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Original Research

Developing a Roadmap for a Competency-Based Point-of-Care Ultrasound Education Program

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Introduction

Teaching and implementing point-of-care ultrasound (POCUS) has been rapidly expanding across almost every medical specialty. Reasons for increased popularity are due to technologic advances of ultrasound devices that can produce high-quality, easily available images at the patient's bedside. With increasingly smaller and less expensive machines, clinicians can now obtain high-quality digital images at the bedside to make diagnostic and management decisions in real time. This diagnostic expediency achieved by POCUS has major implications in transforming health care delivery.

Anesthesiologists have been using ultrasound for performing nerve blocks and obtaining vascular access for many years. The push to extend ultrasound applications beyond current uses and involve whole-body POCUS requires a more comprehensive approach. This expansion involves developing ultrasound protocols relevant for anesthesia practice and providing training for faculty and trainees.[1,2] Ultrasound has been introduced in medical student and resident education early on and has proven to be a valuable educational tool in courses that incorporate anatomy, physiology, and physical examination.[3,4] More than 60% of US medical schools have reported an ultrasound curriculum.[5,6]

Although POCUS curriculum is being developed and refined across different health care specialties, questions regarding defining acceptable competency have not been fully addressed across multiple specialties, including anesthesiology, internal medicine, and emergency medicine. The goal of POCUS education is to have trainees develop multiple levels of skills that involve assessing for POCUS indications, mastering technical proficiency to obtain images, interpreting sonoanatomy, and providing an understanding of functional changes in the clinical context. This approach can translate into making quick and informed clinical decisions that can potentially reverse disease course and prevent organ dysfunction.

Professional societies in anesthesiology, emergency medicine, and internal medicine are beginning to develop curricula and provide guidelines for establishing adequate levels of training.[6–8] Anesthesiology residency training programs are also reevaluating their individual POCUS training efforts.[8] Our POCUS curriculum was developed to allow trainees to obtain familiarity, knowledge, and skills so that they can make the relevant diagnosis and management decisions for safe perioperative practice. The field of anesthesiology has not yet addressed the level of competence needed for POCUS-trained faculty to be credentialed for POCUS. Our study assessed the knowledge acquisition of anesthesiology residents at Loyola University Medical Center (LUMC) before and after they completed a 2-week POCUS rotation. It also provides a review of the challenges involved in equipping anesthesiology residents with POCUS-related skills and knowledge, developing techniques for image acquisition, and understanding general principles in interpreting basic image.

Methods

Developing a POCUS Training Program for Anesthesiology Residents

The Joint Commission Journal on patient quality and safety states, "key factors for implementation included executive administrative support, dedicated POCUS courses, equipment standardization, a robust electronic medical record capable of logging training scans, and competency assessment for attainment of privileges."[9] With the introduction of POCUS as an elective rotation for our second-year clinical anesthesiology residents (CA-2), we were made aware of the many challenges to develop a robust POCUS program focusing on the key criteria enumerated previously. We developed the following goals for POCUS training that were long-term, open-ended, and provided us a "big picture" of how we would achieve a strategic direction to competency:

To promote the effective use of clinical ultrasound by our residents-in-training so that they can confidently use their ultrasound skills and knowledge for the purpose of diagnosis and management that will ultimately benefit our patients.

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To foster educational opportunities in clinical ultrasound education through attendance of workshop, provision of related books, and availability of physician supervision across anesthesiology and emergency medicine specialties.

To provide a roadmap for evidence-based practice in clinical ultrasound and in achieving POCUS credentialing. This rotation will cover materials for residents who plan to appear for Critical Care Echocardiography (CCEeXAM) Exam and American Society of Anesthesiology POCUS certification.

To support residents interested in seeking credentialing with completion of a POCUS rotation and maintenance of documentation.

To further the concept that appropriately trained residents will encourage development of research and the building of a network of professional peers.

The elective POCUS course was planned for a 2-week period covering the outline laid down by the American Board of Anesthesiology (ABA) and National Board of Echocardiography provided for the CCEeXAM Exam. We planned to have 3 to 4 key instructors each responsible for provision of didactics and supervision of the hands-on training session in their respective areas. The curriculum for POCUS was devised with a set of learning expectations that outline the knowledge and skills students are expected to learn and apply. In the 2-week period, we provided an average of 15 to 20 hours of didactics, 8 to 10 hours of bedside instruction, and access to online videos and lectures. Given a limited time period of 2 weeks for this elective course and reduced availability of resources, we focused on POCUS applications relevant to our practice in anesthesiology. Content for the POCUS training was primarily based on content outline specified by the ABA (Supplemental Online Material, Appendix 1); additional learning content outline was based on the CCEeXAM Exam (Supplemental Online Material, Appendix 2). We developed the following outline to focus on short-term, achievable objectives to provide structure and monitor our progress:

Institutional review board approval and written resident consent was obtained for the study before starting the POCUS elective.

Residents participated in didactics, bedside scanning, and self-directed learning that cover 3 areas, including (1) cardiac and vascular ultrasound, (2) lung ultrasound, and (3) abdominal and related ultrasound.

Cardiac component enabled residents to observe and practice with a technician in the echo lab and an anesthesiologist in the post anesthesia care unit (PACU) and intensive care unit (ICU).

Lung and abdominal component allowed residents to interact with anesthesiologists in the ICU and with emergency medicine instructors on an individual basis for review.

Knowledge, application, and ultrasound principles were assessed by baseline multiple-choice exam before POCUS rotation and multiple-choice exam 2 weeks after the POCUS rotation.

POCUS instructors taught image generation and image interpretation in clinical context and provided a validated score reflecting the trainees' level of technical competence.

Short feedback via survey from each resident toward the end of their rotation was requested.

Evaluation of Objective Achievement

Resident trainees in the anesthesiology department at LUMC who completed the POCUS elective were included in the study. Each trainee completed 2 separate untimed 65-question (50 cardiac, 10 lung, and 5 abdomen) multiple-choice examinations aimed at evaluating various domains within the theory and practice of ultrasound. The baseline examination (example questions in the Supplemental Online Material, Appendix 3) was administered 1 week before the start of the POCUS course. The 2-week post examination (example questions in the Supplemental Online Material, Appendix 4) was administered 2 weeks after completion of the POCUS course and served as a competency test following the elective. Trainee responses were collected and stored in REDCap as de-identified data. POCUS instructors and interested faculty members took the baseline and 2-week post examinations receiving an average score of 75% to 90% correct. Data from the residents' multiple-choice examinations were analyzed to assess change in knowledge in several ultrasound domains. Trainees received individual feedback regarding each test, including scores and feedback on POCUS content; however, correct answers to the questions were not provided.

During the training period, residents completed a survey that was aimed at gauging participants' degree of involvement with the POCUS rotation as well as their perceptions of ultrasound and utilization of ultrasound in their future practice. At the end of the elective period, each trainee underwent a technical competence evaluation. Trainees were evaluated by individual staff anesthesiologists and were tasked with obtaining transthoracic and lung ultrasound images. For transthoracic ultrasound images, the trainees were evaluated using the Rapid Assessment of Competency in Echocardiography (RACE) Scale, a validated tool that evaluates image generation and interpretation domains.[10] For lung ultrasound images, trainees were evaluated using the American College of Emergency Physicians – Council of Residency Directors (ACEP-CORD) Lung Scale, a set of guidelines that evaluate technical skills for lung ultrasound.[11] Primary outcomes are the results from the multiple-choice examinations, and secondary outcomes are the results from ACEP-CORD and the RACE Scale.

Statistical Analysis

Comparisons of the differences between average POCUS scores from baseline to 2 weeks for total questions, knowledge questions, application questions, and subcategories were performed using dependent, paired t tests. A P value $\leq .05$ denoted statistical significance. Statistical analyses were performed using Excel version 1908 (Microsoft Excel for Office 365 MSO).

Results

Twenty-one anesthesiology residents who completed a 2-week POCUS rotation at LUMC were included in the study. Figure 1 shows the results of the multiple-choice

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exams for total questions by POCUS exam type (cardiac, lung, abdomen) and overall score. Scores are reported as percent correct of all questions of that type and includes the standard deviation. There were 65 questions (50 cardiac, 10 lung, and 5 abdomen) on both the baseline exam and the 2-week exam. Average cardiac score at baseline was 52% (SD 11) and at 2 weeks was 50% (SD 8) with no significant difference between the groups (*P* = .46). Average lung score at baseline was 44% (SD 16) and at 2 weeks was 51% (SD 13) with no significant difference between the groups (*P* = .15). Average abdomen score at baseline was 65% (SD 23) and at 2 weeks was 59% (SD 17) with no significant difference between the groups (*P* = .37). Average total score at baseline was 53% (SD 10) and at 2 weeks was 51% (SD 7) with no significant difference between the groups (*P* = .49). There was no statistically significant improvement in performance across any category or overall.

Figure 2 depicts test results for knowledge questions by POCUS exam type (Figure 2, left) and application questions by POCUS exam type (Figure 2, right). For knowledge questions, the average cardiac score at baseline was 52% (SD 11) and at 2 weeks was 52% (SD 10) with no significant difference between the groups (*P* = .88); average lung score at baseline was 46% (SD 16) and at 2 weeks was 52% (SD 24) with no significant difference between the groups (*P* = .33); average abdomen score at baseline was 65% (SD 29) and at 2 weeks was 51% (SD 23) with no significant difference between the groups (*P* = .07). For application questions, the average cardiac simple score at baseline was 52% (SD 13) and at 2 weeks was 52% (SD 11) with no significant difference between the groups (*P* = .95); the average cardiac complex score at baseline was 52% (SD 16) and at 2 weeks was 44% (SD 11) with no significant difference between the groups (*P* = .07); the average lung score at baseline was 40% (SD 19) and at 2 weeks was 50% (SD 15) with no significant difference between the groups (*P* = .06); average abdomen score at baseline was 55% (SD 38) and at 2 weeks was 72% (SD 28) with no significant difference between the groups (*P* = .11). There were no statistically significant improvements in performance in any category.

Figure 3 depicts subcategories (assessing ultrasound view *P* = .48, ultrasound principles *P* = .77, Doppler principles *P* = .36, systolic function *P* = .13, diastolic function *P* = .81, coronary flows *P* = .26, cardiomyopathy *P* = .90, US quantification *P* = .48, and valvular pathology *P* = .22) of ultrasound characteristics. There was also no statistically significant improvement from baseline to 2 weeks across any subcategory (Figure 3).

The Image Generation Score on the RACE Scale (Figure 4, left) was highest for the parasternal long-axis view with an average score of 4.2 (SD 0.8). The parasternal short-axis and apical 4-chamber views had average Image Generation Scores on the RACE Scale of 3.6 (SD 0.67) and 3.3 (SD 0.73), respectively. The Image Generation Scores on the RACE Scale were lowest for the subcostal view and the inferior vena cava (IVC) view with an average score of 3.0 (SD 0.74 and 0.86, respectively) for both, indicating basic image interpretation is possible despite suboptimal image quality. When analyzing the RACE Scale Image Interpretation Scores on a binary scale (meaningful or not meaningful), the image interpretation was highest for left ventricular (LV) function at 100% meaningful and lowest for volume status at 38% meaningful (Figure 4, right). RACE Scale Image Interpretation Scores for right ventricular (RV) function and pericardium were 67% meaningful and 62% meaningful, respectively.

The ACEP-CORD lung scores across technical skills demonstrated a similar performance across all categories with an average score between 2.0 and 2.4. The outlier was the “Ability to use advanced functions” technical skills with an average score of 1.7 (SD 0.66) shown in Figure 5.

At the end of the POCUS course, the anesthesiology residents completed a participant interest survey that assessed resident perception of comfortability and on clinical application. Responses to each question were assessed using a 5-point Likert scale with *1 being strongly disagree and 5 being strongly agree*.

The resident perception questions (Figure 6) demonstrated that participants believe the course was helpful in gaining knowledge and skills with an average score of 4.23 (SD 0.64); there was a strong level of interest and motivation to learn ultrasound imaging with an average score of 4.38 (SD 0.59). Participants expressed a strong desire for more training and exposure to ultrasound with an average score of 4.42 (SD 0.51). The resident perception question of “I am very comfortable and confident enough to conduct US imaging on my own” had the lowest score of the 8 questions in the survey with a score of 3.7 (SD 0.64).

Discussion

Our study of anesthesiology residents who underwent a 2-week POCUS rotation provides us a snapshot of the challenges involved in equipping anesthesiology residents in acquiring POCUS-related knowledge, developing techniques for image acquisition, and understanding general principles in interpreting basic images. We used various methods for determining basic competency during POCUS training, which included traditional testing with POCUS questions, observation of bedside skills, and ability to recognize sonoanatomy and interpret images. In an ideal situation, it would be desirable to provide POCUS education to residents in a longitudinal manner during their postgraduate year-1, first-year clinical anesthesiology resident, and CA-2 years; however, barriers to providing POCUS education were primarily logistical because of a lack of trained POCUS providers, availability of ultrasound equipment, and funding for training. Of note, maintaining a logbook was not mandatory for our short study due to residents performing hands-on scanning during practice sessions and obtaining real-time feedback on the technique. For a longer, longitudinal curriculum (ie, >6 months), a logbook should be considered.

We recognize that competence achieved during a short period may not be indicative of overall learning ability. Although this is beyond the scope of our study, continuous use of POCUS in clinical practice should be emphasized and encouraged so that knowledge and skills are maintained by the residents who complete the POCUS rotation. It is desirable that trainees

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continue to apply and maintain their skills and knowledge in their clinical practice on an ongoing basis both in the preoperative, intraoperative, and PACU environment where applicable. Further studies would be needed to assess long-term behavior change in residents using POCUS skills over future weeks, months, and years.

Our findings across the anesthesiology residents from the multiple-choice exams show that POCUS education provided over a 2-week period did not lead to significant growth in knowledge at 2 weeks compared with baseline across cardiac, lung, and abdomen ultrasound domains. Furthermore, there was no significant growth in knowledge in any of the additional subcategories for the multiple-choice exams. For the RACE Scale, it should be noted that suboptimal image generation can still translate into image interpretation and thus assessment of clinical decision making. Although participants noted a significant interest and motivation in learning these techniques and principles, participants were less comfortable conducting ultrasound imaging on their own and unsure if they planned to use ultrasound imaging in making clinical diagnoses.

The results from the multiple-choice exams, technical exams, and participant surveys highlight the need for continued efforts to develop a road map for anesthesiology residents-in-training to integrate POCUS skills into clinical practice. Despite its broad use across many medical specialties, and the appearance of POCUS skills and knowledge on board examinations, there is currently no standard ultrasound curriculum for anesthesiology residents.[1] Several recent studies have highlighted variable success for POCUS in their anesthesiology residents' training programs while emphasizing the need to formalize a curriculum.[2,3] Although our study examined anesthesiology trainees, there is also a notable interest in POCUS skills in internal medicine residency programs, emergency medicine residency programs, and critical care fellowship programs to develop and implement a POCUS curriculum.[4–7] Li et al,[1] in their 2020 publication, highlight the need for proper training due to the "operator-dependent" imaging modality of ultrasound that may lead to misinterpretation of images for diagnostic purposes. Their study emphasizes a standard curriculum incorporating "I-AIM"—image, acquisition, interpretation, medical decision—is needed for anesthesiology residents to feel confident making consistent diagnoses. Furthermore, Ramsingh et al[8] demonstrated with a randomized controlled trial in 2014 that a simulation-based lecture series was effective at teaching anesthesiology residents POCUS skills.

There could be multiple reasons that learning was not demonstrated via our 2-week post examinations. Learning POCUS is analogous to learning a new language. Similar to the mechanics of learning a new language, learning ultrasound may be more beneficial if done using spaced learning over a longer period with more consistency and at different levels of training. Principles of ultrasound are complex and take time to master. There is also a steep learning curve for residents who have had limited exposure during medical school. A standardized ultrasound curriculum for anesthesiology residents encompassing didactics, simulations, and bedside clinical teaching needs to be further explored to create a protocol framework for POCUS. Despite the lack of a significant difference in baseline and 2-week examination scores, it is interesting that residents rated the 2-week POCUS course as helpful for gaining knowledge and skills and that they were likely to incorporate POCUS into clinical practice. With the residents' perception survey demonstrating a comparatively lower score for comfort with ultrasound, it is important to develop a program that emphasizes consistency throughout residency in order to build the confidence needed to begin learning POCUS technical skills for clinical practice.

Moreover, future curricular developments need to include both goals: demonstration of medical knowledge acquisition and increased confidence to perform at the bedside. A limitation of our study is the sample size (n = 21) of anesthesiology residents from the same program. If the study was completed at a single institution, the number of participants is limited to the number of residents in each program, but this sample size was similar to other single-institution studies.[8] The strength of our study is that 3 anesthesiologists and intensivists provided consistent training in the pilot curriculum to the anesthesiology residents. Additional research is needed to structure and develop a formalized, longitudinal POCUS curriculum that programs are able to incorporate for residents to effectively learn and integrate POCUS into their practice.

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Abstract

Background: The clinical applications of point-of-care ultrasound (POCUS) have proliferated across multiple specialties with technologic advances. POCUS education in residency programs has challenged educators to develop a POCUS-based clinical practice curriculum. The level of exposure needed to achieve POCUS competence is evolving with programs adopting diverse POCUS training initiatives. Our study aims to evaluate our POCUS curriculum and use evaluation results and survey feedback to optimize and improve trainee competence.

Methods: Twenty-one anesthesiology residents participated in a baseline POCUS and a 2-week POCUS exam comprising 65 questions (50 cardiac, 10 lung, and 5 abdominal). Technical competence in lung and cardiac ultrasound was assessed by POCUS supervisors using validated tools. The Rapid Assessment of Competency in Echocardiography (RACE) Scale was used to assess image generation and interpretation domains. The American College of Emergency Physicians – Council of Residency Directors (ACEP-CORD) guidelines measure technical skills for lung ultrasound. Resident perception to POCUS education and training was based on a survey.

Results: Score comparisons between the baseline and 2-week post course multiple-choice exams did not show a statistically significant change in performance. The technical competency assessment demonstrates that Image Generation Scores on the RACE Scale were highest for images in the parasternal long-axis view and lowest for the subcostal view and inferior vena cava view. Results of the resident perception survey showed a strong interest and motivation to learn ultrasound and strong desire for more exposure and training with ultrasound.

Conclusions: Anesthesiology programs have incorporated POCUS training; however, training methods are not uniform. This study aims to provide a road map for residents-in-training to integrate POCUS skills into clinical practice.

Keywords: Point-of-care ultrasound (POCUS), medical education, anesthesia

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Figures

Figure 1. *Percentage of total questions correct out of 100% by POCUS exam type.*

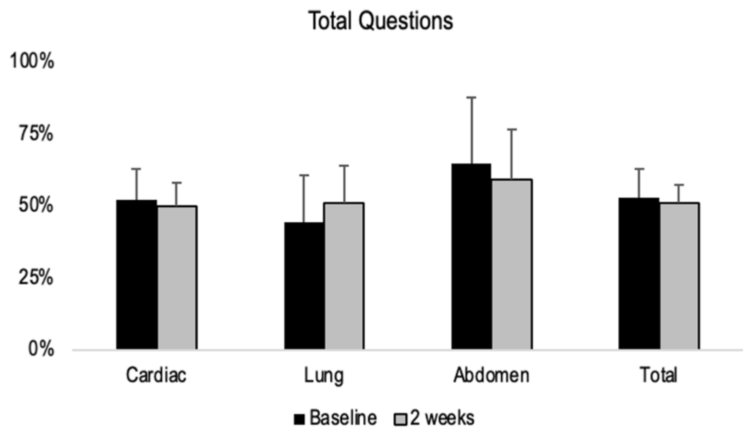
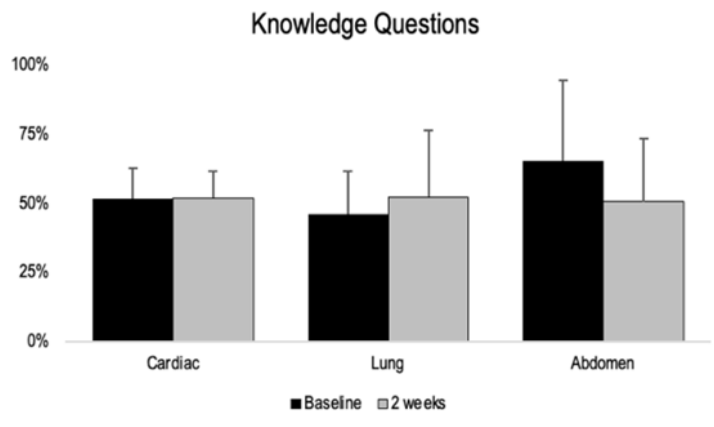


Figure 2. *Percentage of knowledge (left) and application questions (right) correct out of 100% by POCUS exam type.*



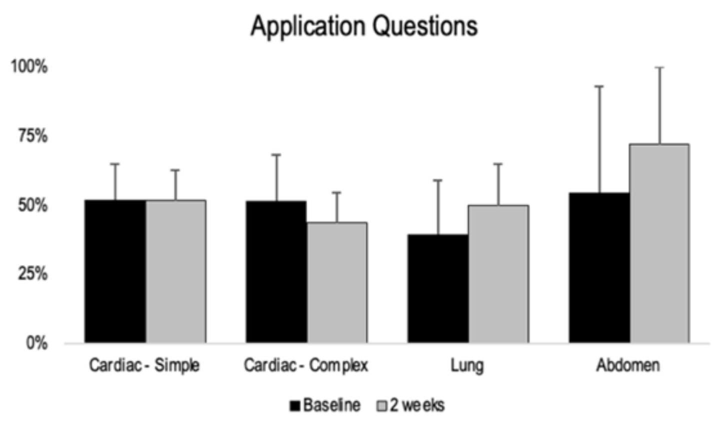


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Figure 3. *Percentage of multiple-choice questions correct out of 100% by subcategories.*

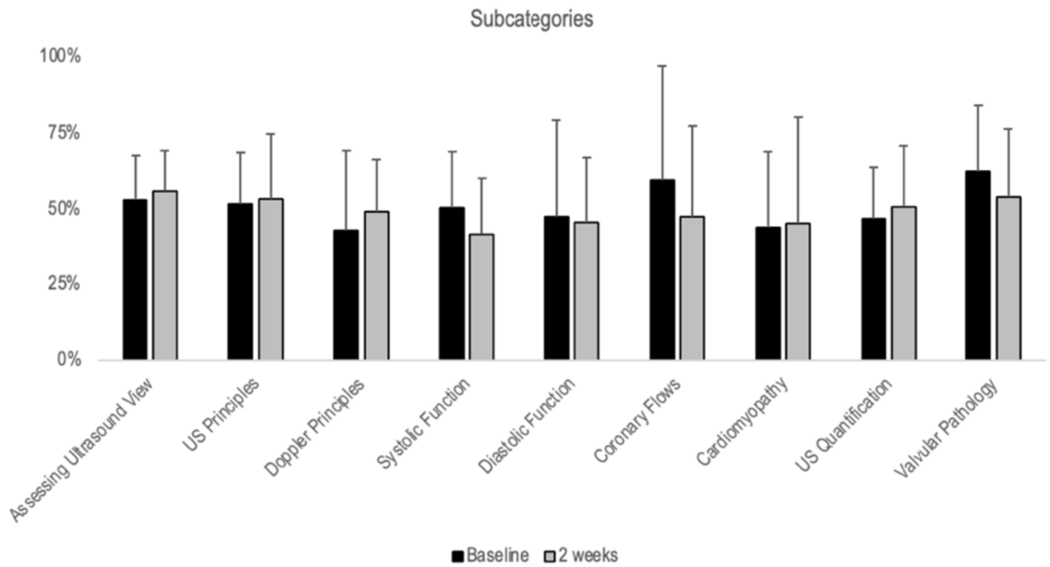

Figure 4. *Rapid Assessment of Competency in Echocardiography (RACE) Scale Image Generation Scores (left) and RACE Scale Image Interpretation (right). A4C, apical 4-chamber; IVC, inferior vena cava; LV, left ventricle; PSL, parasternal long axis; PSS, parasternal short axis; RV, right ventricle; SC, subcostal.*

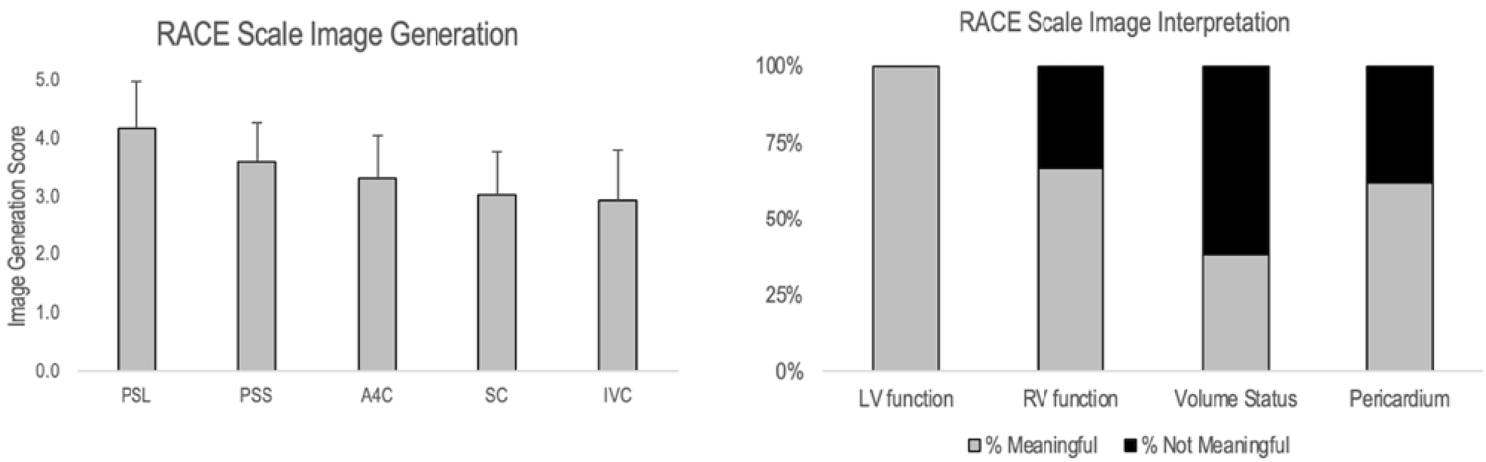

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Figure 5. *American College of Emergency Physicians – Council of Residency Directors (ACEP-CORD) lung average scores across technical skills.*

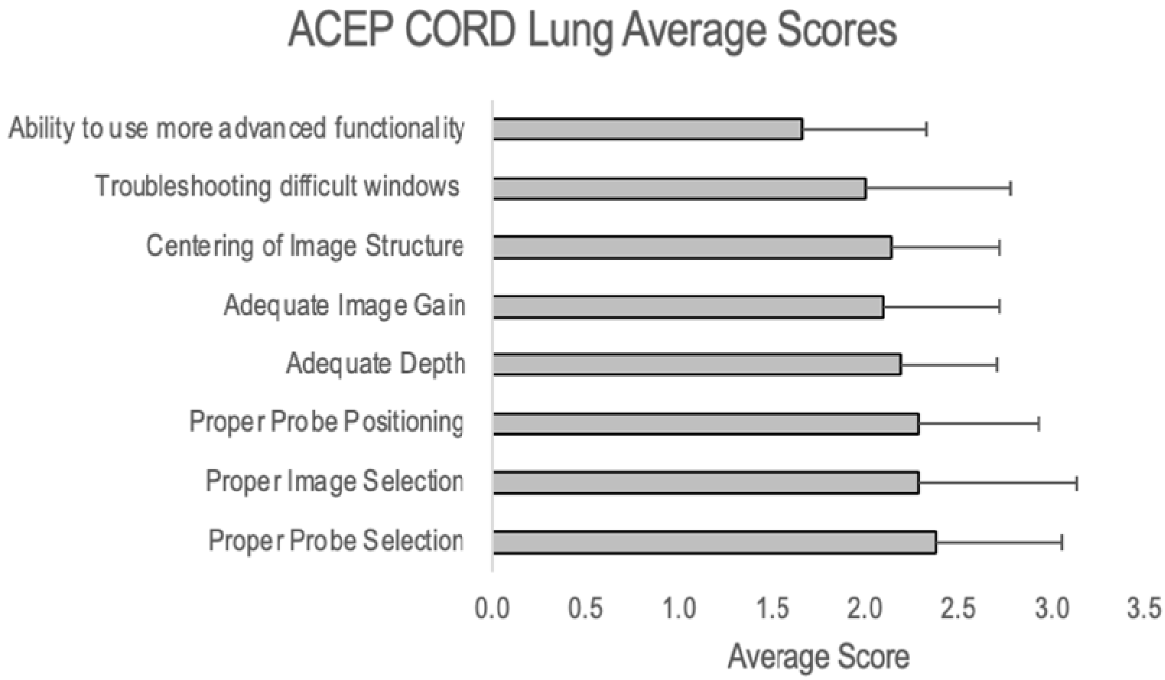
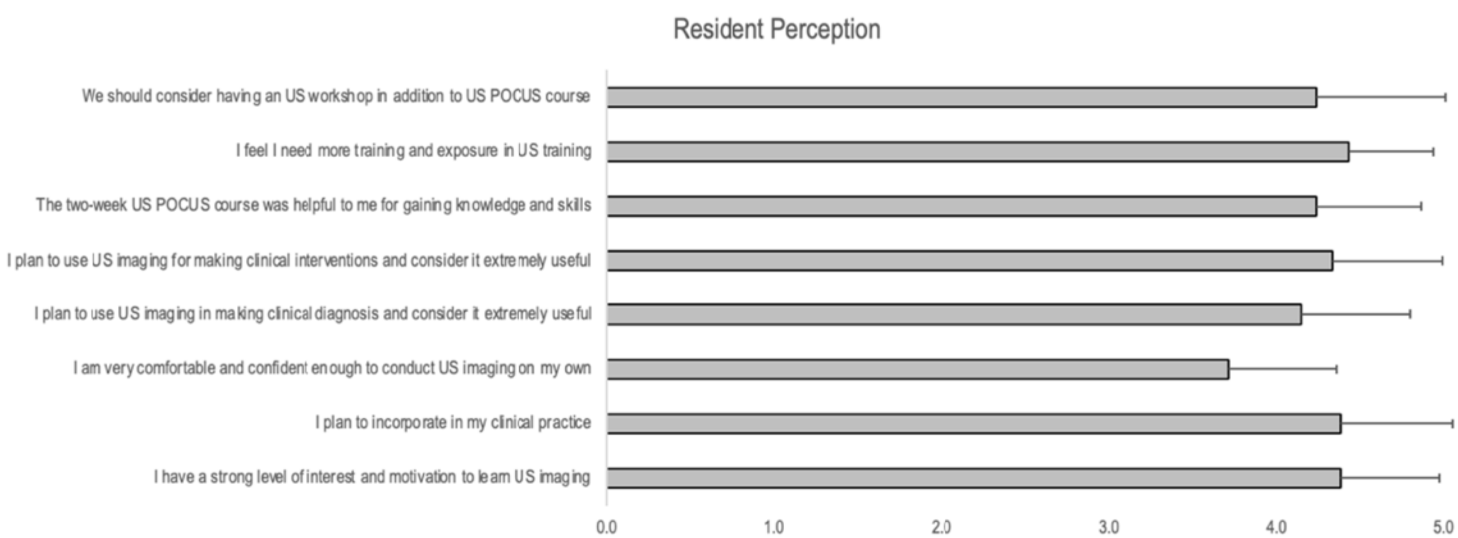


Figure 6. *Participant interest survey—resident perception.*



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Supplemental Online Material

Appendix 1. ABA Content Outline

2. Interpretation of echocardiograms and surface ultrasound of lung (*Interpret basic transthoracic or transesophageal, lung and pleura images relevant to anesthesia practice*)

   The successful candidate will be able to identify the view, identify relevant anatomy, make qualitative diagnostic assessments, and provide treatment recommendations for scenarios chosen from among the following areas:

   a. Biventricular function and wall motion
   b. Presence or absence of an atrial septal defect
   c. Volume status assessment- hypovolemia and response to volume therapy
   d. Pulmonary emboli
   e. Air emboli
   f. Basic valvular lesions
   g. Pericardial effusions
   h. Aortic dissection
   i. Pleural effusion
   j. Pneumothorax
   k. Pulmonary edema

   Transesophageal echocardiography images will be chosen from the following 11 views specified in the Consensus Statement on Basic Perioperative Transesophageal Echocardiography (*J Am Soc Echocardiogr* 2013;26:443-56):

   a. Midesophageal Four Chamber
   b. Midesophageal Two Chamber
   c. Midesophageal Long Axis
   d. Midesophageal Ascending Aortic Long Axis
   e. Midesophageal Ascending Aortic Short Axis
   f. Midesophageal Aortic Valve Short Axis
   g. Midesophageal Right Ventricular Inflow-Outflow
   h. Midesophageal Bicaval
   i. Transgastric Midpapillary Short Axis
   j. Descending Aortic Short Axis
   k. Descending Aortic Long Axis

   Transthoracic echocardiography images will be chosen from the following 5 views specified in the International Evidence-Based Recommendations for Focused Cardiac Ultrasound (*J Am Soc Echocardiogr* 2014;27:683.e1-e33) (testing to start in 2021):

   a. Parasternal Long Axis
   b. Parasternal Short Axis (Left Ventricle Midpapillary)
   c. Apical Four Chamber
   d. Subcostal Four Chamber
   e. Subcostal IVC Assessment

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Supplemental Online Material *continued*

Lung and diaphragm ultrasound images will be chosen from the Anterior Mid-Clavicular Line and Posterior Axillary Line views, respectively (testing to start in 2021)

3. Application of ultrasonography (*Identify relevant normal anatomy using ultrasonography*)

   The successful candidate will identify the relevant anatomy using an ultrasound probe with a simulated patient and, where applicable, may be asked to demonstrate simulated needle placement technique for scenarios chosen from among the following procedures:

   c. Point of care ultrasound
      i. Heart (testing to start in 2021)
         - Parasternal Long Axis
         - Parasternal Short Axis (Left Ventricle Midpapillary)
         - Apical Four Chamber
         - Subcostal Four Chamber
         - Subcostal IVC View
      ii. Lung Pleura (testing to start in 2021)
         - Pleura
         - Diaphragm
         - Artifacts (A-lines, B-lines)
      iii. Abdomen (testing to start no earlier than 2022)
         - Right upper quadrant (assessment for free fluid)
         - Left upper quadrant (assessment for free fluid)
         - Pelvis (assessment for free fluid)
         - Gastric (assessment of content and volume)

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Supplemental Online Material *continued*

Appendix 2. Critical Care Echocardiography (CCEeXAM®) Exam Content Outline

Critical Care Echocardiography Exam Content Outline (CCE)

01 Functional Anatomy

01.A Left ventricle

- 01.A.01 Systolic function (qualitative, quantitative)
- 01.A.02 Diastolic function
- 01.A.03 LV chamber quantification
- 01.A.04 Masses/thrombi
- 01.A.05 Cardiomyopathies

01.B Right ventricle

- 01.B.01 RV chamber quantification
- 01.B.02 Function
- 01.B.03 Estimated right heart pressure

01.C Atria

- 01.C.01 Chamber quantification
- 01.C.02 Atrial septum
- 01.C.03 Masses/thrombi
- 01.C.04 Left atrial hemodynamics

01.D Valvular disease

- 01.D.01 Aortic
- 01.D.02 Mitral
- 01.D.03 Tricuspid
- 01.D.04 Pulmonic
- 01.D.05 Endocarditis
- 01.D.06 Prosthetic valve disease/dysfunction

01.E Pericardium

- 01.E.01 Pericardial effusion
- 01.E.02 Constrictive pericarditis
- 01.E.03 Hematoma

01.F Great vessels

- 01.F.01 Aorta
- 01.F.02 Pulmonary artery
- 01.F.03 IVC and SVC

01.G Devices and foreign bodies

- 01.G.01 Catheters
- 01.G.02 Pacing wires
- 01.G.03 Cannulae

01.H Intracardiac masses

- 01.H.01 Left ventricle
- 01.H.02 Right ventricle
- 01.H.03 Atria

01.I Adult congenital

- 01.I.01 Atrial septal defect
- 01.I.02 Ventricular septal defect
- 01.I.03 Bicuspid valve
- 01.I.04 Patent foramen ovale
- 01.I.05 Persistent left superior vena cava

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Supplemental Online Material *continued*

02 Clinical Diagnosis and Management

- **02.A Shock**
  - 02.A.01 Obstructive
  - 02.A.02 Hypovolemic
  - 02.A.03 Distributive
  - 02.A.04 Cardiogenic
- **02.B Volume assessment**
  - 02.B.01 Fluid responsiveness
  - 02.B.02 Volume overload
- **02.C Acute cardiovascular presentations**
  - 02.C.01 Myocardial infarction
  - 02.C.02 Regional wall motion abnormalities
  - 02.C.03 Pulmonary embolism
  - 02.C.04 Aortic dissection
  - 02.C.05 Valvular heart disease
  - 02.C.06 Cardiomyopathy
  - 02.C.07 Congenital heart disease
- **02.D Trauma**
  - 02.D.01 Blunt
  - 02.D.02 Penetrating
- **02.E Respiratory failure**
  - 02.E.01 Cardiac versus pulmonary
  - 02.E.02 Adverse effects of mechanical ventilation
- **02.F Cardiac arrest**
  - 02.F.01 Etiology
  - 02.F.02 Classification
  - 02.F.03 Appropriate implementation

03 Technical Skills & Equipment Optimization

- **03.A Physics**
  - 03.A.01 2D ultrasonography
  - 03.A.02 Doppler ultrasonography
  - 03.A.03 M mode
  - 03.A.04 Enhanced cardiac ultrasound (contrast)
- **03.B Artifacts**
  - 03.B.01 Reverberations
  - 03.B.02 Side lobe
  - 03.B.03 Mirror image/refraction
  - 03.B.04 Acoustic shadowing
  - 03.B.05 Aliasing
  - 03.B.06 Electrical interference
- **03.C Image Acquisition**
  - 03.C.01 Probe position
  - 03.C.02 Probe manipulation
  - 03.C.03 Probe selection
  - 03.C.04 Indications
  - 03.C.05 Canonical view

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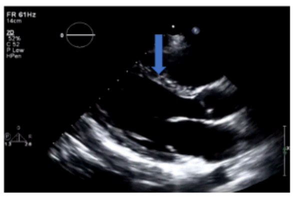
Supplemental Online Material *continued*

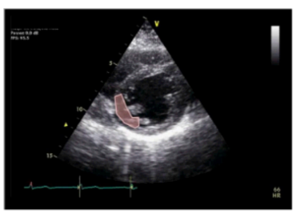
Appendix 3. Sample Baseline Multiple-Choice Examination Questions

Cardiac Q5



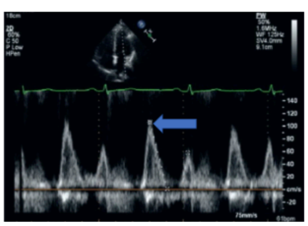
The arrow in this picture is pointing to the
a) Anterior wall
b) Septal wall
c) Anteroseptal wall
d) Inferolateral wall

Cardiac Q6



Regarding the TTE image in question 6 which wall is highlighted:
a) Anterior
b) Anterolateral
c) Inferolateral
d) Inferior

Cardiac Q10



The TTE view is obtained from a Pulse wave doppler interrogation of the mitral valve from an apical 4 chamber view. The arrow points to:
a) Early diastolic flow across mitral valve
b) Late diastolic flow across mitral valve
c) Systolic regurgitant flow across mitral valve
d) Flow during diastasis across mitral valve

Cardiac Q23

The parasternal long axis view is obtained by placing the probe in the
a) seventh intercostal space
b) right fifth intercostal space
c) Second left intercostal space
d) third, fourth or fifth left intercostal space

Lung Q1

A pneumothorax on lung ultrasound
a) Will show stratosphere sign on M mode.
b) Will show A lines
c) Will show B lines
d) Will show lung sliding

Lung Q4

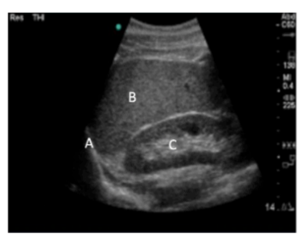
60-year-old male while recovering from cardiac surgery developed SOB. Lung US shows above pattern l.

These multiple lines are
a) always caused by pulmonary edema
b) cannot be used for decisions for diuresis during weaning
c) Is not affected by volume loading
d) If present unilaterally in lung suggests early pneumonia

Abdomen Q1

The POCUS FAST EXAM
a) consists of perihepatic, perisplenic, gastric, and pelvic views
b) initial imaging modality in trauma patients during resuscitation
c) less sensitive than xrays in diagnosing free fluid and free air in peritoneum,
d) not reliable for rapid recognition of hemoperitoneum and perforated viscera in hypotensive patients

Abdomen Q5



The transducer is again placed at approximately the left mid axillary line. Structures ABC are:
a) diaphragm, kidney, spleen
b) diaphragm, spleen , pancreas
c) diaphragm, spleen, kidney
d) diaphragm, spleen and colon

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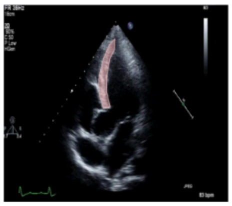
Supplemental Online Material *continued*

Appendix 4. Sample 2-Week Multiple-Choice Examination Questions

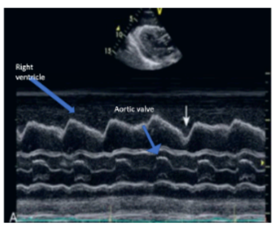
Cardiac Q4



Which wall of the left ventricle is highlighted in the TTE image

- a) anterior wall
- b) anteroseptal wall
- c) inferoseptal wall
- d) posterior leaflet P1 scallop

Cardiac Q9



68-year-old male who underwent CABG and aortic valve replacement developed hypotension. TTE was done using M mode through a parasternal long axis view. The blue arrows reveal the right ventricle and aortic valve. The white arrow shows an abnormality. Based on this M mode study the most likely cause of hypotension is

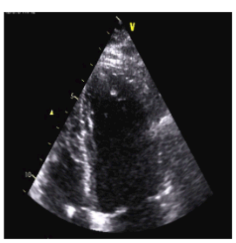
a) hypovolemia

b) Right ventricular dysfunction

c) Pericardial effusion

d) Vasoplegia

Cardiac Q23



What is the name of this view, and which walls of the LV are seen?

a)apical two-chamber view focused on LV showing inferior and anterior walls

b) apical long axis view focused on LV showing inferior and anterior walls

c) apical long axis view focused on LV showing anterior septum and inferolateral walls

d) apical two-chamber view focused on LV showing anterior septum and inferolateral walls

Lung Q2

Lung sliding present on the left side but absent on the right side immediately after intubation suggests

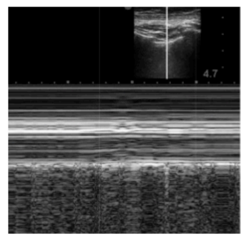
a) Left main stem intubation

b) right mainstem intubation

c) Tracheal intubation with ETT tube above carina

d) Esophageal intubation

Lung Q7



One hour after a right IJ central line placement in a patient who is on mechanical ventilation in OR for lower extremity surgery develops high airway pressure. A right lung US (M mode) is performed as shown. The lung US shows

a) Pneumothorax

b) Pleural effusion

c) Lung consolidation

d) Normal lung aeration

Abdomen Q2

FAST exam on the right side shows image in question 2. The arrow points to:

a) liver

b) kidney

c) Free fluid

d) lung

Abdomen Q3

Which of the following can't typically be ruled out by a FAST exam:

a) hollow viscus perforation

b) bowel wall contusion

c) diaphragmatic injury

d) retroperitoneal hemorrhage