

Evaluation of staff and ambient exposures during orthopedic procedures

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Abstract

Objectives: The aims of this study were to evaluate staff radiation doses during dynamic hip screw (DHS) and dynamic cannulated screw (DCS) procedures and also to measure the ambient exposure in three orthopedic departments in Khartoum state -Sudan.

Methods: Staff doses were measured in 34 procedures using thermoluminescence dosimeters (TLDs) LiF:Mg,Cu,P type (GR200) at five anatomic locations (forehead ,thyroid ,hand chest and leg). Ambient dose was measured using area monitoring survey meter (Rados 120).

Results: The mean radiation dose for both procedures were 0.15 mGy, 0.18 mGy, 0.2 mGy, 0.23 mGy, 0.19 mGy for the forehead, thyroid, chest, right hand and for the leg, respectively.

Conclusion: The radiation dose to the staff is well within established safety limits, in the light of the current workload. The results encourage operators for further dose optimization.

Key Words: Occupational medical exposure; Staff orthopedic dosimetry; Orthopedic procedures; X-Ray C-Arm

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INTRODUCTION

The use of fluoroscopic guidance in orthopedic surgery now is common practice, because of the lower infection occurrence and small incision wounds at surgery sites. Due to the increasing number of invasive procedures in orthopedic surgery (e g dynamic hip screw (DHS), dynamic cannulated screw (DCS)), particular attention to radiation exposure and protection measures for the staff is warranted. The radiation dose of a surgeon depends on many factors, including the type and generator of the C-arm (Mini or conventional C-arm), the exposure time, the distance from the beam's central axis, the orientation of the fluoroscopic beam relative to the patient, the position of the surgeon in the operating room and the use of protective shields ^[1]. The data available in the open literature on the level of exposure to radiation during the normal working pattern of individual surgeons is limited ^[2]. However, hands of surgeons remain very close to primary radiation beam during fluoroscopy where the scattered radiation is high. Therefore, the measurements

of radiation doses delivered to the hands, the thyroid and the waist of the surgeon as well as scattered radiation within the operating room is crucial. Since the staff changes its position frequently during the procedure, ambient radiation exposures around the c-arm are indicative.

Although, the scattered radiation measurement is important, only few studies have been reported ^[1,2]. High radiation doses delivered to the staff during orthopedic procedures were reported by several authors ^[1-7]. These studies indicated that the radiation dose to the different parts of the surgeons' body and his assistant is significant with wide variations. These variations were attributed to differences in beam orientation, mini or conventional C-arm, field of view (FOV) and staff experiences. Many studies have encouraged staff to identify the safety precautions in order to prevent serious complications from radiation ^[8,9]. However, in practice as authors noted orthopedist did not follow these recommendations. In Sudan, no data has been published in open literature regarding patient and staff radiation doses during orthopedic procedures. This might be attributed to the lack of adequate dosimetry laboratories and weak health care infrastructure. Therefore, the current study will seek to provide first-hand information on orthopedist staff entrance skin dose (ESD). In spite of the fact that this is

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not a dosimetric quantity but it can be used to extract organ dose which is a dosemetric quantity.

MATERIALS AND METHODS

Dosimeters

Radiation doses were measured using TLD chips LiF: Mg, Cu, P type (GR200). A total of 72 chips were used in this study. The TLDs were calibrated under reproducible reference conditions using typical diagnostic x-ray beam qualities according to the protocol reported by Sulieman *et al*^[10], with different fluoroscopic factors and beam geometry. The uncertainty of TLD readings was estimated to be <10% for all the procedures.

X-ray machines

Three different x-ray machines were used

throughout this study, all of them equipped with high frequency (HF) generator and have last image hold capability. All machines were not equipped with Kerma air product (KAP), but have ability to be operated in continuous beam and pulse fluoroscopy modes (0.2 sec/pulse) during different procedures. The technical specifications of the machines used during this study are shown in Table 1. All the three machines passed the quality control tests performed by Sudan Atomic Energy Commission (SAEC).

Staff dose measurements

Radiation doses were measured during 34 procedures performed in three hospitals namely, Mulazimeen hospital (MH), National Ribat University hospital (NRUH) and Omdurman Medical corps hospital (OMC).

Table 1: The technical specifications of the C-arm machines used in this study

Machine	Origin country	Model	Max kVp	Generator type	Beam Filtration AL(mm)	Installation date	Last image hold
Siemens	Germany	Siremobil 2000	120	HF	2.5	2009	Yes
Siemens	Germany	Siremobil 4K	120	HF	2.7	2004	Yes
Wolverson	Italy	TCA3M9/6	140	HF	2.5	1999	Yes

HF=High Frequency

The patients were divided into two groups according to the procedure type: group A consists of 19 patients who underwent DHS procedure and group B consists of 15 patients who underwent DCS procedure. Three TLD chips enclosed in a transparent polyethylene foil envelope were taped at different anatomic locations. All personnel involved wore a rubber lead apron of 0.5 mm lead equivalent for protection against scattered radiation. No protective equipment were available in the room such as ceiling suspended shield, shield attached to the operating table, etc. Similarly, no thyroid collar or lead glasses were used. The dose received by the surgeons was measured by taping the TLD envelope on five sites: thyroid region, the forehead (eye lenses), at chest over the protective shield, right hand (wrist) and left leg. Patient set-up and staff location during the procedures is shown in Figure. 1.

The staff-absorbed dose was taken as the 10% of the dose recorded by the TLD outside the lead apron^[11]. For the unprotected parts of the body, the ESD was assumed to be the same as the dose recorded on the TLDs. The equivalent dose has been taken as equal to the absorbed dose (applicable for low LET radiation). The effective dose to the organs and tissues has been

calculated using the methodology and tissue weighting factors reported by Bethesda^[11]. A computer based program was used for calculating the doses to 4 organs and tissues^[12].

At each x-ray Department, one operating team was selected (locations was depicted in Figure 1) to perform all the procedures, in order to avoid inter-operator variations which may occur as the result of different skills and experiences among the operators.

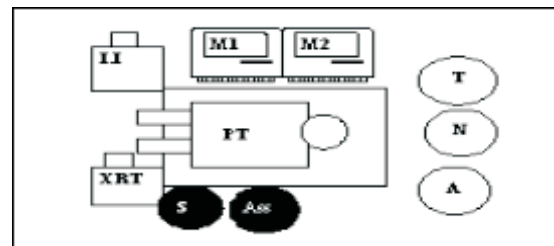


Figure.1: Patient and staff location during the procedures (XRT= X-ray tube, I.I= image intensifier; S=surgeon; ASS= assistant surgeon, A= anesthetist, N = nurse, T= X- ray technologist; PT = patient, M1 & M2 = monitors).anesthetist, N = nurse, T= X- ray technologist; PT = patient, M1 & M2 = monitors).

Ambient dose measurements

The scattered radiation within the operating room around the c-arm machine was measured using a calibrated radiation protection area monitoring survey meter (Rados 120). Measurements were carried out at different distances (20 cm, 40 cm, and 60 cm) from beam central axis, in different directions at the level of operating surgery couch as depicted in Figure 2. These distances are the positions where the personnel commonly stand during the procedures. A water tank phantom with dimensions 20 x20 x10 cm³ was employed during the measurement process.

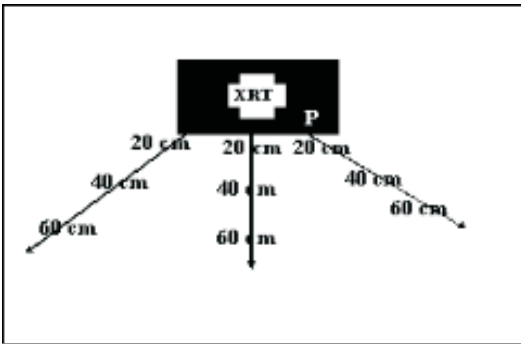


Figure. 2: Setup of ambient dose measurement locations from central beam axis (P = Phantom; XRT= X-ray tube).

RESULTS AND DISCUSSION

The mean values of fluoroscopic exposure factors for both DHS and DCS procedure were 71±2 kVp, 1.3±0.6 mA and 0.68±0.13 min. The radiation doses delivered to the different parts of the surgeon during DHS and DCS procedures as measured using TLDs were presented in Table 2. The average, the values obtained were 0.15±0.02 for the forehead, 0.18±0.04 for the thyroid, 0.20±0.06 for the chest, 0.23±0.2 for the right hand and 0.19±0.04 mGy for the left leg. Compared this results with data reported by Lo *et al*^[4], Bahari *et al*

^[5] and Abu Shab *et al*^[15], it seems there is no considerable variation to the radiation doses received by the different parts of the surgeon's body that were monitored, however, from the value of the standard deviation it is clear that there is a high fluctuation to the dose at the right hand in contrast to other sites because the hand always remains near the primary beam for the necessary manipulation of the procedure (plate insertion or keep plate at accurate position).

Likewise, Bahari *et al*^[5] reported similar radiation dose for thyroid (0.21 mGy), but relatively higher to the hands (0.8 mGy) and this might be attributed to the differences in practical experiences among surgeons and workload. It is known that the radiation exposure received by an individual surgeon usually related to the workload of patients, the type of procedure being performed, the techniques employed, the age, standard performance of the image intensifier and x-ray system used. Goldstone *et al*^[6] reported that the maximum radiation dose to the surgeon's hand who performed about 15 different procedures would be 2.3 mSv for one month, accordingly the radiation dose per annum would exceed 30 mSv which is far below the annual dose limit of 500 mSv according to ICRP, 2007^[13]. In this study, the radiation doses to the staff were measured per procedure during DHS and DCS procedures because they are more frequently performed and constitute 72% of the total procedures. DHS procedure requires more fluoroscopic time and hence higher fluoroscopic exposure factor (mean time 0.97 min, 75 kVp, 1.8 mA) as compared to DCS procedure (mean fluoroscopic time 0.81 min, 69 kVp, 1.1 mA). High kVp and long fluoroscopic time results in more scattered radiation and consequently more radiation dose to surgeon. Accordingly, the orthopedist should take care about shielding and distance to minimize radiation exposure during DHS procedures.

Table 2: Staff ESD (mGy) incurred during procedures present study and literature

Current study				Previous studies	
Site	Mean ±STD	Max	Min	Bahari <i>et al</i> ^[5] mean ESD mSv	Abu Shab <i>et al</i> ^[15] mean mSv
Eye	0.15±0.02	0.19	0.12	N.A	N.A
Thyroid	0.18±0.04	0.19	0.17	0.21	0.16
Chest	0.20±0.06	0.29	0.16	N.A	N.A
Hands	0.23±0.2	0.26	0.21	0.80	0.18
Leg	0.19±0.04	0.22	0.19	N.A	N.A

N.A= Not available

The staff-absorbed dose is given in Table 3 for different organs as estimated from TLD attached at chest level over lead apron. The total effective dose per procedure for orthopedist amounts to 0.05 mSv, subsequently an orthopedist needs to perform about 400 procedures per year to receive an annual dose limit of 20 mSv.

Table 3: The staff-absorbed dose (mSv) for different organs

Tissue or organ	Wt	Ht(mSv)	E(mSv)
Gonads*	0.08	0.02	0.0016
Lung*	0.12	0.02	0.0024
breast*	0.12	0.02	0.0024
Thyroid*	0.04	0.02	0.0008
Total	1		0.0452

Table 4: Mean ambient dose rates ($\mu\text{Sv}/\text{min}$) at specific distances from central beam averaged over three hospitals and compared to literature values

Distance (cm)	Present study	Badman et al (2005)	Mesbahi et al (2008)
20	4.63	2.4	3.68
40	1.09	0.65	0.75
60	0.48	0.26	0.36

Ambient exposure rates ($\mu\text{Sv}/\text{min}$) during the entire procedures (DHS& DCS) have been measured at specific distances from central beam axis (Figure.2). The results were shown in Table 4 as average values of the three hospitals. The values obtained here at 40 and 60 cm are typical of those reported by Badman et al^[1] and Mesbahi et al^[2], except at 20 cm distance which is slightly higher. This could be due to variations in equipment specifications such as filtration, collimation and fluoroscopic factor or field of view FOV encountered during the procedures

The radiation dose rate decreases as distance from X-ray tube focal spot increases. Therefore, the orthopedist hands should be moved away as far as possible from the irradiated part of the patient, and the assistant personnel in the operating room should stand as far away as possible from the primary beam (Figure 1). In addition, the amount of scattered radiation increases proportionally with the irradiated area, hence beam collimation should always be used. Laxman et al^[3] have stated that the surgeons and their assistants always remain near the surgery sites; therefore they should always use an effective shield barrier and other relevant protective devices to prevent exposure to radiation. Brian et al^[7] reported that surgeon exposure was much

greater when large C-arm was used compared to mini C-arm. Therefore, since this study has used large C-arm, higher exposure rates are encountered compared to values reported by Brian et al^[7].

CONCLUSION

Based on the results obtained it could be concluded that, the mean radiation doses received by the surgeon during DHS and DCS procedures fall within the acceptable limits in the light of the current workload. Measurement of ambient exposure rate during procedures is useful for staff protection because it guides them to change their positions to safe areas in a manner to minimize radiation exposure. Further radiation dose reduction could be achieved by using mini C-arm. Staff training is crucial, in spite of the low radiation doses during selected procedures, no matter other procedures may carry risk to both patient and theatre staff.

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