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INVESTIGATION ON PATIENTS' RADIATION DOSE RECEIVED DURING SKULL DIAGNOSTIC X-RAY PROCEDURES IN KEBBI STATE

BY

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Abstract

***Background**: Radiological Skull X-ray procedures are well-known and universally accepted diagnostic method of Skull injuries and other disease. Despite the benefit derived from these examinations, its involved adverse health effects. Patients are exposing to ionizing radiation during the procedure that might cause problem to his health status.*

***Objectives:** The purpose of this research was to investigate and assess the effective dose and entrance skin dose received by the patients during the skull x-ray procedures performed in the two x-ray units available in health care system of Kebbi State.*

***Material and Method:** The exposure factors [such as kV, mAs, FFD & FSD] and patient demographic data [such as age & gender] of 70 patients were collected prospectively in November, 2021 to February, 2022. The collected data was analyzed using Cal Dose _X 5.0 software for assessment of ESD & ED and Excel spread sheets for determination of statistical parameters such as Mean, Min, Max, STDEV, and Diagnostic reference levels (75th percentile).*

***Results:** The ESD, ED and DRLs estimated in this research work were greatly high in Skull AP and LAT while least value was found in Skull PA projection. The consequences of selecting exposure parameters are significance variation in the size of radiation doses absorbed by the patient during the same radiological procedures.*

***Conclusion:** The results obtained in this research were remarkably higher than results of other studies when compared. Therefore, efforts should be made to reduce patient radiation exposure in skull radiological x-ray procedure while securing image quality. Need to provide educational training to personnel ordering and performing radiological x-ray procedures in relevant fields is of great significance. This research serves as baseline research for future reference.*

***Keywords:** Skull, Entrance Skin Dose, Effective dose and X-ray*

Introduction

Worldwide populations are exposed to the danger of radiation that is ionizing in nature from many roots and the greatest exposures by the humans are from its medical uses. Although different types of artificial ionizing radiation are applied for medical imaging and therapy, diagnostic imaging radiology carry the lion share to artificial exposure in Kebbi (Xiang, 2013). Different scholars who have carried out investigations have reported large differences in radiation doses received by the patients during specific X-ray procedures. Recently, these differences in patient dosimetric quantities observed in many countries have drawn the attention of researchers in patient doses worldwide (Samaila, 2022). From the point of view of the healthcare system about 80% of the dose worldwide averages to humans were estimated to cause by medical x-ray procedures (Sonawane *et al.*, 2010). Research on radiation doses delivered to the patients from diagnostic X-ray procedures have been performed in many countries outside Nigeria and African countries. Recently, in Africa various investigations on radiation doses have been published from diagnostic x-ray examinations. The present study is among the first study to investigate and evaluate the radiation doses delivered to the patient during Skull diagnostic X-ray procedures in Kebbi State, Nigeria. There are no systematic data records in relation of radiation dose received by the

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patient during the Skull x-ray procedures performed in Kebbi State. Furthermore, no regional/local diagnostic reference levels (DRLs) available in the centres (Xiang, 2013). There are numerous risks associated with radiation exposure, including acute radiation injury and cancer effects. At high doses, the acute effects include organ damage, which can result in death (Samaila, 2022). The main purpose of this study is to determine amount of radiation received by the patients regarding the radiation exposure associated with lower extremities imaging

Material and Method

The materials require in this research involves X-ray machines, lead protective Gown, Excel spread sheets software for statistical analysis of data and Cal Dose _X 5.0 software for calculations of the X-ray outputs and other parameters. The sub-sections below described the study area, X-ray machines used in the research and how X-ray data was been collected.

Description of the study area

The study was carried out in two selected centres in Kebbi State. The selected centre is comprised of Sir Yahaya Memorial Hospital (SHM) and Federal Medical Centre (FMC) Kebbi. Kebbi State is located in the north-western part of Nigeria. It is situated between latitudes 10° 8′ N – 13° 15′ N, and longitudes 3° 30′ E – 6° 02′ E. The State is bordered by Sokoto and Zamfara States to the east, Niger State to the south, the Benin Republic to the west and the Niger Republic to the north.

Description of x-ray machines used

The two different mobile X-ray machine models were used in the study centres. The SHIMADZU Mobile X-ray machine with model: collimator R-20CA, and nominal kVp of 150 Kv made by Japan was used in Sir Yahaya Memorial Hospital. In Federal Medical Centre is also a mobile x-ray with model of Model: 2185226 and Nominal Kv of 125kv made by India was used. The inherent filtrations of the two machines are 1.0mmAl and 0.8mmAl for SMH and FMC respectively.

Data Collection

The data were collected prospectively from two selected centres in Kebbi State. The collected data were divided into two different parts. Part one involves Patient demographic data such as Name, Age, and Gender, while Part two involve exposure parameters such as tube kilovoltage (kV), exposure time product (mAs), Focus to skin distance (FSD), and Focus to Film Distance (FFD) from the X-ray tube.

Estimation of Entrance Skin Dose

A windows-based computer program, CAL Dose_X 5.0, software developed by (Kramer *et al.*, 2008) was used in this research. It covers 24 examinations with 2.5 mm Al standard filtration for standing and/or supine posture. The software requires the user to manually input the patient's age, sex, select type of examination, posture projections and exposure parameters [such as kV, mAs, FFD and FSD]. The software automatically calculate ESAK, BSF and INAK and plot the graph of kV against mAs and the output curve (slope) between kV and mAs is given by the relation

$$K = 0.0419 \times V^{1.774} \qquad (1)$$

Where K is constant and V is the tube voltage. The entrance skin dose can be obtained by multiplying tube outputs such as Entrance Surface Air Kerma [ESAK] and Back Scattered Factor

$$\text{ESD [mGy]} = \text{ESAK} \times \text{BSF} \qquad (2)$$

Effective Dose calculated with Cal Dose_X 5.0

The effective Dose was estimated as weighted- dose by the CAL Dose_X 5.0. The cal dose X calculates Effective Dose according to the report of ICRP 103, section (132), using an equation below:

$$\text{Effective dose} = \sum \frac{W_T[H_T(\text{female}) + H_T(\text{male})]^2}{2}$$

$$\text{Effective dose} = \frac{1}{2}\left[\sum W_T\ H_T\,(\text{female}) + \sum W_T\ H_T(\text{male})\right]$$

$$\text{Effective dose} = \frac{1}{2}[F + M] \qquad (3)$$

Therefore, the effective dose based on CALDose_X 5.0 is the average of the sex-specific weighted doses as shown above

Diagnostic Reference Levels (DRLs)

The DRLs is an indicator of whether patient doses are higher or lower. It is not universal in nature and diagnostic x-ray examination. The diagnostic Reference levels in this research were decided from entrance Skin Dose of each radiological procedure performed in the two centres. The mean ESD were used in the excel spreadsheets to find 75th percentile or third Quartile of dose distribution in a sample for its radiology examination deliberately (Mohsenzadeh *et al.*, 2018).

Result and Discussions

In the present study, the exposure factors were collected from two centre such as tube voltage (kV), load current-time (mAs) and patient's data such as Age and gender. The data were inserted into Cal Dose X 5.0 software for individual examinations. The software automatically calculates the tube output as ESAK, BSF and INAK which was tabulated in table 1. The statistical analysis was done on exposure parameters, Age of patients, ESD, ED and DRLs using an excel spread sheet which was summarized in table 2, while comparison of exposure parameters, ESD, ED and DRLs tabulated in table 3-7.

Table 1: X-ray tube output calculated by Cal Dose_X 5.0 software

Examination	ESAK (mGy)		BSF		INAK (mGy)	
	SMH	FMC	SMH	FMC	SMH	FMC
Skull AP	6.13	5.14	1.19	1.24	4.28	4.15
Skull PA	5.47	5.94	1.20	1.17	5.12	4.41

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Skull LAT	5.22	4.43	1.22	1.21	4.28	3.65

Table 2: Statistical distributions of exposure parameters, ESD, Effective Dose and Cancer Risk for individual Centres

Examination	SMH						FMC					
	Min	Med	Mean	Max	Mx/min	STDEV	Min	Med	Mean	Max	Mx/Mn	STD
Skull AP												
Age(years)	20.00	30.00	33.00	53.00	2.65	9.36	25.00	33.00	32.00	37.00	1.48	5.38
FFD (cm)	100.00	100.00	101.10	113.00	1.13	3.75	86.00	101.00	98.75	107.00	1.24	8.99
FSD(cm)	75.00	83.50	83.00	93.00	1.24	6.23	68.00	70.00	70.80	75.00	1.10	2.99
KV	74.00	78.00	78.33	82.00	1.12	2.27	70.00	73.00	74.00	80.00	1.14	4.89
Mas	20.00	32.00	31.20	35.00	1.75	3.93	20.00	26.50	26.30	32.00	1.60	5.06
ESD (mGy)	2.16	5.11	5.18	7.44	3.44	1.48	3.62	5.02	4.77	5.42	1.49	0.81
ED (mSv)	0.04	0.88	0.83	1.05	26.25	0.26	0.03	0.05	0.09	0.22	7.33	0.09
Skull PA												
Age(years)	20.00	35.00	37.00	65.00	0.67	13.38	42	65.00	54.00	54.00	1.55	16.2
FFD (cm)	100.00	100.0	101.70	113.00	0.05	4.57	89	94.50	94.50	100.00	1.00	0.00
FSD(cm)	73.00	85.00	84.74	93.00	0.09	5.70	70	70.00	70.00	70.00	1.00	0.00
KV	70.00	78.00	77.80	80.00	0.04	2.73	74	74.50	74.50	75.00	1.01	0.71
Mas	18.00	32.00	29.70	36.00	0.28	5.12	20.0	22.50	22.50	25.0	1.25	3.53
ESD (mGy)	2.16	4.97	4.66	6.11	0.56	1.21	3.73	4.08	4.08	4.43	1.19	0.49
ED (mSv)	0.03	0.59	0.47	0.78	9.76	0.29	0.02	0.03	0.03	0.04	2.0	0.01
Skull LAT												
Age(years)	20	35	37.00	65	3.25	13.38	20	41	46	80	4.0	18.9
FFD (cm)	100	100	101.73	113	1.13	4.57	86	99	96.45	112	1.30	7.96
FSD(cm)	73	85	84.46	93	1.27	5.70	55	69	70.45	85	1.54	6.71
KV	70	78	77.8	80	1.14	2.73	70	75	74.2	80	1.14	4.03
Mas	18	32	29.73	36	2.00	5.12	20	25	27.4	35	1.75	5.43
ESD (mGy)	2.16	4.97	4.66	6.11	2.83	1.21	2.46	4.75	5.31	9.82	3.99	2.09
ED (mSv)	0.03	0.59	0.47	0.78	26	0.29	0.02	0.03	0.03	0.05	2.5	0.01

Table 3: Comparison of Mean Exposure parameters with other studies

Projections	Exposure Parameters	This study		Deoknam *et al.*, 2014	Mohamed, 2010	Mohammad *et al.*, 2018	Abubaker *et al.*, 2017
		SMH	FMC				
Skull AP	FFD [cm]	101.10	98.75	-	--	100	-
	kV	78.30	74.00	76	--	73	-

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	mAs	31.20	26.30	34	--	17	-
Skull PA	FFD	101.70	94.50	-	180.3		--
	kV	77.80	74.50	-	80		-
	mAs	29.70	22.50	-	18.71		-
Skull LAT	FFD	101.73	99.00	-	-	-	100
	kV	77.80	75.00	74	-	-	70
	mAs	29.73	25.00	31	-	-	66

Table 4: Comparison of Mean ESD [mGy] with national and international studies

This study/Literatures	Skull AP	Skull PA	Skull Lateral
This study	5.11	4.66	5.13
Hamza& Lamara, 2020 [Gombe]	-	0.52	0.31
Nsika& Obed, 2015 [AkwaIbom]	1.65	-	1.48
IRAN, 2008	2.32	2.72	1.47
Gholami *et al.*, 2015 [Iran]	-	2.98	1.94
Gaetano *et al.*, 2005 [Italy]	-	1.71	1.18
ARPNSA, 2017	3.00	3.00	1.50
NRPB, 2000	--	3.00	1.50
Osibote & Azevdo, 2008 (Brazil)	--	1.26	--
Mohammad *et al.,* 2018	2.20	-	-
Abubaker *et al.*, 2017	11.24	--	-
Olowookere *et al.*, 2011	-	12.10	8.5
Schandorf & Tetteh, 1998 [Ghana]	-	5.8	-
Daryoush and Milad, 2013 [Iran]	6.84	6.84	7.89

Table 5: Comparison of mean Effective Dose [mSv] with national and international studies

This study/Literatures	Skull AP	Skull PA	Skull Lateral
This study	0.64	0.18	0.22
Olowookere *et al.*, 2011	--	0.10	0.10
Mettler *et al.*, 2008	--	0.10	---
Kharita *et al.*, 2010	--	0.05	--
Durga &Seife, 2012	--	0.33	--
Ernest & Johnson, 2013	-	0.02	0.007
Mohammad *et al.*, 2018	0.05	-	-
Daryoush and Milad, 2013	0.07	0.07	0.08
Hart & Wall, 2002 [UK]	0.06	0.06	-
UNSCEAR, 2000 (UK)	0.03	0.03	0.01

Table 6: Local Diagnostic Reference Levels [3rd quartile (75th Percentile)] of an individual centre

CENTRES	Skull AP	Skull PA	Skull LAT
SMH	6.56	5.58	5.58

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FMC	5.28	4.25	6.83

Table 7: Comparisons of LDRLs [75th percentile) with National and International Studies

This study/Other study	Skill AP	Skull PA	Skull LAT
FMC & SMH	6.46	5.62	6.09
Joseph *et al.*, 2017 [Nigeria]	--	1.02	1.01
EC, 1999[a]	-	5.00	3.00
Asadinezhad&Bahreyni,2008 [Iran]	2.85	2.83	1.93
Zarghani & Bahreyni, 2018 [Iran]	--	2.85	1.93
Sonowane *et al*., 2010 [India]	--	6.89	5.16
IAEA, 1996	--	5.00	3.00
MIRIN, 2015 [Japan]	--	3.00	--
Hart *et al*., 2000[UK]	3.00	3.00	1.50

Discussion

The ESDs, ED and DRLs results were determined for Skull AP, PA and LAT procedures. These kinds of procedures are the most routine radiographical x-ray procedures with the higher absorbed radiation doses to the patients (Daryoush and Milad, 2013). Table 1; Shown an x-ray tube output estimated by Cal Dose_X 5.0 software in Skull projection in the two centres. It was observed that the ESAK obtained in SMH for Skull AP & LAT projections was higher than that of FMC. But the value obtained for Skull PA in SMH was lower than that of FMC as indicated. The difference in exposure setting contributed to the variation of the results. Table 2; shown the statistical parameters of exposure factors, ESD and ED that involve Minimum, Maximum, Mean, Median, Ratio of Max/Min and Standard Deviation, for the two x-ray units. All these parameters revealed variations of practice among the studied centres. Table 3 the exposure parameters Such as kV was compared with other studies and found to be high in SMH when compared with FMC and the work of (Deoknam *et al.*, 2014 and Mohammad *et al.*, 2018) for Skull anterior posterior projection but for mAs value, the work of (Deoknam *et al.*, 2014) recorded higher value than this study. Similarly for Skull PA, the research recorded lower kV than (Mohamed, 2010) but mAs were remarkably high than the other studies. For Lateral X-ray procedure of the skull, the mAs were high in the work of (Deoknam *et al.*, 2014 and Abubaker *et al.*, 2017) but kV of this research was higher than the results obtained in other studies.

In table 4: The ESD estimated was well-compared with the literature and found to be higher than the values obtained in the research work of (Hamza& Lamara, 2020; Nsika& Obed, 2015; IRAN, 2008; Gholami *et al.*, 2015; Gaetano *et al.*, 2005; ARPNSA, 2017; NRPB, 2000; Osib & Azevdo, 2008 and Mohammad *et al.*, 2018) for Skull AP, PA & LAT respectively. But in comparison of the ESD values with the values yielded by the research work of (Abubaker *et al.*, 2017; Olowookere *et al.*, 2011; Schandorf & Tetteh, 1998 and Daryoush & Milad, 2013) were greatly higher than this research work. This indicated that justifications are needed highly in these areas. This variation of the results may likely be caused by differences in exposure factors selection which contributed greatly in higher radiation dose delivered during the procedures. Table 5; indicated that effective dose was remarkably higher in Skull AP projections than that of PA and LAT. In order of magnitude: Skull AP > Skull Lat > Skull PA. To test the practices of the two centres, the comparison of the ED was done and found to be remarkably higher than the ED results obtained in literatures except for the work of (Durga &Seife, 2012) which recorded 0.33mSv for Skull PA. The ED results were lower than the threshold value of 1.0 mSv/year. Table 6; shown the DRLs of the two centres, even between centres to centre there's variation due to the exposure factors. Table 7: For skull AP, the DRLs value was found to be higher than the results of (Asadinezhad & Bahreyni, 2008 and Hart *et al.*, 2000) respectively in Iran and UK. For Skull PA, the result of this research were greatly much higher than the reported values in the literatures above except for the research work conducted in India by (Sonowane *et al*., 2010) whose value recorded 6.89. Similarly, in Skull Lat projections the results were highly above the values reported in the literatures. The whole procedures performed in this work need an urgent optimization and justifications for the studied facilities in Kebbi State.

Conclusion

The entrance skin dose and effective dose obtained in this research were comparatively higher than the other countries in the world. The effective dose values are remarkably lower than Nigerian Nuclear Regulatory Agency [NNRA] of 1.0 mSv per year. Similarly, diagnostic reference levels estimated in this research were compared with other reference countries in the world. Almost all DRLs are comparatively higher. The reasons may be attributed to the lack of quality assurance program. It was observed that, the value of DRLs depends on the X-ray machine used in the X-ray Unit. In addition, high variability of the dose is the reason for harmonizing the different techniques in X-ray services and for desirable

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diagnostic imaging at reasonable doses for establishment of diagnostic reference levels. It was concluded ultimately that by justifying and optimizing exposure parameters could be realistic to preserve quality of image while lowering patient dose during skull x-ray procedure. Therefore, dose monitoring during Skull X-ray examinations and the establishment of both local and regional DRLs should be considered strongly. Moreover, Periodical review of the values of ESD, ED and DRLs could be serving as optimization tool. Further researches are suggested to evaluate technicians work quality environment.

Ethical Clearance

The ethical approvals were obtained prior to the conduct of this research from the ethical committee of the two hospitals and Kebbi State Ministry of Health [KSMH] Birnin Kebbi.

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