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The impact of educational interventions on clinicians' knowledge of radiation protection: An integrative review.

**Abstract**

***Objective:*** The aim of this review is to explore the impact of educational interventions on clinicians' knowledge of radiation protection.

***Key Findings:*** Following a comprehensive search of MEDLINE and EMBASE from 2000 to 2018, 1795 studies were identified, 8 of which met the criteria for this review. All 8 studies utilised pretest-posttest designs and involved the education of medical students or doctors. All studies reported an increase in participants' knowledge of radiation protection, 5 of which were statistically significant. In 2 studies, over half of participants stated that education received would impact on their future imaging requesting practice.

***Conclusion:*** Whilst a range of educational interventions have been shown to improve knowledge of radiation protection, there was wide variation in the study settings and type of educational programmes delivered. No studies assessed long-term knowledge retention or the impact on clinical practice. Therefore, robust research is needed to accurately measure the impact of educational programmes on knowledge of radiation protection in the UK and the implications this may have on referral practices.

***Implications for Practice:*** This review revealed that educational interventions are effective in increasing participants knowledge levels of radiation protection. It is necessary to assess and ensure that this improvement in knowledge actually translates into an impact on referral practice/behaviour. The ideal outcome being that fewer unnecessary examinations are requested and our patients are protected from a needless increased radiation burden.

**Keywords:** radiation protection, radiation safety, medical education, health personnel, integrative review.

## Introduction

Medical imaging is a vast and complex field, which has become indispensable to modern medicine. Ever-evolving technological advances have brought faster and more reliable diagnoses and vital information for patient management and treatment[1]. The use of investigations involving ionising radiation has dramatically increased over the past few decades. Globally, it is estimated that over 3.6 billion radiological examinations are conducted each year and this number is likely to increase significantly in the future[2]. A large proportion of diagnostic imaging examinations involve the use of ionising radiation; the use of which carries a level of risk, namely a potential increased chance of carcinogenesis associated with causation of resultant genetic damage[3,4]. The generally used theory of the 'Linear Non-Threshold' (LNT) hypothesis states that this likelihood increases with greater intensity and duration of exposure, referred to as higher doses[5]. For example, a single chest x-ray carries a potential additional lifetime risk of developing cancer in later life of 1 in 1,000,000, compared to the significantly higher risk of 1 in 2000 following a Computed Tomography scan of the abdomen[6]. The concept of both dose and risk are complex; for example, for an identical examination, doses will vary between individuals dependent on their size and Body Mass Index, and levels of risk also vary with age, sex and the organs exposed[7]. It must be noted here that much controversy and debate exist over the use of such estimations at the low doses used for general x-ray medical imaging. International agencies such as the International Organization for Medical Physics and the Health Physics Society strongly recommend caution in the use of estimated risks at low dose levels, due to their unproven certainty[8,9,10].

For the purposes of radiation protection risk estimation is largely adopted overall and over time, various organisations and legislation have been formed to regulate the use of radiation in medicine and guide best practice under the umbrella term of radiation protection. The International Commission on Radiological Protection (ICRP) developed radiation protection as a system of principles, one of the most significant being the need for justification. Justification requires that any potential harm posed by the radiation involved in a diagnostic examination is always outweighed by the resultant benefit for the individual[11]. In the UK, the legislation that enforces such tenants, The Ionising Radiation (Medical Exposure) Regulations IR(ME)R (2017)[12] and IR(ME)R NI (2018)[13] regulations which repeal the earlier IR(ME)R (2000)[14] directive, and subsequent amendment states that the referrer is duty bound to provide the practitioner with adequate clinical information for them to decide if there is sufficient net benefit for the patient, and therefore justify the dose of radiation required. The World Health Organization (WHO) states in the 'Global Initiative on Radiation Safety' in healthcare settings that referral guidelines and appropriateness criteria are key in aiding physicians in the process of appropriate imaging practices[15,16]. In order for an individual to make an informed choice and truly 'justify' requesting an imaging modality using radiation, an accurate knowledge of the doses and risks involved is imperative[17,18]. The concept of risk in terms of radiation and medicine can be difficult in terms of comprehension as the effects are not immediate or even visible[19,20]. It has been widely documented in the literature that referrers worldwide have an inadequate understanding of the basic principles of ionising radiation and radiation protection, and largely underestimate the doses and risks associated with common radiological imaging investigations[21-29]. Some of the literature expresses concerns that such lack of understanding can prevent patients receiving the most appropriate imaging.

Internationally radiation protection is being recognised as a global issue, evidenced by campaigns such as the 2013 'Bonn Call for Action', an action plan to improve radiation protection in medicine over the next decade by the International Atomic Energy Agency (IAEA) and the World Health Organization (WHO)[33]. As well as movements such as 'Image Wisely' and 'Image Gently in the United States and the 'Eurosafe' campaign in Europe, which all aim to raise awareness of the importance of radiation protection within medical imaging [34-36].

In the UK, in regulations IR(ME)R (2017), (IR(ME)R NI (2018) there is no explicit requirement for referrers to undertake specific radiation protection training[12,13]. Efforts are being made to address gaps in clinicians' knowledge of ionising radiation with European Union regulations recommending the introduction of basic radiation protection in courses (of between 20 and 40 hours) into the undergraduate curricula of all medical and dental schools[37,38]. Whilst studies have attempted to measure the impact of radiation educational interventions, this evidence has not previously been synthesised[1,18,39-42].

The aim of this review is to summarise the existing scientific literature by exploring the impact of education on clinicians' knowledge of radiation protection.

**Research questions:**

1. What types of educational interventions have been developed for clinicians to improve knowledge of radiation protection?
2. What was the content and duration of intervention?
3. How has the impact of radiation protection education been assessed?
4. Is there any association between radiation protection education and improvements in clinicians' knowledge and/or referral practices?

**Method**

An integrative review utilises a systematic methodology for searching and appraisal to ensure that it is comprehensive and inclusive. However, unlike other systematic review approaches, integrative review enables the synthesis of research studies utilising diverse methodologies[43].

An integrative review, following PRISMA guidance where possible[44], was performed and a search strategy developed; including the MeSH terms radiation protection, awareness, education (medical education, postgraduate) and health personnel of different grades and roles. MEDLINE and EMBASE were searched from 2000 to 2018 and any intervention studies included if they focused on the education of clinicians involved in requesting x-ray examinations. Citations were initially screened on title and then abstract, this process was undertaken independently by the two authors, and any articles that met the inclusion criteria were read in full. Uncertainty over the inclusion of 5 articles were discussed by RH (Diagnostic Radiographer) and SJ (Senior Research Fellow in Applied Health Research), and backward and forward citation searches were performed to test the quality of the search strategy.

*Eligibility criteria*

Primary research studies (any methodology) that assessed the impact of an education intervention on clinicians' (including; medical students, all grades of doctors, all grades of nursing practitioners) knowledge relating to radiation protection.

*Types of outcome measures*

Studies were included if they reported an evaluation of the impact of the educational intervention on clinicians' knowledge and included using any methodology.

*Types of articles*

Studies were included from any country, if they were published in full and in English.

*Search methods for the identification of studies*

The search strategy was adapted to search a range of databases from 2000 to July 2018.

*Assessment of risk of bias in included studies*

The inclusion of studies with varying methodologies required the development of a framework to assess study quality which could encompass a range of study designs. The Cochrane 'risk of bias' tool[45] was used as the starting point to develop this method and selection, performance, detection, attrition and reporting biases were included in order to assess study quality.

*Data extraction and management*

A data extraction form was designed that summarised the following characteristics:

i. Study detail (author, year of publication, country of origin, study type);

ii. Staff participants (setting, professions, sample size);

iii. Type of education and training (content, format, method of delivery, by whom delivered, duration, frequency);

v. Outcomes (main results, inferential and descriptive statistics);

vi. Risk of bias (selection, performance, detection, reporting).

Data extraction forms were piloted, due to the small number of included studies piloting took place using 2 (25%) of the included studies. The accuracy of data extraction was checked by a second independent extractor for all included studies, measurements of inter/and intra-observer reliability were not undertaken.

Study authors were not contacted for missing data or for clarification.

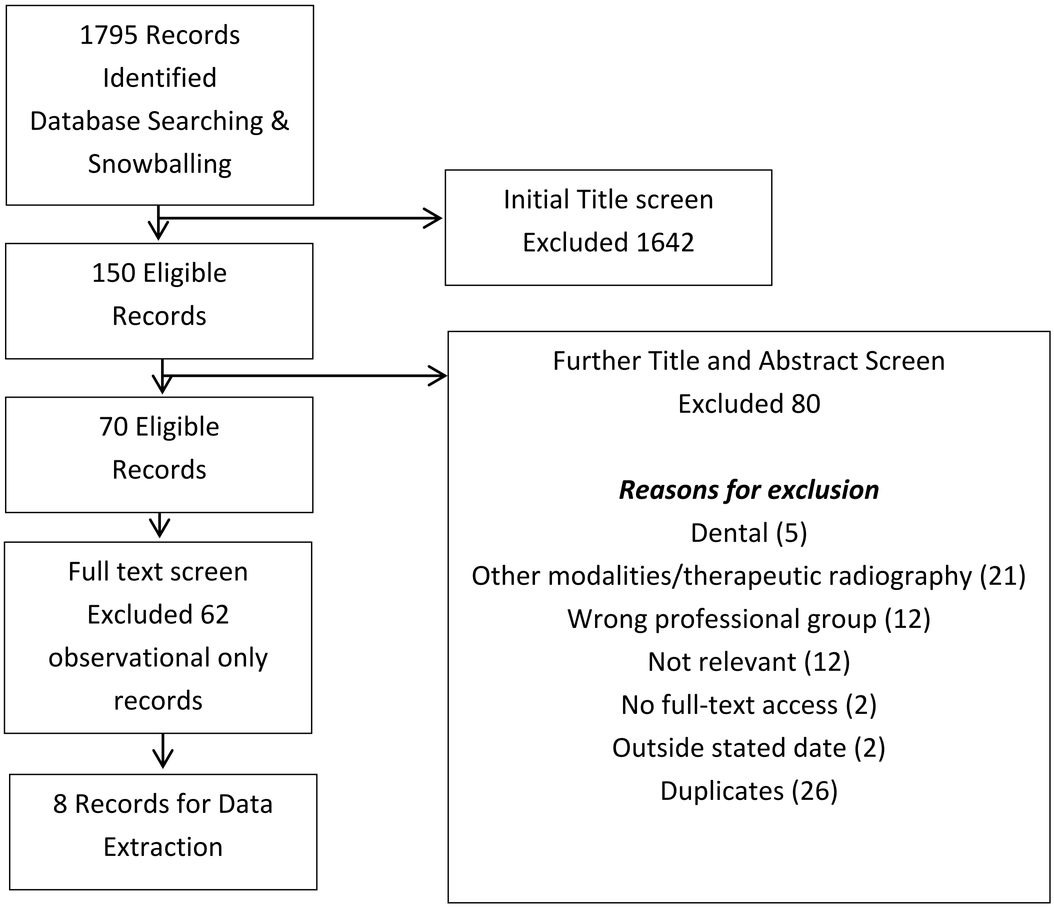
**Analysis**

There was a great deal of heterogeneity between the type and format of the education interventions and the outcomes reported, therefore study findings have been described narratively for each included study.

**Results**

The search strategy initially identified 1795 articles. Following screening of the title, abstract or complete article, 8 studies met the inclusion criteria (see Figure 1). All eight studies utilised pretest-posttest designs and involved the education of medical students or doctors. Six studies (75%) included education around radiation protection and/or safety, 2 focussed on knowledge of radiology in general. The majority of studies used face-to-face methods to deliver education (6 = 74%), the remaining 2 used on-line or media-based approaches.

Figure 1. Flow diagram of included studies




**Narrative review**

*Description of eligible studies*

Of the 8 included studies carried out between 2010 and 2016, 3 were undertaken in the USA[1,40,42], 2 in the UK[41,46] and the remaining 3 took place in Turkey, Saudi Arabia and Australia[3,18,39]. All 8 were pre-test post-test studies and the number of participants involved across all 8 studies totalled 1642, median 179, range 25 to 670. Over half of the studies involved medical students (63%), others included junior doctors (13%), a combination of junior doctors and medical students (13%), and varying grades of doctors (13%); details of study characteristics are summarised in Table 1.

1. *What types of educational interventions have been developed for health care staff?*

Seven studies[1,3,18,40-42,46] included educational interventions for a single group of medical students or doctors (Table 2). Only one study involved the delivery of the intervention to both doctors and medical students and no studies included non-medical referrers as participants. Six studies involved the delivery of face-to-face training[1,18,39-42,46]; one study delivered training on-line[41] and one via public information[3]. Educational content was delivered differently in each study including; through an interactive tutorial, a lecture, a lecture series with case-studies, clinical radiology modules, small group discussions and role play, interactive lectures, as well as the above mentioned on-line module with problem-based learning, and public/media information; see Table 1 for further details.

Table 1: Summary of included studies and educational interventions

| Author (Year) Country | Study Type | Setting | Staff Participants | Response Rate | Content and Format | Delivery and Duration | Results |
|---|---|---|---|---|---|---|---|
| **Ackland (2012) Australia** | Pre-test post-test | 1 Hospital | Junior doctors and medical students | 63 (100%) Pre-test; 21 (33%) Post-test | Format: Short interactive tutorial. Content: Radiation doses for common examination, overall risks/susceptible groups and appropriate use of imaging. | Delivery: face-to-face. Duration: 20-30 minutes, once. | Significant improvement in knowledge of radiation (43% to 51%, p=0.0007). |
| **Eksioglu (2012) Turkey** | Pre-test post-test | 10 Hospitals | Paediatricians - attending doctors department chiefs, fellows, senior and junior doctors | NS Pre-test; 237 (100%) Post-test | Format: Publications, campaigns and news media. Content: NS | Delivery: No dedicated intervention delivered. Public information. Duration: NS. | Improved general awareness (Underestimation of doses reduced from 92% to 75.2%). |
| **Hagi (2011) Saudi Arabia** | Pre-test post-test | 1 Medical School | Fourth year medical students | 253 (76%) Pre and post-test. | Format: Single didactic lecture. Content: Modalities and their use of radiation, doses/risks common examinations, radiation protection principles and role of medical physicist | Delivery: Face-to-face. Duration: One 3 hour session. | Significant Improvement of knowledge on ionizing radiation & radiation protection (47% to 78%, p=0.01). |

| Author (Year) Country | Study Type | Setting | Staff Participants | Response Rate | Content and Format | Delivery and Duration | Results |
|---|---|---|---|---|---|---|---|
| **Koontz (2012) USA** | Pre-test post-test | 1 Medical school | 4th year medical students | 238 (80%) Pre-test; 231 (78%) post-test | Format: Lecture series - image-rich interactive format. Content: Nature of radiation and its' effects, radiation units, sources of ionizing radiation, techniques for limiting radiation exposure. | Delivery: Face-to-face. Duration: 2 hours during a month-long clerkship. Total number NS. | Significantly improved students' knowledge of radiobiology and radiation safety. (50.3% to 83.9%, $p<0.01$). |
| **Leong (2012) UK** | Pre-test post-test | 1 Medical school | 4th year medical students | 113 (89%) Pre-test; 126 (99%) Post-test | Format: E-learning module, question-and-answer format using problem-based learning. Content: Modalities and their use of radiation, nature of radiation and its' adverse effects, doses/risks common examinations and radiation dosimetry. | Delivery: On-line. Duration: NS. | Improved radiation protection knowledge (56% to 81%). |
| **Leschied (2013) USA** | Pre-test post-test | 1 Medical school | 2nd year medical students | 24 (100%) Pre-test intervention group; 12 (100%) Post-test | Format: Lectures and interactive case-based sessions. Content: Modalities, their use of radiation and associated doses/risks, official appropriateness criteria and most appropriate imaging in emergency medicine and implication of inappropriate imaging | Delivery: Face-to-face. Duration: Three, 2 hour sessions | Significantly improved knowledge on imaging and radiation issues in Emergency radiology (43% to 66%, $p<0.001$). |
| **O'Sullivan (2010) UK** | Pre-test post-test | 1 Medical school | Medical students intervention years 1-5 and | 744 (100%) Pre-test; post-test 670 (90%) | Format: Modules. Content: Normal modules whilst attending medical school - | Delivery: Face-to-face. Duration: Normal modules in diagnostic | Significantly improved knowledge of |

| Author (Year) Country | Study Type | Setting | Staff Participants | Response Rate | Content and Format | Delivery and Duration | Results |
|---|---|---|---|---|---|---|---|
| | | | control year 0 | | limited info reported in the article as to duration, content, delivery mode etc. | radiology whilst attending medical school - limited info reported. | radiation (38% to 60%, p<0.001). |
| **Sheng (2016) USA** | Pre-test post-test | 1 Hospital | Junior Doctors in emergency medicine | 25 (100%) Pre-test; 22 (88%) post-test | Format: Lecture, small group discussion, role play (interactive). Content: The use of and nature of radiation and its' adverse effects, doses/risks common examinations, appropriateness criteria and best way to discuss radiation with patients | Delivery: Face-to-face. Duration: 1 hour, once. | Improved knowledge of radiation risks in Emergency Medicine, 45% to 87%. |

N: number; NS: not stated; MI: Medical Imaging; IR: Ionising Radiation

Table 2: Type of staff participating and the number of studies in which they were included

| Staff type | Number of studies by participant group | Number of studies participant group trained alone |
|---|---|---|
| Mixed group | 1 | 0 |
| Doctors | 2 | 2 |
| Medical Students | 5 | 0 |

2. *What was the content and duration of intervention?*

The content for each intervention varied widely and is detailed in Table 1. Duration of training was reported by 4 studies and ranged from 25 minutes to 360 minutes; mean 149 minutes[1,4,18,39]. Of those studies that did not report the duration of training this was often because training was delivered as part of an existing education module or course and specific details about the elements relating to radiation protection were not provided.

3. *How has the impact of education intervention been assessed?*

None of the 8 studies specified a main outcome measure. All included studies used non-validated questionnaires measuring clinician knowledge pre and post intervention.

4. Is there any association between radiation protection education and improvements in clinicians' knowledge and/or referral practices?

All studies reported increases in participant knowledge, of which five reported statistically significant improvements[1,18,39,40,46]. Six studies (75%) included dedicated education around radiation protection and/or safety, whilst 2 focussed on knowledge of radiology in general. Knowledge increased from a mean of 50% (ranging from 38% to 75%) to 75% (ranging from 60% to 92%). In two studies, over half (50% and 63%) of participants stated that education received would impact on their future imaging requesting practice[40-42]

**Risk of bias**

The proportion of studies demonstrating each type of bias can be seen in Figure 2.

The judgement as to whether each bias domain was high, low or unclear for each paper was conducted by each author according to the Cochrane collaboration's risk of bias tool [45]. These were discussed and agreed upon, as above. None of the studies were identified as having a low risk of bias across all five domains. Selection and performance biases were high across all studies. Detection bias was unclear for all but one study[1]. Evidence for attrition bias varied across studies. One study was at high risk for attrition bias[39], five were low risk[1,18,40-42] and in two studies the risk off attrition bias was unclear[3,46]. The risk of reporting bias was high in three studies[3,39,46] and low in the remaining studies.

Figure 2. Risk of bias

| | **Selection bias** | **Performance bias** | **Detection bias** | **Attrition bias** | **Reporting bias** |
|---|---|---|---|---|---|
| **Ackland 2012** | High | High | Unclear | High | High |
| **Eksioglu 2012** | High | High | Unclear | Unclear | High |
| **Hagi 2011** | High | High | Unclear | Low | Low |
| **Koontz 2012** | High | High | Unclear | Low | Low |
| **Leong 2012** | High | High | Unclear | Low | Low |
| **Leschied 2013** | High | High | High | Low | Low |
| **O'Connor 2010** | High | High | Unclear | Unclear | High |
| **Sheng 2016** | High | High | Unclear | Low | Low |

**Discussion**

All studies included in this review concluded that the use of an educational intervention improved participants' knowledge of radiation and/or radiation protection. The degree of success reported varied widely, from an improvement in knowledge of 8% [39] to an increase of 42%[42], across a range of radiation protection concepts including: radiation[3,39,46], radiation and radiation protection[18,40-41] and radiation issues in emergency radiology[1,42]. The variation in the aspects of radiation protection delivered, highlights the significant issue that no consensus within the radiological community exists in terms of what the essentials of radiation protection should include. Future agreement is needed to inform the focus of future education, training and research. All but one study specified utilising a multiple choice structured questionnaire[1,3,18,39,40,42,46] and where reported, the time period following the intervention varied considerably. For example, the participants with the highest reported increase in knowledge (42% [42]) completed the questionnaire within 4 hours of the intervention, in comparison to the study with the least improvement in knowledge (8%[39]) where the post-intervention questionnaire was taken up to 1-2 months after the intervention. However, conclusions cannot be made as to whether the type of questionnaire or the time frame in which it was conducted post-intervention has influenced changes in radiation protection knowledge.

Studies with medical students[1,18,40,41,46] all emphasised the importance of delivering relevant and accurate radiation protection in the undergraduate setting, in order to inform the "consulting physicians' (of) the future"[1].

In two studies exploring self-reported ordering practices, education was found to have a positive impact on future imaging requesting practice. For example, following the completion of a 1-hour module on the risks of ionizing radiation in medical imaging, emergency medicine residents were reported to order fewer computed tomography scans in half of the posed clinical scenarios [42]. This study also saw an improvement in participants perceived comfort levels in discussing radiation risk with their patients increasing from 24% to 41%. Although this is not a measurement of actual referral practice, it does exemplify the possible potential impact of an increased understanding of radiation. Second year medical students who participated in an emergency medicine radiology elective, increased their perceived confidence in their ability to select the most appropriate imaging modality by almost half, post-intervention [1]. In two further studies, over half of all participants believed that their future ordering practices were likely to change[1,40]. Future research needs to investigate whether there is a measurable link between improvements in levels of radiation protection knowledge and/or confidence in practice and an actual positive impact on attitudes and behaviours. Such as fewer unnecessary or inappropriate referrals and ultimately a reduction in the patient population radiation burden. It is suggested that incorporating these into further research could benefit educational institutions, helping to determine the best overall educational package for radiation protection.

The majority of studies used interactive teaching methods (5 = 63%), with only one taking a purely didactic approach[18]. Research into effective continuing professional education advocates the use of techniques that engage the learner in mental processing, for example case studies and simulation, as more effective techniques when compared to didactic lectures[48]. The didactic study which utilised a single 3 hour, reported a significant improvement of knowledge of 31% (from 47% to 78%)[18], suggesting that didactic methods should not be seen as outdated and excluded altogether.

The study with the greatest improvements in knowledge levels (42% increase) not only included interactive elements but also presented information specifically relating to the participants' clinical field[42], this aligns with Mayer's recommendation of targeting information within a programme for greater educational success[49]; this was also the only study to describe the educational approach used, utilising adult learning theory to underpin active participation[42]. The 'least successful' study utilised a 20-30 minute tutorial, which the authors themselves state demonstrates how even minimal teaching can still create an impact of some degree [39]. The most successful study was only 40 minutes longer and was also specifically devised, again making evident the difficulties of pinpointing causal factors.

Seven studies involved the delivery of education and training to a single group, either doctors or medical students. No studies included non-medical referrers as participants. Given that education was largely undertaken within established educational programmes it is perhaps unsurprising that approaches to multi-professional teaching were not possible. In hospital Trusts that train both student radiographers and medical students, is it possible to provide shared radiation protection modules. The World Health Organisation's framework on inter-professional education suggests that multi-professional teaching develops the ability of students to share knowledge and skills collaboratively, leading to more efficient healthcare practices, an approach that should be considered in the delivery of any future interventions[50].

It must be acknowledged that there was a wide variation in study quality, study setting and the educational interventions delivered. The 8 included studies all shared a common key limitation, in that all utilised a pre-test, post-test design, of these, only two studies included a control group. Selection and performance biases were high across all studies mainly due to the selection of participants from existing courses, and the fact that those participants were aware of the pre-post-test methods of knowledge capture. It is not known whether participants would perform similarly in other scenarios, such as in continuing professional development. Reporting bias was evident across some studies, this was namely in the quality of the information reported regarding the content, delivery and duration of the education and training provided making it difficult to evaluate the actual effectiveness of the education or training delivered. Further detail may have allowed a more in-depth synthesis and evaluation of the components of the interventions, informing the development of future programmes.

Due to limited resources, only Medline and Embase databases were searched and studies published in English were included in the review, authors of included studies were not contacted for clarification or further information. The number of search terms could also be expanded and therefore, it must be recognised that relevant articles could have been missed which would have added to the validity of this review.

Given European Union regulations[51] recommend that basic radiation protection content should be included within the undergraduate curricula of all medical and dental schools[37-38], educational providers should consider a range of factors including:

- the most effective mode of delivery;
- underpinning educational theory;
- learner preferences;
- challenges and advantages of delivering education to multi-professional groups;
- and implications for practice.

**Conclusion**

A range of educational interventions have been shown to improve knowledge of radiation protection, radiation safety and perceived self-reported ordering practices, however, there was wide variation in study quality, study settings and the educational interventions delivered. No studies assessed long-term knowledge retention or the impact on actual clinical practice. Further robust research is needed to accurately measure the impact of educational interventions on knowledge of radiation protection and safety in the UK and more specifically the implications this may have on referral practices.

**Conflict of interest statement**

None

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