Evaluation of Patient Radiation Dose during Orthopedic Surgery

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Abstract

The number of orthopedic procedures requiring the use of the fluoroscopic guidance has increased over the recent years. Consequently the patient exposed to un avoidable radiation doses. The aim of the current study was to evaluate patient radiation dose during these procedures.37 patients under went dynamic hip screw (DHS) and dynamic cannulated screw (DCS) were evaluated using Thermolumincent Dosimeters (TLDs), under c-arm fluoroscopic machines ,in three centers in Khartoum-Sudan. The mean Entrance Skin Dose (ESD) was 7.9 mGy per procedure. The bone marrow and gonad organ exposed to significant doses. No correlation was found between ESD and Body Mass Index (BMI), or patient weight. Well correlation was found between kilovoltage applied and ESD. Orthopedic surgeries delivered lower radiation dose to patients than cardiac catheterization or hysterosalpingraphy (HSG) procedures. More study should be implemented to follow radiation dose before surgery and after surgery

Key words :

Radiation dose, patient ,TLDs, orthopedic surgery

1-Introduction

The number of orthopedic procedures requiring the use of the fluoroscopic guidance has increased over the recent years (1). It is now accepted that closed operative procedures are the treatment of choice in many types of complex fractures because of their lower infection, smaller incision wounds and relatively low morbidity at implant removal (2), so fluoroscopic guided procedure in orthopedic surgeries now is common and favorite practice. However, patients exposed to un avoidable radiation exposure during these procedures, consequently radiation dose to radiosensitive organ just like bone marrow or gonads organs, which addressed as an important issue that must be taken into consideration. Moreover, most of those patients are subjected to additional exposure before surgery for diagnosis and after surgery for follow up. However, if the practice is justified and the protection optimised, the dose to the patient will be as low as reasonably achievable (ALARA) and compatible with the medical purpose(3).

The radiation beam in interventional fluoroscopy procedures is typically directed at a relatively small patch of skin for a substantial length of time. This area of skin receives the highest radiation dose of any portion of the patient's body. The dose to this skin area may be high enough to cause a sunburn-like injury, hair loss, or in rare cases, skin necrosis (5). Therefore, there is an imperative need to optimise the radiation dose and to assess the radiation risk per procedure, since tissue reactions (stochastic effects) are involved, in order to encourage the staff for further optimisation of patient doses. Optimisation of patient dose could be achieved by selection of modern equipment, adoption of good radiographic technique, well-trained personnel and well-defined Diagnostic Reference Level (DRL) in order to avoid unnecessary exposure to the patient(3,4).Patient entrance skin dose (ESD) is significant parameter which has been used to report patient doses, and this has been studied in many parts of the world (5,6,7,8,18). In Sudan, as far as authors know, no study has been published in open literature regarding patient radiation doses during orthopedic procedures. This might be attributed to the lack of adequate monitoring facilities, lower infrastructure in health care and the generally low level of interest among orthopedic surgeons as users of ionizing radiation. Therefore this will seek to provide first-hand data on patients ESD , and hence extrapolated effective dose E from the ESD value.

The current study intends to; (I) evaluate radiation dose to patients in three different orthopedic centers and (II) estimate patient organs doses .

2-Materials and Methods

2-1 Patients dose measurements

A total of 37 patients were examined, and evaluated in this study. Patients were divided into two groups according to type of orthopedic procedure (18 underwent Dynamic hip screw , fixation of the proximal end of the femur [DHS] and 19 dynamic cannulated screw, fixation of the distal end of the femur [DCS].

The indications for the investigations included the trauma fracture and pathologic fractures, which had been well diagnosed in the emergency department and out clinics. Ethics and research committee at each targeted orthopedic center approved the study and informed consent was obtained from all patients prior to the procedure. TLDs were packed on a thin envelope made of transparent plastic foil to protect the TLDs from any contamination, and at the same time not to appear in the final image or produce any image artifact . Each envelope contained three TLDs. The envelope kept in place at beam entry site with adhesive tape during the procedure.

For each patient, the following parameters were recorded i.e. fluoroscopic data: tube voltage, tube current and total screening time and patient data: name, age, weight, height, clinical indication and surgeon name, start and end time of the procedure.

2-2 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).

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

2-3 Dosimeters

Thermo luminescence dosimeters (TLD-GR200A) of lithium fluoride (LiF:Mg,Cu,P).TLD calibrated under reproducible reference condition using C arm machine Siemens siremobil mentioned in table one at72Kv , one mA and three pulses of pulsed fluoroscopy. against ionization chamber PTW.CONNY II connected to radiation monitor controller at standard distance of focal spot and image intensifier of the C-arm (this approach the average energy used during most orthopedic procedures encountered in the study) .Both the chamber and electrometer were calibrated for the energy range 30-120 kv at the national standard laboratory. The calibration was performed manually, a number of 120 TLDs irradiated on a Perspex calibration test bed , which had been constructed having dimensions of 25x25x1cm and the area of holes is 13x16x1cm irradiated at field size of 20x20cm. Perspex slab was used to accommodate the TLD chips in an array of slots 10 column x 12 rows of holes .

Each TLD was identified by its position in the array (raw, coulomb) three exposure performed, on the ionization chamber measured doses were 0.512mGy ,0.542mGy and 0.548mGy .Individual calibration factors were obtained by irradiating the entire group to the same dose. The measured signal of each TLD obtained by the reader was divided by the mean signal of the group, this process was repeated three times to remove the effect of statistical variations, and to determine the stability and reproducibility of the signal .After completing the calibration process, any element exceeded 20% error was excluded (9 chips) and the remaining chips were used to carry out the study measurements (111 chips).

2-4 Determination of detector correction factor (Ci):

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

Ci: TLD correction factor *TLi: Thermoluminiscense of TLD chip after irradiation*
BGR: mean background radiation *$TL_{mean:}$ Mean TL signal*

2-5 Estimation of organ dose and effective dose

ESD was used to assess the equivalent dose organ dose for selected organs during orthopedic procedures. Organ dose (mGy) estimation was made using computer software provided by the National Radiological Protection Board (NRPB-SR262)(9). Organs doses from DHS and DC S were obtained from the average value of conversion factors for anteroposterior pelvis view. The organ or tissue-specific weighting factor accounts for the variations in the risk of cancer induction or other adverse effects for the specific organ.

3- Results

Thirty seven patients were included in this study. The main indications for orthopedic surgery was trauma cases (75.7%),pathologic fracture (24.3%).all of the patients have examined with conventional x-ray prior to surgery procedure, and also have imaged after surgery procedure directly. And 57% have done two to three x-ray image as follow up (all pathologic fracture patients) Patients demographic data (height, age , weight, BMI), screening time per procedure and number of fluoroscopic images are presented in Table 2. Table 3 presents the minimum , median, mean third quartile and maximum values of the ESD.

Effective Organs radiation dose (mSv) was estimated using computer soft ware provided by the National radiological protection Board (NRPB SR 262) (9), as showed in Table 4.

The mean fluoroscopic factor for both procedure was 74 ±2.07 kV,1.12±0.2mA and 0.62 ±0.16 mins. DHS showed higher exposure factor (mean 74 ±2.2 kV,1.15±0.2mA and 0.64 ±0.18 mins) compared to DCS (72.3 ±1.9 kV,1.09±0.18mA and 0.6 ±0.14 mins). Moreover more fluoroscopic image were obtained during DHS compared to DCS, which will result in more ESD delivered to patient in DHS technique (ESD were 8.2 and 7.9 mGy for DHS and DCS procedure respectively).

Table 2 Patients physical characteristics (height, age, weight and BMI), screening time per exposure and number of fluoroscopic exposure (mean and the range in the parentheses.

Group	N	Height (cm)	Patients age	Weight (Kg)	BMI	Screening time per exposure	No of fluoroscopic images
All	37	163.4 (151-179)	49.5 (29-67)	69.6 (50-89)	25.9 (21.4-30.1)	0.6 (0.2-0.9)	6 (3-7)
DHS	18	166.2 (151-177)	46.7 (29-62)	71.8 (58-89)	25.8 (22.9-27.8)	0.7 (0.4-0.9)	5.8 (4-7)
DCS	19	1160.7 (152-179)	52.2 (35-67)	67.5 (50-80)	26 (21.4-30.1)	0.5 (0.2-0.9)	4.5 (3-6)

Table 3 Minimum, median, mean, ,third quartile and maximum values of ESD (mGy)

Group	No	Minimum	Median	Mean	3^{rd} quartile	Maximum
All	37	5.2	8.1	7.9	9.2	14.2
DHS	18	5.5	7.8	8.2	9.1	14.2
DCS	19	5.2	8.3	7.9	8.8	10.8

Table 4 Estimation of patient organ radiation dose

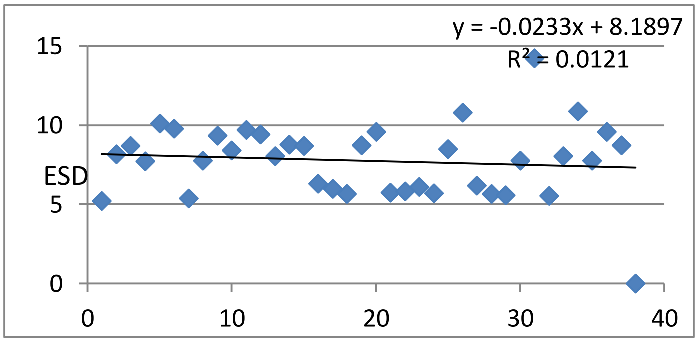
Tissue or organ	**Wt**	**E(mSv)**
Gonads	0.2	0.158
Bone marrow	0.12	0.0948
Bladder	0.05	0.0395
Breast	0.05	0.0395
Thyroid	0.05	0.0395
Bone surface	0.005	0.0395
Remainder	0.05	0.806
Total	1	**1.217**

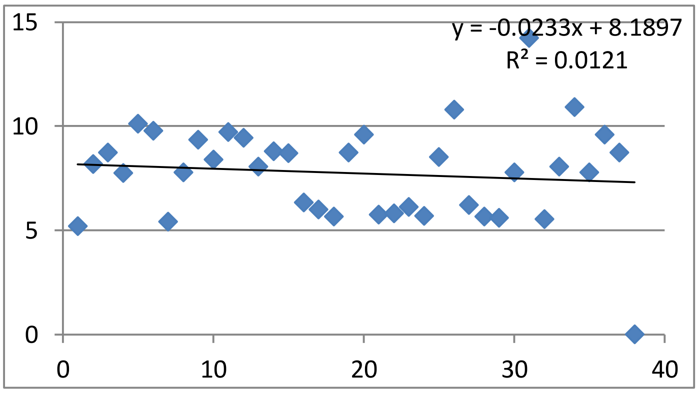
4- Discussion

Patient demographic data and exposure factors

The main factors affecting patients dose in fluoroscopic guided orthopedic surgery are: exposure factors, filtration, source to surface distance, collimation, pathology and complication of surgery. There were no significant differences between the two patients groups in terms of height, weight, BMI and fluoroscopic images.

A correlation was not found between ESD and patient weight and BMI (Figure 1 (a) and (b)),this might be attributed to complexity of procedure and number of exposure taken in each procedure. Correlation was found between kv applied and radiation dose (Figure 1 (c)) in which R^2 =0.9.





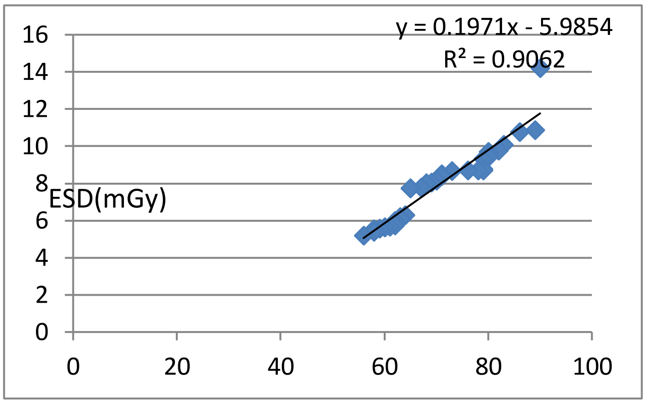


Figure 1 (a), (b) and (c) correlation between BMI , patient weight and Kv applied and ESD mGy.

Bone marrow and Gonad organ showed the higher organ dose compared to other organ and about 2% and 1.2% from ESD for aforementioned organs respectively.

In this study no dose area product DAP were used in all hospitals encountered throughout the study, however all of available literature DAP found to be an important tools in determining the ESD values for patients and hence extrapolated effective dose *E* from the ESD value, also as DAP is easy to assess.(10).

In a study carried by Crawely et al (11) , authors calculated the ESD using the formula

$$ESD= DAP/A_p$$

$$A_p = A_{ii}(d_p/d_{ii})^2$$

Where A_p is area irradiated at the patients input surface, A_{ii} is the field area at the intensifier input face, d_p is the distance from the x-ray tube focus to patients and d_{ii} is the distance from x-ray tube focus to the input image intensifier face. They revealed that the first, third quartiles and median of DAP (Gy-cm^2) for the patients in DHS were to be 1.7,3.7,2.6 (Gy-cm^2) respectively. and hence the average ESD for the aforementioned procedure was 4.76 mGy per procedure.

Compared the results of Crawely et al (11) to the current study, the current study showed higher value, and this could be attributed to varied x –ray C-arm machine used in each study and the type of practice used by different orthopedic surgeon. And the latter depend on the experience of the staff.

Table 5 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)(12)	37	HSG	3.40	4.94	3.60	0.43
Crawely et al(11)	43	Iorthopedic	2.58	3.74	N A	0.72

			Gy-cm^2	Gy-cm^2		
Sulieman et al (2011)(13)	57	I ERCP	44.79 mGy	86.10 mGy	75.6	4.16
Kirousis et al (2009)(14)	25	I ortho IMN	2.87 Gy-cm^2	4.47 Gy-cm^2	4.1	N.A
Klaus et al (2007)(15)	60	TOCE IC	4.53 Gy-cm^2	12.3 Gy-cm^2	34.2	4.6
Mehdizadeh et al (2007)(16)	18	IC	2.56 mGy	3.24 mGy	2.97	N.A
Current study	37	I ortho	8.1 mGy	9.02 mGy	7.9	1.21

Pt=patients TOCE=Transarterial oily chemoembolization
I ortho= interventional orthopedic IMN=Intramedullary nailing
IC interventional cardiology HSG =Hysterosalipingography
ERCP= Endoscopic retrograde cholangio pancreatography

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 (2oo7) (15) 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(17)), 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 (17).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.

Compared the results of this study with other studies in orthopedic procedures (11), this study showed higher value and this might be due to the physical of individual procedure, type of machine used and /or experience of surgeon.

In the study performed by Goldstone et al (18) the experiences of the staff play a gold role in the reduction of the radiation dose to both staff themselves and patient.

Conclusion

This study evaluated the patients radiation dose in orthopedic surgery under C arm fluoroscopic machines, using TLDs. The mean ESD was 7.9 mGy. And high organ dose was estimated for bone marrow and gonad organ (2% and 1.2% from ESD respectively. No correlation was found between ESD and BMI. Orthopedic procedure radiation dose depend mainly on orthopedist surgeon procedure, and delivered less radiation doses to patients than cardiac or hysterosalpingography procedures. More study should be implemented to follow radiation dose before surgery and after surgery

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