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TO EVALUATE RADIATION SAFETY MEASURES IN UROLOGY AND ORTHOPEDIC OT

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Abstract

Ionizing radiation is widely used in fluoroscopy-guided procedures in urology and orthopedic surgery, providing significant benefits in diagnosis and intraoperative guidance; however, it also poses occupational health risks to healthcare professionals due to repeated exposure. This study aimed to evaluate radiation exposure, safety practices, and awareness among operation theater staff. A cross-sectional descriptive study was conducted among 132 healthcare professionals, including surgeons, anesthetists, surgical technicians, anesthesia technicians, and circulating nurses, at Saidu Group of Teaching Hospital and Miangul Abdul Haq Jahanzeb Kidney Hospital. Data were collected using a structured questionnaire assessing radiation exposure frequency, use of protective equipment, awareness of safety principles, and training status. Statistical analysis was performed using IBM SPSS Statistics. The findings revealed frequent occupational exposure, with many participants reporting radiation exposure more than three times per week. Lead aprons were the most commonly used protective measure, while the use of thyroid shields and dosimeters was notably low. A significant proportion of participants did not use any protective equipment, particularly circulating nurses. Major barriers included lack of trust in protective devices, discomfort, and inadequate training. Overall awareness of radiation safety principles was limited.

The study concludes that radiation safety practices are suboptimal among healthcare professionals, highlighting the need for structured training programs, strict adherence to safety protocols, and improved use of protective equipment to minimize occupational radiation risks.

INTRODUCTION

Ionizing radiation has become an indispensable component of modern medical practice, contributing significantly to both diagnostic imaging and therapeutic interventions. Its utility spans across multiple specialties, enabling clinicians to visualize internal anatomical structures, guide procedures, and improve patient outcomes. However, the increasing dependence on radiation-based technologies has also raised important concerns regarding occupational

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exposure among healthcare professionals. Among these, orthopedic surgeons represent a particularly high-risk group due to their frequent and often prolonged use of fluoroscopy during surgical procedures.

Fluoroscopy, especially in the form of C-arm imaging, provides real-time visualization of bony structures and is widely utilized in orthopedic trauma surgeries, fracture reductions, and implant placements. Its integration into minimally invasive surgical techniques has enhanced precision, reduced operative time, and improved overall surgical outcomes. Nevertheless, this advancement has come at the cost of increased exposure to ionizing radiation for both patients and operating room personnel, including surgeons, anesthesiologists, nurses, and supporting staff. During fluoroscopic procedures, radiation is emitted not only directly from the source but also as scattered radiation, thereby posing a risk to all individuals present in the operating environment. Since the discovery of X-rays by Wilhelm Roentgen in 1895, their application in medicine has expanded rapidly, becoming a cornerstone of modern healthcare. Despite its undeniable benefits, ionizing radiation is associated with potential biological hazards. High-dose radiation exposure is well known to cause cellular damage, DNA mutations, and tissue injury, which may ultimately lead to malignancies and other health complications such as cataract formation. Although the effects of low-dose radiation remain a subject of ongoing debate, the linear no-threshold model is commonly used to estimate associated risks, suggesting that even minimal exposure may carry some degree of harm. This concern is particularly relevant given the cumulative nature of occupational radiation exposure over time.In fluoroscopic procedures, radiation doses can vary significantly depending on the duration and complexity of the intervention. It has been reported that patients may receive radiation doses ranging from 12 to 40 millisieverts per minute during standard fluoroscopy. To mitigate these risks, international regulatory bodies such as the National Council on Radiation Protection (NCRP) and the International Commission on Radiological Protection (ICRP) have established guidelines recommending that occupational radiation exposure should not exceed 20–50 millisieverts annually. These limits emphasize the necessity for strict adherence to radiation safety measures in clinical practice. Radiation protection is fundamentally guided by three core principles: time, distance, and shielding. Minimizing the duration of exposure is one of the most effective strategies to reduce radiation dose. This can be achieved by optimizing fluoroscopy settings, using intermittent rather than continuous imaging, and employing advanced imaging techniques such as beam collimation and filtration. Increasing the distance from the radiation source is another critical factor, as radiation intensity decreases significantly with distance according to the inverse square law. Even small increases in distance can result in substantial reductions in exposure. Shielding, through the use of protective equipment such as lead aprons, thyroid collars, lead goggles, and gloves, provides an additional layer of protection by attenuating scattered radiation. The concept of ALARA (As Low As Reasonably Achievable) serves as a guiding principle in radiation safety, emphasizing that exposure should be minimized to the lowest possible level while still achieving the desired clinical outcome. Despite the availability of clear guidelines and protective strategies, studies have consistently demonstrated gaps in knowledge and practice among healthcare professionals. A significant proportion of surgeons lack formal training in radiation safety, underestimate radiation exposure levels, and do not consistently utilize protective equipment. This lack of awareness increases the risk of unnecessary exposure and highlights the need for structured education and training programs.

In the field of urology, particularly in endourology, radiation exposure is a well-recognized concern. Procedures such as percutaneous nephrolithotomy (PCNL), which are commonly used for the management of large renal calculi, rely heavily on fluoroscopic guidance for accurate access and stone removal. As the use of such minimally invasive techniques continues to rise, so does the cumulative radiation exposure for both

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patients and healthcare providers. Studies have shown that radiation exposure during these procedures is often non-uniform, with higher doses affecting the extremities and head, while the trunk receives relatively lower doses due to protective shielding. Similarly, in orthopedic surgery, the reliance on fluoroscopy has increased substantially over recent years. While it offers significant advantages in terms of intraoperative visualization and procedural accuracy, it also exposes surgeons to repeated radiation doses over the course of their careers. Occupational exposure in orthopedic settings is influenced by several factors, including the duration of fluoroscopy use, the positioning of the surgeon relative to the radiation source, and the use of magnification or continuous imaging modes. Evidence suggests that orthopedic surgeons are at an elevated risk of radiation-related health effects, making them a high-risk group requiring targeted interventions. Research conducted in operating theater environments has demonstrated that radiation levels are highest near the operating table and decrease significantly with increasing distance from the source. These findings reinforce the importance of maintaining appropriate positioning and utilizing protective barriers. Furthermore, surveys among orthopedic surgeons have revealed concerning trends, including low rates of formal training, inconsistent use of protective equipment, and limited use of dosimeters for monitoring radiation exposure. Such findings underscore the urgent need for improved education, awareness, and adherence to safety protocols. Encouragingly, structured educational interventions have been shown to significantly improve radiation safety practices. Training programs focusing on the principles of radiation protection, appropriate use of protective equipment, and optimization of fluoroscopy techniques have resulted in reduced fluoroscopy time and improved compliance with safety guidelines. These outcomes highlight the effectiveness of targeted educational strategies in promoting a culture of safety within healthcare settings. In conclusion, while ionizing radiation remains an essential tool in modern medicine, its use is not without risk. The increasing reliance on fluoroscopy in orthopedic and urological procedures necessitates a comprehensive understanding of radiation safety principles among healthcare professionals. Emphasizing education, adherence to established guidelines, and implementation of protective measures is critical to minimizing occupational exposure. This review aims to highlight the importance of radiation safety awareness and to promote best practices among orthopedic surgeons, ensuring the safe and effective use of fluoroscopy while protecting both patients and healthcare providers.

Materials and Methods

This study was conducted using a cross-sectional descriptive design to assess radiation safety measures among healthcare professionals working in urology and orthopedic operation theaters. The research was carried out at Saidu Group of Teaching Hospital and Miangul Abdul Haq Jahanzeb Kidney Hospital over a period of five months (July to November).

The study population comprised operation theater personnel, including surgeons, anesthetists, surgical technologists, anesthesia technicians, and circulating nurses. A total of 132 healthcare professionals participated in the study, including 120 males and 12 females. Participants were recruited through a convenience sampling technique, and all individuals who consented were included, while those unwilling to participate were excluded.

Data were collected using a structured, self-administered paper-based questionnaire adapted from previous studies. The questionnaire gathered information on demographic characteristics, frequency of radiation exposure, use of protective measures (such as lead aprons and thyroid shields), awareness of radiation safety principles, training status, dosimeter usage, and knowledge regarding radiation-sensitive organs. It also included items assessing self-reported symptoms related to radiation exposure.

Prior to data collection, institutional approval was obtained, and participants were informed about the study objectives through a covering letter. Voluntary participation, confidentiality, and anonymity were ensured throughout the study.

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Investigators personally visited both hospitals to distribute and collect the questionnaires, achieving a 100% response rate.

The collected data were analyzed using IBM SPSS Statistics. Descriptive statistics, including frequencies and percentages, were used to summarize the data, while the Chi-square test was applied to assess associations between variables. A p-value of less than 0.05 was considered statistically significant.

Results

A total of 132 healthcare professionals from Saidu Group of Teaching Hospital and Miangul Abdul Haq Jahanzeb Kidney Hospital participated in the study, with males comprising 90.9% and females 9.1%. Participants included surgeons, anesthetists, surgical and anesthesia technicians, and circulating nurses, with surgeons and surgical technicians forming the majority.

Frequent occupational exposure to radiation was reported, with a notable proportion of participants—particularly surgeons and technical staff—exposed more than three times per week. Although lead aprons were the most commonly used protective measure, a considerable number of participants, especially circulating nurses and anesthesia technicians, reported not using any protection.

Barriers to protective equipment use included lack of trust, discomfort due to weight, back pain, laziness, and sweating. The most commonly reported symptom following exposure was full-body aches, while many surgeons reported no symptoms. The use of dosimeters was low, and most participants reported absence of warning signs in fluoroscopy areas.

Although many respondents recognized the role of lead aprons and thyroid shields in reducing radiation exposure, overall knowledge of radiation safety was limited, and most had not received formal training. Additionally, awareness regarding lead shielding in operation theater walls was inadequate.

Overall, the findings highlight high radiation exposure, poor compliance with safety measures, and insufficient training, emphasizing the need for improved education and stricter implementation of radiation protection protocols.

Figure 1. Demographic and Professional Distribution of Study Participants (n=132)

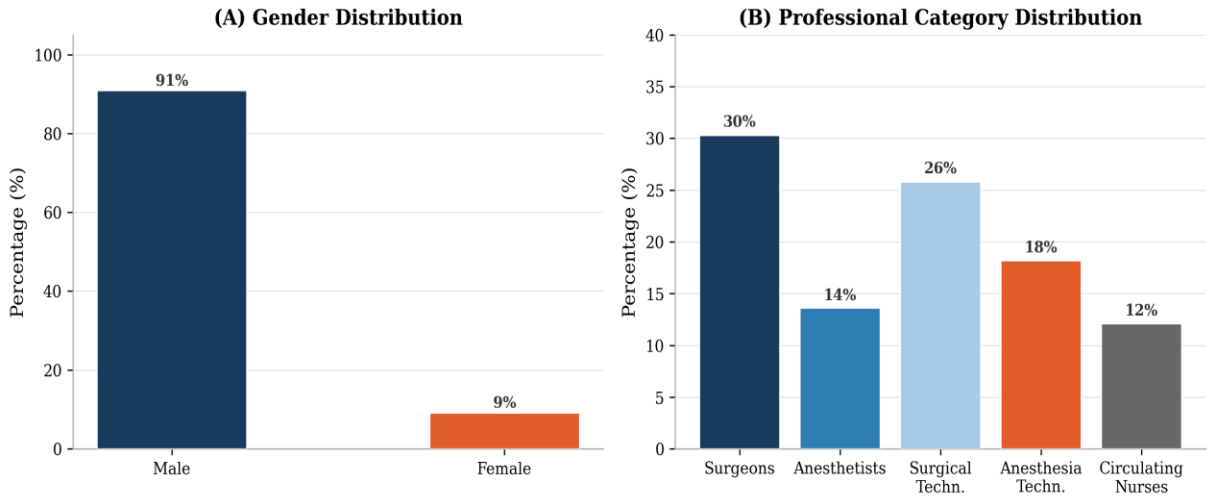

Figure 1. Demographic and Professional Distribution of Study Participants (n=132)

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Figure 2. Frequency of Occupational Radiation Exposure by Professional Category

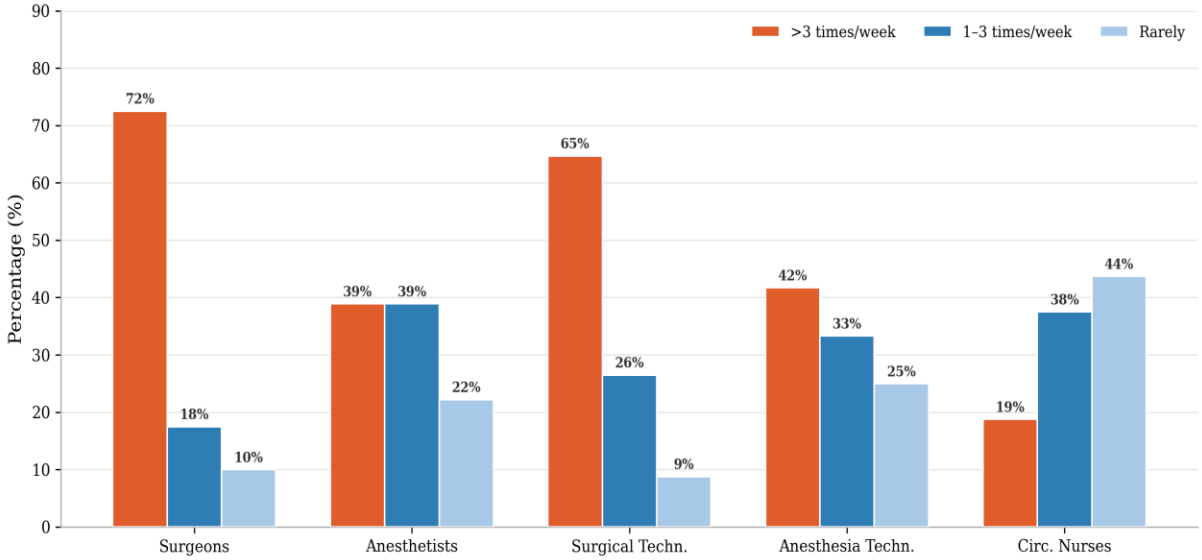

Figure 2. Frequency of Occupational Radiation Exposure by Professional Category

Discussion

Ionizing radiation remains an essential component of modern medical practice, particularly in urology and orthopedic surgeries where fluoroscopy plays a vital role in diagnosis and intraoperative guidance. While its benefits in improving surgical precision and patient outcomes are well established, its use is associated with potential health risks for both patients and healthcare professionals. Therefore, strict adherence to radiation safety measures is critical to minimize these risks and ensure safe clinical practice.

The findings of this study demonstrate significant gaps in radiation safety practices among healthcare professionals. Although lead aprons were the most commonly used protective equipment, the use of other essential protective measures, such as thyroid shields and dosimeters, was notably limited. This is consistent with previous studies, which have reported inadequate compliance with radiation safety protocols and poor utilization of personal protective equipment among healthcare workers. The observed lack of warning signs and uncertainty regarding structural protection, such as lead shielding in operation theaters, further highlights deficiencies in institutional safety measures.

A key concern identified in this study is the frequent exposure to radiation, particularly among surgeons and technical staff who reported exposure multiple times per week. Prolonged and repeated exposure increases the risk of both deterministic effects, such as tissue damage and cataracts, and stochastic effects, including malignancies that may develop years after exposure. These risks are compounded by the inadequate use of monitoring tools such as dosimeters, which are essential for tracking cumulative radiation exposure.

In the context of endourology, procedures such as percutaneous nephrolithotomy (PCNL) rely heavily on fluoroscopic guidance, leading to continuous and cumulative radiation exposure for urologists. Similarly, orthopedic surgeons frequently depend on fluoroscopy during trauma and minimally invasive procedures, placing them in a high-risk category for occupational radiation exposure. Previous research has shown that many healthcare professionals underestimate radiation risks and fail to adopt adequate protective

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measures, which aligns with the findings of this study.

Another important observation is the lack of formal training in radiation safety among the majority of participants. Limited awareness regarding radiation hazards, protective strategies, and sensitive organs indicates a need for structured educational programs. Studies have demonstrated that targeted training significantly improves compliance with safety measures and reduces radiation exposure by minimizing fluoroscopy time.

The study also identified practical and perceptual barriers to the use of protective equipment, including discomfort, back pain, and lack of trust in its effectiveness. Addressing these barriers is essential to improve compliance and promote a culture of safety in operation theaters.

In conclusion, this study highlights inadequate radiation safety practices, insufficient training, and high levels of occupational exposure among healthcare professionals. There is a clear need for comprehensive strategies, including regular training programs, strict enforcement of safety protocols, routine use of dosimeters, and availability of complete protective equipment. Strengthening these measures will help minimize radiation risks and ensure the safety of both patients and healthcare providers while maintaining the clinical benefits of fluoroscopy.

Figure 3. Protective Equipment Use Among Healthcare Professionals

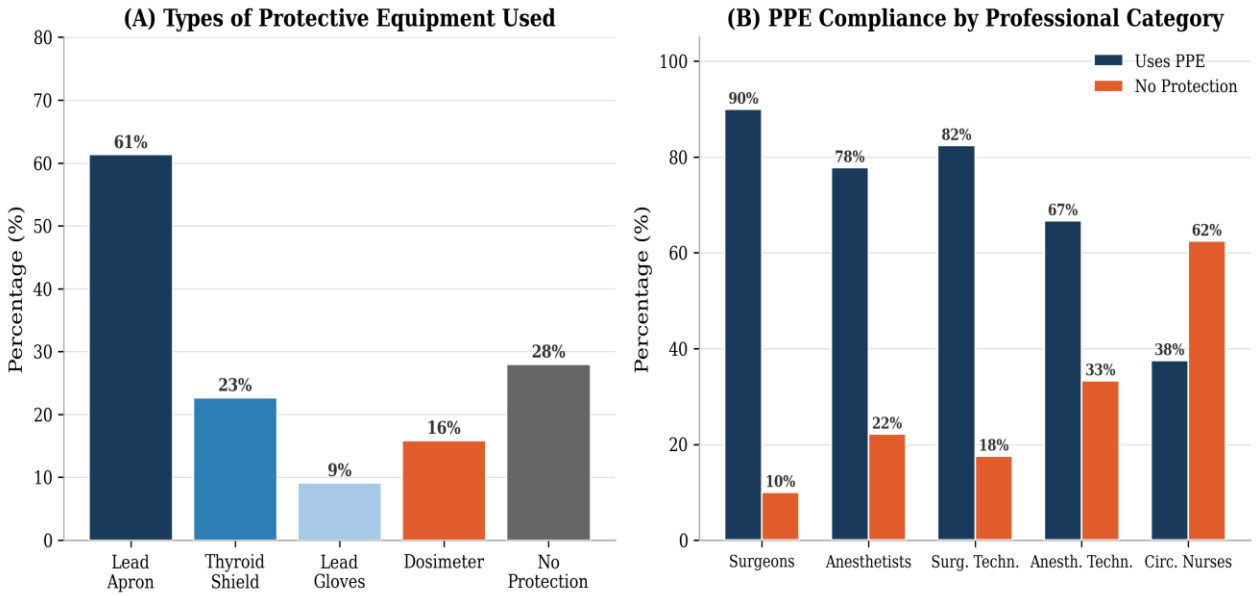

Figure 3. Use of Protective Equipment Among Healthcare Professionals

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Figure 4. Barriers to Protective Equipment Use and Self-Reported Symptoms

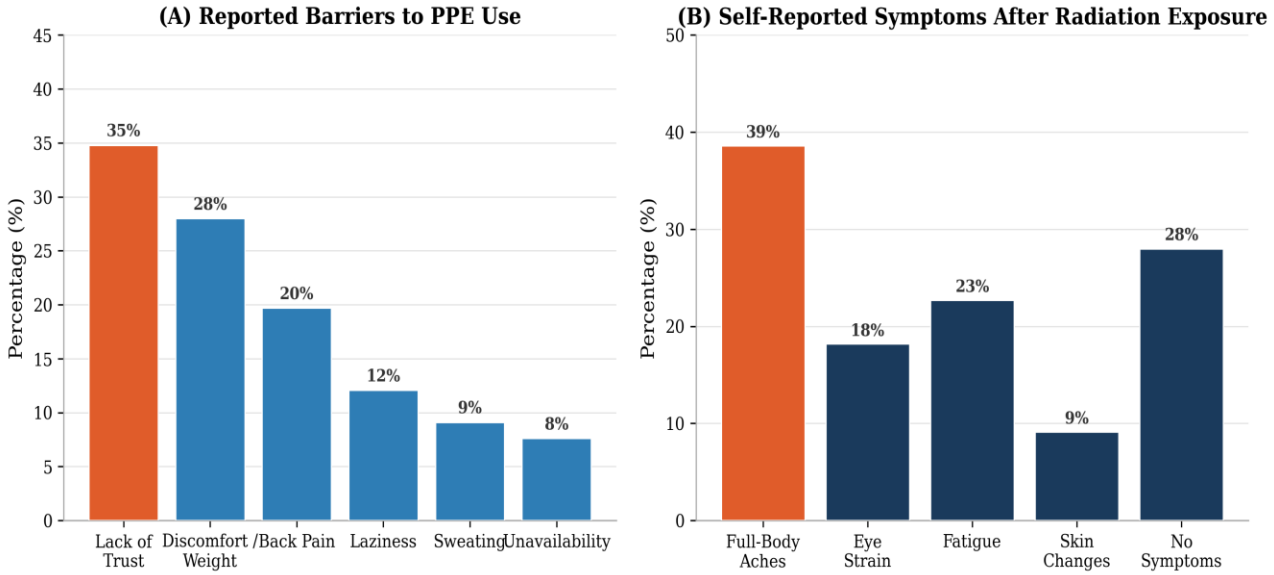

Figure 4. Barriers to Protective Equipment Use and Self-Reported Symptoms

Figure 5. Radiation Safety Knowledge, Training, and Awareness Among Participants

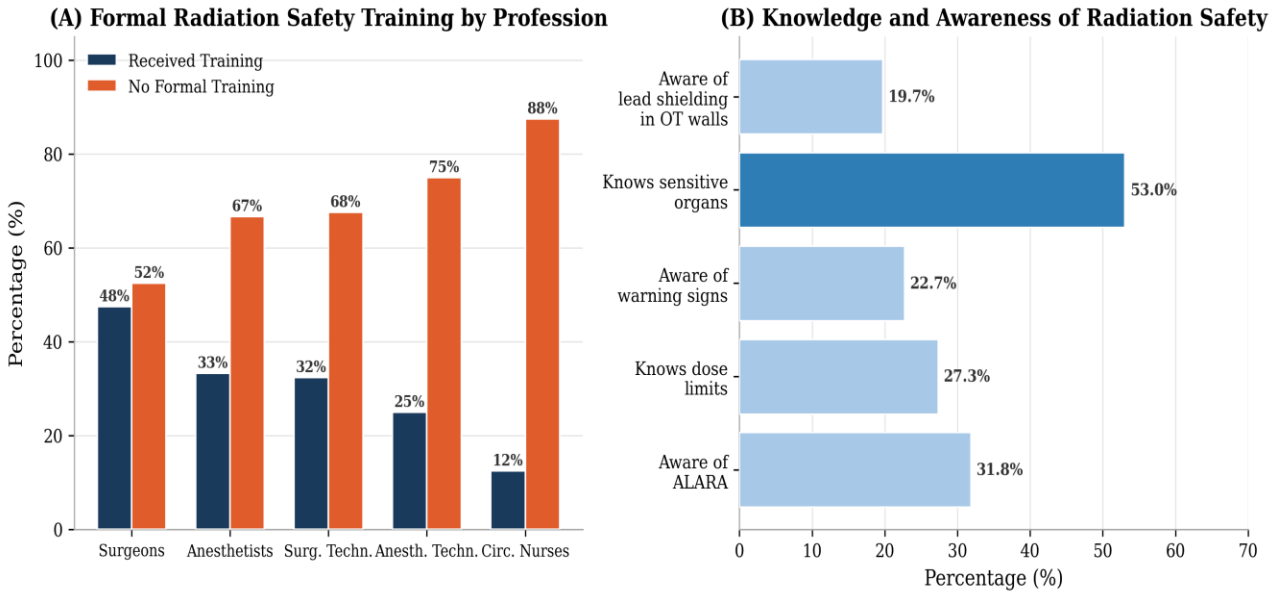

Figure 5. Radiation Safety Knowledge, Training Status, and Awareness

Conclusion

This study highlights important gaps in radiation safety practices, awareness, and compliance among healthcare professionals involved in fluoroscopy-guided urology and orthopedic procedures. Although lead aprons were commonly used, the limited use of thyroid shields and dosimeters reflects inadequate adherence to comprehensive radiation protection measures.

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A significant proportion of participants demonstrated poor compliance with protective practices, particularly circulating nurses, with barriers including lack of trust in equipment, discomfort, and negligence. Additionally, knowledge regarding radiation safety was insufficient, with most participants lacking formal training.

These findings emphasize the urgent need for structured training programs, strict implementation of safety protocols, and improved availability and use of protective equipment, including dosimeters and thyroid shields. Promoting a culture of radiation safety and awareness is essential to minimize occupational risks and ensure the safety of both healthcare professionals and patients.

Author Contributions

M Ihtisham Ul Haq: Conceived and designed the study, supervised data collection at both hospital sites, and led the overall coordination of the research project.

Zahoor Ahmad: Developed and validated the structured questionnaire, conducted literature review, and contributed to the introduction and background sections.

Wajid Ali Shah: Carried out data collection at Saidu Group of Teaching Hospital, administered questionnaires to participants, and assisted in participant recruitment.

Basit Khan/Ahmad Ali: Performed data collection at Miangul Abdul Haq Jahanzeb Kidney Hospital and contributed to participant follow-up and response verification.

Zohair Ayaz/Faiz Ullah: Conducted statistical analysis using IBM SPSS Statistics, interpreted quantitative findings, and contributed to the Results section.

M Ziyad khan/Inam Ullah: Drafted and critically revised the manuscript, contributed to the discussion and conclusion sections, handled correspondence, and served as the corresponding author.

All authors read and approved the final manuscript.

Strengths and Limitations

Strengths

This study has several notable strengths. First, it achieved a 100% response rate, as investigators personally visited both hospital sites to distribute and collect questionnaires, minimizing non-response bias. Second, the study included a diverse sample of healthcare professionals — surgeons, anesthetists, surgical technicians, anesthesia technicians, and circulating nurses — providing a comprehensive picture of radiation safety practices across multiple professional roles within the operation theater. Third, data were collected from two distinct tertiary-care institutions (Saidu Group of Teaching Hospital and Miangul Abdul Haq Jahanzeb Kidney Hospital), which improves the representativeness of the findings within the regional context. Fourth, the multi-domain questionnaire captured a broad range of variables including exposure frequency, protective equipment use, institutional safety infrastructure, self-reported symptoms, and formal training status, enabling a thorough assessment of radiation safety culture.

Limitations

Despite these strengths, several limitations should be acknowledged. The cross-sectional design of the study captures a single point in time and does not allow for causal inference or assessment of changes in radiation safety practices over time. The use of a convenience sampling technique may introduce selection bias, as participants from only two hospitals in the Swat district were included, limiting the generalizability of findings to other regions or healthcare settings in Pakistan. Additionally, data were collected entirely through self-administered questionnaires, which rely on self-reporting and are susceptible to social desirability bias; participants may have overestimated their compliance with safety measures. Objective measurements of radiation doses — such as direct dosimetry readings — were not performed, meaning actual cumulative exposure levels could not be quantified. The study also had a gender imbalance, with females comprising only 9.1% of the sample (12 out of 132), which may limit the ability to draw gender-

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specific conclusions. Finally, as the questionnaire was adapted rather than newly validated for the local context, some items may not fully capture culturally or institutionally specific barriers to radiation safety compliance.

Conflict of Interest

The authors declare no conflict of interest. This research received no specific funding from any public, commercial, or not-for-profit funding agencies. No author has any financial relationship, personal affiliation, or other interest that could inappropriately influence or bias the conduct or reporting of this study. The findings and conclusions presented in this manuscript reflect solely the independent academic work of the authors.

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