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Dose Optimization and Radiation Safety for Paediatric Patients in North Eastern Nigeria

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Abstract
Ionizing radiation from medical sources, primarily diagnostic X-rays, constitutes the largest artificial contribution. Variances in patient doses across radiological departments for similar examinations prompted surveys on patient doses in diagnostic radiology globally. The study Assess the Entrance Skin Dose for paediatric patients during specific radiological exams (Chest AP/PA, Skull AP, and Pelvic AP) and then compare the findings to the diagnostic reference levels established by international organizations. Three x-ray machines from three different tertiary health institutions with facilities for paediatric radiography were used under clinical conditions for the selected radiological examinations. A total of 135 TL dosimeter chips positioned selectively on patients at the axis of the primary X-ray beam to capture entrance skin dose/dose equivalent Hp (0.07). The TLD chips underwent analysis by heating using Harshaw 4500 automatic TLD reader and ESD for each patient was calculated using a given equation. Result indicated that the total average maximum and minimum mean and standard error (SE) value of age group of the participants are 0.60±0.3 – 13.50±0.7, tube loading kVp as 54.90±0.0 – 73.70±1.3 and tube current mAs 4.5±0.2 – 12.5±1.0 respectively. The mean values of ESDs found at each hospital are much higher than, the same published studies and the internationally recommended values and dose reference levels by National Radiation Protection Board (NRPB), International Commission on Radiological Protection (ICRP), and European Commission (EU). This is presumably due to the use of low kVp and high mAs at all hospitals compared to the recommendations by National Radiation Protection Board (NRPB), International Commission on Radiological Protection (ICRP) and European Commission (EC).

Keywords: Radiation, Dose, Dosimetry, Paediatric, Entrance skin dose

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INTRODUCTION

X- radiation remains the most commonly utilized ionizing radiation source in medicine, playing a crucial role in disease diagnosis and treatment, and significantly contributing to the effective dose for both patient and personnel (Yahaya *et al.,* 2019). Radiation protection for children in radiology is crucial because their tissues are more sensitive to radiation, and they have more time for potential effects to manifest. Exposure can lead to genetic mutations and higher risks of cancer in developing organs and tissues (Mesfin, Elias and Meskamu, 2017). According to the European Commission (EC), radiation exposure during the first 10 years of life is estimated to pose a risk approximately four (4) times greater than exposures experienced between the ages of 30, and 40, with potential adverse effects (EC, 1999).

Over the past two decades, numerous dose surveys have been conducted worldwide to study patient radiation doses. These surveys have highlighted significant variations in doses among different radiological departments performing the same examination type (Eric *et al.,* 2013), indicating potential for pediatric dose reduction.

Dosimetry plays a crucial role in radiation protection, particularly for occupational radiation workers, ensuring that regular levels are not exceeded (Bappah et al., 2019). Additionally, medical dosimetry is essential for monitoring the required treatment absorbed dose and any collateral absorbed dose using radiation dosimeters (Izewska & Rajan, 2012). The basic safety standards (BSS) recommend equivalent doses limits to be applied and represented for the whole body, as indicated by the operational quantity Hp (10); and for the extremities, via the operational quantity Hp (0.07). Hp (0.07) dose. defined as the dose at a depth of 0.07mm, is considered the dose received by the skin of workers according to BSS. In this study, dosimeters were employed to evaluate the entrance skin dose using Hp (0.07) and radiation protection levels for the most common radiological procedures in pediatrics. This approach aids in optimizing patient protection and establishing standards of good practice in the study area. Various methods exist for estimating the Entrance Skin Dose 9ESD) in patients undergoing radiological examinations. In diagnostic radiology, ESD estimation commonly relies on dosimeters such as TLD, Ionization chambers and semiconductors (Ackom, 2016). TLD chips were the dosimeter of choice in this study due to its advantage of tissue equivalent and high sensitivity to x-rays. This study was restricted to the most common paediatric x-ray procedures which include; Chest x-ray, Skull and Abdomino-pelvic x-rays. During the study three major hospitals in North eastern Nigeria have granted ethical approval for the study.

The study evaluates the absorbed dose/entrance skin dose (ESD) and radiation protection for pediatric patients during X-ray exams, comparing results with international diagnostic reference levels, and identify opportunities for optimizing protection for pediatric patients.

MATERIALS AND METHODS

Materials

The instruments that were used for data collection in this research study are shown with their specification in Table 1

Table 1: equipment used with their features

S/N	EQUIPMENTS	FEATURES
1.	X ray Machines	GE HUALUM Medical Radiography X-ray machine with Model number XR 6000, Serial number S0S09084 and frequency of 50/60Hz manufactured October 2009: Philips Brilliance x-ray machine (model) manufactured 1997 Nortek (model GAHI840743), frequency of 50/60Hz
2.	Thermoluminescent Dosimeters (TLD)	TLD 100H: Detectors made of LiF:Mn.(Mg)/LiF:Mg, Ti (TLD-100), Reader; Harshaw 4500
3.	Harshaw 4500 automated TLD reader	Hot gas type with two PMTs and nitrogen generator cooling system incorporating WinREMS software resident on a PC
4.	Portable Computer (PC) with internet access	HP elite-book FOLIO 1040 G1, Serial no. 8CG5200 JD5 (Lap top)
5.	Measuring tape	Centi-metered (cm), Inches
6.	Weighing balance	Maximum capacity of 120 kg and error of ±1.2 kg for mass below 60 kg and ±2.0 kg for mass above 60 kg
7.	Masking tape	For levelling

The specification details, including types, model, waveform, filtration, and year of manufacture of the X-ray machines, were documented and displayed in Table 2.

Table 2: X-ray machine specific data used in each hospital.

Specifications	HOSPITAL A	HOSPITAL B	HOSPITAL C
Manufacturer	NORTEK	GE HUALUM	GE
Model/Type	GAHI840743	XR 600 SOS9084	GE DX300
Year of manufacturer	2015	2009	2015
Year of installation	2020	2010	2018
Inherent filtration	1.2mmAL/75kV	1.2mmAL/75kV	1.2mmAL/75Kv
Added filtration	------	-----	-----
Film type	Agfa	Agfa and CR	Agfa
Film screen combination	Fast (200)	Fast (200)	Fast (200)
Focal spot	1.0/2.0mm	1.0/2.0mm	1.0/2.0mm
Processor type	Manual	CR/Automatic	Manual
Used of grid	Yes	Yes	Yes

Methods

The study was conducted in three tertiary health institutions in North Eastern Nigeria, which has facilities for paediatric diagnostic radiology examinations where a primary data was generated on children under 15 years of age during three radiographic procedures that include: Skull FO, Chest AP/PA and Abdomino-pelvic AP examinations performed normally with the paediatric patient lying or standing on a bulky along the central axis of the x-ray beam emanating from the x-ray machine. Before the procedure, each patient's anthropometric parameter like age, sex, mass, height and types of examinations (Chest/Skull/Pelvic) are documented in a data capture sheet together with body mass index (BMI) which was used in the classification scheme for size and shape of a person. The patients mass indices were measured using a personnel bathroom weighing scale with a maximum capacity of 120 kg and error of ±1.2 kg for mass below 60 kg and ±2.0 kg for mass above 60 kg. Patient's height was taken with meter rule. In addition, exposure parameters like tube potential (kVp), tube current and time (mAs) were recorded at the time of the examination and a 90 to 100 focus to skin distance (FFD) in cm was maintained for each exposure made. No interference was made on the radiographers' routine radiographic practices.

Before the beginning of the study the x-ray set ups of each hospital were not assessed as a quality control test as there was no quality control test material available. But a self-administered questionnaire regarding x-ray units and their awareness which assessed the presence of radiation protection devices and adherence to the safety practice of ALARA principles was prepared in English and completed by radiographers. Three X-ray machines were used in this study one from each hospital. Critically ill patients were excluded from this investigation.

The ESD was determined using calibrated LiF TLD chips (TLD-100) positioned on the patient along the primary X-ray beam axis. ES doses were acquired through TLD heating using a Harshaw 4500 automated TLD reader, equipped with various components including data processing electronics, TLD heating system, light measurement system, voltage power supply, data storage system, and video display monitoring with a keyboard for instruction. The entire system integrates two Photomultiplier Tubes (PMTs) housed in a sliding unit, utilizing both planchet and hot gas (nitrogen or air) heating techniques. In this experiment, hot gas is employed, followed by cooling through a nitrogen generator system (Bappah et al., 2019). The system comprises two main components: the TLD Reader and the Windows Radiation Evaluation and Management System (WinREMS) software installed on a personal computer (PC), linked to Reader through a serial communications port. Air kerma measurements were perfumed using calibrated LiF TLD chips (TLD-100), with each kVp set calculated by multiplying the patient's air kerma by the backscatter factor (BSF) value of 1.3, as recommended in the 2018 European guideline published (EC, 2018). A total of one hundred and thirty-five (135) TLD chips were used for the study. The ESD was calculated following the work of Joseph *et al.* (2014) as follows:

$$ESD = ID_{air} \ X \ BSF \qquad (1)$$

Where;

ESD is Entrance Skin Dose

ID_{air} is Incident Absorbed Dose to Air

BSF is back scatter factor with value 1.3

Methods of Data Analysis

Data from the TLD chips were processed using the Harshaw 4500 automated TLD reader at CERT, Zaria. Analysis of the data involved both quantitative and descriptive statistics. Quantifiable data from each radiographic examination were analyzed and presented using mean, range, maximum, minimum, standard error (SE), and visualized through charts and tables. The Calculated ESD was compared with internationally recommended values from organizations like the National Radiation Protection Board (NRPB), International Commission on Radiological Protection (ICRP) and European Commission (EC), along with similar local studies. Dose distributions among the hospitals under study were also analyzed

Ethical Clearance

Ethical clearance was secured from the ethical clearance committee through the head of Radiology Department at the participating hospitals. Additionally, all information was handled with utmost confidentiality.

RESULTS AND DISCUSSION

This study centered on measuring ESD for paediatric Chest (AP), Skull (AP), and Pelvic (AP) examinations. The children were categorized into four (4) age groups: 0-1 year, 1–5 years, 5–10 years, and 10–15 years. During data presentation, acronyms A, B and C were utilized to maintain confidentiality for the three hospitals involved. The outcome of the self-administered questionnaire was deemed satisfactory.

Analysis of Radiographic Parameters and Patient Information

The tube potential (kVp) and tube loading (mAs) are the major radiographic parameters that determine the level of radiation dose to patient. The summary of the mean and standard Error (SE) values of the radiographic parameters used for the paediatric patients undergoing x-ray examination at the three hospitals are given in Tables 3, 4 and 5 for hospitals A, B and C respectively.

Table 3: Mean, Standard Error (SE) of data parameters used in Hospital A

	Age group (Years)											
Exam	**0-1**			**1–5**			**5–10**			**10–15**		
	Age	**kVp**	**mAs**	**Age**	**kVp**	**mAs**	**Age**	**kVp**	**mAs**	**Age**	**KVp**	**mAs**
Chest	0.92	58.0±0.0	j6.4±0.0	3.38	59.3±2.5	6.3±0.3	9.0	68.5±1.0	9.0±1.0	13.5	72.5±1.4	10.6±0.6
Skull	0.67	76.5±1.5	16.0±0.0	3.5	76.3±0.9	12.9±1.2	8.0	64.0±2.9	8.4±0.6	12.7	63.8±2.4	8.7±0.8
Pelvic	---	---	----	2.3	54.7±0.3	5.0±0.0	8.7	65.3±3.0	9.5±1.6	13.2	69.5±2.5	9.9±1.0

It is indicated that the maximum and minimum mean and SE value of age group of the participant is 0.67±0.30 and 13.5±0.7, tube loading kVp as 54.7±0.3 and 76.5±1.5 and tube current mAs 5.0±0.0 and 16.0±0.0 respectively. As indicated, there is a significant level of consistency in the mean age across all age groups for all examinations. A small mean kVp was used in all examination, which is less than internationally recommended value. The maximum kVp variation were the kVp used for skull for the (0-1 year) age backet which extends from 63-76kVp. The minimum kVp used were 54kVp for pelvic for the (1-5 year) age bracket and the maximum mean kVp were 76kVp which were used for skull examination for the (1-5 years) age backet. It was seen that mean kVp increased with age and different kVp were used for the same age bracket for different examination. The mean mAs used were relatively higher compared to internationally recommended value but lower than other international studies (Mesfin, Elias and Meskamu, 2017). Very high mean tube loading (mAs) was seen at this hospital more than recommended value. The minimum mean mAs were 5mAs and the maximum were 16mAs. There was high degree of uniformity in mAs except for the skull examination for the age group (0-1 year) which extends from 8.4-16mAs. The mean mAs showed an increased with patient age across various examinations, with varying mAs for the same examination (Table 3).

Table 4: Mean, Standard Error (SE) of data parameters used in Hospital B

	Age group (Years)											
Exam	**0-1**			**1–5**			**5–10**			**10–15**		
	Age	**kVp**	**mAs**	**Age**	**kVp**	**mAs**	**Age**	**kVp**	**mAs**	**Age**	**KVp**	**mAs**
Chest	0.67	61.0±1.0	4.5±0.5	3.00	63.3±3.3	7.4±0.6	8.2	66.0±2.0	8.8±0.5	13.0	72.0±1.2	10.8±1.4
Skull	1.00	65.0±0.0	8.0±0.0	3.5	66.3±1.3	8.5±0.5	8.0	69.4±0.9	8.9±0.4	13.3	74.7±2.4	10.8±0.8
Pelvic	1.00	60.0±0.0	6.3±0.0	3.8	61.3±1.3	6.0±0.3	7.7	67.5±1.1	8.05±0.5	13.25	68.6±1.3	9.0±0.6

The Data in Hospital B indicated that the maximum and minimum mean and SE value of age group of the participant is 0.67±0.30 - 13.3±0.9, tube loading kVp as 60.0±0.0 - 74.7±2.4 and tube current mAs 4.5±0.5 – 10.8±1.8 respectively. The mean kVp used in all examinations at this facility is below the internationally recommended values, which are typically 80-90kVp (NRPB, 1999) and 60-80kVp (EC, 1991). No desperation of kVp was seen in most examinations. The mean tube potential ranges from 61-72kVp; 65-75kVp; 60-68kVp for chest AP, skull AP and Pelvic AP respectively. High uniformity of mean kVp was seen in most of the examinations. The same kVp were used for the same age group for different examinations. The mean value of mAs extends from 4.5-10.8mAs; 8-10.8mAs; and 6-9mAs in the order of chest AP; skull AP and Pelvic AP examinations.

Table 5: Mean, Standard Error (SE) of data parameters used in Hospital C

	Age group (Years)											
Exam	0 -1			1 – 5			5 – 10			10 – 15		
	Age	kVp	MAs	Age	kVp	Mas	Age	kVp	mAs	Age	KVp	mAs
Chest	0.47±0.2	56.17±2.2	4.67±0.2	2.90±0.5	60.00±2.9	5.00±0.3	8.00±0.0	54.00±0.0	4.00±0.0	13.00±0.0	57.00±0.0	5.00±0.0
Skull	1.00±0.0	68.0±0.0	8.0±0.0	3.4±0.6	59.4±2.9	6.12±0.6	9.00±0.5	62.80±2.1	7.16±0.9	13.00±0.8	70.00±0.0	10.6±1.1
Pelvic	1.00±0.0	50.0±0.0	4.00±0.0	2.95±0.5	57.33±2.1	5.7±0.3	8.75±0.8	63.75±4.7	7.00±1.2	13.75±0.5	67.5±1.5	9.0±0.6

The maximum and minimum mean and standard error (SE) value of age group of the participants in Table 5 are 0.47±0.20 - 13.75±0.5, tube loading kVp as 50.0±0.0 - 70.0±0.0 and tube current mAs 4.0±0.0 – 10.6±1.1 respectively. The mean age extends from (0.5-13) for chest AP (1.0-13) for skull AP and (1.0-13.7) pelvic AP. This study highlights the use of very low tube loading; kVp at this hospital. It's noteworthy that different mean kVp values were employed for the same age group in various examinations. No mean kVp variation was seen in specific age group for specific examinations. The skull (AP) examination in the (0-1 year) age bracket showed a relatively high mean kVp. The mean tube loading extends from 54-60kVp, 59-70kVp, and 50-67kVp in the order of chest AP, skull AP and Pelvic AP.

Range of kVp and mAs of Various Hospital

Table 7 indicates that the mean tube loading (mAs) use d at these hospitals were lower compared to study by Mesfin, Elias and Meskamu. (2017) who found that the mean mAs for his study extends from 30-45mAs for examination of chest, skull and pelvic which were also, higher compared to recommended standards by European Commission. High tube loading (mAs) was used in the study area, which gives higher dose to patient. Hospital B used large range of mean kVp for chest AP examination which extends from 61-72kVp relative to the rest two hospitals. Equal range in mean kVp for skull examination was seen at both A and B.

Table 6: Range of kVp and mAs of various Hospitals for all examinations

	HOSPITAL A		HOSPITAL B		HOSPITAL C	
Exam	KVp	mAs	KVp	mAs	KVp	mAs
Chest	58.0-72.0	6.4-10.6	61.0-72.00	4.5-10.8	54.0-60.0	4.00-5.00
Skull	63.8-76.6	8.4-16.0	65.0-74.67	8.0-10.8	59.4-70.0	6.12-10.8
Pelvic	54.7-69.5	5.0-9.90	60.0-68.80	6.30-9.0	50.0-67.5	4.00-9.00

The comparison of the current study with research carried out in other countries showed that the mean value of tube potential (kVp) is similar to those used in Bilal Hospital (BH), Mariam Work Hospital (MWH) and Dilchora Referral Hospital (DRH) Addis Ababa, Ethiopia. Conversely, increase of 10kVp has shown to decrease dose by 40% without affecting image quality in Mesfin, Elias and Meskamu. (2017) with some countries allowing higher kVp (up to 90 kVp) to reduce patient does.

In general, for all hospitals, they exhibited a trend of utilizing lower tube potentials (kVp) and higher tube loadings (mAs) across all examinations and age groups. All the departments performed their radiological practices with mean tube potentials lower than 80kVp, for age group (0- 1yrs) and (1-5yrs) and less than 90kVp for the age group (5-10yrs) and (10-15yrs) for all types of examinations. These values align with recommendations from the ICRP and other international guidelines, promoting optimal radiographic practices to achieve a balance between minimizing patient dose and obtaining high-quality diagnostic images.

Yet, the radiographers at the study hospitals were unable to provide any rational for achieving acceptable images. It has been shown that increasing the tube potential in chest radiography from 60kVp to 90kVp will result in an Entrance Surface Dose (ESD) saving of 60% (Don 2004). Moreover, research by Gogos *et al.* (2003) has demonstrated that employing high tube voltage and low tube loading techniques during chest X- ray examination can reduce the effective dose equivalent by 20%. The prevalent utilization of low tube potentials (kVp) and high tube loadings (mAs) is likely the primary contributing factor to the high entrance surface doses (ESDs) observed in pediatric patients undergoing chest (AP), skull (AP), and Pelvic AP X-ray examinations across all age groups. This suggests that each hospital pays insufficient attention to patient doses. lower tube potential (kVp) and the higher tube loading (mAs) result in higher entrance skin doses for patients.

Incident absorbed dose to air (ID_{air}) in (mGy)

The TLD chips were analyzed at CERT Zaria and Data obtained from the reading of TLDs are presented in Table 6.

Table 7: Incident absorbed dose to air (ID_{air}) in (mGy) from the three hospitals in all examinations

	Hospital A			Hospital B			Hospital C		
S/No	Chest	Skull	Pelvic	Chest	Skull	Pelvic	Chest	Skull	Pelvic
1	2.52	2.67	3.17	1.05	0.85	2.32	0.08	2.64	2.51
2	1.17	0.00	1.27	1.71	0.66	2.15	0.21	4.52	1.03
3	2.42	0.00	4.79	3.25	0.47	8.55	8.53	1.37	2.22
4	1.55	0.27	10.75	1.43	0.58	5.20	0.87	1.89	3.26
5	1.72	0.80	10.18	3.34	0.9	2.65	0.70	0.79	0.54
6	0.66	0.16	0.37	2.11	1.51	1.93	0.14	0.73	1.80
7	0.76	0.14	27.73	0.85	4.21	0.21	0.28	1.37	1.52
8	1.57	0.19	0.15	1.76	3.18	0.33	0.31	0.72	3.63
9	1.20	0.79	0.34	3.52	0.76	0.97	0.27	3.36	0.96
10	1.54	0.34	3.17	1.05	0.64	1.20	9.61	1.47	0.96
11	1.23	0.09	2.17	4.36	3.49	0.76	0.00	0.59	0.44
12	0.10	0.88	2.88	3.03	2.71	0.35	13.74	0.73	0.57
13	7.35	0.90	1.66	1.24	5.32	0.21	1.22	2.64	0.62
14	7.32	0.12	1.69	3.15	2.17	0.78	1.92	2.30	0.31
15	5.51	0.08	1.57	2.68	2.39	0.52	1.13	1.98	0.60

The values of incident absorbed dose to air (ID_{air}) in (mGy) recorded by TLD chips per each examination.

Entrance Surface Doses

The data, acquired through equation (1), correlates with the incident absorbed dose using a backscatter factor (BSF) of 1.3, as recommended by EC (2018). Summary of the mean ESD (mGy) for Chest (AP), Skull (AP) and Pelvic (AP) examination at the three hospitals were presented in Table 8. As reported elsewhere there were significant differences in the value obtained for the different hospitals, for the same examination and the same age range of the patients. Differences also existed between the data for the same examinations within the same hospitals.

Table 8: Mean ESD (mGy) for the Age groups (Years) and three examination types for all hospitals

	Exam	0-1	1-5	5-10	10-15
Hospital A	Chest	0.99±0.00	2.67±1.04	2.64±0.64	5.06±1.96
	Skull	0.31±0.14	0.63±0.27	0.82±0.55	0.56±0.31
	Pelvic	----	13.30±11.50	2.67±0.93	6.26±2.39
Hospital B	Chest	2.73±1.62	3.95±1.21	2.83±0.56	2.69±0.49
	Skull	0.86±0.00	3.27±1.03	2.63±0.91	1.84±0.85
	Pelvic	0.97±0.00	4.34±2.36	1.74±1.01	1.60±0.76
Hospital C	Chest	0.92±0.37	4.75±2.16	-----------	1.60±0.00
	Skull	1.78±0.00	3.03±0.57	2.62±0.86	1.30±0.39
	Pelvic	2.89±0.00	1.74±0.65	1.61±0.64	1.88±0.79

Mean ESD (mGy**)** is highest in Hospital A for patients in all age groups presenting for Pelvic radiography. Doses were highest for the age range (1-5years) at Hospital A than doses in the other two hospitals for Pelvic (AP). Mean ESD (mGy) is lowest in the same hospital for all age group presenting for Skull radiography. Doses recorded for the age group range (0 – 1years) were lowest at the same hospital than doses in the other two hospitals for Skull (AP). Generally, chest and pelvic examinations from Hospital A and Hospital C of all age group indicated mean ESD value higher than recommended value by National Radiation Protection Board (NRPB), International Commission on Radiological Protection (ICRP) and European Commission (EC), while skull examination for all age groups are within recommended DRL by NRPB, ICRP and EC. For Hospital B, skull and pelvic are within recommended values while chest showed mean ESD higher than value recommended by NRPB, ICRP and EC.

Comparison of the Mean Entrance Skin Dose (ESD) results from the current study with those published in domestic studies

Table 9 illustrates the comparison of mean Entrance Skin Dose (ESD) between this study and a similar study conducted at the University of Calabar Teaching Hospital (UCTH) in Cross River, Southern Nigeria by Hill, as well as that of Ademola et all. From the Westhern region of Nigeria. This study indicates that the mean ESD for chest radiography recorded here is higher across all age groups compared to the same work in UCTH (0-1yrs) and (1 – 5years) are higher than in this study. No established ESD found for the age group from (5 – 10years) and (10 – 15years). For the Pelvic radiography, the ESD found were only for the age group (0 – 1 year) in the work of UCTH which were within the same range with this study for all Hospitals. No established ESD found for the rest of the age groups in UCTH work. No ESD value was established in Hospital A for the age group (0 – 1year) in Pelvic examination. The overall result of this study reveals that pediatric dose for Chest and Pelvic are higher than the dose obtained in a work in UCTH and lower for Skull radiography compared to that of UCTH as shown in (Table 9).

Table 9: Displays the Comparison of Mean Entrance Skin Dose (ESD) results in (mGy) with studies conducted in Nigeria

Exam	Age group	Ademola *et al.* (2013) Nigeria	UCTH, (2013) Nigeria	Current Study Nigeria		
				HA	HB	HC
Chest	0 - 1yr	--	0.65	0.99	2.73	0.92
	2 - 5yrs	0.11	1.82	2.67	3.95	4.75
	6 - 10yrs	0.16	1.70	2.64	2.83	--
	11-15yrs	0.62	--	5.06	2.69	1.60
Skull	0 - 1yr	--	6.22	0.31	0.86	1.78
	2 - 5yrs	0.66	5.16	0.63	3.27	3.03
	6 -10yrs	0.74	--	0.82	2.63	2.62
	11-15yrs	0.86	--	0.56	1.84	1.30
Pelvic	0 - 1yr	--	1.82	--	0.97	2.89
	2 - 5yrs	0.57	--	13.30	4.34	1.74
	6-10yrs	0.85	--	2.67	1.74	1.61
	11-15yrs	1.35	--	6.26	1.60	1.88

Key: -- = No establish value, HA = Hospital A, HB = Hospital B, HC = Hospital C, UCTH = University of Calabar Teaching Hospital

The values of mean ESD in the current study are higher compared to the two studies with least of 0.11mGy in Chest examination of age group 1-5 years while the current study obtained 0.31mGy in Skull examination of age group 0-1year as the least ESD which are all within the recommended values by standard reference bodies.

Comparison of Mean ESD (mGy) Results from Current Study with International Published Studies and Standard International Reference.

Mean ESD values (mGy) from current study were compared with international published studies and National Reference Levels (NRPB) recommended by ICRP and EC for the three procedures (Table 10). The mean ESD recorded in this study exceeds that of studies in Dire Dawa, Ethiopian hospitals (BH, DRH) and MWH Brazil by Mohammadain *et al.* (2004) Furthermore, it surpasses the reference level recommended by NRPB. With the exception of skull examination in Hospital A across all age groups, the mean ESD values (mGy) were lower when compared to internationally published studies and international reference level (NRPB). In Chest AP examinations, the highest mean ESD was observed in Hospital A for (0-1yrs) age backet compared to the work by Mesfin, Elias and Meskamu, for the same (0 – 1year) age bracket. However, for Skull AP examinations, the mean ESD was higher in the same hospital (BH, DRH and MWH) for (0-1year) and (1 – 5years) of age brackets, yet remained lower than the international reference level (NRPB).

Table 10: Comparison of Mean ESD (mGy) with International Published Studies and Standard National Reference

Exam	Age group	NRPB, (1999)	MWH (Brazil)	Ethiopia (2017)		Current Study (Nigeria)		
				BH	DRH	HA	HB	HC
Chest	0 – 1	0.05	0.05	1.37	0.78	0.99	2.73	0.92
	2 – 5	0.07	0.06	2.08	0.93	2.67	3.95	4.75
	6 -10	--	--	2.03	1.31	2.64	2.83	--
	11-15	--	--	2.15	0.84	5.06	2.69	1.60
Skull	0 – 1	0.80	1.23	2.31	1.53	0.32	0.86	1.78
	2 – 5	1.10	1.60	2.62	2.59	0.63	3.27	3.03
	6 -10	1.10	2.04	3.33	2.59	0.82	2.63	2.62
	11-15	1.10	2.55	72.32	1.41	0.56	1.84	1.30
Pelvic	0 – 1	0.50	0.51	1.29	1.08	--	0.97	2.89
	2 – 5	0.60	0.80	1.29	0.93	13.30	4.34	1.74
	6 -10	0.70	1.29	1.44	1.14	2.67	1.74	1.61
	11-15	2.00	1.82	2.18	1.14	6.27	1.60	1.88

-- = No establish value, HA = Hospital A, HB = Hospital B, HC = Hospital C, DRH = Dire Dawa Referral Hospital, BL = Bilal Hospital.

For Pelvic AP examinations, the mean ESD was seen higher to both internationally published studies and international reference level (NRPB). The overall result of this study reveals that the mean ESD is higher than published reference levels recommended by NRPB, ICRP and EC which could be attributed to factors like poor quality control and the state of some of the radiographic equipment used in the institutions.

CONCLUSION

The mean values of ESDs found at each hospital are much higher than, the same published studies and the internationally recommended values and dose reference levels by National Radiation Protection Board (NRPB), International Commission on Radiological Protection (ICRP), and European Commission (EU). This could be attributed to the use of high mAs and low kVp as against the as low as reasonably achievable (ALARA) principle and poor-quality control checks on the x-ray generators. Establishing and implementing regular Quality Assurance (QA) programs, along with fostering a culture of frequent dose measurements, analysis of film rejects, and assessment of image quality, are essential practices to maintain dose levels.

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