The Role of Radiology in Medical Student Education

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MB ChB, MRCS, FRCR, MSc (Research)

Submitted in fulfilment of the requirements for the

Degree of

PhD by Published Works

School of Medicine, Dentistry and Nursing

College of Medical, Veterinary and Life Science

Graduate School

University of Glasgow

2022

Acknowledgements

I am grateful to Professor P J O'Dwyer for his guidance, encouragement, robust discussions and support – without whom this thesis could not be completed.

My sincere gratitude to my Radiology colleagues across Scotland who gave of their time to help us understand how much radiologists contribute towards educating medical students.

I would like to thank medical school colleagues across Scotland who shared their time and data generously to allow a truly national, collaborative perspective of undergraduate Radiology education and assessment across Scotland.

Professor IC McManus and his 187 co-authors from Medical Student Investigators Collaborative (MSICo) for their monumental task of coding every time-tabled activity for each UK medical school, peeling back an almost impenetrable curriculum curtain, if only for a moment in time, and granting us access to that invaluable data.

Professor JA Gracie and Ms Suzanne McDowall for their patience, support and assistance in acquiring and understanding Glasgow's data.

This thesis is dedicated to Peadar and my students – past, present and future.

Table of Contents

Summary

Introduction

Radiologists have been espousing the merit of Radiology in teaching medical students for almost a hundred years. Yet, despite all the above, the role of radiology in medical student education is poorly defined and understood.

With technological advances in CT, MRI, ultrasound and interventional radiology, Radiology not only details human anatomy and pathology, but is central to the practice of modern clinical medicine.

The aims of this thesis were to

(1) Perform a literature review of the role of radiology in teaching medical students and its evolution through time.
(2) Assess the current role of Radiologists in undergraduate medical education.
(3) Evaluate and quantify the hours allocated to Radiology teaching in medical schools and to determine if they can fulfil the requirements expected of Clinician Teachers of other disciplines and the upcoming GMC Medical Licensing Assessment.
(4) Examine how frequently radiologic images features in summative assessments in Medical Schools.
(5) Determine if small group teaching in Radiology impacted Anatomy scores in summative end of year assessment.
(6) Explore the potential role of Radiology in teaching Clinical Reasoning to Medical Students.

Methods

MEDLINE (Ovid), Embase (Ovid), the Cochrane Database of Systematic Reviews and CENTRAL (Wiley Interscience) and the Education Resources Information Centre and British Education Index (EBSCOhost) databases were searched up to 2018 for relevant articles for the literature review to evaluate the role of Radiology in undergraduate medical education.

A national online survey of Consultant Radiologists was performed in November 2019.

Raw data from Analysis of Teaching of Medical Schools survey (2020) was evaluated to determine the hours allocated to radiology. A survey evaluating what University Lead Clinician Teachers consider essential Radiology knowledge for medical students was performed in 2020.

Data (up to 2019) from all Scottish medical schools' summative written and clinical assessments was collected and analysed to determine how frequently Radiologic images appeared in written and OSCE examinations.

Anonymised end of year summative total and anatomy scores over 5 years were retrospectively collected and analysed to determine if small group teaching improved Anatomy scores.

Interactive online learning resource was produced together with a student. The materials were built around radiology images, to teach students' clinical reasoning as well as the central role of radiology in acute clinical scenarios through gamification of learning.

Results

377 records were included in the review spanning 1925 – 2019. There was a 100 fold increase in rate of publication over time. The vast majority (60%) of publications were expositions ("how we teach") and surveys, with few truly experimental articles. Radiology was involved in both clinical (63%) and pre-clinical (Anatomy) teaching, but almost half of Anatomic Radiology teaching was conducted without a Radiologist's input. Compulsory Radiology blocks / clerkships were offered infrequently (35%).

102 responses were collected from the online survey, representing 34% of Consultant Radiologists in Scotland. All agreed Radiology should be taught to medical students, with over 70% currently teaching. The most common barrier cited to teaching was the lack of time, with 76% of those who do not teach expressing a desire to do so. Median time spent teaching medical students was 10 hours/year.

Medical students in Scottish Universities were allocated 59 hours in Radiology (0.3%) out of a total 19,325 hours of time tabled teaching. Hospital based radiology teaching was variable and ranged from 0 – 31 hours. Almost half (15/31) of University Lead Clinician Teachers felt there was insufficient radiology teaching in their specialty. Of the 30 conditions included in the GMC MLA under Clinical Imaging, 13 were cited as important by Clinician Teacher, while 23 other conditions listed by them were not included in the GMC MLA.

10, 534 MCQ and 1083 OSCE stations were included in the evaluation of Radiologic inclusion in medical schools. There was a wide variation in the number, type and timing of assessments across Scottish medical schools. There were significant differences in the number of OSCE stations and the number of MCQs set over the study period ($p<0.001$). Radiologic images were used on average 0.6 times (0 – 1.1) in each OSCE examination and 2.4 times (range 0.1 -3.7) for written assessments.

Student numbers ranged 238-290 per year. Mean Anatomy scores ranged 62-74%, compared to mean Total examination score of 62-65%. Anatomy scores were significantly higher than

Total examination scores for the study period of 2017 and 2018 [68.97 (17.32) vs 63.12(11.51) and 73.77 (17.85) vs 64.99 (10.31); p< 0.001]. Combined Anatomy scores 2017 and 2018 were significantly higher than base line years 2015 and 2016, difference of 5.50 (95% C.I 3.31-7.70; p<0.0001). No significant difference in Anatomy and Total scores was observed at baseline and post intervention years (2015, 2016 and 2019).

Radiology online learning resource has been popular and extremely well received by students. Feedback comments include : “Good thinking about how the history/presentation can change when different or new factors were added into consideration”; “Good systematic approach to learning”; “Relevant to real cases + ILOs”; “Easy to know where to improve”. Adding a student voice to the making of the material made it more relevant and student- centric.

Conclusion

Given the importance of Radiology in modern medicine, it is not surprising to find that it permeates all aspects of the medical student education and assessment. However, the hours allocated to teaching Radiology by medical schools are clearly insufficient to meet the expectations of both Clinician Teachers and the GMC. Innovative solutions combined with resource and faculty development is required to meet the need of the medical student. Collaboration between Universities, Health Boards and Radiologists is required if this is to be achieved.

Dissertation

Introduction

Radiology and Glasgow.

"A new kind of rays" was accidentally discovered by Wilhelm Röntgen on 8 November 1895[1]. Rontgen wrote to British Physicist William Thomson (Lord Kelvin of Glasgow, infamously quoted as saying initially "Xrays will prove to be a hoax" and "radio will have no future") in January 1896 to help him verify his discovery. Thomson created an x-ray machine with instructions from Röntgen, for public demonstration. Dr John MacIntyre was asked to step in for the ill Lord Kelvin by Thomson's nephew, physicist and engineer James T Bottomley, to perform the demonstration[2]. Together with Lord Blythswood, the first Xray demonstration in Scotland took place on 5 February 1896 to the Glasgow Philosophical society[3,4]. Mere weeks later, Glasgow Royal Infirmary opened the first Radiology department in the World in March 1896, with every Scottish hospital having an Xray department within the year[3,5]. The first Chest Xray and fluoroscopic video were also recorded by MacIntyre. In 1955, the Glasgow X Ray Campaign screened 70% of its population in just 5 weeks, detecting over 2000 active cases of Tuberculosis with over 5000 more cases needing surveillance. Clinical ultrasound was also first developed in Glasgow by Prof Ian Donald (Obstetrics, 1963). The first NHS funded Breast Cancer Screening Centre was opened in Glasgow in 1987.

First X ray image of Bertha Röntgen's hand by Wilhelm Röntgen, 1895.

Image courtesy of Wilhelm Röntgen, Public domain, via Wikimedia Commons.

Radiology in Medical Student Education

Just 30 years after Rontgen discovered Xrays, Dr JH Dempster (Detroit, Michigan, 1925) shared his opinion on the role of Radiology in medical student education to the Radiological Society of North America, Kansas City[6].

In it he stated "*we do not aim, especially in the undergraduate period, to produce specialists. The object of all undergraduate medical education is to give the student a view of the whole field of medicine and surgery.*" He further added that the extent radiology should be taught should be commensurate with the "*time and stress*" given the other subjects of the medical curriculum, with the exception of the practice of medicine and surgery. He quantified this time as "*one hour a week for a college year, supplemented with the examining of radiographs illustrating medical or surgical cases assigned to the student*". Dempster further exemplified the use of radiology in teaching medical students normal anatomy and physiology, using not just didactic lectures, but small group teaching for intense Xray interpretation in hospitals. He extolled the importance of correlating Xray findings with other clinical data in working up case histories, and in so doing hopefully "*lead to more intelligent cooperation and understanding*" between the physicians, surgeons and radiologists.

Interestingly, since 1927, there is seemingly sanguine acceptance of Radiology's role in teaching Anatomy throughout this period[7]. It is generally accepted that Radiology is a good way to augment and marry the pre-clinical subject with clinical imagery as well as impress upon students the clinical relevance of the topic. Around 1990, an increasing number of articles were published encouraging the use of Radiology to teach Anatomy. This may be related to the medical school trend towards an integrated, and away from cadaveric, pure Anatomy teaching of the traditional curriculum. After all the purpose of this teaching is to produce good doctors - not anatomists[8]. Radiologists deliver a quarter of anatomy teaching in some UK medical schools, while all schools in a survey used clinical imaging to teach anatomy[8,9]. This ties in with increasing reports of teaching Anatomy with radiologic images - without attending Radiologists. This despite reports suggesting merely exposing students to clinical images alone, without accompanying clinical input, was poorly received and understood[10].

While modern clinical medicine is ever more dependent on advancements made in Radiology – from ultrasound to CT to MRI and PET-CT in all specialities - the presence of Radiology in the medical student curriculum has not kept up. In fact, there has been a dramatic reduction from Dempster's day in the foot print of radiology in the medical student curriculum in many parts of the world, with many UK medical schools not having any radiology component at all! We are at a moment in time where one of the most important medical specialties, integral to almost every patient's care pathway is paradoxically disappearing from the medical school curriculum.

Evolution of Radiology and Medical Student Education - USA

Dempster's prescient work is echoed down the ages. Academics in the 1970s introduced the mini-tests and self-learning to supplement large group didactic lectures and regular small group work during compulsory clinical clerkships. Electives are mentioned, signalling the reduction of Radiology from the "main" curriculum. By the 1980s, there was a strong emphasis on "structured learning" for students on Radiology clerkships – comprising seminars with Attending (Consultant) Radiologists, immersing in reporting rooms, written instructions throughout the clerkship, daily quizzes and an end-of-clerkship test. The concept of case based learning was introduced in 1990s and the theme of stressing the importance of teaching students the appropriateness of imaging studies for patients emerged in 2000[11]. Radiology teaching moved with the trend of integrated curriculum, problem-based learning and the flipped-class room[12]. However, as recent as 2014, expositories on strategies to incorporate radiology into the curriculum, calls for compulsory clinical clerkship and radiology electives, continue to pepper the literature – suggesting continued erosion of radiology in the curriculum[13]. To combat this and to open access of Radiology teaching to students, there is increased reports of online Radiology teaching – promoting "gamification" of web-based learning and "edutainment" of the student[14]. At last count (2012), only a minority (≈25%) of medical schools in the US with compulsory radiology component in the curriculum remain. For those medical schools without compulsory radiology, electives are the only means for physical radiology exposure and only 45% students enrol for these[15]. Some programs even pay students ($20/hr) to help triage emergency imaging – suggesting rising clinical need and insufficient staff) in an effort to provide "real life" radiology exposure[16].

There is increasing use of ultrasound in teaching medical students – in anatomy and also clinical medicine, particularly in the US[8]. This reflects increasing use of portable ultrasound in the clinical setting ("non-radiologist point of care ultrasound") to deliver timely and safe patient care so much so that these new equipment have been hailed as the "modern stethoscope"[17,18]. Since 2001, the American Accreditation Council for Graduate Medical Education (ACGME) mandated that all emergency medicine residents should be trained in non-radiologist point-of-care US - vast majority of these initiatives are conducted by clinicians with no Radiologist involvement or even by commercial firms[19]. The concern regarding implementing such programs without a governance infrastructure is that it could lead to erroneous diagnoses, poor patient outcomes and health care practitioner litigation[19].

Technology was adopted early in radiology teaching, with the description of "multimedia – audio-visual video teaching machines" in 1973[20]. This proved so successful they evolved into the famous "Lucy Squires Tapes" – which were made commercially available at a nominal price to any medical school, promoting standardised teaching, self-directed learning and improved efficiency for the busy Radiology academic. These teaching resources were digitised onto computer discs / CD-ROM in the 1980-90s. One university described giving each medical students IBM laptops for use at home to replace lectures, embedded with 300 radiologic images, 7 case based videos and 50 interactive quizzes[21]. Radiology teaching started moving online circa 1999, with web based repositories of Radiologic images linked with Pathology and Clinical scenario – encouraging both passive and active learning through interactive online quizzes[22]. This quickly evolved to include web-based, automatically marked assessments and by 2013-15, a national standardised, web based, self-marking Radiology assessment is available to every medical school teaching Radiology (EXAMWeb)[23]. All these is made possible on the back of technological advances in the field of Radiology over the last few decades – converting the acquisition and storage of images from the ubiquitous Xray "wet film" to a digital format, often integrated into a networked Picture Archiving and Communication System (PACS), allowing seamless data linkage of patient records with imaging, allowing easy and safe information sharing.

The current *Alliance of Medical Student Educators in Radiology*'s (AMSER) National Medical Student Curriculum is a comprehensive document listing the framework, core topics (including

radiation safety issues, diagnostic shortlists, emergency "do not miss" findings and imaging appropriateness algorithms) as well as a wealth of curriculum resources to complement individual programs' teaching methods[24]. These span the gamut of group based conference, 1:1 teaching/shadowing, self-learning exercises, hands-on practical experiences, student presentations, informal quizzes, formal exams and games. In addition to a list of reference books, it is key to note the significant presence of teaching websites - with casefiles and teaching programs – and educational social media accounts are also included. The *American College of Radiology* (ACR) has its own recommendations. ACR, in collaboration with AMSER, has taken over the administration of the web-based standardised national Radiology assessment program (renamed STAR from EXAMWeb and REW) – which currently boasts a bank of almost 3000 questions.

Radiology and Medical Student Education – Europe and UK

Almost all European countries, with the exception of the UK and Denmark, have Radiology clinical clerkship embedded within the medical student curriculum. These range from 1 day to 24 weeks, with a median of 76 hours of radiology teaching[25]. The European Society of Radiology (ESR) publishes a Curriculum for Undergraduate Radiological Education as well as guidance on teaching the subject[26,27]. Recently it issued a statement on new approaches to undergraduate teaching in Radiology (2019). In it highlights Radiology as a ***significant*** part of undergraduate education and that electronic learning is essential asset. There is encouragement for the use of flipped classrooms and interactive sessions. In it, ESR promotes a paradigm shift towards a more holistic approach of teaching Radiology: appropriateness of imaging. Radiologists, as experts in diagnostic reasoning, are best placed to mentor students how to make clinical decisions in a student centred, problem-based and community designed approach to systemically integrating radiology to define clinical reasoning as a core goal[28].

In the UK, among the early papers was one published in 1970, wherein Prof G Smart, Professor of Medicine and Dean of Newcastle Medical School, described the integral role "*radiodiagnosis*" plays in the their curriculum – both pre-clinical and during clinical years, and expressing how much more he wished to help instead of relying "*too heavily*" on the good will and enthusiasm of consultant radiologists[29]. In it, Professor of Anatomy RJ Scothorne – latterly the Regius Professor of Anatomy at the University of Glasgow – was quoted as saying "*'I am*

sure that it is better to teach it in an integrated fashion…. encourage the students to think of radiology as another way of looking at the structural organization of the body". Yet 1981, only Bristol, Cambridge, Cardiff, Edinburgh, Liverpool, Manchester, Nottingham and Oxford have any radiology input into medical student education, with no medical student teaching in London at all[30]. The author called on the Royal College of Radiologists (RCR) to correct and lead on this issue as a matter of urgency. A further call, as recently as 2002, came for including core teaching in Radiology for medical students as soon as possible[31]. The first RCR Undergraduate Curriculum was published in 2012, linked to the General Medical Council's (GMC) Tomorrow's Doctors / Outcomes for Graduates[32-34].

While it is clear that the clinicians of today require a broad knowledge of how and when to use Radiology for the benefit of their patients, we are at a point in time when medical schools are slow to embrace and meet this need.

My thesis explores the history and reviews the literature of Radiology teaching for medical students, the current role of Radiology in medical school curricula and assessment, as well as the input of Consultant Radiologists to teaching medical students - through the lens and national perspective of Scotland.

Role of Radiology in Medical Student Education – An Overview

We performed the largest and most extensive narrative review of the literature into Radiology for medical students to date. Of 3589 records identified in the initial search, 613 full texts were assessed with 377 finally included in the study. From the first paper published in 1925 there has been a 10-fold increase in the rate of publication on the subject over the best part of a century. In the last decade of study 20.3 journal articles were published per year compared to just 0.2 during the earlier period of 1950-1959. By far and away the most common type of articles published were expository *"this is how we did it"* type articles (39%), followed by surveys. Only 13% were true experimental papers with adequate control for internal validity, randomly assigned test and control groups, pre and post test control group design. This in part reflects the difficulty and lack of resource into conducting educational research[35].

The literature is dominated by authors and institutions from the USA, making up 60% of the articles and almost quarter of all articles on the subject were published in *Academic Radiology* (despite only starting in 1994). European academics contributed just over a fifth of the articles, with the UK contributing 41% of those. The majority of first authors were male (62%) radiologists (70%), with gender parity (47%) almost reached in the last decade.

While almost 2/3 of articles involved radiology in clinical education, only 35% of medical schools were described as offering compulsory Radiology clerkships (clinical rotations). Pre-clinical Radiology is mainly in the context of teaching Anatomy – with a persistent trend of anatomists teaching without any Radiologist input (43%) observed from 1990.

Specific point of care ultrasound (POCUS) is standard practice in many specialties in Europe eg Orthopaedics (joints and muscle), Obstetrics and Gynaecology (fetus, reproductive organs) and Cardiology (echocardiogram). There has been a steep rise in use of POCUS in USA over the last 10 years[36]. Papers on teaching medical students ultrasound constituted 8% of articles in our study and almost a third did not include Radiology input.

Since our review, there has been updated guidelines by several bodies on how to teach Radiology as well as on the issue of "point of care" bedside ultrasound education and

governance[28,37,38]. More recently, articles on Radiology teaching during covid-19 pandemic have also appeared. These continue to advocate and demonstrate the move of teaching (and learning) medicine through Radiology via active, interactive, online methodology and away from the passive “sit and watch me” clinical clerkships/blocks or even lecture style of teaching[39-43].

Role of Radiology in Medical Student Education – Position in Scotland

Data pertinent to the 4 larger Scottish medical schools from McManus et al's dataset, obtained through Freedom of Information request, was acquired. Information on how much radiology teaching across all years in each Schools was extracted. This demonstrated that Radiology was allocated 59 (0.3%) out of a total of 19, 325 hours of time tabled teaching in Scottish Medical Schools. This is against the backdrop of Clinical Radiology having 30 conditions - the 7th highest number of all the medical specialties - listed against it in the GMC MLA Content Map[44].

Concurrently, we performed the first longitudinal study to quantify the use of Radiologic images in summative written assessments (3 years) and OSCEs (5 years) in Scottish medical schools. 10, 534 multiple choice questions (MCQ) and 1083 OSCE stations were included in this study. We demonstrated wide variation in the way assessments are conducted across all Schools in terms of frequency of assessments, types of assessments, number of MCQs as well as stations included in OSCEs. While Radiologic images were used relatively infrequently (average of 0.6 times per OSCE and 2.4 times per written assessment), they were included in every written assessment.

We conducted the first national survey to evaluate the role of consultant Radiologists in teaching Medical students. One hundred and two responses – 34% of all Scottish Radiology Consultants – from 14 health boards were received. All respondents agreed Radiology teaching should be taught to medical students, with over 70% contributing towards this teaching. 76% of those who did not would like to teach. Scottish Radiologists delivered a median of 10 hours (IQR 0-22 hours) of teaching a year to medical students. This is a large drop from previously reported UK (44-112 hours) and European (76 hours) median teaching hours in 2011. The main barrier to teaching was not having enough time. Indeed, most teaching by Radiologists take place during Supporting Professional Activities (SPA), Direct Clinical Care (DCC) or Study Leave. More Radiologists teach in their own time for free, than people with dedicated teaching time in their job plan. Although this is not significant ($p=0.124$), it is nonetheless remarkable given the acknowledged pressure of skyrocketing demand in clinical work. Further, 1 in 3

consultant Radiologist post lie vacant and management has reduced SPA allocation to less than half its previous level in consultant job plans in the last 11 years[45].

We invited all Scottish medical schools to participate in a survey to understand how Lead Clinician Teachers (who determine what their students are taught) feel about including Radiology in the medical student curriculum and what should be included. Thirty-one responses from two of Scotland's larger medical schools (Edinburgh and Glasgow) from 18 specialties were received. 97% of respondents agreed Radiology is important for medical students in their own speciality and for 87%, Radiology is used frequently clinically in their speciality. 48% (n=15) stated there was insufficient Radiology teaching in their speciality, while 77% of Lead Clinician Teachers stated they taught medical students Radiology relevant to their speciality themselves. When asked what skills and knowledge graduating medical students should have regarding Radiology in their speciality – there was discordance between the response from Lead Clinician Teachers and those listed in the GMC MLA Content Map. While there was 43% (n=13) agreement in conditions between MLA content map and Clinician Teachers, there were 23 additional items listed by Clinician Teachers as essential knowledge not included in the MLA content map. The most frequently cited knowledge/skill Clinician Teachers felt was important for graduating medical students to master are how to read a CXR and what imaging tests to request/indications for tests/when not to image patients.

Role of Radiology in Teaching Anatomy

We evaluated anonymised Anatomy and Total scores for first year medical students' end of year summative examination over a 5 year period. Using the first year as a baseline (2015), we examined the impact small group teaching in Radiology (2017, 2018) – embedded within existing Anatomy teaching in the laboratory (no additional hours, just additional resource) – had on students' end of year summative Anatomy and Total scores. While no difference was observed on Total scores over the study period, the mean Anatomy score was significantly higher during the two years where students experienced Radiology small group teaching ($p<0.001$). This effect was lost when Radiology teaching ceased.

This is the first study to objectively demonstrate Radiology small group teaching is feasible and it improved assessment outcome for medical students in Anatomy.

Role of Radiology in Teaching Clinical Reasoning

Clinical Reasoning has been linked with Patient Safety and is now mandated by the GMC to be included explicitly in the medical school curriculum[34]. While it is ubiquitous to how doctors perform their job and arrive at the diagnosis, there is as yet no agreement on exactly how best to teach this important subject. A consensus statement on the teaching of clinical reasoning to medical students was published by the UK Clinical Reasoning in Medical Education Group (CreME)[46]. They identified 30 consensus ideas that were grouped into five domains: (1) clinical reasoning concepts, (2) history and physical examination, (3) choosing and interpreting diagnostic tests, (4) problem identification and management, and (5) shared decision making. Their literature review demonstrated a lack of effectiveness for teaching the general thinking processes involved in clinical reasoning, whereas specific teaching strategies aimed at building knowledge and understanding led to improvements.

We present our initial experience of using Radiology together with computing software to produce an online, interactive learning resource to teach Clinical Reasoning to medical students. It specifically addresses choosing and interpreting diagnostic tests as well as problem identification and management – centred around the entire CT brain series for each patient. Each case take approximately 15 minutes to complete, concluding with 3 reflective questions and key learning points to consolidate the learning.

This has been used to teach students attending University Hospital Hairmyres as well as those attending Neurology Speciality block to overwhelming good response. It is a proof of concept of feasibility and potential scalability. Radiology should be at the centre of teaching clinical reasoning to medical students. It can be harnessed to teach clinical reasoning in a fun, interactive way without excessive cognitive load. The following figures illustrate a typical case example we produced for students.

Neuro 3

Resources

Mr X (78Y)

Brought in by Ambulance

Clinical History

Physical Examination

Neuro 3

Resources

Physical Findings & Examination

- Pulse 75 BP 156/86 Oxygen Sat : 99%
  Temp 36.8 BM 6.2

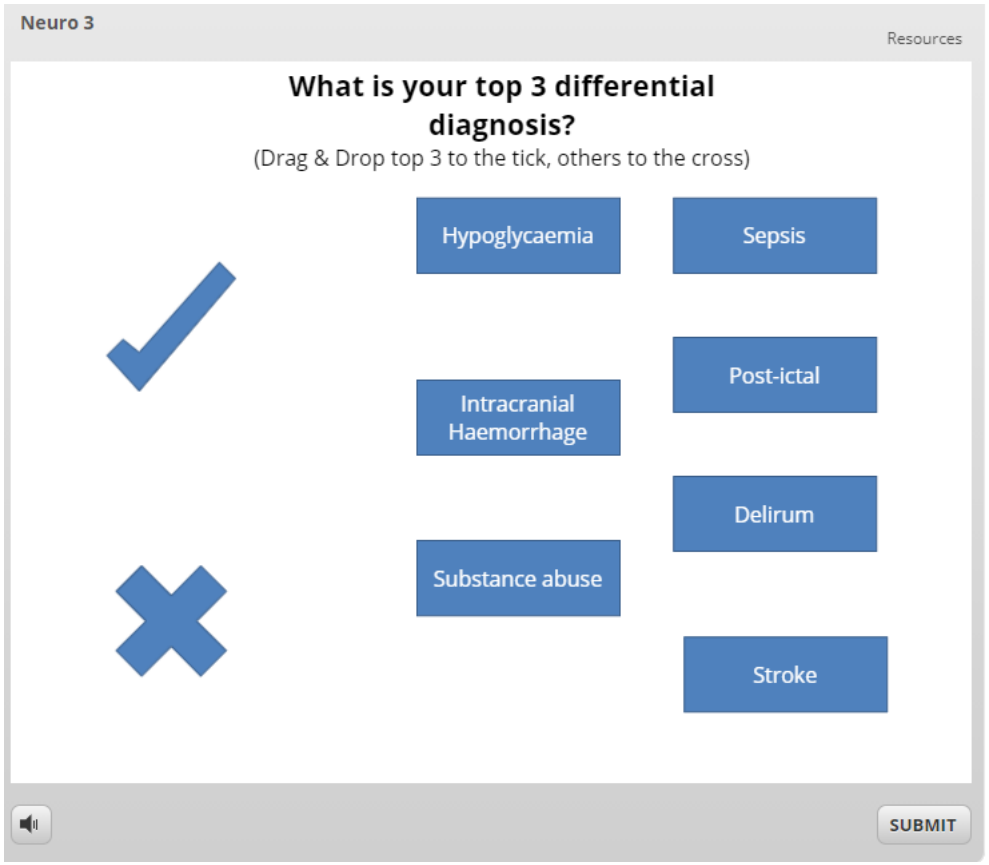
Neurological Exam – carried out but patient not completely compliant

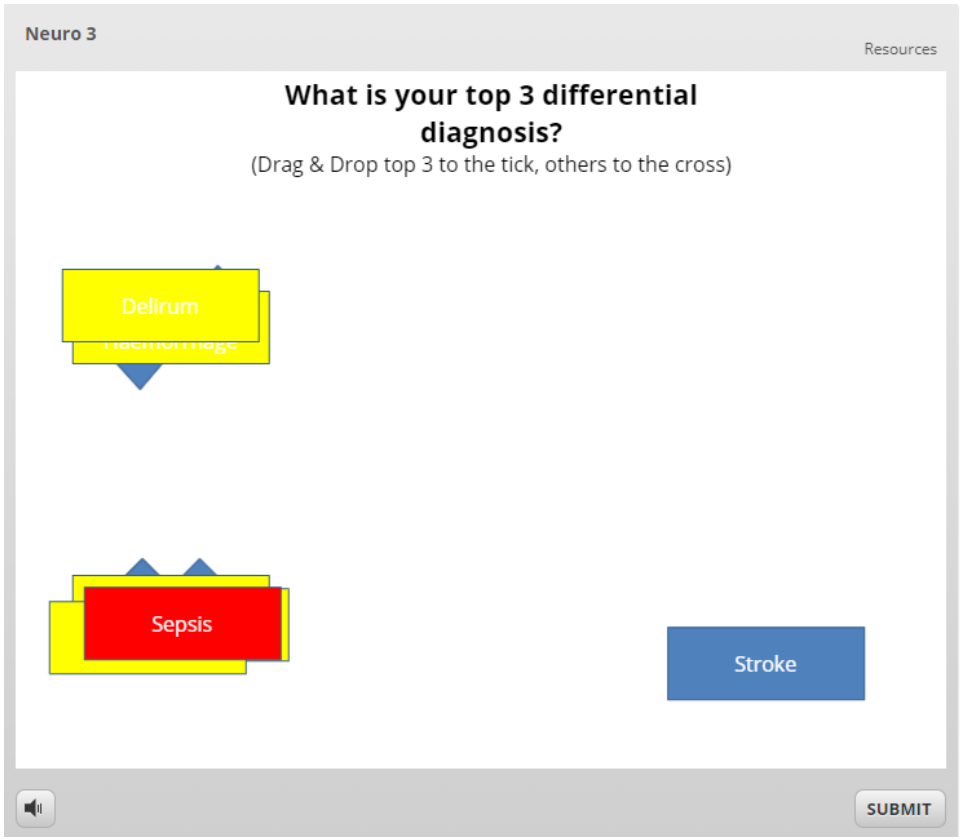
- Tone: normal
- Power: did not follow instructions
- Sensation: reduced in left leg, normal otherwise

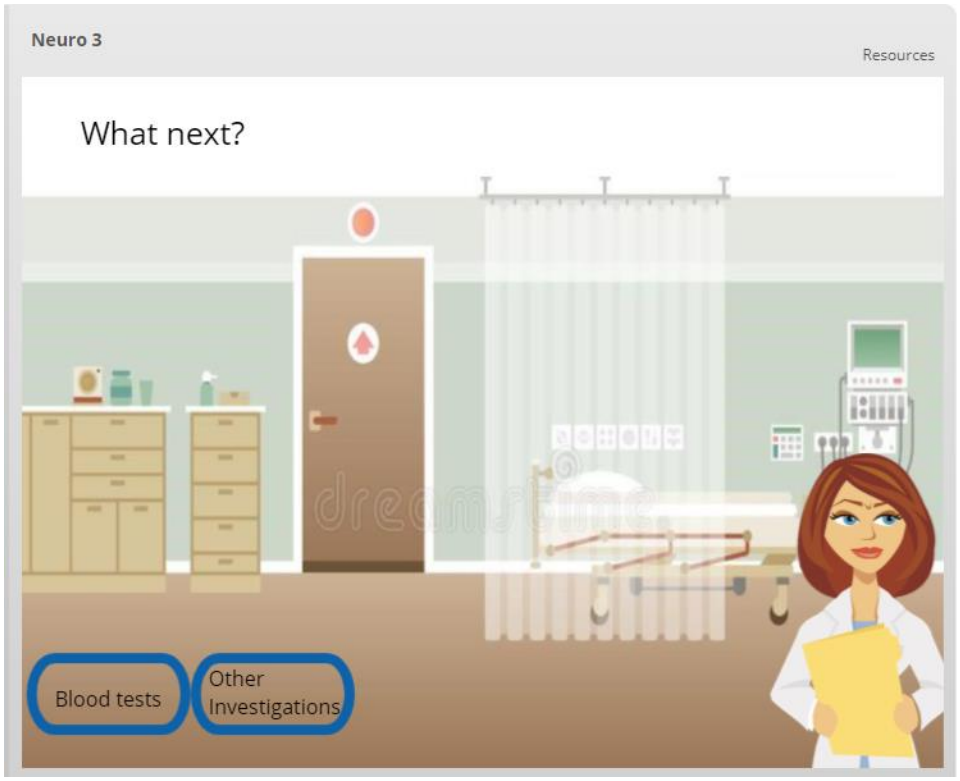
What is the patient's GCS Score?

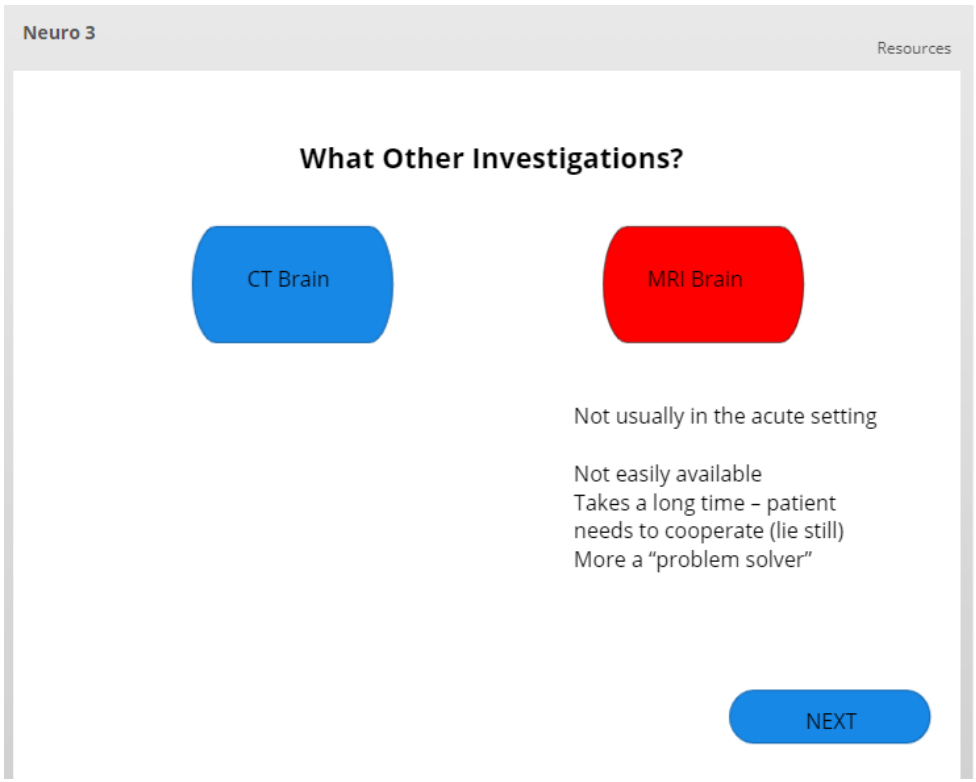
15 **14** **10**

Next


Neuro 3
Resources
What is your top 3 differential diagnosis?
(Drag & Drop top 3 to the tick, others to the cross)
Hypoglycaemia
Sepsis
Post-ictal
Intracranial Haemorrhage
Delirum
Substance abuse
Stroke
SUBMIT


Neuro 3
Resources
What is your top 3 differential diagnosis?
(Drag & Drop top 3 to the tick, others to the cross)
Delirum
Sepsis
Stroke
SUBMIT


Neuro 3
Resources
What next?
Blood tests
Other Investigations


Neuro 3
Resources
What Other Investigations?
CT Brain
MRI Brain
Not usually in the acute setting
Not easily available
Takes a long time – patient needs to cooperate (lie still)
More a "problem solver"
NEXT

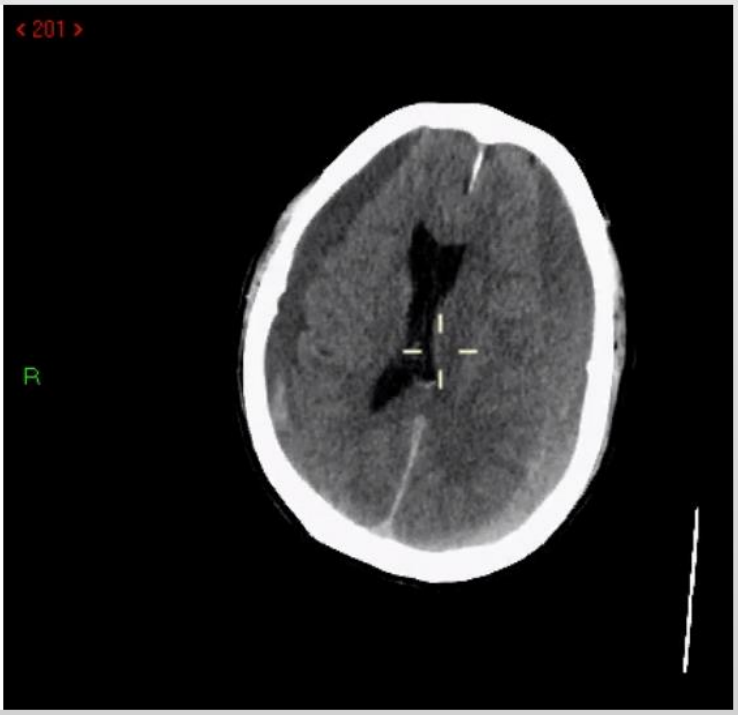
Neuro 3

Resources

CT BRAIN

* Click on image to start video. Click again to pause video.

What do you see?



Neuro 3

Resources

What Do You See?

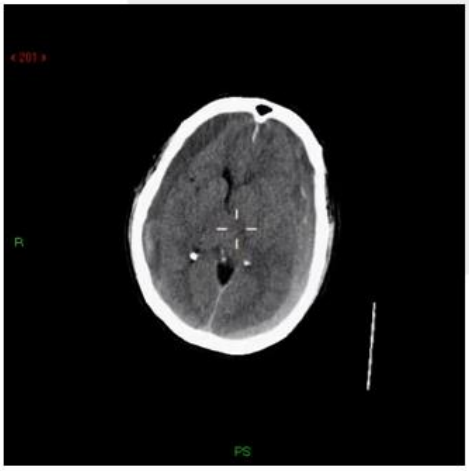
(Drag & Drop answer to the tick, rest to the cross)

Subarachnoid Haemorrhage

Hydrocephalus

Intracerebral Haemorrhage

Subdural Haemorrhage



NEXT

Neuro 3

Resources

Diagnosis : Subdural Haemorrhage

CT :

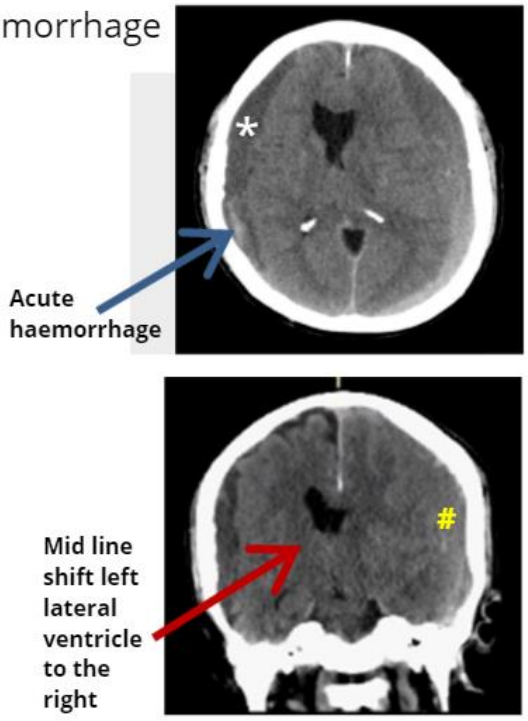
Bilateral acute on chronic subdural haematoma.

There is mid line shift.

* = Chronic subdural blood (grey)

= Newer blood

What Next?



Neuro 3

Resources

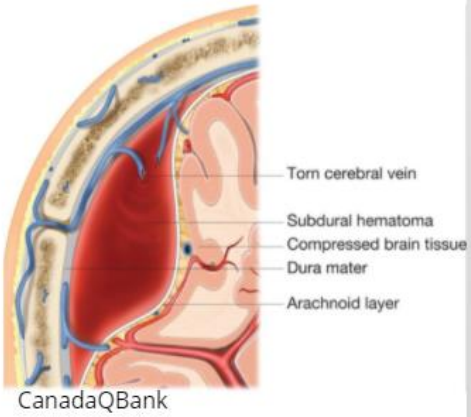
Subdural Haematoma (SDH)

Subdural haematoma is a collection of blood outside the brain.

Some are small, self limiting and resolve. Others are life threatening (by compressing the brain) and require surgery drainage.

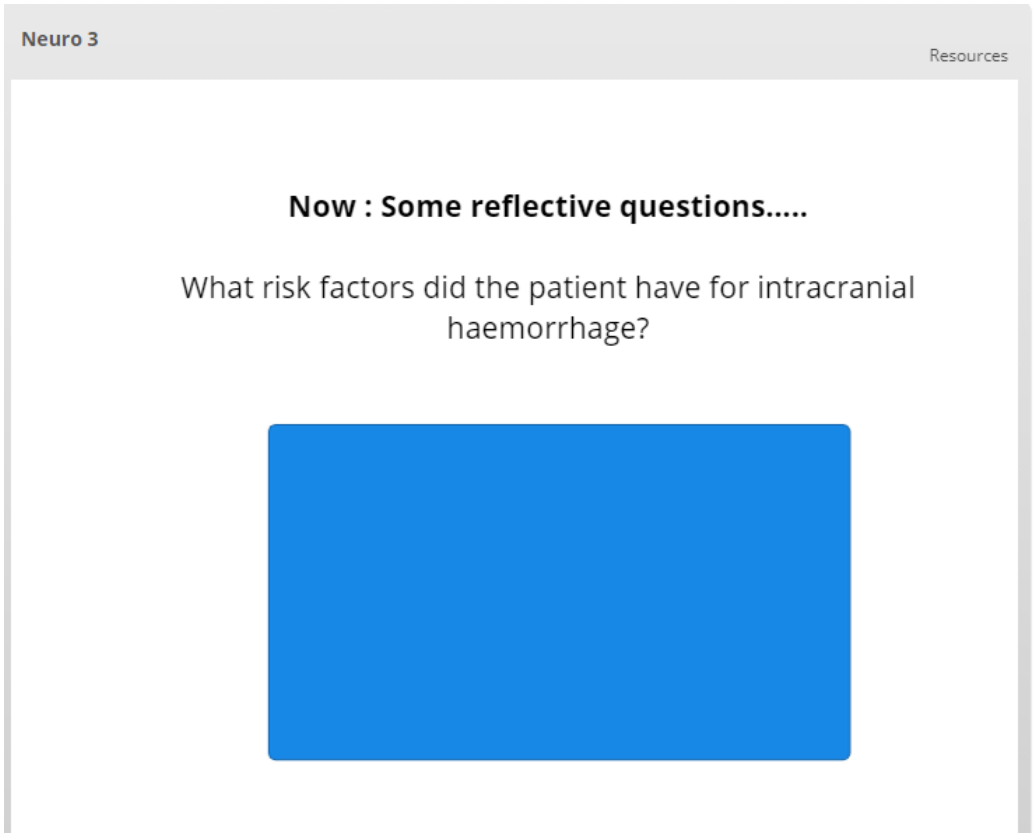
SDH is usually the result of trauma. Often in elderly patients on anticoagulants.

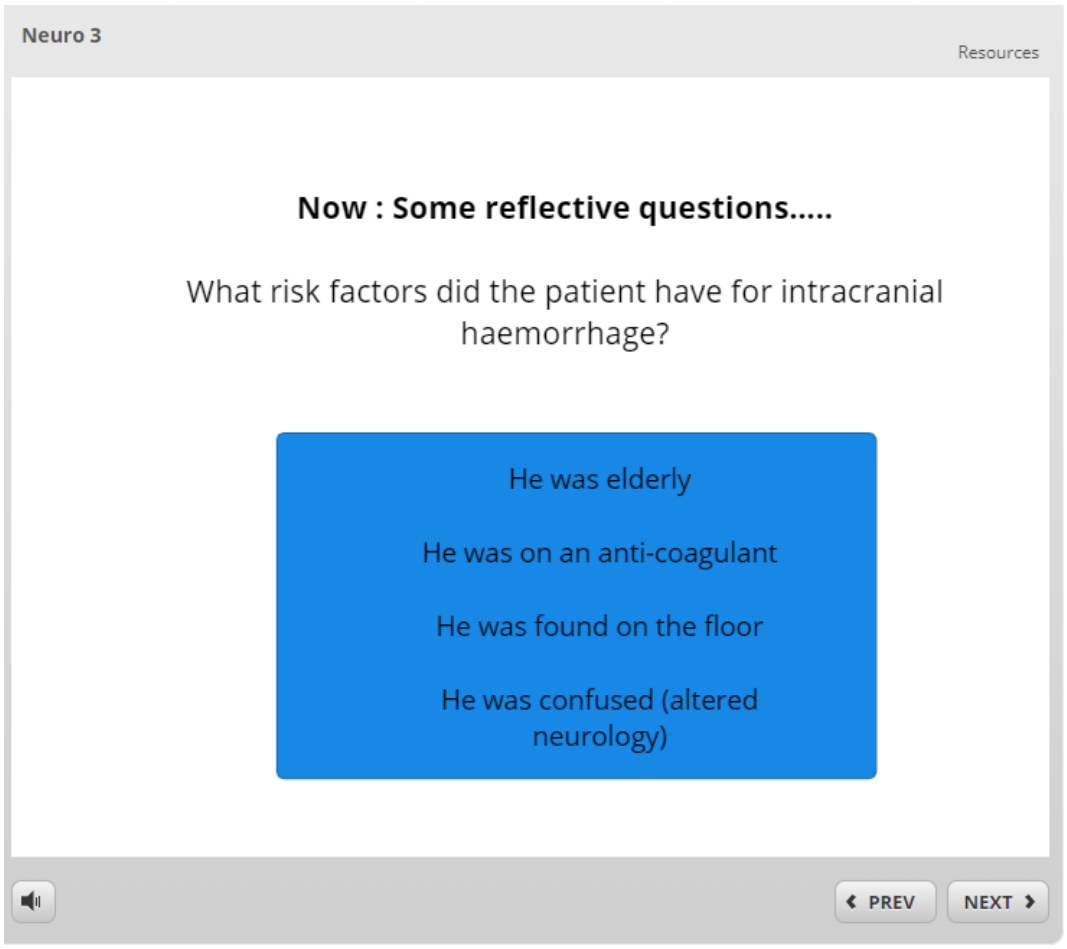
CT Brain is key diagnostic test.



CanadaQBank

Next


Neuro 3
Resources
Now : Some reflective questions.....
What risk factors did the patient have for intracranial haemorrhage?


Neuro 3
Resources
Now : Some reflective questions.....
What risk factors did the patient have for intracranial haemorrhage?
He was elderly
He was on an anti-coagulant
He was found on the floor
He was confused (altered neurology)
PREV
NEXT

Discussion

A recent editorial in JAMA concluded that diagnostic radiology contributes value in clinical workup by refining differential diagnoses formulated from history-taking, physical examination and sometimes laboratory test results, thereby decreasing the time required to initiate appropriate treatment, ultimately helping to reduce patient morbidity and mortality[47]. When optimally utilised, the value of radiology is also delivered to hospitals and health services and to the economy as a whole[47]. For example the radiologic diagnosis of acute appendicitis or pulmonary embolism can hasten appropriate treatment and obviate the need for further investigation. In appendicitis, increased utilisation of imaging is associated with significantly lower negative appendicectomy rate, with its potential post-operative complications[48]. This is particularly important during a pandemic as this also allows the approach of non-operative intervention for this condition. This is just one example on how Radiology impacts on the common conditions clinicians manage.

Medical imaging is central to modern practice. It is essential for accurate disease diagnosis in both emergency and elective settings. It is crucial for cancer diagnosis, staging and follow up. There is thus increasing clinician reliance on radiology to aid diagnosis and treatment: with complex CT and MRI examinations increasing by almost 10% annually[49]. Imaging can also increase costs and patient harm, such as over-diagnosis, anxiety, and radiation exposure associated with increased risk of cancer[50] It has been estimated that 30% or more of imaging examinations may be unnecessary, costing approximately $30 billion annually in the United States [50-52]. This is why education in Radiology for medical students is so important.

These challenges are compounded by the global shortage of radiologists – with at least 1 in 3 consultant radiologist posts unfilled in Scotland – to meet these clinical and educational needs[49]. What can we do? While there is no empirical data linking the above, could these seeming disparate issues be related and potentially solved by having adequate inclusion of Radiology teaching to medical students? These difficulties faced by Radiology today mirror and are exaggerated versions of pipeline issues faced by General Practice in the UK and we can learn much from the strategies they have adopted [53,54].

Firstly – there needs to be national and organisational advocacy for Radiology as a medical school curricula requirement with financial support and accountability[55]. Next there needs to be an acknowledged radiology curriculum and frame work from which stakeholders can work off. This needs to be supported by readily available resources, reflecting a consensus of what medical students should know. "*Provide one unified organisation responsible for medical imaging education that works with medical schools and the [appropriate Association of Medical Colleges] to set standards and competencies and increase visibility of this group*". Finally, urgent and big steps need to be taken by Government Funding bodies to address this by providing educational services to generate the supply of workforce needed to meet the demands of the health care system[56]. As the Lancet report pointed out: education and workforce development are inextricably entwined – and radiology is already proving to be the healthcare bottle neck for many health systems[47,56].

Advocacy: The ACR, RCR and ESR have Taskforce, Steering group and Sub-committee respectively within their organisations promoting medical student education, supported by medical student outreach programs. Within the UK context much more work needs to be done by RCR to engage with the Medical School Councils to include Radiology in the standard medical school curriculum. The individual enthusiastic Radiologist who tries his best under increasing clinical pressure can only have so much impact. It has been shown that increased radiology teaching is associated with having Radiology Chairs[57,58]. The inclusion of 30 conditions listed under "Clinical Imaging" by the General Medical Council (GMC) in its Medical Licensing Assessment (MLA, scheduled for students graduating in 2025) is a welcomed and strong advocate in clarifying medical schools' accountability deliver the necessary training for students to meet these assessment criteria.

Acknowledged Curriculum and Framework: ACR, ESR and RCR have all produced their own curricula. It is the medical schools' responsibility to meet these. Assessments – particularly those set at a national level – can be an effective tool to drive inclusion into the curriculum to allow student teaching and learning. Radiologists in the UK need to push their medical schools for engagement, to enable the schools and students to meet the criteria set out by and excel in the GMC MLA.

Readily Available Radiology Teaching - Learning Resource: AMSER and many Radiology Departments have led the literature with "how to teach" expositories. Learned articles on the role of Radiology in medical student education is dominated by academics from the USA, responsible for around 60% of all output. It has been reported that the rate of publications relating to the role of radiology in medical student education has increased 100 fold[59]. This currently sits at an average of 20 articles per year – a paltry figure compared to thousands of Radiology articles published annually, 481 by European Journal of Radiology and 350 by Radiology in 2020 alone. However, given the oft use "medical student curriculum is too full", many departments and individual radiology teacher have had to adapt, utilise the latest technological advancement and move their teaching and resources online – often delivered outside normal working hours just to reach the students. Juxtaposed with ever increasing clinical pressure, there is a clear need for efficiency and sharing of pooled resource. Instead of each wasting effort "reinventing the wheel", a more collegiate even global sharing of resource is required. This is already organically happening – with many (mainly American) Radiology learning resource pivoting online for storage and delivery, allowing egalitarian open access learning for students. One of the most popular of these online resources is *Radiopaedia*.

Radiologist are increasingly using social media platforms to engage students in learning radiology. This not only taps into the accessible, instant feedback, technologically driven learning preferred by millennials and Generation Z, but it also has the added advantage of increased reach to students without Radiology input at their medical schools[60,61]. One school reported 1480% increase in number of student engagement after pivoting to Facebook[62]. Others create Radiology learning games online or through apps to reach students outside of the traditional teaching environment. It is said therefore that the Radiology teacher need only to curate, instead of *create*, learning resources for student.

These "free" learning websites are indeed a boon for the radiology teacher and student alike. However, to depend entirely on them would be inappropriate. It is important to note that many of these resources are currently created to meet local needs and learning objectives – which may not be aligned to the "visiting" individual medical school or student. Further, some resources (eg *Radiopaedia*) mainly target a post-graduate clinical audience. Inequity in access

to such learning resources may raise (ethical) issues, especially if they were advantages for summative examinations[63]. It remains important and the responsibility for each medical school to actively include Radiology into its standard curriculum, define its remit and scope, have its team of Radiology teachers to incorporate appropriate teaching and resource to their medical students across the continuum of preclinical and clinical education.

The ideal scenario would be a set of nationally developed learning resources meeting all the curricular needs of a medical student that can be deployed to every medical school for each medical student nationally. It should encompass all the best teaching and learning models including lectures, flipped classrooms, small group teaching, recommended books and interactive quizzes. These could all be stored online and accessible via social media platforms – making them available at any time to suit the learner or as live sessions with feedback[28,55]. It should be further supplemented with a bank of validated assessment questions suitable for all manner of assessments used in medical schools.

Future Research Directions

Empirical data linking Radiology teaching to better student outcome require strengthening to further encourage buy in by Stakeholders to include Radiology into the curriculum. There are papers linking radiology teaching and student performance in Radiology clerkships with summative assessment results, in particular identifying students who are under review[64,65]. We will investigate if increased Radiology teaching can be related to better student outcome. We are in the process of developing and curating online teaching resource for students. We will evaluate the impact of such initiatives and uptake from students in the local, national and international context. We will also try to determine what is the best way to engage students – is it through live interactive sessions, videos of lectures, quizzes, games or more than one of the above.

We have shown Radiology improved Anatomy scores when incorporated into basic anatomy teaching for medical students. Future research could investigate the feasibility of teaching Anatomy entirely by Radiology. Such a trial could compare student assessment outcome comparing standard Anatomy, Standard Anatomy with Radiology and Radiology only, and whether more Radiology correlated to better scores.

The Radiology workforce is in crisis – and without sufficient radiologists, patient pathways bottleneck at this diagnostic juncture to the detriment of patients. We will be looking at the best way to encourage interest in a career in Radiology – does increased Radiology teaching encourage more interest in Radiology as a career? What do students know about the field, barriers or misconceptions students may perceive of the specialty and addressing those through education and collaboration nationally/internationally to improve recruitment.

With Radiology staffing shortage, the perennial question of who should be teaching students Radiology should be answered. Should only Radiologists teach Radiology or Clinicians or both? A study investigating this might compare standardised outcomes between students taught only by Radiologists, Clinicians or both to evaluate the optimal way to teach students.

Point of care ultrasound at the patient's bedside continues apace. While largely taught at post-graduate level in the UK, there has been a large movement in the medical student curriculum in the US in the last decade, with some universities handing portable ultrasounds out free to medical students – harking back to those days when students were given laptops or ipads on enrolment[66-69]. In many European countries, ultrasound examinations are predominantly performed by the treating physician of the corresponding medical discipline, such as internists, gynecologists, fetal medicine specialists, surgeons, urologists, neurologists, etc. and considered an integral part of their specialist training and daily care of patients[17,70]. This in contrast to who performs ultrasound in the UK: about 80% of the examinations are performed by trained sonographers, 19% by radiologists and only 1% by physicians of other specialties[70]. We will look to investigate the feasibility and efficacy in teaching pragmatic and focus ultrasound to "rule in" common conditions where management needs altered quickly (eg obstructed kidneys) to medical students who have opted into the COMET program. The new Community Orientated Medical Experience Track (COMET) program is an intensive experience of primary care in deprived and rural settings for medical students to encourage a future career in GP.

Unnecessary imaging contributes towards cost of healthcare as well as patient anxiety and harm. We will be investigating whether by teaching medical students about test probabilities and disease prevalence, we can improve medical students' clinical reasoning and ability to judiciously use imaging for the betterment of their patients.

References:

1. Röntgen W. "Ueber eine neue Art von Strahlen. Vorläufige Mitteilung" ("On a New Kind of Rays: Provisional Communication"), in: Aus den Sitzungsberichten der Würzburger Physik. medic. Gesellschaft Würzburg 1895;: 137–47.
2. John MacIntyre, University of Glasgow. https://universitystory.gla.ac.uk/biography/?id=WH3015&type=P
3. Guy J. Rontgen's Rays and his Scottish Disciples. Scottish Society of History of Medicine. 1995:21-26. http://sshm.ac.uk/wp-content/uploads/2013/10/PROCEEDINGS-SESSION-1994-1995-and-1995-1996.pdf.
4. Bottomley JT, Blyswood, MacIntyres J. The Rontgen X Rays or the New Photography. Proceedings of the Philosophical Society of Glasgow 1895-6. https://wellcomecollection.org/works/n45ek99q/items?canvas=1
5. Radiology. Significant Medical History. University of Glasgow. https://www.gla.ac.uk/schools/medicine/mus/ourfacilities/history/20thcentury/1948-2018/radiology/#:~:text=As%20noted%20earlier%20in%20this,Wilhelm%20Conrad%20Roentgen%20in%20late.
6. Dempster JH. The teaching of radiology to undergraduates. Radiology 1925; 4: 325–6. doi: https://doi.org/10.1148/4.4.325.
7. Bardeen CR. The use of radiology in teaching anatomy. Radiology 1927; 8: 384–6. doi: https://doi.org/10.1148/8.5.384
8. McMenamin P, McLachlan J, Wilson A, Pickering J, McBride, Evans D, Winkelmann A. *Do we really need cadavers anymore to learn anatomy in undergraduate medicine?* Medical Teacher 2018;40(10):1-1-10. https://www.researchgate.net/publication/327947982_Do_we_really_need_cadavers_anymore_to_learn_anatomy_in_undergraduate_medicine [accessed Apr 19 2021].
9. Gogalniceanu P, Fitzgerald O'Connor EF, Raftery A. Undergraduate Anatomy Teaching in the U K. Ann R Coll Surg Engl.(Suppl) 2009; 91:102–106.
10. Boon JM, Meiring JH, Richards PA. Clinical anatomy as the basis for clinical examination: development and evaluation of an Introduction to Clinical Examination in a problem-oriented medical curriculum. Clin Anat. 2002 Jan;15(1):45-50. doi: 10.1002/ca.1091.
11. Scheiner JD, Novelline RA. Radiology clerkships are necessary for teaching medical students appropriate imaging work-ups. Acad Radiol 2000; 7:40-5. 9.
12. O'Connor EE, Fried J, McNulty N, Shah P, Hogg JP, Lewis P, Zeffiro T, Agarwal V, Reddy S. Flipping Radiology Education Right Side Up. Acad Radiol. 2016 Jul;23(7):810-22. doi: 10.1016/j.acra.2016.02.011. Epub 2016 Apr 7. PMID: 27066755.
13. Naeger DM, Webb EM, Zimmerman L, Elicker BM. Strategies for incorporating radiology into early medical school curricula. J Am Coll Radiol 2014;11:74-79.
14. Grunewald M, Heckemann RA, Gebhard H, Lell M, Bautz WA. COMPARE Radiology: Creating an Interactive Web-Based Training Program for Radiology with Multimedia Authoring Software. Academic Radiology, 2003 v(10);5:543-553
15. Poot, Jeffrey D.; Hartman, Matthew S.; Daffner, Richard H. (2012). Understanding the US Medical School Requirements and Medical Students' Attitudes about Radiology Rotations. Academic Radiology, 19(3), 369–373. doi:10.1016/j.acra.2011.11.005.

16. Davis DJ, Moon M, Kennedy S, DelBasso S, Forman HP, Bokhari SA. Introducing medical students to radiology as paid emergency department triage assistants. J Am Coll Radiol. 2011 Oct;8(10):710-5. doi: 10.1016/j.jacr.2011.06.002. PMID: 21962786.
17. Celebi N, Griewatz J, Malek NP, Krieg S, Kuehnl T, Muller R, Pauluschke-Frohlich J et al. Development and implementation of a comprehensive ultrasound for undergraduate medical students – a feasibility study. BMC Med Ed 2019;19:170. http://doi.org/10.1186/s12909-019-1611-1 (Accessed 20 April 2021)
18. Chiem, A. T.; Soucy, Z.; Dinh, V. A.; Chilstrom, M.; Gharahbaghian, L.; Shah, V et al. Integration of Ultrasound in Undergraduate Medical Education at the California Medical Schools: A Discussion of Common Challenges and Strategies From the UMeCali Experience. J Ultras Med 2016;35(2):221–33. doi:10.7863/ultra.15.05006.
19. van Rijn, R.R., Stafrace, S., Arthurs, O.J. et al. Non-radiologist-performed point-of-care ultrasonography in paediatrics — European Society of Paediatric Radiology position paper. Pediatr Radiol 51, 161–167 (2021). https://doi.org/10.1007/s00247-020-04843-6.
20. Squire IF, Blotnick .1/, Becker IA: Self-Instruction In radiology for medical students. Radiology 105:651.4, Dec 73.
21. Chen MYM, Boehme JM, Schwarz DL, Liebkemann WD, Bartholmao BJ, Wolfman NT. Radiographic Anatomy: Multimedia Interactive Instructional Software on CD-ROM. AJR 1999;173:1 181-1184.
22. Zaidel M, Hopper K, lyriboz T. Interactive Web-Based Radiology Teaching File. J Dig Imag, 1999; v112(2), Suppl 1 (May) : pp 203-204
23. Lewis PJ, Chen JY, Lin DJ, McNulty NJ. Radiology ExamWeb: development and implementation of a national web-based examination system for medical students in radiology. Acad Radiol. 2013 Mar;20(3):290-6. doi: 10.1016/j.acra.2012.09.023. PMID: 23452473.
24. AMSER National Medical Student Curriculum. 2020. https://www.aur.org/-/media/Files/AUR/Affinity-Group-SIGS/AMSER/Curriculum/AMSER-National-Medical-Student-Curriculum-2020-v-2020-11-13.ashx?la=en&hash=00E92860764954FE8C8C73CE7187E6FA3D2A0A0D (accessed 10 April 2021).
25. Kourdioukova EV, Valcke M, Derese A, Verstraete KL. Analysis of radiology education in undergraduate medical doctors training in Europe. Eur J Radiol 2011; 78: 309–18. https://doi.org/10.1016/j.ejrad.2010.08.026.
26. European Society of Radiology. Curriculum for Undergraduate Radiological Education. https://www.myesr.org/media/6070. Accessed 10 April 2021.
27. European Society of Radiology. Teaching Undergraduates Radiology. https://www.myesr.org/media/188. Accessed 10 April 2021.
28. European Society of Radiology (ESR)., Oleaga, L., Dewey, M. et al. ESR statement on new approaches to undergraduate teaching in Radiology. Insights Imaging 10, 109 (2019). https://doi.org/10.1186/s13244-019-0804-9.
29. Smart G. The place of radiodiagnosis in the undergraduate medical curriculum. Proc R Soc Med. 1970 Aug;63(8):837-8. PMID: 5452246; PMCID: PMC1811906.
30. Laws JW. Teaching of diagnostic radiology in the undergraduate curriculum. Clin Radiol 1981; 32: 601–5. doi: https://doi.org/10.1016/S0009-9260(81)80312-1.

31. Afaq A, McCall J. Improving undergraduate education in radiology. Acad Radiol. 2002;9:221–223.
32. Royal College of Radiologists. Undergraduate Radiology Curriculum. (2012). https://www.rcr.ac.uk/sites/default/files/Undergraduate_Radiology_Curriculum_2012.pdf.
33. General Medical Council. Tomorrow's Doctors. 2003. https://www.educacionmedica.net/pdf/documentos/modelos/tomorrowdoc.pdf. (Accessed 11 April 2021).
34. General Medical Council. Outcomes for Graduates. 2020. https://www.gmc-uk.org/education/standards-guidance-and-curricula/standards-and-outcomes/outcomes-for-graduates/outcomes-for-graduates. (Accessed 11 April 2021).
35. Ponce OA, Maldonado NP. Educational research in the 21st century: challenges and opportunities for scientific effectiveness. International Journal of Educational Research and Innovation (IJERI) 2017: 8, 24-37.
36. Feilchenfeld, Zac; Dornan, Tim; Whitehead, Cynthia; Kuper, Ayelet (2017). Ultrasound in undergraduate medical education: a systematic and critical review. Medical Education, 51(4), 366–378. doi:10.1111/medu.13211.
37. European Society of Radiology (ESR)., Clevert, DA., Nyhsen, C. et al. Position statement and best practice recommendations on the imaging use of ultrasound from the European Society of Radiology ultrasound subcommittee. Insights Imaging 11, 115 (2020). https://doi.org/10.1186/s13244-020-00919-x
38. Prosch H, Radzina M, Dietrich CF, et al. Ultrasound Curricula of Student Education in Europe: Summary of the Experience. Ultrasound Int Open. 2020;6(1):E25-E33. doi:10.1055/a-1183-3009.
39. Lilly, John F; Verma, Neha; Jordan, Sheryl G; Oldan, Jorge D; Fordham, Lynn A; Noone, Peadar G; Beck Dallaghan, Gary L (2019). Medical student imaging case files in the cloud. The Clinical Teacher, (), tct.13059–. doi:10.1111/tct.13059
40. Gomez, Erin; Azadi, Javad; Magid, Donna (2020). Innovation Born in Isolation: Rapid Transformation of an In-Person Medical Student Radiology Elective to a Remote Learning Experience During the COVID-19 Pandemic. Academic Radiology, (), S1076633220303354–. doi:10.1016/j.acra.2020.06.001
41. Adams CC, Shih R, Peterson RG et al. The Impact of a Virtual Radiology Medical Student Rotation: Maintaining Engagement During COVID-19 Mitigation. Military Medicine, Volume 186, Issue 1-2, January-February 2021, Pages e234–e240, https://doi.org/10.1093/milmed/usaa293.
42. Wu, Yuhao; Theoret, Christina; Burbridge, Brent Edward (2020). Flipping the Passive Radiology Elective by Including Active Learning. Canadian Association of Radiologists Journal, (), 084653712095390–. doi:10.1177/0846537120953909.
43. Durfee SM, Goldenson RP, Gill RR et al. Medical Student Education Roadblock due to COVID-19: Virtual Radiology Core Clerkship to the Rescue. Acad Rad 2020; 27:1461-66.
44. General Medical Council. Medical Licensing Assessment Content Map (2019). https://www.gmc-uk.org/-/media/documents/mla-content-map-_pdf-85707770.pdf
45. Jaques H. Two thirds of newly appointed consultants in Scotland are employed on 9:1 contracts BMJ 2012; 344 :e1422 doi:10.1136/bmj.e1422.

46. Cooper N, Bartlett M, Gay S, Hammond A, Lillicrape M, Matthan J et al. Consensus statement on the content of clinical reasoning curricula in undergraduate medical education. Medical Teacher 2021, VOL. 43(2):152-9. https://doi.org/10.1080/0142159X.2020.1842343.
47. Brady, A.P., Bello, J.A., Derchi, L.E. et al. Radiology in the era of value-based healthcare: a multi-society expert statement from the ACR, CAR, ESR, IS3R, RANZCR, and RSNA. Insights Imaging 11, 136 (2020). https://doi.org/10.1186/s13244-020-00941-z.
48. Bhangu A; RIFT Study Group on behalf of the West Midlands Research Collaborative. Evaluation of appendicitis risk prediction models in adults with suspected appendicitis. Br J Surg. 2020;107(1):73-86. doi:10.1002/bjs.11440.
49. Clinical radiology UK workforce census 2019 report key findings. Royal College of Radiologists. https://www.rcr.ac.uk/system/files/publication/field_publication_files/clinical-radiology-uk-workforce-census-2019-report.pdf . (Accessed 14 April 2021.)
50. Smith-Bindman R, Kwan ML, Marlow EC, et al. Trends in Use of Medical Imaging in US Health Care Systems and in Ontario, Canada, 2000-2016. JAMA. 2019;322(9):843–856. doi:10.1001/jama.2019.11456.
51. Institute of Medicine. Best Care at Lower Cost: The Path to Continuously Learning Health Care in America. Washington, DC: Institute of Medicine; September 6, 2012.
52. Brownlee S, Chalkidou K, Doust J, et al. Evidence for overuse of medical services around the world. Lancet. 2017;390(10090):156-168. doi:10.1016/S0140-6736(16)32585-5.
53. Wass V, Gregory S. Not "just" a GP: A call to action. Br J GP 2017; 67 (657): 148-149. DOI: https://doi.org/10.3399/bjgp17X689953.
54. Gillies J, Bartlett M, Dowell J, Fairhurst K, Lawton K, Pope L, Walmsley R. The Wass report: moving forward 3 years on. Br J GP 2020; 70 (694): 228. DOI: 10.3399/bjgp20X709493.
55. Strauss CM, Webb EM, Kondo KL, Phillips AW, Naeger DM, Carico CW et al. Medical Student Radiology Education: Summary and Recommendations from a National Survey of Medical School and Radiology Department Leadership. J Am Coll Radiol 2014; 11:606-10. http://doi.org/10.1016/j.jacr.2014.01.012.
56. Frenk J, Chen L, Bhutta ZA et al. Health Professionals for a new century: transforming education to strengthen health systems in an interdependent world. The Lancet 2010:376 (9756):1923-58. https://doi.org/10.1016/S0140-6736(10)61854-5.
57. Subramaniam RM, Kim C, Scally P. Medical student radiology teaching in Australia and New Zealand. Australasian Radiology. 2007; 51(4): 358-61.
58. Gunderman RB, Alexander S, Jackson VP, Lane KA, Siddiqui AR, Tarver RD. The value of good medical student teaching: Increasing radiology residency applicants. Acad Rad 2000; 7 (11):960-4.
59. Chew C, Cannon P, O'Dwyer PJ. Radiology for medical students (1925–2018): an overview. BJR| Open. 2020. https://doi.org/10.1259/bjro.20190050.
60. Nicholas, A. (2008). Preferred learning methods of the millennial generation. https://digitalcommons.salve.edu/cgi/viewcontent.cgi?article=1017&context=fac_staff_pub.

61. Nicholas, A. (2020). Preferred learning methods of Generation Z. https://digitalcommons.salve.edu/cgi/viewcontent.cgi?article=1075&context=fac_staff_pub..
62. Zanon M, Altmayer S, Pacini GS, Guedes A, Watte G, Marchiori E, Hochhegger B. Facebook as a tool to promote radiology education: expanding from a local community of medical students to all of South America. Radiol Bras. 2018 Jul/Ago;51(4):242–247. http://dx.doi.org/10.1590/0100-3984.2017.0112.
63. Heptonstall NB, Ali T, Mankad K. Integrating Radiology and Anatomy Teaching in Medical Edicatino in the UK – The Evidence, Current Trends and Future Scope. Acad Rad 2016;23:521-6.
64. Guest A, Blane CE, Fitzgerald JT, Bowerman RA, RochesterA, Roubidoux MA. Limitations of student evaluations of curriculum. Acad Rad 1999; 6(4): 229–235. doi:10.1016/S1076-6332(99)80210-4.
65. Morag E, Lieberman G, Volkan K, Shaffer K, Novelline R, Lang EV. Clinical Competence Assessment in Radiology - Introduction of an Objective Structured Clinical Examination in the Medical School Curriculum Academic Radiology 2001; 8(1):74-81.
66. Oteri, V., Occhipinti, F., Gribaudo, G. et al. Integration of ultrasound in medical School: Effects on Physical Examination Skills of Undergraduates. Med.Sci.Educ. 30, 417–427 (2020). https://doi.org/10.1007/s40670-020-00921-4.
67. Bahner DP, Goldman E, Way D, Royall NA and Liu YT. The state of ultrasound education in U.S. medical schools: Results of a national survey. Acad Med. 2014; 89(12): 1681–1686. DOI: 10.1097/ACM.0000000000000414 [PubMed] [CrossRef] [Google Scholar]
68. So S, Patel RM and Orebaugh SL. Ultrasound imaging in medical student education: Impact on learning anatomy and physical diagnosis. Anat Sci Educ. 2017; 10(2): 176–189. DOI: 10.1002/ase.1630 [PubMed] [CrossRef] [Google Scholar].
69. https://www.mobihealthnews.com/news/north-america/uc-irvine-medical-school-gifts-butterfly-handheld-ultrasounds-its-whole-class.
70. Statement from the DEGUM board regarding the editorial entitled “Who’s Doing Your Scan? A European Perspective on Ultrasound Services”. Ultraschall Med. 2018;39(1):11–3. https://doi.org/10.1055/s-0044-100805.

Submitted Publication List

1. Chew C, Cannon P, O'Dwyer PJ. “Radiology for medical students (1925–2018): an overview”. British Journal of Radiology Open 2020, 2(1) : https://doi.org/10.1259/bjro.20190050.

2. Chew C, O'Dwyer PJ. “Undergraduate medical education: a national survey of consultant radiologists”. British Journal of Radiology 2020;93(1112):20200380. https://doi.org/10.1259/bjr.20200380.

3. Chew C, O'Dwyer PJ, Young D, Gracie JA. “Radiology teaching improves Anatomy scores for medical students.” British Journal of Radiology 2020; 93(1114):20200463. http://doi.org/10.1259/bjr.20200463.

4. Chew C, O'Dwyer PJ, Jaap A, McDowall S, Remers OJL, Williams JJZ, McPhee I, Bjelogrlic P. “Medical student assessments—frequency of radiological images used: a national study”. British Journal of Radiology Open 2020, 2(1) : https://doi.org/10.1259/bjro.20200047.

5. Chew C, O'Dwyer PJ, Sandilands E. “Radiology for medical students: Do we teach enough? A national study”. British Journal of Radiology 2021; 94(1119): 20201308. https://doi.org/10.1259/bjr.20201308.

6. Lui J, Chew C. “Clinical Reasoning and Radiology : The Untapped Potential for Medical Students.” Clinical Teacher. 2020; v17 (s1):49.