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Doses to Patients in Routine X-Ray Examinations of Chest, Skull, Abdomen and Pelvis in Nine Selected Hospitals in Nigeria

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Abstract: Entrance Skin Dose (ESD) and Effective dose (E) to adult patients undergoing Chest (AP and Lat), Skull (AP and Lat), Abdomen (AP) and Pelvis (AP) radiography were estimated in (9) selected hospitals in Southern Nigeria. A total of 766 patients were considered in this study. The ESD was obtained using standard factors and a mathematical algorithm. The estimated mean ESD obtained were as follows: 0.4 mGy for Chest (PA), 1.7 mGy for Chest (Lat), 6.7 mGy for Skull (AP), 4.2 mGy for Skull (Lat), 5.4 mGy for Abdomen (AP) and 6.9 mGy for Pelvis (AP).These values were compared with those reported in similar studies carried out in UK, USA and by the International Atomic Energy Agency (IAEA). The mean effective doses were found to be generally low when compared with those found in the literature (Finland, Germany, Japan, Netherlands and UK). The results presented in this present study call for Quality Assurance Programme (QAP) in X-ray diagnostic units in Nigeria hospitals to ensure that doses are kept as low as reasonably achievable and also for the formulation of Local Diagnostic Reference Levels (LDRL).

Key words: Entrance skin dose, effective dose, tube potential, current-time product, Nigeria

INTRODUCTION

The need for radiation dose assessment of patients during diagnostic X-ray examinations has become imperative by the increasing knowledge of the hazards of ionizing radiation. The International Commission on Radiological Protection (ICRP Report No60, 1990) recommended that all Medical exposures should be subjected to the radiation safety principles of justification and optimization. Also in this publication 60, 1990, it was stated that absorbed radiation dose to the issues or organs should be used for estimating the likelihood of patients to develop stochastic effect.

In 1993, the National Radiation Protection Board (NRPB, 1993) in the United Kingdom published a national protocol for measuring radiation dose to patients in diagnostic radiology. It has also been recommended that the absorbed dose be included in the medical record of patient for certain radiographic procedure such as Entrance Skin Dose (ESD) measurement (ICRP, Publication 85, 2000).

International Atomic Energy Agency (IAEA, 1996), recommended Entrance Skin Dose (ESD) as dose descriptor for guidance levels in diagnostic radiography because it provides an indication of maximum skin dose and is useful for periodic checking of patient dose. Also, it serves as an indication of effective dose for particular radiography procedure.

In Nigeria, Ajayi and Akinwumiju (2000) carried out a research on the measurement of entrance skin doses to patients in four common diagnostic examinations by thermo luminescence dosimetry in Nigeria, it was discovered that there is variation in patients dose from hospital to hospital. Ogunseyinde *et al*. (2002) carried out a research financed by the International Atomic Energy Agency (IAEA). In their work, patients' doses in the X-ray examinations of chest Poster Anterior (PA), skull PA, skull AP and skull Lateral (LAT) were reported.

A survey of X-ray diagnostic services in Delta State, Nigeria (1991-1994) was conduted by Anomohanran *et al*. (2002). The results showed that as of 1994 there were 17 x-ray machines installed at 14 different locations within seven local government areas of the state. The results of their findings showed that the background radiation for different x-ray centers was greater than the background radiation for the environment outside the centers but the value of dose was found to be lower than the limit recommended by the International Commission on Radiological Protection. Also the research on radiological parameters and radiation doses of patients undergoing abdomen, pelvis and lumbar spine X-ray examinations in three Nigerian hospitals by Ogundare *et al.* (2004) in

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which Thermo Luminescent Dosemeters (TLDs) have been used to measure the Entrance Surface Doses (ESDs) of patients undergoing pelvis, abdomen and lumbar spine diagnostic X-ray examinations in Nigeria showed that for each of the examinations, the individual ESD values are comparable with and higher than, those from Ghana and Tanzania. The mean ESD values of their result are also found to be within the range of mean ESD values that have been previously reported in literature from countries outside Africa. According to the classification by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000). Nigeria is in the healthcare level IV category.

The aim of this study is to estimate patients' doses arising from X-ray examinations of the chest (PA and Lateral), skull (AP and Lateral), Pelvis (AP) and Abdomen (AP) in nine selected hospitals in Nigeria. The results of this work will serve as a useful baseline against which individual X-ray departments in Nigeria hospitals may compare their doses to reduce patients' doses and will also be a useful review of dose assessment of patients in Nigeria hospitals.

MATERIALS AND METHODS

The six projections considered in this study include chest (PA and LAT), skull (AP and LAT), Abdomen (AP) and Pelvis (AP). Data were collected for three months between June and August, 2005 for 766 patients. For each patient, the age, sex, weight, height and thickness were recorded. Technical parameters used during each radiographic exposure such as (tube voltage (kV), current-time product (mAs), Focus to Skin Distance (FSD), Field Size and Projection) were recorded. Information on film-screen speed was not available. The only information available is the type of films used in each hospital during the data collection. The study was carried out in nine major hospitals in South-Western Nigeria. All the X-ray machines used in these hospitals are analogue systems and are used without grids. The operating potential used for each radiographic examination is determined based on the type of examination, patient's weight and thickness. The qualities of image were compared among the hospitals and were found acceptable for diagnostic purposes. Acceptability of diagnostic images is purely personal and is assessed by the radiographers. For the same projection and type of examination, differences were observed in techniques in each hospital depending on experience of staff.

In order to facilitates measurement and optimization of patient dose. The National Radiological Protection Board (NRPB) introduced the National Protocol for patient dose measurement in 1992. The National Protocol recommended that Entrance Skin Dose (ESD) be directly measured on a sample of patients using Thermo-Luminescent Dosimeters (TLDs). Free-air measurement of a tube's radiation output together with the calculation of ESD using standard factors can be employed in appropriate circumstances (Davies *et al*., 1997). The use of software to perform patient doses is a modern resource in dosimetry and is being widely used in hospitals (Kyriou *et al*., 2000; Cook *et al*., 1998; Davies *et al*., 1997).

In this research, we employed calculation of Entrance Skin Dose (ESD) based on standard exposure data due to unreadily availability of TLD chips and TLD reader in Nigeria. The result obtained with use of this software was compared with results from TLD measurement (Ogundare *et al*., 2004) and was found to have an error of ±2%.

The software used for the calculation of dose is based on Davies *et al*. (1997) formula for calculating ESD. The software is specially developed for the evaluation of ESD and E.

$$ESD = Output \times \left(\frac{kV}{80}\right)^2 \times \left(\frac{100}{FSD}\right)^2 \times mAs \times BSF$$

The output is the output in mGy/mAs of the X-ray tube at 80 kV at a distance 100 cm normalized to 10 mAs. BSF is backscatter factor for a particular examination at the required potential and was taken from NRPB numerical simulations (Jones and Wall, 1985).

The output is calculated from (Boone *et al*., 1997) polynomial

$$Output = a_0 + a_1 kV + a_2 kV^2 + a_3 kV^3$$

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
The output is in mR/mAs.

Effective dose was estimated by using the dose conversion coefficient (Hart *et al*., 1994) which depends on the radiographic procedures (tube potential and filtration (mm Al) and projections studied.

RESULTS

A total of 776 patients were included throughout the 9 hospitals. Only 8 of the nine hospitals undertook skull

Table 1: Patients' information and exposure parameters for four routine x-ray examinations. Values indicated are the mean values and the ranges in bracket

Radiograph	Projection	Patient age (year)	Patient weight (kg)	Tube potential (kVp)	Mean (mAs)
Chest	PA	40(16-75)	61(35-116)	62(50-85)	18(5-60)
	LAT	44(16-70)	78(42-88)	69(33-100)	52(5-75)
Skull	AP	37(23-60)	62(48-95)	79(63-100)	23(51-60)
	LAT	35(20-60)	66(48-100)	56(63-80)	69(51-25)
Abdomen	AP	39(16-58)	63(45-81)	87(60-100)	78(51-25)
Pelvis	AP	39(18-72)	81(37-85)	83(71-100)	79(51-25)

Table 2: Distribution of ESD (mGy)

Radiograph	Projection	Number	Min	1stquartile	Median	Mean	3rdquartile	Max	Mean E(μSv)
Chest	PA	201	0.12	0.3	0.35	0.4	0.5	3.1	18
	LAT	100	0.17	0.3	0.8	3.7	4.1	6.6	35
Skull	AP	91	0.66	4.4	7.5	6.7	9.2	13.3	47
	LAT	91	0.60	3.6	5.8	4.2	7.2	8.0	38
Abdomen	AP	94	0.21	1.0	3.7	5.4	9.7	11.5	300
Pelvis	AP	100	0.6	5.4	7.0	6.9	9.2	12.1	540

Table 3: Maximum /minimum ratio, Standard deviation and coefficient of variation of ESD

Radiograph	Projection	Ratio of Max/min for Individual patient	Ratio of third /first for individual patient	Coefficient of variation (%) for individual patients	Standard deviation of ESD
Chest	PA	25.8	1.6	85	0.34
	Lat	38.8	13.6	111	1.9
Skull	AP	20.2	2.1	54	3.6
	Lat	13.3	2.0	59	2.5
Abdomen	AP	54.7	9.4	80	42
Pelvis	AP	20	1.7	54	37

Table 4: Comparison of ESD with the international established reference dose values in mGy

Radiograph	Projection	The present study	USA1992 (CRCPD/CDRH) Median dose	Malaysia (1998) Median dose	NRPB (2000)	IAEA basic safety standard (1996)
Chest	PA	0.35	0.3	0.17	0.2	0.4
	Lat	0.81	1.2	-	1.0	1.5
Skull	AP	7.5	4.7	-	3	5
	Lat	5.8	3.0	1.6	1.5	3
Abdomen	AP	3.7	9.2	5.6	6	10
Pelvis	AP	7.0	5.3	-	4	10

and abdominal projection and all the hospitals had at least 15 patients for each projection considered. Both sexes were included in the research. Patient's information (i.e. age, weight) and exposure parameters (tube potential and current-time product) for the four routine X-ray examinations considered are shown in Table 1.The mean patient weight is 66.4kg and the mean age is 39.3 which show that the study sample is younger than the UK (47-66) (Hart *et al*., 1996) and nearly the same as Malaysia (37-49) (Ng *et al*., 1998) surveys. Also the range of tube potential for all the projections is (62-87) kVp which is similar to that of UK and Malaysia study which is (66-89) kV. The descriptive statistics of ESD i.e. the minimum, first quartile, third quartile, maximum, mean and median are shown in Table 2. Table 3 shows the maximum/minimum ratio, interquartile range (ratio of 3rd quartile to first quartile), standard derivations and percentage coefficient of variation of ESD of individual adult patient. All the doses (Median Value) are below the reference level (IEAE, 1996 basics safety) except for skull (AP and Lat). The maximum/minimum ratio of ESD ranged from 13.3 for skull (lateral) to 54.7 for AP abdomen. Table 4 shows the comparison of calculated ESD with the international established reference dose from CDRH (1992) and NRPB (2000), IAEA basic safety standard, 1996 and Malaysia survey 1998. All the hospitals considered used low tube potential and three of them employed filtration of 2.5 mm Al, nevertheless the filtration values in this study were not measured, but given by the radiographers, so effective dose for those hospitals cannot be estimated. Figure 1a-1f is the histogram of the median Entrance Skin Dose (ESD) for the six projections across all the hospitals with the reference level according to NRPB, 2000 inserted.

DISCUSSION

There is a wide variation in patient doses within and outside hospitals for individual patient for each projection but the mean of the dose does not vary widely/greatly from hospital to hospital. The highest variation in dose is from chest (Lat) examinations with CV of 111% and the least variation from Skull (AP) and Abdomen examinations.

The median of entrance skin dose ESD obtained in this study (Table 2) are compared with the established reference dose values from Malaysia (1998), USA (CRCP/CDRH) (1992), NRPB (1993) and IAEA (1996) Basic safety standard. All the median values are below the basic safety standard except for the Skull (AP and Lat) examinations (Table 4) but are higher than the UK reference level.

The reason for the variation in dose may be due to lot of factors among which are performance of equipment, type of x-ray generator, the processing system and radiographic techniques used in different hospitals. Similar results had also been reported (Ogundare *et al*., 2004; Johnston and Brennan, 2000; Warren-Forward *et al*., 1995). The wide variations of dose suggested that

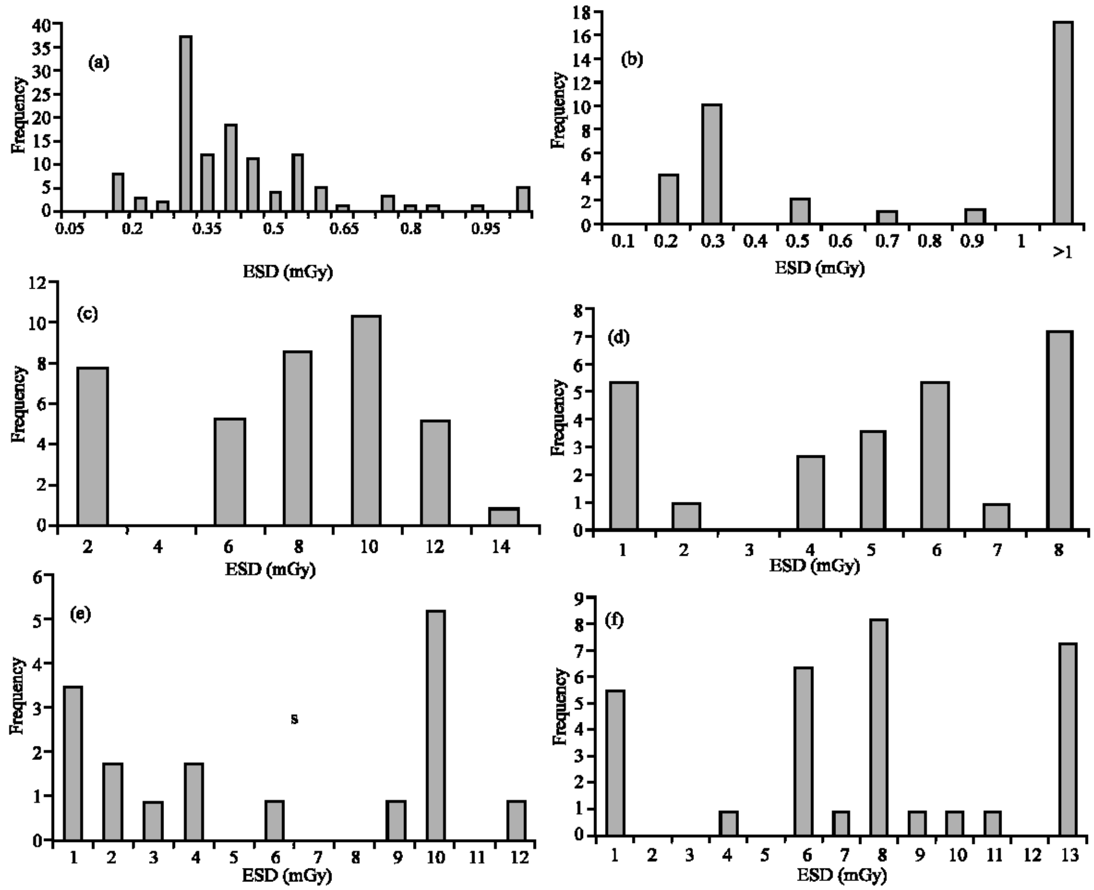

Fig. 1: Histogram showing the frequency of the dose for the six projections.(median in bold line and NRPB reference levels in dotted line) (a) Chest AP (b) Chest Lat (c) skull AP (d) Skull Lat (e) Abdomen AP (f) Pelvis AP

the causes required investigation to reduce the variability and to ensure that doses to patients are as low as reasonably achievable. It also suggests that dose can still be reduced by adherence to guidelines that will correct operative modalities and which will enable doses to become lower.

The Entrance Skin Dose (ESD) measured for individual patients varied and it ranges from a factor of 13-55 (Table 3). These values are greater than those obtained in previous study in Malaysia and Italy (Gaetano *et al.*, 2004) which indicated that dose can still be reduced.

In general the use of a low tube potential and a high mAs values was common in most hospitals surveyed and has been observed as the sole causes of dose variation. The radiographers when ask could not give any reason for this other than it gives good resolution. Lanhede *et al.* (2002) observed that increase in tube potential is associated with a 33% drop in entrance skin dose and increasing the tube potential by 8-13 kV in Lumbar and Thoracic spine examination resulted in a dose reduction of 26-39%.

The setting of reference value by ICRP was based on average standard-size man of 70 kg. The average weight in this study is 66.4 kg and range between (35-116). This difference in the weight will also influence the variability of the calculated dose. All the median values obtained in the study are below the reference level except for the Skull (AP and Lat) examinations (Fig. 1c and d). The effect of age of the facilities and lack of a good quality assurance program also is a factor in dose variation.

CONCLUSION

Entrance Skin Doses (ESD) of patients undergoing chest (PA and Lat), skull (AP and Lat), Abdomen (AP) and Pelvis (AP) examinations in nine Nigerian hospitals have been monitored. The individual ESD values were observed to be consistent with the range of values that have been reported in past studies. The median values of the present study are compared with reference levels in literature and the values in this present study are mostly comparable.

The median ESD values in all the examinations are below the reference level (NRPB, 2000) except for skull examinations. The range factor obtained in this work is generally high compared with those reported from Malaysia, Italy and Ireland. The large range factors observed indicate that dose can still be reduced by adherence to guidelines that will correct operative modalities and which will enable doses to become lower. The mean effective doses when compared with those found in literature (Aroua *et al*., 2002) are lower. This mean that the radiation risk to an average patient in the hospitals included in this work is low and the risk to workers in the hospitals will be generally low.

The findings in this study point to the fact that there is a serious need for quality assurance programme and monitoring aimed towards reducing patient dose in Nigeria. This may include organization of regular workshops/conferences for radiographers, setting of guidelines for different exposure, regular assessment of patient's dose in all hospitals and finally formulation of diagnostic reference levels with which individual hospitals may compare their dose.

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