# Innovative Approach to Teaching Osteopathic Manipulative Medicine: The Integration of Ultrasonography

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**Context:** Noninvasive diagnostic methods and palpatory physical examination skills are especially important for osteopathic medical students intending to work in rural, underresourced, or underserved areas. The A.T. Still University–Kirksville College of Osteopathic Medicine integrates ultrasonography into the osteopathic manipulative medicine (OMM) courses required during the first 2 years of medical school, allowing students to learn the technology and to visualize anatomical structures and regions.

**Objective:** To assess the feasibility of integrating ultrasonography into the first-year and second-year OMM curriculum through the evaluation of students' success in demonstrating the technology and visualizing the anatomy.

**Methods:** As part of their OMM requirements at the A.T. Still University–Kirksville College of Osteopathic Medicine, all first- and second-year students in OMM courses were given ultrasonography assignments that required them to obtain images of musculoskeletal structures in different regions of the body. First-year students studied craniocervical structures and the thoracic, lumbar, and sacral regions. Second-year students studied the glenohumeral joint and the suprapatellar recess. The assignments focused on identifying structures of interest, making annotations, and measuring the structures of interest. Handouts with detailed instructions and a demonstration were provided before each assignment.

**Results:** A total of 183 first-year students and 165 second-year students participated. Of the first-year students, on average, 177 of 181 were able to successfully complete the assignments, with an average completion rate of 98%. The costotransverse joint assignment yielded the lowest completion rate (97%), and the craniocervical landmarks assignment had the highest completion rate (99%). Of the second-year students, 162 of 165 participants were able to successfully complete the assignments, with an average completion rate of 98%. Mean scores were the same for both second-year assignments.

**Conclusion:** First-year and second-year osteopathic medical students successfully demonstrated their use and understanding of ultrasonography and found their assigned structures using live ultrasound imaging. The skills gained through these assignments added another dimension to students' understanding of normal and pathologic musculoskeletal anatomy and vasculature. The integration of ultrasonography into OMM courses may have created a foundation for learning ultrasound-guided injection techniques.

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In the osteopathic medical curriculum, a strong knowledge of anatomy is essential for learning osteopathic manipulative medicine (OMM); however, studies[1,2] suggest that students' retention of anatomic knowledge is poor from the first year of medical school to clinical rotations in the third and fourth years. One study showed that the introduction of sonographic techniques in medical school increased physician expertise with diagnostic imaging technology and improved the quality of patient care.[3] Currently, undergraduate education in imaging in allopathic and osteopathic medical schools is limited to passive experiences that include lectures, videos, and observations of internists and residents, with little or no student participation in image collection or evaluation.[4] Previous studies[5,6] have suggested that medical students can obtain a resident-level understanding of ultrasonography provided that they are given the proper means and methods of training. Considering its cost-effective nature, portability, safety for patients, and wide range of clinical applications, ultrasonography is an ideal teaching tool for medical students.[7] The broad applicability of ultrasonography makes it an ideal modality to improve the quality of care delivered in resource-limited rural clinics and emergency departments, where it can add critical information to patients' history and physical examination findings, improve diagnostic accuracy and efficiency, and assist in safer, more effective procedures.[8]

Because osteopathic medical curricula emphasize the musculoskeletal system, ultrasonography can be an important tool for students to visualize musculoskeletal landmarks using live imaging. Therefore, the purpose of the current study was to assess the feasibility of integrating ultrasonography into the first-year and second-year OMM curriculum through the evaluation of student success in mastering the technology and visualizing the anatomy.

## Methods

First-year osteopathic medical students in the class of 2017 and second-year osteopathic medical students in the class of 2016 at the A.T. Still University–Kirksville College of Osteopathic Medicine were required to complete the ultrasonography assignments described in the current study during the 2013-2014 academic year. Scores on these assignments were included in the OMM course grade. The local institutional review board granted an exempt status for all educational procedures used in the current study.

Students had learned the basic principles of ultrasonography as part of a gross anatomy course, of which 10 hours were dedicated to the introduction of ultrasound physics, machine use, probe selection, scanning techniques, concepts of color and pulsed wave Doppler, and imaging of the organ systems. Student success in the ultrasonography component of the OMM course was evaluated through ultrasonography assignments in which students obtained images of each other.

Twenty-five portable ultrasonography machines were used for training and assignments. Each assignment was preceded by a brief faculty presentation that explained the objectives and clinical relevance of the given exercise. A live demonstration of the scanning technique by faculty and fellows followed. Detailed handouts with instructions were also provided to students. Three full-time faculty members and 4 academic fellows provided assistance to students during the scanning sessions to help with image acquisition and interpretation. Additional instruction was provided during the allotted scanning time for each assignment period. The academic fellows, who had completed 2 years of medical school and who had taken a year off from school to help faculty facilitate such courses, provided individual assistance to students as needed.

The assignments focused on identifying structures of interest, making annotations, and measuring musculoskeletal structures either at rest or under mechanical stress (*Figure*). Students were given 30 minutes to com-

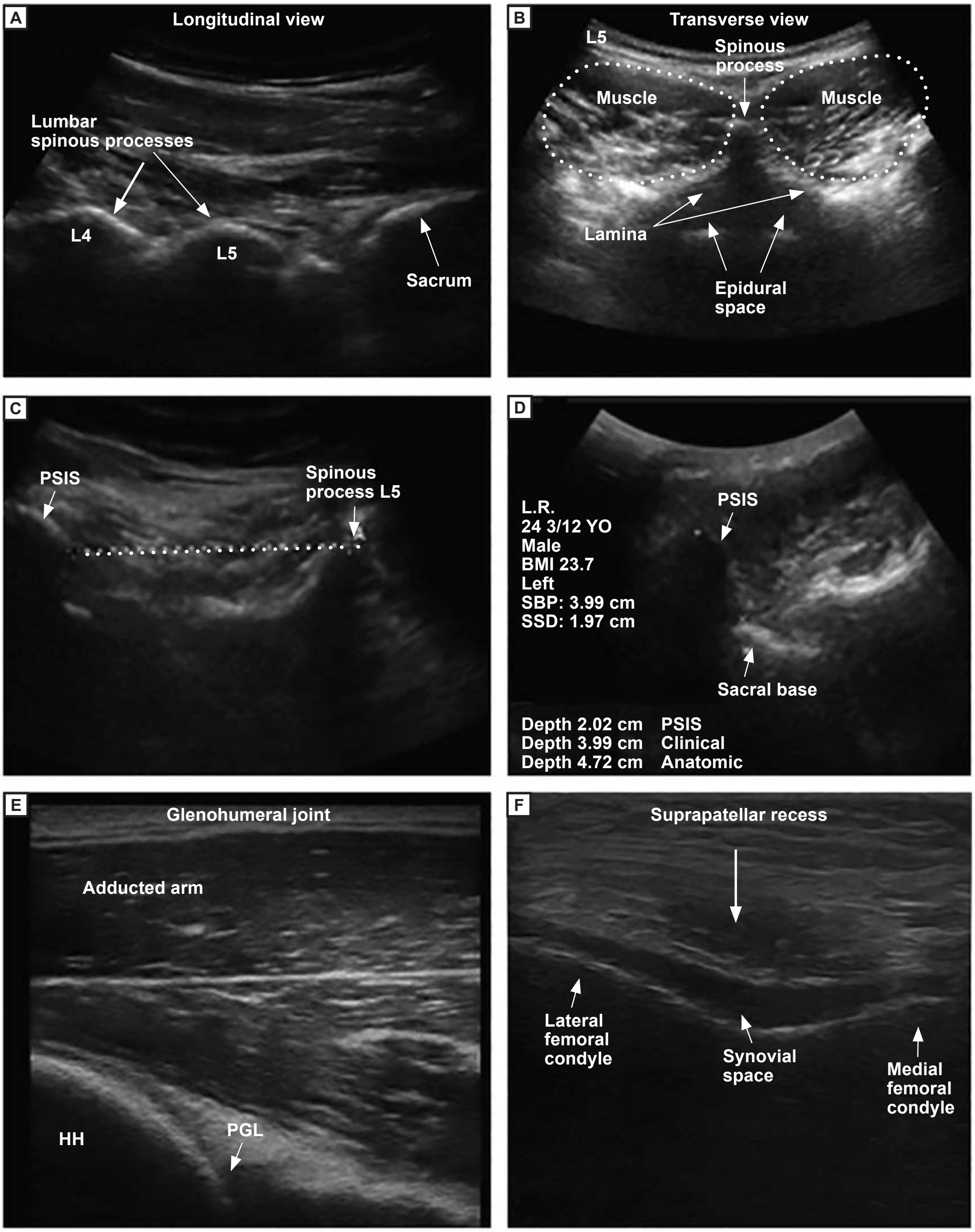


**Figure.**
Examples of ultrasonography images taken by first- and second-year osteopathic medical students. (A) Lumbar spine in the longitudinal view. (B) Lumbar spine in the transverse view. (C) Spinous process of the fifth lumbar vertebra (L5) and posterior superior iliac spine (PSIS) in the transverse view. (D) Sacral base position and sacral sulcus depth. (E) Posterior glenohumeral joint with the arm in the adducted position. (F) Suprapatellar recess in the transverse view (sunrise view). *Abbreviations:* HH, humeral head; PGL, posterior glenoid labrum.

plete each assignment. During this time, they were required to identify target structures; acquire the images, which they labeled and saved on an external memory card; and record the demographic data of the student being scanned, including his or her initials, sex, age, and body mass index. Students then submitted the images electronically through a learning management system. Grading criteria included proper labeling of the structures of interest, proper measurements (if applicable), and demographic information obtained.

### First-Year Students

The assignments for first-year students included scanning the cranial and cervical structures and the thoracic, lumbar, and sacral regions (*Table 1*). For the first assignment, spinal landmarks, students were required to obtain images of the lumbar vertebrae and sacrum. The images had to include a longitudinal view of the spinous processes of the fourth and fifth lumbar vertebrae (L4 and L5) and the base of the sacrum, as well as a transverse view of the lumbar vertebrae with labeled spinous processes, laminae, and erector spinae muscles. For the second assignment, sacral landmarks, students were required to locate the spinous process of L5, identify the posterior superior iliac spine (PSIS) directly lateral to the spinous process of L5, measure the distance between the skin and the sacral base (sacral base position), and measure the distance between the skin and the tip of the PSIS. Students then used this information to define the distance between the tip of the PSIS and the sacral base position to determine the sacral sulcus depth. For the third assignment, costotransverse joint, students identified the joint of the first thoracic vertebra (T1) and the first rib. Students were required to identify T1 in the transverse view, including the spinous process and laminae, and to identify the joint of the transverse process of T1 and the first rib. For the fourth assignment, craniocervical landmarks, students had to find the atlas (first cervical vertebra [C1]), its posterior arch, and the vertebral artery and vein.

### Second-Year Students

Assignments for second-year students included scanning of the glenohumeral joint and the suprapatellar recess (*Table 2*). For the first assignment, the glenohumeral joint, students obtained 2 images of the joint in the posterior view, 1 with the arm in the anatomical position and the other with the arm in the adducted position. Students were required to label the humeral head and posterior glenoid labrum and to measure the glenoid labrum in each position. For the second assignment, suprapatellar recess, students obtained 3 images. The first image was of the flexed knee in the longitudinal view and had to include the quadriceps tendon, patella, suprapatellar recess, synovial space, and distal femur. The second image was of the flexed knee in the transverse view and had to include the medial femoral condyle, lateral femoral condyle, and synovial space (sunrise view). The third image was also in the transverse view but included the suprapatellar recess and synovial space.

## Results

First-year osteopathic medical students were successful in completing all of their ultrasonography assignments, with an average completion rate of 98% (*Table 3*). Of 183 participants, 179 (98%) completed the spinal landmarks assignment successfully, and 178 (97%) completed the sacral landmarks assignment successfully. Of 178 participants, 173 (97%) completed the costotransverse joint assignment successfully, and 176 (99%) completed the craniocervical landmarks assignment successfully.

Second-year osteopathic medical students were also successful in completing all of their ultrasonography assignments, with an average completion rate of 98% (*Table 3*). Of the 165 second-year participants, 162 (98%) completed both the glenohumeral joint assignment and the suprapatellar recess assignment successfully.

**Table 1.**
**Osteopathic Manipulative Medicine Ultrasonography Assignments for First-Year Osteopathic Medical Students (n=183)**

| Assignment | Region | Objectives and Image Annotations |
|---|---|---|
| Spinal landmarks | Lumbar spine | Spinous processes of L4 and L5<br>Base of the sacrum<br>Transverse and longitudinal view of the lumbar vertebrae<br>Spinous processes<br>Laminae<br>Erector spinae muscles |
| Sacral landmarks | Sacrum and pelvis | Spinous process of L5<br>Sacral base<br>PSIS<br>Measurement of the distance between the skin and the tip of the PSIS<br>Sacral base position (measurement of the distance between the skin and the sacral base)<br>Sacral sulcus depth (distance between the tip of the PSIS and the sacral base position) |
| Costotransverse joint | Thoracic region | Joint of T1 and the first rib<br>T1 vertebra in the transverse view including the spinous process and laminae<br>Joint of the transverse process of T1 and the first rib<br>Clavicle<br>Subclavian artery and vein |
| Craniocervical landmarks | Cervical spine | Atlas (C1)<br>Posterior arch<br>Vertebral artery and vein |

**Abbreviations:** C1, first cervical vertebra; L4, fourth lumbar vertebra; PSIS, posterior superior iliac spine; L5, fifth lumbar vertebra; T1, first thoracic vertebra.

## Discussion

The osteopathic medical paradigm requires physicians to manage all stages of disease and to enhance patients' quality of life by addressing anatomical, physiologic, and psychospiritual problems before they become detrimental to patients' health. As part of osteopathic medical education, therefore, experience in ultrasonography, which allows students to explore anatomical structures and organ systems in real time, is a valuable complement to the curriculum.

The current study demonstrated successful ultrasonography education and assessment of osteopathic medical students and therefore the appropriateness of integrating ultrasonography into the first-year and second-year OMM curriculum. Sonographic training for medical students has been proven to provide useful foundational knowledge for their future medical practice.[9] For example, previous studies have suggested that ultrasonography could be a useful adjunct to the examination of the poste-

**Table 2.**
**Osteopathic Manipulative Medicine Ultrasonography Assignments for Second-Year Osteopathic Medical Students (n=165)**

| Assignment | Region | Objectives and Image Annotations |
|---|---|---|
| Glenohumeral joint | Posterior glenohumeral joint | Glenohumeral joint in the posterior view<br>Humeral head<br>Posterior glenoid labrum (PGL)<br>Image with the arm in the anatomic and adducted arm position<br>Measurement of the PGL in the anatomic and adducted arm position |
| Suprapatellar recess | Knee | Quadriceps tendon<br>Patella<br>Suprapatellar recess<br>Synovial space<br>Femur<br>Medial femoral condyle<br>Lateral femoral condyle |

rior ligament complex of the thoracolumbar spine[10] and the identification of specified lumbar interspaces before spinal anesthesia.[11,12]

The integration of ultrasonography into OMM courses seemed to provide the students in the current study with a better understanding of anatomy and may have created a foundation for learning ultrasound-guided injection techniques. Further, the incorporation of measurements, labeling, and obtaining demographic data into each assignment required students to use physician data-management behaviors and to maintain the integrity of patient data.

Novice students often have difficulty palpating the bony landmarks and anatomical structures that are necessary to form a diagnosis of somatic dysfunction.[13] The ultrasonography assignments described in the current study were designed to reinforce the understanding of landmark anatomy and integrate another set of kinetic skills. Training with ultrasound imaging seems to be a unique, noninvasive, safe tool that can provide students with external validation of anatomical structures, such as the spinous processes, transverse processes, facets, and laminae. The spinous processes are some of the easiest landmarks to palpate. The spinal landmarks assignment was intended to confirm the placement of palpatory contacts and to discern sacral findings from lumbar findings by the use of passive motion induced at the lumbosacral junction. Visualization was also intended as a confirmation of relative sizes and morphologic differences between S1, L5, and L4.

The understanding of anatomical relationships between arthrodial structures and vascular, myofascial, and soft tissue structures can be reinforced by direct ultrasound imaging. For imaging of the sacral landmarks, students identified and confirmed the relative similarities or differences in sacral base position and sacral sulcus depth. These features are integral for establishing a correct diagnosis of sacral dysfunction. This assignment allowed students to

**Table 3.**
**First- and Second-Year Osteopathic Medical Student Performance on Osteopathic Manipulative Medicine Ultrasonography Assignments (N=348)**

| Assignment | n | Successful Completion, No. (%) |
|---|---|---|
| **First-Year Students** | | |
| Spinal landmarks | 183 | 179 (98) |
| Sacral landmarks | 183 | 178 (97) |
| Costotransverse joint | 178 | 173 (97) |
| Craniocervical landmarks | 178 | 176 (99) |
| **Second-Year Students** | | |
| Glenohumeral joint | 165 | 162 (98) |
| Suprapatellar recess | 165 | 162 (98) |

reevaluate their findings or confirm their presumptive findings before formulating a diagnosis of sacral somatic dysfunction.

Ultrasonography offers an effective evaluation of the presence of asymmetry of anatomical landmarks, which is one of the characteristics of somatic dysfunction.[14] To date, minimal research has been conducted on methods of assessing bilateral asymmetry using imaging, and a lack of consistency in the assessment methods that have been studied limits reliability comparisons. Ultrasonography can help fill in this gap.

Ultrasound images and measurements taken by students may validate their psychomotor processing. In the current study, visualization of such landmarks as the sacrum using ultrasonography allowed students to appreciate unique age, sex, and body habitus differences in the appearance of these landmarks. By including assignments with an increased level of difficulty and higher expectations in the OMM curriculum, students seemed able to advance their skill set from the fundamental level of image acquisition to the measurement and discernment of clinically relevant structures. This advanced skill set is necessary to obtain the specialty views required to evaluate dynamic stress testing of joints. Furthermore, the success of students in finding the correct target structures using live imaging seemed to give them a better understanding of the anatomy of the palpatory landmarks.

One of the advanced assignments in the current study was imaging of the costotransverse joint. Because thoracic spine and rib diagnoses require accurate identification of the involved structures, identification was intended to validate the location of structures while enhancing confidence and indirectly reinforcing the idea that proper osteopathic manipulative treatment is predicated on accurate diagnosis. Another assignment that needed a greater degree of clinical thinking was imaging of the cranial landmarks. In addition to confirming the position and morphology of arthrodial elements, students had to identify vascular structures using a color Doppler modality. The identification of associated vascular and neural elements was intended to better contextualize regional anatomical structures of interest.

The feasibility of ultrasound needle guidance has been confirmed in a number of studies.[11,12,15-19] In the current study, the glenohumeral joint and suprapatellar recess assignments were intended to highlight the clinical importance of anatomical landmarks for guided procedures. The posterior glenoid labrum, one of the targeted landmarks, is the site for injections in patients with shoulder pain. Similarly, imaging of the knee was intended to show the clinical importance of positional changes to the suprapatellar recess and its importance as an access point for injections. The skills required to identify injection points are particularly important in the specialties of sports and family medicine.

Spatial orientation and 3-dimensionality can be challenging concepts for many students, and the use of ultrasound probes to obtain images in longitudinal, transverse, and oblique planes can establish a foundation for students to successfully interpret living human anatomy.[20] When viewing the resulting images, students can learn muscle fiber orientation, relative density and firmness of muscle and connective tissue elements, compressibility and extensibility, motion characteristics of living tissues, and continuity and attachments of various structures. Further, measuring the depths of structures with ultrasonography provides feedback to the students about the accuracy of their perceived distances between these anatomical features.

Despite ample directions, demonstration, and resources available through our learning management system, a number of students found the scans to be challenging. These challenges can be attributed to students being unfamiliar with ultrasound devices, having little or no experience with ultrasound techniques, and having limited time. Some students had difficulty when scanning partners with a body mass index greater than 30. In those cases, the student was typically asked to scan another student. In the future, we anticipate increasing the scheduled time for image acquisition.

The current study provided a necessary foundation for future research on the validation of palpatory techniques using ultrasonography. One of the possible directions for future research is the ultrasonographic assessment of anatomical structures before and after manipulation to identify any tissue changes, including vascular and lymphatic flow, and the appearance and density of the muscles and fasciae. Another direction for research is the effect of ultrasonography training on the development of palpatory diagnostic skills, which can be evaluated by comparing diagnostic accuracy between a control group (no ultrasonography training) and study group (after ultrasonography training) or by having students take a test on palpatory skills before and after ultrasonography training. Also, to expand on the current study, assignments could be created for the many anatomical areas that were not studied.

### Limitations

The current study was conducted at a single institution and no control group was studied. Both limitations were nearly impossible to avoid at the time the study was conducted because to our knowledge, few osteopathic medical schools have integrated ultrasonography into their curricula. Further, the designation of a control group was problematic because the exercise was required for the whole class. In the future, we will look into designing pre- and posttests to assess the effect of the ultrasonography training on the development of palpatory skills.

## Conclusion

The integration of ultrasonography into the OMM curriculum as a supplement to OMM teaching can only strengthen students' skill sets and competency as they prepare for their careers. Noninvasive diagnostic methods and palpatory physical examination skills are especially important diagnostic tools for osteopathic medical students intending to work in rural, underresourced, or underserved areas. Thus, the acquisition of another set of diagnostic skills will provide students with an advantage in serving their future patients in a wide variety of settings. Assigning future value to specific educational activities is challenging, but the incorporation of ultrasonography into the OMM curriculum may provide students with a better understanding of anatomy and expose them to a new information management approach.

### Author Contributions

Both authors provided substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; both authors drafted the article or revised it critically for important intellectual content; both authors gave final approval of the version of the article to be published; and both authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

*(continued)*

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