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Measurement of Entrance Surface Dose of Chest and Pelvis: A Study with the use of Thermoluminescent Dosimeter

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ABSTRACT

The main aims of this study were to measure the entrance surface dose of chest and pelvis X-ray examinations using thermo-luminescence dosimeter crystal and to compare these data with the national and international recommendations of diagnostic reference level of these two examinations. A total of 200 crystals were calibrated at diagnostic energy level and exposed while performing 36 chest PA and 24 pelvis AP X-ray examinations of adult patients. This study demonstrated that the measured entrance surface dose for the chest and the pelvis were 0.384 mGy and 2.624 mGy. The diagnostic reference level for the chest obtained from this study was found lower than the local recommendation of Norway but it was higher than international recommendations. On the contrary, the diagnostic reference level for the pelvis was found higher than the local recommendation but it was lower than the international recommendations. The main cause of this variation was due to the difference in physical parameter of the patients and the equipments used.

INTRODUCTION

Medical exposure is by far the largest human-made source of exposure to ionising radiation and it continues to grow considerably due to its usages in modern health care practice (Suliman et al, 2014). In recent days, dramatic increase in the application of latest technologies such as digital radiography, computed tomography (CT) and fluoroscopy have even increased the exposures and the patient undergoing radiological examinations are committed to receive high radiation doses(Warren-Forward et al., 2007). The latest report of the United Nations Scientific Committee on the Effects of Atomic Radiation states that medical exposures contribute to 20% of the total annual effective dose per caput globally(Mahesh, 2009). It is interesting to note that the corresponding figure is as high as 50% in a developed country like the United States(States, 2009). Furthermore, there is a great variation in radiation doses exposed to the patients for the same type of radiological examinations performed locally and internationally (Gray et al., 2005). For instance, a significant disparity in radiation dose has been reported for the same type of investigations such as chest and pelvis in different hospitals in Europe(Brennan & Johnston, 2002). This indicates that there is a need for the standardization of dose for a particular type of radiological examination.

Digital imaging systems offer several important clinical and economical benefits over conventional film-screen systems. However, the implementation of the digital imaging is likely to invite an added radiation dose to the patients due to the fact that radiographers tend to use over exposures to increase the image quality and to avoid repeat examinations. This practice of over exposure is termed as exposure factor creep (Edmonds, 2009). To overcome this foreseeable pitfall, different measures were adopted for the dose optimization, and one of the most conducive ways is the implementation of diagnostic reference level (DRL)(European Commission, 2001). The commonly used parameters for the measurement of DRLs are entrance surface dose (ESD) and dose area product (DAP). The ESD is the dose entering the patient's skin including backscattered radiation from the patient during a particular investigation. Out of various methods of measurement of ESD, the most reliable method is the use of thermo-luminescent devices (TLD) (J.C. Waite, M. Fitzgerald).

METHODOLOGY

The dosimeters used in this study were TLD-100 (Lithium Fluoride) LiF: Mg, Ti (rods) with the dimension of 1x1x6mm^3 and 16mg weight. A total of 200 crystals were used for annealing process. All crystals were heated at 400^{o}C for one hour, then 15 minutes between the blocks of aluminium and finally at 100^{o}C for 20 hours. The crystals were calibrated for diagnostic energy (120Kv) at the radiation field of a Philips Medical System (MEDIO 50 CP-H X). A DAP meter was adjusted on the exit of x-ray tube and was used to correlate the readings with the properly calibrated patient skin dosimeter (PSD) Raysafe Multimeter (Unfors AB, Mølndal, Sweden). The TLDs were positioned on a thin plastic tape in air, 10cm above the patient table, to avoid backscatter. Four detectors of the PSD were placed just below the crystals beneath the plastic to check the homogeneity of the exposure to all crystals. All the crystals were irradiated to the same dose level of approximately 3 mGy (with 70kV, 6.3mAs) to calculate individual calibration factor (ICF). The irradiated crystals were read out in a TLD reader (HARSHAW 5500) and a unique identification code was given to all the crystals. This procedure was repeated twice to check the reproducibility. The individual calibration factor (ICF) for each TLD was calculated by;

$$ICF= \frac{(Average\ PSD\ Reading)}{(Individual\ Crystal\ Reading)} \quad \ldots\ldots\ldots\ldots\ldots\ (1)$$

Thus, the dose obtained in crystals from x-ray examination was calculated with the relationship;

$$Dose=TLD\ Reading \times ICF \quad \ldots\ldots\ldots\ldots\ldots\ (2)$$

All the patients included in this study gave a written informed consent before their participation. The TLD crystals in a triplet set for a single patient were exposed while performing X-ray examinations of chest postero-anterior (PA) and pelvis antero-posterior (AP) view. The calibrated TLD crystals were irradiated using the X-Ray machines of Department of Radiology at UNN (Philips 700 mA, 150 KV installed in 2008). These TLD crystals were irradiated on 36 adult patients of chest PA examination at the Skin-Focus Distance (SFD) of 180 cm using high kV technique (137-144 kV) in erect position. Likewise, for the pelvis the TLD crystals were exposed in supine at 80cm SFD at (70-85 Kvp) on 24 adult patients. In both examinations, the TLD crystals were exposed on the skin surface at the centre of X-ray beam. The irradiated TLD crystals of only acceptable quality radiographs were selected and this was decided by the concerned radiological technologists.

The irradiation process of all the TLD crystals was completed in three weeks of time. During this period, the unexposed and exposed crystals were kept separately in a room away from the radiography lab. Following irradiation, the crystals were taken for the read out with a TLD reader at the radiotherapy department of the same hospital. To remove background noise, the crystals were heated in an oven at 100^{0}C for 10 minutes before read out. The TLD reader was connected with a personal computer and the data obtained from each individual crystal was stored in an Excel spead sheet according to the prior identification code. Since, three TLD crystals were used for a single patient; these three readings were averaged to get an ESD of an individual patient. These average ESD values were used for the statistical analysis. A simple descriptive statistical analysis was performed with the Minitab (version 16, © Minitab Inc. State College, PA, USA)

RESULT

The obtained mean ESD value for the chest was 0.384mGy and its third quartile value was 0.435mGy.

Table 1: Types of THR

Part examined	No. of Patients	Mean	St Dev	Maxi mum	Mini mum	Q3
Chest PA	36	0.384	0.053	0.480	0.278	0.435
Pelvis AP	24	2.624	1.273	4.873	0.549	3.721

Similarly, the mean ESD value for pelvis was 2.624 mGy and its third quartile was 3.721 mGy. It can be observed that there was a small variation in the ESD value of chest (0.480 – 0.278) mGy

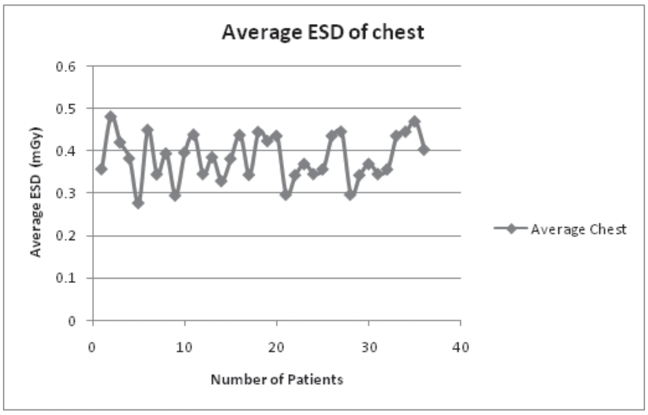

Figure 1: Entrance surface doses (ESD) from patients of chest X-ray (PA view)

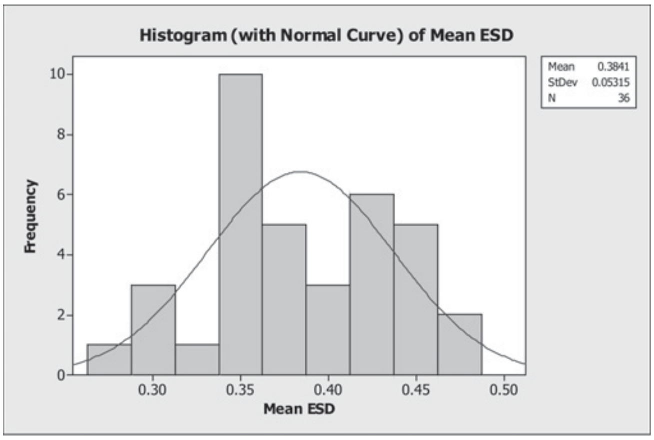

Figure 2: Histogram plot of the mean ESD (mGy) of chest examination (PA views)

Conversely, in the case of pelvis, the range between the maximum and the minimum ESD was high (4.873 – 0.549) mGy.

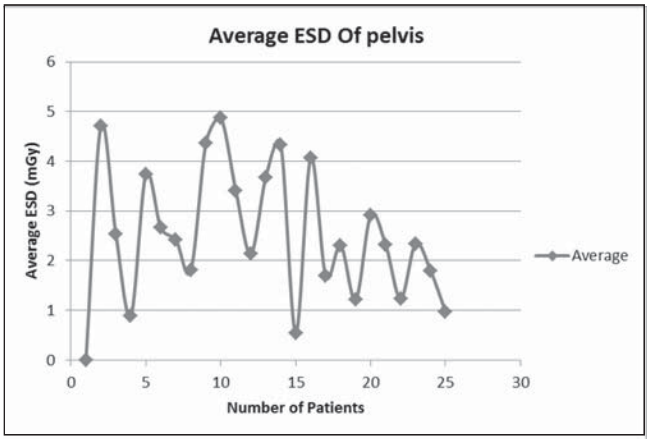

Figure 3: Entrance surface doses (ESD) of pelvis X-ray (AP view)

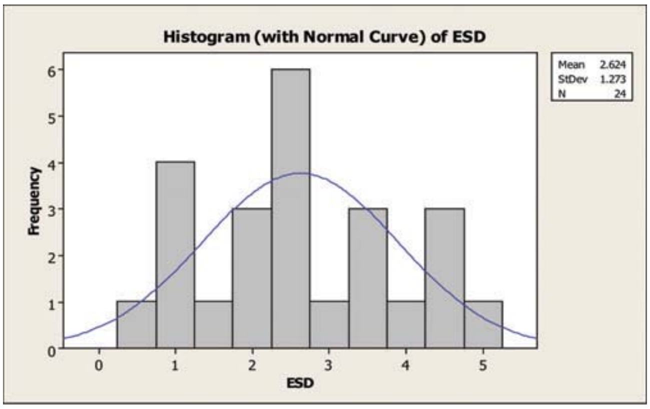

Figure 4: A histogram plot of the mean ESD (mGy) of pelvis x-ray (AP View)

Furthermore, Table 2 compares the recommendation of DRL values provided by the NRPA and the CEC. It is evident that the obtained third quartile value for chest was lower than the recommendation of NRPA but it was higher than those of CEC and UK recommendations. Similarly, the obtained value of pelvis was higher than the NRPA recommendation but it was lower than those of the CEC and UK recommendations.

Table 4: Comparison of obtained DRL values with the DRLs given by the NRPA and the CEC

Examinations (Body Part)	Obtained DRL (mGy)	UK recommendation DRL (mGy)	NRPA recommendation DRL (mGy)	CEC recommendation DRL(mGy)
Chest PA view	0.435	0.2	0.52	0.3
Pelvis AP view	3.721	4	2.4	10

DISCUSSION

Some of the benefits of TLD crystal over DAP meter are its smaller in size, being tissue equivalent and can be placed directly on the patient skin to measure the entrance surface dose along with the back scatter. The obtained DRL values for chest and pelvis were found different from the recommendations of international organizations (Table 2). The obtained mean of ESD for chest was 0.384mGy whereas the mean for pelvis was 2.624 mGy, which suggests that the average dose used for pelvis radiography was about more than six times higher than that of the chest radiography. Furthermore, the range of dose for pelvis examination was high (4.873-0.549mGy) whereas this variation was very low for chest radiography (0.480-0.278mGy). The main reason behind this variation could be due to the difference in physical dimension (size and weight) of the patients and the equipment set up.

Although there are several other factors apart from the radiation dose that determine the image quality, it is important that the exposure used during standard radiography practice should not be higher than its local DRL value. The DRL is usually taken as the third quartile value of ESD so it provides the information that 75% of the participating radiological units use lower dose than the recommended DRL value. The NRPA and the CEC have given DRLs for all radio-diagnostic examinations.

In this study, TLD was used to measure ESD which is energy dependent. So, the calibration should have taken place at different diagnostic energy levels. Additionally, it did not take the patients' parameters (such as height and weight) into consideration for the ESD evaluation which varies with size and weight. Therefore, it is recommended that further ESD evaluation should consider these issues while performing prospective DRL measurements.

In this study, the ESD of chest and pelvis were measured using TLD crystals. The obtained results were compared with international recommendations. It was found that the chest DRL was lower than the NRPA recommendation but it was higher than the CEC and other recommendations. Similarly, the obtained pelvis DRL was higher than the given value of the NRPA but it was lower than the CEC and UK recommendations. The results of different studies at several times show a decreasing trend of EDS value.

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