

Measurements of Entrance Surface Dose and Effective Dose of Patients in Diagnostic Radiography





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Abstract

In radiography, a dose to patients primarily depends on the Entrance Surface Dose (ESD) and the sensitivity of organs which are irradiated during treatment plan. The main goal of this study is to look into the patient's dose to assess ESD and ED for patients in digital diagnostic radiography examinations for the optimization of radiation protection of the patients who are exposed to radiation dose thereby facing the increasing probability of fatal cancer risk and other biological effects. Patients dosimetry carried out on 15 adult patients (Male-4 and Female-11) of age 20 to 69 years. The IAEA TRS No. 457 dosimetry protocol was followed in accordance with non-invasive kV-meter, DIAVOLT UNIVERSAL T43014-001400, locating at 100 cm from focus to surface distance for measurement of radiological parameters such as kVp and mAs. The ESD has a wide range from 0.05 mGy to 0.35 mGy for chest even for the same examination carried out on the patients of different age and gender and the corresponding effective dose lies from 0.01 to 0.04 mSv, additionally, in other parts like L-spine AP, Lat and in foot ESDs are 1.24 mGy, 2.06 mGy and 0.07 mGy respectively with their corresponding EDs are 0.13 mSv, 0.05 mSv and 0.0003 mSv. The ESDs and EDs reported in this study are generally lower than the doses published in literatures.

Keywords: Ionizing Radiation; X-Ray; Radiography; Entrance Surface Dose; Effective Dose

Introduction

Now-a-days, diagnostic X-ray examinations are very common and important source of all the medical exposures used in the medical diagnosis for world population [1]. Extensive demand of X-ray examinations in the developing countries and the increases of the number of X-ray machines have driven the increase use of this. Therefore, it is of being crucial importance to enforce radiation protection following the principles of justifications, optimization and individual dose limits during radiographic projection for lessening the corresponding risks. Quality control and dose measurement help the physician and physicist to assure that the doses received by the radiographic patients should be in according to the principle of As Low as Reasonably Achievable (ALARA) and the dose does not exceed the amount required to get proper radiographic imaging [2]. Due to the ionizing nature of the X-rays which means that their use is not completely riskless, dose assessment is necessary to enhance the optimization of the radiation protection of the patients and to

deliver minimum dose during examinations in the field of radiology [3].

As, X-rays are potentially harmful, the dose measurement is used either as a representative for radiation risk or as a step in actual estimation of the risk. A survey of personal performing ERCP found that patents as well as staff are also exposed to radiation which was equivalent to an estimated lifetime fetal cancer risk of between 1 in 3500 and 1 in 7000 [4]. It is therefore worthwhile that patient doses should be expressed in terms of a quantity which is closely related to radiation risk associated with X-ray examinations [5]. From this point of view, it is very important to figure out on what amount of radiation exposure has occurred during diagnosis in order to lessen extraneous radiation to patients [6]. Possibility of harm could estimate by quantifying the radiation received by patients who is undergoing X-ray examinations. In radiography, doses to patient depend on the Entrance Surface Dose (ESD), the

sensitivity of the organs and tissues which being irradiated during the radiographic projections [7].

In this study, three common examinations are focused as their importance to investigate whether the ESDs are within the recommended value of International Atomic Energy Agency (IAEA) to keep the patient dose as low as possible. Moreover, investigation finished to measure the patients' dose who are undergoing X-ray examinations and the estimation of the lethal risk for cancer incidence. The results of this study would be beneficial to lessen the patients' dose and would be used as the value for the quality assurance in optimizing the patient dose specially for that projection which is not in the Diagnostic Reference Level (DRL) like EC and NRPB.

Materials and Methods

This study includes three commonly performed diagnostic X-ray examinations at two hospitals namely; Delta Hospital Ltd. and Institute of Cancer Research and Hospital (NIRCH), Dhaka, Bangladesh. These hospitals were selected because of the high workload of patient. These most frequently used examinations on which the measurements were conducted are Chest (AP/PA/LAT), L-Spine (AP/LAT) and Foot on 15 (male - 4 and female - 11) patients and they were selected from a larger group of patients. As for convenient study, the patients were selected randomly considering their age, weight, gender where most of the patients were recommended to check disorder of chest. Besides, there were also two patients where one was recommended to check fracture in foot and another was for disorder of L-Spine. The inherent filtration of X-ray machines of two hospitals were 1 mm and 1.5 mm Al respectively. The radiographic equipment's were digital and the examinations were performed by Shimadzu (IEC60601-1-2-2001) and Siemens (Siemens part8375545g2107) units. Before initiating the measurement, X-ray generator and equipment were tested for time accuracy, voltage accuracy, output linearity, filtration (HVL) using PTW DIAVOLT Universal T43014 as a part of quality control test. Dosimetry protocol in this study was in according to the IAEA Technical Report Series No. 457 [8]. The ESD for patients were determined by measuring air kerma in indirect method during

the examination by using a calibrated kVp meter (PTW DIAVOLT Universal T43014). When the tube current, the exposure time and the focus to surface distance were known, ESD can be found by entering those parameters into the following formula [9]:

$$ESD = {}_n K_a (U, F) \times (100 \text{ cm} / \text{FSD})^2 \times P_{it} \times \text{BSF} \quad (1)$$

Where, ${}_n K_a$ is the tube output determined in units of $\mu\text{R}/\text{h}$ at a distance of 100 cm from the focus to surface with voltage U and total filtration F. FSD is the focus to surface distance (cm), P_{it} is the tube current product used (mAs). BSF is the backscattering factor measured experimentally using Alderson Rando Phantom by taking different field sizes and tube voltages as well as photon energies into account. Effective energies were evaluated by using the established empirical formula which was obtained by the interpolation value from Hubble mass attenuation coefficients [10] and backscattering factor was used correspond to the measured effective energy. Patients' information including gender, weight, age, examination type and projection was also recorded. After determination of ESD, the Effective Dose (ED), E (mSv), is calculated by using the following formula [11]:

$$E (\text{mSv}) = ESD (\text{mGy}) \times CC_{ESD} (\text{mSv/mGy}) \quad (2)$$

Where CC_{ESD} is the conversion coefficient found from the report of NRPB-R262 [12] which relates ESD to ED. Risk factor was estimated by risk calculator using effective dose and other physical parameters of the patients [13].

Results and Discussion

The measurements of doses in this study were performed on adult patients and patients of extreme body weight have been excluded from the analysis. Table 1 shows a summary of the patients' information and the technical parameters selected for various types of examination which was prescribed in both hospitals. Information about patients like age, number of patients, gender, types of projection and also the examination of X-ray are summarized as well as tube current-time (mAs) product and the applied tube voltages for digital radiography are tabulated as the technical parameters.

Table 1: Summary of patients' information and examination technical parameters from digital radiographic examinations.

Projection	Examination	Patient age (year)	No. of Patients		Examination Technical Parameters	
			Male	Female	kVp (mean)	mAs (mean)
PA	Chest	20-69	4	8	66.48	12.63
AP	Chest	50	0	1	62.40	20
Lat	Chest	50	0	1	65.60	28
AP	L-spine	55	0	1	71.40	40
Lat	L-spine	55	0	1	76.90	56
-	Foot	48	0	1	40.80	8

It can be seen from Table 1 that the tube voltage used for different X-ray examinations varied with respect to the type of examination. Very High voltages were avoided in this study for few reasons. As the use of very high voltages can cause the damage of tubes, so it was avoided to use kVps more than 85 for adult patients of average sizes. In case of fatty patients that consideration may be changed. For each type of radiograph, ESD values for each patient were calculated for each set of dose measurement in both hospitals. For all examinations, the ages ranged from minimum of 20 years to the maximum 69 years in this work. Table 2 summarizes the key dosimetry parameters for three types of radiographic examinations with risk factor in this study.

Effective dose is evaluated as a dose descriptor in diagnostic radiology that enables a direct comparison of the detriment

associated with different radiologic procedures. If patients' dose is expressed in terms of effective dose, it provides a congruent method of reporting effective doses from diagnostic radiologic examinations. The use of effective dose may also permit an estimate of patient risk to be obtained by using risk calculator. Table 2 also shows the risk factor for patients of different ages with different x-ray examination which is prescribed to them. For all x-ray examinations, ESD ranged from a minimum 0.05 mGy to the maximum of 2.06 mGy and the effective doses were 0.0003 mSv to 0.13 mSv. The estimated ESDs compared with published works elsewhere and internationally established diagnostic reference level [3,14-20] and the estimated ED compared with published works elsewhere [3,15,21,22] are shown in Tables 3 & 4 respectively. In this study the tube voltages used for different examinations were between 50 and 77.40 kVp except in foot where the value is 40.80 kVp.

Table 2: Shows that in the same x-ray room and same projection there were variations in the ESD values which may be related to the patient size and the different technical parameters of radiological equipment used.

Organ	Gender	Entrance surface dose (mGy)	Age (years)	Effective dose (mSv)	Risk factor (%): incident per population
Chest	Female	0.1210±0.0050	35	0.0120	1.35×10^{-4} (1:740741)
Chest	Male	0.1140±0.0040	20	0.0110	1.27×10^{-4} (1:787402)
Chest	Female	0.1030±0.0030	60	0.0100	4.8×10^{-5} (1:787402)
Foot	Female	0.0660±0.0020	48	0.0003	2×10^{-6} (1:50000000)
Chest	Male	0.1360±0.0050	54	0.0140	6.3×10^{-5} (1:1587302)
Chest AP	Female	0.2210±0.0060	50	0.0220	1.49×10^{-4} (1:671141)
Chest Lat.		0.3480±0.0100		0.0350	2.37×10^{-4} (1:421941)
Chest	Male	0.1180±0.0040	50	0.0120	6.1×10^{-5} (1:1639344)
Chest	Female	0.1100±0.0040	35	0.0110	1.24×10^{-4} (1:806452)
Chest	Female	0.0750±0.0020	45	0.0080	6.4×10^{-5} (1:806452)
L-Spine AP	Female	1.2400±0.0410	55	0.1330	7.58×10^{-4} (1:131926)
L-Spine Lat		2.0600±0.0810		0.0520	2.97×10^{-4} (1:336700)
Chest	Female	0.0450±0.0010	32	0.0050	6.2×10^{-5} (1:131926)
Chest	Male	0.0750±0.0040	66	0.0080	2.6×10^{-5} (1:3846154)
Chest	Female	0.0600±0.0020	55	0.0060	3.4×10^{-5} (1:2941176)
Chest	Female	0.1660±0.0050	45	0.0170	1.36×10^{-4} (1:806452)
Chest	Female	0.2160±0.0060	69	0.0220	7.8×10^{-5} (1:131926)

Table 3: ESDs for various X-ray examinations compared with radiographic procedures surveyed in other countries and DRLs.

Projection	Examination	ESD in Present study	ESD in Previous work				DRL		
			D. Hart et al., 2012 [14]	Ernest et al., 2012 [15]	Al-Kinani et al., 2014 [16]	Rasuli et al., 2016 [17]	EC (1999) [18]	IAEA (1996) [19]	NRPB (2000) [20]
AP	Chest	0.2210	0.16	0.57	-	1.12	-	-	-
Lat	Chest	0.3480	0.48	0.94	1.73	2.20	1.5	1.5	1.0
PA	Chest	0.1100	0.12	0.14	0.64	1.0	0.3	0.4	0.2
AP	L-Spine	1.2400	4.6	3.72	13.3	3.09	10	10	6
Lat	L-Spine	2.0600	7.9	6.28	35.97	7.5	30	30	14
-	Foot*	0.0660	-	-	-	-	-	-	-

*The ESDs value in foot is 0.1 which is given by M. T. Taha et al., 2015 [3].

Table 4: Comparison of ED for representative radiographic examinations.

Projection	Examination	ED in Present study (mSv)	ED in Previous work(mSv)			
			D. hart et al.,2002 [21]	Mettler et al.,2008 [22]	Ernest et al.,2012 [15]	M.T. Taha et al.,2015 [3]
AP	Chest	0.0220	-	0.1	0.066	-
Lat	Chest	0.0350	-	0.1	0.11	-
PA	Chest	0.0110	0.016	0.02	0.0204	0.018
AP	L-Spine	0.1330	1.0	1.5	0.38	-
Lat	L-Spine	0.0520	1.0	1.5	0.13	-
-	Foot	0.0003	0.0005	-	-	0.001

The range of mAs used for most X-ray examinations performed on patients were from 8 to 56 mAs, it can be seen that the exposure factor used for patients in this study is not comprised of very high voltages and mAs is low. The ESD (mGy) for all examinations are lower than that reported by IAEA [19] and European Committee (EC, 1999) [18] as well as NRPB -2000 [20] due to the use of a low tube current. But, for chest PA it is very close to the recommended value. With the increase of tube potential, the value of ED will increase thereby increasing ESD. The ESD value in chest PA is closely related to the value of M. T. Taha et al. [3] and D. Hart et al. [21]. Estimated value of an ED in foot is very closely related to the value given by D. Hart et al. [21] and M. T. Taha et al. [3]. For chest AP, ED is related to Ernest K. Osei [15]. For other X-ray exposure the value of ED is lower than that mentioned in Table 4.

Conclusion

The ESD measured indirectly does not exceed the values which are recommended by the international organizations. ESD values differ in the same X-ray room due to the patient size as well as exposure parameters because of maintaining the stability. Though due to short duration only three examinations were focused, further study is required for other X-ray examinations. As X-rays are prescribed in a large number to check the condition of chest for getting information about any diseases or in case of any accidental case, proper care is needed during conducting such kind of examination. For Chest AP there is no DRL. So, this study will be useful in establishing DRL recommended by EC and IAEA as well as NRPB which will help delivering dose to patients during this projection (Anterior to Posterior). This study also contained data about foot on which a few survey has been done that will help in establishing DRL because there are no international recommended values for foot and it will stand for the present condition about foot. This will help in providing compact information about patients' whole body dose that is ED during examination of different projection of organs which is difficult to get in other references. There is also information about risk factor which is required to create awareness in using this radiography system.

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