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Evaluation of Entrance Skin Dose from Paediatric Diagnostic X-Ray Examination

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Abstract

As children are prone to be more radiosensitive than adults, it is imperative to assess the Entrance Skin Doses (ESDs) for patients being examined by X-rays, in order to ensure the optimization of dose while considering a number of other fickles. The ESD received by 50 paediatrics (aged 1 - 13 years) undergoing 8 types of X-ray examinations were measured at Federal Teaching Hospital, Ido-Ekiti, Ekiti, Nigeria, within a period of February 2019 to March 2020 using thermoluminescent dosimeters. The mean ± SD of ESDs were 0.85 ± 0.32, 2.04 ± 0.75, 0.60 ± 0.07, 0.62 ± 0.22, 0.57 ± 0.24, 1.75 ± 0.76, 0.93 ± 0.31 and 0.63 ± 0.06 mGy for Chest, Skull, Hand, Forearm, Knee, Abdomen, Leg and Feet, respectively. The mean ESDs were found to be within the recommended reference dose in all examinations, except for the Chest examination which was higher. The data obtained in this study will serve as existing data in Nigeria for future research works, as it would assist in optimizing dose to patients, especially the paediatrics.

Keywords

Entrance Skin Dose, Paediatrics, X-Rays

1. Introduction

In the diagnosis of pathological conditions, both in children and in adults, diagnostic radiology (otherwise known as X-rays) is an accepted imaging procedure that is typically used to diagnose bone degeneration, fractures, dislocations and infections in patients. However, it is important to understand the level of patient dose and corresponding factors that affect them [1] in order to achieve a good image quality production while minimizing the amount of dose a patient is being exposed to, most especially in paediatrics [2] [3]. This is because children live longer than adults, have growing organs and are prone to be more sensitive to radiation effects than adults [4]. Thus, radiation protection of paediatric patients becomes important, as a result of the increased radiation risks to children.

It is worthy of note that the major focus of medical concerns is to produce a good quality image while limiting the levels of radiation exposure to patients. This becomes more essential while handling children; unfortunately, the same cannot be said about the medical concerns in Nigeria. Substantial dose reduction during the X-ray examination is possible without detriment to the image quality [2] through proper justification, optimization and application of dose limits in the examination procedures used.

The patient dose is often described by the Entrance Skin Dose (ESD), which is defined as the absorbed dose to air on the X-ray beam axis at the point where the X-ray beam enters the patient skin. Due to the fact that most diagnostic X-ray centres in Nigeria do not have a designated X-ray unit for paediatrics, such that the practice of radiographers in such units is basically for adults and inconsiderate of children. Hence, there is a possibility of children being exposed to higher levels of radiation while undergoing X-ray examinations, which is why optimization of dose and X-ray imaging parameters must be guided by the ALARA (As Low As Reasonably Achievable) principle [3]. Research work conducted in Nigeria on radiation dose to children in routine X-ray examination attributed the high ESD received by paediatric patients to a lack of dedicated X-ray units and personnel [5].

A large number of examinations are being carried out in Nigeria; however, the available dose information for paediatric patients is grossly inadequate. On this note, this research aims to measure the Entrance Skin Dose (ESD) of paediatric patients undergoing diagnostic X-ray examinations in Federal Teaching Hospital, Ido-Ekiti, Ekiti State.

2. Materials and Methods

This study was carried out at the radiology centre of Federal Teaching Hospital, Ido-Ekiti, Ekiti State, Nigeria in the period from February 2019 to March 2020. Due clearance was obtained from the ethical committee of the hospitals before commencing the research work, after which consent was obtained from parents or guardians of the patients. The sample size of 50 paediatric patients (male and female) between the ages of 1 - 13 years, who were referred to the X-ray unit of this hospital for diagnosis within the stated period, was considered.

The specification of the X-ray machine in this facility is as follows: Neusoft XG-CS-R-N Model; manufactured in year 2011, Installed in year 2013 with a Filtration of 2.0 mm Al/24 kV; 3600 W.

Different X-ray examinations including Chest PA, Skull AP, Hand AP, Forearm AP, Knee AP, Abdomen AP, Leg AP and Feet AP at a focus range of 70 - 100. Abdomen AP was done at 100 cm while Chest PA was at 120 cm. The age, weight, height, gender and BMI, type of X-ray examination, exposure projection (AP/PA) and X-ray tube details (kVp and mAs) for each patient were duly recorded.

Entrance Skin Dose (ESD) was measured using calibrated Thermo Luminescent Dosemeters (TLDs), affixed to the skin of patient along the path of the primary X-ray beam to measure doses to the chest, skull, hand, forearm, knee, abdomen, leg and feet. The weight of the patients were recorded using the hospital weighing scale, with a measuring tape held against a vertical pole to measure the height of the patient. The Body Mass Index (BMI) of the patient was calculated by dividing the weight (kg) of the patient by the square of the patient's height (m). Data obtained were transferred to Microsoft Excel spreadsheet, presented as mean ± SD and afterwards analysed using statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA) version 23.0. Correlation between ESD and patient characteristics/exposure parameters was statistically significant at the $p < 0.05$.

3. Results

Table 1 shows the mean ± SD values of all paediatric patients examined in this study. The sample size consists of 50 patients (30 males, 20 females) within the age range of 1 - 13 years with a mean age of 5.99 ± 3.80 years; weight ranged from 10 to 35 kg with a mean value of 22.56 ± 8.18 kg; the height ranged from 79 to 128 cm (99.92 ± 20.30 cm) and the Body Mass Index (BMI) of 22.17 ± 3.03 kg/m^2 which ranged from 17.72 to 36.22 kg/m^2.

The mean ± SD values of the X-ray tube exposure parameters are presented in Table 2. The tube voltage (kVp) of 55.14 ± 15.05 ranged from 25 to 80, the tube current (mAs) of 9.60 ± 8.80 ranged from 2 to 30, the mean Focus to Skin Distance (FSD) ranged from 62 to 110 with a mean value of 87.98 ± 15.56 and the Entrance Skin Dose (ESD) had a mean value of 0.91 ± 0.49 mGy ranging from 0.23 to 2.90 mGy.

Table 3 shows a comparison of mean ESDs for different examinations observed in this study with other published works. The maximum ESD was observed in Skull AP (2.04 ± 0.75 mGy) while the minimum ESD was observed in Knee AP (0.57 ± 0.24 mGy).

Table 1. Mean and standard deviation of patient demographic data.

	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m^2)
Mean ± SD	5.99 ± 3.80	22.56 ± 8.18	99.92 ± 20.30	22.17 ± 3.03
Min	2	10	79	17.72
Max	13	35	128	36.22

Table 2. Mean and standard deviation of radiography X-ray machine.

	kVp	mAs	FSD	ESD
Mean ± SD	55.14 ±15.05	9.60 ± 8.80	87.98 ± 15.56	0.91 ± 0.49
Min	25	2	62	0.23
Max	80	30	110	2.90

In Table 4 and Table 5, it was observed that age and type of exposure projection had no significant relationship with ESD. However, the age group of 5 - <10 years had the maximum number (21) of paediatric patients presenting for X-ray examinations and received the maximum ESD as seen in Table 6.

The weight and height of the patients had significant impact on the ESDs while there was no correlation between the patients' BMI and ESD (Table 7). A correlation between the exposure parameters in Table 8 shows that there is a significant relationship between the ESDs and kVp/mAs, however, there is no correlation between FSD and ESD. A published work has earlier stated that dose absorbed by the skin is directly proportional to the square of the peak voltage, the tube current and the duration of exposure [1].

Table 3. Mean and standard deviation of ESDs for different X-ray examinations.

	ESD					Recommended Standards	
	N	Mean	Min	Max	*p-value*	EC, 1996 mGy	NRPB, 2000 mGy
Chest PA	8	0.85 ± 0.32	0.46	1.47		0.3	0.2
Skull AP	3	2.04 ± 0.75	1.59	2.90		5	3
Hand AP	11	0.60 ± 0.07	0.48	0.71		-	-
Forearm AP	5	0.62 ± 0.22	0.42	0.95	0.001	-	-
Knee AP	9	0.57 ± 0.24	0.29	1.10		-	-
Abdomen AP	2	1.75 ± 0.76	1.22	2.29		10	-
Leg AP	10	0.93 ± 0.31	0.60	1.44		-	-
Feet AP	2	0.63 ± 0.06	0.58	0.67		-	-
Total	50	1.00 ± 0.57	0.71	1.44			

Table 4. Mean and standard deviation of ESDs according to gender.

		ESDs			
Gender	N	**Mean ± SD**	Min	Max	*p-value*
Male	30	1.01 ± 0.55	0.23	2.90	
Female	20	0.75 ± 0.34	0.29	2.06	0.658
Total	50	0.88 ± 0.45	0.26	2.48	

Table 5. Mean and standard deviation of examination projections.

		ESDs			
Projection	N	**Mean ± SD**	Min	Max	*p-value*
AP	39	0.81 ± 0.48	0.29	2.90	
PA	11	0.96 ± 0.34	0.46	1.47	0.445
Total	50	0.89 ± 0.41	0.28	2.19	

Table 6. Mean and standard deviation of ESDs according to age group.

	ESDs				
Age (Years)	N	**Mean ± SD**	Min	Max	*p-value*
1 - <5	17	0.68 ± 0.20	0.32	1.29	
5 - <10	21	1.10 ± 0.62	0.29	2.90	0.807
10 - 15	12	1.00 ± 0.43	0.23	2.06	
Total	50	0.93 ± 0.42	0.28	2.08	

Table 7. Correlation between the Entrance Skin Dose (ESD) and the patient characteristics.

Correlation between ESD and the Patient Characteristics		
Weight (kg)	Pearson Correlation (r)	0.266**
	R^2	0.071
	Significant Difference (p)	0.007
Height (cm)	Pearson Correlation (r)	0.253*
	R^2	0.064
	Significant Difference (p)	0.011
BMI (kg/m^2)	Pearson Correlation (r)	−0.054
	R^2	0.003
	Significant Difference (p)	0.593
Age (years)	Pearson Correlation (r)	0.263**
	R^2	0.069
	Significant Difference (p)	0.008

*significant at 0.05 level (2-tailed), **significant at 0.01 level (2-tailed).

Table 8. Correlation between the Entrance Skin Dose (ESD) and exposure parameters.

Correlation between ESD and Exposure parameters		
Tube Voltage (kVp)	Pearson Correlation (r)	0.663**
	R^2	0.440
	Significant Difference (p)	0.000
Tube Current (mAs)	Pearson Correlation (r)	0.735**
	R^2	0.540
	Significant Difference (p)	0.000
FSD (cm)	Pearson Correlation (r)	0.108
	R^2	0.012
	Significant Difference (p)	0.286

*significant at 0.05 level (2-tailed), **significant at 0.01 level (2-tailed).

4. Discussion

The ESD of 50 patients (30 male; 20 female) were measured. In Table 3, it was observed that the measured ESDs in this study were lower than what was recorded in other studies; although the measured ESD for chest (0.85 ± 0.32 mGy) in this study is higher than the recommended values [6] [7]. Also, the measured ESD for Skull AP (2.04 ± 0.75 mGy) in this study is close to what was recorded by the NRPB report [7] by 0.96 mGy, but lower than the value recorded by the

European Commission [6].

Similar examinations carried out in Sudan showed the measured ESDs for Chest PA, Skull AP and Abdomen AP to be 0.16, 0.55 and 0.46 mGy respectively [8]. A study in Iran recorded 0.09 mGy for Chest PA and 0.10 mGy for Abdomen AP [9] while a similar study in Saudi Arabia recorded 0.32, 0.40 and 0.35 mGy for Chest PA, Skull AP and Abdomen AP respectively [10].

The type of equipment and radiographic technique used determines the quantity of radiation dose received by a patient; however, this procedure differs from one hospital to another. For example, a study conducted in Korea used a focus range of 180 cm [11], a similar study conducted in Zimbabwe maintained a focus range of 100 cm [12] while this study used a focus range of 70 - 100 cm. The use of different focus range by different authors has an effect on reported patient doses and may explain the reason for having varying entrance skin dose as reported by the authors. A report of a study conducted in year 2003 stated that an increase in film focus reduces, to some extent, the radiation dose for X-ray examinations by about 33% - 44% [13].

Furthermore, the use of low kVp and high mAs contribute to the dose a patient receives. It was observed for all types of examinations and projections in this study, that the tube current (mAs) comprises of low tube voltage (25 - 80 kVp) and high tube load (2 - 30 mAs) which is lower than the value [high voltage (60 - 79 kVp) and low tube load (2 - 7 mAs)] recommended by the European Commission [6]. As a result, this study recorded a significant correlation ($p < 0.01$) between the ESDs and kVp/mAs (r = 0.663/r = 0.735 repectively). A similar study carried out in three Nigerian Eastern hospitals recorded high doses of about 44.7% difference when compared with a similar study conducted in three Nigerian western hospitals; which was traceable to the use of low kVp and high mAs, as well as lack of standardization in procedures [14].

It is expected that the ESD should increase as the patients' weight increases. A correlation between ESD and patient weight in this study showed that the weight of the patients had significant impact on the ESDs (r = 0.266, $p = 0.007$). In addition to this, the age of patients is expected to affect the ESD value, however, it did not significantly contribute to the patient dose in this study (r = 0.263, $p = 0.008$). This is similar to the findings reported by Atalabi *et al.*, where age had no significant effect on the patient dose [5].

However, it is expected that exposure factors should be selected carefully to ensure dose optimization while examining paediatric patients. Thus, the higher dose observed in this study for Chest PA is unhealthy for the paediatric population. It was also observed in the course of the study that there is no designated X-ray department for children, such that the same X-ray exposure parameters are being used for both adult and paediatric populations.

The major limitation of this study was that the number of paediatric patients coming for X-ray examination is very small, compared to adults…thus, took more time to get the desired number of patients.

5. Conclusion

This study which was conducted at Federal Teaching Hospital Ido-Ekiti, Ekiti is considered to take a run at evaluating doses received by paediatric population between the ages of 1 - 13 years undergoing different X-ray examination procedures; taking into account, there is a wide variation in patient sizes as children grow in body sizes and in age. The mean ESDs were found to be within the recommended reference dose in all examinations, except for the Chest PA which was higher than the recommended dose reference. The data obtained in this study will serve as existing data in Nigeria for future research works, as it would assist in optimizing dose to patients, especially the paediatric population.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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