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Radiology curriculum for undergraduate medical studies—A consensus survey

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AIM: To establish an expert consensus of what, when, and how the teaching of radiology should be incorporated into the core undergraduate medical curriculum.

METHODS AND MATERIALS: This Delphi survey consisted of four iterative rounds, with feedback given at the start of each successive round in the form of the results of the previous round. The participants consisted of both radiologists and non-radiologists with significant interest and involvement in radiology and undergraduate/Foundation training. The study addressed the questions of how, where, when, and by whom radiology should be taught.

RESULTS: The number of responses in rounds 1–4 was 20, 23, 41, and 25 (25, 22, 31, and 61% response rate, respectively). There was good consensus amongst the responders on the following: radiology teaching must be delivered in conjunction with anatomy and clinical case-based teaching, if possible in the department of radiology on picture archiving and communication system (PACS) workstations, and the teaching should be delivered by a competent and credentialled individual. Case-based assessment was the most agreed method of assessment. The majority of the responders concurred that the curriculum should include general indications for commonly requested radiological investigations, consent and safety issues around radiological tests, and their basic interpretation.

CONCLUSION: The consensus points reached by the present study not only serve as directive principles for developing a more comprehensive radiology curriculum, but also places emphasis on a broader range of knowledge required to promote the best use of a department of radiology by junior doctors in an attempt to improve patient experiences and care.

Introduction

Medical graduates must be adequately trained to achieve the minimum standards of medical practice,[1,2] and educational priorities in undergraduate training must reflect this. It has been recognized that medical education has to keep pace with shifting patterns in the organization and delivery of patient care.[3] A study of quality assurance by the medical schools that was conducted by the General Medical Council (GMC; 2005–2010) reported inconsistencies and variation that raised the question of whether all graduates had the same standards of clinical competence.[4] The recently published GMC's "State of Basic Medical Education" stresses that some aspects of medical practice

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might not have been covered well enough by the existing curricula.[3] Although undergraduate medical curricula have been continuously evolving,[5] the availability of "time" on the curriculum has always been limited, a fact that was identified early in the 20th century when attempts were first made to integrate "x-ray teaching" into the undergraduate curricula.[6,7]

Medical imaging is central to the diagnosis and management of patients. Imaging demonstrates anatomy, physiology, and pathology and can be used as a powerful teaching aid. Considering its importance, radiology is under-represented in many undergraduate curricula.[8] This may result in undergraduate radiology teaching being provided on an "ad-hoc basis", which can potentially leave students with two significant problems. First, they may not be able to interpret basic imaging findings adequately and safely. Second, they may not be able to request examinations appropriately or interpret reported results.[9] These are specific competences that are recommended by the Academy of Medical Royal Colleges (AOMRC) Foundation Programme.[1]

The aim of the present study was to establish an expert consensus of what, when, and how the teaching of radiology should be incorporated into the core undergraduate medical curriculum. This was based on the opinions of a panel of experts in medical education using responses to serial questionnaires (Delphi analysis).

Methods and materials

The Delphi analysis technique was used to acquire consensus. Experts in medical and radiology education were invited to take part in a qualitative stepwise Delphi study. The study comprised of a total of four rounds.

Educational experts

Educational experts with special interest/involvement in undergraduate/early postgraduate medical training (foundation training) from across the UK were approached. Experts were at consultant level from both radiology and non-radiology (i.e., medical/surgical) specialities. Members of the Royal College of Radiologists (RCR) Education Board/Speciality advisory Committee, and the Foundation Programme Committee of the Academy of Medical Royal Colleges were consulted throughout the study (total of 79 members). To improve responses, members of an undergraduate radiology interest group (50 delegates) were additionally invited to join the study for the round 3. In the final round (5), only experts who participated in round 3 were invited ($n = 31$).

Questionnaires

Four rounds of the Delphi process were undertaken using questionnaires covering whether medical students require formal radiology training; what imaging knowledge and skills should be acquired by medical students; how radiology should be taught; who should deliver teaching; and where and when radiology teaching should occur. The main aim of rounds 3 and 4 was to achieve consensus on what specific subjects must be included in the undergraduate radiology curriculum.

Electronic questionnaires were designed using the Bristol Online Surveys tool (www.survey.bris.ac.uk). Questions were answerable in forms of single and multiple choice, and free text (Appendix A). Experts were contacted by e-mail to present the aims and details of the study with an invitation to participate. Reminders (one for rounds 1–3, two for round 4) were sent to improve the response rate. Participants were kept anonymous to each other to maintain the individuality of responses.

In the earlier rounds of the study, opinions were solicited using open questions, which were broad and general and intended to elicit informed opinion and explanation. In the further rounds, questionnaires were informed by translating the responses to the earlier questionnaires into statements.[10] The expert panel were asked to comment on and evaluate their agreement with each statement to gain a perspective on the importance of individual statements. Questionnaires from rounds 2–4 provided an anonymized summary of the responses to questionnaires 1–3. When consensus was not achieved, the opinion of the panel was re-examined in the next round of the study. Consensus took two forms: first, the extent to which each expert agreed with each statement, and second, the extent to which the experts agree with each other.[10]

Data analysis

Quantitative and qualitative methods were used to analyse the data. The level of participants' agreement to the questions was drafted on a four-point agreement scale comprising "completely agree", "mostly agree", "mostly disagree", and "completely disagree". "Neutral" was intentionally excluded, as the intention was to generate consensus based on majority. The number of "completely agree" and "mostly agree" selections were combined to provide a percentage referred to as "agreement" (selected by $\geq$65%), "limited agreement" (51–64%), and "no-agreement" ($\leq$50%). When the panel agreed or disagreed to the subject in question, this was concluded to be "consensus" to include or exclude the subject. When only limited agreement was achieved, the subject was recommended as optional.

The requirement for inclusion of each clinical subject within the curriculum was examined. Available options included: "must know" (a), "should know" (b), "could know" (c), and "not needed" (d). When over 60% of the responses were for either option (a) or (a)+(b), this subject was concluded as recommended for inclusion in the curriculum. When option (c) or (b)+(c) were selected in more than 60%, the subject was recommended as optional. Otherwise the subject was not recommended for inclusion in the curriculum.

The panel was also asked about the appropriate timing of the each subject within the course curriculum. Options were preclinical, early clinical years, and late clinical years

(i.e., pre-foundation training/internship). When neither of the options was chosen by more than 50%, two highly selected adjacent time options were selected (e.g., early and late clinical years).

Results

The total responses from experts in each round were: round 1 = 20; round 2 = 17; round 3 = 41; round 4 = 25 responses, respectively. The response rate was 25, 22, 31, and 61%. Full responses to all questions were received. Consensus (as defined by agreement or disagreement) was achieved in 94/108 (87%) of the discussion subjects. Limited agreement was observed in 14/108 (13%) of the discussion subjects.

There was agreement that radiology must be integrated into the undergraduate curriculum. The panel agreed that the main reasons for insufficient radiology training at the undergraduate level was insufficient time on the existing curriculum or on the part of the teacher (e.g., teaching not included in job plans or not remunerated).

Table 1 summarizes the general recommendations of the expert panel on the delivery of undergraduate radiology curriculum: who can teach, where teaching should be delivered, and also the assessment methods.

The panel agreed that the suitable areas for undergraduate radiology teaching were clinical environment (e.g., wards, clinics), the radiology department, or wherever picture archiving and communication system (PACS) access is available, in virtual space using online electronic learning devices, and also, in conjunction with anatomy dissection. There was limited agreement that radiology can be taught by traditional lecture courses and that dedicated radiology skills laboratories are unnecessary. It was agreed that undergraduate radiology could be taught by radiologists of any grade after first year, senior radiographers, clinical consultants, and university radiology lecturers. It was also agreed that there is no role for medical physicist-led teaching at the undergraduate level.

There was agreement that formal assessment of radiology is necessary. The panel was of the view that this could be performed using the objective structured clinical examination (OSCE) technique, and must be case-based in conjunction with other clinical specialities. There was limited agreement that written examinations were not indicated.

Tables 2 and 4 summarize the general and specific recommendations on what radiological areas should be included in the curriculum. Table 3 recommends which radiological methods should be used to teach radiological anatomy to medical students. Forty-eight clinical subjects were recommended to be included in the curriculum (Table 4). Twelve additional subjects were recommended as optional. All these clinical subjects were recommended to be included within the clinical years of the curriculum, and not during the basic medical sciences. The recommended clinical subjects were rather broad (e.g., trauma).

Table 1
Delivery and assessment of undergraduate radiology curriculum.

Subject	Level of recommendation	Level of agreement
Where should radiology teaching be delivered?		
Linked to the clinical environment and "active cases" including wards, clinics	R	A (95.3%)
Department of radiology/on PACS station	R	A (85.7%)
Personal study using online electronic learning	R	A (81%)
In conjunction with anatomy dissection	R	A (90.5%)
Special skills laboratory	O	LA (56.1%)
Who should teach radiology?		
A competent and credentialled individual	R	A (90.5%)
Consultant radiologists and senior radiology trainees	R	A (95.3%)
Radiologists of any grade after first year	R	A (76.2%)
Senior radiographers	R	A (71.5%)
Clinical consultants	R	A (71.4%)
University lecturers (radiology)	R	A (76.2%)
University lecturers (non-clinical)	N	A (71.4%)
Medical physicist	N	A (70.7%)
Options for the delivery of teaching		
Integration into the undergraduate curriculum	R	A (95.2%)
Integration with clinical teaching as part of clinical decision-making process	R	A (95.2%)
Visits to the department of radiology	R	A (95.2%)
Radiology module for a proportion of interested students	R	A (90.5%)
Using electronic learning tools (ELD)	R	A (95.7%)
Modules divided into early (anatomy, lectures), middle (skills lab) and late (imaging department) courses	R	A (71.4%)
Formal lecture course in medical school	O	LA (56.1%)
Dedicated radiology teaching environment	O	LA (58.5%)
Assessment		
Interpretation slide shows	R	A (66.7%)
OSCE based	R	A (85.7%)
In conjunction with other clinical specialities	R	A (90.4%)
Case-based studies	R	A (90.5%)
Written examinations including MCQs/EMQs, etc.	N	LA (58.5%)
Formal assessment not required	N	A (71.4%)

Level of recommendation: R = recommended; N = not recommended; O = optional. Level of agreement: <50% = no agreement; 50–64 = limited agreement (LA); >65% = agreement (A).
PACS = picture archiving and communication system; ELD = electronic learning device; MCQs = multiple choice questions; EMQs = extended matching questions.

Discussion

Both the GMC "Trainee Doctor" and the Academy of Royal Colleges "Foundation curriculum" documents emphasize the importance of core skills that are necessary for Foundation trainees. It has been particularly mentioned that a foundation doctor "must be able to ask for and interpret the results of appropriate investigations to confirm clinical findings in a timely manner". Other desired core competencies as mentioned include the applicability and limitations of investigations, relevant adverse events, and patient safety.[1,2] The undergraduate curriculum must prepare students for postgraduate training.

Table 2
Recommended general subject areas in undergraduate radiology curriculum: principals of imaging and radiological procedures.

Subject	Level of recommendation	Level of agreement
Principles/processes/safety		
Making the best use of a department of radiology	R	Agreement (95.1%)
Limitations of imaging techniques	R	Agreement (92.7%)
Principles of consent for imaging	R	Agreement (90.2%)
How to interact appropriately with imaging department	R	Agreement (90.2%)
Radiation protection legislation	R	Agreement (64%)
Contrast media reaction and their management	R	Agreement (87.8%)
Radiation hazards	R	Agreement (82.9%)
Practical radiation protection	R	Agreement (78%)
Use of PACS workstations	O	Limited agreement (58.5%)
Advanced imaging physics	N	Limited agreement (51.2%)
Radiological procedures		
Indications for various procedures	R	Agreement (95.1%)
Principles of procedures	R	Agreement (70.7%)
Seeking consent for procedures	R	Agreement (68.3%)
Technical and practical aspects of performing procedures	O	Agreement (63.4%)

Level of recommendation: R = recommended; N = not recommended; O = optional. Level of agreement: <50% = no agreement; 50–64 = limited agreement; >65% = agreement. PACS = picture archiving and communication system.

Radiology is undeniably becoming more central to clinical practice but this changing clinical role has not been matched by an equivalent change in the education delivery system.[10] An editorial in the *American Journal of Roentgenology* described undergraduate radiology education as "at best, spotty".[11] Similarly, a previously published national survey of UK medical schools reported that many schools have little or no formal radiological teaching. Moreover, it found that few have a stated curriculum for radiology or specify how radiology integrates into the rest of the medical school curriculum.[12] The present authors hypothesize that having a widely accepted radiology curriculum may define the baseline educational goals and objectives on which undergraduate teaching can be organized.

The present study used the Delphi technique to reach a group consensus on what should be included in the undergraduate medical radiology curriculum. A standard Delphi technique is a structured and interactive communication forecasting method that relies on the opinion from a panel of experts.[13] In this technique, the "experts" answer questionnaires in two or more rounds. After each round, the facilitator (the "researcher") provides an anonymous summary of the experts' opinions from the previous round. The process is completed when a pre-defined stop criterion (e.g., number of rounds, achievement of consensus, stability of results) is achieved.[14]

Table 3
Techniques that may be used to teach radiological anatomy.

Technique	Level of recommendation	Level of agreement
Plain radiography	R	(A) 97.6%
Cross-sectional imaging (CT, MRI)	R	(A) 100%
Non-cross-sectional contrast-enhanced studies	R	(A) 90.2%
Ultrasound	N	(LA) 52.0%
Nuclear imaging	N	(A) 68.3%

Level of recommendation: R = recommended; N = not recommended; O = optional. Level of agreement: <50% = no agreement; 50–64 = limited agreement (LA); >65% = agreement (A).
CT, computed tomography; MRI, magnetic resonance imaging.

Compared to other group decision-making processes, there are key differences, including the use of experts in the field, anonymity of the panel, controlled feedback after each round of the study, and statistical group response.[15,16]

The main outcome of this study is a suggested radiology curriculum based on the recommendation from the expert panel. Broad but specific recommendations were made. For example, although musculoskeletal trauma radiology was recommended to be included in the curriculum, details of what fractures taught or examined were not defined. Moreover, this study does not indicate the necessary depth of knowledge for each subject, but only refers to what generally must be known by students (e.g., when to investigate; what is the radiological technique of choice in each clinical condition; and how to interpret results). The main criticism of this design is that this may result in oversimplification of a complex concept.[17,18] However, other methodical approaches that focus on detailed curriculum content (cookbook method) often result in objectives that are notoriously laborious to write and descriptions can be very long. The objectives of one American medical school's curriculum ran to 806 pages and some argue that it is the main reason that this approach had fallen from favour.[19,20] Moreover, giving broad subject headings will give universities the flexibility to design their detailed teaching programme and reach educational objectives.

The method that is used for the identification of the expert panel for a Delphi study may be a source of criticism.[13] In this study, a group of physicians, both radiologists and non-radiologists were approached who had a significant interest and involvement in undergraduate/early postgraduate medical and radiology education. As with any questionnaire-based study, recruiting and sustaining the interest of the panel of experts in this study has been a challenge. Whilst sending reminders improved the response rate, this gradually dropped towards the end of the study. The decision to invite a third group for the level 3 and 4 rounds resulted in heterogeneity of the panel throughout the course of the study. Despite this, the collective responses from the panel resulted in a consensus study. Another potential weakness of the study is that whilst the list of recommended subjects is very comprehensive, there may be a small number of clinical topics that were not discussed for inclusion or exclusion by the panel. However, if such topics are identified, decision for their inclusion may be made at a local level.

In summary, this study provided consensus recommendations on what elements of imaging should be included in undergraduate curriculum.

Table 4
Recommended model of undergraduate radiology curriculum by subject areas: what & when.

Subject	LoR	When	What
Neuroradiology			
Guidelines for emergency neuroimaging	R (92.7%)	EY (70.7%)	W (96%); C (88%)
Head injury	R (95.1%)	EY (82.9%)	W (92%); C (88%)
Headache	R (75.6%)	EY (73.2%)	W (92%); C (80%)
Stroke	R (90.2%)	EY (80.5%)	W (96%); C (80%)
Intracranial haemorrhage	R (87.8%)	EY (80.5%)	W (96%); C (76%)
Cord compression syndromes	R (90.2%)	EY (65.9%)	W (96%); C (84%)
Altered consciousness levels	R (87.8%)	EY (75.6%)	W (96%); C (68%)
A&E brain CT	R (80%)	EY/LY (88%)	W (92%); C (80%); I (76%)
Neck injury	R (80%)	EY/LY (88%)	W (92%); C (80%)
Backache	O (60%)	EY (56.1%)	W (92%); C (64%)
Brain neoplasm	O (76%)	EY/LY (97.6%)	W (80%)
Neurological infection	O (72%)	LY (60%)	W (76%)
Epilepsy	O (72%)	LY (52%)	W (72%)
Paediatric neuroimaging	N (48%)		
Less common conditions (eg. neurocutaneous syndromes)	N (63%)		
Abdominal/pelvic imaging			
Guidelines for emergent imaging	R (90.2%)	EY (51.2%)	W (96%); C (72%)
Abdominal trauma	R (90.2%)	EY (53.7%)	W (96%); C (80%)
Jaundice	R (92.7%)	EY/LY (78%)	W (96%); C (76%)
Acute abdominal pain	R (100%)	EY (76%)	W (100%); C (80%)
Abdominal distension	R (72%)	EY (68%)	W (96%); C (72%)
Change in bowel habits	R (92.7%)	EY/LY (85.4%)	W (96%); C (56%)
Colorectal cancer	R (95.1%)	EY/LY (88%)	W (92%); C (68%)
Obstruction and perforation	R (97.6%)	EY/LY (68.3%)	W (92%); C (84%); I (56%)
Urinary tract infection	R (75.6%)	EY/LY (84.5%)	W (88%); C (72%)
Haematuria	R (80.5%)	EY/LY (87.8%)	W (84%); C (72%)
Urinary retention	R (87.8%)	LY (56.1%)	W (88%); C (68%)
Renal colic	R (95.1%)	EY/LY (82.9%)	W (88%); C (84%)
Gynaecological emergencies	R (75.6%)	LY (65.9%)	W (92%); C (64%)
Testicular pathologies	R (65.9%)	LY (70.7%)	W (88%); C (72%)
Weight loss	R (65.9%)	EY/LY (56%)	W (100%); C (52%)
Anaemia	R (80.5%)	EY/LY (83%)	W (100%); C (56%)
NGT position checking	R (87.8%)	EL/LY (78.1%)	W (92%); C (80%); I (76%)
Swallowing disorders	R (63.4%)	LY (58.5%)	W (92%); C (52%)
Paediatric GI conditions	O (72.2%)	LY (75.6%)	W (88%)
Antenatal imaging	N (52%)		
Cardiac and thoracic imaging			
Guidelines for emergency thoracic imaging	R (87.8%)	LY (56.1%)	W (96%); C (60%)
Breathless patient	R (95.1%)	EY/LY (78.1%)	W (96%); C (88%); I (56%)
Chest pain	R (97.6%)	EY/LY (70.7%)	W (92%); C (68%)
Chest infection	R (100%)	EY/LY (68.3%)	W (96%); C (76%); I (56%)
Cough	R (87.8%)	EY/LY (82.9%)	W (84%); C (72%)
Congestive cardiac failure	R (100%)	EY/LY (66%)	W (92%); C (80%)
Peripheral vascular disease	R (78%)	LY (65.9%)	W (92%); C (60%)
Thoracic trauma	R (70.7%)	LY (61%)	W (96%); C (80%)
Line placement check	R (82.9%)	LY (58.5%)	W (96%); C (96%); I (80%)
Pneumothorax	R (100%)	EY/LY (75.6%)	W (92%); C (92%); I (76%)
Pleural diseases including effusion	R (87.8%)	EY/LY (87.8%)	W (88%); C (76%)
Suspected lung cancer	R (85.4%)	EY/LY (75.6%)	W (84%); C (76%)
Haemoptysis	R (87.8%)	EY/LY (87.8%)	W (88%); C (72%)
Pulmonary embolism	R (97.6%)	LY (56.1%)	W (96%); C (76%)
Deep vein thrombosis	R (90.2%)	LY (56.1%)	W (96%); C (72%)
Aortic pathologies	R (80%)	LY (80%)	W (88%); C (68%)
Valvular heart diseases	O (51.2%)	LY (63.4%)	W (76%); C (52%)
Paediatric cardiothoracic emergencies	O (87.8%)	EY/LY (70.7%)	W (94%)
Congenital heart disease	O (73.2%)	LY (70.7%)	W (56%)
Musculoskeletal imaging			
Guidelines for emergent MSK imaging	R (82.9%)	LY (56.1%)	W (96%); C (68%)
Trauma	R (87.8%)	EY/LY (70.7%)	W (92%); C (88%)
Non-accidental injury	R (78%)	LY (61%)	W (96%); C (60%)
MSK infections	R (68.3%)	EY/LY (90.3%)	W (92%); C (56%)
Metabolic bone diseases	O (53.7%)	LY (58.4%)	W (64%)
Limping child	O (82.9%)	LY (61%)	W (92%); C (56%)
Tumours	O (65.9%)	LY (65.9%)	W (76%)
Chronic arthropathies	O (85.4%)	LY (51.2%)	W (80%)

Level of recommendation (LoR): R = recommended; N = not recommended; O = optional. Level of agreement (LA): <50% = no agreement; 50–64 = limited agreement; >65% = agreement.
When: PC = preclinical years; EY = Early clinical years; LY = late clinical years.
What (what should be covered for each subject?): W = when to investigate; C = choice of radiological test modality; I = interpretation of results.

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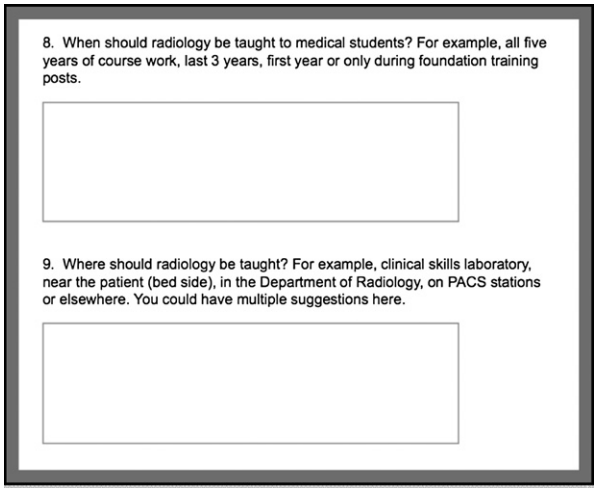
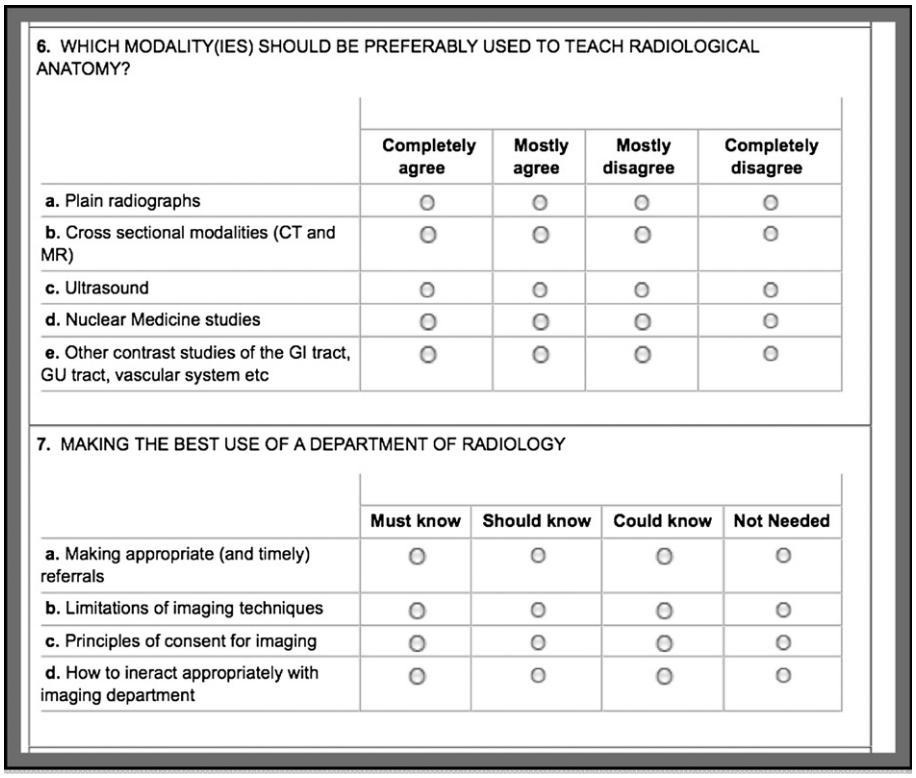
Appendix A. Examples of questions from the questionnaires of rounds 1–4.


8. When should radiology be taught to medical students? For example, all five years of course work, last 3 years, first year or only during foundation training posts.

9. Where should radiology be taught? For example, clinical skills laboratory, near the patient (bed side), in the Department of Radiology, on PACS stations or elsewhere. You could have multiple suggestions here.

(A) Screen print from the round 1 questionnaire. In this part of the study, open questions to express views of the expert panel were asked. An unlimited text box space was offered to print views.

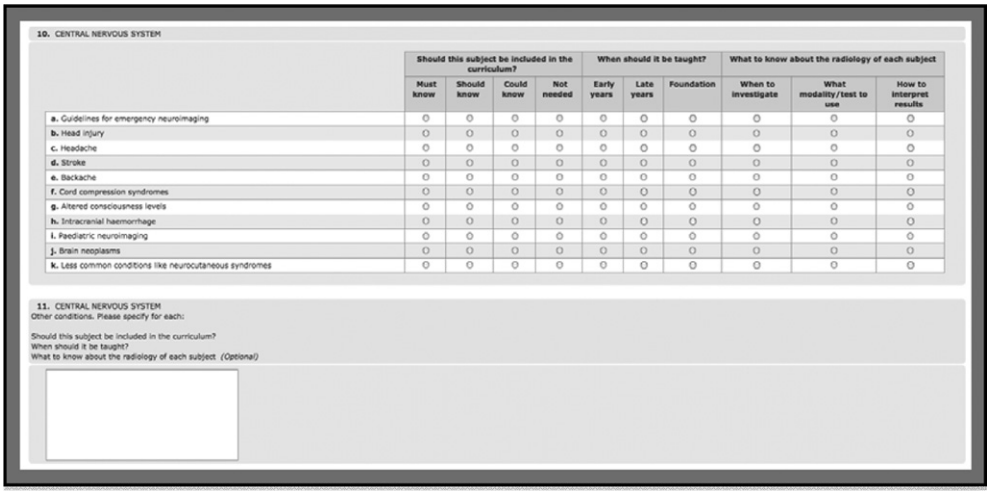

6. WHICH MODALITY(IES) SHOULD BE PREFERABLY USED TO TEACH RADIOLOGICAL ANATOMY?

	Completely agree	Mostly agree	Mostly disagree	Completely disagree
a. Plain radiographs	O	O	O	O
b. Cross sectional modalities (CT and MR)	O	O	O	O
c. Ultrasound	O	O	O	O
d. Nuclear Medicine studies	O	O	O	O
e. Other contrast studies of the GI tract, GU tract, vascular system etc	O	O	O	O

7. MAKING THE BEST USE OF A DEPARTMENT OF RADIOLOGY

	Must know	Should know	Could know	Not Needed
a. Making appropriate (and timely) referrals	O	O	O	O
b. Limitations of imaging techniques	O	O	O	O
c. Principles of consent for imaging	O	O	O	O
d. How to ineract appropriately with imaging department	O	O	O	O

(B) Screen print from the round 2 questionnaire. In this part of the study, questions were answerable in forms of single and multiple choice, and free text single.



10. CENTRAL NERVOUS SYSTEM

	Should this subject be included in the curriculum?				When should it be taught?			What to know about the radiology of each subject		
	Must know	Should know	Could know	Not needed	Early years	Late years	Foundation	When to investigate	What modality/test to use	How to interpret results
a. Guidelines for emergency neuroimaging										
b. Head injury										
c. Headache										
d. Stroke										
e. Backache										
f. Cord compression syndromes										
g. Altered consciousness levels										
h. Intracranial haemorrhage										
i. Paediatric neuroimaging										
j. Brain neoplasms										
k. Less common conditions like neurocutaneous syndromes										

11. CENTRAL NERVOUS SYSTEM
Other conditions. Please specify for each:

Should this subject be included in the curriculum?
When should it be taught?
What to know about the radiology of each subject *(Optional)*

(C) Screen print from the round 3 questionnaire. In this part of the study, questions were answerable in forms of single and multiple choice, and free text single. In round 4 (final round), no free text box was available.

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