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Radiation Exposure Knowledge among Anaesthesia Residents: A Cross Sectional Study in Karachi Teaching Hospitals

Asir Nasiruddin[1], Adeel Ur Rehman[1], Kashif Naeem[1], Atif Pervaiz Lawrence[1], Syed Faraz Ahmed[1]

[1]Department of Anesthesia, The Indus Hospital and Health Network, Karachi, Sindh, Pakistan.

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Corresponding Author: Adeel Ur Rehman,
Department of Anesthesia, The Indus Hospital and Health Network, Karachi, Sindh, Pakistan.
Email: Adeel.rehman@tih.org.pk

Declaration

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ABSTRACT

Introduction: Preventive strategies to reduce radiation-induced harm among anaesthesiologists are directed by the National Council on Radiation Protection and Measurements and the US Environmental Protection Agency. These instructions underscore the necessity of minimising exposure intensity and duration, maintaining distance from the radiation source, and employing shielding against both primary and dispersed radiation. This study sought to assess the knowledge and apprehension of radiation exposure among anaesthesia residents in teaching hospitals in Karachi via an online questionnaire. **Objective:** To evaluate the understanding of radiation exposure and protective protocols among anaesthesia residents in teaching hospitals in Karachi. **Method:** A cross-sectional study was performed at many teaching hospitals in Karachi, including The Indus Hospital, AKUH, Ziauddin Hospital, Civil Hospital, JPMC, NICVD, LNH, and Abbasi Shaheed Hospital. The research was conducted during a six-month period, from January 6, 2023, to July 5, 2023, subsequent to the endorsement of the research Participants who satisfied the inclusion criteria submitted written informed consent. An online questionnaire, self-administered via Google Forms, gathered data on knowledge regarding radiation exposure. All responses were recorded electronically for analysis. **Result:** The study comprised residents aged 24 to 50 years, with a median age of 29 years. Of the 119 participants, 79 (66.4%) were male, while 40 (33.6%) were female. Merely 10 residents (8.4%) exhibited sufficient understanding of radiation exposure and preventative strategies. **Conclusion:** This study demonstrated a minimal proportion of anaesthesia residents have sufficient information regarding radiation exposure and safety protocols.

INTRODUCTION

Since the advent of X-rays, medical sciences, especially orthopaedics, cancer, and cardiology, have experienced significant advancement and development. Clinicians now consistently utilise various radiation-based methods for diagnostic and therapeutic applications. Nonetheless, radiation-based procedures can have significant detrimental effects on clinicians, particularly anaesthesiologists and interventionists, who are constantly exposed to radiation in their daily work [1]. X-rays are universally recognised as harmful to the human body. Nonetheless, specific tissues and organs such as the thyroid, eyes, blood, and bone marrow exhibit heightened radiosensitivity, necessitating the implementation of stringent protective measures for their safeguarding [2,3]. The eye lens is the most susceptible component to radiation damage, and extended exposure may lead to radiation-induced cataracts [4]. Routine radiological procedures emit radiation levels typically between 3 to 30 mSv(millisievert); however, the likelihood of cancer increases with radiation doses above 100 mSv [5]. According to the recommendations of the International Commission on Radiological Protection (ICRP), the maximum occupational radiation exposure should be limited to 20 mSv per year over a five-year period, with a cap of less than 50 mSv in any single year. Furthermore, according to the general population, the ICRP's guidelines recommend limiting exposure to 1 mSv per year during a one-year period [6]. Of almost two million healthcare personnel engaged in radiation-related activities worldwide, at least fifty percent are subjected to ionising radiation.

Anaesthesiologists engaged in the operating room and non-operating room anaesthesia (NORA), including fluoroscopy and CT scans. [7] Radiological operations are often subjected to radiation exposure. Anaesthesiologists must recognise the potential detrimental effects of radiation and possess a comprehensive awareness of radiation protection methods to mitigate this risk. The statistics reveal that radiation exposure for anaesthesiologists in interventional radiology suites is up to six times greater than that of other workers and three times greater than that of radiology workers. [8]

The fundamental tenet of radiation safety, as advocated by the ICRP, is to maintain exposure 'as low as reasonably practicable' or ALARP. The ALARP concept posits that radiation exposure can be mitigated through the strategic application of time, distance, and shielding. The duration of exposure is more critical in fluoroscopic procedures than in standard radiographs, such as chest films. Furthermore, exposure can be diminished by augmenting the distance between the beam and the source. In addition to time and distance, personal shielding, including lead aprons, thyroid collars, and protective eyewear, is crucial for radiation protection [9].

A study indicated that 98.7% of paediatric anaesthesiologists are routinely exposed to radiation, with 78% expressing significant concern regarding this exposure; notably, the majority do not consistently adhere to conventional safety protocols [10]. A separate study indicates that 82% of anaesthesiologists did not wear dosimeters [11]. In teaching hospitals, novice anaesthesia trainees are susceptible to radiation exposure because to a lack of awareness regarding the detrimental effects of radiation, safety measures, and available resources. A survey conducted in a teaching hospital in Pakistan revealed that only 20% of anaesthesia trainees implement adequate preventive measures [12]. A separate study of 491 anaesthesiologists revealed that trainees had the lowest compliance rate (5.1%) in implementing preventive measures, as shown by the survey [13]. Consequently, it is essential for them to receive enough training and guidance. This study aims to assess and analyse anaesthesiology trainees' understanding of radiation hazards and their awareness of current safety protocols. This study will highlight the significance of adequate protection for novice anaesthesia trainees. The objective of this research is to investigate this field and to gather data that may indicate the awareness of radiation exposure among anaesthesia residents in teaching hospitals in Karachi. In the event of insufficient knowledge among residents, awareness seminars may be implemented to augment their understanding of radiation exposure, thereby mitigating the detrimental effects of radiation and ensuring adherence to safe procedures.

METHODOLOGY

This cross-sectional study was performed at various teaching hospitals in Karachi, including The Indus Hospital, AKUH, Ziauddin Hospital, Civil Hospital, JPMC, NICVD, LNH, and Abbasi Shaheed Hospital. The study lasted six months, from January 6, 2023, to July 5, 2023, subsequent to the approval of the research department. The sample size was determined with OpenEpi software, informed by a pilot study that revealed a 10% prevalence of sufficient information regarding radiation exposure among anaesthesia residents. The necessary sample size, with a 95% confidence interval and a 6% precision requirement, was 98. Increasing the sample size from 98 to 119 enhances statistical power, precision, and reliability, reduces bias, ensures representativeness, addresses potential dropouts, and meets updated study or analysis requirements. Non-probability consecutive sampling was utilised.

Participants were anaesthesia residents aged 22 to 50 years who are presently engaged in postgraduate training (FCPS or MCPS) at the designated teaching hospitals. Inclusion requirements mandated that residents provide assent, ensuring representation of both genders. Residents from non-teaching hospitals, individuals who opted out of participation, and those with previous experience in radiography departments were excluded.

Approval for the study was secured from the Institutional Review Board of The Indus Hospital. Individuals meeting the inclusion criteria were approached and informed about the study's objective. Following the acquisition of online consent, a self-administered questionnaire was distributed online. The questionnaire included demographic information (age, gender, and institution) and enquiries evaluating knowledge on radiation exposure.

Data analysis was conducted utilising SPSS version 26. Categorical variables, such as gender, radiation exposure frequency, and knowledge sufficiency, were presented as frequencies and percentages. Quantitative data, including age, years of experience, length of radiation exposure, and knowledge scores, were summarised as mean (SD) or median (IQR) contingent upon normality evaluated by the Shapiro-Wilk test. Effect modifiers such as age, gender, years of experience, and radiation duration were managed using stratification. Post-stratification analyses were performed utilising the Chi-square or Fisher’s Exact test, with a p-value of less than 0.05 being statistically significant.

RESULTS

In this study 119 residents were included to assess the knowledge of radiation exposure and protective measures among anaesthesia residents in teaching hospitals of Karachi and the results were analysed as: The distribution of continuous variables was tested by applying the Shapiro-Wilk test for age (P=0.0001), years of experience (P=0.0001), duration of (P=0.0001) and knowledge score (P=0.0001) as shown in **table 1**.

The data reveals an average age of 30.05 years, with a median of 29 and a range of 26. Experience averages 3.034 years, ranging from 1 to 30. Radiation exposure lasts 6.18 minutes on average, with a wide variability. Knowledge scores average 4.03, with a range of 6 points. Table 2

Table 3 reveals that merely 8.4% (10 persons) of the population have acceptable knowledge, whilst a substantial 91.6% (109 individuals) lack sufficient understanding. Table 4 indicates that sufficient knowledge is substantially correlated with age and length of radiation exposure (p-values 0.048). Among younger adults (22–30 years), 10 (8.4%) possessed appropriate knowledge, however none in the over 30 age group did. Concerning exposure time, 9 individuals (7.6%) with shorter exposures (1–5 minutes) demonstrated appropriate knowledge, in contrast to 1 individual (0.8%) with longer exposures.

Gender has no significant correlation (p-value 0.551), with 7 males (5.9%) and 3 females (2.5%) demonstrating appropriate understanding. Regarding experience, 9 individuals (7.6%) with 1–3 years and 1 individual (0.8%) with above 3 years possessed acceptable knowledge (p-value 0.288).

Table 1
Descriptive statistics of shapiro wilk test n=119

VARIABLE	MEAN±SD	P-VALUE
Age Group	30.05±4.47	0.0001
Years of Experience	3.03±2.96	0.0001
Duration of Radiation	6.18±5.54	0.0001
Knowledge Score	4.03±1.55	0.0001

Table 2
Descriptive statistics for age, experience, duration of radiation exposure, and knowledge score

Descriptive		Statistic
Age (years)	Mean	30.05
	Median	29.00
	Variance	20.031
	Std. Deviation	4.476
	Minimum	24
	Maximum	50
	Range	26
	Interquartile Range	3
Experience (years)	Mean	3.034
	Median	3.000
	Variance	8.808
	Std. Deviation	2.9679
	Minimum	1.0
	Maximum	30.0
	Range	29.0
	Interquartile Range	1.0
Duration of Radiation Exposure (minutes)	Mean	6.18
	Median	5.00
	Variance	30.740
	Std. Deviation	5.544
	Minimum	1
	Maximum	23
	Range	22
	Interquartile Range	6
Knowledge Score	Mean	4.03
	Median	4.00
	Variance	2.406
	Std. Deviation	1.551
	Minimum	1
	Maximum	7
	Range	6
	Interquartile Range	2

Table 3
Adequate Knowledge Distribution

Adequate knowledge	Frequency	Percentage
Yes	10	8.4%
No	109	91.6%

Table 4
Adequate Knowledge Analysis by Demographics and Variables

Adequate Knowledge	Age Group [years]		P-VALUE
	22 – 30	>30	
Yes	10 (8.4%)	0 (0.0%)	0.048
No	79 (66.4%)	30 (25.2%)	
Adequate Knowledge	**Gender**		**P-VALUE**
	Male	Female	
Yes	7 (5.9%)	3 (2.5%)	0.551
No	72 (60.5%)	37 (31.1%)	
Adequate Knowledge	**Years of Experience**		**P-VALUE**
	1 – 3	>3	
Yes	9 (7.6%)	1 (0.8%)	0.288
No	83 (69.7%)	26 (21.8%)	
Adequate Knowledge	**Duration** [minutes]		**P-VALUE**
	1 – 5	>5	
Yes	9 (7.6%)	1 (0.8%)	0.048
No	64 (53.8%)	45 (37.8%)	

DISCUSSION

Ionising and non-ionizing radiations are frequently employed in routine medical practice. It serves crucial functions in both diagnostic and therapeutic approaches. Ionising radiation poses significant risks to interventionists and anaesthesia staff exposed to radiation in their work environments. Numerous investigations have shown that exposure to medical radiation elevates the risk of bone marrow suppression, cataracts, infertility, congenital anomalies, and various cancers, particularly thyroid carcinoma [14-16]. The threshold dose differs among radiation-induced disorders. For instance, 100–200 mGy correlates with teratogenic consequences and cancer [16], while 500 mGy is linked to cataracts [17].

Consequently, awareness and understanding of radiation dangers and protective measures are crucial in mitigating radiation exposure among healthcare professionals.

The International Commission on Radiological Protection (ICRP) has proposed a fundamental principle of radiation protection, which encompasses three tenets: rationale, optimisation (as low as reasonably attainable, ALARA), and dose limiting. [18] This constitutes the basis of radiation protective strategies. The expertise of healthcare staff regarding radiation dangers and protection has been thoroughly examined, however findings have varied across various medical subspecialties.

A remarkable rise has been observed in the periprocedural application of imaging modalities in operating theatres, interventional suites, and intensive care units in recent years. These zones comprise the primary workforce of anaesthesiology consultants, residents, technicians, and nursing personnel. As a result of providing anaesthesia services and ensuring optimal patient care, they are subjected to substantial levels of radiation exposure. [19] Ionising radiations are established carcinogens, and it has been noted that medical practitioners' understanding of them is insufficient, irrespective of their specialisation. [20,21] The rising utilisation of medical radiation, coupled with insufficient understanding of radiation safety and dosages, poses considerable health hazards [22,23]. Prior research indicates significant radiation exposure among anaesthesiologists [24-26]. Nevertheless, the anaesthesiology residents, technicians, and nursing personnel, who constitute the majority of the workforce providing anaesthesia services, sometimes remain unacknowledged in these research. It is essential to integrate their feedback to formulate future educational and training methods aimed at enhancing safety standards.

Given that radiation has established detrimental biological consequences that depend on the dose and length of exposure, it is crucial to understand physicians' awareness of these issues, particularly the accompanying dangers [27,28]. Physicians, by referring patients for such studies, inherently assume a degree of duty under the Ionising Radiation (Medical Exposure) laws [29,30]. Globally, the issue pertains to the inadequate understanding of referring physicians on radiation doses from regular radiological tests and their awareness of the associated dangers of radiation exposure [31,32]. Another study from Pakistan revealed that the majority of radiation workers surveyed possessed insufficient awareness of radiation protective protocols. [33] These findings are analogous to our study's results. Our research indicates a deficiency in radiation safety knowledge among residents, necessitating targeted education, specialised training, and evaluation of intervention effectiveness.

This study's drawbacks encompass its dependence on self-reported data via an online questionnaire, potentially introducing response bias and constraining the precision of the results. The cross-sectional design prevents the establishment of causation between knowledge levels and their influencing factors. The study was limited to teaching hospitals in Karachi, perhaps constraining the generalisability of the findings to other regions or healthcare environments.

CONCLUSION

The findings indicate that few residents possess adequate knowledge of radiation exposure, underscoring the urgent need for targeted educational campaigns and specialised training programs on radiation safety in anaesthesia. Future research and quality improvement efforts should concentrate on evaluating the efficacy of training interventions in enhancing knowledge and practices regarding radiation safety among anaesthesia residents.

REFERENCES

1. Haga, Y., Chida, K., Kimura, Y., Yamanda, S., Sota, M., Abe, M., Kaga, Y., Meguro, T., & Zuguchi, M. (2020). Radiation eye dose to medical staff during respiratory endoscopy under X-ray fluoroscopy. *Journal of Radiation Research*, *61*(5), 691-696. https://doi.org/10.1093/jrr/rraa034
2. Khamtuikrua, C., & Suksompong, S. (2020). Awareness about radiation hazards and knowledge about radiation protection among healthcare personnel: A Quaternary care academic center–based study. *SAGE Open Medicine*, *8*. https://doi.org/10.1177/2050312120901733
3. Taqi Ali, H., Faraj Kharman, A., & Zaynal Sarah, A. (2018). The effect of long-term X-ray exposure on human lymphocyte. *Journal of Biomedical Physics and Engineering*. https://doi.org/10.31661/jbpe.v0i0.935
4. Della Vecchia, E., Modenese, A., Loney, T., Muscatello, M., Paulo, M. S., Rossi, G., & Gobba, F. (2020). Risk of cataract in health care workers exposed to ionizing radiation: a systematic review. *La Medicina del*

lavoro, *111*(4), 269. https://doi.org/10.23749/mdl.v111i4.9045
5. Ali, Y. F., Cucinotta, F. A., Ning-Ang, L., & Zhou, G. (2020). Cancer Risk of Low Dose Ionizing Radiation. *Frontiers in Physics*, *8*. https://doi.org/10.3389/fphy.2020.00234
6. Narain, A. S., Hijji, F. Y., Yom, K. H., Kudaravalli, K. T., Haws, B. E., & Singh, K. (2017). Radiation exposure and reduction in the operating room: Perspectives and future directions in spine surgery. *World Journal of Orthopedics*, *8*(7), 524. https://doi.org/10.5312/wjo.v8.i7.524
7. Erkan, I., Yarenoglu, A., Yukseloglu, E. H., & Ulutin, H. C. (2019). The investigation of radiation safety awareness among healthcare workers in an education and research hospital. *International Journal of Radiation Research*, *17*(3), 447-453.
8. Wong, T., Georgiadis, P. L., Urman, R. D., & Tsai, M. H. (2020). Non-Operating room anesthesia: Patient selection and special Considerations. *Local and Regional Anesthesia*, *13*, 1-9. https://doi.org/10.2147/lra.s181458
9. Kim, J. H. (2018). Three principles for radiation safety: Time, distance, and shielding. *The Korean Journal of Pain*, *31*(3), 145-146. https://doi.org/10.3344/kjp.2018.31.3.145
10. Whitney, G. M., Thomas, J. J., Austin, T. M., Fanfan, J., & Yaster, M. (2019). Radiation safety perceptions and practices among pediatric anesthesiologists: A survey of the physician membership of the society for pediatric anesthesia. *Anesthesia & Analgesia*, *128*(6), 1242-1248. https://doi.org/10.1213/ane.0000000000003773
11. Thambura, M. J., & Ikiara, N. J. (2020). Anesthesiologist knowledge on radiation safety in northern Gauteng hospitals, South Africa. *Journal of Radiology Nursing*, *39*(3), 245-248. https://doi.org/10.1016/j.jradnu.2020.01.004
12. Khan, M., Ali, M., Salim, B., & Siddiqui, K. (2020). Attitudes and knowledge of anesthesiology trainees to radiation exposure in a tertiary care hospital. *Saudi Journal of Anaesthesia*, *14*(4), 459. https://doi.org/10.4103/sja.sja_659_19
13. Burman, S., Das, A., Mahajan, C., & Rath, G. P. (2020). Radiation concerns for the Neuroanesthesiologists. *Journal of Neuroanaesthesiology and Critical Care*. https://doi.org/10.1055/s-0040-1715354
14. Dagal, A. (2011). Radiation safety for anesthesiologists. *Current Opinion in Anaesthesiology*, *24*(4), 445-450. https://doi.org/10.1097/aco.0b013e328347f984
15. Iglesias, M. L., Schmidt, A., Ghuzlan, A. A., Lacroix, L., Vathaire, F. D., Chevillard, S., & Schlumberger, M. (2017). Radiation exposure and thyroid cancer: A review. *Archives of Endocrinology and Metabolism*, *61*(2), 180-187. https://doi.org/10.1590/2359-3997000000257
16. Sont, W. N., Zielinski, J. M., Ashmore, J. P., Jiang, H., Krewski, D., Fair, M. E., Band, P. R., & Létourneau, E. G. (2001). First analysis of cancer incidence and occupational radiation exposure based on the national dose registry of Canada. *American Journal of Epidemiology*, *153*(4), 309-318. https://doi.org/10.1093/aje/153.4.309
17. Chodick, G., Bekiroglu, N., Hauptmann, M., Alexander, B. H., Freedman, D. M., Doody, M. M., Cheung, L. C., Simon, S. L., Weinstock, R. M., Bouville, A., & Sigurdson, A. J. (2008). Risk of cataract after exposure to low doses of ionizing radiation: A 20-Year prospective cohort study among US radiologic technologists. *American Journal of Epidemiology*, *168*(6), 620-631. https://doi.org/10.1093/aje/kwn171
18. Park, J., Park, S., Choi, S., Shin, H., Lee, H., Lim, H., Yoon, S., & Chang, S. (2007). Target-controlled Propofol infusion for sedation in patients undergoing Transrectal ultrasound-guided prostate biopsy. *Journal of International Medical Research*, *35*(6), 773-780. https://doi.org/10.1177/147323000703500605
19. Brenner, D. J., & Hall, E. J. (2007). Computed tomography — An increasing source of radiation exposure. *New England Journal of Medicine*, *357*(22), 2277-2284. https://doi.org/10.1056/nejmra072149
20. SOYE, J. A., & PATERSON, A. (2008). A survey of awareness of radiation dose among health professionals in Northern Ireland. *The British Journal of Radiology*, *81*(969), 725-729. https://doi.org/10.1259/bjr/94101717
21. Heyer, C. M., Hansmann, J., Peters, S. A., & Lemburg, S. P. (2010). Paediatrician awareness of radiation dose and inherent risks in chest imaging studies—A questionnaire study. *European Journal of Radiology*, *76*(2), 288-293. https://doi.org/10.1016/j.ejrad.2009.06.01

4
22. Yurt, A., Çavuşoğlu, B., & Günay, T. (2014). Evaluation of awareness on radiation protection and knowledge about radiological examinations in healthcare professionals who use ionized radiation at work. *Malecular Imaging and Radionuclide Therapy*, *22*(2), 48-53. https://doi.org/10.4274/mirt.00719
23. Brown, N., & Jones, L. (2012). Knowledge of medical imaging radiation dose and risk among doctors. *Journal of Medical Imaging and Radiation Oncology*, *57*(1), 8-14. https://doi.org/10.1111/j.1754-9485.2012.02469.x
24. Mohapatra, A., Greenberg, R. K., Mastracci, T. M., Eagleton, M. J., & Thornsberry, B. (2013). Radiation exposure to operating room personnel and patients during endovascular procedures. *Journal of Vascular Surgery*, *58*(3), 702-709. https://doi.org/10.1016/j.jvs.2013.02.032
25. Ismail, S., Khan, F., Sultan, N., & Naqvi, M. (2010). Radiation exposure to anaesthetists during interventional radiology. *Anaesthesia*, *65*(1), 54-60. https://doi.org/10.1111/j.1365-2044.2009.06166.x
26. Tüfek, A., Tokgöz, O., Aycan, İ. Ö., Çelik, F., & Gümüş, A. (2013). Current attitudes of Turkish anesthesiologists to radiation exposure. *Journal of Anesthesia*, *27*(6), 874-878. https://doi.org/10.1007/s00540-013-1623-7
27. Brenner, D. J., Elliston, C. D., Hall, E. J., & Berdon, W. E. (2001). Estimated risks of radiation-induced fatal cancer from pediatric CT. *American Journal of Roentgenology*, *176*(2), 289-296. https://doi.org/10.2214/ajr.176.2.1760289
28. Brenner, D. J., Doll, R., Goodhead, D. T., Hall, E. J., Land, C. E., Little, J. B., Lubin, J. H., Preston, D. L., Preston, R. J., Puskin, J. S., Ron, E., Sachs, R. K., Samet, J. M., Setlow, R. B., & Zaider, M. (2003). Cancer risks attributable to low doses of ionizing radiation: Assessing what we really know. *Proceedings of the National Academy of Sciences*, *100*(24), 13761-13766. https://doi.org/10.1073/pnas.2235592100
29. Jacob, K., Vivian, G., & Steel, J. (2004). X-ray dose training: Are we exposed to enough? *Clinical Radiology*, *59*(10), 928-934. https://doi.org/10.1016/j.crad.2004.04.020
30. Integrated Environment Management Inc (IEM). The ALARA concept. http://www.iem-inc.com/information/radioactivitybasics/radiation-risks/the-%20alaraconcept
31. Arslanoglu, A., Bilgin, S., Kubali, Z., Ceyhan, M. N., İlhan, M. N., & Maral, I. (2007). Doctors' and intern doctors' knowledge about patients' ionizing radiation exposure doses during common radiological examinations. *Diagnostic and Interventional Radiology*, *13*(2), 53.
32. SOYE, J. A., & PATERSON, A. (2008). A survey of awareness of radiation dose among health professionals in Northern Ireland. *The British Journal of Radiology*, *81*(969), 725-729. https://doi.org/10.1259/bjr/94101717
33. Jafri, M. A., Farrukh, S., Zafar, R., & Ilyas, N. (2022). A survey on radiation protection awareness at various hospitals in Karachi, Pakistan. *Heliyon*, *8*(11), e11236. https://doi.org/10.1016/j.heliyon.2022.e11236