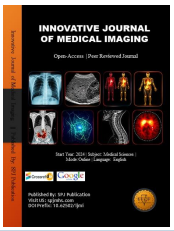
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Original Article

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

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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

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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 intervention.

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 assess occupational radiation safety awareness, radiation protection practices, and institutional safety culture among healthcare professionals working in diagnostic imaging departments. The study was carried out over an eight-week period from 1 June 2024 to 25 July 2024 across five medical imaging centers providing conventional radiography, computed tomography (CT), fluoroscopy, and other ionizing radiation-based diagnostic services. The study aimed to generate preliminary evidence on radiation safety practices and identify areas requiring improvement for future multicenter investigations.

Study Population: The study included healthcare professionals directly involved in diagnostic imaging procedures, including radiologists, radiologic technologists, imaging assistants, and other staff routinely exposed to ionizing radiation. Participants were recruited using a convenience sampling method, and 35 healthcare professionals voluntarily completed the survey. Demographic characteristics, including age, gender, professional designation, and years of experience, were recorded and are presented in Table 1.

Inclusion and Exclusion Criteria: Eligible participants were healthcare professionals employed in medical imaging departments, directly involved in radiation-based diagnostic procedures, and willing to provide informed consent. Administrative personnel, individuals without occupational radiation exposure, staff on prolonged leave during the study period, and respondents with incomplete questionnaires were excluded from the analysis.

Data Collection Instrument: Data were collected using a structured, self-administered questionnaire developed following an extensive review of published literature on radiation protection and occupational safety. The questionnaire consisted of four sections covering demographic characteristics, knowledge of radiation protection principles, routine radiation safety practices, and perceptions of institutional radiation safety culture. Questions assessed awareness of ALARA principles, occupational dose limits, personal dosimetry, use of personal protective equipment (PPE), compliance with safety protocols, and organizational support for radiation protection. The questionnaire was reviewed by experts in radiological sciences to ensure content validity and clarity.

Variables Assessed: The primary study variables included awareness of radiation protection principles, knowledge of occupational dose limits, utilization of PPE, compliance with personal dosimetry monitoring, participation in radiation safety training, and perceptions of institutional radiation safety culture. Secondary variables included demographic and professional characteristics such as age, gender, occupation, and years of work experience.

Data Collection Procedure: Following institutional approval, eligible participants were approached during working hours and informed about the objectives of the study. Written informed consent was obtained before questionnaire administration. All responses were collected anonymously to maintain confidentiality and minimize response bias. Completed questionnaires were reviewed for completeness before inclusion, and identical data collection procedures were followed across all participating centers to ensure methodological consistency.

Statistical Analysis: Data were entered into Microsoft Excel, verified for accuracy, and analyzed using descriptive statistical methods. Categorical variables were summarized as frequencies and percentages, while continuous variables were expressed as mean ± standard deviation where appropriate. Results are presented in tables to facilitate interpretation. Owing to the pilot nature of the study and the relatively small sample size, the analysis focused primarily on descriptive statistics rather than inferential statistical testing.

Ethical Considerations: The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Participation was voluntary, and written informed consent was obtained from all participants before enrollment. Confidentiality and anonymity were strictly maintained by assigning coded identifiers to questionnaires, and no personal or institutional identifiers were collected or reported. Data were securely stored and accessed only by the research investigators.

RESULTS

A total of 35 healthcare professionals from five medical imaging centers participated in the study, with all questionnaires completed and included in the final analysis. The findings are presented under four domains: participant demographics, radiation safety knowledge, radiation protection practices, and institutional radiation safety culture. The demographic characteristics of the participants are presented in Table 1. Radiologic technologists constituted the largest professional group (60.0%, n = 21), followed by radiologists (22.9%, n = 8) and imaging assistants (17.1%, n = 6). Male participants accounted for 62.9% (n = 22) of the study population, while females represented 37.1% (n = 13). Regarding professional experience, 40.0% (n = 14) had less than five years of experience, 34.3% (n = 12) had 5–10 years of experience, and 25.7% (n = 9) had more than ten years of experience (Table 1). This distribution indicates that the survey included professionals with varying levels of clinical expertise, providing a representative overview of radiation safety practices across different experience levels.

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

Variable	Frequency (n)	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

Radiation Safety Knowledge and Awareness: Participants demonstrated a high level of knowledge regarding radiation protection principles (Table 2). Awareness of radiation health risks was reported by 94.3% (n = 33) of respondents, followed by knowledge of personal dosimetry monitoring (91.4%, n = 32) and familiarity with the ALARA principle (88.6%, n = 31). Formal radiation safety training had been received by 85.7% (n = 30) of participants, while 82.9% (n = 29) were aware of occupational dose limits. The lowest level of awareness was observed for emergency radiation procedures, with 77.1% (n = 27) reporting adequate knowledge, suggesting the need for additional emergency preparedness training.

Table 2. Radiation Safety Knowledge and Awareness (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)

Radiation Protection Practices: Compliance with recommended radiation protection measures is summarized in Table 3. Most participants reported following departmental radiation exposure protocols (94.3%, n = 33) and regularly using lead aprons (91.4%, n = 32).

Maintaining an appropriate distance during radiation exposure was reported by 88.6% (n = 31) of respondents, while 80.0% (n = 28) consistently wore personal dosimeter badges. Routine use of thyroid shields (74.3%, n = 26) and participation in periodic radiation safety training (77.1%, n = 27) were comparatively lower, indicating opportunities for improving compliance with personal protective measures and continuing education.

Table 3. Radiation Protection Practices (n = 35)

Practice Indicator	Compliance n (%)
Regular use of lead apron	32 (91.4)
Routine use of thyroid shield	26 (74.3)
Consistent use 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)

Institutional Radiation Safety Culture: Participants generally perceived a positive radiation safety culture within their institutions (Table 4). Adequate availability of protective equipment was reported by 88.6% (n = 31), while 85.7% (n = 30) expressed overall satisfaction with institutional radiation safety practices. Management support for radiation protection initiatives was acknowledged by 82.9% (n = 29), and 80.0% (n = 28) felt encouraged to report radiation safety concerns. However, regular radiation safety audits (65.7%, n = 23) and access to continuing radiation safety education (68.6%, n = 24) received comparatively lower ratings, suggesting areas for institutional improvement.

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

Institutional Indicator	Positive Response n (%)
Management supports radiation safety	29 (82.9)
Adequate protective equipment available	31 (88.6)
Regular radiation safety meetings	25 (71.4)
Periodic radiation safety audits	23 (65.7)
Continuing radiation safety education	24 (68.6)
Encouragement to report safety concerns	28 (80.0)
Overall satisfaction with radiation safety culture	30 (85.7)

Overall, the survey demonstrates a strong occupational radiation safety culture among the participating imaging professionals. High levels of knowledge regarding radiation hazards, ALARA principles, and personal dosimetry were accompanied by good compliance with standard radiation protection practices. Nevertheless, gaps remain in emergency preparedness, routine thyroid shield use, periodic safety audits, and continuing professional education. These findings suggest that while the participating institutions maintain satisfactory radiation protection standards, strengthening continuous training programs, emergency response preparedness, and regular safety monitoring could further enhance occupational radiation safety within medical imaging departments.

DISCUSSION

The present pilot study evaluated occupational radiation safety awareness, radiation protection practices, and institutional radiation safety culture among healthcare professionals working in medical imaging departments. Overall, the findings indicate a favorable level of knowledge regarding radiation protection principles, high compliance with standard safety practices, and positive perceptions of organizational support for radiation safety. These results suggest that the participating imaging facilities have established a satisfactory radiation safety culture while also identifying several areas requiring further improvement. A high proportion of participants demonstrated awareness of the ALARA principle, occupational dose limits, radiation health risks, and personal dosimetry monitoring.

Such findings reflect the growing emphasis on radiation protection education and regulatory compliance in diagnostic imaging. Adequate knowledge is essential for minimizing occupational exposure and ensuring safe clinical practice. However, comparatively lower awareness of emergency radiation procedures indicates that emergency preparedness training should receive greater attention within institutional radiation safety programs.

The study also demonstrated good compliance with routine radiation protection practices. Most participants reported consistent use of lead aprons, adherence to departmental radiation safety protocols, and maintenance of appropriate distance during radiation exposure. These findings indicate that the fundamental principles of radiation protection time, distance, and shielding are generally well implemented in daily clinical practice. Nevertheless, routine utilization of thyroid shields and consistent personal dosimetry monitoring were comparatively lower, suggesting opportunities to strengthen compliance with personal protective measures through regular supervision and reinforcement. Institutional factors play a critical role in establishing a sustainable radiation safety culture. The majority of respondents perceived strong management support, adequate availability of protective equipment, and overall satisfaction with workplace radiation safety. These findings demonstrate organizational commitment toward protecting healthcare professionals from occupational radiation exposure. However, lower positive responses regarding periodic radiation safety audits and continuing professional education suggest that quality assurance activities could be further strengthened. Regular audits, competency assessments, and continuing education programs are essential to maintain compliance with evolving radiation protection standards and technological advancements.

The findings further emphasize that radiation safety culture extends beyond individual knowledge and depends on continuous organizational commitment. Establishing structured radiation safety committees, conducting periodic refresher training, implementing routine safety audits, and promoting a non-punitive reporting system for radiation-related incidents can further improve workplace safety. Such initiatives are likely to enhance staff awareness, reinforce safe practices, and support continuous quality improvement in medical imaging departments. Despite providing valuable preliminary evidence, the study has several limitations. The relatively small sample size and convenience sampling from five imaging centers may limit the generalizability of the findings. Furthermore, the use of self-reported questionnaires may introduce reporting bias, while the cross-sectional design precludes causal inferences between knowledge, institutional support, and safety practices. Future multicenter studies involving larger and more diverse populations, combined with objective occupational dose measurements, are recommended to validate these findings and provide a more comprehensive assessment of radiation safety culture.

CONCLUSION

This pilot study demonstrates that healthcare professionals working in medical imaging departments possess generally good knowledge of radiation protection principles and exhibit satisfactory compliance with recommended occupational radiation safety practices. The participating institutions also showed a positive radiation safety culture characterized by management support and adequate availability of protective equipment. However, improvements are warranted in emergency preparedness, routine thyroid shield utilization, personal dosimetry compliance, continuing professional education, and periodic radiation safety audits. Strengthening these areas through regular training, quality assurance programs, and institutional commitment will further enhance occupational radiation protection and promote a sustainable culture of safety within medical imaging facilities

DECLARATION

Ethics Approval and Consent to Participate:

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the Institutional Ethics Committee prior to the commencement of the study. Written informed consent was obtained from all participants before questionnaire administration.

Consent for Publication: Not applicable.

Availability of Data and Materials: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing Interests: The authors declare that they have no competing interests.

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Authors' Contributions: All authors contributed substantially to the study conception and design, data collection, analysis, interpretation of results, manuscript preparation, and final approval of the submitted version.

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Conflict of Interest: The authors declare that there is no conflict of interest regarding the publication of this article.

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Informed Consent Statement: Written informed consent was obtained from all participants prior to their inclusion in the study.

Acknowledgment of AI Use: No generative artificial intelligence tools were used for data collection, data analysis, or interpretation of the study findings. AI-assisted language editing was used only to improve the clarity and readability of the manuscript, while all scientific content, interpretation, and conclusions remain the responsibility of the authors.

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