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Integration of Ultrasound in Undergraduate Medical Education at the California Medical Schools

A Discussion of Common Challenges and Strategies From the UMeCali Experience

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Abbreviations

AIUM, American Institute of Ultrasound in Medicine; UMeCali, Ultrasound in Medical Education, California

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Since the first medical student ultrasound electives became available more than a decade ago, ultrasound in undergraduate medical education has gained increasing popularity. More than a dozen medical schools have fully integrated ultrasound education in their curricula, with several dozen more institutions planning to follow suit. Starting in June 2012, a working group of emergency ultrasound faculty at the California medical schools began to meet to discuss barriers as well as innovative approaches to implementing ultrasound education in undergraduate medical education. It became clear that an ongoing collaborative could be formed to discuss barriers, exchange ideas, and lend support for this initiative. The group, termed Ultrasound in Medical Education, California (UMeCali), was formed with 2 main goals: to exchange ideas and resources in facilitating ultrasound education and to develop a white paper to discuss our experiences. Five common themes integral to successful ultrasound education in undergraduate medical education are discussed in this article: (1) initiating an ultrasound education program; (2) the role of medical student involvement; (3) integration of ultrasound in the preclinical years; (4) developing longitudinal ultrasound education; and (5) addressing competency.

Key Words—curriculum development; medical student; ultrasound education

Background

Since the first medical student ultrasound electives became available more than a decade ago, ultrasound in undergraduate medical education has gained increasing popularity. More than a dozen medical schools have fully integrated ultrasound education in their curricula, with several dozen more institutions planning to follow suit. Three annual World Congresses on Ultrasound in Medical Education have been held, with representatives from more than 100 US medical schools in attendance during the 2014 convention. The initiative has the backing of many specialty and multidisciplinary societies, including the American Institute of Ultrasound in Medicine (AIUM),[1]

Society of Academic Emergency Medicine,[2] Society of Ultrasound in Medical Education,[3] and Alliance of Medical School Educators in Radiology.[4]

Medical students and other trainees at these institutions are taught the point-of-care or clinical ultrasound model, which is distinct from the traditional model involving sonographers to perform image acquisition and radiologists or specialists to perform interpretation. In point-of-care ultrasound, clinicians perform focused ultrasound examinations to answer a clinical question and use their findings in real-time patient care.[5]

Clinical ultrasound training draws heavily from the specialty of emergency medicine, which has trained residents to perform bedside ultrasound examinations for more than 2 decades. In the process, a large body of research has been generated, showing high accuracy in diagnosis of many acute conditions.[6–14] Many studies document reductions in patient lengths of stay[15,16] as well as overall costs and reductions in radiation exposure with ultrasound.[17,18] In addition, ultrasound guidance in procedures such as central venous catheterization[19] and paracentesis[20] has led to substantial increases in patient safety, leading the Agency for Healthcare Quality and Research to recommend its use. This recommendation has led the AIUM, the largest multispecialty organization promoting ultrasound, to endorse these training guidelines,[21] with Accreditation Council for Graduate Medical Education–based milestones being created in emergency medicine[22] and critical care[23] to address ultrasound competency.

Rationale for Ultrasound Education in the Medical School Curriculum

Incorporating ultrasound into undergraduate medical education is optimal for 4 main reasons: (1) it can enhance traditional learning; (2) it can train future physicians to improve their diagnostic and procedural skills; (3) it can promote coordinated and efficient patient care; and (4) it can serve as a template for advanced, specialty-specific, or interdisciplinary ultrasound training in graduate medical education and continuing medical education.

Ultrasound education has been incorporated traditionally into anatomy, physiology, and physical examination courses. Several studies have shown an increase in knowledge[24,25] as well as student satisfaction[26] in anatomy courses that integrate ultrasound.[27–35] The same advantage is seen in physical diagnosis courses using ultrasound, with medical students reporting enhanced confidence.[36] In fact, several studies show that medical students and junior trainees using ultrasound are able to more reliably diagnose diseases than cardiologists[37] and surgeons.[38] A recent editorial on the "UCI 30" advocates for ultrasound education in conjunction with physical diagnosis training by highlighting the advantages of clinical ultrasound in diagnosis.[39]

Training medical students in ultrasound can improve communication between specialties and lead to more efficient patient care. Classic examples are the focused assessment with sonography for trauma and rapid ultrasound for shock and hypotension examinations in quickly determining the need for surgical intervention in trauma[40] and shock etiology.[41] The surgeon, intensivist, and emergency physician often share decision making during the resuscitation, but this shared management relies on each other's ability to acquire and interpret the necessary views. Multiple clinical situations exist in which clinical ultrasound can reduce additional imaging studies if both the generalist and specialist are proficient in ultrasound, including evaluation of acute cholecystitis and nephrolithiasis.[10]

In addition, the development of core ultrasound competencies during medical school allows for advanced training during residency, as well as collaborative training between specialties. Clinical ultrasound fellowships could be standardized via a common curriculum[42] and lead to training of core educators and researchers in clinical ultrasound.

Objectives

The main objective of this work is to highlight the development and implementation of ultrasound education in the California medical schools. We will discuss how regional collaboration among ultrasound educators can both promote senior medical school leadership support and student involvement. We will focus on key topics and discuss barriers encountered, as well as strategies for success and lessons learned.

Methods

Starting in June 2012, a working group of emergency ultrasound faculty at the California medical schools began to meet to discuss barriers as well as innovative approaches to implementing ultrasound education in undergraduate medical education. Schools represented included University of California Los Angeles, University of California Irvine, University of California Davis, University of California San Francisco, University of California San Diego, University of Southern California, Stanford University, Loma Linda University, and Touro University. The various institutions differ in the level of integration of ultrasound education, academic structure, student body size, faculty and equipment support, and areas of concentration for ultrasound

education. It became clear that an ongoing collaborative could be formed to discuss barriers, exchange ideas, and lend support for this initiative.

An initial Web-based survey to elicit the characteristics of the ultrasound curriculum for each institution was disseminated. The 38 questions asked about the size and composition of the ultrasound faculty involved, the level of medical school and departmental support, ultrasound-based curricular activities in place, as well as barriers encountered (Appendix 1).

The group, termed Ultrasound in Medical Education, California (UMeCali), convened to discuss these responses. The 2 main goals of UMeCali are as follows: (1) to exchange ideas and resources in facilitating ultrasound education; and (2) to develop a white paper to discuss our experiences. Regarding the first goal, engagement with social media, through a website and a Facebook group page, began to allow for open dissemination of ideas and events, as well as equipment and instructor sharing. This process facilitated collaboration among institutions, as detailed later in this article. Development of a white paper underwent multiple rounds of discussion over a 3-year period as successes and further barriers were encountered (Figures 1 and 2). Based on these experiences, topical themes emerged from the discussion and are detailed below.

Theme 1: Initiating a Program

Since the group's inception, one of the primary topics discussed dealt with starting a program that was sustainable. Universally, this topic was a difficult theme, as it was broad, encompassing all components of a program. Additionally, no two schools had the same administrative infrastructure or curricular design.

In the face of heterogeneity, several common themes arose through group discussion. Four key steps were identified as critical to successfully establishing an ultrasound presence at all UMeCali institutions: (1) identification of a champion; (2) a top-down administrative approach; (3) a bottom-up student-focused grassroots initiative; and (4) broad faculty collaboration.

Identifying Ultrasound Champions

Introducing a new area of study and teaching tool into a medical school curriculum is time and resource intensive, requiring firm accountability. At least 1 or 2 clinicians with a broad background in various clinical applications of ultrasound are needed to champion the program. The position requires strong leadership skills and the ability to find common ground within a diverse group of educators. Champions must appreciate institutional processes and develop a realistic stepwise curriculum given administrative, personnel, and resource barriers. One of the initial primary tasks of the champion is to identify stakeholders at all levels who are involved in curriculum development, vetting, and implementation. This process varies from institution to institution, and this power may lie in the dean's office, within a curriculum committee, or at the level of the course director. Gaining the collective trust and support of these groups will help with downstream conversations.

Other tasks include but are not limited to advocacy within the administration, nurturing student interest, development of a core group of instructors, and collaborating with course and clerkship directors. Champions must also develop ultrasound education curricula, evaluation methods,

Figure 1. Timeline of development of the UMeCali group. CalACEP indicates California American College of Emergency Physicians annual assembly; UME, undergraduate medical education; and US, ultrasound.

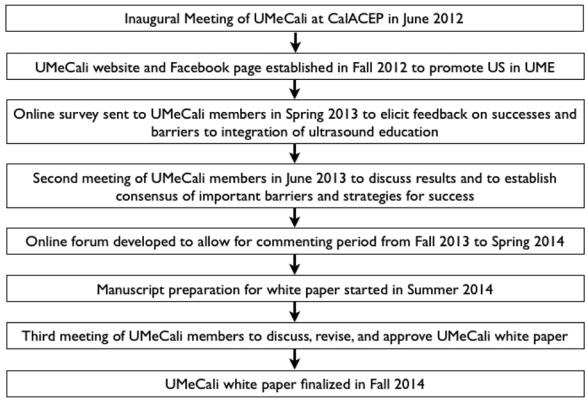
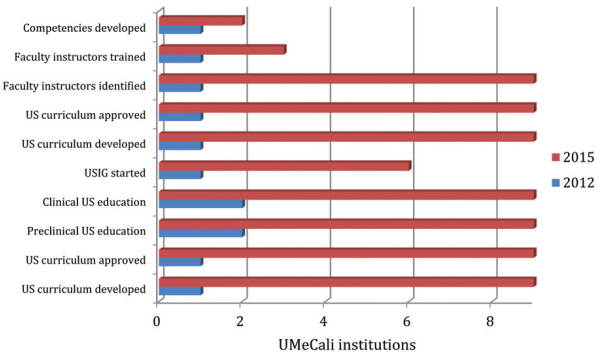


Figure 2. Progress made by the UMeCali institutions in implementing ultrasound education at baseline (2012) and as of submission of the manuscript (2015). US indicates ultrasound; and USIG, ultrasound student interest groups.



workshops, online resources complementary to the school's curriculum and vision, as well as ongoing feedback and improvement. Some ultrasound champions may have reductions in clinical obligations, but all must understand that the task of initiating ultrasound education typically requires a heavy burden of unsupported time for at least several years.

Many online resources are available to new ultrasound champions, including the AIUM's Ultrasound in Medical Education portal. This resource provides new ultrasound curricular developers with building blocks, pointers, presentations, and connections to fellow curriculum developers.[43] In addition, the Mentors Program tab within the website allows expert consultation through the AIUM via e-mail or phone and also serves as a regional database of individuals who may be available to help teach.

Top-Down Administrative Approach

All UMeCali institutions advocate a parallel top-down administrative and bottom-up student-focused approach. Engaging the medical school administration including the dean's office early in the process is essential for several reasons. Through the dean's office, champions may participate in discussion and enlist support from relevant committees, key faculty, and administrative staff. Also, the dean's office oversees all medical school operations, and its guidance can help streamline the proposal process at the course level. However, enlisting administrative advocates can initially be challenging and may require several meetings, presentations, demonstrations, and a multidisciplinary effort.

Often a brief written proposal about the background of point-of-care ultrasound, target educational metrics, and plans for implementation can be developed for key stakeholders. Champions spearheading this proposal should address both potential barriers (eg, equipment, space, and faculty involvement/instruction) and key evidence-based strategies to address these issues. A needs assessment can be conducted for both faculty and medical students with regard to the curriculum. Timelines should be included for stepwise integration of ultrasound education into the curricula. This proposal can offer tiered levels of integration, with the basic level involving occasional ultrasound labs for junior medical students and the highest level involving all 4 years of integration with supervised ultrasound education during clerkships and development of individualized learning portfolios that can be applied toward graduation milestones and competencies. Each tier of integration should include equipment costs, facility time, and faculty hours needed for implementation (Table 1).

Our group had the most success discussing integration with both a formal, written proposal and hands-on demonstration of the capabilities of modern bedside ultrasound units. Several institutions included the idea of a single-course pilot, usually anatomy, to demonstrate the proof of concept before expansion. If allowed the opportunity, demonstrating ultrasound use on a live participant can have a substantial impact. Ideally, this demonstration is performed by one of the institution's medical students and can "bring to life" an abstract concept while demonstrating both basic science and clinical correlates.

Bottom-Up Student-Initiated Approach

The UMeCali institutions have found students and trainees to be vital components of the formulation and implementation process. These next-generation physicians have an intimate connection with technology and, combined with a first-hand account of the curriculum, are important stakeholders and offer valuable perspectives. They provide the frequent feedback to the faculty and dean's office on curricular content, as well as an unbridled "blue sky" view of point-of-care ultrasound use in a variety of specialties. Engaging students and trainees through lectures, pilot workshops, and clinical ultrasound electives is critical. In addition, providing mentorship for ultrasound student interest groups and key resources for advanced learners facilitates the development of a sustainable mechanism for ultrasound education advocacy and peer instruction.

Most UMeCali institutions have found ultrasound student interest group events and fourth year electives to be very popular with students and quicker routes to introducing students to the utility of ultrasound. Compiled event surveys can be important components of the written proposal and during discussions with administration and course directors. Additionally, students who are interested in leadership positions frequently self-identify and are strong student ambassadors to the dean's office.

Broad Faculty Support and Development

The fourth fundamental component to successful initiation is broad departmental support and participation. One of the major perceived barriers to ultrasound integration is the lack of faculty instructors. Ultrasound integration is heavily hands-on, often requiring several instructors to efficiently guide machine operation and case-based small group discussion. No one specialty is able to cover all areas of the body, nor does a single instructor have the ability to teach and manage all aspects of ultrasound integration. For these reasons, it is critical to success that the initiative involves forming strong communities of practice.

The use of communities of practice is a social learning theory developed by Lave and Wenger[44] and was first applied to teaching ultrasound within medical curricula by Bahner and Royall.[45] Communities of practice are "groups of people with a concern or passion for something they do and learn how to do it better as they interact." There is strong consensus within the UMeCali group that the any ultrasound curriculum benefits from several perspectives, which can be obtained by involving faculty from multiple disciplines. Involving faculty from multiple specialties also garners investment from students with varied interests. Additionally, early exposure to a diversity of physicians can spark new interests, clinical shadowing, and student research opportunities.

Table 1. Elements of a Successful Proposal for Ultrasound Education in the Undergraduate Medical Curriculum With Suggested Accompanying Components

Element	Components
Introduction	Define the problem
	Use of computed tomography, drawbacks of radiation, public health concerns
	Students distracted from bedside clinical examination
	Less time with patients
	Bedside ultrasound benefits
Background	Ultrasound in medical education review
	Demonstrate extensive use at many other institutions
	Increasing use clinically: who is using it?
	Increasing use as teaching modality
Benefits of teaching ultrasound	Active vs passive learning
	Small groups: instructor contact
	Clinical correlation
	Gain additional patient care skill
	Improve physical examination skill
	Improved ability to diagnose
	Improved efficiency
	Improved patient satisfaction
Curricular needs assessment	Multidisciplinary approach: clinical and basic science
	Meet with course directors
	Determine optimal courses for high impact implementation
	Develop pilot with course directors
Ultrasound needs assessment	Account for all ultrasound resources:
	Number of machines, industry machine loans, etc
	Facility space for instruction
	Instructors: faculty, residents, sonographers
Plan for implementation	Putting it all together
	Highlight multidisciplinary collaboration
	Course-specific goals and objectives
	Address barriers, propose solutions
	Demonstrate tiered approach: pilot to 4-year integration over time in stepwise fashion
	Demonstrate system to assess course
	Address needs: "the ask" from administration
References/resources	References to cited literature
	Resources for further topic exploration

Theme 2: Medical Student Involvement

Medical student involvement not only enhances senior leadership and faculty support but also provides feedback to ultrasound champions on curricular development. Medical students can help identify and recruit faculty champions, as well as enhance extracurricular ultrasound educational activities such as in regional symposia and community outreach programs. In addition, trained students can function as peer instructors, a vital part of the ultrasound curriculum, with benefits for both the learner and instructor. Students have a better grasp of the level of instruction appropriate for their peers, and learners may be more comfortable in training sessions, leading to earlier identification of learning errors. In addition, instructors benefit by developing teaching skills, which solidify their understanding of ultrasound as well as preparing them to teach in residency and beyond.[46]

One major disadvantage of peer instruction is the recurrent training cycle involved due to graduation of medical students and residents. However, interest can be sustained by ultrasound student interest group members, who can liaise with instructional ultrasound faculty to develop periodic training labs. These events can be planned with other student interest groups and involve peer-to-peer teaching, without a heavy burden on faculty time.

A typical ultrasound student interest group activity may include a brief lecture on an ultrasound application by faculty, followed by a hands-on workshop to practice the application. See Appendix 2 for example topics in ultrasound education. Image acquisition, interpretation, including relevant anatomy, and physiologic concepts are reviewed. Peer instruction allows for smaller trainee-to-instructor ratios, allowing for more hands-on experience.

In addition, ultrasound student interest group members can often propose innovative projects to faculty. For example, interest group–led community projects at the UMeCali institutions have included hypertrophic cardiomyopathy screening at local high schools, abdominal aortic aneurysm screening at health fairs, and education of high school teenagers on the career options in medicine and ultrasound. Another example is UltraFest, the first medical student-driven ultrasound symposium, held in 2012, which taught more than 200 medical students in a single day. That ultrasound student interest group has

helped advise interest groups from other institutions to host similar symposia, which is also an excellent way to identify faculty from multiple specialties who are interested in teaching point-of care ultrasound. Specialties frequently willing to teach include general internal medicine, cardiology, critical care, surgery, obstetrics and gynecology, emergency medicine, anesthesiology, family medicine, urology, and radiology (Table 2).

Theme 3: Preclinical Experience

The preclinical (years 1 and 2) ultrasound experience for students should focus on image acquisition of normal anatomy and physiology, as well as recognition of basic ultrasound pathology. Image acquisition and recognition of normal ultrasound anatomy is most commonly taught by organ system. This process can be implemented concurrently in the anatomy or physical examination curriculum. These two blocks lend themselves well to ultrasound implementation, since they are usually taught by organ system. Furthermore, modeling the ultrasound curriculum to complement preexisting curricula can facilitate ultrasound integration for the medical school's administration.

Ultrasound pathology can be introduced concurrently with image acquisition or can be taught independently. Regardless, identification of pathologic conditions with ultrasound should begin in year 2 of medical education. The optimal method is to demonstrate pathologic conditions in live patients in a clinical or standardized setting. Logistically, ensuring access to patients with desired pathologic conditions in a clinical setting is often very difficult. Although some standardized patients may volunteer their time, enlisting standardized patients is often costly. Other venues include using online resources (websites, podcasts, e-books, and smartphone applications). There are also many ultrasound simulation devices and phantoms that allow students to see pathologic images using 3-dimensional rendering or actual recorded pathologic patient images. Early clinical opportunities can also be offered in the preclinical setting by shadowing providers. The emergency department may be a good initial setting for junior students to shadow clinicians in the form of "bedside ultrasound rounds," since it offers a broad array of patients with undifferentiated presentations and multiple conditions.

Table 2. Suggested Areas for Medical Student Involvement With Ultrasound Education and Example Activities

Objective	Activities
Student-run symposiums/ workshops	School-wide courses State-wide courses Nationwide courses
Ultrasound interest groups	Peer-to-peer teaching Leadership roles Collaboration with local and national ultrasound interest groups Liaison between students and school administrators
Community service	Screening: hypertrophic obstructive cardiomyopathy, abdominal aortic aneurysm, etc High school student mentoring
Representation at conferences	World Congress of Ultrasound in Medical Education American Institute of Ultrasound in Medicine Association of American Medical Colleges Specialty-specific colleges (American College of Emergency Physicians, American College of Radiology, American College of Physicians, American College of Surgeons, etc)

Theme 4: Integrating Clinical Reasoning and Longitudinal Development

Incorporating ultrasound education during the clinical years of medical school is more logistically difficult. There may be multiple clinical sites with variable availability of ultrasound equipment, as well as inconsistent faculty interest and knowledge of clinical ultrasound. As a result, students who benefit from ultrasound education during their first 2 years potentially lose their skills as a result of a lack of dedicated ultrasound activities during their clerkships. It is fundamental that ultrasound is taught during the clerkships, and many schools have developed novel strategies to address this problem.

Highlighted below are recommended strategies for incorporating ultrasound education in the clinical years of undergraduate medical education (Table 3).

Pre–Senior Year Course

A concise workshop and refresher lecture, with primarily online didactics to be studied before the workshop, will focus on an abbreviated ultrasound protocol to identify the etiology of shock, cardiac arrest, and ultrasound-guided intravenous line placement. This workshop could be integrated into the pre–third or fourth year orientation.

Clerkships and Interest Groups

Using the communities of practice concept, interested faculty could be identified from various specialties and Dean's office–supervised mentoring groups (eg, an acute care college). Students from the ultrasound student inter-

est group and other selected interest groups and residents may help identify these colleagues. Interested students, residents, and faculty can participate in a longitudinal train-the-trainer course, which will prepare them to teach clinical ultrasound within their clerkships and specialty interest groups. Although there is intense investment during this training period, this process can lead to sustainable capacity within the various specialties to teach ultrasound. These champions will be responsible for developing specialty-specific ultrasound education. In addition, they may lead periodic "ultrasound rounds," which enhance bedside learning for the clinical team by identifying patients' conditions on ultrasound imaging.

In terms of clerkship selection, initially these should be hospital based to ensure adequate pathologic conditions as well as efficient distribution of machines and trainers. Medicine, surgery, and obstetrics and gynecology clerkships for medical student year 3 as well as emergency medicine and critical care electives for medical student year 4 are ideal for implementation of ultrasound education. Later clerkships and rotations may be integrated depending on interest and capacity.

Flipped Classroom, Social Media, and Digital Education

The concept of "flipping the classroom" involves directing learners to view lecture- based content before the training session to promote discussion.[47] This process is beneficial for faculty, as it reduces the time commitment devoted to lecturing and instead allows for more active teaching styles. The school's information technology resources can be used to create an online curriculum consisting of faculty lectures, textbook chapters, simulated cases, and journal articles. Multiple tracks can be developed for various trainee levels. Training sessions or labs can be devoted to hands-on instruction of image acquisition as well as discussion of simulated cases.

To ensure retention of knowledge, multiple commercial products exist that deliver quick content and evaluation to learners. These products reinforce learning via perceptual adaptive learning module (eg, PALM), as well as a spaced education concept (Qstream, Burlington, MA).[48,49] Results can be tracked on an individual basis by subject area, and deficient areas can be automatically delivered on a more frequent basis until mastery and retention are achieved.

Intern Boot Camp

Intern boot camp will be a final point of ultrasound education and assessment before graduation. Students will review common applications for ultrasound, such as for procedures (eg, central line, paracentesis, peripheral intravenous line, and lumbar puncture) and for resuscitation in trauma (focused assessment with sonography for trauma) and medical and perioperative (rapid ultrasound for shock and hypotension) patients. In addition, students may be assessed on these components by using simulated cases, as well as direct observation for image acquisition.

Theme 5: Addressing Proficiency and Competency

Competency models are traditionally used in training, with at least 3 major areas of knowledge, skills, and attitude.

Table 3. Strategies for Integrating Ultrasound Education Into Clinical Clerkships and Electives

Strategy	Specific Activities
Communities of practice	Departmental faculty champion training
	Longitudinal course for advanced students
Clinical rotations	Introductory ultrasound workshop patterned for the rotation (eg, focused assessment with sonography for trauma for surgery clerkship) taught by clerkship faculty
	Weekly bedside ultrasound rounds
	Simulation block featuring ultrasound simulators
Social media	Use of Facebook or Twitter to promote faculty and student-run ultrasound training
	Qstream or similar e-mail/messaging software that distributes daily cases with 1–3 questions to promote long-term retention
	Qpath or similar image archival component that allows for remote quality assurance image review and student feedback via email
Preclinical and Pregraduation boot camp	Preclinical boot camp can review core ultrasound applications before clinical clerkships
	Pregraduation boot camp can review core ultrasound applications before internship
Competency evaluation	Faculty and resident evaluation
	Objective structured clinical examination
	Review of trainee images
	Use of milestones and entrustable professional activities

Each area is specifically addressed in developing competency. However, the end product, whether the learner is able to perform the task, is not explicitly assessed. Proficiency models differ by addressing the end result, whether trainees are able to perform the application. Although there are distinct differences, for the purposes of this section, both terms will be used interchangeably unless otherwise specified.

Proficiency for clinical ultrasound can be assessed generally or for particular ultrasound applications. The scope and level of proficiency can be tailored for the institution's current goals and resources. For example, one institution may decide that graduating students should be able to perform limited ultrasound applications with minimal supervision, whereas another may decide that all graduating students should be able to perform an expanded set of applications independently. For each application, milestones can be developed according to the training level,[12] or individual entrustable professional activities can be developed (Table 4).[50] Alternatively, a limited number of ultrasound skills may be required for all graduating medical students, to be integrated with Association of American Medical Colleges core entrustable professional activities 10 and 12, pertaining to recognition and initial evaluation of patients requiring emergency or urgent care and general medical procedures, respectively.[51]

Currently, per AIUM and American College of Emergency Physicians guidelines, all scans used for patient care should be archived (typically on a network server) and reviewed by ultrasound faculty. In addition to knowledge assessment, a portfolio of 150 to 250 total scans is needed to achieve a certificate of proficiency in bedside ultrasound at the completion of the residency, with at least 25 each in core applications such as focused assessment with sonography for trauma and echocardiography. If resources permit, this approach can be adopted for medical students scanning on clinical rotations. Alternatively, objective structured clinical examinations involving ultrasound may be developed for evaluation. Trainees needing remediation are given feedback and reassessment until they perform the necessary applications independently.[52]

To scale up this system for medical students, considerable coordination and informational technology support must be invested at the major teaching hospitals affiliated with the institution. They must share the same archiving system (eg, Qpath; Telexy, Everett, WA) and

Table 4. Example of an Abbreviated Entrustable Professional Activity Developed Specifically for an Ultrasound Skill or Procedure

Entrustable Professional Activity 1: Ability to Perform and Aortic Ultrasound Examination	
1. Description of the activity	Physicians need to recognize indications for aortic ultrasound, be able to obtain the necessary views of the aorta in assessing for abdominal aortic aneurysm, be able to diagnose abdominal aortic aneurysm or aortic dissection, and be able to integrate ultrasound findings into clinical management Functions Understand and explain the anatomy, physiology, indications, risks, contraindications, benefits, alternatives, and potential complications of the procedure Explanation and consent for the procedure Premedication and positioning of the patient Obtaining transverse views of the aorta at the level of the superior mesenteric artery to the bifurcation Obtaining a long-axis view of the distal aorta Measurement of the widest diameter of the aorta Identification of abdominal aortic aneurysm or dissection and associated free fluid On identification of pathology, initiate resuscitation and communicate findings to surgical services Communicate with the patient/family to ensure preprocedure and postprocedure explanation and instructions
2. Most relevant domains of competence	Patient care Knowledge for practice Interpersonal and communication skills Professionalism Systems-based practice Interprofessional collaboration Personal and professional development
3. Competencies within each domain critical to entrustment decisions	PC1–8, KP3, ICS2–3, P2, SBP1–2, IPC1–4, PPD6–8

The critical competencies are excluded from this table. ICS indicates interpersonal and communication skills; IPC, interprofessional collaboration; KP, knowledge for practice; PC, patient care; PPD, personal and professional development; and SBP, systems-based practice.

allow for access to instructional ultrasound faculty to review images remotely. Commensurate shared protected time is needed to ensure that ultrasound faculty members are able to review scans and remediate deficiencies for large medical student classes.

Through this process, students are able to perform ultrasound examinations during clinical training with supervision while ensuring patient safety, as potentially missed abnormal scans can be identified and acted on by ultrasound faculty. Students who meet the requirements under the portfolio system may be given a certificate of clinical ultrasound competency or awarded individual entrustable professional activities.[51] based on topics in Appendix 2.

Conclusions

Many medical schools are contemplating or actively integrating ultrasound education in undergraduate medical education. The UMeCali group has collaborated in this process to develop effective strategies to common barriers encountered. Specifically, initiation of an ultrasound education program requires identification of ultrasound champions, a combined top-down administrative and bottom-up grassroots approach, and development of strong multidisciplinary faculty support. Ensuring adequate pathologic examples and ultrasound education during the clinical years involves the use of simulators and bedside ultrasound rounds, as well as development of broad faculty ultrasound education and medical student peer instructor training programs.

Appendix 1. Quantitative Data From Initial Needs Assessment Survey (n = 8)

What best describes your position?	
Junior faculty	63%
Senior faculty	13%
Department chair	13%
Medical school leadership	13%
Average clinical load per month	
Less than 75 hours	25%
75–100 hours	38%
100–125 hours	13%
125–150 hours	13%
More than 150 hours	13%
How many hours per week do you spend on teaching ultrasound outside clinical duties?	
1–5 hours	13%
5–10 hours	25%
10–20 hours	50%
More than 20 hours	13%
My department supports my efforts to integrate ultrasound education in the medical school.	
Completely disagree or disagree	0%
Neutral	38%
Agree	38%
Completely agree	25%
If your department supports your efforts, please specify how.	
Clinical work reduction	38%
Equipment	0%
Facility/laboratory time	13%
Funds	0%
The medical school leadership supports my efforts to integrate ultrasound education.	
Completely disagree or disagree	0%
Neutral	29%
Agree	57%
Completely agree	14%
If your medical school leadership supports your efforts, please specify how.	
Clinical work reduction	0%
Equipment	17%
Facility/laboratory time	67%
Funds	17%
What additional support would help increase your productivity in this effort?	
Clinical work reduction	50%
More faculty involvement	88%
Equipment	75%
Facility/laboratory time	50%
Funds	100%
Are you the primary faculty member leading ultrasound integration at your institutions?	
Yes	86%
No	0%
Not sure	14%
What is the size of the core faculty group that meets on a periodic basis to discuss medical student ultrasound education?	
Myself only	14%
2–5	86%
6–10	0%
More than 10	0%

Aside from emergency medicine, what other specialties are represented in your core group?	
Critical care	50%
Hospital medicine	50%
Cardiology	0%
Radiology	13%
Sports medicine	25%
Obstetrics and gynecology	25%
Surgery	25%
Pathology	13%
In which years is ultrasound education a formal part (ie, required student participation) of the medical school curriculum?	
Year 1	50%
Year 2	38%
Year 3	25%
Year 4 (not elective)	0%
How are student-performed ultrasound examinations evaluated on preclinical rotations?	
Informal feedback during scan sessions	50%
Quality assurance image review	13%
Written examination	25%
Practical examination	38%
How are ultrasound education didactics (ie, not hands-on scan sessions) delivered to medical students?	
Usually via formal lecture	38%
Usually via online podcast	75%
Usually via small-group discussion	63%
How often are these didactics delivered or developed?	
Weekly	38%
Monthly	25%
Quarterly	13%
Semiannually or less frequently	13%
Who develops or delivers these didactic sessions?	
Usually faculty	63%
Usually fellows	50%
Usually residents	0%
Usually medical students	25%
Based on your experience, how long does it take to develop a 30-minute didactic session?	
4 hours or less	0%
4–8 hours	13%
8–16 hours	50%
More than 16 hours	13%
Aside from emergency medicine, please list the background of other ultrasound educators.	
Critical care	50%
Cardiology	13%
Hospital medicine	13%
How often are hands-on scan sessions held?	
Weekly	38%
Monthly	13%
Quarterly	13%
Less frequently	0%
Who leads the scan sessions?	
Usually faculty	75%
Usually fellows	75%
Usually residents	63%
Usually medical students	50%
How many students are typically paired with an instructor during scan sessions?	
Fewer than 4	50%
4–6	38%
More than 6	0%

Appendix 2. Ultrasound Education Topics by Clinical Specialty

Specialty Rotation	*Ultrasound Topics*
Anesthesiology	Ultrasound-guided peripheral nerve blocks
	Central line insertion
	Fluid responsiveness
Cardiology	Normal cardiac structure and function
	Pericardial effusion vs tamponade
	Cardiac valve stenosis, insufficiency, prolapse
	Atrial septal defect, ventricular septal defect, patent foramen ovale
	Systolic and diastolic heart failure
	Hypertrophic obstructive cardiomyopathy
	Procedural guidance: pericardiocentesis, Swan-Ganz catheter
Ear, nose, throat surgery	Normal vasculature of the neck
	Differentiate lymph nodes, cysts, abscesses, masses
Emergency medicine	Focused assessment with sonography for trauma
	Rapid ultrasound for shock and hypotension
	Pneumothorax, pneumonia, pulmonary edema, acute respiratory distress syndrome, pleural effusion
	Pulmonary contusion
	Heart failure

	Pericardial effusion vs tamponade
	Differentiate abscess from cellulitis
	Deep venous thrombosis
	Cholecystitis, choledocolithiasis, cholelithiasis
	Abdominal aortic aneurism
	Urinary retention
	Hydronephrosis
	Procedural guidance: thoracentesis, paracentesis, lumbar puncture, pericardiocentesis, arthrocentesis, central line
Endocrinology	Normal thyroid lobes
	Differentiate thyroid nodules, cysts, masses
Family medicine	Urinary retention
	Hydronephrosis
	Pneumothorax, pneumonia, pulmonary edema, acute respiratory distress syndrome, pleural effusion
	Abscess vs cellulitis
	Foreign body identification
	Abdominal aortic aneurysm screening
Gastroenterology/ hepatology	Normal hepatobiliary anatomy and blood flow
	Liver masses, cysts, angiomas
	Cholecystitis, choledocolithiasis, cholelithiasis
	Ascites
	Bowel obstruction
Intensive care unit	Rapid ultrasound for shock and hypotension, pneumothorax, pneumonia, pulmonary edema, acute respiratory distress syndrome, pleural effusion
	Heart failure
	Pericardial effusion vs tamponade
	Inferior vena cava evaluation for fluid resuscitation
	Increased intracranial pressure (optic nerve sheath diameter)
	Deep venous thrombosis
	Procedural guidance: thoracentesis, paracentesis, lumbar puncture, pericardiocentesis, central line
General internal medicine	Pneumonia, pulmonary edema, acute respiratory distress syndrome, pleural effusion
	Heart failure
	Abscess vs cellulitis
	Procedural guidance: thoracentesis, paracentesis, lumbar puncture, pericardiocentesis, arthrocentesis, central line
Neurology	Cartoid intimal thickness
	Transcranial Doppler
Neurosurgery	Intracranial pressure monitoring (optic nerve sheath diameter)
Obstetrics and gynecology	Normal intrauterine pregnancy (crown-rump length, heart rate, biparietal diameter)
	Ectopic pregnancy
	Uterine, adnexal, and ovarian masses and cysts
	Ovarian torsion
	Fetal anomalies
Ophthalmology	Normal extraocular movement and pupillary response
	Retinal detachment
	Vitreous hemorrhage
	Vitreous detachment
	Lens dislocation
	Retrobulbar hematoma
	Masses
	Foreign bodies
Orthopedic surgery	Long bone fracture and post reduction
	Shoulder dislocation and post reduction
	Abscess vs cellulitis
	Tendon and ligament disruption (Achilles/patellar)
	Foreign body identification
Pathology	Ultrasound-guided biopsies
Pediatrics	Cellulitis vs abscess
	Bladder volume before catheterization
	Pneumonia
	Skull fracture
	Long bone fracture
	Foreign body identification
Radiology	Normal abdominal viscera and blood flow
	Appendicitis
	Intussusception
	Liver masses, cysts, angiomas

	Cholecystitis, choledocolithiasis, cholelithiasis
	Bladder retention
	Testicular torsion, masses, cysts
	Hydronephrosis, hydroureter
	Aortic abnormalities
General/trauma surgery	Focused assessment with sonography for trauma
	Small-bowel obstruction
	Appendicitis
	Pneumothorax
	Abscess vs cellulitis
	Acute cholecystitis
	Increased intracranial pressure
	Pulmonary contusion
Urology/ nephrology	Bladder retention
	Testicular torsion, masses, cysts
	Hydronephrosis, hydroureter
	Procedural guidance: prostate biopsy
Vascular surgery	Normal vs abnormal arterial and venous flow
	Deep venous thrombosis
	Abdominal aortic aneurysm

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