) a pandemic [5]. This declaration and the virus has impacted the world; as of June 14, 2020; 188 out of 195 countries have been impacted, there are 7,893,700 confirmed cases, an increase of over 5 million since April 18, 2020, and 432,922 global deaths (156,064 April 18, 2020) [1]. Canada reported 98,787 confirmed infections on June 14, 2020; this number has tripled in 2 months and 8,146 deaths, a six-fold increase from April 18, 2020 [14].

COVID-19 is predominantly a respiratory disease, with severity ranging from mild to fatal [2]. Transmission is thought to be by contact, droplets and aerosol generating medical procedures (AGMP) [14,16]. COVID-19 findings are consistent with a viral pneumonia caused by viral infections such as Severe Acute Respiratory Syndrome (SARS) or Middle East Respiratory Syndrome [2,4,7].

Methods
Articles were extracted from PubMed, Ovid, and Google Scholar, to identify meta-analysis, original research and case reports. Information from government and educational websites such as The World Health Organization, Canadian provincial government resources and guidelines from the American college of Radiology (CAR) were also reviewed for current statistics and recommendations.

The last search of each database was conducted on June 14, 2020.
dyspnea while awaiting confirmatory testing or in areas where molecular assays are unavailable” [11]. Serial ultrasounds can also aid in tracking the clinical path and guide appropriate treatment or interventions [11].

Computed Tomography (CT) of the chest is the best diagnostic imaging for lung consolidation; however, it is not recommended for diagnostic use in COVID-19 [12, 17]. Instead it is recommended to be used as a diagnostic test in cases where it will impact patient management, or to evaluate for urgent or emergent conditions [6,7]. Use of this diagnostic test requires transfer of patients to and from the CT scanner, potentially exposing transportation staff, staff in the CT room as well as passersby [6,11,12]. Patients having this test are exposed to radiation and it is contraindicated for pregnant patients [12,17]. Proper disinfection of this unit can be lengthy; limiting access to the equipment, as many hospitals have only 1 or 2 CT suites [7,12]. Chest radiographs (CXR) may be used but have the same transit path if not portable, and regardless of portable or radiology suite based, it will require the same disinfection and contraindications due to the radiation dose [2,12]. The American College of Radiology (ACR) recommends that Chest CT not be used to screen for or diagnose COVID-19 and that it be used sparingly in hospitalized or symptomatic patients to decrease the risk of infection transmission [12].

Lung ultrasound (LUS) if performed at the patient’s bedside (Figure 1) will reduce patient transit, contact with additional health care workers (HCWs) and medical devices [2,4,8,11]. This in turn may decrease human resources and personal protective equipment used, thus providing more efficient, higher value care for the COVID-19 patient [11]. Ultrasound performed at the patient’s bedside is also more feasible for the critical patient that cannot be moved to the CT scanner. LUS is without radiation exposure which is of extra benefit in pregnant patients, young children and patients in the reproductive age where CT radiation is contraindicated or should be limited. Disinfection of the portable or hand-held ultrasound devise is easier and more efficient to complete than that for a CT or CXR suite [2,12]. Finally, lung ultrasound at the bedside may provide more compassionate care to the patient who is in physical or emotional distress.

Conclusions

COVID-19 is an unprecedented, extremely contagious disease in modern times. Chest CT has been historically utilized for lower respiratory tract infections and has excellent diagnostic value, but at this time ACR recommendations are to limit its use. LUS can be utilized for imaging and assessing for lung consolidation; however, there is little research or reports to establish the correlation between the 2 imaging tests or the sensitivity or specificity for lung ultrasound in COVID-19 patients. Regardless, LUS could potentially reduce exposure and thus transmission to HCWs, reduce human resources and provide more efficient care. It is also ideal for patients in whom CT is not recommended, or would not tolerate transfer to the CT suite.

For some, LUS is a new diagnostic imaging test emerging in this pandemic; for others it has been used for years. This diagnostic imaging test may prove to be valuable but more rigorous research and reporting needs to be done.

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