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Estimation Of Entrance Skin Dose And Effective Dose In Cervical Spine X-Ray Procedures

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ABSTRACT

The use of ionizing radiation in medical field is the largest and a growing man-made source of radiation exposure. The aim of this study is to estimate the doses received by patients during radiological examinations in order to standardize the examination procedures and optimize the patient dose. Two most referral hospitals, located in the Capital City of Kebbi State, were investigated. The Patients undergoing cervical spine X-ray examinations were involved in this study. Entrance Skin Dose (ESD) and Effective Dose were calculated using exposure parameters (voltage, tube loading, focus-patient distance). The Cal Dose _X 5.0 software was used to determine ESD and ED. Entrance surface airkerma were converted to effective dose using conversion coeffiecients. A total of 65 radiographic examinations data were collected from the two hospitals during three months of the year December 2021 to 2022. The highest ESD was found for the lateral cervical view in Sir Yahaya Memorial Hospital, with an average value of 4.12 mGy. The highest value of ED and DRLs was also observed for the AP projection in FMC with an average of 0.27 mSv and 4.73. The ESDs reported in this study are generally higher than value obtained from the research conducted in Nigeria and other country like Iran, and Brazil, while ED was remarkably high compared to other studies except the study conducted by Aborisade, (2021)
In Nigeria. The ED results were comaparatively lower than Nageria Nuclear Regulatory Authority standard of 1.0 mSv/year (2006). This trend is an indication that the patient radiation protection practices in these two hospitals need to be justified and optimized. The results of this study showed that there is a need for justification and optimization in order to reduce patients' radiation dose without affecting the quality of the radiographic image. The results obtained in this research will serve as baseline data for the development of gegional guidance levels.

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1. INTRODUCTION

Recently, diagnostic x-ray imaging procedure found to be very significant examination. I n the past, the international organization such as International Commission on Radiological Protection approved dose reference level (DRL) as essential tool to optimize the use of X-ray in medical imaging procedures in accordance with the principle of optimization and justification to confirm the patient dose in medical imaging is not ignored [1]. The promotion of optimization of protection for particular medical exposures emphasizes routine estimation of radiation dose received by the patient in all radiology complexes and determination of diagnostic reference levels [DRLs]. DRLs are determined based on patient's average dose 75% percentile (third quartile). The use of Entrance Skin Dose [ESD] for radiation dose estimation is suitable in radiographic examination. The Eropean Commision (1997) introduced the use of DRLs as significant standard for optimization of patient's radiation protection [1].

Populations are universally exposed to ionizing radiation from different sources and the largest among the sources are exposure from medical x-ray imaging i.e. conventional radiography. Although different types of artificial radiation are applied for medical reasons, conventional diagnostic radiological procedures are the major contributor to artificial exposure in Kebbi State and Nigeria at large [2]. Research on radiation hazard to patient from conventional x-ray procedures have been performed in different parts of Nigeria especially in South-South and South-eastern part of the country with few focus on north-west and north-eastern parts [2]. Several reports and surveys have been trending in online journals published on the radiation dose from conventional x-ray procedures in Africa. The current research is the first to determine entrance skin dose and effective dose to patients undergoing cervical spine in conventional x-ray imaging in Kebbi State. There are no previous records found with regard to patient exposure in Kebbi. Moreover, no existence of diagnostic reference levels for routine cervical spine x-ray procedures [2]

RESEARCH METHOD

Two referral hospitals were included in this work and are located in Kebbi State, Nigeria. The criteria for the selection of the hospitals considered for this study is the high number of patients that visit the facility for X- ray examinations. And they are the most referral hospitals in Kebbi State. Radiation dose estimation was conducted for 65 patients during the period of study, from 2021-2022. Inclusion criteria were the age of patients which were over 20 years and who underwent cervical spine radiographic examinations in the two selected hospitals. The data collected were divided into the following:

- Demographic data of patient such as age and sex
- Exposure parameters such voltage, tube loading, Focus Film Distance (FFD) and focus to skin distance
- X-ray procedures and projections

The Data was analyzed using Cal Dose_X software version 5.0. The exposure parameters collected were transferred into Cal Dose_X software for output calculations such as Backscattered factor, Incident airKerma and entrance surface airkerma which later was used to compute ESD as indicated in equation (1), starting this work, an ethical approval was obtained from Kebbi State Ministry of Health and FMC ethical Clearance committee. Demographic information of individual patient was recorded. The tube outputs of the x-ray machine were obtained from the graph of mAs versus kV in the software [3].

2.1 Estimation of Entrance Skin Dose and Effective dose

Entrance skin dose is the radiation doseto air at the skin entrance of the x-ray beam. It was determined for all patients using mathematical expression. In this study, the ESD for patients was estimated by an indirect method, using software and empirical formula:

$$\text{ESD} = \text{BSF} \times \text{Tube Output}\left(\frac{\text{mGy}}{\text{mAs}}\right) \times \left[\frac{\text{kV}}{80}\right]^2 \times \left[\frac{100}{\text{FSD}}\right]^2 \times \text{mAs} \quad (1)$$

Where tube Output is the beam output in mGy/mAs measured from the X-ray tube at different kvp settings at distance of 1 m divided by mAs which is the product of the tube current (mA) and the exposure time in seconds. The focus-to-skin distance (FSD/cm) was calculated from the Focus Film Distance (FFD/cm) for all projections by subtracting the standard patient thickness for each projection [3]. The effective dose parameter used to assess radiation risks such as Cancer risks and genetic risk (Samaila et al., 2021a). The ED value was obtained using CALDose_X 5.0. The effective dose based on CALDose_X 5.0 is then the average of the sex-specific weighted doses

$$\text{Effective Dose} = \frac{1}{2}[\text{F} + \text{M}] \quad (2)$$

CALDose_X 5.0 calculates a weighted female dose (F) and a weighted male dose (M) given at the end of the result [3].

2. RESULTS AND DISCUSSIONS

The mean, minimum, maximum, max/min ratio and STDV values of tube potential (kVp), tube loading (mAs), focus - film distance (FFD) and Entrance Skin Dose (ESD) for all examinations were recorded and are shown in table 1 & 2. Dynamic nature of exposure parameters was highly noted. This can be attributed by the differences in examination protocols adopted by each hospital. According to previous studies made, the patient age is a significant parameter in the selection of the technical parameters and in considering the interpretation of radiological images. The selection of large voltage, the tube loading and FFD in this research was done for quality image according to the various morphology of the patient.

Table 1: The mean value of exposure parameters of an individual centres with several patients examined for each procedure

Examination	Age (year)		FFD (cm)		FSD (cm)		KV		mAs		No of Patients	
	SMH	FMC	SMH	FMC	SMH	FMC	SMH	FMC	SMH	FMC	SMH	FMC
Neck LAT	43	41	100.00	106.69	80.73	85.08	74.73	77.23	25.64	24.69	11	13
Neck AP	46	43	100.00	104.40	82.71	82.10	75.27	78.00	25.60	24.20	20	21
TOTAL											**31**	**34**

Table 2: Statistical distributions of exposure parameters for individual Centres

Examination	SMH						FMC					
	Min	Med	Mean	Max	Mx/mn	STDEV	Min	Med	Mean	Max	Mx/Mn	STD
Neck LAT												
Age(years)	25	43	43	71	2.84	15.81	23	40	41	70	3.04	15
FFD (cm)	100	100	100	100	1	0	100	107	106.6	115	1.15	5.25
FSD(cm)		80.7									1.46	9.18
	73	3	80.73	87	1.19	4.58	70	85	84.69	102		
KV		74.7									1.20	3.56
	66	3	74.73	77	1.17	3.26	70	76	77.23	84		
MAs		25.6									1.6	4.75
	18	4	25.64	36	6.68	2.00	20	25	24.67	32		
ESD (mGy)	1.48	4.11	4.12	7.23	4.89	1.43	2.39	4.07	4.08	7.42	3.09	1.36
ED (mSv)	0.03	0.12	0.12	0.33	11.00	0.10	0.05	0.07	0.07	0.10	2.00	0.02
RCI	0.38	0.67	0.67	0.99	2.61	0.19	0.4	0.6	0.70	1.39	3.47	0.26
RCM	0.24	0.49	0.49	0.67	2.79	0.13	0.34	0.46	0.48	0.78	2.29	0.12
Neck AP												
Age(years)	20.0	48.0	46	71	3.55	16.66	23	40	43	78	3.39	15.4
FFD (cm)	100	100	100	100.0	1	0.0	100	102	104.4	115	1.15	4.75
FSD(cm)	77.0	79.0	82.4	94	1.22	5.80	69	80	82.1	102	1.48	9.76
KV	70.0	75.0	75.0	77	1.10	1.83	70	80	78	85	1.21	3.88
MAs	18.0	22.0	25.6	36	2.0	7.06	20	25	24.2	32	1.60	3.78
ESD (mGy)	1.54	3.49	3.46	4.80	3.12	1.04	2.29	3.85	3.91	6.45	2.82	1.27
ED (mSv)	0.15	0.24	0.27	0.54	3.60	0.11	0.12	0.19	0.21	0.67	5.58	0.11
RCI	1.54	3.49	3.46	4.80	3.12	1.04	0.53	0.93	1.24	2.90	5.47	0.74
RCM	0.51	0.69	0.75	1.08	2.12	0.18	0.45	0.72	0.71	0.99	2.82	1.27

RCI = Risk of Cancer Incidence cases per 100,000 patients; RCM = Risk of Cancer Incidence cases per 100,000 patients

Table 3: Comparison of ESD [mGy] of all centres with national and international studies

Examination	These studies		Entrance Skin Dose [mGy]					
	SMH	FMC	[4] (Iran)	[5] [Iran]	[6] (Brazil)	[7] (Nigeria)	[8] (Nigeria)	[9] (Nigeria)
Cervical AP	3.46	3.91	1.36	1.90	0.64	0.411	1.12	2.7
Cervical LAT	4.12	4.08	0.82	1.18	0.60	0.226	-	-

Table 4: Comparison of mean ED of all centres [mSv] with National and international studies

Examination	This study		National and International Studies on Effective Dose [ED] in mSv						
	SMH	FMC	[10]	[11]	[12]	[13]	[14]	[8] (Nigeria)	[15] (Nigeria)
Cervical AP	0.27	0.21	--	0.20	0.27	0.05	0.02	0.004	0.038
Cervical LAT	0.12	0.07	0.37	--	--	0.03	0.003	-	-

Table 5 Local Diagnostic Reference Levels of each individual centre

Examination	This study		National and International Studies			
	SMH	FMC	[16] [Nigeria]	[4] (Iran)	[17] (Japan)	[18]
Neck LAT	4.73	4.37	0.79	0.93	-	-
Neck AP	4.54	4.81	0.62	1.83	0.90	1.73

3. Discussion

The average values of the entrance skin dose (ESD) by the two centres for each examination were calculated according to the formula given above and are shown in Tables 1&2. Table 3 indicates that FMC recorded higher value of ESD than SMH in cervical AP procedure, while in Lateral view, SMH recorded the higher value. Therefore, comparatively the results of this research are much larger than the results reported by [4, 5, 6]. Similarly, the effective doses obtained in SMH (table 3) were remarkably high compared to the results reported in the literatures except the result reported by [10 & 12] whose values are larger and equal to the one reported in this work. But the effective dose reported in Nigeria by [8] was greater than the value obtained in this work. But in all the centres effective doses were comaparatively lower than Nageria Nuclear Regulatory Authority standard of 1.0 mSv/year (2006) [19]. In the same vein, diagnostic reference levels were also remarkably high compared to the results obtained by [10, 4, 17 & 18]. The mean risks of cancer incidence associated with each exposure to radiation are 3.46 and 1.24 cases per 100,000. This means that out of 100,000 patients only 3.46 & 1.24 patients can develop cancer in the near future. Similarly, for Risk of cancer mortality were 0.75 and 0.71 respectively for SMH and FMC. This means that probability of death due to exposure to x-ray was 0.75 out of 100,000 in SMH and 0.71 in FMC. Both the RCI and RCM of SMH were remarkably higher than that of FMC. It may likely be as result of different protocols used by the radiographers and x-ray technicians. Optimization and justification of the cervical procedure are highly needed in the two centres. Therefore, in all cervical spine projections there is greater need for optimization and justification in the selection of exposure factors so as to reduce the radiation dose to the patients' skins and organs [20].

5. CONCLUSION

This study estimated the Entrance Surface Dose and Effective Dose for patients undergoing Cervical AP and Lateral projections in two selected hospitals in Kebbi State, regions of Nigeria. Effective Dose determination was carried out as it is an effective approach of risk estimation to patient exposed to medical radiation. The results shown that the Entrance Skin Dose is remarkably high compared to the published results, Similarly Effective Dose values obtained in this study is higher than the published value in literatures but lower than 1.0 mSv/year issued by Nigeria Nuclear Regulatory Agency. This implies that the radiation exposure risk for the patients undergoing AP and lateral radiographic examinations in the two hospitals included in this study is relatively high. However, it is necessary to take precaution, due to the stochastic nature of the X-rays radiation effects. From this study, it is proposed to reduce patient dose while maintaining image quality by using high voltage (kVp) and low charge (mAs). The findings of this work indicated the need of quality assurance program, Clear protocol to describe patient radiation exposure during radiation examination is also suggested to avoid repeating X-ray examination. Finally, this study was carried out only in two referral hospital in Kebbi State. Actions are underway to extend measurements into nationwide level. For this purpose, estimation of patient doses through some regional approach and at national level is needed for establishing national diagnostic reference level.

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