Effective Dose Evaluation for Chest and Abdomen X-ray Examinations

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Abstract: *Background: The aim of this study was to estimate effective dose (ED) via the indirect measurement of the entrance surface dose (ESD) to patients undergoing chest and abdomen examinations in Hera General Hospital (HGH). Material and Methods: The ESD per examination was calculated from X-ray dose output measurements at 80 KV, 10 mAs and tube output parameters for a patient sample size of thirty eight cases conducted X-ray units at HGH. Effective doses (ED) were then estimated using ED/ESD conversion factors based on ICRP-103. Results: Hospital mean ESD for chest posterior anterior was 0.126 ± 0.027 mGy and for abdomen anterior posterior was 1.89±1.14mGy. Themean effective doses for chest posterior anterior and abdomen anterior posterior were 0.02mSv and0.25mSvrespectively. Indirect measurement of ESD is easier than measuring ESD directly for reasons related to patient collaboration. Conclusions: Hospital mean ESD for chest posterior anterior was 0.126 ± 0.027 mGy and for abdomen anterior posterior was 1.89 ± 1.14 mGy. The mean effective doses for chest posterior anterior and abdomen anterior posterior were 0.02 mSv and 0.25 mSv respectively. Indirect measurement of ESD is easier than measuring ESD directly for reasons related to patient collaboration.*

Keywords: ESD, ED, ED/ESD conversion factors, Radiology, Indirect, X-ray dose out put

1. Introduction

X-ray medical imaging is the largest manmade or artificial source of radiation to the general public and the population (1,2).Dose measurements are required to comply with certain international guidelines and regulations. The International Atomic Energy Agency (3) as well as the European Commission (4) have recommended diagnostic reference levels, (DRL) for radiation dose in medical imaging. DRLs is not a regulatory limit on the dose that can be administered to a patient, it is simply an indicative value. If the dose delivered by an imaging facility consistently exceeds the DRL, it is an indication that the facility should further optimize their scanning protocols. In Saudi Arabia, the National Center for Radiation Protection (SNCRP) in King Abdul-Aziz City for Science and Technology (KACST) is responsible for the optimization of radiation protection and suggesting the best guidance levels for radiation dose in medical imaging.

Entrance skin dose (ESD) is defined as the absorbed dose to air on the X-ray beam axis at the point where the X-ray beam enters the patient or a phantom including the contribution of the backscatter radiation [3].On the other hand, effective dose(ED) is the best quantity for estimating radiation detriment to patients. The major benefit of using the effective dose is that this parameter accounts for the absorbed doses and relative radio sensitivities of the irradiated organs, and therefore, better quantifies the patient risk. However effective dose has the limitation that it cannot be measured directly on a patient, it must instead be calculated. Effective doses are generally calculated from routine dose measurements using conversion factors appropriate to the conditions of the exposure (4). ESD can be measured directly on a patient or inferred from technique parameters and a measurement of the x-ray output under reference conditions. For this reason ESD is the quantity of choice for the optimization of radiation protection of patients in conventional diagnostic radiology examinations. Moreover, assessment of the ESD for patients plays an important role in generating a guidance level for diagnostic X-ray machines (4).Indirect measurement of ESD is easier than measuring the ESD directly for reasons related to patient collaboration, convenience, and the feasibility of using X-ray dose output factors and the operating parameters of the X-ray machine in a reference mathematical equation. Our aim in this study is to perform indirect measurement of the entrance skin dose (ESD) and estimate the effective dose (ED) to patients undergoing chest and abdomen diagnostic X-ray examinations in Hera General Hospital, (HGH).The results were compared with established international diagnostic reference levels (DRLs).

2. Materials and Methods

The study was conducted at Hera General Hospital (HGH).The ranges of the mean exposure parameters, tube voltage (kVp), current time product (mAs) and focus to skin distance (FSD) at the selected hospital for chest and abdomen examinations are shown in Table 1. The output of each x-ray unit under reference conditions was determined with a calibrated solid-state detector, Unfors [Mult-O-Meter 407L]. The detector was placed at 100 cm from the tube focus along the beam axis and the output was measured at 80 kVp and 10 mAs for X-ray machine at HGH. The ESD was calculated using an indirect method. Once the tube potential (kV), the tube current time product (mAs),) and the focus to skin distance (FSD) are known, the ESD can be calculated from equation (1) as discussed by Davies et al(5).

Table 1: Mean X-ray exposure parameters for posterior anterior (PA) projections of the chest and anterior posterior projections (AP) of the abdomen

kVpmAs FSD, cmProjection Examination				
Chest	PA	108-119	1.41-4.15	125-156
Abdomen	AP	59-81	1-30	95-158

$$ESD = OP \quad \left(\frac{kVp}{80}\right)^2 \quad mAs \quad \left(\frac{100}{FSD}\right)^2 \quad BSF \quad (1)$$

Where (OP) is the output (OP) , in µGy (mAs)-1 of the X-ray tube ,(kV) the tube potential, mAs, the product of the tube current in (mA) and the exposure time (ins), FSD, the focus-to-skin distance (in cm) and BSF, the backscatter factor.,The IAEA reported that a backscatter factor (BSF) of 1.37 should be used for calculating the ESD for a tube potential of 80 kVp, a field size of 30 x 30 cm ^{2} and a total filtration of 3 mm Al equivalent (6). All technique parameters and the BSF were entered in equation (1) to calculate the ESD for each patient to predict the ESD before X-ray imaging. The effective dose is estimated by multiplying the mean ESD by conversion factors, E103/ESD, using equation (2). E103/ESD is the conversion factor reported by Wall et al(7).

$$ED = ESD \quad E103/ESD (2)$$

3. Results

The tube output per mAsof the X-ray machines at HGH was50.8 ± 0.1µGy/mAsHalf value layer and radiographic technical data for the modern X-ray unitarepresented in Table 2. Half value layer (HVL) was determined experimentally.

Table 2: X-ray tube outputs, in µGy(mAs)$^{-1}$ at 80 kVp for HGH

Hospital	Radiographic unit/model	Half Value Layer, mm Al eq.	X-ray tube outputs, in µGy (mAs)$^{-1}$
HGH	GE/XR 650	2.9	50.8 ± 0.1

A total of 38radiographs were included in this study. The proportion of each examination by number of patients was 66% for chest-PA, 34 %for abdomen-AP. The distribution and mean value of ESD for each examination across all individualadult patients' exposures, calculated according to equation (1), are reported in Table 3. Standard sized patients (70 ±15) kg including chest-PA and abdomen-AP radiographic procedures. Some radiographic such as skull, lumber spin and cervical spin omitted because of missed in Orthopedic doctor.

Table 3: Summary of ESD (mGy) used for effective dose calculations

Projection	Min	Max	Mean	Standard Deviation	Max/Min ratio
Chest-PA	0.07	0.17	0.126	0.027	2.4
Abdomen-AP	0.72	2.93	1.89	1.14	5.4

The meanvalues are shown in the Table 3. A comparison between the mean ESD obtained in this work and established international reference dose levels (3,8,4) for each examination is shown in Table 4.

Table 4: Comparison of the hospital mean of the ESDs (mGy) in the present work to some international dose values (in mGy)

Organization with DRLs				
Projection	This Work	IAEA [3]	NRPB [8]	CEC[4]
Chest PA	0.126	0.2	0.2	0.3
Abdomen-AP	1.14	5	-	-

The mean ESDfor chest PA examinations was found to be 0.126mGy and the mean ESDs for abdomen AP were found to be 1.14mGy respectively. The effective doses for each type of X-ray examinations were estimated as shown in table 5. An effective dose, E (given in µSv) is calculated by multiplying the mean ESD by conversion factors, E103/ESD with coefficients (9).The comparison of the effective doses for Chest PA and Abdomen AP of X-ray examinations with the international publications (8,9 and 10)were estimated and compared as shown in table 6.

Table 5: Effective doses (mSv) estimated from ESDs

Projection	No. of patients	E_{103}/ESD[13]	Min	Max	Mean
Chest	25	0.131	0.01	0.02	0.02
Abdomen	13	0.132	0.1	0.38	0.25

Table 6: Comparison of present hospital mean EDs (mSv) to some international EDs

	Mean Effective Dose , mSv,			
Projection	Present	Hart et al (9)]	NRPB (8)	Suliman and Habbani, (10)
Chest PA	0.02	0.014	0.03	0.03
Abdomen AP	0.25	0.43	1.36	-

4. Discussion

As shown in Table 4 all the ESDs calculated for chest, abdomen were found to be within the corresponding diagnostic reference levels (DRL) recommended by the former National Radiological Protection Board (8)now Public Health England and International Atomic Energy Agency, IAEA (3) and lower than the DRL recommended by the European Commission (4) The variations in ESDs studied may be attributed to factors such as exposure parameters (kV, mAs) and FSD. However, the relative low dosage levels found in this study could be attributed to another factor, such as new equipment that was in use. The results are useful to national and professional organization and can be used as a baseline upon which future dose survey could be computed. As shown in table 6 all the EDs calculated for chest and abdomen were found to be within the effective doses calculated by other groups (8-10). The effective dose is the best quantity for estimating radiation risk to patients. The results reflect the necessity of optimizing the parameters for X-ray imaging.

5. Conclusion

The indirect method for calculating the ESD assists medical physicists predicting the ESD before X-ray imaging. The indirect entrance skin doses for chest PA, abdomen AP computed for the patients in this study does not exceed the reference diagnostic levels reported by international organizations. The results are useful to national and

professional organizations and can be used as a baseline for future dose surveys.

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