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Assessment of Dose – Area Product of Common Radiographic Examinations in Selected Southern Nigerian Hospitals

Bamidele. L[1], Osahon O.D[2]
[1]*Department of Science Laboratory Technology, Osun State College of Technology, Esa – Oke, Nigeria.*
[2]*Department of Physics, University of Benin, Benin – City. Nigeria..*

Abstract
Background: *Over the years, radiographic examinations is the most used diagnostic tools in Nigerian health care system but most diagnostic examinations carried out do not have records of patient doses. Lack of adequate information on patient doses has been a major hindrance in quantifying the radiological risk associated with radiographic examinations. This study aimed at estimating dose – area product (DAP) of patient examined in X – ray units in selected hospitals in Southern Nigeria.*
Materials and Methods: *The standard projections selected are Chest Posterior-Anterior (PA), Abdomen Anterior-Posterior (AP), Pelvis AP, Pelvis Lateral (LAT), Skull AP/PA, Skull LAT, Lumbar Spine AP, Lumbar Spine, LAT. Measurement of entrance surface dose (ESD) was carried out using thermo luminescent dosimeter (TLD). Measured ESDs were converted into DAP using the beam area of patients.*
Results: *The results show that the DAP ranged from 48 to 4804 mGycm^2 with mean value of 937 mGycm^2 for chest PA, 1470 to 1760 with mean value of 1649 mGycm^2 for abdomen AP, 1482 to1680 with mean value of 1614 mGycm^2 for pelvis AP, 1482 to1680 with mean value of 1609 mGycm^2 for pelvis LAT, 720 to780 with mean value of 757 mGycm^2 for skull AP/AP. 720 to 900 with mean value of 778 mGycm^2 for skull LAT, 1170 to 1320 with mean value of 1211 mGycm^2 for lumbar spine AP, 900 to1300 with mean value of 1160 mGycm^2 for lumbar spine LAT..*
Conclusion: *The results obtained in this study when compared with those of NRPB-HPE were found to be higher. These are an indication of non optimization of operational conditions.*
Keywords: *dose – area product, optimization, patient doses, radiographic examinations.*

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I. Introduction

X – ray diagnostic examination remains the most used diagnostic tools despite the recent development in the medical imaging techniques especially in developing countries like Nigeria. It has been observed from various reports that medical diagnostic procedures contribute the larger percentage of the collective dose to the population from all man – made artificial sources of ionizing radiation [1–3.] For instance in Norway it contributed 1.1 mSv per inhabitant in 2002 [4] and diagnostic X – ray provided 90% of the total collective dose to the population of UK [5, 6]

Patients undergoing either X – ray diagnostic or interventional radiography are subjected to various level of exposure. The deleterious health effect of ionizing radiation on patients is of major concern. European Union recommends patient dose measurements and the establishment of appropriate Diagnostic Reference Levels (DRLs) in the 1997 EC Directive 97/43 EURATOM Article 4 dealing with optimization,[7]. Patient dose measurement is very important in providing information on the degree of radiation exposure on patient during examination and minimizing the risk of stochastic effects such as cancer induction or hereditary effects. Optimization principle requires that the amount of radiation doses to patient should be as low as reasonably achievable. These involve regular monitoring of equipment performance and technique employed in performance of X – ray procedures.

In Nigeria, it has been reported that there are over 4000 X – ray machines in thirty – six states, with less than 5% under any regulatory control and that over 2.5 million medical examinations involving conventional radiography and computed tomography (CT) examinations are performed annually [8,9] . Due to the lack of efficient and dynamic regulatory control in Nigeria, there is need for regular monitoring of X- ray facilities to assess radiation risk to an average patient undergoing X – ray examinations.

In this study, the level of exposure to patients in routine X – ray examinations in eight X – ray units in selected hospitals in Southern part of Nigeria are to be evaluated.

II. Materials and Methods

Eight (8) hospitals in three (3) states in Southern part of Nigeria were included in this study and data were collected for five hundred and eighteen (518) patients from November 2015 to May 2018. The hospitals included in the study are: Private Hospitals, State Hospitals and University Teaching Hospitals. The standard projections selected during the examinations are: Chest Posterior-Anterior (PA), Abdomen Anterior-Posterior (AP), Pelvis AP, Pelvis Lateral (LAT), Skull AP/PA, Skull LAT, Lumbar Spine AP, Lumbar Spine, LAT. For each patient undergoing X – ray examinations in the study the following information were obtained: Age, Weight, sex, thickness of irradiated area, exposure parameters (kVp, mAs) and focus to film distance (FFD).

Quality control (QC) tests

The following QC tests were carried out in the study the kVp parameters (accuracy, reproducibility and accuracy) the exposure time (accuracy and reproducibility) and the machine output (linearity coefficient and reproducibility) and the results were compared with tolerance limit recommended by international organizations [10,11].

Entrance surface dose (ESD) measurements

Measurement of entrance surface dose (ESD) was carried out using Lithium Flouride thermoluminescent dosimeter (TLD). The LiF TLD – 100 chips were attached to the body of patients at the center of x-ray beam. The TLD chips used in the investigation were calibrated at the Secondary Standard Dosimetry Laboratory facilities of National Institute for Radiation Protection and Research (NIRPR), University of Ibadan. The calibrated chips were annealed in an oven under the temperature of 400^0c in 1 hour and allowed to cool down for 18 hours. The annealed chips were further kept for 24 hours before use.

Dose – Area Product Assessment

The dose – area products (DAPs) were estimated for each examinations from the measured ESD (to air without backscatter). The relationship between DAP and ESD is given by the following equation [12]:

$DAP = D_{FCD}(air) \times A_{FCD} = D_{FSD}(air) \times A_{FSD} = (ESD/BSF) \times A_{FSD} = (ESD/BSF) \times A_{FFD} \times (FSD/FFD)^2$.

Where D_{FCD} (air) is the absorbed dose to air at the Dap – meter position (collimator) and is the irradiated area at the DAP position. The FSD is Focus – to – skin distance and FFD is the Focus – to – film distance. BSF is the backscatter factor, which is 1.35 for adult [13].

Output Measurements

The X – ray tube output in mGy/mAs at a distance of 100 cm were measured for each unit using calibrated QC kit (NERO™ 6000M, manufactured by Victoreen, INC, Cleveland, Ohio, USA). The output were measured at 80 kV tube potential and tube load of 10 mAs, since anode current and potential across the X – ray tube is known to be highly stable at this value.

III. Results

A total of five hundred and eighteen patients undergoing conventional radiography in seven routine examinations were investigated in this study. The specifications of X – ray machines considered in the study were shown in Table 1

Table1: Specific features of X - ray units in the investigated centre

Hospitals	Model/ Type	Manufacturer	Year of Installation	Filtration (mmAl)	Output (mGy/mAs)
Q1	Silhouette V.R	G.E Haulum Medical System	2010	2.7	0.061
Q2	LEXRAY 500	R. Liecati A. G R. Liecati A. E	2013	3.0	0.065
Q3	Allengers	N A	2012	2.5	0.035
Q4	Giladonia Ri05	Ralco	2013	2.0	0.0347
Q5	Ketron 300	Kehrli Rontgen Inc.	2013	2.5	0.048
Q6	Siemens Healthineers	Siemens USA	2008	3.0	0.034
Q7	Toshiba Rotande	Toshiba medical system	2014	2.5	0.032
Q8	RAD-12 G.E	General Electric Company	2010	1.6	0.068

NA - Not available

Patient information and exposure parameters are presented in Table 2, the age of the patients ranged between 19 and 90 years and the patient weight was within 70 ± 3kg and Table 3 shows the mean and the range of ESD (mGy) for each projection in all X-ray units in the study.

Table 2: Patients' information exposure parameters for eight routine examinations mean values and range in all X – ray units in this study

Examinations	Projection	No. of Patients	Patient Age mean (range) (years)	Patient weight mean (range) kg	FFD mean (range) (cm)	kVp mean (range)	mAs mean (range)	KVp UK Hart et al (2012)
Chest	PA	251	42 (20-80)	67 (67-72)	149 (90-182)	69 (57-80)	25 (10-40)	88(65-125)
Abdomen	AP	50	63 (49-79)	70 (68-72)	124 (70-131)	81 (80-81)	49 (40-64)	76(60-94)
Pelvis	AP	56	42 (19-70)	69 (68-84)	118 (80-124)	75 (55-81)	40 (25-63)	75(62-92)
Pelvis	LAT	50	40 (19-70)	68 (69-72)	115 (80-125)	73 (60-81)	36 (10-50)	NA
Skull	AP/PA	25	38 (30-45)	71 (70-74)	112 (70-153)	74 (70-80)	38 (32-40)	72(69-83)
Skull	LAT	25	39 (30-46)	70 (61-74)	110 (70-150)	72 (63-85)	28 (25-32)	NA
Lumbar Spine	AP	31	75 (38-90)	67 (60-75)	117 (90-160)	78 (73-96)	91 (40-125)	78(65-109)
Lumbar Spine	LAT	30	75 (38-90)	67 (60-75)	114 (90-130)	90 (81-96)	110 (64-125)	NA

Table 3: Mean and Range (in brackets) of ESD (mGy) for each X – ray units in the study

EXAM	HOSPITAL							
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Chest PA	0.67	0.47	0.71	0.37	0.17	1.97	0.82	0.56
	(0.03-1.19)	(0.21-1.97)	(0.03-2.12)	(0.08-0.56)	(0.08-1.97)	(0.46-3.43)	(0.18-1.79)	(0.35-0.84)
Abdomen PA	2.59	1.24	17.20	1.32	1.01	4.97	4.04	1.88
	(1.77-4.74)	(0.68-1.81)	(2.74-21.68)	(0.72-2.44)	(0.94-1.22)	(3.07-7.51)	(1.74-7.17)	(1.49-2.18)
Pelvis AP	2.25	1.08	16.16	1.52	1.33	3.28	1.97	1.92
	(0.18-4.74)	(0.90-1.42)	(6.80-22.45)	(0.99-2.49)	(061-1.66)	(2.77-5.15)	(2.77-5.15)	(1.13-3.18)
Pelvis LAT	2.24	1.15	10.06	1.87	1.25	3.39	1.78	2.21
	(0.70-3.43)	(0.71-1.56)	(5.56-22.44)	(0.62-2.49)	(0.61-1.48)	(2.22-4.24)	(1.41-2.45)	(1.21-2.90)
Skull AP	2.36	1.14	6.42	0.88	1.19	3.65	2.13	1.89
	(1.92-2.92)	(0.69-1.37)	(4.45-8.98)	(0.57-1.38)	(0.16-1.48)	(2.77-6.23)	(1.50-2.73)	(1.08-2.62)
Skull LAT	1.67	1.52	4.71	1.11	1.07	3.24	2.26	1.42
	(1.26-1.99)	(0.87-2.35)	(3.42-6.43)	(0.57-1.38)	(0.90-1.25)	(2.75-4.03)	(1.22-3.45)	(0.64-2.62)
Lumber-	5.02	2.71	12.65	5.73	1.67	4.03	4.39	2.31
Spine AP	(2.49-5.45)	(0.65-4.20)	(5.56-22.45)	(2.45-9.37)	(0.46-2.44)	(2.65-5.57)	(3.42-5.33)	(0.73-3.96)
Lumber-	6.89	3.33	14.26	3.02	1.91	2.34	4.86	4.04
Spine LAT	(4.55-7.30)	(2.56-4.47)	(5.45-30.57)	(2.44-4.16)	(0.72-3.25)	(3.79-5.46)	(3.45-5.74)	(2.43-5.99

The distribution of mean, median, inter -quartile range and maximum/minimum ratio (range factor) of DAP for the various examinations under investigation is given in Table 4.

Table 4: Statistical distribution of DAP among the X-ray centers in mGycm^{-2}

Projection	Number	Min	1st quartile	Median	Mean	2nd quartile	Max	Max/Min
Chest PA	257	48	268	716	937	1174	4804	98
Abdomen AP	50	1470	1638	1672	1649	1716	1760	1.2
Pelvis AP	56	1482	1520	1672	1614	1680	1680	1.1
Pelvis LAT	50	1482	1520	1672	1609	1680	1680	1.1
Skull AP/PA	25	720	720	768	757	780	780	1.0
Skull LAT	25	720	725	725	778	900	900	1.3
Lumb Sp AP	31	1170	1196	1215	1211	1222	1320	1.1
Lumb Sp LAT	30	900	1080	1200	1160	1250	1300	1.4

Table 5 shows the comparison of DAP of different radiographic procedures with NRPB –HPE, NDRLs from Finland, data from USA and earlier study from Nigeria[5], [19, 20, 21].

Table 5: Comparison of DAP (Gy cm^2) estimated in this study with other studies DAP (Gy cm^2)

Examination Type	DAP (Gy cm^2)					
	This Study (mean)	This Study (upper quartiles)	UK (NRPB-HPE 2012) NRDLs	DAP from Finland 2017[a]	DAP from USA 2014[b]	DAP from Nigeria 2016[c]
Chest PA	0.94	1.17	0.1	0.1	0.1	3.14
Abdomen AP	1.65	1.71	2.9	1.6	2.5	28.59
Pelvis AP	1.61	1.68	2.2	-	2.5	4.77
Pelvis LAT	1.61	1.68	-	-	-	-
Skull AP	0.76	0.78	1.5	-	1.5	5.06
Skull LAT	0.78	0.90	-	-	0.5	-
Lumb. sp AP	1.21	1.22	-	1.0	-	3.20
Lumb. Sp LAT	1.16	1.25	-	2.1	-	-

[a] STUK, (2017); [b] Walter Huda, (2014); [c]Jibiri and olowookere, (2016)

IV. Discussion

The X -ray machines in this study were installed between the year 2008 and 2014, though the year of manufacturing was not available. The X – ray tube output of the machines across the hospitals measured at 80 kVp, ranges between 0.032 and 0.068 mGy/mAs. The X- ray tube output was measured at a distance of 100 cm from the X- ray source. The filtration of two X – ray machines were below recommended value of 2.5 mmAl required for machine operating above 75 kVp [14,] which may be one of the reasons for higher doses recorded in the study.

The focus – to – film distance (FFD) employed during the examinations in some cases were outside recommended criteria by Committee of the European Communities (CEC) for good practice [14.] Comparison of mean kVp values in this study with UK data shows that the mean values are comparable in pelvis AP and lumbar spine AP. Table 3 shows the mean and range of entrance surface doses (ESDs) for each X – ray center under the survey. It can be seen that the ESD varied widely for the same type of examinations within the same X –ray unit and in different centers. Wide variations have been reported from various surveys from different countries [15 -18] and these have been attributed to the following reasons: radiographic technique, patient size, radiographic equipment, filtration of the X-ray machine, screen – film speed, etc. These variations indicated that operational techniques were not fully optimized and that significant reductions in patient dose are possible without affecting image quality

From Table 4, Large variations were observed for the same procedure among the centers from maximum/minimum ratio calculations of DAP. The maximum/minimum ratio ranged from 1.0 for skull AP/PA to 98 for chest PA. The large variations recorded in chest PA may be due to the large number of chest examinations considered in the study.

Table 5 shows the comparison of DAP of different radiographic procedures with NRPB –HPE, NDRLs from Finland, data from USA and earlier study from Nigeria[5], [19, 20, 21, 22]. It can be seen from the table that the dose obtained in chest PA examination was higher than the values obtained in NRPB – HPE, Finland and USA but lower than the value obtained earlier in Nigeria. Also the dose value recorded in Abdomen AP is lower than that of NRPB – HPE, USA and the value earlier obtained in Nigeria but higher than that of Finland. Other data recorded are in general within the range of other reported data from other countries but lower than the values reported earlier in Nigeria. This study discovered that the techniques employed were not fully optimized to allow patient dose to be as low as reasonably achievable and that substantial dose reduction is possible without loss of image quality.

In Nigeria; although there is an agency saddled with the responsibility of monitoring the use of ionizing radiation but presently there is no legal frame-work or guidance on appropriate levels of patient exposure. Therefore, there is need for consistent and regular monitoring of radiographic equipment and technique being adopted by the radiographer in all x-ray centers.

The establishment of legal framework on dose optimization and National Dose Reference Level (NDRLs) to provide an evaluation of the performance of medical examination in order to reduce the radiation dose and improve image quality is necessary.

V. Conclusion

In this study, the patient dose levels have been analyzed in terms of entrance surface dose and area – dose product of 518 patients in eight X-ray units in southern part of Nigeria. A wide variations have been observed for the same type of projections. This observed variations of patient doses show that the radiographic techniques were not fully optimized and that could also mean unjustified risk to the patients undergoing the same types of examinations. It also shows the possibility of dose reduction without influencing the quality radiographic images.

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