Southern African Journal of Anaesthesia and Analgesia. 2022;28(2):68-71
https://doi.org/10.36303/SAJAA.2022.28.2.2673

South Afr J Anaesth Analg
ISSN 2220-1181 85EISSN 2220-1173

ORIGINAL RESEARCH

Radiation exposure of anaesthesia providers in Africa: an occupational exposure study

K Louw, R Naidoo, S Chetty

Department of Anaesthesiology and Critical Care, Faculty of Medicine and Health Sciences, Stellenbosch University, South Africa
Corresponding author, email: *kurt.louw02@gmail.com*

Background: Radiation exposure has significant physiological and cellular dysfunctional effects. Anaesthesia providers globally are increasingly exposed to interventional hybrid theatres where the risk of radiation exposure is of concern. Currently, there is no policy to monitor occupational radiation exposure of anaesthesia providers in Africa. This observational study aims to quantify occupational radiation exposure of anaesthesia providers at a tertiary academic hospital in a low- to middle-income country.

Methods: Twenty-five anaesthesiology trainees were recruited to participate in this study. Study participants were allocated two passive personal radiation detection devices (dosimeters) to record radiation exposure from X-ray sources during routine anaesthetic practice over a single continuous month. The positioning of the dosimeters was standardised. Participants wore both dosimeters during all working hours over the study period. Participant attendance at work as well as exposure to X-rays were documented. The occupational whole-body effective dose (WBED) was calculated for each participant and extrapolated to determine an estimation of annual radiation exposure.

Results: The number of participants who were exposed to ionising radiation exceeding the threshold radiation dose were 19 (76%) and nine (36%), as detected by dosimeters worn on the outside of or underneath the protective lead apron, respectively. There was a statistically significant difference ($p = 0.012$) between the readings measured by the dosimeter worn underneath the lead apron compared to readings from the dosimeter worn on the outside of the lead apron. None of our study participants exceeded the annual occupational dose limits. However, the maximum extrapolated annual WBED in our study was 1.127 mSv, which exceeds the recommended exposure limit for pregnant women.

Conclusion: Our study sample was exposed to occupational radiation at levels within acceptable limits, except for pregnant women. This study reiterates the importance of wearing protective lead equipment when working in areas with radiation exposure. Caution should be taken when rostering pregnant staff to areas where radiation exposure occurs.

Keywords: occupational radiation exposure, anaesthetic safety, radiation safety, low- to middle-income countries

Introduction

With advances in diagnostic and interventional radiological procedures, the occupational exposure and risk to anaesthesiologists from ionising radiation has increased.[1] Interventional radiology now involves anaesthesiologists to a greater extent.[2] Radiation exposure to anaesthesiologists may occur both in the operating theatre and in remote locations, especially the radiological/hybrid suite.[3] The recognition of potential harm from occupational radiation exposure has led to the formulation and implementation of established standards of safety within occupational medicine. Although current literature suggests that radiation exposure is less than the current recommended safety limit, this should not lead to complacency.[4] Currently, there are no policies to monitor exposure to anaesthetic staff in South Africa. It is recommended that radiation safety should also form part of the formal education of anaesthesiology training programmes.[5]

There is a need for safety surveillance tools to monitor ionising radiation exposure among anaesthesiologists. As a first step, it is important to measure the level of ionising radiation exposure of trainees at our institution. We hope to implement these surveillance strategies to identify doctors who are at an elevated risk from the harmful effects of ionising radiation.

This prospective observational study was conducted at Tygerberg Hospital (TH). TH is a 1 384 bed tertiary academic hospital in the Western Cape, South Africa. An average of 2 300 theatre cases are performed monthly. From January 2019 to April 2019, 13% of theatre cases utilised radiological screening. A significant volume of clinical work in the Department of Anaesthesiology and Critical Care (DACC) is performed in locations where ionising radiation exposure may occur. Currently, anaesthesiologists at TH are not monitored for their occupational exposure to ionising radiation in the operating theatres. This study was conducted from 4 November 2019 to 1 December 2019.

The primary objective of this study was to quantify the dose of ionising radiation exposure among anaesthesiology registrars and medical officers at a tertiary academic hospital. Furthermore, we aimed to establish if routine monitoring of radiation exposure of anaesthesiologists should become standard practice in South Africa.

Methods

This study was conducted in accordance with the Declaration of Helsinki on Ethical Principles of Medical Research.[6] Ethical approval for the research was granted by the Human Research Ethics Committee of Stellenbosch University (reference number: S19/08/145). Permission to conduct this study was granted by the TH management.

The study population included all registrars and medical officers working in the DACC at TH. We excluded participants on annual leave or those on out-of-theatre clinical rotations during the study period. Written informed consent was obtained from the study participants. A key code, only decipherable by the principal investigator, was used to protect participants' identity.

After informed consent was obtained, each study participant was issued two Panasonic® Thermoluminescent Dosimeters (TLD) (UD 802 model), which has a radiation detection range between 10 micro Sieverts (mSv) and 10 Sieverts (Sv). A Panasonic TLD (UD 802) dosimeter is a passive radiation dosimeter and contains four different radiation detectors. It measures ionising radiation exposure by measuring the intensity of visible light emitted from a sensitive crystal in the detector when the crystal is heated.[7] The positioning of the dosimeters was standardised. One dosimeter was worn on the outside of the standard lead protective gown at the level of the collar, while the second dosimeter was worn at nipple height under the protective lead apron. Participants wore both dosimeters during all working hours for a period of 28 days, after which the dosimeters were sent for analysis. Analysis of the dosimeters was performed by South African Bureau of Standards radiation protection services (Rosebank, Western Cape, South Africa; https://www.sabs.co.za/).

A register was kept of each participant's attendance at work for each day of the study, which recorded the operating theatre they were allocated to and if X-ray imaging was used in the operating theatre on that day. This information was transposed onto a spreadsheet against allocated dosimeter numbers.

Microsoft® Excel 2010 (Microsoft, Redmond, WA, USA) was used for the initial data capture while subsequent descriptive statistics were conducted using IBM SPSS Statistics version 26.0 (IBM, New York, USA). Continuous variables were summarised as median and interquartile range (IQR) as well as absolute range. Nominal variables were summarised as counts and percentages. Comparison of the median dose values obtained from dosimeters worn on the inside and the outside of the protective aprons were performed using Wilcoxon signed-rank test. The Wilcoxon signed-rank test is used when data are not normally distributed, as it is a nonparametric alternative to compare paired data. Spearman's rank-order correlation was used to assess the relationship between the total whole-body effective dose (WBED) exposure and the doses measured on the inside and outside dosimeters. Spearman's rank-order correlation is a nonparametric measure of the strength and direction of association that exists between two variables. Occupational WBED was calculated and extrapolated to determine an estimation of annual radiation exposure. WBED was calculated by using the following formula:[3]

Whole-body effective dose = trunk dose/2 + collar dose/40.

Annual dose was then calculated by the following formula:

Annual dose = whole-body effective dose/28 x 365

A critical analysis of the absolute highest and lowest exposure values was made to determine factors that contributed to these.

Results

A total of 25 anaesthesia providers participated in the four-week data collection period. Twenty per cent ($n = 5$) of the group had no exposure to X-rays during the study period. The maximum number of radiation exposure days in the cohort was 8. Twelve per cent ($n = 3$) of the participants had the maximum of 8 days of work which included X-ray exposure. The participant with the highest calculated annual WBED (1.127 mSv) had 4 days of work, which included X-ray exposure, during the 28-day study period. The median number of days worked, involving X-ray exposure, for all participants, was 3 days (IQR: 1–5 days).

Seventy-six per cent ($n = 19$) of the study population exceeded the threshold for ionising radiation detected by the Panasonic® TLD, which has a radiation detection range between 10 mSv and 10 Sv, worn on the outside of the protective lead apron. The median radiation dose detected by the dosimeter worn on the outside of the lead apron was 0.0187 mSv (IQR: 0.005–0.046 mSv; range = 0.0–2.35 mSv). Nine of the 25 (36%) trunk dosimeters worn on the inside of the lead apron exceeded the threshold dose for ionising radiation detectable by the Panasonic® TLD. The median radiation dose detected by the inside dosimeter was 0.002 mSv (IQR: 0–0.021 mSv; range = 0–0.057 mSv).

Assessing the correlation, using Spearman's rank-order correlation, between the total number of days of exposure to ionising radiation and readings from the TLD radiation badges, worn either on the inside or the outside of the protective lead aprons, revealed these correlations to be statistically insignificant (sig. (2-tailed) $p > 0.05$). Both correlation coefficients were close to 0. Correlation between number of days of exposure and inside dose was calculated at rho = -0.284 (sig.(2-tailed), $p = 0.168$). Correlation between number of days of exposure and outside dose was calculated at rho = 0.162 (sig.(2-tailed), $p = 0.590$).

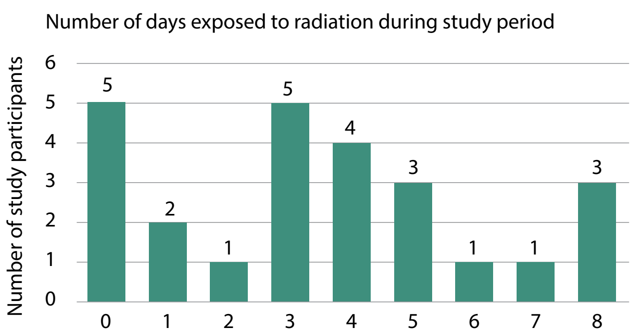

Figure 1: Histogram showing total exposed workdays for study participants

WBED ranged from 0 mSv to 0.086 mSv. The median WBED was 0.004 mSv (IQR: 0–0.012 mSv). The highest extrapolated annual WBED was 1.127 mSv. A negative weak correlation was calculated for total days of exposure and the annual dose (rho = -0.305, $p = 0.138$).

Discussion

There has not been an evaluation of occupational ionising radiation exposure of anaesthesia providers in South Africa yet. The aim of our study, therefore, was to quantify radiation exposure among anaesthesia providers at our institution. Although none of our study participants were exposed to radiation levels that exceeded the annual occupational dose limits, the maximum extrapolated annual WBED (1.127 mSv) exceeds the recommended exposure limit for pregnant women.

The International Commission on Radiological Protection (ICRP) for occupational exposure set occupational exposure limits at less than 20 mSv per year over a 5-year period or less than 50 mSv in any one year.[8] The maximum extrapolated annual WBED in our study was 1.127 mSv which is lower than the safety limits set by the ICRP and is comparable with an observational study reported by Durack et al.[3] from Australia. Both our results and those of Durack et al.[3] support the conclusions made by Rhea et al.[9] in 2016. Their systematic review indicated that anaesthetists are exposed to very little radiation and called into question the need for anaesthetists who are greater than 1.5 m from the radiation source, to routinely wear lead protection. However, research done by Anastasian et al.[10] demonstrated significantly higher radiation exposure for anaesthetists in interventional radiology suites and does not support the opinions expressed by Rhea et al.[9]

Recommendations for ionising radiation exposure for the general public and for pregnant women is less than 1 mSv per year. The maximum extrapolated annual WBED in our study was 1.127 mSv, which exceeds the recommended exposure limit for pregnant women. Pregnant staff should, therefore, not be rostered to areas where higher levels of ionising radiation are encountered.

In our study, twelve per cent ($n = 3$) of the participants experienced 8 days of work which included X-ray exposure. However, the participant with the highest radiation exposure only had 4 days at work which included X-ray exposure during the 28-day study period. Arii et al.[11] demonstrated that the duration of exposure to fluoroscopy and the distance from the radiation source are important factors in radiation exposure. However, in general, the duration of exposure is not within the control of the anaesthesia provider.[2]

Our study showed a statistically significant difference between the readings obtained from the dosimeter worn under the protective lead apron compared to the dosimeter worn above the lead apron ($p = 0.012$). Although radiation exposure risk appears to be minimal in modern anaesthetic practice, this finding reiterates the importance of wearing protective lead during radiological procedures. Gendelberg et al.[12] demonstrated that formal training in radiation safety among orthopaedic residents correlated with a greater likelihood of implementing surveillance and monitoring of exposure, and that formal training resulted in a change in practice, incorporating dose reduction strategies while operating. In a prospective cohort study by Tasbas et al.[13] orthopaedic surgeons are exposed to the highest amount of ionising radiation due to proximity of exposure while operating. Despite this, it is unlikely that orthopaedic surgeons will reach annual recommended safety limits. Distance from the radiation source for anaesthesia providers has consistently been shown to be further away compared to surgeons.[9] Multiple studies have demonstrated that should the distance of the anaesthetist be greater than 1.5 meters from the radiation source, exposure to significant amounts of radiation is unlikely.[9] However, chronic low dose radiation exposure is associated with potential long-term biological effects, and should also be taken into consideration when establishing occupational radiation safety programmes.[14]

Study strengths and limitations

A strength of this study is that it is the first reported investigation in Africa and corroborates findings that occupational exposure to anaesthesia providers is low with the exception of exposure in radiology intervention suites.[11] Conducting this study in a single centre allowed for control of the confounder, namely staff who were out of theatre for significant periods during the study period (i.e. those who are either on leave or on out-of-theatre rotations).

However, this study had several limitations. Duration of data collection was limited to 28 days due to financial constraints. This study considered the population as a single-centred community. Our study population may not be representative of anaesthesia providers across Africa. Radiation exposure to anaesthesia providers not only depends on the number of days exposed, but also the duration of each exposure. This may vary at different institutions, thereby hindering us from extrapolating the TH population as a sample reflecting the anaesthesia provider community in Africa as a whole.

No actual data on dose of radiation emitted was obtained from the radiographer. This may be valuable information, as actual exposure varies within each operating theatre. Each actual trigger made by the radiographer while the study participant was in the operating room would have to be calculated. This will also take into consideration whether the participant was out of theatre, and also if there was just a single radiation shot taken compared to serial screenings. Such data are logistically impossible to obtain. However, dose measurement is likely to be the best solution to assess the risk to the anaesthetist as performed in this study.

Recommendations

We recommend that radiation safety education should form part of the formal education of surgical and anaesthesiology training programmes. Radiation from X-ray sources can be reduced by keeping the time of exposure to a minimum, maintaining a distance from the radiation source, placing a shield between the person and the source and by wearing personal protective clothing. Lead protective aprons and thyroid shields of between 0.35 mm and 0.5 mm thick are standard required protection to anyone being exposed to radiation. Lead aprons need to be properly stored and inspected every six months for cracks or ruptures to ensure adequate protection. Anaesthesia providers working frequently in higher exposure risk areas, like the cardiology catheterisation and neuro-radiological interventional laboratories, warrant the need to monitor radiation exposure levels. Anaesthesia providers should be rotated through high- and low-risk radiation exposure areas to distribute the radiation exposure load. As a preliminary precaution and due to sparse data, it is recommended that pregnant staff should not be rostered to areas where higher levels of ionising radiation are encountered.

Conclusion

Despite reports of increasing levels of exposure to ionising radiation occurring in modern anaesthetic practice, doses received by our study population during this observational occupational exposure study were within acceptable international limits. Our study data support previously published international work and suggest that the radiation exposure to anaesthesia providers working in the operating room do not exceed the recommended dose limits set by the ICRP.[8] This study supports the importance of wearing lead protective equipment when working in high-risk areas. No practice guidelines on occupational radiation exposure for anaesthesia providers are currently available in South Africa. Future studies specifically investigating anaesthesia providers and other personnel frequently working in higher exposure risk areas (e.g. cardiology catheterisation suites and neuro-radiological interventional laboratories) will provide valuable information and aid in determining the necessity of routinely monitoring these staff members' occupational exposure to ionising radiation.

Acknowledgements

We wish to thank Mr Christoph Trauernicht, head of division Medical Physics, and Mrs Cheryl Johnson, secretary Department of Medical Physics for their invaluable input and supplying the radiation detection devices. We wish to thank Ms Tonya Esterhuizen (Biostatistical Unit, Centre for Evidence Based Health Care, Stellenbosch University) who assisted us with data analysis.

Conflict of interest

The authors report no conflict of interest.

Funding source

The study was conducted with support from the Department of Anaesthesiology and Critical Care, Stellenbosch University.

Ethical approval

Ethical approval for the research was granted by the Human Research Ethics Committee of Stellenbosch University (reference number: S19/08/145).

ORCID

K Louw https://orcid.org/0000-0002-7926-8194
R Naidoo https://orcid.org/0000-0002-8661-3646
S Chetty https://orcid.org/0000-0002-9878-5488

References

1. Phillips G, Monaghan WP. Radiation safety for anesthesia providers. AANA J. 2011;79(3):257-67.
2. Ismail S, Khan FA, Sultan N, Naqvi M. Radiation exposure of trainee anaesthetists. Anaesthesia. 2006;61(1):9-14. https://doi.org/10.1111/j.1365-2044.2005.04419.x.
3. Durack DP, Gardner AI, Trang A. Radiation exposure during anaesthetic practice. Anaesth Intensive Care. 2006;34(2):216-7. https://doi.org/10.1177/0310057X0603400235.
4. Dagal A. Radiation safety for anesthesiologists. Curr Opin Anaesthesiol. 2011;24(4):445-4. https://doi.org/10.1097/ACO.0b013e328347f984.
5. Dauda AM, Ozoh JO, Towobola OA. Medical doctors' awareness of radiation exposure in diagnostic radiology investigations in a South African academic institution. SA J Radiol. 2019;23(1):1-7. https://doi.org/10.4102/sajr.v23i1.1707.
6. World Medical Association. World Medical Association Declaration of Helsinki. Ethical principles for medical research involving human subjects. Bulletin of the World Health Organization. 2001;79(4):373-4.
7. Tootell A, Szczepura K, Hogg P. An overview of measuring and modelling dose and risk from ionising radiation for medical exposures. Radiography. 2014;20(4):323-32. https://doi.org/10.1016/j.radi.2014.05.002.
8. ICRP International Commission on Radiological Protection. Annals of the ICRP. ICRP Publication 92, annals of ICRP 28; 2003.
9. Rhea EB, Rogers TH, Riehl JT. Radiation safety for anaesthesia providers in the orthopaedic operating room. Anaesthesia. 2016;71(4):455-61. https://doi.org/10.1111/anae.13400.
10. Anastasian ZH, Strozyk D, Meyers PM, et al. Radiation exposure of the anesthesiologist in the neurointerventional suite. Anesthesiology. 2011;114(3):512-20. https://doi.org/10.1097/ALN.0b013e31820c2b81.
11. Arii T, Uchino S, Kubo Y, Kiyama S, Uezono S. Radiation exposure to anaesthetists during endovascular procedures. Anaesthesia. 2015;70(1):47-50. https://doi.org/10.1111/anae.12841.
12. Gendelberg D, Hennrikus W, Slough J, Armstrong D, King S. A radiation safety training program results in reduced radiation exposure for orthopaedic residents using the mini C-arm. Clin Orthop Relat Res. 2016;474(2):580-4. https://doi.org/10.1007/s11999-015-4631-0.
13. Tasbas BA, Yagmurlu MF, Bayrakci K, Ucaner A, Heybeli M. Which one is at risk in intraoperative fluoroscopy? Assistant surgeon or orthopaedic surgeon? Arch Orthop Trauma Surg. 2003;123(5):242-4. https://doi.org/10.1007/s00402-003-0516-x..
14. Heydarheydari S, Haghparas A, Eivazi MT. A novel biological dosimetry method for monitoring occupational radiation exposure in diagnostic and therapeutic wards: from radiation dosimetry to biological effects. J Biomed Phys Eng. 2016;6(1):21-6.