

ASSESSMENT OF ENTRANCE SKIN DOSE TO PAEDIATRIC POPULATION IN SOME HOSPITALS IN SOUTH-WEST, NIGERIA.

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ABSTRACT: *The use of radiographic procedures generates a number of benefits with an existing potential for radiation-induced injuries in patients. The risk is higher in the paediatric population as children are more radiosensitive than adults and have an increased life time risk per unit dose. Hence, this research aims to assess radiation doses to paediatric patients in some south western hospitals in Nigeria. In this study, Entrance Skin Dose (ESD) was measured in six radiology departments of six hospitals using Thermo-luminescent Dosimeters (TLDs). The study population included 528 consented paediatric patients of both genders referred to the centres aged 0 – <16 years. Fourteen different radiographic techniques were considered in this study. However, only four (Chest PA, Skull AP, Abdomen AP and Pelvis AP) were found comparable with other similar published studies. The mean ESD values obtained were 1.01, 2.02, 2.08 and 1.16 mGy for Chest PA, Skull AP, Abdomen AP and Pelvis AP respectively. The mean ESDs were found to be relatively higher than those recorded in literature.*

Keywords: Entrance Skin Dose, Paediatric Population, x-ray, Thermo-luminescent Dosimeters, Hospitals in Southwest Nigeria, Radiographic Techniques

I. INTRODUCTION

Diagnostic Radiology (such as Radiography/Conventional x-rays, Computed Tomography, CT and Fluoroscopy) is an accepted imaging modality for the diagnosis of pathological conditions in both children and adults. The imaging techniques are based on the absorption of x-rays as they pass through different parts of a patient's body. The reaction of the human skin to ionizing radiation also plays a vital role in the use of x-rays for diagnosis and treatment of malignant radiation diseases.

Therefore, it is important to understand the level of patient dose and corresponding factors that affect them [1]. However, radiographic procedures could increase the radiogenic risk of cancer in paediatric patients because children have an increased life time risk per unit dose, growing organs/tissues, developing immature bones and are

more radiosensitive than adults. The higher risk is due to longer life expectancy in children for any harmful effects of radiation to manifest and the fact that developing organs and tissues are more sensitive to the effects of radiation [2]. As a result of the increased radiation risks, radiation protection of paediatric patients becomes important.

It is worthy of note that the main purpose of any radiological procedure is ultimately to achieve the well-being of the patient by minimizing the stochastic risks and avoiding deterministic injuries while producing a good image quality. Substantial dose reduction during the x-ray examination is possible without detriment to the image quality [3]. This can be achieved through proper justification, optimization and application of dose limits in the examination procedures used. However, optimization of dose and x-ray imaging parameters must be guided by the ALARA (As Low As Reasonably Achievable) principle [4].

Studies on patient dose have indicated that the dose a patient receives can vary considerably from one healthcare unit to another, even for the same type of examination/x-ray projection, suggesting that there is a considerable margin for optimization and dose reduction [5, 6, 7, 8], which could be as a result of patient attributes, radiographic procedures, technical/equipment factors and level of quality assurance put in place [9]. In general, the major focus of medical concerns is to limit the levels of radiation exposures when handling paediatric patients.

In spite of the large number of examinations carried out each day/year in Nigeria, the available dose information for paediatric patients is grossly inadequate. It has been observed that most diagnostic x-ray centres in Nigeria do not have dedicated x-ray unit for paediatric patients, as a result, x-ray operators use radiographic parameters/techniques meant for adults on paediatric patients. Thus, there are possibilities of high exposures to radiation as children are known to be highly radiosensitive.

Hence, this research aims to assess radiation doses to paediatric patients undergoing x-ray examinations in some south western hospitals of Nigeria.

II. MATERIALS AND METHODS

A large-scale survey of doses to paediatric patients undergoing the most frequent radiological examinations was carried out in some hospitals in Southwest, Nigeria which comprises one (1) Private, three (3) State and two (2) Federal hospitals. Thermo-luminescence dosimeters (TLDs) were used to evaluate the entrance skin dose (ESD) to the patients. Entrance Skin Dose (ESD) was used as the dose parameter for setting the diagnostic reference level as recommended by the European Union and the International Atomic Energy Agency [10, 11]. The TLDs were calibrated before use to ensure validity and reliability. Chest, Skull and Lumbar Spine examinations were included in the trial. Consent was obtained from parents or guardians of the paediatric patients. Due clearance was obtained from the ethical committee of the hospitals before the commencement of the research. This study was conducted in six healthcare centres in Soutwestern region of Nigeria (as seen in Table 1) following the guidelines outlined in European Commission Guidelines [12].

Table 1: Study Area

S/N	Name of Hospital	Abbreviation
1	Federal Medical Centre, Owo	FMC
2	State Specialist Hospital, Akure	SHA
3	Ekiti State University Teaching Hospital, Ekiti	ETH
4	Federal teaching Hospital, Ido, Ekiti	FTH
5	Adeoyo State Hospital, Ibadan	ASH
6	Two-Tees Diagnostic Centre, Ibadan	TTD

A total of 528 (298 males and 230 females) patients below 16 years of age who came to the hospitals for x-radiographic examination were included in the study, using calibrated TLD chips for dose measurement. Summary of the radiographic equipment (tube potential kVp, tube load etc), patient distribution (weight, sex, age and name of the irradiated part) and average radiographic parameters (exposure projections; AP/PA) for each examination were recorded for each hospital. The most frequent/routine examinations were investigated in this study. For all examinations, TLD chips were attached to the skin of each patient along the path of the primary x-ray beam, to measure doses for the chest (AP/PA/Lateral), abdomen (AP), lumbar

spine (AP), skull/brain (AP/lateral), pelvis (AP), knee (AP) and hand (AP), Leg (AP/LAT) respectively.

Materials used are:

- A simple bathroom weighing scale capable of weighing up to 120kg and graduated at 0.1kg intervals, to measure patients weight
- A measuring tape held against a vertical pole to measure the height of patients
- TLD chips to measure Entrance Skin Dose
- A tape to affix TLD chips to patients skin

Data collected were categorized according to the hospitals, patient’s identification number, age, etc. The data generated from the study were analysed based on the objectives of the study and presented on tables and graphs as appropriate with the aid of Microsoft Excel 2010 software and statistical software SPSS Version 23 for descriptive and inferential analysis.

III. RESULTS AND DISCUSSION

Data in Table 2 shows that the filtrations of two of the machines fall short of the minimum filtration requirement for good practice [9].

Table 2: Personnel and x-ray Machine Specification at all Centres

Hospital	X-ray Tube Model	Year of Manufacture or Installation	Number of Radiologist (Radiographer)	Total Filtration (mm Al)
SHA	Allengers 525	-- (2011)	1 (2)	0.9
FMC	Roentgen 500	N/A	2 (1)	2.1
ETH	Allengers 40	2012	1 (2)	0.9
FTH	Neusoft XG-CS-R-N	2011 (2013)	2 (3)	2.0
ASH	GE ML-02-F	2009	1 (2)	0.9
TTD	Allengers 525	2007 (2008)	2 (2)	0.9

N/A – Not Available

Summary of mean and group mean of ESD with the corresponding Standard Error on Mean (SEM) in each hospital for different examinations are shown in Table 2. The last

column of Table 3 shows the Mean of Means (Group Mean) of all the six hospitals with its corresponding SEM [SEM (N_R)]. Thus, the mean value of each hospital in a group is considered to be a random variable [3]. It is visibly shown on the table that there are insufficient dose data for Humerus AP, Elbow AP and Pelvis AP.

This error [SEM (N_R)] can therefore be expressed as a percentage of the group mean value which varies for each examination, ranging from 21% for Knee LAT examination to 51% for Lumbar Spine AP examination. The variation observed in this study could be as a result of differences in sample size (that is, number of x-ray rooms) as well as the inherent variations in patient dose values for different examination types. For the purpose of dose optimization studies, inherent variations in patient dose value are of utmost relevance, as it indicates that the fundamental nature of the radiological process will lead to inherently different variations within a population of x-ray rooms for different types of examination [3].

The higher group mean for the investigated population sample observed in this study falls short of a standard radiological practice. Children are usually considered to be at higher risk from radiation effect since they have an increased sensitivity for certain forms of cancer and also an increased life-time risk to exhibit induced malignancy [3]. As observed in this study, the wide spread in doses require an investigation into the major causes of delivering relatively higher doses to the paediatric population.

Table 4 shows the summary of mean and range of exposure factors selected during the routine examinations and the associated characteristics of all patients during the imaging procedures in the hospitals visited. The exposure factors include tube potential (kVp), tube load (mAs), focus to image receptor distance (FIRD) and patient characteristics such as age and weight. Published data (kVp and mAs) for paediatric patients are not available for comparison in the NRPB (2002) document [14].

Table 3: Mean ESD (mGy) for each hospital and corresponding SEM including the group mean

Exam	SHA	FMC	ETH	FTH	ASH	TTD	Group
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	SEM(R)	SEM(R)	SEM(R)	SEM(R)	SEM(R)	SEM(R)	Mean SEM(N _R)
Chest PA	1.10 (0.13)	0.68 (0.07)	0.66 (0.03)	0.85 (0.11)	0.36 (0.02)	2.38 (0.33)	1.01 (0.29)
Shoulder AP	1.59 (0.60)	1.21 (0.02)	0.72 (0.13)	--	--	3.76 (0.55)	1.82 (0.67)
Skull AP	1.08 (0)	0.90 (0.12)	--	2.04 (0.43)	--	4.07 (1.07)	2.02 (0.73)
Skull LAT	0.54 (0)	4.48 (1.83)	--	1.65 (0.15)	--	5.29 (0.52)	2.99 (1.13)
Leg AP	0.86 (0.13)	1.52 (0.34)	0.62 (0.05)	0.93 (0.10)	--	3.01 (0.30)	1.39 (0.43)
Leg LAT	1.02 (0.21)	1.40 (0.16)	0.61 (0.04)	0.88 (0.14)	0.34 (0.11)	3.35 (1.00)	1.27 (0.44)
Humerus AP	--	--	--	0.63 (0.16)	0.37 (0.06)	--	0.50** (0.13)
Hand AP	1.06 (0.47)	0.85 (0.13)	0.48 (0.06)	0.60 (0.02)	--	2.69 (0.17)	1.13 (0.40)
Hand LAT	0.82 (0.17)	1.34 (0.35)	0.69 (0)	0.74 (0.09)	0.27 (0.10)	2.20 (0.16)	1.01 (0.28)
Forearm AP	0.94 (0)	--	--	0.62 (0.10)	0.32 (0.02)	2.77 (0.40)	1.16 (0.55)
Forearm LAT	--	2.19 (0.35)	--	0.66 (0.05)	0.23 (0.04)	3.14 (1.06)	1.56 (0.67)
Ankle AP	1.23 (0.60)	1.52 (0.52)	0.70 (0.06)	--	0.35 (0.01)	--	0.95 (0.26)
Knee AP	1.14 (0.36)	--	0.61 (0.08)	0.57 (0.08)	0.28 (0.03)	2.96 (0.56)	1.11 (0.48)
Knee LAT	0.61 (0.02)	--	0.63 (0.05)	0.65 (0.04)	0.30 (0.04)	1.17 (0.16)	0.67 (0.14)
L/Spine AP	2.14 (0)	0.32 (0)	0.75 (0.21)	--	--	--	1.07 (0.55)
Elbow AP	0.94 (0)	--	0.6 (0.05)	--	--	--	0.77** (0.17)
Abdomen AP	--	0.673 (0)	2.57 (0)	1.75 (0.54)	--	3.307 (0.63)	2.08 (0.57)
Pelvis AP	--	--	0.84 (0.20)	--	1.49 (0.30)	--	1.16** (0.33)
Feet AP	--	--	0.79 (0.02)	0.63 (0.04)	0.25 (0.03)	2.67 (0.27)	1.08 (0.54)

L/Spine – Lumbar Spine **insufficient data

Table 4: Summary of mean and range of patient characteristics and exposure parameters selected for the different examination in all the hospitals visited

Exam/	Mean	Mean	Mean	Mean	Mean
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Projection	kVp (range)	mAs (range)	FIRD (cm) (range)	Age (y) (range)	Mass (kg) (range)
Chest PA	67.55 (45-83)	41.50 (3-150)	151 (90-180)	9.91 (6m-15½)	31.97 (9-50)
Shoulder AP	63.09 (50-76)	44 (5-150)	90 (70-100)	2.57 (3m-6)	13.36 (5-22)
Skull AP	76.23 (63-90)	94.23 (25-150)	94 (65-100)	6.46 (1½-13)	21.69 (12-38)
Skull LAT	74.77 (50-85)	69.27 (24-150)	87.85 (65-100)	5.92 (1-13)	22.50 (12-38)
Leg AP	60.06 (25-70)	60.55 (2-150)	96.51 (80-103)	6.02 (17d-15)	23.12 (4-46)
Leg LAT	61.43 (45-70)	40.05 (2-150)	96.71 (80-108)	7.99 (2½-15½)	27.83 (14-50)
Humerus AP	50 (43-57)	4.25 (2-10)	97.50 (97-98)	3.5 (1-6)	16.5 (10-23)
Hand AP	52.82 (41-65)	20.59 (2-150)	85.68 (67-100)	5.80 (8m-15½)	22.95 (10-44)
Hand LAT	55.08 (43-65)	31.92 (2-150)	86.92 (67-100)	6.60 (11m-14)	24.31 (10-41)
Forearm AP	48.89 (25-68)	7.19 (2-30)	85.44 (45-100)	5.62 (9d-12)	19.89 (3-43)
Forearm LAT	53.50 (25-75)	42.46 (2-150)	90.50 (60-100)	7.86 (9d-12)	24.50 (3-43)
Ankle AP	54.36 (43-66)	34.22 (2-150)	95.82 (90-100)	9.64 (3-15)	33.18 (15-48)
Knee AP	51.40 (41-70)	9.42 (2.5-30)	95.92 (90-100)	5.06 (2-11)	21.20 (10-35)
Knee LAT	47.65 (41-65)	6.55 (2-30)	94.70 (90-100)	5.05 (2-11)	20.95 (10-35)
L/Spine AP	62.75 (55-81)	60 (25-150)	95 (90-100)	6.92 (1¼-16)	24.50 (15-45)
Elbow AP	57.67 (50-63)	11.33 (2-30)	93.33 (90-100)	7 (4-9)	24.33 (18-28)
Abdomen AP	70.22 (60-75)	41.78 (18-150)	94.67 (80-106)	2.96 (24d-9)	12.89 (2-30)
Pelvis AP	60.25 (45-70)	14.50 (2-25)	95.25 (90-101)	9.88 (2-14)	34.63 (13-45)
Feet AP	52 (6-67)	8.85 (2-15)	91.18 (80-100)	6.07 (17d-15)	24.35 (4-46)

Table 4: Comparison of group mean of ESD (mGy) measured PLRDLs-G with other published works (NDRLs)

Exam	PLRDLs-G					
	Group Mean SEM (N = 6)	Saudi Arabia NRDLs ^(a)	Iran NDRLs ^(b)	Sudan NDRLs ^(c)	UK NDRLs ^(d)	UK NDRLs ^(e)
Chest PA	1.005 (0.29)	0.32	0.09	0.16	0.3	0.2
Shoulder AP	1.820 (0.67)	DNA	DNA	0.46	DNA	DNA
Skull AP	2.022 (0.73)	0.40	DNA	0.55	5	3
Skull LAT	2.990 (1.13)	DNA	DNA	DNA	DNA	DNA
Leg AP	1.386 (0.43)	DNA	DNA	0.39	DNA	DNA
Leg LAT	1.265 (0.44)	DNA	DNA	DNA	DNA	DNA
Humerus AP	0.497 (0.13)	DNA	DNA	0.27	DNA	DNA
Hand AP	1.132 (0.40)	DNA	DNA	0.15	DNA	DNA
Hand LAT	1.010 (0.28)	DNA	DNA	DNA	DNA	DNA
Forearm AP	1.163 (0.55)	DNA	DNA	0.20	DNA	DNA
Forearm LAT	1.556 (0.67)	DNA	DNA	DNA	DNA	DNA
Ankle AP	0.951 (0.26)	DNA	DNA	0.41	DNA	DNA
Knee AP	1.112 (0.48)	DNA	DNA	DNA	DNA	DNA
Knee LAT	0.671 (0.14)	DNA	DNA	DNA	DNA	DNA
L/Spine AP	1.069 (0.55)	DNA	DNA	DNA	DNA	DNA
Elbow AP	0.771 (0.17)	DNA	DNA	0.29	DNA	DNA
Abdomen AP	2.077 (0.57)	0.35	0.098	0.46	10	DNA
Pelvis AP	1.162 (0.33)	DNA	DNA	0.63	10	3
Feet AP	1.082 (0.54)	DNA	DNA	0.21	DNA	DNA

PLRDLs-G: Preliminary Local Reference Dose Levels across the six hospitals

DNA: Data Not Available ^a [15]; ^b [16]; ^c [17]; ^d [12]; ^e [14]

Table 4 shows a comparison of measured ESD in the group during the local dose audit with results published in other countries (only few countries were included due to dearth of published data on paediatric population) for all paediatric age groups. The ESD (proposed LDRLs-G) obtained in this study was compared with the published national diagnostic reference levels (NDRLs) in Asia (Saudi Arabia, Iran, Sudan), Europe (UK) and London (UK) for paediatric patients, which is conveniently shown in Figure 1.

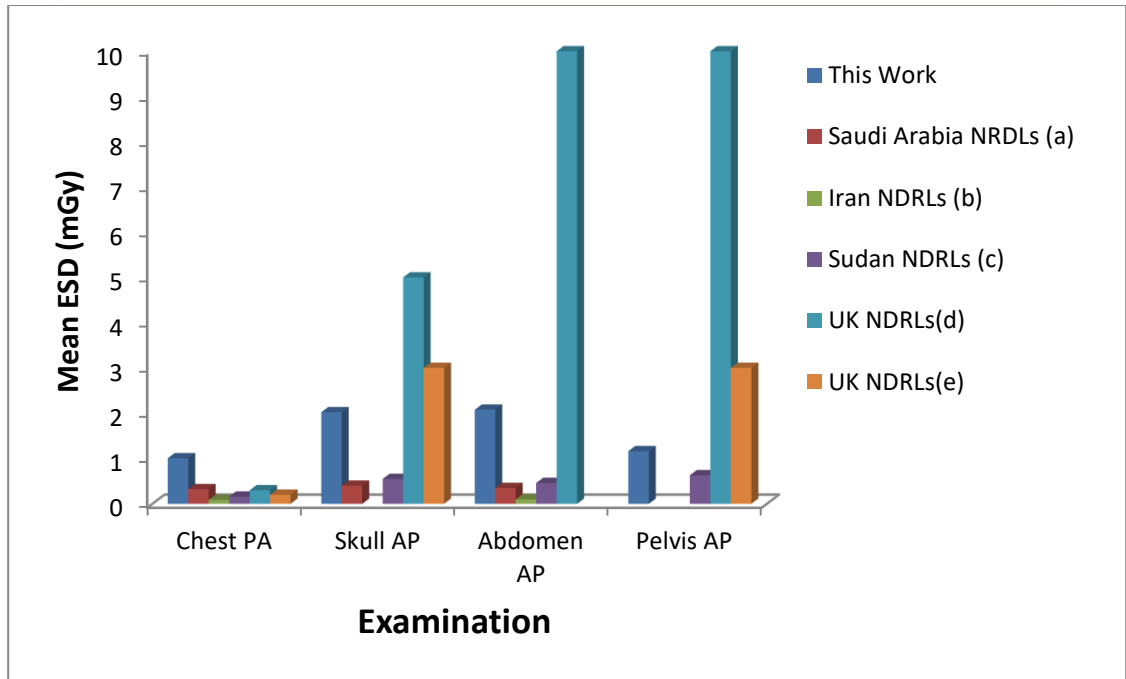


Figure 1: Comparison of group mean of ESD (mGy) with National Diagnostic Reference levels (NDRLs)

The comparison reveals that the group mean ESDs of this study is substantially higher than the values (published NDRLs) obtained in other countries in Chest PA, Skull AP, Abdomen AP and Pelvis AP examinations for all the patients examined. Thus, it is necessary to ensure that regular dose measurement and optimization is put into practice in Nigeria. Nevertheless, it is noteworthy that dose of Abdomen AP and Pelvis AP is lower than the NDRLs published in the UK. This trend is acceptable but does not indicate a good radiological practice because several factors can affect patient dose.

There are different methods used in measuring ESD which could be the reason why there are so many different variations in dose values. Studying the paediatric population, it is important to note that there is a wide variation in patient sizes as the children grow and increase in age, this can affect the ESD value in children of different ages. The European Commission discouraged the use of tube voltage less than 60 kVp for paediatric patient [12].

However, in this study, for all types of examinations and projections, it can be seen that the exposure factors used for all paediatric patients comprises of low tube voltage (41

– 81 kVp) and high tube load (2 – 60/150 mAs), which is lower than the value [high voltage (60–79 kVp) and low tube load (2–7 mAs)] recommended by the European Commission [12] and some other international guidelines as a measure of good practice to be ALARA compliant (that is, optimising dose to patients while producing good diagnostic images). This implies that the quantity of incident radiation is higher while its penetrating energy is low, which explains the reasons for recording high ESD values in some examinations in this study. Similar studies conducted on paediatric patients in some hospitals [18–20] also reported the use of low tube voltage and high mAs against recommended values, which resulted in high ESD values.

IV. CONCLUSION

Entrance Skin Doses (ESDs) were estimated in this study for paediatric patients undergoing routine x-ray examinations in six different hospitals in South-West Nigeria using thermo-luminescent dosimeters (TLDs). It is observed that there is a wide variation in patient sizes as the children grow and increase in age, which affected the ESD value in children of different ages. A comparison of the ESD values in this study with published NDRLs (Europe, Ethiopia, UK and USA for standard paediatric patients) revealed that the dose in this study is higher than those of published NDRLs in other countries in Chest PA, Shoulder AP, Skull AP and Abdomen AP; but the dose of Pelvis AP is lower than the NDRLs published in the UK. The results revealed that the higher doses recorded in this study is due to the use of the same x-ray facilities for both adult and paediatric population (including new-borns) which is however unhealthy for the paediatric population and does not indicate a good radiological practice.

Thus, there is a need to make available a special radiological centre for the paediatric population alongside a review of the exposure parameters used during the examination according to the paediatric age group. It was also observed that low kVps and high mAs were used as exposure parameters on paediatric patients in all the radiological centres studied, which explained why the patients were exposed to high radiation doses. Hence, it is necessary to train radiologists/medical physicists on the importance of dose reduction and optimization while achieving an image of good quality.

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VI COMPETING INTERESTS

The authors declare that there is no competing interest.

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