INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

OPEN ACCESS

Received: 22-03-2024

Accepted: 18-04-2024

Published: 03-05-2024

Citation: Sajeesh S Nair , Gupta SK, Shine NS, Thomas KT, Bijumon PR, George S, Nair SS, George AK (2024) Evaluating the Cumulative Effects of Fundamental Radiation Safety Measures on Health Professionals in Cath Lab. Indian Journal of Science and Technology 17(19): 1961-1967. https://doi.org/10.17485/IJST/v17i19.881

* **Corresponding author**.

pgphb19268_sajeesh@banasthali.in

Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Evaluating the Cumulative Effects of Fundamental Radiation Safety Measures on Health Professionals in Cath Lab

Sajeesh S Nair[1,2]*, Saral Kumar Gupta[1], N S Shine[1], K T Thomas[2], P R Bijumon[3], Stanly George[3], Sarath S Nair[4], Anu K George[2]

1 Department of Physical Science, Banasthali Vidyapith, Jaipur, Rajasthan, India
2 Department of Radiotherapy, General Hospital, Ernakulam, Kerala, India
3 Department of Cardiology, General Hospital, Ernakulam, Kerala, India
4 Department of Radiotherapy, KMC, Manipal, Karnataka, India

Abstract

Objectives: The significant rise in modern cath lab units has led to a proportionate increase in cath lab procedures and subsequent radiation environment may elevate the occupational radiation exposure to staff. This study aimed to assess the collective impact of fundamental radiation safety devices in the cath lab on decreasing occupational radiation exposure to staff. **Methods**: This study was conducted in our cath lab room, equipped with a Siemens Artis cath lab unit. Measurements were performed using RaySafe X2 detectors and Thermo Luminescent Dosimeters (TLDs). Dose assessments were conducted without safety measures and then found a considerable reduction of dose by adding basic radiation safety measures. **Findings**: The use of lead aprons resulted in a substantial reduction(92%) in radiation dose. The effect of time and distance versus dose was plotted. The impact of lead flaps and the use of a ceiling suspension shield quantify reductions in scattered doses. The cumulative impact of each safety measure was calculated, and the outcome indicates a 99% reduction in dose. The importance of utilizing all available protective measures when working with radiation cannot be overstated. It is essential for maximizing safety, minimizing risks, and fostering a culture of safety within radiation environments like cath labs. **Novelty**: This is a thorough assessment of different radiation protection strategies in the specific setting of a Cath lab. It not only evaluates individual measures but also considers their combined impact and the calculation based on the exit dose from the patient.

Keywords: Cardiologist; Radiation Dose; Interventional Radiology; Radiation protection; Cath lab

1 Introduction

Cath labs are indispensable facilities within healthcare institutions, playing a pivotal role in the diagnosis, treatment, and management of cardiovascular diseases. Its timely and advanced provision of care plays a crucial role in enhancing the overall health and quality of life for individuals suffering from heart-related ailments. Recent advancements in medical radiological technologies have significantly streamlined procedures, particularly in cardiology, leading to a notable surge in interventional procedures [1]. This uptick in procedures brings forth concerns regarding radiation exposure for cardiologists and supporting staff. Prolonged exposure to radiation beyond recommended limits set by international agencies [2,3] can result in deterministic effects and increase the risk of stochastic effects [4] on both patients and staff. High risk of cataracts [5] and even some brain cancers to cardiologists were reported as an occupational risk due to these interventional procedures [6]. Fortunately, adherence to safe work practices and the utilization of appropriate protective equipment have shown promise in reducing occupational radiation exposure by up to 90% [7,8]. However, the effectiveness of these measures hinges on adequate training for personnel. Most radiation workers know radiation safety practices, but they frequently fail to consistently implement or adhere to them [9]. To ensure the safety of patients and healthcare workers, ongoing education and training on radiation safety protocols are essential for medical professionals and technicians handling radiation equipment. The primary contributor to staff exposure was the scattered radiation [10] emitted by the patient's body, yet many studies overlook the importance of assessing exit doses when estimating exposure. This study aims to assess the collective impact of fundamental radiation safety measures in the cath lab on decreasing the occupational exposure of staff to radiation and the estimation is based on the exit dose from the patient.

2 Methodology

The study was conducted in our cath lab room equipped with Siemens Artis dFC/dFA system. For image acquisition, the system has a 20cm^2 Flat detector (FD). The control panel, allows the user to select different protocols, frame rates, exposure modes, and post-processing options. A foot switch allows the user to operate the machine to be used in either Fluoroscopic or Acquisition mode. Monitors that are suspended from the ceiling are used to view the fluoroscopic images, along with other setup factors. The dose was measured using a calibrated Ray Safe X2 device manufactured by Unfors RaySafe AB. The RaySafe X2 detectors were designed exclusively for quality assurance in diagnostic radiology. It can measure the dose ranges from 1nGy to 999Gy with 5% uncertainty. To simulate the scattered condition for measurement, water-equivalent phantoms were also used.

The lead apron is the first and primary protective item used in all radiology departments. The efficacy of the lead apron was evaluated by measuring the dose rate with a Ray Safe X2 survey sensor. The survey sensor was placed on the right side of the couch, one meter away from the patient entrance reference point [11], which represents the most likely position for the interventional radiologist or cardiologist to stand during the procedure. This point is denoted as M P (Measuring Point) throughout this study. The phantom of 20 cm thickness is arranged on the couch to produce maximum scatter. The machine was operated in fluoroscopic mode with an AP projection. When the X-rays strike the phantom, scattered radiations are produced and a portion of this scattered radiation falls on the survey sensor. The procedure was repeated and the mean dose rate was calculated. The same procedure was repeated with a lead apron which covers the survey sensor, without disturbing the position of the Survey sensor. The measured data was used to calculate the percentage of reduction of dose rate with lead apron. The length of the procedure plays a significant role in increasing the staff and patient dose. An experienced doctor might finish the procedure more quickly than a new Cardiology fellows-in-training [12]. The effect of the time of procedure against the dose was evaluated by measuring the dose at the M P explained in the above section. The dose was measured by exposing the machine to a phantom of thickness 20cm, in various exposure times with constant exposure factors. While discussing the other major modalities like Computed Tomography, Magnetic Resonance Imaging and X-ray, the operator used to control the machine by sitting in a control room or standing behind a lead barrier. However, in the Cath lab procedure, the operator needs to stand very near to the X-ray tube. The effect of distance was measured by placing the RaySafe X2 survey sensor at various distances from the iso-centre of the machine. The dose rate from each position was measured at constant time and exposure factors.

Additional radiation shields like Ceiling Suspension Shield (CSS) and table curtains are the mandatory requirements of radiation protection insisted on by major regulatory authorities for the installation of interventional radiology facilities [13]. CSS is a transparent 0.5mm lead shield suspending on an independent handle very near the Cath-lab unit which can easily be positioned in between the operator and Flat detector. Table curtains are lead flaps hanging down from the table. The CSS protects the upper half of the operator from scattered radiation, while the table curtains cover the lower half [14,15]. This section evaluates the dose rate at the measuring point with and without CSS and table curtains. The CSS efficacy was measured in various projections that are routinely used in our Cath lab.

The biological effects of radiation are well studied and understood. According to the International Commission on Radiological Protection (ICRP) report 85, high dose rate fluoroscopy radiation exposure for 10 minutes may cause skin reactions. The possibility of the Cardiologist's hands being in the field of view during Cath lab procedures is very high. Utmost care should be taken to avoid this situation. To evaluate the severity of this scenario, the dose rate in the field of view and outside the field of view was compared. During medical exposure, a major part of radiation was absorbed by the patient's body itself. Only a small portion of the incident radiation was transmitted and exited from the patient's body. This was verified using TLD chips on a 20cm thick phantom. The phantom was arranged on the patient's couch. Five TLD chips were placed at the entrance side of radiation in the order of one at the center of the field and the remaining four TLDs at each corner of the field. Similarly, another five TLDs were used in the same way at the radiation exit side of the phantom. The exposure was made randomly in both fluoroscopic mode and acquisition mode for getting sufficient doses in the TLDs. The same procedure was repeated with another ten sets of TLD chips with various exposure times and different combinations of fluoroscopic and acquisition modes. Finally, each set of TLD reads separately and tabulated the entrance dose and exit dose in each setup.

The recommended arrangement of the cath lab machine was the x-ray tube positioned under the patient couch and just opposite the Flat detector, above the couch. In some situations, the staff may set the machine in the opposite way, which leads to an increase in the intensity of scattered doses to the staff. The primary source of scattered radiation is the patient body itself, which contributes to the occupational dose to the staff. The effect of both arrangements of the X-ray tube and flat detector was evaluated by measuring the dose rate at the cardiologist position in both settings. The use of personal dosimeters is a mandatory requirement for all radiation workers. As per the Bhabha Atomic Research Centre (BARC) report, there are 220,000 radiation workers covered by the TLD Badge System for monitoring Gamma, X-ray and beta radiations[16]. In this aspect, we evaluated the cumulative dose recorded in the TLD badges of our staff of Cath lab who have worked continuously in the same department for the last five years and the average dose was calculated. The whole study was carried out with the approval of the institution's ethical committee (IEC/2020/29). All the procedures were performed according to the current standard of care and after receiving the patient's informed consent.

3 Result and Discussion

Basic radiation protection measures in the cath lab were evaluated and the significance of its implementation. The dose rate with and without lead aprons was 0.15 and 1.875 μGy /min respectively. The use of the lead apron resulted in a reduction of radiation dose to the cath lab staff was approximately 92%. This is a substantial decrease and demonstrates the effectiveness of lead aprons in protecting individuals from ionizing radiation during fluoroscopy procedures. It's a crucial safety measure for staff in a cath lab or any environment where radiation exposure is a concern.

Table 1. Reduction of scattered dose using CSS in different projections used in the Cath lab

Projections	Without CSS μGy/min	With CSS μGy/min	Reduction of Scattered Dose %
AP	1.281	0.934	27.09
AP-CRA	7.399	6.797	8.14
AP - CAU	4.46	2.215	50.34
AP -CRA	1.97	1.806	8.32
Plain RAO	4.145	3.196	22.9
Plain LAO	4.707	1.945	58.68
RAO-CRA	33.1	30.49	7.89
LAO-CRA	5.243	2.262	56.86
RAO-CAU	2.492	0.286	88.52
LAO-CAU	16.17	6.503	59.78

Protective equipment such as lead aprons and thyroid shields are readily available in the procedure room, requiring no special conditions for regular use. These devices serve as the primary protective barrier for staff in the cath lab and interventional procedure room[17,18]. Regular inspection to detect wear and tear on the apron is crucial to prevent radiation leakage through these protective gears. Additionally, healthcare professionals should be trained on the proper use and storage of aprons to ensure their longevity and effectiveness. The other protective accessories are lead equivalent face shields and goggles, for the protection of the head region; however, these items are often not readily available in sufficient quantities in many departments. The correlation between time and dose was calculated and the results demonstrated how procedural time affects the radiation exposure for both patients and staff (Figure 1). The dose rate was drastically decreased by increasing the distance, this ensured the safety of individuals exposed to radiation (Figure 2).

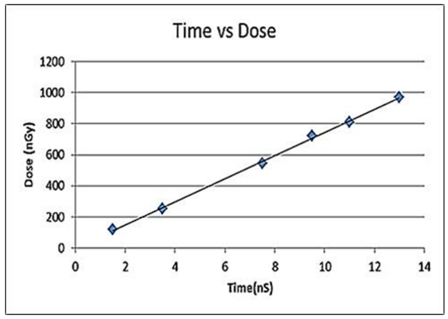

Fig 1. Relation of exposure time on dose

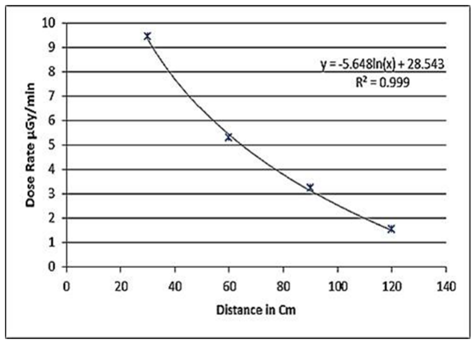

Fig 2. Relation of dose rate vs distance

The TDS principle is widely acknowledged as an effective approach to minimize occupational radiation exposure for staff members. The experience of staff plays a crucial role in successfully implementing this principle. The reduction of dose rate with CSS in various projections was measured and given in Table 1. The ceiling suspension shield plays a crucial role as a protective barrier in the cath lab. It offers additional protection to medical staff by blocking scattered radiation from the patient's body from all projections. The selection of projection and the effectiveness of CSS may vary, but data indicates that this protective barrier can greatly reduce potential radiation exposure to staff during medical imaging procedures. Unfortunately, there are instances where staff members overlook or neglect to maintain this important device in its proper position. This situation continues to be significant when examining the radiation protection survey report in both historical [19] and contemporary contexts [9]. The data also shows that the major dose-contributing projections in cath lab procedures are RAO-CRA (Right anterior oblique–cranial) and LAO-CAU (Left anterior oblique–caudal), therefore reducing the frequency of the usage of these projections. The measurements with and without lead flaps were 0.443 and 2.4 μGy/min respectively. The reading shows an 82% dose reduction at the measuring point. The dose rate inside the exposure field was sufficiently high to the dose rate outside the field. The infield dose rate was 129 μGy/min and the reading at 20cm away from the center of the field was 14.26 μGy/min. Most modern units are typically operated in AEC mode. As a result, hands-on exposure during procedures not only increases radiation dose to the staff but also raises patient exposure through automatic adjustment of the machine's factors. The entrance dose and exit dose were measured using TLD chips and the readings were given in Table 2. The reading shows that only 1.3% of the incident dose was coming out from the body. In international atomic energy agency posters, this value is in between 1-5% [20].

The dose rate from the X-ray tube was higher at the cardiologist's position when it was positioned above the couch. The reading shows that 66% more doses may be received by the cardiologist at the time of the procedure if the x-ray tube is positioned above the couch. The TLD dose report of the staff from a period of 18 months was noted and the values range from 0.2 mSv to 1.7 mSv. The average dose was 0.44mSv. Figure 3 depicts a simplified illustration of the impact of safety barriers on reducing radiation exposure in the cath lab. The diagram clearly shows that the missing of any of these protective measures during the procedure could result in a higher level of scattered dose to the staff. The cumulative impact of each safety measure was calculated, and the outcome indicates a 99% reduction in dose (Table 3). The exit dose emitted from the patient's body serves as the reference dose for the calculation.

The frequent classes about radiation protection conducted by Medical Physicists or Radiation Safety Officers help to increase the confidence of staff engaged in radiation work. Recent surveys [21] indicate that nearly 75% of employees have not participated

Table 2. Measurements of Entrance dose and exit dose using TLD chip

No	Entrance dose (mGy)	Exit Dose (mGy)	Percentage of exit dose
1	1500	13.2	0.9%
2	3500	13.8	0.4%
3	850	6.5	0.8%
4	400	8.2	2.1%
5	100	1.9	1.9%
6	100	2.0	2.0%
7	800	10.4	1.3%
8	1900	8.2	0.4%
9	300	4.9	1.6%
10	1750	38.5	2.2%
Average			**1.36%**

Table 3. Reduction in radiation dose with each successive level of protective measures

No	Entrance dose (mGy)	Exit Dose(mGy)	Dose at 20cm from the center of the field (mGy)	Dose after CSS (mGy)	Dose after Pb apron (mGy)
1	1500	13.2	1.452	0.900	0.072
2	3500	13.8	1.518	0.941	0.075
3	850	6.5	0.715	0.443	0.035
4	400	8.2	0.902	0.559	0.045
5	100	1.9	0.209	0.130	0.010
6	100	2	0.22	0.136	0.011
7	800	10.4	1.144	0.709	0.057
8	1900	8.2	0.902	0.559	0.045
9	300	4.9	0.539	0.334	0.027
10	1200	13	1.43	0.887	0.071

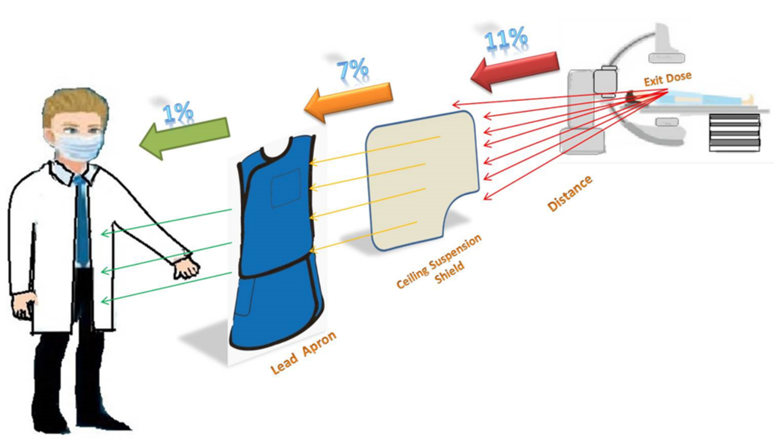

Fig 3. The schematic representation of the reduction of radiation dose through the implementation of distance, CSS and lead apron in the cath lab

in any radiation safety training courses, and 80% are unaware of the dosage used in each procedure. The periodic quality assurance of the machines and radiation protection survey under the supervision of a Medical Physicist ensures a proper radiation safety atmosphere in the cath lab. Better knowledge about the machines and its capabilities may help the operator to use it in optimum conditions by providing better images and lesser doses to the patient and staff. By implementing these radiation protection measures[22], healthcare professionals can effectively mitigate the risks associated with prolonged exposure to ionizing radiation in the cath lab environment. The surveys indicate that most institutions fail to effectively implement collective safety measures and protocols. This study suggests that the combined use of all basic protective measures could significantly reduce radiation risk for individuals working in environments with potential exposure. By adopting a comprehensive approach encompassing these fundamental protective measures, individuals can substantially decrease their radiation-related risk. The failure to adhere to or neglect even a single measure could lead to an increase in the risks for individuals working in radiation environments.

4 Conclusion

This study highlights the critical aspects of radiation protection measures in cath labs and interventional procedure rooms. It emphasizes the importance of regular inspection and maintenance of protective equipment such as lead aprons and thyroid shields to prevent radiation leakage and ensure the safety of the staff. The novelty of this work lies in its collective effects of various radiation protection measures in cath labs and interventional procedure rooms, as well as its emphasis on practical recommendations for improving staff safety. By utilizing a combination of fundamental protective measures, it is possible to decrease the radiation dose by 99%, effectively alleviating the potential health hazards linked with radiation exposure. This study was limited by its focus solely on measuring the exit dose at the front of the chest, possibly overlooking radiation exposure on other parts of the body. This study is phantom-based, so it does not take into account the dynamic changes that occur in a real procedure room. Future research should consider accounting for lateral scatter of radiation to comprehensively assess overall exposure.

Acknowledgements

The authors thank all the cardiologists, Cath-lab technologists, Staff nurses and other supporting staff in the Department of Cardiology, General Hospital Ernakulam for supporting this study.

References

1) Sources, Effects and Risks of Ionizing Radiation. 2008. Available from: https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf.
2) Use of Dose Quantities in Radiological Protection. 2021. Available from: https://www.icrp.org/publication.asp?id=ICRP%20Publication%20147.
3) Radiation Safety in the Use of Radiation Sources in Research and Education. INTERNATIONAL ATOMIC ENERGY AGENCY. 2024. Available from: https://doi.org/10.61092/iaea.0f4a-dm2n.
4) Chang DS, Lasley FD, Das IJ, Mendonca MS, Dynlacht JR. Basic Radiotherapy Physics and Biology. Cham. Springer International Publishing. 2021. Available from: http://link.springer.com/10.1007/978-3-030-61899-5.
5) Roguin A, Nolan J. Radiation protection in the cardiac catheterisation lab: best practice. *Heart*. 2021;107(1):76–82. Available from: https://dx.doi.org/10.1136/heartjnl-2019-316369.
6) Nowak M, Sans-Merce M, Lemesre C, Elmiger R, Damet J. Eye lens monitoring programme for medical staff involved in fluoroscopy guided interventional procedures in Switzerland. *Physica Medica*. 2019;57:33–40. Available from: https://dx.doi.org/10.1016/j.ejmp.2018.12.001.
7) de Ceuninck M, Muyldermans P, van de Walle S, Bergez B, Haspeslagh R, Stammen F, et al. A quality project for radiation reduction in the cath lab. *Acta Cardiologica*. 2019;74(1):38–44. Available from: https://dx.doi.org/10.1080/00015385.2018.1439705.
8) Biso SMR, Vidovich MI. Radiation protection in the cardiac catheterization laboratory. *Journal of Thoracic Disease*. 2020;12(4):1648–1655. Available from: https://dx.doi.org/10.21037/jtd.2019.12.86.
9) Uthirapathy I, Dorairaj P, Ravi S, Somasundaram S. Knowledge and practice of radiation safety in the Catherization laboratory among Interventional Cardiologists – An online survey. *Indian Heart Journal*. 2022;74(5):420–423. Available from: https://dx.doi.org/10.1016/j.ihj.2022.08.001.
10) Ylimaula S, Räsänen L, Hurskainen M, Peuna A, Julkunen P, Nieminen MT, et al. X-ray scatter in projection radiography. *Radiation Protection Dosimetry*. 2024;200(2):120–129. Available from: https://dx.doi.org/10.1093/rpd/ncad275.
11) Andersson J, Bednarek DR, Bolch W, Boltz T, Bosmans H, Gislason-Lee AJ, et al. Estimation of patient skin dose in fluoroscopy: summary of a joint report by AAPM TG357 and EFOMP. *Medical Physics*. 2021;48(7):e671–e696. Available from: https://dx.doi.org/10.1002/mp.14910.
12) Vlastra W, Claessen BE, Beijk MA, Sjauw KD, Streekstra GJ, Wykrzykowska JJ, et al. Cardiology fellows-in-training are exposed to relatively high levels of radiation in the cath lab compared with staff interventional cardiologists—insights from the RECAP trial. *Netherlands Heart Journal*. 2019;27(6):330–333. Available from: https://dx.doi.org/10.1007/s12471-019-1254-1.
13) Diagnostic Radiology (DR) User Guidelines for regulatory applications submission in eLicensing of Radiation Applications (e-LORA) system. . Available from: https://aerb.gov.in/images/PDF/DiagnosticRadiology/drg2021.pdf.
14) Roguin A, Wu P, Cohoon T, Gul F, Nasr G, Premyodhin N, et al. Update on Radiation Safety in the Cath Lab – Moving Toward a "Lead-Free" Environment. *Journal of the Society for Cardiovascular Angiography & Interventions*. 2023;2(4):1–11. Available from: https://dx.doi.org/10.1016/j.jscai.2023.101040.

15) Cammann VL, Schweiger V, Cieslik M, Seifert B, Gilhofer T, Koleva I, et al. Effectiveness of radiation protection systems in the cardiac catheterization laboratory: a comparative study. *Clinical Research in Cardiology*. 2023;112(5):605–613. Available from: https://dx.doi.org/10.1007/s00392-022-02142-8.
16) Srivastava K, Pal R, Bakshi AK. Self Reliance in Personnel Monitoring of Radiation Workers in India. 2023. Available from: https://www.barc.gov.in/barc_nl/2023/2023030405.pdf.
17) Gutierrez-Barrios A, Cañadas-Pruaño D, Noval-Morillas I, Gheorghe L, Zayas-Rueda R, Calle-Perez G. Radiation protection for the interventional cardiologist: Practical approach and innovations. *World Journal of Cardiology*. 2022;14(1):1–12. Available from: https://dx.doi.org/10.4330/wjc.v14.i1.1.
18) Shankar S, Padmanabhan D, Chandrashekharaiah A, Deshpande S. Strategies to Reduce Radiation Exposure in Electrophysiology and Interventional Cardiology. *US Cardiology Review*. 2020;13(2):117–122. Available from: https://dx.doi.org/10.15420/usc.2019.21.2.
19) Lynskey GE, Powell DK, Dixon RG, Silberzweig JE. Radiation Protection in Interventional Radiology: Survey Results of Attitudes and Use. *Journal of Vascular and Interventional Radiology*. 2013;24(10):1547–1551.e3. Available from: https://dx.doi.org/10.1016/j.jvir.2013.05.039.
20) 10 Pearls : Radiation protection of Staff in Fluoroscopy. . Available from: http://rpop.iaea.org/RPOP/RPoP/Content/Documents/%0AWhitepapers/poster-staff-radiation-protection.pdf.
21) Salem HT. A Questionnaire Survey on Radiation Protection among Medical Staff Working in Cardiac Catheterization Laboratory. *Egyptian Journal of Radiation Sciences and Applications*. 2022;35(1):83–89. Available from: https://doi.org/10.21608/ejrsa.2023.174112.1142.
22) Dev DS, Hinton J. Radiation safety in the cath lab: does it still matter?. . Available from: https://www.britishcardiovascularsociety.org/resources/editorials/articles/radiation-safety-in-the-cath-lab-does-it-still-matter.