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Authors

DesJardin, Jacqueline T
Ricceri, Santo K
Brown, Stephen D
et al.

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A Near-peer Point-of-care Ultrasound Elective for Medical Students: Impact on Anatomy Knowledge, Perceptions About Ultrasound, and Self-reported Skill Level

Jacqueline T. DesJardin, BS, Santo K. Ricceri, BS, Stephen D. Brown, BA, Emily M. Webb, MD, David M. Naeger, MD, Nathan A. Teismann, MD

Rationale and Objectives: We aimed to assess the impact of our institution's recently created point-of-care ultrasound (POCUS) course for preclinical medical students by examining its effect on first–year-level medical knowledge, self-reported skill level, and beliefs regarding the importance of ultrasound in future clinical practice.

Materials and Methods: A total of 18 first-year medical students completed a 5-month near–peer-led training program in POCUS consisting of 3-hour teaching sessions (7), 4-hour clinical sessions (10–12), and an independent study. Students completed pre- and postprogram assessments examining (1) student perceptions about ultrasound and its importance to future careers, (2) students' self-reported skill level with ultrasound, and (3) performance on an anatomy and physiology knowledge quiz. Scores and responses were compared to 20 controls.

Results: The majority of students believed that ultrasound was useful for learning anatomy and would be important in their future clinical practice. Students who completed our training program tended to perform better than controls on a test of medical knowledge. Despite reporting far fewer hours of formal ultrasound training, control students rated their skill level comparably to POCUS-trained students.

Conclusions: This study provides evidence that ultrasound is well received by medical students and may be useful for teaching basic anatomy concepts.

Key Words: Medical student education; point-of-care ultrasound; preclinical curricula; near-peer teaching.

INTRODUCTION

The increasing portability and affordability of ultrasound technology has allowed physicians from a wide range of fields to adopt its uses at the bedside. As point-of-care ultrasound (POCUS) expands both in clinical practice and in residency training programs in emergency medicine, anesthesiology, obstetrics and gynecology (1–3), and more, there is an increasing interest in teaching basic ultrasound skills to medical students at the earliest stages of training. However, as the popularity of medical student ultrasound education grows, it is important that institutions offering this training continually assess the utility and impact of their programs. Potential concerns include the observation that student-reported benefit of ultrasound as an anatomy learning tool has been shown to be greater than the actual measured improvement in anatomical knowledge (4), as well as the question of whether students with almost no clinical training can appreciate the nuances of this complex clinical tool (5). Nonetheless, several U.S. medical schools that have already developed well-integrated, longitudinal programs generally report a high degree

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From the School of Medicine (J.T.DJ., S.K.R., S.D.B.); Department of Radiology and Biomedical Imaging, University of California, San Francisco, San Francisco, California (E.M.W., D.M.N.); Department of Emergency Medicine, University of California, San Francisco, 533 Parnassus Ave., U-575, San Francisco, CA 94143 (N.A.T.). Received August 28, 2016; revised November 30, 2016; accepted December 2, 2016. Financial sources: Funding for the elective was provided by the University of California San Francisco Fund for Associated Students of the School of Medicine. This source was not involved in the preparation or development of this manuscript. **Address correspondence to:** N.T. e-mail: nateismann@gmail.com

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of student satisfaction and excellent performance on assessments of basic skills (6–8). To assess the impact of our own recently created elective in POCUS, we undertook the following study.

In the summer of 2014, eight second-year medical students at our institution designed and implemented a faculty-supervised, near–peer-taught ultrasound course for first-year medical students that consisted of seven educational classes, an independent study using course materials, and additional clinical sessions. The primary objectives of this course were to provide training in basic ultrasound skills via a self-sustaining, near-peer education model; to reinforce the anatomy and physiology being taught concurrently in the first-year curriculum; and to instill in students an appreciation for the complexities of POCUS in clinical practice. The design and content of the course were based on programs at other institutions (8–11). A near-peer education model was adopted as it has been shown to benefit the learner and the teacher (12–15) and because of the limited availability of faculty instructors, a common obstacle also encountered at other programs (16–18).

At the conclusion of the course, we assessed our program's impact on (1) student perceptions about ultrasound and its importance to future careers, (2) students' self-reported skill level with ultrasound, and (3) performance on an anatomy knowledge assessment when tested against first-year medical students who did not participate. Next, we describe the structure of our course and report the results of the written examination and survey aimed at evaluating these outcomes.

MATERIALS AND METHODS

Ethical Approval

The study design was reviewed and approved as a minimal risk project by our institution's Committee on Human Research.

Study Design and Population

We conducted a prospective cohort study examining the effects of the near–peer-taught POCUS elective on familiarity with ultrasound, perceptions about ultrasound and its uses, and knowledge of related anatomy and physiology concepts.

The study population was composed of first-year medical students at our institution. The intervention group consisted of 18 first-year medical students (7 female, 39%; 11 male, 61%) who chose to participate in the elective. Students were recruited at a school activity fair and via an email sent to all first-year medical students. The control group consisted of 20 first-year medical students (8 female, 40%; 12 male, 60%) who did not enroll in the POCUS elective but went on to complete the standard first-year curriculum. Controls were selected around the same time that the POCUS participants were recruited, at the beginning of the first year of medical school. Controls were selected at random from students in attendance at a standard curriculum lecture.

Intervention

The POCUS elective was designed in 2014 by eight medical students. The program included an instruction on the applications of ultrasound that were most relevant to core third-year clinical rotations and most important to general medical practice as determined by consensus among faculty from radiology, emergency medicine, internal medicine, anesthesiology, surgery, and family medicine. Previously published curricular guidelines were also consulted (18,19). Learning objectives for the course were finalized by the radiology and emergency medicine faculty who coordinate medical student education in ultrasound for the School of Medicine. The supervisor for the elective was an ultrasound fellowship-trained emergency medicine faculty member with 10 years of experience in performing POCUS.

The POCUS elective consisted of three components: (1) 3-hour educational sessions (7), (2) 4-hour clinical sessions (10–12) in emergency departments or clinics, and (3) an independent study using an iBook.

Seven sessions lasting 3 hours were held on Wednesday evenings over the course of 5 months. The content of the courses was designed to correspond with the standard first-year curriculum; for instance, the cardiac ultrasound examination was taught during the cardiovascular block in the standard curriculum. The sessions included training in the following applications: (1) Introduction to Ultrasound and Knobology, (2) Inferior Vena Cava and Fluid Responsiveness, (3) Measurement of Jugular Venous Pressure and Identification of Pericardial Effusion, (4) Identification of Pleural Effusions and Deep Venous Thrombosis (Part I), (5) Deep Venous Thrombosis (Part II), (6) Renal Ultrasound, and (7) Gallbladder and Common Bile Duct. An iBook with scanning instructions, embedded videos, and clinical pearls was created by second-year student teaching aids and reviewed by the faculty course director. The iBook was distributed to those in the elective so they could prepare for each session and review afterward.

During the structured teaching sessions, two to three first-year students were paired with a second-year student "teaching aid," creating a "pod." Teaching aids were trained by the course director in the summer before the elective. Each pod had a portable ultrasound (SonoSite Edge II; SonoSite, Bothell, WA). All sessions were supervised by the faculty supervisor as well as additional attendings, fellows, and senior residents well versed in POCUS. Each session consisted of a 15-minute lecture presented by one of the teaching aids followed by hands-on practice with the first-year students practicing the examination on each other or the teaching aids as models. At the conclusion of each session, first-year students were also provided with cases and video materials of POCUS scans demonstrating pathologic findings.

In addition, each participating first-year student was matched with a faculty member familiar with POCUS and was given the opportunity to perform or assist with ultrasound studies in a clinical setting such as an emergency department or clinic. Students completed 4-hour shifts (10–12) in their assigned emergency department or clinic throughout their first year.

At the conclusion of the course, 10 first-year medical student participants were recruited to serve as the subsequent year's teachers, thereby sustaining the near-peer character of the program. In addition to completing the POCUS elective, all students also completed the standard first-year medical school curriculum.

Control Group Experience

Control students did not participate in the POCUS elective but completed the standard first-year medical school curriculum. With regard to exposure to ultrasound, the curriculum for first-year medical students during the 2014–2015 school year included the completion of a 1-hour online module covering ultrasound basics as well as an instruction on the Focused Assessment with Sonography for Trauma (FAST) examination, followed by a single 1-hour hands-on session with attending and resident instructors from the departments of radiology and emergency medicine. During this session, most students had the opportunity to practice the FAST examination once or twice. Additional voluntary proctored practice sessions were also offered.

Measures

Both POCUS elective participants and control students took a 14-question multiple-choice "knowledge quiz" approximately 2 months into their first year of medical school, before the start of the POCUS elective (Table 1). All questions on the quiz covered content in the standard first-year medical school curriculum, which would be reinforced by the POCUS elective. The quiz was composed of nine general anatomy questions, three pathology questions, and two physiology questions. The same quiz was subsequently administered to both the POCUS participants and to controls following the POCUS elective.

Additionally, POCUS students took a five-question multiple-choice "perceptions survey" regarding their thoughts about the importance of ultrasound, comfort level in teaching ultrasound, experience with ultrasound, and self-perceived skill level—this survey was taken both before and following completion of the course (Table 2). Controls took the perceptions survey at the end of their first year.

Quizzes were written and reviewed by authors with experience in question writing and survey design. A faculty educator was consulted to review the items for common errors and validity. The final surveys were pilot tested on a group of medical students. Analysis of pilot responses and direct feedback were used to develop the final survey instrument.

All quizzes were proctored and administered in paper form, in person. The content of the knowledge quiz was unknown to the teaching aids.

Data Analysis

To quantify improvement in knowledge, the difference between pre- and postprogram scores on the knowledge quiz was calculated for each student (both POCUS elective and control students). Then, these differences were compared between POCUS elective students and control students using a two-tailed Student t test assuming equal variance. The Fisher exact test was used for analysis of categorical data. All other statistical analyses performed in the present study used a two-tailed Student t test assuming equal variance. For all statistical analyses, $P < .05$ was considered statistically significant.

RESULTS

Elective's Impact on Student Perceptions About POCUS in Medical Training and Future Practice

A total of 18 (100%) POCUS-trained students completed both the perceptions survey and knowledge quiz precourse assessments, and 14 of these students (78%) completed both postcourse assessments. In the control group, a total of 20 students (100%) completed the knowledge preassessment; of the 20 students, 8 (40%) completed the perceptions postsurvey and 9 (45%) completed the knowledge postassessment. Students who did not complete the postprogram knowledge quiz were excluded from the final analysis comparing pre- and postprogram data (Fig 1).

Importance of the Ultrasound to Future Career

Before the program, 11 of the 18 the POCUS elective participants (61%) reported feeling that ultrasound would be

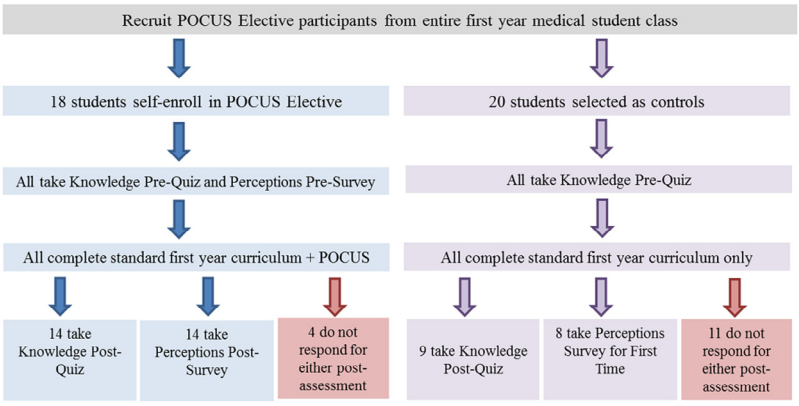

Figure 1. Testing schedule, sample sizes, and response rates for participants and controls. POCUS, point-of-care ultrasound.

TABLE 1. Knowledge Quiz

1. Where is the Morison pouch?
a) Between the bladder and the anus
b) **Between the liver and the kidney**
c) Between the spleen and the kidney
d) Between the diaphragm and the liver
Classification: Anatomy

2. Which of the following are retroperitoneal?
a) **Kidney and aorta**
b) Kidney and liver
c) Liver and spleen
d) Gallbladder and aorta
Classification: Anatomy

3. The hepatic veins empty into the _____.
a) Portal vein
b) Superior epigastric vein
c) Inferior epigastric vein
d) **Inferior vena cava**
Classification: Anatomy

4. Which vessels are the most affected by volume depletion (ie, most compliant)?
a) **Veins**
b) Arteries
c) Arterioles
d) Capillaries
Classification: Physiology

5. In general, what is the relationship of the carotid artery to the internal jugular vein?
a) **The artery is 2 cm deep into the vein.**
b) The artery is 2 cm superficial to the vein.
c) The artery sits against the vein and is slightly anterior and lateral.
d) The artery sits against the vein and is slightly posterior and medial.
Classification: Anatomy

6. Which is a normal central venous pressure?
a) 0.5 cm of water
b) **7 cm of water**
c) 10 cm of water
d) 13 cm of water
Classification: Physiology

7. What is the anteriormost chamber of the heart?
a) The right atrium
b) **The right ventricle**
c) The left atrium
d) The left ventricle
Classification: Anatomy

8. The common femoral vein is derived from which two vessels?
a) **Superficial femoral and deep femoral veins**
b) Anterior tibial and posterior tibial veins
c) Lateral circumflex and the inferior epigastric veins
d) Great saphenous and deep femoral veins
Classification: Anatomy

9. In the popliteal fossa, which vessel is most posterior?
a) Anterior tibial artery
b) Great saphenous vein
c) Popliteal artery
d) **Popliteal vein**
Classification: Anatomy

10. When a person is in the upright position, where is the fluid in a pleural effusion?
a) Between the upper and middle lobes
b) In the splenorenal recess
c) **Costodiaphragmatic recess**
d) In the lower lung parenchyma
Classification: Pathology

11. Hydronephrosis would most typically be seen in which of the following pathologies?
a) Renal artery stenosis
b) **Ureterolithiasis**
c) Glomerulonephritis
d) Polycystic kidney disease
Classification: Pathology

12. Where are the ureterovesical junctions located?
a) **Posterolateral aspect of the bladder**
b) Anterolateral aspect of the bladder
c) Renal pelvis
d) Distalmost aspect of the urethra
Classification: Anatomy

13. What is the first duct into which the gallbladder empties?
a) Right hepatic duct
b) Common hepatic duct
c) Common bile duct
d) **Cystic duct**
Classification: Anatomy

14. In its advanced stages, what would happen to the size of the liver in a patient with cirrhosis?
a) Slight increase in size
b) **Decrease in size**
c) No change in size
d) Major increase in size
Classification: Pathology

Answer counted as correct is shown in bold. Classification as either an anatomy question, a physiology question, or a pathology question is shown in italic.

important for their future careers. The remaining 7 of the 18 participants (39%) reported that they were unsure if ultrasound would be important to their careers. After the program, the percentage of students who anticipated that ultrasound would be important to their future careers had increased to 79% (11 of 14). Similarly, 88% (seven of eight) of the controls felt POCUS would be useful to their future careers.

TABLE 2. Perceptions Survey

1. How much formal training (lectures, didactics, dedicated hands-on training) have you had in ultrasound to date?
a) 0–5 h
b) 5–10 h
c) 10+ h
2) What is your skill level in ultrasound?
a) No previous experience
b) Basic
c) Moderate
d) Advanced
3. Do you envision point-of-care ultrasound to be an important clinical skill in your professional career?
a) No
b) Unsure
c) Yes
4. Do you think ultrasound would be beneficial in helping you retain the basic anatomy learned during the first year of medical school?
a) No
b) Unsure
c) Yes
5. Do you feel confident teaching ultrasound to your fellow classmates?
a) No
b) Unsure
c) Yes

Relevance of Ultrasound in Learning Anatomy

Before starting the program, 15 of the 18 enrolled students (83%) reported that they felt ultrasound training would help them retain basic anatomy knowledge. After the program, all 14 respondents (100%) felt that ultrasound training was in fact helpful in this regard. As for the controls, similarly, all eight respondents (100%) believed that ultrasound would be helpful in retaining anatomy knowledge.

Confidence Teaching Ultrasound

Before the program, only 1 of the 18 enrolled students (6%) felt he or she would be comfortable teaching ultrasound to peers. By the end of the program, 11 of the 14 students (79%) said they would be comfortable teaching fellow classmates. In comparison, of the eight controls, none reported that they would be comfortable teaching POCUS to peers.

Self-ratings of Ultrasound Skill Level

Students were asked to rate their skill level in ultrasound using a four-point Likert scale from "no previous experience" to "advanced."

Before the POCUS elective, the majority of enrolled students (15 of 18, 83%) rated their skill level as basic, with a small number of students (3 of 18, 17%) rating their skill level as moderate (Fig 2). Additionally, of the 18 enrolled students, 16 (89%) reported that they had 5 hours or less of formal ultrasound training, whereas 2 (11%) reported 5–10 hours of formal ultrasound training before the program.

After the POCUS elective, all but one (13 of 14, 93%) reported that they had completed over 10 hours of formal ultrasound training and all (14 of 14, 100%) rated their skill level as moderate. No students rated their skill level as advanced after the POCUS elective.

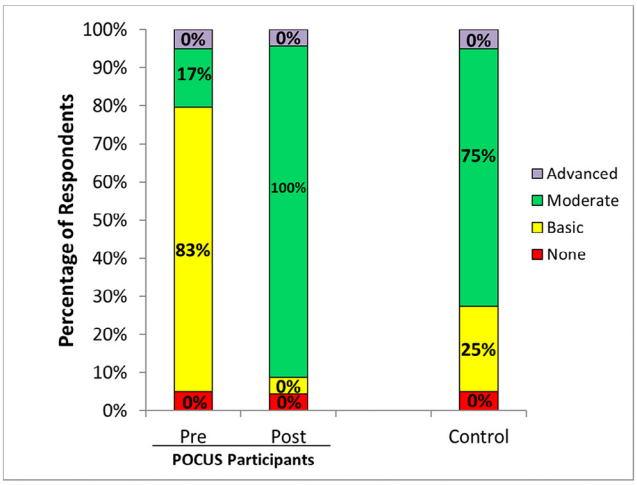

Figure 2. Effects of POCUS training program on self-ratings of ultrasound skill level pre- and post program and compared to controls. POCUS, point-of-care ultrasound.

In comparison, members of the control group reported either 0–5 hours (four of eight) or 5–10 hours (four of eight) of formal ultrasound training. The majority of controls (six of eight, 75%) rated their skill level in ultrasound as moderate. The difference in the proportion of students reporting a moderate skill level between the POCUS group (14 of 14) and the control group (6 of 8) was not statistically significant. However, the difference in the proportion of students reporting 10+ hours of experience (13 of 14 vs 0 of 8) was statistically significant ($P < 0.001$), with controls reporting less experience.

Performance of POCUS Elective vs Control Students on Knowledge Quiz Pre- and Post Program

POCUS students scored an average of 46% on the knowledge preprogram quiz, whereas controls who took the quiz

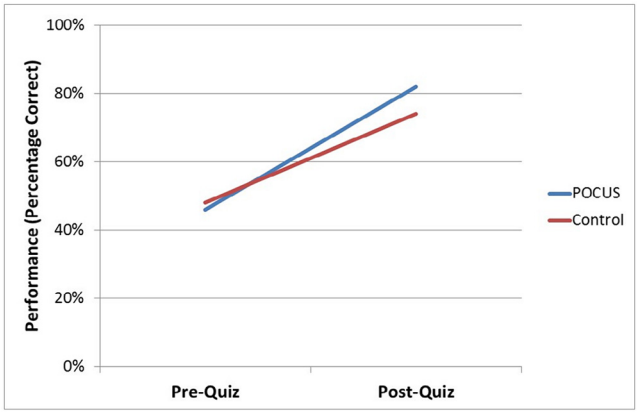

Figure 3. Performance of POCUS elective participants vs control students on the knowledge quiz pre- and post program. POCUS, point-of-care ultrasound.

concurrently scored an average of 48% ($P > 0.80$). These data excluded those students from both groups who did not respond to the end-of-year survey; however, there was also no difference ($P > 0.30$) between enrolled and control students in performance on the preprogram knowledge quiz even when post-test nonrespondents were included in the analysis.

After the program, the POCUS students scored a mean of 82% on the same knowledge quiz, which corresponded to a 76% improvement in the preprogram quiz scores. In comparison, the control group scored a 74% on the knowledge postprogram quiz, corresponding to a 55% improvement in their prior scores. Both program and control students showed a statistically significant improvement in their scores. Although not statistically significant, the ultrasound group tended to score better ($P = 0.11$) and tended to show greater improvement ($P = 0.16$) on the knowledge quiz compared to controls (Fig 3).

DISCUSSION

We compared POCUS participants to controls in terms of their performance on a quiz of general first-year material and also on their perceptions about their own skill level, teaching ability, and perceived importance of POCUS in future clinical work. Our data indicate that most medical students, regardless of experience, felt that ultrasound is a useful tool for reinforcing anatomy knowledge, and that learning ultrasound is a valuable skill for their future careers. These findings are similar to those of previous authors who have shown that medical students are generally enthusiastic about the inclusion of ultrasound in medical school curricula (8,9,20).

The POCUS elective group and control group rated their ultrasound skill levels similarly in the present study. This finding was unexpected, as the POCUS elective group received significantly more training. Potential risks of the incorporation of ultrasound into undergraduate medical student curricula have been previously described (5); most notably, students may develop an exaggerated sense of their own skill. The student-reported benefit of ultrasound as an anatomy learning tool has been shown to exaggerate the actual measurable improvement in anatomical knowledge (4), although it has been suggested that more extensive exposure might mitigate these risks of overconfidence (4,5). In addition to its educational applications, ultrasound is a complex diagnostic tool used to make clinical decisions, making it especially important that students' perception of their skill level matches their actual skill level. After participating in an intensive ultrasound program spanning multiple months and accompanied by numerous clinical sessions, all students in the POCUS elective group rated their skill level as moderate. Interestingly, whereas controls reported fewer hours of ultrasound training, the majority said their skill level was also moderate. This finding is despite the fact that their exposure to ultrasound in the standard curriculum consisted of only a single session with 1 hour of hands-on time. Although some control students reported ultrasound training in the range of 5–10 hours, suggesting they participated in some additional optional ultrasound teaching sessions, none had as much experience as the students who took the POCUS elective. It seems likely that a more thorough training in ultrasound with extensive hands-on time may make students appreciate the technique's complexities. We also believe that the many clinical sessions incorporated into the POCUS program were crucial for allowing students to appreciate the difficulties and limitations of POCUS in real clinical settings. Therefore, the danger to patient care may actually be in underexposing students to ultrasound and its clinical uses and in oversimplifying the teaching of a nuanced imaging modality.

Ultrasound has previously been shown to increase medical students' perceived understanding of basic anatomy (8,10,21,22). However, there is limited evidence that ultrasound objectively improves retention of anatomy knowledge. Most studies that have shown student improvement in anatomy knowledge following ultrasound training have used ultrasound-based assessments such as sonographic anatomy for their outcome measures (9–11,20). However, ultrasound has the potential to reinforce concepts that transcend ultrasound-specific knowledge—especially in anatomy retention, presumably through direct visualization of organs and their interrelationships. Models of anatomy learning describe a process of learning, forgetting, reformatting, and applying (23), and so knowledge retention is of utmost importance in anatomy teaching. To evaluate the true impact of our study, conscious effort was made to assess student retention of standard preclinical course material that was not specific to ultrasound. Thus, the present study focused not on a student's skill in performing ultrasound scans or interpreting ultrasound images, but on how learning ultrasound affects retention of general first-year anatomy, physiology, and pathology. Our findings that all students, including control students, showed improvement in quiz performance confirmed that we were in fact testing content that reflected general material in the standard first-year curriculum. Although not statistically significant, we found that students who completed the POCUS elective

tended to have greater improvement in their preprogram knowledge scores compared to controls. This finding lends objective support to our own experience as educators, in which we feel that the hands-on, spatial understanding taught in programs such as ours have an enduring and complementary effect on standard anatomy curricula. To our knowledge, this is one of the first studies to examine the effects of ultrasound training on medical student general anatomy retention even when measured with non–ultrasound-based assessments.

As POCUS becomes progressively more relevant to the practice of numerous medical specialties, the increasing demand for the incorporation of ultrasound into undergraduate medical education has created questions related to who should teach ultrasound and in what context (5). Intuitively, numerous sessions of comprehensive, hands-on small groups led by formally trained practitioners offer the greatest potential benefit. However, such sessions are not cost-effective or feasible in the majority of educational settings. Here, we offer a sustainable alternative in which students acquire basic ultrasound knowledge from near-peers in a supervised hands-on setting, and this knowledge is then supplemented by well-trained faculty members during clinical sessions. A small group of students educated in this program can then serve as the near-peer educators for the next group of students. The method has been shown to benefit both the learner and the teacher (12–15), and student involvement in ultrasound programs has been suggested as a method to improve sustainability (17). The model allows for more extensive exposure to ultrasound with fewer constraints on busy faculty members. The sustainability of our program is predicated on the ability of students educated in the program to teach the following year's students. We were encouraged that, in contrast to controls, the majority of POCUS elective participants felt confident in teaching ultrasound by the end of the program.

This model also allows for easy collaboration among faculty instructors from different clinical departments. Broad faculty collaboration has been outlined as a key step in the successful initiation of ultrasound curricula (17). We have found that it is important to have radiologists involved in the curriculum design and teaching of our POCUS programs, not just because of their imaging expertise but also for their perspective on the role of POCUS in patient care. Radiologists are often best equipped to guide students as to what limited skills they can reasonably expect to master, and when a formal diagnostic ultrasound examination or another type of imaging study is indicated. Similarly, practitioners from other disciplines—such as emergency medicine—should also be centrally involved given their expertise in hands-on teaching and also because many pertinent POCUS examinations, such as the FAST and measurement of jugular venous pressure, are not routinely performed by radiologists. The format of this course, which allows for multiple or rotating faculty proctors, can ensure that those with the most relevant expertise are present for any given session.

Our study has several limitations. The primary limitation was the small sample size. The POCUS elective described in the present paper was a pilot program at our institution and thus was limited to only 18 participants from a single institution for the first year. Additionally, the response rates, particularly for controls, were less than ideal. This may be in part because our tests required participation using an on-paper, in-person proctored format rather than a more convenient online or email-based format. Although in-person proctored testing may have adversely affected our response rates, administering the tests in this format helped to assure us that performance on the tests reflected true knowledge and understanding of their content. Finally, the medical knowledge examination was fairly brief and may not have provided a comprehensive assessment of students' knowledge of basic anatomy and physiology or the potential impact of the ultrasound training. We hope that the present study provides a framework for more comprehensive research on the effects of learning ultrasound on basic anatomy retention.

In summary, we found that (1) students are enthusiastic about ultrasound as a teaching tool and clinical skill set; (2) more extensive training on bedside ultrasound may help students assess their skill level more accurately; (3) near-peer teaching programs can serve as an efficient educational model for POCUS training; and (4) learning to use ultrasound may help students learn basic anatomy. The present study provides support to the principle that incorporating extensive near-peer ultrasound training early into medical student education improves understanding of anatomy and increases basic knowledge of a clinically important tool. The data gathered in this study are of value to those attempting to design novel medical school ultrasound curricula or expanding their current ultrasound curricula.

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