Effective Dose and Dose Area Product Assessment for Postero-Anterior Erect Chest X-ray Examinations of Adult Patients in a Selected Teaching Hospital in SriLanka

LHMIM Herath[1] and S Rosairo[2]

[1]Department of Radiography/Radiotherapy, Faculty of Allied Health Sciences, General Sir John Kotelawala Defence University, SriLanka
[2]Department of Radiology, Faculty of Medicine, University of Peradeniya, SriLanka
<# indeewariherath23@gmail.com>

Abstract— *Since the use of X-ray facilities and equipment has increased rapidly in medical practices and diagnostic radiology has an enormous share of public dose from man-made sources, a much greater attention has been paid to maintain the doses received by patients at a low level. According to the International Commission on Radiological Protection (ICRP) 1991 publication, the effective dose (ED) is a convenient indicator of overall risk-related exposure of the patient from an X-ray examination and dose area product (DAP) is a valuable radiation dose descriptor. This study aimed to assess the EDs (mSv) and DAPs (mGy.cm^2) to the patients of age over 18years, who were undergoing Postero-Anterior (PA) erect chest X-ray examinations at Kurunegala Teaching Hospital and to determine whether the estimated mean ED and DAP values are higher than the reference values or not. A quantitative study was done on a convenience sample of fifty (50) patients selected separately for two (2) X-ray machines using an indirect method to estimate the ED and DAP values. Mean ED and mean DAP values were calculated for each machine. Calculated mean EDs were compared with the typical value given by International Atomic Energy Agency (IAEA) and with the values found in similar literature. The results have shown that the estimated mean EDs of 0.0019 mSv and 0.0024 mSv were less (P<0.05) than the recommended value of 0.02 mSv and those in Sudan of 0.025 mSv and in Iran of 0.055 mSv. The estimated mean DAPs of 13.13 mGy.cm^2 and 17.51 mGy.cm^2 were also less (P<0.05) than those in UK of 120 mGy.cm^2 and in Romania of 110 mGy.cm^2. Therefore, the results of the present study suggest that the X-ray machines and the exposure parameters used are acceptable in terms of dose to the patient. The findings of this study can serve as basic data for effective radiation protection and safe radiation management. This study suggests that establishing of local diagnostic reference levels (LDRL) is important so that researchers can compare their work.*

Keywords: Effective Dose, Dose Area Product, Postero-Anterior

I. INTRODUCTION

The X-ray examination with image-receptor (film) represents the first method of radiological investigation for more than one century. Its benefits are immense and have revolutionized the practice of the medicine. The radiation doses received by the patients during such investigations have been very poorly taken into consideration during the first years of using this method (Bogucarskis, *et al.* 2005).

The use of X-ray facilities and equipment has increased rapidly in medical practices and diagnostic radiology has an enormous share of public dose from man-made sources. For example, diagnostic radiology and nuclear medicine procedures are the cause of about 88% of collective effective dose from man-made sources in the US (Faulkner, *et al*. 1999).

From the stochastic point of view, the probability, but not the severity, of the stochastic effects grows up in parallel with the increase of the exposure since there is no evidence of the existence of any threshold for radiation. This means that any radiation dose, regardless of its size, may have a potential to make tissue damages.

To assess the stochastic risk from heterogeneous radiation, ICRP has recommended determination of ED and it has been introduced to express a radiation dose related detriment in situations where the dose to the patient body is not uniform (Toosi, *et al*. 2006).

DAP is a product of surface area of patient that is exposed to radiation at the skin entrance multiplied by the radiation dose at this surface and it could be measured either directly by using a transmission ionization chamber (DAP meter) at the surface of the X-ray tube collimator or indirectly by using a mathematical approach. Since the measurement of DAP is suitable for achieving optimum degree of safety during radiological examination of patient and radiation-induced bioeffects are directly related to both the magnitude of the radiation dose and the total amount of tissue that is irradiated, DAP is a valuable radiation dose descriptor (Bidemi, *et al*. 2012).

The general objective of this study was to assess the EDs and DAPs to the patients who are undergoing chest X-ray examinations in a selected Teaching hospital. The specific objectives were to estimate the EDs and DAPs to the patients of age over 18years, undergoing PA erect chest X-ray examinations at the Kurunegala Teaching Hospital and to determine whether the estimated mean ED and DAP values are higher than the reference values or not.

This work will contribute to the reduction of patient's dose and the results from this study would provide useful means of estimating DAP and ED received by patients during chest X-ray examination.

II. METHODOLOGY

A quantitative study was done using a convenience sample of fifty (50) patients selected separately for two (2) X-ray machines. Patients of age over 18years who underwent PA erect chest X-ray examinations were selected for the study and the subjects who refused to contribute to the research study, who were under 18 years of age, who were examined using high speed screen-film combination, who were very ill and old were not included. All the patients were given an informed consent form to take their consent. EDs and DAPs for patients were assessed by indirect method, using data of radiation output of the X-ray tubes, exposure factors (kVp and mAs) and the anatomical thickness of the patients. In this study the electronic pocket dosimeter (EPD) was used to plot the radiation output graph for each X-ray machine. The range of dose measurement used in the EPD varied from 1-9999 µSv. It has a silicon semiconductor detector with accuracy within ±20% from 10 to 9999 µSv. Ethical clearance was obtained from the ethical review committee of Faculty of Allied Health Sciences, University of Peradeniya.

First, a lead sheet was attached to the erect Bucky holder and then the EPD was attached on that lead sheet at the focus to film distance (FFD) of 180 cm. The radiation output values at different kVp settings were then measured using the EPD as given in Tables 1 and 2. After that the radiation output graphs were plotted by using these radiation output measurements as shown in Figures 1 and 2. Using those graphs, radiation output values were taken for the selected kV values in the study.

The anatomical thicknesses and radiographic exposure factors (kVp and mAs) used for each examination were recorded on a self-designed sheet. The anatomical thickness (cm) of the patients who met the inclusion criteria was measured using a tape measure of least count of 1mm, at the center point of the exposure field at the level of eighth thoracic vertebrae (i.e. spinous process of seventh thoracic vertebrae assessed by using the inferior angle of the scapula) which in turn was used to estimate the focus to skin distance (FSD) for the examination (Osibote and Azevedo, 2008). All FFD measurements were taken from the center of the tube to the film. Field sizes were also recorded at FFD (A_{FFD}) and Back Scatter factors (BSFs) were obtained from the values given by International Commission on Radiation Protection (ICRP) 85.

FSDs were calculated by using FFD and anatomical thickness of patients. In order to perform calculations of ED and DAP, information such as selected kV, mAs, and the FSD were entered into an Excel datasheet. The entrance surface doses (ESD) were calculated first by using the following equation (Obed, *et al* 2007) and those values were used to calculate ED (mSv) and DAP ($mGy.cm^2$) for patients.

$$ESD = BSF \times \text{Tube Output } (\mu Gy/mAs) \times \left|\frac{180}{FSD}\right|^2 \times mAs$$

Then the ED, which is almost 10% of ESD, was found for each patient using following equation (Mohamadain, *et al* 2005). $Cf_{(ED)}$ is National Radiological Protection Board (NRPB) factor, which is almost 0.1, used to convert the ESD to ED. Mean value of EDs was taken to compare with the typical mean value given by IAEA (2000) and with the values given in similar studies using Z-test. P values less than 0.05 were considered as significant.

$$ED = ESD \times Cf_{(ED)}$$

The DAP was calculated for each patient using following equation (Toosi, *et al*. 2006), and the mean value of DAPs was also taken to compare with the values given in similar studies which were done recently using Z-test. P values less than 0.05 were considered as significant.

$$DAP = (ESD/BSF) \times A_{FFD} \times (FSD/FFD)^2$$

III. RESULTS

Table 1. The radiation outputs of SHIMADZU type X-ray
7 **ne with 400 mA of tube current**

kV	Radiation Output (µGy) in 10 mAs			Mean Radiation Output (µGy) in 10 mAs	Mean Radiation Output (µGy) in 1 mAs
	1st Data set	2nd Data set	3rd Data set		
40	13	11	12	12.00	1.200
50	16	14	14	14.66	1.466
60	17	16	16	16.33	1.633
70	18	16	16	16.66	1.666
80	19	17	17	17.66	1.766
90	19	17	18	18.00	1.800
100	20	18	19	19.00	1.900
110	20	19	21	20.00	2.000
120	20	20	20	20.00	2.000

Table 2. The radiation outputs of AMRAD MEDICAL type X-ray machine with 400 mA of tube current

kV	Radiation Output (µGy) in 10 mAs			Mean Radiation Output (µGy) in 10 mAs	Mean Radiation Output (µGy) in 1 mAs
	1st Data set	2nd Data set	3rd Data set		
40	8	8	8	8.00	0.800
50	14	14	14	14.00	1.400
60	17	17	17	17.00	1.700
70	19	18	18	18.33	1.833
80	19	19	19	19.00	1.900
90	20	20	19	19.66	1.966
100	20	20	20	20.00	2.000
110	20	20	20	20.00	2.000
120	20	20	21	20.33	2.033

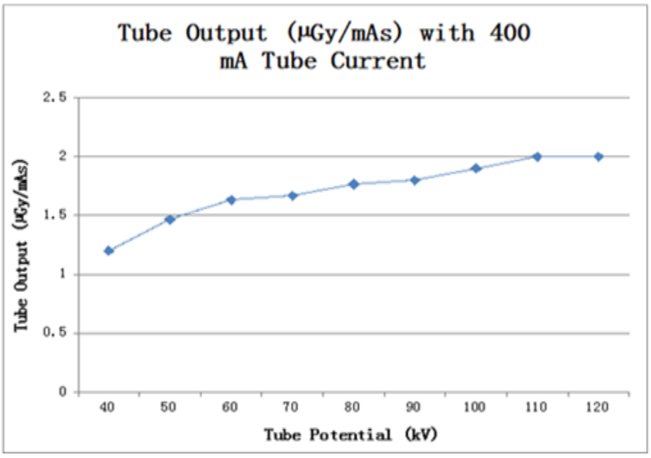

Figure 1. Tube output chart of SHIMADZU type X-ray machine

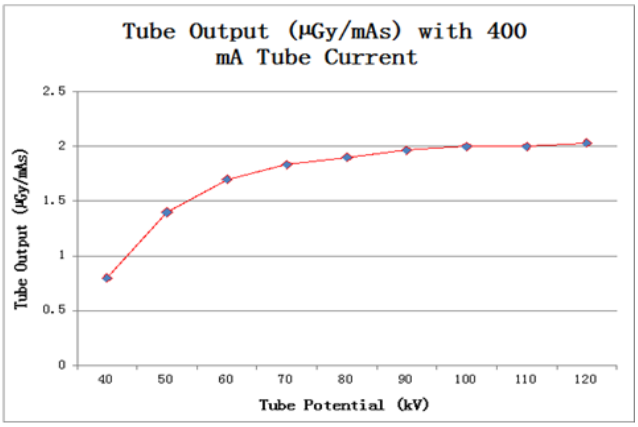

Figure 2. Tube output chart of AMRAD MEDICAL type X-ray machine

Table 3. The ED and DAP values with 400 mA tube current

Type of X-ray Machine	Range of ED (mSv)	Mean of ED (mSv)	Range of DAP ($mGy.cm^2$)	Mean of DAP ($mGy.cm^2$)
SHIMADZU	0.001-0.0034	0.0019	6.56-27.33	13.13
AMRAD MEDICAL	0.0014-0.0035	0.0024	10.79-24.00	17.51

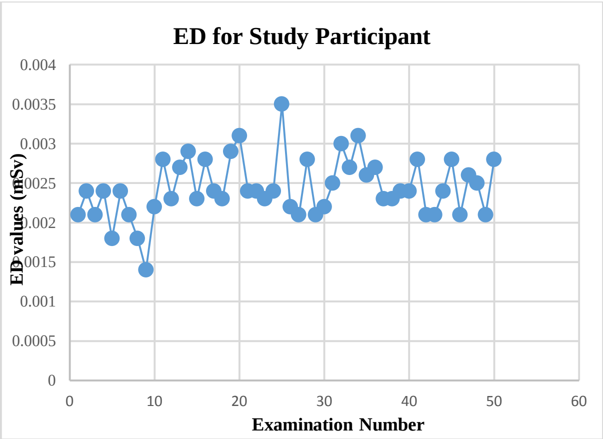

Figure 3. ED values of patients came for SHIMADZU machine

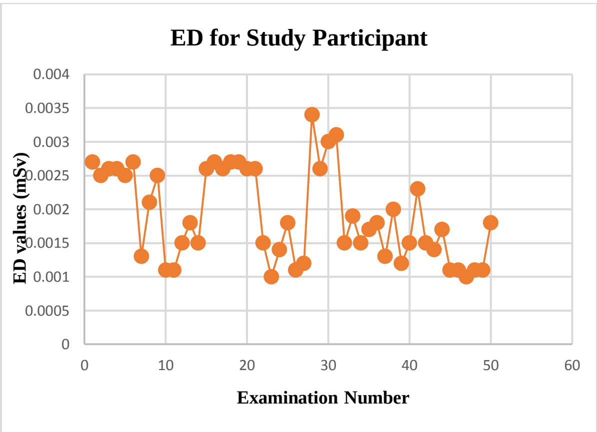

Figure 4. ED values of patients came for AMRAD machine

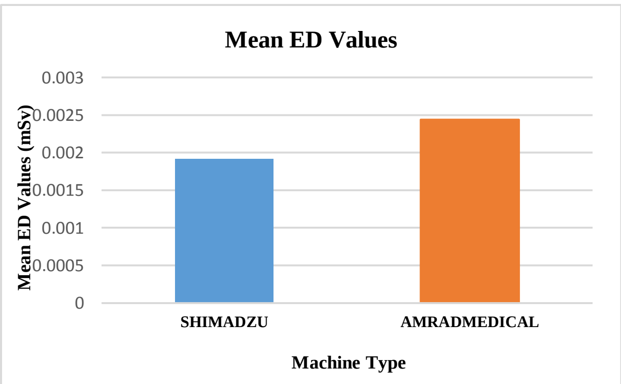

Figure 5. Mean ED values for machines used

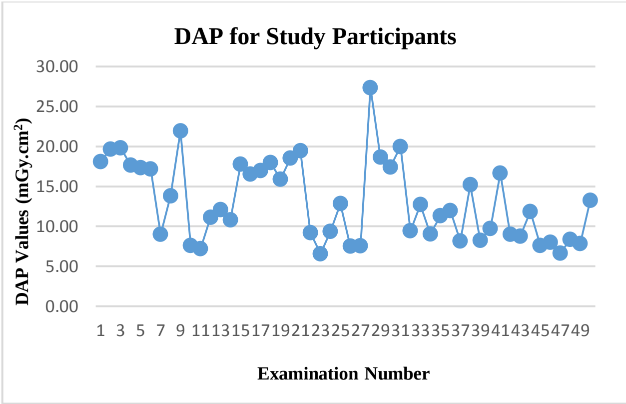

Figure 6. DAP values of patients came for SHIMADZU machine

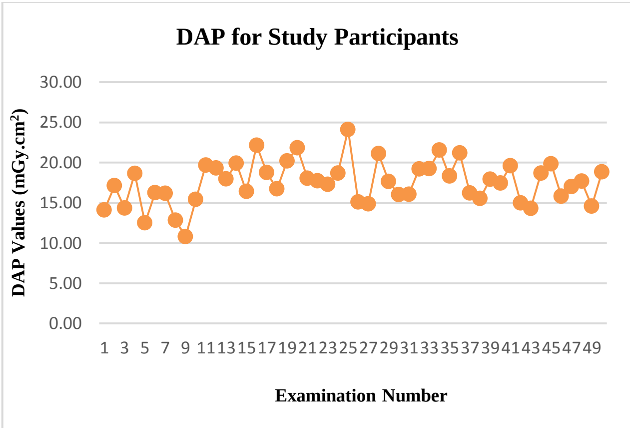

Figure 7. DAP values of patients came for AMRADMEDICAL machine

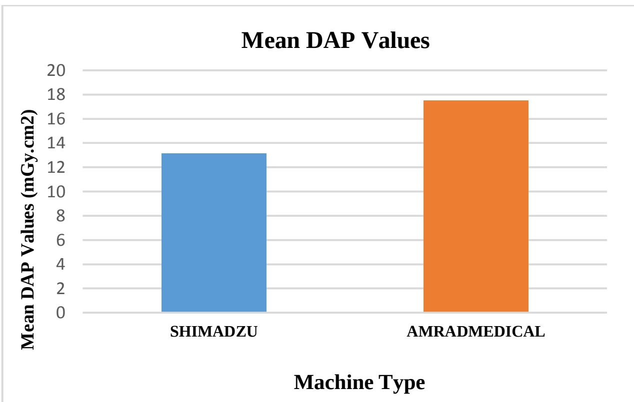

Figure 8. Mean DAP values for machines used

IV. DISCUSSION AND CONCLUSION

Determining the ED and DAP using the PA erect chest X-ray examination described in this study requires an estimate of the ESD to the patient. According to the calculations, mean ED values of the present study are 0.0019 mSv and 0.0024 mSv and the mean DAP values are 13.13 mGy.cm^2 and 17.51 mGy.cm^2.

Table 4 compares the mean values of ED obtained in this study with those in Iran (Aliasgharzadeh, *et al* 2015), Canada (Ernest, *et al* 2013), and Saudi Arabia (Taha, *et al* 2015) and with the recommended typical value given by IAEA (2000). Moreover, table 5 shows a comparison of mean DAP values obtained in this study with those in UK 2000 (Hart, *et al* 2000), Saudi Arabia (Nassef and Massoud 2014) and Nigeria (Bidemi, *et al* 2012).

Table 4. Comparison of mean ED values of present study with similar literature and with the typical value for chest PA examination

Type of Examination	This Study (mSv)	Iran (mSv)	Canada (mSv)	Saudi Arabia (mSv)	IAEA, 2000 (mSv)
Chest PA	0.0019 0.0024	0.04	0.0204	0.018	0.02

Table 5. Comparison of mean DAP values of present study with similar literature

Type of Examination	This Study (mGy.cm^2)	UK 2000 (mGy.cm^2)	Saudi Arabia (mGy.cm^2)	Nigeria (in three centers for male and female respectively) (mGy.cm2)
Chest PA	13.13 17.51	120	240	142 , 127 206 ,193 258 , 303

Comparing the calculated mean ED and DAP values applied in this study with the recommended value and with the values found in literature for chest PA reveals that there is statistical significant difference with the probability (P less than 0.05), i.e., mean ED and DAP values are below the guide levels. This mean that the radiation risk to an average patient in the hospital included in this work is low and the risk to workers in the hospital will be generally low. Therefore, the results of the present study suggest that the X-ray machines and the exposure parameters used are acceptable in terms of dose to the patient.

Moreover, the findings of this study show that there is a variation in the ED and DAP values in the same X-ray room may be due to differences in the patient size and exposure parameters, and between the rooms may be due to the differences in the patient size, exposure parameters and different technical characteristics of radiographic equipment.

The variations in the data obtained demonstrate the importance of creating awareness of radiation protection and regular quality control testing of radiographic equipment. In addition, it shows the importance of using standard protocols among the radiographic staff in order to standardize practice and to reduce the dose as low as reasonably achievable while quality of image is still preserved.

The findings of this study can serve as basic data for effective radiation protection and safe radiation management. In conclusion, the authors wish to suggest that establishing of local diagnostic reference levels (LDRL) is important so that the researchers can compare their work and change their attitude and philosophy and wish to recommend that further studies are necessary in other areas of the country based on the same and other diagnostic X-ray examinations.

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