



Patient Dose Assessment for Common Digital Diagnostic Radiology Examination in Hamad Medical Corporation Hospitals in the State of Qatar

Huda M. Al-Naemi¹, Ibrahim I. Abdallah¹, Osman B. Taha¹,
Mahmoud A. Tarabieh¹, Nabil A. Iqeilan¹, Samya M. Al-Manea¹,
Abeer O. Al-Attar¹, Mohamad H. Kharita¹ and Antar E. Aly^{1*}

¹Hamad Medical Corporation, Doha, Po: 3050, Qatar.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

The aim of this study was to estimate radiation doses to patients undergoing standard radiographic examinations using Computed Radiography (CR) and Direct Digital Radiography (DDR) in two hospitals within Hamad Medical Corporation (HMC) in Qatar, and compare the results with regional and international Diagnostic Reference Levels (DRLs). Data on 3391 patients were recorded from different X-ray rooms in HMC hospitals. Entrance Skin Dose (ESD) was measured for 1046 patients for the most five common X-ray examinations (a total of 7 projections) namely: Skull, Chest, Abdomen, Lumbar Spine and Pelvis. Exposure factors such as kV, mAs and Focal to Skin Distance (FSD) were recorded for each patient. Tube Output was measured for a range of selected kV values. ESD for each individual patient was calculated using the tube output and the technical exposure factors for each examination. The ESD values were compared with some international DRLs for all types of examinations. HMC patient demographic data evaluated from this study were:

*Corresponding author: E-mail: anter_protect@yahoo.com;

average age of 39 years, average weight of 60-80 kg and mean height of 165 cm. The most procedure performed during the time of this study was chest PA (52%), and the least procedure performed was skull AP/LAT (1%) examination. The mean ESD values found to be generally lower than the published values. With exception of abdomen examinations at Hamad General Hospital (HGH), mean ESD values were found to be within the established IAEA (DRL). The mean ESD values at HGH were found to be much higher than that at Al Khor Hospital (AKH) for abdomen, Lumbar spine AP, Lumbar Spine LAT and pelvis, but generally lower than the published values.

Keywords: Entrance skin dose; X-ray; diagnostic reference levels.

1. INTRODUCTION

Diagnostic X-ray examinations procedures, in particular the widespread use of X-ray, are the most common application of radiation in medicine, and represent the largest man-made source of public exposure to ionizing radiation (UNSCEAR 2000) [1]. Current estimation puts the worldwide annual number of diagnostic exposures at 2500 million, 78% of diagnostic exposure are due to medical X-rays, 21% due to dental X-rays and the remaining 1% due to nuclear medicine techniques. Increases in the uses of medical radiation and the resultant doses can be expected following changes in patterns of health care resulting from advances in technology and economic development [2].

The establishment of Quality Criteria for Diagnostic radiology Images started in 1984 when the first Directive on the radiation protection of the patient was adopted by the Member States of the European Union, and they first set up for conventional radiography, concentrating on examination of high frequency or with relatively high doses to patient [3]. Furthermore, the document defines the diagnostic requirements for normal, basic radiographs, specifying anatomical image criteria and important image details; it indicates criteria for the radiation dose to patient and gives examples for good radiographic technique by which the diagnostic requirements and dose criteria can be achieved [3]. Patient radiation dose is very important parameter to control the quality of X-ray services within the hospital. It is widely accepted that dose monitoring helps to ensure the best possible protection of the patient and provides an immediate indication of incorrect use of technical parameter or equipment malfunction [2]. Diagnostic Reference Level is useful tool to manage patient doses in the medical imaging [4]. Many specialized organization in radiation protection such as International Atomic Energy Agency (IAEA), European Commission (EC), Health Protection

Agency (HPA) UK and American College of Radiology [2,5-8] have produced corresponding documents of patient doses and recommended DRLs or guidance levels of most radiation doses for the common types of diagnostic examinations. These recommended DRLs are in general determined for with film-screen radiography. DRLs should be expressed in terms of quantities that can be easily measured or estimated, such as the entrance skin dose (ESD) [2,8].

In recent years there has been a very rapid introduction of digital images technologies in the diagnostic radiology [9]. The change of technology from film-screen to digital is quite significant. Moreover digital radiological techniques offer potential for improved image quality and, given the higher sensitivity of its image receptors compared with film, also offers the potential for dose reduction [9,3]. Recently the replacement of conventional radiography equipment with digital image system has increased rapidly in HMC. Limited data on digital DRL exist in the literature. HPA UK (2005) review used 45% digital systems and 55% film-screen combination [8]. It is necessary to consider the balance of image quality and patient dose and to establish national DRLs for the country. Since there is no data recorded in the country for patient doses, this study started in HMC under the IAEA Technical Cooperation (TC) project (Strengthen Radiation Protection in Medicine) between the government of Qatar and the IAEA, the project focused on achieving patient protection through several optimization actions including both, image quality and patient dose assessment.

The aim of this study was to estimate radiation doses to patients undergoing standard radiographic examinations using Computed Radiography (CR) and Direct Digital Radiography (DDR); Entrance Skin Dose (ESD) was calculated for five standard examinations (a total of 7 projections). Patient mean values were

evaluated in this study in two busy radiology departments in HMC and the result were then compared with regional and international DRLs. This study will provide a valuable baseline for patient doses in HMC, since there is no previous data on patient dose has been recorded.

The results will be used to optimize patient doses in all HMC hospitals and can be used with more data from other hospitals and clinics to establish national DRLs for Qatar. Regular dose measurements and image quality assessment as recommended by IAEA need to become part of the diagnostic radiology Quality Control (QC) program in Qatar.

2. MATERIALS AND METHODS

HMC was selected for this project as it is the biggest healthcare provider in country with a total number of 2066 beds, and annual number of more than 25412 X-ray examinations. Two hospitals within HMC were selected namely: Al Khor Hospital (AKH) which is located in the north with a total number of 115 beds and Hamad General Hospital (HGH) located in the central capital Doha with a total number of 603 beds. HGH and AKH were chosen for this study because they have the large number of patients (more than 50% of HMC patients) and they perform the highest percentage of the selected X-ray examinations (abdomen, chest anterior-posterior (AP), Lumbar spine AP / lateral (LAT), pelvis and skull AP/LAT examinations) in this study. Due to that fact, dose values obtained from those two hospitals will present a good estimation of patient doses of patient in HMC.

Data on 3391 patients were recorded from several X-ray rooms in HMC hospitals to provide information on patient demographic information.

To obtain an estimate of typical ESD to an average patient, the measurements were performed on a representative sample of adult patient with average weight of 60-80 kg. From this sample, 1046 patients had the selected for the 5 common examinations from the selected two hospitals, so at least more than 10 patients were recorded for each examination type [8].

The radiographic examinations were carried in 9 rooms equipped with two different X-ray machines manufacturers: Siemens; with flat-panel detector (1 room in HGH installed in 2007) and Philips DIGITAL DIAGNOST with flat-panel detector (2 rooms at HGH installed in 2003 and

2009 respectively, and 3 at AKH installed in 2004).

This dose survey was conducted between "November 2011 to May 2012" using the IAEA forms that were distributed to member states under the TC project "RAS/0/55" [9]. Based on these forms, data sheet were distributed to each X-ray room to collect the data for each examination. The following personal data and technical parameters were collected: (1) hospital name, department, room number; (2) patient age, weight and heights, (3) type of procedure; (4) exposure parameters: tube voltage (kVp), milliampere-seconds product (mAs) and Focal to Flat-panel Detector Distance (FFD).

Quality control protocol was established in HMC in 2005 to all conventional X-ray machines. Calibrated Barracuda Multi Purpose Detector (MPD) (RTI Electronics, Mölndal, Sweden) is used for the output measurements; the dosimeter was positioned in the central beam axis at 100 cm distance from X-ray tube focal spot. The radiation field size was set just to cover the dosimeter to avoid the scatter radiation. The tube potential ranged from 50 to 125 kVp and the current time product at 20 mAs. The measurement was repeated three times for each kVp value and the average dosimeter reading was determined, the values of the X-ray tube output per mAs were plotted against the tube potential and the resulted curve was fitted using a power function to get the equation that was then used to estimate the ESD for each patient for each specific room.

ESDs were determined on the basis of X-ray exposure parameters for patient by using the equation (1).

$$ESD = OP(\mu Gy / mAs) \times mAs \times \left(\frac{FFD}{FSD}\right)^2 \times BSF \quad (1)$$

Where; OP is the output obtained from the measurements on the X-ray machine, Focal Skin Distance (FSD) is obtained by subtracting the nominal patient thickness (calculated using patient height and weight) from the FFD, and (BSF) is the back scatter factor which is range from 1.34 to 1.46 depending on the examination kVp [10].

3. RESULTS

HMC patient demographic data are presented in Table 1 which has been obtained from recorded

data of 3391 patients. As can be seen from Table 1; the studied group was of average age of 39 years, mean weight of 74 kg and mean height of 165 cm.

The parameters used for standard radiographic examinations on adult patients with CR and DDR in the two X-ray departments are reported in Table 2. The use of optimum FFD is considered very important, since a direct relationship between short FFD and the patient dose [11]. It has been estimated that increasing the tube potential from 60 to 90 kV and decreasing the mAs will result in a dose reduction of 60% [12]. The mean values of the kVp and FFD for the standard radiographic examination on adult patients are similar to the values recommended by the EC 1996 [3]. It should be noted that for some examinations performed with the DDR equipments the mAs and the kVp are different to those used with CR as the system is self-positioning and self-centering.

M. Zhang et al. [4] optimized patients ESDs by applying FFD recommended by EC and manually reducing the mAs he found also that the ESDs from most examinations before optimization (OT) were three times higher than that after OT. For DAPs, the difference is more significant. Image rejection rate after OT is significantly lower than that before OT ($\chi^2 = 36.5$, $p < 0.005$). The substantial reductions of dose after OT resulted from appropriate mAs and exposure field. For DDR patient dose, less than

recommended diagnostic reference level can meet quality criteria and clinic diagnosis.

A total of 1046 patients from two different X-ray departments (723 from HGH and 323 from AKH), were included in this study. Does to patients were assessed by calculating mean ESD values for five standard radiographic examinations (a total of 7 projections). The number of patients for each exam is illustrated in Fig. 1. The most performed procedure during the time of this study was chest PA (52%), and the least performed procedure was skull AP/LAT (1%). Table 1 shows that the ESDs values are generally higher in HGH than in AKH for abdomen, Lumbar spine AP, Lumbar Spine LAT and pelvis examination while it is lower in the case of chest examination, It should be noted that the examinations: abdomen, Lumbar spine AP, lumbar spine LAT and pelvis were performed by Siemens (MULTIX TOP ACSS, 3-phase 6-pulse) with the CR in HGH. The fact that different in the evaluated doses are due to different in the radiological parameters used in both hospitals Table 2. Compagnone et al. [13] found that doses values for patient undergoing standard radiographic from CR system were higher than doses from the DDR system. ESD values obtained using CR in HGH compared with Compagnone et al. [13]. All the values are lower for abdomen and lumbar spine AP examinations. This comparison shows the need for patient dose reduction in HGH, and action must be taken to ensure optimization in the HGH CR systems in the near future.

Table 1. Hamad medical corporation patient demographic data, age, weight, height and thickness

	Age (y)	Wight (Kg)	Height (cm)
Average	39	74	165
Minimum	15	34	105
Maximum	88	184	199

Table 2. Radiological parameters kV_p, mAs and FFD, for the selected examination for HGH and AKH

Examination and projection	HGH					AKH		
	kVp		mAs		FFD	kVp	mAs	FFD
	DDR	CR	DDR	CR				
Abdomen		73		33	108	82	8	110
Chest PA	122		1.1		180	117	2	180
LS AP	78.2	74.81	24.8	42	110	80	12	110
LS LAT	90	82.5	23	72	112	89	15	110
Pelvis	77.2	70	20	32	110	77	10	110
Skull AP	66		15		127			
Skull LAT	64		21		143			

Zhang et al. (2011) is a good reference to compare the ESD values obtained from AKH since they used DDR systems, and they are in the same region. This comparison shows that the carried out DRLs from this work are lower than those performed by Zhang et al. (2011) before optimization [14].

The third quartile of the mean ESDs values for adult patient in this work was compared with some international DRLs; IAEA 2002, EC1999 and HPA UK 2005 [2,5,8] in Table 3. There are a recommendations DRL dose values based on conventional film-screen systems by IAEA [2] and EC [5]. Also, the United Kingdom recently have been published the DRL dose values for both film-screen and digital diagnostic examinations [8].

As shown in Table 3, the DRLs values from this work were less than the DRLs recommended by the HPA UK 2005 and EC 1996. With exception

of the abdomen examination, all recommended DRLs values for the other examination were found to be within the corresponding Dose Guidance levels recommended by the IAEA for 400 speed film screen [2].

Since all the imaging equipments used in this study was digital systems (CR and DDR) and the ESD values obtained is for digital radiography, then the more compatible reference to be compared with is the HPA UK 2005 because they obtained 45% of the information from digital system. The DRLs as presented in the UK (2005) review (using 55% film-screen combination) were approximately 16% lower than those reported in the (2000) review (using 98% film-screen combination). As shown in Fig. 1 the doses in our study are generally lower may be due to the difference in technical radiological parameters or the use of film-screen combination.

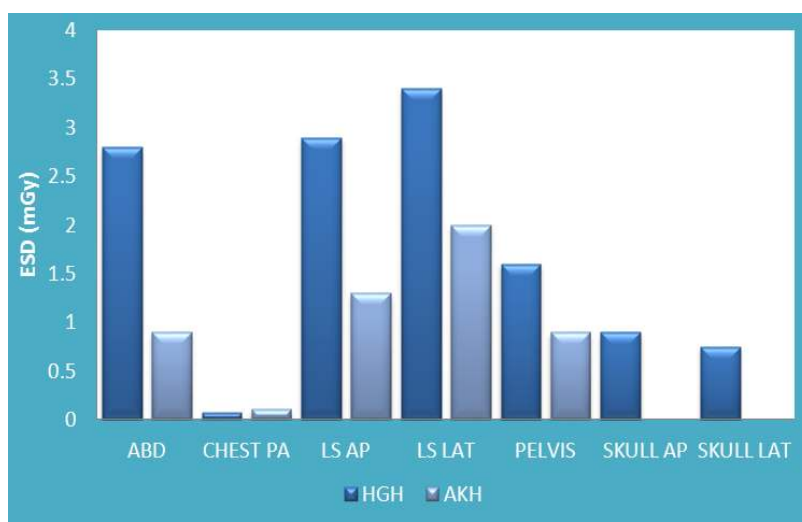


Fig. 1. Entrance Skin Dose (ESD) values with the number of patients for six standard radiographic examinations in HGH and AKH hospitals

Table 3. Comparison between the proposed DRLs for HMC values in mGy of this work with data from other countries

Examination	DRL(mGy)	HPA UK 2005 [8]	EC (1999) [5]	IAEA 2002 [2]	HMC 2012
Chest PA		0.15	0.3	0.2	0.13
Abdomen AP		4	5	2.5	3.3
LS AP		5	10	5	4.6
LS LAT		11	30	15	4.5
PELVIS		4	10	5	3
SKULL AP		2	5	5	1.14
SKULL LAT		1.3	3	3	0.81

4. CONCLUSION

In this study, patient doses from common diagnostic radiology examination in two HMC hospitals in Qatar are presented. The mean ESD values at HGH were found to be much higher than that at AKH for abdomen, Lumbar spine AP, Lumbar Spine LAT and pelvis. The mean ESD values obtained in this work was compared with values from the literature and found to be generally lower than the published values. This study indicates that there is considerable scope for dose reduction for examination of abdomen and lumbar spine AP at HGH.

The results of this study provide baseline data for the Qatar patient doses. There is a need of national survey so as to set a NDRLs for examination so that hospital can always compare their local DRLs with these NDRLs and take improving action without effecting image quality. Regular dose measurements and image quality assessment as recommended by the IAEA need to become part of the diagnostic radiology procedures, so the measured ESDs values can be used as a baseline for patient doses in Qatar.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

DISCLAIMER

This manuscript was presented in the conference "55th AAPM Annual Meeting & Exhibition: 4 to 8 August 2013, Indiana, USA," available link is "<http://www.aapm.org/meetings/2013AM/PRAbs.asp?aid=21980>"

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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