Occupational Radiation Safety and Protection Culture in Medical Imaging Facilities: A Pilot Study

Abstract

Background: Occupational exposure to ionizing radiation remains a significant concern for healthcare professionals working in medical imaging facilities. A strong radiation safety culture is essential for minimizing radiation-related risks and promoting safe workplace practices.
Objective: To assess radiation safety awareness, protection practices, and safety culture among healthcare professionals working in medical imaging facilities.
Materials and Methods: A pilot cross-sectional study was conducted from 1 June 2024 to 25 July 2024 across five medical imaging facilities. Thirty-five healthcare professionals participated in the study. Data were collected using a structured questionnaire assessing radiation protection knowledge, safety practices, personal protective equipment use, dosimetry monitoring, and institutional safety culture. Data were analyzed using descriptive statistics.
Results: Awareness of radiation health risks was reported by 94.3% of participants, while 88.6% were familiar with the ALARA principle. Regular lead apron use was reported by 91.4% of respondents, and 80.0% consistently used personal dosimeters. Most participants reported positive institutional support for radiation safety, including adequate protective equipment availability (88.6%) and management commitment (82.9%). Lower compliance was observed for thyroid shield use (74.3%), continuing education (68.6%), and safety audits (65.7%).
Conclusion: Participants demonstrated satisfactory radiation safety awareness and protective practices. However, improvements in training, safety audits, and compliance with protective measures are needed to further strengthen radiation safety culture in medical imaging facilities.

Keywords: Radiation Safety, Radiation Protection Culture, Occupational Exposure, Medical Imaging, Radiologic Technologists

Introduction

The use of ionizing radiation has become indispensable in modern healthcare, particularly in diagnostic radiology, computed tomography, fluoroscopy, mammography, and interventional imaging procedures. These imaging modalities contribute significantly to disease diagnosis, treatment planning, and patient management. Despite their clinical benefits, radiation-based procedures expose healthcare professionals to occupational radiation hazards, making radiation protection a critical component of medical imaging practice [1]. Healthcare workers who routinely operate imaging equipment or assist during radiation-based procedures are at risk of cumulative radiation exposure, which may result in both stochastic and deterministic biological effects if appropriate safety measures are not implemented [2].
Occupational radiation exposure remains a global concern because of the increasing utilization of advanced imaging technologies and image-guided interventions. Radiologic technologists, radiologists, medical physicists, and other imaging personnel may encounter varying levels of exposure depending on their work environment, workload, and adherence to radiation protection protocols [3]. Although technological advancements have substantially improved radiation safety features in modern imaging equipment, human factors continue to play a pivotal role in maintaining safe working conditions [4].
International organizations such as the International Commission on Radiological Protection (ICRP), the International Atomic Energy Agency (IAEA), and the World Health Organization (WHO) emphasize the importance of radiation protection principles in healthcare settings [5]. The fundamental principles of radiation protection include justification, optimization, and dose limitation. These principles are designed to ensure that radiation exposure remains as low as reasonably achievable (ALARA) while maintaining diagnostic image quality and clinical effectiveness [6].
The concept of radiation safety culture has gained increasing attention in recent years. Radiation safety culture refers to the collective values, attitudes, competencies, and behaviors that determine an organization's commitment to radiation protection. A positive safety culture promotes awareness, accountability, and continuous improvement in radiation safety practices [7]. Institutions with strong safety cultures are more likely to demonstrate compliance with radiation protection regulations, provide adequate training opportunities, and encourage proactive reporting of safety concerns [8].

Knowledge and awareness of radiation protection principles are fundamental determinants of occupational safety. Previous studies have demonstrated that healthcare professionals with adequate radiation safety knowledge are more likely to adhere to protective measures such as the use of personal dosimeters, lead shielding devices, and exposure reduction strategies [9]. Conversely, insufficient knowledge and inadequate training may contribute to unsafe practices, increased occupational exposure, and reduced compliance with safety guidelines [10].

Personal protective equipment (PPE) remains one of the most effective methods for reducing occupational radiation exposure. Lead aprons, thyroid shields, lead glasses, mobile barriers, and protective gloves are commonly used in imaging departments. Consistent utilization of these protective devices has been associated with significant reductions in radiation dose to healthcare workers [11]. However, variations in PPE availability, accessibility, and utilization continue to be reported in different healthcare settings.

Regular monitoring of occupational radiation exposure through personal dosimetry programs is another essential component of radiation protection. Dosimeter badges provide valuable information regarding cumulative exposure and facilitate compliance with regulatory dose limits. Monitoring programs also assist institutions in identifying high-risk work practices and implementing corrective measures when necessary [12].

Education and continuing professional development play a critical role in sustaining radiation protection culture. Continuous training programs improve healthcare professionals' understanding of radiation risks, technological advancements, and evolving regulatory requirements. Studies have reported that periodic radiation safety training enhances compliance with protective practices and contributes to improved workplace safety outcomes [13].

Despite increasing awareness regarding radiation protection, challenges remain in achieving consistent implementation of safety protocols across healthcare institutions. Variations in training, workload, organizational support, resource availability, and regulatory compliance may influence radiation safety practices among imaging professionals. Evaluating occupational radiation safety culture can provide valuable insights into existing strengths and areas requiring improvement, thereby facilitating the development of targeted interventions and institutional policies [14].

Therefore, the present pilot study was undertaken to assess occupational radiation safety awareness, radiation protection practices, and safety culture among healthcare professionals working in selected medical imaging facilities. The study aimed to evaluate knowledge levels, adherence to radiation protection measures, utilization of personal protective equipment, dosimetry monitoring practices, and perceptions regarding institutional commitment to radiation safety.

Materials and Methods

Study Design and Setting

A pilot cross-sectional observational study was conducted to evaluate occupational radiation safety awareness, radiation protection practices, and safety culture among healthcare professionals working in medical imaging facilities. The study was carried out over a period of approximately eight weeks, from 1 June 2024 to 25 July 2024. Data were collected from five medical imaging centers that routinely perform diagnostic radiological examinations using ionizing radiation. The participating centers included facilities providing conventional radiography, computed tomography (CT), fluoroscopy, and other diagnostic imaging services.

The pilot nature of the study was intended to generate preliminary evidence regarding radiation safety culture and identify areas requiring further investigation in larger multicenter studies. The study focused on professionals who were directly involved in radiation-based imaging procedures and who were regularly exposed to occupational radiation hazards as part of their professional responsibilities.

Study Population

The study population consisted of healthcare professionals employed in medical imaging departments across the participating centers. Individuals eligible for participation included radiologic technologists, radiologists, imaging assistants, and other personnel directly involved in the operation of imaging equipment or patient positioning during radiological examinations.

Participants were recruited using a convenience sampling approach. A total of 35 professionals consented to participate and completed the study questionnaire during the data collection period. Participation was voluntary, and respondents were informed about the objectives and scope of the study before enrollment.

The demographic characteristics of the study population, including professional designation, gender distribution, and years of professional experience, are presented in Table 1.

Inclusion Criteria

The study included healthcare professionals who met the following criteria:

1. Employed in a medical imaging department utilizing ionizing radiation.
2. Directly involved in diagnostic imaging procedures.
3. Willing to participate in the study and provide informed consent.
4. Available during the study period for questionnaire completion.

Exclusion Criteria

The following individuals were excluded from participation:

1. Administrative personnel not directly involved in imaging procedures.
2. Healthcare workers without occupational exposure to ionizing radiation.
3. Staff members on prolonged leave during the study period.
4. Incomplete or partially completed questionnaires.

Data Collection Instrument

Data were collected using a structured self-administered questionnaire developed after reviewing published literature on occupational radiation safety and radiation protection culture. The questionnaire was designed to evaluate participants' knowledge, attitudes, and practices related to radiation protection in medical imaging environments.

The questionnaire consisted of four sections:

1. Demographic and professional characteristics.
2. Radiation protection knowledge and awareness.
3. Radiation safety practices and utilization of protective measures.
4. Organizational and institutional radiation safety culture.

The knowledge section included questions related to radiation hazards, occupational dose limits, ALARA principles, personal dosimetry, and radiation protection regulations. The practice section assessed routine use of personal protective equipment, compliance with radiation safety protocols, and exposure monitoring practices. The organizational culture section evaluated participants' perceptions regarding management support, availability of safety resources, training opportunities, and institutional commitment to radiation protection.

Prior to administration, the questionnaire was reviewed by professionals experienced in radiological sciences and radiation protection to ensure content relevance and clarity.

Variables Assessed

The primary variables assessed in the study included:

- Awareness of radiation protection principles.
- Knowledge of occupational dose limits.
- Utilization of personal protective equipment.
- Compliance with personal dosimetry monitoring.
- Participation in radiation safety training programs.
- Perceptions regarding institutional radiation safety culture.

Secondary variables included demographic factors such as age, gender, professional role, and years of professional experience.

Data Collection Procedure

Following institutional permission from the participating imaging facilities, eligible participants were approached during working hours. The objectives of the study were explained, and written informed consent was obtained before questionnaire distribution.

Participants completed the questionnaire anonymously to encourage honest responses and minimize reporting bias. No personally identifiable information was collected. Completed questionnaires were reviewed for completeness before inclusion in the final analysis.

The data collection process was conducted uniformly across all five participating centers to ensure consistency in methodology and reduce procedural variation.

Ethical Considerations

The study was conducted in accordance with established ethical principles governing human participant research. Participation was entirely voluntary, and respondents were informed that they could withdraw from the study at any stage without consequence.

Confidentiality and anonymity were maintained throughout the research process. Questionnaire responses were coded and stored securely, and access to collected data was restricted to the investigators. No information capable of identifying individual participants or institutions was included in the analysis or reporting of results.

Statistical Analysis

Data obtained from completed questionnaires were entered into Microsoft Excel and verified for accuracy prior to analysis. Descriptive statistical methods were used to summarize participant characteristics and study variables.

Categorical variables were expressed as frequencies and percentages, whereas continuous variables, where applicable, were summarized using means and standard deviations. The findings were presented in tabular form to facilitate interpretation and comparison of responses.

The demographic profile of participants is presented in Table 1, while radiation protection knowledge, safety practices, and organizational culture indicators are summarized in subsequent tables within the Results section.

Given the pilot nature of the study and relatively small sample size, the analysis primarily focused on descriptive statistics rather than inferential testing.

Results

A total of 35 healthcare professionals from five medical imaging facilities participated in the study and completed the questionnaire, yielding a response rate of 100% among those who agreed to participate. The respondents represented various professional categories involved in radiation-based diagnostic imaging procedures, including radiologic technologists, radiologists, and imaging assistants. The findings provide insights into participant demographics, radiation safety knowledge, radiation protection practices, and perceptions regarding institutional radiation safety culture.

Demographic Characteristics of Participants

The demographic profile of the study participants is presented in **Table 1**. Among the 35 respondents, radiologic technologists constituted the largest professional group (60.0%), followed by radiologists (22.9%) and imaging assistants (17.1%). Male participants accounted for 62.9% of the study population, while females represented 37.1%. Regarding professional experience, 40.0% of participants had less than five years of experience, 34.3% had between five and ten years of experience, and 25.7% had more than ten years of professional experience.

Table 1. Demographic Characteristics of Participants (n = 35)

Variable	Frequency	Percentage (%)
Professional Category		
Radiologic Technologists	21	60.0
Radiologists	8	22.9
Imaging Assistants	6	17.1
Gender		
Male	22	62.9
Female	13	37.1
Years of Experience		
< 5 Years	14	40.0
5–10 Years	12	34.3
> 10 Years	9	25.7

As shown in **Table 1**, the workforce participating in the study was predominantly composed of radiologic technologists, reflecting their central role in routine imaging operations. The distribution of professional experience suggests representation from both early-career and experienced imaging professionals, providing a broad perspective on radiation safety culture within the participating institutions.

Radiation Safety Knowledge and Awareness

Participants were assessed regarding their knowledge of radiation protection principles and occupational radiation safety concepts. The findings are summarized in **Table 2**.

Table 2. Radiation Safety Knowledge and Awareness Among Participants (n = 35)

Knowledge Indicator	Yes, n (%)	No, n (%)
Familiarity with ALARA principle	31 (88.6)	4 (11.4)
Knowledge of occupational dose limits	29 (82.9)	6 (17.1)
Awareness of radiation health risks	33 (94.3)	2 (5.7)
Received formal radiation safety training	30 (85.7)	5 (14.3)
Awareness of emergency radiation procedures	27 (77.1)	8 (22.9)
Knowledge of personal dosimetry monitoring	32 (91.4)	3 (8.6)

The results presented in **Table 2** indicate generally high levels of radiation protection knowledge among respondents. Awareness of radiation health risks was reported by 94.3% of participants, representing the highest level of knowledge observed in the survey. Similarly, familiarity with personal dosimetry monitoring (91.4%) and the ALARA principle (88.6%) demonstrated strong understanding of fundamental radiation protection concepts.

However, lower awareness was observed regarding emergency radiation procedures, where only 77.1% of respondents reported adequate knowledge. This finding suggests a potential area for improvement through targeted training and emergency preparedness programs.

Radiation Protection Practices

Compliance with occupational radiation protection measures was assessed through questions related to the use of protective equipment, adherence to safety protocols, and monitoring practices. The results are shown in **Table 3**.

Table 3. Radiation Protection Practices Among Participants (n = 35)

Practice Indicator	Compliance n (%)
Regular use of lead apron	32 (91.4)
Routine use of thyroid shield	26 (74.3)
Consistent wearing of dosimeter badge	28 (80.0)
Maintaining safe distance during exposure	31 (88.6)
Following departmental exposure protocols	33 (94.3)
Participation in periodic safety training	27 (77.1)

The findings in **Table 3** demonstrate relatively high compliance with recommended radiation protection practices. Nearly all respondents reported adherence to departmental exposure protocols (94.3%), while 91.4% regularly used lead aprons during imaging procedures. Maintaining appropriate distance from radiation sources, an important component of radiation protection, was reported by 88.6% of participants.

Although compliance with personal dosimeter use was relatively high (80.0%), approximately one-fifth of participants reported inconsistent monitoring practices. Furthermore, thyroid shield utilization was reported by only 74.3% of respondents, indicating a potential opportunity for enhancing protective equipment usage.

Institutional Radiation Safety Culture

Participants were asked to evaluate various aspects of radiation safety culture within their respective institutions. The results are summarized in **Table 4**.

Table 4. Institutional Radiation Safety Culture Indicators (n = 35)

Institutional Indicator	Positive Response n (%)
Management actively supports radiation safety	29 (82.9)
Availability of adequate protective equipment	31 (88.6)
Regular radiation safety meetings conducted	25 (71.4)
Radiation safety audits performed periodically	23 (65.7)
Access to continuing radiation safety education	24 (68.6)
Encouragement to report safety concerns	28 (80.0)
Overall satisfaction with radiation safety culture	30 (85.7)

The institutional assessment presented in **Table 4** indicates generally favorable perceptions regarding radiation safety culture. The majority of respondents reported adequate availability of protective equipment (88.6%) and overall satisfaction with institutional radiation safety culture (85.7%).

Support from management for radiation protection initiatives was acknowledged by 82.9% of participants, suggesting a positive organizational commitment toward workplace safety. Nevertheless, lower percentages were observed for periodic safety audits (65.7%) and continuing education opportunities (68.6%). These findings highlight areas where institutional radiation safety programs may benefit from further strengthening.

Overall Assessment of Radiation Safety Culture

Based on the collective responses obtained from the knowledge, practice, and organizational culture domains, the participating imaging facilities demonstrated a generally positive radiation safety environment. Most respondents exhibited adequate knowledge of radiation protection principles and reported regular adherence to recommended safety measures. Furthermore, institutional support for radiation protection activities was perceived positively by the majority of participants.

Despite these encouraging findings, several gaps were identified, particularly in relation to emergency preparedness, thyroid shield utilization, continuing professional education, and periodic safety audits. Addressing these areas may contribute to further improvements in occupational radiation safety and strengthen the overall radiation protection culture within medical imaging facilities.

Discussion

The present pilot study evaluated occupational radiation safety awareness, radiation protection practices, and radiation safety culture among healthcare professionals working in five medical imaging facilities. The findings indicate that participants generally possessed adequate knowledge of radiation protection principles and demonstrated positive attitudes toward occupational radiation safety. Furthermore, the majority of respondents reported adherence to recommended radiation protection measures and perceived their institutions as supportive of radiation safety initiatives. These findings suggest that the participating imaging facilities have established a reasonably positive radiation protection culture; however, several areas requiring

improvement were also identified. Radiation safety culture has emerged as a critical component of quality assurance and occupational health programs within diagnostic imaging departments. A positive safety culture extends beyond compliance with regulations and encompasses shared values, attitudes, and behaviors that promote safe working practices. The findings of the present study indicate that most participants were familiar with the ALARA principle and recognized the importance of minimizing occupational radiation exposure. This observation is consistent with previous studies that have reported increasing awareness of radiation protection concepts among imaging professionals due to advancements in professional education and regulatory oversight [15,16].

Knowledge of occupational radiation hazards is essential for maintaining safe work environments. In the present study, a high proportion of respondents demonstrated awareness of radiation-associated health risks and occupational dose monitoring requirements. Similar findings have been reported in studies conducted among radiologic technologists and radiology staff in various healthcare settings, where adequate radiation protection knowledge was associated with improved compliance with safety protocols [17,18]. Awareness of radiation risks encourages healthcare professionals to adopt appropriate protective measures and contributes to the development of safer workplace practices. The findings further revealed that a substantial proportion of participants had received formal radiation safety training. Education and training are widely recognized as fundamental elements of radiation protection programs. Regular educational activities enhance knowledge retention, improve understanding of emerging technologies, and reinforce adherence to radiation safety guidelines. Previous investigations have demonstrated that healthcare professionals who participate in continuing radiation protection education exhibit significantly better safety practices compared with those who receive limited training [19]. Consequently, institutions should continue investing in structured educational programs to ensure that personnel remain informed regarding current radiation protection standards. One of the most encouraging findings of the present study was the high rate of lead apron utilization among participants. Lead aprons remain one of the most effective and widely used forms of personal protective equipment in diagnostic imaging environments. Their consistent use significantly reduces radiation exposure to radiosensitive organs and tissues. Similar compliance rates have been reported in studies evaluating occupational radiation protection practices among radiology personnel, indicating widespread recognition of the importance of protective shielding [20]. The high utilization rate observed in the current study suggests that participants acknowledge the value of personal protective equipment in minimizing occupational radiation risks.

Despite favorable findings regarding lead apron use, thyroid shield utilization was comparatively lower. The thyroid gland is highly radiosensitive and vulnerable to the effects of ionizing radiation, particularly during fluoroscopic and interventional procedures. Previous studies have reported inconsistent use of thyroid protection devices despite recommendations from radiation protection organizations [21]. Several factors may contribute to reduced compliance, including discomfort, limited availability, lack of awareness, or underestimation of occupational risk. The findings of the present study suggest that additional emphasis should be placed on promoting routine thyroid shield utilization within imaging departments. Personal dosimetry monitoring represents another essential aspect of occupational radiation protection. In the current study, most participants reported regular use of dosimeter badges; however, complete compliance was not achieved. Similar observations have been documented in previous research, where inconsistent dosimeter usage remained a challenge despite regulatory requirements [22]. Accurate monitoring of occupational exposure is critical for assessing cumulative radiation dose, identifying high-risk practices, and ensuring compliance with established dose limits. Institutions should therefore implement strategies to improve dosimeter compliance, including regular monitoring, education, and accountability measures. The majority of respondents indicated adherence to departmental exposure protocols and reported maintaining appropriate distance from radiation sources whenever possible. These findings are particularly important because the principles of time, distance, and shielding constitute the foundation of radiation protection practice. Adherence to standardized protocols contributes to reduced occupational exposure while ensuring consistent patient care. Previous studies have similarly demonstrated that compliance with established safety procedures is associated with lower occupational radiation doses and improved workplace safety outcomes [23].

Institutional commitment to radiation protection emerged as a significant determinant of safety culture in the present study. Most participants perceived management support for radiation safety activities positively and reported adequate availability of protective equipment. Organizational leadership plays a vital role in fostering a culture of safety by allocating resources, establishing policies, and promoting accountability. Studies investigating healthcare safety culture have consistently emphasized the importance of management involvement in achieving sustainable improvements in occupational safety performance [24]. The positive

perceptions reported by participants may therefore reflect effective institutional efforts to prioritize radiation protection. The availability of personal protective equipment was viewed favorably by respondents, suggesting that participating facilities generally provide the resources necessary for safe radiological practice. Access to protective devices is an important prerequisite for compliance with radiation safety guidelines. Inadequate equipment availability has been identified as a barrier to radiation protection in several healthcare settings, particularly in resource-constrained environments [25]. The findings of the current study indicate that equipment shortages were not perceived as a major concern among the participating institutions. Although overall perceptions of radiation safety culture were positive, opportunities for improvement were identified in relation to periodic radiation safety audits. Regular audits are essential components of quality assurance programs because they facilitate evaluation of compliance, identification of deficiencies, and implementation of corrective actions. The relatively lower proportion of participants reporting routine safety audits suggests that some facilities may benefit from strengthening audit mechanisms and documentation practices. Previous studies have similarly highlighted the importance of periodic safety assessments in maintaining high standards of radiation protection [26]. Continuing professional education also emerged as an area requiring further attention. While a majority of respondents reported access to educational opportunities, the proportion was lower than observed for several other safety indicators. Continuous education is particularly important in medical imaging because of rapid technological advancements, evolving clinical practices, and updates to radiation protection recommendations. Regular educational interventions have been shown to improve both knowledge and practical compliance with radiation safety standards [27]. Expanding continuing education initiatives may therefore contribute to further improvements in occupational radiation safety culture. Another notable finding was the comparatively lower level of awareness regarding emergency radiation procedures. Effective management of radiation-related incidents requires prompt recognition, appropriate response, and adherence to established emergency protocols. Inadequate preparedness may increase the likelihood of occupational exposure during unexpected events. Previous investigations have reported similar deficiencies in emergency response knowledge among healthcare workers exposed to ionizing radiation [28]. Simulation-based training, emergency drills, and periodic competency assessments may help address these knowledge gaps and strengthen institutional preparedness. The present study contributes to the growing body of literature emphasizing the importance of radiation safety culture in healthcare organizations. Unlike traditional assessments that focus exclusively on technical compliance, safety culture evaluations provide a broader understanding of organizational attitudes and behaviors influencing occupational safety outcomes. By examining knowledge, practices, and institutional factors simultaneously, the current study offers a comprehensive perspective on radiation protection within medical imaging facilities. Nevertheless, several limitations should be considered when interpreting the findings. First, the study involved a relatively small sample of 35 participants from five imaging centers. As a pilot investigation, the findings may not be representative of all medical imaging facilities or healthcare systems. Second, the use of self-reported questionnaires introduces the possibility of reporting bias, whereby participants may overestimate compliance with recommended safety practices. Third, the cross-sectional design limits the ability to establish causal relationships between knowledge, institutional support, and safety behaviors. Finally, direct measurements of occupational radiation exposure were not included in the study, preventing correlation between reported practices and actual exposure levels. Despite these limitations, the study provides valuable preliminary evidence regarding occupational radiation safety culture in medical imaging facilities. The findings highlight strengths such as high awareness of radiation protection principles, widespread use of protective equipment, and positive perceptions of institutional support. At the same time, the results identify opportunities for improvement in emergency preparedness, thyroid shield utilization, dosimetry compliance, continuing education, and safety auditing processes.

Conclusion

This pilot study assessed occupational radiation safety awareness, radiation protection practices, and safety culture among 35 healthcare professionals working in five medical imaging facilities between 1 June 2024 and 25 July 2024. The findings revealed that participants generally possessed adequate knowledge of radiation protection principles, demonstrated positive attitudes toward occupational radiation safety, and reported satisfactory compliance with recommended protective measures, including the use of lead aprons, adherence to exposure protocols, and participation in dosimetry monitoring programs. The study also identified a generally favorable institutional radiation safety culture, characterized by management support, availability of protective equipment, and commitment to workplace safety. However, gaps were observed in certain areas, including routine use of thyroid shields, awareness of emergency radiation procedures, participation in continuing radiation safety education, and implementation of periodic safety audits. These findings suggest that while the participating facilities have established a positive foundation for radiation protection, ongoing efforts are required to strengthen safety culture through regular training, enhanced monitoring, improved

compliance with personal protective measures, and continuous quality improvement initiatives. Although limited by its small sample size and reliance on self-reported data, the study provides valuable preliminary evidence regarding occupational radiation safety culture in medical imaging facilities and highlights the importance of sustained institutional commitment to protecting healthcare professionals from unnecessary radiation exposure.