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To cite this article: Hussien Abid Ali Mraity and Hayder Abbas Harees 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **928** 072058

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with the 18th International Meeting on Chemical Sensors (IMCS)

**ABSTRACT DEADLINE: DECEMBER 4, 2020**



May 30-June 3, 2021

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## Patients effective dose estimation during AP pelvis radiography in some hospitals of Al Najaf city, Iraq

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**Background:** Monitoring patients radiation dose during anterior-posterior (AP) pelvis radiography is of paramount importance. This is due to the existence of the gonads within the pelvic region.

**Objective:** The purpose of this work is to estimate effective dose (ED) for adult patients who examined for AP pelvis radiography in the governmental hospitals of Al Najaf city-Iraq.

**Materials and methods:** The ED was estimated for 64 patients (male and female) who undertaking AP pelvis radiography using CALDOSE-X5 Monte Carlo software. The calculation of the ED was based on the measurements of X-ray tube output and the knowledge of exposure factors. The X-ray output was measured using Rad-Check ionization chamber for each X-ray tube. In total, seven X-ray tubes were enrolled to assess the patients' ED. Exposure factors includes tube potential (kVp), tube loading (mAs) and X-ray source to image detector distance-SID (cm)); these were recorded for each patient together with their demographic data (weight(kg) and height(m)). Five major hospitals were considered in this work (i.e. Al Sadder, Al Hakeem, Al Furat , Al Manzrah and Middel Euphrates cancer center).

**Results:** The average value of the estimated ED was ranged from  $0.156 \pm 0.041$  mSv to  $0.4068 \pm 0.049$  mSv across all hospitals. The value of max/min of the ED was ranged from 1.25 to 2.58 across different hospitals. The corresponding average values of the kVp used for this examination was ranged from 75 to 113.75 kVp; mAs: ranged from 11.7 to 42.1 mAs and for the SID the range was between 100 and 140.6 cm.

### **Conclusion:**

The resulted data demonstrate there is a clear variability in patient dose and exposure factors set among the selected hospitals. The ED values were seen to be slightly lower than those reported by the UK (Survey-2010, 0.284 mSv) and were higher than those reported by certain countries (e.g. Canada, Ghana etc.). Overall, a periodic checking together with conducting a quality control testing is highly recommended.

**Keywords:** Effective dose, AP pelvis, Patient dosimetry, Radiation safety, Radiation protection



## Introduction

Ionizing radiation has widely been in almost every hospital and clinics for diagnostic imaging purposes [1, 2]. In this regards, X-ray is the most commonly type of ionizing radiation that used in everyday life, in which an accurate diagnosis for many different types of diseases are required [2].

X-ray examination provides physicians with the important information concerning an individual's health which, in turn, ensure the suitability of patient treatment. A rapid increase in use of the X-ray facility, worldwide, has recently been reported. The reason for this increment could be attributed to advances reached in the X-ray technologies that made the diagnostic procedures with using the X-ray is notably simple [3]. However, using this type of radiation is inevitably exposing patients radiation risk. For this, many measure have been set by the radiation protection authorizes and organizations. For example, all medical exposures should consider the balance between benefit and risk to the patient. The patient can benefit from successful treatment, which may both prolong his/her life and improve its quality. Overall, the advantages should outweigh the risks associated with radiation exposure[4].

Different body parts, when examined by X-ray, require different radiographic techniques that must be adopted to meet the requirement of X-ray attenuation. To illustrates, thick body parts require high dose for a proper penetration such as in AP pelvis radiography [5]. Nevertheless, it should be emphasized that the pelvic region contains the reproductive organs which are considered one of the radiosensitive organs in the body[6]. This means that, during pelvis radiography, the reproductive organs are inevitably exposed to the primary X-ray beam and, therefore, the possibility of cancer incident within next generations does exist[7].

Reviewing the literature reveals that the AP pelvis and hip radiography have been classified to be the third most frequent X-ray examination when compared with the biggest dose contributing X-ray examinations in the United Kingdom, with an annual frequency of 39/1000 of population [8]. Hence, adopting radiation protection measures to reduce patients gonads from unnecessary radiation dose is paramount during (AP) pelvic X-ray examinations. In this context, measurement of patient dose during this X-ray examination was one of the goals for many published researches [9-13]. However, other researchers were attempted to reduce the patient dose during AP pelvis radiographic examination via optimizing its radiographic practice [14-16]. Optimization refers to the way by which the dose can be minimized while maintaining the quality of the X-ray image suitable for diagnosis[17].

From a radiation protection point of view, effective dose is utilized to compare the stochastic risk in conditions where the received dose not uniform, while the absorbed doses are low enough to avert deterministic effects of the radiation. The stochastic risk is in fact can induce a genetic effect[18, 19].

This article is aimed at investigating the effective dose for those patients undergoing AP pelvis radiographic examination in some hospitals of Al Najaf governorate- Iraq.

## 2. Materials and Methods

The current work was conducted in the major hospitals of Al Najaf governorate, Iraq. This include Al Sadder teaching hospital (ASTH), Al Hakeem general hospital (AHGH), Al Manzrah Hospitals (AMH), Al Furat Al Ausit hospital (AFAH) and Middel Euphrates cancer center (MECC). The latter hospitals were chosen because they are the biggest hospitals when considering their workload. From them, seven X-ray rooms were included in this study. Before starting this work, an ethical approval was obtained from Al Najaf Health Administration of Al Najaf governorate. The work started with recording data on each X-ray unit. The data includes the manufacturer of X-ray tube, model, year of installation and the type of the X-ray system. These data can be seen in table 1.

**Table 1.** This table presents the X-ray systems information considered in this work.

Hospital	Manufacturer	Model	Year of installation	System types (DR/CR)
ASTH(1) *	Toshiba/Japan	E7254FX	2017	DR
ASTH(2) **	Shimadzu/Japan	R-20J	2006	CR
AHGH (1)	Toshiba/Japan	E7254FX	2017	DR
AHGH (2)	Shimadzu/Japan	R-20J	2006	CR
AFAH	Shimadzu/Japan	R-20J	2005	CR
AMH	Toshiba/ Japan	E7254FX	2017	DR
MECC	Shimadzu/Japan	R-20J	2016	CR
* and ** Refer to the room numbers in a given hospital.				

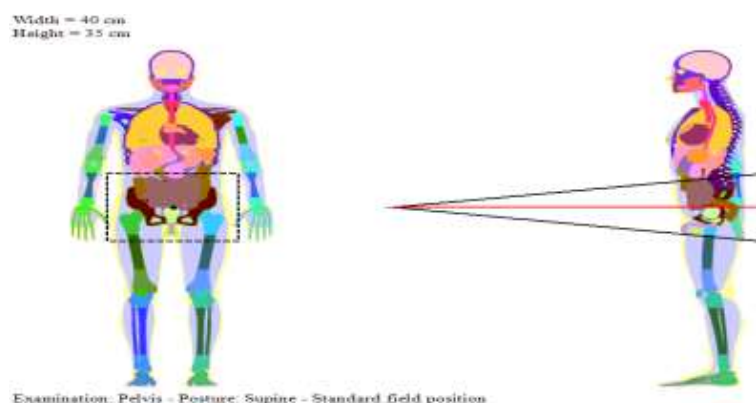
Next, demographic information on each patient were gathered. It includes patients' weight (kg), height (cm) and gender, so this allows the calculation of the body mass index ( $BMI = kg/cm^2$ ) for individual patient. A minimum number of 10 patients ( $\geq 18$  years) was considered [20]. Consequently, 64 patients in total of both male and female were recorded.

To estimate the effective dose, exposure factors (physical parameters) were recorded for all patients undergoing AP pelvis radiography (i.e. kVp, mAs and SID ).

In this study, the effective dose was estimated using a windows based computer software called CALDose\_X version 5.0. This software has been developed by Kramer et al. The CALDose\_X 5.0 is a tool that enables the researchers to calculate some dosimetric quantities to include incident air kerma (INAK) and entrance surface air kerma (ESAK). The latter quantities are considered keys to be used in diagnostic X-ray. Additionally, this software allows the possibility of assessing body organs doses for different radiographic examinations [21] . All the aforementioned quantities of this software, have been calculated using the FAX06 and the MAX06 phantoms

and for 44 X-ray projections of ten frequently and commonly conducted X-ray examinations.

This software provides a combination of forty kVps (50 - 120 kVp) and filtration (2.0 - 5.0 mm Al) together with different focus to detector distance (FDD)[21]. Relying on the reported exposure factors, CALDose\_X demonstrates images of the phantom as well as the site of the beam of X-ray (see figure 1)[22].



**Figure 1.** This image represents the CALDose software modeling of the AP pelvis X-ray examination.

To run the software, it is necessary to provide it with the tube output (mGy/mAs) of all X-rays units considered in this study. For the effective to be calculated, the software provides calculated weighted MAX06 and FAX06 whole body absorbed doses separately. The latter represent the sex specific contributions to the effective dose [21]. Once the doses of the individual organs as well as tissues are defined, the effective dose can then be estimated using equation (1):

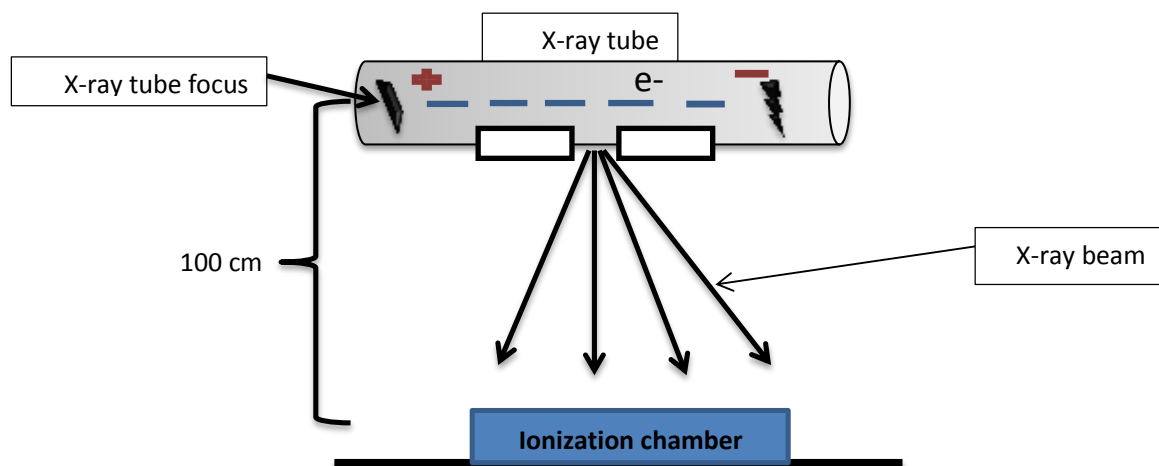
$$E = \sum_T w_T \sum_R w_R D_{T,R} \quad , \quad E = \sum_T w_T H_T \dots\dots\dots(1)$$

where  $H_T$  or  $w_R D_{T,R}$  represent the equivalent dose in a tissue/organ, T, and  $w_T$  represent the tissue weighting factor. The unit that is used to measure effective dose is similar to that unit used for absorbed dose (i.e.  $J kg^{-1}$ ), and its common known name is the Sievert (Sv). Using the CALDose\_X 5, the ED can then be calculated from average sex-specific weighted doses using the following expression(2) [23].

$$E = \sum \frac{w_T [H(female) + H(male)]}{2} \dots\dots\dots (2)$$

The output of the X-ray tube was measured using Rad-Check Plus model 06-526 X-ray ionization chamber (Nuclear Associates, Victoreen Division, NY, USA) at 80 kVp, 10 mAs and 100 cm distance from tube focus (see figure 2). Three measurements were taken for each kVp setting to allow the calculation of mean

value, and to therefore to reduce the random error. A 8.7 mGy/R conversion factor was used to convert the output from R (Roentgen) to mGy in air (i.e. 1 R = 8.7 mGy)[24].



**Figure 2.** A schematic diagram illustrates the procedure of measuring X-ray output.

## Results and discussion

64 of the patients who were examined for pelvic X-ray position were included in this study. Patient demographic data are presented in table (2). From table (2), it is clear that the average patients' weight (kg) is ranged from  $76.7 \pm 7.4$  to  $88.6 \pm 10.3$  kg. The average patients' heights are ranged from  $1.66 \pm 6.38$  to  $1.70 \pm 3.9$  m.

The BMI for all patients of this research is ranged from 26.46 to 32.24, 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[9, 24].

**Table 2.** Weight (kg), height (m) and the BMI for patients examined for AP pelvis radiographic examination in this study

Hospital Code	Patients demographic data		
	Weight (kg) Average (SD)	Height (m) Average (SD)	BMI (kg/m <sup>2</sup> ) Average (SD)
ASTH(1)*	81.30(8.6)	1.70(5.3)	27.96(2.3)
ASTH(2)**	77.50(5.8)	1.67(4.9)	27.63(3.1)
AHGH(1)	78.20(7.8)	1.67 (5.1)	27.76(2.7)
AHGH(2)	76.77(7.2)	1.70 (3.9)	26.49(1.8)
AFAH	77.5(8.66)	1.64(7.8)	28.75(4.4)
AMH	76.75(7.44)	1.68(4.9)	27.05(2.9)
MECC	88.66(10.39)	1.66(6.38)	32.24(4.1)
* and ** represent the number of the room in a given hospital			

The tube output values (mGy), after they were normalized to 10 mAs, for the all X-ray units can be seen in table (3). According to table 3, it can be seen that the highest tube output was measured at ASTH(2) at 0.067 mGy/mAs and the lowest was (0.037 mGy/mAs) was recorded at AMH.

**Table (3).** Lists the X-ray tube output factors measured at the seven X-ray units of the five hospital.

Hospital code	X-ray tube output (mGy/mAs)
ASTH(1)*	0.044
ASTH(2)**	0.067
AHGH (1)	0.044
AHGH (2)	0.049
AFAH	0.060
AMH	0.037
MECC	0.047
* and ** represent the number of the room in a given hospital	

The exposure factors that were set for all patients undergoing AP pelvis X-ray examinations are presented in table (4). From this table, it is clear that the lowest average kVp set was at AHGH (1) with 75 kVp, while the highest average value was seen in AMH at 113.75 kVp. It is important to note that the range of kVp reported in the current study is almost comparable to those which were reported by UK survey[8] and published literature [9-11,14-16]. By contrast, The lowest and the highest average mAs which were used for AP pelvis X-ray were 11.7 and 42.1 mAs, respectively (table 4). The reported values of the mAs, when compared with others, can be considered as slightly lower than those used in literature and international survey[8, 9,

11]. The lowest SID set for AP pelvis X-ray in this study was 100 cm whereas the highest SID was 140.6 cm.

**Table4.** This table presents the average, minimum and the maximum values of the exposures factors (kVp, mAs and SID) set for AP pelvis X-ray projection across the studied hospitals.

Hospital code	Tube potential (kVp)	Tube loading (mAs)	SID (cm)
ASTH(1)*	89.60(85-91)	20(20-20)	129.9(125-135)
ASTH(2)**	86.75(83-90)	23(20-26)	100(100-100)
AHGH (1)	75(65-80)	42.1(36-45.8)	140.6(140-143)
AHGH (2)	86(80-92)	36.44(32-40)	100(100-100)
AFAH	81.5(80-83)	22(18-25)	100(100-100)
AMH	113.75(105-120)	11.7(8-14)	122.5(120-125)
MECC	87.33(80-91)	18(18-18)	100(100-100)

\* and \*\* represent the number of the room in a given hospital

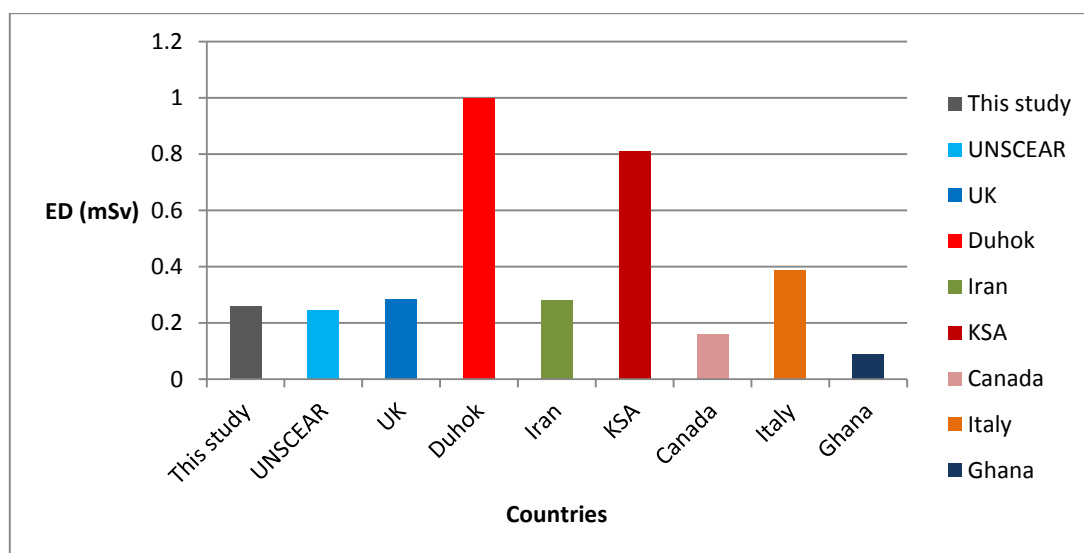
The resulted of the estimated ED for the patients undergone AP pelvis X-ray examination are presented in table (5). According to this table, it is clear that minimum ED value was reported at AMH with a value of 0.0875 mSv, whereas the maximum ED value was reported at ASTH room (2) with 0.465 mSv. The average value of the ED for AP pelvis X-ray through the seven units was from ranged from 0.156 mSv to 0.4068 mSv. Looking through the results of ED demonstrates that there is a clear variability whether among different hospitals or even among different units of the same hospital as that evidenced by the range of the SD (e.g. 0.009- 0.051). Another evidence for the dose variability is via the information of the ratio of the maximum to minimum of the ED (see table (5)). To illustrate, the ratio of max/min of the ED demonstrates that max value was around 2.5 times higher than that of the minimum at AHGH(1), while the lowest ratio was in ASTH(1) at 1.25 times.

**Table 5.** This table presents, minimum, maximum, average and the standard deviation (SD) of the ED ( $mSv$ ) for patients undergoing AP pelvis X-ray examination across the studied hospitals.

Hospital Code	Patient number	Minimum	Maximum	Average	$\pm SD$	Median	Max/Min
ASTH(1)*	10	0.1510	0.1895	0.1800	0.009	0.1825	1.25
ASTH(2)*	8	0.331	0.431	0.378	0.036	0.3865	1.30
AHGH (1)	10	0.1005	0.2595	0.1904	0.051	0.194	2.58
AHGH (2)	9	0.319	0.465	0.4068	0.049	0.416	1.45
AFAH	10	0.219	0.341	0.285	0.041	0.284	1.55
AMH	8	0.0875	0.224	0.1563	0.041	0.162	2.56
MECC	9	0.16	0.246	0.216	0.028	0.238	1.54

\* and \*\* represent the number of the room in a given hospital; SD represents standard deviation.

Comparing the obtained results of the current study with those published internationally, it can be seen that the average ED value for the seven X-ray units were slightly comparable to that reported for AP pelvis by UNSCEAR report- 2010 [10] (see figure 2). However, the results demonstrate that the ED was slightly lower than that reported by UK-surevy-2010, Iran and that of Italy [9, 13, 14].



**Figure 2.** Comparison of the overall average ED reported for the seven X-ray units with those doses published by internationally for PA pelvis X-ray.

Nevertheless, the current study results were also found to be highly lower than that reported by [12, 15]. This is because, , when examining [12], it was found that mAs values used were high (e.g. 80mAs) compared with mAs reported by the current study, while for [15], it was found that SID values used were low (e.g. 85 cm) as it

the authors were mentioned. This would contribute to increasing the ED of the examined patients taking into account the inverse square law [25]. Furthermore, comparing the current results with that of Canada[11] and Ghana[16] demonstrates that their results were low which reflects that the used exposure factors were almost comparable together with similar tube outputs.

The noticeable increase in number of X-ray examination conducted worldwide is a global issue that is needed to be considered. This is, perhaps, an issue that might be attributed to the rapid development in the facility of medical diagnostic imaging. However, in countries that are classified as 'developing countries', the employment of this technology is performed with almost less training. Consequently, this might lead to produce high quality image but on the expense of patient dose.

Studies on this case had indicated that the patient doses are increasing throughout time without the awareness of radiographic operators. The latter case is what well known by 'dose creep' [26]. In addition to this, the recognized wide variability in the doses of the patients among hospitals and even among X-ray units of the same hospital is an issue that is questionable [20]. In this regards, the variation in the patient dose should be reduced to the its lowest level aiming to attain the quality assurance targets in the diagnostic radiography departments. One way to achieve these targets is by periodically monitoring the radiation dose and therefore to find out the way of keeping it as "low as reasonably possible" [27]. In practice, many factors behind the noted variations that can be spotted. For example, setting variable kVp, and mAs across different X-ray units for the same examination would produce variable patient dose [28]. Operators with different experience can also lead to variable X-ray practice. Finally, human body habitus together with their different clinical situations may also impose some limitations that reflect on the patient radiation dose consistency [29].

## **Conclusion**

The EDs were estimated for patients undergoing AP pelvis X-ray examinations at the main hospitals of Al Najaf governorate. According to the results, the average EDs values were almost closer to those values reported by UK survey, and slightly higher than that reported by UNSCEAR for CR technology. Clear variations in the exposure factors set for this AP pelvis were identified. The findings of this study can be adopted as a baseline for future assessment. Finally, to ensure that the patient dose is maintained at the acceptable level, equipment quality control checking together with achieving a training course for operators is highly required.

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