

## TWELVE TIPS

# Twelve tips for teaching with ultrasound in the undergraduate curriculum

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## Abstract

With ever increasing use of imaging as a diagnostic tool in medicine, medical schools are being urged to further integrate imaging into their curricula. Ultrasound is one such way of doing so—enabling students to bridge the gap between form and function, medical school and clinical practice. As a non-invasive imaging technique, with low risk when compared to other methods of imaging, ultrasound is ideal for integration into basic science and clinical teaching. The twelve tips given in this article offer advice on the practicalities of running a successful ultrasound imaging session in an appropriate environment, promoting safety and curriculum integration.

## Introduction

“The (medical undergraduate) curriculum will be structured to provide a balance of learning opportunities and to integrate the learning of basic and clinical sciences, enabling students to link theory and practice” (GMC 2009). With regulators such as the GMC calling for an increase in clinically relevant teaching within the undergraduate medical curriculum, even at the early pre-clinical stages, many medical schools are relying more heavily on the use of clinical imaging to provide context for their basic science teaching (Tshibwabwa & Groves 2005; Patten et al. 2010; Finn et al. 2012; Griksaitis et al. 2012; Swamy & Searle 2012).

Using ultrasound within undergraduate teaching has numerous benefits. Ultrasound enables students to consider the dynamic nature of both anatomy and physiology in real time; students can observe the opening and closing of heart valves, they can appreciate blood flow by observing colour doppler flow, or they can grasp differing tissue densities and the three-dimensional nature of anatomies, something unachievable within a dissecting room or didactic physiology lecture.

Ultrasound signposts living anatomy and physiology to students in a manner not easily achieved within the dissecting room or lecture theatre. This imaging technique integrates form and function dynamically, and highlights to students the future clinical application of the basic sciences they must learn. This clinical contextualisation is important as students can appreciate why the anatomy, physiology or pathology is important. This clinical relevance hopefully facilitates retention of knowledge by signposting the clinical significance of the information. (Koens et al. 2003; Finn et al. 2010). Contextualised learning in medical education has previously been considered in the three categories of “Physical, Semantic and Commitment Dimensions” (Koens et al. 2005). Teaching and learning with ultrasound can easily be applied to these;

the physical dimension (pertaining to the environment in which learning occurs) can take place in a simulated ward, or clinical skills lab, mimicking the environment in which ultrasound takes place clinically. The semantic dimension considers the interaction of the knowledge of the learner to the performance of the task. Ultrasound enriches this process by reducing the need to learn endless facts without the students appreciating the clinical application. Finally, the commitment dimension relates to the students motivation for learning. In ultrasound, especially when introduced early into the curriculum, allows the student to see why their basic science teaching is important, and furthermore can spur the student on to gain further skills and knowledge so that one day they could perform and interpret this test (Koens et al. 2005).

As with all teaching modalities, ultrasound has its drawbacks; machines are expensive, operator expertise is required, volunteers are needed to be scanned and there is always the potential to discover a pathology a volunteer is not aware of. Furthermore, without careful instruction it is possible to confuse students with ultrasound, and may actually hinder their learning (see Tip 9). Within this article we offer guidance on all of these issues.

With appropriate and well planned use, ultrasound can be the key to engaging students in their learning, promoting the development of deeper approaches to learning through clinical application of knowledge. As future doctors, students must learn to interpret the results of clinical investigations from an early stage in their learning – integrating modalities such as ultrasound early on provides students with an invaluable foundation.

This article offers practical tips for those considering introducing ultrasound into their undergraduate curricula, whether it is for medical students or other health care professions. The tips guide the reader through important considerations before embarking on a teaching session, to

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teaching delivery, evaluation and what to do when unforeseen circumstances arise.

## Tip 1

Identify a session in which ultrasound can be integrated with the other basic clinical sciences, to help you deliver your learning objectives

Ultrasound is a dynamic teaching modality that can be applied to many aspects of the undergraduate, and indeed postgraduate, curriculum. It is important that the ultrasound session is carefully integrated within your own curriculum, and at an appropriate timing to best deliver the learning outcomes to your student. We have successfully demonstrated that students in the first year with no prior ultrasound or anatomy experience can benefit from this teaching modality (Finn et al. 2012; Griksaitis et al. 2012).

At our institution, we integrate ultrasound teaching at several points throughout the curriculum. The first is a general introduction to clinical imaging, where we discuss ultrasound in a wider context of imaging. More anatomical specific sessions include echocardiography during thoracic teaching, abdominal sonography during gastrointestinal teaching, joint ultrasound during musculoskeletal teaching and then we introduce ultrasound in clinical skills teaching, for instance identification of the internal jugular vein or femoral vein and then link this anatomy to central line insertion.

At whatever point you introduce ultrasound into the curriculum our advice is that the organ/body system under review is relevant to what the students are learning about at that time elsewhere in other curriculum strands, and you try and integrate the session to discuss the anatomy, physiology and clinical aspects of the ultrasound scan. The ultrasound session could provide a nice synopsis of a module or a concluding session with other faculty members all contributing. Once a session is identified in advance, it is time to plan and prepare for that session.

## Tip 2

A suitable physical environment should be chosen to maximise the students' learning experience by promoting interaction and optimising their opportunities for observation of the patient, sonographer, image and equipment

The environment in which the teaching is to take place needs consideration, both in terms of group size and the physical environment. Given the interactive nature of ultrasound, small group teaching is preferred by the authors (less than 20 students) as we find it promotes discussion and allows students a "close up view" of the procedure. In many cases limitations on time, staffing, equipment and space may necessitate large group sessions. The layout of the room should facilitate the students in seeing the orientation and position of the ultrasound probe, the ultrasound screen and the demonstrator (both the probe and the screen need to be visible to enable visuospatial orientation). Similarly, the use of

a projector and dim-able lighting can improve the students' view of the examination and thus learning potential. In our institution, we connect the ultrasound to an LCD-projector so that the ultrasound image is projected on to a lecture theatre screen. Care needs to be taken that this is a high-quality connection, so that image clarity is not lost in the projection.

Ensure that all equipment you need is available. This includes the ultrasound machine with probe suitable to the organ to be studied, ultrasound jelly and tissue to clean off the jelly is required. You also require the presence of a correctly adjusted examination couch in a position that allows the demonstrator to scan the patient, see the ultrasound machine and be in a position to identify key structures. We find a laser pointer an invaluable tool to have.

## Tip 3

**Knobology:** Ensure familiarity with the ultrasound machine and appropriate ultrasound setup before the session in order to ensure smooth delivery of the session

Being familiar with the ultrasound machine is a prerequisite for a smoothly run teaching session. Ensure the operator is skilled in optimisation of the ultrasound images to aid visualisation of structures for demonstration. Factors to consider include probe selection suitable to the organ under study; superficial structures like the internal jugular vein and carotid artery are easiest assessed with a relatively high frequency linear probe (10–20 MHz), whilst for deeper abdominal organs (e.g. Liver and gallbladder) a curvilinear lower frequency probe (4–8 MHz) is more suitable.

Attention also needs to be paid to setting up the correct focal zones, image depth, time gain compensation and Doppler settings. These are best optimised prior to the teaching session, while pre-scanning the volunteer, in order to maximise demonstration time during the teaching session. The students in the undergraduate curriculum, in our view, do not need a detailed understanding of these physical concepts of the mechanics of the ultrasound machine, simply the principles behind ultrasound.

Finally, ensure your ultrasound machine has the capability to connect to the LCD-projector, should you wish to do so.

## Tip 4

Ensure that appropriately trained staff are available to perform the scan, orientate the students to the relevant anatomy and integrate the session to the wider curriculum and learning outcomes

When planning to deliver an ultrasound teaching session, it is important to determine that the correct personnel are available to ensure the session runs smoothly. It is important to have a member of staff trained in using the ultrasound machine, obtaining consent, and with the ability to recognise any incidental abnormalities (see Tips 5 and 6). At this institution, we utilise a mix of radiologists, ultrasonographers, cardiologists and intensivists to perform the scan and deliver the

teaching. This is in combination with a member of the anatomy team. This combined approach ensures clinical accuracy of the scan (important for the subject undergoing the scan, as opposed to the need of the audience), along with the ability to link the ultrasound content to various parts of the curriculum and to help the students identify the key learning outcomes for the session. It also provides a clinical context for the anatomy teaching. The ideal scenario is for the team involved in the teaching to meet beforehand to discuss the key learning outcomes, how the session will be delivered and who will teach what (see Tip 9). It is also possible for anatomy staff to be trained to a level of basic proficiency in order to perform focused scans to delineate the anatomy of specific regions, such as the femoral triangle or anterior triangle of the neck.

### Tip 5

The volunteers undergoing the ultrasound as demonstration subjects should provide informed consent, and undergo a pre-session scan of the area to be demonstrated in case of incidental pathology being discovered

It is important that all volunteers undergoing an ultrasound for teaching demonstration purposes should be suitably counselled prior to the teaching session. The counselling and subsequent written consent should be undertaken by an appropriate member of staff (see Tip 4) who is aware of the ultrasound procedure, what to do if an abnormality is discovered (see Tip 6) and is able to answer any of the volunteers questions (GMC 2008). We do not allow students with known conditions to be the volunteer; our aim is to demonstrate normal anatomy and physiology.

The consent process not only provides a degree of protection for the demonstrator, but also pre-warns the volunteer about the possibility of finding incidental abnormalities. It is for this reason that volunteers should be scanned prior to the session, in private. Ideally this should be by the same demonstrator who will be delivering the session and with experience of identifying lesions of the relevant anatomical area. This enables any abnormality to be brought to light in a confidential environment. However, it is important that the students are aware that this is not a true diagnostic scan.

The second advantage of pre-scanning is to help the demonstrator identify the best ultrasound windows and probe positions to enable optimum visualisation of the desired structure for that particular student, and to familiarise oneself with and set-up the ultrasound machine. This will save time in the teaching session, and improve the “slickness” of the delivery. Selection of the volunteer is important. A volunteer being selected in whom the structures to be demonstrated can easily be identified and are normal is the ideal scenario. It is no use trying to demonstrate normal hepatobiliary anatomy in a morbidly obese individual. Equally, echocardiographic images of the heart are often easier for students to appreciate in a slim male.

Students should not feel pressured to volunteer and of course life-models or clinical skills partners are available as an

alternative. When working with student volunteers, be aware of cultural sensitivities (Finn 2010).

### Tip 6

Have a departmental protocol in place for “Situations Requiring Further Investigation” if an incidental pathology is identified on the healthy volunteer

The majority of young “healthy” volunteers do have normal ultrasound studies. However in a minority, abnormalities may be identified. This ranges from incidental lesions such as hepatic haemangioma, renal cysts and gallstones to, to cardiac defects (mitral regurgitation and small atrial septal defects). Very occasionally significant and worrisome pathology can be identified. For instance, in one study 10% of the 40-year olds have renal cysts (Carrim & Murchison 2003).

While many demonstrators do have a medical/imaging background, it is important in the eventuality of finding an abnormality that the volunteer understands that the tutor/demonstrator is not their personal physician and further investigation and management will need to be undertaken through their own general practitioner (GP). In the eventuality of finding an abnormality the volunteer should be advised to consult their GP. In our experience, an open letter from the demonstrator to the GP helps to explain the situation.

Obviously volunteer confidentiality must be respected and re-iterating this to the volunteer is often helpful. Similarly, offering as much re-assurance as possible given the limited information available to you can help calm an often worried volunteer. Care should be taken to avoid false re-assurance, however as a small minority will be significant pathology. There is a duty to ensure care is given to the subject when this happens. These students should not be used as subjects in class. Formalised guidance is available from the Royal College of Radiologists (2011) for situations such as those described.

### Tip 7

An introductory lecture helps to set the scene, signpost the key points of the anatomy needed and orientate the students to the ultrasound images that will be studied

In order to maximise the learning potential of the ultrasound demonstration, the students need to first be primed with the relevant factual information and basic understanding. We feel this is best achieved during a separate dedicated lecture, with a brief refresher at the start of the practical session. This content can however be delivered during the practical session itself. It is crucial to use the introductory lecture to orientate students to the ultrasound image (e.g. superficial, deep, left and right).

Other areas that should be covered in the introductory session include the learning outcomes so that the students can understand exactly what they are expected to be able to identify. We find an overview of the relevant gross and surface anatomy of the structures to be viewed, along with this structures other anatomical relationships, very helpful.

Continued orientation back to the gross anatomy is particularly helpful and helps to reinforce the learning process.

## Tip 8

Patient dignity, patient positioning and ergonomics need to be considered both before and consistently throughout the teaching session

The physical layout of the room should be considered in order that the students are able to easily see either the ultrasound screen, or a clear projection of the image and the probe within the sonographer's hand. This allows visuospatial orientation and thus a better appreciation of the structures being demonstrated and their relationships.

In order to prevent the volunteer being disadvantaged, they too should be able to see. Ways around this include using a volunteer from a different year group, a life model or delivering the session twice, so that the volunteer can observe the procedure on the second run.

A bed sheet can be used to keep the volunteer as covered as possible, helping to maintain their privacy and dignity. Consider the temperature of the room, as the volunteer may be in a state of undress for a significant period of time. The comfort of both the volunteer and the demonstrator should also be considered, with the volunteer positioned comfortably on the examination couch, which itself should be adjusted to the correct height and positioned adjacent to the ultrasound scanner, thus removing the need for the demonstrator to become a contortionist. Consider using a laser pointer in the other hand of the demonstrator to identify the structures on a projected screen, or ideally have a second staff member doing the teaching, allowing the demonstrator to obtain maximal image quality. A practice session with fellow colleagues is recommended if this is the first time you are delivering an ultrasound-based teaching session. Ask the volunteer to come suitably dressed, for example, if scanning the femoral triangle they may wish to wear shorts.

## Tip 9

When delivering the teaching, allow for the initial "wow-factor" then consistently reinforce the key learning outcomes with regards to orientation and anatomy and signpost the clinical relevance throughout

After all the preparation, it is time to deliver the session! As mentioned previously, introduce the session clearly with very specific learning outcomes. It is easy for the students to be distracted by the "wow" factor of ultrasound, especially a dynamic scan such as echocardiography. This has the potential to hinder the learning experience. When the first image is obtained for the students to see, give them time to just watch the image. Once you have done this, you can then get their attention to orientate them (left and right, superficial and deep). A laser pointer or a second staff member to point to the screen makes life much easier when teaching this. Ensure that every time you move the probe this is conveyed to the

students. A common mistake is to forget to orientate the students; if this occurs the students will not know what they are looking at and the learning opportunities are significantly reduced. Move the probe slowly, and only identify structures that are clearly seen. A 3D model of the organ under study (for instance the heart) can be helpful when teaching students. Our experiences are that orientation of superficial/deep, left/right and cranial/caudal is what confuses the student the most. Deliberate attention should be paid to helping the students orientate the image to the volunteer before any teaching on the anatomy is delivered. Demonstration of the leading edge of the probe with a finger tapping on one side of the probe can be a helpful technique to explain left versus right. In addition, a basic understanding of the principles of ultrasound together with its strengths and limitations will be beneficial.

Offer students the option to ask questions throughout, and if there is anything else they would like to see, or revisit. Conclude the session by again recapping the learning outcomes. If possible try to link the session to other parts of the curriculum. A good example is with echocardiographic four chamber view of the heart. We identify the key anatomy, then discuss the phases of the cardiac cycle from the image and associated ECG trace and then briefly discuss heart failure and how the cardiac function would appear different.

## Tip 10

Should permit time, allow students supervised "Play Time" as students learn significantly by being able to hold the probe and relate the orientation and anatomy themselves as they scan

Students frequently request to have "hands on" time with the ultrasound machine during their evaluation of the sessions. It is important to be clear to the students at the outset, that it is not a learning outcome to be able to perform an ultrasound at this stage of their training. However, there are advantages to giving students' structured supervised "playtime" with the ultrasound.

Benefits include the increase in students' appreciation of the image orientation (especially left and right), the familiarity of the dynamic and user-dependent nature of ultrasound and the physics behind the doppler effect. Many clinicians are now expected to utilise ultrasound to guide procedures (central line access (NICE 2002), draining pleural effusions) and early exposure to ultrasound may improve students' confidence in performing these types of focussed scans later in their careers.

We allow students hands on experience of ultrasound of the neck (to identify the arrangement of the carotid artery and internal jugular vein) and the groin (to identify the arrangement of the femoral artery and vein). These are quite simple scans to perform and relevant to many parts of clinical practice, but do not contain complex anatomy and so ensure the students focus the basics of image orientation. It is important that enough facilitators skilled in ultrasound are available to help students; this can often be a limiting factor in the ability to run this style of session. Hands-on time is beneficial to students but it is a luxury that often a tight curriculum will not permit.

## Tip 11

Evaluation of the session is pivotal to further develop your ultrasound teaching programme

Evaluation is particularly important when introducing any new teaching modality into the curriculum. Teaching clinical sciences with ultrasound is a specific skill; unlike clinical settings you are not teaching the students how to perform the ultrasound, but teaching the anatomy/physiology. This distinction should be stressed to students, especially when asking them to evaluate whether the learning outcomes were achieved, you are not certifying them as being able to scan but are providing clinical context into the basic science curriculum.

Evaluation of ultrasound teaching is therefore strongly advised to help improve future sessions and enable the demonstrator's personal development. This evaluation should be provided by the students in the form of feedback questionnaires, but should also be evaluated by fellow colleagues observing the session. As the demonstrator you should also evaluate your own session. Combining this personal reflection with student feedback and discussion with other tutors/demonstrators will enable positive changes to be implemented in the way the sessions are undertaken and tailored to the curriculum to improve future course delivery.

We have delivered ultrasound teaching over several years, and the formats of the sessions have changed dramatically based on extensive feedback. Common themes that arise from our local evaluation include difficulties in orientation of the image (improved by more time setting the scene and spiral learning of revisiting ultrasound orientation each time a session is delivered), wanting more small group sessions to allow students to have closer inspection of the ultrasound machine, probe and sonographer's hand position to help orientate themselves and students report they feel they get more from the sessions having spent some time learning the gross anatomy first, although our data has not demonstrated this to be true (Finn et al. 2012; Griksaitis et al. 2012).

## Tip 12

Application of ultrasound to formal assessment

It is important the students appreciate the importance of ultrasound, both as a valid teaching tool but also as a relevant clinical investigation in the future that as doctors they will be requesting, or perhaps even be performing. This importance can be highlighted by the inclusion of ultrasound assessment in the undergraduate examination.

Whilst ultrasound is a dynamic process, it is still possible to incorporate ultrasound into examination. For instance, the static picture of cardiac four chamber view of the heart lends itself nicely for questions relating to identification of atrioventricular valves or phases of the cardiac cycle. Generic questions can be asked about superficial versus deep structures to assess the students' orientation of images. In OSCE

assessments, you can put short loops of ultrasound sequences on a laptop for students to view and answer questions. Similarly, movie loops can be accessed using computer-based assessments. Ultrasound images can be utilised within anatomy practical examinations to test for the transfer of knowledge between cadaveric anatomy and living anatomy, as in reality, the majority of students will not experience anatomy in the cadaveric/prosection form in the clinical setting and thus ultrasound in the examination is arguably a more realistic way of assessing the students' understanding of clinically orientated anatomy.

## Conclusion

Ultrasound is an enjoyable and beneficial teaching modality in the undergraduate curriculum of health care professionals, for both students and the teaching faculty. We present our tips on teaching with ultrasound based on several years of ultrasound teaching experience along with our research. We hope that these tips encourage others to use ultrasound in their teaching repertoire.

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## References

- Carrim ZI, Murchison JT. 2003. The prevalence of simple renal and hepatic cysts detected by spiral computed tomography. *Clin Radiol* 58:626–629.
- Finn G. 2010. Twelve tips for running a successful body painting teaching session. *Med Teach* 32(11):887–890.
- Finn GM, Patten D, McLachlan JC. 2010. The impact of wearing scrubs on contextual learning. *Med Teach* 32:381–384.
- Finn GM, Sawdon MA, Griksaitis MJ. 2012. The additive effect of teaching undergraduate cardiac anatomy using cadavers and ultrasound echocardiography. *Eur J Anat* 16(3):199–205.
- GMC. 2008. GMC guidance. Consent: Patients and doctors making decisions together; June 2008.
- GMC. 2009. GMC Tomorrow's doctors: Outcomes and standards for undergraduate medical education.
- Griksaitis MJ, Sawdon MA, Finn GM. 2012. Ultrasound and cadaveric prosections as methods for teaching cardiac anatomy: A comparative study. *Anat Sci Educ* 5:20–26.

- Koens F, Mann KV, Custers EJ, Ten Cate OT. 2005. Analysing the concept of context in medical education. *Med Educ* 39:1243–1249.
- Koens F, Ten Cate OT, Custers EJ. 2003. Context-dependent memory in a meaningful environment for medical education: In the classroom and at the bedside. *Adv Health Sci Educ Theory Pract* 8:155–165.
- National Institute for Clinical Excellence. (NICE). 2002. Guidance on the use of ultrasound locating devices for placing central venous catheters. *Technology Appraisal Guidance No. 49*, Sept 2002.
- Patten D, Donnelly L, Richards S. 2010. Studying living anatomy: The use of portable ultrasound in the undergraduate medical curriculum. *IJOCS* 4(2):72–77.
- Royal College of Radiologists. 2011. *Management of incidental findings detected during research imaging*. London: The Royal College of Radiologists.
- Swamy M, Searle RF. 2012. Anatomy teaching with portable ultrasound to medical students. *BMC Med Educ* 12:99.
- Tshibwabwa ET, Groves HM. 2005. Integration of ultrasound in the education programme in anatomy. *Med Educ* 39:1148.