Measurement of Entrance Surface Air Kerma of Plain Abdominal Radiography in Some Nigerian Health Facilities

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DOI: https://dx.doi.org/10.4314/ajhs.v36i3.14

Abstract

BACKGROUND

Patient dose assessments in many Nigerian radiological departments have shown large inter- and intra-hospital variations for the same type of radiological examinations, hence, there is a need for regular monitoring of radiological equipment and measurement of patient dose in our health facilities. The main objective of this survey was to evaluate the Entrance Surface Dose Air Kerma (ESAK) of the patients who underwent abdominal (anteroposterior; AP) radiography in ten health facilities in Southern Nigeria.

MATERIAL AND METHODS

A total of ten health facilities comprising private and public health facilities were included in this investigation. A total of 223 adult patients who weighed within 70±5kg `were considered in this survey. The ESAK was calculated from the tube output of the x-ray machines and the exposure parameters utilized during examinations according to the International Atomic Energy Agency code of practice.

RESULTS

The mean ESAK values obtained from the health centres ranged from 1.00 milligray (mGy) to 17.21mGy. The maximum/minimum ratio of individual ESAK which is the range factor (RF) varied from 1.3 to 6.1.

CONCLUSION AND RECOMMENDATION

Variations were observed in patient dose values among radiological units. The entrance surface air kerma (ESAK) obtained in the study were comparable with the dose values in the UK- 2010 review in most cases. The intra-radiological unit patient dose variations, as revealed by the range factor show that the operation technique employed was not fully optimized and that dose reduction is possible without degrading image quality. Therefore, there is a need for regular monitoring of radiographic equipment and periodic surveys of the patient dose.

***Keywords**: Abdomen, Entrance Surface Air Kerma, Optimization, X-Ray Radiography*

[*Afr. J.* *Health Sci*. 2023 36 (3): [319-325]

Introduction

The evaluation of doses to patients during diagnostic examinations has become more important to medical physicists due to an increase in the recent understanding of the undesirable effects accompanied by the use of ionizing radiation. [1,2] The exposure of patients to radiation during diagnostic exams may increase the risk of cancer, malignant conditions, and other hereditary effects. One of the important assignments in radiation protection is to reduce the stochastic risk and avoid deterministic injuries. [3.4] To safeguard medical personnel and patients from the hazard of ionizing radiation, there is a need to adopt the principles of justification and optimization in diagnostic radiology. The optimization principle involves the assessment of doses to patients during diagnostic examinations and evaluating the degree of their exposure.

Surveys show significant variations in patient doses for similar radiographic exams, indicating suboptimal optimization of radiography processes. The wide variations in dose levels being obtained in various surveys have led to global interest in assessing patient doses [2,5].

In Nigeria, various patient dose studies have been carried out in which large intra- and inter-radiological unit patient dose variations for the same type of radiographic examination have been observed; therefore, there is a need for regular monitoring of diagnostic procedures in the health centres [4, 6-11].

A plain abdominal diagnostic examination using an X-ray involves exposing the abdomen to a dose of ionizing radiation to produce an image of the organ within the abdomen. The common abdominal projections are the Anteroposterior, Supine and Erect. The standard abdominal radiograph should include the area from the diaphragm to the pubic symphysis[12]. The evaluation of abdominal X-ray examination is very important because the reproductive organs of the patients are either in the primary beam or close to it. Therefore, the radiation risk to the patient being examined and future generation is much higher compared to chest or skull examinations in which gonads are far from the primary beam. Therefore, it is necessary to investigate the doses for patients during abdominal examination and identify the technique for minimizing it.

The present survey aimed at performing a radiation dose audit of patients undergoing plain abdominal Anterior-Posterior (AP) x-ray examinations in ten health facilities in Nigeria and compares the results obtained with international dose reference levels (DRLs).

Materials and methods

A total of ten (10) functional radiological departments from the health facilities in four states (Oyo, Osun, Ekiti and Edo) in Southern Nigeria were investigated in this study in line with European guidelines. The health facilities included in this study were: Obafemi Awolowo University Teaching Hospital Complex (OAUTHC) Wesley Guild, Ilesa; Federal Medical Center (FMC), Ido Ekiti; the University of Benin Teaching Hospital (UBTH) Benin – City; Ayinke Diagnostic Center (ADC) Ilesa; Ladoke Akintola University Teaching Hospital (LTH), Osogbo; Central Hospital (CH) Benin – City; Two Tees Diagnostic Centre (TTS), Ibadan; Seventh Day Adventist Hospital (SDAH), Ile – Ife; University Teaching Hospital (UTH), Ado – Ekiti; Oba Adenle Memorial Hospital (OAMH), Ilesa.

In this study, 223 adult patients (male and female) undergoing routine abdominal diagnostic examinations with ages ranging from 18 to 90 years and an average weight of 70±5kg were examined. Data were collected between August 2016 and May 2020.

The technical parameters such as tube load (mAs), tube potential (kVp), filtration of the machine, focus to film distance (FFD), and thickness of the irradiated part (t_p), were recorded during exposure. Patient information such as sex, age and weight were obtained and recorded.

Radiation outputs (mGy(mAs)$^{-1}$ of the machines were measured using a calibrated QC kit (NERO™ 6000M, manufactured by Victoreen, INC, Cleveland, Ohio, USA) at a distance of 1m. Quality control tests such as reproducibility, linearity and timer accuracy were carried out on each x-ray machine and the results obtained were compared with the acceptable standard tolerance limits set by the American Association of Physicists in Medicine (AAPM).[13]

The Entrance Surface Air Kerma (ESAK) was calculated using an indirect method as suggested by the IAEA code of practice.[14] Microsoft Excel was used to manipulate the data collected and calculate the individual patient dose.

Calculation of entrance surface kerma

According to the IAEA Code of Practice, the entrance surface air kerma (ESAK) is calculated using the following relationship:

$$ESAK = Y(d) \times mAs \times \left[\frac{d}{FFD - t_p}\right]^2 \times BSF$$

where Y(d) is the X-ray tube output at a distance of 100cm normalized by 10m As, FFD is the focus-film-distance, where, t_p is the patient thickness and BSF is the backscatter factor, which depends on tube potential, device filtration and the size of the radiation field. [14, 15].

Results

Analyses were performed on 223 adult patients in ten radiological departments in ten health facilities. The patient information and exposure parameters in all health facilities are shown in Table 1. The mean ages of the patients ranged from 26 to 72 years which were comparable to the patients' ages used in the UK 2010 review.

The weight of the patients ranged from 65 to 75 kg and the mean weight ranged from 67 to 72kg which was in line with the weight of standard human body size defined by ICRP.[16] The exposure parameters employed in this survey are in good agreement with international criteria[17] but in some cases, the kVp and FFD employed were beyond the stipulated values.

Table 1:
Patient information and exposure parameters in all X-ray departments

	Health centers	No. of Patients	Patient Age Mean (range) years	Patient weight Mean (range) kg	FFD Mean (range) cm	kVp mean (range)	mAs mean (range)
1	TTS	20	61(28-80)	68(67-70)	85(78-90)	88(65-104)	56(20-90)
2	OAUTHC	27	63(49-79)	70(68-72)	124(104-131)	81(80-86)	49(40-64)
3	SDAH	18	56(41-76)	67(65-72)	95(88-97)	91(86-95)	55(20- 85)
4	UTH	24	49(31-57)	71(67-75)	109(96-120)	79(75-90)	29(20-35)
5	FMC	28	59(38-80)	68(66-72)	121(90-123)	82(77-90)	36(25-49)
6	CH	15	45(18-75)	70(68-74)	85(80-90)	103(100-110)	155(150-160)
7	LTH	33	44(29-65)	70(65-71)	106(10-112)	74(71-76)	25(10-30)
8	OAMH	15	26(22-29)	67(66-69)	94(70-116)	91(81-100)	55(45-64)
9	ADC	18	44(19-79)	67(65-75)	109(94-121)	73(65-81)	76(50-100)
10	UBTH	25	72(64-82)	72(65-74)	120(110-130)	78(70-81)	30(25-32)
UK	Guideline	NA	57(16-100)	71(41-130)	NA	77(68-90)	39(1- 440)

Table 2A:
Quality Control test results in the four (4) x-ray units

Parameters	Measurements	Acceptable Limits	Health Centers			
			SDAH	LTH	TTS	OAUTHC
kVp	Accuracy kVp	≤±5%	0.50%	0.32%	0.85%	0.96%
	Reproducibility%	≤±5%	0.23%	0.25%	0.46%	0.48%
Exposure	Accuracy %	≤±10%	0.30%	0.50%	0.50%	0.68%
	Reproducibility	≤±0.05	0.03	0.04	0.03	0.04
Output	Linearity	≤ 0.10	0.06	0.08	0.07	0.06
	Reproducibility	≤ 0.05	0.02	0.04	0.04	0.03

Tables 2A &B are the quality control results of the X-ray machines in the radiological department. The kVp accuracy value should not be above ±5%, and the reproducibility and consistency should not exceed 10%. The kVp accuracy 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. It can be seen from the tables that exposure times were up to standard in all X-ray units. Also, the coefficient of output linearity and the reproducibility of the machines in all X-ray units were up to the standard recommended by the American Association of Physicists in Medicine (AAPM).[13]

The distributions of entrance surface air kerma (ESAK) are presented in Table 3. The values of mean ESAK are 2.00, 1.00, 2.59, 2.78, 4.97, 4.04, 1.25, 17.21, 1.33, and 1.88mGy respectively for TTS, LTH, OAUTHC, SDAH, OAMH, ADC, UTH, CH, FMC and UBTH.

The range factor (i.e. maximum/minimum ratio) of ESAK value for individual patients varies from 1.3 to 6.1 which shows that there are intra-radiological centre dose- variations. The image quality of all the patients in this survey fulfilled all the diagnostic requirements as described by European guidelines.[17]

Discussion

This survey aimed at performing a radiation dose audit of patients undergoing plain abdominal Anterior-Posterior (AP) x-ray examinations in ten health facilities in Nigeria and compares the results obtained with international dose reference levels (DRLs).

Table 2B:
Quality Control Tests Results of the Remaining Five (5) X-Ray Units

Parameters	Measurements	Acceptable Limits		Health Centers				
			UTH	UBTH	FMC	OAMH	CH	ADC
kVp	Accuracy kVp	≤±5%	0.84%	0.52%	0.65%	0.75%	0.78%	0.85%
	Reproducibility%	≤±5%	0.42%	0.24%	0.43%	0.38%	0.65%	0.33%
Exposure Time	Accuracy %	≤±10%	0.50%	0.96%	0.65%	0.76%	0.55%	0.45%
	Reproducibility	≤±0.05	0.03	0.03	0.03	0.04	0.03	0.04
Output	Linearity	≤ 0.10	0.04	0.03	0.08	0.06	0.04	0.07
	Reproducibility	≤ 0.05	0.02	0.03	0.02	0.04	0.03	0.04

Table 3:
Distribution of Entrance Surface Air Kerma in all Health Centers

Health Centers	No of Patients	Min.	1st quartile	Median	Mean	3rd quartile	Max.	Max/Min
TTS	20	1.68	1.72	1.82	2.00	2.40	2.60	2.5
OAUTHC	28	1.76	1.78	2.67	2.59	2.79	4.74	2.68
SDAH	18	1.25	1.54	2.25	2.78	3.02	4.56	3.65
UTH	24	0.68	0.99	1.28	1.25	1.49	1.81	2.66
FMC	28	0.40	0.72	1.06	1.33	1.96	2.44	6.10
CH	15	12.74	13.29	17.20	17.21	21.13	21.68	1.70
LTH	33	0.94	1.77	1.00	1.00	1.04	1.22	1.30
OAMH	15	3.07	3.82	4.66	4.97	5.82	7.51	2.45
ADC	18	1.74	2.13	4.06	4.04	5.33	7.17	4.12
UBTH	25	1.49	1.58	1.74	1.88	2.18	1.89	1.26

The summary of exposure parameters (tube potential, tube loading, FFD) in each unit is given in Table 1. These parameters were within the international criteria except in a few cases where the FFD and kVp employed were below the established levels. For example, the FFD employed in CH were between 80.0 and 90.0cm with a mean FFD value of 85.0cm instead of FFD of 100.0 to 150.0 cm with a mean value of 115.0cm recommended by the European committee as good practice. Also, the tube potential (kVp) employed varies from 100 to 110 kVp with a mean kVp of 103 kVp which was outside the ranges of values reported in the UK 2010 review.[18] Table 2 shows the quality control results of the x-ray unit in all the radiological departments. The kVp (accuracy, reproducibility and consistency), exposure time (accuracy and reproducibility) and the coefficient of output linearity and reproducibility of the machines obtained were lower than the tolerance levels recommended by AAPM.[13]

The distributions of ESAK in all health facilities investigated in this study are presented in Table 3. The variation in the ESAK as shown in range factors is partly due to variations in human physique and radiographic technique employed by the radiographers and it shows that the radiography process is not fully optimized.

A comparison of ESAK in this study with other studies and international organizations is made in Table 4. Only 20% of radiological centres have mean dose values higher than ESAK determined in the UK 2010 review, while 80% have lower dose values. Generally, the average dose values obtained in this survey are lower than those obtained in previous studies in Nigeria[4] except in CH and also it was similar to those of other countries.[19-21] The high mean dose value obtained in CH could be attributed to high tube loading (mAs) employed during examinations. In Nigeria, there are no published national reference dose levels (NDRLs), resulting in exposure parameter choices being based on radiographers' experience.

Conclusion

Entrance surface air kerma (ESAK) of 223 adult patients undergoing plain radiography in ten health facilities in four states in the southern part of Nigeria have been investigated in this study.

Table 4:
Comparison between the mean ESAK (mGy) obtained in this work with other studies

Health Centers/Organizations	Abdomen (AP) ESAK(mGy)
TTS	2.00
OAUTHC	2.59
SDAH	2.78
UTH	1.25
FMC	1.33
CH	17.21
LTH	1.00
OAMH	4.97
ADC	4.04
UBTH	1.88
[a]UK (NRPB HPA 2012)[18]	4.42
[b]USA(NDRLs)[19]	4.50
[c]NIGERIA (2016)[4]	5.67
[d]CANADA (2012)[20]	1.82
THAILAND (2018) (MALE)[21]	1.06
(FEMALE)	0.98

Key: a. Hart *et al*., 2012 b. Crawley & Rogers 2000
c. Jibiri & Olowookere 2016 d. Osei & Johnson 2012, d. Atchara *et al*., 2018

The results obtained from the study show that the mean mAs used in the health centres are comparable with those used in the 2010 UK review except for one of the centres, where the mAs employed are higher. Also, there are intra-radiological unit patient dose variations, as revealed by the range factor. This shows that the operation technique employed was not fully optimized and that dose reduction is possible without degrading image quality. Therefore, there is a need for regular monitoring of radiographic equipment and periodic surveys of the patient dose. Also, there is a need to institute programs, conferences and workshops aimed at reducing patient dose in Nigeria.

Acknowledgement: The authors would like to express their gratitude to the radiology department staff for their cooperation.

Conflict of interest statement: No conflict of interest.

Source of funding: No external funding

References

1. **Asadinezhad, M., Toosi, M.T.B**. Doses to patients in some routine diagnostic x-ray examinations in Iran: the first Iranian diagnostic reference levels. *Radiation Protection Dosimetry* 2008: dio:10. 1093/rpd/ncn308
2. **Mohamed Anwar. K.** Abdelhalm. Patient dose levels for seven different radiographic examination types. *Saudi Journal of Biological Science*. 2010:17(2):115 – 118
3. **Edmond K. D.** Diagnostic reference levels as quality assurance tool. *The Radiography*, 2009:56(3):32 37.
4. **Jibiri N. N., Olowookere C. J.** Patient Dose Audit of the Most Frequent Radiographic Examinations and the Proposed Local Diagnostic Reference Levels in South-Western Nigeria: Imperative for Dose Optimization. *Journal of Radiation Research and Applied Sciences*. 2016: 9: 274 – 28
5. **Fung Karl. K.** L Investigation of domestric characteristics of the high sensitivity LIF; Mg, CU, P thermoluminescent dosimeter and its applications in diagnostic radioklogy – a review. *Radiology* 2004; 10(2): 145 – 150.
6. **Ajayi I.R.; Akinwumiju A** (2000) Measurement of entrance skin dose to patients in four common diagnostic examinations by thermoluminescence dosimetry in Nigeria. *Radiat. Prot. Dosim*. 87: 217-220.
7. **Ogunseyinde A.O., Adeniran, S.A.M., Obed. R.I., Akinlade, B.I., & Ogundare V.I.** Comparison of entrance surface doses of some x-ray examinations with CECreference doses. *Radiation Protection Dosimetry* 2002: 98: 231 – 234.
8. **Ogundare F.O.; Uche C.Z.; Balogun F.A.** Radiological Parameters a Radiation Doses of Patients undergoing Abdomen, Pelvis and Lumber Spine Examinations in three Nigerian hospitals. *Br. J. Radiol,* 2004:77, 934-940.
9. **Olowookere, C, J, Babalola, N.N; Jibiri N. N., Obed R.I., Bamidele L., Ajeetumobi E.O.** A Preliminary Radiation Dose Audit in some Nigerian Hospitals: Need for Determination of National Diagnostic Reference Levels (NDRLs). *The Pacific Journal of Science and Technology*. 2012: 13(1): 487 – 495.
10. **Olarinoye I.O, Sharifat,I.** A Protocol for Setting Dose Reference Level for Medical Radiography in Nigeria. *Bayero Journal of Pure and Applied Sciences*, 2010:3(1): 138 – 141
11. **Oyeleke O.I.** Entrance Skin dose (ESD) Evaluation for pediatric chest examinations in Minna and Ibadan. *Journal of Science, Education and Technology*, 2009: 2(1): 146 – 150.
12. **American College of Radiology, (ACR)**. Practice parameters for the performance of Abdominal radiography. Available at http/www.arc.org/-/media. 2014.
13. **AAPM**. American Association of Physicists in Medicine: Quality Control in Diagnostic Radiology. AAPM Report No. 74. *Madison*: Medical Physics Publishing. 2002.

14. **International Atomic Energy Agency (IAEA).** Technical Report Series Number 457: An international code of practice. 2007, Vienna.
15. **ICRP**. Radiological protection in medicine. International Commission for Radiological Protection publication 105. *Ann ICRP*.2007: 37(6).
16. **ICRU**. Patient Dosimetry for X-rays used in Medical Imaging. *International Commission on Radiation Units and Measurements publications.*2005.
17. European Commission (1990): Quality criteria for diagnostic radiographic images. working document cec xii/173/90.2nd edition. *Commission of European Communities*.Bruxelles.1990.
18. **Hart D, Hillier M, Shrimpton P** (2012): Doses to patients from radiographic and fluoroscopic X-ray imaging procedures in the UK-2010 review. *HPA CRCE*-034.
19. **Crawley, M.T & Rogers, A. T**. Dose area product measurements in a range of common orthopaedic procedures and their possible use in establishing local diagnostic reference levels. *British Journal of Radiology*, 2000:70: 740 – 744.
20. **Osei E. K & Darko J. A.** Survey of organ equivalent and effective doses from diagnostic radiology procedures. *ISRN Radiol*. 2013:204346. http://dx.doi.org/10.5402/2013/204346. [PMC free article] [PubMed]
21. **Atchara Promduang., Napapong Pongnapang., Napat Ritlumlert., Sutthirak Tangruangkiat., Monchai Phonlakrai**. A study of entrance surface air kerma for patients undergoing chest and abdomen from digital radiography at Chulabhorn Hospital. *J. Health Sci Med Res* 2019: 37(1):51 – 60.