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Measurement of Patient Radiation Levels During Chest X-ray Examination at Madonna and Nigerian Airforce Hospitals in Makurdi, Nigeria

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Abstract- This work seeks to measure the level of entrance skin dose (ESD) during chest posterior-anterior (PA) examination and compare results with standard diagnostic reference level set by International Atomic Energy Agency (IAEA) and International Commission for Radiological Protection (ICRP). The Thermoluminescence Dosimetry (TLD) technique was employed with phantoms to measure the amount of radiation received by patients during routine PA chest X-ray examinations at Madonna and Nigerian Airforce Hospitals, Makurdi. The average ESD recorded at Madonna and Nigerian Airforce Hospitals were 1.810 ± 0.34 mGy and 0.963 ± 0.34 mGy respectively. These doses were found to be above the safe radiation dose limit of 0.4 mGy recommended for patients undergoing PA chest examinations. However, the mean skin dose at the Nigerian Airforce Hospital was within the safe limit of 1.0 mSv recommended by ICRP for members of the public.

Indexed Terms- X-ray; ESD; Diagnostic reference level; TLD; Phantom

I. INTRODUCTION

The entrance skin dose (ESD) is a measure of the radiation dose absorbed by the skin where the X-ray beam enters the patient. The extensive use of X-rays for medical diagnosis shows that diagnostic medical radiology represents by far the most significant artificial source of exposure to ionizing radiation worldwide (Taha et al., 2015). Considering the importance of optimized medical exposures, the major concern in radiological protection is the reduction of unnecessary exposures either from examinations that are unlikely to be beneficial to the patient management or involve doses that are not as low as reasonably practicable (Aşlar et al., 2020). It has been estimated that, over 70% of the world population is exposed to medical X – rays annually, and that over 95% of all artificial radiation is from diagnostic X-rays (Ujah, Agba and Iortile, 2012).

It is important to note that, the aim of any diagnostic X-ray examination is to generate images of patients of sufficient quality, to provide adequate diagnostic information for a clinician. However, the somatic and genetic health risk related to exposures to X – rays require that, these examinations should be carried out with the least amount of radiation as stipulated in the ALARA principle (Memon et al., 2010). The ESD associated with X-ray examination have come under great scrutiny, requiring quantitative monitoring and accurate measurement (Ujah, Agba and Iortile, 2012). This is to determine whether or not the radiation levels in our hospitals are within the maximum permissible dose limit set up by the international radiation regulatory bodies such as the International Atomic Energy Agency (IAEA) and the International Commission on Radiological Protection (ICRP). The basic principles put forward by the ICRP for all medical examinations are the justification of practice, and the optimization of protection (Do, 2016).

The most important parameter of interest in radiation measurement is the radiation dose (Yuan *et al.*, 2007), this is defined as the energy absorbed by a unit mass of an absorbing medium. Patient radiation levels can be acquired by measuring the ESD using thermoluminescence dosimeters (TLD) or the output factor method, the dose area product (DAP) and the computed tomography dose index (CTDI) could also be checked to ascertain radiation dose to patient.

In most hospitals in Makurdi town, the radiation protection programmes put in place to monitor patient exposures are inadequate. There exist some fears that many patients may have been overexposed during X-ray examinations. In view of the vital benefits to patients from properly conducted medical exposures, the use of X-ray cannot be completely ruled out from medical practice hence the need for patient dosimetry. Patient dosimetry is employed to get a proper insight into the amount of radiation absorbed by a patient during a radiological examination, since over exposure could result in serious health problems like cancer and gene mutation. The objective of this work is to measure the ESD of patients who undergo PA chest X-ray examination using the TLD technique with phantoms, and compare the results obtained with the standard diagnostic reference level set by ICRP and IAEA.

II. MATERIALS AND METHOD

The X-ray machines used for this work were situated at the Madonna and Nigerian Air Force Hospitals, both in Makurdi. Other materials include calibrated TLDs – LiF enclosed in sachets from the Centre for Energy Research and Training (CERT), Ahmadu Bello University (ABU), Zaria. The TLD reader employed was Harshaw 4500 located at CERT Zaria. Polymethyl methacrylate (PMMA) phantoms of various sizes that mimic the different categories of chest thickness (24cm, 20cm, 18cm, and 16cm) were fabricated. Phantoms are generally made of materials that absorbs and scatters photons in the same way as human (Kabir, Okoh and Mohd Yusof, 2021; Okoh *et al.*, 2022) They ought to have the same density as tissue and contain the same number of electrons per gram. Water and wet tissues absorb photons in almost the same manner, and for this reason water has been used in many investigations (Khan, 2010). Other materials used to build the PMMA water filled phantom include RTV Silicone sealant and a measuring tape.

The dose to the skin was directly measured using annealed and calibrated LiF TLDs attached to the phantom. The annealing was carried out at the CERT, ABU Zaria, using Harshaw 4500 TLD reader. Dose measurement was done by first positioning the phantom and X-ray equipment for posterior-anterior (PA) chest X-ray examination, and inputting the exposure parameters (kVp, mAs, SSD) used during actual patient examinations in the hospitals. Each measurement was carried out by attaching the TLD badge on the front view of the water filled phantoms which was positioned in front of the X-ray source, and the corresponding SSD, KVp, mAs and the average thicknesses of the phantom recorded on a worksheet. A sachet of the TLDs is retained so that a background correction may be made. The exposed TLDs, as well as those used for background readings were read at CERT, ABU Zaria and the results tabulated.

A total of 20 TLDs were exposed on phantoms of various sizes (24cm, 20cm, 18cm and 16cm) for chest PA projection view using the range of radiographic parameters normally used for adult patients of various sizes in the hospitals. Twelve (12) and Eight (8) TLDs were employed at the Madonna and Nigerian Airforce Hospital respectively.

III. RESULTS AND DISCUSSION

3.1 Experimental data from Madonna Hospital Makurdi

Table 1 shows the radiographic parameters and phantom doses acquired from Madonna Hospital Makurdi. The results revealed skin dose levels ranging from 153.27 ± 0.77 to 4318.81 ± 21.59 µGy with an average value of 1808 µGy (1.801 mGy). Higher doses were recorded when mAs was increased from 1.2 to 2.0 for all phantom sizes. This result is above the ICRP recommended dose of 0.4 mGy for PA chest examination and 1 mSv for the general public. However, it is in agreement with some past studies (Shahbazi-Gahrouei, 2006). The regression (R^2) values obtained from the graphs of kVp/ESD and mAs/ESD were 0.327 and 0.689 respectively, as demonstrated in Figures 1 and 2. Regression values below 0.5 are insignificant and demonstrate nonlinearity of a data set while the reverse is the case for R^2 values above 0.5.

Table 1 Radiographic parameters and phantom doses from Madonna Hospital Makurdi.

S/no	Phantom size(cm)	SSD (cm)	kVp	mAs	Measured dose (µGy) ± S.E

1	24	91	65	1.2	153.27 ± 0.77
2	24	91	65	1.2	392.87 ± 1.96
3	24	91	75	2	4318.81 ± 21.59
4	20	95	60	1.2	3739.51 ± 18.69
5	20	95	60	1.2	417.53 ± 2.08
6	20	95	65	2	4250.71 ± 21.25
7	18	97	60	1.2	375.39 ± 1.88
8	18	97	60	1.2	407.38 ± 2.04
9	18	97	65	2	3036.01 ± 15.18
10	16	99	60	1.2	440.79 ± 2.20
11	16	99	60	1.2	478.21 ± 2.39
12	16	99	65	2	3690.01 ± 18.45

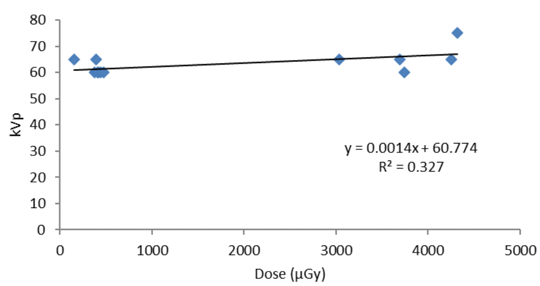

Figure 1 Graph of kVp against dose for Madonna Hospital Makurdi

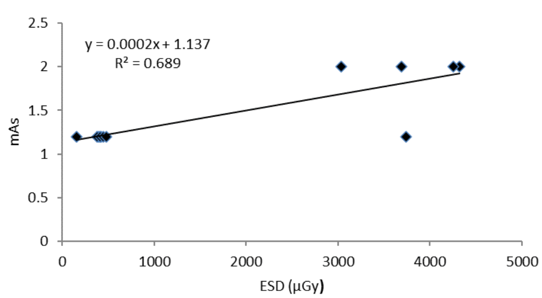

Figure 2 Graph of mAs against dose for Madonna Hospital Makurdi

3.2 Experimental Data from Nigerian Air Force Base Hospital Makurdi.

The radiographic parameters and phantom doses acquired from the Nigerian Airforce Hospital Makurdi are shown in Table 2. Acquired skin doses ranged from 92.46 ± 0.46 to 2823.8 ± 14.12 µGy with an average value of 963.225 µGy (0.963 mGy). This was found to be within the recommended skin dose limit of 1mGy for members of the general public but above the reference ESD of 0.4mGy recommended for patients undergoing PA chest examination by ICRP. The graphs of kVp/ESD and mAs/ESD demonstrated in Figures 3 and 4 respectively show good regression coefficients, $R^2 = 0.8097$ for kVp/ESD and $R^2 = 0.5961$ for mAs/ESD. This result validates the linearity between kVp/dose and mAs/dose.

Table 2 Radiographic parameters and phantom doses from Nigerian Airforce Hospital Makurdi

S/no	Phantom size (cm)	SSD (cm)	kVp	mAs	Measured dose (µGy) ± S.E
1	24	126	60	100	932.92 ± 4.66
2	24	126	75	120	2823.8 ± 14.12
3	20	130	50	80	564.62 ± 2.82
4	20	130	55	100	184.25 ± 0.92
5	18	132	60	100	1688.92 ± 8.44
6	18	132	50	80	92.46 ± 0.46
7	16	134	50	80	660.7 ± 3.30
8	16	134	50	100	758.13 ± 3.79

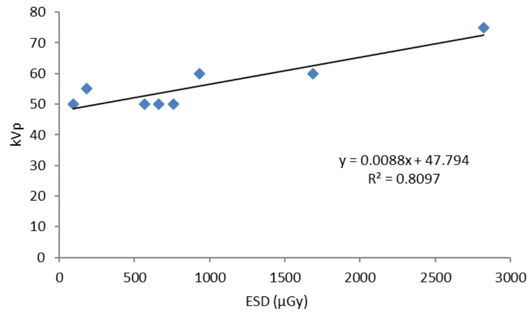

Figure3 Graph of kVp against dose for Nigerian Air Force Base Hospital Makurdi

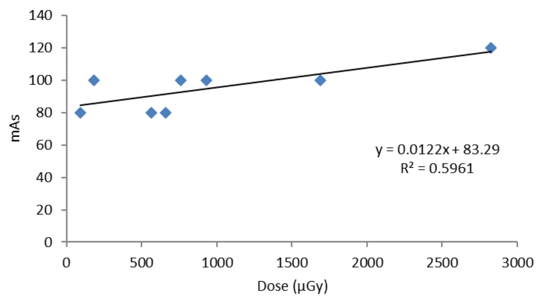

Figure 4 Graph of mAs against dose for Nigerian Air Force Base Hospital Makurdi

Table 3 presents a summary of the mean ESDs obtained from the two hospitals investigated. Both values are higher than the ESD recommended by ICRP for patients undergoing chest PA examination. This result could be attributed to poor choice of radiographic parameters, the age of the machines, and lack of quality assurance tests. Other inconsistencies in the results acquired in this study, such as variation in measured doses for the same values of technical factors ie kVp and mAs, an increase in kVp and mAs not yielding a corresponding increase in ESD, may be linked to the workload of the machine - as the electrons released hits the focus on the anode, a lot of heat is experienced at the point which increases the scattered radiation and reduces the transmitted rays, this in turn decreases the efficiency of the machine. Insufficient trained manpower in those hospitals could also be a factor.

Table 3 The mean entrance skin doses (ESD) with standard error (S.E)

S/no	Hospital	Number of TLDs used	Measured mean ESD (mGy)
1	Madonna Hospital Makurdi	12	1.810±0.34
2	Nigerian Air Force Base Hospital Makurdi	8	0.963±0.34

CONCLUSION

The mean ESD values obtained in this work shows that there is need to apply quality control measures to reduce the radiation dose to patients and the public in the 2 hospitals investigated. This could be achieved by increasing the SSD slightly above the current values, increasing the kVp, reducing the mAs and/or applying X-ray filtration to reduce the number of low energy photons that contribute to ESD. Acquiring newer equipment in addition to employing correct radiological parameters would significantly reduce the ESD to patients without a reduction in the quality of diagnostic information obtained.

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