The Impact of Occupational Radiation Exposure on Radiographers and the Practical Realities of Radiation Protection Practices

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ABSTRACT

Occupational radiation exposure poses a significant health risk to radiographers working with ionizing radiation in clinical settings. This study investigates exposure levels and evaluates the effectiveness and implementation of radiation protection practices. Using a mixed-methods approach, it combines dosimetry data, surveys, interviews, and observations across healthcare institutions. Findings reveal that while radiographers understand radiation safety protocols, factors such as heavy workloads, inadequate infrastructure, outdated training, and weak institutional enforcement hinder consistent application. Although exposure levels often fall within limits set by the International Commission on Radiological Protection (ICRP), cumulative exposure can lead to long-term health risks like cancer, cataracts, and reproductive issues. Psychological impacts, including stress and burnout, are also prevalent. The study highlights disparities in safety practices, especially between well-resourced urban hospitals and underfunded rural facilities. To address these challenges, the research recommends standardized safety training, investment in shielding technologies, appointment of radiation safety officers (RSOs), and promotion of transparent reporting and communication systems. Ultimately, ensuring radiographers' safety requires more than regulatory compliance; it demands a cultural shift toward prioritizing radiation safety in daily clinical operations to protect health professionals and maintain quality radiological services.

1.INTRODUCTION

Background

Radiation plays a vital role in modern medicine, enabling essential diagnostic and therapeutic procedures such as X-rays, CT scans, and interventional imaging. Radiographers are responsible for conducting these procedures, ensuring both image quality and patient safety. However, in performing their duties, they are routinely exposed to low doses of ionizing radiation, which, over time, may pose health risks including cancer, cataracts, and genetic damage. Although occupational exposure is generally within limits set by organizations like the ICRP, cumulative exposure remains a concern—especially in settings where safety compliance is weak. Guidelines such as the ALARA principle, proper use of personal protective equipment (PPE), radiation monitoring, and staff training are designed to minimize these risks. Despite these measures, gaps between policy and practice persist. PPE may be neglected due to discomfort or time pressures, while underfunded institutions often lack adequate equipment and oversight. These challenges are particularly acute in low- and middle-income countries (LMICs), where outdated technology and weak regulations can lead to higher exposure levels. Beyond physical health risks, working in radiation-prone environments can cause psychological stress and anxiety. This study explores both the physiological and practical challenges of occupational radiation exposure and seeks to identify strategies to improve safety and compliance.

Biological Effects of Ionizing Radiation

Ionizing radiation produces two types of biological effects: stochastic and deterministic. Stochastic effects, such as cancer and genetic mutations, occur randomly with no threshold, while deterministic effects like cataracts and skin burns appear above a specific dose. Radiographers exposed to radiation long-term face increased risks of leukemia, thyroid disorders, and reproductive issues. Studies also indicate higher rates of fatigue, headaches, and psychological stress, which may result from chronic exposure or anxiety related to working in radiation-prone environments.

Radiation Protection Principles

Limit time spent near a radiation source, increase distance away from a radiation source, or use shielding.

The core radiation protection principles include:

- Time: Minimizing exposure duration.
- Distance: Maximizing distance from the radiation source.
- Shielding: Using physical barriers like lead aprons, thyroid collars, and leaded glass.

The ALARA principle underpins all safety practices. Despite widespread awareness, adherence to these principles is inconsistent, often due to workflow pressures or lack of institutional enforcement.

Regulatory Standards and Guidelines

International bodies such as the ICRP, WHO, and IAEA, along with national agencies (e.g., NRC in the U.S., NRPA in Nigeria, ARPANSA in Australia), set safety standards for radiation protection. These include personal dosimetry, appointing radiation safety officers, regular training, audits, and health surveillance. Despite these frameworks, studies highlight a gap between regulatory intent and real-world implementation, particularly in resource-limited settings.

Challenges in Radiation Protection Practices

Key challenges include inconsistent PPE use due to discomfort, time pressure, or perceived low risk; inadequate training on evolving risks; and limited access to up-to-date equipment, especially in developing countries. Weak enforcement, unclear accountability, and lack of institutional commitment also contribute to a poor safety culture and compromised radiation protection practices.

2. LITERATURE REVIEW

Leonie E. Paulis, Roald S. Schnerr, Jarred Halton, Zhi Zhen Qin, Arlene Chua (2024) has conducted a research study on 'Monitoring Occupational Radiation Dose in Radiography Students' Implications for Safety and Training to examined scatter and leakage radiation from ultraportable chest X-ray units used in TB screening. Using anthropomorphic thorax phantoms and precise dose measurements at 90 kV/2.5 mAs, they determined “safe distance” zones to ensure annual occupational exposure remained below 1 mSv. They highlighted time-distance-shielding principles—minimize time near device, stay at a safe distance, and use shielding—as sufficient to maintain safety. Their findings support the safe deployment of ultra-portable X-ray systems in limited-resource settings, so long as basic radiation protection guidelines are followed rigorously.

Adliene et al.(2023) has conducted a study on 'Evaluation of Occupational Radiation Exposure during Diagnostic Imaging Examinations' to analyse the used of thermoluminescent dosimeters (TLD-100) to monitor 145 radiology staff over two years in four Saudi hospitals. The average annual dose was 1.42 mSv, with a maximum of 3.9 mSv, all well below the IAEA limit of 20 mSv/year . Although these results confirm regulatory compliance, the study recommends continuous monitoring, especially for individuals approaching 15% of exposure limits, to ensure long-term safety and trend analysis.

Osman et al.(2023) conducted a study on 'Investigation of Radiographers' Compliance with Radiation & Infection Control during COVID-19 Mobile Radiography'Osman et al. performed a scoping review of pandemic-era mobile radiography, evaluating how infection control measures affected radiation protection practices. They found that efforts to minimize infection risk—like distancing and mobile workflows—sometimes compromised radiation safety (e.g., distancing vs. optimal radiographer position controls). The study emphasizes the importance of balancing infection control with radiation protection through adaptable protocols, clear PPE guidance, and situational awareness.

Gebremedhin et al. (2022) Conduct a study on 'Occupational Exposure in Eastern Amhara, Ethiopia'This cross-sectional study involved 198 radiology personnel using TLDs to record occupational exposure. The research revealed variability in annual dose levels linked to factors such as equipment maintenance quality, room layout, and personnel training. The authors advocate for strengthened equipment quality control, ongoing staff education, and environmental adjustments in radiology units to improve radiation protection practices.

Yi Guo, Li Mao, Gongsen Zhang, Zhi Chen, Xi Pei, X. George Xu (2020) has conducted a study on 'Conceptual Design of a VR-Based Radiation Safety Training System' Yi Guo and colleagues designed a mixed-reality system using HoloLens to train interventional radiology staff. This immersive platform overlays real-time radiation dose feedback and visualized scatter fields, enhancing spatial awareness and reinforcing time-distance-shielding concepts. Their pilot implementation demonstrated that such interactive tools not only engage learners but could also lead to improved adherence to radiation safety protocols by making invisible hazards tangible.

Gebre Mesay Geletu, Fikru Abiko, Shamble Sahlu (2019) has conducted a study on 'Implementation of a Radiation Protection System at Four Ethiopian Hospitals' this paper audited radiation protection systems at four hospitals in Ethiopia using walk-through surveys, staff questionnaires, and dose-rate measurements . The findings highlighted a lack of protective protocols, insufficient shielding equipment, and inadequate staff training—even though control room and waiting area dose rates were within safe limits. The authors call for dedicated radiation protection advisers, improved training programs, and upgraded monitoring systems.

Pandey, Singh, Sonawane, Rawat (2016) has conducted a study on 'FMEA-Based Risk Assessment in Industrial Radiography' Pandey, Singh, Sonawane, and Rawat applied Failure Modes and Effects Analysis (FMEA) to industrial radiography operations. They identified 56 potential points of failure that might lead to elevated operator exposure. Through ranking severity, occurrence, and detectability, they prioritized risk control measures and recommended systematic enhancements in operational design and maintenance to reduce radiation incidents, reinforcing proactive safety management in industrial settings.

Al-Rashid et al.(2013) has conducted a study on 'Assessment of Occupational Radiation Exposure among Medical Staff in Eastern Province, Saudi Arabia'Salama et al. measured radiation levels in X-ray and CT rooms across four Saudi hospitals and surveyed staff compliance with PPE and dosimeter usage . Despite lead aprons and thyroid shields being widely available, only 50% of sites provided lead glasses/shields. Dosimeter usage was low (57–69%), and radiation levels sometimes exceeded recommended limits. The study underscores the need for improved equipment, stricter dosimetry policies, and enhanced training to close the protection gaps.

3. RESEARCH METHODOLOGY

Problem Statement

Despite awareness of radiation risks and the existence of comprehensive radiation protection protocols, radiographers in many institutions continue to experience unnecessary exposure due to lapses in safety practices. There exists a gap between regulatory requirements and practical implementation, often influenced by systemic, organizational, and individual factors. This study seeks to identify and understand these gaps and assess the actual impact of occupational exposure on radiographers' health and wellbeing.

Research Objectives

- To assess the level of occupational radiation exposure experienced by radiographers.

- To evaluate the effectiveness and practicality of current radiation protection practices.
- To identify barriers to compliance with radiation safety protocols.
- To understand the health implications of chronic occupational radiation exposure on radiographers.
- To propose recommendations for improving radiation safety practices in clinical settings.

Population and Sampling

Sampling method: Stratified purposive sampling was used to ensure representation across different types institutions and levels of experience.

Sample size: Approximately 26 radiographers

Data Collection Methods

Structured Questionnaire- A structured questionnaire was designed to gather quantitative data from radiographers across selected healthcare facilities. This instrument focused on obtaining factual information about participants' radiation protection behaviors, awareness, training, and self-reported exposure levels.

Distribution:

The questionnaire was distributed through Google form, depending on the convenience of the healthcare facility and the availability of the radiographers.

Pilot Testing:

The instrument was piloted on a small group of radiographers to test clarity, reliability, and average response time. Necessary revisions were made based on feedback.

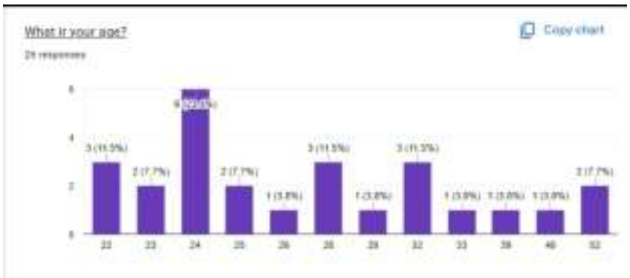
4.DATA ANALYSIS AND INTERPRETATIO

Method of Analysis

A total of 26 responses were collected using a structured questionnaire covering demographic details, work experience, radiation exposure frequency, imaging modalities used, and safety practices followed. Both quantitative and qualitative variables were analyzed to identify patterns, correlations, and gaps in radiation protection.

The survey data were organized into categories such as: Demographics,Work-related exposure, Knowledge and training, Workplace infrastructure, Challenges and perceptions,Health impact perceptions

Data Analysis


What ir your age?
Copy chart
3 (11.5%)
2 (7.7%)
2 (7.7%)
1 (3.8%)
3 (11.5%)
1 (3.8%)
3 (11.5%)
1 (3.8%)
1 (3.8%)
1 (3.8%)
2 (7.7%)
22
23
24
25
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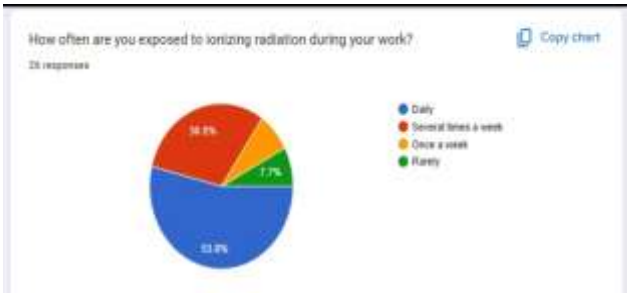
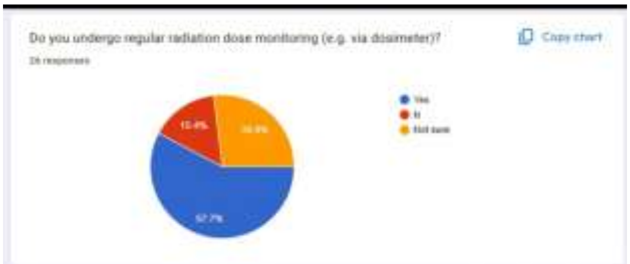
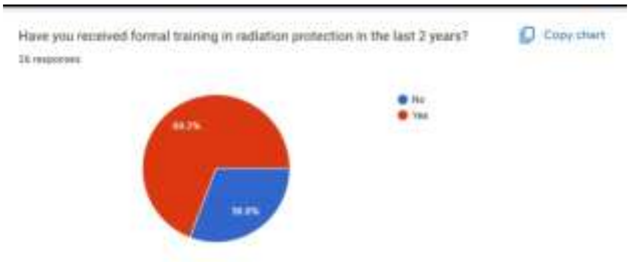
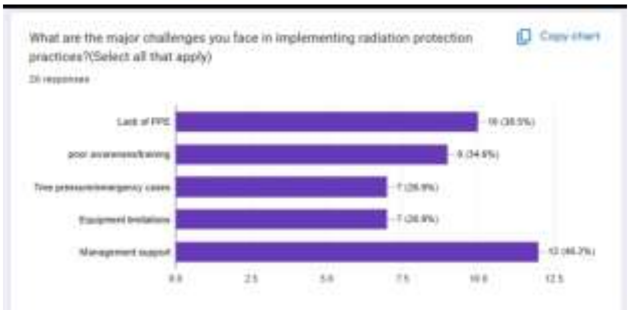
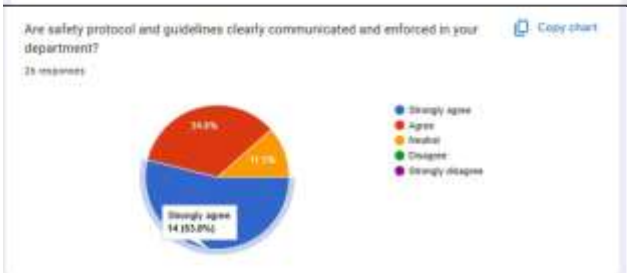
40
52

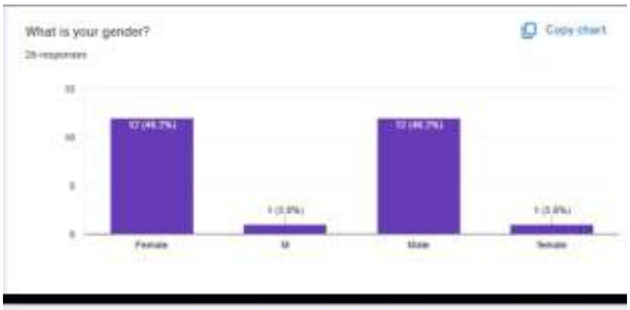

How often are you exposed to ionizing radiation during your work?
Copy chart
Daily
Several times a week
Once a week
Rarely
7.7%

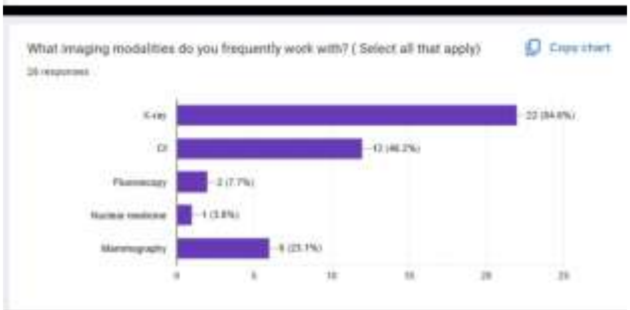

Do you undergo regular radiation dose monitoring (e.g. via dosimeter)?
Copy chart

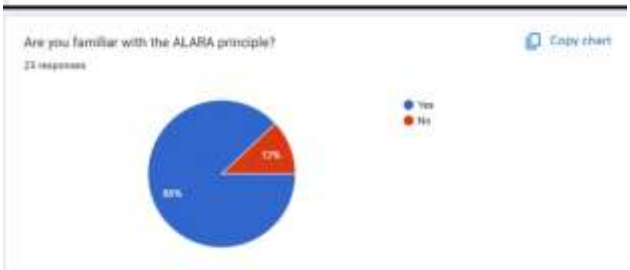

Have you received formal training in radiation protection in the last 2 years?
Copy chart
No
Yes

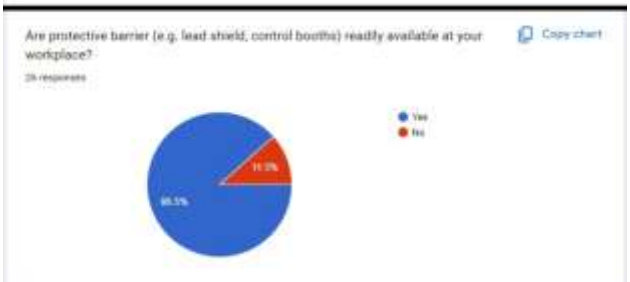

What are the major challenges you face in implementing radiation protection practices?(Select all that apply)
Copy chart
Lack of PPE
Management support

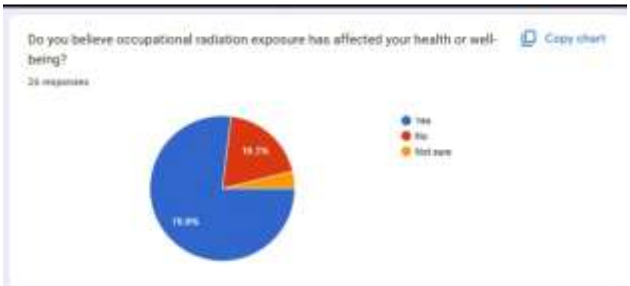

Are safety protocol and guidelines clearly communicated and enforced in your department?
Copy chart
Strongly agree
Agree
Neutral
Disagree
Strongly disagree


What is your gender?
Copy chart
1 (3.8%)
1 (3.8%)
Female
Male


What imaging modalities do you frequently work with? (Select all that apply)
X-ray
CT
Fluoroscopy
Nuclear medicine
Mammography
22 (84.6%)
12 (46.2%)
2 (7.7%)
1 (3.8%)
6 (23.1%)


Are you familiar with the ALARA principle?
Copy chart
Yes
No


Are protective barrier (e.g. lead shield, control booths) readily available at your workplace?
Copy chart
Yes
No


Do you believe occupational radiation exposure has affected your health or well-being?
Copy chart
Yes
No
Not sure

5.FINDINGS

Demographic Profile and Experience

Survey data showed a young, gender-inclusive workforce, with most radiographers aged 24–32. Experience varied: 35% had under 3 years, 54% over 4 years. This diversity in experience may influence the level of awareness and consistency in applying radiation safety measures across different professional groups.

Frequency of Exposure and Imaging Modalities

Daily exposure to ionizing radiation was reported by 58% of respondents, and 27% faced exposure several times weekly. X-rays (92%) and CT scans (42%) were the most used imaging tools, indicating high cumulative exposure. These findings highlight the need for consistent radiation protection in routine clinical practice.

Radiation Monitoring and ALARA Awareness

About 77% of radiographers undergo regular radiation monitoring, and 81% are familiar with the ALARA principle. However, 23% lacked clarity on either, pointing to gaps in awareness or communication. These deficiencies may reflect limited experience or inadequate training, emphasizing the need for improved education and monitoring practices.

Training and Safety Infrastructure

A strong majority (77%) received formal radiation protection training within two years, and 92% reported access to protective barriers. However, 23% lacked recent training, raising concerns about compliance with evolving protocols. Regular, mandatory training is essential to ensure updated knowledge and adherence to safety standards in practice.

Safety Protocol Enforcement

Most respondents (85%) felt safety protocols were clearly communicated and enforced. However, 15% were neutral or disagreed, revealing potential communication or enforcement gaps. Inconsistent enforcement can undermine safety practices, stressing the need for robust oversight and clear institutional commitment to upholding radiation protection guidelines consistently.

Challenges in Implementing Radiation Protection

Key barriers included lack of PPE (42%), poor management support (38%), limited training (31%), time constraints (23%), and equipment shortages (23%). These challenges reflect systemic, administrative, and logistical issues that hinder radiation safety implementation, particularly under emergency conditions or in poorly resourced clinical environments.

Perceived Health Impact

A striking 73% believed radiation exposure had negatively impacted their health or well-being. This perception may result from chronic exposure, insufficient PPE, or psychological stress. Although subjective, it underscores the need to address both physical protection and mental health concerns in radiation-prone work environments.

6.LIMITATION OF THE STUDY

While this study provides valuable insights into radiographers' radiation exposure and safety practices, several limitations should be noted:

1. Small Sample Size:With only 26 participants, the findings lack statistical power and generalizability. A larger sample could allow more accurate subgroup comparisons.

2. Geographical Scope: Participants were likely from a specific region or institution, limiting the applicability of results to broader healthcare contexts with differing regulations and resources.

3. Self-Reported Data: Reliance on self-reporting introduces recall and social desirability biases, potentially affecting the accuracy of responses related to exposure and training.

4. Modality Representation:Most respondents worked in X-ray and CT, underrepresenting other modalities like nuclear medicine and MRI, which may face different safety challenges.

5. No Objective Dose Data:The study lacked actual dosimeter or medical surveillance data, limiting the ability to link perceived exposure with measurable risk.

6. Cross-sectional Design: A one-time survey limits the ability to assess causality or changes over time, such as improvements following training or policy changes.

7. Limited Qualitative Insights: Closed-ended questions restricted the depth of feedback. Richer insights might have emerged from interviews or open-ended responses.

8. Potential Data Errors:Some inconsistencies in responses (e.g., incomplete fields or unclear answers) may have introduced minor interpretation or data cleaning biases.

7. CONCLUSION AND RECOMMENDATIONS

Conclusion:

This study examined radiation exposure, safety practices, and perceived health effects among radiographers. Most respondents reported daily exposure to ionizing radiation, primarily from X-ray and CT modalities. While awareness of safety principles like ALARA is high and dose monitoring is common, challenges persist. Key issues include lack of PPE, inadequate management support, limited training—especially for newer staff—and high workload pressures that hinder compliance. Notably, over 70% believe occupational exposure has harmed their health, revealing a serious concern. These findings expose a gap between safety policies and their effective implementation.

Recommendation:

1. Ensure PPE Availability and Use

- Provide adequate, high-quality PPE (e.g., lead aprons, thyroid shields).
- Conduct regular audits to replace damaged or missing items.

2. Boost Management Engagement

- Promote a safety-first culture through active leadership.
- Establish clear accountability and empower staff to report risks.

3. Standardize Radiation Safety Training

- Offer mandatory, regular refresher courses.
- Include scenario-based simulations and emergency protocols.

4. Improve Awareness and Communication

- Display safety guidelines prominently.
- Hold briefings to share incidents, tips, and updates.

5. Implement Objective Dose Monitoring

- Use real-time dosimetry where feasible.
- Maintain accessible exposure records for staff and health teams.

6. Address Workload and Staffing

- Optimize scheduling to reduce pressure.
- Assign radiation safety officers in busy departments.

7. Support Further Research

- Conduct larger, multi-center studies on modality-specific risks.
- Include qualitative interviews to explore mental health impacts.

Final Note

While the study affirms that radiographers possess foundational knowledge of radiation safety, there is an urgent need to bridge the gap between policy and practice. By addressing equipment shortages, management inertia, and systemic pressures, healthcare institutions can significantly improve radiation protection standards and promote long-term well-being for frontline radiologic staff.

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