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Research:

Does the addition of ultrasound enhance cardiac anatomy learning in undergraduate medical education?

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Case Report

Point of care ultrasound of a broken heart
by Winnie Chan, MD, FRCPC and Joseph Newbigging, CCFP(EM), FCFP
Queen’s University, Kingston Ontario

Clinical case

Mrs. K, a 70 year old lady, presented to the urgent care with severe retrosternal chest pain that started at rest. She described the pain as a constant heaviness and rated it as 9/10 in severity. The pain did not radiate to the neck, arms, or back. The pain had started one hour after she was informed that her son had passed away unexpectedly. She denied any associated shortness of breath, nausea, diaphoresis, or presyncope. There was no relief with nitroglycerine spray. Mrs. K denied any previous episodes of similar chest discomfort. Her only cardiac risk factor was dyslipidemia. Her other comorbidities included gastroesophageal reflux disease and a previous hip arthroplasty.

Mrs. K was hemodynamically stable on presentation. Her blood pressure was 147/93, heart rate 96 BPM, RR 22 breaths per minute, oxygen saturation (SPO2) 100% on room air, afebrile. She had a normal physical exam and was euvolemic. Her initial ECG showed 0.5 mm of ST elevation in aVL (online Figure S1). There was no evidence of ST depression or T wave inversions. Q waves were present in the right precordial leads (V1 to V3). There were no pathologic ST or T wave changes in these leads. These Q waves were new since her last documented ECG in 2007. Her QT interval was 462ms. The 15 lead ECG did not show any additional pathology. Serial ECGs over the next two hours did not show any dynamic changes, however, there was further prolongation of the QT to 503 ms. Her initial chest x-ray was normal. Her initial high sensitivity troponin was 2355 ng/L (Normal <30ng/L) and CK was 512 U/L (Normal 35-164U/L).

Clinical dilemma

Mrs. K presented with visceral chest pain and troponin rise. The most likely diagnosis accounting for her presentation was acute coronary syndrome. Myocarditis, acute pulmonary embolism, and aortic dissection were other possibilities in the differential, although atypical for this type of presentation. The temporal relationship between the onset of chest pain and acute emotional stressor raised the suspicion of a possible Takotsubo syndrome. Looking at prevalence alone, the diagnosis of acute coronary syndrome was more likely, Takotsubo syndrome accounts for approximately 1-2% of all patients who present with suspected acute coronary syndrome or ST- elevation myocardial infarction [1]. Both Takotsubo syndrome and acute coronary syndrome would be expected to present with wall motion abnormalities.

Indication for point of care ultrasound

1. Assess for left ventricular wall motion abnormalities (Table 1).
2. Screen for other cardiac emergencies which would present with chest pain.

Image interpretation

The apical four-chamber view (Figure 1, online Video S1) showed moderate reduction of left ventricular systolic function. There was akinesis/hypokinesis of the mid inferoseptal and anterolateral segments and the apex. The base appeared hyperdynamic. Right ventricular size and systolic function were normal.

The parasternal long axis view (online Video S2) similarly showed a hyperdynamic base with mid anteroseptal akinesis. The inferolateral basal and mid segments were contracting normally.

The parasternal short axis view (online Video S3), taken at the papillary muscle level, demonstrated diffuse hypokinesis/akinesia. Only the inferolateral segment in this view was contracting normally.

The subcostal view (online Video S4) did not demonstrate any

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Table 1. Image acquisition (Note: All images were acquired using general radiology convention, used frequently in emergency medicine. Screen index marker is on the left)

<table>
<thead>
<tr>
<th>Parasternal long axis view</th>
<th>3rd or 4th intercostal space, left parasternal border, index marker to the right shoulder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parasternal short axis view</td>
<td>3rd or 4th intercostal space, left parasternal border, index marker to the right hip</td>
</tr>
<tr>
<td>Four chamber view</td>
<td>4th or 5th intercostal space, mid clavicular line or at the apical pulsation, index marker at patient’s right (9 o’clock)</td>
</tr>
<tr>
<td>Subcostal view</td>
<td>Subxiphoid region with index marker pointing to the right (9 o’clock) To visualize the IVC, rotate probe clockwise such that indicator is towards patient’s head (12 o’clock), then heel the probe to see IVC enter right atrium.</td>
</tr>
</tbody>
</table>
The diagnosis of Takotsubo syndrome is felt to be a diagnosis of exclusion and requires that acute coronary syndrome be ruled out. Often, Takotsubo presents with ST-changes that are indistinguishable from an acute ST elevation myocardial infarction or a high-risk NSTE-MI. These patients should be referred for urgent evaluation by a Cardiologist. Patients who meet criteria for reperfusion strategies should be referred for urgent coronary angiography or consideration of fibrinolytic therapy in places without urgent angiography.

Point of care focused cardiac ultrasound can be a useful tool in the assessment of patients with chest pain. Focused cardiac ultrasound can be used to look for findings which are often seen in many emergency causes of chest pain including left ventricular dysfunction, right ventricular dysfunction, and pericardial effusion. The presence or absence of these findings can be used by physicians to guide their clinical decision making.

References

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A wolf in another wolf’s clothing: point-of-care ultrasound in a patient with an acute exacerbation of chronic obstructive pulmonary disease

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Patients often present to hospital, and to the Intensive Care Unit (ICU) in particular, in situations that render them unable to provide an accurate (or any) clinical history to facilitate diagnosis. These patients also typically have multiple, serious medical co-morbidities, which further makes diagnosing and initiating an appropriate treatment difficult. Furthermore, the investigations performed to optimally diagnose acute critical medical conditions are often only possible in remote locations in the hospital or only available during regular daytime work hours, both of which are a concern with critically ill patients.

Point of care ultrasound (POCUS) is a tool well described in critical care and peri-operative literature that alters management and improves patient care. It is used as an adjunct to physical exam and basic laboratory investigations to answer a specific clinical question and direct management [1]. We present a case in which POCUS was used in a critically ill patient and resulted in a significantly different approach to treatment.

Case

A 61 year-old female was transferred from a community emergency department to the Intensive Care Unit (ICU) at Kingston General Hospital (KGH) with the diagnosis of an acute exacerbation of chronic obstructive pulmonary disease (COPDE). She presented in extremis with severe respiratory distress and decreased level of consciousness and was sedated and intubated to facilitate safe transfer. This was preceded by a 3-day history of fever and increased sputum production, for which she had been started on an antibiotic by her family physician. The patient had a medical history significant for COPD, schizophrenia and a non-specific seizure disorder.

Tests from the referring hospital showed a Troponin I of 2.27 (normal range 0.000 to 0.060 μg/L), as well as an electrocardiogram (ECG) suspicious for Wellens’ sign (Figure 1). Wellens’ sign, biphasic or deeply inverted t-waves in leads V2 and V3, is a marker of critical left anterior descending (LAD) coronary artery stenosis that predicts both mortality and coronary artery disease that is often refractory to medical management alone [2]. Cardiology was consulted and initially suspected demand ischemia resulting in the increased troponin. Nonetheless, the patient became more difficult to stabilize, with increasing fluid and vasopressor (norepinephrine and epinephrine) requirements.

Figure 1. Electrocardiogram showing subtle biphasic t-waves, one of the presentations of Wellens’ sign, in leads V2 and V3.
A POCUS exam was performed which revealed a moderate-to-severely hypokinetic left ventricle (Online Video S1). This video was forwarded to the interventional cardiologist, and the patient was taken for an urgent cardiac catheterization, revealing an 80% stenosis in the LAD and a 70% stenosis in the proximal circumflex that had predisposed the patient to type II cardiac ischemia. A drug-eluting stent was placed in the former, a bare metal stent in the latter and the patient returned to the ICU and was rapidly weaned off norepinephrine and epinephrine.

**Discussion**

This case demonstrates a classic late night ICU admission – unstable, multiple co-morbidities and a presumed diagnosis from the primary physician with a wide differential that could be contributing to her presentation. In the context of borderline investigations (Troponin and ECG changes) and hemodynamic instability including difficulty oxygenating and ventilating, neither a primary respiratory nor cardiac etiology could be adequately ruled out. POCUS was required in this case to enhance our understanding of the etiology of her hemodynamic instability, arming us with more definitive evidence to compel interventional cardiology to activate the Acute Coronary Syndrome (ACS) Protocol.

**Scanning Technique**

There are five views commonly used in a cardiac POCUS examination: parasternal long axis (PLAX), parasternal short axis (PSAX), apical 4-chamber, subcostal 4-chamber and inferior vena cava (IVC). The PLAX and PSAX are typically the easiest to acquire given the ease of maintaining transducer contact, proximity of cardiac structures and readily identifiable landmarks. However, in clinical scenarios where time is limited, best practice is to target high-yield views such as the apical 4-chamber and, in particular, the subcostal 4-chamber view. The subcostal 4-chamber allows assessment of virtually all elements of the clinically focused exam [3]. A low-frequency transducer with a small footprint (head size) marries the need for 15-20cm of depth penetration with the ability to fit between the intercostal spaces to optimize the image. A detailed description of scanning technique is well described and beyond the scope of this case report, but can be found in this practical approach to point-of-care echocardiography by Walley et al [1].

**Interpretation of Findings**

The goal-directed echocardiographic examination aims to determine the etiology for hemodynamic instability or respiratory failure by answering one (or more) of the following questions: 1) Left ventricular (LV) size and function, 2) right ventricular (RV) size and function, 3) volume status and 4) presence of pericardial effusion. These goals, interpretations and correlated clinical conditions are summarized in Table 1.

**Left Ventricular Size and Function**

Each of the four views obtained in POC echocardiography (combining subcostal 4-chamber and IVC views into one category) gives subjective information regarding LV function, obtained by observing the global function of the LV and assessing it

<table>
<thead>
<tr>
<th>Assessment Goal</th>
<th>Clinical Condition</th>
<th>PLAX</th>
<th>PSAX</th>
<th>Apical 4-Chamber</th>
<th>Subcostal 4-Chamber &amp; IVC</th>
</tr>
</thead>
</table>
| LV Size and Function | •Myocardial Infarction and/or Ischemia  
•Heart Failure | Yes | Yes | •Yes  
•Size – Ratio of RV/LV and composition of apex | Yes |
| RV Size and Function | •Pulmonary Embolism  
•COPD  
Pulmonary Hypertension | Limited | Limited | Yes | Yes |
| Volume Status (Hypovolemia) | •Sepsis  
•Hemorrhage  
•Under-resuscitated | No | •Yes  
•Mid-papillary view shows LV cavity systolic obliteration ("kissing paps") | No | •Yes  
•IVC view shows <2cm IVC w/ >50% collapse with respiration |
| Pericardial Effusion | Yes – best view to distinguish pericardial from pleural effusion | Yes | Yes | Yes |
for uniformity and kinesis (hypo-, hyper-kinetic or normal function) [4]. The LV is considered hyperdynamic and underfilled if the papillary muscles touch or come close to touching in the PSAX mid-papillary view (“kissing papillary muscles” sign) [5].

Right Ventricular Size and Function
The RV is best assessed in the apical or subcostal 4-chamber view as either normal, moderately or severely dilated based on the ratio of RV to LV size. A normal RV is less than two-thirds the size, a moderately dilated RV is equal in size and a severely dilated RV forms the apex of the heart and is greater in size than the LV [6].

Volume Status
In addition to the “kissing papillary muscle” sign in the PSAX view, volume status is best assessed in the subcostal IVC view. This allows visualization of the IVC as it enters the right atrium (RA), using the liver as an acoustic window. The diameter of the IVC is measured approximately 3 cm from the junction of the RA and IVC during normal tidal volume breathing and during sniffing. Normovolemia is noted when the IVC is greater than 2 cm and the change in diameter is less than 50% with sniffing. If the IVC is less than 2 cm or shows greater than 50% collapse with sniffing, the patient is judged to be hypovolemic and will likely be fluid responsive. The assessment of volume status using IVC measurements is only valid in spontaneously breathing patients, and interpretation is limited in ventilated patients [7].

Pericardial Effusion
Finally, each of the views can be used to assess for the presence of a pericardial effusion, but it is best appreciated in the subcostal 4-chamber view as the liver provides an excellent acoustic window. A pericardial effusion appears as a hypoechoic strip posterior, anterior or surrounding the heart. The effusion will be first seen posterior to the heart, as this is the dependent region in a supine patient (usually a minor effusion), then will gradually increase to surround the heart and be visualized in the anterior pericardial space (moderate to severe). The epicardial fat pad is often mistaken for an effusion, but can be distinguished from fluid accumulation as it a) often appears granular, not purely hypoechoic and b) is observed on the anterior surface of the heart without significant posterior accumulation [8].

Conclusion
POCUS is rapidly becoming an essential tool in the critical care setting. Given the frequent combination of hemodynamic instability, multiple co-morbidities and a broad differential in any given patient, accurate diagnosis is greatly facilitated by a goal-directed cardiovascular assessment [9]. Here we present a case in which POCUS was used to diagnose an acute coronary event in lieu of borderline ancillary tests (ECG, troponin) and enabled swift intervention and stabilization.

References

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Does the addition of ultrasound enhance cardiac anatomy learning in undergraduate medical education?

by Joshua Durbin, MD; Amer M. Johri, MD; Anthony Sanfilippo, MD

Queen's University, Department of Medicine

Abstract

With the advent of portable hand-held ultrasound units, the use of point of care ultrasound (POCUS) has become increasingly popular amongst a wide array of medical specialists for both diagnostic and therapeutic interventions. Canada-wide surveys demonstrate a desire for increased utilization of POCUS in primary medical education. In this study, we aim to assess the efficacy of an ultrasound based anatomy tutorial and the perspectives of a cohort of first year medical students at Queen’s University. Students were recruited, randomized to pre- or post-test analysis, and provided with a supplementary lecture on cardiac anatomy utilizing echocardiography studies. In this study, we were unable to demonstrate a difference between understanding of basic cardiac anatomy between groups. However, we were able to report the opinions and perspectives of a small cohort of first year medical students at Queen’s University, illustrating a desire for increased exposure and training towards cardiac POCUS in primary medical education. Further evidence is required to delineate the true value of these experiences.

Introduction

With the advent of portable hand-held ultrasound units, the use of point of care ultrasound (POCUS) has become increasingly popular amongst a wide array of medical specialists for both diagnostic and therapeutic interventions. As a result of bedside ultrasound’s widespread use in emergency medicine, internal medicine, anesthesia, obstetrics and gynecology, and surgical specialties, POCUS may provide excellent learning opportunities for medical students in their pre-clinical studies and clerkship. These technologies are being adapted and integrated into undergraduate medical education where they have been utilized to supplement clinical anatomy courses, demonstrate pathophysiology of disease, and are employed as extensions and adjuncts of the physical exam and patient history [1-3]. Studies have demonstrated their efficacy, with better diagnostic accuracy in medical students who utilize POCUS studies as an adjunct to physical examination than compared to their non-POCUS guided counterparts [2]. The results of a national survey across Canadian medical school deans demonstrate that there is a desire for increased ultrasound integration within their scholastic programs, with 77% of those medical schools responding deans indicating that bedside ultrasound education should be integrated into the medical school curriculum [1]. Of those responding medical schools, 13/17 had already integrated some form of bedside ultrasound teaching to their core undergraduate curriculum [1]. With that in mind, there is currently no formal ultrasound curriculum at the Queen’s University School of Medicine for undergraduate medical education. Through the use of supplementary lecture and survey for a group of first year medical students, we aimed to assess a) the efficacy of an ultrasound guided anatomy tutorial and b) current perspectives of Queen’s University medical students towards ultrasound and other medical imaging in undergraduate medical education.

Methods

All first year medical students at Queen’s University School of Medicine were invited to participate in this study and attend a supplementary one-hour ultrasound based lecture on basic cardiac anatomy and ultrasound physics. Following recruitment, the 33 participating students provided written consent in compliance with the Queen’s University Health Sciences and Affiliated Hospitals Research Ethics Board. Students were randomized into two groups. Both groups had previously received the Queen’s University School of Medicine traditional core educational component of anatomical teaching in cardiac structures. Prior to the supplementary lecture, all students in Group 1 (n=19) completed a short multiple-choice test on basic cardiac anatomy and responded to survey questions scored on a 5-part Likert scale. One student from Group 1 did not answer the series of Likert scaled perspective questions and was excluded from perspective analysis (total n= 18). Both groups (n=33) then received a supplementary lecture on cardiac anatomy utilizing echocardiographic studies as the primary teaching tool. Group 2 (n= 14) wrote the same multiple-choice test following this session. Three students in Group 2 did not complete this test and were thus excluded from analysis (total n=11). Tests were collected and scored. Overall test scores were averaged and perspective ratings were tabulated within groups.

Results

Pre- and post-test score averages were 75% and 77%, respectively, for the total of 15 questions directed towards basic cardiac anatomy. There were no significant differences in overall testing scores between pre- and post-test groups. A 5-part Likert scale analysis was used to assess perspectives of medical students with respect to a) the utility of ultrasound imaging in the teaching of clinical anatomy, b) student desire to have increased integration of medical imaging into core educational content, c) personal level of engagement and, d) the belief of the importance of early and broad exposure to imaging studies. These results show that a large proportion of the medical students assessed perceive ultrasound to be useful in teaching clinical anatomy (67% and 64% of pre and post-test groups, respectively). The cohort assessed desired more integration of medical imaging into their core curricular content (61% and 64%, pre and post-test groups, respectively) and felt that it was important to their education to have
early and broad exposure to these imaging studies (44% and 82%, pre and post-test groups, respectively). Finally, the majority of medical students assessed agreed or strongly agreed that lectures integrating imaging tools such as ultrasound improved their level of engagement with the lecture content. Results of Likert scale analysis are summarized in Table 1.

**Discussion**

It has been shown that POCUS studies have become increasingly attractive in the teaching of clinical anatomy and as an adjunct to physical examination throughout undergraduate medical education [1-4,6]. The critics of this trend suggest the perceived benefits of the integration of POCUS technologies are not supported by sufficient research, and lack proof of their value in undergraduate medical education [7]. In this pilot study, we aimed to assess the efficacy of echocardiographic-based anatomy lectures in addition to the perspectives and opinions of Queen's University first year medical students. Although this study was small, we were unable to show a significant difference in overall testing scores between groups receiving ultrasound teaching targeted for anatomic learning. This unexpected finding could be due to a variety of factors including overall test design relating to the difficulty and choice of questions selected, lecture content and style, and the overall small cohort sizes studied. Subjective analyses demonstrated that those medical students who participated within this study strongly believed that ultrasonography was useful as an adjunct to traditional anatomical studies, and stated a desire for more exposure to these imaging tools within their core educational content. A similar but weaker trend was observed with respect to the level of engagement of lecture content. These results must be taken within context, as there is an inherent selection bias in recruitment towards students with a predilection towards medical imaging and cardiology studies.

### Table 1. Summary of perspectives of a cohort of medical students. Students were assessed before and after a supplementary lecture utilizing echocardiographic studies to demonstrate cardiac anatomy. Pre-test (n=18), Post-test (n=11).

<table>
<thead>
<tr>
<th>Ultrasound is useful in teaching clinical anatomy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strongly Disagree</strong></td>
</tr>
<tr>
<td>Pre-test</td>
</tr>
<tr>
<td>Post-test</td>
</tr>
</tbody>
</table>

**There should be more imaging integrated into medical education curriculum**

| Pre-test            | 0% (0/18)    | 0% (0/18)    | 6% (1/18)  | 33% (6/18)         | 61% (11/18) |
| Post-test           | 0% (0/11)    | 0% (0/11)    | 0% (0/11) | 36% (4/11)         | 64% (7/11)  |

**Lectures integrating imaging such as ultrasound are more engaging than traditional lectures**

| Pre-test            | 0% (0/18)    | 0% (0/18)    | 33% (6/18) | 28% (5/18)         | 39% (7/18)  |
| Post-test           | 0% (0/11)    | 0% (0/11)    | 18% (2/11) | 45% (5/11)         | 36% (4/11)  |

**It is important to have early and broad exposure to medical imaging studies**

| Pre-test            | 0% (0/18)    | 0% (0/18)    | 6% (1/18)  | 50% (9/18)         | 44% (8/18)  |
| Post-test           | 0% (0/11)    | 0% (0/11)    | 0% (0/11) | 18% (2/11)         | 82% (9/11)  |

Although the learning of anatomy was not enhanced by an objective measure of test performance, medical students subjectively felt that they had a better understanding of content from ultrasonography teaching, and it may be the case that this enhanced understanding cannot be captured by an objective written test. It is unknown whether this sense of enriched training would translate into improved clinical practice. The majority of a Canadian medical student’s education, in the pre-clinical years, is largely composed of didactic lecture format, setting the stage for medical students to learn the skills and background knowledge required to be formidable clinicians. This study, in addition to published perspective analyses across Canadian medical institutions, demonstrates an increasing desire to integrate imaging studies such as ultrasound into core medical education [4].

**Conclusion**

Although we could not demonstrate a direct benefit on test scores of integrating ultrasound teaching to cardiac anatomy learning, medical students nevertheless expressed a desire for increased exposure and teaching directed towards ultrasound in the curriculum. Thus the perceived enhancement of learning appears to be related to enhanced engagement and a broader understanding of imaging rather than a measurable increase in test scores. Additional research remains to be required to determine the optimal structure for the integration of ultrasound within the medical school core curriculum and its full value to not only enhancing the educational experience but also eventual clinical practice.

**References:**

Announcements

28th Annual Scientific Sessions, American Society of Echocardiography
POCUS Workshop - Friday June 2, 2017
www.asescientificsessions.org
June 2-6, 2016 – Baltimore, MD, USA

5th World Congress, Ultrasound in Medical Education
wcume2017.org
October 12-15, 2017 – Montreal, QC, Canada

The Canadian Society of Echocardiography has formed a new POCUS subcommittee.
More information coming soon
csecho.ca

The American Society of Echocardiography is in the process of creating a POCUS taskforce.
More information coming soon.
asescientificsessions.org

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