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Teaching Point of Care Ultrasound Skills in Medical School:

Keeping Radiology in the Driver's Seat

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Rationale and Objectives: Ultrasound is used increasingly in medical practice as a tool for focused bedside diagnosis and technical assistance during procedures. Widespread availability of small portable units has put this technology into the hands of many physicians and medical students who lack dedicated training, leaving the education and introduction of this key modality increasingly to physicians from other specialties. We developed a radiology-led program to teach ultrasound skills to preclinical medical students.

Materials and Methods: To develop this new ultrasound program we 1) established a program leader, 2) developed teaching materials, 3) created a hands-on interactive program, and 4) recruited the necessary instructors. The program was piloted with the first-year medical student class of 154 students. The introductory session was assessed by pre- and post-activity Likert scale–based surveys.

Results: Of 154 (68.8%) students, 106 completed a voluntary online survey before starting the program and 145 students (94.2%) completed a voluntary survey after the session. Students found the program educationally valuable (4.64 of 5) and reported that it improved their understanding of ultrasound imaging (4.7 of 5). Students' reported confidence in identifying abdominal organs, intra-abdominal fluid, and Morison pouch that was significantly higher on the postactivity survey compared to the presurvey ($P < .001$ for all).

Conclusions: We piloted a radiology-led program to teach ultrasound skills to preclinical medical students. Students found the experience enjoyable and educationally valuable.

Key Words: Medical student education; point of care ultrasound; preclinical curricula.

Ultrasound has been a useful diagnostic imaging tool since the introduction of grayscale imaging in the 1970s. While originally the purview of radiologists, rapidly evolving technology, and smaller ultrasound units have put this imaging modality into the hands of a wider range of physicians including subspecialists closer to the point of service. Ultrasound is now used routinely by cardiologists, obstetricians and gynecologists, emergency medicine physicians, critical care physicians, surgeons, and hospitalists for point of care uses including focused diagnostics, as a physical examination adjunct, and for bedside procedure guidance (1). A portable ultrasound device is a far more accurate and powerful tool to identify a suspected pleural effusion, for example, rather than relying simply on a stethoscope. In 1988, ultrasound was called "the stethoscope of the future" in the Journal *Radiology* (2) and that future has largely arrived.

Although ultrasound can be a powerful tool, it is a complex imaging modality, and skillful interpretation and mastery takes years of specialized training. Formal diagnostic examinations, as well as ideally focused examinations, should be performed by imaging experts with specialized training in residency or fellowship. That said, targeted limited ultrasound examinations are already being performed routinely at the bedside by a wide array of physicians, often with little or no formal imaging training.

Medical students now encounter bedside ultrasound as soon as they begin clinical rotations, and similar to other tools in the physician's armamentarium, they are eager to learn to use it appropriately. Several medical schools have begun incorporating hands-on ultrasound training into their formal curricula (3,4) rather than assuming that students will learn

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these skills adequately on the wards. Benefits to formal instruction include more quality control, standardization of training, and opportunity for competency assessment. Additionally, the complexity of ultrasound imaging can be stressed, so that physicians with limited focused skills do not overestimate their level of expertise and better understand when a radiologist must be consulted. Even at programs without a longitudinal clinical ultrasound program, ultrasound is sometimes used in the preclinical years as an educational tool to teach anatomy. This has been shown to be both effective and well received by the learners (5–8).

Although becoming more common, most medical schools have yet to include an ultrasound program into their formal curriculum, and they may face a number of logistical challenges in doing so. These no doubt vary from institution to institution but may include lack of time in the existing curriculum, a lack of ultrasound units available for dedicated student use, a lack of level-appropriate teaching materials, and a lack of teaching time resources among busy clinical faculty.

National organizations are creating programs to help schools in this capacity, mainly by creating and offering shared teaching materials. The American Institute of Ultrasound in Medicine has an "ultrasound in medical education portal" on its Web site with many resources for developing ultrasound teaching programs (9). Another group, the Society for Ultrasound in Medical Education has a number of online resources such as independent learning modules available for public use (10). A live event called ULTRAfest hosted by the emergency medicine departments at the University of California, Irvine and Stanford University over the past 3 years even offers free hands-on ultrasound training to medical students who register for the annual course. At this event, physicians from various specialties including "anesthesia, cardiology, critical care, emergency medicine, internal medicine, nephrology, obstetrics/gynecology, ophthalmology, orthopedics, pediatrics, rheumatology, sports medicine, and urology" teach students a variety of workshops ranging from abdominal diagnostics (aorta, renal, gallbladder, and obstetrics/gynecology) to basic echocardiography (11). Although these shared resources may be valuable and the common educational mission is admirable, the concerning thing about these groups is the relative absence of radiologists from their ranks (12). The groups are led almost exclusively by emergency medicine physicians and obstetricians/gynecologists who may be less expert in medical imaging than career radiology-trained ultrasonographers. Likewise, in the literature, radiologists are absent from the group of early investigators exploring ultrasound as an innovation in medical education.

As most schools have yet to use these resources or develop their own ultrasound curricula for medical students, radiologists still have an important opportunity to get involved at the beginning of this educational shift by establishing content guidelines and curricular standards, as the experts. It is reasonable that a future internist might learn to use ultrasound to guide vascular access or diagnose pleural effusion during a standardized medical school curriculum. However, it is not reasonable to assume that they would learn an adequate amount to competently perform more complex diagnostic studies. Demand for ultrasound programs in medical school curricula will likely continue to increase. Maintaining control over the content can ensure that level-appropriate knowledge and skills are emphasized. For the sake of both patients and our specialty, if radiologists are not performing all imaging studies, it is best to "maintain a seat at the table" with regards to education standards, training, and competency assessment. Additionally, when radiologists are directly involved and perceived by students as the "imaging experts," this type of program increases exposure to and interest in our field (13).

Herein, we describe the development of a radiology-led program to teach ultrasound skills beginning the very first week of medical school. We addressed issues of limited resources and teaching time and specifically describe methods by which radiologists are central to the effort. We evaluated the program created at our institution via qualitative surveys. We hypothesized that students would respond very favorably to the program and find it educationally valuable.

MATERIALS AND METHODS

Needs Assessment

Our medical school has approximately 150 students per class. Our setting is an academic tertiary care facility, which has a strong emphasis on primary care. The school has an integrated curriculum that introduces clinical content alongside basic science material from the first day students arrive. Modernization of the school's anatomy lab facility provided an opportunity to explore new curricular innovations and acquire new digitally based equipment to improve the anatomy education program (14). A multidisciplinary team of educators, including both anatomists and radiologists, was charged with assessing needs for the new laboratory space and teaching program.

The needs assessment was comprised of

- A literature search found that ultrasound is a useful, interactive tool in teaching preclinical anatomy (5–8). Before the program began, radiologic anatomy was taught using a conventional lecture format, and x-ray and computed tomography images that were reviewed during cadaveric dissections. Ultrasound had not been previously incorporated into the anatomy curriculum. The multidisciplinary group decided that the lack of ultrasound instruction in the anatomy program was an educational gap, as a teaching aid, and because broad exposure to the technology would be important for future point of care uses.
- A review of student use of various technologies, specifically ultrasound, compared to the level of training provided. Ultrasound units were already being provided for senior medical student use in a patient simulation center, so students were already using the equipment, but there was no formal training program available in the curriculum.

- A survey of clinical departments at our university which revealed that obstetrics and gynecology, cardiology, emergency medicine, and multiple inpatient services such as surgery and critical care medicine were already independently using bedside ultrasound in the clinical care of their patients.
- Student feedback was solicited. Students felt ill prepared to use ultrasound for point of care uses on clinical rotations and were relying mostly on the guidance of their supervising residents and clinical faculty, few of them were dedicated imaging experts, or had extensive experience in ultrasound imaging.

Implementation

A second literature search also assessed the feasibility of incorporating a point of care ultrasound curriculum into undergraduate medical training and found that it was both possible and beneficial (1,3–8,15–17). A proposal was submitted to the university for funding to purchase ultrasound machines for student use in the anatomy program, which was subsequently accepted. Funds were adequate to purchase two portable ultrasound units (Sonosite Inc., Bothell, Washington). Plans were also made to build a physical classroom directly adjacent to the dissection laboratory to accommodate small-group teaching sessions.

To develop this new ultrasound program, school of medicine educators needed to 1) establish a program leader, 2) find or develop relevant teaching materials, 3) create a program of hands-on interactive instruction, and 4) define and recruit the necessary instructors.

Program Leader

We felt it was critical that a radiologist lead the program. The radiologists centrally involved in undergraduate medical education were the most knowledgeable about where ultrasound was already included over the 4-year curriculum and likewise, what content gaps could be improved upon. Additionally, we were eager to establish our own content guidelines and curricular standards—geared toward a limited skill set that would be reasonable for a student to practice and master as an undergraduate.

Teaching Materials

Given the introduction of this program in the first week of medical school, we opted to develop new level-appropriate teaching materials focusing on normal anatomy in the absence of underlying pathology. Many of the shared resources available for student teaching (9–11) emphasize focused diagnostic examinations (identifying gallstones and diagnosing abdominal aortic aneurysms), and although valuable, these are more advanced skills that will only be applicable to certain physicians in limited practice settings, and in our opinion are best left to imaging experts. Our goal was to create sessions that focused on fundamental skills and practical applications across many subspecialties. These skills would include a basic understanding of the technology, operation of the machine, and adjustment of scanning parameters, optimal scanning technique, and special attention to identification of tissues and structures that would be important in simple bedside diagnostics and ultrasound-guided procedures, for example, identification of normal structures, identification of fluid pockets (ultrasound-guided aspiration), and identification and differentiation of arteries and veins (vascular line placement) (18–20). Additionally, we hoped to convey that ultrasound imaging is complex, skilled interpretation of varied pathologies takes years of dedicated practice, and furthermore that diagnostic machines are far more sophisticated than the portable units they will have access to in the laboratory or at the bedside.

Surface anatomy is one of the first topics addressed in our anatomy curriculum. It is taught primarily to improve physical diagnosis, and using ultrasound as a correlate in that process is very powerful (21–23). For example, learning the surface anatomy landmark for the liver edge and then being able to confirm its location by ultrasound provides excellent hands on reinforcement. The first educational activity in our program was created to complement coincident surface anatomy content in the curriculum. We decided to focus predominately on abdominal anatomy to limit the scope of the material. Basic vascular concepts were also included. Two subsequent ultrasound sessions were scheduled later in the year to parallel different anatomy topics.

To maximize the efficiency of face-to-face teaching, we decided on a "flipped classroom model" (24) in which students review necessary background information (typically online or through other digital media) before classroom sessions. To this end, we first needed to create an introductory independent learning module (ILM) for the students to review before their session. The ILM would be "mandatory," with completion tracked online and points allocated towards the students' final grade.

The introductory module was created in PowerPoint, with the basic ILM content written by a faculty radiologist (EMW) familiar with the course content and medical school curriculum. Then the ILM was further expanded and narrated using Articulate software (Articulate Global, Inc.) by two medical students (JBC, KK) who had just completed their first year of medical school. This type of near-peer teaching has been shown to improve educational outcomes by ensuring that content is level appropriate (25–29). Final review and editing of the ILM were performed by the same radiology faculty member, as well as faculty from the department of anatomy (KST).

The introductory ILM was 75 slides in total requiring about 30 minutes to review. This time estimate is based on the length of the narrated presentation, not direct student feedback. The ILM content covered:

- The basic physics of ultrasound
- Description of echogenicity and comparison of echogenicities of different tissues
- Description of several common artifacts (shadowing and posterior acoustic enhancement)
- Discussion of advantages and limitations of ultrasound
- Scanning tips (orientation of transducers and use of gel)
- Image optimization tips (use of gain, depth, and color)
- Explanation of the clinical relevance to multiple medical specialties
- Focused assessment with sonography for trauma (FAST) examination examples showing both normal and abnormal findings (hemoperitoneum).

Creating a Hands-on Program

For the in-person classroom-based component of the pilot, we wanted to create a program that was both hands on and interactive, necessitating a small-group setting. We divided the class of 153 into six separate groups of approximately 25 students. We scheduled six 1-hour blocks of classroom time, so that each group of 25 students would have an hour to practice with the machines. Each group of students rotated out of the dissection laboratory for 1 hour to the adjacent "small-group pullout" classroom, a common practice at our institution for anatomy-related small-group instruction. The students are given an opportunity after the anatomy laboratory to "catch up" and review what was dissected during their 1-hour absence.

To ensure that each student would have an adequate opportunity to practice scanning during the classroom session, we acquired two additional "loaner" ultrasound units (Sonosite Inc.) in addition to the two that were purchased, for a total of four units for each group of 25. Thus, students were divided into groups of approximately six per machine. Students scanned each other, with the student model rotating on a volunteer basis, so that all participants had an opportunity to practice.

In the classroom, students and instructors had a written laboratory guide (as follows) and were asked to accomplish the following:

1. After putting gel on the ultrasound transducer and placing it on the ventral surface of the abdomen, practice adjusting the machine settings. Locate the on/off button (but don't turn the machine off!)
    a. Turning up the gain will make the image brighter.
    b. Turning the gain down will make the image darker.
    c. Adjust the depth and see how that changes the image on the screen.
2. Practice orienting the transducer in both a transverse and longitudinal plane. Remember to look for the direction marker on the transducer!
3. Use ultrasound to image the skin, subcutaneous fat, muscle, and bone. Note the echogenicity of each. Note the shadowing artifact when imaging bone.
4. Locate the liver. Practice changing transducer orientation, adjusting gain, and adjusting depth.
5. Locate the right kidney. Try imaging the kidney in both longitudinal and transverse planes.
6. Locate Morison's pouch and the right hemi-diaphragm. Note artifact created by air in the adjacent lung.
7. Locate the spleen. Compare its echogenicity to the liver.
8. Locate the abdominal aorta. Turn on color and place the color section box over the vessel.
9. Practice imaging vessels by locating the carotid artery and jugular vein.
    a. Turn on the "color" function to see the motion of blood within the vessels. Remember that the color (red/blue) is not specific to artery or vein, but rather indicates the direction of blood flow toward or away from the transducer marker.
    b. Compress the jugular vein with the transducer.

Recruiting Instructors

A major obstacle to instituting a small group, hands-on program at any institution, is the large number of radiology instructors that it requires. Clinically busy radiologists, already juggling multiple academic and teaching obligations, are often reluctant or unable to take on additional assignments. The program leader was responsible for instructor recruitment. We attempted to diffuse the impact on any particular person by identifying a large group of potential instructors including ultrasound faculty, faculty in abdominal imaging and pediatric radiology who use ultrasound in their clinical practices, fellows in these disciplines, and senior radiology residents. At some institutions, sonographers might also be available as potential instructors. However, this was not feasible at our institution because of their scheduling practices and lack of flexible "academic time". Radiologists were only asked to participate in a single session, although some volunteered to participate in more. To provide an incentive, we emphasized that direct teaching of medical students is valued by the promotions committee at our institution, and we developed an instructor database designed to store the relevant data for our participants' curriculum vitae. A total of 24 instructor slots were filled, so that each group of six students had a radiologist at the bedside to help guide them through the activity.

Assessment

Before viewing the ILM, students were asked to voluntarily complete a brief eight-question online survey as to their prior experience with, knowledge of, and attitudes toward ultrasound. These questions are listed in Table 1.

Following the small-group classroom session, students were asked to complete a voluntary survey as to their opinions of the utility of both the independent learning module and the hands-on facilitated training session.

TABLE 1. Survey Questions, Answer Choices, and Responses from First-year Medical Students Before Beginning the Ultrasound Training

Survey Question	Answer Choices	Number of Responses, *n* (%)	Mean Response (Standard Deviation)
I have used ultrasound prior to medical school	5 Strongly agree	2 (1.9)	1.22 (0.77)
	4 Agree	3 (2.8)	
	3 Neutral	1 (0.9)	
	2 Disagree	4 (3.8)	
	1 Strongly disagree	96 (90.6)	
I am excited to learn more about ultrasound	5 Strongly agree	45 (42.5)	4.24 (0.79)
	4 Agree	44 (41.5)	
	3 Neutral	14 (13.2)	
	2 Disagree	3 (2.8)	
	1 Strongly disagree	0 (0)	
I am familiar with how ultrasound works	5 Strongly agree	3 (2.8)	2.34 (1.07)
	4 Agree	13 (12.3)	
	3 Neutral	27 (25.5)	
	2 Disagree	37 (34.9)	
	1 Strongly disagree	26 (24.5)	
I am familiar with the concept of gain	5 Strongly agree	1 (0.9)	1.56 (0.92)
	4 Agree	6 (5.7)	
	3 Neutral	7 (6.6)	
	2 Disagree	23 (21.7)	
	1 Strongly disagree	69 (65.1)	
I am familiar with the appearance of fluid on ultrasound	5 Strongly agree	1 (0.9)	1.82 (1.04)
	4 Agree	10 (9.4)	
	3 Neutral	13 (12.3)	
	2 Disagree	27 (25.5)	
	1 Strongly disagree	55 (51.9)	
I can confidently identify the liver, kidneys, spleen, and diaphragm with ultrasound	5 Strongly agree	0 (0)	1.54 (0.82)
	4 Agree	3 (2.8)	
	3 Neutral	13 (12.3)	
	2 Disagree	22 (20.8)	
	1 Strongly disagree	68 (64.1)	
I feel confident identifying Morison's Pouch with ultrasound	5 Strongly agree	0 (0)	1.27 (0.66)
	4 Agree	3 (2.8)	
	3 Neutral	3 (2.8)	
	2 Disagree	14 (13.2)	
	1 Strongly disagree	86 (81.1)	
I feel ultrasound can facilitate learning of anatomy	5 Strongly agree	44 (41.5)	4.17 (0.93)
	4 Agree	45 (42.5)	
	3 Neutral	11 (10.4)	
	2 Disagree	3 (2.8)	
	1 Strongly disagree	3 (2.8)	

This study and the administered survey content were approved by our institutional review board. Responses were kept anonymous.

Statistical Analysis

Stata version 12.0 (College Station, TX) was used for statistical tabulation and analysis. Data were summarized by the absolute number and percentage of students answering each answer choice. Likert scale answers were also summarized by a mean value with a standard deviation. The Wilcoxon rank sum test was used to compare statistical differences between groups for questions asked on both the pre- and post-surveys. P values $<.05$ were considered statistically significant.

RESULTS

All 154 students completed both the introductory ILM and the classroom-training session. One hundred and six of 154 (68.8%) first-year students completed the voluntary online survey before viewing the independent learning module. Immediately after completing both the independent learning module and the classroom-based hands-on ultrasound session, 145 of 154 students (94.2%) completed a voluntary survey about their experience. Results are presented in Table 1 and Table 2, respectively.

On the survey preceding the program, most students reported little exposure to the modality and very little knowledge of ultrasound concepts or identifying anatomy by ultrasound, although the vast majority reported being "excited" to learn more about it.

After completing the program (both the ILM and classroom small-group instruction), students found both experiences to be educationally valuable (4.64 out of 5) and reported that the program improved their understanding of ultrasound imaging (4.7 out of 5).

Students' reported confidence in identifying abdominal organs, intra-abdominal fluid, and Morison pouch that was significantly higher on the postactivity survey compared to the presurvey ($P < .001$ for all). Students were overall enthusiastic that the program helped improve their knowledge of anatomy and felt the program was appropriate for a first-year medical student.

Free-text feedback was elicited; responses in their entirety were too numerous to list individually, although the responses were summarized. To the question, "What was the best part of this program?" comments indicated the advantages of "hands-on experiential learning," ($n = 52$), an appreciation for "working directly with a radiologist for the whole session to guide us through" ($n = 36$), enjoying imaging a particular organ ($n = 18$), value of the small group format ($n = 7$), and confirmation that the session helped reinforce their understanding of the relevant anatomy ($n = 7$).

Responses to the question, "What aspect of the program could be improved?" also elicited several common responses. Most common was a request to make the session longer ($n = 20$). The most frequent complaint was report of technical glitches in the ILM (video clips freezing or taking too long to load; $n = 13$). Students also expressed concern about being missing a portion of the concurrent anatomy dissection

TABLE 2. Survey Questions, Answer Choices, and Responses from First-year Medical Students After Completing the Introductory Training Session

Survey Question	Answer Choices	Number of Responses, *n* (%)	Mean Response (Standard Deviation)
The **Introductory Module** was educationally valuable	5 Strongly agree	85 (59.4)	4.59 (0.51)
	4 Agree	57 (39.9)	
	3 Neutral	1 (0.7)	
	2 Disagree	0 (0)	
	1 Strongly disagree	0 (0)	
The **Introductory Module**'s length was	5 Far too long	1 (0.7)	3.12 (0.43)
	4 Too long	20 (14)	
	3 About right	117 (81.8)	
	2 Too short	5 (3.5)	
	1 Far too short	0 (0)	
The **In-person Instruction** was educationally valuable	5 Strongly agree	115 (79.9)	4.79 (0.42)
	4 Agree	28 (19.4)	
	3 Neutral	1 (0.7)	
	2 Disagree	0 (0)	
	1 Strongly disagree	0 (0)	
The **In-person Instruction** length was	5 Far too long	0 (0)	2.94 (0.36)
	4 Too long	4 (2.8)	
	3 About right	128 (88.9)	
	2 Too short	11 (7.6)	
	1 Far too short	1 (0.7)	
Overall, this program of Ultrasound Instruction was educationally valuable:	5 Strongly agree	93 (64.1)	4.64 (0.48)
	4 Agree	52 (35.9)	
	3 Neutral	0 (0)	
	2 Disagree	0 (0)	
	1 Strongly disagree	0 (0)	
This program improved my understanding of ultrasound imaging	5 Strongly agree	102 (70.3)	4.7 (0.48)
	4 Agree	42 (29)	
	3 Neutral	1 (0.7)	
	2 Disagree	0 (0)	
	1 Strongly disagree	0 (0)	
I can confidently identify fluid at ultrasound	5 Strongly agree	28 (19.3)	4.03 (0.62)
	4 Agree	96 (66.2)	
	3 Neutral	19 (13.1)	
	2 Disagree	2 (1.4)	
	1 Strongly disagree	0 (0)	
I can confidently identify the liver, spleen, and kidneys at ultrasound	5 Strongly agree	14 (9.7)	3.67 (0.77)
	4 Agree	82 (56.5)	
	3 Neutral	38 (26.2)	
	2 Disagree	10 (6.9)	
	1 Strongly disagree	1 (0.7)	
I can confidently identify Morison's pouch at ultrasound	5 Strongly agree	16 (11)	3.68 (0.79)
	4 Agree	81 (55.9)	
	3 Neutral	34 (23.4)	
	2 Disagree	14 (9.7)	
	1 Strongly disagree	0 (0)	
This program improved my knowledge of anatomy:	5 Strongly agree	38 (26.2)	4.19 (0.55)
	4 Agree	96 (66.2)	
	3 Neutral	11 (7.6)	
	2 Disagree	0 (0)	
	1 Strongly disagree	0 (0)	
The overall amount of time allotted for this program was	5 Far too long	0 (0)	2.86 (0.43)
	4 Too long	4 (2.8)	
	3 About right	118 (81.9)	
	2 Too short	21 (14.6)	
	1 Far too short	1 (0.7)	
This program is appropriate for the 1st year (as opposed to later in medical school)	5 Strongly agree	71 (49)	4.42 (0.64)
	4 Agree	66 (45.5)	
	3 Neutral	6 (4.1)	
	2 Disagree	2 (1.4)	
	1 Strongly disagree	0 (0)	

(*n* = 10), which is a commonly voiced concern with all our pullout sessions across the anatomy curriculum. Other frequent responses included a desire for even smaller group size (*n* = 6), questioning whether the session would be more valuable later in the year (*n* = 6), and opinions that the session was "perfect" and did not need to be altered (*n* = 6).

DISCUSSION

The idea of teaching ultrasound scanning skills to medical students has been somewhat controversial within our specialty (30). Most of our medical student education programs focus on proper imaging utilization and examination appropriateness, as most students will become future referring clinicians (13,31). Knowing the extensive training required to perform ultrasound at the level of a board-certified radiologist, it seems unwise to teach students a few basics and potentially instill a false sense of confidence about their skill set. Furthermore, there are no systems in place to ensure minimum competency or examination quality. It is our opinion that all ultrasound examinations should be performed by trained imaging experts. However, in reality the "horse is already out of the barn" with regard to dissemination of this technology, and ultrasound units have found their way into the hands of physicians from a wide variety of specialties (1). As such, students and medical school administrators are beginning to demand the inclusion of ultrasound training into medical school curricula (15,16). If radiologists do not step forward as the leaders in this area, physicians from other specialties will fill the gap. (32) It is inarguable that if students and physicians are already using this technology, good standardized training by trained imaging experts will only improve patient care.

Our survey results demonstrate that initiating a radiology-led ultrasound program in the first year of medical school is both possible and appreciated. Students found the ultrasound training to be educationally beneficial. They felt their ability to identify abdominal organs, intra-abdominal fluid, and Morison pouch by ultrasound improved after the training and that the program improved their understanding of abdominal anatomy. Although, perhaps the most obvious benefit to beginning such a program so early in medical school training is providing just such a hands-on interactive aid in anatomy learning (6–8), these skills will also provide foundational knowledge for eventual point of care uses of ultrasound on the wards and beyond. While many shared multidisciplinary resources emphasize focused diagnostic examinations which may be more appropriate in advanced specialty training programs, in our program the course content was designed to achieve maximum point of care impact for a broad array of specialties. Learning the ultrasound appearance of abdominal organs can reinforce physical examination skills and ultimately patient care through improved diagnosis (21–23). Identifying intra-abdominal fluid in Morison pouch is important in focused assessment with sonography for trauma examinations (17). Furthermore, more general recognition of fluid at ultrasound has many applications including diagnosis of ascites, localization of fluid collections, confirmation of effusions, and in ultrasound-guided fluid aspirations and paracentesis practiced later in our medical school curriculum.

One challenge in administering this program was finding an appropriate time slot within the already full-course calendar. We achieved this by scheduling our sessions during as "pull-out" sessions during anatomy dissection laboratories. Although this is a common practice at our medical school, it is a somewhat controversial practice, as some students feel anxious about missing a portion of the dissection. Nevertheless, it is a method that allows students exposure to this material, which would have otherwise been impossible during the preclinical years. Our only other schedule option would have meant optional "after-hours" sessions, which would have inevitably only reached a portion of the class.

We were able to maximize our limited classroom time using a "flipped classroom model" and having students learn the basics in a digital ILM before the hands-on teaching experience. We had some technical problems with our ILM, with some students reporting that video clips took an excessive amount of time to load. However, overall, this approach proved an effective use of time. Many students reported that they would have preferred even more classroom time for hands-on ultrasound practice. If we had used class time to review all the subjects contained in the ILM (physics, tissue echogenicities, artifacts, benefits and limitations of the modality, etc.), there would have been little time left for actual interactive hands-on learning, which was definitively one of the most favored components of the program. This would have also diminished the opportunity to integrate the ultrasound imaging concepts into the larger anatomic understanding, which is most effective through direct questioning and discussion in these small-group situations.

Although having a program led and staffed entirely by radiologists is ambitious and required active and aggressive instructor recruitment, our participation has very important benefits to us as radiologists and to our specialty. When radiologists design and administer ultrasound content in a medical school curriculum, we are able to establish appropriate parameters and expectations through these designated learning objectives. In other words, radiologists can emphasize the appropriate and expected focused diagnostic skills and procedure guidance techniques that students should optimally master, as opposed to concentrating on more complex clinical circumstances requiring a formal examination performed by an imaging expert. The experience of trying to scan a "patient" for the first time under the direct supervision of a radiologist clearly demonstrates to the students that simply having a machine at their disposal, and cursory knowledge of the subject matter, is not in any way a substitute for the expertise of a board-certified and often fellowship-trained radiologist ultrasonographer. Additionally, through this program, students are introduced to our specialty literally in the first week of medical school, and from their first moments of training, see us as "the imaging experts". It is telling that one of the students' favorite aspects of this activity was getting to work closely alongside a radiologist. We are the first clinicians that they have close contact with in their medical training and the experience helps to imprint our role as central and critical to modern medical practice.

Over the next decade, ultrasound will likely be included increasingly in formal medical school curricula (3,15–17). In recognition of this educational trend, and given the clear benefits of having radiologists centrally involved, the Society of Radiologists in Ultrasound and the Alliance of Medical Student Educators in Radiology have recently formed subcommittee groups on the subject and designed a suggested ultrasound curriculum for medical students (33). This curriculum first acknowledges that ultrasound imaging is a complex and deep subject matter that requires more than a superficial understanding to practice competently. However, it strives to teach students the fundamental basics that may be beneficial for simple point of care uses at the most optimal point in their educational experience. Stated more simply, the goal is to cover what every student graduating from medical school needs to know about ultrasound (33).

Although discussion of ultrasound training in undergraduate medical education has been a part of the medical literature for a number of years, the importance of radiologists being involved in these programs has not been previously addressed.

There are several limitations to our study. First, it was performed at a single institution and only describes the introductory session within our 4-year curriculum. The practical details of implementing an ultrasound program, outlined here, will vary from institution to institution based on a number of factors including available time in the curriculum,

support of the medical school and departmental leadership, and availability of radiologist instructors. Additionally, there were no objective measures of learning, only a self-reported qualitative assessment. Furthermore, our survey tools were locally developed rather than using an expert in survey assessment. A standardized measured skills assessment or ultrasound OSCE (objective structured clinical examination) setting will be an important next step in ensuring practice standards for point of care ultrasound performed by nonradiologists. Finally, because this pilot program was recently implemented, we do not have long-term follow-up as to whether these first-year medical students will find this program useful when they begin using ultrasound on clinical rotations, or whether this program, and the resultant early exposure to the field of radiology, will have any impact on future career plans.

CONCLUSIONS

We describe introduction of an ultrasound training program for first-year medical students with the dual goals of providing an interactive aid for anatomy learning and providing foundational skills for eventual point of care uses of ultrasound. Although we would prefer that all ultrasound examinations were performed by trained imaging experts, this technology is already being used by nonradiologist physicians in a wide array of practice settings, and at most institutions, there is no standardized ultrasound training for medical students and no agreed upon competency standards for noncertified physicians (16). Our curriculum was both designed and administered by radiologists which allowed us to focus on skills that we felt were appropriate for all medical students to learn: to support focused bedside use, and procedure guidance. The participation of radiologists in the program exposed students to our specialty early in their medical training and helped establish our role as ultrasound imaging experts. Through our presence in the classroom, we were able to stress that ultrasound is a complex modality and that achieving diagnostic expertise takes years of dedicated training. We strongly recommend that radiologists play a central role in the development of any medical student ultrasound curricula at their own institutions. The students enjoyed the experience, enjoyed having an opportunity to practice hands-on learning in a small group with a radiologist, and found it educationally valuable.

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