ASSESSMENT OF DOSE FOR CHEST X-RAY EXAMINATION AT STATE SPECIALIST HOSPITAL GOMBE (SSHG) AND FEDERAL TEACHING HOSPITAL GOMBE (FTHG), GOMBE STATE

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ABSTRACT

Assessment of dose for chest x-ray examination is of great value in radiation protection field. This study was carried out in two hospitals in Gombe, Gombe State Nigeria**.** The aim and objective of this work was to assess the Entrance Skin Dose delivered to patients during routine chest x-ray examination and the Effective dose. A total of forty-two (42) Thermoluminescent Dosimeters (TLD) were placed on the patients during chest x-ray exposure to estimate the Entrance Skin Dose received by patients of different ages and heights. The irradiated TLD chips used were read with a Hashaw 45100 TLD reader available at the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria. The ESDs and EDs were obtained using six approaches: Thermoluminescence Dosimeter (TLDs) chips, Edwin & McCullough's formula, Edmond's formula, Kumar *et al.*'s formula, Chougule & Hussaini's formula and Pratik *et al.*'s formula. The ESD result shows that the mean doses obtained in the two hospitals were 0.33 ± 0.04 mGy and 0.35 ± 0.07 mGy for SSHG and FTHG respectively. While the mean ED results were 0.04 ± 0.002 mSv and 0.04 ± 0.004 mSv for SSHG and FTHG respectively. The results obtained were slightly higher compared to other established work.

Key Words: X-ray Thermoluminescent Dosimeters, Effective Dose (ED) and Entrance Skin Dose (ESD).

INTRODUCTION

Diagnostic radiology is a rapidly developing branch of modern medicine. It has over the past few decades evolved into a highly sophisticated diagnostic tool; improving the imaging of human internal anatomy and detection of lesions which were previously impossible to detect (Ogbole et al., 2012). Despite its contribution to diagnosis, diagnostic radiology is burdened with the concern of the safety of patients and radiology staff. This is because the procedures of diagnostic radiology utilize X-ray. The harmful biological effects of X-ray have long been established (Hankouraou and Hamza, 2019). It was estimated that diagnostic radiology and nuclear medicine contributed 96% to the collective effective dose from manmade sources in the U.K reported by the National Radiological Protection Board (NRPB) in 1993 The study of biological effects of X-rays on living tissues started soon after its serendipitous discovery by Wilhelm Roentgen in 1895. To reduce the untoward biological effects associated with X-ray and the dose delivered to patients during medical intervention, the dose has to be kept as low as reasonably achievable

(ALARA principle) while at the same time trying to obtain optimum image for accurate diagnosis as recommended by the Internal Commission on Radiological Protection (ICRP) in 2001 report.

Dose measurement is also necessary so as to establish dose constraints, determine risk to patient and to justify the examination (Faulker *et al*., 1995). However, the use of X-ray radiation, even at low doses typically encountered in diagnostic radiology, is associated with the risk of cancer induction and other stochastic effects. In interventional radiology procedures radiation doses often exceed the threshold for deterministic effects. Numerous cases were reported in the literature for skin injuries during such procedures (ICRP, 2001).

Radiation dose to patients represents an estimate of the likelihood of patients to develop stochastic radiation effects. Thus, the greater the dose absorbed, the greater the chances of stochastic effects, and may even reach a level that can elicit some non-stochastic effects. In view of this, the objective of radiation protection is to keep the probability of developing stochastic radiation effects to a minimum. This is achieved by constant dose monitoring to ensure that doses delivered per examination are within safe limits, but dosimetry is rarely routinely carried out in many radiology departments because of lack of equipment and personnel. The significance of the study is to increase awareness of medical personals about the dose side effect that might arise after the X-ray examination. This study will assist in providing a base line data used in managing patients so as improve the radiographic modalities in use. The study is limited to Specialist Hospital Gombe (SSHG) and Federal Teaching Hospital Gombe (FTHG) radiology departments. The research is limited to chest X-ray examination for some adult patients using conventional X-ray.

MATERIALS AND METHODS

Materials and Study Area

A cross-sectional prospective design was adopted for this study. Ethical approval for this study was sought from Research Ethics Committee of the Federal Teaching Hospital and Specialist Hospital Gombe, Gombe state, prior to the commencement of data collection. The data that was used in this research was sourced from the two hospitals namely: Federal Teaching Hospital (FTHG) and Specialist Hospital Gombe (SSHG). The hospitals are located within the city of Gombe, the capital of Gombe state. It was located between the latitude$10^0$15'N and 10.25^0N (Latitude) and $10^0$10'E and 11.167^0E within the Sahel savannah belt as shown in (Figure 1).

Samples of 42 adult patients who came for chest X-ray examination at Federal Teaching Hospital Gombe and Specialist Hospital Gombe was used for this study. The patients were male and female. The choice of 42 adult patients was as a result of limited number of the TLD badges hired from the Centre for Energy Research Ahmadu Bello University Zaria. The X-ray machines that were used for this study are floor-mounted three-phase X-ray machine and Mobile X-ray machine at the Federal Teaching Hospital Gombe and State Specialist Hospital Gombe, Gombe State.

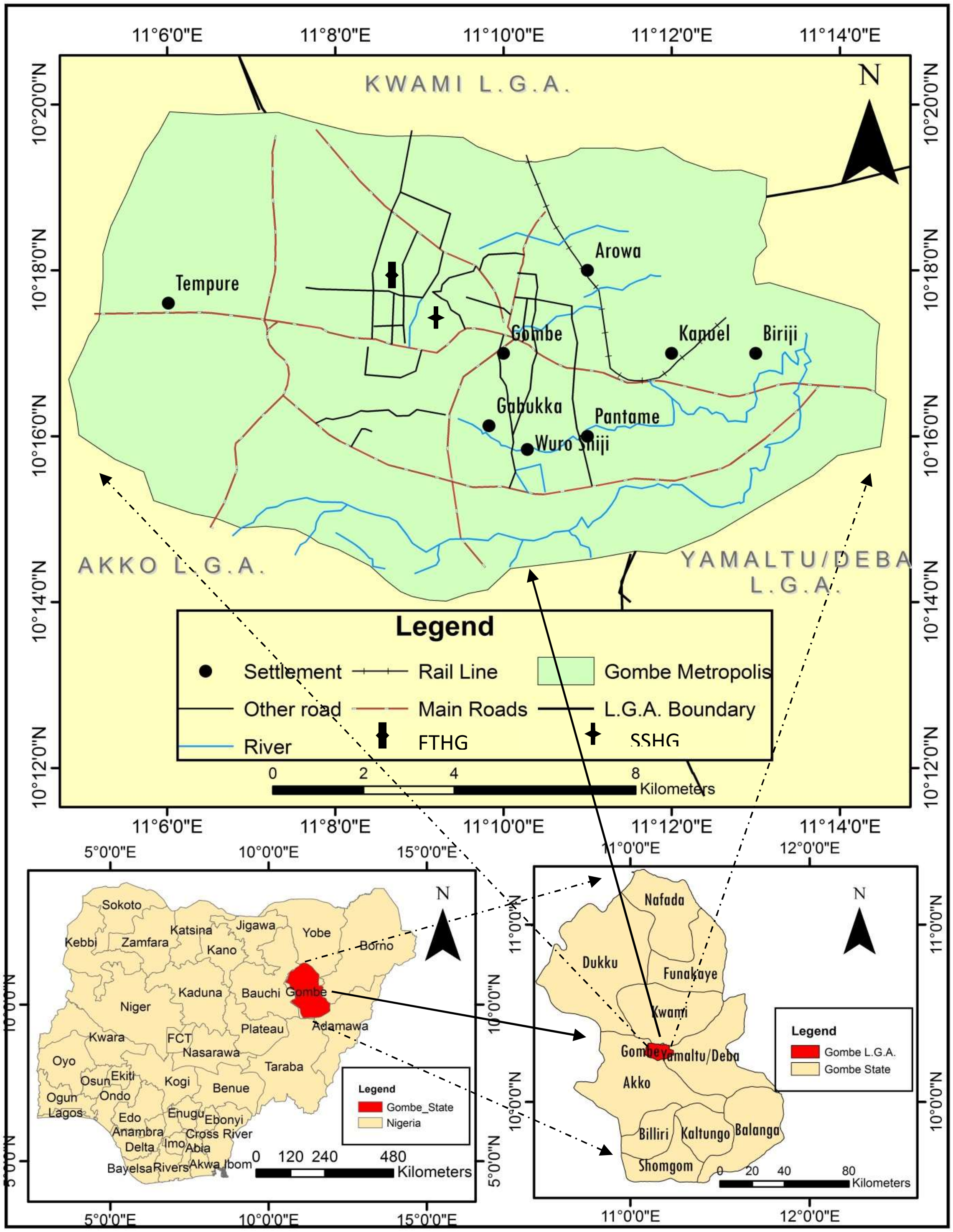

Figure 1. Gombe Metropolis (Adopted and modified from administrative map of Gombe state)

Consent is sought and obtained before the patient was included in the study. Before the radiographic examination, the patient's weight and height were measured and recorded using the simple bathroom weighing scale and measuring tape respectively. Body Mass Index (BMI) was computed from the two parameters as:

$$BMI\left(kg/m^2\right) = \frac{weight}{\left(Height\right)^2} \quad (1)$$

The technical parameters used in this study during each radiographic exposure such, as voltage (kVp), current time product (mAs), Focus to Films Distance (FFD) and Source to Skin Distance (SSD) were also recorded.

Experimental Design

In the present study, two methods were used in order to assess the dose for chests X-ray examination:

(i) Theoretical calculation using formulae in section (2.2.1) below.

(ii) (ii) Experimental method (TLD reading result obtained from Centre for Energy research and Training, A.B.U Zaria).

Theoretical Determination of Entrance Skin Dose

Entrance Skin dose is one of the important parameters used to represent the output of an X-ray machine. Ideally, an exposure meter (Dose-Area product meter) fitted to the machine could be used to measure exposure to patient but since the facility is not available on X-ray machines, alternative methods have to be developed to determine the exposure to patients (Earnest, 2014). The radiation produced from the X-ray unit is dependent on the kVp, mAs, Target-Skin Distance (TSD), filtrations of the unit and type of generator.

The theoretical ESDs in this study were calculated from the X-ray exposure parameters according to the following formulae: Edwin and McCullough, 1970; Edmonds, 1984; Arun Kumar *et al.*, 1991; Chougule and Hussain, 1993 and Pratik Kumar *et al.*, 1996.

$$ESD(mGy) = \frac{0.00867 \times (kVp)^{2.749} \times (mAs)}{(SSD)^2 \times P \times T} \quad (2)$$

$$ESD\ (mGy) = \frac{836 \times (kVp)^{1.74} \times (mAs)}{(SSD)^2} \times \left(\frac{1}{T} + 0.114\right) \quad (3)$$

$$ESD(mGy) = \frac{0.0129 \times (kVp)^{2.558} \times (mAs)}{(SSD)^2 \times T} \quad (4)$$

$$ESD(mGy) = \frac{107 \times (kVp)^{1.985} \times (mAs)}{(SSD)^2} \times \left(\frac{1}{T} + 0.114\right) \quad (5)$$

$$ESD(mGy) = \frac{0.00867 \times (kVp)^{2.79} \times (mAs)}{(SSD)^2 \times P \times T} \quad (6)$$

Where, kVp = Kilovolt peak, mAs =Milliampere seconds, T =Total tube filtration in mmAl
SSD =Source to Skin Distance, P =1(For 3-phase and single-phase units).
ESD is the absorbed dose to air on the X-ray beam axis at the patient skin where the X-ray beam enters the patient. But to compute the ESD, we first of all have to obtain an incident absorbed dose to air (ID_{air}) which is defined as the absorbed dose to air on the X-ray beam axis at the Focus-to-Skin Distance (FSD). These values were obtained directly from the TLD (Joseph *et al.,* 2014). ESD of each patient was calculated by multiply by the patient's air KERMA by backscatter factor of 1.06 as suggested in the European guidelines (Joseph *et al*., 2014). Also, Effective Dose (ED) was calculated using equation 7 and equation 8 as follows:

$$H_E = W_R D_T \quad (7)$$

$$ED = \sum W_T H_E \quad (8)$$

Where H_E is equivalent dose, W_R is radiation weighting factor for radiation R, W_T is Tissue weighting factor, and D_T is absorbed dose for tissue T.

2.2.2 Experimental Method

Standard techniques were adapted for the various body parts according to Clarks positioning in radiography 12th edition. The TLD chips are placed in the Region of Interest (ROI) without obstruction of vital structures for each projection. It is ensured that the TLD chips were in the region of the body but not obstructing structure of interest. The Focus to Film Distance (FFD) and Source to Skin Distance (SSD) is recorded for each examination after which an exposure factors appropriate for the patient is selected. The thickness of the part exposed is calculated using equation 9 below.

$$T_{tb} = FFD - SSD \quad (9)$$

Where T_{tb} is Thickness of Body parts, FFD is Focus to Films Distance and SSD is Source to skin distance. At the end of each exposure the TLD is removed from the patient and labeled with a number assigned to identify the patient and the exposure parameters were recorded for each subject. The TLD chips which are used to measure the ESD of the patients were annealed at the temperature of 400^0c. This is to ensure that there was no prerecorded radiation dose on the TLDs before being used for measurement. The irradiated TLD chips were stored in a safe container away from the diagnostic room to prevent additional radiation. The irradiated TLD chips used in this research were read with a Hashaw 45100 TLD reader available at the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria, Kaduna State.

RESULTS

The mean ESDs of the forty (42) patients who were presented for chest X-ray examinations were determined by the use of LiF TLDs and theoretical calculations at the Radiology Department of FTHG and SSHG. Table 1 shows the mean (range) of demographic information used in this work while the mean (range) of radiographic data used are shown in Table 2.

Table 1: Mean (range) of demographic information used in this work

Hospital	No of Patients	Age(year)	Weigh(kg)	BMI (kg/m^2)
SSHG	18.00	43(20-76)	58(31-92)	21(11-240)
FTHG	24.00	34(16-72)	66(38-120)	24(16-380)

Table 2: Mean (range) of radiographic data use in this work

Hospital	KVp	MAs	FSD (cm)
SSHG	70(60-80)	12.5(10-15)	116(70-135)
FTHG	76(73-79)	16.9(12.5-25.1)	154(120-169)

Table 3 and Table 4 give the mean Equivalent Dose (mSv) received by the patients at SSHG and FTHG respectively.

Table 3: Theoretical ESD mean Values (mGy) for FTHG and SSHG using various methods (n=18)

	Edwin(1984) & McCullough and Cameron Method 1970	Edmonds 1984 Method	Kumar *et al.*, 1993 Method	Chougule &Hussaini 1991 Method	Pratik*et al.*, 1996 Method
FTHG	0.35 ± 0.03	1.10 ± 0.07	0.48 ± 0.04	0.38 ± 0.03	0.83 ± 0.07
SSHG	**0.36 ± 0.03**	**1.21 ±0.10**	**0.52 ± 0.04**	**0.44 ± 0.03**	**0.88 ± 0.07**

Table 4: Mean Experimental ESD values (in mGy) for SSHG and FTHG (n=42)

	SSHG	FTHG
Mean	0.33 ± 0.04	0.46 ± 0.07

DISCUSSION

In order to facilitate measurement and optimization of patient dose, the National Radiological Protection Board, UK (NRPB, 1993) introduced the National protocol for patient dose measurement in1993. The National Protocol Recommended that ESD be directly measured on patients using TLD. Free-air measurement of tube's radiation output together with calculation of ESD using standard factors can be employed in appropriate circumstances Davies et al., 1997.

The theoretical ESDs are calculated using parameters in Table 1, Table 2 and equations 2 to 6. The values are shown in Table 3 and Table 4. The ESD and the mean ESDs of FTHG and SSHG, determined by calculations of Edwin and McCullough (1970), Edmonds (1984), Arun et al., (1991), Chougule and Hussain (1993) and Pratik et al. (1996), formulae were 0.46 mGy,0.35mGy, 1.10 mGy, 0.45 mGy, 0.38 mGy and 0.83 mGy respectively. This is similar to the findings of Hanan (2006) in which all the ESDs obtained by calculation methods were comparable. The mathematically obtained mean ESDs in this work were relatively low except the mean ESDs of the chest X-ray examination by Edmonds (1984) and Pratik et al., (1996) formulae. This is consistent with the report of Hanan (2006) that the mathematically obtained ESDs in her work for the various X-ray examinations were relatively low and she attributed it to low exposure factors used by the radiographers and size of the patients. This could also be the reason for the low ESDs obtained in this work. The implication of low ESDs is reduced radiation risk to patients and also to workers, hence adherence to the ALARA principle. The variations of the ESDs found in the mathematical formulae could also be attributed to the difference in the nature of the various formulae used in this work. For example, the values of the constants (K) used in the formulae differ from each other. The TLD reading is the Measured ESD (mGy) result obtained from forty (42) patients coming for routine chest X-ray examination at SSHG and FTHG. This analysis was carried out at the Centre for Energy Research (CERT), Ahmadu Bello University Zaria. The measured ESD obtained using the TLDs for the two hospital was shown in Table7, the results were 0.33 (mGy) and 0.46 (mGy) respectively. The measured ESD using TLDs is agreed with some calculated ESD results obtained from of Edwin and McCullough, (1970) method, Arun *et al.,* (1991) formulae and Chougule and Hussain, (1993) formulae. The results in this work was higher to the findings of Nwokorie *et al.,* (2011), in their investigations they obtained ESDs for Chest as 0.13mGy.

According to Arun, 2005, the reference dose levels for chest radiograph were set at 0.3 mG, and 0.4 mGy for both NRPB and CEC respectively. The disparity with the values in this work may be as a result of uncertainty in the TLDs measurements. This could be because the TLD chips were not appropriately annealed to read 0.00 levels after the read out had been recorded. This causes possible increase in value in the subsequent patients when taking reading with the same TLD chips (Arun, 2005). Similar study carried out in the South western part of Nigeria by (Obed *et al.*, 2007) reported ESD of 0.35mGy for chest X-rays examinations. Low doses of 0.13 mGy and 0.075 mGy for chest X-rays were however, computed by (Nwokorie, 2005). Mean Effective dose and mean equivalent dose obtained using equation 6 and 7 for the two hospitals (SSHG and FTHG) were shown in Table 5 and Table 6 respectively. The Entrance Skin Dose (ESD) dose and Equivalent dose H_E are found to be the same, because the radiation weighting factor used as recommended by ICRP is 1.

Table 5: SSHG and FTHG Mean Equivalent Dose (H_E) Values in mSv

	Calculated & Theoretical HE (n=18)					
	Measured H_E (mSv) (n=42)	Edwin &McCullough 1970 Method	Edmonds 1984 Method	Kumar *et al.,* 1993 Method	Chougule and Hussaini 1991 Method	Pratik*et al.,* 1996 Method
SSHG	0.33 ± 0.04	0.36 ± 0.03	1.21 ± 0.10	0.52 ± 0.04	0.44 ± 0.04	0.88 ± 0.07
FTHG	0.06± 0.008	0.04 ± 0.004	0.13± 0.008	0.06 ± 0.004	0.05 ± 0.004	0.10 ± 0.008

Table 6: SSHG and FTHG Mean Effective Dose (ED) values in mSv

Measured ED (mSv) (n=42)	Calculated & Theoretical ED (n=18)				
	Edwin & McCullough 1970 Method	Edmonds 1984 Method	Kumar *et al* 1993 Method	Chougule and Hussaini 1991 Method	Pratik*et al* 1996 Method
0.04 ± 0.004	0.04 ± 0.002	0.15±0.012	0.06 ± 0.004	0.05 ± 0.004	0.11 ± 0.007
0.06± 0.008	0.04± 0.004	0.13±0.008	0.06± 0.004	0.05 ± 0.004	0.10± 0.008

Taha *et al.,* (2013) evaluate the Effective Dose (ED) at Hera General Hospital (HGH) Saudi Arabia via the indirect measurement of the Entrance Surface Dose (ESD) to patients undergoing chest and was found to be 0.02mSv. Similar study was carryout by (Suliman and Habbani, 2007) in Sudan to calculate Effective Dose (ED) in conventional diagnostic X-ray examinations. The ED was 0.03mSv. The ED values in this study were found to be higher than other ED values in the literature.

Comparisons of ESD (mGy) in this work with other work carryout within and outside the Nigeria were shown in Table 7. The ESD obtained in this work was higher than ESD obtained in Malaysia, Portugal, and UK, but similar to values obtained by Hankouraou and Hamza, 2019. A similar results were obtained from the work of Abdullah *et al.,* 2010 and Nwokorie *et al.,* (2011) in their work in which the mean ESDs were lower than ICRP and other work showing that, radiation risk to patient was minimized. Also the results obtained from the works of Obed *et al.*, (2007), Sharifat and Olarinoye (2009) and Egbe *et al.*, (2008) showed variations in ESD when compared to international bodies.

Table 7: Comparison of mean ESD (mGy) with different countries

Malaysia, Kia *et al*., 1998	**Portugal** Serro *et al.,* 1992	**Uk** ICRP 2012	**Nigeria** Hankouraou *and Hamza.,* 2019	**This work**	
				SSHG	**FTHG**
0.28	0.31	0.16	0.50	0.33	0.46

The variations in the exposure parameters selected by the radiographers could also be a contributory factor to the values of the ESDs. The individual ESD distribution showing the min, max, mean, median, 1st quartile and 3rd quartile are shown in Table 8. ESD values of the two hospitals SSHG and FTHG were compared as shown in Figure2 using Bland- Altman plot. In the Bland-Altman plots, the point "0" or the zero-difference line is the point where there is no difference between the two techniques. At that point, the two techniques are equivalent. The points on the plots in this work are near the zero-difference line showing that there is no significant difference between the ESD obtained in the two hospitals using TLD badge.

Table 8: Individual Entrance Skin Dose (ESD) distribution for the two hospitals

Hospital	Min (mGy)	1st Quartile (mGy)	Mean (mGy)	Median (mGy)	3rd Quartile (mGy)	Max (mGy)
SSHG	0.13	0.19	0.33	0.30	0.43	0.13
	0.20	0.30	0.36	0.37	0.41	0.20
	0.74	1.00	1.12	1.22	1.31	0.74
	0.29	0.43	0.54	0.52	0.58	0.29
	0.27	0.36	0.44	0.44	0.48	0.27
	0.37	0.68	0.88	0.85	1.06	0.37
FTHG	0.11	0.25	0.46	0.37	0.54	1.42
	0.18	0.24	0.35	0.32	0.41	0.68
	0.67	0.81	1.10	1.01	1.29	2.01
	0.33	0.33	0.48	0.44	0.57	0.95
	0.27	0.27	0.38	0.35	0.45	0.75
	0.56	0.56	0.83	1.05	1.03	1.96

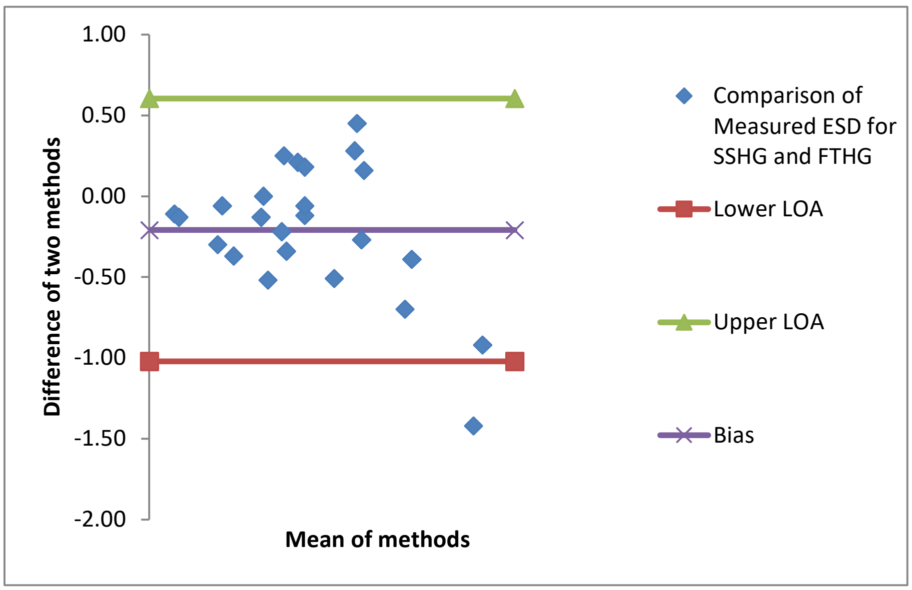

Figure 2: Bland & Altman Plot showing the Comparison of measured ESD values for SSHG and FTHG.

Effective dose provides an approximate indicator of potential detriment from ionizing radiation and should be used as one parameter in evaluating the appropriateness of examinations involving ionizing radiation. Comparisons of ED (mSv) in this work with other work carryout within and outside the Nigeria were shown in Table 9. Generally, EDs obtained in this study were found to be higher than those in other published works are within the recommended values reported by Hankouraou and Hamza, 2019.

Table 9: Comparison of mean EDs (mSv) of the present work with other work

Taha *et al.* (2013)	Kori *et al.* (2014)	Hart *and Mcwall* (2007)	*Sulima and Habbani (2006)*	NRPB (1996)	Present Work SSHG	FTGH
0.02	0.02	0.01	0.03	0.03	0.04	0.06

A comparison of theoretical ESD in the two hospitals; SSHG and FTHG was carryout and is shown in Figure 3 and Figure 4 using Box and Whisker plot. Box and Whisker plot is techniques used in comparing more than two methods, showing the mean difference of each method. Measured values of ESD using TLD at SSHG are similar to those obtained using methods 1, 2, 4 and 5. Method (3) and method (6) are nearly the same even though the values obtained are much larger compared to those obtained in methods 1, 2, 4 and 5. This difference might be due to the presence of a number constants appearing in respective equations.

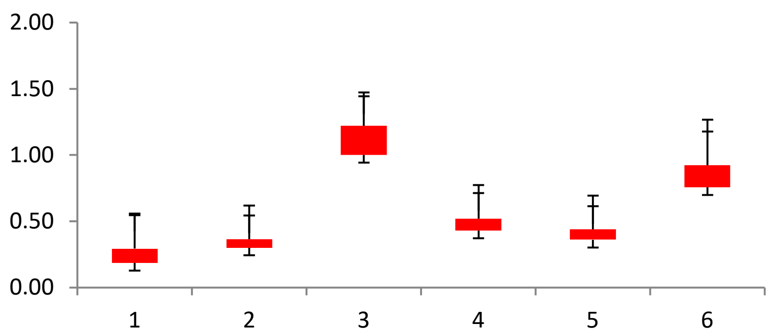

Figure 3: Box and Whisker plot comparing measured ESD and Calculated ESD of SSHG

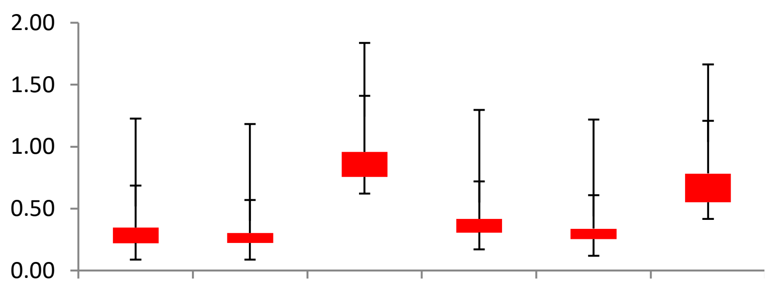

Figure 4: Box and Whisker plot comparing measured ESD and Calculated ESD of FTHG

CONCLUSION

Patient dose monitoring helps to ensure that the best standard practice is achieved and served as a verification method of appropriate dose delivery to the patient. It is also an important tool in quality assurance of the treatment and diagnosis of the individual patient. The result obtained from this study are slightly higher compared with some publish work. This may be due to systematic errors due to patient immobilization, inhomogeneity and or machine setting. However, it also indicates that the ESDs received by patient during chest X-ray examination at SSHG and FTHG was found to be within the guidance level of 0.4mGy recommended by International Commission on Radiation Protection (ICRP). The results are useful to the Departments and National professional bodies especially now that the issue of establishing a reference dose level is at stake.

The Entrance Skin Dose (ESD) of patient was determined using Thermoluminescent (TLD). The result obtained shows a mean of 0.33 mGy and 0.46 mGy for State Specialist Hospital Gombe (SSHG) and Federal Teaching Hospital Gombe (FTHG) respectively. The calculated Entrance Skin Dose (ESD) using theoretical equations was evaluated. There is insignificant variation between the Entrance Skin Dose (ESD) obtained in this work with the one obtained in Malaysia (0.28 mGy) and Portugal (0.31 mGy), but almost similar to work obtained in Nigeria (0.50 mGy).The higher Entrance Skin Dose (ESD) obtained occur due to the nature of patient's separation, inhomogeneity and patients immobilization.

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