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ORIGINAL RESEARCH

Assessment of the Occupational Radiation Exposure of Anesthesia Staff in Interventional Cardiology

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Introduction: This research seeks to evaluate the occupational radiation dose, quantified as the whole-body Annual Mean Effective Dose (AMED), received by anesthesia personnel in interventional cardiology.

Methods: Thermoluminescent dosimetry data was collected over five years (2019–2023) for a total of 175 anesthesia staff. Technologists comprised approximately 72.4% of the participants (55% male and 45% female), while consultants accounted for 27.6% (70% male and 30% female). Statistical tests, including Independent Samples *T*-Test and One-Way ANOVA, compared AMED across genders, job titles, and years.

Results: The study's findings on AMED across all staff from 2019 to 2023 showed marked variability in AMED. There was a significant rise in AMED from 0.72 mSv in 2019 to 0.92 mSv in 2020, then a decline to 0.82 mSv in 2021, with further decreases to 0.67 mSv in 2022 and finally to 0.65 mSv in 2023 ($p < 0.001$). The average AMED over the five-year span (2019–2023) was 0.76 ± 0.4 mSv. In terms of gender, the overall AMED for males was 0.73 ± 0.36 mSv and for females 0.79 ± 0.45 mSv, showing no significant statistical difference ($p = 0.272$). Significant differences in exposure were observed between the technologists who experienced a higher overall AMED (0.8 ± 0.43 mSv) compared to consultants (0.63 ± 0.29 mSv, $p = 0.008$).

Discussion: Despite these variations, AMED values remained lower than the annual occupational dose limit of 20 mSv, indicating generally low radiation exposure for anesthesia staff. This study emphasizes the importance of ongoing monitoring and enhanced protective measures to safeguard the health of medical professionals working with radiation.

Keywords: interventional cardiology, whole-body dose, radiation exposure, occupational safety, medical staff

Introduction

The increasing utilization of interventional cardiology procedures has heralded a new era in medical therapeutics, offering minimally invasive solutions for a range of cardiovascular diseases. However, these procedures often involve the use of ionizing radiation, which can pose significant health risks to both patients and healthcare professionals involved, including anesthesia staff.[1,2]

Occupational exposure to ionizing radiation presents numerous health risks, primarily due to its ability to damage cellular and genetic material.[3] This interaction can lead to both acute and long-term health effects, with chronic low-level exposure—common in occupational settings—particularly increasing the risk of cancer, including leukemia,[4,5] and cardiovascular diseases such as Coronary Artery Disease, heart valve damage, cardiomyopathy, peripheral vascular disease, and stroke. The pathophysiology behind these cardiovascular conditions involves a series of interconnected mechanisms: ionizing radiation first causes direct damage to endothelial cells, leading to dysfunction and inflammation, which then promotes atherosclerosis. Concurrently, fibrosis contributes to the stiffening of heart and blood vessels, while oxidative stress exacerbates damage to cardiovascular tissues.[6–8] Beyond cancer and cardiovascular issues, radiation exposure is also associated with skin and blood damage, cataracts, infertility, and birth defects. It's important to note that

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the probability of these adverse health effects is proportional to the dose received, but no level of radiation exposure is considered completely safe.[5]

In interventional cardiology, procedures such as angioplasty, stenting, and electrophysiological interventions have become commonplace. These procedures rely extensively on fluoroscopy, a technique that uses real-time X-ray imaging to guide catheters and other medical devices within the body.[9,10] While the benefits of fluoroscopy in enhancing procedural accuracy and patient outcomes are indisputable, its implications for radiation exposure among healthcare professionals have not been sufficiently explored, particularly concerning anesthesia staff.[1]

Anesthesia staff are integral to the interventional cardiology team, providing critical care and pain management. In contrast to radiologists and interventional cardiologists, staff in anesthesia may not consistently receive sufficient training in radiation protection or understand the long-term consequences of radiation exposure.[11–13] This gap in knowledge and practice raises significant concerns about their occupational health and safety. Historically, research on occupational radiation exposure has focused predominantly on interventional cardiologists and radiologists, owing to their direct involvement with radiation-emitting equipment. However, this focus has inadvertently marginalized the exposure risks faced by other healthcare professionals, such as anesthesia staff, who are also present in the interventional suite and often work in close proximity to the radiation source.[1] The potential underestimation of radiation exposure among anesthesia staff is a notable oversight, given their proximity to the radiation source during procedures.

In environments like interventional cardiology, where staff are regularly exposed to radiation, adhering to these limits is vital for health safety. Monitoring and managing radiation doses through dosimeters such as thermoluminescent dosimeters (TLDs) are essential to prevent both deterministic effects and minimize stochastic risks from ionizing radiation.[14] This process involves assessing effective and equivalent doses, thereby ensuring the well-being of medical personnel through regular exposure monitoring. The International Commission on Radiological Protection (ICRP) sets the annual occupational radiation exposure limits to protect workers. The whole body- effective dose limit is 20 millisieverts (mSv) per year, 100 mSv averaged over five years with a maximum of 50 mSv in any single year. Additionally, specific limits for sensitive organs are in place: 20 mSv/year for the eye lens, and 500 mSv/year for the skin, hands, and feet.[15]

Given the potential health risks associated with occupational radiation exposure and the critical role of anesthesia staff in interventional cardiology, there is a pressing need to better understand the extent of radiation exposure among these healthcare professionals. Therefore, This research seeks to evaluate the occupational radiation dose, quantified as the whole-body Annual Mean Effective Dose (AMED), received by anesthesia personnel in interventional cardiology.

Materials and Methods

This study was conducted to assess the levels of radiation exposure encountered by anesthesia personnel in interventional cardiology in Saudi Arabia from 2019 to 2023. Within the anesthesia domain, a range of professionals work together to deliver safe and efficient care to patients. Anesthesiologists, who are highly trained doctors, manage the full spectrum of anesthesia care, which includes evaluating patients before surgery, managing them during the operation, and looking after them afterwards. Anesthesia Technologists are integral to the team, responsible for setting up and maintaining the necessary equipment and aiding in the preparation for procedures. They operate under the supervision of anesthesiologists, helping with patient observation and the handling of medical apparatus. The investigation measured the radiation doses received by both consultants and technologists involved. Adherence to the ethical standards set forth in the Declaration of Helsinki was ensured, with ethical approval for the study being granted by the ethics committee of Jazan University, which also guaranteed the confidentiality of all participants involved.

For radiation monitoring, TLDs were used, distributed, and collected every quarter by the Ministry of Health's radiation protection departments in each region. TLD was worn at chest level for accurate whole-body radiation assessment. The TLDs are designed to measure the Personal Dose Equivalent (PDE), which is an operational quantity for individual monitoring of radiation exposure. The PDE is given the symbol Hp(d), and the common operational quantity for individual monitoring defined by the ICRP are Hp(10), which is an operational quantity for individual monitoring for the assessment of effective dose. The effective dose received by each worker was estimated by equating it to the measured Hp(10). This approach is generally considered a conservative method for assessing effective dose, particularly under the assumption of uniform whole-body exposure.[15] Thus, the whole-body effective dose in this study was estimated by setting it as equal to the measured Hp(10).

The TLDs (TLD-100 chip; Thermo Fisher Scientific, USA) were made of lithium fluoride (LiF: Mg.Ti). Dosimetric data were read using a Harshaw Model 6600 Plus Automated Reader (Thermo Electron Corporation, USA), calibrated with a 137Cs source and capable of detecting doses between 10 µGy and 1 Gy. Element correction coefficients (ECCs) were generated using the reader's 90Sr/90Y internal irradiator to normalize the TLD responses. Control TLDs measured background radiation, which was then deducted to ascertain the actual exposure.

Statistical analysis was performed using SPSS version 20 (IBM Inc., Chicago, IL, USA). The analysis presented the AMED and the averaged AMED over the study period (overall AMED). Independent Samples *T*-Test and One Way ANOVA were performed to compare AMED between genders, job title, and years. The Dwass-Steel-Critchlow-Fligner pairwise comparisons for AMED over various years was conducted. A p-value of less than 0.05 was considered significant.

Results

The study's population encompassed 181 personnel from anesthesia departments in interventional cardiology settings. The group of technologists consisted of 131 members, with 72 being male (55%) and 59 being female (45%). Within the consultant group, the study accounted for 50 participants, with males making up 35 (70%) and females comprising 15 (30%) of the total.

The results of the AMED for all staff over a five-year span were as follows: In 2019, the average dose was 0.72 mSv (0.14–1.35), increasing to 0.92 mSv (0.21–2.3) in 2020, then slightly decreasing to 0.82 mSv (0.44–1.66) in 2021, 0.67 mSv (0.12–3.23) in 2022, and 0.65 mSv (0.42–2.23) in 2023. The findings from the research indicate that the mean AMED value was 0.76 ± 0.4 mSv (Table 1). However, there were notable variations in the AMED measurements when comparing different time periods, and these differences were found to be statistically significant ($p < 0.001$).

The Dwass-Steel-Critchlow-Fligner pairwise comparisons for AMED over various years revealed key findings (Table 2). Notably, significant differences in radiation exposure were observed between certain years. The comparisons between 2020 and subsequent years (2022 and 2023) revealed significant differences ($p < 0.001$), indicating a marked decrease in exposure from 2020 onwards. Similarly, significant reductions in radiation exposure were noted when comparing 2021 with both 2022 ($p < 0.001$) and 2023 ($p = 0.014$). A significant increase in exposure was observed between 2022 and 2023 ($p = 0.02$). Comparisons between other years, such as 2019 and 2020, 2019 and 2022, and 2020 and 2021, did not show statistically significant differences.

Based on the anesthesia staff role and gender, male technologists had an overall AMED of 0.74 ± 0.4 mSv (0.21–2.3 mSv), while female technologists showed a higher overall AMED of 0.87 ± 0.46 mSv (0.37–3.23 mSv) (Table 3). Among consultants, males had an overall AMED of 0.71 ± 0.29 mSv (0.32–1.49 mSv), and females had a lower overall AMED of 0.47 ± 0.18 mSv (0.12–0.77 mSv).

The overall AMED for technologists was recorded at 0.8 mSv (ranging from 0.21 to 3.23 mSv), while for consultants, it was 0.63 mSv (ranging from 0.12 to 1.49 mSv), as shown in Figure 1. When comparing by role, a significant difference

Table 1 Annual Mean Effective Dose for All Anesthesia Staff in Interventional Cardiology (2019–2023)

Year	Mean ± SD	Minimum – Maximum
2019	0.72 ± 0.29	0.14–1.35
2020	0.92 ± 0.35	0.21–2.3
2021	0.82 ± 0.32	0.44–1.66
2022	0.67 ± 0.6	0.12–3.23
2023	0.65 ± 0.32	0.42–2.23
Overall	0.76 ± 0.4	0.12–3.23

Table 2 Comparative Analysis of Mean Annual Effective Dose in Interventional Cardiology: Dwass-Steel-Critchlow-Fligner Pairwise Comparisons (2019–2023)

Pairwise Comparisons		W	p
2019	**2020**	3.5	0.097
2019	**2021**	0.88	0.972
2019	**2022**	−3.79	0.057
2019	**2023**	−2.78	0.282
2020	**2021**	−2.69	0.316
2020	**2022**	−6.05	<.001
2020	**2023**	−6.42	<.001
2021	**2022**	−5.97	<.001
2021	**2023**	−4.45	0.014
2022	**2023**	4.31	0.02

Table 3 Comparative Mean Annual Effective Dose by Anesthesia Staff Role and Gender in Interventional Cardiology

Job Title	Gender	Mean ± SD	Minimum – Maximum
Technologists	Male	0.74 ± 0.4	0.21–2.3
	Female	0.87 ± 0.46	0.37–3.23
Consultant	Male	0.71 ± 0.29	0.32–1.49
	Female	0.47 ± 0.18	0.12–0.77

in overall AMED (p-value = 0.008) was observed between technologists and consultants. In gender-specific analysis, males had a lower overall AMED of 0.73 ± 0.36 mSv (ranging from 0.21 to 2.3 mSv), compared to females with an AMED of 0.79 ± 0.45 mSv (ranging from 0.12 to 3.23 mSv), with no significant difference (p- = 0.272).

In the analysis of the AMED exceeding 1 mSv (Figure 2), the analysis revealed varied counts across different categories. Gender-wise, there were 16 instances for males and 19 for females, indicating a slightly higher frequency among females. Occupation-wise, technologists recorded 31 instances of exceeding the 1 mSv, markedly higher than the 4 instances noted among consultants. Over the years, the distribution showed a fluctuating pattern: 4 instances in 2023, 5 in 2022, 9 in 2021, the highest at 13 in 2020, and then down to 4 in 2019. Collectively, these instances total 35 occurrences of exceeding the 1 mSv across all categories and years.

Discussion

The main objective of this study was to assess the occupational radiation dose received by anesthesia staff in interventional cardiology. The importance of this study lies in its focus on regular monitoring of occupational radiation exposure, a necessary aspect of ensuring the safety and health of medical professionals who are routinely exposed to ionizing radiation. By providing detailed insights into exposure levels, this research emphasizes the necessity for ongoing surveillance and the implementation of effective radiation safety protocols in healthcare settings.[16–18]

The results of the AMED for all staff from 2019 to 2023, offers valuable insights into the fluctuating levels of radiation exposure over this period. The AMED values ranged from 0.65 ± 0.32 in 2023 to 0.92 ± 0.35 in 2020 mSv. The results revealed significant differences in AMED across different years ($p < 0.001$). The initial increase in AMED from 0.72 mSv in 2019 to 0.92 mSv in 2020 could be attributed to changes in operational routines, increased workload, or

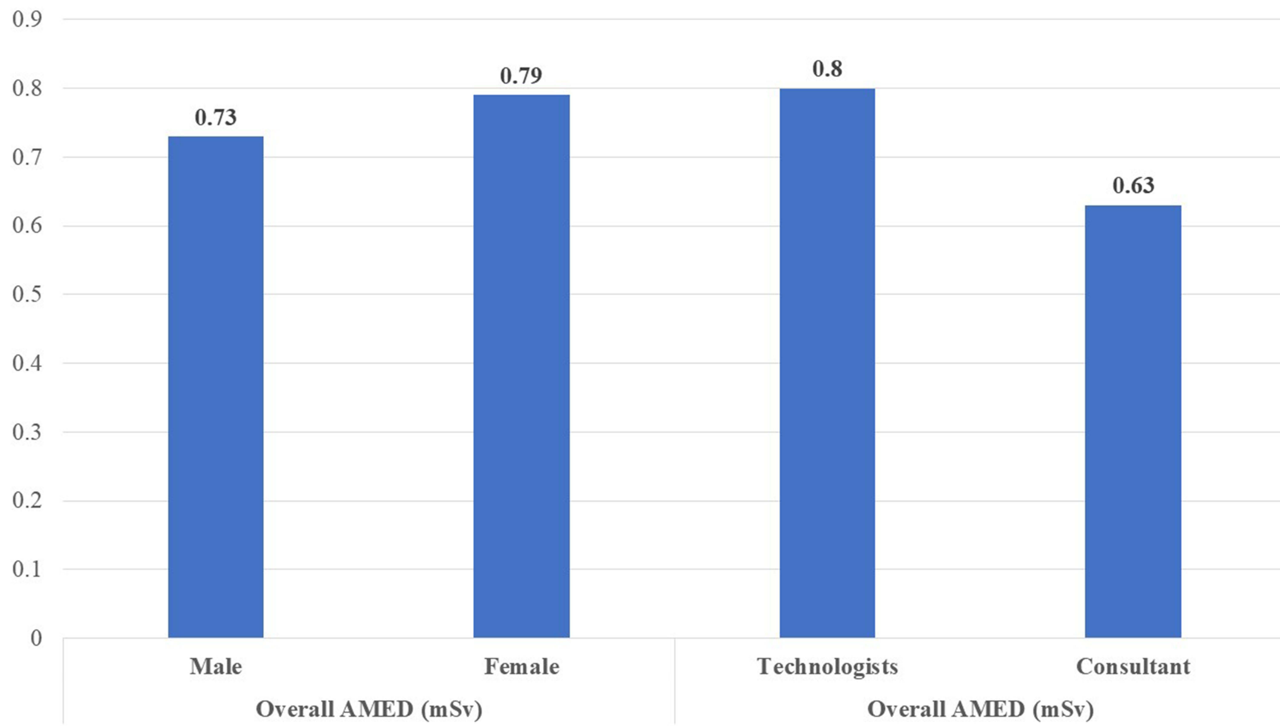

Figure 1 Role and Gender-Based Analysis of the overall AMED.

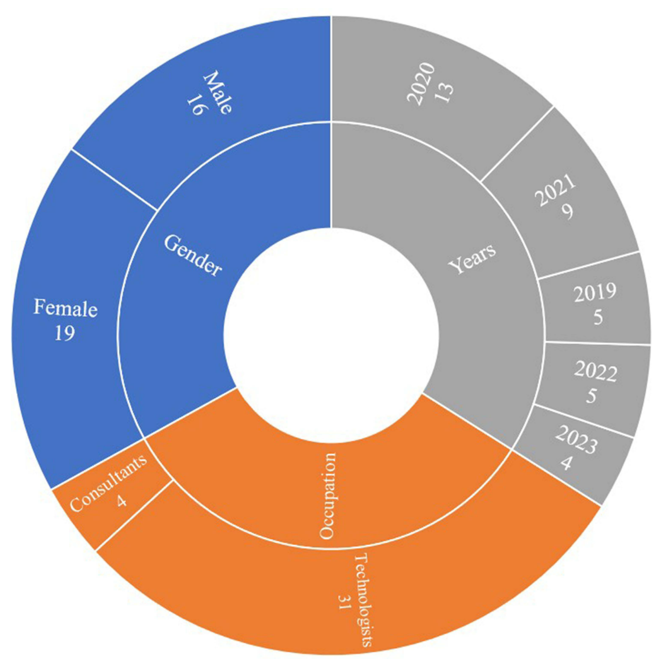

Figure 2 Counts of instances exceeding 1 mSv AMED by gender, occupation, and year.

alterations in radiation safety protocols. The subsequent decrease to 0.82 mSv in 2021 and further to 0.67 mSv and 0.65 mSv in 2022 and 2023 respectively. These findings indicate a need for continuous monitoring and enhancement of radiation safety practices. This variability highlights the importance of regular training, adherence to safety guidelines, and the implementation of advanced protective technologies to ensure the safety of medical staff in environments with radiation exposure.

The findings of this study suggest that anesthesia staff are exposed to a low level of radiation during interventional cardiology procedures. The AMED values were below the annual dose limit of 20 mSv for occupational exposure, with only 35 instances exceeded the public limit of 1 mSv. Generally, these findings are consistent with previous studies that have reported low levels of AMED for anesthesia personnel during interventional cardiology procedures. The overall AMED observed in our study, averaging 0.76 ± 0.4 mSv, stands in contrast to other studies, which reported higher levels such as 1.6 mSv and 2.32 mSv,[19,20] while other studies noted a considerably lower average of 0.48 mSv and 0.162 mSv.[21,22]

The study found that the overall AMED values for males was 0.73 ± 0.36 mSv and 0.79 ± 0.45 mSv for females. The variation between the two groups was not statistically significant (p = 0.272). Previous research has also reported gender disparities in radiation exposure, although the reasons for these differences remain unclear.[3,23] The overall AMED for technologists (0.8 ± 0.43 mSv) was significantly (p = 0.008) higher than consultants (0.63 ± 0.29 mSv). This could be attributed to the proximity of technologists to radiation sources and their longer duration in the procedural environment compared to consultants.[16] This disparity underscores the need for implementing specific protective measures and training, particularly for technologists, due to their exposure to higher radiation doses.[24]

The study's cross-sectional design limits its scope, omitting a thorough examination of variations in workload, procedure types, and the consequent radiation dose exposures. To comprehensively understand the cumulative effects of radiation and enhance protective measures for anesthesia personnel, future research should employ a longitudinal approach that delves into these variables. This focus is vital for developing effective strategies to mitigate radiation risks in interventional settings.

Conclusion

The research analyzes the AMED among anesthesia personnel in interventional cardiology, showing that both male and female personnel encounter relatively low radiation levels, with average AMED values of 0.73 ± 0.36 mSv for males and 0.79 ± 0.45 mSv for females. Remarkably, technologists experience a significantly higher exposure (0.8 ± 0.43 mSv) compared to consultants (0.63 ± 0.29 mSv), highlighting a potential area for targeted radiation safety interventions. Despite the overall AMED values (0.76 ± 0.4 mSv) remaining lower than the annual dose limit of 20 mSv, the occurrence of 35 instances exceeding the public limit of 1 mSv warrants continued vigilance. This study emphasizes the importance of ongoing monitoring and the implementation of enhanced protective measures to safeguard the health of professionals working in environments with potential radiation risks.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethical Approval

This study was reviewed and approved by the ethics committee at Jazan University, Saudi Arabia, and complies with the Declaration of Helsinki.

Informed Consent

Informed consent was waived by an ethics committee due to the retrospective nature of the data.

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Disclosure

The author declares that he has no conflicts of interest in relation to this article.

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