SECTION 20. Medicine.

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ASSESSMENT OF PATIENT'S DOSE DURING AP PELVIS RADIOGRAPHIC EXAMINATION IN SELECTED HOSPITALS OF AL NAJAF CITY, IRAQ

Abstract: *Background: Protecting patients reproductive organs from unnecessary radiation is paramount during anterior-posterior (AP) pelvis radiography. Therefore, assessing patients' dose is necessary to ensure that the doses are within recommended levels.*

Objective: This work is aimed at investigating patients' radiation dose undergoing AP pelvis x-ray examination in selected hospitals of Al Najaf.

Material and Method: Patients' doses were assessed for 93 patients. The Entrance Surface Dose (ESD) was calculated through the knowledge of X-ray tube output and exposure factors. The X- ray output was measured using a calibrated dosimeter for each X-ray tube. Seven X-ray tubes were used to assess the patients' ESD. Exposure factors (e.g. tube potential (kVp), tube loading (mAs) and X-ray source to image detector distance-SID (cm)) were recorded for each patient. This data was used to calculate the ESD taken into account the backscatter factor. Four main hospitals were selected in this study, namely, Al Sadder (ASTH)), Al Hakeem (AHGH), Al Furat (AFH) and Al Zahraa(AZH).

Results: The mean ESD value for AP pelvis X-ray examination was ranged from 0.81± 0.16 mGy to 3.4±0.36 mGy across all hospitals. The corresponding means of each of kVp used for this examination was ranged from 73.3 to 87.3 kVp; mAs: ranged from 13.6 to 35.38 mAs and for the SID the range was between 100 and 123.07 cm. The value of max/min of the ESD was ranged from 1.5 to 3.3 across different hospitals

Conclusion:

The results demonstrate a clear variation in patient dose and exposure factors set among the selected hospitals. These values (i.e. ESD) were seen to be slightly comparable to those values of the UK (Survey-2010, 3.2 mGy) and were higher than those reported by certain countries (e.g. Iran, Sudan etc.). Therefore, a periodic checking together with conducting a quality control testing is highly recommended.

Key words: *ESD, AP pelvis, Patient dosimetry, Radiation safety, Radiation protection*

Language: *English*

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Introduction

Increasing the knowledge concerning the hazards associated with exposure of patient to low doses of ionizing radiations during diagnostic X-ray examinations impose the need for radiation dose assessment [1]. In this regards, a number of organizations that specialized in the radiation protection have issued recommendations which aimed to reduce the patients' doses to its lowest levels. These include organizations such as the International Commission on Radiological Protection-ICRP [2], International Atomic Energy Agency (IAEA)[3], and European Commission, 2000. Imaging of different body parts necessitate that different radiographic techniques must be adopted to meet the requirement of X-ray attenuation which, in turn, include different exposure levels especially for those thick parts that requires high dose for a proper penetration such as in AP pelvis radiography [4]. Nevertheless, it should be noted that the pelvic region include the gonads which are considered to be one of the most radiosensitive organs in the body [3]. This means that, during pelvic X-ray examination,

the reproductive organs are inevitably exposed to the primary beam of X-ray and, therefore, the risk of inducing cancer within next generations does exist [5]. According to the literature, AP pelvis together with hip radiography has been reported to be the 3rd most frequent X-ray examination when compared with the biggest dose contribution examinations in the United Kingdom, with a 39/1000 of population annual frequency [6]. Therefore, protecting patients gonads from unnecessary radiation dose is paramount during anterior-posterior (AP) pelvis radiography. Measurement of patient dose during AP pelvis X-ray examination was one of the aims of many researches [7-10]. However, other research attempts were conducted to minimize the patient dose during AP pelvis radiographic examination through optimizing its radiographic practice [11-13]. Optimization means finding an approach through which the dose can be reduced while maintaining the quality of the X-ray image acceptable for diagnosis [14]. One of most common and reliable dosimetric quantities used in diagnostic radiography to give an indicator for patient dose is the entrance surface dose (ESD). This quantity includes the contribution of backscatter radiation in the range of diagnostic X-ray (i.e. 40 to 150 keV) [15]. Assessment of patient dose undergoing routine radiographic examinations and specifically the AP pelvis X-ray projection has not been given the required attention that recommended by radiation protection organizations in Iraq and in Al Najaf in specific. Hence, this study is aimed at investigating the patient dose undergoing AP pelvis projection in selected hospitals of Al Najaf using indirect based dosimeric approach (i.e. depend on the knowledge of X-ray output measurements)

Material and methods

This study was undertaken in selected hospitals of Al Najaf city, Iraq; these include Al Sadder teaching hospital (ASTH), Al Hakeem general hospital (AHGH), Al Zahraa (AZH) and Al Furat Al Ausit hospitals (AFAH)). These hospitals were selected because they were covered the whole center of the city. Seven X-ray tubes were involved in this work. Before work was started, an ethical approval was obtained from the Al Najaf Health Administration of Al Najaf city. The research began by collecting information about the X-ray units; this includes X-ray tube manufacturer, model, year of installation and the type of the X-ray system (i.e. computed or digital radiography- CR/DR). These data are listed in table 1.

Table 1.

This table presents the X-ray systems information considered in this research.

Hospital	Manufacturer	model	Year of installation	System types (DR/CR)
ASTH	Siemens/Germany	AL01C	2017	DR
AHGH (1)*	Shimadzu/Japan	R-20J	2006	CR
AHGH (2)**	Shimadzu/Japan	R-20J	2006	CR
AZH (1)	Shimadzu/ Japan	R-20J	2015	CR
AZH (2)	Shimadzu/ Japan	R-20J	2006	CR
AFAH(1)	Shimadzu/Japan	R-300	2005	CR
AFAH (2)	Shimadzu/ Japan	1/2P13DK	2012	CR

* and ** Refer to the room numbers in a given hospital.

Following this, demographic data were collected for all patients enrolled in this study, this includes patients' weight (kg), height (cm) and gender (male/female); these data were used to calculate the body mass index(BMI = kg/cm^2) for individual patient. A minimum number of 10 patients (≥18 years) was considered for each X-ray unit [16]. This led to 93 patients in total (male and female) to be enrolled.

Prior to the dose calculation, exposure/physical factors were recorded for individual patient and X-ray projection. These include kVp (peak tube voltage), mAs (milli amper. second) and and X-ray source to image detector distance-SID (cm). The latter parameters are necessary to calculate the ESD (mGy = J/kg). The ESD is the absorbed dose in air on the X-ray beam axis at a point where the beam is just entering the skin of the patient. The ESD calculation includes the backscatter contribution. The ESD was then calculated using the following equation [17, 18]

$$ESD \ (mGy) = output \left(\frac{mGy}{mAs}\right) \times \left(\frac{kVp}{80}\right)^2 \times \left(\frac{100 \ cm}{FSD}\right)^2 \times mAs \times BSF$$

where output is the X-ray tube output factor in mGy/mAs measured at a standard distance of 100 cm from the X-ray tube focus and 80 kVp normalized to 10 mAs, kVp is the peak tube potential, mAs is the product of the tube current (mA) and exposure time (sec), FSD is the focus to patient surface (skin) distance (cm). The FSD was calculated by subtracting the patient thickness (cm) from the SID. Patient thickness used in this work was sourced from perry et al [19] since measuring patient thickness directly during workload is difficult and might cause some inconvenience for the patients. The BSF is the backscatter factor and a value of 1.35 is usually used in diagnostic range [19].

The X-ray output (R/mAs) was measured using Rad-Check Plus model 06-526 X-ray exposure meter (Nuclear Associates, Victoreen Division, NY, USA) at 80 kVp, 10 mAs and 100 cm distance from tube focus (see figure 1). Three measurements were taken to allow the calculation of average value and to reduce random error. A 8.7 mGy/R conversion factor was applied to convert the output from R (Roentgen) to mGy in air (i.e. 1 R = 8.7 mGy) [20]. The ESD was finally calculated for all patients.
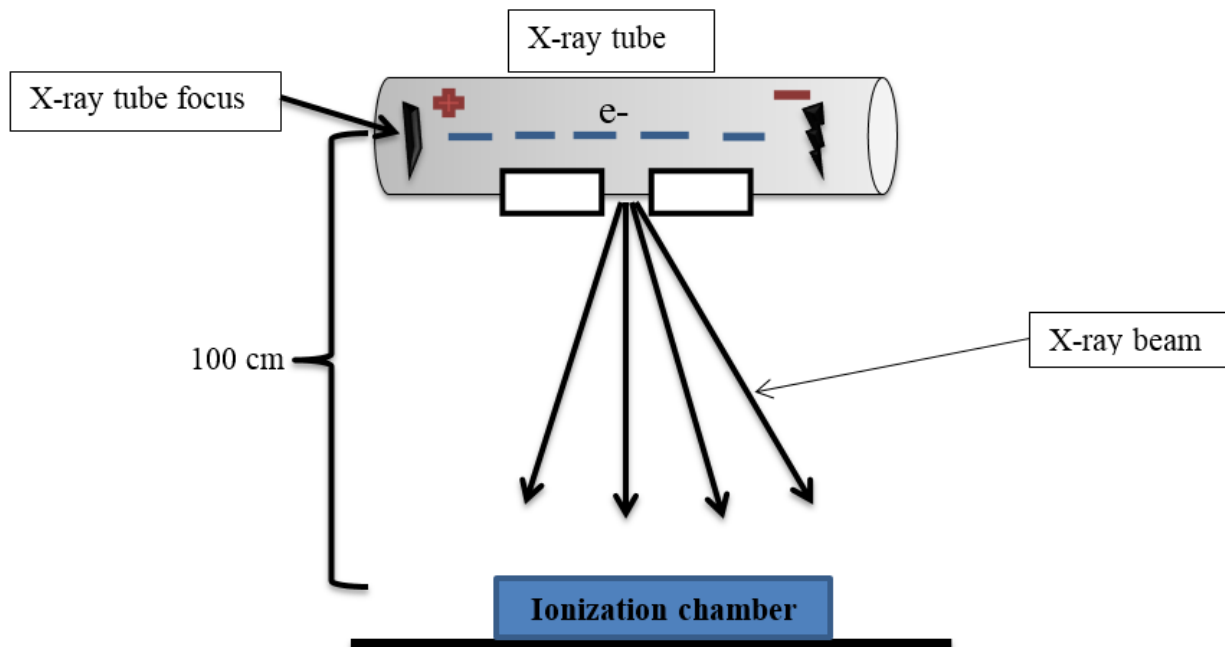

Figure 1. A schematic diagram illustrates the procedure of measuring X-ray output.

Results

Ninety three patients who were examined for AP pelvis radiography were recorded in this study. The study data were sourced from four hospitals in Al Najaf city. These hospitals include seven X-ray units. Patient demographic data are presented in table (2). From table (2), it is clear that the average patients' weight (kg) is ranged from 73±6.3 to 80.6±5.6 kg. The average patients' heights are ranged from 1.65±0.09 to 1.69±0.08 cm.

Table 2.

Weight (kg), height (m) and the BMI for patients examined for AP pelvis radiographic examination in this study.

Hospital code	Weight (kg) Average (SD)	Height (m) Average (SD)	BMI (kg/m²) Average (SD)
ASTH	80.6(5.6)	1.69(0.08)	28.07(2.8)
AHGH (1)*	76.5(5.1)	1.69(0.10)	26.90(2.7)
AHGH (2)**	75.3(7.02)	1.66(0.08)	27.2(3.01)
AZH (1)	75.07(6.6)	1.65(0.10)	27.8(4.77)
AZH (2)	73.30(6.3)	1.65(0.09)	27.05(3.03)
AFAH(1)	79.00(5.5)	1.66(0.07)	28.5(3.20)
AFAH (2)	76.10(6.7)	1.67(0.07)	27.3(3.40)
BMI: Body mass index			

The BMI for all patients of this research is ranged from 27.05 to 28.07, this in turn indicates for a relative homogeneity of the sample size in term of the weight and length. Nevertheless, patients' weight (kg) and height (m) variations are expected due to the natural variability of the population of the current governorate. By contrast, the average weight (kg) of sample size considered in the UK was around 70 kg and this reflects the cultural variability of different population [6, 20].

The X-ray output values (mGy) normalized to 10 mAs for the seven X-ray units presented in table (3). From this table, it can be seen that the highest tube output was measured at AFAH (1) at 0.063 mGy/mAs and the lowest (0.031 mGy/mAs) was recorded at AZH- room (1).

Table 3.

This table lists the X-ray tube output factors measured at the seven X-ray units of the four hospital

Hospital code	X-ray tube output (mGy/mAs)
ASTH	0.041
AHGH (1)*	0.061
AHGH (2)**	0.046
AZH (1)	0.031
AZH (2)	0.040
AFAH(1)	0.063
AFAH (2)	0.053
* and ** represent the number of the room in a given hospital	

Tables (4) and (5) present the exposure factors applied to patients undergoing AP pelvis X-ray examinations and the corresponding ESD (mGy) calculated across the seven X-ray units. From table (4), it can be seen that that the minimum tube potential (kVp) used was at AHGH (2) with 73.07 kVp while the highest values was reported in ASTH at 87.3 kVp. The range of kVp reported in this study is comparable to those that reported in UK [6] (e.g. Average; 75 - Range 62-90 kVp).

Table 4.

This table presents the average and range values of the exposure factors (kVp, mAs and SID) applied for AP pelvic X-ray projection across the studied hospitals.

Hospital code	Tube potential (kVp)	Tube loading (mAs)	SID (cm)
ASTH	87.3(80-95)	13.6(12-16)	123.07(120-130)
AHGH (1)*	73.3(65-80)	30.9(24-40)	100.7(100-110)
AHGH (2)**	73.07(70-82)	32.15(24-40)	102.3(100-110)
AZH (1)	78.6(75-86)	28.9(19-40)	106.15(100-110)
AZH (2)	82(76-86)	35.38(22-46)	106.9(100-110)
AFAH(1)	80.6(80-82)	18.4(16-24)	100.0(100-100)
AFAH (2)	80.6(80-82)	19.3(16-24)	100.0(100-100)
* and ** represent the number of the room in a given hospital			

The minimum and the maximum tube loading (mAs) that were used for AP pelvis radiography is (13.6- 35.38 mAs). The current average values of the mAs are almost similar to those reported in literature [6-10]. The SID recorded for AP pelvis radiography is ranged from 100 cm 123 cm.

Patient ESD is presented in table (5). From this table, it can be seen that lowest ESD value was reported at ASTH with a value of 0.6 mGy, whereas the highest ESD value was reported at AHGA (1) with 4.14 mGy. The range of the average value of the ESD for AP pelvis examination across the seven units is from 0.81 mGy to 3.4 mGy.

Table 5.

This table presents, minimum, maximum, average and the standard deviation (SD) of the ESD (mGy) for pelvis X-ray examination across the studied hospitals.

Hospital code	Patient number	Minimum	Maximum	Average	±SD	Max/Min
ASTH	13	0.6	1.14	0.81	0.16	1.9
AHGH (1)*	13	2.68	4.14	3.4	0.36	1.54
AHGH (2)**	14	1.9	3.55	2.7	0.47	1.86
AZH (1)	13	0.89	2.48	1.66	0.52	2.7
AZH (2)	13	1.79	5.91	3	0.99	3.3
AFAH(1)	14	2.21	3.4	2.59	0.54	1.53
AFAH (2)	13	1.9	2.85	2.3	0.4	1.5
* and ** represent the number of the room in a given hospital; SD represents standard deviation						

Discussion

Monitoring the radiation dose for those patients undergoing routine radiographic X-ray examinations is of high importance from a radiation protection point of view. The latter argument is based on the fact that no safe dose ever no matter how small when considering the 'Linear No threshold Theory' (LNT). Therefore, attempts should be carried out to reduce the radiation dose and subsequently to reduce the patient radiation risk [21].

Examining the results of this work reveals that there was a clear variation in the calculated ESD whether among different hospitals or sometimes among the same hospital as evidenced by the SD (range: ±0. 0.16-±0.99). Another evidence for the dose variation is demonstrated by the data of the ratio of the maximum to minimum of the ESD (table 5). For example, the ratio of max/min of the ESD demonstrates that max value is around three times that of the minimum at AZH (2), while the lowest

ratio is in AFAH (2) at 1.5 times. However, the range of the ratio of this study is lower than that reported for pelvis radiography in a previous study [22], while it is almost comparable to ratio of the max/min reported in [9].

By way of comparison, the results of ESD for AP pelvis demonstrate that the average ESD for the five out of seven of the X-ray units was higher than those reported by UNSCEAR report- 2010 [23] for AP pelvis using computed radiography imaging equipment (see figure 2). However, the results demonstrates that the patients doses were a almost lower than that reported by UK-surevy-2010 for six X-ray units out of seven ones except at one unit (i.e. AHGH (1)) where the ESD value was slightly higher than that reported in the UK [6]. High patient dose at AHGH (1) as compared to other local units and other international reported data on the doses could be attributed to the high mAs settings used together with high X-ray output (table 3).
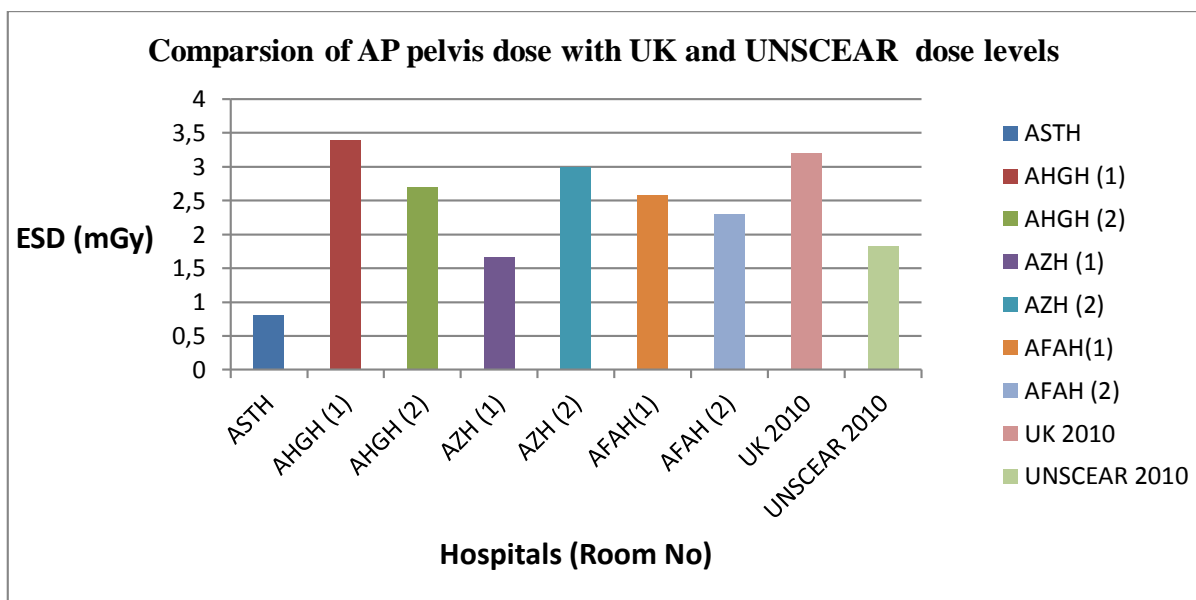

Figure 2. Comparison the ESD reported at the seven X-ray units with those doses reported by UK and UNSCEAR for AP pelvis.

On the other hand, comparing the doses obtained by this study with the patients' doses undergoing pelvis radiography of the neighboring countries and other developing countries reveals that in the Saudi Arabia [24], the dose was higher than the doses calculated in all the X-ray units considered in this study (e.g. 5.41 mGy). This could be due to the high mAs used in the Saudi Arabia study (e.g. 80 mAs). However, a recent study in Iran [25], the ESD of pelvis projection was reported to be lower than the doses calculated in six units out of seven and higher than one local unit (e.g. 1.47 mGy). Examining this case demonstrates that the Iranian hospitals are using approximately recommended level of the exposure factors together with achieving a regular quality control testing which our radiology departments may lack when compared with that of Iran. In a study conducted in Ghana (2014)[26], the AP pelvis ESD was reported to be considerably lower than the ESD obtained by the current study (i.e. 6 out of 7 units) by around 61% when compared with the highest ESD values reported in this study. This low dose level in Ghana can be clearly attributed to the low exposure settings adopted by Ghanaian operators.

However, another similar two studies conducted in Nepal and Ghana to assess the AP pelvis patients' dose in 2016 and 2013 respectively [8, 27] reveal that the ESD values were almost comparable to this study ESD except at two units in Ghana were the dose were extremely higher than this study and the international published levels [6, 23]. Finally, a recent study conducted in India in 2017 [28] demonstrates that ESD for pelvis radiography was higher than the ones calculated in this study (e.g. average ESD 4.33 mGy).

The variations exist in the ESD among different hospitals and sometimes among the same X-ray unit for the same X-ray examination is an issue that needs to be discussed [29]. The latter argument is based on the fact that the variability in the patient exposure should be reduced to a minimum level aiming to achieve the quality assurance/control goals within the diagnostic X-ray units. To achieve these goals, it is important to periodically assess the patient dose and then to find the measure of keeping it as low as reasonably possible [30]. In practice, there are a number of causes behind these variations. For instance, setting different exposure factors among different X-ray units for the same X-ray projection would lead to different radiation exposure [31]; operators with different experience levels may cause the variability in the radiographic practice; finally, patients' sizes and could also impose certain limitations that can be reflected on the patients dose consistency at different units [32].

Conclusion

The radiation dose was calculated for those patients undergoing AP pelvis radiographic examination at the main hospitals of Al Najaf city. According to the results, the average ESDs values were almost comparable to those reported in UK survey for the majority of Najaf X-ray units, and higher than that reported by UNSCEAR for CR technology. A clear variation in setting the exposure factors for this X-ray projection was identified. The results of this study can be used as a baseline for future dosimetry assessment. Finally, to ensure that the patient dose is kept at the controlled level, equipment quality control testing together with performing a training course for operators is highly recommended.

Acknowledgement

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