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MEDICAL EDUCATION

Teaching medical students about radiation protection—what do they need to know?

Aim: To reach a consensus opinion on the competency-based topics in radiation protection that a UK medical student should possess at the time of graduation.
Materials and methods: A group of 69 varied, but highly-qualified experts (including 48 radiologists and 21 clinicians), took part in a three-stage e-mail-based Delphi study to establish the competencies in radiology, including knowledge and practice of radiation protection, expected of a medical student at the time of graduation. The information gathered from the first two questionnaires was refined into 57 individual clinical competencies directly relevant to radiation protection. On the final third questionnaire, the expert panel rated these on a seven-point Likert scale from ''Definitely not core'' to ''Definitely core'', with an 82% response rate.
Results: When 70% of the experts rated a competency >4, it was judged ''core''. If a competency was rated >4 but by less than 70% of the panel, it was judged ''possibly core'' due to the lack of consensus. If a competency was rated <4, it was judged ''not core''. In relation to radiation protection, 32 competencies were judged core, another 19 were considered as possible core and remaining five were considered not core.
Conclusions: This is the first UK study to establish a core curriculum in radiology in relation to radiation protection using a formal consensus method. The consensus of this study is detailed, wide-ranging, and insightful into the teaching of vital issue of radiation protection in radiology to medical students, and provides a valuable resource to enrich radiology teaching.

Introduction

Many radiological investigations involve exposing patients to significant amounts of ionizing radiation, particularly with the increasing use of CT.[1] The estimated risks of carcinogenesis are significant. A single CT of the abdomen is estimated to give an overall lifetime risk of fatal cancer of one in 2000.[2]

This worrying rise in medical exposure to ionizing radiation has been addressed by the Ionizing Radiation (Medical Exposure) Regulations (IRMER) 2000.[3] IRMER enshrines various roles, including that of the ''referrer'' and ''practitioner''. The referrer (who is commonly, but not invariably, a doctor) requests an examination. The practitioner (who must be radiologically trained and is generally a radiologist or radiographer) justifies the examination. All doctors, unlike any other healthcare group, are invariably referrers for the first part and, most probably, for all of their professional life. IRMER does not require referrers to be trained in radiation protection, but because of the inevitability of their requesting x-rays and the requirement that they follow the referral criteria, there is a consensus view that they receive the training in ionizing radiation at the undergraduate level. Practitioners now have legal responsibility to ensure each exposure is ''justified''. Unjustified exposures render the practitioner liable to criminal prosecution.

The assumption that practitioners can justify their requests is dependent on knowledge of radiation doses of common investigations and the estimated risks. Unfortunately, several studies have demonstrated that doctors have severe shortcomings in their knowledge of radiation protection.[4–7]

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In the study by Quinn et al.,[4] all responders made an underestimate of radiation dose ($p < 0.001$). The study of Shiralkar et al.[5] found that 5 and 8% of doctors respectively failed to realize that ultrasound and MRI do not entail exposure to ionizing radiation. Similarly, the study of Jacob and colleagues[6] found that 28 and 15% of doctors thought that magnetic resonance imaging (MRI) and ultrasound, respectively, involved as much radiation as a chest radiograph.

A recent study by Burney et al.[7] confirmed the well-acknowledged professional concerns that doctors of all grades and experience have incorrect knowledge of the amount of radiation involved in different radiological procedures when compared with the dose for a chest x-ray, the possible risks associated with ionizing radiation, and when, or whether, to inform a patient of such risks.

Jacob et al.[6] showed that those who had had radiation protection training had a significantly better knowledge of radiation protection matters. UK radiologists have long been involved in teaching medical students about the hazards of ionizing radiation and basic radiation protection.[8] Clearly, there is room for improvement but considering that the vast majority of medical exposure to ionizing radiation takes place in radiology departments, it seems logical for radiologists to continue to be involved in such teaching.

Although the published studies have emphasized the need to educate the next generation of doctors about radiation protection, they offer few practical suggestions about what doctors need to know. Assimilating and disseminating evidence for best educational practice would be possibly the most positive step that could be taken to facilitate change.[9] The logical first step in this would be to define the goals of medical school radiology teaching, in particular, in relation to radiation protection. This can be best achieved by developing an explicit curriculum for this in radiology teaching for medical students.

Rather than seeking to create a rigid national curriculum that must be enforced, this study was designed to create a widely-agreed set of specific goals that may be then used as a tool to develop and hopefully improve medical student radiology teaching across the UK.

Materials and methods

This study used the Delphi technique, a widely used consensus method that has been used for over 25 years for a wide variety of educational research purposes. This technique has several key characteristics that distinguish it from other group decision-making processes.[10,11] (1) Expert input. Each expert has an equal opportunity to express an opinion that is usually accorded equal importance and weight during each analysis. (2) Anonymity. Ideas and views are freely and fully elicited from geographically isolated individuals via anonymized questionnaires. (3) Iteration with controlled feedback. Communication between experts only occurs via the researcher using sequential written questionnaires. The iterative process summarizes, averages, and recycles views of the panel members yet it allows complex problems to be discussed. (4) Statistical group response. Methods of quantification are used to provide a statistical summary of the strength of panel feeling on individual items.

Expert selection

An expert panel of medical educators was recruited from across the UK. After initial recruitment of radiologists, a second group of non-radiologist clinicians were recruited to temper any potential educational zeal of radiologists and ensure wider representation. Four basic criteria for being an expert were established. He or she must be a medical doctor or medical academic, experienced (the majority were consultants or senior lecturers with at least 6 years of postgraduation experience), involved in clinical or academic practice in UK within a 3-year period before this study, and involved in teaching or education of either of medical students or junior doctors within a 3-year period before this study. Of the 155 individuals who were approached, 111 were radiologists and 44 non-radiologists. The eventual expert panel consisted of 50 radiologists and 19 non-radiologists.

Questionnaires

The whole process involved three rounds of questionnaires, which started by asking the expert group the competencies in knowledge of radiation protection expected of a newly qualified doctor. The first questionnaire was designed to generate curriculum topics in the form of clinical competencies. This produced a response from 61 experts, an 88% response rate. The second questionnaire provided feedback with statistics in the form of an anonymized summary of the responses to questionnaire one. It also refined those topics and competencies generated in round one. All ideas were clustered into three broad sections and further subsections within them. Within the subsections, the entities were reordered in order of the degree of convergence (i.e., most frequently mentioned first) and sequentially numbered. In the third round, a third questionnaire was constructed and circulated to the expert panel with the aim of achieving a consensus.

Construction of competencies

Once modified, the individual notions and ideas were rephrased as competency-based outcomes arranged in a suitably hierarchy. Each outcome had an empty box alongside it, in the column entitled ''V'' (for vote). The expert panel were instructed to denote their agreement with the outcome by annotating the box with an integer from a seven-point Likert scale, where 1 was strongly disagree, 4 was neutral, and 7 was strongly agree. At the end of third round, Fifty-seven responses (83%) were received and a decision was made to close the study. Of these 57 responses, 12 were non-radiologists (21%) and 45 were radiologists (79%).

Consensus method by Likert scale

The consensus was based on numerical thresholds derived from a seven-point Likert scale. The unique characteristic of a Likert scale is that the responses to a statement are framed on an agree—disagree continuum. Our scale was very deliberately chosen. Seven-point scales are more reliable than five-point scales, but not much more than 10-point scales.[12] An odd number allows a neutral midpoint. Each expert rated each competency, from 1 = ''strongly disagree'' to 7 = ''strongly agree'' with a score of 4 being neutral.

Outcomes were judged core if the average score was greater than 4 and over 70% of the expert panel agree with the statement and with each other. They were judged ''not core'' when either the average score was $\leq$4 on the seven-point Likert scale *or* if $<$50% of the experts rated the outcome positively (i.e. a score of 5, 6, or 7). It is known that if definition of the curriculum is too tight then it may be too restrictive, lead to confrontation, and be difficult to implement [13](Peyton, 1998). Thus, an additional equivocal category called ''possibly core'' was introduced where the average score was positive, i.e., $>$4, but there was insufficient consensus, that is, where 51—69% of the group ranked the statement positively.

Statistical analysis

The division into ''not core'', ''possibly core'' and ''core'' was performed by computing the averages and percentage of scores $>$4 for each outcome. Only one other analysis of the data was performed. This analysis was to elicit any significant difference between the scores of the radiology and non-radiologist group. Therefore, for each outcome, the data of the two groups were compared using the Mann—Whitney (U) test, considering the nature of the scale and likelihood that some of the scores may not be normally distributed.

Results

Data tabulation

Fifty-seven experts scoring 57 outcomes resulted in 3207 individual scores. The occasional outcome was left blank, but the expert panel were assiduous, scoring an average of 621 or 98.7% of the outcomes. A summary is presented in Table 1.

Radiologists versus non-radiologists

There was little difference between the scoring of radiologists and non-radiologists (Table 2). Of the 57 outcomes, only four (7.01%) were significantly different ($p < 0.05$ on U-test). One out of these four outcomes was related to radiation dose to patients (Table 3) and other three were related to radiation dose to the staff (Table 4). These four competencies have been marked in the relevant tables with corresponding p score.

Discussion

With the increasing use of medical imaging, particularly those studies involving a high radiation dose, the knowledge and legislation about radiation protection needs to be given more emphasis in the fundamental radiology teaching curriculum. This set of competencies that should be expected of a newly qualified doctor was derived by a robust consensus method with a high level of consensus. The effects of curriculum decisions being taken by individuals or small groups of monospeciality academics will no longer suffice, as the effects are too far reaching.[14] In this study, the external validity of the study was improved by the content of the

Table 1 Summary of consensus data

Number of outcomes	Core	Possibly core	Not core
57	32 (56%)	20 (35%)	5 (9%)

Table 2 Competencies the newly qualified doctor should possess: dose and risks

No	Competency		Av[a]	C[b]
1.1	**Explain that all radiographs, fluoroscopic procedures, CT, and nuclear medicine involve ionizing radiation, whereas ultrasound and MRI do not**		5.8	91
1.2	**Describe the hazards of ionizing radiation**		5.7	91
	A	**Specifically, that certain tissues are more radiosensitive than others**	5.3	77
	B	**Specifically, the concept that dose is cumulative**	5.2	75
	C	Specifically, how it interacts with living tissue to cause cancer	5	68
	D	Specifically, the time-scale of possible effects	4.7	58
	E	Specifically, that hazard should been seen as both a risk to the individual and to the population as a whole, as it is difficult to directly prove causality	4.5	54
	F	Specifically, that cataract formation is known specific risk	4.5	53
	G	*But that stated risks are only statistical estimates extrapolated from data on those exposed to very high doses (e.g. from nuclear explosions) and may vary by 2–4× of that stated*	4.3	42
	H	*And outline the historical background of cancers in early workers from the promiscuous use of x-rays*	4.1	44
1.3	**Be able to describe which common imaging procedures are low, moderate, or high dose**		5.3	80
	A	Specifically, examples of high-dose investigations include body CT and angiography	5.2	77
	B	Specifically, plain films are low dose, but some (e.g. abdomen and lumbar spine) are 20–50 times that of a chest film	5.1	67
	C	Specifically, examples of moderate dose investigations include barium studies, venograms, and IVUs	4.8	61
1.4	**Recall that typical doses for commonly performed investigations are listed in the Royal College of Radiologists' guidelines "Making the Best Use of a Department of Clinical Radiology"**		5.1	72
1.5	Explain the risk from ionizing radiation to patients		4.8	68
	A	**And that discussions of dose from complicated investigations should be left to radiologists**	5.4	79
	B	And explain this is offset by the clinical information gained	4.8	61
	C	And give comparable risks to give meaningful perspective, such as that from general anaesthetic and laparoscopy	4.6	61
	D	Such as the theoretical lifetime risk of fatal cancer for a given investigations (e.g. CXR = 1 in million, CT abdomen = 1 in 2000)	4.4	46
1.6	Explain that annual background radiation dose, though variable across the UK, is equivalent to an annual moderate dose procedure		4.8	60
1.7	Have a common dose "currency" with which to compare dose from common imaging procedures		4.6	52
	A	Such as a single chest radiograph (e.g., CT abdomen = 500 CXRs)	4.7	56
	B	*Such as a period of normal exposure background radiation (e.g., a CXR = 3 days, but CT abdomen = 4 years)*	4.5	44
	C	*Such as a period of air travel (e.g., a CXR, a flight to Spain)*	4.2	46

Core competencies listed in bold, possible core competencies are listed in standard type, and not core competencies are in italics.
[a] "Av" gives the average score (from 1–7).
[b] "C" gives the percentage of experts who rated that competency >4.

expert panel. The panel were a large representative group of senior doctors involved in education of medical students, both radiologists and non-radiologists. As a result, those competencies ranked as core or not core are eminently reasonable, and it would be easy for medical students to achieve these. Those competencies ranked as possibly core are more arguable, but this allows for local variation in depth of teaching about radiation protection.

The expert panel judged only approximately 9% of the outcomes to be not core. One of the downsides of the IRMER legislation is that radiation protection education is no longer mandatory for clinical practice. Clearly, the strength of feeling of the expert panel would reinforce both the perceived importance of this topic and the literature that suggests radiation protection should be part of a core curriculum for medical students.

By establishing the core in terms of a hierarchy of outcomes, the curriculum is readily accessible by potential students and teachers alike. Also, the possibly core section is an important aspect in achieving this accessibility by de-emphasizing a very strict divide between core and not core. The output from such consensus approaches is

Table 3 Competencies the newly qualified doctor should possess: reducing dose to patients

No.	Competency	Av[a]	C[b]
2.1	**Explain that ionizing radiation (medical exposure) regulations (IRMER) 2000 have placed certain legal responsibilities on individuals referring patients for investigations or procedures that involve exposing the patient to ionizing radiation**	6	93
	A Specifically, that all exposures should be clinically justified and such ''justification'' entails providing sufficient clinical information on a request form to ensure that the benefits of imaging outweigh the risks	6.1	95
	B Specifically, care should be taken over patient identity to avoid irradiating the wrong patient	6.1	95
	C Specifically, care should be taken to prevent unnecessary duplicate exposure	6	93
	D Specifically, any unjustified exposure is illegal and could lead to prosecution for assault	5.7	84
2.2	**Explain that the younger the patient is, the more they should be protected from ionizing radiation**	5.9	93
	A Specifically, the foetus of any pregnant patient or accompanying carer	6.4	98
	B And explain that the potentially pregnant should have a careful menstrual history elicited so as to apply the 10 and 28 day rules	6.1	91
	C And explain that particular care should be taken with those who may be pregnant and are about to undergo exposure to ionizing radiation whilst under sedation or anaesthesia (e.g. ERCP or operative cholangiogram)	5.8	82
	D Specifically, that gonad shields should be applied to younger patients ([c]$p = 0.03$)	5.1	65
	E Specifically, that breast feeding may need to be suspended after a nuclear medicine investigation	5	61
2.2	**Recognize that plain films are prone to overuse**	5.5	81
	A Specifically, lumbar spine films for backache	5.7	84
	B Specifically, preoperative chest films	5.6	82
	C Specifically, abdominal films for abdominal pain	5.4	75
	D Specifically, skull films in head injury	5.3	70
	E Specifically, repeat chest films	5.2	72
	F Specifically, cervical spine films in trauma	4.6	53
2.3	**Explain that dose to patients should be ''as low as reasonably achievable'' (the ALARA principle)**	5.5	76
	A By doing the minimum number of investigations	5.7	86
	B By using ultrasound and MRI if practical	5.4	74
	C By using low-dose investigations	5.2	70
	D By requesting the minimum number of views	5	58
	E By paying attention to dose issues during fluoroscopic activities (e.g. cardiac pacing and during orthopaedic procedures)	4.7	54

Core competencies listed in bold, possible core competencies are listed in standard type, and not core competencies are in italics.

[a] ''Av'' gives the average score (from 1–7).

[b] ''C'' gives the percentage of experts who rated that competency >4.

[c] This was the competency for which there was a significant discrepancy between two groups.

Table 4 Competencies the newly qualified doctor should possess: reducing dose to staff

No.	Competency	Av[a]	C[b]
3.1	**By not entering an x-ray room whilst in use**	6.2	95
3.2	**By explaining that all staff should take precautions, but particularly those women who are (or may be) pregnant**	6	91
3.5	**By recalling that most exposure to ionizing radiation comes from x-ray-based machines, but that patients who have recently undergone nuclear medicine investigations should be considered a source**	5.3	77
3.3	By recalling that ionizing radiation travels in straight lines ([c]$p = 0.02$)	4.8	59
	A So standing behind specific shields or walls achieves protection	**5.3**	74
	B So radiosensitive organs should be shielded appropriately (e.g. lead aprons for the torso and thyroid) ([c]$p = 0.02$)	**5.1**	72
3.6	By explaining that the inverse square law means protection can be achieved by simply increasing distance from the ionizing radiation source	4.8	60
3.2	By explaining that dose is time-dependent so that dose can be reduced by spending the minimum time possible near the source ([c]$p = 0.03$)	4.6	51

Core competencies listed in bold, possible core competencies are listed in standard type, and not core competencies are in italics.

[a] ''Av'' gives the average score (from 1–7).

[b] ''C'' gives the percentage of experts who rated that competency >4.

[c] These were the competencies for which there was a significant discrepancy between two groups.

rarely an end in itself, but dissemination and implementation of such findings are the ultimate aim.[15]

One potential difficulty in the implementation is that modern medical curricula tend to be integrated rather than disparate clusters of ''-ologies''. However, the importance of rigorous definition of content should not be glossed over.[16] Certainly, at a local level, techniques, such as curriculum mapping, can be used to integrate single speciality content into any integrated curriculum.

In conclusion, the core set of outcomes produced by the study are specifically defined in terms of clinical competencies. The core is defensible due to a high consensus level having been reached by a sufficiently large, heterogeneous, and representative expert panel as part of a methodologically robust Delphi.

This is the first UK study to address what medical students should know about radiation protection by the time of graduation. Its validity is highlighted by a large, highly qualified expert panel and robust methodology. By providing a clear, achievable curriculum, it represents a valuable resource to assist the development of education about radiation protection.

References

1. Rehani MM, Berry M. Radiation doses in computed tomography. *BMJ* 2000;**320**:593–4.
2. RCR. *Making the best use of clinical radiology services: referral guidelines*. 6th ed. London: The Royal College of Radiologists; 2007.
3. *The ionising radiation (medical exposure) regulations*. London: HMSO; 2000. Available from: http://doh.gov.uk/irmer.htm.
4. Quinn AD, Taylor CG, Sabharwal T, et al. Radiation protection awareness in non-radiologists. *Br J Radiol* 1997;**70**:102–6.
5. Shiralkar S, Rennie A, Snow M, et al. Doctor's knowledge of radiation exposure: questionnaire study. *BMJ* 2003;**327**: 371–2.
6. Jacob K, Vivian G, Steel JR. X-ray dose training: are we exposed to enough? *Clin Radiol* 2004;**59**:928–34.
7. Burney K, Miles JA. A study of the awareness of radiation doses of radiological investigations amongst clinicians. BJR Congress series. In: *Proceedings of the United Kingdom Radiological Congress (UKRC)*; 2005. 89.
8. RCR. Teaching of diagnostic radiology in the undergraduate curriculum. *Clin Radiol* 1981;**32**:601–5.
9. Harden RM, Crosby J, Davis MH. AMEE Guide No. 14: outcome-based education. Part 1 – an introduction to outcome-based education. *Med Teach* 1999;**21**:7–14.
10. Goodman CM. The Delphi technique: a critique. *J Adv Nurs* 1987;**12**:729–34.
11. Jones JMG, Hunter D. Qualitative research: consensus methods for medical and health services research. *BMJ* 1995;**311**:376–80.
12. Likert R. A technique for the measurement of attitudes. *Arch Psychol* 1932;**140**:1–55.
13. Peyton L, Peyton JWR. Curriculum and course development. In: Peyton J, editor. *Teaching and learning in medical practice*. Rickmansworth: Manticore; 1998. p. 14–39.
14. Jolly B. Charting the course. In: Rees L, Jolly B, editors. *Medical education in the millennium*. Oxford: Oxford University Press; 1998. p. 21–41.
15. Murphy MK, Black NA, Lamping DL, et al. Consensus development methods and their use in clinical guideline development. *Health Technol Assess* 1998;**2**(3).
16. Sanson-Fisher R, Rolfe I. The content of undergraduate health professional courses: a topic largely ignored? *Med Teach* 2000;**22**.

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