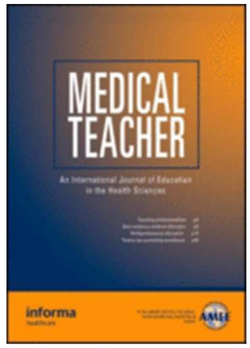
Article:

Wakefield, RJ orcid.org/0000-0001-5352-8683, Weerasinghe, A, Tung, P et al. (13 more authors) (2018) The development of a pragmatic, clinically driven ultrasound curriculum in a UK medical school. Medical Teacher, 40 (6). pp. 600-606. ISSN 0142-159X

https://doi.org/10.1080/0142159X.2018.1439579



The development of a pragmatic, clinically driven ultrasound curriculum in a UK medical school

Journal:	*Medical Teacher*
Manuscript ID	CMTE-2018-0160
Manuscript Categories:	Special Issue
Date Submitted by the Author:	02-Feb-2018
Complete List of Authors:	Wakefield, Richard; University of Leeds, Leeds Institute of Rheumatic and Musculoskeletal Medicine Weerasinghe, Asoka; Mid Yorkshire Hospitals NHS Trust, Department of Emergency Medicine Tung, Patrick; Mid Yorkshire Hospitals NHS Trust, Department of Emergency Medicine Smith, Laura; Leeds Institute of Medical Education, Clinical Skills Education Team Pickering, James; University of Leeds, Division of Anatomy, Leeds Institute of Medical Education Msimanga, Tendekayi; Mid Yorkshire Hospitals NHS Trust Arora, Mohit; Leeds Teaching Hospitals NHS Trust, Emergency Medicine Flood, Karen; Leeds Teaching Hospitals NHS Trust Gupta, Pawan; Leeds Teaching Hospitals NHS Trust Bickerdike, Susan; Leeds Institute of Medical Education, University of Leeds McLaughlan, James; University of Leeds School of Electronic and Electrical Engineering; Leeds Institute of Cancer and Pathology Uttley, Ashley; Leeds Teaching Hospitals NHS Trust Wilson, Jean; School of Medicine, University of Leeds Evans, Tony ; Leeds Institute of Cardiovascular and Metabolic Medicine, University of Leeds Wolstenhulme, Stephen; Leeds Teaching Hospitals NHS Trust, Radiology; Faculty of Health Sciences, University of Malta Roberts, Trudie; Leeds Institute of Medical Education, University of Leeds
Keywords:	Integrated < Curriculum, Curriculum, Undergraduate < Phase of education

Title: The development of a pragmatic, clinically driven ultrasound curriculum in a UK medical school

Authors (qualifications and positions):

Dr Richard Wakefield, BM, MD, PGCE, FRCP (UK). Senior Lecturer and Honorary Consultant in Rheumatology, Leeds Institute of Rheumatic and Musculoskeletal Medicine, University of Leeds, UK

Dr Asoka Weerasinghe, MBBS, MRCS, MSc (Medical Ultrasound) FRCEM. Department of Emergency Medicine Dewsbury and District Hospital, Mid Yorkshire Hospitals NHS Trust, UK

Dr Patrick Tung, MBChB, FRCEM, PGCert (Medical Ultrasound). Consultant in Emergency Medicine. Department of Emergency Medicine Dewsbury and District Hospital, Mid Yorkshire Hospitals NHS Trust, UK

Ms Laura Smith. RN. Head of Clinical Skills Education, Leeds Institute of Medical Education, University of Leeds.UK

Dr James Pickering, BSc (Hons), PhD, PGCLTHE, SFHEA, NTF. Associate professor of Anatomy in the Division of Anatomy, Leeds Institute of Medical Education, University of Leeds, UK

Dr Tendekayi Msimanga, MBChB, MRCP, BSE(Transthoracic). Consultant in Acute and General Medicine, Mid Yorkshire NHS Trust, Honorary Senior Lecturer, University of Leeds, UK

Dr Mohit Arora, MBBS, MRCEM, FRCEM, PG Cert Medical Ultrasound
Consultant Emergency Medicine, Leeds Teaching Hospitals NHS Trust, UK

Dr Karen Flood MBBS, FRCR. Consultant vascular interventional radiologist at Leeds Teaching Hospitals NHS Trust, UK.

Dr Pawan Gupta, MD, FRCA Consultant and Honorary Associate Professor in Anaesthesia, Leeds Teaching Hospitals NHS Trust, UK

Dr Susan Bickerdike; PhD Chemical Engineering, eLearning Project Manager, Leeds Institute of Medical Education, University of Leeds, UK

Dr James McLaughlan, MPhys PhD School of Electronic and Electrical Engineering / Leeds Institute of Cancer and Pathology, University of Leeds, UK

Dr Ashley Uttley, MBBS, BSc, FRCR. Radiology registrar. Leeds Teaching Hospitals NHS Trust, UK

Mrs Jean Wilson, Senior Ultrasound Lecturer (retd.), School of Medicine, University of Leeds, UK

Dr Tony Evans BSc, MSc, PhD. Senior Lecturer in Medical Physics (retd.) Leeds Institute of Cardiovascular and Metabolic Medicine, University of Leeds, UK

Dr Stephen Wolstenhulme, BSc, PhD Advanced Practitioner Radiographer (Sonographer), the Leeds Teaching Hospitals NHS Trust and Lecturer/Clinical Educator, the Faculty of Health Sciences, University of Malta

Professor Trudie E Roberts. BSc, MB ChB, PhD, FRCP, FHEA, FAoME. Director of the Leeds Institute of Medical Education, University of Leeds, UK

Address for correspondence:

Dr Richard J Wakefield

Senior Lecturer and Honorary Consultant in Rheumatology,

Leeds Institute of Rheumatic and Musculoskeletal Medicine,

Chapel Allerton Hospital,

Leeds. UK.

LS7 4SA

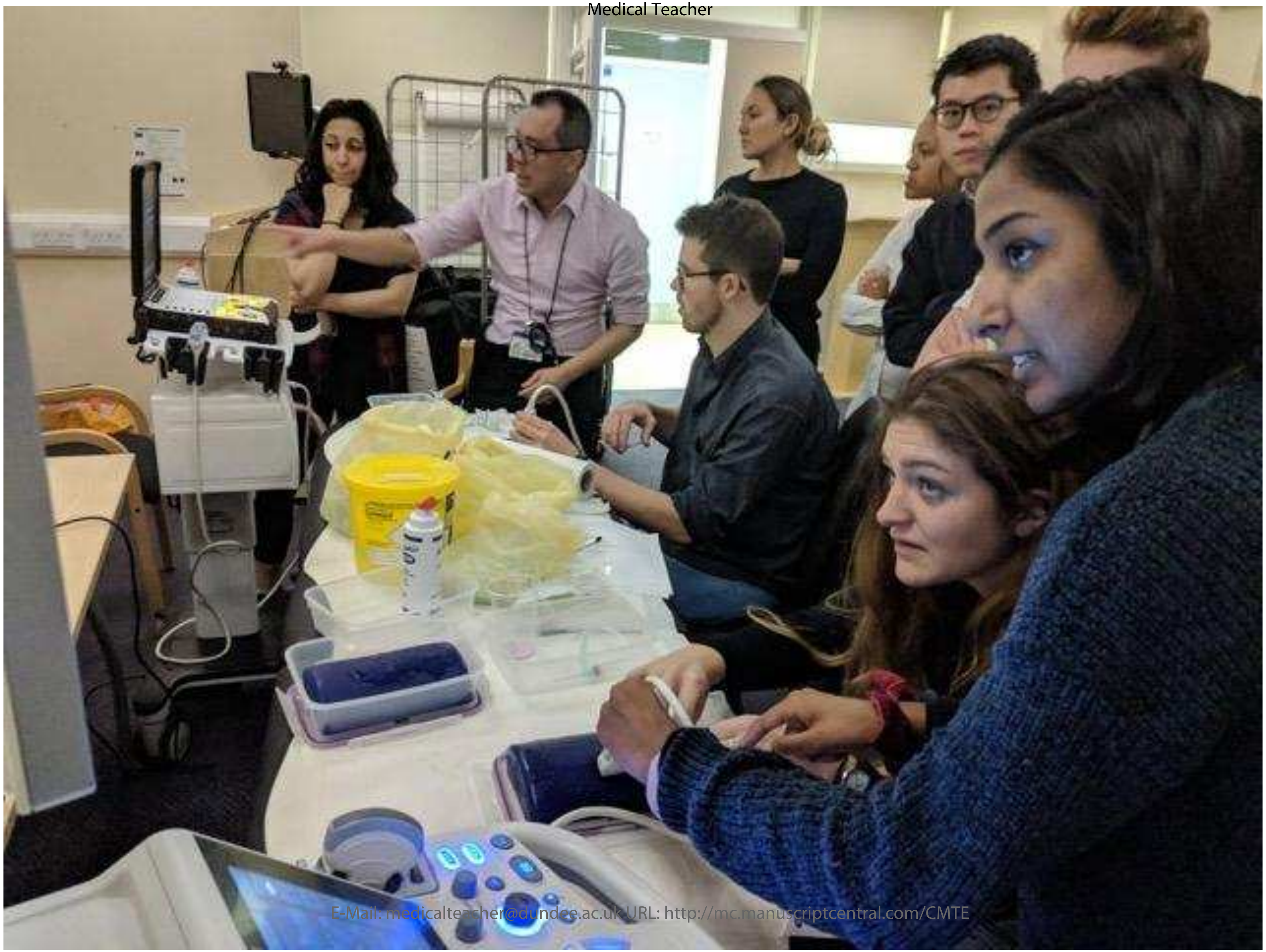
Tel: 00 44 113 3924883

Email: medrjw@leeds.ac.uk

Table 1: Leeds Integrated Ultrasound Curriculum Map (2017-2018)

Year	Ultrasound Teaching	Scan Area	Objectives	Teaching Method	Assessment
All years	Introduction to Medical Ultrasound	N/A	Ultrasound Physics Ultrasound 'Knobology' Ultrasound Artefacts Ultrasound Safety & Ergonomy & Governance	VLE	Formative
1	Year 1 Session 1 (Ultrasound in Anatomy - Neck / Thorax)	Heart Lung Thyroid Anterior Neck	Using various cardiac "windows", correlate the 4 chambers of the heart and associated valves and great vessels with ultrasound appearance Scanning the thorax, appreciate the ultrasound appearance of the ribs and its association with intercostal muscle and pleural Scanning the anterior neck, appreciate the ultrasound appearance of the thyroid in its relation to common carotid artery, internal jugular vein and trachea.	VLE Hands on/ small groups	Formative and summative
	Year 1 Session 2 (Ultrasound in Anatomy - Abdomen)	Liver / Gall Bladder Spleen Kidney Aorta / IVC	Appreciate the size and location of the liver within the abdomen with particular attention to its extension into the thorax and epigastrium. Appreciate the relationship between the gall bladder and liver Appreciate the size and location of the spleen within the abdomen with particular attention to its extension into the thorax Appreciate the location of the kidneys and their location within the abdomen Highlight the aorta and inferior venal cava and their major branches	VLE Hands on/ small groups	Formative and summative
2	Year 2 Session 1 (Ultrasound in Anatomy - Upper Limb) [Vascular]	Upper Arm Forearm	Highlight the ultrasound appearance of artery and vein Identification of the upper limb artery and trace its course down to periphery Identification of the venous system of the upper limb	VLE/ workbooks/ Hands on- small groups	Formative
	Year 2 Session 2 (Ultrasound in Anatomy - Lower Limb) [MSK]	Knee	To highlight the ultrasound appearance of different musculoskeletal tissues (bone, cartilage, tendon, ligament, muscles, blood vessels and popliteal fossa To correlate the ultrasound appearance with anatomical features that have previously been learnt	VLE/ workbooks/ Hands on- small groups	Formative

Year	Ultrasound Teaching	Scan Area	Objective	Teaching Method	Assessment
3	Year 3 (US Facilitated Clinical Examination)	Neck / Thyroid Thorax (Heart & Lung) Abdomen	Neck Examination (including thyroid, trachea, lymph node & neck muscles) CVS Examination (identification of heart sound with corresponding valve closure) Respiratory Examination (identification of lung sliding with corresponding auscultation of lung field) Abdominal Examination (identification of liver edge, McBurney's point for gall bladder, renal angle, aorta palpation)	Worbooks/ Hands on - small group	Formative
4	Year 4 (US in Clinical Application)	Thorax Abdomen	Introduction to Point of Care Echo Introduction to Rapid Ultrasound in Shock (RUSH) Introduction to Abdominal and Cardiac Evaluation with Sonography in Shock (ACES) Central line insertion (Observe only)	Didactic lecture and hands on- small group	Formative
5	Year 5 (MUST Course - Ultrasound Guided Cannulation & ABG sampling), MSK teaching	Upper Limb	Identification of transverse and longitudinal views of vessels Acquiring Image & Image Optimisation Needle tracking in dynamic approaches Identification of joint fluid	Small group (5 per group)	Formative assessment at the end of the course



Abstract

Whether ultrasound should be incorporated into a medical undergraduate curriculum remains a matter of debate within the medical education arena. There are clear potential benefits to its early introduction particularly with respect to the study of living anatomy and physiology in addition to the learning of clinical skills and procedures required for the graduate clinical practice. However, this needs to be balanced against what is perceived as added value in addition to financial and time constraints which may potentially lead to the sacrifice of other aspects of the curriculum. Several medical schools have already reported their experiences of teaching ultrasound either as a standalone course or as a fully integrated vertical curriculum. This article describes and discusses the initial experience of a UK medical school that has taken the steps to develop its own pragmatic vertical ultrasound curriculum based on clinical endpoints with the intent of using ultrasound to enhance the learning experience of students and equipping them with the skills required for the safe practice as a junior doctor.

Key words: Integrated, Curriculum, Undergraduate

Strapline: Ultrasound Curriculum Development

Ultrasound (US) is an imaging technique now used in the management of patients in most medical and surgical specialties. In recent years, there has been a shift towards clinicians performing scans themselves in an attempt to optimise efficiency of patient care and improve safety which has been enabled by falling costs of equipment and the improved usability of machines. The traditional focus of this type of 'point of care' US often referred to as POCUS has been largely directed towards emergency medicine and cardiology (Moore and Copel, 2011), (Lane 2015) but increasingly it has also been applied to non-acute specialities such as rheumatology (Sudoł-Szopińska I, 2017). It is now common place to see machines in or in close proximity to most hospital out-patient and ward facilities to enable these applications.

In recent years there has been a growing interest in the concept of incorporating US into the medical undergraduate curriculum with a number of editorials in high profile medical journals (Solomon and Saldana, 2014) (Wittenberg, 2014). Despite the many potential advantages of US (Chiem, 2016) and enthusiasm for US (Stone-McLean, 2017), some have expressed caution until there is further evidence (Feilchenfeld, 2017). To date, most of the published literature on the use of US in medical education comes from North America and Canada; there, many medical schools have started to use it in some aspect of their courses with a smaller proportion opting for full integration throughout the whole course (Bahner, 2014), (Dinh, 2016), (Steinmetz, 2016), (Tarique, 2018). Indeed, some of these have already reported a decade of experience (Hoppmann, 2015). In contrast, Europe has less well developed undergraduate programmes; this is particularly true of the UK where its use is sporadic with no medical school to our knowledge developing a fully integrated curriculum into all its years.

In 2014, in light of this growing interest, the School of Medicine at Leeds, began to investigate the question: how and where could this developing and increasingly versatile diagnostic tool be incorporated into our medical programme in order that our graduating doctors develop the appropriate skills to support and enhance patient care? This paper presents/outlines the iterative process that was undertaken to develop a fully integrated ultrasound curriculum spanning a traditional 5 year UK undergraduate medical school course with the intention of informing colleagues who might have similar intentions.

Pilot project - The first steps

In 2012-2013, the emergency medicine department at a local hospital began to teach US as part of a final year (Year 5) medical undergraduate clinical placement. The objectives were to use US to identify superficial blood vessels in order to improve peripheral vascular access for venesection, cannulation and arterial blood gas sampling. The perception had been that newly qualified doctors were often lacking in confidence and ability to take blood samples from more complex patients. It was postulated, therefore, that utilising US would support the future junior doctors in being able to locate relevant vasculature and improve the success rate of both blood sampling and cannulation. It was anticipated that this would reduce the number of attempts and thereby decrease the need to call senior colleagues which is not uncommon across the healthcare profession (Kumar, 2009). The teaching session involved half-day focused training on the underlying and relevant physics, 'knobology', machine functionality and clinical governance, a demonstration by experienced faculty and hands-on practice using phantoms to visualise needle insertion and how to direct it towards a vessel. The feedback received from the students was universally positive and previously reported (Weerasinghe, 2017). In particular, students felt that this was highly relevant to their training.

Curriculum Development:

Given the above positive evaluation, in early 2014, a multi-disciplinary working group of educators, clinicians and academics from the School of Medicine was created to explore the feasibility of utilizing US more widely in the medical curriculum. Many of the group had some involvement with US and this experience, alongside a scoping literature review, highlighted clinical competencies thought to have the most potential value to future graduates. Subsequently, we contacted clinicians working in a range of medical and surgical specialties across the region, to complete an online 'needs assessment' to determine if there was agreement with the working group suggestions. From this list, each clinician was asked to rank each competency (e.g., 1. Should be observed only; 2. Performed under supervision or 3. Performed independently'). The respondents were also invited to provide a qualitative commentary and any additional competencies not otherwise mentioned.

The main clinical competencies highlighted by the respondents as 'perform independently' included peripheral vascular assessment, evaluation of bladder size, achieving a 4 chamber cardiac view and identification of a joint effusion. Those under supervision included FAST 9, eFAST, identification of pleural effusion and ascites, Basic ECHO, assessment of IVC volume assessment. Other competencies such as enlarged thyroid, central venous cannulation, chest drain insertion, nerve blocks were for observation only. It was noted that the questions being asked for very specific indications in order to answer narrow clinical questions in line with the concept of POCUS. Given that we now had clinical competencies to work towards, we considered the possible stages of learning that would have to take place.

We considered that a spiral curriculum starting from Year 1 would be the most effective means of embedding all the required knowledge, skills and attitudes required before graduation.

Academic Year 2015-2016

It was decided to introduce the vascular course to the entire year, resulting in the programme being escalated from an initial number of 60 students to 275/ year. This increased provision meant the course needed to be delivered on the university campus as a more central location. Simultaneously, a second pilot was launched in anatomy in Year 1 to provide US teaching sessions on the heart, thorax and abdomen in line with our clinical end-points. A suitable place in the anatomy curriculum alongside existing teaching sessions on surface anatomy was identified by the curriculum team members of the group.

In order to teach the whole year, it was necessary to recruit enough ultrasound teaching faculty and locate a sufficient number of machines to deliver the sessions effectively. Theoretically this should have been a relatively simple exercise given the number of clinical colleagues who perform ultrasound and the abundance of machines located in the clinical areas. However, finding appropriate teachers took some time which led the need to train some non-clinicians from the anatomy and clinical skills department during half day training sessions. As it was not deemed not feasible to use the hospital machines due to their location, we needed to consider loaning/ buying our own machine. We therefore entered into an educational partnership with an US company which agreed to loan machines to us on the days that were needed for the study.

Finally, as most students would not have experienced any US training before, the TEL team with medical physics and radiology helped create VLE materials introducing the students to the principles of ultrasound including relevant physics, machine controls ('knobology') and how to hold a transducer. Clinical colleagues also created instructional videos demonstrating basic scanning anatomy of the heart, chest and abdomen, alongside the production of an electronic workbook and self-assessment questions to be used formatively alongside the sessions. The teaching was conducted in groups with 5-10 students/ group. We also considered it important to highlight at this early stage of training, the importance of good ergonomics and clinical governance.

In January 2016, we held a launch day at the university for all potential stakeholders with invitations given to the Dean of the Medical School, CEOs/ medical directors of the local hospitals, clinicians from around the region, educators and potential funders. This allowed us to present our rationale for the project and in particular, highlight the need for future involvement of clinicians, both as faculty and delivering teaching in clinical areas. There was overwhelming support for the project in principle although some clinicians expressed concern about the potential deskilling of future doctors through the increased use of technology.

Formal evaluation of the anatomy sessions was undertaken by two 4th year students as part of a research placement. Feedback was completed by Y1 students immediately after the sessions and later from focus groups. This helped provide a number of important insights such as the importance of receiving the US teaching after the gross anatomy/ cadaveric dissection teaching (some had done the ultrasound first), using young normal volunteers rather than patients who often had pathologies), the need for small groups and that there was variability in teaching content between facilitators (Owen and Sharpe, 2017, unpublished, UoL).

Academic Year 2016-2017.

Y1/Y2 anatomy: This year saw the refinement of teaching in Year 1 anatomy following the previous evaluations. In Year 2, US was used to evaluate different aspects of the anatomy the upper and lower limbs in small groups. The students had previously completed Y1 with US and so had some familiarity with the machines. They were however advised to revisit the VLE resources from the previous year. The aim was to identify the vasculature of the upper limb, appreciate the US differences between arteries and veins and understand the basics of Doppler. The lower limb session introduced the US appearance of musculoskeletal tissues. Videos and self-guided workbooks were prepared for each session and the sessions were guided by facilitated by practitioners. Patient volunteers were recruited for the sessions but again it was noted that many had abnormalities such as sarcopaenia making muscle assessment around the knee problematic in the lower limb session.

Year 3: Clinical skills teaching. These students, having not done ultrasound in the previous years, were provided with a short introduction at the start of the session. All students had been taught physical examination skills beforehand in a separate session. In small group, tutor led rotations, students were asked to clinically examine the heart, lungs, peripheral, central pulses and thyroid and to compare these with the US findings. Electronic workbooks helped provide instruction for this process.

Year 4: Acute and critical care course. As in year 3, these students had not previously been exposed to ultrasound and so required new basic ultrasound and machine knowledge. The students were taught about the potential role of US in critical care with respect to venous access, in managing the shocked patient and in abdominal and cardiac evaluation.

Academic Year 2017-2018

This has involved further refinement of the previous years in addition to expansion of the course. In Year 1 and 2, student teaching sessions had needed to be repeated on 4 days in order to accommodate the whole year. Changes in the time tabling allowed teaching all the students to be taught on the same day with back to back sessions. This made the process more efficient and less onerous for team with no repetition required for setting up and significantly less faculty time who were previously attending on 4 separate days. The anatomy team also ensured that ultrasound scheduling occurred after that topic had been covered by all the students beforehand.

In year 3, we included the abdomen examination into the clinical skills teaching. We also supported a student nephrology society meeting taking students from all years, where we ran a session on basic kidney and bladder scanning, bladder volume assessment, ultrasound guided venepuncture, basic echocardiography and IVC volume status (Figure 1). In year 5, rheumatology we have also incorporated ultrasound into placement teaching for the assessment of a swollen joint.

The current curriculum framework is presented in Table 1. This will evolve over time as clinical placements using ultrasound are initiated.

Discussion:

Although still ongoing, our programme of work has demonstrated that it is feasible to incorporate a vertical ultrasound curriculum into a traditional UK undergraduate medical course within a relatively short time frame and is very well received by students. We have aimed to follow a pragmatic approach by defining our clinical end-points for graduation and working backwards to embed the required knowledge, skills and attitudes from Year 1. Our experiences are consistent with the experience of other medical schools who have developed an integrated curriculum (Rao, 2008), (Hoppmann, 2011), (Bahner, 2013), (Hoppmann, 2015), (Rempell, 2016). In agreement with other schools, teaching was well received by students who consider that learning how to use and apply this technology is highly relevant to their clinical careers.

In an acute medical situation, when a clinical history may not be available or the patient is in too much pain or unable to communicate the site of pain, bedside ultrasound is able provide rapid diagnostic information. Additionally, in non-acute patients, it is our experience that rather than breaking down the doctor-patient relationship, a clinician who is able to perform a scan as part of their assessment, instils a feeling of trust between the doctor and patient and a better patient understanding of the disease process. In a study of patients with arthritis, being able to show real time images to patients of their joint inflammation increased drug compliance (Joplin, 2015). It is only relatively recently that technological advances have made US available to non-radiology specialists; it is these individuals that have been in a position of exploring new ways of applying US in a way radiologists were unable to. In a similar way, it is likely that new graduates will innovate medical practice in their own way with new applications. This will be facilitated by further miniaturisation of machines and transducers now able to connect to electronic notepads and smart phones.

There has been much previously written about the use of US in medical undergraduate education. Uptake by medical schools has been variable ranging from a blended introduction in anatomy teaching (Tshibwabwa, 2005), (Brown, 2012), (Finn, 2012), (Swamy,2012), (Sweetman, 2013), (Griksaitis, 2014), (Jurjus, 2014), (Patten, 2015), (So, 2017), (Patel, 2017), to its use in learning clinical examination skills (Mouratev, 2013), (Blacksock, 2015), (Turner, 2015), (Kim, 2017), (Patel, 2017), (Walrod, 2018). What a school decides to deliver is often dependant on who initiates the teaching. An educational programme initiated and led by an anatomist is likely to focus on anatomy and physiology whilst a clinician based programme will focus on clinical skills and procedures. In our case, the early development of a multi-disciplinary group greatly assisted the creation of a common vision and the development of strategies to thread or 'spiral' this through the whole curriculum.

An ability to demonstrate the added value of incorporating ultrasound into an undergraduate curriculum is important especially when trying to convince sceptical colleagues and future funders. However, this can be difficult to measure, especially early on in a new teaching programme. Although there are many research articles stating a benefit of ultrasound to students, criticism has recently been raised about the design of these studies and outcomes used with the suggestion that they have inherent bias as they are conducted by groups potentially wanting to demonstrate a benefit (Feilchenfeld et al, 2017). It is important to reflect on this and not assume that US is able to answer all questions. We have reinforced throughout the course that it cannot not replace good history and examination techniques, especially as these provide the context for the scans being done. We have moved cautiously by focussing on areas that clinicians felt that there would be most added value. Student evaluation forms and focus groups in Y1 welcomed the opportunity to use new technology and considered it an advantage to be prepared for future clinical practice before graduation.

This is in line with a study by Stone-Mclean (2017) where the same level interest continued throughout the clinical years. Encouragingly, in a small follow up study of previous students who had previously been taught vascular access skills in year 5 and were now working as junior doctors, many had continued to use their skills and had felt they had been able to work more autonomously. Some had stated that having the skill from the first day provided them with confidence and helped bridge the gap between normal cannulation attempts and the escalation for the requirement for senior support (Barnard, 2017-unpublished, UoL).

It is clear that as with any technology, the users need to understand the appropriate uses and limitations of the technology and that they need to be appropriately trained. Of particular note is the importance of clinical governance which is highlighted in the online resources and further discussed in the practical sessions throughout the course. Currently, assessment via the online resources and electronic workbooks is largely formative but in anatomy, we have introduced images and questions as part of the summative assessment. It is likely this will follow in the later years.

The future success of the programme requires significant central administrative support especially for the recruitment and coordination of teaching faculty. This will be even more important as the course develops. The delivery of teaching in blocks on the same day helped minimize the setting up of rooms and travel of staff. As the project has gained momentum, an increasing number of clinical colleagues have expressed an interest to be involved. This increase in faculty will enable us to further optimise the use of the machines and minimise the number of students/ tutor/ machine as well as provide new ward based opportunities for students to learn whilst on placements. However, with increasing work pressure on clinicians, we intend to explore other teaching methods such as using peer students to provide training opportunities (Siegel-Richman, 2017).

There is undoubtedly a financial cost to running an ultrasound programme including purchase of machines and training equipment (phantoms and simulators) and the training and utilization of staff. We decided to purchase our own equipment to allow us some flexibility in providing training opportunities especially across sites. The initial vascular pilot study in Year 5 utilised machines loaned on the day from companies but there is a certain degree of risk as companies may not always be able to provide machines on the required days. In addition, we wanted to provide extended learning opportunities by placing machines in the clinical skills laboratory. It was decided therefore that as the project expanded to involve the whole year, that we would look to purchase our own machines or at least some of them for which we were able to secure local funding. It is likely that the need for more machines will increase in the future, and we will continue to investigate other funding opportunities. An ideal would be to have a dedicated ultrasound teaching laboratory and we are considering 'models' which could assist in making this sustainable such as running fee paying courses for postgraduates. The use of simulators has been a point of discussion, as whilst there are advantages to their use such as the demonstration of pathologies and the standardisation of assessments, the costs are substantial and increase with the level of sophistication such as those with haptic capabilities.

The timing of the delivery of the ultrasound sessions was considered important. Our anatomy student evaluation in our first year of delivery reported that some students, due to their rotations had not covered all the relevant anatomy previously with cadaveric dissection or had not done the surface anatomy teaching before the ultrasound session. Those students who had not covered the material beforehand felt at a disadvantage to those that had and as a result of not having had a prior ground, found concept of ultrasound images difficult to understand. Furthermore not all students in the first year of our programme had read the VLE teaching materials prior to the sessions which meant valuable time was lost during the practical sessions in revisiting this. Interestingly, our students perceived that ultrasound might be best used as one for reinforcement and consolidation of prior knowledge and as a tool for bridging the gap between in vitro and in vivo, rather than a primary teaching tool (Owen and Sharpe –unpublished, 2017-UoL). The student evaluation also highlighted the need for clear and attainable learning objectives for each session with a focus that is shared by curriculum developers, facilitators and students in order for the most effective learning to be achieved. For example, having a list of organs and landmarks to visualise within the session with accompanying ultrasound stills of ideal images for students to compare to, originally suggested by Swamy and Searle (2012).

The next phase of our work will aim to expand the course horizontally in each year. We are seeking further opportunities to incorporate ultrasound into further teaching sessions in both the preclinical and clinical years. We are engaging with clinicians to develop ultrasound teaching opportunities within their specialties as part of their placements in order to provide opportunities to consolidate what has been learnt and to develop skills as well as observing situations where ultrasound might be useful. For example, a chest physician might demonstrate the clinical findings suggestive of a pleural effusion; an ultrasound is then applied to confirm/ refute this and then the US might be used to direct a needle for aspiration. This latter activity might be an observation only competency but the student should be more aware of how and when ultrasound is applied in this situation.

In conclusion, we report the experience of the first UK medical school in developing a vertical ultrasound curriculum for medical undergraduates. Over a 3 year period we have created a successful and secure platform from which the course can now develop horizontally throughout each year. We have found that building the course on clinical outcomes has provided a useful focus for development. Although the benefit of applying ultrasound to a medical undergraduate course remains controversial, we have found that students throughout all the years are enthusiastic and engaged, particularly as they consider it relevant to their future careers.

Acknowledgements:

Dr James Bernard, Dr Eleanor Owens, Dr Alexander Sharpe (formally medical students at the University of Leeds) for their educational project work. Ethical Committee approval was granted by the School of Medicine ethics committee. Health Education England (Yorkshire and Humber) and the Leeds Institute of Medical Education (LIME), University of Leeds for funding the purchase of the machines and other equipment. GE Healthcare (UK) for educational partnership and loan of machines.

Disclosure statement

AW and PT have been loaned ultrasound machines for teaching by Sonosite and GE. RW has been loaned machines for teaching by GE.

References

Bahner DP, Adkins EJ, Hughes D, Barrie M, Boulger CT, Royall NA (2013). Integrated medical school ultrasound: Development of an ultrasound vertical curriculum. Crit Ultrasound Journal 5; 1-9

Bahner DP, Goldman E, Way D, Royall, Liu YT. (2014). The state of medical education in US medical schools: results of a national survey. Acad Med 89:1681-86

Blacksock U, Munson J, Szyld D (2015). Bedside ultrasound curriculum for medical students: report of a blended learning curriculum implementation and validation. J Clin Ultrasound 43:139-144

Brown B, Adhikari S, Marx J, Lander L and Todd GL (2012). Introduction of ultrasound into gross anantomy curriculum: perceptions of medical students. J Emergency Medicine 43:1098-1102

Chiem AT, Soucy Z, Dinh VA, Chilstrom M, Gharahbaghian L, Shah V, Medak A, Nagdev A, Jang T, Stark E, Hussain A, Lobo V, Pera A, Fox JC. (2016). Integration of Ultrasound in Undergraduate Medical Education at the California Medical Schools: A Discussion of Common Challenges and Strategies from the UMeCali Experience. J Ultrasound Med. 35:221-33

Dinh VA, Lakoff D, Hess J, Bahner DP, Hoppmann R, Blaivas M, Pellerito JS, Abuhamad A, Khandelwal S (2016). Medical Student Core Clinical Ultrasound Milestones: A Consensus Among Directors in the United States. J Ultrasound Med.35:421-34

Feilchenfeld Z, Dornan T, Whitehead C, Kuper A. (2017) Ultrasound in undergraduate medical education: a systematic and critical review. Med Educ. 51:366-378.

Finn GM, Sawdon M and Griksaitis M (2012). The additive effect of teaching undergraduate cardiac anatomy using cadavers and ultrasound echocardiography. European Journal of Anatomy16:199-205

Griksaitis MJ, Scott MP and Finn GM. (2014). Twelve tips for teaching with ultrasound in the undergraduate curriculum Medical Teacher; 36:19-24

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

Hoppmann RA, Rao VV, Bell F, Poston MB, Howe DB, Riffle S, Harris S, Riley R et al. (2015). The evolution of an integrated ultrasound curriculum (iUSC) for medical students: 9-year experience. Crit Ultrasound J. 7:18.

Hoppmann RA Wilson LB, Bell III FE (2015). Using ultrasound to teach medical students cardiac physiology. Adv Physiol Edu 39;392-396

Joplin S, van der Zwan R, Joshua F, Wong PK. (2015). Medication adherence in patients with rheumatoid arthritis: the effect of patient education, health literacy and musculoskeletal ultrasound. Biomed Res Int. 2015;2015:150658

Jurjus RA, Dimorier K, Brown K, Slaby F, Shokoohi H, Boniface K, Liu YT (2014). Can anatomists teach living anatomy using ultrasound as a teaching tool? Anat Sci Educ. 7:340-9.

Kim EY, Park KH, Choi SJ, Chung W-J (2017). Educational value of pocket sized ultrasound devices to improve understanding of ultrasound examination principles and sonographic anatomy for medcial students. PloS One 12:e0185031

Kumar A, Chuan A (2009). Ultrasound guided vascular access: efficacy and safety. Best Pract Res Clin Anaesthesiol. 23:299-311.

Lane N, Lahham S, Joseph L, Bahner DP, Fox JC. (2015). Ultrasound in medical education: listening to the echoes of the past to shape a vision for the future. Eur J Trauma Emerg Surg 41:461-467

Moore, CL and Copel JA (2011). Point of care ultrasonography. NEJM; 364:749-57

Mouratev G, Howe D, Hoppmann R, Poston MB, Reid R, Varnadoe J, Smith S, McCallum B, Rao V, DeMarco P (2013). Teaching medical students ultrasound to measure liver size: comparison with experienced clinicians using physical examination alone. Teach Learn Med.25:84-8.

Patel SG, Benninger B, Mirjalili SA (2017). Integrating ultrasound into modern medical curricula. Clin Anat. 30:452-460.

Patten D (2015). Using ultrasound to teach anatomy in the undergraduate medical curriculum: an evaluation of the experiences of tutors and medical students. Ultrasound 23;18-28

Rao S, van Holsbeeck L, Musial JL, Parker A, Bouffard JA, Bridge P, Jackson M, Dulchavsky SA (2008). A pilot study of comprehensive ultrasound education at the Wayne State University School of Medicine: a pioneer year review. J Ultrasound Med. 27:745-9.

Rempell JS, Saldana F, DiSalvo D, Kumar N, Stone MB, Chan W et al (2016). Pilot Point-of-Care Ultrasound Curriculum at Harvard Medical School: Early Experience. West J Emerg Med. 17:734-740.

Siegel-Richman Y, Kendall J (2017). Establishing an Ultrasound Curriculum in Undergraduate Medical Education: How Much Time Does It Take? J Ultrasound Med. Sep 6. doi: 10.1002/jum.14371. [Epub ahead of print]

So S, Patel RM, Orebaugh SL. (2017). Ultrasound imaging in medical student education: impact on learning anatomy and physical diagnosis. Anat Sci Educ 10:176-189

Solomon SD, Saldana F (2014). Point of care ultrasound in medical education – stop listening and look. NEJM 370:1083-1085

Steinmetz P, Dobrescu O, Oleskevich et al. (2016). Bedside ultrasound education in Canadian Medical schools: a national survey. Can Med Edu J 7:78-86

Stone-McLean J, Metcalfe B, Sheppard G, Murphy J, Black H, McCarthy H, Dubrowski A (2017). Developing an Undergraduate Ultrasound Curriculum: A Needs Assessment. Cureus 28;9:e1720.

Sudoł-Szopińska I, Schueller-Weidekamm, Plagou A, Teh J. (2017). Ultrasound in Arthritis. Radiol Clin North Am. 55:985-996.

Swamy M and Searle RF. (2012). Anatomy teaching with portable ultrasound to medical students BMC Medical Education 12,99

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

Tarique U, Tang B, Singh M, Kulasegaram KM, Ailon J (2018). Ultrasound Curricula in Undergraduate Medical Education: A Scoping Review. J Ultrasound Med. 37(1):69-82.

Tshibwabwa ET and Groves HM (2005). Integration of ultrasound in the education programme in anatomy Med Educ; 39:1148

Turner EE, Fox JC, Rosen M, Allen A, Rosen S, Anderson C (2015). Implementation and assessment of a curriculum for bedside ultrasound training. J Ultrasound Med 34:823-828

Walrod BJ, Schroeder A, Conroy MJ, Boucher LC, Bockbrader M, Way DP, McCamey KL, Hartz CA, Jonesco MA, Bahner DP. (2018). Does Ultrasound-Enhanced Instruction of Musculoskeletal Anatomy Improve Physical Examination Skills of First-Year Medical Students? J Ultrasound Med. 37:225-232.

Weerasinghe A, Tung P, Okereke C (2017). Medical student Ultra Sound Training – a MUST. 6, Paper No: 29 , DOI: https://doi.org/10.15694/mep.2017.000091

Wittenberg M (2014). Will ultrasound scanners replace the stethoscope? BMJ. 29; 348
Wong I, Jayatilleke T, Kendall R, Atkinson P. (2011). Feasibility of a focused ultrasound training programme for medical undergraduate students. Clin Teach. 8:3–7.

Practice points

- Defining clinical end-points can act as a focus for developing the strands through the curriculum.
- Choosing a relatively small ultrasound topic to start with which is relevant to clinical practice and potentially less controversial e.g. venous access,, can assist in

introducing the concept to colleagues and improve acceptance of the project

- From the start, develop a multi-disciplinary team of educators and curriculum developers, administrators, academics and clinicians from both the university and clinical arena.
- Continuously evaluate the course in order to improve
- Create partnerships with the ultrasound companies in order to receive on-going support.

Notes on contributors

Dr Richard Wakefield, BM, MD, PGCE, FRCP (UK) is a Senior Lecturer and Honorary Consultant in Rheumatology, Leeds Institute of Rheumatic and Musculoskeletal Medicine, University of Leeds, UK

Dr Asoka Weerasinghe, MBBS, MRCS, MSc (Medical Ultrasound) FRCEM, Department of Emergency Medicine Dewsbury and District Hospital, Mid Yorkshire Hospitals NHS Trust, UK

Dr Patrick Tung, MBChB, FRCEM, PGCert (Medical Ultrasound) is a Consultant in Emergency Medicine, Department of Emergency Medicine Dewsbury and District Hospital, Mid Yorkshire Hospitals NHS Trust, UK

Ms Laura Smith, RN is Head of Clinical Skills Education, Leeds Institute of Medical Education, University of Leeds, UK

Dr James Pickering, BSc (Hons), PhD, PGCLTHE, SFHEA, NTF is Associate Professor of Anatomy in the Division of Anatomy, Leeds Institute of Medical Education, University of Leeds, UK

Dr Tendekayi Msimanga, MBChB, MRCP, BSE(Transthoracic) is a Consultant in Acute and General Medicine, Mid Yorkshire NHS Trust, Honorary Senior Lecturer, University of Leeds, UK

Dr Mohit Arora, MBBS, MRCEM, FRCEM, PG Cert Medical Ultrasound Consultant Emergency Medicine, Leeds Teaching Hospitals NHS Trust, UK

Dr Karen Flood MBBS, FRCR is a Consultant Vascular Interventional Radiologist at Leeds Teaching Hospitals NHS Trust, UK.

Dr Pawan Gupta, MD, FRCA is a Consultant and Honorary Associate Professor in Anaesthesia, Leeds Teaching Hospitals NHS Trust, UK

Dr Susan Bickerdike, PhD Chemical Engineering, is eLearning Project Manager, Leeds Institute of Medical Education, University of Leeds, UK

Dr James McLaughlan, MPhys PhD School of Electronic and Electrical Engineering / Leeds Institute of Cancer and Pathology, University of Leeds, UK

Dr Ashley Uttley, MBBS, BSc, FRCR, is a Radiology Registrar, Leeds Teaching Hospitals NHS Trust, UK

Mrs Jean Wilson, is a Senior Ultrasound Lecturer (retd.), School of Medicine, University of Leeds, UK

Dr Tony Evans BSc, MSc, PhD is a Senior Lecturer in Medical Physics (retd.) Leeds Institute of Cardiovascular and Metabolic Medicine, University of Leeds, UK

Dr Stephen Wolstenhulme, BSc, PhD is an Advanced Practitioner Radiographer (Sonographer), the Leeds Teaching Hospitals NHS Trust and Lecturer/Clinical Educator, the Faculty of Health Sciences, University of Malta

Professor Trudie E Roberts, BSc, MB ChB, PhD, FRCP, FHEA, FAoME, is Director of the Leeds Institute of Medical Education, University of Leeds, UK