FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 9 No. 2, February, 2025, pp 237 - 241
DOI: https://doi.org/10.33003/fjs-2025-0902-3187

DETERMINATION OF ADULT PATIENT SKIN ENTRANCE AND EFFECTIVE DOSES FOR SOME SELECTED X-RAY DIAGNOSTIC EXAMINATION IN NIGER STATE

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ABSTRACT

The ionizing radiation exposure to patients receiving standard X-ray examinations was evaluated in this paper. To make sure the patient's X-ray dose was within an acceptable range, the skin entrance dose (SED) and effective dose (ED), which determine the amount of absorbed radiation dose to the body, were measured. The mean SED and ED results were then compared with the international standard threshold values. Caldose_x 5.0 software was employed to examine the Skin Entrance Dose (SED) and effective dose (ED) of seven types of routine X-ray examinations in three public hospitals in Niger State, Nigeria. The routine examinations are: cervical spine (AP/LAT), thoracic spine (AP), pelvis (AP), thorax (PA/LAT) and lumber spine (AP). For each projection, the X-ray tube supplied a constant potential (no ripple), with X-ray emission angle of 17^o and a total filtration of 2.5 mm aluminum (Al). 229 patients diagnostic X-ray were examined with approximately 52 % male and 48 % female. In other to calculate patients' SED and ED using Caldose_x, patients' data such as age, sex, projection, type of examination, mAs and kVp were inputed. The output mean SED and ED were compared with internationally established diagnostic reference levels and published results. The estimated mean SED were 0.23, 1.99, 1.09, 0.38, 3.95, 0.24, 0.41 mGy and the mean ED were 0.05, 0.65, 0.06, 0.02, 0.35, 0.05, 0.03 mSv, for the seven examination projection. The Caldose_x software analysis of routine X-ray examinations revealed that the SED and ED values were largely in agreement with international standards.

Keywords: Caldose_x, Skin Entrance Dose (SED), Effective Dose (ED), Medical imaging, Diagnostic X-ray

INTRODUCTION

Diagnostic radiology involves interpreting medical images in an attempt to improve and cure human illnesses. This process contributes about 80 % of the world average dose of the known man-made radiation (Sonawane et al., 2009). This is evident from the work of Benjamin, 2000 (Archer & Wagner, 2000). This poses a serious concern to the responsible authorities as this represent the largest X-ray radiation exposure to the general population.

Medical imaging is gaining more attention in the medical arena because of it application in computed tomography (CT), fluoroscopy and radiotherapy to cure verse number of illnesses. Although, all these advancement in medical imaging became possible with the help of X-rays which are used to identify diseases and injuries in the human body, but they equally expose people to ionizing radiation especially when not guided by the principle of radiation optimization (Tsapaki, 2020).

In light of this, the International Commission on Radiological Protection (ICRP) (Osman Hamid, 2020) recommends that the radiation safety guidelines (justification and optimization) be applied while using ionizing radiation for medical treatments and only consider examination that are confined within the dose constraints for applications and prove to be beneficial in the given diagnostic examination (Sonawane et al., 2009). This implies that exposure should be as low as reasonably achievable (ALARA) (Osman Hamid, 2020).

The DRLs (diagnostic reference levels) also called guidance level (GLs) is an international concept used to describe the common type of medical diagnostic X-ray examination aimed at ensuring that optimize dose is delivered to the patients. The IAEA (International Atomic Energy Agency) recommended in its series No. 115 of the Basic Safety Standards (BSS) for the protection against ionizing radiation that GLs for any medical exposure to radiation be established for use by medical experts, professional bodies, and relevant regulatory organizations to ensure that the patient receives the appropriate dose during X-ray diagnostic examination (*Protection of the Patient in Diagnostic Radiology : A Report of Committee 3 of the International Commission on Radiological Protection, Adopted by the Commission in May 1982*, 1982). The maximum radiation dosage that any group of cells in the human body can receive is indicated by the skin entrance dose (SED). For a long film chest X-ray, the SED can be as low as 100 μGy, whereas for cardiac catheterization, it can reach as high as 1 Gy (Ofori et al., 2014). 75th percentile third quartile value is considered for the DRLs. Therefore, SED is an important variable used in determining the absorbed dose of radiation received by patient during the X-ray procedures (Ofori et al., 2014). Consequently, it is now crucial to measure X-ray machines to determine whether ones adhere to the safety regulation (Taha et al., 2015). Given the aforementioned and the detrimental effects of ionizing radiation on patients, it is essential to determine and estimate the dosage to patients as a function of radiographic exposure parameters before a medical examination (Ibrahim et al., 2014). Ibrahim et al. (2014) state that Edmond's formula for calculating the radiation dose to patients from diagnostic X-ray machines uses a straightforward functional dependence on radiographic exposure parameters like tube potential (kVp), tube current (mA), exposure time (mAs), Source to Skin Distance (SSD), filtration, and thickness. Adult patients undergoing standard X-ray examinations of the cervical spine (AP/LAT), thoracic spine (AP), pelvis (AP), thorax (PA/LAT), and lumber spine (AP/LAT) at three (3) public hospitals will have their skin entrance dose (SED) and effective dose (ED) estimated using the Caldose_x software. Therefore, this study aimed to evaluate the entrance skin dose and effective dose from common X-ray routine examination of patients from three major hospitals in Niger State.

MATERIALS AND METHODS

This study was carried out at three (3) public hospitals with traditional X-ray machines in the three largest cities of Niger State, Nigeria: Minna, Suleja, and Bida. Every unit has a total aluminum (Al) filtration of 2.5 mm, constant potential generators (which means there are no ripples), and an X-ray emission angle of 18°. The X-ray generator and all of its components were cross-examined for timer accuracy, generator type, half-value layer (HVL), kilo-voltage peak (kVp), beam alignment, collimation, and output consistency before the measurement process started.

A multi-function multi-meter with model number 820 kVp was used to carry out the measurements. Output consistency and HVL were measured using Radcheck plus ionizing chamber, inc. USA with model number 06-143. Collimation and perpendicular alignment test was preformed using the middleton, WI.53462 US.

These equipment's were used to carry out measurement on seven most examined organs in the human body (Table 1).

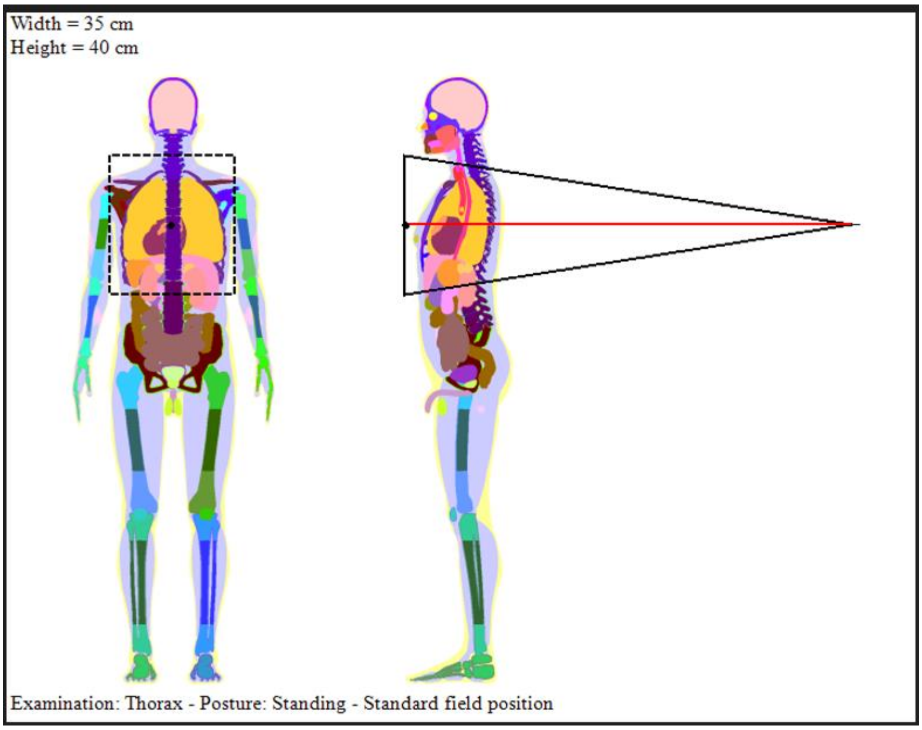

Figure 1: X-ray exposure geometry for a Thorax standing posture

The SED AND ED were computed using the Caldose_x 5.0 program. The X-ray tube's output can be used by the program to estimate incident air Kerma (INAK). Additionally, based on the individual posture and orientation of the female and male adult Phantom, the software can compute entrance surface air Kerma (ESAK) by multiplying the INAK by a backscatter factor from the X-ray tube, organ dose, tissue absorbed doses, and ED. Additionally, it can use the conversion coefficients (CCs) normalized to the INAK and the air Kerma area product (AKAP) for the commonly performed X-ray diagnosis in the hospital (Kramer et al., 2008). Based on the operator's chosen examination type, Caldose_x 5.0 software also calculates cancer risk and cancer mortality. Additionally, the focus detector distance (FDD) used in Caldose_x 5.0 procedures can be changed by the operator within a specific range. Finally, patient's age, sex, posture projections, type of examination, filed position, X-ray tube potential and the mAs are inputed manually in the software for the estimation of SED and ED, respectively.

The Radcheck plus ionization chamber, model number 06-518, manufactured by Nuclear Associates Div. Victoreen, Inc., USA, was used to determine the X-ray output curve in mAs. Similarly, the AAPM (American Association of Physicists in Medicine) task group protocol number 61 was used to retrieve the X-ray machine's output (Ma et al., 2001). Once the tube voltage, tube current, exposure duration, and focus to skin distance (D) are known, SED can be calculated (Wall & Hart, 1997):

$$\mathrm{SED} = O \times \left(\frac{V}{80}\right)^2 \times \left(\frac{100}{D}\right)^2 \mathrm{BIT} \qquad (1)$$

where D is the focus to skin distance in centimeters (cm), B is the backscatter factor, I is the current in milliampere (mA), T is the exposure period in seconds (s), and O is the tube output in milliampere seconds (mAs).

At 80 kV, 1 m focus to skin distance, and 10 mAs, the X-ray tube was calibrated. Equation 2 is used to determine the effective dose once the skin entrance dose (SED) has been estimated using equation 1 as follows:

$$E = \frac{1}{2}\left[\sum W_T H_T(female) + \sum W_T H_T(male) +\right] = \frac{1}{2}[F + M] \qquad (2)$$

According to equation (2), the average of the weighted dosages for each sex as stated in ICRP report 103 (Annals of the ICRP Published on Behalf of the International Commission on Radiological Protection, n.d.) is the effective dose.

RESULTS AND DISCUSSION

Table 1: Showing patient's characteristics and exposure parameters used in the various examination in the public hospital, Niger State

Examination	Projection	Male Patients	Female Patients	Age Range	mAs Range	kVp Range	FDD Range (cm)	Total Patients
Pelvis	AP	23	15	56 (25−75)	27.8 (11.8−41)	69.5 (63−82)	105.7 (100−110)	38
Thoracic spine	AP	4	5	59 (25−78)	45.1 (29−62)	71.2 (70−88)	125.6 (115−155)	9
Cervical spine	AP	8	10	44 (25−75)	25.3 (12.1−42.2)	72.4 (63−81)	102 (100−105)	18
Cervical spine	LAT	6	7	39.3 (25−75)	24.2 (15.4−47.2)	73.3 (63−81)	101 (100−105)	13
Lumber spine	AP	22	24	62.1 (25−78)	40.6 (18−55)	86.3 (70−92)	126.8 (100−155)	46
Thorax	PA	30	31	44 (25−73)	23.2 (11.9−28.7)	79.8 (63−91)	122 (91−130)	61
Thorax	RLAT	25	19	46 (25−73)	26.7 (15−43)	82.1 (63−91)	160 (130−185)	44

Table 2: Sample output results from CALDose_X 5.0 for a PA Thorax radiograph for a 44-year old male patient

INSTITUTION: xxx		
ROOM: 000		
X-RAY TUBE (Filter: 2.5 mm Al): Rendimento Teórico/Theoretical Output		
ADULT PATIENT: Male Standing Age: 44 years		
Name: .		
ID: 2717		
Calculation date: 02/02/2025 CALDose_X_5.0		
EXPOSURE CONDITIONS		
MASH3STA: THORAX, POSTERIOR-ANTERIOR (PA)		
IMAGE IN FRONT OF THE BODY		
72.4 kVcp 2.5 mm Al 17 Deg Tungsten IPEM/SR78		
MEAN SPECTRAL ENERGY: 39.9 keV ABSORBED FRACTION: 0.63		
SOURCE-TO-DETECTOR (FILM): 122 cm		
SOURCE-TO-SKIN: 94.0 cm		
FIELD SIZE IN DETECTOR PLANE: 35 cm x 40 cm		
FIELD POSITION: STANDARD POSTURE: STANDING		
MALE ADULT (ICRP89)		
BODY MASS: 73.0 KG, STANDING HEIGHT: 176.0 CM		
CHARGE: 25.3 mAs		
ORGAN/TISSUE ABSORBED DOSES		
ORGAN/TISSUE	mGy	%
ESAK	3.262	1.38
ADRENALS	0.394	2.58
ORAL MUCOSA	0.024	4.18
COLON WALL	0.010	2.85
BREASTS, glandular	0.065	7.12
KIDNEYS	0.272	0.60
LIVER	0.120	0.41
LUNGS	0.485	0.25
OESOPHAGUS	0.323	1.69
PANCREAS	0.053	1.91
SMALL INTESTINE WALL	0.005	3.08
SKIN ENTRANCE 7.2cm X 7.2cm	3.303	1.38
SPLEEN	0.232	0.99
STOMACH WALL	0.086	1.53
SALIVARY GLANDS	0.024	3.89
THYMUS	0.139	3.19
THYROID	0.237	2.69
EXTRATHORARCIC AIRWAYS	0.024	3.29
HEART WALL	0.261	0.66
LYMPHATIC NODES	0.108	0.91
SKELETON AVERAGE	0.452	0.10
MAXIMUM RBM ABSORBED DOSE	0.545	1.54
MAXIMUM BSC ABSORBED DOSE	0.750	2.55
WEIGHTED MASH DOSE	0.151	0.42
RISK OF CANCER INCIDENCE	1.03	CASES PER 100000
RISK OF CANCER MORTALITY	0.929	CASES PER 100000

Table 3: Estimated Skin Entrance Dose (SED) and Effective Dose (ED) for the common projection and examination from a Radiograph examination from public hospitals Niger State

S/N	Examination	Projection	Mean Skin Entrance Dose (mGy)	Mean Effective Dose (mSv)
1	Pelvis	AP	0.23	0.05
2	Thoracic spine	AP	1.99	0.65
3	Cervical spine	AP	1.09	0.06
4	Cervical spine	LAT	0.38	0.02
5	Lumber spine	AP	3.95	0.35
6	Thorax	PA	0.24	0.05
7	Thorax	RLAT	0.41	0.03

Table 4: Comparison of SED (mGy) in this study with results from other countries

Examination	Projection	This study	Other References				
			(UNSCEAR, 2000)	EUROPEAN COMMISSION, 1996	(Ofori et al., 2014)	(Taha et al., 2015)	(Samaila & Samaila, 2022)
Pelvis	AP	0.23	-	10.0	1.31	-	-
Thoracic spine	AP	1.99	9.91	7.0	2.10	-	-
Cervical spine	AP	1.09	9.91	-	1.05	-	3.91
Cervical spine	LAT	0.38		-	0.45	-	4.08
Lumber spine	AP	3.95	5.95	10.0	3.25	2.50	-
Thorax	PA	0.24	0.31	0.30	0.43	0.14	-
Thorax	RLAT	0.41	-	-	0.27	-	-

Table 5: Comparison of ED (mSv) in this study with results from other countries

Examination	Projection	This study	Other References		
			(Ofori et al., 2014)	(Harrison et al., 2023)	(Samaila & Danyaro Rilwanu, 2023)
Pelvis	AP	0.05	0.09	0.28	-
Thoracic spine	AP	0.65	0.13	-	-
Cervical spine	AP	0.06	0.05	-	-
Cervical spine	LAT	0.02	0.03	-	-
Lumber spine	AP	0.35	0.41	0.39	-
Thorax	PA	0.05	0.01	0.01	0.18
Thorax	RLAT	0.03	0.02	0.04	0.09

Table 1 displays the exposure parameters and patient characteristics for the chosen examination performed in the three (3) public hospitals.

In all, 229 patients diagnostic X-ray was examined with the approximately 52 % male and 48 % female, respectively. Patients with estimated mean weight exceeding 70 kg were considered in the present study. However, based on the chosen means for the ranges of ages, mAs, kVp, and FDD for the seven examaminations, patients weighing above 70 kg were not allowed to participate in the study. These were computed, and Table 2 shows the outcomes.

The lowest age was 27 and the maximum age was 78. The mAs ranges from 11.8 mAs at the minimum to 55 mAs at the maximum. Comparably, the FDD ranges from a minimum of 91 cm to a maximum of 185 cm, and the kV ranges from a minimum of 63 kV to a maximum of 92 kV.

The wide ranges of the mean results for the mAs, kVp and FDD were as a result of the variation in the patient body weights, thicknesses, height and the method used by the different radiographic operators in the hospital.

Table 3 shows the estimated mean Skin Entrance Doses (SED) and Effective Doses (ED) for the different types of human body projection (see Figure 1) and examinations. The results obtained for all examination at different projection suggest that the mean SED varied from 0.23 mGy−3.95 mGy and ED varied from 0.02 mSv−0.65 mSv, respectively.

Table 4 shows the comparison of the results for the mean SED and mean ED obtained in this study with the international standard (UNSCEAR, 2000), (Kohn et al., 2000); (Ofori et al., 2014) as well as research work reported in other countries. These results were in agreement with the international threshold set by UNSCEAR, 2000 and European Commission, 1996, but it is slightly above the results reported (Ofori et al., 2014, Taha, 2015, Harrison et. al., 2023), all for Lumber spine and Thorax (PA/RLAT) examinations, respectively. The variation in the results for the SED and ED for the patients could be as result of the patient size, weight, focus to film distance, manual exposure control settings, and other exposure parameters (Ofori et al., 2014). This indicates the significance of variation in examination protocol as well as body dimension for the determination of precise radiation dose to a specific organ of interest (Shuaibu et al., 2024)

Table 5 shows the comparison of effective dose in this study and results from other parts of the world. The mean effective doses in this study were in the range of values obtained by (Ofori et al., 2014), (Harrison et al., 2023) and (Samaila & Danyaro, 2023), respectively.

CONCLUSION

The SED and ED of seven different types of routine X-ray examinations were examined in this study using the Caldose_x 5.0 program. The results indicated that the mean Effective Dose (ED) ranged from 0.02-0.65 mSv and the mean Skin Entrance Dose (SED) ranged from 0.23-3.95 mGy. The absorbed and effective dose was processed using the patient's information and exposure factors. The study found that the results were generally in agreement with international standards and results from other countries, except in few cases where the result was higher than the results for Lumber spine and thorax examination; yet below IDRL, respectively. In general, these results pointed out that when clinical factors (patient weight, height, age) and technical factors (mAs, KvP, projection, FDD) are optimized to the required standard, patient doses are maintained as low as reasonably achievable (ALARA).

ACKNOWLEDGEMENT

The authors would like to express their heartfelt gratitude to the staff of the public hospitals who provided the datasets, for their invaluable support and cooperation throughout this study.

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