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Paediatric entrance surface doses in routine X-ray examinations in three radiology facilities within South-South Nigeria

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ABSTRACT

There is paucity of published studies on the radiation dose received by children in diagnostic radiology sections in radiology facilities within the south – south region of Nigeria. The risk of ionizing radiations on children is higher than the adult patients. Hence, measuring radiation dose to children is mandatory for optimization in radiation protection to compare with international reference dose level. The aim of the study is to measure Entrance Surface Dose ESD of paediatric patients for the most routine types of X-ray examination and to compare the result with internationally recommended dose levels. A cross sectional prospective study was conducted on paediatric patients equal to or less than 15 years of age in three diagnostic centres labeled A, B and C. Exposure factors used for commonly performed X-ray examination like chest, skull, abdomen and pelvis were obtained from each radiology facility and studied for age group 0-1, 1-5, 5-10 and 10-15 years. The mean ESD for chest AP X-ray were 0.992-2.019mGy, 1.373-2.173mGy, and 0.612-1.786mGy for A, B and C Radiology facilities respectively. The mean ESD values for skull AP X-ray were in the range of 1.215-1.526mGy, 2.311-3.332mGy and 0.861-2.059mGy in the selected radiology facilities. Most of the ESD found in this study were higher than the internationally recommended dose levels. Wide variation of doses for same types of examination and projection were detected in each radiology facility. The result of the study indicates a need for quality assurance program to be undertaken regularly to avert considerable cost and high patient doses.

Keywords: Paediatrics, Entrance Surface Doses, x-ray examinations, south-south Nigeria, Radiology Facilities.

1. INTRODUCTION

Living things have evolved in an environment that has significant levels of ionizing radiation. Many of us owe our lives and health to radiation that is artificially produced. X-ray is the type of radiation that is widely used in medical diagnoses but with hidden problems. Radiation is used to diagnose ailments and to treat patients thus people benefit from a multitude of products and services made possible by the careful use of radiation (Hall, 1980). Ionizing radiation damages living tissue; the extent of damage may vary. If this damage is limited to a small number of insignificant cells, the effect on the body may be insignificant. However, if a large amount of cells or if only one cell vital to the functioning of the body is damaged; this may be harmful to the patients' health and wellbeing (Ball & Moore, 1994).

The ICRP recommended that medical activities involving ionizing radiation should fulfil the three basic principles of justification, optimization and dose limitation. One of the requirements of the optimization process is regular periodic monitoring of the performance of radiological equipment and assessment of techniques employed in their use.

Diagnostic Radiology is an accepted imaging modality for the diagnosis of pathological conditions in both children and adults. However, x-rays have inherent hazards that are of special concern when applied to young children. Studies have shown that children less than ten years of age are more sensitive to ionizing radiation than middle-aged adults (Mooney and Habbian, 1998). This is because ionizing radiation can cause genetic mutations and congenital malformations in the fetus. Furthermore, the risk of inducing malignancy is greater in growing organs and tissues. In general, children have a longer life expectancy than adults have and are therefore, at a greater risk to the long-term side effects of radiation. The risk of movement procedure during x-ray procedure is greater with children and this can lead to repeating of the x-ray procedure. This in turn, leads to an increase of the absorbed dose of radiation to the patient.

For these reasons, it is mandatory to minimize radiation dose or exposure in children as much as possible (Azevedo, 2006). Patient dose reduction in diagnostic radiology is important in radiation protection program, and is nowadays a public concern and a legal issue, especially in developed world. Since there is increasing awareness and greater realization of the effect of ionization radiations, users are demanding of dose information and dose reduction (Don, 2004). Quality radiographs and safety to patients undergoing x-ray examinations have become hallmarks of efficient and successful diagnostic radiology unit. Quality control measures have been developed in different countries (Ogundare et al., 2002, 2004). Entrance surface dose (ESD) have been used to report patient doses, and this has been studied for both adult and pediatric patients in many parts of the world (NRPB; 2004). Nigeria has not recorded similar evidence of research in patient radiation concerns, especially with regards to children, who have greater susceptibility to radiation effect.

In south-south Nigeria, there is a shortage of information on patient radiation dose in diagnostic medical radiology. Although there are large number of medical x-ray units in public as well as private health institutes there is neither well established standard dose level, nor published report or study. This might be due to less attention given to radiation protection in the country. Due to lack of standard protocol, Radiography techniques are practiced through experience and depend on a guess of radiographs (SeifeTeferi et al., 2011). Therefore, this study was conducted to estimate dose by using indirect method of ESD measurement to pediatric patients undergoing common diagnostic x-ray examinations in selected radiology facilities within south-south Nigeria.

2. MATERIALS AND METHODS

This was a cross-sectional prospective study conducted on pediatric patients equal to or less than 15 years of age who visited to seek X-ray examinations in Radiology facilities labeled A, B and C between June and July 2017. The sex and age group were randomly selected but care was taken to have adequate sample size in each of sex-age group. Four types of examinations were evaluated. Namely: chest, skull, abdomen and pelvic in different projections. Age category of 0-1 years, 1-5 years, 5-10 years and 10-15 years were chosen based on previous studies (Mohammadain et al., 2004). For each patient, anthropometric parameters like, age, weight and types of examinations (chest, skull, abdomen and pelvic) with their, postero-anterior (PA), Antero-posterior (AP) and Lateral (LAT) projections were documented in the format. In addition, exposure parameters like; tube potential (kVp), tube current (mA), exposure time (sec) and focus to skin distance (FSD) in (cm) were recorded at the time of examination for each exposure made. Missing data appeared as (--) since for some age groups that particular kinds of projection were not used. No interference was made on the radiographers routine radiographic practices.

X-ray tube output measurement

The tubes outputs of all the X-ray equipments were measured by RADEX RD1212 dosimeter. Normalization at 80 kVp 20mAs and focus to skin distance (FSD) of 100cm was used. The potential across the x-ray tube and anode current are highly stabilized at this point. RADEX RD1212 was calibrated for sensitivity in terms of absorbed dose to air kerma or air. Finally, the measured tubes output in units of mGy/mAs for each X-ray tube were obtained.

$$O/P = \frac{AverageDosimeterReadings}{tubecurrenttimeproduct(mAs)} \quad \text{...............(1)}$$

Where, OP is x-ray tube output in (mGy/mAs)

ESD determination

While measuring the air kerma, the following X-ray tube exposure parameters were recorded for each patient undergoing the specified diagnostic procedure: peak tube voltage (kVp), exposure current–time product (mAs), patient weight, patient age, focus-to-patient distance (FSD).

In measuring the entrance surface dose in air, the following x-ray tube exposure parameters were recorded for each patient undergoing a specified diagnostic procedure: peak tube voltage (kVp), tube loading (mAs), focus-to-skin distance (FSD), focus-to-film distance (FFD), film-screen combination, film type and inherent filtration. In addition, patients' information, *i.e*. patient age, and weight were collected taking into consideration only examinations with acceptable image quality. A Backscatter Factors (BSF) value of 1.35 was used as suggested in the ICRP guidelines (ICRP, 1996) for the purpose of this study.

Data Analysis Procedure

Both qualitative and descriptive statistics were used for data analysis. Quantifiable information collected from each radiographic examination was analyzed and presented using table 1.

Table 1 X-Ray Machine Specific data used in each Radiology facility

Specification	A	B	C
Manufacturer	GE Hualun Medical LTD	INUP International Co.	GE Muwaukee Systems corp. Wisconsin. USA.
Model/Type	5189248	46-270615PI	6682743
Year of Manufacture	2013	2012	1995
Year of Installation	2013	2016	---
Inherent Filtration	2.0mmAl	2.0mmAl	1.5mmAl
Added Filter	---	---	---
Type of Generator	3 – Phase & 12 Pulse	3 – phase & 12 Pulse	3 – phase & 12 Pulse
Film Type	AGFA	AGFA and Retina	Retina
Filmscreen C	400	400	400

Screen Type	FLB – 400	BaF FLB – 400	BaF---
Processor	CR	CR	CR
Use of Grid	No	Yes	Yes
Focal Size	1.0mm	1.00mm	1.0mm
Tube Output	0.087	0.092	0.063

3. RESULTS AND DISCUSSION

The mean and SD values of the radiographic parameters (patient age weight; tube potential and tube loading) used for pediatric patients undergoing routine X-ray examination at the facilities are given in Table 2, Table 3 and Table 4 below.

Table 2 Mean, SD, Sample size of patient data in Centre A

Projection	Total Patient		(0-1)				(1-5)				(5-10)				(10-15)			
			Age (yrs)	weight (kg)	KVP	mAs	Age (yrs)	weight (kg)	KVP	mAs	Age (yrs)	weight (kg)	KVP	mAs	Age	weight	KVP	mAs
Chest (AP)	15	Mean	0.4	17.4	110	4	3.7	23	110	4	6.3	32	110	4	--	--	--	--
		SD	0.4	3.4	--	--	1.2	3.2	--	--	0.6	7	--	--	--	--	--	--
		S/Size	5	5	5	5	7	7	7	7	3	3	3	3	--	--	--	--
Chest (PA)	6	Mean	--	--	--	--	--	--	--	--	7	29	110	4	11	43	110	4
		SD	--	--	--	--	--	--	--	--	1	4	--	--	1	10	--	--
		S/Size	--	--	--	--	--	--	--	--	3	3	3	3	3	3	3	3
Skull (AP)	8	Mean	0.4	18	60	8	3	23	63	9	7	29	63	11	12	54	60	10
		SD	0.3	4.3	--	--	1.4	4	4	1.4	1.4	6	4	1.4	--	--	--	--
		S/Size	3	3	3	3	2	2	2	2	2	2	2	2	1	1	1	1
Skull (LAT)	5	Mean	--	--	--	--	2.5	22	60	8	8	33	60	10	13	51	60	10
		SD	--	--	--	--	0.7	4	--	--	--	--	--	--	14	42	--	--
		S/Size	--	--	--	--	2	2	2	2	1	1	1	1	2	2	2	2
Abdomen (AP)	3	Mean	0.8	16	35	8	--	--	--	--	7	25	50	10	11	48	55	12
		SD	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		S/Size	1	1	1	1	--	--	--	--	1	1	1	1	1	1	1	1
Pelvic (AP)	4	Mean	--	--	--	--	4	28	50	10	--	--	--	--	14	31	57	12
		SD	--	--	--	--	--	--	--	--	--	--	--	--	1.5	9	1.7	4
		S/Size	--	--	--	--	1	1	1	1	--	--	--	--	3	3	3	3

Table 3 Mean, SD, Sample size of patient data in Centre B

Projection	Total Patient	(0-1)				(1-5)				(5-10)				(10-15)			
		Age (yrs)	weight (kg)	KVP	mAs	Age (yrs)	weight (kg)	KVP	mAs	Age (yrs)	weight (kg)	KVP	mAs	Age (yrs)	weight (kg)	KVP	mAs

		Mean	0.7	8	55	25	3	13	63	30	8	19	65	30	12.9	24	69	40
Chest	30	SD	0.1	0.8	5	5	0.8	1	3	--	2	2.7	--	--	1.2	1.8	2.7	--
(AP)		S/Size	6	6	6	6	9	9	9	9	8	8	8	8	7	7	7	7
		Mean	--	--	--	--	--	--	--	--	8.5	22	68	30	13.7	24	65	40
Chest	7	SD	--	--	--	--	--	--	--	--	0.6	1	--	--	0.6	1	2.9	--
(PA)		S/Size	--	--	--	--	--	--	--	--	4	4	4	4	3	3	3	3
		Mean	0.8	8.5	65	30	3.5	14	70	30	8	21	75	40	13	22	75	40
Skull	10	SD	0.1	0.7	--	--	0.7	1.4	--	--	1.4	1.4	--	--	0.6	1	--	--
(AP)		S/Size	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3
		Mean	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Skull	0	SD	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
(LAT)		S/Size	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Mean	--	--	--	--	5.5	14.7	60	20	--	--	--	--	12.5	20.5	65	30
Abdomen	5	SD	--	--	--	--	0.6	1.5	--	--	--	--	--	--	0.7	0.7	--	--
(AP)		S/Size	--	--	--	--	3	3	3	3	--	--	--	--	2	2	2	2
		Mean	0.8	7.5	60	20	2.5	11	57	12	8	17	65	20	13	23.5	70	30
Pelvic	9	SD	0.1	0.7	--	--	0.7	1.4	--	--	1	2	--	--	1.4	2	--	--
(AP)		S/Size	2	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2

Table 4 Mean, SD, Sample size of patient data in Centre C

Projection	Total Patient		(0-1)				(1-5)				(5-10)				(10-15)			
			Age (yrs)	weight (kg)	KVP	mAs	Age (yrs)	weight (kg)	KVP	mAs	Age (yrs)	weight (kg)	KVP	mAs	Age	weight	KVP	mAs
		Mean	0.5	17.4	50	4	2.9	22	55	12	6	37	58	12	--	--	--	--
Chest	19	SD	0.3	2.9	--	--	1.4	4	6	4	--	--	--	--	--	--	--	--
(AP)		S/Size	7	7	7	7	10	10	10	10	2	2	2	2	--	--	--	--
		Mean	--	--	--	--	--	--	--	--	8.5	38	58	11	13.3	42	55	10
Chest	10	SD	--	--	--	--	--	--	--	--	1.3	7.3	--	1.5	1.6	8.2	1.4	1.3
(PA)		S/Size	--	--	--	--	--	--	--	--	4	4	4	4	6	6	6	6
		Mean	0.7	15.5	40	8	4.3	25	59	11	7	29	63	1.8	12	54	60	10
Skull	8	SD	0.1	3.5	--	--	1.2	7.4	5.6	1.2	1.4	5.7	--	2.8	--	--	--	--
(AP)		S/Size	2	2	2	2	3	3	3	3	2	2	2	2	1	1	1	1
		Mean	--	--	--	--	2.5	27	56	12	--	--	--	--	13.5	50	57	11
Skull	4	SD	--	--	--	--	0.7	11	2.8	--	--	--	--	--	2.1	6.4	4.2	1.4
(LAT)		S/Size	--	--	--	--	2	2	2	2	--	--	--	--	2	2	2	2

Mean	0.4	15	35	9.3 3	22	40	12	5	19	40	12	12.5	45	64	11		
Abdomen 7	SD	0.3	3.1	--	1.2	--	--	--	--	--	--	--	--	2.1	13.4	8.5	1.4
(AP) S/Size	3	3	3	3	1	1	1	1	1	1	1	1	2	2	2	2	
Mean	--	--	--	--	4	23	48	13	8	33	40	16	11 48	55	12		
Pelvic 4	SD	--	--	--	--	2.1	1.4	3.5	4.2	--	--	--	--	--	--	--	--
(AP)	S/Size	--	--	--	--	2	2	2	2	1	1	1	1	1 1	11		

Table 5 Comparison of Mean ESD (mGy) with internationally recommended values by CEC

Projection	Age Group (Years)	A	B	C	CEC
Chest (AP)	0 – 1	0.992	0.612	1.373	0.050
	1– 5	1.612	1.077	2.084	0.070
	5 – 10	2.019	1.786	2.173	0.073
	10– 15	--	--	2.155	0.071
Chest (PA)	0 – 1	--	--	--	--
	1 – 5	--	--	--	0.032
	5 – 10	1.413	1.295	2.173	0.062
	10 – 15	0.794	0.719	1.863	0.083
Skull (AP)	0 – 1	1.215	0.861	2.311	0.800
	1 – 5	1.367	1.349	2.621	1.100
	5 – 10	1.526	1.378	3.332	1.100
	10 – 15	1.159	2.059	2.323	1.100
Skull (LAT)	0 – 1	--	--	--	--
	1 – 5	1.341	0.977	--	0.500
	5 – 10	1.609	--	--	0.800
	10 – 15	1.671	2.603	--	1.012
Abdomen	0 – 1	0.351	0.170	--	--
	1 – 5	--	0.583	1.312	0.500
	5 – 10	0.919	0.915	--	0.800
	10 – 15	1.170	1.587	1.884	1.200
Pelvis	0 – 1	--	--	1.293	0.500
	1 – 5	0.608	0.547	1.293	0.600
	5 – 10	--	0.581	1.441	0.700
	10 – 15	1.000	1.594	2.183	2.000

The study investigated the ESD (mGy) of pediatric patients equal to or less than 15years undergoing routine x-ray procedures in selected radiology facilities within south-south Nigeria. A total of 154 pediatric patients equal to or less than 15years of age from selected facilities were included in this study; among 61 (40%) from Centre B, 41 (27%) from Centre A and 52 (34%) from Centre C. Four types of examinations were evaluated namely; chest AP/PA, skull AP/LAT, abdomen AP and pelvic AP. For each patient, anthropometric parameters (age, weight) and exposure parameters like tube potential (kVp), tube current (mAs) and FSD (cm) were recorded. Three x-ray machines were used in this study one from each facility. Tube outputs of all the x-ray equipment were measured by RADEX RD1212 dosimeter.

Entrance Surface Dose (ESD) is defined as the absorbed dose in air at the point of intersection of the x-ray beam axis with the entrance surface of the patient including backscattered radiation. ESD was calculated according to the equation;

$$ESD = (O/P) \times \left(\frac{kVp}{80}\right)^2 \times (mAs) \times \left(\frac{100}{FSD}\right)^2 \times (BSF) \quad \text{.....................} \textbf{(2)}$$

The average value of BSF=1.35

In this study, the mean tube potential at Centre A was fixed 110kVp for chest AP/PA, 60-65kVp for skull AP, fixed mean potential for skull LAT 60kVp, 35-55kVp for abdomen, 50-58kVp for pelvic examination. The mean mAs was fixed for chest AP/PA, 8-12, 8-10, 8-12, and 10-16 for skull AP/LAT, abdomen AP, pelvic AP examinations respectively. The mean tube potential at Centre B extends from 55-67kVp and mean mAs was from 25-40mAs for chest AP, similarly for skull AP examination the tube extends from 65-75kVp the mean mAs in the same facility. For Centre C, the smallest mean kVp is 35kVp and smallest mean mAs are 4mAs (similar to that of Centre A). A large variation of ESD (mGy) was observed for all age groups undergoing different examinations.

Centre C recorded the highest dose levels compared to the other two facilities. The large variations obtained are because of the differences in kVp and mAs between the three facilities used in this study.

The comparison of this study with internationally recommended reference dose levels revealed that the mean values of ESDs found at each facility are higher than the internationally recommended values. This indicates that there is a need for reduction in dose levels in the selected radiology facilities used in this study.

The reasons for such high ESDs obtained in the selected facilities may be due to;

- The use of low kVp, which is less than the internationally recommended values 80-90kVp (NRPB, 1999).
- The low inherent tube filtration of all the x-ray units which is less than the 2.5mm recommended inherent tube filtration

The use of dose calculation from exposure factors can give information on radiation burden to the patient and the public as well (UNSCEAR, 2000). In this study, wide variation of doses was obtained for patients within the same facilities for similar examinations. Compared to international levels the reason(s) may be due to;

- Lack of any form of standardization in procedure. There are therefore as many techniques as there are different radiographers in one system (Kyrious et al., 1996)
- To reduce the high doses found in the study facilities the following should be done;
- Using low kVp and high mAs which improves image quality while increasing dose to the patient must be changed so that the dose should be maintained as low as reasonably achieved (ALARA principles).
- The optimization steps should start with the regulatory mandating radiographers and radiologists to take part in various refresher courses for them to be aware of the recent developments on how to properly select technical parameter that will not compromise image quality but lead to reduction patient dose.
- Dose reduction would be possible without adversely affecting image quality by simple programming of education, regular, provision of dose information and an approach involving collaboration between physicists, radiographers and radiologists, a significant impact can be made on doses received by patients in medical x-ray.
- Further courses, trainings, workshops and participation in national and international meetings, on radiation protection for the radiographers and the staffs should be organized and planned so as to update their knowledge.
- Quality assurance (QA) programs must be set up and executed on regular basis so that to have significant effect in reducing doses and improving image qualities.
- Pediatric radiology unit should be separated if possible since children need special attention to minimize the dose and risks.

4. CONCLUSION

From the results obtained, it can be concluded that the ESDs of (ESD) of paediatrics for routine X-ray examinations in the selected radiology facilities within south-south Nigeria were higher than the reference levels recommended by CEC.

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