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Research Article

Radiation Doses of Chest, Skull, Hand and the Effects of Chest Radiographic Examinations on Paediatric Patients in Nigeria

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SUMMARY

Objective: Entrance surface doses (ESD) of chest, skull and hand of paediatric patients were measured in this study. The implications of chest radiographic examinations for cancer incidence and mortality among children in Nigeria were also examined.

Methods: Thermolumenescent dosimeter (TLD) chips were used to measure entrance surface doses. The ESD measured in chest PA were converted to organ dose using DoseCal software. Organ doses for five organs in chest region were used with Risk Tables to estimate life attributable risk (LAR) of cancer in Nigeria.

Results: The results of ESD obtained from the first group (GROUP A) are chest PA (2.42), skull AP (3.86), and hand AP (1.66) mGy, while the results of the second group (GROUP B) are chest PA (0.60), skull AP (1.46) and hand AP (1.97) mGy. The 75th percentile which can be taken aspreliminary reference levels for paediatric patient in southwestern Nigeria are chest PA (2.46 mGy), skull AP (3.04 mGy) and hand AP (2.63 mGy) for both groups. These are higher than the value obtained the United Kingdom. The incidence and mortality of lung cancer are higher in female (LARin-554, LARmort- 544) patient than for male patient (LARin-533, LARmort-502) in spite of lower female dose indicating it is gender dependent.

Conclusion: Relatively higher doses recorded in this study indicate that there is room for dose reduction in Nigeria without impairing image quality. The higher incidence and mortality of lung cancer in female patients calls for caution during radiographic examination of female paediatric patients.

INTRODUCTION

Radiographic Imaging is a non-invasive method of assessing abnormalities in a body using radiation sources, such as x-rays and gamma rays. This method has proved effective even with the introduction of computer tomography (CT). However, in spite of its effectiveness, it has its attendant risk of detrimental radiation effects. As a result of the risk involved in the use of radiation, it is important to carry out radiation protection of patient, public and the personnel. Radiation Protection is the process of safeguarding the society from radiation effects. In the UK approximately 90% of population dose from all sources, except natural background radiation, is due to medical x-rays.[1]Since radiological procedure are thought to carry some health risk,[2] it is important that x-rays imaging be performed within the framework of the established principle of radiation protection.[3]

The two major principles of radiation protection are: (i) principle of justification and (ii) principle of optimization. These principles are put in place by International Regulatory bodies such as; International Atomic Energy Agency (IAEA) and International Commission on Radiological Protection (ICRP).

The principle of justification stipulates that for the radiological procedures to be performed, its benefits must exceed the risk involved in the examination. Moreover, the concept of optimization as indicated in the ICRP 26 document, that the limitation of stochastic effects is achieved by keeping all justifiable exposure as low as reasonably achievable (ALARA), economic and social factors being taken into account.[4]

Risks of detrimental radiation effects are higher for paediatric than for adult.[5] Therefore, it is particularly important to ensure that radiation doses to paediatrics are kept low. Studies on radiation doses from diagnostic x-ray examinations have largely focused on adult population. Several radiation dose measurements have been carried out in Nigeria to determine the levels of patient exposures. However, few paediatric dose assessment and risk estimation were undertaken especially among different age groups of paediatric patients.

Dose optimisation is of particular importance in paediatric radiology for a number of reasons: (1) there is greater chance for expression of radiation-induced effects (such as cancer and leukaemia),[6] (2) some examinations are carried out with greater frequency in children especially, the

premature babies or sick neonates which receive a large number of radiation doses during the first few months of life, as their health conditions are monitored, and this can sometimes continue through early childhood, (3) children will often be uncooperative during x-ray examinations, and this leads to repeat or longer exposures (4) comparison of paediatric dose data are also problematic. This is due to the wide range of patient sizes involved (neonate to adolescence-0-15 years). The variability in age band and sizes create problems in both the actual dosimetry such as the application of the organ dose data[7] meant for adult to paediatric patients of different age groups and sizes.

Against this background radiation dose measurement of paediatric patients is very important. The present study aims to determine paediatric doses of chest PA, skull AP and hand AP. Cancer risks associated with chest PA diagnostic imaging of paediatric patients in Nigeria would also be determined. Knowledge of the number of patients that are likely to incur cancer could help Physicians, Radiologists and Radiographers optimize dose received by paediatric patients during routine diagnostic examination.

MATERIALS AND METHODS

Radiation dose measurements were carried out in fifteen x-ray units in SW, Nigeria during routine diagnostic examinations of paediatric patients. Entrance surface doses were measured using calibrated thermoluminescence dosimeters (TLD) chips. The TLD chips were obtained from Standford Dosimetry, LLC (Bellingham, USA) and calibrated with the facilities of National Institute of Radiation Protection and Research (NIRPR), University of Ibadan. The study was carried in five states of SW, Nigeria. These are: Lagos state (4 units); Ogun State (2 units); Oyo State (2 units); Osun State (5 units); Ekiti State (2 units). For better analysis, the centres were divided into two groups: GROUP A and GROUP B. The first group (GROUP A) consists of the following units coded: OAUTHI, FMID, EKTH, LH A, LH B, VHI, SDAI and the second group (GROUP B) coded : TT A, TT B, ANID, AYS, FKJL, ALH A, ALH B and AGH. Quality control test of seven out of fifteen x-rays machines investigated are recorded elsewhere [8] and were found to be within the acceptable limit required by the international regulatory bodies such as International Commission on Radiological Protection (ICRP) and National Radiological Protection Board (NRPB).

The radiation outputs in mGy (mAs)-1 of eleven x-ray units were measured at a distance of 1metre using calibrated QC kit (kV metre NEROTM 6000M, manufactured by Victoreen, INC, Cleveland, Ohio, USA). Machine output was measured at a voltage of 80 kV and 10 mAs as the potential across the x-ray tube. At this voltage, the anode currents are highly stable.[9] These were used to test the linearity and reproducibility of tube potential (kV) and tube load (mAs). At the time of examination, patient parameter such as thickness of the examined region, patient height, and patient weight were recorded during examinations. Exposure parameters used for patient exposures-tube potential (kVp), tube load (mAs), x-ray tube to patient surface distance (FSD), x-ray tube to film distance (FFD), and patient thickness (d)- were also recorded during diagnostic examination.

Entrance surface doses (ESD) were measured during routine diagnostic examination of the paediatric patients using TLD chips. This was done to assess the level of patient exposures. The ESD is a measure of radiation dose absorbed by the skin where the x-ray beam enters the patient. It includes the scattered radiation from the patient. The measured ESDs were converted to organ dose using DoseCal Software.[10,11] This was developed by Radiological Section of Saint George's Hospital, London. The organ doses obtained were used to calculate the lifetime attributable risk (LAR), using risk tables for male and female patients.[12] Both incidence of cancer and mortality rate were calculated. The values of LAR were calculated by multiplying the specific patient organ dose by the LAR for a given age group (0-5 and 6-10yr), and organ of interest in a population of 10,000. The risk calculated was extrapolated to a population of paediatrics in Nigeria. In this study, the age band of paediatrics is assumed to be 0-15 years. The mean age of male and female paediatrics considered for calculating LAR was 5 years and 7 years respectively.

The report of the State of the World Population [13] indicates that, children constitute 43.8% of the population. Meanwhile, the population Nigeria is 178.5 million [13], therefore the population of children is about 78.2 million children in Nigeria. The results of LAR obtained from a population of 10,000 were extrapolated to a population of 78.2 million children in Nigeria.

RESULTS AND DISCUSSION

Table 1 is the summary of mean range of exposure parameters selected during routine diagnostic examinations and the associated characteristics of patients examined during the imaging of paediatric patients at different centres (GROUPS A and B). The exposure factors include tube potential (kVp), tube load (mAs), focus to skin distance (FSD), and patient characteristics such as: age, thickness (De-also known as patient equivalent diameter especially for the trunk region derived from patient height and weight).

The table (Table 1) shows that the value of kVp recorded in GROUP A and B are lower than the mean value recorded by [14] in the USA by at least a factor of 1.1 for chest PA, Skull AP and Hand AP. Meanwhile, the mAs selected in Chest PA, Skull AP and Hand AP are higher than the published value by factors ranging between 2.7 and 11.5. The result of tube load (mAs) in GROUP B is comparable with the value found in the data recorded in the published work in the United State of America. [14]

In another comparison of exposure parameter data in this study with earlier study [15] carried out in the eastern part of Nigeria (Table 2), results of chest PA, and skull AP show that kVp of both GROUP A and B are lower than the value recorded in UCTH but higher than values recorded in FMCO and NAUTH by at least a factor of about 1.3. Similar trend is seen in Skull AP. The results of mAs recorded in GROUP A indicate that the value for Chest PA is higher than the value used in FMCO. The X-ray unit used in FMCO appeared to be digital with automatic exposure device (AED). However, the value selected in GROUP A is lower than the exposure parameter selected in UCTH and NAUTH. The same trend was found in Skull AP for values of mAs recorded. The value of mAs selected in UCTH is higher by a factor of 2.5 than the tube loads recorded in both GROUP A and GROUP B recorded in this study. If higher tube loads are used, it could lead to poor image contrast and quality; and thus leading to

repeated examination and higher doses.

Table 3 and Table 4 are the results of mean entrance surface dose (ESD) measured in GROUP A and GROUP B diagnostic centres. Columns 2-8 are the mean ESD measured during routine diagnostic examinations of paediatric patients. The last column is the group mean with standard error of mean (SEM-NR) obtained for each examination.

In Table 3, the range of doses in Chest PA, Skull AP and Hand AP are 0.67 -3.34 mGy, 0.29-7.13 and 0.045-2.72 mGy respectively. The ranges of ESD recorded in GROUP B in Chest PA, Skull AP and Hand AP are 0.13-1.03, 0.032 -4.38 and 0.51 -3.39 mGy respectively. Table 3 shows that the group mean and the standard error of mean for Chest PA, Skull AP and Hand AP are 2.42 (0.54), 3.86 (1.98) and 1.66 (0.62) mGy respectively.

Table 4 shows that the group mean of ESD for six centres (eight X-ray units) and the equivalent standard error of means for Chest PA, Skull AP and Hand AP are 0.60 (0.14), 1.46 (1.007), and 1.97 (1.48) mGy. The group mean obtained in Tables 3 and 4 could be regard as local reference values for paediatric patients in the two groups investigated in Nigeria. This is based on the acceptable fact that when data from several X-ray rooms are combined, the group mean forms a local reference value. [16] In addition, it is the standard error on the mean obtained from multiple X-ray room (SEM(NR)) that determines the tolerance limit of each examination. The mean dose measured in each room is considered as random variable. The standard error of mean for all hospital (SEM(NR)) can be expressed as the a percentage of group mean for each examination. [8,17]

By expressing standard error of mean (SEM(NR)) as a percentage of group mean, the results obtained range between 22.3 %(chest PA) and 51.3% (Skull AP) for GROUP A. For GROUP B, the percentage of (SEM (NR)) to the group means range from 23.3% (Chest PA) to 75.1% (Hand AP). The variation could have arisen from both the difference in the number of X-ray rooms (n) as well as inherent variation in the patient dose values for different types of examinations.[17] A comparison of this paediatric study with study for adult patients[8] indicates that the group mean entrance surface doses (ESDs) calculated in adult patient (GROUP A) are higher than the paediatric patient in chest PA and Skull AP by factors of 1.24 and 1.02 respectively. In GROUP B, the calculated adult group mean ESD are higher than the group mean ESD of paediatric in Chest PA and Skull AP by higher factors of 2.96 and 6.02 respectively. However, in both GROUP A and B, the mean doses delivered to the Hand AP measured in paediatric patient are higher than the dose received by the adult group.

The higher paediatric group mean dose observed in the present study falls short of a good radiological practice. Children are usually considered to be at higher health risk from radiation as they have both an increased opportunity for expression of induced malignancy, and increased sensitivity for certain forms of cancer.[6] The trend found in this study requires that investigation into the causes of relatively higher doses in paediatric patient be carried out to find out the major factors leading to higher doses. Examination of the trigger level (doses level at which investigation into reason for higher values), shows that the condition for further investigation into the causes of high doses were found in skull AP (GROUP A) and Hand AP (GROUP B). This is because the values of 2 x SEM (NR) for the groups exceed the group mean in both cases. This requires that the factors responsible for high doses in each of the mentioned projection be identified and corrected by optimisation.

The action levels recommended by the International Atomic Energy Agency (IAEA) were also determined in this study. The ESD action levels (ALs) in this study were found to be 0.22 mGy (Chest PA) and 0.14 mGy (Skull AP). This action level is taken to be 10 percentile of the total dose measured. The action level is the appropriate dose level of the population at which to initiate evaluation of image quality. This level indicates that, if the mean dose at local institution is less than the 10th percentile for the same procedure in the population used to define the reference levels, evaluation of image quality should be performed. [18]

Determination of ALs is encouraged because poor image quality could lead to loss of diagnostic information which might engender repeated examinations, and thus leading to increase in dose burden.

Table 5 shows statistical parameter for the overall mean, minimum, maximum, 75thand 80th percentile entrance surface dose distribution for different procedures. The overall mean and the corresponding 75th percentile for Chest PA, Skull AP and Hand AP are 1.99 (2.46), 2.05 (3.04) and 1.42 (1.73) mGy respectively. This 75th percentile could be regarded as paediatric preliminary regional reference levels in southwestern Nigeria where the study was carried out.

Mean doses of for chest PA and Skull AP for GROUP A are greater than GROUP B. However, in Hand AP, the mean ESD in GROUP Ais less than those of GROUP B. Both mean ESD measured and derived 75th percentile in GROUP A and B are greater than CEC and UK diagnostic reference levels.[19] The differences in the mean ESD and 75th percentile could be as result of differences in patient size, experience of radiographer, filtration of machine, nature of film used and the chemical used for film processing. It is therefore important that Radiographer undergo further training to be abreast on various methods of reducing patient dose while maintaining quality image. The implication of the 75th percentile being greater than the CEC and UK reference dose [19] is that, it is possible to further reduce the dose in this study without impairing the image quality.

Table 7 and Table 8 are the results of estimated life attributable risk of cancers (incidence and mortality) in Nigeria. The estimates are from the average ages of 7-year old male and 5-year old female patients during chest routine examinations. Five organs of interest examined were lung, breast, easophagus, stomach and liver. Life attributable risks for solid cancer were also estimated. Life attributable risk is defined as additional cancer risk above and beyond baseline cancer risk.[20] It can be calculated for both specific as well as cancer combined.

In Tables 7 and 8 column 2 shows the estimated organ dose using DoseCal Software for the 7 year-old boy and 5-year old girl. It is clear from Table 7 that breast cancer is not expected from male population. In male paediatric, the number of cancer cases are as follows: lung cancer (incidence-533, mortality-503); easophagus (incidence-60, mortality-45); stomach (incidence-182, mortality-94); liver (incidence-228, mortality-198), and solid cancer (incidence-16,00, mortality-8,000). For female group, the number of

expectedcancer cases are as follows: lung cancer (incidence-554, mortality-544); breast cancer (incidence-488, mortality-221);easophagus(incidence-18, mortality-18); stomach (incidence-113, mortality- 78); liver (incidence-46, mortality- 42),andfor solid cancer (incidence-12,000, mortality-5,000). The incidence and mortality of solid cancer is higher in male than in female. A Comparison of incidence and mortality of lung cancer in both male and female patients shows that, in spite of low doses in female group (0.47 mGy) as against (0.87 mGy) in male group, lung cancer incidence and mortality are still higher in female than in male paediatric population.

The percentage mortality of lung cancer is also higher (97.7% as against 94.5%) in female than in male patient. Asides, there are additional cases of about 488 incidence of breast cancer and 221 cases of mortality in female population. This shows that examination of female patients should be handled with utmost care. Owing to the nature of female paediatric patient, alternative imaging techniques can be used, being mindful of the radiological impact of chest X-rays on female group as revealed in this study. Patient could also be tilted away from primary X-ray beam.

The results in Column 2 and 5 for lung cancer (in Tables 7 and 8) show that lung cancer is gender dependent rather than dose dependent. It is also evident from the two tables that the percentage of cancer mortalities is higher in lung cancer (94.5%) than liver cancer (87.5%). In addition, in female group, higher percentage of mortalities is observed in lung cancer (98.2%), Easophagus cancer (99.2%) and liver cancer (91.7%). The percentage of mortality in Easophagus is relatively lower in male group (74.1%). It is clear from the results of this study that, the percentages of cancer mortalities are generally lower in male than in female group. The percentage differences of cancer mortality between female and male groups areas follows: Lung (3.7%), Easophagus (25.1%) and Liver (4.2%). The percentage of mortality is relatively lower for both male and female group in solid cancer.

Table 1: Summary of mean and range of patient characteristics and exposure parameters selected for the different examinations in GROUPS A and B (paediatric) centres studied

Exam/ Projection	Group	No of units (n)	Mean kVp (range)	Mean mAs (range)	Mean FSD (cm) (range)	Mean Age (yr) (range)	Equivalent diameter De (cm) (range)	Mean weight (kg) (range)	kVp (mAs) US Huda et al, 1998
Chest PA	A	5	65 (55-85)	22 (6-48)	91 (69-184)	8 (0-15)	15 (12-18)	22 (5-40)	70 2.5mAs)
	B	3	62 (51-78)	11 (4-24)	115 (67-162)	10 (1-14)	15 (11- 20)	21 (5-55)	
Skull AP	A	3	67 (60-75)	23 (19-30)	95 (90-122)	14 (10-19)	10 (9-12)	26 (23-29)	76 (2.0 mAs)
	B	2	61 (46-76)	21 (6-64)	89 (60-185)	10 (4-15)	16 (5-18)	27 (8-40)	
Hand AP	A	3	58 (53-60)	15 (4-32)	91 (101-128)	8 (2-12)	11 (7-13)	29 (9-32)	64 (5.5 mAs)
	B	2	42 (37-45)	4 (2-8)	72 (50-79)	12 (11-14)	10 (8-12)	39 (24-50)	

Table 2: Comparison of Exposure parameters in this study with the published data

Centre		Tube Potential (kVp)	Tube Load (mAs)	Age (yrs)
Chest PA				
This study	A	65 (55-85)	22 (6-48)	8 (0-15)
	B	62 (51-70)	11 (4-24)	10 (1-14)
*UCHTH		70.4(60-84)	28.91 (10-80)	2.13 (0-9)
**FMCO		50.8 (50-55)	1.39 (0.3-6.4)	2.57 (0-9)
+NAUTH		49.89 (48-50)	25.66 (15-45)	2.25 (0-6)
Skull AP				
This study	A	67 (60-75)	23 (19-30)	14 (9-12)
	B	61 (46-76)	21 (6-64)	10 (4-15)
*UCHTH		78.4 (75-88)	58.6 (50.0-62.5)	3.43 (1-9)
**FMCO		50	2.13 (2.-3.2)	1.41 (0-2)
+NAUTH		50	43.2 (30-45)	1.56 (0-2)

*UCTH- University of Calabar Teaching Hospital, ** FMCO- Federal Medical Centre, Owerri, +NAUTH- Nnamdi Azikwe University Teaching Hospital (Egbe *et al*., 2007).

Table 3: Mean ESD (mGy) for each centre and corresponding SEM including group mean GROUP A (paediatric)

Exam	OAUTHI SEM(R)	FMID SEM(R)	EKTH SEM(R)	LH A SEM(R)	LH B SEM(R)	VHO SEM(R)	SDAI SEM(R)	Group mean SEM (N_R)
Chest PA	3.25 (2.01)	-	0.67 (0.30)	3.34 (2.37)	-	1.60 (0.65)	3.22 (1.65)	2.42 (0.54)
Skull AP	-	-	4.16 (0.35	0.29 (0.21)	7.13 (0.46)	-	-	3.86 (1.98)
Hand AP	-	-	2.58 (0.19)	-	2.72 (0.019)	1.30 (0.23)	0.045 (0.011)	1.66 (0.62)

Table 4: Mean ESD (mGy) for each centre and corresponding SEM including group mean of GROUP B paediatric.

Exam	TTPC 1 SEM (R)	TTPC 2 SEM(R)	ANHS SEM(R)	AYHS SEM(R)	FKJSH SEM (R)	ALSH 1 SEM(R)	ALSH 2 SEM(R)	OAGSH SEM(R)	Group mean SEM(N_R)
Chest PA	0.68 (0.17)	-	-	0.13 (0.0012)	0.56 (0.14)	1.03 (0.32)		0.60 (0.12)	0.60 (0.14)
Skull AP	1.22 (0.83)	-	-	0.032 (0.0031)	-	0.21 (0.068)		4.38 (2.17)	1.46 (1.007)**
Hand AP	0.56 (0.055)	-	3.39 (0.35)	-	-	-	-	-	1.97 (1.48)

Table 5: Statistical parameters for the overall mean, minimum, maximum 75th and 80th percentile ESD (mGy) distribution for different procedures and patient information (paediatrics).

Exam Type	N	Mean Weight (kg)	Mean Age (yr)	Mean ESD (SEM)	Min ESD (mGy)	Max ESD (mGy)	Median ESD (mGy)	75th Percentile ESD (mGy)	80th Percentile ESD (mGy)	Max/min
Chest PA	47	19.0 (4-55)	6.1 (5d-15)	1.99 (0.43)	0.11	15.11	0.81	2.46	2.85	137
Skull AP	24	23 (5-40)	8.1 (5d-15)	2.05 (0.66)	0.07	15.04	1.45	3.04	3.86	215
Hand Ap	18 (5-50)	26 (0.16-14)	7.9 (0.24)	1.42	0.26	2.63	1.64	1.73	1.81	100

Table 6: Comparison of group mean of GROUP A and B with 75th percentile of ALL distribution of doses (ESD and DAP- paediatric)

Exam	ESD (mGy)				
	GROUP A	GROUP B	75th percentile	*DRL(CEC)	**DRL (UK)
Chest PA	2.42 (0.54)	0.60 (0.14)	2.46	0.1	0.07
Skull AP	3.86 (1.98)	1.46 (1.01)	3.04	1.5	-
Hand A	1.66 (0.62)	1.97 (1.48)	1.75	-	-

*CEC, 1997 ** SRPA (2002)

Table 7: Organ dose and the life attributable risks derived from organ dose and risk tables for 7 year old boy

Organ of interest	Organ dose (mGy)	LARin Per 10,000	LARin for Nigeria	LARmort Per 10,000	LARmort for Nigeria	Percentage of mortality
Lung	0.87	0.0697	532.70 (533)	0.0658 (503)	502.9	94.5
Breast	0.21	-	-	-	-	-
Easophagus	0.32	0.00790	60.38	0.00585	44.72	74.1
Stomach	0.17	0.0238	181.91	0.0123	94.04	51.7
Liver	0.34	0.0296	226.24	0.0259	197.96	87.5
All solid	1.91	2.096	16,020.5	1.109	8,476.55	2.91

Table 8:Organ dose and the life attributable risks derived from organ dose and risk tables for 5 year old girl

Organ of interest	Organ dose (mGy)	LARin Per 10,000	LARin for Nigeria	LARmort Per 10,000	LARmort for Nigeria	Percentage of mortality
Lung	0.47	0.07255	54.15	0.0712	544.20	97.66
Breast	0.12	0.0639	487.65	0.0289	220.89	45.30
Easophagus	0.16	0.0232	17.73	0.00230	17.58	99.15
Stomach	0.017	0.0148	113.12	0.0102	77.96	68.92
Liver	0.15	0.00600	45.86	0.00550	42.04	91.67
All solid	0.92	1.559	11,916.0	0.7042	5,382.47	45.17

CONCLUSION

This analysis shows that, it is essential that the principle of justification and optimization be adopted during X-ray diagnostic examinations in Nigeria. This will ensure that paediatric doses and the detrimental effects are kept at a reasonably lower level.

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Conflict of Interest

The authors declare no competing interests.

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