BJR|Open https://doi.org/10.1259/bjro.20180014

Received: 24 July 2018 | Revised: 10 October 2018 | Accepted: 21 October 2018

Cite this article as:
Khan MO, Khan MS, Janjua O, Ali A, Hussain S. Knowledge of radiation legislation and radiation exposure in common radiological investigations among final year medical students, foundation doctors, specialist radiology registrars and radiographers at a UK university teaching hospital. *BJR Open* 2018; **1**: 20180014.

ORIGINAL RESEARCH

Knowledge of radiation legislation and radiation exposure in common radiological investigations among final year medical students, foundation doctors, specialist radiology registrars and radiographers at a UK university teaching hospital

MUHAMMAD OMAR KHAN, MBChB, MUHAMMAD SADDIQUE KHAN, MBChB, OSMAN JANJUA, MBChB, AHMED ALI, MBChB and SHAHID HUSSAIN, MB BChir

Department of Radiology, University Hospitals Birmingham NHS Foundation Trust, Birmingham, United Kingdom

Address correspondence to: Dr Muhammad Omar Khan
E-mail: *muhammad.khan25@nhs.net*

Objective: Junior doctors routinely request radiological investigations for patients. Prior studies have noted that among this group there is a lack of knowledge on radiation legislation and radiation exposure in common radiological investigations. However, no studies have compared this against radiology trainees and radiographers. We compared knowledge of radiation legislation and radiation exposure in common radiological investigations among final year medical students (FYMS), foundation year doctors (FY1, FY2) against specialist radiology trainees (SRT) and radiographers (RG).

Methods: A 12-question multiple choice questionnaire (MCQ) was distributed to FYMS, FY1, FY2, SRT and RG at a UK teaching hospital. Questions assessed knowledge of radiation legislation and radiation-dose estimates of common radiological investigations. Mean MCQ scores were compared using one-way ANOVA and Tukey post-test to determine statistical significance (p-value < 0.05).

Results: 127 participants were included in the study. Mean scores (%) for FYMS (49.3%), FY1 (52.6%) and FY2 (51.1%) were significantly lower compared to SRT (64.4%) and RG (66.3%) (p-value < 0.05). Mean test scores between FYMS, FY1 and FY2 did not significantly differ (p-value > 0.05).

Conclusion: FYMS, FY1 and FY2 knowledge of radiation legislation and radiation exposure in common radiological investigations was poor compared to SRT and RG. Patients require knowledge of radiation risk to provide informed consent as per IRMER regulations, thus we propose formal teaching on the subject matter to promote radiation safety culture among medical undergraduates and postgraduates.

Advances in knowledge: First study to compare knowledge of radiation legislation and radiation exposure in common radiological investigations between medical students and junior doctors to radiology trainees and radiographers.

INTRODUCTION

Radiology now forms the cornerstone of clinical diagnosis and effective patient management. With continuing advances in the field of radiology, improving the diagnostic efficacy and availability of radiological imaging, there has been a significant increase in the utilisation of radiological imaging techniques. This is best exemplified by the number of CT scans performed within hospitals increasing from 1 to 5 million between 1997 to 2013, a percentage increase of approximately 400%.[1]

As radiological imaging becomes widely adopted as an integral part of the clinical diagnostic process, increasing evidence has emerged regarding the radiation associated risks with various imaging modalities.[2–5] In the UK alone, studies have reported that the cumulative risk of cancer associated with diagnostic X-rays equated to 700 cases of cancer per year.[6] To minimise the risk associated with unnecessary radiation exposure, healthcare regulators have formulated legislation to increase the awareness of the risks associated with radiation amongst clinicians and other allied healthcare professionals. In the UK, this resulted in

© 2018 The Authors. Published by the British Institute of Radiology. This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Table 1. Number of participants per group

Group	Number of participants
FYMS	34
FY1	27
FY2	40
SRT	13
RG	13

FY1, foundation year one doctors; FY2, foundation year two doctors; FYMS, final year medical students; RG, radiographers; SRT, specialist radiology trainees;

the Department of Health formulating the Ionising Radiation Medical Exposure Regulations legislation.[7] Moreover, other organisations involved in the training of healthcare professionals exposed to radiation, such as the Royal College of Radiologists (RCR), have drafted guidelines on the need for adequate training on the risks of radiation. Moreover, tools such as the RCR's iRefer tool have been developed to guide healthcare professionals in requesting the most appropriate imaging modality, thereby limiting patient exposure to unnecessary radiation.[8]

Despite this, multiple studies have shown that radiation awareness and knowledge about its associated risks is poor among healthcare professionals at both an undergraduate[9–11] and postgraduate level.[12–15] However, to the best of our knowledge, there have been no studies in the UK that compare knowledge of radiation legislation and radiation exposure in common radiological investigations between clinicians, at both an undergraduate and postgraduate level, to radiographers (RGs). Therefore, we developed a study that aimed to compare knowledge of radiation legislation and radiation exposure in common radiological investigations among final year medical students (FYMS), foundation year one doctors (FY1), foundation year two doctors (FY2) against specialist radiology trainees (SRT) and RG. We hypothesise that FYMS may not be aware of radiation legislation or the radiation dose associated with the different radiological investigations. However, we expect that with increasing clinical seniority and training, knowledge on these topics should improve.

METHODS AND MATERIALS

A written multiple choice questionnaire (MCQ), consisting of 12 questions in total with 6 questions assessing knowledge on radiation awareness and radiation exposure in common radiological investigations (Supplementary Material 1). The maximum test score attainable was a score of 16. Questions were derived with expert input from senior consultant radiologists and from tools such as iRefer. This was distributed to FYMS, FY1, FY2, SRT and RG within a university teaching hospital in the UK. None of FYMS, FY1 and FY2 had been provided with any formal regional training on radiation awareness, thus were reliant on any knowledge attained during their undergraduate or clinical training. Conversely, SRT and RG are provided formal training on radiation awareness as part of their specialty training programmes, therefore acted as the comparison groups. Throughout the study, all groups were supervised in their completion of the MCQ to prevent participants from utilising resources to assist in answering the questions. Responses were collated for each group as a number of correct versus incorrect answers and presented as the mean ± standard error of the mean (SEM). One-way analysis of variance with Tukey post-test was utilised using GraphPad Prism® to determine if the observed differences in test scores between groups were of statistical significance (defined as a p-value < 0.05). Kruskal–Wallis test was used to determine if observed differences between groups for non-parametric categorical data was of statistical significance (defined as a p-value < 0.05).

Table 3. Number (%) of participants in each training cohort aware of the RCR undergraduate radiology curriculum

	Training group				
	FYMS	FY1	FY2	SRT	RG
Number (%)	1 (2.94)	5 (18.5)	4 (10)	10 (76.9)	8 (61.5)

FY1, foundation year one doctors; FY2, foundation year two doctors; FYMS, final year medical students; RG, radiographers; SRT, specialist radiology trainees;RCR, Royal College of Radiologists;
p-values: FYMS *vs* FY1, $p > 0.99$; FYMS *vs* FY2, $p > 0.99$; FYMS *vs* SRT, $p < 0.0001$*; FYMS *vs* RG, $p = 0.0002$*; FY1 *vs* FY2, $p > 0.99$; FY1 *vs* SRT, $p = 0.0003$*; FY1 *vs* RG, $p = 0.022$*; FY2 *vs* SRT, $p < 0.0001$*; FY2 *vs* RG, $p = 0.0011$*; SRT *vs* RG, $p > 0.99$. *denotes statistically significant results.

RESULTS

A total of 127 participants were involved in the study (Table 1). The mean ± SEM test scores observed for FYMS, FY1 and FY2 were significantly lower when compared to SRT and RG (Table 2). Moreover, despite increasing seniority and clinical exposure, the mean ± SEM test scores did not significantly differ between the FYMS, FY1 and FY2 training groups ($p > 0.05$). Additionally, there was no significant difference observed in the mean ± SEM test scores between the SRT and RG groups ($p = 0.99$).

As highlighted by Table 3, the proportion of FYMS, FY1 and FY2 were significantly less aware of the RCR undergraduate radiology curriculum compared to SRT and RG. Additionally, there was

Table 2. Mean (%) ± SEM test scores between training groups (maximum test score of 16)

	Training group				
	FYMS	FY1	FY2	SRT	RG
Mean (%) ± SEM test score	7.88 (49.3) ± 0.26	8.41 (52.6) ± 0.39	8.18 (51.1) ± 0.36	10.3 (64.4) ± 0.64	10.6 (66.3) ± 0.43

FY1, foundation year one doctors; FY2, foundation year two doctors; FYMS, final year medical students; RG, radiographers; SEM, standard error of the mean; SRT, specialist radiology trainees;
p-values: FYMS *vs* FY1, $p = 0.84$; FYMS *vs* FY2, p=0.97; FYMS *vs* SRT, $p = 0.0024$*; FYMS *vs* RG, $p = 0.0004$*; FY1 *vs* FY2, $p = 0.99$; FY1 *vs* SRT, $p = 0.041$*; FY1 *vs* RG, $p = 0.011$*; FY2 *vs* SRT, $p = 0.0086$*; FY2 *vs* RG, $p = 0.0017$*; SRT *vs* RG, $p = 0.99$. *denotes statistically significant results.

Table 4. Number (%) of participants within each training group aware of the iRefer tool

	Training Group				
	FYMS	FY1	FY2	SRT	RG
Number (%)	0 (0)	1 (3.7)	1 (2.5)	13 (100)	5 (38.5)

FY1, foundation year one doctors; FY2, foundation year two doctors; FYMS, final year medical students; RG, radiographers; SRT, specialist radiology trainees;

p-values: FYMS vs. FY1, $p>0.99$; FYMS vs. FY2, $p>0.99$; FYMS vs. SRT, $p<0.0001$*; FYMS vs. RG, $p=0.0126$*; FY1 vs. FY2, $p>0.99$;FY1 vs. SRT, $p<0.0001$*; FY1 vs. RG, $p=0.0487$*; FY2 vs. SRT, $p<0.0001$*; FY2 vs. RG, $p=0.0207$*; SRT vs. RG, $p=0.0002$. *denotes statistically significant results.

no statistically significant difference in the proportion of trainees aware of the RCR undergraduate radiology curriculum between FYMS to FY2. Moreover, no statistically significant differences were noted between the SRT and RG cohort concerning the proportion aware of the RCR undergraduate curriculum.

Similarly, Table 4 outlines that FYMS, FY1 and FY2 comparatively noted a lack of awareness of the iRefer tool developed by the RCR, with no FYMS reporting an awareness of the resource, compared to both the SRT and RG cohort. Nonetheless, a statistically significant greater proportion of SRT were aware of the iRefer tool compared to the RG cohort.

When determining existing knowledge of governmental regulations underpinning radiation, Table 5 denotes a statistically significant greater proportion of SRT and RG were aware of existing governmental regulations on radiation compared to the FYMS, FY1 and FY2 groups. Furthermore, a statistically insignificant difference was noted between the SRT and RG cohort with regards to the proportion aware of governmental regulations on radiation. Additionally, no significant increase in the proportion of study participants' awareness of governmental regulations on radiation between the FYMS, FY1 and FY2 training groups despite increasing seniority and perceived clinical acumen.

The SRT and RG cohorts had a significantly greater proportion of healthcare professionals aware of existing national referral guidelines for requesting images compared to the FYMS, FY1 and FY2 groups ($p < 0.0001$) (Table 6). However, no statistically significant difference was noted between the number of SRT and RG aware of national referral guidelines on requesting imaging ($p > 0.99$). Similarly, no significant differences were noted in the proportion of FYMS, FY1 and FY2 cohorts aware of national referral guidelines for requesting radiological imaging ($p > 0.99$).

Table 5. Number (%) of participants aware of any governmental regulations on radiation

	Training group				
	FYMS	FY1	FY2	SRT	RG
Number (%)	1 (2.9)	1 (3.7)	3 (7.5)	13 (100)	12 (92.3)

FY1, foundation year one doctors; FY2, foundation year two doctors; FYMS, final year medical students; RG, radiographers; SRT, specialist radiology trainees;

p-values: FYMS *vs* FY1, $p > 0.99$; FYMS *vs* FY2, $p > 0.99$; FYMS *vs* SRT, $p < 0.0001$*; FYMS *vs* RG, $p < 0.0001$*; FY1 *vs* FY2, $p > 0.99$; FY1 *vs* SRT, $p < 0.0001$*; FY1 *vs* RG, $p < 0.0001$*; FY2 *vs* SRT, $p < 0.0001$*; FY2 *vs* RG, $p < 0.0001$*; SRT *vs* RG, $p > 0.99$. *denotes statistically significant results.

Table 6. Number (%) of participants aware of any national referral guidelines for requesting imaging

	Training group				
	FYMS	FY1	FY2	SRT	RG
Number (%)	2 (5.88)	0 (0)	2 (5)	11 (84.6)	10 (76.9)

FY1, foundation year one doctors; FY2, foundation year two doctors; FYMS, final year medical students; RG, radiographers; SRT, specialist radiology trainees;

p-values: FYMS *vs* FY1, $p > 0.99$; FYMS *vs* FY2, $p > 0.99$; FYMS *vs* SRT, $p < 0.0001$*; FYMS *vs* RG, $p < 0.0001$*; FY1 *vs* FY2, $p > 0.99$; FY1 *vs* SRT, $p < 0.0001$*; FY1 *vs* RG, $p < 0.0001$*; FY2 *vs* SRT, $p < 0.0001$*; FY2 *vs* RG, $p < 0.0001$*; SRT *vs* RG, $p > 0.99$. *denotes statistically significant results.

DISCUSSION

Medical imaging plays a key role in the diagnosis and management of a disease. Radiological imaging is widely available and can provide invaluable information promptly that can guide clinical diagnosis and management. However, the risks of radiation exposure vary depending on the radiation dose and duration. Effects such as hair loss, skin erythema, sterility and malignancy have been associated with radiation exposure.[16] Previous studies have shown radiation doses as low as 10 mSv can provoke malignancy in 1 in 2000 patients and it is estimated that around 700 new cases per year develop after radiation exposure from medical imaging in the UK.[6,16]

The results of our study illustrate a poor baseline knowledge of radiation exposure awareness in FYMS, FY1 and FY2. Moreover, knowledge within these domains did not improve among these groups despite increasing seniority (mean score FYMS = 49.3%, FY1 52.6%, FY2 51.1%, *p*-value > 0.05). These findings correlate with previous studies such as that conducted by Soye et al who assessed radiation awareness among 153 health professionals from varied training schemes. Within their study, they noted that their cohorts average test score was 39%.[12] Furthermore, McCusker et al found out of 269 participants, including medical students and junior doctors, 99% underestimated radiation doses in a variety of imaging with 90% underestimating radiation doses associated with CT abdomen/pelvis. Moreover, they identified that only 1% of their study cohort had attended formal radiation protection teaching.[10] Similar results have been found in studies abroad whereby doctors and medical students both underestimated radiation doses and their knowledge lacking.[9,17–20]

The above highlights the underlying concern that teaching appears ineffective from the undergraduate level to the initial formative year's post-graduation. With recent changes to the legal basis of informed consent, it is crucial that clinicians should have sufficient knowledge to communicate the risks and benefits of requested investigations to receive informed consent from patients. Furthermore, the European Directive 2013/59/Euratom from the European Commission which addresses diagnostic

imaging, emphasises a need for justifying medical exposure with a requirement to provide information to patients.[21]

Awareness of the undergraduate curriculum specified by the RCR was seen by the majority of SRT in our study (76.9%). Comparatively, there was a lower percentage of trainees in the other clinical groups aware of the RCR curriculum (FYMS = 2.94%, FY1 = 18.5%, FY2 = 10%). This could be due to a lack of formal teaching present both at the undergraduate and postgraduate level. This corresponds with data obtained by Selmi et al who reported that out of 49 respondents to their questionnaire, 76% of trainees did not have previous radiology teaching in dosimetry in diagnostic imaging either at the undergraduate or postgraduate level.[16] This suggests there is a need for continued development from the undergraduate level up, which is also strongly emphasised by the International Commission on Radiological Protection who provide guidance for academic institutions.[22]

The iRefer tool is a comprehensive guide that details the most appropriate investigation with radiation dosing information. 100% of SRT were aware of this tool however, awareness of iRefer among was lower in the other study groups (FYMS = 0 %, FY1 = 3.7%, FY2 = 2.5%, RG 38.5%). This correlates with Selmi et al findings which found 88% of their cohort (FY1 and FY2) reported no knowledge of iRefer.[16] This is also consistent with Borgen et al who found 84.8% of their radiologist cohort knew of their respective guidelines compared to 38.9% of their radiographer counterparts.[23]

Awareness of government regulations on radiation showed a substantial disparity between those in the SRT (100%) and RG (92.3%) cohorts when compared to FYMS (2.9%), FY1 (3.7%) and FY2 (7.5%). This trend was also reflected in the awareness of national referral guidelines for imaging requests. Such results reinforce the need to implement teaching at both the undergraduate and foundation training level. At the undergraduate level, radiology teaching, a study by Nyhsen et al 64% of their foundation year study cohort stated they had not enough exposure to radiology teaching at undergraduate level.[24] Additionally, Selmi et al also reported that 76% of their foundation trainees had no formal teaching at the undergraduate level.[16] Moreover, in our study no statistically significant difference in the mean ± SEM test score was noted between FYMS, FY1 and FY2 cohorts. This correlates with Selmi et al study, suggesting that increasing seniority and experience did not lead to improved understanding.[16] Overall, our findings alongside those reported previously highlights the need to incorporate education, at all stages of training, on radiation legislation and radiation exposure in common radiological investigations, thereby promoting a strong radiation safety culture among medical professionals.

To increase knowledge at both the undergraduate and foundation level we suggest, like Selmi et al, specific teaching sessions for both demographics. Teaching should encompass educational domains on radiation legislation, application to clinical practice, national referral guidelines for requesting imaging, roles of tools such as iRefer and communicating risk of radiation to their patients.[16] Concerning the method of delivery, interactive case-based teaching would be appropriate to deliver radiology and radiation awareness teaching. Nyhsen et al suggested that teaching should be interactive sessions rather than self-directed learning resources including textbooks, journals and online learning modules.[24,25] Similarly, Dellie et al and Abuelhia et al both found their cohort stated workshop sessions as their preferred method of learning for ionising radiation.[17,18] Incorporating technology into teaching can also be valuable in delivering radiology-based education. Maleck et al assessed 225 third year medical students and concluded that computer-based teaching improves students problem-solving ability in radiology.[26]

In the UK, IRMER (Ionising Radiation Medical Exposure Regulations) is not part of an annual mandatory update for medical staff and there are no specific guidelines relating to this.[9] A 5-year revalidation process exists for dentists which would be useful to include with medical staff to keep their awareness up to date. This could be used to improve awareness of radiation exposure and consequently, the risk to patients.

LIMITATIONS

There are some limitations to our study. Firstly, this was a single centre and although our sample size is comparable to existing studies within this area, our study could have been improved by conducting a cross-centre study, allowing us to increase our sample size.[12,14,17–19,23,24,27,28] Another limitation of our study was a lack of clinicians more senior than foundation year doctors, *e.g.* medical and surgical specialist trainees. Existing literature has conflicting evidence regarding the relationship between non-radiologist experience and knowledge of radiation doses, with some studies expressing an inverse relationship and other demonstrating more linear results.[29,30] Consequently, repeat studies could incorporate more senior clinicians to assess radiation awareness in these groups and compare these with junior doctors. Furthermore, we did not assess attitudes to the importance of radiation awareness. Previous studies have demonstrated a proportion of their cohorts did not believe knowledge of radiation was important.[9,17] Future studies could include this component to assess if there is a fundamental lack of importance towards awareness for radiation risk among clinical professionals.

CONCLUSION

Our study highlights an overall lack of knowledge of radiation legislation and radiation exposure in common radiological investigations among FYMS, FY1 and FY2. This suggests there is a need for structured teaching at both the undergraduate and postgraduate level regarding these topics to help prepare junior doctors but also ensure informed consent is taken from patients. Future suggestions include incorporating interactive teaching sessions among these groups, supplementary educational posters and utilisation of information technology to aid learning. Expanding on this study would involve assessing knowledge in all training grades up to consultant level in all clinical specialties. Furthermore, assessing knowledge at other centres throughout the UK would allow us to gauge if this knowledge level is prevalent nationally, therefore highlighting if multicentre teaching is required.

REFERENCES

1. NHS England. NHS Imaging and Radiodiagnostic activity. 2014. Available from: https://www.england.nhs.uk/statistics/wp-content/uploads/sites/2/2013/04/KH12-release-2013-14.pdf [Accessed 29 Jan 2018].
2. Linet MS, Slovis TL, Miller DL, Kleinerman R, Lee C, Rajaraman P, et al. Cancer risks associated with external radiation from diagnostic imaging procedures. *CA Cancer J Clin* 2012; **62**: 75–100. doi: https://doi.org/10.3322/caac.21132
3. Kleinerman RA. Cancer risks following diagnostic and therapeutic radiation exposure in children. *Pediatr Radiol* 2006; **36 Suppl 2**(Suppl 2): 121–5. doi: https://doi.org/10.1007/s00247-006-0191-5
4. Hendee WR, O'Connor MK. Radiation risks of medical imaging: separating fact from fantasy. *Radiology* 2012; **264**: 312–21. doi: https://doi.org/10.1148/radiol.12112678
5. Lin EC. Radiation risk from medical imaging. *Mayo Clin Proc* 2010; **851146**: 1142–6quiz. doi: https://doi.org/10.4065/mcp.2010.0260
6. Berrington de González A, Darby S. Risk of cancer from diagnostic X-rays: estimates for the UK and 14 other countries. *Lancet* 2004; **363**: 345–51. doi: https://doi.org/10.1016/S0140-6736(04)15433-0
7. Department of Health. The Ionising Radiation (Medical Exposure) Regulations 2000. 2000. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/227075/IRMER_regulations_2000.pdf [Accessed 29 Jan 2018].
8. Royal College of Radiologists iRefer. Available via. 2018;. Accessed 29 Jan 2018.
9. Zhou GZ, Wong DD, Nguyen LK, Mendelson RM. Student and intern awareness of ionising radiation exposure from common diagnostic imaging procedures. *J Med Imaging Radiat Oncol* 2010; **54**: 17–23. doi: https://doi.org/10.1111/j.1754-9485.2010.02132.x
10. McCusker MW, de Blacam C, Keogan M, McDermott R, Beddy P. Survey of medical students and junior house doctors on the effects of medical radiation: is medical education deficient? *Ir J Med Sci* 2009; **178**: 479–83. doi: https://doi.org/10.1007/s11845-009-0341-5
11. O'Sullivan J, O'Connor OJ, O'Regan K, Clarke B, Burgoyne LN, Ryan MF, et al. An assessment of medical students' awareness of radiation exposures associated with diagnostic imaging investigations. *Insights Imaging* 2010; **1**: 86–92. doi: https://doi.org/10.1007/s13244-010-0009-8
12. Soye JA, Paterson A. A survey of awareness of radiation dose among health professionals in Northern Ireland. *Br J Radiol* 2008; **81**: 725–9. doi: https://doi.org/10.1259/bjr/94101717
13. Foley SJ, Evanoff MG, Rainford LA. A questionnaire survey reviewing radiologists' and clinical specialist radiographers' knowledge of CT exposure parameters. *Insights Imaging* 2013; **4**: 637–46. doi: https://doi.org/10.1007/s13244-013-0282-4
14. Faggioni L, Paolicchi F, Bastiani L, Guido D, Caramella D. Awareness of radiation protection and dose levels of imaging procedures among medical students, radiography students, and radiology residents at an academic hospital: Results of a comprehensive survey. *Eur J Radiol* 2017; **86**: 135–42. doi: https://doi.org/10.1016/j.ejrad.2016.10.033
15. Krille L, Hammer GP, Merzenich H, Zeeb H. Systematic review on physician's knowledge about radiation doses and radiation risks of computed tomography. *Eur J Radiol* 2010; **76**: 36–41. doi: https://doi.org/10.1016/j.ejrad.2010.08.025
16. Selmi M, Natarajan M. Radiation awareness amongst junior doctors. *J Adv Radiol Med Image* 2016; **1**: 205.
17. Dellie ST, Admassie D, Ewnetu Y. An Assessment of final-year medical students and interns awareness of radiation exposure to common diagnostic imaging procedures. *Adv Radiol* 2014; **2014**: 1–7. doi: https://doi.org/10.1155/2014/426909
18. Abuelhia E. Awareness of ionizing radiation exposure among junior doctors and senior medical students in radiological investigations. *J Radiol Prot* 2017; **37**: 59–67. doi: https://doi.org/10.1088/1361-6498/37/1/59
19. Kada S. Awareness and knowledge of radiation dose and associated risks among final year medical students in Norway. *Insights Imaging* 2017; **8**: 599–605. doi: https://doi.org/10.1007/s13244-017-0569-y
20. Lee RK, Chu WC, Graham CA, Rainer TH, Ahuja AT. Knowledge of radiation exposure in common radiological investigations: a comparison between radiologists and non-radiologists. *Emerg Med J* 2012; **29**: 306–8. doi: https://doi.org/10.1136/emermed-2011-200481
21. European Society of R (2015) Summary of the European Directive 2013/59/Euratom. *essentials for health professionals in radiology. Insights Imaging* **6**: 411–7.
22. International Commission on Radiology Protection. 2009. http://www.icrp.org/publication.asp?id=ICRP%20Publication%20113 (Accessed 29 Jan 2018).
23. Borgen L, Stranden E. Radiation knowledge and perception of referral practice among radiologists and radiographers compared with referring clinicians. *Insights Imaging* 2014; **5**: 635–40. doi: https://doi.org/10.1007/s13244-014-0348-y
24. Nyhsen CM, Lawson C, Higginson J. Radiology teaching for junior doctors: their expectations, preferences and suggestions for improvement. *Insights Imaging* 2011; **2**: 261–6. doi: https://doi.org/10.1007/s13244-010-0052-5
25. Nyhsen CM, Steinberg LJ, O'Connell JE. Undergraduate radiology teaching from the student's perspective. *Insights Imaging* 2013; **4**: 103–9. doi: https://doi.org/10.1007/s13244-012-0206-8
26. Maleck M, Fischer MR, Kammer B, Zeiler C, Mangel E, Schenk F, et al. Do computers teach better? A media comparison study for case-based teaching in radiology. *Radiographics* 2001; **21**: 1025–32. doi: https://doi.org/10.1148/radiographics.21.4.g01jl091025
27. Uri IF. Lack of radiation awareness among referrers: implications and possible solutions. *Int J Clin Pract* 2012; **66**: 574–81. doi: https://doi.org/10.1111/j.1742-1241.2012.02938.x
28. Arslanoğlu A, Bilgin S, Kubal Z, Ceyhan MN, Ilhan MN, Maral I. Doctors' and intern doctors' knowledge about patients' ionizing radiation exposure doses during common radiological examinations. *Diagn Interv Radiol* 2007; **13**: 53–5.
29. Brown N, Jones L. Knowledge of medical imaging radiation dose and risk among doctors. *J Med Imaging Radiat Oncol* 2013; **57**: 8–14. doi: https://doi.org/10.1111/j.1754-9485.2012.02469.x
30. Wong CS, Huang B, Sin HK, Wong WL, Yiu KL, Chu Yiu Ching T. A questionnaire study assessing local physicians, radiologists and interns' knowledge and practice pertaining to radiation exposure related to radiological imaging. *Eur J Radiol* 2012; **81**: e264–8. doi: https://doi.org/10.1016/j.ejrad.2011.02.022