X-ray therapy safety and awareness education for medical trainees and attending physicians

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Acknowledgements: *Authors would like to acknowledge the University of Saskatchewan Clinical Research Support Unit for their help with statistical analysis.*

Cite as: Smith M, Yanko E, Huynh M, et al. X-ray therapy safety and awareness education for medical trainees and attending physicians. *Can Urol Assoc J* 2022 September 30; Epub ahead of print. http://dx.doi.org/10.5489/cuaj.8087

Published online September 30, 2022

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ABSTRACT

Introduction: Medical imaging involving ionizing radiation is common in the clinical setting. Little is known about the level of radiation safety training for medical trainees and attending physicians. We sought to identify the level of radiation safety knowledge and training at the undergraduate, postgraduate, and attending physician level.
Methods: A 29-question survey was sent by email to two sites in Canada. We pooled the results of medical students, residents, and attending physicians. The primary outcome was to describe the amount of radiation safety training among these groups. The secondary outcomes were to describe the frequency of radiation exposure, level of radiation knowledge, and preferred training method for radiation safety.

KEY MESSAGES

- Medical trainees may not be receiving adequate education to protect themselves during ionizing radiation-based procedures.
- Most medical trainees and attending physicians wore radiation protection equipment; although the use of dosimeters, measuring total fluoroscopic time, and checking equipment for damage was rare.
- The best strategy for implementing radiation safety education remains unknown.

Results: Of 115 surveys that were properly completed, 31 (26.9%) medical students, 17 (14.7%) residents, and 67 (58.3%) attending physicians responded. A greater number of medical students (41.9%) reported they had zero hours of training time for radiation safety compared to attending physicians (14.9%) ($p<0.05$). A higher number of attending physicians (47.8%) and residents (64.7%) participated in patient care involving fluoroscopy daily or at least several times per week compared to medical students (3.2%) ($p<0.001$). Attending physicians had the greatest number of correct responses to radiation safety questions. Online courses and workshops were the most preferred training method.
Conclusions: Radiation safety training is an important component of medical education for medical trainees and attending physicians. Current radiation safety training requirements and procedures at various levels of medical training in Canada should be addressed. Implementing radiation safety education may improve adherence to the radiation safety principles.

INTRODUCTION

Medical students, residents, and attending physicians in Canada must be aware of the adverse effects of ionizing radiation and the methods of protection available to them. Use of ionizing radiation for diagnostic imaging in the clinical setting is highly valuable; however, healthcare professionals are at greater risk of radiation exposure. These groups should have adequate training in radiation protection to minimize harms associated with radiation exposure, such as increased risk of developing cataracts, cancer, and potentially genetic changes.[1] Radiation safety is particularly relevant for specialties exposed more frequently to radiation, including interventional cardiology, interventional radiology, orthopedic surgery, vascular surgery, urology, and gastroenterology.[1] Although education on radiation exposure is important for the safety of medical personnel, there are relatively few studies evaluating radiation safety education for medical students, residents, and attending physicians.

Previous studies have suggested that medical students typically overestimate their knowledge of radiation protection, and both residents and students have suboptimal knowledge of radiation protection.[2] One reason for the lack of radiation safety knowledge may be that undergraduate[3] and postgraduate students do not have adequate training on radiation principles.

The aim of this study is to describe the current level of radiation safety training for medical students, residents, and attending physicians. In doing so, medical curricula may be altered to meet the radiation safety needs of medical trainees and attending physicians.

METHODS

Study design, setting, and participants

In this study, a 29-question survey was sent by email to medical students, residents of high radiation use specialties, and attending surgeons at two sites: College of Medicine, University of Saskatchewan and Schulich School of Medicine & Dentistry, Western University. All responses were collected anonymously. High radiation use specialties include interventional cardiology, interventional radiology, orthopedic surgery, vascular surgery, urology, general surgery, and gastroenterology. The study was approved by the University of Saskatchewan Behavioral Research Ethics Board.

Study outcome

The primary study outcome was to describe the amount of radiation safety training medical students, residents, and attending physicians receive. Our secondary outcomes were to describe the frequency of radiation exposure, level of radiation knowledge, and the preferred training method for radiation safety.

Statistical methods

Statistical analyses were completed with the IBM SPSS Statistics Version 28. Statistical significance was defined by an alpha level of $p \leq 0.05$. Descriptive analysis was performed to summarize the data. To examine the current radiation safety training for three professional groups (medical students, residents, and attending physicians), chi-square tests were used. Furthermore, for pairwise comparisons between groups, multiple column proportion comparisons were calculated adjusting p-values for multiple comparisons with the Bonferroni method. Survey data from the entire population of interest was collected; therefore, an a priori power analysis to determine an appropriate sample size was not completed.

RESULTS

A total of 117 surveys were completed. 115 surveys were included in statistical analysis; two responses were excluded as one did not belong to our target groups, and the other did not specify their training level appropriately. Table. 1. provides a demographic summary of the respondents.

Radiation safety training (Figure 1)

A greater number of medical students (58.1%) rated their current knowledge level of radiation safety as below or far below average compared to resident physicians (17.6%) and attending physicians (16.4%) ($p<0.05$). Attending physicians (52.2%) attended significantly more training events on radiation safety organized by their training program, workplace, or medical association compared to medical students (12.9%) ($p<0.001$). Fewer residents (35.3%) attended training events ($p > 0.05$). An examination on radiation safety was required by 9.7% of medical students, 23.5% of residents, and 29.9% of attending physicians ($p=0.091$). A greater number of medical students (41.9%) reported they had zero hours of training time for radiation safety compared to attending physicians (14.9%) ($p<0.05$) without any significant differences for residents (17.6%) ($p>0.05$). Resident physicians (31.3%) had the highest requirement for annual radiation safety training, in comparison to zero medical students reporting this requirement ($p<0.05$) without any significant differences for attending physicians (11.9%) ($p>0.05$).

Radiation exposure (Figure 2)
Attending physicians (47.8%) and residents (64.7%) participated in patient care involving fluoroscopy daily or at least several times per week, compared to medical students (3.2%) ($p<0.001$). Medical students (94.7%) reported never wearing a dosimeter in comparison to residents (56.3%) and attending physicians (56.1%) ($p<0.05$). For those who wore a dosimeter, the most common overall position to wear it was in front of the radiation garment at the collar level (15.9%). Less than half of respondents (40.9%) indicated they knew who checked the dosimeter readings. Radiation protection equipment was always or usually worn by 93.3% of medical students, 100% of residents, and 92.5% of attending physicians ($p=0.512$). Over 60% of all respondents were unsure how often their equipment was checked for damage and 75.0% of medical students, 73.3% of residents, and 48.4% of attendings never record their cumulative fluoroscopic dose ($p>0.05$). Most individuals providing fluoroscopically guided care did so in the hospital setting (100% of residents, and 98.5% of attending physicians). Sixty percent of participants were concerned about the effects of radiation without a significant difference between groups. The most frequently used method to reduce radiation exposure was to positioning the image intensifier as close as possible to the area of interest (51.3%), followed by last image hold (40.9%), pulse images over continuous exposure (39.1%), routine collimation to the area of interest (37.4%), physician operated fluoroscopy (37.4%), and auto-swap image functionality (8.7%).

Radiation metrics knowledge and preferred training method (Figure 3)
Attending physicians had the greatest number of correct responses to radiation safety questions, with a mean score of 4.6, compared to a mean score of 3.13 for medical students ($p<0.001$). Residents had a mean score of 4.24 ($p>0.05$). Over half of all respondents (50.9%) did not know what the stochastic effects of radiation were, with medical students (74.2%) having the greatest number who did not know compared with attending physicians (39.4%) ($p<0.05$). Most participants (68.4%) knew the general health consequences of ionizing radiation without significant differences between groups. Most respondents (81.6%) correctly responded that fluoroscopy is responsible for the greatest radiation exposure for medical staff, with medical students (61.3%) correctly answering less frequently than attending physicians (92.4%) ($p=0.001$). Only half of respondents (53%) knew the correct relationship between distance from the radiation source and radiation intensity, with a difference between medical students (29%) and attending physicians (66.7%) ($p<0.05$). Only 51% of all participants knew the limit for occupational exposure to radiation without significant differences between groups.

Preferred training methods for radiation safety were online courses (36.8%), workshops (29.8%), didactic lectures (14.0%), seminars (14.9%), and other (4.4%) (p=0.3). The suggested time to implement radiation safety training was during medical school (47.0%), residency (47.8%) or as an attending physician (5.2%).

DISCUSSION

The use of ionizing radiation as a tool for diagnosis and treatment in medicine has become a mainstay in clinical practice for many medical specialties. With the pervasive use of radiation in medicine, an understanding of radiation risk is essential amongst medical students, residents, and attending physicians. Radiation protection aims to reduce the exposure to ionizing radiation to decrease the possible adverse effects of ionized free radicals which may indirectly damage DNA.[4] More specifically, ionizing radiation is known to cause cancer,[5,6] cataracts,[7] and genetic mutations.[8] Few studies to date have evaluated radiation safety knowledge in medical students, residents, and attending physicians.

Radiation safety training

Our results show that a striking number of medical students (41.9%) reported zero radiation safety training despite being involved in patient care using fluoroscopy. However, fewer residents (17.6 %) and attending physicians (14.9%) reported no radiation safety training. Furthermore, the current study found that annual radiation safety training was not required for medical students (100%), most residents (68.8%), and most attending physicians (88.1%). These results suggest that medical students may be unknowingly exposed and harmed by ionizing radiation. Although there may be some level of radiation safety training for all groups, it is not standardized or mandatory.

The amount of time medical trainees receive radiation education differs among Canadian medical schools. At the University of British Columbia, the largest medical school in Canada, students receive approximately 40 hours of mandatory, direct radiology education throughout their four years of medical school which includes radiation safety.[9] McGill University reports that prior to graduation, medical students receive a minimum of 50 hours of radiology education which also includes radiation safety.[3] In the same range of hours, the European Union recommends 20 - 40 hours of radiation protection training in medical schools.[10] A previous study by Hagi et al. found that only a three-hour didactic lecture on radiation safety resulted in a 31% knowledge gain amongst fourth-year medical students.[11] A previous study by Mengnjo et al. found that a majority of medical and dental students preferred radiation safety lectures before clinical practice.[3] The timing of radiation safety education is important, and a push for earlier radiation safety education is needed. The amount of radiation education that medical trainees in Canada receive differs among medical schools and an appropriate amount of radiation safety education should be established.

Radiation exposure

Unsurprisingly, attending physicians and residents were most involved in fluoroscopy with medical students having lower participation. The high adherence to wearing radiation protection equipment reflects an informal radiation education occurring at hospital sites. However, low rates of using radiation exposure reducing techniques (e.g., last image hold, pulse images over continuous exposure), and lack of wearing dosimeters, measuring total fluoroscopy time, and checking radiation equipment for damage suggest there is still a benefit to additional training.

Despite use of a dosimeter being the most simple and cost-effective method available to monitor personnel working with radiation, only 43.9% of attending physicians, 43.7% of residents, and 5.3% of medical students in our study reported wearing a dosimeter. Similarly, a previous study surveying health care professionals in high radiation use specialties reported that only 42% of physicians owned dosimeters and of that, only 60% used them regularly.[12] Furthermore, a study of urology operating room personnel in Turkey report that only 46.5% of urology operating room staff used dosimeter badges during fluoroscopic procedures for monitoring of their radiation exposure.[13] Vano et al. also report that only 40% of interventional cardiologists wore dosimeters regularly.[14]

The As Low As Reasonably Achievable (ALARA) guiding principles for radiation safety include: duration of radiation exposure, distance from the radiation source, and physical shielding.[1] In spite of these guiding principles, our results show that radiation dose and fluoroscopy time are not frequently measured, and a low proportion knew the relationship between radiation intensity and distance. Given that many physicians outside the field of radiology are practicing fluoroscopic procedures at increasing rates, there is a need for increased training, education, and standardization regarding radiation exposure reduction techniques and dosimeter use.[15]

Radiation metrics knowledge and preferred training method

As we anticipated, radiation safety knowledge increased by duration of training: medical students scored the lowest and attending physicians the highest. This is also concordant with participants' self-reported levels of radiation knowledge which showed a decreasing proportion of individuals with below or far below average radiation safety knowledge with increasing training. This implies that medical trainees receive some form of education, whether formal or informal, later in their clinical practice. At a minimum, all medical trainees and attending physicians should be aware of the possible adverse health effects of radiation exposure and understand the ionizing radiation doses associated with different imaging modalities.

There are two main types of radiation exposure effects including deterministic and stochastic. Deterministic effects, or dose-dependent effects, occur when a specific exposure threshold has been exceeded (e.g., dermatitis or cataracts) with symptoms occurring in a relatively short time. Stochastic effects, or dose-dependent probability, occur with a certain probability but without a defined threshold where the effects are triggered (e.g., cancer).[1] It is crucial for medical trainees and attendings to be aware of these effects of radiation as they may impact health in different ways, and stochastic effects are discovered many years after radiation exposure. The current study demonstrates that a majority of medical students (74.2%) were not aware of what the stochastic effects of radiation are.

However, a study by Amare et al. reported that of 401 medical students surveyed, 84.8% of subjects indicated that cancer is the most common health risk associated with radiation exposure[16], and this is a stochastic effect. Additionally, a general understanding of the amount of radiation associated with different imaging modalities is important to assess the level of risk to both patients and physicians. In our study, 61.3% of medical students, and 76.5% of residents, correctly responded that fluoroscopy is responsible for the greatest radiation exposure for medical staff, while 38.7% and 23.5% believed it was computed tomography, respectively. Ricketts et al., found that 43% of Canadian medical students were unaware that interventional procedures were associated with ionizing radiation.[17] Similarly, a study conducted in Ireland reported that 99% of medical students and junior house doctors surveyed underestimated the dose of radiation involved in a variety of procedures involving ionizing radiation.[18] These gaps in radiation safety knowledge amongst medical trainees and physicians spans worldwide and must be addressed to ensure the safety of those exposed to ionizing radiation.

Healthcare providers and trainees should be knowledgeable regarding ways in which to reduce radiation exposure to themselves, but also to their patients. Studies have demonstrated that in younger patients, the risk of developing cancer increases from 1 in 2000[19] to as high as 1 in 80[20] following certain computed tomography scans. Young patients with urolithiasis are at increased risk for significant radiation exposure from the use of non-contrast computed technology.[21]

Along with being aware of high-risk patient populations, the operator should be knowledgeable in techniques used to reduce radiation exposure. As fluoroscopic procedures are commonly used in many specialties, radiation exposure may be reduced by using last image hold and pulsed fluoroscopy beams.[22] As such, patient safety and reduction in radiation harm is crucial to include in radiation safety training of future and current healthcare providers.

Discrepancies arise regarding the best method for delivering radiation safety training. The most popular options were online courses (36.8%), workshops (29.8%), seminars (14.9%), didactic lectures (14.0%), and other (4.4%). A previous study by Singh et al. in the United Kingdom utilized a group of 69 highly-qualified experts to develop a core set of outcomes, defined in terms of clinical competencies, that outline what medical students should know about radiation protection by the time of graduation.[23] To our knowledge, no such competency-based curriculum has been developed for Canadian medical trainees.

Several associations including the Canadian Association of Medical Radiation Technologists and the Canadian Association of Radiologists have acknowledged the gap in radiation education and consequently put forth recommendations and informational packages about diagnostic radiology usage and safety for medical trainees in Canada.[24] However, there is no standardized implementation of radiation safety training across medical schools in Canada.

Discrepancies in radiation safety curriculum amongst Canadian medical schools remain, both in which ways radiation safety is taught and the amount of training medical trainees receive.[3] Models for radiation safety education include didactic sessions and clinical instruction with participation in a monitoring program,[25] pre-residency boot camps,[26] and e-learning modules,[27,28].

The limitations of the current study include a relatively small sample size (115 respondents). However, the sample size was sufficient to detect significant differences amongst groups. There were also fewer residents who responded to the survey. Secondly, the survey was administered to medical trainees and attending physicians in only two provinces and other academic institutions in Canada may have a different levels of radiation safety education. A selection bias exists where medical students will inherently have less exposure and experience with ionizing radiation producing procedures, and results must be considered in this context. Lastly, our survey is not validated which makes it difficult to predict the reproducibility of this study.

CONCLUSIONS

Radiation safety training is an important component of medical education for medical students, resident physicians, and attending physicians. Current radiation safety training requirements and procedures at various levels of medical training at two centres in Canada need to be addressed. Implementing radiation safety education may improve adherence to the ALARA principles and enhance radiation safety at these sites. This study also highlights the need for further research at the national level to evaluate broader radiation safety practices in Canada.

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Figures and Tables

Figure 1. Differences in radiation safety training between groups. * and ** indicate statistically significant differences between groups for each variable.

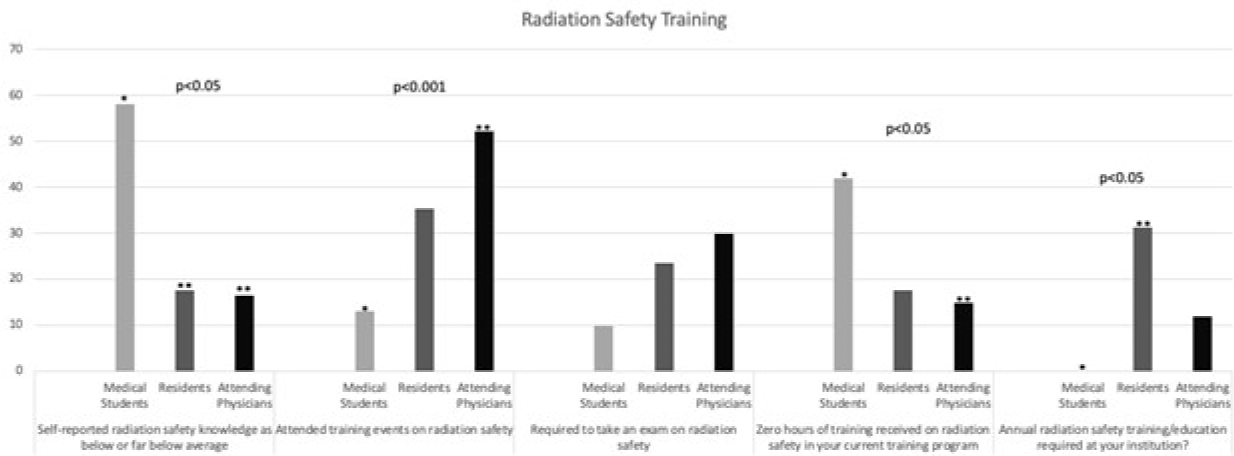

Figure 2. Differences in radiation exposure and use of radiation protective equipment between groups. * and ** indicate statistically significant differences between groups for each variable.

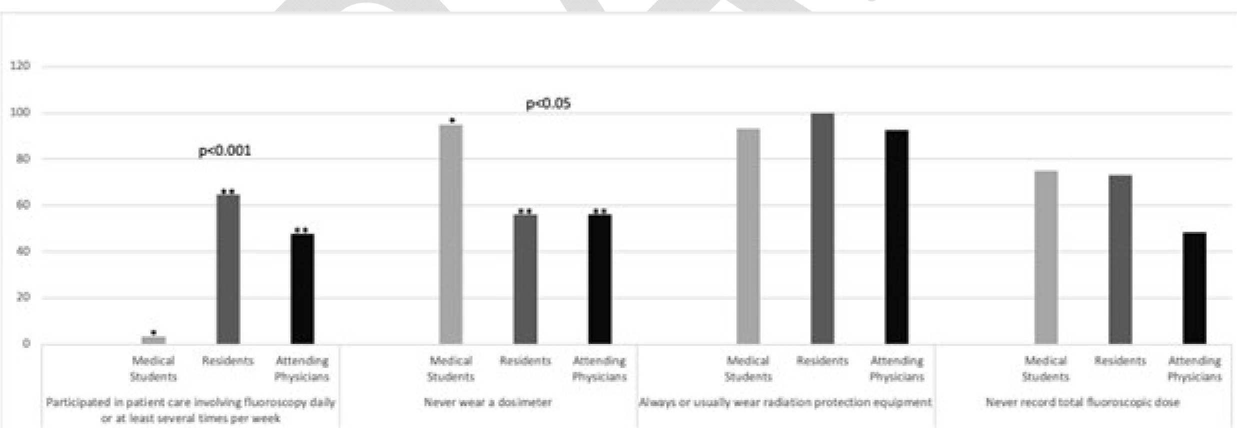

Figure 3. Differences in radiation metrics knowledge. * and ** indicate statistically significant differences between groups for each variable.

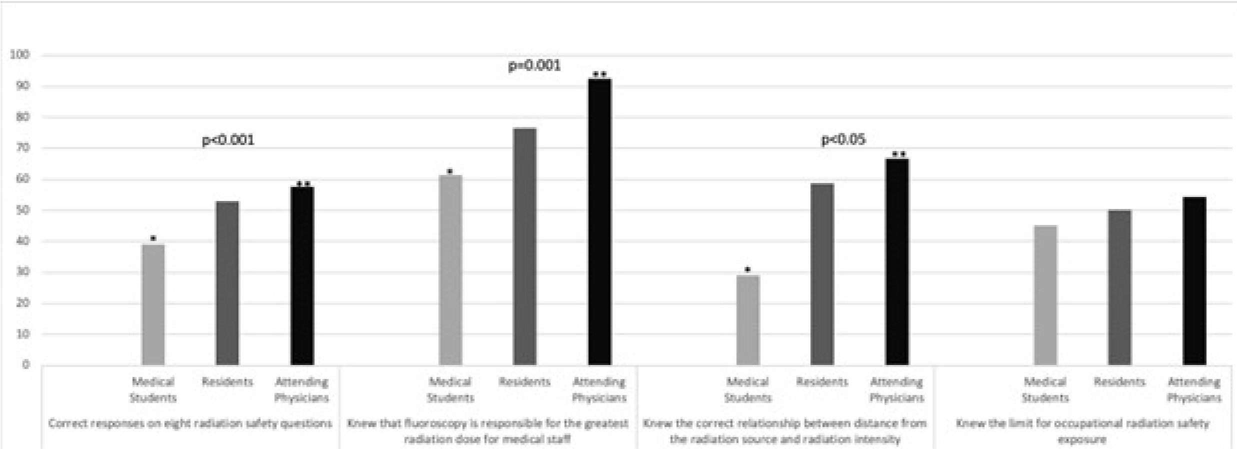

Table 1. Demographic information of study participants			
Characteristics		**n**	**Full sample (%)**
Gender			
	Male	74	64.3
	Female	39	33.9
	Unidentified	2	1.7
	Total	115	100
Training	Year 1-2 medical student	12	10.4
	Year 3-4 medical student	19	16.5
	PGY 1-2 resident	12	10.4
	PGY 3+ resident	5	4.3
	Attending physician	67	58.3
	Medical student	31	27.0

Field of training	General surgery	18	15.7
	Urology	19	16.5
	Vascular surgery	6	5.2
	Orthopedic surgery	18	15.7
	Radiology	13	11.3
	Interventional cardiology	2	1.7
	Other	8	7.0

Other: plastic surgery (n=4), general surgical oncology (n=1), thoracic surgery (n=1), otolaryngology (n=1) neurosurgery (n=1). PGY: postgraduate year