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Estimation of Patient Doses for Common Diagnostic X-ray Examination in Some Selected Hospitals in Makurdi, North Central, Nigeria: Analysis of Radiographic Techniques

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ABSTRACT

Entrance skin dose (ESD) to adult and pediatric undergoing chest (PA), pelvis (AP), lumber spine (AP) and lumber spin (LAT) radiography were estimated in two selected hospitals in Makurdi, North Central, Nigeria. A total of 223 patients were examined. The standard measurement of ESDs was based on Faulkner formular and by using NERO^{TM} detector and standard factors. For all examinations, the values of the mean ESDs obtained ranged from 0.08 mGy/mAs to 10.15 mGy/mAs for examinations of chest PA-pediatrics and Adult lumber spin LAT respectively. All the results were discussed using patients' data, machine-specific data and the technical parameters used for the examinations. Comparison with published values showed that the doses reported in this work were generally lower than the International Atomic Energy Agency (IAEA) dose reference levels due to the regulatory activities in these centres, thereby making their examination better optimized. Doses delivered to patients were as low as reasonably achievable and hence the development of both stochastic and non-stochastic effects of radiation to patients in these two X-ray centres will be minimal. The results presented in this study may be used for the formulation of Local Diagnostic Reference Level (LDRLs).

Keywords: Benue, Entrance Surface Dose, Estimation, Radiographs, X-ray

INTRODUCTION

The need for radiation dose assessment of patients during diagnostic X-ray examinations has become imperative by the increasing knowledge of the hazards associated with ionizing radiation [1]. Patients undergoing diagnostic imaging involving ionizing radiation are subject to a wide range of exposure levels. The principal concern in radiological protection is the reduction of unnecessary exposures by requiring adequate clinical justification and optimization of patient

protection as recommended by the International Committee for radiological protection [2]. During a radiological examination, the irradiation of the patient should be minimized by using the best available techniques. Measures should be taken to reduce as far as possible dose to other parts of the body [3].

International Atomic Energy Agency, recommended entrance skin dose as a dose descriptor for guidance levels in diagnostic radiography because it provides an indication for maximum skin dose and is useful for periodic checking of patient dose [4]. Patient dose measurement is an integral part of this optimization procedure. Such measurements will reveal X-ray facilities with high doses after possible dose reduction measures may be specified.

Various dosimetry quantities have been suggested for the assessment of patient dose. These quantities include entrance surface dose, organ dose and effective dose. Most of the patients' dose assessments reported in radiography have been used on entrance surface dose measurements [5-8]. However, entrance surface dose cannot be directly used to assess the risk associated with diagnostic examinations. To assess stochastic risk, the International Commission on radiological protection in 1977 (ICRP publication 23) has recommended the determination of effective doses [9]. In 1999, ICRP further recommended that patient exposures in diagnostic radiology be denoted by organ dose and effective dose. The effective dose is given as a weighted average of the organ doses [10]. The preferred and most complete approach for risk estimation is accurate knowledge of all patient organ doses.

However, measurements or calibrations of organ doses are complex and it is often regarded as a troublesome job in diagnostic centers [11]. This may explain why there is scanty information about organs doses of patients in diagnostic radiology. As with individual exposures, organ doses or a set of organ doses gives the most comprehensive description of patient exposure. It reveals the actual dose received by each of the organs of the patient. In routine radiological examinations, it is not practical to conduct in vivo measurements of organ doses.

In Nigeria, X-ray diagnostic examination (conventional or computed tomography) is one of the integral parts of both local and national health care [1]. The number of X-ray facilities and examinations are on the increase. It is expected that individuals and population doses would also increase. Radiation doses are to be kept as low as reasonably achievable to avoid stochastic and deterministic effects on patients undergoing radiographic examinations.

Several dose measurements have been carried out in Western Nigeria but only a few have been carried out in North Central Nigeria [1, 5, 6 & 12]. Diagnostic medical X-rays constitute the largest man-made source of ionizing radiation exposure to the population. The importance of such surveys enables the establishment of diagnostic reference levels which aid in minimizing radiation dose to the patients and the general population in line with a justification of practices and optimization of protection such that radiation doses are kept as low as reasonably achievable taking economic and social factors into account.

Some countries in Europe have established national diagnostic reference levels (NDRLs) for common X-ray procedures as an efficient standard for optimizing the radiation protection of patients. Such reference dose levels have not been established in Nigeria.

This work is aimed at estimating the doses received by patients undergoing radiological examinations of chest PA, Cervical AP, Extremities, Lumber spine AP, Lumber spine LAT and pelvis AP at Federal Medical Centre (FMC), Makurdi, and Bishop Murray Medical Centre (BMMC), Makurdi, and comparing the results with the established international reference doses. The results may be useful to national and professional organizations and can be used as a baseline upon which future dose measurements may be compared.

MATERIALS AND METHODS

Research procedures

The radiation doses to patients undergoing radiological examinations in Makurdi, Benue State Nigeria, were monitored in two centers. The survey was carried out at the Federal Medical Centre and Bishop Murray Medical Centre, Makurdi

The Federal Medical Centre, Makurdi was used because of its strategic location and the fact that most people in Makurdi-the state capital, prefer to make use of government health care facilities. Bishop Murray Medical Center was used in order not to have only one source for data collection and also to be able to compare the results of a government-owned center with a privately owned center. The implication of this is that dose values obtained from this study for Makurdi to a large extent represent a good estimate of population dose of the patient in Makurdi. In both places, the two X-ray machines used were analogue and without grids.

A total of 223 patients (211 adult patients and 12 pediatric patients) were examined at the Federal Medical Center and Bishop Murray Medical Center. Patients monitored were those referred on various medical grounds after clinical examinations.

The following six routine types of X-ray examinations were studied; Chest (PA), Pelvis (PA), Cervical (PA), Extremities, Lumber Spine (PA) and Lumber Spine (LAT). Critically ill patients were excluded from this study because they could not be taken for x-ray examination.

The focus to film distance (FFD), the focus to skin distance (FSD), the tube voltage in (kV) and the product of current and time (mAs) during each measurement were recorded.
The kVp and mAs values for each examination were read directly from the control panel of the X-ray machine.

Method of analysis

The X-ray tube parameters (kVp, mAs, FSD) and the output measurement from the NERO^{TM} KV meter were used for the analysis and estimation of patients' doses during radiological examinations. Table (i) shows the parameters of the X-rays machines used.

Table (i): Personnel and specific data of X-ray machines used in the centers in Makurdi

	Federal Medical Center	Bishop Murray Medical Centre
Model/type	HF120/60/PPWV power plus^{TM}/MXRSLW	HXT51-2040Nx/TR300A
Serial number	34514	061005
Manufacturer	Min Xray Inc	Triup Inc
Year of installation	October, 2009	September, 2006
Total filtration	2.0mm Al > 2.7mmAl	≥ 2.5 mmAl
Phase Type	Single	Single
Film type	Agfa	Agfa
Processor	Manual	Manual
Number of radiographers	2	2
Use of Grid	No	No

Calculation of dose

Entrance surface dose was calculated from machine output parameters.

The parameters are:

Focus to skin distance "FSD" in cm

The tube potential (in kV)

The product of current and time (mAs)

Backscatter factor (BSF)

According to Faulkner *et al* [15], the formula for calculating ESD is given by equation 1

$$ESD = Output\ x \left(\frac{kV}{80}\right)^2 xBSFx \left(\frac{100}{FSD}\right)^2 x\ mAs \qquad Equation\ (1)$$

The output is the output of the X-ray tube at 80 kVP at a distance of 100 cm normalized by mAs. The value of the backscatter factor used for adult patients is 1.35 while that for pediatric patients is 1.30 obtained by Yakomakis *et al* [16] using a Monte Carlos simulation for different tube voltages.

Output measurement

The outputs of the machines in mGy/mAs at a distance of 100 cm were obtained using calibrated KV meter (NERO^{TM} 6000M, manufactured by Victoreen INC, Cleverland, Ohio, USA). This was used to test linearity and reproducibility of kV and mAs. The outputs of the machines were measured at a voltage of 80 kV and 10 mAs as the potential across the X-ray tube and the anode current are highly stabilized at this voltage [3]. The KV meter was cross calibrated with the facilities of Secondary Standard Dosimetry Laboratory (SSDL) of the National Institute of Radiation Protection and Research (NNRA), Ibadan.

The NERO KV meter measured the outputs of the machines in mR (millirontgen) and the dose rate in R/s (rontgen per second). Plates 1 and 2 show the NERO detector and the NERO Microprocessor and Display unit respectively.

Plate 1: The NERO detector

Plate 2: The NERO Microprocessor and Display unit

RESULTS AND DISCUSSION

The data and corresponding ESDs calculated for the projections of the selected X-ray examinations at both centers are presented in Tables 3- 6. The quality control tests carried out in the two hospitals (the Federal Medical Center and Bishop Murray Medical center) are presented in Tables 1 and 2 respectively. The range and mean values of the ESDs for individual adult patient exposures calculated for both centers (the Federal Medical Center and Bishop Murray Medical Center) using excel are presented in Tables 3 and 4 respectively. Also, the exposure parameters which include the tube voltage, range, mAs range and ESD range for Federal Medical Center and Bishop Murray Medical Center are presented in Tables 3 and 4 respectively.

At Federal Medical Center, the entrance dose per examination was found to be in the range from 0.005 – 0.47, 0.01 – 0.19, 0.006 – 0.37, 0.005 – 0.007, 0.012 – 5.77 and 0.12 – 0.84 for chest PA-adult, chest PA-pediatrics, extremities-adult, extremities-pediatrics, pelvis PA and cervical PA respectively.

At Bishop Murray Medical Center, the entrance dose per examination was found to be in the range from 0.11 – 0.58, 2.09 – 4.41, 0.75 – 7.08 and 3.15 – 21.06 for chest PA, pelvis PA, Lumber spine AP and Lumber spine LAT respectively.

Table 1: Quality control test at the Federal Medical Center, Makurdi

Set kV	mAs	Mean kV eff	mean kV Avg.	Mean kV Max.	Output mGy/mAs
80	10	76.78	77.1	78.28	0.0152075
70	10	67.6	67.82	69.44	0.013618968
60	10	57.9	58.2	59.08	0.011020658
50	10	47.44	47.76	48.46	0.008059106

The output of the machine was calculated at 10 mAs and FSD 100 cm: conversion factor from mR to mGy/mAs is 0.00869.

Table 2: Quality control test at Bishop Murray Medical Center, Makurdi

Set kV	mAs	Mean kV eff	mean kV Avg.	Mean kV Max.	Output mGy/mAs
80	20	95.6	95.26	99.76	0.0074629
70	20	69.58	68.42	73.44	0.00609256
60	20	71.34	69.9	76.92	0.00222289
50	20	53.42	53.02	54.72	0.001132307

The output of the machine was calculated at 20 mAs and FSD 100 cm: conversion factor from mR to mGy/mAs is 0.00869.

Table 3: Exposure parameters in Federal Medical Center, Makurdi

Radiographs	Projections	Tube potential voltage	mAs range	FSD (cm)
Chest	PA	50 – 80	10 – 18	75 – 139
Pelvis	AP	58 – 120	4 – 60	33 – 88
Cervical	PA	70 – 80	18 – 25	71 – 137
Extremities	PA/AP	50 – 80	5 – 12	71 – 120

Table 4: Exposure parameters in Bishop Murray Medical Center, Makurdi

Radiographs	**Projections**	**Tube potential voltage**	**mAs range**	**FSD (cm)**
Chest	PA	65 – 75	25 – 30	66 – 136
Pelvis	AP	75 – 90	120 -190	59 – 78
Lumber Spine	AP	75 – 90	120 – 200	56 – 124
Lumber Spine	LAT	80 – 90	180 – 240	36 – 82

Table 5: Distribution of individual dose in Federal Medical Center, Makurdi

Type of examination	**Number of patients**	**Range of ESDs (mGy/mAs)**	**Mean ± STD (mGy/mAs)**
Chest PA-Adult	57	0.05 – 0.47	0.19 ± 0.12
Pediatrics	8	0.01 – 0.19	0.08 ± 0.07
Pelvis AP	36	0.012 – 5.77	1.77 ± 1.51
Extremities-Adult	35	0.06 – 0.37	0.12 ± 0.09
Pediatrics	4	0.005 – 0.007	0.006 ± 0.001
Cervical AP	21	0.12 – 0.8	0.38 ± 0.18

Table 6: Distribution of individual dose in Bishop Murray Medical Center

Type of examination	**Number of patients**	**Range of ESDs (mGy/mAs)**	**Mean ± STD (mGy/mAs)**
Chest PA	32	0.08 – 0.59	0.21 ± **0**.11
Pelvis PA	13	2.09 – 4.41	3.23 ±0.84
Lumber Spine AP	10	0.75 – 7.08	3.83 ±2.26
Lumber Spine LAT	7	3.15 -21.06	10.15 ±5.84

The differences in kVp, mAs and FSD set values for individual patients brought about spread in the Entrance Surface Doses received while some patients received high ESDs, some received low ESDs for the same type of examination. At the Federal Medical Center, in Fig. 3, 92.7% of the patients examined received ESDs below the IAEA reference dose of 0.4 mGy for chest PA examination. In Fig. 4, all the patients examined received doses below the IAEA and the NRPB reference levels of 10 mGy for pelvis PA examination. At Bishop Murray Medical Center, in

Fig. 5, 93.5% of the patients examined, received ESDs below the IAEA reference of 0.4 mGy for chest PA examination.

In Fig. 6, all the patients were examined with doses below the IAEA and the NRPB reference dose levels of 10 mGy for pelvis PA examination. In Fig. 7, for lumber spine AP examination, all the patients received doses below IAEA reference dose level of 10 mGy. Fig. 8, for lumber spine LAT, all the patients were examined with doses below the reference dose level of 30 mGy.

As far as the image quality is concerned, all the images of the standard patients obtained in the studied examinations fulfilled all the diagnostic requirements prescribed by the European Commission [20]. The patients' doses are similar to the results obtained elsewhere in some of the European countries. Table 7 shows the comparison of the ESDs with results from IAEA and other European Countries.

It is also observed that certain X-ray examinations like the chest PA were performed with mean ESDs higher than the recommended values, however, relatively higher ESDs may be allowed only were indicated by clinical judgment [14].

A situation where variations of factors of 20 to 40 can be observed for the same type of X-ray examination in ESDs for patients of similar size may not be justified.

Carrying X-ray examinations, using a low kV technique rather than high kV technique as recommended by the Commission of the European Communities [20], film processing conditions within centers, high mAs variations of up to ± 30% during the examination of patients of similar size and setting FSDs are the possible causes of the varying patient doses in the same type of examination.

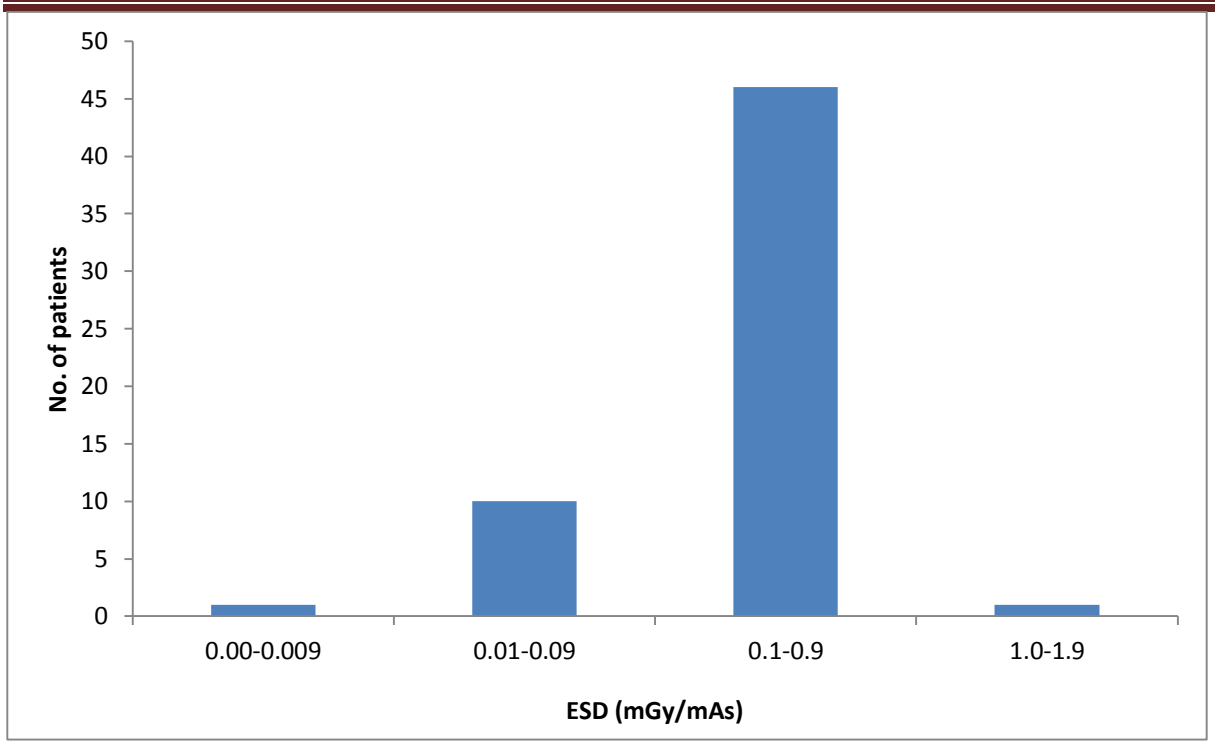

Fig. 3. Chart of the ESDs calculated for Federal Medical Center: Chest PA-Adult

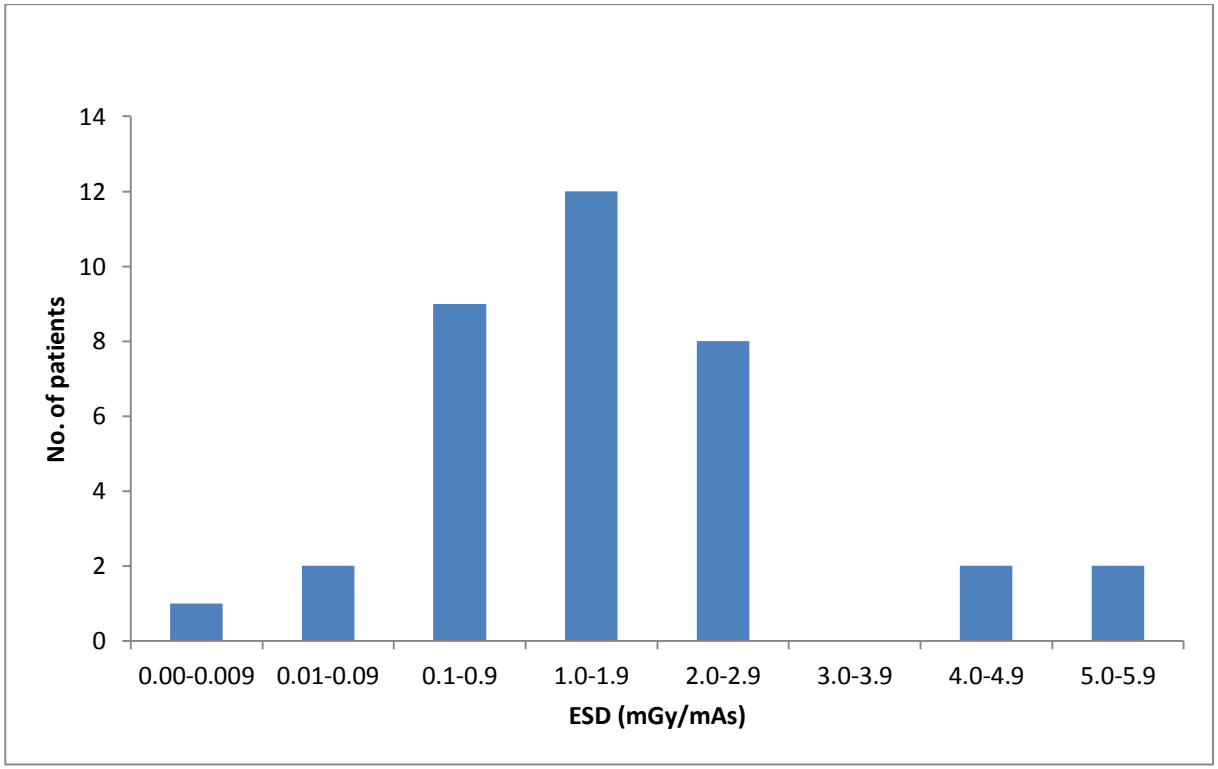

Fig. 4: Chart of the ESDs calculated for Federal Medical Center: Pelvis PA

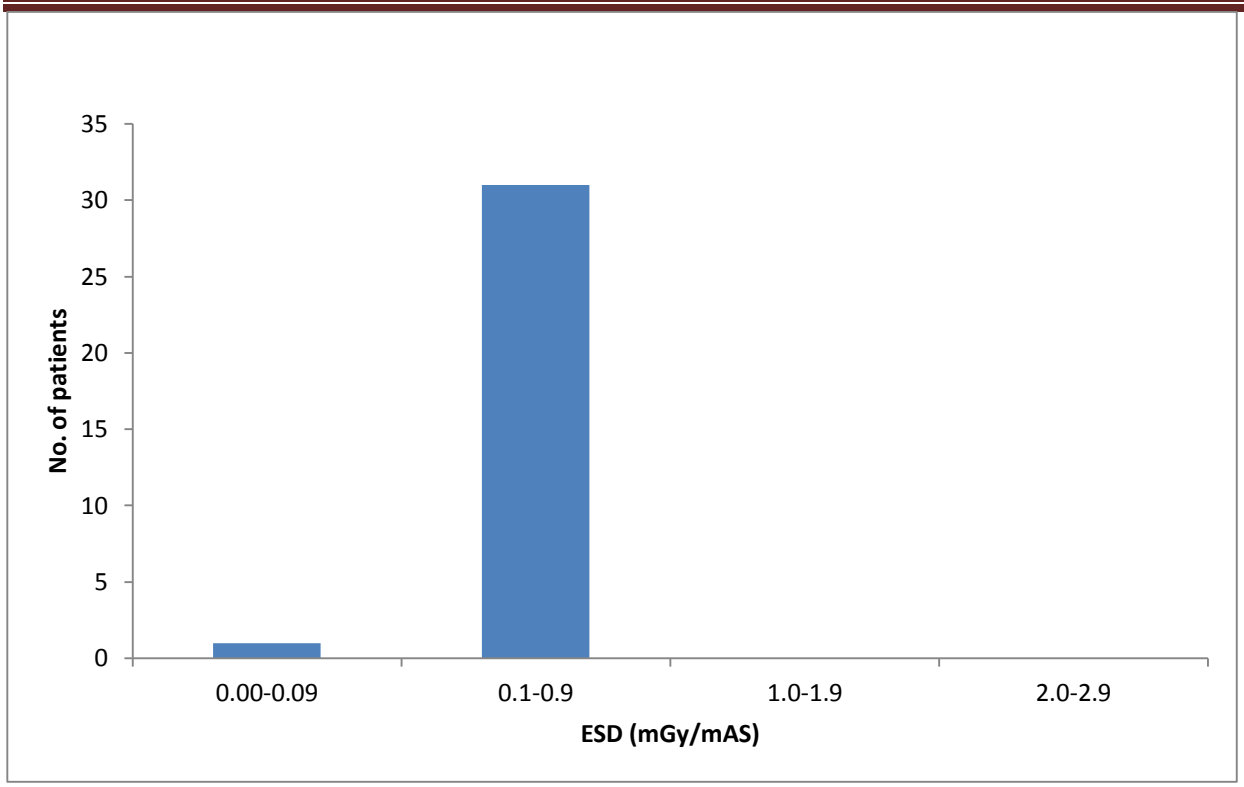

Fig. 5: Chart of the ESDs calculated for Bishop Murray Medical Center: Chest PA

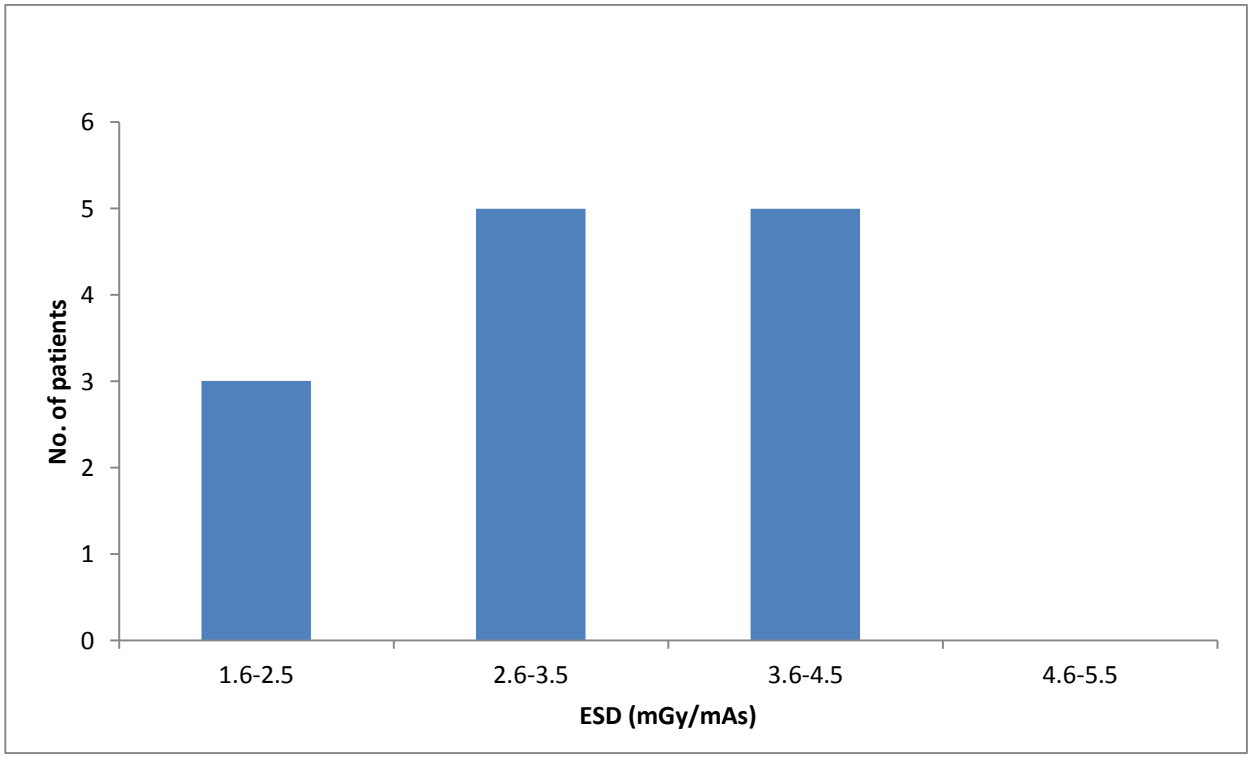

Fig. 6: Chart of the ESDs calculated for Bishop Murray Medical Center: Pelvis PA

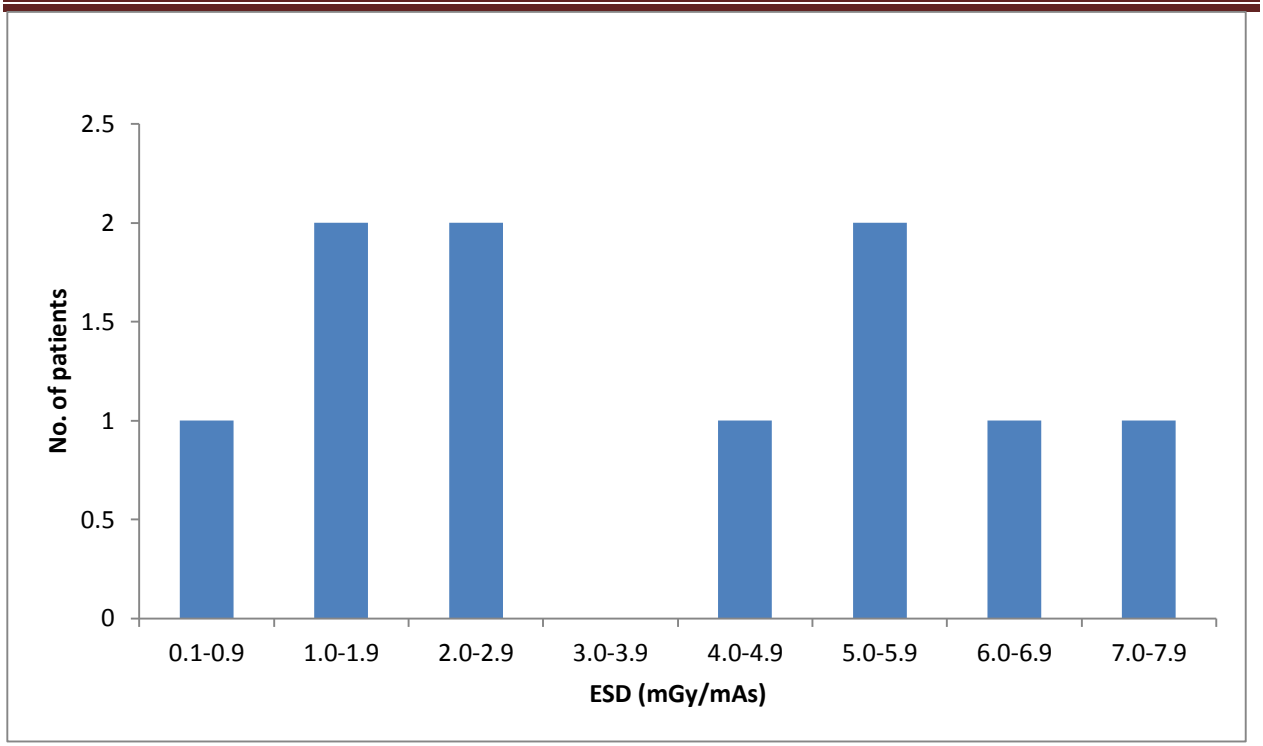

Fig. 7: Chart of the ESDs calculated for Bishop Murray Medical Center: Limber spine AP

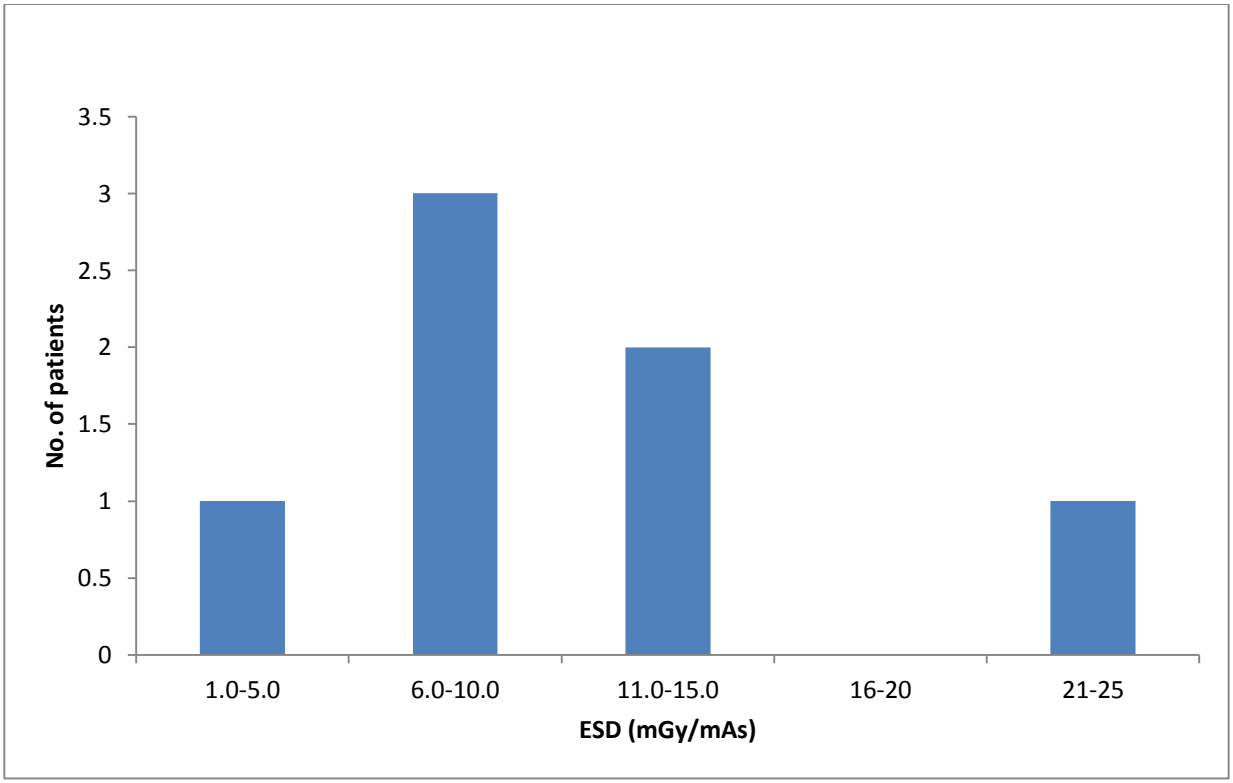

Fig. 8: Chart of the ESDs calculated for Bishop Murray Medical Center: Lumber spine LAT

Table 7: Comparison of the ESDs with results from IAEA and other European Countries

Organization/ Country	Chest PA	Pelvis PA	Cervical PA	Extremities AP/PA	Lumber Spine AP	Lumber Spine LAT	References
IAEA	0.4	10.0	-	-	10.0	30.0	[4]
U.K	0.3	4	-	-	10.0	30.0	[14]
NRPB	0.3	10.0	-	-	10.0	30.0	[17]
ITALY	0.57	10.0	-	-	8.9	30.0	[18]
LAUTECH, NIGERIA	0.39	9.31	-	0.45	10.59	20.80	[19]
FMC, Makurdi, NIGERIA	0.19	1.77	0.38	0.12	-	-	Present study
BMMC, Makurdi, NIGERIA	0.21	3.23	-	-	3.83	10.15	Present study

CONCLUSION

This work has shown a large variation in patient dose for the same type of X-ray examination carried out in the two X-ray centers: The Federal Medical Center and Bishop Murray Medical Center, Makurdi. The results are consistent with IAEA dose reference levels. The results of Federal Medical Center, Makurdi, were consistent with variation factors of only 1 to 2, while there were large variations in those obtained at Bishop Murray Medical Center. The reasons for variation of doses could be as a result of high mAs, low kVp used and focus to skin distances which depend on the skills of the radiographers concerned.

The ESDs results obtained at Federal Medical Center, Makurdi, can be taken as Local Diagnostic Reference Level (LDRL) for any X-ray examination in the Federal Medical Center, Makurdi. In as much as obtaining image quality is considered by the technicians as the most important parameter, mAs value should also be appropriately selected in order not to cause the delivery of high avoidable doses to the patients. The doses delivered to the patients should be kept as low as reasonably achievable. For all examinations considered at the Federal Medical Center, Makurdi, the mean ESD values obtained ranged from 0.19 ± 0.12, 1.77 ± 1.51, 0.12 ± 0.09 and 0.38 ± 0.18 for Adult Chest PA, Pelvis PA, Extremities and Cervical PA respectively.

It can be concluded that ESDs received by patients at the Federal Medical Center during these examinations are reasonably low and hence there is no significant health hazards associated with these exposures to patients during the X-ray examinations. At Bishop Murray Medical Center, the mean ESDs ranged from 0.21 ± 0.11, 3.23 ± 0.84, 3.83 ± 2.26 and 10.15 ± 5.84 for Adult Chest PA, Pelvis PA, Lumber Spine AP and Lumber Spine LAT respectively. These results are also reasonably low as they are not above the recommended values by IAEA. Hence, there will be no development of both stochastic and non-stochastic (deterministic) effects in patients.

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