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

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Abstract: Medical X-ray imaging is extensively used in Nigeria making the practice the most significant source of medical exposure from ionizing radiation compared to therapeutic components. This study is aim at estimating the diagnostic reference level for chest posterior-anterior in some radiological facilities in Abuja metropolis, Nigeria. A total of 265 patients from the six selected centres undertook chest X- ray examination. Entrance surface air kerma was evaluated by indirect method. The peak tube potential, tube loading, focus to film distance, X-ray machine output and the back scattered factor were determined. The mean values of entrance surface air kerma and diagnostic reference level are 0.67mGy and 0.64mGy respectively. The entrance surface air kerma and diagnostic reference level is slightly higher than the international reference levels. This implies that there could be risk to patients that underwent X- ray examination in the centres. It is recommended that there is need to develop standard operating protocol for different X-ray examination procedures.

Keywords: Entrance surface air kerma, diagnostic reference level, chest X- ray examination, and radiological facilities.

1 Introduction

The use of X-rays as a medical diagnostic tool is increasing day by day. The diagnostic radiology centres extensively use these medical imaging X-rays that generate ionizing radiation for diagnosis thereby causing radiation doses to be deposited in the body of patients [1]. It is an established fact among all other man-made radiation exposure; it is the one with highest contributor to population exposure, constituting 95% [2]. Therefore, it would seem reasonable that efforts to minimize these radiation exposures which may cause cancer-related diseases resulting from stochastic/deterministic effects associated with this practice while maximizing the benefits of ionizing radiation in diagnostic X-ray examinations is put in place if the long-term benefits are guaranteed [3]. It is essential as the whole world, Nigeria inclusive, is gradually moving from conventional X-ray to digital X-ray where overexposures can go undetected due to electronic post-processing of images compensating for overexposures and underexposures in the image quality [4]. This increasing knowledge on the exposure effects of ionizing radiation in diagnostic radiology practice has prompted the need for dose reduction. The methods for dose reduction in diagnostic radiology practice include quality assurance (QA) programs, such as accepting guidelines for good radiography and application of diagnostic reference levels (DRLs) [5].

This study aims to estimate the diagnostic reference level for chest PA. Diagnostic reference levels are quality assurance and improvement tools for controlling radiation doses. It is expected that these levels are not exceeded in standard procedures when good and normal practice regarding diagnostic and technical performance is carried out [3]. The DRL is determined by estimating incident air kerma and entrance air kerma which are two important quantities in X-ray diagnostic radiology [3]. The determined DRL for chest PA will be used to propose the establishment of DRL for chest PA in Abuja. However, it is essential to follow proper operating and protection procedures and other areas of QA to exploit the benefits and minimize the risk associated with diagnostic radiology

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practices. National and International radiation protection regulations should also be strictly followed to achieve utmost radiation safety objectives in dealing with artificial radiation sources.

2 Materials and Methods

2.1 Study area and population

A total of 265 adult patients between the age of 19 and 75 sampled from six (6) selected diagnostic radiology centres in Abuja Metropolis, represented as A, B, C, D, E and F, that have NNRA authorizations were considered for this study. Patients that visited the selected centres were approached and their consent was sought before their data were collected. This study was carried out between the period of April and June 2022. The specification of X-ray machines in these six selected centres are indicated in Table 1.

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	NA
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

2.2 Data collection

Data for this study was obtained using a data collection template that captured the date, sex, age, weight, type of exam, X-ray equipment details, tube focus to patient surface distance, tube focus to film distance, type of x-ray procedure, and exposure details (KV and mAs or mA and time). The body weight and height of each patient from which their respective patient thickness (t_p) were calculated, were measured directly using a weighing balance and measuring tape respectively. The protocol for measuring the X-ray tube output was adopted from IAEA [3]. The radiographer positions the patient, the tube focus-to-film distance and the distance of the body part to be imaged referred to as the focus to source distance also termed as focus to detector distance (d) preferably a distance of 100cm were measured and recorded on the designed template along with the X-ray exposure factors and the examination projection used. The X-ray tube focus-to-patient surface distance was then calculated as the difference between the X-ray tube focus to film distance (FFD) and patient thickness (t_p). All the X-ray units had a 2.5 mm Aluminum filter and all the studies were performed with grids. After the patients has left, a Cobia Smart R/F (semiconductor detector) manufactured by RTI Group with serial number CB3-19098461 calibrated to measure tube potential between 18 – 150KVp was positioned in the central beam axis at a preferable X-ray tube focus–detector distance (d) of 100cm to measure the X-ray tube output value. The radiation field size of 10cm x 10cm at focus–detector distance was set to cover the detector completely in the useful beam to avoid the possible influence of 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.

2.3 Data Analysis

Data were analysed using excel version 2007. First and third quartile values of the mean distribution were computed. DRLs were computed as the third quartile value of the distribution of the mean ESAK from the selected centres following the ICRP and IAEA definitions [6, 3]. The first quartile value was used as the lower limit below which centres are recommended to review their parameters to check if they are not using very low doses that produce poor-quality images.

2.4 Entrance surface air KERMA (ESAK) evaluation

The entrance surface air kerma (ESAK) was evaluated by indirect method by measuring x-ray exposure technique factors and patients' parameters using the semi empirical formula as recommended in International Atomic Energy Agency protocol and code of practice [3]. ESAK was evaluated using the following relations [1]:

i. The X-ray tube output

$$Y(d, KV) = \frac{K_a(d,KV)}{P_{it}} \quad (1)$$

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

ii. Incident Air Kerma Estimation

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

Where, D_{FSD} is the distance of focal spot to surface distance and was calculated from the focus- to film distance (FFD) and film distance (t_p) using the equation:

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

Patient thickness was gotten from patient weight (W) and height (h) [7]:

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

iii. *Entrance - Surface Air Kerma (ESAK) calculation:*

$$ESAK = K_i B \quad (5)$$

Where Ki is the Incident Air Kerma and B is the backscatter factor using tabulated B values given by IAEA [3].

3 Results and Discussion

The patients' parameters and the exposure factors used for patients that underwent Chest PA in the selected six centres are presented in Table 2. The mean age of patients for Centres A, B, C, D, E and F were 51.2yrs, 2 45.9yrs, 50.5yrs, 35.2yrs, 47.3yrs and 40yrs respectively. Mean weight of patients were 63kg, 71kg, 79.2kg, 70.6kg, 80.5kg and 75.5kg for Centres A, B, C, D, E and F respectively. The height of patients for Centres A, B, C, D, E and F ranged from 1.5m to 1.7m, 1.4m to 1.8m, 1.5m to 1.6m, 1.5m to 2.6m, 1.45m to 1.9m and 1.5m to 1.7m respectively. The mean KVp used for patients that underwent the Chest PA in all centres ranged from 64.5 to 76.3, with Centre B having the lowest mean KVp of 64.5 while the highest mean KVp of 76.3 was recorded in Centre E.

The lowest mean mAs or P_{it} of 14.3 was recorded in Centre F while highest mean mAs or P_{it} of 19.5 was recorded in Centre C, while the FFD used for patients that underwent Chest PA in all Centres ranged from 150cm to 180cm. The patient thickness for Chest PA for all Centres varied from 7.0kg/m to 7.9kg/m with Centres A and D having the lowest value of 7.0kg/m and Centre C with the highest value of 7.9kg/m. The values of X-ray Tube Output for Centres A, B, C, D, E and F are 0.0578mGy/mAs, 0.0559mGy/mAs, 0.0528mGy/mAs, 0.0572mGy/mAs, 0.0635mGy/mAs and 0.0720mGy/mAs respectively. The distance of focal spot to surface distance varied from 142.3cm to 173.0cm with Centre F having the lowest value of 142.4cm and Centres A and D with the highest value of 173.0cm.The values of Incident Air Kerma for Centres A, B, C, D, E and F are 0.3437mGy, 0.4727mGy, 0.4330mGy, 0.3457mGy, 0.4315mGy and 0.5084mGy respectively as shown in Table 3.

The mean values of Entrance Surface Air Kerma as presented in Table 3 showed variations in mean ESAK values across different centres. It varied from a minimum of 0.45mGy to maximum of 0.67mGy. 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 [8, 9]. 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 [10].

DRLs were calculated as the third quartile distribution of the mean ESAK distribution from the six centres, the same approach was adopted by several organizations including the NRPB, ICRP and IPSM. For the chest PA examination DRL was 0.64mGy which is close to DRLs obtained by Sudan [1] which was 0.5mGy but higher than that the value obtained by IAEA [11] of 0.4mGy, Japan [12] of 0.30mGy and UK [13] of 0.15mGy. This indicated need for improvement in optimization of doses to the patients as regards to this chest PA examination procedures in these centres, even though the result obtained in this study is similar with the work of Umaru & Adamu [14] who obtained ESAK of 0.60mGy using indirect method at Maiduguri, Borno State, Nigeria. This finding is also similar to the findings of other researches reviewed in this study such as Olaide et al. [15] who obtained ESAK of 0.77mGy using indirect method at Minna, Niger State, Nigeria and Awad [1] who obtained 0.5mGy at Khartoum, Sudan. The results from the present study however differed from the findings of Owoade et al. [16] who obtained ESAK of 0.31mGy using indirect method at Ogun State, Nigeria. This could be attributed to the fact that the hospital where this research was carried out was not under the regulatory control of Nigerian Nuclear Regulatory Authority and hence regulatory standard such as quality control may not have been 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, the study results deviated from the findings of other researches reviewed in this study such as Nyathi et al. [17] who obtained ESAK of 0.22mGy using indirect method at Johannesburg, South Africa and Samba et al.

Table 2: Mean (range) Values of Patients' Parameters and X-ray exposure factors for Chest PA Examination.

Centres	No.	Age (yrs)	Weight (Kg)	Height (m)	KVp	mAs	FFD (cm)
A	15	51.2 (22-75)	63 (45-85)	1.6 (1.5-1.7)	70.2 (68.0-80.0)	17.8 (16-20)	180 (180-180)
B	30	45.9 (20-72)	71 (40-89)	1.5 (1.4-1.8)	64.5 (60.0-70.0)	18.4 (15-30)	155.2 (150-180)
C	45	50.5 (19-75)	79.2 (67-85)	1.6 (1.5-1.6)	75.2 (70.0-80.0)	19.5 (19-25)	165.1 (150-180)
D	90	35.2 (22-58)	70.6 (58-98)	1.8 (1.5-2.6)	70.4 (60.0-85.0)	18.1 (16-25)	180 (180-180)
E	50	47.3 (19-75)	80.5 (60-110)	1.7 (1.45-1.9)	76.3 (70.0-85.0)	16.2 (10-32)	162.1 (150-180)
F	35	40 (31-73)	75.5 (65-95)	1.6 (1.5-1.7)	71.2 (70.0-77.0)	14.3(12-16)	150 (150-150)

[18] who obtained 0.39mGy at Yaounde, Cameroun. This

Table 3: Variation of Estimated Mean ESAK for the Different Centres for Chest PA Examination

Centres	t_p(Kg/m)	Y(d,KV) (mGy/mAs)	D_{FSD} (cm)	K_i (mGy)	BSF (IAEA, 2007)	ESAK (mGy)
A	7.0	0.0578	173.0	0.3437	1.32	0.45
B	7.7	0.0559	147.5	0.4727	1.31	0.61
C	7.9	0.0528	154.2	0.4330	1.32	0.57
D	7.0	0.0572	173.0	0.3457	1.32	0.46
E	7.7	0.0635	154.4	0.4315	1.32	0.56
F	7.7	0.0720	142.3	0.5084	1.32	0.67

could also be attributed to same reasons stated above.

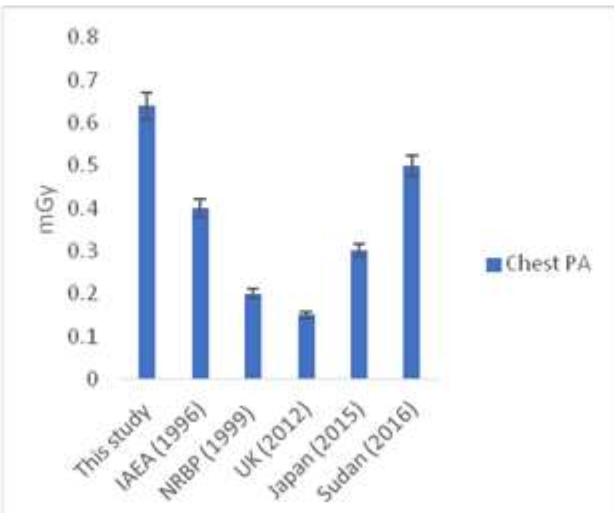

Fig. 1: Comparison of the determined DRL for Chest PA procedure with established DRLs.

4 Conclusions

Entrance Surface Air Kerma (ESAK) for 265 patients who undertaken chest PA examinations in six centres in Abuja metropolis, Nigeria using indirect method were evaluated and used to determine the DRL in these centres. The determined DRL for Chest AP was slightly higher than the international reference levels. This implies that there may be radiation risk to average patients in the centres. Results from this study has shown that most entrance surface air kerma values in the selected centres need to be improved upon by the regular assessment of their radiological techniques of X-ray examination and the personnel in charge. Hence, the need to establish diagnostic reference level in Nigeria cannot be overemphasized.

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References

[1] E. M. S Awad, Estimates of diagnostic reference levels for common radiographic x- ray examinations in some Sudanese hospitals s.l.:s.n. 2016.
[2] UNSCEAR. Sources and effects of ionizing radiation: report to the General Assembly, annex D, medical radiation exposures. New York, NY: United Nations. 2000.
[3] International Atomic Energy Agency Dosimetry in Diagnostic Radiology, International Code of Practice, IAEA technical report series 457, Vienna. 2007.
[4] N. Ncube, Baseline Survey of Diagnostic Reference Levels for the Three Most Frequent X-ray Procedures in the Bulawayo Metropolitan Province, Zimbabwe: The Possibility of Dose Reduction. s.l.:s.n.2017.
[5] UNSCEAR Sources and Effects of Ionizing Radiation: UNSCEAR 2008 Report to the General Assemble with Scientific Annexes , New York: 2010.
[6] International Commission on Radiological Protection Radiological Protection in Medicine. ICRP Publication 105. Ann. ICRP 37 (6), ELSEVIER. 2007.
[7] S.O Inyang, S., I. E Essien, & A.D. Antia, Entrance surface air kerma for chest x-ray examination in some diagnostic facilities in Akwa Ibom State, Nigeria. Advances in Physics Theories and Applications, 48, 27-35. 2015.
[8] K. Bacher. et al.. Dose Reductions in Patients Undergoing Chest Imaging: Digital Amorphous Silicon Flat Panel Detector Radiography Versus Conventional Screen-Film Radiography and Phosphor Based Computed Radiography. American Journal of Radiology, pp. 923-929. 2003.
[9] W.R. Hendee & R.E. Ritenour. Medical Imaging Physics. 4th ed. New York: John Wiley & Sons, Inc. 2002.
[10] International Atomic Energy Agency, Diagnostic Radiology Physics – A Handbook for Teachers and Students. Vienna:. 2014.
[11] IAEA International Atomic Energy Agency IAEA Safety Series No. 115. International basic safety standards for protection against ionizing radiation and for the safety of radiation sources. IAEA, Vienna, Austria. 1996.
[12] Japan Network for Research and Information on Medical Exposure. Diagnostic Reference Levels Based on Latest Surveys in Japan: Japan DRLs. 2015.
[13] D. Hart & P. Shrimpton. Fourth Review of the UK National Patient Dose Database British Journal of Radiology, Volume 85. 2012.
[14] B. Umaru & A. Adamu. Determination of Entrance Surface Dose of Patients Undergoing X-Ray Examination in Federal Neuropsychiatric Hospital Maiduguri, Nigeria IOSR Journal of Applied Physics, 13: 2278-4861. 2021.

[15] K. Olaide., M.T Kolo., U. Ahmadu & I. Olarinoye, Estimation of Entrance Surface Dose during Diagnostic X-Ray Procedure at Minna General Hospital. 2019.

[16] L. R. Owoade., I. Sambo & S.A Tijani. Assessment of entrance surface air kerma in patients undergoing chest X-ray from conventional diagnostic radiology in Ogun State, Nigeria. International Journal of Medicine and Medical Sciences, 7(6), 117-120. 2015.

[17] T. Nyathi., L. C. Nethwadzi., T. Mabhengu, T., M.L Pule & D.G. Van der Merwe. Patient dose audit for patients undergoing six common radiography examinations: potential dose reference levels: peer reviewed original article. South African Radiographer, 47(2), 9-13. 2009.

[18] O.N Samba., J. Yomi., R.F Talla., A.G Juimo & F.C. Lukong. Local reference dose level evaluation in chest radiography in Yaounde. Journal of African Image Medicine, 7(3), 152-162. 2015.