Radiation Dose Assessment of Patients undergoing Lumbar Spine Radiography

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Abstract- Measurement of patient dose is an essential tool in optimizing dose and protecting patient against the ionizing radiation during diagnostic radiology. Quantifying the patient dose safe guard both the patient undergoing examination and medical personnel from health hazard of ionizing radiation. In this study the entrance surface air kerma (ESAK) of 150 patients undergoing lumbar spine radiographic examinations in eight radiological departments in Southern part of Nigeria. Patient doses were evaluated based on IAEA code of practice using exposure factors. The calculated mean ESAK values ranged 1.68 mGy to 12.66 mGy for lumbar spine AP and ranged from1.91 mGy to 10.53 mGy for lumbar spine LAT. The results obtained in this study were compared with the values of doses reported in UK 2010 review and it was found to be higher in some health facilities. The higher doses observed in this survey can be attributed to the use of higher tube loading (mAs) during exposures, which shows lack of optimization of exposure settings.

Index Terms- Entrance surface air kerma, radiation dose, lumbar spine, exposure factors.

I. Introduction

X-ray is the most used ionizing radiation in medical imaging for diagnosis both in developing and developed countries. It contributed majorly, to collective effective dose of the general populace but it plays a major role in health care delivery system.[1-3]

Effect of ionizing radiation on human tissue made it necessary to develop a method of evaluating radiation dose in all fields of human endeavor. The parameters recommended for evaluating and monitor the patient dose in conventional radiography by International Atomic Energy Agency (IAEA) in 1995 and European Union in 1997 was the entrance surface dose (ESD) and the measuring method were clearly spelt out in the European guidelines.[4,5] The ESD measured in mGy or µGy, is defined as the radiation dose at the surface of the patient where the X-ray field enters the body. It includes contributions from primary beam and also the radiation backscattered from the tissue below the surface. An alternative method is in terms of incident air kerma (IAK) which is to take free-in-air measurements without the contribution of backscattered radiation from the patient.[6] Incident air kerma and entrance surface air kerma are two important quantities in X – ray diagnostic radiology.[2] The entrance surface air kerma is defined as the kerma to air measured on the central beam axis at the position of the patient or phantom surface. This measurement includes radiation incident on the patient or phantom and backscattered radiation.

Various radiation dose surveys had been carried out in Nigeria. [7-17] These studies had shown large intra- and inter-radiological center dose variation for the same diagnostic procedure which shows that radiological procedures were not optimized. These large dose variations showed that the patients were given unwanted radiation doses and that radiographic process optimization is possible. Also, there is possibility for substantial reductions in the patient doses without affecting radiographic image quality. Due to the wide patient dose variations observed in various survey, the Royal College of Radiologists (RCR) and the National Radiological Protection Board (NRPB) recommended that the regular monitoring of patient dose should be an essential part of quality assurance (QA) programme in diagnostic radiology. [18]

The regular monitoring of patient doses became necessary in Nigeria; because, in previous studies, wide variations of doses to patients were obtained. Also, it was reported that there are over 4000 X – ray machines in Nigeria with less than 5% of them being under any form of regulatory control [16] and that there is no published National Diagnostic Reference Levels (NDRLs) which is essential for the management of patient dose to ensure that the benefit outweighs any health hazard to the patients.[16,19]
The current study aimed at carrying out dose assessment of patients undergoing lumbar spine radiography in some health facilities in southern Nigeria..

II. Materials and Methods

Eight hospitals were purposely selected to include all other health care systems except primary health care centers that do not have radiological centers in southern part of Nigeria for this study. These include: Federal Medical Center (FMC) Ido Ekiti; Ayinke Diagnostic Center (ADC) Ilesa; Central Hospital (CH) Benin – City; Ladoke Akintola University Teaching Hospital (LTH)

Osogbo; Oba Adenle Memorial Hospital (OAMH) Ilesa; University of Benin Teaching Hospital (UBTH) Benin – City; University Teaching Hospital (UTH) Ado – Ekiti; and Obafemi Awolowo University Teaching Hospital Complex (OAUTHC) Wesley Guild Ilesa;

The Quality Control (QC) test for each machine was carried out using QC kit (NERO™ 6000m, manufactured by Victoreen, INC, Cleveland, Ohio, USA). The QC kit was positioned at the centre of the beam axes at focus to image distance (FID) of 100cm.[20] The QC tests carried out on each machine are: the kVp parameters (accuracy, reproducibility and consistency); the exposure time (reproducibility and accuracy); and the output linearity coefficient and output reproducibility.

Exposure parameters and patient characteristics such as tube potential (kVp), focus-to-film distance (FFD), tube loading (mAs), filtration of the machine (inherent and added), exposed film area (assumed to be beam area), thickness of the exposed (irritated) part of the body, projections (e.g. AP,PA and LAT) were recorded during the routine exposure.

The indirect method of calculating ESAK was adopted in this study. According to the IAEA Code of Practice [2], the incident air kerma is calculated using:

$$K_i = Y(d) * P_{It} \left(\frac{d}{d_{FTD} - t_p}\right)^2$$

Where

- $Y(d)$ is the output (mGy/mAs) of the X- ray tube at particular exposure settings
- d is the focus to chamber distance
- P_{It} is the tube loading during the exposure of the patient
- d_{FTD} is the focus table distance
- t_p is the patient thickness at the irradiation site

The ESAK was calculated from incident air kerma by multiplying using an appropriate backscatter factor:

$ESAK = K_i * BSF$

Where BSF is the backscatter factor,

Results and Discussion

This survey include 150 patients who underwent lumbar spine (AP and LAT) examinations in eight health facilities in the Southern part of the Nigeria between April 2016 and June 2019. All the X- ray generators used are three – phase (6 or 12) pulse models or high – frequency generators.

Table 1: The Quality Control test of the X - ray units

Parameters	Measurements	Acceptable Limits	LTH	ADC	OAMH	UTH	OAUTH	FMC	CH	UBTH
KVp	Accuracy kVp	≤±5%	0.32%	0.96%	0.84%	0.52%	0.65%	0.75%	0.78%	0.85%
Reproducibility %		≤±5%	0.14%	0.48%	0.42%	0.25%	0.45%	0.58%	0.65%	0.53%
Consistency %		≤±10%	0.30%	0.95%	0.85%	0.50%	0.64%	0.45%	0.75%	0.74%
Exposure	Accuracy %	≤± 10%	0.30%	0.50%	0.50%	0.96%	0.65%	0.76%	0.05%	0.45%
Time	Reproducibility	≤ 0.05	0.03%	0.03%	0.03%	0.04%	0.03%	0.04%	0.03%	0.03%
Output	Linearity	≤0.10	0.07%	0.09%	0.04%	0.06%	0.08%	0.06%	0.05%	0.07%
Reproducibility		≤ 0.05	0.04%	0.04%	0.02%	0.03%	0.04%	0.03%	0.04%	0.03%
Remarks			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Table 1 present the results of quality control of the X - ray machines in all the units. According to American Association of Physicists in Medicine (AAPM 2002), the kVp accuracy should not exceed ± 5% and the reproducibility and consistency should not exceed 10%. The kVp accuracy that was calculated ranged from 0.32% to 0.96% which was lower than the tolerance limit. The kVp reproducibility and consistency ranged from 0.14% to 0.65% and 0.30% to 0.95% respectively. This shows that the exposure time accuracy and reproducibility of the x-rays were up to standard in all X- ray units. Also, the output linearity coefficient and the reproducibility of the machines in all X – ray units were within the limits recommended by the American Association of Physicists in medicine. [20]

Table 2: Mean values of exposure parameters for routine lumbar spine AP examinations. Ranges are shown in parentheses

Hospital	No of patient	Patient thickness (cm)	Tube potential (kVp)	Exposure setting (mAs)	Focus-film-distance (FFD) cm
LTH	24	22 (13 -35)	76 (72 – 80)	45 (40 – 57)	103 (102 – 104)
OAUTHC	16	27 (18 – 36)	87(73-96)	(91(40-125)	117(110-125)
UBTH	22	23 (21 – 32)	85 (74 – 91)	31 (20 – 40)	115 (100 – 160)
OAMH	14	26 (24 – 29)	75 (73 -77)	45 (40 – 50)	116 (110 – 120)
ADC	14	22 (14 – 28)	93 (89 -96)	103 (100 – 110)	116 (110 – 120)
UTH	24	24 (20 – 28)	88 (78-97)	40 (30-50)	108 (96-120)
CH	14	28 (26 – 34)	103 (90 – 110)	170 (100 – 250)	93 (90 – 95)
FMC	22	23 (22 – 27)	97 (95 – 100)	45 (40 -50)	92 (90 – 95)

UK Guideline	NA	NA	78 (69 - 109)	46 (1 – 246)	NA

NA: Not Available; UK guideline [21]

The technical parameters employed for lumbar spine AP is shown in Table 2. Variations were observed in tube voltage (kVp) and tube load (mAs) due to the varying weight of the patient. The film to focus distance (FFD) employed in some radiological units were inconsistent with the international recommended values. This was observed at CH and FMC where the FFD employed, ranged from 90.0 cm to 95.0 cm with mean value of 92.0 cm and 93.0 cm respectively compared to FFD range of 100.0 cm to 150.0 cm with mean value of 115.0 cm recommended by European guidelines (EC, 1996). The kVp and mAs employed in all X- ray units were comparable with the value used in UK – 2010 review.[21]

The mean values and ranges of exposure parameters used lumbar spine LAT examination in all X- ray units are shown in Table 3. The FFD employed in most X-ray units were consistent with the stipulated value by the international organization except in UTH and CH. The kVp and mAs employed in most units were within the value used in UK – 2010 review.

Table 3: Mean values of exposure parameters for routine lumbar spine LAT examinations. Range are shown in parentheses

Hospital	No of patient	Patient Thickness (cm)	Tube potential (kVp)	Exposure setting (mAs)	Focus-film-distance (FFD) cm
LTH	24	23 (22 – 27)	80 (75-85)	49 (35-64)	132 (104 -180)
OAUTHC	16	25 (23 – 32)	90 (81-96)	110 (64-125)	114 (110-123)
UBTH	22	22 (17 – 28)	90(83-96)	44(32-50)	108(100-130)
OAMH	14	24 (20 – 28)	87 (77 – 96)	45 (40 – 50)	105 (100 –120)
ADC	14	28 (26 – 34)	92 (90 – 96)	112 (100 – 125)	115(110 – 120)
UTH	24	27 (18 – 36)	86 (75-97)	35 (20-50)	108 (96-120)
CH	14	23 (21 – 32)	104 (100-110)	200 (150-250)	94 (90-98)
FMC	22	26 (24 – 29)	92 (90-95)	43 (40-50)	95 (90-100)
UK Guideline	NA	NA	88 (75 -118)	48 (1 -560)	NA

NA: Not Available; UK guideline [21]

The statistical distribution of the ESAK values from the X- ray units for the lumbar spine AP is shown in Table 4. From the Table, the ESAK ranged from 0.46 to 2.44 mGy with mean value of 1.68 mGy in LTH, the value ranged from 2.49 to 6.08 mGy with the mean of 5.02 mGy in OAUTH. In OAMH; the ESAK value ranged 1.77 to 2.65 mGy with the mean value of 4.03 mGy and at ADC, it ranged from 1.56 to 3.42 mGy with mean value of 4.40 mGy.

Table 4: Distribution of Entrance surface dose air kerma (ESAK) in mGy for lumbar spine AP in all health facilities

Hospitals	Number Of Patients	Min	1st quartile	Median	mean	3rd quartile	max	Max/min
LTH	24	0.46	1.44	1.77	1.68	1.97	2.44	5.30
OAUTHC	16	2.49	5.35	5.37	5.02	5.45	6.08	2.44
UBTH	22	0.73	1.57	2.54	2.31	2.81	3.96	5.42
OAMTH	14	2.65	3.15	3.94	4.03	4.82	5.57	1.77
ADC	14	3.42	4.09	4.42	4.40	4.72	5.33	1.56
UTH	24	0.65	2.01	3.01	2.72	3.72	4.20	6.46
CH	14	5.56	7.58	11.31	12.66	16.38	22.45	4.04
FMC	22	2.45	3.92	5.37	5.74	7.38	9.37	3.82

In UTH, the ESAK value ranged from 0.65 to 6.46 mGy, the mean value is 2.72 mGy and in CH, the value of ESAK ranged from 5.56 to 22.45 mGy with the mean value of 12.66 mGy. While the dose value ranged from 2.45 to 9.37 mGy with the mean of 5.74 mGy im FMC, the value ranged from 0.73 to 3.96 mGy and the mean value is 2.31 mGy in UBTH.

The range factors (i.e minimum/maximum ratio) ranged from1.56 in ADC to 6.46 in UTH, this shows that there is a significant intra- and inter- radiological center dose variation.

Statistical distribution of the ESAK values for individual patient for the lumbar spine LAT in all the health facilities is presented in Table 5. The ESAK value ranged from 0.72 to 3.25 mGy with the mean of 1.91 mGy, it ranged from 4.55 to 6.08 mGy with the mean of 6.78 mGy in OAUTHC. In OAMH, the ESAK value ranged from 3.79 to 5.46 mGy with mean value of 4.34 mGy and it ranged from 3.45 to 5.74 mGy with the mean of 4.87 mGy in ADC.

Table 5: Distribution of Entrance surface dose air kerma (ESAK) in mGy for lumbar spine LAT in all health facilities.

Hospitals	Number Of Patients	Min	1st quartile	Median	mean	3rd quartile	max	Max/min
LTH	24	0.72	1.43	1.65	1.91	2.41	3.25	4.51
OAUTHC	16	4.55	6..39	6.59	6.78	6.90	7.08	1.34
UBTH	22	2.43	3.63	3.69	4.04	4.35	5.99	2.46
OAMTH	14	3.79	4.24	4.48	4.34	4.79	5.46	1.44
ADC	14	3.45	4.26	5.14	4.87	5.74	5.74	1.66
UTH	24	2.44	2.46	2.45	3.02	3.31	4.16	1.70
CH	14	5.45	6.45	10.53	14.27	18.35	30.57	5.61
FMC	22	2.44	2.46	2.45	3.02	3.31	4.16	1.70

The ESAK value for individual patient ranged from 2.56 to 4.37 mGy with the mean value of 3.33 mGy in UTH and it ranged from 5.45 to 30.45 mGy with the mean of 14.27 mGy in CH. In FMC, it ranged from 2.44 to 4.16 mGy with mean of 3.02 mGy and ESAK value ranged from 2.44 to 4.16mGy with mean of 4.02 mGy in UBTH. The range factor ranged from 1.34 in OAUTHC to 5.61 in CH, which shows that there is significant intra- and inter- radiological center dose variation.. The variation observed in this study are smaller probably due to the smaller number of health facilities involved since, wide dose variation were always observed in large scale survey. Although various reasons have been adduced for wide variation in patient doses for the same type of examination. These include: the levels of training of the operators, patient anatomical thickness; differences in exposure technique employed by the radiographers; the film-screen combination type in use; and the status of implementation of radiation protection standards, the basics is that the optimization of the radiation protection is not achieved.

III. Conclusion

Entrance surface air kerma (ESAK) were measured for lumbar spine (AP & LAT) using mathematical model from exposure parameters in eight health facilities in Southern part of Nigeria.

The results obtained in this study show that generally the kVp and mAs employed in most of X-ray units were comparable with those reported in 2010 UK review. The mean ESAK value obtained for lumbar spine AP in this study were lower than 5.7 mGy obtained in 2010 UK review except in CH where the mean ESAK obtained is 12.66 mGy. However, there is a significant dose variation which could mean unjustified risk to patients undergoing similar types of radiographic examinations and that there is the possibility of dose reduction to patients without affecting image quality.

Since the quality assurance (QA) in radiology is proven to be a powerful tool for decreasing doses and increasing diagnostic efficiency, there is need for QA program which involves training and re-training of personnel, constant monitoring of X-ray facilities in all these health facilities in order to help the operators in dose optimization.

References

[1] Prince K.G, Adu S, Emi-Reynolds G, Yeboah J, Inkom S, Cythia K.E, and Wotorchi G.S. "Radiation dose estimation of patients undergoing lumbar spine radiography". Journal of Medical Physics.vol 38 (4), pp 1 -5, 2013.

[2] International Atomic Energy Agency (IAEA). Technical report series number 457 Dosimetry in diagnostic radiology: An international code of practice, IAEA, Veinna, 2007.

[3] UNSCEAR. United Nation Scientific Committee on the Effect of Atomic Radiation. Sources and effects of ionizing radiation: report to the General Assembly, annex D, medical radiation, New York, NY: United Nations, 2000.

[4] International Atomic Energy Agency (IAEA). Radiation doses in diagnostic radiology and methods for dose reduction. IAEA – TECDOC 796, Brussels.1995.

[5] European Commission,. European guidelines on quality criteria for diagnostic radiographic images. Report EUR 16260EN (Luxembourg: Office for Official Publications of the European Communities, 1996.

[6] ICRP. Radiological protection in fluoroscopically guided procedures outside imaging department. ICRP Publication 117, Ann. ICRP, vol 40(6), 2010.

[7] Ajayi, I. R., & Akinwumiju, A. "Measurement of entrance skin doses to patients in four common diagnostic examinations by thermoluminescence dosimetry in Nigeria". Radiation Protection Dosimetry, vol 87, pp 217- 220, 2000.

[8] Ogundare, F. O., Uche, C. Z., & Balogun, F. A. "Radiological parameters and radiation doses of patients undergoing abdomen, pelvis and lumbar spine X-ray examinations in three Nigerian hospitals". British Journal of Radiology, vol 77, pp 934 – 940, 2004.

[9] Ogunseyinde, A. O., Adeniran, S. A. M., Obed, R. I., Akinlade, B. I., & Ogundare, F. O. "Comparison of entrance surface doses of some X-ray examinations with CEC reference doses". Radiation Protection Dosimetry, vol 98, pp 231 – 234, 2002.

[10] Akinlade, B. I., Farai, I. P., & Okunade, A. A. "Survey of dose area product received by patients undergoing common radiological examinations in four centres in Nigeria". Journal of Applied Clinical Medical Physics, vol 13(4), pp 37-42, 2012.

[11] Obed R.I, Ademola A.K, Adewoyin K.A and Okunade O, "Doses to patient in routine x- ray examination of the chest, skull, abdomen and pelvis in nine selected hospitals in Nigeria". Research Journal of Medical Sciences. vol 1 (4) pp 209 – 214, 2007.

[12] .Olowookere C J, Babalola I A, Jibiri N N, Obed R I, Bamidele L, and Ajeunmobi. "A preliminary dose audit in some Nigerian hospitals: Need for determination of national diagnostic reference levels (NDRLs)." The pacific Journal of Science and Technology, vol 13(1), pp 487-494, 2012.

[13] Egbe N.O; Chiaghanam N.O; Azogor W.E; Inyang S.O. "A baseline study of entrance dose and image quality for lumbar spine radiography in Calabar, Nigeria". radiography. Vol 15 (4), pp: 306 – 312, 2009.

[14] Jibiri N N, Olowookere C J. "Patient dose audit of the most frequent radiographic examinations and proposed local diagnostic reference levels in southwestern Nigeria: Imperative for dose optimization". Journal of Radiation Research and Applied Sciences. Vol 9, pp 274- 281, 2016.

[15] Joseph D.Z, Nzotta C.C, Umar M.S, Ogenyi A.P, Njoku G, Dauda M.F, Moi A.S, Shem S.L. "Establishment of local diagnostic reference levels (DRLS) for radiography examinations in North Eastern Nigeria". Science World Journal. Vol 12(4), pp 51 – 57, 2017.

[16] Joseph D.Z, Christian C.N, Joseph D.S. "Diagnostic reference levels (DRLs) for contrast radiography examinations in North Eastern Nigeria". Parkistan Journal of Radiology, vol 28 (1), pp 9 – 16, 2018.

[17] Ishiekwen A.C, Aliyu A.S, and Nwafor M.S. "X- ray dose audit and potential local diagnostic reference levels in selected hospitals in Kaduna state, Nigeria". Journal of Radiography & Radiation Sciences, vol 32(1), pp104 – 109, 2018.

[18] NRPB. Institute of Physical Sciences in Medicine (IPSM), National Radiological Protection Board (NRPB) College of Radiographers. National protocol for patient dose measurements in diagnostic radiology. Oxfordshire, United Kingdom, 1992.

[19] Akpochafor M.O Omojola A.D, Soyebi K.O, Adeneye S. O, Aweda Adebayo M. A, Ajayi H.B. "Assessment of peak kilovoltage accuracy in ten selected centers in Lagos metropolis, South-Western Nigeria: A quality control test to determine energy output accuracy of an generator". J Health Res Rev [serial online]; vol3, pp 60-5, 2016.

[20] Welander U and Wickman G. "Mean energy imparted in relation to the focus to object distance". Acta Radiological diagnostic (Stockh), vol 19 (10), pp14 – 24. 1978.

[21] AAPM. American Association of Physicists in Medicine: Quality control in diagnostic radiology. AAPM Report NO 74. Medical Physics Publishing 2002.

[22] Hart, D., Hillier, M. C., & Shrimpton, P. C. Doses to patients from radiographic and fluoroscopic X-ray imaging procedures in the UK-2010 review. Health Protection Agency (HPA-CRCE-034). HPA Center for Radiation, Chemical and Environmental Hazards, ISBN 978-0-85951-716-4, 2012.

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