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Patients' dosimetry during lumbar radiographic examination (Lat) in certain hospitals at Dhi Qar governorate, Iraq

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ABSTRACT

The work is aimed at investigating the entrance surface dose (ESD) for adult patients undertaking routine lumbar X-ray examination, and therefore ensure that the patients receive no excessive radiation dose during this radiography. This study was conducted at 4 selected hospitals: Al-Hussein Teaching Hospital (AHTH), Al-Nasiriyah Teaching Hospital (ANTH), Al-Haboubi Teaching Hospital (AHTH) and Souq Al-Shuyoukh General Hospital (SASGH) in Dhi Qar, Iraq. The ESD was calculated for 102 adult patients who underwent X-ray examinations of the lumbar spine using the physical parameters (i.e. Tube voltage-kVp, Tube loading- mAs and distance between X-ray tube and detector- SID) from all considered X-ray units, as well as on the X-ray tube output that was measured using an ionization chamber (Rad-Check Plus). The enrolled patients also had their demographic information recorded (gender, weight and height). The finding demonstrated that the average ESD values were (4.886, 4.288, 6.047, 6.378, 5.949, 9.322, 12.731, 4.094) mGy for AHTH1, AHTH2, AHTH3, ANTH1, ANTH2, ANTH3, AHTH, SASGH, respectively. The ESD values were seen to be comparable with internationally recognized sources UNSCEAR 2010, UK 2012, EC, and IAEA and with previously published studies such as those in Sudan 2014, Iran 2020, Nigeria 2019, and Ghana 2023. Finally, further studies must be carried out, and the relevant institutions must conduct continuous training courses for radiographers to ensure that the radiation dose is within the recommended level.

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قياس الجرعة الشعاعية للمرضى أثناء الفحص الشعاعي القطني (الجانبي) في بعض مستشفيات محافظة ذي قار، العراق

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الــــخُـــلاصـــة **الكلمات المفتاحية:**

يهدف هذه العمل إلى التحقق من الجرعة السطحية الداخلة (ESD) للمرضى البالغين الذين يخضعون لفحص روتيني للأشعة السينية للعمود الفقري القطني الجانبي، وبالتالي التأكد من عدم تلقي المرضى أي جرعة إشعاعية زائدة أثناء هذا التصوير الشعاعي. أجريت هذه الدراسة في 4 مستشفيات مختارة: مستشفى الحسين التعليمي (AHTH)، مستشفى الناصرية التعليمي (ANTH)، مستشفى الحبوبي التعليمي (AHTH) ومستشفى سوق الشيوخ العام (SASGH) في ذي قار، العراق. تم حساب ESD لـ 102 مريض بالغ خضعوا لفحوصات الأشعة السينية للعمود الفقري القطني باستخدام المعلمات الفيزيائية (جهد الأنبوب-kVp، حمل الأنبوبة-mAs والمسافة بين أنبوب الأشعة السينية والكاشف-SID) في جميع وحدات الاشعة السينية التي تم اخذها بالدراسة، وكذلك على مخرجات أنبوب الأشعة السينية التي تم قياسها باستخدام عداد غرفة التأين (Rad-Check Plus). تم أيضًا تسجيل المعلومات الديموغرافية للمرضى المسجلين (الجنس والوزن والطول). أظهرت النتائج أن متوسط قيمة لـ ESD كانت (4.886، 4.288، 6.047، 6.378، 5.949، 9.322، 12.731، 4.094) mGy لكل من AHTH1، AHTH2، AHTH3، ANTH1، ANTH2، ANTH3، AHTH، SASGH، على التوالي. واعتبرت قيم الجرع المحسوبة قريبة بالمقارنة مع المصادر المعترف بها دوليا UNSCEAR 2010، والمملكة المتحدة 2012، والمفوضية الأوروبية، والوكالة الدولية للطاقة الذرية ومع الدراسات المنشورة سابقا مثل تلك التي أجريت في السودان 2014، وإيران 2020، ونيجيريا 2019، وغانا 2023. وأخيرا، يجب إجراء المزيد من الدراسات. ويجب على المؤسسات المعنية إجراء دورات تدريبية مستمرة لمصوري الأشعة للتأكد من أن الجرعة الإشعاعية ضمن المستوى الموصى به.

الجرعة السطحية الداخلة
الأشعة السينية للعمود الفقريالقطني(الجانبي)
جرعة المريض
الأشعة السينية التشخيصية

1. Introduction

Ionizing radiation such as X-ray is the highest frequently radiation used in medicine. Developing and developed countries use X-rays to produce high-quality diagnostic images, and because of the harmful side effects, it is necessary to protect patients undergoing diagnostic radiology examinations from unnecessary radiation [1]. Although alternative methods of diagnostic procedures are provided, the X-rays are still the mostly used in the field of medical diagnosis. In the recent years, the X-ray was the most significant contributor of people exposure to ionizing radiation from the sources of man-making radiation [2, 3]. Ionizing radiation has a high ability to ionize atoms, and this can lead to the breakdown of the chemical bond of DNA of tissue cells under exposure. Therefore, it is necessary to monitor the radiation dose for patients exposed to X-rays. In this regards, radiation protection involves regulating how ionizing radiation sources are utilized so that both the user and the general public are not exposed to levels of radiation that are too high, as advised by the International Commission on Radiological Protection [4]. Numerous research to assess the patient dose in term of ESD have been done in various countries. Additionally, organizations like the International Atomic Energy Agency (IAEA) and the National Radiological Protection Board advised using dosage restrictions to provide guidelines for medical exposures where X-rays must be justified [5]. According to a United Nations Scientific Committee on the Effects of Atomic Radiation report (UNSCEAR), the number of medical X-ray exams performed worldwide constantly increases. Radiologists are continually faced with the challenge of reducing patient exposure whenever possible while still employing doses sufficient to provide images of sufficient quality to enable accurate diagnosis [6,7]. The physician and physicist can be assisted by routine quality control and dosimetry measures to make ensure that the dose received by patients undergoing radiologic procedures complies with the ALARA (As Low as Reasonably

Achievable) standard [8]. Concerns about subjecting patients to increasing doses of diagnostic X-rays have grown, and the International Committee on Radiation Protection (ICRP) made recommendations to address this risk [9]. In order to lower patient dose without affecting the necessary level of image quality, the European Commission (EC) and the International Commission on Radiological Protection (ICRP) have advised using diagnostic reference levels (DRLs) for X-ray examinations [10, 11]. Previous studies dealt with the evaluation of patient dosimetry during Lumber spine X-ray examination [12-15]. The main goal of this work is to evaluate the ESD during Lumber spine (Lat) conventional X-ray Procedure in selected hospitals in Dhi Qar Governorate.

Study region:

This work was conducted in the main and large hospitals in Dhi Qar Governorate to include both the center and suburbs (see Figure 3.1). The hospitals are Al-Hussein Teaching Hospital (AHTH), Al-Nasiriyah Teaching Hospital (ANTH), Al-Haboubi Teaching Hospital (AHTH), Souq Al-Shuyoukh General Hospital (SASGH), in Dhi Qar, Iraq. Figure (1) presents an illustration for the Iraqi map (Left) and study region map to include the sites of studied hospitals.

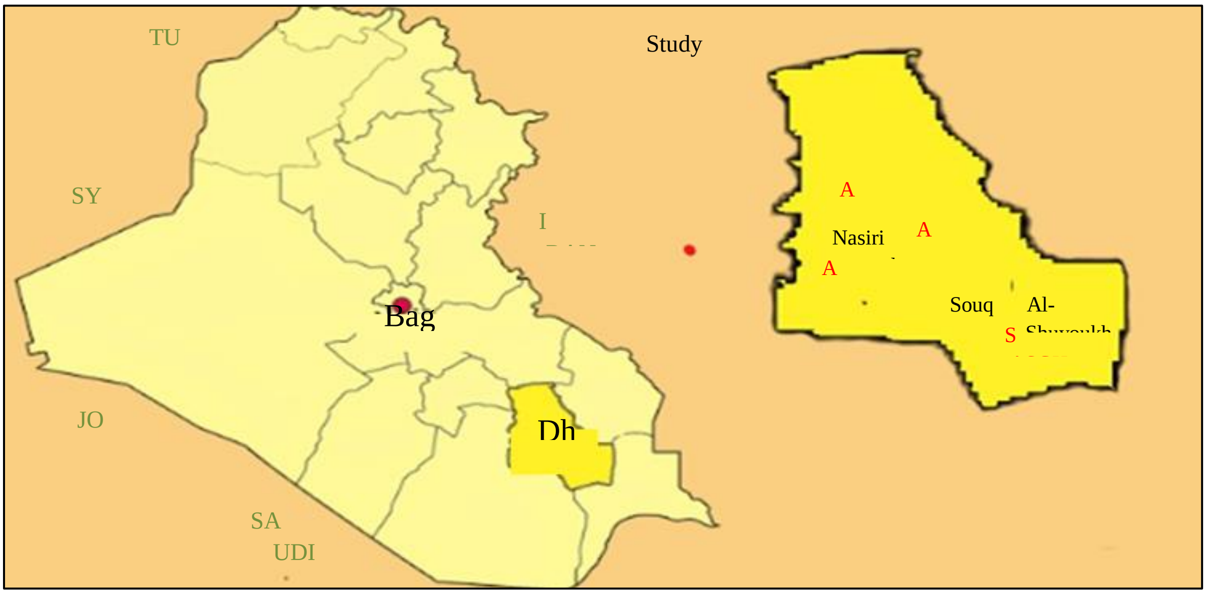

Figure (1): An illustration of the study region map.

Materials and Methods

The current work was carried out in the city of Dhi Qar – Iraq, it includes considering four main hospitals: (i.e. Al-Hussein Teaching Hospital, Al-Nasiriyah Teaching Hospital, Al-Haboubi Teaching Hospital, Souq Al-Shuyoukh General Hospital). This research work was began after obtaining official approvals from the Dhi Qar Health Department. This study includes eight X-ray units. Basically, information on each X-ray unit was reported. The latter information includes the X-ray tube manufacturing company, the unit model, the year of installation, and systems' type (see Table (1)).

Table (1): The particular data about the X-ray units.

Hospitals	Manufacturer	Model	Installation	System

			date	kinds (DR or CR)
AHTH [1]	Shimadzu (Japan)	R-20J	2008	CR
AHTH [2]	Shimadzu (Japan)	R-20J	2008	CR
AHTH [3]	Shimadzu (Japan)	R-300	2007	CR
ANTH [1]	GE (China)	5189248	2021	CR
ANTH [2]	GE(China)	5189248	2021	CR
ANTH [3]	GE(China)	5173054	2021	CR
AHTH	Shimadzu (Japan)	R-20J	2006	CR
SASGH	Shimadzu (Japan)	R-300	2012	CR

After obtaining patients' consent, demographic information for each patient, including sex, weight, and height, was recorded. Height was estimated using the height measurement tool (Tape measure), and these data were utilized to calculate the body mass index (BMI- $kg.m^{-2}$). The BMI was employed to know the size and shape of the patient body and how this might be related to physical parameters and radiation dose. Only adult patients were enrolled in this study (i.e. ≥18 years). A minimum number of 10 patient was considered in this work [16, 17]. The RAD-CHECK Plus ionization chamber, Nuclear Associates Div. For Victoreen, Inc., USA, serial number 0000107690 and X-ray model 06-526, was utilized for the determination of the X-ray output factor for each X-ray unit. During X-ray output measurement, the kVp values were taken to be ranged from (50 to 120 kV), while the mAs value was fixed at ten, and the distance was taken at100 cm from the X-ray unit (see Figure 2) [18, 19]. The measurement for each kVp was repeated three times to reduce random error of the X-ray output factor. After that, all the output factor values for each X-ray device were multiplied by the conversion factor of (8.7) mGy per Roentgen (R), and then divided by ten so that the output factor would be in (mGy/mAs) [20].

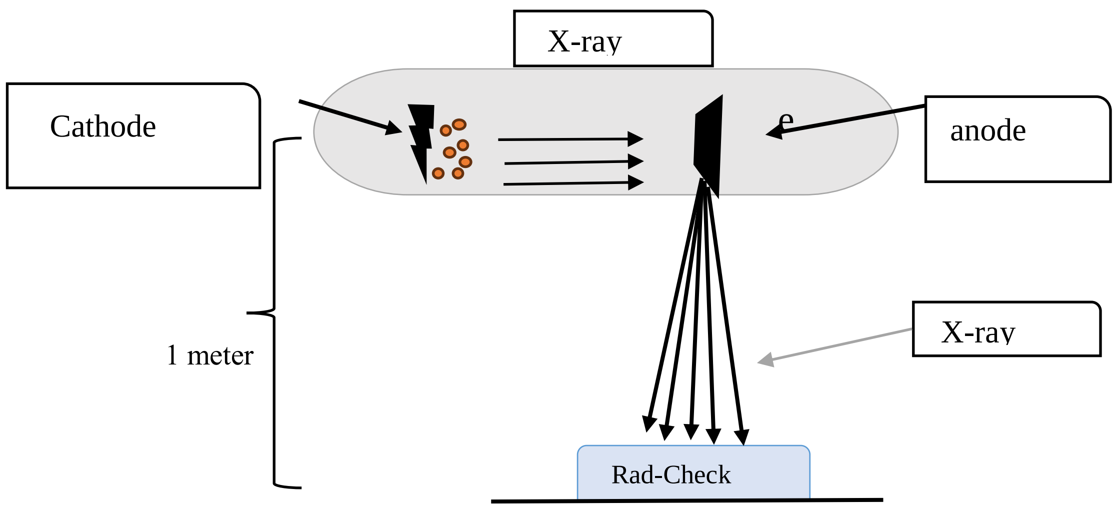

Figure (2): Shows the process of calculating the output factor of an X-ray tube.

After this, the following physical factors were reported: voltage of the X-ray tube (kVp), exposure product (milliampere × exposure time (s), mAs), and source-to-image detector distance (SID) for all patients undergoing lumber spine (Lat) radiographic examinations. These recorded factors were adopted to calculate the entrance surface dose for patients using the following formula:

$$\text{ESD (mGy)} = \text{OP}\left(\frac{mGy}{mAs}\right) \times \left(\frac{kVp}{80}\right)^2 \times \left(\frac{100}{FSD}\right)^2 \times \text{mAs} \times \text{BSF [21]}.$$

Where (OP) is the output of the X-ray tube (mGy/mAs) which was measured using 80 kVp and at a distance of 1 m (i.e.100 cm) and 10 mAs, FSD is the focus-to-skin distance (FSD = SID - patient thickness). BSF is a backscatter parameter whose value is 1.35 as reported in previous published studies [22]. The above equation was developed into a simple visual basic program to speed up and improve the accuracy of the ESD calculations. Additionally, the program would enable the execution of numerous calculations, which lowers the likelihood of error (Figure 3) [21].

Figure (3): The platform of the program used to calculate the ESD.

Results and Discussion

A total patient's number who were enrolled in this research was 102 patients (adults) who underwent lumbar spine (Lat) X-ray examinations. Table (2) presents the demographic data of the patients. According to this Table, it is clear that the average weight of the patients ranges from 74.50 ± (9.2) kg to 78.57± (9.5) kg. Regarding the height of patients, the average height was ranged from 167.70 ± (6.2) cm to 171± (6.3) cm; therefore, the average Body mass index (BMI) in this study ranges from 26.16 ± (5.2) to 27.11± (5.0) (kg.m^{-2}). Nevertheless, the observed slight difference in the average values of weight and height can be attributed to the natural variation of the country's people and the governorate in particular [23]. Also, the BMI can reflect the homogeneity of the patients considered in this study.

Table (2): Mean and standard deviation of weight, height and BMI for patients undergoing lumber spine (Lat) X-ray examinations for selected hospitals in Dhi Qar Governorate.

Hospital	Patient's demographic information		
	Weight (kg) Mean (SD)	Height (cm) Mean (SD)	BMI (kg/m^2) Mean (SD)
AHTH (1)	78.08(8.8)	171.00(6.2)	26.99(4.9)
AHTH (2)	75.58(9.6)	171.00(6.3)	26.16(5.2)
AHTH (3)	75.46(9.7)	170.62(6.7)	26.26(5.3)
ANTH (1)	76.28(9.5)	170.43(7.3)	26.65(5.5)
ANTH (2)	75.92(9.6)	170.54(7.2)	26.48(5.5)
ANTH (3)	78.16(9.6)	170.67(5.7)	27.11(5.0)
AHTH	74.50(9.2)	169.17(6.3)	26.35(5.2)
SASGH	78.57(9.5)	167.70(6.2)	26.91(5.2)

The highest value recorded for the tube output factor was 0.0763 (mGy/mAs) at AHTH, whereas the lowest value recorded was 0.0363 (mGy/mAs) at ANTH- room (2), as shown in Table (3).

Table (3): The output factors Measured for all X-ray units considered.

Hospital	X-ray units' output (mGy/mAs)
AHTH (1)	0.0554
AHTH (2)	0.0574
AHTH (3)	0.0476
ANTH (1)	0.0464
ANTH (2)	0.0363
ANTH (3)	0.0505
AHTH	0.0763
SASGH	0.0653

The exposure parameters used in calculating the ESD are presented in Table (4). From Table (4), it is clear that the minimum average value of kVp was 84 kVp reported at AHTH and SASGH, while the highest average value was recorded at AHTH 1 at 107.67 kVp. The average mAs value ranged from 21.23

mAs at AHTH 2 to 75.33 mAs at ANTH 3. The minimum average SID value for diagnostic examinations of the lumbar spine (Lat) was 98.07 (cm), while the maximum is 123.21 (cm) in the X-ray units studied. According to European standards, the recommended distance when performing X-ray examinations of the lumbar spine is 130 (cm). In this context, the distance reported in this study was less than 130 cm in all X-ray units, where the ESD value is linked to the SID value in an inverse relationship according to the inverse square law. This indicates that the shorter the distance from the X-ray source to the image detector, the greater the radiation dose to which the patient is exposed [24].

Table (4): Mean, Min and Max values of the physical parameters (kVp, mAs, SID) used for lumber spine (Lat) X-ray examinations in selected hospitals in Dhi Qar Governorate.

Hospital	kVp Mean (Min-Max)	mAs Mean (Min-Max)	SID Mean (Min-Max)
AHTH (1)	107.67 (90-120)	28.10 (22.0-32)	117.08 (110-125)
AHTH (2)	105.83 (90-120)	21.23 (16-25.6)	112.08 (100-120)
AHTH (3)	105.69 (90-122)	25.07 (20-34.0)	98.07 (90-115)
ANTH (1)	95.28 (80-110)	61.92 (50-75.0)	123.21 (110-140)
ANTH (2)	87.38 (80-95)	74.76 (63.0-80)	115.77 (110-120)
ANTH (3)	99.08 (80-110)	75.33 (60.0-85)	122.08 (110-130)
AHTH	84.00 (80-89)	72.50 (60-82.0)	110.42 (100-120)
SASGH	84.00 (80-88)	28.11 (20-40.25)	112.00 (112-112)

After calculating the ESD value using the above equation, the minimum, maximum, Mean, standard deviation, median, and Max/Min ratio of the ESD values for patients undergoing lumbar spine (Lat) examinations are all recorded in Table (5).

Table (5): Min, Max, Mean and standard deviation (SD) of the ESD (mGy) for patients undertaking lumber spine (Lat) X-ray projection of selected hospitals in Dhi Qar Governorate.

Hospital	No. of patient	Min.	Max.	Mean	SD	Median	Max/Min
AHTH (1)	12	3.253	5.966	4.886	0.980	4.658	1.833
AHTH (2)	12	3.202	5.510	4.288	0.840	4.122	1.720
AHTH (3)	13	4.518	7.032	6.047	0.874	6.026	1.556
ANTH (1)	14	4.893	7.340	6.378	1.660	6.166	1.500

ANTH (2)	13	4.823	6.825	5.949	0.820	6.125	1.415
ANTH (3)	12	6.391	10.955	9.322	1.596	9.628	1.714
AHTH	12	12.612	12.905	12.731	0.125	12.646	1.023
SASGH	14	2.622	6.385	4.094	0.905	3.984	2.435

According to the results presented in Table (5), AHTH recorded the highest ESD value with an average of 12.731 mGy, while SASGH recorded the lowest ESD value with an average of 4.094 mGy. From this Table, it is clear that there was a variation in the average values of the ESD across X-ray units in the same hospital and in other hospitals. The latter variation can be confirmed by the standard deviation, which ranged from (0.125 to 1.660). The data in Table (5) provides further evidence of the variation in ESD values through the ratio of Max/Min ESD values, where the maximum value is about 2.435 times larger than its associated minimum value in SASGH. In contrast, the minimum ratio is 1.023 times recorded in AHTH [25]. It is possible to argue that the variability in ESD values seen in the current study might be attributed to the difference in physical factors as can be seen in Table 4. From the resulted data of the output, the high output factor measured at certain X-ray unit can have an effect on the amount of radiation dose [26]. The ESD values obtained from this work were compared with the values reported in recognized international references and previously published studies, and the comparison was made with the UNSCER [27], UK [28], EC [24], IAEA [29], Sudan [22], Iran [30], Nigeria [31], Ghana [32] as shown in Figure (3).

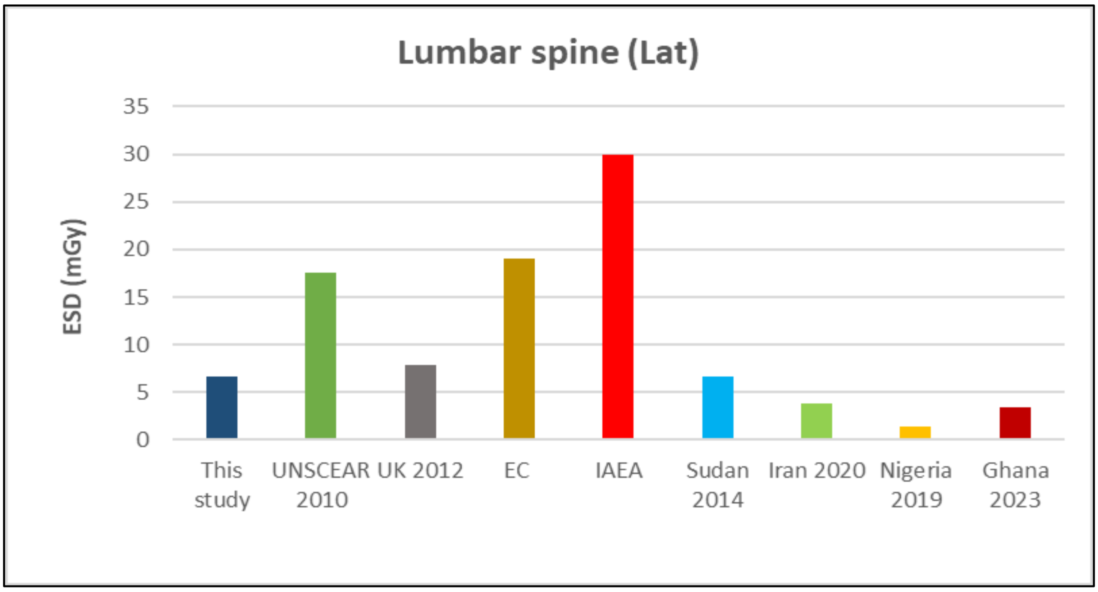

Figure (3). Chart showing ESD values in this research work comparison with international sources and published studies of X-ray examinations of the lumbar spine (Lat).

It can be noted from Figure (3) that Nigeria had recorded the lowest value for ESD value when compared with this study and previous publications. In contrast, the measured value for ESD in this work was lower compared to the level reported in UNSCEAR 2010 [27], UK 2012 [28], EC [24] and IAEA [29], while it was seen to be higher than those published in previous works: Sudan 2014 [22], Iran 2020 [30], Nigeria 2019 [31] and Ghana 2023 [32]. The results of this work demonstrated that the radiation dose to which the patient is exposed to during X-ray examinations is within the values allowed in international references UNSCEAR 2010, UK 2012, EC, IAEA. Nevertheless, the high level of ESD seen at certain hospital could be attributed to the high mAs adopted and the SID set for lumbar spine. It is also important not that the noticed variation may be resulted from a number of reasons. For example, different experience levels of operators in the field of radiography as well as natural variability in the body habitus of patients being examined radiologically can have a certain impact on patient dose variability [26]. Based on above and according to the radiation protection standards, it is, therefore, necessary to establish a diagnostic reference level (DRL) for the institution considered to ensure that the patient is not exposed to high doses of ionizing radiation. In these regards, radiographers and other radiography operators must implement all necessary procedures for optimizing the patient's dose and reaching the lowest dose levels. Medical physicists have made many efforts to reduce the radiation dose received by the patient in diagnostic imaging. In return, this reduction in dose should not affect the image quality which is not covered by this study. The currently used computed radiography (CR) system could be a reason for the high dose, as the image characteristics cannot be affected by the high dose. Nevertheless, modern systems can modify the image characteristics, and this, in turn, could be a reason for the patients to be exposed to an additional dose without the need for it [2, 26, 33]. Ultimately, this work is the beginning of conducting quality control of the excessive radiation doses to which the patient is exposed. Additionally, other studies must be carried out in the future to monitor the quality of the image while reducing the patient's doses. The patient's weight can also determine the dose the patients need while conducting diagnostic exam using the X-rays.

Conclusion

The ESD value was evaluated for patients examined radiographically by X-ray in a group of selected hospitals in Dhi Qar Governorate, Iraq. These included eight X-ray units with only a computed radiography system. It was noted, according to the results, that there was an apparent variation in the estimated ESD values, as well as a difference in the physical exposure factors adopted in calculating the radiation dose. The research results are comparable to international references and organizations UNSCEAR, UK, EC, and IAEA. Finally, it is highly recommended that it is necessary to conduct further studies and quality control checking for the radiation dose to which the patient is exposed.

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