Integration of Ultrasonography into the Undergraduate Medical Curriculum: Seven Years of Experience

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Our published research shows that integration of dissection-based Gross Anatomy and ultrasound imaging resulted in better retention of anatomical knowledge, significantly enhanced student learning of the human body's structure and function, and helped students to better understand correlations with the clinical applications of anatomy and imaging.

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Abstract

Ultrasound education has been part of the curriculum at A.T. Still University's Kirksville College of Osteopathic Medicine for over seven years (since 2011), and has been successfully integrated into the first two years of the four-year medical school curriculum. Students master ultrasound techniques through hands-on laboratories covering all body regions and systems. Ultrasound training has the potential to enhance the medical school learning experience for students and improve the quality of their future patient care.

Introduction

Ultrasound education is becoming an important component of the undergraduate medical school curricula. Early ultrasound education has a positive effect on student clinical decision-making skills and results in a higher level of comfort and better ability when using ultrasonography during clinical rotations.[1, 2] Such training reinforces the anatomical knowledge of students,[3-9] solidifies understanding of physiological processes in the human body,[10, 11] and fosters development of clinical skills.[12] Early ultrasound training for medical students may prevent future diagnostic mistakes by maximizing the ability of students to obtain accurate ultrasound images.[13] Further, research suggests that medical students can attain a sufficient degree of proficiency in ultrasonography techniques in the early stages of their medical education.[1] Its growing influence and importance in medical practice makes ultrasound education an increasingly popular addition to medical school curricula.[14-16] Even though several medical schools in the United States have incorporated ultrasound imaging into medical education,[13, 15, 17-20] there has been no standardization in the ultrasound training programs.

Ultrasound education has been part of the curriculum at A.T. Still University's Kirksville College of Osteopathic Medicine (ATSU-KCOM) for over seven years and is now fully integrated into the first two years of the four-year medical school curriculum. At ATSU-KCOM, the first two years of the curriculum are didactic and taught on campus; the last two years are clinically based in various hospital systems across the United States.

In 2011, the first few ultrasound laboratories were integrated into the KCOM Gross Anatomy I and II courses and were followed by a Clinical Ultrasound Elective course offered to second-year students.

Ultrasound as Part of Gross Anatomy

Initially, the ultrasound curriculum consisted of five ultrasound laboratories for first-year osteopathic medical students that were aligned with the gross anatomy laboratories:

- Ultrasound Laboratory 1. Introductory, neck
- Ultrasound Laboratory 2. Heart
- Ultrasound Laboratory 3. Abdomen
- Ultrasound Laboratory 4. Pelvis
- Ultrasound Laboratory 5. Lower extremities

Students received an opportunity to learn and visualize "living anatomy" with the use of ultrasound technology through correlations with cadaveric dissection. Our efforts resulted in the implementation of a successful hybrid of a dissection-based Gross Anatomy course with embedded ultrasound imaging. Our published research[5] shows that such integration resulted in better retention of anatomical knowledge, significantly enhanced student learning of the human body's structure and function, and helped students to better understand correlations with the clinical applications of anatomy and imaging. These benefits will hopefully be reflected in quantitative outcomes (board subscores) and qualitative outcomes (student satisfaction surveys).

Initially, the first class of 172 students had to be divided into three teams to provide the best hands-on experience to students because ATSU-KCOM only had 10 ultrasound machines. Within two years, the number of ultrasound machines at KCOM was increased to 25 machines comprised of 10 SonoSite-MSK (Fujifilm SonoSite, Inc.) and 15 MindRay M5 (Shenzhen Mindray Bio-Medical Electronics Co., Ltd.) units. The class was then split into two groups so that every ultrasound laboratory had a maximum of 3-4 students per ultrasound machine to provide the best educational experience for the students. Student satisfaction with the ultrasound laboratories and student eagerness to learn clinical concepts through ultrasound imaging has been very high since the first year of integration of ultrasound laboratories into the Gross Anatomy course.

Clinical Ultrasound Elective

Based on student feedback and a high level of student interest in the ultrasound program, a Clinical Ultrasound Elective course was developed. This course was first offered to second-year students in March 2012 to improve student learning in clinical disciplines and provide students with hands-on skills before departing for rotations. During the 2012-2013 academic year, the elective course consisted of seven ultrasound hands-on laboratories that were enriched with clinical correlations:

- Clinical Ultrasound Elective Laboratory 1. Musculoskeletal ultrasound of the upper limb
- Clinical Ultrasound Elective Laboratory 2. Musculoskeletal ultrasound of the lower limb
- Clinical Ultrasound Elective Laboratory 3. Ocular ultrasound
- Clinical Ultrasound Elective Laboratory 4. Advanced echocardiography
- Clinical Ultrasound Elective Laboratory 5. FAST exam (focused assessment with sonography for trauma)
- Clinical Ultrasound Elective Laboratory 6. Breast ultrasound exam with use of breast biopsy model
- Clinical Ultrasound Elective Laboratory 7. Needle-guided procedures with use of ultrasound models

The Clinical Ultrasound Elective course was very successful and received overwhelmingly positive student evaluations. On completion of the course, 100% of students replied "Yes" to the post-semester survey question, "Would you recommend this course to other students?" This positive response resulted in a 70% ultrasound elective course participation for the next year's class despite the fact that there was no elective requirement for second-year students. The elective course continued to be offered through 2014 until it was included as part of the new, required four-semester Clinical Ultrasound course. Formal survey of second-year students revealed that 94% of students agreed that the elective course helped them develop their diagnostic skills.

Clinical Ultrasound Course

The Clinical Ultrasound course for first- and second-year medical students was successfully included in ATSU-KCOM's curriculum during the 2014-2015 academic year as a replacement for the Clinical Ultrasound Elective course and the Gross Anatomy ultrasound laboratories. During semester 1, the Clinical Ultrasound course laboratories are aligned with the Gross Anatomy laboratories. During semesters 2-4, ultrasound laboratories correlate with the systems blocks, and students are exposed to the clinical applications of ultrasound and its use to diagnose pathological conditions (See Table 1).

When planning the Clinical Ultrasound course, the main goals were: (1) to provide students with bedside ultrasound skills at the point-of-care through hands-

Table 1. Ultrasound Laboratories in the Ultrasound Curriculum

Semester 1 Ultrasound Labs	Semester 2 Ultrasound Labs	Semester 3 Ultrasound Labs	Semester 4 Ultrasound Labs
Lab 1. Introduction to ultrasound and neck ultrasound	Lab 1. Abdomen	Lab 1. Lung	Lab 1. Nerve imaging
Labs 2 and 3. Upper limb MSK	Lab 2. Gastrointestinal	Lab 2. Endocrine	Lab 2. Ultrasound needle-guided procedures
Labs 4 and 5. Lower limb MSK	Lab 3. Echocardiography	Lab 3. Obstetrics	Lab 3. FAST exam
Lab 6. Neck	Lab 4. Advanced Echocardiography	Lab 4. Gynecology	
Lab 7. Ocular ultrasound	Lab 5. ECG/echocardiography workshop Lab 6. Upper limb vascular ultrasound Lab 7. Lower limb vascular ultrasound Lab 8. Pelvis and urinary system ultrasound	Lab 5. Breast	

Abbreviations: ECG, electrocardiography; FAST, focused assessment with sonography for trauma; MSK, musculoskeletal ultrasound.

Figure 1. Medical Students Learning Ultrasound Imaging during Ultrasound Laboratories.
A - Medical students learning knee anatomy during the lower limb musculoskeletal ultrasound laboratory.
B - Medical students learning breast normal anatomy and pathology using Breast Ultrasound Training Model (Kyoto Kagaku).

on practical experience; (2) to improve integration of clinical and basic science education through the use of clinical cases and ultrasound simulation; and (3) to incorporate ultrasound imaging into other courses, such as anatomy, osteopathic manipulative medicine (OMM), and physiology.[11, 21]

Because ultrasound education is a fairly new component of medical school curricula, there were limited supplemental materials and textbooks available at course implementation. Therefore, we developed detailed handouts and PowerPoint® (Microsoft Corp.) presentations for the students so that they could be successful in the ultrasound course. To increase the hands-on experiences of students with the ultrasound techniques, the class was split in half to have 3-4 students per ultrasound machine during each ultrasound laboratory. To promote self-learning, open hours for free-scan ultrasound practice were available for students every day after their curricular activities (~10 hours per week), which was much appreciated by students since it helped them improve their proficiency with the ultrasound technology.

Many ultrasound laboratories included clinical cases, which utilized a clinical topic that was demonstrated through ultrasound imaging. For example, when studying ultrasound imaging of the neck vessels, students were first presented a case on carotid artery disease with a related carotid endarterectomy surgery video, which illustrated related anatomical structures. Then students were presented with the ultrasound demonstration on

Table 2. Ultrasound Laboratories for the Clinical Ultrasound Course Using Ultrasound Phantoms

Ultrasound Laboratory	Ultrasound Training Model	Structures of Interest/Objectives

Obstetrics ultrasound	Fetus Ultrasound Examination Phantom SPACEFAN-ST (Kyoto Kagaku)	• Placenta
		• Fetus
		  ○ Fetal head with the face profile
		  ○ Heart
		  ○ Stomach
		  ○ Cerebellum and third ventricle
		  ○ Spine
		• Sex of the fetus
		• Fetal position, breech or vertex
		• Fetal age using
		  ○ Biparietal head diameter
		  ○ Head circumference
		  ○ Femur length

Gynecology ultrasound	Transvaginal SonoHysterography and Sonosalpingography Ultrasound Training Model (CAE Healthcare)	• Urinary bladder • Pouch of Douglas with free fluid • Uterus • Uterine tubes • Endometrial stripe • Left and right ovaries • Ovarian follicles • Uterine fibroma • Ovarian mass/abscess
Breast ultrasound	Breast Ultrasound Training Model (Kyoto Kagaku)	• Breast layers • Axillary lymphatic nodes • Lactiferous ducts • Benign tumor • Cysts • Intraductal papilloma • Ductal carcinoma
Lumbar puncture	Lumbar Puncture and Spinal Epidural Training Model (CAE Healthcare)	• Iliac crests • Spinous processes of L3-L5 • Interspace of L3/L4 and L4/L5 • Ligamentum flavum • Epidural space • Subarachnoid membrane • Subarachnoid space containing cerebral spinal fluid • Measure cerebral spinal fluid pressure
Central line	Gen II Ultrasound Central Line Training Model (CAE Healthcare)	• Internal jugular vein • Common carotid artery • Algorithm of the procedure
Thoracentesis	Midscapular Thoracentesis Ultrasound Training Model (CAE Healthcare)	• Ribs • Intercostal spaces • Lung ○ Left pleural space in costodiaphragmatic recess • Algorithm of the procedure

FAST exam and abdominal aorta	FAST Exam Real Time Ultrasound Training Model (CAE Healthcare) Abdominal Aortic Aneurysm Ultrasound Training Model (CAE Healthcare)	• Right upper quadrant, free fluid in hepatorenal recess
		• Left upper quadrant, free fluid in splenorenal recess
		• Lung
		  ○ Right and left pleural spaces in costodiaphragmatic angles
		  ○ Signs of pneumothorax
		• Pericardial effusion
		• Free fluid in pelvis
		• Abdominal aorta measurements
		• Inferior vena cava

Abbreviation: FAST, focused assessment with sonography for trauma.

how to perform the carotid artery ultrasound examination and identify possible atherosclerotic plaques. After the demonstration, students scanned each other and mastered scanning skills (See Figure 1). The introduction of clinical cases provided correlations between the ultrasound laboratories and clinical courses, such as Internal Medicine and The Complete Doctor. These correlations allowed students to visualize and learn the imaging material better and in a more clinically relevant context.

In planning the new Clinical Ultrasound course, significant assets were committed by the college to add ultrasound phantoms to the ultrasound laboratories,

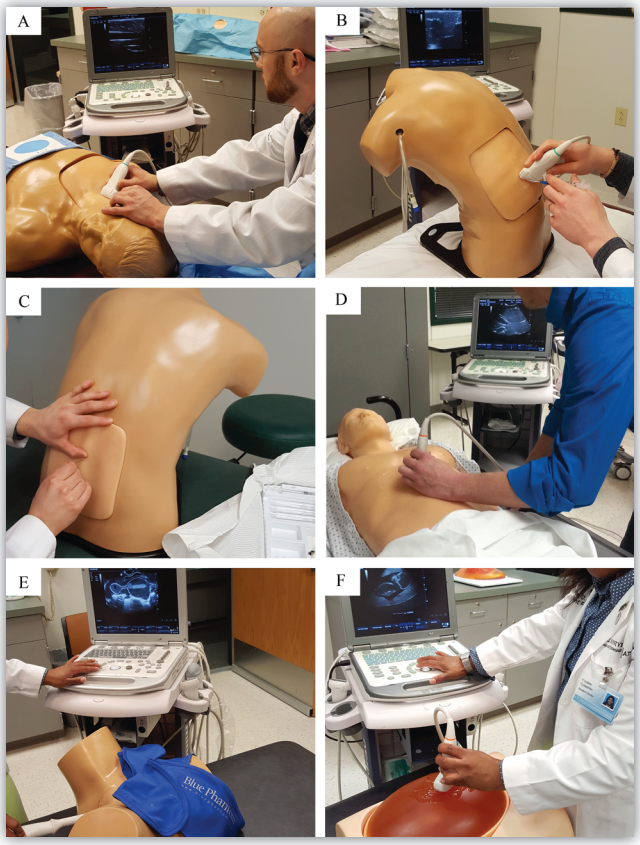

Figure 2. Ultrasound Training Models Used for the Clinical Ultrasound Course
A - Gen II Ultrasound Central Line Training Model (CAE Healthcare).
B - Midscapular Thoracentesis Ultrasound Training Model (CAE Healthcare).
C - Lumbar Puncture and Spinal Epidural Training Model (CAE Healthcare).
D - Focused Assessment with Sonography for Trauma (FAST) Exam Real Time Ultrasound Training Model (CAE Healthcare).
E - Transvaginal Sonohysterography and Sonosalpingography Ultrasound Training Model (CAE Healthcare).
F - Fetus Ultrasound Examination Phantom SPACEFAN-ST (Kyoto Kagaku).

including simulators with pathological conditions that allow a realistic approach to teaching ultrasound imaging during the clinical blocks (See Figure 2, Table 2). Some phantoms simulate pathological conditions, while others allow for needle-guidance training.

While integrating ultrasound into the first and second years of osteopathic medical education, we also identified the curricular areas of anatomy, osteopathic manipulative medicine (OMM), physiology, and internal medicine as ones that would benefit most from the inclusion of ultrasound. A workshop combining electrocardiography and echocardiography has been integrated into the cardiology block, and has been well received by students. Importantly, it significantly improved their understanding of the electrophysiology of the heart.[11] Students were able to better correlate electrical activity with cardiac mechanical events and understand cardiac physiology.[11]

While integrating ultrasound into the ATSU-KCOM curriculum, an ultrasound component was added to the OMM course.[21] It included six ultrasound assignments that required students to obtain ultrasound images of musculoskeletal structures, which were correlated with the body regions presented in the OMM course. Students scanned cranial and cervical structures and lumbar, sacral, and thoracic regions. Students were required to obtain images of the spinous processes of L4 and L5 and the base of the sacrum, laminae, and erector spinae muscles. Students also had to find the atlas (C1), its posterior arch, and the vertebral artery and vein.

Dental Ultrasound Laboratories

The integration of ultrasound has also opened new opportunities for dental medical education[22] because we introduced ultrasound technology to first-year dental students at A.T. Still University's Missouri School of Dentistry & Oral Health. The ultrasound laboratories focused on head, neck, and abdominal anatomy. Laboratories introduced dental students to a new, noninvasive imaging modality that does not use ionizing radiation. Survey results indicated that students enjoyed the ultrasound laboratory exercise and felt ultrasound was an effective learning tool because it provided a better understanding of maxillofacial anatomy.[22]

Student-Initiated Research Resulting from the Ultrasound Curriculum

Successful implementation of the ultrasound curriculum triggered significant research interest among medical students on a variety of topics, such as determining whether an ultrasound experience reinforced learning in Gross Anatomy [5] or the efficiency of assessing ultrasonography skills using a practical exam.[23] Students also researched 3-dimensional/4-dimensional ultrasound technology and its impact on medical education and rural health (unpublished study). Students also began to study how point-of-care ultrasonography has been used in urban versus rural areas.

Conclusions

Medical imaging presents significant challenges to medical students and, despite its importance, only 5% of total teaching time is dedicated to radiology in medical education.[24] The training that students receive through the KCOM ultrasound curriculum may help them better understand other diagnostic imaging modalities that are widely used in medical practice and become more versed in medical imaging in general. Ultrasound training has the

potential to enhance the learning experience for students and improve the quality of their future patient care.

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Disclosure

None reported. **MM**