Evaluation of the occupational radiation exposure from C-arm fluoroscopy during common orthopaedic surgical procedures: DAP-based dose simulation method

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Abstract

The use of fluoroscopy in orthopaedic operations cause a risk for radiation-induced carcinoma for the theatre staff. Thus, the aim of the study was to calculate the occupational radiation doses (ORD) for the orthopaedic theatre crew during fluoroscopy-guided surgeries and to compare them with accepted reference standards. The end dose area products (DAP) were recorded for the commonest 3 types of orthopaedic surgeries by observing 50 surgeries in 2 hospitals. The ORD for 4 types of theatre personnel were simulated. ORDs were statistically analyzed. The calculated mean annual dosage was 0.977mSv. All dosages fell significantly below the reference threshold (20mSv) or less annually. The mean doses that each member of the staff received during the same surgery was different from one another. The orthopaedic surgeon predominantly receives the highest ORD (88.89%), whilst the anaesthetist receives the least (77.78%).

Introduction

Over the past several decades, the use of fluoroscopy has become universal in orthopaedic surgery [1]. Fluoroscopy increases the accuracy of procedures allowing minimally invasive techniques with a reduced operation time [2]. However, the unavoidable radiation exposure of the surgical team is a major disadvantage [3]. Many studies have reported on the radiation exposure of medical personnel during procedures with C-arm. They conclude that the whole-body dose of the orthopaedic theatre personnel is well maintained with recommended levels, but have emphasized the caution due to long-term exposure to even low doses of ionizing radiation. Thus, suitable precautions should be followed to avoid any amount of exposure to radiation leading to secondary ORDs.

Therefore, the investigation of the ORDs of the theatre personnel who are routinely working in a radiation field is highly essential. And it will improve the quality of the radiation protection standards in hospitals. Thus, the current study will positively affect the occupational safety of healthcare professionals as well as provide maximum safety for patients undergoing orthopaedic surgeries.

Therefore, the general objective of this study was to determine the ORDs to the orthopaedic theatre staff during fluoroscopy-guided common orthopaedic procedures and to compare them with standard international reference values.

Methods

This prospective and quantitative study was designed to mathematically simulate ORDs during a set of orthopaedic surgeries using DAP values and to compare them with international reference values.

The ethical clearance was obtained from the Ethics Review Committee of the Faculty of Allied Health Sciences, University of Peradeniya, Sri Lanka. Permission to conduct the study was obtained from the directors of the selected two hospitals. Written consent was obtained from the study subjects during the data collection procedure.

The study population was composed of four occupations; orthopaedic surgeons, anaesthetists, radiographers, and nurses performing the most common three types of orthopaedic surgeries in two hospitals, National Hospital, Kandy, Sri Lanka (Hospital A), and Teaching Hospital, Peradeniya, Sri Lanka (Hospital B). A set of 50 surgeries from three of the commonest

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orthopaedic surgery types were selected for the study from both hospitals i.e. Dynamic Hip Screw (DHS), Tibial Plateau Fracture (TPF), and Distal Radial Fracture (DRF). The minimum sample size was set to 300 using consecutive sampling technique according to Hulley *et al*. 1988 and the [7] 400 study subjects were included in the sample, where 100 participants from each occupation representing selected hospitals. All the staff were presented at the theatre during the study following standard radiation protection measures including wearing lead protective equipment.

A preliminary observation was carried out in the selected hospitals, and the operation theatre records for the last three months were obtained. The output DAP values indicated by the C-arm itself per procedure were recorded separately for each surgery, considering the procedure and the hospital. The distance between each participant's target organ and the center of the X-ray beam of the C-arm was measured.

The calculation was carried out to obtain the simulated dose quantities per each theatre personnel using the DAP. Three different dose values for each participant were calculated for three different body organs (D_H - Dose to hands, D_T - Dose to Thyroid, D_L - Dose to Lenses).

All the hypothesis tests were conducted at a significance level of 0.05. ANOVA was carried out to compare the ORDs received by each theatre personnel. and one sample t-test to compare the extrapolated mean annual doses with the standard international reference level.

Table 1. Measurements and parameters used for the dose value simulation

Dose Value	*DHS*			*TPF*			*DRF*		
	R(m)	*È (Degrees)*	*S (1/cm²)*	*R(m)*	*È (Degrees)*	*S (1/cm²)*	*R(m)*	*È (Degrees)*	*S (1/cm²)*
D_H of OS	0.2000	90.00	0.0000040	0.2000	90.00	0.0000040	0.2000	90.00	0.0000040
D_T of OS	0.5385	21.80	0.0000050	0.5385	21.80	0.0000050	0.5385	21.80	0.0000050
D_L of OS	0.6515	17.90	0.0000050	0.6515	17.90	0.0000050	0.6515	17.90	0.0000050
D_H of Anaesthetist	2.0000	90.00	0.0000045	2.2000	90.00	0.0000045	1.5000	90.00	0.0000045
D_T of Anaesthetist	2.0616	75.90	0.0000042	2.2561	77.20	0.0000042	1.5811	71.60	0.0000042
D_L of Anaesthetist	2.0939	72.80	0.0000042	2.2857	74.20	0.0000042	1.6231	67.50	0.0000042
D_H of Radiographer	1.6500	90.00	0.0000045	1.6500	90.00	0.0000045	1.6500	90.00	0.0000045
D_T of Radiographer	1.7241	73.14	0.0000040	1.7241	21.80	0.0000040	1.7241	21.80	0.0000040
D_L of Radiographer	1.7627	69.40	0.0000040	1.7627	17.90	0.0000040	1.7627	17.90	0.0000040
D_H of Nurse	0.3000	90.00	0.0000045	0.5000	90.00	0.0000045	0.2000	90.00	0.0000045
D_T of Nurse	0.5381	30.90	0.0000050	0.7071	45.00	0.0000045	0.5385	21.80	0.0000050
D_L of Nurse	0.6888	25.80	0.0000055	0.7965	38.90	0.0000042	0.6515	17.90	0.0000050

Results

All the p values (Table 2) are less than the significance level. It indicates that the mean dose values acquired by each type of theatre personnel are different from one another.

Table 2. p values obtained from ANOVA

Comparison	*p value from ANOVA*	*Hypothesis*
D_H of four types of participants for DHS	0.000	Reject the H0
D_T of four types of participants for DHS	0.000	Reject the H0
D_L of four types of participants for DHS	0.000	Reject the H0
D_H of four types of participants for TPF	0.000	Reject the H0
D_T of four types of participants for TPF	0.000	Reject the H0
D_L of four types of participants for TPF	0.000	Reject the H0
D_H of four types of participants for DRF	0.000	Reject the H0
D_T of four types of participants for DRF	0.000	Reject the H0
D_L of four types of participants for DRF	0.000	Reject the H0

According to the mean dose values (Table 3) and the interval plots shown (Figure 1), it is evident that the highest ORD is mostly acquired by the orthopaedic surgeon, while the lowest is acquired by the anaesthetist, except in certain instances. In particular, the DH acquired by the scrub nurse during the DRF surgery is higher than that of the orthopaedic surgeon.

Table 3. Mean dose values (in mSv) acquired by theatre personnel during selected orthopaedic surgeries

	DHS			*TPF*			*DRF*		
Theatre personnel	D_H	D_T	D_L	D_H	D_T	D_L	D_H	D_T	D_L
OS	0.123	0.021	0.014	0.039	0.007	0.005	0.011	0.002	0.001
SN	0.061	0.021	0.014	0.007	0.004	0.003	0.012	0.002	0.001
RA	0.002	0.002	0.002	0.001	0.001	0.001	0.000	0.000	0.000
AN	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000

The simulated doses were extrapolated to annual doses considering the mean dose per each type of surgery and the mean number of particular surgeries carried out per month. One-sample t-test was performed at the significance level of 5% on the extrapolated annual doses to compare them with the international recommended dose level of 20.0mSv per year. The p-value which equals to 0.000 and figure 2 confirm that all the estimated doses per each type of surgery are well within the international recommended dose level of 20.0mSv per year [8].

Discussion

The current study has investigated the ORDs to the orthopaedic surgeon, anaesthetist, radiographer, and assisting nurse during a selective set of orthopaedic surgeries. This simulated doses of D_H, D_T, and D_L per each type of surgery are well within the international recommended dose level of 20.0mSv per year. Similarly, according to the study conducted by Mustafa S Rashid *et al*. the measured mean ORD during common orthopaedic surgeries were well within permissible limits of International Council for Radiation Protection (ICRP). Further, the individual dose of right wrist had the maximum mean exposure dose followed by left wrist, neck, chest, and gonads [9].

ANOVA test has confirmed that the individual mean dose values are different from occupation to occupation depending on their location inside the theatre. In terms of organ specific doses (D_H, D_T, and D_L) the theatre personnel from the selected sample are exposed to mean ORDs that are well within the standard references. The mean ORDs received by hands, thyroid, and lenses are 0.02141mSv, 0.00175mSv, and 0.0035mSv respectively. Based on the results highlighted by Mahajan *et al*. the orthopaedic surgeons in India were also exposed to organ-specific radiation doses to neck (0.328mSv), chest (0.17mSv), gonads (0.15mSv), right wrist (0.73mSv), and left wrist (0.58mSv) that were well below the ICRP limits. In comparison of these values, it is evident that the doses obtained by the theatre staff of the current study are even below the values of the Indian population for hand and thyroid [9].

Other than that, maintaining local diagnostic reference levels (DRL) could be more helpful to establish local guidelines regarding occupational exposure. Among the studies that suggest DRLs for ORDs during orthopaedic surgeries, Mustafa S Rashid *et al*. have suggested considerable DRLs, separately for common orthopaedic surgeries. The researchers suggest median DAP values of 0.6675Gycm^2 for DHS, 0.1850Gycm^2 for Tibial surgery, and 0.00274Gycm^2 for DRF surgery. In the current study, the authors have obtained median DAP values of 0.5600Gycm^2 for DHS, 0.2035Gycm^2 for Tibial surgery, and 0.0303Gycm^2 for DRF surgery. This indicates that the median DAP per DHS, TPF, and DRF surgery in the selected two hospitals in Sri Lanka are around the DAP values suggested by Mustafa S Rashid *et al* [4].

Conclusion

During the orthopaedic surgeries of the selected hospitals, all the theatre staff are exposed to radiation doses well within the permissible limit. Each individual dose quantity of D_H, D_T, and D_L acquired per single type of orthopaedic surgery is below the annual permissible dose limit of 20.0mSv.

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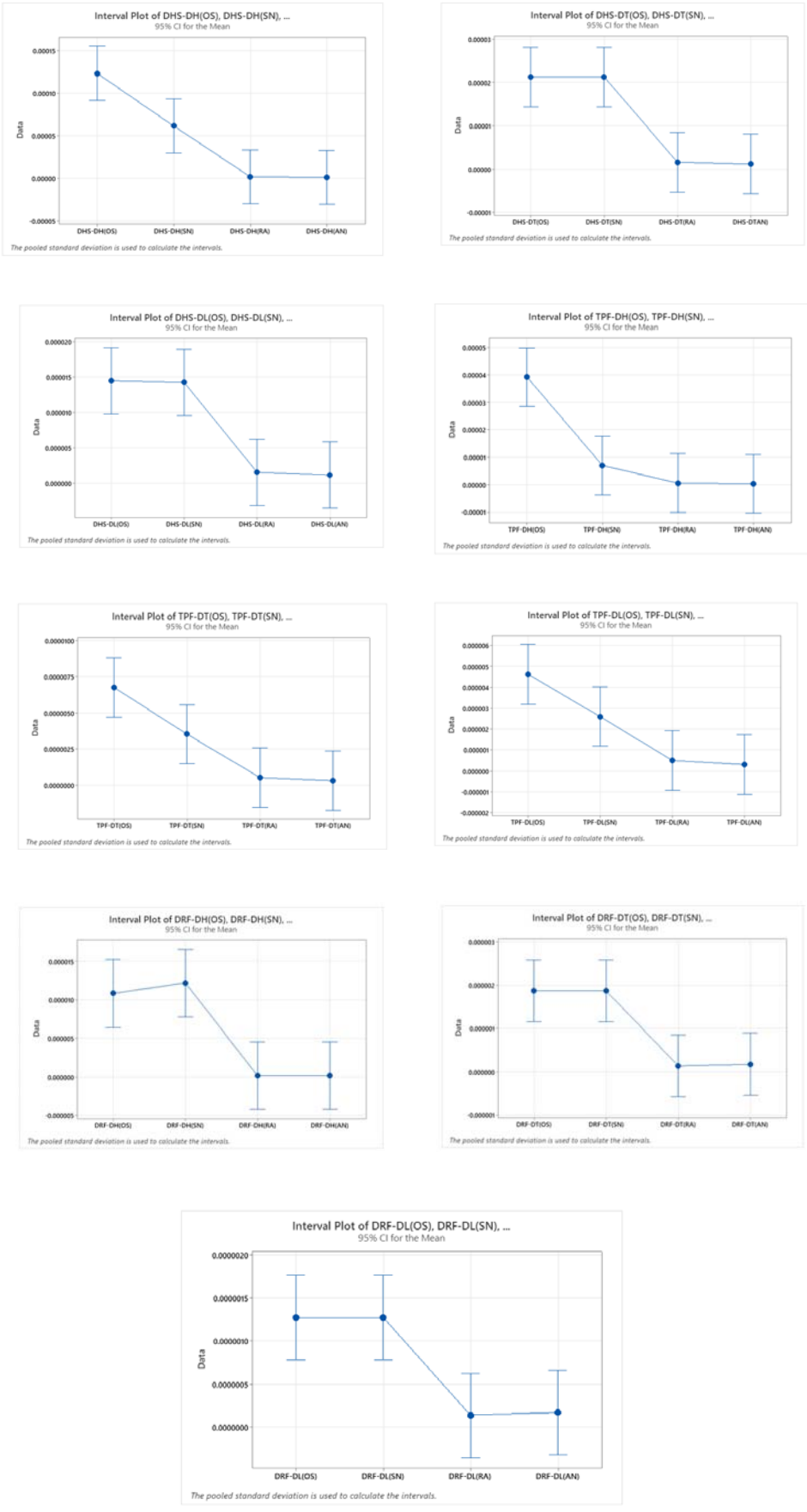

Figure 1. **Comparison of mean dose values acquired by theatre personnel during selected orthopaedic surgeries**

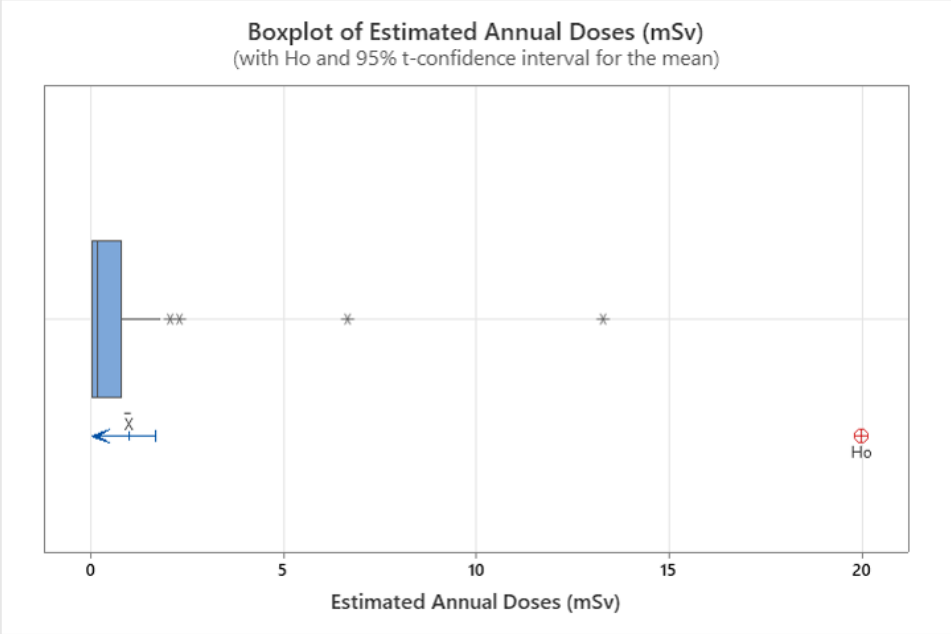

Figure 2. **Comparison of the extrapolated annual mean occupational radiation doses with the standard international reference values**

Conflict of interests

There are no conflict of interests.

References

1. "History of radiology – British Institute of Radiology." https://www.bir.org.uk/useful-information/history-of-radiology.aspx (accessed Jul. 14, 2021).
2. Mohammad H. "An Introduction to Orthopaedic Surgery," W*orld J. Med. Educ. Res*. 2013; **3**(3): 68-71.
3. "When to Use Mobile C-arm Machines? (Guide) - LBN Medical," 2019. https://lbnmedical.com/when-to-use-c-arm-machines/ (accessed Nov. 22, 2020).
4. Rashid MS, Aziz S, Haydar S, Fleming SS, Datta A. "Intra-operative fluoroscopic radiation exposure in orthopaedic trauma theatre," *Eur. J. Orthop. Surg. Traumatol*. 2018; **28**(1): 9-14. doi: 10.1007/s00590-017-2020-y.
5. Tsalafoutas IA *et al*. "Estimation of radiation doses to patients and surgeons from various fluoroscopically guided orthopaedic surgeries," *Radiat. Prot. Dosimetry*. 2008; **128**(1): 112-9. doi: 10.1093/rpd/ncm234.
6. Abas AA, Rahman RA, Yahya N, Kamaruzaman E, Zainuddin K, Manap NA. "Occupational radiation exposure to anesthetists from fluoroscopic projections during orthopedic operative procedures," *Clin. Ter*. 2014 **165**(4). doi: 10.7417/CT.2014.1739.
7. Hulley SB, Cummings SR, Browner WS, Grady DG, Newman TB. *Designing Clinical Research*. Lippincott Williams & Wilkins, 1988.
8. "Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards General Safety Requirements Part 3," *IAEA Saf. Stand.* 2014; **3**.
9. Mahajan A, Samuel S, Saran AK, Mahajan MK, Mam MK. "Occupational radiation exposure from C arm fluoroscopy during common orthopaedic surgical procedures and its prevention," *J. Clin. Diagn. Res.* 2015; **9**(3): RC01-RC4. doi: 10.7860/JCDR/2015/10520.5672.