



Using ultrasound to teach living anatomy to non-medical graduate students

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Abstract

Purpose Ultrasound technology is used to supplement gross anatomy instruction in many medical sciences programs. However, this technology is not common practice for anatomy instruction in nonmedical graduate-level courses. Ultrasound sessions provide a clear view of local anatomy and could help graduate students transfer anatomical content from a didactic context onto a living, moving body. This approach to instruction complements the rapidly evolving technological advances in science education and may assist with spatial understanding, knowledge retention, and student engagement. The main objective of this article was to describe the methods used to incorporate ultrasound sessions into a graduate level gross anatomy course.

Methods The goal of the curricula was to use ultrasound technology to create a supplemental hands-on and engaging method of learning anatomy that would appeal to graduate students and possibly reinforce content. Graduate students participated in three interactive, 2-h-long ultrasound sessions that corresponded to their gross anatomy lecture material.

Results Questionnaire results showed that students overwhelmingly believed that the ultrasound sessions were beneficial and that ultrasound technology should be used for anatomical instruction in graduate programs. While students found the sessions to be helpful, they sought more and longer sessions with smaller group sizes.

Conclusion Overall, this article describes the methods used to incorporate multimodal learning into a graduate level anatomy course and found that students supported the methods as a potentially effective and engaging way to supplement traditional gross anatomy lectures and practical laboratory sessions.

Keywords Anatomy · Ultrasound · Learning · Teaching

Introduction

Ultrasound technology is used to reinforce gross anatomy instruction in 62% of clinical medical school programs in the United States [1]. However, these techniques have not frequently been transferred to gross anatomy instruction into nonmedical graduate-level courses. Only 15% of graduate anatomy programs in the United States incorporate any use of ultrasound technology into their courses [14]. Johnson and colleagues (2016) demonstrated that the characteristics of ultrasound technology that make it successful in clinical medical school programs may also be applicable to students in nonmedical, life sciences programs [9]. Ultrasound technology is a unique imaging technique that produces dynamic, real-time images while posing no risk of ionizing radiation [13]. It provides a safe method to explore, for educational purposes, normal anatomical variations and movement of structures in the human body [13].

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Graduate students benefit from instruction where they can actively engage and connect the sessions' learning objective to their interests and future careers [3, 12]. Therefore, even without additional medical knowledge, it is likely that graduate students could benefit from supplemental gross anatomy ultrasound sessions. They are unlikely to be intimidated by their limited anatomical background or the novelty of the technology because they have been exposed to rapid evolution of knowledge throughout their lives [6]. Instead, graduate students may be stimulated and intrigued by the opportunity to contextualize what they learn in books and lectures by personally using ultrasound imaging to examine a living, moving body [2]. Furthermore, by providing a clear view linking surface and internal anatomy, ultrasound sessions could assist with spatial understanding, leading to improved graduate student engagement, comprehension, and retention of gross anatomy concepts [10].

Beyond the theory that graduate students may not have the basic anatomical knowledge to benefit from the integration of ultrasound technology into gross anatomy curricula, other barriers have also limited its use in graduate school programs. A recent survey showed that 65% of anatomy faculty had little to no experience with ultrasound technology [14]. This is a relevant issue because anatomy faculty will be the primary instructors for most, if not all, gross anatomy courses for graduate students. Without trained faculty, graduate school programs will have more difficulty adding this type of supplemental learning activity, narrowing their instructional modules. Additionally, a limited amount of time is allocated per course for both students and faculty. Adding a new teaching technique requires balancing all other facets of instruction and time. Many graduate-level gross anatomy courses already have laboratory portions that use the established and supported process of dissection or inspection of prosected cadavers to supplement learning [14]. Lastly, although ultrasound machines are becoming higher quality and more portable, not all nonmedical programs have easy access to these machines. Even graduate life sciences programs associated with medical schools will likely have limited access; they have to be fit into a tight timeslot in the school's clinical learning or simulation center [10]. This article is only the second to observe ultrasound technology being implemented to complement gross anatomy instruction for nonmedical programs, so these issues are only beginning to be examined [15].

The main objective of this article is to describe the methods used to incorporate ultrasound sessions into a graduate level gross anatomy course. The goal of the curricula was to use ultrasound technology to create a supplemental hands-on and engaging method of learning anatomy that would appeal to graduate students and possibly reinforce content. In addition, to provide context and purpose for future studies, the graduate students evaluated the ultrasound sessions by rating

their level of enthusiasm, comfort with the technology, and perceived amount of academic benefit.

Materials and methods

The Institutional Review Board (#021744) of The George Washington University considered this project exempt. This article describes the prospective cross-sectional study of graduate anatomy students at The George Washington University taking part in a newly designed, supplemental ultrasound curriculum. Participants consisted of two cohorts of first-year graduate students ($n=48$) in the Anatomical and Translational Sciences program, which was designed to prepare students to enter a medical school or physician assistant program, as well as those working toward an advance doctorate degree in biomedical sciences. Therefore, all students had an undergraduate degree and completed all pre-medicine course work in biology, chemistry, organic chemistry, physics, math, and English. These graduate students were enrolled in both graduate-level Human Gross Anatomy (ANAT 6181) and Projects in Anatomical Sciences (ANAT 6292) from spring 2016 to spring 2017. The gross anatomy course ran over 15 weeks and provided a broad overview of the structural organization and related regional and system functions of the human body. The course was divided into three sections corresponding to different regions of the body: upper and lower limbs; head, neck, and thorax; and abdomen and pelvis. Relevant prosection-based laboratory sessions were held weekly. The course consisted of 37.5 lecture hours and 18.67 laboratory hours. The special projects course was an independent course that ran parallel to gross anatomy over the 15-week semester. The course was designed to introduce graduate students to various imaging techniques and approaches to visualize normal anatomy. Sessions consisted of three 2-h hands-on ultrasound sessions and weekly in-class discussions on student presentations of diagnostic imaging modalities and relevant gross anatomy topics. The ultrasound sessions were implemented hand-in-hand with the three corresponding body regions from the gross anatomy lecture material. For the ultrasound sessions, students were divided into two groups of 11–13 students, led by one anatomy faculty each. The two instructors who taught in these sessions had experience teaching gross anatomy and previously underwent training taught by physician sonographers [10].

The ultrasound sessions were conducted at the Clinical Learning and Simulation Skills Center at the George Washington University School of Medicine and Health Sciences. Two high-quality portable ultrasound machines equipped with a range of transducers were available for use. They provided quality image resolution and large screens to aid small groups of novice students in identification and

comprehension of images [17, 18]. The machines used were a Zonare z.one ultra sp ultrasound system with P4-1c and L8-3 probes (Zonare Medical System, Mountain View, CA) and a Sonosite M-turbo ultrasound system with L25 and P21 probes (FUJIFIM Sonosite, Bothell, WA). Low-frequency (2–5 MHz) or high frequency (6–13 MHz) ultrasound transducers were used during the sessions depending upon the area of the body being scanned (e.g., low frequency for abdomen and high frequency for musculoskeletal structures).

To assess content mastery of gross anatomy concepts, students took a final examination with multiple choice questions (MCQs) and a lab practical with “fill in the blank” questions. All of the questions were focused on basic gross anatomy relevant to the ultrasound sessions. The grades from the final examination and lab practical relevant to the ultrasound sessions were recorded and averaged individually, along with an average combined score.

Design of the ultrasound sessions

The three ultrasound sessions were designed in parallel with the three body regions in the lecture material in ANAT 6181 (Table 1). Overall, the ultrasound sessions were focused on locating and identifying anatomical structures and various tissue types, observing structures in motion, and briefly connecting this information to its clinical significance. The sessions were designed to engage different types of learners by keeping the groups small and

encouraging hands-on learning. This was done by following the PLHET model for teaching: preparation, linking, hooking, engagement, and transfer (Table 2) [10, 11].

Before the first session, students received handouts that provided an overview of ultrasound technology and terminology. The first session also began with an introduction to the properties of the ultrasound machine and how to use it effectively for the sessions’ purposes. For each session (details of teaching in the appendix), the students were provided with clear learning objectives, teaching points, key terminology, and relevant images. During the sessions, the instructor linked the anatomical content from the gross anatomy lecture material by reviewing the key structures and demonstrating how to find them using the appropriate ultrasound transducer. To make the sessions engaging and hands-on, the students were then given the opportunity to practice using the ultrasound machine under the guidance of the instructor. They were prompted to decide what structure they were looking for, select the appropriate transducer, and then identify specific structures on a volunteering classmate. All students were given the opportunity to use the ultrasound machine, to be a model for ultrasound by a classmate, or both. Due to the high volume of students using the center’s resources, students were only able to access the ultrasound machines only during the teaching sessions and were not given the opportunity to practice outside these times allocated.

Table 1 Learning objective for ultrasound sessions

Session	Objectives
Session 1	To illustrate the difference between various tissue types (bone, tendon, vessel, muscle, nerve) on ultrasound To illustrate the 3D anatomy in motion of the knee joint using ultrasound as a tool and its clinical significance
Session 2	To describe the 3D anatomy of the neck using ultrasound as a tool and its clinical significance To describe the 3D anatomy in motion of eye using ultrasound as a tool and its clinical significance
Session 3	Describe the 3D anatomy relating to the major organs in the abdomen, including the liver, spleen, kidneys, and aorta

Table 2 The PLHET teaching process. Adapted from Jurjus et al. [11]

Session component	Purpose	Example in ultrasound curriculum
Preparation	Provide learners with background information, set expectations	Session handouts given prior to the sessions
Linkage	Stimulate learners’ brains: Link what is to be learned and what learners already know and/or have experienced	Connection to gross anatomy lecture materials while introducing key structures
Hook	Excite learners by showing the relevance of the material to their interests	Use of clinical scenarios to relate to “real life” and show variations in anatomical structures relevant to the subject
Engagement	Have learners apply the material, integrate it with their prior knowledge/skills, and create new knowledge/skills	Demonstration by instructors of the structures using the ultrasound machine while encouraging students to participate in identifying structures and tissues
Transfer	Reinforce the retention of new learning by having learners apply it to a new situation	Students’ use of the ultrasound machine to look at the key structures and explore others structures in the region

Student feedback

At the end of the semester, students were sent a 12-question anonymous survey through Qualtrics software to measure their learning experience and interest level in the ultrasound sessions. The survey included ten questions rated on a four-point Likert scale (strongly disagree, disagree, agree, strongly agree), one yes or no question, and one free response question. Quantitative analysis was done to visualize the general trend of responses for each question. The free response question was qualitatively analyzed using Qualtrics software, which recorded the most frequently used words or phrases.

Results

At the end of the semester, 31 of the 48 graduate students (65%) completed the questionnaire (Table 3). Nearly all (96.8%) agreed or strongly agreed that the ultrasound sessions aided in their comprehension of the underlying living anatomy (Questions 5, 6). Although these students had a limited background in anatomy and 74.2% had never used ultrasound technology before, most (80.6%) did not find

the ultrasound images too difficult to interpret, and 90.3% thought they had enough anatomical knowledge to benefit for the sessions (Questions 1, 7, 8). Furthermore, 90.3% of students felt that they had enough anatomical knowledge from the gross anatomy lectures to benefit from the ultrasound sessions, and 80.6% reported that the sessions were organized in a way that efficiently and effectively reinforced the material covered in the lecture (Questions 4, 7). Overall, students unanimously “agreed” or “strongly agreed” that ultrasound technology should be used for anatomical teaching for graduate students (Question 11).

The last question of the questionnaire asked for any additional comments about the ultrasound sessions (Table 4). Eighteen students responded. They most often reported that while they found the ultrasound sessions helpful ($n = 8$), they would have benefitted more from additional sessions throughout the course ($n = 10$) and from smaller group sizes ($n = 11$).

The end of the course final theoretical examination and lab practical assessed the efficacy of the ultrasound sessions, showing the students’ level of content mastery of anatomical concepts that were relevant to the ultrasound sessions. The average score of the combined final examination and lab practical was 79% correct (Fig. 1).

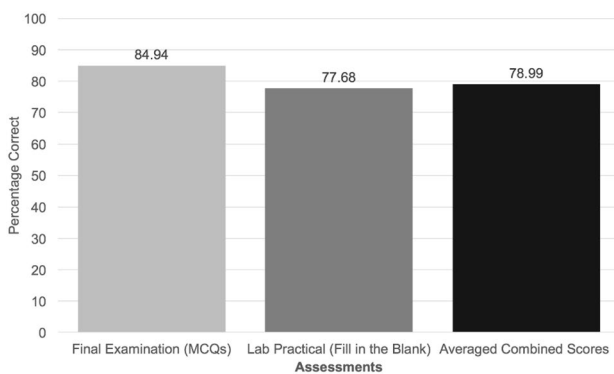
Table 3 Student responses to the survey

Question	Percentage (<i>n</i>)			
	Strongly disagree	Disagree	Agree	Strongly agree
2. I would have liked the opportunity to get [more] hands-on practice with the ultrasound technology	0% (0)	3.2% (1)	51.6% (16)	45.2% (14)
3. I found the use of the ultrasound technology stimulated my interest of anatomy	0% (0)	3.2% (1)	38.7% (12)	58.1% (18)
4. The sessions were organized efficiently, so that they promoted reinforcement of the lecture material	6.5% (2)	12.9% (4)	54.8% (17)	25.8% (8)
5. The ultrasound sessions aided in my understanding of the underlying living anatomy, specifically the spatial orientation and relationships	3.2% (1)	0% (0)	58.1% (18)	38.7% (12)
6. These sessions improved my understanding of the relationship between surface and internal anatomy	3.2% (1)	0% (0)	61.3% (19)	35.5% (11)
7. I had enough anatomical knowledge to benefit from the ultrasound sessions	3.2% (1)	6.5% (2)	51.6% (16)	38.7% (12)
8. I found it too difficult to learn to interpret the ultrasound images	9.7% (3)	71.0% (22)	12.9% (4)	6.5% (2)
9. I want to participate in more ultrasound training opportunities during my academic career	0% (0)	0% (0)	45.2% (14)	54.8% (17)
10. These sessions were of value to my future career	3.2% (1)	0% (0)	32.3% (10)	64.5% (20)
11. I think that the use of ultrasound technology should be used for anatomical teaching for graduate students	0% (0)	0% (0)	29.0% (9)	71.1% (22)

The first question asked “Have you ever used ultrasound technology before class in either an academic or clinical setting?”; 23 of the 31 respondents (74.2%) answered no. The last question was open-ended; common results are included in Table 4

Table 4 Categorized examples of student reflections from the free response question

Category	Student responses
Enhances learning of gross anatomy	<p>“The ultrasound sessions were extremely valuable and enhanced the educational experience of students taking this class”</p> <p>“Personally, using the ultrasound machine on a living, moving person enhanced my understanding of anatomy”</p> <p>“I learn best by physically manipulating things, so getting to use the ultrasound probe helped me to remember the anatomy and how it changes when one breathes or moves differently”</p> <p>“A great learning experience and a good introduction into ultrasound technology”</p> <p>“Getting hands on practice with the ultrasound machine helped me orient the images and better understand the view from which I was looking at the structures”</p>
Limited time and access to ultrasound technology	<p>“I think smaller groups of 3–5 students with multiple sessions would be much more beneficial.”</p> <p>“One needs more time to truly understand what they are looking at with ultrasound imaging than what we had.”</p> <p>“I think the ultrasound sessions would be even more beneficial if they were scheduled more frequently and with smaller groups of students”</p> <p>“Smaller group size would provide more time”</p>
Professor quality	<p>“The ultrasound sessions were very valuable precisely because of the instructor’s professional enthusiasm, superb knowledge, and willingness to show students—again and again—how to interpret the images”</p>

**Fig. 1** Average percent correct for ultrasound questions related to basic anatomy on ANAT6181 final examination, lab practical, and combined scores

Discussion

This article demonstrates that the methods and format used to implement the ultrasound sessions into this graduate-level gross anatomy curricula was not only supported by academic literature, but also by the graduate students involved in the sessions. For example, Dettmer and colleagues (2010) demonstrated that there is a positive correlation between multimodal learning approaches for medical students and their improved academic performance in the pre-clinical first year of medical school [4]. Therefore, the addition of the ultrasound sessions to the gross anatomy course, which already included lecture and laboratory components, may have supported a more diverse group of learning.

Students also found the sessions to be organized efficiently, in a manner that reinforced the lecture material. By following the three main focus areas of the body as indicated in the gross anatomy lectures, instructors were able to help students visualize structures’ functional anatomy and normal anatomical variations. This created a direct link between the abstract thinking required to visualize anatomy in lectures or reference books and a more concrete view of anatomy through manipulating ultrasound images with expert guidance. Connecting the ultrasound sessions to lecture material and encouraging students to be active participants in their learning using the ultrasound transducer themselves made the session more meaningful to the students. This type of contextualized learning has been shown to be effective for adult learners to help foster deeper understanding and promote retention of material [15].

Graduate student responses from the questionnaire for this article support the view that, like medical students, graduate students experience positive benefits from the incorporation of ultrasound sessions in gross anatomy instruction [16]. Despite graduate students’ novice status in understanding anatomy and using ultrasound technology, they appeared to have sufficient knowledge from the anatomy lectures to understand how to interpret the images. However, the ultrasound sessions were focused on simple concepts, such as: general tissue types as well as basic static and dynamic anatomy, so students were not expected to master interpreting ultrasound images. Even so, the graduate students perceived the ultrasound sessions as beneficial to the gross anatomy course and wanted more time with the ultrasound machines to explore the living anatomy. This demonstrates that the sessions sparked the students’ inquisitive nature and left

them seeking an even more in-depth understanding of how to use ultrasound technology to interpret anatomy beyond the scope of the course. Therefore, while the purpose of the ultrasound sessions—to supplement gross anatomy instruction—was well received, these engaging sessions may have the potential to promote self-inquiry and critical thinking skills in graduate students.

The efficacy of the ultrasound sessions is also supported by authentic learning theory. In authentic learning, “real world” context should be woven into instruction as soon as possible to hook students’ attention [19]. Ultrasound technology is becoming more suitable for use in anatomical research and will be a useful resource for graduate students throughout their careers. Participating in the ultrasound sessions moves students from their previous role as passive observers in lectures to active and dynamic learners who will drive innovation as students. These connects allow for the new knowledge from the ultrasound sessions to be consolidated with existing cognitive schemas that will be able to be more easily recalled as needed [5].

The design of the ultrasound sessions was based on similar sessions for medical students [10]. While the sessions were adapted for graduate students, many aspects found to be effective for medical students were also effective for graduate students. For example, medical students have been shown to prefer ultrasound sessions that are scheduled after relevant gross anatomy content is presented [10]. Following this format likely would support graduate students in being able to benefit from the sessions, even though they potentially have less time focused on gross anatomy in lectures and studying cadavers than medical students. Furthermore, the strength of any educational exercise lies in well-prepared and enthusiastic instructors [20]. Professors followed the PLHET Process (Table 1), which helped to organize the ultrasound sessions in a way that provided students with enough support and information to be confident that they would succeed using the ultrasound technology to supplement their gross anatomy lectures.

Future directions

This article provides an overview of how to implement a supplemental ultrasound curriculum in a graduate-level gross anatomy course and identified some potential barriers to its success. The graduate students who participated in the sessions supported the view that the ultrasound session can be beneficial to graduate students in gross anatomy courses. Even so, there are still more questions about how to further develop these sessions in the most engaging yet cost- and time-effective manner. First, future adjustments to ultrasound sessions in gross anatomy courses should be made according to the students’ most

common responses. This includes an increased number of longer ultrasound sessions throughout the course, as well as smaller group sizes. Due to time constraints of faculty leaders and the availability of ultrasound machines, there will always be a limit to the amount of focused ultrasound instruction, but there may be other effective ways for students to feel that they are receiving supplemental instruction. For example, the Anatomy-Centered Ultrasound Curriculum developed by Royer et al. (2017) was successful with graduate students and used six 1-h sessions throughout the gross anatomy course [10]. Even though the approximate instruction time was the same between their curriculum and the one described in this study, further studies would need to be conducted to determine if one method has greater success than the other. Analysis should be done of future cohorts within this institution with minor adjustments to the curriculum so that the results identify the effect of each specific modification. Also, as more administrators of graduate programs feel confident in adding ultrasound sessions to their gross anatomy courses, a more in-depth comparison between methods and outcomes will be possible. This will yield more definitive results and highlight the need for relevant changes in curriculum for improved efficacy.

Furthermore, as mentioned by Royer et al. (2017), there is no official or validated manner of assessing students’ knowledge of anatomical concepts in conjunction with ultrasound instruction. This makes it difficult to determine its true academic benefit—which is the ultimate goal of the supplemental ultrasound curriculum. A good starting point for developing a more standard assessment is adjusting the evaluation methods used to test students’ comprehension of gross anatomy concepts relevant to ultrasound sessions [15].

To help implement effective ultrasound sessions in additional graduate school programs, the institutions that have successfully done so need to share their curriculum—as is being done in this article—and help to address common concerns. For example, Jurjus et al. (2014) showed that anatomy faculty can be trained to teach clinically relevant anatomy using ultrasound [10]. These data made the case for creating professional development training for anatomists in ultrasound techniques so that there will be enough faculty to facilitate educational ultrasound sessions. Training more faculty in relevant fields will improve the collaboration among colleagues and enhance the further development of innovative educational techniques. As more graduate students take gross anatomy courses with ultrasound sessions, it will become more viable to begin implementing peer education and teaching assistant roles for senior graduate students to continue developing their ultrasound knowledge. Encouraging graduate students to become proficient in the educational use of ultrasound technology will also help to develop a new generation of

anatomy faculty ready to implement ultrasound sessions to supplement the gross anatomy courses at their universities.

In addition, the availability and cost of ultrasound machines is a common limiting factor for the success of these sessions, especially in graduate programs without direct association with a medical school [8]. However, the use of ultrasound technology is becoming increasingly essential in clinical medicine, which is leading to the development of more affordable and portable machines [15]. New technology is continuously being developed and becoming more affordable and portable, while still producing high-quality digital images [7]. New ultrasound machines that are small enough to carry in one's pocket and plug into a phone have the potential to not only change clinical medicine, but also encourage more educational uses of ultrasound technology. Further research involving these more portable and affordable ultrasound options will need to be done to determine their efficacy in educational settings, but the potential is undeniable. With continued technological innovation and collaboration among academic faculty, there will be fewer limitations to successfully implementing ultrasound sessions as a standard addition to gross anatomy education for graduate students.

Conclusion

This article describes the methods used to incorporate supplemental ultrasound sessions into a graduate-level gross anatomy course. The graduate students who participated in this course also felt that they benefited from the sessions by gaining a better understanding of the relationship between surface and underlying functional anatomy. Therefore, supporting that the ultrasound sessions may be an effective and engaging method of learning anatomy for graduate students and possibly reinforce content. In summary, ultrasound sessions should be used as a supplement to traditional didactic lecture and laboratory learning methods, creating a unique multimodal learning environment. The sessions should be designed in parallel to corresponding body regions presented in lecture material and instructors should link the content throughout the sessions. To guide lesson plan development instructors should follow the PLHET model for teaching and provide clear learning objectives, teaching points, key terminology, and relevant images for each session to the students. The student to instructor ratio should be kept small to encourage active participation and learning for all students. To conclude, the methods described in this article are a starting point for implementing ultrasound sessions into more non-medical graduate programs and have the potential to academically and intellectually benefit the students.

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Compliance with ethical standards

Conflict of interest None.

Ethical approval The Institutional Review Board (#021744) of The George Washington University considered this project exempt.

Appendix

Ultrasound practical session 1

MSK

Learning objectives

1. To illustrate the difference between various tissue types (bone, tendon, vessels, muscle, nerves) on ultrasound.
2. To illustrate the 3D anatomy in motion of the knee joint using ultrasound as a tool and its clinical significance.

Teaching points Refresh from the interactive lecture session and demonstrate:

- A. Properties of the ultrasound machine:
 - a. Power
 - b. Gain
 - c. Depth
 - d. Probes/change probes
 - e. Orientation mark
 - f. How to hold the probe/tripod position
- B. Basic ultrasound of tissues

Demonstrate the difference between the following:

 - Bone (hyperechoic with shadow)- tendon (In short axis, looks like the end of a broomstick).
 - Vessel
 - Muscle (hypoechoic, “filet mignon”)
 - Subcutaneous tissue
 - Nerve (“honeycomb cereal”)

Use the upper arm and the wrist area as example, Achilles Tendon and Gastrocnemius can also be used.

Ultrasound practical session 2

Neck/eye session

Learning objectives:

1. To describe the 3D anatomy of the neck using ultrasound as a tool and its clinical significance
2. To describe the 3D anatomy in motion of eye using ultrasound as a tool and its clinical significance

Teaching points: Neck.

- Antero-lateral neck

carotid artery
 internal jugular vein
 esophagus, sternocleidomastoid muscle and anterior/middle scalenes.
 brachial plexus forming a traffic light sign between the anterior/middle scalenes: site of interscalene block.

- Midline

- Tracheal rings and associated air artifacts
- Thyroid cartilage
- (Optional) Vocal cords
- Thyroid gland. Note homogenous texture and isthmus.

Face

- Ocular:

Note optic nerve sheath.
 Note anterior chamber, posterior lens, posterior chamber.

Ultrasound practical session 3

Abdomen session

Learning objective:

- Describe the 3D anatomy relating to the major organs in the abdomen, including the liver, spleen, kidneys, and aorta.

Abdominal organs:

- Right upper quadrant (RUQ).

- Positioning: with the patient supine position, locate the xyphoid process; draw a horizontal line down to the mid-axillary line; position your probe at this point with the probe marker oriented toward the patient's head.
- Organs to note:
 Initial view should demonstrate the liver and the mirror artifact of the diaphragm.

Liver: demonstrated initially in this view; note its homogenous echogenic texture and three different circulations within liver; differentiate between systemic veins and portal veins (systemic hepatic veins appear to have no wall).

Diaphragm: should appear as a hyperechoic line surrounding the superior border of the liver; superior to the diaphragm is lung; however in the non-pathological condition, the lung is not visible, and what you actually see is a mirror image of the liver.

Kidney: demonstrated by moving the probe inferior (caudally) and fanning it posteriorly; note its echogenic texture and central vasculature; note hyperechoic renal capsule, and the hyperechoic renal cortex relative to the hypoechoic renal medulla.

Morrison's pouch: demonstrated as the boundary between liver and the kidney; represents a potential space for fluid to collect; Under non-pathological conditions, you should not see a clear separation between the walls of the kidney and liver here.

Gallbladder (fundus/body/neck): The neck points toward the portal triad (portal vein, common bile duct, and hepatic artery); because it appears as an anechoic structure within the liver, it may be confused for the hepatic or portal veins. Use color to confirm.

- Left upper quadrant (LUQ)

Positioning: with patient supine, locate the xyphoid process and draw a horizontal line to the left to the posterior-axillary line. This is the initial position of the probe, with probe marker oriented toward the patient's head.

Organs to note:

Spleen: Note homogenous echo texture; by fanning anteriorly, you may be able to see **stomach bubble**.

Diaphragm: visible as a hyperechoic line on the superior edge of the spleen; note mirror artifact

Kidney: demonstrated by moving probe inferiorly; note hyperechoic renal capsule, and the hyperechoic renal cortex relative to the hypoechoic renal medulla

Spleno-renal recess: the potential space between the spleen and kidney; under non-pathological conditions, there is very little separation between the two organs, resulting in a close approximation at the interface of the organs

Aorta—Positioning—orient the probe similarly as the subxiphoid heart view; scan inferiorly down the abdomen looking for major branches; rotate the probe 90° to visualize structures in longitudinal view.

Structures to note:

Spine: the most posterior structure in the midline; may see spinal canal.

Inferior vena cava is to the patient's right and **abdominal aorta (AA)** is to patient's left.

Celiac trunk: First branch to come off AA; bifurcation into splenic and common hepatic arteries may create a "seagull sign".

Superior mesenteric artery (SMA): second branch to come off of AA, around 0.5–2.0 cm distal to celiac trunk.

By scanning further inferiorly, you will see the **splenic vein** arching over SMA.

Renal arteries and veins: arise 1.0–1.5 cm inferior to the SMA; the **right renal artery** travels posterior to the IVC and the **left renal vein** crosses between SMA and aorta.

Bifurcation into **common iliac arteries** occurs at about the level of the umbilicus (LV4).

Once you have identified celiac trunk and SMA in transverse view, rotate the probe to demonstrate them in the longitudinal view as well: Celiac trunk comes off aorta and travels superiorly, while SMA will come off aorta just distal and travel inferiorly.

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