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Radiation Doses to Patients Undergoing Some Selected X-Ray Diagnostic Procedures

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Abstract: The level of dose and its distributions in adult patients undergoing seven selected common types of x-ray examination in two public hospitals in Nigeria were investigated using exposure parameters. A total of 224 patients were included in this investigation. The ages of the patients involved were from 18 years to 75 years, while their average weights ranged from 67kg to 73kg. Mean, median, first and third quartiles, and maximum to minimum ratio of Entrance Surface Doses (ESDs) are determined. The results show that for each of the examinations, the individual ESD values were found to be comparable with those from similar studies in Ghana, Sudan and in Nigeria. When compared with established international reference doses, the mean ESDs were found to be below the reference values, except in chest AP and pelvis AP where the ESDs of 0.47mGy and 12.0mGy were recorded. The value of ESD obtained was validated by direct measurement using thermo luminescent dosimeter (TLD). The difference between the calculated and the measured radiation dose was quite small.

Keyword: Entrance Surface Dose, Exposure Parameters, X-ray Output

INTRODUCTION

Despite rapid development in medical imaging, including the advent of computed radiography and digital imaging, conventional radiography remains the most preferred radiological examination technique. X-ray examination remains the most frequently used ionizing radiation method in medicine, constituting the most significant man-made source of radiation exposure for the world population[1].

In recent years, concern has been raised over the hazards of overexposure to small doses of ionizing radiation. The probability of a fatal cancer being induced in an individual patient from a single x-ray examination, although small, is dependent on the age of the patient and the type of examination[2].

During the past two decades, several dose surveys have been performed for the study of patient radiation doses in many countries around the world[3-7]. It was discovered that there is significant variations in patient doses between different radiological departments for the same type of examination. For nominally the same types of radiograph surveyed, maximum-to-minimum ratios of Entrance Surface Dose (ESD) per film in the UK were up to 100 for individual patients and over 20 for X-ray room mean values[8]. This revealed that there was much room available for patient dose reduction.

In recent years, health physicists have devoted much effort to the minimization of patients' doses in diagnostic radiology. Through these efforts, substantial reductions in radiation doses to patients resulting from radiographic procedures have been achieved in many countries[9]. A useful background for such efforts is the knowledge of radiation doses to patients. This has led to surveys of patients doses in diagnostic radiology in many countries[5]. Also guidance levels or reference dose levels (DRLs) have been recommended by various international organizations as a means of patient dose reduction[8, 10-12].

Furthermore, several major dose surveys have been reported, especially in advanced countries[7, 13-16]. But in developing countries like Nigeria such basic information is still lacking. Therefore there is need to provide such patient dosimetry information.

MATERIALS AND METHOD

This survey was carried out in two public hospitals located in Benin City, Southern part of Nigeria. They are University Benin Teaching Hospital (UBTH) Benin-City and Central Hospital (CH), Benin-City. The Teaching hospital was included in this study because they have many qualified radiologist and radiographers and also because regulatory activities had been reasonable effective, therefore, their operations are better optimized. A total of two hundred and twenty four (224) patients which comprises 114 males and 110 female referred to X-ray departments during the study were investigated. For each patient and X-ray unit, the following parameters were recorded: sex, age, weight Focus-to-Film Distance (FFD), anatomical area examined, thickness of the area examined, and tube potential (kVp), and product of the tube current and time (mAs). All measurements were made at the centre of the X-ray beam with a fixed field size. The exposure parameters used for each projection was recorded before exposure. In the study seven routine types (11 projections) of X-ray examinations were considered. They are: Posterior-Anterior (PA) Chest, Lateral (LAT) Chest, Anterior-Posterior (AP) Abdomen, AP/PA Skull, LAT Skull, AP Pelvis/Hip, AP Lumbar Spine, LAT Lumbar Spine, AP Extremities, AP Cervical Spine and LAT Cervical Spine. Three X-ray machines in three X-ray rooms were investigated. They included a 3 -phase Toshiba Machine and a 3-phase Watson stylos machine at UBTH Benin-city, and a 3 -phase Siemens machine at CH Benin city. The two x-ray rooms investigated were equipped with a stationary machine and one X-ray room at UBTH was equipped with mobile X-ray. Only films that were considered suitable for diagnosis by the radiographer were accredited for this study. This ensured that all dose levels used were representative of diagnostic image. In order to demonstrate that the mathematical model was in agreement with practical measurements, comparisons were made of computed ESD with doses measured with thermo luminescent dosimeter (TLD) chip attached to entrance surface of the patient and placed in the center of X-ray field for 10 patients in each projection.

CALCULATION OF DOSE

The entrance surface dose (ESD) was determined using the software developed by Faulkner K. *et al*[17] for calculating ESD.

$$ESD = output \times \left(\frac{KV^2}{80^2}\right) \times \left(\frac{100^2}{ESD^2}\right) \times \frac{mAs}{BSF}$$

Where output is the output in mGy/mAs of the X – ray tube at 80KV at a distance of 1m normalized by mAs (m by/mAs). KV is the tube potential, mAs are the product of the tube current and exposure time, FSD is the focus-to-skin distance and BSF is the backscatter factor. The backscatter factor suggested in European guidelines was used in the calculations i.e. 1.35 for adult radiography[18]. The output is calculated from polynomial

$$Output = a_0 + a_1 kV + a_2 kV^2 + a3Kv3$$

Where kV is the tube potential used and a_0 a_1 a_2 and a_3 are constant which depend on the filter thickness.

RESULT AND DISCUSSION

Table-1: Patient information and exposure parameters for seven routine X-ray examinations (11 projections), mean values and range (in parentheses) for University of Benin Teaching Hospital, (UBTHC) Benin-City

Radiography	Projection	Number	Patient Age (years)	Patient weight (Kg)	FFD (cm)	kVp	mAs
Chest	PA	76	42(18-72)	68 (60-75)	141(106-155)	73(50-85)	20(8-30)
	LAT	-	-	-	-	-	-
Pelvis/Hip	AP	3	70(66-72)	73(65-70)	99(86-120)	85(82-87)	123(50-200)
Skull	AP/ PA	7	45(35-65)	72(60-75)	97(94-105)	79(69-90)	44(30-60)
	LAT	4	50(35-65)	71(65-75)	102(100-106)	78(69-83)	40(30-60)
Lumbar spine	AP	4	41(27-53)	72(65-73)	105(100-110)	86(78-91)	150(50-250)
	LAT	3	37(27-53)	73(65-72)	76(63-98)	88(85-91)	233(200-250)
Extremities	AP	20	45(20-75)	70(68-73)	77(52-98)	56(45-72)	8(5-12)
	LAT	15	42(20-75)	67(67-75)	77(82-98)	59(45-91)	8(5-12)
Abdomen	PA	5	39(28-57)	70(65-72)	100(94-103)	71(69-75)	96(80-100)
Cervical Spine	AP	7	39(26-46)	71(69-75)	105(93-110)	76(69-79)	30(25-35)
	LAT	8	39(26-53)	73(60-78)	104(96-111)	76(69-83)	30(30)

PA: Posterior-Anterior; AP: Anterior –Posterior; LAT: Lateral

A total number of 224 radiographs were included in this study. The data was collected from two major hospitals in Benin-city comprising three X-ray facilities. The patient information and exposure parameters for selected examination are shown in **Tables 1 and 2**. The mean age of the study sample range from 36 to 70 years and the mean weight ranged from 67kg to 73kg. This mean weight was within 70 ± 3kg which was comparable with the standard sized person recommended by International commission on

Radiological Protection[12]. The overall accuracy of the mathematical model, as validated by direct measurement showing variations between 10% to 14% for chest PA and lumbar spine AP respectively, this value is of the same order as that reported by Compagnone *et al*.[19]

Table-2: Patient information and exposure parameters for seven routine X-ray examinations (11 projections), mean values and range (in parentheses) for Central Hospital, (CH) Benin-City

Radiography	Projection	Number	Patient Age (years)	Patient weight (Kg)	FFD (cm)	KVp	mAs
Chest	PA	3.1	43(14-71)	68(67-72)	131(90-180)	94(60-110)	19(16-40)
	LAT	-	-	-	-	-	-
Pelvis/Hip	AP	3	56(54-60)	71(70-71)	112(90-115)	100(90-112)	133(80-160)
Skull	AP/ PA	3	38(23-65)	67(68-73)	91(90-92)	87(85-90)	77(60-100)
	LAT	3	38(2365)	67(67-72)	91(90-92)	83(80-90)	68(60-80)
Lumbar spine	AP	3	65(54-65)	72(70-73)	92(90-95)	103(90-110)	170(100-250)
	LAT	3	60(54-65)	72(70-73)	93(90-98)	107(100-110)	217(150-250)
Extremities	AP	7	44(19-70)	69(68-73)	82(36-90)	65(55-75)	28(16-40)
	LAT	7	44(19-70)	68(67-72)	90(90)	68(55-75)	30(16-40)
Abdomen	PA	4	36(18-55)	68(67-72)	88(80-100)	103(100-110)	155(150-160)
Cervical Spine	AP	3	52(45-65)	70(67-73)	70(64-75)	78(75-80)	31(30-32)
	LAT	3	52(45-65)	70(67-72)	70(64-75)	78(75-80)	33(32-35)

It can be seen from the **Tables 1 and 2** that low kVp were used by the hospitals. For chest PA, the kVp employed ranged between 50 and 85 KV, with a mean of 73kVp at UBTH, and ranged between 60 and 110 kVp, with a mean of 94kVp at CH. This is lower than 125kVp recommended for chest PA in commission of European Community[10] guidelines for quality radiographs. Both low and high – kVp techniques were reported to be commonly used in chest radiographic examinations in Europe and the USA[20], but it has been shown that the use of a high voltage technique for the chest has been calculated to reduce entrance surface dose by half and effective dose equivalent by 20% and therefore values lower than recommended tube potentials should not be used[21, 22]. The radiographic parameters (kVp and mAs) used in projections other than chest PA examinations were comparable to those recommended in CEC[10] guidelines for quality radiographs.

The FFD employed by the two hospitals in most cases were below the recommended levels. Cases were observed where FFD as low as 63cm were used for lumbar spine LAT at UBTH instead of 155cm recommended by CEC guidelines for quality radiography examinations[18]. The use of optimum FFD is considered very important since a direct relationship between shorter FFD, higher patients' dose and decreased geometric sharpness is well established[23,24] The distributions of ESDs for individual patient seven routine X-ray examinations (11 projections) from the two hospitals are shown **Tables 3 and 4** respectively.

The variation for individual patients is smaller than the 1983-1985 UK survey[21]. For example chest PA has a maximum/minimum ratio for individual patients of 4.3 in UBTH and 2.24 in CH compared with UK

values of 47.7. Lumbar spine AP projection has a maximum/minimum ratio for individual patients of 2.7 UBTH and 3.95 at CH compared with UK values of 71.2.

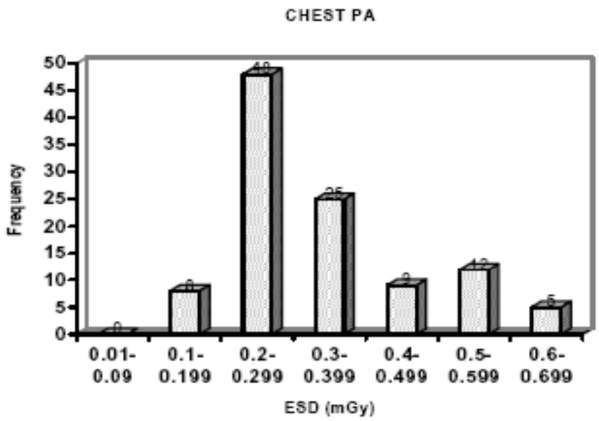
Table-3: Distribution of Entrance Surface Dose values (mGy) for individual patients for eleven projections at University of Benin Teaching Hospital, Benin City

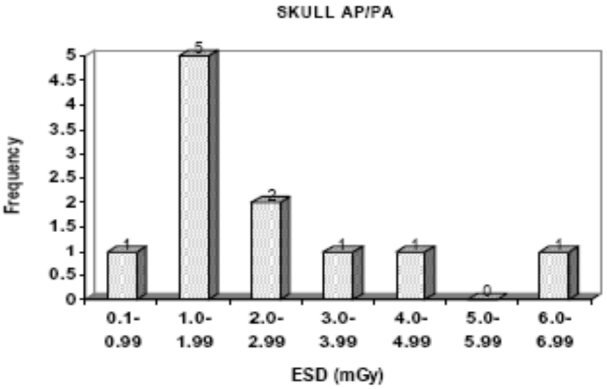
Radiograph	Projection	Number	Min	1st quartile	Median	Mean	3rd quartile	Max	Max/ min
Chest	PA	76	0.11	0.21	0.44	0.26	0.30	0.50	4.3
Pelvis/hip	AP	3	1.19	1.19	10.18	8.38	10.18	10.18	8.5
Abdomen	AP	5	2.21	2.08	3.08	2.36	3.26	3.55	1.6
Skull	AP/PA	7	1.00	1.06	1.68	2.09	2.98	4.45	4.4
Skull	LAT	4	0.85	0.85	1.53	1.67	2.05	2.75	3.2
Lumbar spine	AP	4	3.65	3.65	6.09	6.43	7.52	9.89	2.7
Lumbar spine	LAT	3	12.89	12.89	14.18	14.1	14.18	15.5	1.2
Extremities	AP	20	0.06	0.12	0.17	0.213	0.26	0.49	7.6
Extremities	LAT	15	0.11	0.15	0.23	0.25	0.28	0.53	4.5
Cervical Spine	AP	7	0.54	0.64	0.78	0.85	0.86	0.97	1.7
Cervical Spine	LAT	8	0.62	0.64	0.81	0.82	0.87	1.18	1.8

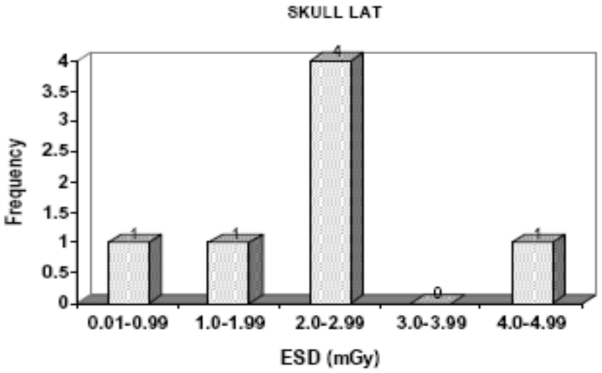
Table-4: Distribution of Entrance Surface Dose values (mGy) for individual patients for eleven projections at Central Hospital Benin City

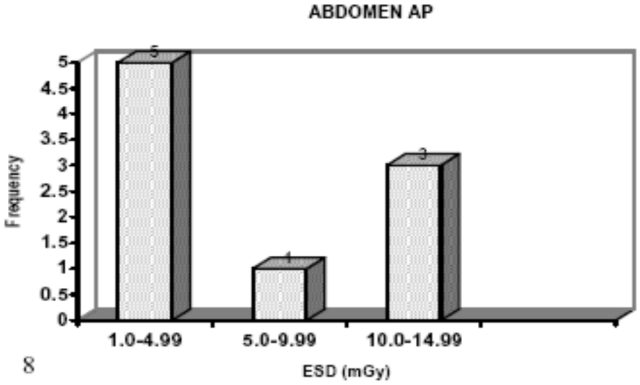
Radiograph	Projection	No	Min	1st quartile	Median	Mean	3rd quartile	Max	Max/min
Chest	PA	31	0.30	0.35	0.51	0.47	0.56	0.68	2..24
Pelvis/hip	AP	3	4.94	4.94	14.10	12.04	17.06	17.06	3.44
Abdomen	AP	4	8.81	8.81	12.42	12.08	13.69	14.66	1.66
Skull	AP/PA	3	2.89	2.89	3.86	4.43	6.54	6.54	2.26
Skull	LAT	3	2.31	2.31	2.85	3.28	4.68	4.68	2.02
Lumbar spine	AP	3	6.18	6.18	15.64	15.42	24.44	24.44	3.95
Lumbar spine	LAT	3	12.84	12.84	33.27	27.23	35.39	35.59	2.77
Extremities	AP	7	0.31	0.37	0.81	0.72	1.04	1.19	3.79
Extremities	LAT	7	0.36	0.37	0.82	0.72	0.99	1.11	3.07
Cervical Spine	AP	3	1.91	1.91	1.97	2.05	2.27	2.27	1.18
Cervical Spine	LAT	3	2.04	2.04	2.19	2.17	2.30	2.30	1.12

The variations in ESDs among the different radiological departments studied may be attributed to several factors, such as differences in patient weights, exposure parameters, radiological technique, FFD and total filtration. The contribution of the patient size to the mean ESD variability has been well established[25]. The variations recorded in this study are an indication that operational conditions are less optimized in the hospitals survey in this study and there is therefore much room for dose reduction.

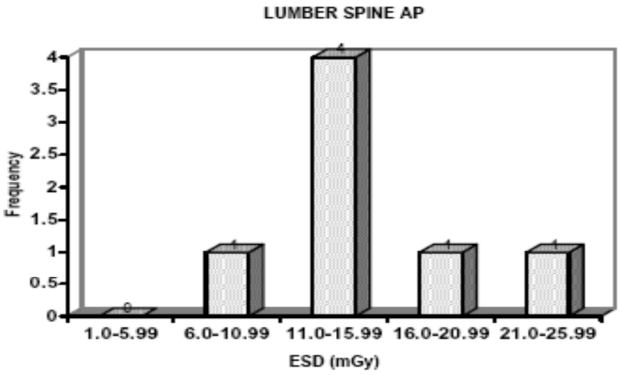

CHEST PA
Frequency
ESD (mGy)
0.01-0.09
0.1-0.199
0.2-0.299
0.3-0.399
0.4-0.499
0.5-0.599
0.6-0.699

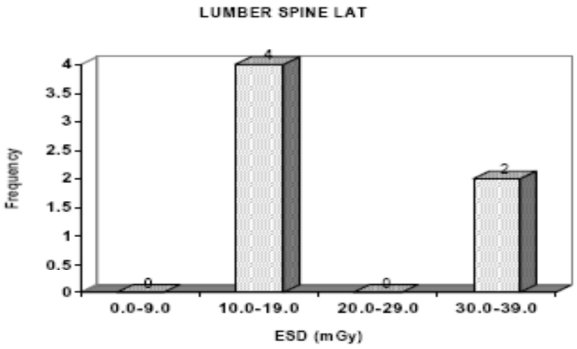

SKULL AP/PA
Frequency
ESD (mGy)
0.1-0.99
1.0-1.99
2.0-2.99
3.0-3.99
4.0-4.99
5.0-5.99
6.0-6.99

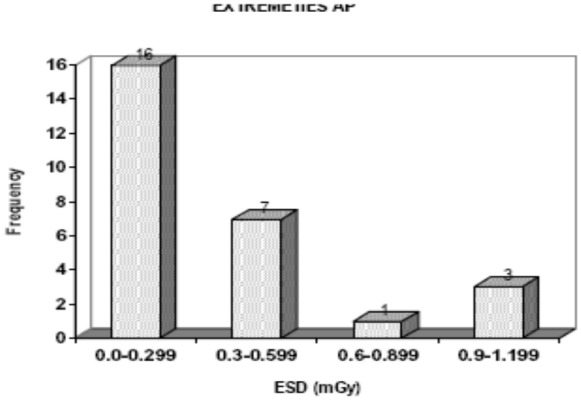

SKULL LAT
Frequency
ESD (mGy)
0.01-0.99
1.0-1.99
2.0-2.99
3.0-3.99
4.0-4.99

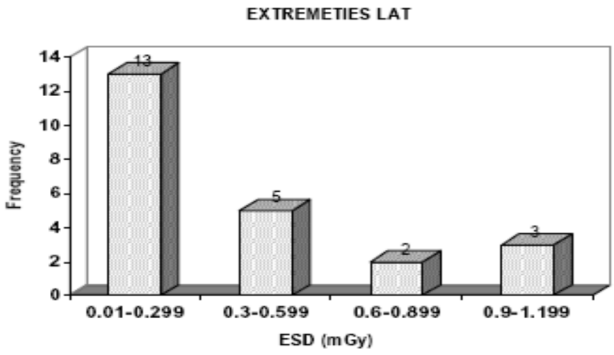

ABDOMEN AP
Frequency
ESD (mGy)
1.0-4.99
5.0-9.99
10.0-14.99

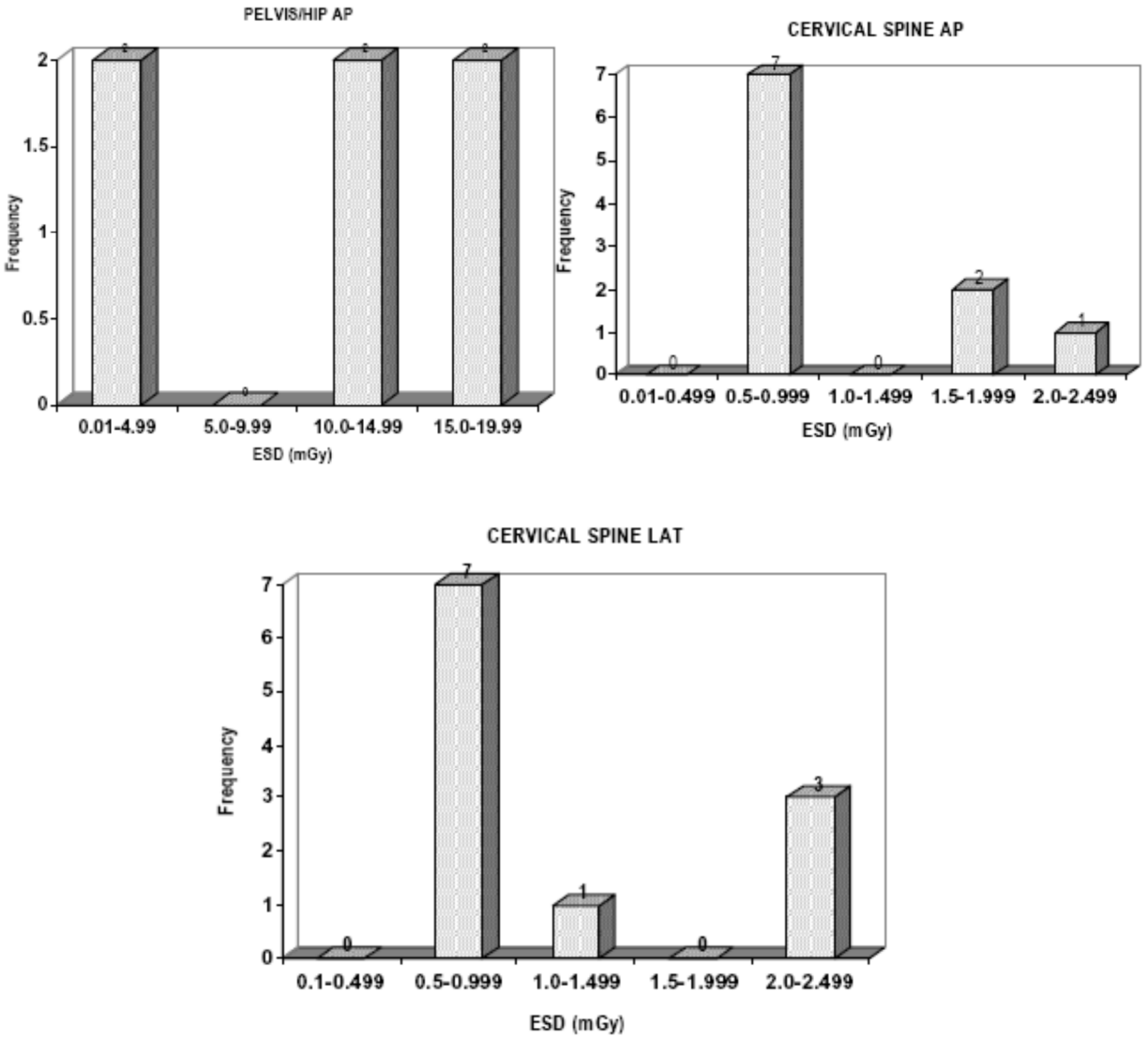
8


LUMBER SPINE AP
Frequency
ESD (mGy)
1.0-5.99
6.0-10.99
11.0-15.99
16.0-20.99
21.0-25.99


LUMBER SPINE LAT
Frequency
ESD (mGy)
0.0-9.0
10.0-19.0
20.0-29.0
30.0-39.0


Frequency
ESD (mGy)
0.0-0.299
0.3-0.599
0.6-0.899
0.9-1.199


EXTREMETIES LAT
Frequency
ESD (mGy)
0.01-0.299
0.3-0.599
0.6-0.899
0.9-1.199



Figures 1(a-k): show histograms for the individual projections for the selected examinations

In **Table 5**, a comparison is given between the ESDs obtained in the present study with some internationally established reference levels (DRLs) [11, 18, 26]. The lowest mean ESD of 0.26mGy for chest PA was observed at UBTH which was within the internationally recommended DRLs but at CH the mean ESD value of 0.46mGy observed was higher than the recommended DRLs. As it can be observed from table 5 the mean ESD value of 12.08mGy obtained for Abdomen AP, 12.04mGy for pelvis/hip AP, 3.28mGy for skull LAT, and 15.42 mGy for Lumbar spine at CH were higher than the recommended DRLs values by NRPB, CEC and IAEA. For skull AP/PA, CH demonstrated a higher mean ESD value of 4.43 mGy, while at UBTH the lowest value mean ESD of 2.09mGy was observed. For lumbar spine LAT, mean ESD of 14.1 mGy was observed at UBTH, while mean ESD value of 27.23mGy was observed at CH. These mean ESD values were within the range of internationally recommended levels DRLs. Generally, it is observed that higher mean ESDs were obtained at CH. This may be due to the equipment performance and radiographic techniques employed by the radiographer. Comparisons of both extremities

and cervical spine are not possible as there are no available reverence dose values for these projections. Comparison between the present measurements with those from Sudan[3] Ghana[5] and other works in Nigeria[27-29] revealed that the ESD values in the present study are mostly comparable with those from Sudan, Ghana and some studies carried out in Nigeria.

Table-5: Comparison of the Hospital Mean ESDs obtained in the Present Study with Some International Reference Dose Values (in mGy)

Hospital/Projection	Present Study		Organisation with DRLs		
	UBTH	CH	NRPB(2000)	CEC (1996)	IAEA (1996)
Chest PA	0.26	0.47	0.2	0.3	0.2
Abdomen AP	2.36	12.08	6.0	10.0	10.0
Pelvis/Hip AP	8.38	12.04	4.0	10.0	5.0
Skull AP/PA	2.09	4.43	3.0	5.0	2.5
Skull LAT	1.67	3.28	1.5	3.0	1.5
Lumbar Spine AP	6.43	15.42	6.6	10.0	5.0
Lumbar Spine LAT	14.1	27.23	14.0	30.0	10.0
Cervical Spine AP	0.82	2.05	NA	NA	NA
Cervical Spine LAT	0.82	2.17	NA	NA	NA
Extremities AP	0.21	0.72	NA	NA	NA
Extremities LAT	0.25	0.72	NA	NA	NA

CONCLUSION

Radiological parameters of patients undergoing some selected x-ray diagnostic procedures in two Nigerian hospitals together with their radiation doses have been measured. The individual ESD values were observed to be within the range of values that have been reported in other studies. Comparison between present measurements and those form internationally established reverence dose levels, revealed that mean ESD values in the present work are mostly comparable with and with some higher than those from NRPB, CEC and IAEA. The mean ESD values are also found to be within the corresponding range of values that have been reported from countries like Ghana[5], Sudan[3], and other studies in Nigeria[28]. The maximum/minimum ratio obtained in this work is generally low compared with those reported from other countries. These variations are an indication that X-ray machines need to be better monitored and the various factors that may be responsible for the observed variations in patients' doses for the same examination be identified. At CH, the mean ESD's values are general high which may be due to radiographic technique employed by the radiographer. These findings point to the fact that there is need to institute programmers like trainings, workshops, conferences aimed towards reducing patient dose in Nigeria. The findings of the present study can be used as a base line upon which future dose measurements may be compared.

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