JHWCR JOURNAL OF HEALTH, WELLNESS AND COMMUNITY RESEARCH 3007-0570

DOI: https://doi.org/10.61919/s3ff2g80

Original Article

Assessment of Knowledge, Awareness, and Practices Regarding Radiation Hazards Among Radiological Staff

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"Cite this Article" **Received**: 06 December 2025; **Accepted**: 03 March 2026; **Published**: 30 March 2026
Author Contributions: Concept and design: MB, HMF; data collection: MB, IZ, ST, EF, RG; methodology and supervision: HMF, TI; data analysis and interpretation: MB, HMF, TI; manuscript drafting: MB, IZ, ST, EF; critical revision and final approval: HMF, TI, RG. **Ethical Approval**: Al Razi Institute, Pakistan. **Informed Consent**: Written informed consent was obtained from all participants; **Conflict of Interest**: The authors declare no conflict of interest. **Funding**: No external funding; **Data Availability**: Available from the corresponding author on reasonable request; **Acknowledgments**: NA

ABSTRACT

Background: Ionizing radiation is essential in diagnostic and interventional radiology, but repeated occupational exposure may pose avoidable biological risks when radiation protection principles are not adequately understood or applied. Objective: To assess knowledge, awareness, and practice-related indicators regarding radiation hazards and radiation protection among radiological staff. Methods: A descriptive cross-sectional questionnaire-based study was conducted among 96 radiological staff members working in public and private hospital settings. Participants included radiologists, technologists, and technicians. Data were collected using a structured questionnaire assessing demographic characteristics, professional profile, previous radiation safety training, radiation hazards, dose limits, ALARA principles, protective equipment, dosimetry, and imaging-related dose estimation. Data were analyzed using IBM SPSS Statistics version 27. Descriptive statistics were calculated, and knowledge scores were compared by gender and professional category using independent-samples t-test and one-way ANOVA. Results: Females constituted 61.5% of participants, and 64.6% were younger than 25 years. Overall, 67.7% had received radiation safety training. The mean knowledge score was 46.09 ± 4.46 out of 66, corresponding to 69.83% of the total score. Higher response percentages were observed for ALARA, safe positioning, lead apron protection, and training importance, whereas lower response percentages were found for deterministic effects, stochastic effects, CT head dose equivalence, and occupational dose limits. Knowledge scores did not differ significantly by gender or professional category. Conclusion: Radiological staff demonstrated moderate overall radiation safety knowledge, with important gaps in radiation biology and dose-related concepts. Regular competency-based training and institutional safety monitoring are recommended. Keywords: ALARA, Ionizing Radiation, Occupational Exposure, Radiation Hazards, Radiation Protection, Radiological Staff, Radiation Safety.

INTRODUCTION

Ionizing radiation is widely used in modern diagnostic and interventional radiology, including radiography, fluoroscopy, computed tomography, mammography, and nuclear medicine. Although these modalities provide substantial clinical benefit, repeated occupational exposure among radiological staff may produce avoidable biological risks when radiation protection principles are not consistently applied. Ionizing radiation can remove electrons from atoms and generate cellular injury through direct and indirect mechanisms, while non-ionizing modalities such as ultrasound and magnetic resonance imaging do not produce the same ionizing effects (1). Radiation exposure in healthcare therefore requires a balance between diagnostic benefit and strict adherence to protection standards, particularly for professionals who work near radiation-generating equipment on a routine basis (2).

Occupational exposure is a major concern for radiologists, radiographers, technologists, technicians, and other personnel working in imaging departments. The potential effects of ionizing radiation include deterministic effects, such as cataract formation and skin injury, and stochastic effects, such as malignancy and genetic damage, for which the probability of occurrence increases with dose (3,4). Because no level of ionizing radiation exposure can be considered entirely risk-free, radiation protection strategies emphasize dose minimization through the principles of time, distance, shielding, appropriate equipment use, dose monitoring, and justification of exposure (5,6). The ALARA principle, which requires radiation exposure to be kept "as low as reasonably achievable," remains a central concept in radiation safety practice and is especially relevant in clinical environments where repeated exposure may occur over prolonged periods (6).

Despite the availability of protective devices and safety guidelines, evidence from different healthcare settings indicates persistent gaps in radiation knowledge and protection behavior among healthcare workers exposed to ionizing radiation. Previous studies have reported variable awareness of radiation hazards, dose limits, radiosensitive organs, personal dosimetry, and protective equipment use among radiology professionals and other healthcare workers (7–10). These gaps are clinically important because inadequate understanding of dose limits, stochastic and deterministic effects, CT-related exposure, and occupational monitoring may contribute to unsafe practices, underuse of dosimeters, inconsistent shielding, and poor compliance with institutional radiation safety protocols (11,12).

Radiation safety training is therefore essential for maintaining occupational safety in radiology departments. Undergraduate teaching alone may not be sufficient to ensure long-term competency, particularly when workers enter high-exposure areas such as CT, fluoroscopy, and interventional radiology. Continuous professional education, refresher training, institutional audits, and regular monitoring of protective practices are required to strengthen radiation safety culture and reduce preventable exposure among both staff and patients (13–15). However, in many developing healthcare settings, training opportunities, monitoring systems, and practical adherence to radiation protection standards remain inconsistent, making local assessment of staff knowledge and safety practices necessary (16,17).

In Pakistan, radiological services are increasingly used across public and private hospitals, but the extent to which radiological staff understand radiation hazards, dose limits, biological effects, and protection measures remains insufficiently documented. Existing evidence suggests that healthcare personnel may recognize basic radiation safety principles while still demonstrating weaknesses in technical knowledge, including radiation biology, occupational dose limits, and dose estimation for common imaging procedures (18–20). Identifying these knowledge gaps is important for designing targeted training programs and improving departmental radiation safety practices. Therefore, the present study aimed to assess knowledge, awareness, and practices regarding radiation hazards and radiation protection among radiological staff working in public and private hospitals. The study specifically sought to determine the level of radiation safety knowledge and examine whether knowledge scores differed according to demographic and professional characteristics.

MATERIAL AND METHODS

This study was conducted as a descriptive cross-sectional questionnaire-based survey among radiological staff working in public and private hospitals. The design was selected to assess existing knowledge, awareness, and self-reported radiation safety practices at a single point in time among personnel occupationally involved in radiological procedures. The study was completed over a period of 90 days after approval of the study synopsis.

The study population comprised radiological staff members working in radiology departments, including radiologists, radiologic technologists, technicians, and assistants involved in imaging areas such as computed tomography, magnetic resonance imaging, fluoroscopy, and interventional radiology. Participants were eligible if they were aged 20 to 60 years, male or female, working in a radiology department, and had more than six months of professional experience in radiological work. Non-radiology staff, including nurses, laboratory technicians, and physicians from departments other than radiology, were excluded. Radiology students, interns without full departmental responsibilities, staff members unwilling to participate, and participants who submitted incomplete or invalid questionnaires were also excluded.

A total sample size of 96 participants was determined using the single population proportion formula, with a 95% confidence level, an expected prevalence of 51.3%, and a 10% margin of error. Eligible radiological staff were approached during the study period, and those meeting the selection criteria were invited to participate. Participation was voluntary, and completed questionnaires were included only when responses were sufficiently complete for analysis.

Data were collected using a structured questionnaire designed to assess demographic characteristics, professional profile, previous radiation safety training, knowledge of radiation hazards, awareness of protection principles, and radiation safety-related practices. The demographic and professional variables included age group, gender, professional category, years of experience, and history of radiation safety training. The knowledge component included items related to ionizing radiation, absorbed dose units, deterministic and stochastic radiation effects, radiosensitive organs, ALARA principles, lead apron protection, lead equivalence, occupational dose limits, dosimeter monitoring, natural background radiation, public dose thresholds, and dose estimation for common imaging procedures such as chest X-ray, CT head, CT abdomen, and mammography.

The primary outcome variable was the overall radiation safety knowledge score. Knowledge was assessed through 22 radiation safety items, and the total score was calculated by summing item-level responses according to the questionnaire scoring criteria. Higher scores indicated better radiation safety knowledge. Secondary variables included gender, profession, work experience, and prior radiation safety training. The study also assessed item-level response patterns to identify specific areas of strength and weakness in radiation safety knowledge, including basic protection principles, dose limits, biological effects, dosimetry, and imaging-related dose estimation.

Data were entered and analyzed using IBM SPSS Statistics version 27. Categorical variables were summarized as frequencies and percentages, while continuous variables were summarized using mean, standard deviation, minimum, maximum, and median where applicable. Item-level knowledge responses were presented as frequencies and percentages. The overall knowledge score was compared between male and female participants using an independent-samples t-test. Differences in knowledge scores across professional categories were assessed using one-way analysis of variance. Statistical significance was assessed using a two-tailed p-value threshold of <0.05. Incomplete or invalid questionnaires were excluded from analysis according to the predefined exclusion criteria.

To improve data integrity, questionnaires were reviewed for completeness before inclusion in the final dataset, and responses were coded consistently before statistical analysis. The study maintained participant confidentiality by analyzing data in aggregated form without identifying individual participants. The methodological approach was intended to provide a reproducible assessment of radiation safety knowledge and related professional factors among radiological staff.

RESULTS

A total of 96 radiological staff members were included in the final analysis. The demographic and professional profile of the participants is presented in Table 1.

Table 1. Demographic and Professional Characteristics of Study Participants

Variable	Category	n	%
Age group, years	<25	62	64.6
	30–40	19	19.8
	40–50	10	10.4
	50–60	5	5.2
Gender	Male	37	38.5
	Female	59	61.5
Profession	Radiologist	42	43.8
	Technologist	34	35.4
	Technician	20	20.8
Experience, years	<1	51	53.1
	1–5	35	36.5
	6–10	10	10.4
Radiation safety training received	Yes	65	67.7
	No	31	32.3

Most participants were younger than 25 years of age, representing 62 of 96 respondents. Females constituted 59 participants, while males constituted 37 participants. Radiologists formed the largest professional group, followed by technologists and technicians. More than half of the participants had less than one year of experience, and 65 participants reported having received radiation safety training.

Table 2. Descriptive Statistics for Age, Experience, and Radiation Safety Knowledge Score

Variable	n	Mean ± SD	Minimum	Maximum	Median
Age category score	96	1.56 ± 0.88	1	4	—
Experience category score	96	1.57 ± 0.68	1	3	—
Knowledge score	96	46.09 ± 4.46	28.00	57.00	46.00
Knowledge score, % of total score	96	69.83 ± 6.76	42.42	86.36	69.70

The mean radiation safety knowledge score was 46.09 ± 4.46 out of a total possible score of 66, corresponding to 69.83% of the total score. Based on the percentage distribution, the overall knowledge level was best interpreted as moderate rather than poor or high. Scores ranged from 28.00 to 57.00, indicating variability in radiation safety knowledge across participants.

Table 3. Distribution of Recorded Responses to Radiation Safety Knowledge Items

Item	Knowledge Domain	Recorded Response	n	%
Q1	Radiation mechanism	Causing atomic ionization	73	76.0
Q2	Radiation dose unit	Gray	65	67.7
Q3	Deterministic effects	Cataract formation	37	38.5
Q4	Stochastic effects	Increase in severity with dose	34	35.4
Q5	Radiosensitive organ	Gonads	58	60.4
Q6	Radiation protection principle	As Low As Reasonably Achievable	78	81.3
Q7	Protective shielding	Scatter radiation	73	76.0
Q8	Lead apron equivalence	0.5 mm Pb	62	64.6
Q9	Occupational dose limit	20 mSv	55	57.3
Q10	Dosimeter monitoring	Monthly	69	71.9
Q11	Natural background radiation	2–3 mSv	66	68.8
Q12	Public annual radiation threshold	5 mSv	59	61.5
Q13	Single-view chest X-ray dose	0.02 mSv	68	70.8
Q14	Two-view chest X-ray dose	Twice the single-view CXR	67	69.8
Q15	CT head dose equivalence	50–100 CXR	43	44.8
Q16	CT abdomen dose equivalence	100–500 CXR	74	77.1
Q17	Two-view unilateral mammogram dose	10–20 times single-view CXR	55	57.3
Q18	Safest staff position	Behind protective barrier	75	78.1
Q19	Benefit of radiation safety training	Minimize harmful radiation exposure	75	78.1
Q20	Source of radiation knowledge	Theoretical teaching in medical school	53	55.2
Q21	Importance of training programs	Improve awareness and safe practices	85	88.5
Q22	Workplace radiation safety training	Yes	65	67.7

Item-level responses showed stronger performance for basic radiation protection concepts than for technical radiation biology and dose-estimation items. The highest recorded response was observed for the importance of radiation safety training programs, followed by knowledge of the ALARA principle, safest staff position during X-ray exposure, the benefit of radiation safety training, CT abdomen dose equivalence, and lead apron protection. Lower response rates were observed for deterministic effects, stochastic effects, CT head dose equivalence, occupational dose limits, mammography dose estimation, and radiosensitive organs.

The stochastic-effects item requires verification against the original answer key because "increase in severity with dose" is conceptually consistent with deterministic rather than stochastic effects. Therefore, this item should not be interpreted as a correct-response rate until the questionnaire key and raw responses are rechecked.

Table 4. Comparison of Radiation Safety Knowledge Scores by Gender

Gender	n	Mean ± SD	Mean Difference	95% CI	t	df	p-value	Cohen's d
Male	37	45.22 ± 3.49	-1.42	-3.25 to 0.41	-1.537	94	0.128	-0.32
Female	59	46.64 ± 4.93	—	—	—	—	—	—

Female participants had a higher mean knowledge score than male participants, with a mean difference of 1.42 points. However, the 95% confidence interval crossed zero, and the difference was not statistically significant. The standardized mean difference was small, indicating limited practical separation between male and female participants in radiation safety knowledge scores.

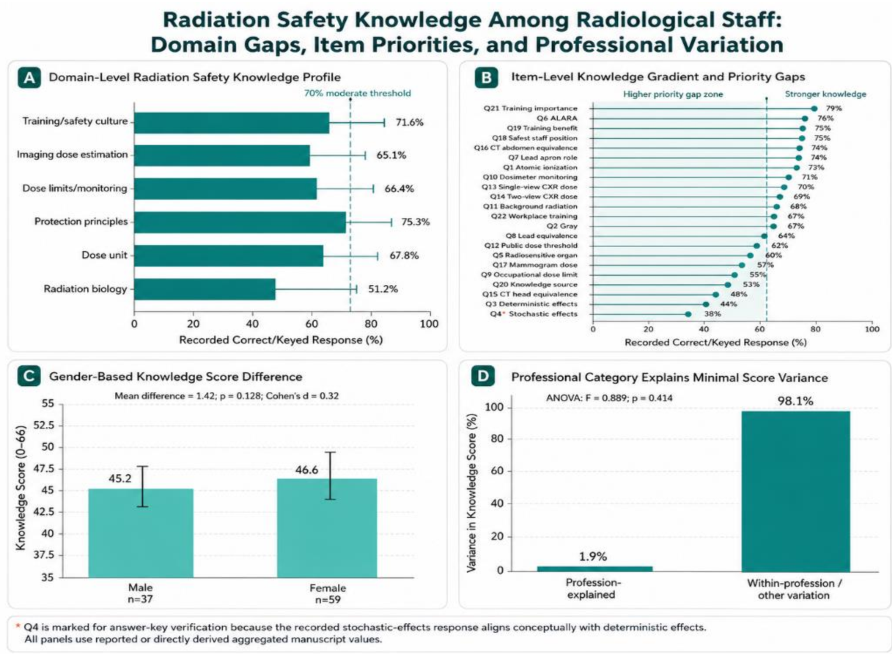

Figure 1. Radiation safety knowledge among radiological staff: domain gaps, item priorities, and professional gradients. Panel A shows domain-level mean recorded response percentages with item-level ranges, indicating stronger performance in protection principles and training-related awareness than in radiation biology. Panel B presents item-level knowledge gradients, with lower response percentages for deterministic effects, stochastic effects, CT head dose equivalence, occupational dose limits, and mammography dose estimation. Panel C shows a small, statistically non-significant gender difference in knowledge scores, with females scoring slightly higher than males. Panel D shows that professional category explained only 1.9% of total knowledge-score variance, indicating that knowledge gaps were broadly distributed across professional groups. Q4 requires answer-key verification because the recorded stochastic-effects response is conceptually more consistent with deterministic effects.

There was no statistically significant difference in radiation safety knowledge scores across professional categories. The effect size was small, with professional category explaining approximately 1.9% of the total variation in knowledge scores. These findings suggest that knowledge gaps were not confined to a single professional group within the sampled radiological staff.

Table 5. One-Way ANOVA for Radiation Safety Knowledge Scores Across Professional Categories

Source	Sum of Squares	df	Mean Square	F	p-value	η^2
Between groups	35.509	2	17.755	0.889	0.414	0.019
Within groups	1856.647	93	19.964	—	—	—

Source	Sum of Squares	df	Mean Square	F	p-value	η^2
Total	1892.156	95	—	—	—	—

Additional analyses comparing knowledge scores by years of experience and previous radiation safety training were not available in the supplied statistical output. Because experience and training were central variables in the study objective, these analyses should be added before final manuscript submission. A comparison of trained versus untrained participants would be particularly important for determining whether prior radiation safety training was associated with higher knowledge scores.

DISCUSSION

The present study assessed radiation safety knowledge, awareness, and related practice indicators among 96 radiological staff members working in public and private hospital settings. The principal finding was that the overall radiation safety knowledge score was moderate, with a mean score of 46.09 ± 4.46 out of 66, corresponding to approximately 69.83% of the total score. This finding indicates that participants had reasonable awareness of basic radiation protection concepts but persistent gaps in more technical domains of radiation biology, occupational dose limits, and imaging-related dose estimation. This pattern is important because radiation safety in clinical practice depends not only on recognizing general protective principles but also on correctly understanding dose limits, biological effects, monitoring requirements, and procedure-specific exposure risks.

The strongest areas of knowledge were related to practical and foundational protection principles. Most participants recognized the importance of radiation safety training, the meaning of the ALARA principle, the safest staff position during X-ray exposure, and the protective role of lead aprons. These findings suggest that basic radiation safety messages are reaching many radiological staff members. However, the item-level findings also showed that this basic awareness did not consistently extend to advanced or technical knowledge. Lower recorded response percentages were observed for deterministic effects, stochastic effects, CT head dose equivalence, occupational dose limits, and mammography dose estimation. Similar gaps have been reported in previous studies of radiology professionals and healthcare workers, where staff often demonstrate awareness of shielding and general protection principles but show weaker understanding of radiation biology, dose quantification, and procedure-specific risk estimation (21,22).

A particularly important finding relates to participants' knowledge of radiation effects. The recorded response for the stochastic-effects item was low and requires verification because the answer documented in the results appears conceptually aligned with deterministic rather than stochastic radiation effects. Deterministic effects generally occur above a threshold and increase in severity with dose, whereas stochastic effects are probability-based and include outcomes such as malignancy and genetic effects. This distinction is central to radiation protection because misunderstanding stochastic and deterministic effects may weaken risk communication, staff counseling, and compliance with exposure-minimization principles. The questionnaire answer key should therefore be rechecked before final interpretation of this item, and if the key is confirmed to be incorrect, the affected item score and total knowledge score should be recalculated.

The findings also showed that knowledge scores did not differ significantly by gender. Although female participants had a slightly higher mean knowledge score than male participants, the difference was small and statistically non-significant. The standardized mean difference was also small, suggesting limited practical separation between male and female staff in radiation safety knowledge. Similarly, professional category was not significantly associated with knowledge score, and the effect size indicated that profession explained only a small proportion of total score variation. This finding suggests that knowledge gaps were distributed across professional groups rather than concentrated within one category of radiological staff. However, profession-wise mean scores were not available in the supplied output, so the direction and magnitude of differences between radiologists, technologists, and technicians should be reported in future revisions.

Previous radiation safety training was reported by 67.7% of participants, yet 32.3% had not received such training. This is a meaningful finding because radiation protection competence should be reinforced through continuous workplace-based training rather than relying solely on undergraduate or pre-service education. More than half of the participants reported theoretical teaching in medical school as their source of radiation knowledge, which suggests that workplace training and continuing professional development may be insufficiently embedded in routine departmental practice. Prior studies have emphasized that structured radiation safety training, personal dosimetry, departmental audits, and institutional safety culture are necessary to improve compliance and reduce unnecessary occupational exposure (23–25). Nevertheless, the present manuscript does not yet include a statistical comparison between trained and untrained participants; therefore, it cannot conclude that training was or was not associated with higher knowledge scores. This analysis should be added before final submission.

The study has several implications for clinical governance and occupational safety. First, training programs should not be limited to general awareness but should specifically address radiation biology, deterministic and stochastic effects, occupational and public dose limits, CT dose equivalence, mammography dose, and correct dosimeter use. Second, training should be repeated periodically because radiation safety knowledge may decline without reinforcement. Third, radiology departments should combine education with practical safety systems, including availability of lead aprons, thyroid shields, lead glasses, personal dosimeters, barrier use, and routine monitoring. Fourth, safety culture should be strengthened through visible departmental policies, supervisory checks, and periodic audits of radiation protection behavior. These measures are particularly important because knowledge alone may not ensure safe practice unless supported by institutional systems and accountability.

The study also has limitations that should be considered when interpreting the findings. The sample size was relatively small, and participants were recruited from public and private hospital settings without detailed reporting of the number, type, or location of participating hospitals. The sampling method was described as random, but the sampling frame and random selection process were not clearly documented, which limits assessment of selection bias. The data were collected using self-completed questionnaires, so responses may have been affected by recall bias, social desirability bias, or misunderstanding of technical items. Direct observation of radiation safety behavior was not performed; therefore, the study assessed self-reported and knowledge-based indicators rather than verified clinical practice. The questionnaire source, validation status, reliability, and detailed scoring criteria were also insufficiently reported and should be strengthened to improve reproducibility. Finally, analyses by years of experience and previous radiation safety training were not available in the supplied statistical output, although both variables are important to the study objective.

Overall, the study demonstrates that radiological staff had moderate overall radiation safety knowledge, with stronger awareness of basic protective concepts and weaker understanding of technical radiation biology and dose-related concepts. The absence of significant differences by gender and professional category suggests that educational interventions should target all radiological staff rather than only selected subgroups. Future studies should use validated questionnaires, larger multicenter samples, clearly defined sampling methods, and direct assessment of safety practices. Additional analyses comparing trained and untrained staff, as well as staff with different experience levels, would provide stronger evidence for designing targeted radiation safety education programs.

CONCLUSION

Radiological staff demonstrated moderate overall radiation safety knowledge, with better awareness of basic protection principles such as ALARA, lead apron use, safe positioning, and the importance of training, but weaker knowledge of radiation biology, stochastic and deterministic effects, occupational dose limits, and selected imaging-dose estimates. Knowledge scores did not differ significantly by gender or professional category, indicating that knowledge gaps were broadly distributed across the sampled workforce. These findings support the need for regular, competency-based radiation safety training, reinforcement of occupational dose-monitoring practices, improved understanding of CT and mammography dose, and stronger institutional safety systems. The stochastic-effects item should be verified against the original questionnaire answer key before final interpretation, and additional analyses by prior training and years of experience should be added to strengthen the manuscript's conclusions.

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