Indian Journal of Modern Research and Reviews

This Journal is a member of the *'Committee on Publication Ethics'*

Online ISSN:2584-184X

Research Article

Radiation Safety Awareness in Cath Lab under Radiology Departments and OT Departments

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DOI: https://doi.org/10.5281/zenodo.20095785

Abstract

Background: The increasing reliance on ionising radiation in catheterisation laboratories (cath labs), radiology departments, and operating theatres (OTs) has significantly enhanced diagnostic accuracy and therapeutic outcomes. Procedures such as fluoroscopy-guided cardiac interventions, computed tomography (CT), interventional radiology techniques, and intraoperative C-arm imaging are now integral to modern medical practice. However, the expanding volume and complexity of these procedures have led to greater occupational radiation exposure among healthcare professionals, including physicians, nurses, radiologic technologists, and operating room staff.

Objective: To review radiation safety awareness and protective practices in the cath lab, radiology department, and operating theatre, and to highlight strategies to minimise occupational radiation exposure and promote a culture of safety.

Methods: A Cross-sectional survey was conducted using a Google Form questionnaire consisting of multiple-choice questions on Radiation Safety Awareness in Cath lab under Radiology department and OT departments, radiosensitive organs, high-risk groups, regulatory bodies, and safety practices related to shielding and contrast safety. Participants included

Students, Nurses, radiologists, radiology technicians, OTT technicians. The response was analysed using descriptive statistics.

Result: Among 200 participants (mostly students and radiology staff), 83.5% reported ionising radiation use in cath labs, mainly from fluoroscopy (52.5%) and C-arm (30%)^16,17. Gonads (43%) and bone marrow (27%) were recognized as most sensitive organs^18. 89.5% knew the ALARA principle, but protective apron knowledge varied^20,21. 81.5% used all recommended PPE; 77.9% knew occupational dose limits^16,23. Awareness was good but gaps remain in organ sensitivity, protective standards, and dose knowledge.

Conclusion: Radiation exposure in the catheterization laboratory, radiology department, and operating theatre poses a significant occupational risk to healthcare professionals. Despite advances in imaging technology and established international guidelines from the International Commission on Radiological Protection and the International Atomic Energy Agency, gaps in awareness, training, and consistent use of protective measures persist. Strengthening radiation safety education, promoting adherence to ALARA principles, and implementing effective monitoring and shielding strategies are essential to minimise occupational hazards.

Manuscript Information

- **ISSN No:** 2584-184X
- **Received:** 02-04-2026
- **Accepted:** 30-04-2026
- **Published:** 09-05-2026
- **MRR:**4(5); 2026: 33-42

- **Plagiarism Checked:** Yes
- **Peer Review Process:** Yes

How to Cite this Article

Kumkum, Dipali, Diksha, Salonia S, Bhardwaj C, Yadav K, Radiation Safety Awareness in Cath Lab under Radiology Departments and OT Departments. Indian J Mod Res Rev. 2026;4(5):33-42.

Access this Article Online

www.mrrjournal.in

KEYWORDS: Radiation Safety Awareness, Catheterisation Laboratory, Occupational Radiation Exposure, Fluoroscopy, ALARA Principle, Personal Protective Equipment, Radiation Dose Limits, Interventional Radiology.

Abbreviation: ALARA – As Low As Reasonably Achievable, **C-arm** – Mobile fluoroscopic imaging system (C-shaped arm), **Cath Lab** – Catheterization Laboratory, **CT** – Computed Tomography, **CIRSE** – Cardiovascular and Interventional Radiological Society of Europe, **DRL** – Diagnostic Reference Level, **Gy** – Gray, **IAEA** – International Atomic Energy Agency , **ICRP** – International Commission on Radiological Protection, **IR** – Interventional Radiology, **mGy** – Milligray, **MRI** – Magnetic Resonance Imaging, **mSv** – Millisievert, **OT** – Operation Theatre, **PPE** – Personal Protective Equipment, **SIR** – Society of Interventional Radiology, **TLD** – Thermo luminescent Dosimeter

INTRODUCTION

The use of ionising radiation in the cardiac catheterisation (cath) laboratory and operating theatre (OT) has grown substantially over the past few decades, driven by rapid advancements in interventional cardiology, vascular surgery, orthopedic procedures, and other minimally invasive techniques. Fluoroscopy and mobile C-arm systems have become indispensable tools for real-time imaging guidance, enabling improved diagnostic accuracy and therapeutic precision. However, the increasing complexity and duration of these procedures have led to higher cumulative radiation exposure for both patients and healthcare professionals, raising significant concerns regarding radiation-induced health risks. [1,3]

Occupational exposure in cath labs and OT environments is particularly important because interventional cardiologists, radiologists, surgeons, nurses, and radiologic technologists work in close proximity to radiation sources for prolonged periods. Repeated exposure to scatter radiation has been associated with deterministic effects such as skin injury, hair loss, and cataract formation, as well as stochastic effects including an increased lifetime risk of malignancy. Furthermore, patients undergoing lengthy or repeated interventional procedures may receive substantial radiation doses, necessitating strict dose optimization and monitoring strategies.[4]

In this context, radiation safety awareness is a fundamental aspect of clinical practice, regulatory compliance, and quality assurance within radiology departments and surgical settings. International recommendations and guidelines emphasize adherence to the ALARA (As Low As Reasonably Achievable) principle, which integrates time reduction, distance maximisation, and appropriate shielding to minimize exposure. The use of personal protective equipment, ceiling-suspended lead shields, radiation-attenuating table skirts, personal dosimeters, and regular equipment quality control checks are critical component of a comprehensive radiation protection program. [2,5]

This review article aims to provide a detailed overview of radiation safety principles applicable to cath labs and OT departments, including radiation physics basics, dose metrics, biological effects, risk assessment, protective strategies, staff training requirements, and institutional safety policies. Additionally, it explores recent technological advancements such as dose-reduction software, real-time dose monitoring systems, and improved imaging protocols that contribute to enhanced radiation protection. By synthesizing current evidence and best practices, this review seeks to highlight the importance of cultivating a strong radiation safety culture to safeguard both patients and healthcare workers while maintaining high standards of procedural efficacy and clinical outcomes. [6,4]

Method & Material: A Cross-sectional survey was conducted using a Google Form questionnaire consisting of multiple-choice questions on Radiation Safety Awareness in Cath lab under Radiology department and OT departments.

Study Setting and Population: The survey was conducted among students, X-ray technicians, and Ot technician of Maharishi Markandeshwar (Deemed to be University), Mullana, located in Haryana, India. Participants were selected from departments associated with radiology and medical imaging.

Study Design: A structured Google Form-based questionnaire was developed, consisting of 20 multiple-choice questions. The question focused on ALARA principle, protective devices, awareness of radiation dose, and knowledge about radiation safety.

Sample Size and Duration: A total of 200 valid responses were received over a data collection period of two weeks in January 2026.

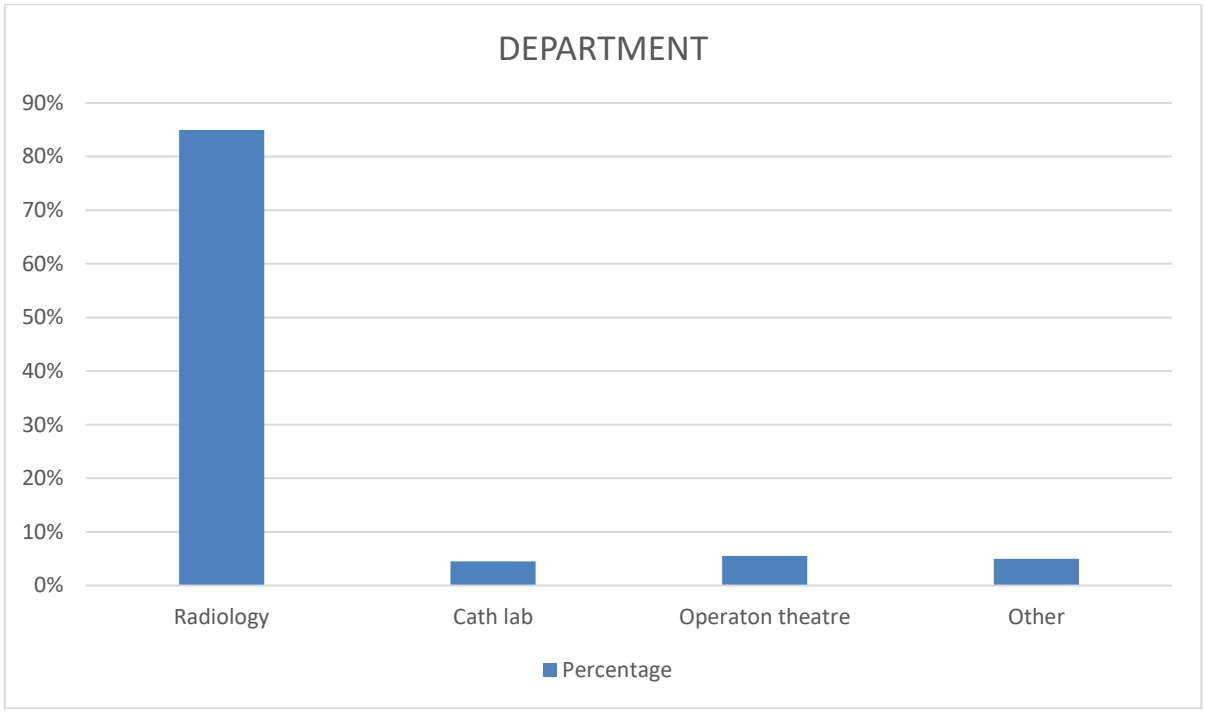
Questionnaire Development: The questionnaire for this study was systematically developed to assess radiation safety awareness and protective practices among healthcare personnel working in catheterisation laboratories (cath labs), radiology departments, and operating theatres (OTs).

Data collection and Analysis: The survey link was distributed electronically via institutional groups and emails. Responses were automatically recorded and exported into Microsoft Excel for analysis. Descriptive statistics, including percentage and frequency distribution, were used to interpret results.

Result: Out of 200 participants, Radiology accounts for 85%, followed by Operation Theatre (5.5%), Other (5%), and Cath Lab (4.5%), indicating Radiology has the highest representation.

Table 1: Department

Department	Percentage
Radiology	85%
Cath lab	4.5%
Operating theatre	5.5%
Other	5%

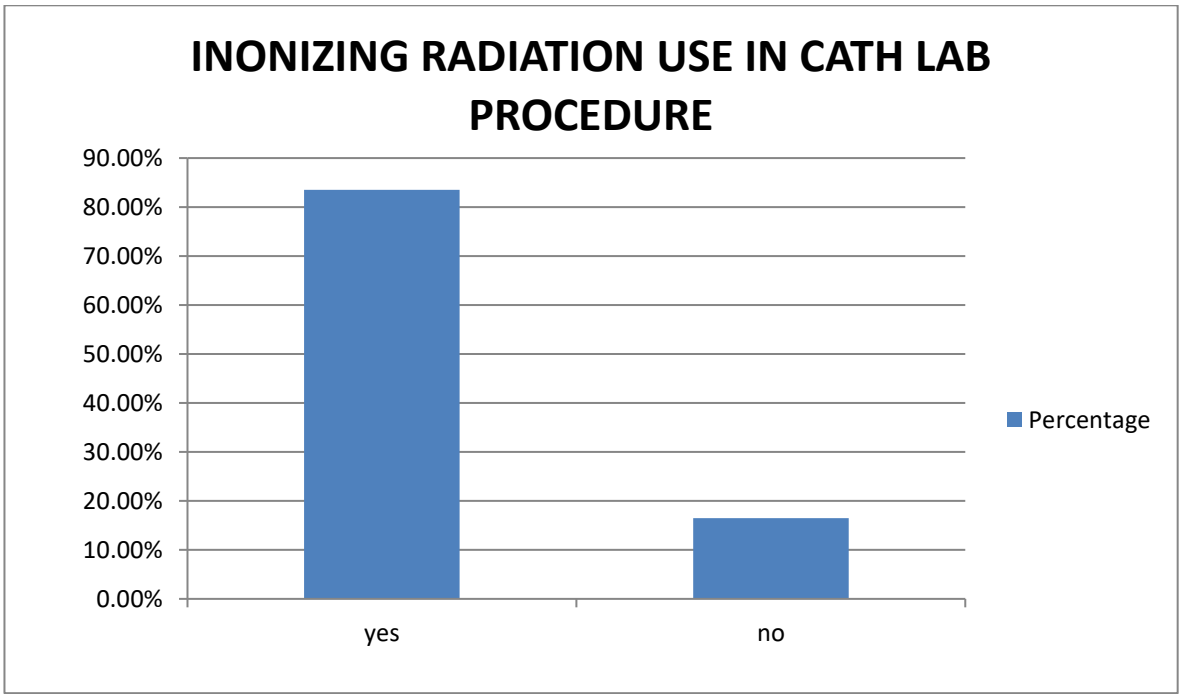


Graph 1: Department

IONIZING RADIATION USE IN CATH LAB PROCEDURES: Out of **200 respondents**, **83.5% (167)** reported that ionising radiation is used in Cath Lab procedures, while 16.5% (33) reported it is not used, indicating that radiation is commonly used for imaging and guidance in most procedures

Table 2: Ionising Radiation Use in Cath Lab Procedures

Ionising Radiation use in cath lab procedures	Percentage
Yes	83.5%
No	16.5%



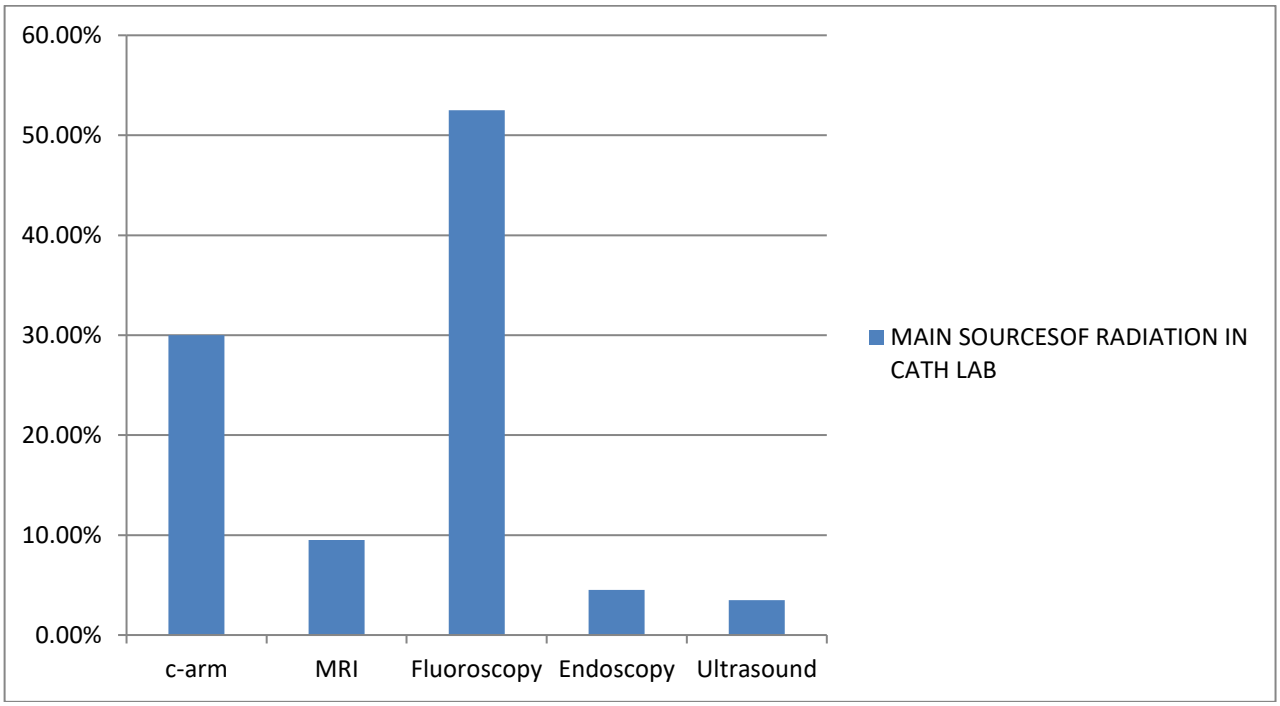
Graph 2: Ionising Radiation Use in Cath Lab Procedures

MAIN SOURCES OF RADIATION IN CATH LAB: Fluoroscopy (52.5%) is identified as the primary source of radiation exposure in the cath lab, followed by the C-arm (30%). Other modalities such as MRI (9.5%), endoscopy (4.5%), and ultrasound (3.5%), contribute much less, highlighting the need for strict radiation safety measures, especially during fluoroscopy-guided procedures.

Table 3: Main Sources of Radiation In Cath Lab

Main Source of Radiation in Cath Lab	Percentage
C-Arm	30%
Mri	9.5%
Fluoroscopy	52.5%
Endoscopy	4.5%
Ultrasound	3.5%

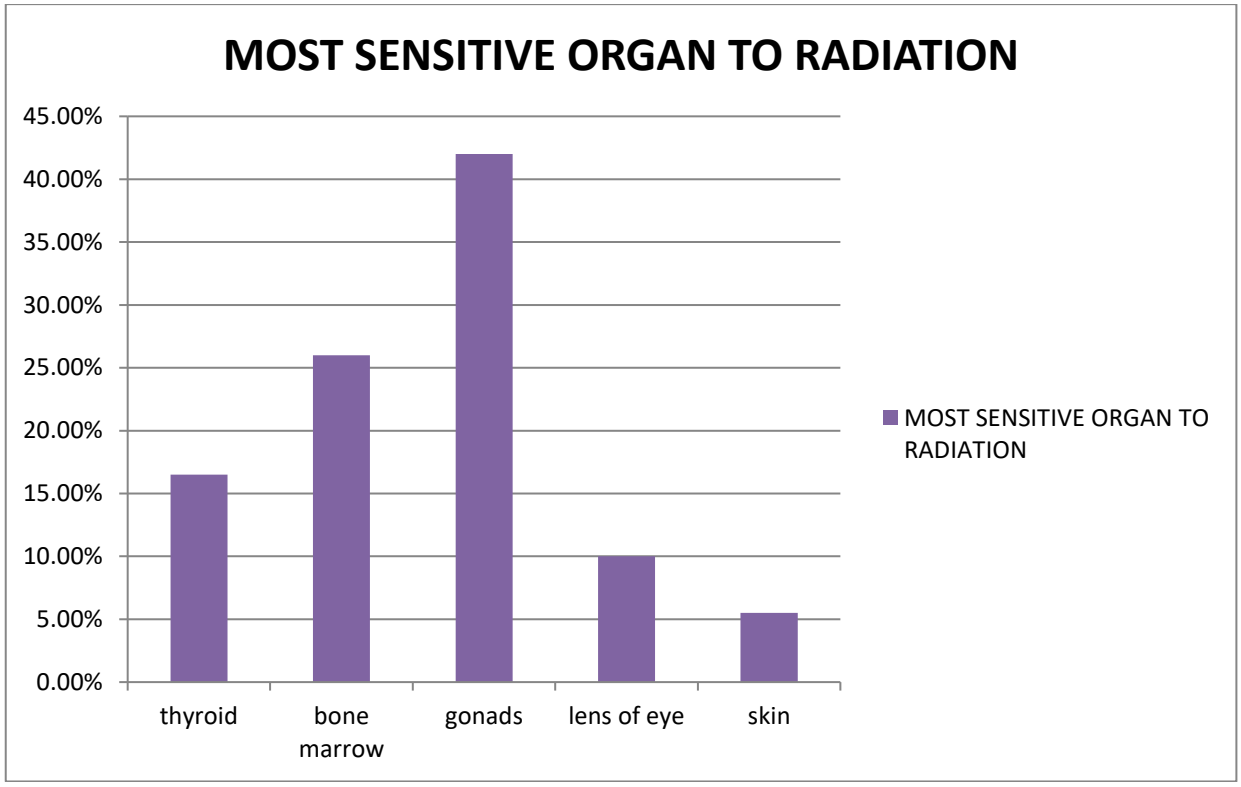
Graph 3: Main Sources of Radiation in the Cath Lab



MOST SENSITIVE ORGAN TO RADIATION: The study shows that the gonads (42%) are the organ most sensitive to radiation exposure in cath lab procedures, highlighting their critical vulnerability. Bone marrow (26%) and the thyroid (16.5%) follow as significant sites of concern. The lens of the eye (10%) and skin (5.5%) were less frequently identified as highly sensitive. These results emphasise that protective strategies should prioritise shielding of reproductive and hematopoietic organs, along with attention to thyroid protection, to minimise occupational and patient radiation risks.

Table 4: Most Sensitive Organ to Radiation

Most sensitive organ to radiation	Percentage
Thyroid	16.5%
Bone marrow	26%
Gonads	42%
Lens of eye	10%
Skin	5.5%

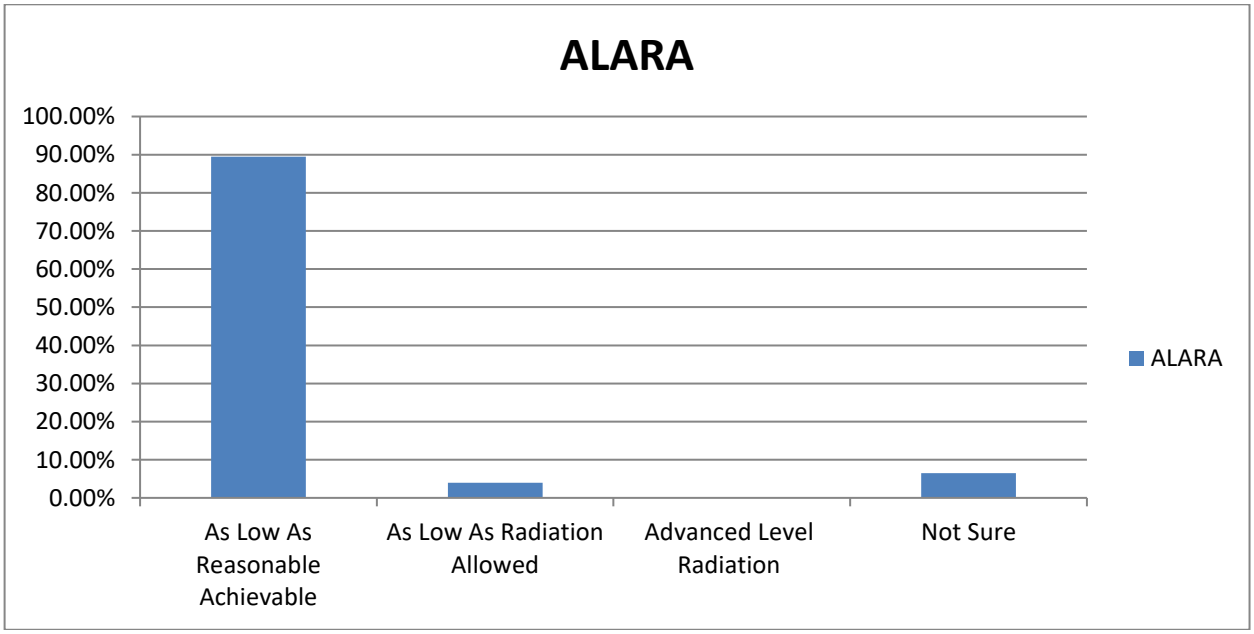


Graph 4: Most Sensitive Organ To Radiation

ALARA: The findings reveal that almost all respondents (**89.5%**) understand ALARA as "As Low as Reasonably Achievable," highlighting strong awareness of occupational and patient radiation safety. Small proportions either misinterpreted the term (**4%**) or were unsure (**6.5%**), emphasising the need for continuous training to ensure adherence to best practices in minimising radiation exposure.

Table 5: Alara

ALARA	Percentage
As Low As Reasonably Achievable	89.5%
As Low As Radiation Allowed	4%
Advanced Level Radiation	0
Not Sure	6.5%

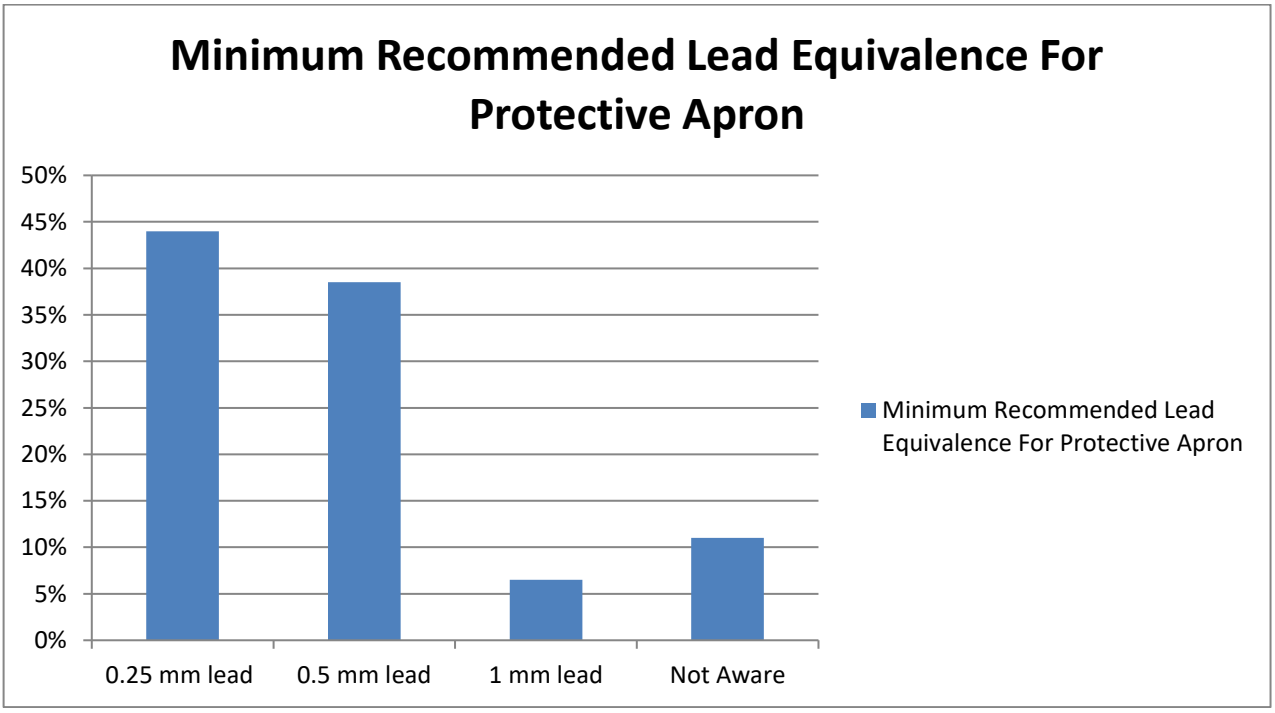


Graph 5: Alara

MINIMUM RECOMMENDED LEAD EQUIVALENCE FOR PROTECTIVE APRON: The results indicate that **44%** of respondents identified 0.25 mm lead as the minimum recommended lead equivalence for protective aprons, while 38.5% selected 0.5 mm lead. A smaller proportion, 6.5%, chose 1 mm lead, and 11% were not aware of the recommended standard. These findings suggest that while most healthcare professionals have some knowledge of protective apron standards, there is variability in understanding the correct minimum lead equivalence, highlighting the need for Reinforcement of radiation safety training and awareness in the cath lab to ensure adequate protection for occupational exposure.

Table 6. Minimum Recommended Lead Equivalence for Protective Apron

Minimum Recommended Lead Equivalence for Protective Apron	Percentage
0.25 Mm Lead	44%
0.5 Mm Lead	38.5%
1mm Lead	6.5%
Not Aware	11%

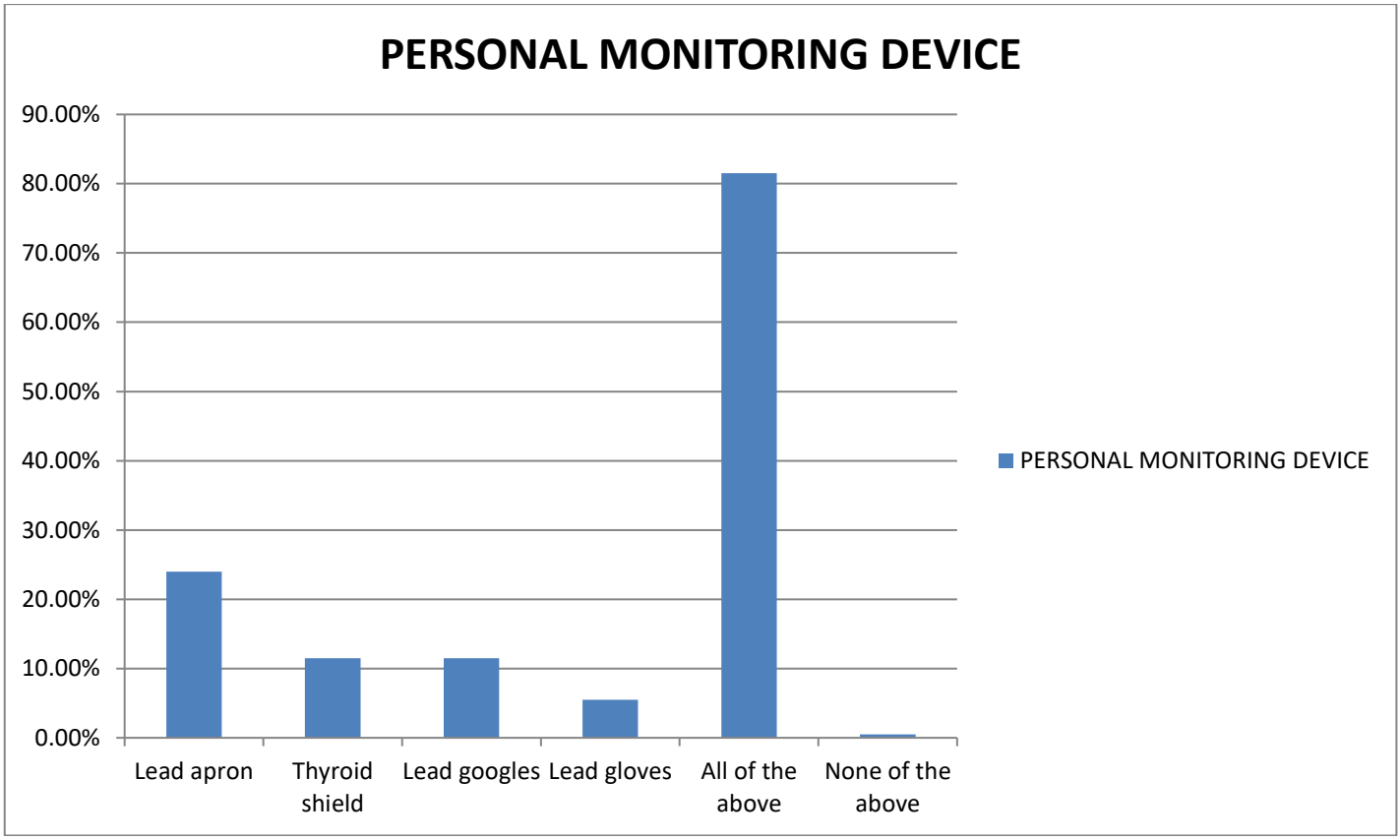


Graph 6: Minimum Recommended Lead Equivalent for Protective Apron

PERSONAL MONITORING DEVICE: The findings demonstrate a high level of radiation safety compliance among healthcare professionals. A substantial majority of participants (81.5%) reported using all recommended personal protective devices, including lead aprons, thyroid shields, lead goggles, and lead gloves, indicating strong overall adherence to radiation protection practices. When analysed individually, lead aprons were the most commonly utilised protective devices (24%), followed by lead goggles (6%) and thyroid shields (11.3%), while lead gloves were the least used (5%). Notably, only 0.5% of respondents reported not using any protective equipment. These results suggest good overall awareness of radiation safety measures, although comparatively lower usage rates of certain individual protective devices highlight the need for continued emphasis on comprehensive radiation protection practices.

Table 7: Personal Monitoring Device

Personal Monitoring Device	Percentage
Lead apron	24%
Thyroid shield	11.5%
Lead goggles	6%
Lead gloves	5%
All of the above	81.5%
None of the above	0.5%

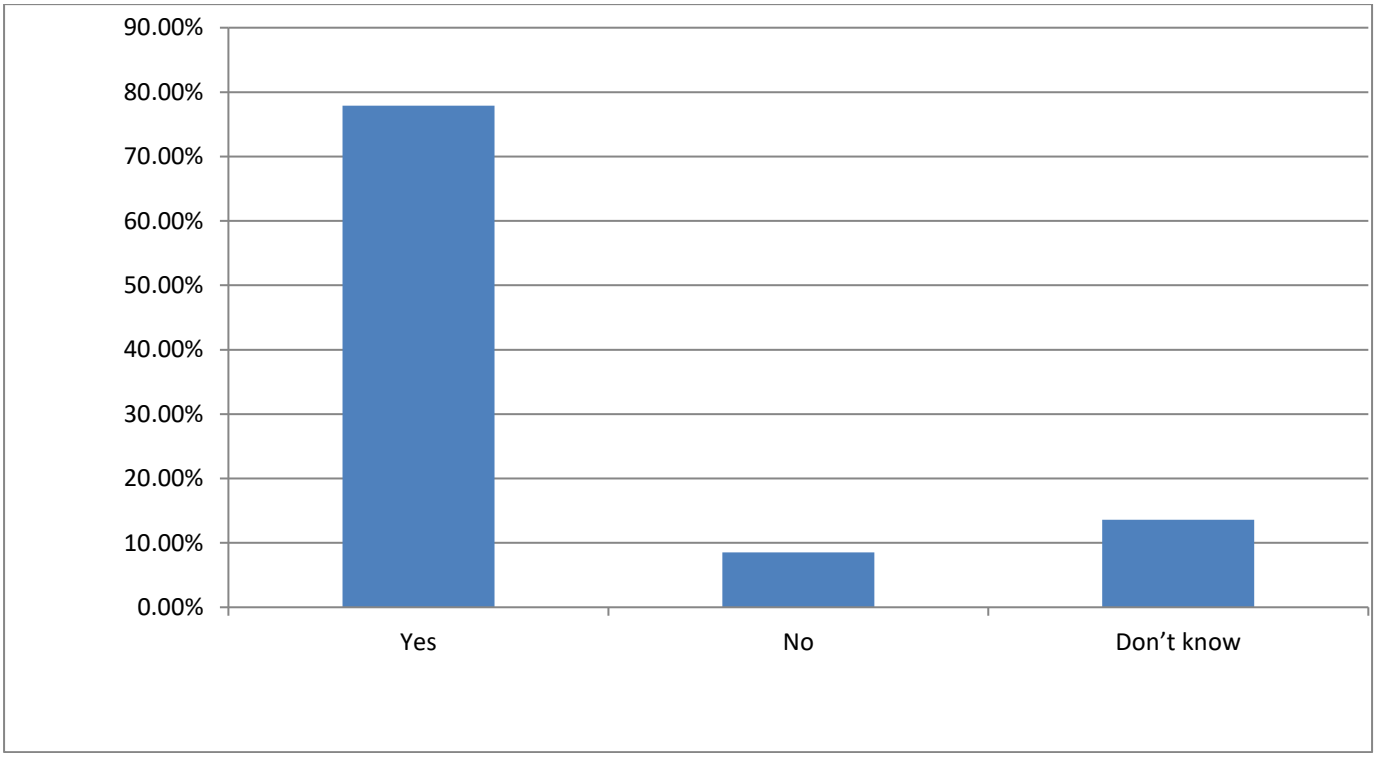


Graph 7: Personal Monitoring Device

AWARENESS ABOUT OCCUPATIONAL RADIATION DOSE LIMITS FOR CATH LAB STAFF: Although 77.9% of participants were aware of occupational radiation dose limits, a combined 13.6 % either lacked knowledge or were uncertain. This deficiency may increase the risk of exceeding recommended exposure thresholds, particularly in high-radiation environments such as cath labs and radiology departments. Targeted training programs and continuous monitoring are essential to bridge this knowledge gap and promote safer work practices.

Table 8: Awareness About Occupational Radiation Dose Limits for Cath Lab Staffs

Awareness About Occupational Radiation Dose Limits	Percentage
Yes	77.9%
No	8.5%
Don't know	13.6%



Graph 8: Awareness About Occupational Radiation Dose Limits for Cath Lab Staffs

DISCUSSION

The present study evaluated radiation safety awareness and practices among healthcare personnel associated with the catheterisation laboratory (cath lab). The findings reveal a predominance of student participants (68.8%), followed by radiology technologists (22.6%) and radiologists (5.9%), with minimal representation from nurses and other categories. This distribution suggests that the results largely reflect the knowledge level of trainees and technical staff, who are frequently present in radiation-prone environments and therefore require strong foundational training in radiation protection principles. [3,8,9]

A substantial majority of respondents (82.3%) reported the use of ionizing radiation in cath lab procedures, confirming that radiation-based imaging remains integral to interventional cardiology. Among the identified sources, fluoroscopy (51.1%)was recognized as the primary contributor to radiation exposure, followed by the C-arm (30.1%). This aligns with established evidence that fluoroscopy-guided interventions are the main source of occupational exposure in cath labs. The relatively lower identification of MRI, endoscopy, and ultrasound suggests some variability in the understanding of radiation-producing versus non-ionising modalities, highlighting the need for clearer differentiation during training programs.[4]

Regarding biological effects, the gonads (42.5%) were most frequently identified as the most sensitive organ to radiation, followed by bone marrow (26.6%) and the thyroid (17.7%). While this demonstrates awareness of radiosensitive tissues, the Comparatively lower recognition of the lens of the eye is noteworthy, especially given the well-documented risk of radiation-induced cataracts among interventional staff. This indicates a need for enhanced education on ocular radiation hazards and consistent use of protective eyewear.[6]

Encouragingly, 90.3% of participants correctly identified ALARA as "As Low As Reasonably Achievable," reflecting strong theoretical awareness of radiation protection principles. However, minor misconceptions and uncertainty among a small proportion of respondents emphasise that conceptual understanding must be reinforced through practical implementation strategies. Knowledge regarding the minimum recommended lead equivalence for protective aprons showed variability, with 43% selecting 0.25 mm and 40.3% selecting 0.5 mm lead. This inconsistency suggests incomplete clarity about recommended standards and underscores the importance of standardized institutional guidelines.

The study also demonstrated high reported compliance with personal protective measures, with 81.7% indicating use of all protective devices. Lead aprons were the most commonly used individual protective equipment, while lead gloves were the least utilised. Although overall compliance appears satisfactory, selective underuse of certain protective devices may increase cumulative exposure risk, particularly during prolonged procedures. [6,7]

Finally, while 78.4% of respondents were aware of occupational radiation dose limits, nearly one-fifth either lacked knowledge or were uncertain. In high-exposure environments such as cath labs, insufficient awareness of dose limits may predispose staff to exceeding recommended thresholds.

Therefore, periodic radiation safety training, mandatory dosimeter usage, routine audits, and continuous professional education are essential to strengthen compliance and foster a robust radiation safety culture.

The findings of the present study align with the study *Radiation Safety Awareness in Cath Lab under Radiology Departments and OT Departments*, with 83.5% of respondents reporting ionizing radiation use in cath labs. Fluoroscopy and C-arm were the main sources, and gonads and bone marrow were recognized as the most radiosensitive organs. Awareness of the ALARA principle (89–90%) and compliance with PPE (over 80%) were high, while 77–78% knew occupational dose limits, indicating good overall radiation safety awareness. However, gaps in detailed knowledge and consistent protective practices highlight the need for ongoing education, structured training programs, and strict enforcement of radiation protection protocols to further minimize occupational risks. [8,10]

CONCLUSION

This review highlights a generally satisfactory level of awareness regarding radiation safety among healthcare personnel working in the cath lab, radiology department, and operation theatre. Most participants demonstrated sound knowledge of ionizing radiation use, correctly identified fluoroscopy as the primary source of exposure, and showed strong familiarity with the ALARA principle. The high reported use of personal protective equipment and reasonable awareness of occupational dose limits reflect a positive safety culture within these high-risk clinical settings. To further enhance radiation safety, it is essential to implement regular training programs for all staff, enforce consistent use of PPE with adherence to recommended lead equivalence standards, and utilize personal dosimeters alongside routine radiation audits to monitor exposure. Additional measures such as dose-optimization strategies, shielding of radiosensitive organs (gonads, bone marrow, thyroid, and eyes), and integration of radiation safety into institutional policies and professional curricula are crucial to minimize occupational hazards and sustain long-term compliance.

However, important gaps remain. Inconsistencies in understanding recommended lead equivalence standards, incomplete knowledge of occupational dose thresholds, and limited recognition of certain radiosensitive organs—particularly the lens of the eye—indicate areas requiring targeted educational reinforcement. Variability in the consistent use of protective devices such as thyroid shields and lead gloves further suggests that awareness does not always translate into full compliance.

To bridge these gaps, institutions should implement mandatory radiation safety training programs, periodic refresher courses, competency-based assessments, and strict monitoring of personal dosimeter usage. Regular audits, policy reinforcement, and integration of radiation safety modules into undergraduate and postgraduate curricula may further strengthen compliance. Promoting a proactive radiation safety culture, supported by administrative commitment and continuous professional development, is essential to minimizing occupational exposure and ensuring long-term health protection for healthcare workers in radiation-intensive environments.

Limitations and future scope:

Limitations: The findings are constrained by a cross-sectional design and reliance on self-reported practices, which may not fully reflect real-world behavior. The disproportionate representation of students over experienced staff limits applicability to professional clinical settings. Additionally, departments with significant radiation exposure beyond cath lab, radiology, and OT were not included, and actual radiation doses were not measured.

Future Scope: Future investigations should adopt longitudinal, multicenter designs including a balanced mix of trainees and experienced staff. Incorporation of objective dosimetry, observational audits, and inclusion of other high-exposure departments can provide more comprehensive insights. Research focusing on improving compliance with underutilized protective devices, such as lead gloves and thyroid shields, is warranted.

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