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ORIGINAL RESEARCH ARTICLE

Determination of Entrance Surface Dose for Patients Undergoing Conventional Chest X-ray Examination at Radiology Department, Federal Teaching Hospital (FTH) Katsina.

Maaruf Abdullahi[1]*, Gide Bashir Muhammed[2], Rufai Ahmad Usman[3]

[1,2&3]Department of Physics, Umaru Musa Yaradua University, Katsina, Nigeria.

ABSTRACT

Concern regarding the radiation doses to patients exposed to x-ray during radiography examination has increased on a global scale. With chest x-ray radiography as the most common performed radiography examination, this study assessed the doses patients undergoing chest x-ray radiography are exposed to, through measurement of ESD (entrance surface dose) exposed at radiology department federal, medical center Katsina, using both direct and indirect methods for the purpose of diagnostic reference levels (DRL). Thermoluminescence (TLD) dosimeter is used for the direct measurements, while Tin and Tsai formula (mathematical equation) and CALDODE_X 5.0 software are used for the indirect measurements. The Entrance Surface Dose (ESD) was found to be; Tin and Tsai: 0.15 mGy (Chest AP), 0.12 mGy (Chest PA), 0.21 mGy (Chest lateral), with CALDODE_X: 0.23 mGy (Chest AP), 0.19 mGy (Chest PA), 0.31 mGy (Chest lateral), and TLD: 0.22 mGy (Chest AP), 0.20 mGy (Chest PA), 0.37 mGy (Chest lateral), and were all below the DRLs recommended by national and international regulatory authorities. The comparison of this study with other international and local reference levels shows that the LDRs from this study were lower than other international and local diagnostic reference levels for the three employed methods and for both projections.

ARTICLE HISTORY

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KEYWORDS

Entrance surface dose, Diagnostic reference levels, Chest radiography, Radiation dose, Thermoluminescent dosimeters.

INTRODUCTION

Alarming concern on radiation doses patients received and the risk of radiation exposure has grown significantly in recent years (Rehani MM., 2015). Global recognition has been given to the necessity to maximize patient protection through the implementation of methods to keep doses to patients having radiological examinations within acceptable ranges for the clinical purpose of each examination (IAEA, 2002). Exposure to ionizing radiation can results in genetic mutations and enhance the possibility of causing cancer in developing organs and tissues (ICRP, 2011). Although exposing patients to ionizing radiation for medical purposes has many advantages, there is also a risk that could occur, so it is important to create methods to measure the radiation exposure that patients receive in order to examine optimization efforts (Akpaniwo GM., et al., 2019). For so many reasons, it's necessary to apply radiation protection principles in medical X-ray procedures and consideration of benefits and risks (Olivera C., et al., 2004; ICRP 2007). Entrance Surface Dose (ESD) has been used to record patient doses, and studies for both adult and pediatric patients have been conducted around the world using this method (Azevedo A. C., 2008). The ESD is defined as the amount of radiation that is absorbed into the air at the point where the X-ray beam axis and the patient's entrance surface meet (CSP, 1994). One of the fundamental quantities for calculating patient dose as well as for maximizing patient dose is ESD. ESD is commonly determined using any one of the following available methods: direct measurements using thermoluminescence dosimeters (TLDs), indirect method using mathematical formula based on the X-ray machine setting, or as simulation using phantom and software (Jornet N., 2013; Gaetano C., et al., 2005; Shabon M., 2014).

Correspondence: Maaruf A., Department of Physics, Umaru Musa Yaradua University, Katsina, Nigeria. ✉ abdullahimaaruf0121@gmail.com, Phone: +234 806 926 5224

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Sharifat et. al. (2009) reported research on patient entrance skin doses in some hospitals of Minna and Ibadan for common diagnostic radiological examinations using TLD, where the range factor was as high as 12 in some cases but as low as around 1 in most cases (Sharifat, et al., 2009). Ibrahim et al. (2014) conducted research on determination of entrance skin dose from diagnostic x-ray of human chest at federal medical centrekeffi, nigeria. Using Edmond's formula, mean skin dose ranges from 0.013 ± 0.01 mGy to 0.851±0.023 mGy (Ibrahim, et al., 2014). Olubunmi (2021) reported a work on assessment of entrance skin dose for patients undergoing diagnostic X-ray examinations at Ahmadu Bello University Teaching Hospital (ABUTH) Shika, Zaria Nigeria, using Caldose_x 5.0 software and TLD. With CALDOSE_X result found to be 0.944 mGy for chest AP and 1.364 mGy for chest Lat and that of TLD as 0.32 mGy for chest AP and 0.43 mGy for chest lateral mGy (Olubunmi, 2021).

It's considered important to examine the ESD, to provide additional direction to national, local, and the clinical community on the use of diagnostic reference levels, control the radiation dosage given to the patient for a clinical purpose (Shahbazi D. G., 2006). The core radiation protection principles of justification of practice, optimization of protection, and dosage limit must be followed because of the risks connected with the use of radiation (Clement C., 2010).

MATERIALS AND METHODS

The equipments used in this research include: Conventional X-ray machine, height and weight scale, digital kVp meter, digital dosimeter, lead apron, pieces of different thickness of Aluminium, adhesive tape, loaded x-ray cassettes, nine metallic coins, thermo-luminescent dosimeters (lithium fluoride) and others.

(a) (b)

Figure 1: CALDOSE_X work environment: (a) Definition of X-ray examinations (b) Definition of different calculations interface.

The study is conducted at radiology department Federal Teaching Hospital Katsina Nigeria, which comprises of thirty-seven patients undergoing conventional chest x-ray radiographic examination, at radiology department FTH Katsina. The research ethics committee of Federal Teaching Hospital Katsina and the heads of radiology department federal medical Centre katsina approved the study. The entrance surface dose (ESD) of the patients was measured using direct and indirect method. Thermoluminescence dosimeter is used to measure the ESD directly, while for the indirect method two methods are employed: CALDOSE_X software and Tin and Tsai formula based on the x-ray machine parameters.

Two TLDs were used as control against background radiation for accurate and reliable data acquisition. A thermoluminescence dosimeter (LiF) is placed on the patient at point of incidence to measure dose received by the patient with varying focus to skin distance (FSD) depending on the examination projection and other exposure factors. Each TLD was marked and stored in a nylon bag for identification before and after exposure to avoid unnecessary exposure to background radiation or radiation leakage. For the indirect method, CALDOSE_X version 5.0 software in addition to Tin and Tsai formula were used. CALDOSE_X is software that can be used in calculating the incident air karma (INAK) and entrance surface air karma (ESAK), based on the X-ray machine output, it can be in the form of software or in the form of online access, which are both reliable for ESD and organ dose calculations (https://www.caldose.org). The online access form was used in this study (Kramer R., et al., 2008). The ESD for patient undergoing conventional chest radiography examination is also evaluated indirectly using Tin and Tsai formula based on data obtained from the machine specification and exposer parameters. Tin and Tsai Formula method involved mathematical evaluation of entrance surface dose (ESD) for patient examination using x-ray machine parameters (Alghoul A. and Yasir M., 2016).

$$ESD(mGy)=c(kVp/FSD)^{\wedge}2(mAs/mmAl) \quad (1)$$

Where; kVp is the peak tube voltage, mAs is the exposer time (Tube current multiply exposer time), FSD is focus to skin distance (the measured distance between the X-ray tube and the patient's part been exposed to X-ray), mmAl is the minimum inherent filtration Aluminium equivalent, C is constant = 0.2775.

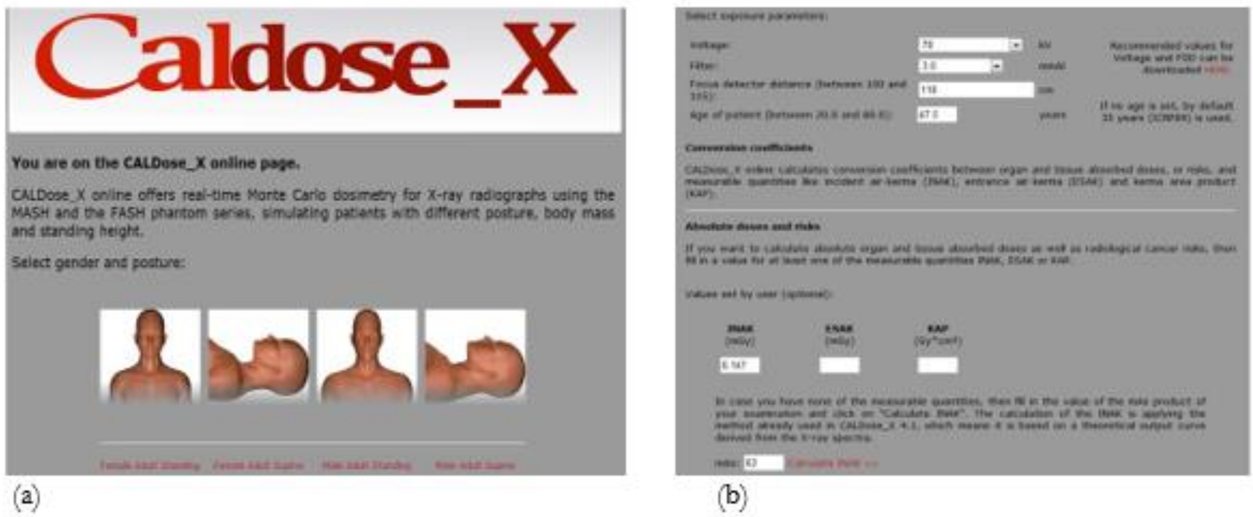

Figure 2: CALDOSE_X: (a) Online page interface (b) Exposure parameters

RESULTS AND DISCUSSION

The ESD for patients performing conventional chest x-ray radiography at radiology department FTH katsina is determined using three different methods; two indirect procedures of Tin & Tsai formula and CALDOSE_X 5.0 software using x-ray machine parameters, and one direct using TLD (LiF). The patient's information and exposure parameters were tabulated. The data is classified into three groups depending on the type of examination projection the patient came for, of either anterior-posterior (AP) or posterior-anterior (PA) or lateral (LAT) view projection. The results of statistical ESD for the three examinations projection (AP, PA and LAT) were presented in different tables and figures with mean, minimum, maximum, standard deviation and standard error included.

Table 1: Mean (range) of radiographic and X-ray machine parameters used during the study.

Examination	kVp Mean (range)	mAs Mean (range)	FSD (cm) Mean (range)
Chest AP	56.05(45-68)	5.52(3.80-8.00)	127.83(114-135)
Chest PA	53.85(45-65)	4.92(3.25-7.40)	125.00(117-134)
Chest LAT	62.60(60-65)	6.73(6.00-7.40)	131.6(129-133)

From Table 1, It is demonstrated that the values of kVp and mAs span a large range. The kVp mean (range) were 56.05 (45-68) for chest AP projection, 53.85 (45-65) for chest PA projection and 62.60 (60-65) for chest lateral projection. While the mAs mean (range) were 5.52 (3.80-8.00) for chest AP projection, 4.92 (3.25-7.40) for chest PA projection and 6.73 (6.00-7.40) for chest lateral projection. These wide range of kVp and mAs were due to differences in patient's thickness and the type of examination. The lowest radiation dosage can be achieved with higher kVp with low mAs, which give rise to optimization of image quality formed, and to limit the dose with increasing focus to film distance (FFD) based on the radiation protection tenets of dose reduction and optimization.

Table 2: Mean (range) of ESD from the three different methods.

Examination	Tin and Tsai (mGy) Mean (range)	CALDOSE_X (mGy) Mean (range)	TLD (mGy) Mean (range)
Chest AP	0.15(0.07-0.27)	0.23(0.12-0.40)	0.22(0.03-0.33)
Chest PA	0.12(0.05-0.21)	0.19(0.10-0.33)	0.20(0.03-0.39)
Chest LAT	0.21(0.19-0.24)	0.31(0.28-0.33)	0.37(0.33-0.43)

In Table 2, the mean ESD is computed with excel spread sheet, and corresponding range for each diagnostic projection determine, for all the three different employed methods. This data is obtained from the collection of all the data obtained during the study. The high mean in the lateral view compared to other projections of AP and PA, is as a result of high exposure factor used during the diagnosis to enable the X-ray beams pass through the patient laterally due more attenuation with organs with different density. AP and PA mean doses are in a closer range as a result of using almost same exposure parameters, unless where the diagnosis specifies the clinical target organ to help the radiographer choose the best possible position and angle of exposure.

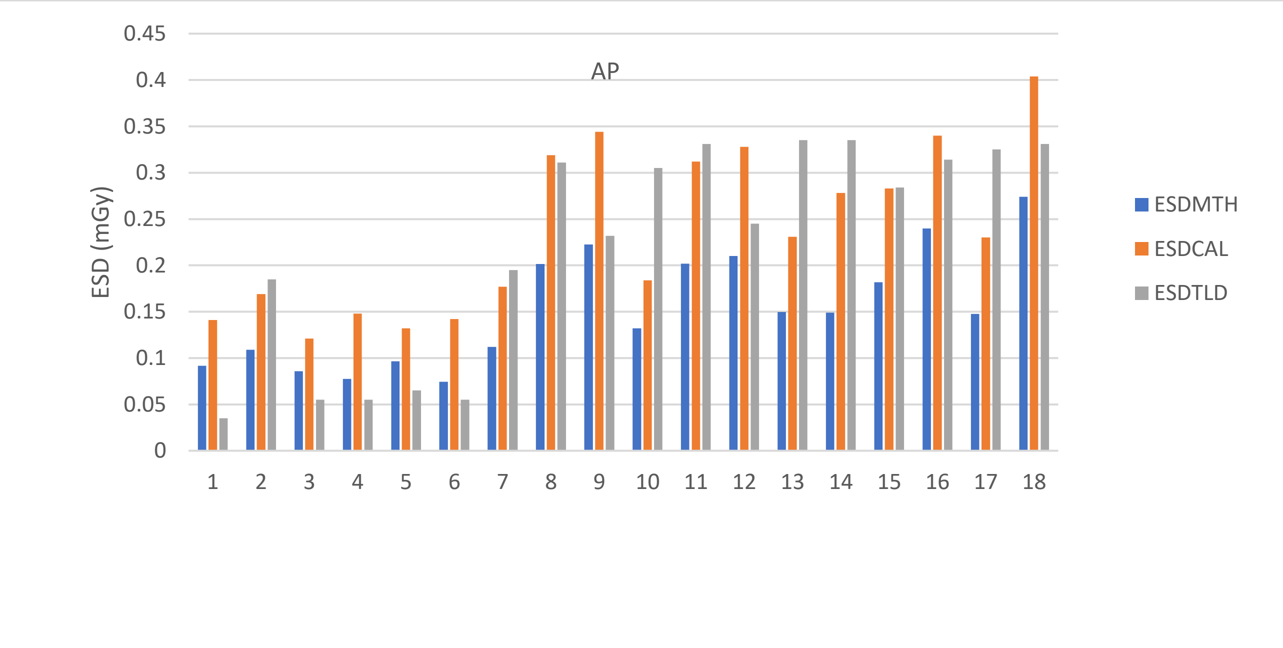

Figure 3: Comparison of ESDs from Tin & Tsai formula (ESD_{MTH}), CALDOSE_X (ESD_{CAL}) and TLD (ESD_{TLD}) for Anterior-posterior (AP) examination.

The figure above is the bar chart representation comparing the exposure levels of the three different employed methods in AP projection for a total of eighteen patients. Depending on the method used, individuals receive up to 0.4 mGy while others receive less than 0.05 mGy, which are all under the accepted level from different international and local dose levels showing patient are safety is achieved.

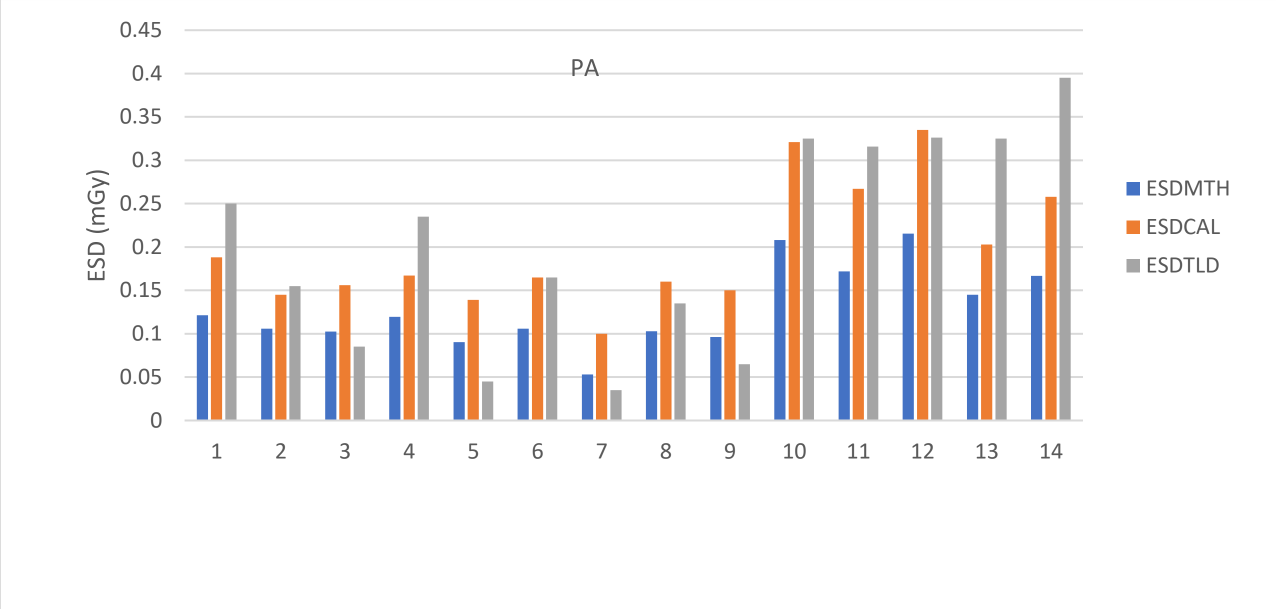

Figure 4: Comparison of ESDs from Tin & Tsai formula (ESD_{MTH}), CALDOSE_X (ESD_{CAL}) and TLD (ESD_{TLD}) for Posterior-anterior (PA) examination.

The figure 4 above is showing a bar chart representation of the PA projection of fourteen patients, with ESD_{TLD} showing a high dose compared to other two methods of ESD_{MTH} and ESD_{CAL}, as a result of ESD_{TLD} (directly measurement) being the most reliable and accepted method compared to ESD_{MTH} and ESD_{CAL} which are measured indirectly based on exposure parameters.

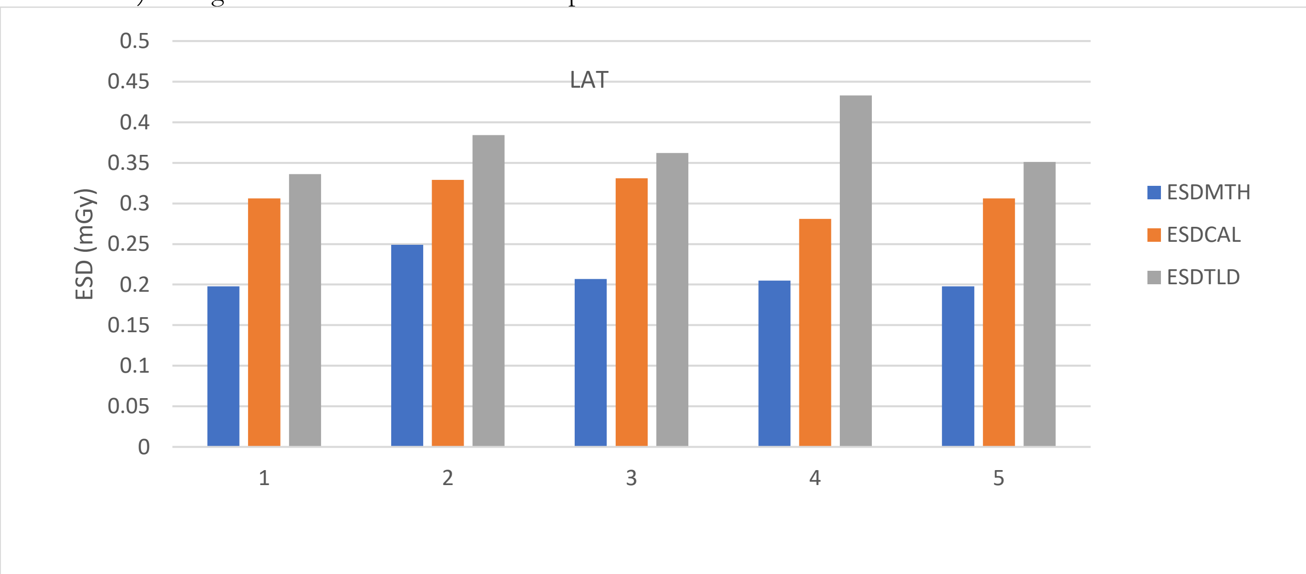

Figure 5: Comparison of ESDs from Tin & Tsai formula (ESD_{MTH}), CALDOSE_X (ESD_{CAL}) and TLD (ESD_{TLD}) for Lateral (LAT) examination.

In figure 5 above, it can be seeing that the measured dose for lateral projection is slightly above that of AP and PA projection, this is due a high exposure parameter being used to produce an x-ray that can penetrate the tissues and organs from left to right or right to left, unlike the patient thickness of AP and PA for lateral projections, because the thicker the patient body part the x-ray is to penetrate the more exposure parameters is needed.

Table 3: Mean Entrance Surface dose (ESD) with standard deviation (SD) for the three different methods.

Examination	Tin and Tsai (mGy) ESD±SD	CALDOSE_X (mGy) ESD±SD	TLD (mGy) ESD±SD
Chest AP	0.15±0.06	0.23±0.08	0.22±0.11
Chest PA	0.12±0.04	0.19±0.07	0.20±0.12
Chest LAT	0.21±0.02	0.31±0.02	0.37±0.03

As Nigeria does not have Diagnostic reference levels, the results from this study are compared to other international diagnostic reference levels as well as other Nigerian studies dose levels. The ESD for the three employed methods are shown to be within acceptable international reference levels. The measured ESDs on Tin and Tsai, CALDOSE_X and TLD were both comparable to the standard recommended for diagnostic reference level (DRL), which indicate the safety of patients undergoing chest x-ray radiographyat FTH Katsina and within acceptable dose limit. The slight increase in dose level at Lateral projection is as a result of higher exposure parameters used during the examination to produce an x-ray that can pass through the patient from either left to right or right to left without being absorbed, unlike the thickness of AP and PA projection.

Table 4: Comparing ESD mean value from this study and other Nigerian states.

	Tin and Tsai (mGy)			CALDOSE_X (mGy)			TLD (mGy)		
Study and State	AP	PA	LAT	AP	PA	LAT	AP	PA	LAT
ATBUTH Bauchi (Dlama J. *et al.,* 2014).	-	-	-	-	-	-	-	0.50	-
FMC Keffi (Ibrahim U. *et al*., 2014).	-	-	-	-	-	-	-	0.01-0.85	-
UMTH Borno (Dlama J. *et al.,* 2014).	-	-	-	-	-	-	-	0.54	-
Sokoto (Akpaniwo G. M., *et al*., 2019).	-	-	-	-	-	-	-	0.24	-
North East Nigeria (Joseph D. Z., *et al.,* 2019).	-	-	-	-	-	-	-	0.45	0.82
ABUTH Zaria (Olubunmi A.O., 2021).	-	-	-	0.94	-	1.36	0.32	-	0.43
This study (2021); FMC Katsina	0.15	0.12	0.21	0.23	0.19	0.31	0.22	0.20	0.37

With ATBU Bauchi having an ESD of 0.5 mGy AP projection, FMC keffi as high as 0.85 mGy for AP projection, UMTH Borno 0.53 mGy, Sokoto as low as 0.24 mGy, North-eastern Nigeria 0.45 mGy AP and 0.84 mGy Lateral, ABUTH Zaria: 0.94 mGy AP with CALDOSE_X, 1.31 mGy lateral using CALDODE_X software, 0.32 mGy AP using TLD and 0.43 mGy lateral using TLD. The findings of this research are contrasted with other results from different part of Nigeria, and it shows to be below the recommended acceptable dose limits and below other reported work from Nigerian states. As Nigeria has no diagnostic reference level, the result would be of use to Nigerian regulatory authorities when setting diagnostic reference levels in Nigeria.

Table 5: Average value of the ESD (mGy) from this study is compared with other countries.

	Tin and Tsai (mGy)			CALDOSE_X (mGy)			TLD (mGy)		
Study and country	AP	PA	LAT	AP	PA	LAT	AP	PA	LAT
Iran (Shahbazi D. G., 2006).	-	-	-	-	-	-	-	0.70	2.51
United Kingdom (Hart D., *et al.*, 2012).	-	0.12	0.48	-	-	-	-	-	-
Libya (Alghoul A. *et al.,* 2017).	7.43	-	-	-	-	-	-	-	-
Bangladesh (Sadeka S. R., *et al.*, 2018).	0.22	0.11	0.34	-	-	-	-	-	-
Iran (Hussein M. Z., *et al.,* 2020).	-	1.00	1.70	-	-	-	-	-	-
South Africa (Junda M. *et al.*, 2021).	-	-	-	-	0.20	0.60	-	-	-
This study, Nigeria (2021).	0.15	0.12	0.21	0.23	0.19	0.31	0.22	0.20	0.37

In Table 5, the mean value of ESD from this research is related with that from other countries using the three different chest radiography examination projections (AP, PA and lateral), based on the three different methods employed in this study, which indicate the dose from this study to be below most of the other countries.

Table 6: Different mean value of the ESD (mGy) from International regulatory authorities and this study.

	This study			(NRPB, 1990)	(IAEA, 1996)	(ICRP, 2001)
Examination	Tin and Tsai (mGy)	CALDOSE_X (mGy)	TLD (mGy)	-	-	-
Chest AP	0.15	0.23	0.22	0.30	0.40	0.3
Chest PA	0.12	0.19	0.20	0.30	0.40	0.3
Chest LAT	0.21	0.31	0.37	1.5	1.50	1.50

From table 6 shown above, the local diagnostic reference levels (LDRLs) as compared to various diagnostic reference levels (DRLs). The DRLs from this research; Tin and Tsai: 0.15 for chest AP, 0.12 for chest PA, 0.21 for chest lateral, with CALDOX_X: 0.23 for chest AP, 0.19 for chest PA, 0.31 for chest lateral, and TLD: 0.22 for chest AP, 0.20 for chest PA, 0.37 for chest lateral, were below the DRLs recommended by international regulatory authorities. The DRs from this study were found to be lower than other international and local reference levels for the three employed methodologies and for both projections, according to a comparison of this study with other international and local reference levels.

CONCLUSION

This study investigated the dose patients undergoing conventional chest x-ray at radiology department federal teaching hospital katsina are exposed to, through determination of Entrance surface dose (ESD) using one direct method of measurement (TLD) and two indirect methods of measurement (Tin & Tsai formular and CALDOSE_X version 5.0 software) based on exposure parameter. A cross section of thirty-seven patients undergoing AP, PA and Lateral chest x-ray projections are considered in this study. The measured ESDs are, Tin and Tsai: 0.15 mGy (Chest AP), 0.12 mGy (Chest PA), 0.21 mGy (Chest lateral), with CALDODE_X: 0.23 mGy (Chest AP), 0.19 mGy (Chest PA), 0.31 mGy (Chest lateral), and TLD: 0.22 mGy (Chest AP), 0.20 mGy (Chest PA), 0.37 mGy (Chest lateral), the ESDs patients received while undergoing conventional chest x-ray radiography examination at radiology department Federal Teaching Hospital Katsina were below the accepted guidance level as well as in other related literature locally and internationally, indicating the presence of Patients' safety during such examinations.

From the three different methods used in this study, the demonstrated methods can be a reliable means as well as cheaper alternative for patient dose monitoring, as long as the x-ray system (machine) work within accepted normal working condition. The mathematical model or CALDOSE_X software model can be adopted for the purpose of patient dosimetry in places where the essential facilities for patient dose monitoring (TLDs and others) are scarce or unavailable as well as financial constraint.

RECOMMENDATION

1. Since machine performance alters with age, further research on quality control (QC) tests on the machines should be undertaken on a regular basic.

2. The need to performed more studies on chest Entrance surface dose (ESD) is necessary, due to the presence of different organs with different radiation sensitivity, in order to keep on monitoring the Diagnostics reference levels (DRLs) in every 3years, according to ICRP guideline.

3. More studies on other examinations not presented in this study (skull, pelvis, neck and others) should also be carried out for the purpose of local diagnostic reference levels.

4. During radiographic diagnosis, high kVp with low mAs should be employed to achieve a lower radiation dosage based on the principle of optimization (ALARA).

5. In situations when TLDs and other measuring devices are unavailable, scarce, or not feasible financially, entrance surface dose (ESD) can be estimated using one of the indirect approaches of CALDOSE_X or a mathematical relation.

CONFLICT OF INTEREST

No conflict of interest to disclose.

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