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**Original Article**

# Doses Received by Patients during Thorax X-Ray Examinations

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## Abstract

**Introduction**
Radiation exposures from diagnostic medical examinations are generally low and are almost always justified by the benefits of accurate diagnosis of possible disease conditions. Therefore, entrance skin dose (ESD), body organ dose (BOD), and effective dose (ED) from adult patients undergoing routine thorax posterior-anterior (PA) and thorax right lateral (RLAT) were estimated in University Hospital, Port Harcourt, Southern Nigeria.

**Materials and Methods**
Totally, 102 patients were considered in this work. Using software packages to carry out ESD, BOD, and ED is a recent resource in dosimetry and is being widely used in hospitals. The software used in this work was CALDose_X 5.0. The software makes use of the technical exposure parameters and the tube output of the X-ray machine.

**Results**
The estimated ESD median values were 0.96 and 1.85 mGy for thorax posterior anterior (PA) and right lateral (RLAT), respectively. The highest BOD was in the adrenals (270 μGy) for thorax PA and Liver (263 μGy) for thorax RLAT. Similarly, ED for thorax PA and RLAT examination were 0.068 and 0.107 mGy, respectively.

**Conclusion**
It could be observed that examinations that imparted the highest ESD were thorax PA when compared with the established dose level. Therefore, these results call for quality assurance program (QAP) in diagnostic X-ray units in Nigeria hospitals.

**Keywords:** Effective Dose, Entrance Skin dose, Radiography



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## 1. Introduction

The radiation protection system for patients subjected to medical exposures in diagnostic radiology is governed by principles of justification and optimization, including the consideration of diagnostic reference levels (DRLs). Therefore, a diagnostic radiological procedure is justified if the benefits to the individual patient from the radiological image balance the individual detriment the exposure may cause. Once a medical exposure has been justified, the principle of optimization is applied, that is, the radiological examination must be carried out with equipment and exposure parameters that ensure doses to patients as low as reasonably practicable and consistent with the intended diagnostic purpose [1].

National Radiation Protection Board (NRPB) [2] 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 [3].

The United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) [4] and International Atomic Energy Agency (IAEA) [5] recommended 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. Moreover, it serves as an indication of effective dose for particular radiography procedure.

In Nigeria, most of the studies on patient dosimetry have been carried out on the measurement of entrance skin doses to patients in four common diagnostic examinations by thermoluminescence dosimetry (TLD) [6-9].

Moreover, the research on radiological parameters and radiation doses of patients undergoing X-ray examinations in three Nigerian hospitals by Ogundare et al., on TLDs have been used to measure ESDs of patients undergoing X-ray examinations [10]. Their findings revealed that their mean ESDs values were within the international level.

The aim of this work is to estimate patients' doses during diagnostic X-ray examination of thorax posterior anterior (PA) and thorax right lateral (RLAT) in University Hospital, Port Harcourt, Southern Nigeria (UPTH). The results of this study will serve as a useful baseline against which individual X-ray unit in Nigeria hospitals may compare their doses to reduce patients' doses and will also be a useful review of dose evaluation of patients in Nigeria hospitals.

## 2. Materials and Methods

In total, 102 patients were included throughout the study. Fifty-two patients for each of the projections were considered. Both males and females were included in the research. Patient's information (age and weight) and exposure parameters (tube potential and current-time product) for the routine X-ray examination considered are indicated in Table 1. The ESD received by 102 patients were included in this study. This dose survey was conducted between May 2012 and September 2012. The patients were randomly selected from adult patients of both sexes (male and female) attending medical investigations in UPTH. The two projections considered on thorax radiograph in this study included PA and Right Lateral (RLAT). For each patient, age, sex, weight, and height were recorded. X-ray factors used during each radiographic exposure such as tube voltage (kVp), charge (mAs), focus-to-film distance (FFD), field size, and projection were recorded. The film-screen speed was 200 (i.e sensitivity 0.64 mR). A Silhouette VR X-ray machine was used in this work. The equipment had a total filtration of 2.5 mmAl with fixed grid configuration. The system had an AEC (X-ray generator) with Bucky grid ratios system of 10:1. Silhouette VR X-ray tube used recommended units (X-ray generator) of 32 and 35 kW. The operating potential used for each radiographic examination was determined based on the type of examination, patient's weight and thickness.

In order to facilitate measurement and optimization of patient dose, the National Radiological Protection Board (NRPB) introduced the national protocol for patient dose measurement [11]. Moreover, from their recommendation, ESD was directly measured on a sample of patient using TLD. Free-air measurement of tube's radiation output together with the calculation of ESD using standard factors may be employed in appropriate circumstances [12]. The application of software to evaluate patients' doses in common routine X-ray examination is a modern resource in dosimetry and is widely used in hospitals [13-19].

For the present study, we employed window-based software for calculation of patients' dose due to unavailability of TLD chips and TLD readers in Nigeria. The result obtained in this study was compared with result obtained from TLD measurement in Southwest Nigeria [10] and Dosecal software for evaluation [6].

In order to increase the speed and efficiency of the patient dosimetry process, a windows-based computer program, CALDose_X 5.0, has been developed by Kramer et al. CALDose_X is a software tool that provides the possibility to calculate incident air kerma (INAK) and entrance surface air kerma (ESAK), two important quantities used in X-ray diagnosis, based on the output of the X-ray equipment. Additionally, the software uses conversion coefficients (CCs) to assess absorbed dose to organs and tissues of the human body, the effective dose as well as the patients' cancer risk for radiographic examinations [15].

The CCs, ratios between organ and tissues absorbed doses and measurable quantities, have been calculated with the FAX06 and the MAX06 phantoms for 34 projections of 10 commonly performed X-ray examinations[15]. A combinations of 40 tube potential and filtration ranging from 50 to 120 kVp and from 2.0 to 5.0 mm Al, respectively. Various field positions, for 29 selected organs and tissues had been simultaneously calculated for the measurable quantities(INAK, ESAK, and kerma area product (KAP))[15]. Based on the X-ray irradiation parameters defined by the user, CALDose_X shows images of the phantom together with the position of the X-ray beam. By using true to nature voxel phantoms, CALDose_X improves earlier software tools, which were mostly based on mathematical MIRD5-type phantoms, i.e. poor representations of human anatomy [14].

For the CALDose _X 5.0 to work, it is necessary to furnish the output in mGy/mAs, of all X-rays machines used in the evaluation of doses. Once the tube potential, the tube current, the exposure time, the FDD, and focus-to-skin distance (FSD) were known, ESD could be calculated by (1)

$$\text{ESD}=\text{Output}\times\left(\frac{kv}{80}\right)^2\times\left(\frac{100}{FSD}\right)^2\times \text{mAs}\times \text{BSF} \quad (1)$$

The output is 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 [13].

In order to determine the effective dose, CALDose _X5 provides separately calculated weighted MAX06 and FAX06 whole body absorbed doses [15], which represent the sex-specific contributions to the effective dose. According to equation 4.5 in International Commission on Radiological Protection (ICRP) publication 103 [20], the effective dose is then just the arithmetic mean of the two sex-specific weighted absorbed doses.

According to ICRP 103 section (132), equation 4.5, the effective dose can be evaluated by this expression:

$$E = \frac{[H\ (\text{female}) + H\ (\text{male})]}{2}$$

$$E = -[\sum\ H\ (\text{female}) + H\ (\text{male})] \quad (2)$$

CALDose_X 5.0 calculates a weighted female dose (F) and a weighted male dose (M) given at the end of the result tables [15]. The effective dose based on CALDose_ X5.0 is then the average of the sex-specific weighted doses as in equation 3

$$E = -[F + M] \quad (3)$$

## 3. Results

The descriptive statistics of ESD, i.e., minimum (Min), maximum (Max), first (1st) and third (3rd) quartile, median, and mean are presented in Table 2. Table 3 presents the max/min ratio, inter-quartile range (ratio 3rd/1st), standard deviation (SD), and percentage coefficient of variation (CV%) of ESD of individual adult patient. All the ESD are below the dose reference level [2-5] except for thorax PA projection. The max/min ratio of ESD for PA and RLAT are 2.538 and 2.068 mGy, respectively. Table 4 presents the distribution of mean value of Effective Dose (ED) with ESD median value. Table 5 presents the obtained values for tissue/organ dose for thorax PA and RLAT. The highest body organ dose (BOD) was in adrenals PA with 194 μGy and liver RLAT with 264 μGy for thorax radiography. Table 6 shows the comparison of calculated ESD with the international established reference dose level for SW (Southwest) Nigeria, IAEA, NRPB and UNSCEAR recommendations. The hospital considered used low tube potential and employed a total filtration of 2.5 mm Al. Nevertheless, the filtration values in this study were not measured, but given by the radiographers. Figure1 is the distribution of the ESD with the established reference level.

Table 1. Exposure parameters and patient's information for UPTH with mean and range in *bracket.*

| Types of Examination | Projection | Patient Age (year) | Patient Height (cm) | Patient Weight (kg) | Tube voltage (kVp) | current-time product (mAs) | FFD (cm) |
|---|---|---|---|---|---|---|---|
| THORAX | PA | 35.62 (20–70) | 169.24 (163–176) | 66.24 (60 – 73) | 71.04 (67–77) | 20.78 (12.5–25) | 186.5 (185–188) |
| | RLAT | 47.40 (27–80) | 169.62 (163–176) | 66.62 (60–73) | 76.19 (70–80) | 30.70 (25–35) | 187.42 (185–189) |

Table 2. Descriptive statistics of ESD (mGy) in UPTH.

| Radiograph | Projection | Min | Max | Median | 1st Quartile | 3rd Quartile | Mean |
|---|---|---|---|---|---|---|---|
| THORAX | PA | 0.504 | 1.279 | 0.911 | 0.849 | 1.151 | 0.958 |
| | RLAT | 1.052 | 2.176 | 1.9 | 1.671 | 1.939 | 1.850 |

Table 3. Distribution of ESD with max/min, 3rd/1st quartile, standard deviation and coefficient of variation of individual patient in UPTH.

| Radiograph | Projection | Max/Min | Median | 3rd/1st Quartile | SD | CV% |
|---|---|---|---|---|---|---|
| THORAX | PA | 2.538 | 0.911 | 1.355 | 0.548 | 57% |
| | RLAT | 2.068 | 1.9 | 1.160 | 0.795 | 43% |

Table 4. Distribution of effective dose (mSv) with doses reported in the literature.

| Radiograph | Projection | ED (Mean) | Values reported in literature (mSv)* |
|---|---|---|---|
| THORAX | PA | 0.06±0.063 | 0.007 – 0.050 |
| | RLAT | 0.62±0.318 | 0.05 – 0.24 |

*Mettler et al. [21]

Table 5. Distribution of tissue/organ dose (mGy) for thorax radiograph

| Organ/tissue | Thorax PA | SD. | Thorax RLAT | SD |
|---|---|---|---|---|
| ESAK | 0.946 | 0.537 | 1.823 | 0.778 |
| ADRENALS | 0.194 | 0.197 | 0.146 | 0.083 |
| BREASTS, | 0.032 | 0.035 | 0.152 | 0.078 |
| KIDNEYS | 0.171 | 0.179 | 0.103 | 0.057 |
| LIVER | 0.078 | 0.092 | 0.263 | 0.155 |
| LUNGS | 0.210 | 0.193 | 0.270 | 0.141 |
| ESD | 0.958 | 0.548 | 1.850 | 0.795 |
| S. AVERAGE | 0.188 | 0.158 | 0.206 | 0.111 |
| MAX.RBM | 0.231 | 0.204 | 0.508 | 0.255 |
| MAX.BSC | 0.302 | 0.260 | 0.620 | 0.318 |
| ED | 0.068 | 0.063 | 0.107 | 0.057 |

Table 6. Comparison of ESD (median value) with the international established reference dose level in (mGy)

| Radiograph | Projection | Present Study | SW Nigeria 2009 | UNSCEAR 2008 | IAEA 1996 | NRPB 2000 |
|---|---|---|---|---|---|---|
| THORAX | PA | 0.911 | 0.59 | 0.35 | 0.4 | 0.2 |
| | RLAT | 1.9 | 0.61 | 0.81 | 1.5 | 1.0 |

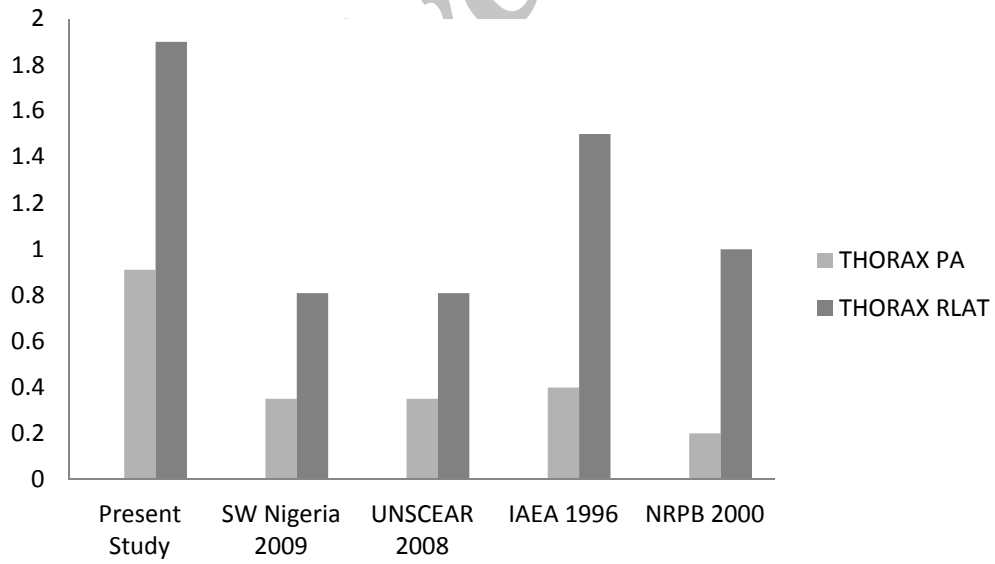


Fig.1 Distribution of the ESD with the established reference level.

## 4. Discussion

From the results obtained, there is a wide difference in patients' doses in the hospital considered for individual patient and for each projection, though the mean dose does not really vary greatly from one projection to another. From Table 6, the highest ESD median value was from both thorax PA and RLAT examinations. The mean patient weight was 66.62 kg and the mean age was 35.62 kg which

show that the study sample is younger than the UK (47–66) [13] and nearly the same as Malaysia (37-49) [19] surveys. Moreover, the range of the tube potential for the projections was (68–80) kVp which is similar to that of UK and Malaysia studies (66–89) kVp.

Tables 2 and 3 present the statistical analysis (minimum, maximum, standard deviation, ratio of max/min, and coefficient of variation) distributions of the patients while Table 4 shows the comparison of this work's mean effective dose with the ranges of effective doses reported in the literature for the different examinations and procedures. Comparing the mean effective dose in the studied hospital with that of the reported literature is greater than the doses obtained in the literature by a factor of 0.1.

Table 5 present the distribution of tissue/organ dose for thorax examination. From the distribution, the highest value was recorded in the lungs with 270 μGy for PA and RLAT projections, respectively.

Table 6 is a comparison of the obtained ESD in this work with established reference doses in the UK (NRPB), IAEA, and UNSCEAR recommendation. In this comparison, the values of the obtained ESD in the study area for thorax examination for PA and RLAT projection are higher than those of UK (NRPB), IAEA, South-West Nigeria (SWN), and UNSCEAR. The ESD for thorax PA was found to be higher than UK and IAEA by a factor of 2.5. The thorax RLAT projection had the lowest variation with the UK, varying with a factor of 2.1.

In all, the use of low potentials and high mAs values was common in the studied hospital and have been observed as the main causes of errors/differences in doses when compared with the reference level. Similarly, results have also been reported regarding the variations in ESD [6, 10, and 15]. They were no better reasons by the radiographer when asked than saying that it gives a better resolution, i.e., a clearer image. In addition, these variations in dose levels for the ESD may be due to many limitations amongst which the efficiency of the equipments, the processing systems, and the radiographic techniques used in each of the hospitals can be mentioned. These variations in doses suggest that investigations are required to be made to ensure the ALARA principle. This also suggests that there could be reduction in doses if radiographers adhere strictly to the guidelines that correct the operative modalities.

## 5. Conclusion

An estimation of entrance surface dose and effective dose during diagnostic X-ray examination of adult patients in University of Port-Harcourt Teaching Hospitals, Rivers State, has been carried out. The patient's individual ESD and body organ dose values were observed to be consistent with the range of values of the existing knowledge. The ESD (median) values of the present study were compared with the reference levels of the existing knowledge and the values obtained on the present study are mostly comparable.

The ESD in all the examinations were below the DRLs [3,5] except for thorax PA projection. The ranged factor obtained in this work was moderately low when compared with those reported from Southwest (SW) Nigeria.

The mean effective doses when compared with those found in existing knowledge were lower. This implies 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 is generally low.

The findings suggest that there is a serious need for quality assurance program and monitoring aimed towards reducing patients' dose in Nigeria. This can be achieve by organizing regular workshops and conferences for radiographers, setting of guidelines for different exposure, and establishing of diagnostic reference levels with which individual hospitals may compare their doses.

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