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Original Article

Effective Dose Calculation for Patients Undergoing X-ray Examinations in Erbil Hospitals

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Abstract

Background: In conventional X-ray examinations, patients are exposed to radiation. Biological hazards from radiation of any source is expressed as effective dose, and is measured in millisieverts (mSv). The purpose of this study was to assess and calculate the effective dose values for patients undergoing posteroanterior (PA) chest, abdomen, *anteroposterior* (AP) pelvis, and cervical spine X-ray examinations in general hospitals of Erbil city and compare it with those of other studies.

Materials and Methods: A total of 255 patients between 20-70 years of age participated in this work (85 per hospital). The patients' characteristics included age, sex, examination type, projection posture, and exposure parameters captured by NOMEX Multimeter including tube potential and current-time product. The mean effective doses (EDs) of four different examinations (chest (PA), pelvis (AP), abdomen, and cervical spine) were measured using the Monte Carlo method and compared with those of other studies.

Results: The mean EDs were calculated 1.04, 2.01, 3.12, and 3.22 mSv for chest (PA), pelvis (AP), abdomen, and cervical spine, respectively. All ED values in this study were higher than those of published studies. The aim of the study was to increase the awareness of the radiographer and patients undergoing conventional X-ray diagnostic radiology on the risk of ionizing radiation for radiological protection in Erbil hospitals.

Conclusion: The mean EDs were increased by an increase in the age; this may increase the probability of cancer incidence and heritable diseases. Hence, dose optimization is required due to more probable incidence of cancer when compared to other studies.

Keywords: Monte Carlo method, Effective dose, X-ray

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Introduction

Diagnostic X-ray is a known diagnostic practice, and the number of examinations by it has increased recently (1), despite an increasing risk of ionizing radiation to human being. Radiation exposure from medical imaging gives the greatest collective absorbed dose to the patients when compared to other activities using ionizing radiation (2, 3). Dose as low as reasonable achievable (ALARA) (2) with a sufficient amount of exposure to radiation improves image quality, and does not exceed the amount required to get proper radiographic images (2, 3). Just as in X-ray radiological image, there is the need to review existing protocols to obtain images with sufficient quality for a reliable diagnosis and also with the optimization purpose for proper application of techniques that use ionizing radiation (4, 5). The International *Commission* on Radiological Protection (ICRP) (2) reported that 36% of human-made radiation comes from diagnostic imaging procedures, with a risk of 5% from X-ray machines (5).

The use of ionizing radiation has become a common practice with unquestionable benefits[2]. Radiation dose can be evaluated in terms of entrance skin dose (EDS) in each radiograph, which is considered an important parameter in evaluating the amount of dose received by the patient during the x-ray examination (6-8). EDS must be monitored to optimize the patient dose. Effective dose (ED) can be measured using the Monte Carlo method for estimating radiation risk of irradiative field during the investigation of many organs and tissues that are exposed to ionizing radiation during the imaging procedures (9-11).The aim of this work was to estimate the dossed values of adult patients in medical imaging centers during the conventional X-ray examinations of posteroanterior (PA) chest, anteroposterior (AP) pelvis, abdomen, and cervical spine in Erbil public hospitals, Iraq.

Materials and Methods

This work was carried out in public hospitals of Erbil city, Kurdistan Region, Iraq. Monte Carlo method was used to measure the ED values for patients in four different examinations, including chest (PA), pelvis (AP), abdomen, and cervical spine. Parameters that were used for the measurement of ED values were collected during the examination performed. Adult patients aged ≥ 18 years old were included in this study.

To calculate the ESD, the following X-ray tube exposure parameters including peak tube voltage (kVp), time of exposure (S), current–time product (mAs), filtration of X-ray tube, and the focus-to-film distance (FFD) were reported.

ED value is the total of the weighted equivalent doses to the determined organ, and gives a useful quantity to assess radiation hazards (ICRP). Monte Carlo method requires the ESD, tube voltage, X-ray tube filtration, current–time product, age, sex, height, and weight of patient, as well as determining the area of the anatomical regions across images (12-14). ESD can be expressed by the following equation (5):

Effective dose value (ESD)= Output of X-ray tube (OP)× (peak voltage of X-ray tube (kV) /80)^2 × current –time product (mAs) × (100/ focus-to-film distance (FFD))^2 × backscatter filter (BSF)

Results

EDs were measured for 255 patients who underwent X-ray diagnostic examinations in public hospitals of Erbil. Projection included chest (PA), pelvis (AP), abdomen, and cervical spine parameters. ED data were collected from September-December 2018 for the present work.

Table 1 shows patients' characteristics and technical factors related to the patients who participated in this work, and had undergone various examinations in general hospitals. Their average weight was 70 kg and overweight patients were excluded from the study. Patients were from 18 to 72 years old, and the voltage was selected from the least 70 kVp to the highest 90 kVp. Moreover, mAs ranged from 42 mAs to 45 mAs. The lowest and the highest ESDs were 7.39 and 17.52 mGy, and the parameters estimated from X-ray machine were calculated as ED (Table 1).

Conversion factors (Table 2) for the calculation of ED values are commonly used to determine radiation dose in conventional x-ray imaging and to realize radiation risks for different investigations and different ages. Table 2 shows variation in conversion factors between projections, which are strongly related to the age of the patient. The results showed that the conversion factor varied according to the location of the field. Using the Monte Carlo method, it is easy to compute the EDs from easily measured quantities. The program is based on stochastic mathematical simulation of the interactions between photons and material, where photons are emitted from a point source into the solid angle specified by the field size and focal distance. The interaction probability depends on the photon energy and the interacting material. A mean value of the absorbed energy in a specific organ, and the effective dose can be calculated via simulation of a limited number of photon histories in an x-ray field.

Table 1. Patients' Characteristics and Technical Parameters for Selected Examinations in 3 Hospitals

Examination and Projection	Age (y)	Voltage (kVp)	mAs	FFD (cm)	Mean ESD (mGy)
PA chest	41 (18-65)	70	42	90	7.39
AP pelvis	49 (28-70)	85	45	90	17.52
Abdomen	55 (20-71)	80	40	100	11.67
Cervical spine	45 (18-72)	90	45	100	8.73

Table 2. ED Conversion Factors for Selected Examinations and Projections

Examination and Projection	Conversion Factor (ED/ESD)	Effective Dose mSv
PA chest	0.141	1.04
AP pelvis	0.123	2.17
Abdomen	0.267	3.12
Cervical spine	0.368	3.22

Table 3. Comparison Between the Present ED and That of Other Published Literature

Examination and Projection	ED of the Present Study (mSv)	Rasuli et al (13)	Mettler (5)
PA chest	1.04	1.00	0.02
AP pelvis	2.17		0.6
Abdomen	3.12	-	0.7
Cervical spine	3.22	3.09	0.20

According to Table 3, ED values of the patients who had gone under PA chest and cervical spine examinations in this study were higher than those of other studies in terms of the same types of examinations (7). For all X-ray examinations in this study, the EDs were 1.04 mSv to 2.22 mSv. Table 3 shows the typical EDs of common X-rays. EDs varied relatively across studies.

Discussion

Parameters shown in Table 1 were used to measure the ED value by Monte Carlo method, which requires the measurement of projection, equipment voltage, current-time product, total filtration, and patient characteristics such as age, sex, height, and weight. Table 3 compares the examination and projection measurements of this study with those of other studies. The results showed a good agreement between the results of the present study and those of Rasuli et al (13) and Mettler et al (5) as depicted in Table 3. The variation with other works is related to the difference in irradiation parameters (e.g., tube voltage, total filtration, and beam direction). For comparing radiological technologies, ED is defined as an instrument for the optimization of cancer deaths. Note that in International Commission on Radiological Protection (ICRP 103, 2007), for an accurate risk factor for stochastic effects, the ED should be e as low as reasonably realizable to reduce the stochastic and deterministic risks. Regarding the ED values measured by Monte Carlo method, the results showed suitable agreement with those of other studies (11). According to Table 3, higher ED values were observed compared to the published articles in terms of similar types of examinations. The use of ED may also permit an estimate of patient risk to be obtained by PCXMC software. The calculation of ED depends on technical parameters of X-ray tube, beam height and width, field of view, and effective radiation dose.

When making images of the cervical spine, the thyroid gland must be protected, as this tissue is a very sensitive organ to radiation and this may significantly contribute to the effective radiation dose (1). According to Table 3, comparing the ED values of this study and those of other studies revealed differences not in the same order (14). Monte Carlo method is very useful in optimizing the radiation exposure, and thereby reducing the radiation-induced damages and cancer (15). The results of this the study showed the usefulness and practicality of using Monte Carlo method in evaluating the EDs in clinical X-ray examinations. Ionizing radiation is potentially harmful, and the ED measurement can be used as a representative of radiation risk.

Conclusion

This study measured the EDs used in public hospitals during performing diagnostic imaging tests. Patient characteristics and exposure factors were entered into the software for the measurement of ED values. This study found higher ED values than recommended values. It seems the technical and clinical factors must be optimized in general hospitals to reduce the risk of cancer incidence in result of excessive radiation doses. The results can form a basis for medical radiation protection. According to ALARA, it is important to lessen the amount of radiation exposure during the imaging examinations. Radiation risk could be estimated by the investigation of radiation quantity received by patients who undergo X-ray examinations in general hospitals.

Conflict of Interest Disclosure

Authors declare no conflict of interests.

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Ethical Statement

This work was registered in College of Medicine, Hawler Medical University, Kurdistan Region of Iraq, and approved by the Ethics Committee of College of Medicine, Hawler Medical University (Meeting Code:6, Paper Code:13, Date 23/6/2020). All patients in the study gave their consent and agreed to participate in counseling sessions.

Authors' Contribution

IKI wrote the first draft of the article; FFH managed the writing of the last version; and NKA edited the article.

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Informed Consent

All the patients in this study gave oral informed consent.

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