

# The Role of Ultrasound in teaching Clinical Anatomy to First year Medical Students

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## Abstract

**Introduction:** Undergraduate medical education training has recently shifted towards making content relevant and applicable for future clinical practice. However, students often encounter difficulties in visualizing the functional living human and apply clinically relevant anatomy content. Hence, the aim of this study is to evaluate the role and efficacy of ultrasound in teaching clinical anatomy to first year medical students.

**Methods:** 300 Year 1 students took part in the practical sessions either using ultrasound mannequins or volunteer. All students were given a specially designed pre-test and post-test using Katz's Percentage to assess their level of ultrasound knowledge. A feedback survey was sought from the students and anatomists after the programme.

**Results:** The results were analyzed based on the 100 students who have taken both pre- and post-tests. The study showed that there was statistical significant difference on normal US images of abdominal organs knowledge before and after the intervention. About 98% of students would like the continuation of this programme into the clinical years. Tutor's perception survey also revealed positive results particularly the interdepartmental collaboration.

**Conclusion:** An ultrasound programme was successfully implemented to complement and enhance the conceptualizing of normal gross anatomy with clinical anatomy for first year medical students.

**Keywords:** Anatomy, Medical Education Research, Ultrasound, Radiology

## Introduction

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Contemporary medical education has shifted its emphasis from learning basic biomedical sciences in silos to integrated clinically relevant content materials. Furthermore, more focus is now placed on clinical phases of learning and assessment. In the process, basic biomedical sciences, which form the foundational knowledge for future clinical practice, particularly in fields like anatomy could get affected. In a study conducted by the International Association of Medical Science Educators, the results from the group of experts showed that teaching of basic science content should be across the entire undergraduate medical education as this is essential for clinical application and development of effective thinking skills needed for clinical reasoning and decision making.<sup>1</sup> Having the right anatomy knowledge may assist in reducing medical errors, and is paramount to ensuring safe clinical practice.<sup>2</sup> Besides these, anatomy classes can also develop essential humanistic values in students, like professionalism and communication skills.<sup>3</sup>

Although anatomy is widely appreciated as being the most significant component of medical education<sup>4</sup>, medical students often find it challenging to visualize the functioning living human<sup>5</sup>. With the advancement of technology in recent years, integration of imaging technology, such as ultrasound, in teaching has become more popular. Medical ultrasound (US) imaging is a modality which encompasses the use of ultrasonic waves to form images of the internal human anatomy. It is a safe and non-radiating tool to study the human organs in real time. Its easy availability and relative low cost coupled with excellent image formation and soft tissue contrast has made it an integral part of the disease diagnosis and patient management<sup>4,6</sup>.

The presence of several challenges in teaching anatomy could have contributed to the lesser attention spent on developing effective anatomy classes. These include the unavailability of qualified teachers, inadequate teaching time and the move away from dissection as a learning tool (due to cost and availability issues).<sup>2</sup> While the use of dissection is a common time-honored tool, it has several limitations. For instance, it is non-responsive to "interactive investigations" like palpation, and it does not really provide cross-sectional views,<sup>7</sup> and students could have difficulties visualizing "the functioning living human" and subsequently "to apply their learning clinically".<sup>5</sup> As such, there is an increasing role of cross-sectional imaging using modalities like computerized tomography and ultrasound to visualize human anatomy, although the former has raised radiation safety concerns. While most of the research articles focused on the alternatives approach in teaching anatomy and collecting merely students' satisfaction data, scarce empirical evidence was published on measurable outcomes in teaching anatomy using ultrasound<sup>3,4,8,9,10</sup>. Furthermore, teaching of ultrasound was normally introduced during students' clinical year, which was disengaged from Anatomy during their pre-clinical year<sup>11,12,13,14</sup>.

In view of the advantages of ultrasound and to eliminate some of the limitations with cadaveric dissection and the existing gap in the literature, an innovative approach was introduced at our Undergraduate Medical School, to complement and enhance first year medical students' learning of anatomy. This joint effort by the Departments of Diagnostic Imaging and Anatomy leverages on ultrasound technology and utilizes mannequins to teach the medical students to recognize the normal anatomical structures depicted by ultrasound and their correlation with anatomical surface markings. The aim of this study is to evaluate the role and efficacy of ultrasound in teaching clinical anatomy to first year medical students as Phase I of the project. Several research question questions were developed to achieve the aim:

Research Question 1: Is there any difference on normal US images of abdominal organs knowledge before and after the intervention among first year medical students?

Research Question 2: What are the students' perception about the strengths and limitations the programme?

Research Question 3: What are the tutors' perception about the strengths and limitations the programme?

## Methods

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### Teaching-learning methods:

Ultrasound requires extensive hands-on training, hands and eyes co-ordination and in-depth knowledge of ultrasound anatomy. The curriculum was developed to provide such hands on training to the medical students, with emphasis on normal ultrasound anatomy and abnormal ultrasound features related to the must know must see conditions. It was decided to deliver the US training after the medical students had learned abdominal anatomy. The curriculum was also designed to be delivered within the limitations and constraints of the provided curriculum time, without adding further load to the already hectic Phase 1 curriculum.

### Preparation of Material to Teach:

Ultrasound images of normal abdominal organs were compiled. A list of "must know must see" ultrasound images of normal anatomical organs was drawn. These included images depicting normal ultrasound anatomy of Liver, Spleen, Kidneys, Gall bladder, pancreas, Urinary Bladder and Aorta. Standard US Mannequins, which showed both normal and abnormal US anatomy of abdominal organs were acquired. Two models of 'Abdomen Blue Phantom" and one model of "AbdoFan Kyoto Kagaku" were obtained. The AbdoFan by Kyoto Kagaku comprises of the liver (segmental anatomy, portal and hepatic venous systems, ligamentum teres and ligamentum venosum), biliary tract (gallbladder, cystic duct, intrahepatic and extrahepatic bile ducts), pancreas (pancreatic duct), spleen, kidneys, detailed vascular structures (aorta, vena cava, celiac artery and its branches, portal vein and its branches, superior mesenteric vessels, renal vessels, etc). The Abdomen Blue Phantom is a training mannequin to perform Focused Assessment with Sonography for Trauma (FAST) scans. Apart from having normal abdominal structures such as liver, spleen, kidneys, and urinary bladder, it also has the capability to simulate ascites and pericardial effusion.

The purpose of the undergraduate US Curriculum was to equip the medical students with knowledge and means to perform bedside general US in relevantly urgent clinical scenarios. As it would have been difficult for the students to get hold of an US machine in the ward, we acquired 10 small hand-held US machines called "V-scan" from General Electric (GE) and incorporated them for use in hands-on training, which we felt were more appropriate, practical and feasible. These hand held ultrasound units are a single transducer machine, with ability to perform abdominal and cardiac ultrasounds and equipped with Doppler and measurement functions as well.

### Training of Anatomy Faculty:

In most circumstances, anatomy and ultrasound were taught separately by anatomist and radiologist (Teichgräber et al, 1996, Tshibwabwa, 2005). To avoid dissonance in the content delivered, we trained our anatomists to carry out the US curriculum. A group of anatomists was formed who would take part in the delivery and training of the US curriculum. A lecture on basic ultrasound physics and clinical applications was given to the anatomists and multiple small group hands-on sessions were held for the anatomists to familiarize them with the hand-held scanner and the US mannequins. Ultrasound training sessions (three hours each) were held once a week for three months. An ultrasound training protocol was also made available for reference and practice on the ultrasound training mannequins. The imaging protocols were standardized for all anatomists and tutors, to ensure the uniformity of teaching and implementation of the curriculum.

### **Implementation of Phase 1 US curriculum:**

The implementation of the US curriculum comprised of didactic lectures and hands-on practical sessions.

A didactic lecture on the basics of Ultrasound was given to the whole cohort, where the basic US physics and clinical uses were discussed. The students were informed of the US curriculum, and its overarching goals were highlighted.

A total of four small rooms were prepared for the hands-on training sessions where three of them were equipped with one of the three US mannequins and a student volunteer was placed in the fourth room. Each room was also equipped with a projector, where normal US images and protocols were projected and explained during the sessions.

300 Year One students from 2013 Cohort took part in a 3-hour practical sessions. The whole cohort of students was divided into 3 groups with 100 students in each group. Each group consisted of 10 sub-groups which are known as the Clinical Groups (CGs), with about 10 students in each CG (Figure 1). Each group of 100 students attended an abdominal prosections for 1 ½ hr in the Anatomy dissection hall, followed by the US hands-on training sessions for the rest of the 1 ½ hr a hands-on sessions at one time. During the hands-on training session, the 100 students (in each group) were further divided into four small groups, with 25 students in each small group. Each small group was rotated through at least two rooms, one rooms with Abdomen Blue Phantom Mannequin and one with either AbdoFan Kyoto Kagaku Mannequin or with Volunteer while spending 45 minutes in each room (Figure 1). Having a volunteer helped to provide a patient's perspective to the students, along with teaching them practical aspects of ultrasound such as holding breath and turning the patient.

A total of three such sessions were held during their prosection days, where the students were rotated to different rooms each time, to ensure they experience all the mannequins and sessions uniformly. The overall flow of the implementation is shown in Figure 1.

### **Figure 1: Grouping of the students and the hands-on training session**



To further enhance the hands-on experience, the whole cohort was broken down to several groups of about 6-8 students in each group, and further hands-on sessions were arranged on other days. Each student was provided with further three hours of intensive hands on training, providing the students to practice on the ultrasound mannequins and volunteers whenever feasible. In total, each student got about 12-15 hours of hands-on training with the hand-held US device. Although this experience might not have been adequate for a student to be an expert in ultrasound, it exposed the students to the abdominal anatomy and technique required to perform and interpret basic ultrasound studies.

### **Data Collection and Analysis:**

An ethical approval was obtained from the institution's ethics review board to facilitate the collection and analysis of the data and documentation pertaining to this programme.

The first research question was aimed to evaluate students' level of knowledge on normal US images of abdominal organs. Ten questions, comprising of normal US images of abdominal organs were designed using Katz's Percentage. Three consultant radiologists were given a scoring chart together with the ultrasound images and the Kartz score obtained was 0.8 (Appendix 1). The pre-test was delivered at the time of the initial didactic lecture before the start of the programme and the results were tabulated. The students were not provided with the correct answers after the

pre-test. A post-test, comprising of the same questions as in the pre-test, was given at the end of the whole US programme and its results were compared with the initial test. The data collected was analysed using T-test by Microsoft Excel 2010. These tests were designed only to be part of the curriculum evaluation and had no bearing towards a student's final academic results.

The second research question was aimed to obtain students' perception about the strengths and limitations and further comments and suggestions were sought. An open-ended student perception survey (Appendix 2) was sought after the first hands-on session during the prosection and at the end of the whole programme, a five-likert scale students' survey (Appendix 3) was performed, where the students are asked to comment about the overall programme and if they would like to continue it in the next phase of their medical school. All data was analysed descriptively using Microsoft Excel 2010.

To answer the third research question, an open ended perception and feedback survey (Appendix 4) was performed for the ten anatomists, to inquire whether the training achieved its goal, to find out the strengths and weaknesses of the programme and to seek any suggestions on improvement of the programme. This was administered at the end of the training sessions for the anatomists. This data was analysed descriptively using Microsoft Excel 2010.

The overall process of curriculum development, implementation and assessment is shown as a schematic flow chart in Figure 2.



**Figure 2. Flow chart of Undergraduate Clinical Ultrasound Programme development and implementation**

## Results

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After the post test, data showed that only 100 students had taken both pre and post tests out of the total cohort size of 300 and hence our results were analyzed based on these 100 students. Our analysis revealed that only 3% of the students obtained the correct answer for all questions in the pre-test. At the post test, there was marked improvement in the post-test results, with about 70% of students answering correctly for all the questions. In addition, the t-test revealed that  $t(99) = -19.03$ , two-tail  $p = 0.000$ , providing evidence that there is a significant difference before and after the integration of US modality teaching method, thus rejecting the null hypothesis.

The descriptive data of the test were shown in Table 1, with the minimum score on the pre-test was 2 out of 10 whilst it was 4 out of 10 on post-test results.

	Pre-test	Post-test
<b>Mean</b>	5.64	9.43
<b>Median</b>	6	10
<b>Mode</b>	6	10
<b>Standard Deviation</b>	1.88	1.22

<b>Minimum</b>	2	4
<b>Maximum</b>	10	10

**Table 1. Descriptive statistics for pre- and post-tests**



**Figure 3. The Pre- and Post-Tests score for each question**

Based on our analysis, it was revealed in Figure 3 that students found ultrasound recognition of pancreas and left hepatic lobe most challenging in their pre-test, with the anatomical conceptualization of hemidiaphragm and Morrison's pouch a close second. This is supported by the pre-test results that show only 40% of the students answered correctly for the question on left hepatic lobe and only 13% of the students answered correctly for the question on pancreas. However, the anatomical recognitions indicated an increased in their post-test's scores after the intervention.

To understand the limitation and strengths of the programme, an initial open-ended student's perception survey (Appendix 2) was administered, it was found that the session was interesting and allowed them to apply their anatomical knowledge in a clinical context. Furthermore, it enabled students to visualize the structure in a 3D perspectives than learning from slides or textbook.

Some of the limitations highlighted in the initial open-ended student's perception survey were the image shown in the ultrasound machine was quite small for everyone in the group to view it. In addition, students commented on the inadequate number of hands-on sessions. As a result, additional hands-on sessions were introduced. A final student's perception survey (Appendix 3) was then administered and the results showed that 71% of students felt that the US sessions were adequate, with only 1% of students claiming these sessions to be too short. Interestingly, about 27% of students felt that the sessions were more than adequate. The usefulness of the US sessions were rated very highly by the medical students, with 75% of students rating them between 4 and 5, 1 being the least useful and 5 being the most useful.

The final student's perception survey also revealed that about 91% of students felt that the radiology content was easily understood and was appropriate for their level. 97% of students either strongly agreed or agreed that these US sessions helped them to correlate ultrasound images of the abdomen with surface anatomy. Another finding shows that about 95% of students either strongly agreed or agreed that these US sessions helped them to learn and understand the gross anatomy of the abdomen and pelvis which was aligned with their post-test results. This marked improvement in student's understanding of 3-dimensional gross abdominal anatomy.

Overall, the students were very happy and keen about the programme and there was an overwhelmingly positive response of about 98% who would like the continuation of this programme in year 2 and into the clinical years.

Similarly, the tutor's perception and feedback survey (Appendix 4) indicated a positive result. All anatomy faculty members felt that their US training was adequate, that the use of US mannequins and hand-held scanners was appropriate and that a radiologist led training was crucial and helpful. They also felt very satisfied with the interdepartmental collaboration and were very happy and excited to be part of this programme. In addition, they felt



more integration should be carried out to improve teaching and learning in future. However, there were still rooms for improvement such as more time was needed for the training workshop and more structured reading or learning materials to be provided.

## Discussion

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In this study, we have found that ultrasound is effective in teaching clinical anatomy to first year medical students as Phase I of the project. Almost all the students showed a very positive response to the programme. They felt that the programme helped them understand the abdominal anatomy better, with better three-dimensional and surface correlation. Most of the students showed marked improvement in their individual scores, which clearly reflects on how well this programme was received and understood by the students. This is supported by the small p-value from the paired t-test which means that there is statistically significant difference between the pre- and post-test scores.

It was interesting to note that most of the students faced difficulty in recognizing the pancreas and the left hepatic lobe. In the case of Pancreas, we felt that one of the main reasons for this was the limitation of US in assessing deeper tissue structures and limited visibility of pancreas in our mannequins and our volunteer students, where the pancreas was mostly obscured by overlying bowel gas. In the case of left hepatic lobe, the main limiting factor could have been the position of the probe. Most students recognized the left lobe as the right hepatic lobe, as they were unaware of the body marker on the image. The third aspect of anatomical imaging that was highlighted by the students was the imaging of diaphragm. Most students pointed out how their three-dimensional concept of a diaphragm was changed and enhanced by the use of ultrasound, reinforcing its anatomical position in the axial and sagittal planes.

In another study done to determine the effectiveness of using ultrasound to understand the dynamic living anatomy of the musculoskeletal system, the results showed that "the use of hands-on musculoskeletal ultrasound examinations in anatomy facilitates learning, significantly enhances knowledge and understanding of the living system, and teaches students physical examination skills. In addition, students not only acquire the skills to perform and interpret ultrasound, but also they are able to analyse and apply this knowledge to surgical, physiological and diagnostic imaging concepts".<sup>15</sup>

In addition, students also felt that the content of the programme and the content delivery was adequate. They also enjoyed the sessions and were keen to continue the programme into their clinical years. This finding is further supported by a study which shows that "the majority of medical students believed that it is feasible and beneficial to use ultrasound in conjunction with traditional teaching methods to teach Gross Anatomy".<sup>16</sup>

Indeed, many other institutions have had positive experiences with the use of ultrasound to study anatomy. The Department of Radiology of McMaster University Medical Centre integrated ultrasound in the education programme in Anatomy and has reported favorable results when implemented as a small group problem based active learning.<sup>5</sup> In addition, the Wayne State University School of Medicine performed a pilot study of ultrasound education and concluded that there was a need to promote this so as the next generation of physicians will be better equipped to take advantage of this powerful diagnostic tool.<sup>17</sup> The School of Medicine of the University of South Carolina has integrated an ultrasound curriculum across all 4 years of medical school.<sup>18</sup> Their report concludes that ultrasound can be introduced successfully across all 4 years of medical school and students report that their medical education has been enhanced. The above studies strongly indicate that ultrasound is an effective pedagogy for teaching and motivates student learning.

Our results also show that the ultrasound curriculum played an important part in the understanding and grasping the basic concepts of abdominal anatomy. With the right tools and assessment, it is possible to teach and introduce basic US curriculum to the undergraduate medical students.

On the other hand, there are studies which show that there are several important considerations with the use of ultrasound in anatomy. "In neck anatomy, ultrasound can be used to measure the distance from skin to trachea and this allows the choice of an appropriately sized tracheostomy tube which certainly might be beneficial for patients with larger necks. However, during an ultrasound-guided tracheostomy, it can be difficult to visualize the actual needle and its tract. Furthermore, another limitation of ultrasound is that it does not image across air interfaces, thus cannot be used to rule out injury to the posterior wall of the trachea."<sup>19</sup>

Another study stated that there are some drawbacks in equipping medical students with basic ultrasound skills to reinforce anatomy. Firstly, it is labour and resource intensive as it requires time and adequate trained supervisors and equipment for small group teachings.<sup>20</sup> Secondly, it is very difficult for students to acquire the skills to perform and interpret ultrasound and learn normal anatomy during such short sessions as "ultrasound imaging is highly operator dependent" and it often takes long time to become competent.<sup>20</sup> It is unlikely that these obstacles can be overcome unless ultrasound imaging is vertically integrated into the curriculum and provides students enough time and exposure to develop the required skills.<sup>21</sup>

## Limitations of our study

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As with any new venture and curriculum introduction, our US curriculum had its fair share of limitations and challenges. Although attempting to be comprehensive, we had to scale down the scope of the programme and its end result to a few clinically relevant must know must see conditions. With the ever expanding curriculum of Phase I medical school, we had to work and deliver the curriculum within the confines of limited curriculum time. This prevented us from expanding the scope of the programme and also limited the number of hands-on sessions and the relatively larger number of students in one trainee group. Another study has shown that short sessions of in vivo imaging using ultrasonography has not much impact on skills related to abdominal anatomy and examination although students have reported an increase in confidence in their anatomical knowledge.<sup>22</sup> Therefore, it is crucial to find the best way to incorporate ultrasound into medical education.

Although we have promoted the use of hand held US machines, they have inherent limitations to the size of the screens, the penetration into the human body and relatively limited versatility to image different body types. This also had led to the limitation of our scope of programme outcome.

As much as we would like to expose students with US experience on different mannequins and a normal human body, due to time constraints and minimizing the obstruction of the US integration to their existing medical curriculum, students were only rotated through two modes of US experience as mentioned in the implementation of US curriculum section. Hence, allocation of sufficient time to allow students to experience a holistic US experience is necessary.

## Conclusion

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Despite these limitations, we have successfully implemented an ultrasound programme with a view to complement



and enhance the learning of clinical anatomy for first year medical students. Our study shows that it is possible to introduce the basics of ultrasound to medical students early in their medical career. Understanding ultrasound anatomy helps the medical students to enhance the learning and conceptualization of the normal gross anatomy. Our work highlighted that an outcome based, focused ultrasound curriculum is necessary and integrating the program into the undergraduate medical program is crucial to achieve good curricular outcomes. This new insight has inspired us to extend the program for the five years of undergraduate medical school in a linear and in a stepwise process.

## **Take Home Messages**

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1. Students often encounter difficulties to visualise the functioning human anatomy.
2. Integration of ultrasound anatomy helps medical students to enhance their learning and conceptualization of the normal gross anatomy.
3. Students showed improvement in their individual scores and would like the continuation of this programme throughout their medical course.
4. All Anatomy faculty members felt that the ultrasound training was adequate and felt very satisfied with the interdepartmental collaboration.
5. An outcome based, focused ultrasound curriculum is necessary and integrating this program into the undergraduate medical program is crucial to achieve good curricular outcomes.

## **Notes On Contributors**

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## Bibliography/References

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1. Finnerty EP, Chauvin S, Bonaminio G, Andrews M, Carroll RG, Pangaro LN. 2010. Flexner Revisited: The Role and Value of the Basic Sciences in Medical Education. *Acad Med.* 85: 349-55.

<http://dx.doi.org/10.1097/ACM.0b013e3181c88b09>

2. Bergman EM, van der Vleuten, CP, Scherpbier AJ. 2011. Why don't they know enough about anatomy? A narrative review. *Med Teach.* 33: 403-9.

<http://dx.doi.org/10.3109/0142159X.2010.536276>

3. Gregory JK, Lachman N, Camp CL, Chen LP, Pawlina W. 2009. Restructuring a basic science course for core competencies: an example from anatomy teaching. *Med Teach.* 31: 855-861.

<http://dx.doi.org/10.1080/01421590903183795>

4. McLachlan, J. C., & Patten, D. 2006. Anatomy teaching: ghosts of the past, present and future. *Med Educ.* 40(3), 243-253.

<http://dx.doi.org/10.1111/j.1365-2929.2006.02401.x>

5. Tshibwabwa ET, Groves HM. 2005. Integration of ultrasound in the education programme in anatomy. *Med Educ.* 39: 1143-72.

<http://dx.doi.org/10.1111/j.1365-2929.2005.02288.x>

6. Butter, J., Grant, T. H., Egan, M., Kaye, M., Wayne, D. B., Carrión-Carire, V., & McGaghie, W. C. 2007. Does ultrasound training boost Year 1 medical student competence and confidence when learning abdominal examination? *Med Educ.* 41(9), 843-848.

<http://dx.doi.org/10.1111/j.1365-2923.2007.02848.x>

7. McLachlan JC. 2004. New path for teaching anatomy: living anatomy and medical imaging vs. dissection. *The Anat Rec (Part B: The New Anatomist.)*. 281: 4-5.

8. Teichgraber, U. K., Meyer, J. M., Poulsen Nautrup, C., & von Rautenfeld, D. B. 1996. Ultrasound anatomy: a practical teaching system in human gross anatomy. *Med Educ.* 30(4), 296-298.

<http://dx.doi.org/10.1111/j.1365-2923.1996.tb00832.x>

9. McLachlan, J. C., Bligh, J., Bradley, P., & Searle, J. 2004. Teaching anatomy without cadavers. *Med Educ.* 38(4), 418-424.

<http://dx.doi.org/10.1046/j.1365-2923.2004.01795.x>

10. Griksaitis, M. J., Sawdon, M. A., & Finn, G. M. 2012. Ultrasound and cadaveric prosections as methods for teaching cardiac anatomy: A comparative study. *Anat Sci Educ.* 5(1), 20-26.

<http://dx.doi.org/10.1002/ase.259>

11. Barloon, T. J., Brown, B. P., Abu-Yousef, M. M., Ferguson, K. J., Schweiger, G. D., Erkonen, W. E., & Schuldt, S. S. 1998. Teaching physical examination of the adult liver with use of real-time sonography. *Acad Radiol.* 5(2), 101-103.

[http://dx.doi.org/10.1016/S1076-6332\(98\)80129-3](http://dx.doi.org/10.1016/S1076-6332(98)80129-3)

12. Shapiro, R. S., Ko, P. K., & Jacobson, S. 2002. A pilot project to study the use of ultrasonography for teaching physical examination to medical students. *Comput Biol Med.* 32(6), 403-409.

[http://dx.doi.org/10.1016/S0010-4825\(02\)00033-1](http://dx.doi.org/10.1016/S0010-4825(02)00033-1)

13. Wittich, C. M., Montgomery, S. C., Neben, M. A., & et al. 2002. Teaching cardiovascular anatomy to medical students by using a handheld ultrasound device. *JAMA,* 288(9), 1062-1063.

14. Alba, G. A., Kelmenson, D. A., Noble, V. E., Murray, A. F., & Currier, P. F. 2013. Faculty staff-guided versus self-guided ultrasound training for internal medicine residents. *Med Educ.* 47(11), 1099-1108.

<http://dx.doi.org/10.1111/medu.12259>

15. Tshibwabwa ET, Groves HM, Levine MA. 2007. Teaching musculoskeletal ultrasound in the undergraduate medical curriculum. *Med Educ.* 41: 517-8.

<http://dx.doi.org/10.1111/j.1365-2929.2007.02745.x>

16. Brown B, Adhikari S, Marx J, Lander L, Todd GL. 2012. Introduction of ultrasound into gross anatomy curriculum: perceptions of medical students. *J. Emerg. Med.* 43: 1098-1102.

<http://dx.doi.org/10.1016/j.jemermed.2012.01.041>

17. Rao S, Holsbeeck LV, Musial JL, et al. 2008. A Pilot Study of Comprehensive Ultrasound Education at the Wayne State University School of Medicine. *J Ultras Med.* 27: 745-9.

18. Hoppmann RA, Rao VV, Poston MB, et al. 2011. An integrated ultrasound curriculum (iUSC) for medical students: 4-year experience. *Crit Ultrasound J.* 3: 1-12.

19. Tremblay LN, Scales DC. 2011. Ultrasound-guided tracheostomy – not for the many, but perhaps the few... or the one. Crit. Care. 15: 147.

<http://dx.doi.org/10.1186/cc10106>

20. Stringer MD, Duncan LJ, Samalia, L. 2012. Using real-time ultrasound to teach living anatomy: an alternative model for large classes. N Z Med J. 125: 37-45.

21. Sweetman GM, Crawford G, Hird K, Fear MW. 2013. The benefits and limitations of using ultrasonography to supplement anatomical understanding. Anat Sci Educ. 6: 141-8.

<http://dx.doi.org/10.1002/ase.1327>

## Appendices

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### Appendix 1:

#### Kartz's Scoring chart

This scoring is for profiling first year medical students on their ability to identify normal ultrasound images of the heart and abdomen using ultrasound mannequins and student volunteers.

Please give a score of **ONE** if you agree or **ZERO** if you do not agree that after one hours of observation and 3 hours of hands-on ultrasound training, the 1<sup>st</sup> year medical student will be able to achieve the learning outcome for the normal anatomy depicted by the ultrasound image shown

Question	Learning outcomes	Score
Right Kidney	Able to identify the right kidney & correlate with surface anatomy	
Diaphragm	Able to identify the diaphragm & correlate with surface anatomy	
Left lobe of liver	Able to identify the left lobe of liver & correlate with surface anatomy.	
Gall bladder	Able to identify the gall bladder & correlate with surface anatomy	
Right lobe of liver	Able to identify the right lobe of liver & correlate with surface anatomy	
Pancreas	Able to identify the pancreas & correlate with surface anatomy	

Spleen	Able to identify the spleen & correlate with surface anatomy	
4 chamber view of the heart	Able to identify the 4 chamber view of the heart & correlate with surface anatomy	
Bladder	Able to identify the bladder & correlate with surface anatomy	
Morison's pouch	Able to identify the Morison's pouch & correlate with surface anatomy	

Total score for all the reviewers \_\_\_\_\_ 28 = 0.8

Total no of questions –15 x (no of reviewers) 35

$\frac{3}{4}$  of the reviewers agreed to the content, hence a content revision was not required.

#### Appendix 2:



#### Appendix 3:



#### Appendix 4:



#### Declaration of Interest

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*The author has declared that there are no conflicts of interest.*