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Evaluation Of Staff And Patient ryRadiation Doses In Orthopedic Surge

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Abstract

Orthopedists are exposed to considerable radiation dose during orthopedic surgeries procedures. The staffs are not well trained in radiation protection aspects and its related risks. In Sudan, no regular monitoring services are provided for all staff in radiology or interventional personnel. Therefore, it is mandatory to measure staff and patient exposure in order to radiology departments. The main objectives of this study are to measure the radiation dose to patients and staff during (i) Dynamic Hip Screw (DHS) (ii)Dynamic Canula Screw (DCS), estimate the risk of the aforementioned procedures and to evaluate entrance surface dose (ESD), organ and surface dose to specific radiosensitive patient's organs. The measurements were performed in two different departments: (i) Omdurman Military Hospital and (ii) Mulazimeen Hospital. The dose was measured unprotected organs of staff and patient as well as scattering radiation. Calibrated Thermo luminescence dosimeters (TLD-GR200) of lithium fluoride (LiF: Mg, Cu,P) were used for ESD measurements. TLD signal will be obtained using automatic TLD Reader model (PLC3). The mean patients' doses were 0.46 mGy and 0.07 for DHS and DCS procedures, respectively. The mean staff doses for thyroid and chest were 4.69 mGy and 1.21 mGy per procedure, at the same order. The mean radiation dose for staff was higher in DHS compared to DCS. This can be attributed to the long fluoroscopic exposures due to the complication of the procedures. Efforts should be made to reduce radiation exposure to orthopedic patients, and operating surgeons especially those undergoing spinal surgery. Well training, continuous monitoring and rich knowledge about hazard among orthopedist are starting steps to reduce radiation risk

Key Words: Radiation ,Doses , Orthopedic Surge.

INTRODUCTION

Medical imaging has become a major source of ionizing radiation exposure to patients and medical staff. This ionizing radiation, impacting the health of human tissues, is significant in dose-intensive medical imaging procedures such as CT, nuclear medicine (SPECT/PET) and fluoroscopy. In the U.S. alone, the radiation exposure from medical procedures in the last few decades has increased more than seven-fold (1).Due to the risk of ionizing radiation, the medical research community, governmental regulators, healthcare labor organizations and the general media are openly discussing their growing concerns of radiation exposure. In addition to a hearing held by the U.S. Congress, both the National Council for Radiation Protection and Measurements (NCRP) (2) and the Food and Drug Administration (FDA) [Food and Drug Administration, Initiative to Reduce Unnecessary Radiation Exposure from Medical Imaging (2010)] have called for new methods to reduce medical radiation exposure to patients and medical staff. Among medical imaging procedures, fluoroscopy has the potential to create the highest radiation exposure.[1]

Interventional radiology:

Interventional fluoroscopy uses ionizing radiation to guide small instruments such as catheters through blood vessels or other pathways in the body. Interventional fluoroscopy represents a tremendous advantage over invasive surgical procedures, because it requires only a very small incision, substantially reduces the risk of infection and allows for shorter recovery time compared to surgical procedures. These interventions are used by a rapidly expanding number of health care providers in a wide range of medical specialties. However, many of these specialists have little training in radiation science or protection measures. The growing use and increasing complexity of these procedures have been accompanied by public health concerns resulting from the increasing radiation exposure to both patients and health care personnel. The rise in reported serious skin injuries and the expected increase in late effects such as lens injuries and cataracts, and possibly cancer, make clear the need for information on radiation risks and on strategies to control radiation exposures to patients and health care providers. This guide discusses the value of these interventions, the associated radiation risk and the importance of optimizing radiation dose. The number of orthopedic procedures requiring the use of fluoroscopic guidance has increased over the recent years.[3] It is now accepted that closed operative procedures are the treatment of choice in many types of complex fractures because of their lower infection and, smaller incision wounds and relatively low morbidity at implant removal.[4] The use of such procedures has increased in popularity. As these procedures require considerable amount of fluoroscopic guidance, the staff in operating theatres have voiced concern over the danger of excessive exposure to radiation. The radiation dose of a surgeon depends on many factors, including 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 within the operative field and the use of protective shields.[5] In addition, the radiation exposure is dependent on the unit's design (input screen sensitivity of image intensifier, conversion factor (Gx)) and x-ray generator type) and irradiation geometry.[6] As there is little information available on the level of exposure to radiation during the normal working pattern of individual surgeons, this study considers measurement of radiation dose during orthopedic fracture fixation. However hands and thyroid of surgeons are most likely exposed to primary radiation beam during

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fluoroscopy since they are unprotected. Therefore, radiation doses delivered to hand, thyroid and waist of the surgeon is significant. Patient entrance skin dose (ESD) is a basic parameter which has been used to report patient doses, and this has been studied in many parts of the world In Sudan, as far as author know, no study has been published in open literature regarding patient and staff radiation doses during orthopedic procedure except one study performed by Osman et al (2011). The means to achieve this are the design and maintenance of equipment, training and experience of surgeon and staff, robust operating procedure (clinical protocol). These matters are controlled by requirement of regulation and legislation, which need not to be discussed further here. The benefits of properly performed interventional fluoroscopy almost always outweigh the radiation risk experienced by an individual. However, unnecessary exposure to radiation can produce avoidable risk to both the patient and operator.

Radiation risk:

The short-term risk to patients is radiation-induced skin damage, which can result from acute radiation doses of ≥2 Gy. The extent of the skin injury may not be known for weeks after the procedure. Repeated procedures increase the risk of skin injury, because previous radiation exposure sensitizes the skin.It is generally accepted that there is probably no low dose “threshold” for inducing cancers, i.e. no amount of radiation should be considered absolutely safe. Recent data from the atomic bomb survivors,[7] and medically irradiated populations (UNSCEAR 2000) demonstrate small, but significant increases in cancer risk even at the level of doses that are relevant to interventional fluoroscopy procedures. The increased risk of cancer depends upon the age and sex of the patient at exposure. Children are considerably more sensitive to radiation than adults, as consistently shown in epidemiologic studies of irradiated populations.

Objectives :The main objective of this study is to keep dose to both staff and patient as low as reasonably practicable (ALARP) and to establish national diagnostic reference level that consistent with international reference level.

Specific objectives to: 1Optimize the radiation dose to patients and staff during (i) Dynamic Hip Screw (DHS) (ii)Dynamic Canula Screw (DCS) (iii) Total Hip Replacement (THR) (iv) Nailing (v) Rush nailing

1.Measure and estimate the risk of the aforementioned procedures.

Evaluate entrance surface dose (ESD), organ and surface dose to specific radiosensitive patient's organs.

MATERIAL AND METHODS

The population and study site

This study was conducted in two orthopedic centers one of them is governmental, and other is specialist centers (i) Omdurman Military hospital and (ii) Mulazimeen hospital.

X-ray machines

Five different x-ray machines were used throughout this study, three of them were similar found in MH and OMH which was Siemens Siremobil 2000 .all of them equipped with high frequency (HF) generator and have last image hold capability., all machines have ability to pulse fluoroscopy (0.2 sec/ pulse) but operator used both continuous and pulse beam during different procedures. The machines specifications were shown in Table 3.1

TLD Dosimeters:Thermo luminescence dosimeters

Table 3.1 C-arm machines specification.
HF=High Frequency

Machine	Origin country	Model	Max kVp	Generator type	Beam Filtration(mm)Al	Installation date	Last frame hold
Siemens	Germany	Siremobil 2000	120	HF	2.5	2009	Yes
Siemens	Germany	Siremobil 4 K	120	HF	2.7	2004	Yes

(TLD-GR200) of lithium fluoride (LiF: Mg, Cu,P) chips doped with magnesium and titanium will be used for staff (effective atomic number 8.2 and linear dose response up to 1 Gy).TLD signal will be obtained using automatic TLD Reader model (PLC3). Annealing will be performed using a manual TLD oven, model (PTW-TLDO)

Instrument Calibration:Calibration of an instrument involves a determination of its response or reading relative to a series of known radiation values covering the range of the instrument, and adjusting the instrument to provide a correct response. Three levels of “calibration” are generally recognized. These include a full characterization (usually done by the instrument manufacturer), a calibration for specific, perhaps unusual, conditions, and a routine calibration for normal working conditions using an appropriate source .Thermo luminescence d o s imeters (TLD – GR 200) oflithiumfluoride (LiF:Mg,Cu,P).TLD calibrated under reproducible reference condition using Toshiba Rotande model (T6-6TL-6) constructed in January 2005,inherent filtration0.7mm AL at75KV ,and focal spot 20/10 mm against ionization chamber PTW.CONNY II connected to radiation monitor controller in distance of 100cm

.Both the chamber and electrometer were calibrated for the energy range 30-120 kv at the national standard laboratory for the TLD and chamber irritation a Perspex calibration test bed had been constructed having dimensions of 25x25x1cm and the area of holes is 13x16x1cm irradiated at field size of 20x20cm and FFD100cm. First Perspex slab was used to accommodate the TLD chips in an array of slots 15 column x10 rows of holes Fig 3.3

Each TLD was identified by its position in the array (rawcoulomb). Individual calibration factors were obtained by irradiating the entire group to the same dose. The measured signal of each TLD was divided by the mean signal of the group this process repeated three times to remove the effect of statistical variations, and to determine the stability and reproducibility of the signal.

1.Used to load and unload TLD chips from the reader ,model Fimel CH/PCL , Germa3.3.4 TLD reader

The TLD signal was read using a manual TLD reader (Fimel PCL3, France), the soft ware program was (Theldo version 1E1) Germany Fig 3.7

Time –temperature profile (TTP):

Pre-heat temperature: (pre-readout)

This is done by heating to 55 0C for 2 seconds to ensure consistency of the reading, and to remove unwanted peaks.

Acquisition

The signal is acquired in 260 0C during 16 s with heating rate 110C/s to get the glow curve.

Table 4.1 Patient exposure factors during orthopedic procedures

Procedure	Tube Voltage (kV)	Tube current-time product(mAs)	ESD(mGy)
DHS	84(76-92)	4.2(3.6-4.8)	0.46
DCS	84(76-92)	4.2(3.6-4.8)	0.07
Total	168(76-92)	8.4(3.6-4.8)	0.53

Table 4.3 Staff doses during DCS procedures

Organ dose	Min	Mean	Median	3rd quartile	Maximum
Thyroid	0.01	1.21	0.10	0.06	0.17
Chest	0.05	0.07	0.06	0.10	0.10

Table 4.4 Patient doses during orthopedic procedures

Organ	DCS	DHS	Total
Patient	0.07	0.46	0.27

Table 4.2 Staff doses during DHS

Organ dose	Min	Mean	Median	3rd quartile	Maximum
Thyroid	0.004	4.69	.041	11.24	16.95
Chest	0.02	1.21	0.92	2.07	3.30

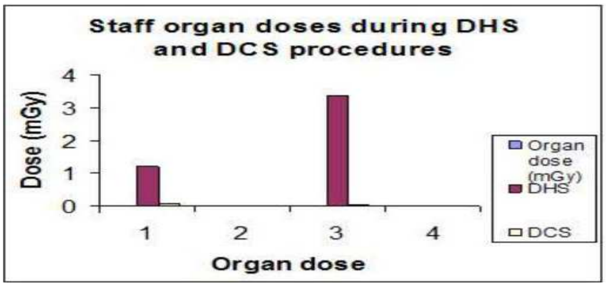

Figure 4.1: staff organ doses during orthopedic procedures

Table 5. 1 Comparison of the average thyroid radiation dose in this study and literature N.A=not available

Author	Procedure	Interventional type	Thyroid radiation dose (mSv)	ESD(mGy)
Hamid et al(2012)	DHS-DCS	Orthopedic	0. 0064	0.064±0.01
Bulsetal(2001)	HSG	Gynecology	0. 15	N.A
Devalia etal (2006)	IM	Orthopedic	0. 055	N.A
Janssenet al (1992)	N.A	Cardiology	0. 34	N.A
Ima et al (2000)	N.A	Cardiology	0. 10	N.A
Suliemanetal(2011)	ERCP	pancreaticobiliary	N.A	0.23
Suliemanetal(2008)	HSG	Gynecology	0. 0006	N.A
Present study	DHS-DCS	Orthopedic	3. 42	.53

Table 5 .2 Comparison of the average entrance radiation dose in this study and literature

Authors	No of Pt	Procedure type	Median	3rd quartile DAP or ESD	Mean ESD (mGy)	Effective dose (msV)
Sulieman et al (2007)	37	HSG	3.40	4. 94	3. 60	0. 43
Crawely et al	43	Iorthopedic	$2.58Gycm^2$	3. 74 $Gy\text{-}cm^2$	N A	0. 72
Suleiman et al 2011	57	I ERCP	44.79mGy	86.10mGy	75.6	4. 16
Kirousis et al (2009)	25	I orthoIMN	$2.87Gycm^2$	4. 47Gyc^2	4. 1	N.A
Klaus et al (2007)	60	TOCEIC	$4.53Gycm^2$	12.3 $Gy\text{-}cm^2$	34.2	4. 6
Mehdizadehetal(2007)	18	IC	2.56 mGy	3. 24 mGy	2. 97	N.A
Current study	110	I ortho	N.A	9. 01 mGy	7. 9	1. 21
Present study	33	DHS-DCS	N.A	N.A	0.53	N.A

The oven

An oven PTW- TLDO (PTW Fieburg-Germany) Fig 3.8 micro switch controlled ,with accuracy better than 1% is used to anneal the detectors at 240 °c for 10 mints Three trays Fig 3.5 can be used at the same time .

Method of dose calculations

Determination of detector correction factor (C_i):

$$C_i = (TL_i - BGR) / (TL - BGR)_{mean}$$

C_i: TLD correction factor.

TL_i: Thermoluminiscense of TLD chip after irradiation

BGR: mean background radiation. TL_{mean}: Mean TL signals.

Dose calculations: manually:

$$D = \frac{(TL-BGR/C)_i}{(TL_c-BGR/D_c*C)_i}$$

D_c Standard dose

Corrected dose = $D.F_{Lin}\ F_{en}.F_{fad}$

D: Dose (Gy). FLin: linearity correction factor

Fen: Energy correction factor :Ffad: Fading correction factor

P1=the orthopdist , P2=the X ray technologist ,P3=the handling nurse and M=monitor.

Method of measurement

Entrance Surface Dose (ESD): ESD is defined as the absorbed dose to air at intersection point of the X-ray beam axis with the entrance surface of the patient, including backscatter radiation. This dose is expressed in mGy. The ESD is estimated in order to assess the possibility of skin dose exceeding the threshold for deterministic effects. The total values of imparted radiation dose from all fluoroscopic and radiographic exposures involved in the specific examination. ESD depends on the exposure parameters (Tube voltage, Total filtration, mAs and FFD), and patient's conditions (patient positioning, field size, and sensitivity of image intensifier.

Staff Entrance skin dose :Radiation doses were measured in 110 procedures performed in five hospitals which are Mulazimeen hospital (MH), National Ribat University hospital (NRUH) , Omdurman Medical corps hospital (OMC).Blue Nile hospital (BNH) and Omdurman teaching hospital (OTH). Due to limited number of TLDs chips procedures were divided according to measurement task as follow for the first surgeon:56 procedure to measure orthopedist hand radiation dose,20 procedure to measure orthopedist thyroid radiation dose and finally 34 procedure to evaluate orthopedist chest, lens and leg radiation doses.

Protocol of measurements and work: The measurements phases were as follow:-

Firstly staff measurements were performed in DHS and DCS for thyroid ,chest and estimation of whole body and risks during these procedures, according to the availability of the TLDs. secondly hands radiation doses was evaluated .thirdly thyroid radiation doses was evaluated, and during these procedures patients dose was measured.

Orthopedist hands ESD: A total of 56 procedures were performed in three hospitals. Orthopedists performed Dynamic hip Screw (DHS, 19 procedures), Dynamic cannulated screw (DCS, 18 procedures), intramedullary nailing of peritrochanteric fractures (11 procedures) and internal fixation of malleolar fractures (8 procedures). Three TLDs were enclosed in a transparent polyethylene foil envelope and were placed over the palm of the hand under the surgery gloves and were kept in the required position with cello-tape. Surgeons' staff wore a rubber lead apron of 0.5 mm lead equivalent as protection from scattered radiation. No lead rubber cola worn during all procedures. At each department, a single operating team was chosen to perform all the procedures, in order to avoid inter operator variations could result from the different skills and experiences of the orthopedists.

Orthopedist's thyroid ESD:A total of 20 procedures were performed in the aforementioned hospitals. Procedures divided into two group according to the type of procedure performed, Group A Dynamic Hip Screw (DHS, 10 procedures), and Group B Dynamic Cannulated Screw (DCS, 10 procedures). These two procedures were selected for the study because they are most commonly performed, and often require significant number of images. Three TLDs were enclosed in a transparent polyethylene foil envelope and were placed over the skin at thyroid site as illustrated in Figure 1 and were kept in the required position with cello-tape. Surgeons' staff wore a rubber lead apron of 0.5 mm lead equivalent as protection from scattered radiation. No thyroid shield worn during all procedures. A single operating team was chosen to perform all the procedures, in order to avoid inter operator variations which could result from the different skills and experiences of the orthopedists.

Patients ESD:In all procedures patients entrance skin dose were evaluated using one envelope include three TLDs chips in a plastic envelop mounted on patient skin at midpoint of radiation field at a part of interest of the central axis beam using a very thin envelope made of transparent polyethylene plastic foil, to protect the TLDs from any contamination. During the radiographic procedure the TLDs are kept in the required position and are fixed in place with cello-tapes to measure ESD.

Patient dose measurement:ESD is directly measured using three TLDs (Lithium Fluoride GR 200A) placed on the organ site of the staff and patients' skin surface at the point of insertion of the central axis beam using a very thin envelope made of white polyethylene plastic foil, each contain three TLDs to protect the TLDs from any contamination and to avoid any shadow in the monitor.During the radiographic procedure the TLDs are kept in the required position and are fixed in place with cello-tapes.

RESULTS

Dose measurements were performed using a clibrated TLD GR 200 chips. To obtain the entrance surface dose, TLD envelop contain 3TLDs were attached on the organ site using an adhesive tape.The results were tabulated in the tables (mean ± standard deviation (sd)) and the range of the readings in parenthesis. The dose for sataff were quite small per procedures, but due to the high wokload and the shaorgae of the orthopedists, this values were considered significant. The dose values were presented in milli-Gray. The mean and the standard deviation were calculated using the excel software & SPSS program.

DISCUSSION

This study intended to measure patient and staff doses during two orthopedicprocedures. The measurements were performed in two different departments. The dose was measured unprotected organs of staff and patient as well as scattering radiation. A total of 100 thremoluminescennce dosimeters (TLDs) of lithium fluoride (LiF) chips (fimel-france) were used. The TLDs calibration was perfamaned according to the protocol reported by sulieman et al(2007).TLDs signal was read using manual TLDs reader (fimel-farnce) the readout at1000c pre heat temperature and reading temperature of 100-3000c with heating

. The mean ESD dose for patients was presented for both procedures in Table 4.2 and Table 4.3. The mean radiation dose for staff was higher in DHS compared to DCS. This can be attributed to the long fluoroscopic exposures due to the complication of the procedures. In Addition, DHS procedures are more common than the DCS procedures; therefore, staff was exposed frequently to high radiation dose. Table 4.1 present the exposure parameters for both procedures. No significant variation was noticed between the two procedures in exposure parameters. Table 5.1, showed a significant variation among interventionalist performed different procedures. The highest thyroid radiation dose associated with interventional cardiology IC due to complex nature of these procedures, where the orthopedist performed intramedullary nailing IM received the lowest radiation dose to thyroid, compared to the present study the radiation dose to thyroid was slightly lower and this may attributed to the different procedure encountered during both studies.In 1996, a preliminary survey of the membership of the Australian Orthopaedic Association (AOA) suggested an increased incidence of thyroid carcinoma in orthopaedic surgeons, due to the used of fluoroscopic image (Dewey 1996). This perception is the subject of ongoing investigation. Dewey and Incoll 1998, stated in their study for evaluation of the thyroid shields that the perceived increase in the incidence of thyroid carcinoma in orthopaedic surgeons prompted an assessment of the use and value of thyroid shields in the operating theatre. They used TLDs to monitor the orthopaedic registrar's thyroid, in addition, thyroid function, thyroid-stimulating hormone (TSH), free Thyroxin (T4)., free Triiodothyronine (T3), antimicrosomal antibody, and antithyrolobulin antibody tests were performed to exclude any abnormality related to radiation exposure. The radiation exposure measured on the TLD monitor ranged from of 0.01 to 0.4 mSv. They found that the thyroid function results were within normal limits, however the higher TSH levels occurred in trainees with the longest service. Dewey and Incoll 1998, concluded that the orthopaedic surgeons may be more likely to develop thyroid carcinoma if not protected from the radiation exposure. In this study authors noticed protective thyroid collar was not available in the current hospital, so no one of staff wore it.

Pt = patients TOCE = Transarterialoily chemoembolization IC interventional cardiology , HSG =Hysterosalipingography ERCP= Endoscopic retrograde cholangiography I ortho= interventional orthopedic ,IMN=Intramedullary nailing .From the values of the mean entrance skin dose obtained during this study, and compared to values in the study carried by Klaus et al 2007 for transarterial oily chemoembolization in interventional cardiology, this study showed lower value and this might be attributed to different procedure in which during cardiology procedure cardiologist required a considerable number of images taken with increased mA value (Technique Known by photospot imaging(FRCR)), in this technique mA value increased (pulsed fluoroscopy) to provide single spot image with adequate image quality with lower image noise, and this increase patient dose by 0.5 µGy for single shot which could result of patient irradiation equivalent to two second of screening with typical image intensifier dose rate of 0.25 µGy/sec (FRCR).Also mean ESD in Endoscopic retrograde cholangiography resulted in higher patient radiation dose than orthopedic procedure (> 11%) and this also might be due to different interventional procedures. As general any way most orthopedic procedure irradiate patient with lower radiation than in most cardiology or ERCP procedures

CONCLUSION

The mini C-arm had universally less radiation exposure than the standard C-arm in the clinical configurations tested. The orthopedic surgeons may be more likely to develop thyroid carcinoma if not protected from this radiation exposure. Digital fluoroscopic system with last frame hold should be encouraged. Efforts should be made to reduce radiation exposure to orthopedic patients, and operating surgeons especially those undergoing spinal surgery. Well training, continuous monitoring and rich knowledge about hazard among orthopedist are starting steps to reduce radiation risk.

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