

Review began 06/08/2023
Review ended 07/07/2023
Published 07/11/2023

© Copyright 2023
Khan et al. This is an open access article
distributed under the terms of the Creative
Commons Attribution License CC-BY 4.0.,
which permits unrestricted use, distribution,
and reproduction in any medium, provided
the original author and source are credited.

Enhancing Radiation Safety Culture: Investigating the Mediating Role of Awareness Among Orthopedic Doctors and Operation Theatre Assistants

Junaid Khan ¹, Bilal Khalid ¹, Muhammad Zulfiqar Abbasi ¹, Raja Adnan Ashraf ², Kamran Asghar ³,
Muhammad Nadeem Kashmiri ⁴, Kashif Tousif ⁵, Faizan Shahzad ⁶, Jawad Basit ⁷, Tehseen Haider ⁶,
Haroon Shabbir ⁸, Abdul Rauf Khalid ⁸, Sajeel Saeed ⁷

1. Orthopaedic Surgery, Benazir Bhutto Hospital, Rawalpindi, PAK 2. Orthopaedic Surgery, Railway General Hospital, Rawalpindi, PAK 3. Orthopaedic Surgery, Fauji Foundation Hospital, Rawalpindi, PAK 4. Orthopaedic Surgery, Watim Medical College, Islamabad, PAK 5. Medicine, Rawalpindi Medical University, Islamabad, PAK 6. Medicine, Rawalpindi Medical University, Rawalpindi, PAK 7. Cardiology, Rawalpindi Medical University, Rawalpindi, PAK 8. Surgery, Rawalpindi Medical University, Rawalpindi, PAK

Corresponding author: Sajeel Saeed, sajeelsaeed007@gmail.com

Abstract

Introduction: The increasing use of minimally invasive orthopedic procedures has led to a greater reliance on fluoroscopy, resulting in elevated radiation exposure for surgeons. This study aimed to evaluate the knowledge, awareness, and daily practices of orthopedic surgeons regarding radiation safety in an academic hospital. Understanding radiation safety is crucial to minimize patient exposure and prevent adverse effects on surgeons.

Methods: This cross-sectional study was conducted at the Department of Orthopedics of different tertiary care hospitals in Rawalpindi, Pakistan. Data were collected prospectively for two years, and a total of 505 participants, including residents, consultants, and operation theatre assistants, completed a questionnaire. The questionnaire was validated by experts and covered information on fluoroscopy usage, frequency of surgeries, awareness of radiation safety, and protective measures. Ethical approval was obtained, and data were analyzed using SPSS version 26.0.

Results: The majority of participants were male (74.1%), and the sample included various ranks of orthopedic surgeons. Only 56.2% of participants were aware of the usage of fluoroscopy, and 40.2% had read some research on the topic. While 44.6% used lead aprons for radiation protection, the usage of other protective measures and dosimeters was limited. The mediation analysis showed an insignificant indirect association between the rank of orthopedic surgeons, number of surgeries performed, and fluoroscopy usage as a mediator. Awareness and reading research on fluoroscopy were significantly associated with radiation protection.

Conclusion: The knowledge, awareness, and daily practices of orthopedic surgeons regarding radiation safety in fluoroscopy use need improvement. The findings emphasize the importance of implementing training programs, providing radiation protection devices, and ensuring compliance with safety guidelines.

Categories: Orthopedics, Epidemiology/Public Health, Osteopathic Medicine

Keywords: risk exposure, fluoroscopy intervention, radiation, awareness, orthopedics

Introduction

There is a growing focus on minimally invasive methods to reduce postoperative problems and injuries, as the number of older people needing orthopedic therapy increases. However, these procedures have led to a higher dependence on fluoroscopy by surgeons, which has increased their exposure to direct and dispersed ionizing radiation. In several orthopedic treatments, including trauma, reconstructive, and pediatric surgery, indirect anatomical observation is crucial. Radiation exposure is well-known to be detrimental [1,2].

Due to the established biological consequences of ionizing radiation, the use of fluoroscopy in the operating room raises hazards for orthopedic surgeons [2,3]. Radiation may have both deterministic (non-random) and stochastic (random) effects, depending on the dosage. While the risk of predictable consequences like cataracts, alopecia, migraines, skin ulceration, and infertility is minimal below a specific threshold, any dosage of radiation has the potential to cause cancer in radiosensitive tissues including the breast, lungs, thyroid, and red bone marrow [4]. According to the linear no-threshold model, any exposure to ionizing radiation is deemed equally dangerous, since the risk of cancer formation rises with increasing doses [3]. To reduce patient exposure during surgical procedures, orthopedic surgeons must have complete awareness of radiation safety.

How to cite this article

Khan J, Khalid B, Abbasi M, et al. (July 11, 2023) Enhancing Radiation Safety Culture: Investigating the Mediating Role of Awareness Among Orthopedic Doctors and Operation Theatre Assistants. Cureus 15(7): e41704. DOI 10.7759/cureus.41704

Interestingly, orthopedic surgeons are less sensitive to radiation exposure to the hand than radiologists and cardiologists [5]. However, investigations done in England and Wales by Khan et al. revealed that basic surgical trainees had minimal understanding of the use of ionizing radiation in orthopedic trauma surgery, and even fewer were aware of the relevant literature [6].

The threat presented by ionizing radiation is exacerbated by the fact that it is unseen and intangible. Those orthopedic surgeons who must operate in the X-ray beam's direction are unfortunately exposed to radiation [7,8]. Many orthopedic surgeons do not get the same amount of radiation safety training as other medical professionals, despite these concerns. Previous researches by Tunçer et al., Saroki et al., and Nugent et al. demonstrated that orthopedic surgeons often lack enough understanding of the use and hazards of ionizing radiation, as well as the essential radioprotective measures to prevent radiation-related injury [7,9,10].

The aim of this research was to assess the knowledge, awareness, and everyday practices of orthopedic surgeons in an academic hospital regarding radiation safety. The research aims to address the research gap that exists in the understanding and implementation of radiation safety measures among orthopedic surgeons. Despite the increasing reliance on fluoroscopy in orthopedic procedures, which exposes surgeons to ionizing radiation, there is limited awareness around and training on radiation safety within the orthopedic field. Previous studies have highlighted the lack of understanding and knowledge among orthopedic surgeons regarding the use and hazards of ionizing radiation, as well as the necessary radioprotective measures. Therefore, this research aims to contribute to the existing body of knowledge by evaluating the current level of awareness and practices related to radiation safety among orthopedic surgeons, ultimately providing valuable insights to improve radiation safety protocols in orthopedic surgery.

Materials And Methods

Study design

This analytical, cross-sectional study was conducted at the Department of Orthopedics of different tertiary care hospitals in Rawalpindi, Pakistan. Data were collected prospectively for a duration of two years, i.e., from September 5, 2020, to September 4, 2022. A total of 505 participants were included in the study. The questionnaire was distributed among the residents, consultants, and operation theatre assistants (OTAs) working in orthopedic operation theatres of tertiary care hospitals. All the participants voluntarily filled out the questionnaire after informed consent.

Content validity

The questionnaire was sent to three experts from different domains of the university to check for content validity of the questionnaire. These experts were from the community medicine department and orthopedics department. These experts were then asked to assess the suitability of the questionnaire in terms of the expression of its instruction, test items, and whether its subtests were in accord with their respective fields. The experts then checked the quality of the questionnaire, and accordingly, it was decided that each item should be retained in the questionnaire.

Questionnaire

Information was recorded on printed questionnaires after taking informed consent from participants. The questionnaire consisted of all the information regarding the use and knowledge of the fluoroscope, the average number of days a surgeon does surgeries, etc. (Table 1).

Questionnaire		
S. no.	Questions	Answers
1.	No. of days when you performed/assisted with surgery per week	1
		2
		3-5
		>5
		5
2.	No. of surgeries performed/assisted with per week	6-10
		11-15
		>15
		All operations
3.	How many of your operations need fluoroscopy?	>50%
		25%-50%
		<25%
		50
4.	Average no. of fluoroscope images taken on an operative day	50-100
		100-200
		>200
5.	Are you aware of the use of a fluoroscope?	Yes
		No
6.	Have you read any research on fluoroscopy?	Yes
		No
7.	Who operates the fluoroscope during the surgical procedure?	Technician
		Nurse
		Assisting surgeon
		None of the above
		Lead apron
8.	How do you protect yourself from radiation during fluoroscopy?	Personal protective equipment
		More than one of these
		None of above
		Headache and fatigue
9.	Have you ever had any of the following complaints?	Nausea/vomiting
		More than one of these
		None of these
10.	Do you use a dosimeter?	Yes
		No

TABLE 1: Radiation safety and fluoroscopy practices questionnaire

This questionnaire was originally written in English, but the research investigators translated it into Urdu to make it easier to understand. This questionnaire was then back-translated to ensure its validity. To guarantee compliance and the clarity of the questionnaire, a pilot research with 30 participants was also carried out before the survey. These responses were not included in the final data.

Ethical approval

Before the start of the study, the Institutional Review Board (IRB) of Benazir Bhutto Hospital in Rawalpindi, Pakistan, granted ethical permission (RSRS-2020-S-022) for the research. The medical superintendents (MS) of Benazir Bhutto Hospital was formally requested for authorization to gather data. Consent was obtained before data collection, and participant anonymity was maintained throughout the investigation. The technique of data collection adhered to national and institutional ethical requirements, as well as the most current edition of the Helsinki Declaration. Each participant provided their informed consent. The anonymity and confidentiality of the data were maintained. The study adhered to the Strengthening the Reporting of Cohort Studies in Surgery (STROCSS) guidelines for cross-sectional research reporting.

Sample size

Using the WHO sample size calculator, a sample size of 505 individuals was determined; with a population size of 735 and a 95% confidence level, the expected proportion (P) of the population with adherence to standard operating procedures (SOPs) was taken as 0.5, and the margin of error (d) as 0.05. The design effect was taken as 2.

Data entry and analysis

Using SPSS Statistics, version 26.0 (IBM Corp., Armonk, NY), data were entered and analyzed. Qualitative factors were transformed into percentages and proportions. Data's normality was determined using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Using binominal and multinominal linear regression, the relationship between dependent (protection against radiation exposure) and independent variables (such as fluoroscope awareness) was determined. In addition, Version 3.5 of PROCESS macro was employed for mediation analysis. p-values less than or equal to 0.05 were deemed statistically significant.

Results

A total of 505 individuals participated in our healthcare survey. Out of these 505 individuals, 374 participants (74.1%) were male and 131 (25.9%) were females. Among these, 8 (1.6%) were professors, 15 (3%) were associate professors, 15 (3%) were assistant professors, 42 (8.3%) were senior registrars, 305 (60.4%) were residents and 120 (23.8%) were operation theatre assistants. About 429 individuals (85%) from the sample data performed or assisted with surgeries for five days in a week, 70 (13.9%) performed surgeries for four days, and 6 (1.2%) for three days. All the professors usually performed surgeries for four days. Among the associate professors, 3 (20%) performed surgeries for three days whereas 12 (80%) performed surgeries for four days. Among the assistant professors, 3 (20%) performed surgeries for three days whereas 12 (80%) performed surgeries for four days. Among the senior registrars, 9 (21.4%) performed surgeries for four days whereas 33 (78.6%) performed them for five days. Among the residents, 29 (9.5%) performed surgeries for four days, whereas 276 (90.5%) performed them for five days. All the OTAs assisted with the surgeries for five days; 2 (0.4%) individuals performed 5 surgeries in a week, 23 (4.6%) did 6-10 surgeries per week, 43 (8.5%) performed 11-15 surgeries per week while the remaining 437 (86.5%) individuals performed more than 15 surgeries per week. From the sample population, 284 (56.2%) were aware of the usage of the fluoroscope and 203 participants (40.2%) had read a research on fluoroscopy. About 225 individuals (44.6%) protected themselves from radiation during fluoroscopy by using a lead apron; 264 participants (52.3%) used more than one lead apron for protection whereas 16 participants (3.2%) used nothing.

Figure 1 indicates mediation model 4; the direct effect of the rank of orthopedic surgeons on the number of surgeries performed daily was significant. However, when using fluoroscopy usage in an operation theater as a mediator, the indirect effect of orthopedic surgeons on several surgeries performed daily was found to be insignificant.

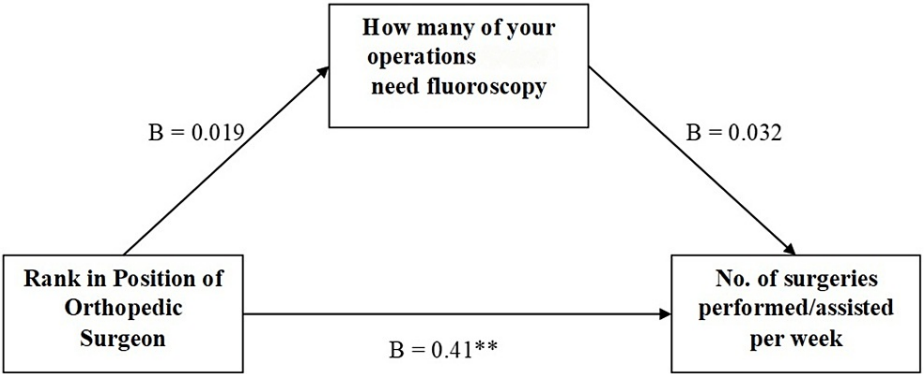


FIGURE 1: Effect of rank and the mediation effect of operations needing fluoroscopy on surgeries performed per week

B indicates the regression coefficient. "No. of surgeries performed per week" is a dependent variable, "rank in position of orthopedic surgeon" is independent whereas "how many of your operations need fluoroscopy" is taken as the mediator.

**p<0.001

Awareness regarding fluoroscopy usage was significantly associated with protection against radiation exposure (B = 0.9917, CI: 0.9428, 1.0406), as shown in Figure 2. By taking the rank of an orthopedic surgeon as a mediating variable, an insignificant indirect relation (B = 0.0103) was found between the independent and dependent variables showing that position did not affect the relationship between the two variables.

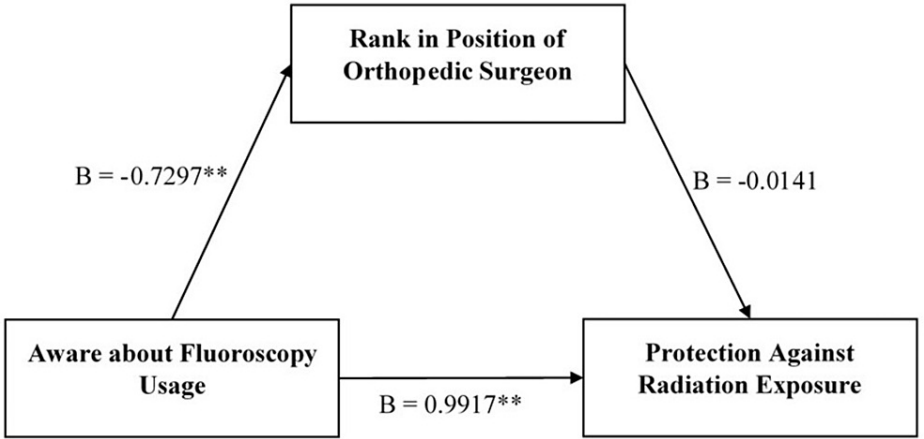


FIGURE 2: Effect of awareness and mediating effect of position of orthopedic surgeons on protection against radiation exposure

B indicates the regression coefficient. "Awareness about fluoroscopy usage" is taken as an independent variable whereas "protection against radiation exposure" is taken as a dependent variable. "Rank in position of orthopedic surgeon" is taken as the mediator.

**p<0.001

Reading research about fluoroscopy usage was significantly associated with protection against radiation exposure (B = 0.8234, CI: 0.7467, 0.9001), as shown in Figure 3. An insignificant indirect association was found between the two variables when taking the rank of orthopedic surgeons as a mediator (B = 0.0111).

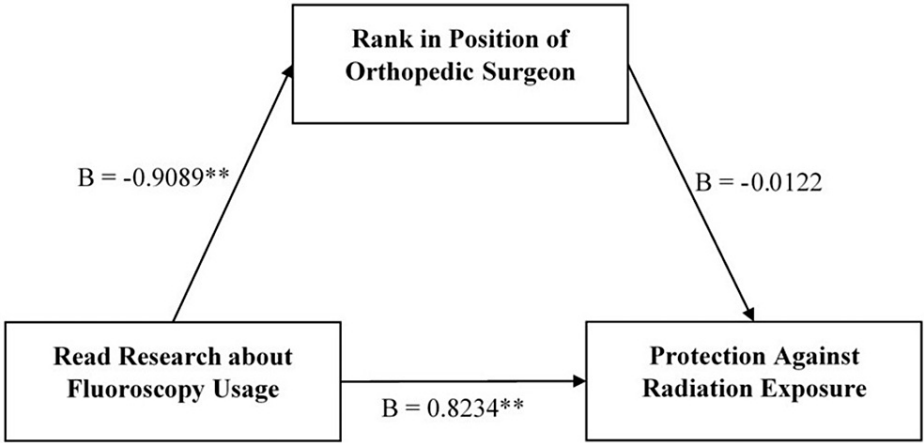


FIGURE 3: Effect of reading research and mediating effect of position of orthopedic surgeons on protection against radiation exposure

B indicates the regression coefficient. "Read research about fluoroscopy usage" is taken as an independent variable whereas "protection against radiation exposure" is taken as a dependent variable. Position of orthopedic surgeons is taken as the mediator.

**p<0.001

Discussion

Fluoroscopic imaging is vital in orthopedic surgery; however, it carries the danger of ionizing radiation exposure [11]. To limit this danger to the operator and colleagues in the operating room, adequate knowledge and awareness of radiation safety are required. This research indicated, however, that the degree of radiation safety education among orthopedic surgery personnel is poor.

Wilhelm Roentgen discovered X-rays in 1895, and since then, scientists have worked to improve the speed and quality of X-ray picture production. This resulted in the creation of the fluoroscopy apparatus [12]. The benefit of fluoroscopy over conventional X-rays is that it offers quicker results and displays the picture in real time throughout the process [13]. However, a significant disadvantage is that it exposes both the patient and surgeon to greater radiation levels than conventional X-rays that can lead to cataract formation, radiation dermatitis, skin cancer, and thyroid cancer. Women are also susceptible to acquiring breast cancer and exposing their unborn children to radiation [14]. Despite this, fluoroscopy has been a crucial tool in the operating room for orthopedic surgeons for many years for procedures such as the insertion of intramedullary nails for long bone fractures, reduction of closed fractures, removal of foreign bodies, external fixation of fractures, and insertion of hardware percutaneously [13].

There is a paucity of understanding among orthopedic residents, consultants, paramedics, and OT personnel about ionizing radiation and the associated equipment, according to research [15]. Only half of the participants in this survey were aware of the fluoroscope's use, and only 40.2% had read any literature on it. These numbers are very low, and this issue requires significant attention. These results are close to those of earlier researches that also showed that orthopedic residents, consultants, paramedics, and OT staff had a limited understanding of fluoroscopy and its radiation dangers [7,9]. According to the study done by Saroki et al., 91.2% of surgeons agreed that the majority of orthopedic surgeons need to be better educated about radiation safety [7].

In this research, 44.6% of participants used one apron to shield themselves from radiation during fluoroscopy, whereas 52.3% used several aprons. This takes the overall percentage to 96.9%, which is consistent with findings from a previous research. An academic unit performed an audit by mailing a questionnaire to 28 orthopedic physicians. The findings revealed that 96.4% of participants reported always wearing a lead apron [14]. A total of 98.4% of registrars reported using a lead apron in a separate survey [16]. This finding is comparable to that of a 2011 research published in the *Journal of Paramedical Sciences* conducted among radiographers at several hospitals in Hamadan City, Iran, where 98% of staff were aware of personal protection gear such as lead aprons and thyroid shields [17]. Only 78.9% of participants wore a lead apron, according to another research from Kerman, Iran [18]. Despite the increased danger of radiation exposure associated with wearing a broken lead apron, over 78% of registrars reported using one and said that it was the only option available.

During surgery, orthopedic surgeons are mostly exposed to scattered radiation, as opposed to direct radiation. The use of a lead apron and protective equipment for the testicles and thyroid gland may reduce

the negative effects of radiation. Studies indicate that adequate protection may minimize a physician's exposure to radiation by up to 90% [19]. Compliance with body shields is often high, but other preventive measures, such as thyroid shields, are employed less frequently [20]. This research did not disclose data on the use of thyroid protectors in our environment, which represents a possible drawback. In addition, the use of dosimeters is not required as part of our radiation protection policy.

Since many radiation protective technologies are unavailable, it begs the issue of whether orthopedic doctors would have used them if they had been widely accessible. Moreover, in a research by van Papendorp et al., some participants were unaware that some equipment might be used for radiation protection, supporting the participants' lack of knowledge and awareness of radiation [15]. Meisinger et al. performed research that indicated various potential reasons why operators may not use particular radiation protective equipment. These included the uncomfortable placement of shields, weight of clothes, the tight fit of thyroid collars, and the rigidity of lead gloves. These results imply that the gadgets may be impractical and painful to use, necessitating additional development [20].

As this was a cross-sectional research study, no information was gathered on any awareness initiatives or their results and impacts. Also, no information was gathered about the potential causes for not using radiation protective gear. In addition, this survey was only done at tertiary care institutions, and thus, information about the knowledge of physicians in secondary care or primary care hospitals was not obtained. This investigation was done in just one Pakistani city. On a nationwide scale, we propose doing multi-center research. This will not only provide accurate statistics but also identify regions with the lowest awareness that need quick interventions.

In conclusion, we strongly recommend implementing the following actions to ensure radiation safety in the field: incorporating radiation safety knowledge into the training curriculum and examination, requiring registrars to use picture intensifiers under supervision, providing radiation protective clothing and equipment, and making the use of dosimeters mandatory. These measures are crucial for safeguarding the well-being of both healthcare professionals and patients, and their implementation will contribute to a safer and more effective radiology practice.

Conclusions

The majority of orthopedic surgeons routinely employ fluoroscopic imaging during surgery; however, they typically lack a comprehensive grasp and awareness of the radiation safety risks connected with this technique. Personal safety equipment is often unavailable or underutilized when it is. Therefore, it is suggested that a radiation safety and protection training program be created within the orthopedic department. This program should cover the radiation dose limits recommended by the International Commission on Radiological Protection (ICRP). It should also teach the use of radiation protection devices and tools, like lead aprons and protective eyewear. Additionally, it should provide information on the correct techniques for using fluoroscopic imaging. It is recommended that a weekly class be held in the orthopedic department on the topic of fluoroscopy. Additionally, experts from the radiology department should be invited to conduct workshops on reducing radiation exposure.

Additional Information

Disclosures

Human subjects: Consent was obtained or waived by all participants in this study. Institutional Research Forum issued approval RSRS-2020-S-022. It is stated that the research project titled "Enhancing Radiation Safety Culture: Investigating the Mediating Role of Awareness Among Orthopedic Doctors and Operation Theatre Assistants" submitted by the principal investigator Dr. Junaid Khan conforms to the accepted ethical standards established by the Institutional Research Forum of Rawalpindi Medical University. As no ethical issues were found in this proposal, this research proposal has been approved. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References

1. Tsalafoutas IA, Tsapaki V, Kaliakmanis A, Pneumatics S, Tsoronis F, Koulentianos ED, Papachristou G: Estimation of radiation doses to patients and surgeons from various fluoroscopically guided orthopaedic surgeries. *Radiat Prot Dosimetry*. 2008, 128:112-9. [10.1093/rpd/ncm234](https://doi.org/10.1093/rpd/ncm234)
2. Johnson DR, Kyriou J, Morton EJ, Clifton A, Fitzgerald M, Macsweeney E: Radiation protection in interventional radiology. *Clin Radiol*. 2001, 56:99-106. [10.1053/crad.2000.0640](https://doi.org/10.1053/crad.2000.0640)
3. Mahajan A, Samuel S, Saran AK, Mahajan MK, Mam MK: Occupational radiation exposure from C arm fluoroscopy during common orthopaedic surgical procedures and its prevention. *J Clin Diagn Res*. 2015,

- 9:RC01-4. [10.7860/JCDR/2015/10520.5672](https://doi.org/10.7860/JCDR/2015/10520.5672)
4. Troisi K, Ferreira N: Radiation exposure to orthopaedic registrars in the Pietermaritzburg Metropolitan Complex. *SA Orthop J*. 2016, 15:38-42.
5. Vano E: Radiation exposure to cardiologists: how it could be reduced. *Heart*. 2003, 89:1123-4. [10.1136/heart.89.10.1123](https://doi.org/10.1136/heart.89.10.1123)
6. Khan F, Ul-Abadin Z, Rauf S, Javed A: Awareness and attitudes amongst basic surgical trainees regarding radiation in orthopaedic trauma surgery. *Biomed Imaging Interv J*. 2010, 6:e25. [10.2349/biij.6.3.e25](https://doi.org/10.2349/biij.6.3.e25)
7. Saroki AJ, Wijidicks C, Philippon MJ, Bedi A: Orthopaedic surgeons' use and knowledge of ionizing radiation during surgical treatment for femoroacetabular impingement. *Knee Surg Sports Traumatol Arthrosc*. 2016, 24:3962-70. [10.1007/S00167-015-3734-1](https://doi.org/10.1007/S00167-015-3734-1)
8. Lee K, Lee KM, Park MS, Lee B, Kwon DG, Chung CY: Measurements of surgeons' exposure to ionizing radiation dose during intraoperative use of C-arm fluoroscopy. *Spine (Phila Pa 1976)*. 2012, 37:1240-4. [10.1097/BRS.0b013e31824589d5](https://doi.org/10.1097/BRS.0b013e31824589d5)
9. Tunçer N, Kuyucu E, Sayar Ş, Polat G, Erdil İ, Tuncay İ: Orthopedic surgeons' knowledge regarding risk of radiation exposition: a survey analysis. *SICOT J*. 2017, 3:29. [10.1051/SICOTJ/2017008](https://doi.org/10.1051/SICOTJ/2017008)
10. Nugent M, Carmody O, Dudeney S: Radiation safety knowledge and practices among Irish orthopaedic trainees. *Ir J Med Sci*. 2015, 184:369-73. [10.1007/s11845-014-1121-4](https://doi.org/10.1007/s11845-014-1121-4)
11. Hafez MA, Smith RM, Matthews SJ, Kalap G, Sherman KP: Radiation exposure to the hands of orthopaedic surgeons: are we underestimating the risk?. *Arch Orthop Trauma Surg*. 2005, 125:330-5. [10.1007/s00402-005-0807-5](https://doi.org/10.1007/s00402-005-0807-5)
12. Sehgal M, Awasthi B, Sood S, Raina S, Kaur R, Singh S, Katoch P: Knowledge and awareness of orthopaedic surgeons about radiation hazards in operation theatres. *Int J Res Orthop*. 2021, 7:1015. [10.18203/issn.2455-4510.IntJResOrthop20213384](https://doi.org/10.18203/issn.2455-4510.IntJResOrthop20213384)
13. Shalom NE, Gong GX, Auster M: Fluoroscopy: an essential diagnostic modality in the age of high-resolution cross-sectional imaging. *World J Radiol*. 2020, 12:213-30. [10.4329/wjr.v12.i10.213](https://doi.org/10.4329/wjr.v12.i10.213)
14. Wan RC, Chau WW, Tso CY, Tang N, Chow SK, Cheung WH, Wong RM: Occupational hazard of fluoroscopy: an invisible threat to orthopaedic surgeons. *J Orthop Trauma Rehabil*. 2021, 28: [10.1177/22104917211035547](https://doi.org/10.1177/22104917211035547)
15. van Papendorp LW, Suleman FE, Hanekom H: The knowledge, awareness and practices of radiation safety amongst orthopaedic surgeons. *SA J Radiol*. 2020, 24:1806. [10.4102/sajr.v24i1.1806](https://doi.org/10.4102/sajr.v24i1.1806)
16. Mohamed S, Awadelseid M, Gashi Y, Elbahri H: Knowledge, attitude and practice of Sudanese orthopaedic registrars towards intra-operative radiation protection. *IJASCFRT*. 2021, 9:43-66.
17. Mojiri M, Mohimbeigi A: Awareness and attitude of radiographers towards radiation protection. *J Paramed Sci*. 2011, 2:2-5.
18. Noohi J: Evaluation of personnel protection among radiographers in diagnostics radiology centers in Kerman (Iran). *Environmental Health Conference Iran*. 2009,
19. Rehani MM, Ciraj-Bjelac O, Vaňó E, Miller DL, Walsh S, Giordano BD, Persliden J: ICRP Publication 117. Radiological protection in fluoroscopically guided procedures performed outside the imaging department. *Ann ICRP*. 2010, 40:1-102. [10.1016/j.icrp.2012.03.001](https://doi.org/10.1016/j.icrp.2012.03.001)
20. Meisinger QC, Stahl CM, Andre MP, Kinney TB, Newton IG: Radiation protection for the fluoroscopy operator and staff. *AJR Am J Roentgenol*. 2016, 207:745-54. [10.2214/AJR.16.16556](https://doi.org/10.2214/AJR.16.16556)