Assessment of a Novel Point-of-Care Ultrasound Curriculum's Effect on Competency Measures in Family Medicine Graduate Medical Education

Paul Bornemann, MD

Objectives—Point-of-care ultrasound has been shown to decrease the use of expensive diagnostic studies and improve quality outcome measures. Currently, there is a large desire for training in family medicine residencies, but very few programs have established curricula. We sought to develop a family medicine residency curriculum and evaluate it with tools we developed. We wanted our curriculum to be easy to adopt by other residency programs, even if they did not have many well-trained ultrasound faculty.

Methods—We developed a curriculum in the form of a 4-week rotation in a family medicine residency program. It consisted of self-study videos, hands-on training, and image review. We followed residents in postgraduate years 1 to 3 over a 12-month period. We developed tools, including a knowledge exam, to test image interpretation and clinical decision making, an observed structured clinical exam to assess scanning skills, and a survey to assess perceptions of point-of-care ultrasound in family medicine. The assessments were administered before and after each resident's rotation.

Results—Seventeen residents completed the rotation. The average knowledge test score improved significantly, from 62 to 84%. The average observed structured clinical exam scores also improved significantly, from 41 to 85%. The average perception survey scores improved slightly from 4.4 to 4.6.

Conclusions—We developed a point-of-care ultrasound curriculum for family medicine residency programs that improves measures of resident attitude, skills, and knowledge. This curriculum can be adopted by residency programs with few faculty members who are experienced in ultrasound.

Key Words—curriculum; graduate medical education; point of care; ultrasound

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Address correspondence to Paul Bornemann, MD, Palmetto Health Family Medicine Residency, University of South Carolina School of Medicine, Columbia, SC 29203 USA.

E-mail: paul.bornemann@uscmed.sc.edu

Abbreviations
OSCE, observed structured clinical examination; PGY, postgraduate years

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Health care in the United States is expensive, limited in availability, and suboptimal in outcomes. We spend more of our gross domestic product on health care than any other industrialized country.[1] Despite this fact, we are near the bottom of most industrialized countries in indicators of health-care quality, such as life expectancy, infant mortality, and chronic disease burden.[1]

Some causes of this discrepancy are high use of specialist care, expensive diagnostic testing, and disparities in access to care. Despite the fact that more than 30 million Americans remain uninsured, 1 in 10 people in the United states have had an MRI,

and nearly 1 in 4 have had a computed tomography scan.[1,2] This is more than double the average rate for other industrialized countries, all of which have systems for universal health care.

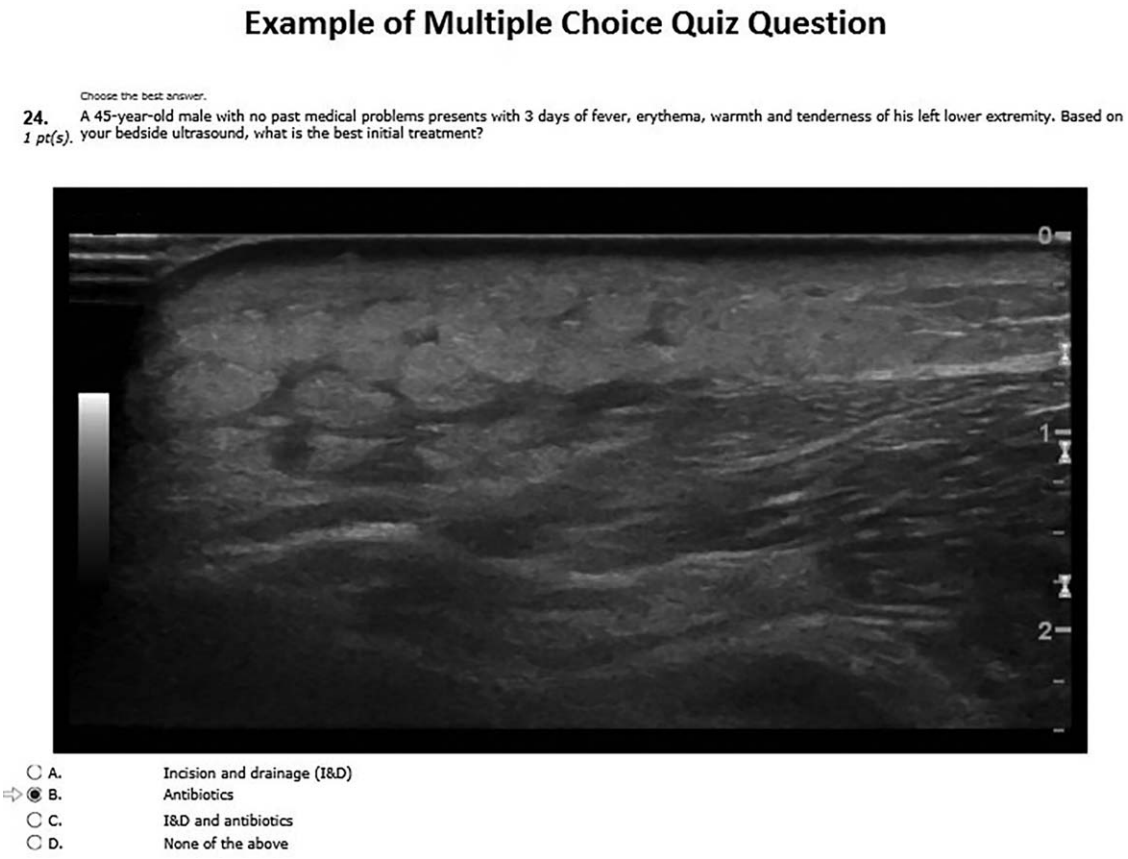
Point-of-care ultrasound has been shown to decrease the use of expensive diagnostic studies and improve quality outcome measures.[3–5] Additionally, there is evidence that it can be performed effectively by nonspecialist physicians after limited training.[6–9] Despite this fact, primary care physicians are not currently well-trained to use point-of-care ultrasound. In 2015, only 5.6% of family physicians reported using ultrasound for nonobstetric purposes, and only 2.2% of family medicine residencies had established point-of-care ultrasound curricula. However, there was a large amount of interest in developing such training.[10–12]

Our goal for this study was to develop a point-of-care ultrasound curriculum for a family medicine residency that would ensure that the residents developed the attitudes, skills, and knowledge needed to become competent at multiple applications of point-of-care ultrasonography. We wanted to test the feasibility of this curriculum via its ability to improve measures of competency. We also wanted our curriculum to be in a format that is easily adoptable by other residency programs, even if they do not have many faculty who are experienced in point-of-care ultrasound.

Methods

This prospective, observational feasibility study took place at the Palmetto Health Family Medicine Residency

Figure 1. Sample knowledge test question. The test was taken online on Quizstar.com and consisted of 35 multiple-choice questions that included ultrasound images and video loops. Residents answered questions regarding image interpretation and patient management based on these interpretations. The residents were not directly observed during the testing. A time limit per question was implemented, to minimize the risk of cheating. The tests were scored automatically.



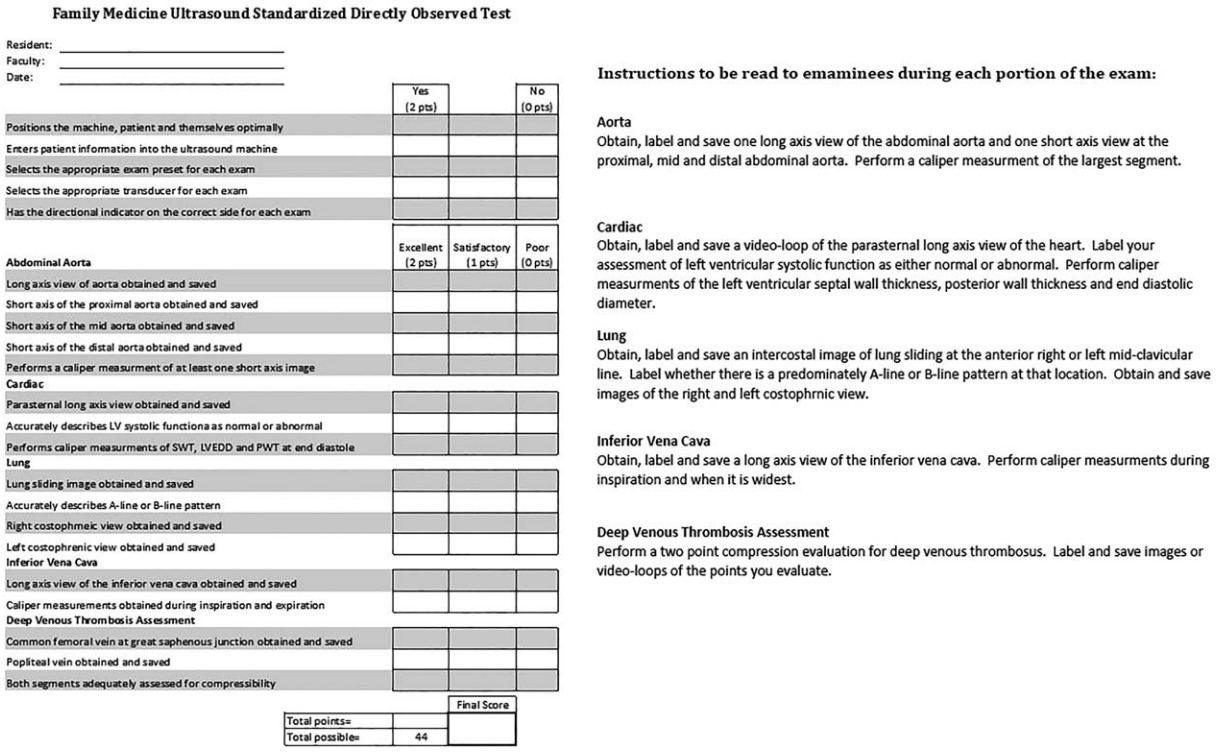
Program in Columbia, South Carolina, and the University of South Carolina School of Medicine Ultrasound Institute. The residency program included postgraduate years (PGY) 1 to 3, with 10 residents per year. All residents were automatically enrolled in the study after participating in the point-of-care ultrasound curriculum. The protocol was reviewed and granted exempt status by the University of South Carolina School of Medicine Institutional Review Board.

The study started in November 2014, and data collection was completed and analyzed in November 2015. All PGY1s were required to participate, and PGY2s and PGY3s could opt to participate as an elective. The residents participated during 4-week ultrasound rotations. One to 3 residents could participate in the rotation during any 4-week period.

The curriculum was developed using Kern's 6-step method.[13] It consisted of a combination of online video lectures, ultrasound simulation, directly and indirectly supervised scanning, and time spent reviewing images in quality assurance sessions. (Please see the online supplement for a detailed description.) The curriculum and assessment tools were developed by the principle investigator (P.B.) with input from the residency director and faculty. Because there were very few faculty trained in ultrasound, the curriculum was designed so that it would require a maximum of 10% of one full-time faculty's time.

Assessment tools were all administered on the first day of the rotation, and again on the last. A multiple choice test of medical knowledge was created on Quizstar.com (Figure 1).[14] An observed structured clinical

Figure 2. Observed structured clinical examination score sheet and instructions. During the OSCE, the resident received instructions on the score sheet only; no further help was provided. Scoring was either "yes" or "no" for questions that were not subjective, such as "Selects the appropriate transducer for each exam." Instructions were given to the residents, and the scoring sheet was used to document the assessments. Two points were awarded for "yes," and zero for "no". More subjective components were scored as excellent (2 points), satisfactory (1 point), or poor (0 points). Criteria for excellent were that the image was obtained perfectly and all settings were set optimally. Criteria for satisfactory were that the image was obtained but did not meet the criteria for excellent, although clinically useful information could be obtained from the image. Criteria for poor were that no clinical useful information could be obtained from the image, or the structure was not imaged at all.



Family Medicine Ultrasound Standardized Directly Observed Test

Resident: _____
Faculty: _____
Date: _____

	Yes (2 pts)		No (0 pts)
Positions the machine, patient and themselves optimally			
Enters patient information into the ultrasound machine			
Selects the appropriate exam preset for each exam			
Selects the appropriate transducer for each exam			
Has the directional indicator on the correct side for each exam			

Abdominal Aorta	Excellent (2 pts)	Satisfactory (1 pts)	Poor (0 pts)
Long axis view of aorta obtained and saved			
Short axis of the proximal aorta obtained and saved			
Short axis of the mid aorta obtained and saved			
Short axis of the distal aorta obtained and saved			
Performs a caliper measurment of at least one short axis image			
Cardiac			
Parasternal long axis view obtained and saved			
Accurately describes LV systolic functiona as normal or abnormal			
Performs caliper measurments of SWT, LVEDD and PWT at end diastole			
Lung			
Lung sliding image obtained and saved			
Accurately describes A-line or B-line pattern			
Right costophmeic view obtained and saved			
Left costophrenic view obtained and saved			
Inferior Vena Cava			
Long axis view of the inferior vena cava obtained and saved			
Caliper measurements obtained during inspiration and expiration			
Deep Venous Thrombosis Assessment			
Common femoral vein at great saphenous junction obtained and saved			
Popliteal vein obtained and saved			
Both segments adequately assessed for compressibility			

		Final Score
Total points=		
Total possible=	44	

Instructions to be read to emaminees during each portion of the exam:

Aorta
Obtain, label and save one long axis view of the abdominal aorta and one short axis view at the proximal, mid and distal abdominal aorta. Perform a caliper measurment of the largest segment.

Cardiac
Obtain, label and save a video-loop of the parasternal long axis view of the heart. Label your assessment of left ventricular systolic function as either normal or abnormal. Perform caliper measurments of the left ventricular septal wall thickness, posterior wall thickness and end diastolic diameter.

Lung
Obtain, label and save an intercostal image of lung sliding at the anterior right or left mid-clavicular line. Label whether there is a predominately A-line or B-line pattern at that location. Obtain and save images of the right and left costophrnic view.

Inferior Vena Cava
Obtain, label and save a long axis view of the inferior vena cava. Perform caliper measurments during inspiration and when it is widest.

Deep Venous Thrombosis Assessment
Perform a two point compression evaluation for deep venous thrombosus. Label and save images or video-loops of the points you evaluate.

examination (OSCE) was developed to assess the residents' technical skill in acquiring adequate images during ultrasound scanning (Figure 2). An online, anonymous survey was also developed on SurveyMonkey (www.surveymonkey.com) to assess the residents' perceptions.

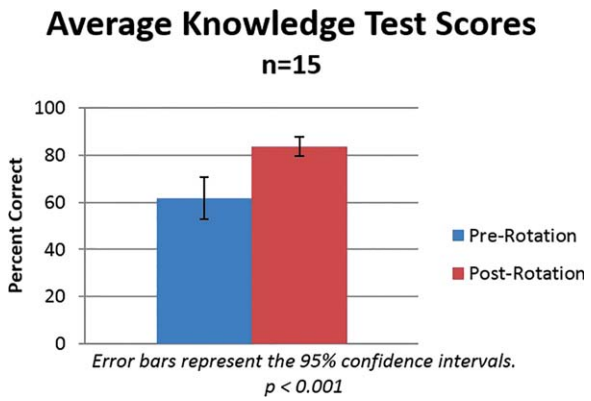
Data were analyzed using paired *t* tests to determine statistical significance using Microsoft Excel 2013 (Microsoft Corp, Redmond, WA) for the multiple-choice test and the OSCE. Before and after Likert-scale scores were compared side by side for the perceptions survey, but a statistical analysis was not performed.

Results

Over the first 12 months of the curriculum, 17 residents participated: 9 were PGY1 and 6 were PGY2 or PGY3. Fifteen completed both the pre- and postrotation knowledge test. Thirteen completed the pre and postrotation OSCE. Twelve completed the pre- and postrotation perception survey. None of the residents failed to complete both the OSCE and the knowledge test. It is not known whether any residents did not complete the perception survey, as it was administered anonymously.

The average multiple-choice test scores showed a statistically significant improvement from 62% (95% confidence interval [CI], 53–71) before rotation, to 84% (95% CI, 80–88) after rotation (Figure 3). The average OSCE scores also showed a statistically significant improvement from 41% (95% CI, 30–52) before rotation, to 85% (95% CI, 79–01) after rotation (Figure 4). On the perception survey (with "1" being the least favorable and "5" being the most favorable perceptions), the overall scores improved from 4.4 before rotation to 4.6 after rotation (Figure 5).

Figure 3. Results of the pre- and postrotation multiple choice test of knowledge scores.



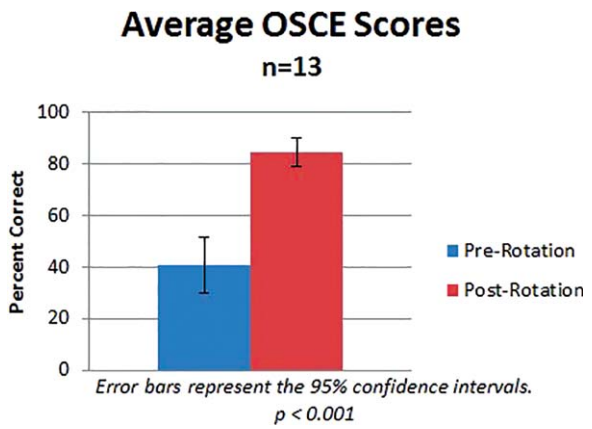
Discussion

We found that the residents improved significantly in the multiple-choice test and OSCE scores. This suggests that the curriculum we developed was successful in improving point-of-care ultrasound skills and knowledge. There was a small but positive improvement in the Likert-scale scores from the perceptions survey. The small degree of improvement is likely related to the highly favorable baseline perceptions of ultrasound in this residency program.

This was the first study to look at a comprehensive, longitudinal point-of-care ultrasound curriculum in a family medicine residency. Several previous studies have demonstrated effective curricula for ultrasound in family medicine, but they were focused specifically on obstetrical uses[15–17] or described only a single day workshop.[18] Additionally, to our knowledge, this is the first study to describe in detail a longitudinal, 4-week-long rotation in point-of-care ultrasound in any of the primary care specialties or emergency medicine. Of the other curricula that have been described in these specialties, it appears that hands-on training and longitudinal practice are important components—both of which are strong points in our curriculum.[19–22]

One limitation of this study is that the assessment tools have not been validated. In future studies we would like to validate the tools to determine cut scores that could be used to reliably distinguish novices from

Figure 4. Results of the pre- and postrotation OSCE skills test scores.



advanced sonographers. Another limitation is that all OSCE testing was administered without blinding. Ideally, we would have used an evaluator who was blinded to the resident performing the OSCE, and to whether it was a pre- or postrotation exam. However, this was prohibitively difficult, given the resources we had and the fact that we only had only one faculty member with the time and expertise to serve as an evaluator. We attempted to minimize the risk by providing detailed instructions and a scoring system that left minimal room for bias. It is reassuring that the improvements in the OSCE score correlated well with the improvements seen in the knowledge test scores, which were less prone to bias. Finally, we had no other groups with which to compare our curriculum group. It is not known whether our curriculum would be more effective in improving ultrasound education than a curriculum consisting entirely of self-learning or with more intense faculty-involved training. We would like to include such a comparison in future studies.

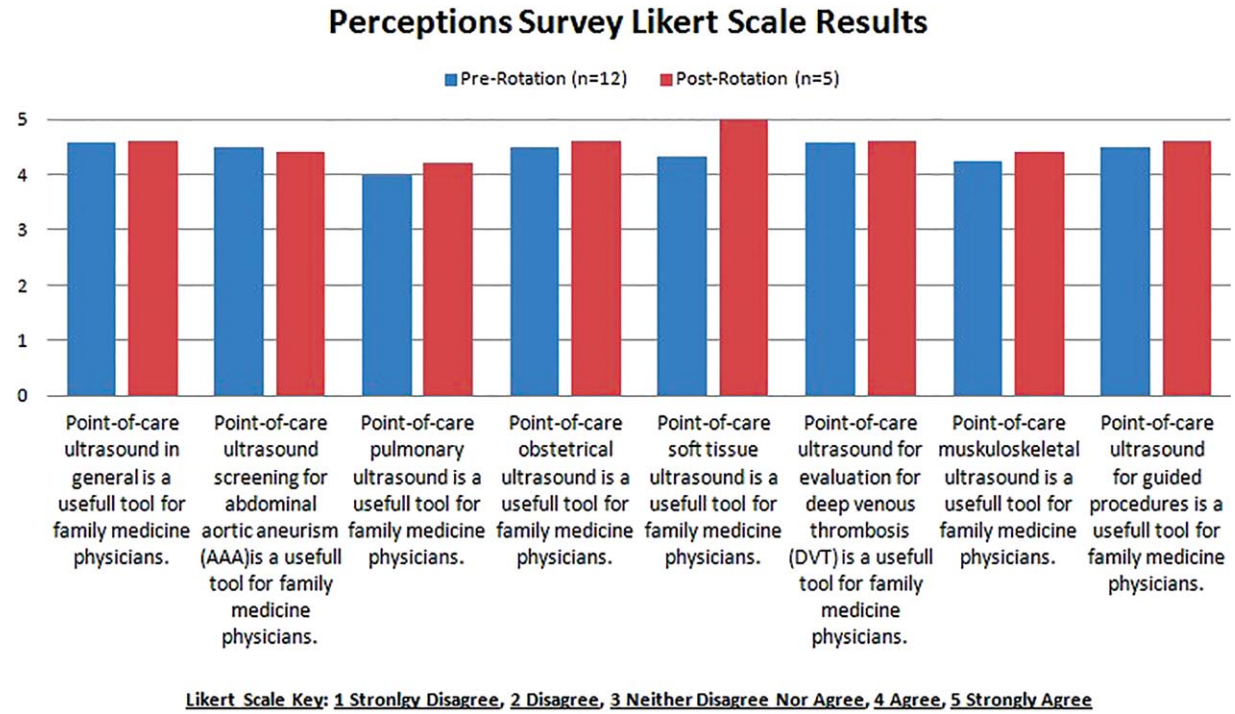
One of the greatest strengths of our curriculum is that it can be implemented in a residency program with few local faculty. In addition to video didactics, most of the hands-on training sessions can be self-directed by the residents who are performing educational ultrasounds. The exams obtained during the self-directed scanning can then be reviewed via an Internet portal with a supervising faculty member. This faculty member would not necessarily need to be located near the residents, but could be anywhere in the world. If some of the supervised scanning sessions were to be done via teleconference, it could be possible to implement the entire curriculum without any local faculty at all. Hopefully, dissemination of this information will make it easier for other residencies to implement similar curricula, even if they are limited in the amount of faculty with point-of-care ultrasound training.

Online-Only Supplemental Section: Details of Curriculum

Self-Study Videos

During the rotation, residents were assigned self-study video lectures to watch on their own time. These included videos from the Society of Ultrasound in Medical Education and the University of South Carolina

Figure 5. Results of the pre- and postperceptions surveys. The surveys had residents use a Likert scale to rate how useful they felt the general point-of-care ultrasound and specific applications were to family physicians.



School of Medicine Ultrasound Institute (www.susme.org/learning-modules/learning-modules), covering topics on ultrasound physics and instrumentation and screening for left ventricular hypertrophy. Videos from the Ultrasound Leadership Academy (www.ultrasoundleadershipacademy.com), covering topics on basic cardiac, lung, inferior vena cava, deep vein thrombosis, soft tissue infection, abdominal aortic aneurism and musculoskeletal ultrasound, were included. Finally, videos from SonoWorld (http://sonoworld.com), covering topics on obstetrical ultrasound guidelines and epidemiology of abdominal aortic aneurism screening, were also included. Many additional video topics were made available as an option to any resident who was interested. Educational programs can access all of these videos free of charge.

Supervised Hands-on Training

Residents received dedicated time for supervised hands-on training. Obstetrical ultrasound simulation training was done for one half day the first week of the rotation using the Vimedix OB/Gyn ultrasound simulator (CAE Healthcare, Sarasota, FL). One half day per week was spent with faculty and a standardized patient, practicing ultrasound image acquisition. One half day was spent per week with an obstetrical sonographer in the prenatal ultrasound clinic, observing and practicing obstetrical ultrasound on pregnant patients. Finally, one half day was scheduled per week to be spent in student health sports clinics with sports medicine faculty, and fellows with time dedicated to musculoskeletal ultrasound practice.

Unsupervised Educational Hands-on Practice

Residents were given 2 to 4 half days per week when they practiced educational ultrasounds on patients in the family medicine clinic, hospital emergency room, and inpatient service. All patients were informed that ultrasounds were being performed by an unsupervised learner and were for education purposes only. No findings were routinely shared with the patients. If the residents found anything on the educational exam that concerned them, they were instructed to notify an attending before discussing this with the patient. During the course of the rotation, residents were required to obtain 5 ultrasound exams in each of 7 required categories: basic cardiac, inferior vena cava, abdominal aorta, lung, deep venous thrombosis evaluation, soft tissue/musculoskeletal, and obstetrical ultrasound. These categories were chosen based on the opinion of the author in conjunction with an informal-needs assessment with other family medicine faculty members. It was necessary to select a set of exams small enough so that they could be taught in 1 month, but that would be high-yield in day-to-day practice in family medicine. Skin, joint, respiratory, and cardiovascular disorders are among the 10 most common reasons why patients visit their primary care providers.[1] Additionally, ultrasound screening for abdominal aortic aneurysm is recommend by the US Preventative Services Task Force for all men between the ages of 65 and 75 who have ever smoked.[2] Deep venous thrombosis is a condition commonly encountered in primary care, and often definitive ultrasound images are not immediately available. There is also good evidence that a limited scanning protocol can be performed quickly at the point of care by nonspecialist providers.[3] Low-risk obstetrical care is also a requirement in family medicine residency training, so it was included, knowing that obstetrical ultrasonography would be high yield. Finally, all of these examinations have a track record of incorporation into graduate medical education requirements. They are all listed in the core ultrasound requirements for emergency medicine residents, as per the American College of Emergency Medicine guidelines from 2008.[4]

Image Review

Educational ultrasound exams were uploaded to QPath Cloud (Telexy, Maple Ridge, BC, Canada). Residents completed the initial reports on their findings and interpretation after uploading the exams. One half day per week was spent with an attending, reviewing these images and reports. Feedback for improvement was provided and exam numbers, including the number of required examinations remaining, were also reviewed during this time. If any of the residents' images and reports were not directly reviewed with an attending, then a feedback form was completed by an attending and sent electronically to the resident after the resident's images and reports were reviewed by the attending. The cloud service was shared with the University of South Carolina School of Medicine. The cost to our program was approximately $1 per image uploaded.

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