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Experiment to evaluate the entrance surface dose delivered to the patient undertaking pelvic and abdominal X-ray examinations

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Abstract: **This study aimed to evaluate the radiation dose (X-ray examinations) received by adult patients (over 18 years of age) undergoing pelvic and abdominal X-ray examinations. The study was conducted at Al-Sadr Teaching Hospital, Al-Hakim General Hospital, and Al-Furat Al-Awsat Hospital. Private Medical Clinic (1) and Private Medical Clinic (2). At least 12-15 X-ray examinations were calculated for each type of radiological examination. The radiation dose was extracted using exposure factors, namely tube voltage (kVp), tube load (mAs), and focal skin distance (FSD-cm). The radiation dose was calculated for all patients involved in this work who underwent pelvic (AP) and abdominal (AP) examinations. The resulting data was analyzed using statistical analysis methods and compared to international reference values. radiation dose was evaluated using mathematical equation and knowledge of exposure factors (kVp, mAs and SID).**

The results at Al-Hakim General Hospital showed that the lowest dose value for the pelvis was (1.96) mGy, while the highest value was (2.94) mGy. The lowest dose per abdominal rradiography was (1.29) mGy, and the highest dose value was (2.84) mGy.

The results at Al-Sadr General Hospital showed that the lowest dose value for the pelvis was (1.73) mGy, while the highest value was (3.55) mGy. The lowest dose for abdominal X-ray was (1.66) mGy, and the highest dose value was (3.47) mGy. At Al-Furat Middle General Hospital, the results showed that the lowest dose value for the pelvis was (1.79) mGy, while the highest value was (3.6) mGy, while the lowest dose with abdominal X-ray was (1.79) mGy, and the highest dose value was (3.17) mGy. Concerning the private medical clinic, the results showed that the lowest dose value for with pelvis was (2.98) mGy, while the highest value was (4.74) mGy. The lowest dose with abdominal skin was (2.4) mGy, and the highest dose value was (3.84) mGy. Regarding the private medical clinic (2) showed that the lowest dose value for the pelvis was (2.41) mGy, while the highest value was (3.61) mGy. The lowest dose for abdominal radiography was (1.55) mGy, and the highest dose value was (3.35) mGy. Finally, the results demonstrates that the radiation doses for each of X-ray examinations are generally within the reference level.

Keywords: **abdominal X-ray examinations, adult patients, private medical clinic, radiological examination.**

1. INTRODUCTION

The beneficial applications of ionizing radiation were quickly discovered by the medical professions after the date of its discovery, more than 100 years ago. Throughout the time, new diagnostic and therapeutic modalities have been developed which resulted in that the health care level to be improved. This, in turn, has made the medical radiation exposures to be an important component of the total populations' radiation exposure [1].

Using of ionizing radiation (e.g. X- and gamma rays) in the medical field are estimated to be the largest established applications amongst other man made radiation sources. Recent estimates have outlined the annual figure of diagnostic and interventional radiological examinations worldwide at over 3000,000,000 and at over 5000,000 radiation therapy procedures. Around 78% of diagnostic exposures are resulted from the use medical X-rays, 21% caused by dental X-rays, while the remaining 1% are resulted from the people exposure during nuclear medicine techniques [2].

It is worth noting that the annual radiation dose resulting from all diagnostic examinations is approximately 2.5 billion Person-Sieverts, which corresponds to a global average of 0.4 micro Sieverts person-years. However, there is significant variation in radiation procedures performed around the world. The average annual values per capita in countries classified as high and low levels of healthcare are 1.3 micro Sieverts and 0.02 micro Sieverts, respectively [1,3].

However, it should be acknowledged that radiation dose resulted from radiotherapy procedures is not included in above mentioned averages, since they include a very high radiation dose (in the limit of 20-60 Gy) precisely administered to target so they can remove disease [4]. Increasing the use of medical radiation together with increasing the resultant doses is an expected matter especially following the improvement in health care pattern which resulted from the introduction of new technology. An example of such increases are likely in the application of computed tomography (CT) [5,6] and digital imaging (CR and DR). Additionally, the continuous growing in medical technology of radiology can also be expected in developing countries. Therefore, the radiation risks that might be associated with such expected increase in the use of medical exposures should always be balanced by its diagnostic benefits.

For the radiation protection purposes, the exposure to the ionizing radiation can be divided into 3 types:

1. Medical exposure: This primarily refers to patients being exposed to ionizing radiation (exposure) as part of their diagnosis/treatment.

2. Occupational exposure: This refers to the exposure of workers (radiographers) to ionizing radiation as part of their medical and industrial work.

3. General exposure: this Includes all other types of exposure to which members of the public are exposed. Medical radiation exposure is defined in the International Basic Safety Standards for Radiation Protection and other international standards and global organizations. standards on ionizing radiation sources and the safety of radiation sources [4,7,8] as: “Exposure to which patients are exposed as part of their medical diagnosis or treatment in dentistry and other medical fields; by persons who are not occupationally exposed to the patients.”[9]

2. MATERIALS AND RESEARCH METHODS

In this study, the ionizing radiation dose was calculated in terms of the patient's entry surface dose (ESD) for two x-ray projections. This included pelvic and abdominal x-ray examinations. The latter projections were considered in this study because they were the most common x-ray projections recorded in x-rays in most departments. Before calculating the dose, exposure factors (physical parameters) were recorded for each patient's radiation exposure and x-ray projection. These included kVp, mAs, and the distance from the x-ray source to the image detector (SID) (cm). This latter information is necessary to calculate the surface dose (ESD) (mGy = J/kg). The ESD is the absorbed dose in air from the x-ray beam at the point of entry of the beam into the patient's skin [10]. The ESD calculation includes the contribution of the scattering coefficient. The ESD was then calculated using the equation shown in (1)

$$ESD = OP\left(\frac{KV}{80}\right)^2 \times mAs \times \left(\frac{100}{FSD}\right)^2 \; BSF \ldots\ldots\ldots\ldots\ldots (1)$$

where output(OP) is the x-ray tube output coefficient in mGy per milliampere. This coefficient was obtained from a set of variables: the distance was 100 cm from the x-ray tube focus, the voltage was 80 kV, the current was 10 mA, kVp is the tube voltage, mAs is the product of the tube current (mA) and the exposure time measured in seconds, and FSD is the distance between the x-ray machine and the patient's skin measured in centimeters. FSD was calculated by subtracting the patient's body thickness (cm) from the SID. The patient's thickness used in this work was obtained [11].Since measuring the patient's thickness directly during workload is difficult and possibly unavailable and may cause some discomfort to patients, or patient refusal, BSF is the backscattering factor and a value of 1.3 is usually used in the diagnostic range and according to the patient's thickness [12]. To accomplish this task more quickly and efficiently, the electrostatic discharge was calculated. Therefore, the above equation (Equation 1) was formulated in a simple, accessible program using Visual Basic. This program also facilitates the execution of a large number of calculations, significantly reducing the error rate.

3. RESULTS AND DISCUSSION

This work was conducted in three major hospitals in: Najaf and two private clinics, including three hospitals considered in this study and two private clinics, namely Sadr City Teaching Hospital, Al-Hakim General Hospital, and Al-Furat Al-Awsat. Hospital, Eid Al-Qassim Clinic 1, and Abdul Qasim Clinic 2. Tables 4-1 to 4-5 show the results obtained from skin dose calculations for the X-ray examinations studied (eg, pelvis and abdomen) in terms of (mean ± σ) and exposure factors (kVp, mAs, SID). Analyzes were performed on measurements in all three radiology departments and the two clinics. It is clear from Table (4-4) that the doses provided at Al-Qassim Private Clinic (1) were higher compared to the doses of the other hospitals included in the study. This can be attributed to the use of relatively higher X-ray tube parameters. From the rest of the radiation units, it can be noted that the highest skin dose values were about 3.34 mGy, which was reported for the abdomen in the Qassim Private Clinic (1), and also for the pelvic examination, the results were higher compared to the rest of the examinations. This is due to the relatively high tube parameters (kVp and mAs) with a small SID (cm), used in this hospital for this type of X-ray examination. Variations in these parameters, as reflected in the range values, are due in part to differences in patient size and the technique used. Compare the average radiation dose values for adult individuals with other reference dose values in Tables (4-6) reveals that the majority of doses were above the corresponding reference levels in Iran [13,14]. Also it was noted that for all three hospitals and two clinics, it was noted that Medical Clinic 1 received the highest dose given to the patient.

Table 4.1. Patient exposure parameters and skin dose for selected x-ray examination in Al-Sadar general Hospital-Najaf.

Type Examination	kVp		mAs		FSD (cm)		Dose (mGy)	
	Avg.	± SD	Avg.	± SD	Avg.	± SD	Avg.	± SD
Pelvis	101.285	7.543	32.142	9.099	128.428	24.102	2.525	0.609
Abdomen	82.57	6.204	31.4	4.561	103.5	11.498	2.685	0.672

Table 4.2. Patient exposure parameters and skin dose for selected x-ray examination in Al- Hakim general Hospital-Najaf.

Type Examination	kVp		mAs		FSD (cm)		Dose (mGy)	
	Avg.	± SD	Avg.	± SD	Avg.	± SD	Avg.	±SD
Pelvis	72.777	3.632	39.666	9.273	101.222	12.715	2.560	0.284
Abdomen	74.5	5.502	67	6.324	145.6	13.301	2.363	0.532

Table 4.3. Patient exposure parameters and skin dose for selected x-ray examination in Al- Furat alawst general Hospital-Najaf.

Type Examination	kVp		mAs		FSD (cm)		Dose (mGy)	
	Avg.	± SD	Avg.	± SD	Avg.	± SD	Avg.	±SD
Pelvis	82	4.294	29.6	2.777	102	22.135	2.550	0.629
Abdomen	82	4.555	29.777	3.961	104.333	22.135	2.433	0.540

Table 4.4. Patient exposure parameters and skin dose for selected x-ray examination in private medical clinic (1) - Najaf .

Type Examination	kVp		mAs		FSD (cm)		Dose (mGy)	
	Avg.	± SD	Avg.	± SD	Avg.	± SD	Avg.	± SD
Pelvis	82.714	3.638	65	14.433	121.285	14.880	3.186	0.641
Abdomen	81.714	4.680	61.714	19.206	123.428	20.959	3.348	0.609

Table 4.5. Patient exposure parameters and skin dose for selected x-ray examination in private medical clinic (2) - Najaf .

Type Examination	kVp		mAs		FSD (cm)		Dose (mGy)	
	Avg.	± SD	Avg.	± SD	Avg.	± SD	Avg.	± SD
Pelvis	**80.857**	**7.515**	**68.57**	**6.9**	**140.142**	**22.857**	**2.942**	**0.529**
Abdomen	**82.333**	**5.391**	**57.333**	**22.606**	**116.5**	**17.930**	**2.610**	**0.725**

Table 4.6. Shows mean skin dose (mGy) for all hospitals included in this study compared with LAEA&NRPB &CEC recommended guidance level[15,16].

Examination	Reference dose	Al Sader Hospital	Al-Hakim Hospital	AI-Furat alawst Hospital	private medical clinic (1)	private medical clinic (2)	Average
Pelvis	2.8	**2.525**	**2.560**	**2.550**	**3.186**	**2.942**	**2.7526**
Abdomen	2.9	**2.685**	**2.363**	**2.433**	**3.348**	**2.610**	**2.686**

4. DISCUSSION

The results in Table 4.6 show the radiation dose for all examinations performed in this study that included five devices in three hospitals, two clinics, and two guidelines' Levels recommended by the International Atomic Energy Agency and the United Kingdom [17]. The radiation dose in (Clinic 1) was higher for all of the X-ray examinations.

This is , in fact, due to the high tube voltage applied with the minimum distance used with the considered examinations. For the pelvis and abdomen, all their values are higher than the level recommended by the International Atomic Energy Agency [18].

Also, it can be attributed to the relatively high exposure standards used in these hospitals and clinics and possibly the experience of the radiographer could have some influence.

It can be concluded from the results obtained in these hospitals that the radiation dose values were observed to be high. In contrast, it is noted that the estimated radiation dose in both Al-Hakim and Al-Furat Al-Awsat hospitals was lower compared to Al-Sadr General Hospital, but it was still higher than those recorded in the United Kingdom and the International Atomic Energy Agency compared to other hospitals in this study and those published internationally [19,20].

From the results obtained, recommendations will be made on how to reduce radiation doses in the tests conducted to below internationally recommended levels. In general, all skin dose values in this study fall within the range of the UK and IAEA recommendations, and in some cases, even slightly exceed them [21].

5. CONCLUSIONS

For radiation units, the estimated average skin radiation dose from most radiological examinations is typically within internationally accepted limits. However, SSD data for individual hospitals showed that the radiation dose in some examinations was slightly higher than the acceptable limit. This is primarily due to the large number of radiological examinations performed. Radiation dose data are recorded frequently across hospitals, and these records vary. Variability in radiation doses is primarily due to the experience of radiographers. Therefore, annual and semi-annual assessments of radiation doses are essential to avoid excessive radiation doses and limit unnecessary overdose exposure, especially for children under 14 years of age, who are more susceptible to disease than adults.

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