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Estimation of Diagnostic Reference Level for Lumbar Spine X- Ray Procedures in Some Radiological Facilities in Abuja Metropolis, Nigeria

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Abstract
The worldwide increase in the use of radiation in diagnostic radiology practice has increased the need for organizations that deal with radiation protection to focus on improving patient protection. The essential aim of this study is to determine the diagnostic reference level for lumbar spine anterior posterior in some radiological facilities in Abuja metropolis, Nigeria. This study was performed to assess the values of entrance surface air kerma via indirect method for 87 adult patients whom their ages ranged between 19 to 75 years that underwent lumbar spine X-ray examination in six diagnostic radiology centres. The age of patients ranged from 20 to 60yrs; their weight ranged from 46 to 90 Kg, while the height of patients ranged from 1.4 to 1.8 m. The mean entrance surface air kerma for centres A, B, C, E and F were 2.41mGy, 2.39mGy, 2.75mGy, 2.91mGy and 2.67mGy respectively while the determined diagnostic reference level was 2.83mGy. This indicates improvement in optimization of patients' doses when compared to established international reference levels.
Keywords: Entrance surface air kerma, diagnostic reference level, lumbar spine X- ray examination and radiological facilities
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1.0 Introduction

Diagnostic reference levels (DRLs) were first mentioned by the International Commission on Radiological Protection (ICRP) in 1990 and subsequently recommended in greater detail in 1996 from the 1996 report (ICRP 1996). The Commission now recommends the use of DRLs for patients. These levels which are a form of investigation level, apply to an easily measured quantity, usually the absorbed dose in air, or in a tissue equivalent material at the surface of a simple standard phantom or representative patient (Joseph *et al.*, 2017).

The worldwide increase in the use of radiation in diagnostic radiology practice has increased the need for organizations that deal with radiation protection to focus on improving patient protection. The concept has been adopted by many international organizations like the International Atomic Energy Agency (IAEA), European Commission (EC), United Kingdom Health Protection Agency, National Council on Radiation Protection (NCRP), American Association of Physics in Medicine (AAPM), and American College of Radiology (ACR) (Ncube, 2017). The use of X-ray in medical examination is of great concern since it could cause harmful effect to the body, the benefits of diagnosis and therapy notwithstanding. Extensive use of X-ray radiation have been reported to result in a large radiation burden on the patients and medical personnel (Vano, 2003, Padovani and Rodella, 2001) and radiation injuries to eye lens also reported in literature (Vano *et al.,* 1998).

Diagnostic X-ray examinations play an important role in health care of the population in Nigeria and globally. In X-ray diagnostics, radiation that is partly transmitted through and partly absorbed in the irradiated object is utilized (Nadia *et al.*, 2018).

1.1 Aim of study

The aim of this study is to determine the diagnostic reference level for lumbar spine anterior posterior (AP) in some radiological facilities in Abuja metropolis, Nigeria.

2.0 Material and Method

2.1 Patient Samples

A total of 87 adult patients were examined in the six centres with the examination of the lumbar spine AP. A template was used to collect the data that captured the date, sex, age, weight, type of exam, X-ray equipment details such as tube focus to patient surface distance, tube focus to film distance, type of X-ray procedure, and exposure details including KV and mAs.

2.2 X-Ray Unit
This work was carried out in six public centres in Abuja, Nigeria that have NNRA authorizations and included six X-ray units from the centres thereafter refereed as: A, B, C, D, E and F as indicated in Table 1. The centres were chosen based on the significant number of X-ray examination performed regularly.

Table 1: Specification of X-ray machines in the selected centres

Centres	Equipment Type	Manufacturer	Serial No.	Model No.
A	Mobile X-ray	GE Company USA	46270615p3	46-270615
B	Mobile X-ray	Elgin Medical, England	1560	----
C	Fixed X-ray	EcoRay Co. Ltd, Korea	COL-1411431	SMS-CM-N
D	Fixed X-ray	Ecoray Co. Ltd Gwangju, Korea	ECO-R4-1605098	HF-525 Plus
E	Fixed X-Ray	G E Haulun Medical System, China	143603BC9	5331186
F.	Fixed X-ray	Toshiba, Japan	11K1130	E725X

2.3 Data Collection
The X-ray measurement protocol was adopted from IAEA (2007). The patient is positioned such that the tube focus-to-film distance and the lumbar spine was at a detector distance (d) of 100cm and measurement taken and recorded along with the X-ray exposure factors and the examination projection used. A Cobia Smart R/F semiconductor detector (model- CB3-19098461) calibrated to measure tube potential between 18 – 150KVp was then positioned in the central beam axis at an X-ray tube focus–detector distance of 100cm to measure the X-ray tube output value. Radiation field size of 10cm x 10cm at focus–detector distance was set to shield the detector completely in the useful beam to avoid scatter radiation to the dosimeter. Exposures were made using the values of X-ray exposure factors used for the patients and were repeated three times for each set, and the average value of X-ray tube output was recorded.

2.4 Parameters and Calculating of ESAK
To calculate the ESAK, patients' parameters such as age, weight and height and X-ray tube exposure parameters such as peak tube voltage (KVp), exposure current-time product (mAs) and focus-to-film distance (FFD) were recorded for each patient undergoing lumbar spine X-ray examination.

2.5 Entrance - Surface Air Kerma (ESAK) calculation:

$$ESAK = K_i B \quad (1)$$

Where Ki = Incident Air Kerma, B= backscatter factor (using tabulated B values given by IAEA (2007)).

$$K_i = Y(d, KV)\, P_{it}\left(\frac{d}{D_{FSD}}\right)^2 \quad (2)$$

Where, D_{FSD} = distance of focal spot to surface distance calculated from FFD and t_p) using the equation:

$$D_{FSD} = FFD - t_p \quad (3)$$

Patient thickness was deduced from patient weight (W) and height (h) (Inyang *et al.*, 2015):

$$t_p = \sqrt[2]{\frac{W}{\pi h}} \quad (4)$$

$$Y(d, KV) = \frac{K_a(d, KV)}{P_{it}} \quad (5)$$

Where Y(d, KV) = X-ray tube output measurement, k_a = quotient of the air KERMA measured at 100cm, P_{it} = tube current exposure - time product.

3.0 Results and Discussion
Table 2 presents the patients' parameters and exposure factors of patients that underwent Lumbar Spine AP in the selected six centres. The age of patients ranged from 20 to 60yrs; their weight ranged from 46 to 90 Kg, while the height of patients ranged from 1.4 to 1.8 m. One of the centres (Centre D) has no data as it only carry out chest X-ray examination. The KVp in Centres A, B, C, E and F had mean value of 79.1, 74.2, 82.5, 90.5 and 77.2 respectively. The mAs or P_{it} used ranged from 25 to 32, 30 to 60, 38 to 50, 20 to 45 and 20 to 25 for Centres A, B, C, E and F respectively, while the FFD ranged from 90 to 100cm across all centres.

The calculated values of the patient thickness varied from 7.0kg/m to 7.4kg/m with centre B having the lowest value of 7.0kg/m and centres A and C with the highest values of 7.4kg/m. The X-ray tube output calculated from X-ray exposure factors for centres A, B, C, E and F are 0.0575mGy/mAs, 0.0475mGy/mAs, 0.0415mGy/mAs, 0.0602mGy/mAs and 0.0676mGy/mAs respectively with the highest value of 0.0676mGy/mAs recorded at centre F and the lowest value of 0.0415mGy/mAs recorded at centre C. The distance of focal spot to surface distance varied from 87.9cm to 93cm with centre F having the lowest value of 87.9cm and centre B with the highest value of 93.0cm.

Also, the values of Incident Air Kerma varied from 1.8123mGy to 2.1414mGy with centre B having the lowest value of 1.8123mGy and centre E with the highest value of 2.1414mGy.

The mean values of Entrance Surface Air Kerma for centres A, B, C, E and F as presented in Table 2 are 2.41mGy, 2.39mGy, 2.75mGy, 2.91mGy and 2.67mGy respectively showing observed variations in mean ESAK values across different centres. These variations could be attributed to the variations of exposure parameters used within the centres and also to the different equipment technologies used which have different detective quantum efficiency and exposure latitude (Bacher *et al*., 2003; Hendee & Ritenour, 2002). Furthermore, the equipment used in the different centres differed in age. Equipment that has been in use for a long time would have aged and the X-ray tube target would have roughened and worn out resulting in self-filtration according to observations by IAEA (2014).

The DRL for the lumbar spine AP procedure as seen in Figure 1 was 2.83mGy which was lower than IAEA (1996) and NRBP (1999) which were 10mGy, UK (2012) of 5.70mGy, Japan (2015) of 4mGy and Sudan (2016) of 3.90mGy. However, this value obtained in this study is still quite comparable to Sudan (2016) of 3.90mGy and Japan (2015) of 4mGy. This indicates an improvement in dose optimization of patients. Also the result obtained in this study is similar with the work of Olaide *et al*. (2019) who obtained ESAK of 2.24mGy using indirect method at Minna General Hospital, Niger State, Nigeria. This finding is also similar to the findings of other researches reviewed in this study such as Awad (2016) who obtained 3.5mGy at Khartoum, Sudan and Bakir *et al*. (2019) who obtained 2.03mGy at Al-Najaf, Iraq. But this finding is not in line with the findings of Nyathi *et al*. (2009) who obtained ESAK of 5.30mGy using indirect method at Johannesburg, South Africa. This could be attributed to the fact that the hospital where this research was carried out may not be under the regulatory control of Regulatory Body and hence regulatory standard such as quality control was not carried out on the machine and also designation of Radiation of Safety Officer who is to ensure standard operating procedures are followed may be lacking. Also not in line with the findings of Taha *et al*. (2014) who obtained 5.41±0.33mGy at Makkah, KSA and Ncube (2017) who obtained ESAK of 6.92mGy using indirect method at Bulawayo Metropolitan Province, Zimbabwe.

Table 2: Mean (range) Values of Patients' Parameters and X-ray exposure factors for Lumbar Spine AP Examination

Centres	No.	Age (yrs)	Weight (Kg)	Height (m)	KVp	mAs	FFD(cm)
A	10	35.0(22-59)	65(46-86)	1.5(1.5-1.7)	79.1(78.0-85.0)	27.3(25-32)	100(100-100)
B	10	39.2(31-58)	63(48-83)	1.6(1.4-1.7)	74.2(70.0-80.0)	33.0(30-60)	100(100-100)
C	37	45.1(25-60)	70(50-80)	1.6(1.5-1.6)	82.5(80.0-85.0)	42.1(38-50)	100(100-100)
D	NA	NA	NA	NA	NA	NA	NA
E	20	33.2(20-60)	60.2(55-90)	1.5(1.5-1.8)	90.5 (85.0-100.0)	30.7(20-45)	100(100-100)
F	10	40.2(28-58)	67.5(65-95)	1.6(1.5-1.7)	77.2 (70.0-80.0)	23.2(20-25)	95.2(90-100)

NA: Not Available

Table 3: Variation of Estimated Mean ESAK for the Different Centres for Lumbar Spine AP Examination

Centres	t_p(Kg/m)	Y(d,KV) (mGy/mAs)	D_{FSD} (cm)	K_i (mGy)	BSF (IAEA, 2007)	ESAK (mGy)
A	7.4	0.0575	92.6	1.8306	1.32	2.41
B	7.0	0.0475	93.0	1.8123	1.32	2.39
C	7.4	0.0415	92.6	2.0375	1.35	2.75
D	NA	NA	NA	NA	NA	NA
E	7.1	0.0602	92.9	2.1414	1.36	2.91
F	7.3	0.0676	87.9	2.0298	1.32	2.67

NA: Not Available

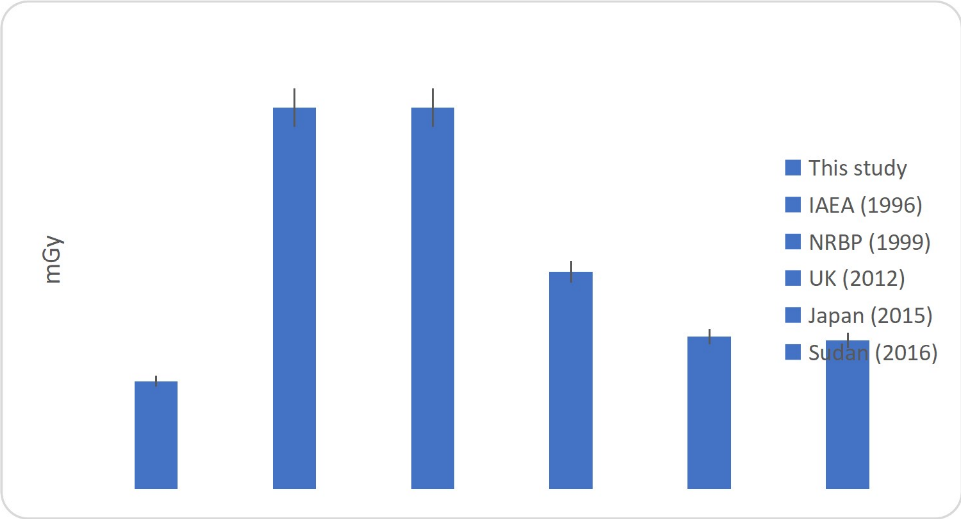

Figure 1: Comparison of the Estimated DRL for Lumbar Spine AP Procedure with other Established DRLs.

4.0 Conclusion

The Entrance Surface Air Kerma (ESAK) for 87 patients who undertook lumbar spine AP examinations in the selected six centres in Abuja Metropolis, Nigeria was evaluated using indirect method and the determined DRL in these centres were found to be lower than the established international reference levels implying that radiation risk to average patients in the centres included in this study is low and hence, the results obtained should be used for the establishment of local DRL for lumbar spine AP in Abuja Metropolis, Nigeria.

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