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Assessment of patients X-ray doses at three government hospitals in Duhok city lacking requirements of effective quality control

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A B S T R A C T

Purpose: The research presented in this article aimed at evaluating patient doses including entrance surface dose (ESD) and effective dose (E) in government hospitals that lack the requirements of quality control standards.

Materials and methods: Three major government hospitals with 409 patients in Duhok were involved in the study. The X-ray diagnostics included five routine radiographic examinations. ESD was determined indirectly by measuring the entrance surface air kerma with a solid state dosimeter. E was calculated from the tissue weighting factor and the equivalent dose.

Results and conclusion: s: Significant variations between exposure factors recorded in this study and those recommended in the context of quality criteria and standards were shown. The results have also shown that about twenty percent of the patient doses (ESD and E) were equal or below the recommended values of the diagnostic reference levels (DRLs). For abdomen, pelvis and skull examinations, the ESD values were slightly above the diagnostic reference levels. For chest and cervical the ESD values were much higher than diagnostic reference levels. These values were more reasonable only in one hospital. High ESD values can be attributed to the slightly higher tube voltages and lower mAs values that were used. The high patient dose values suggest that any adequate change of the exposure parameters that aims at the reduction of dose must be done without compromising the image quality. This study recommends a quick action toward implementing a quality control program and employing special staff of medical physicists in the evaluated hospitals.

1. Introduction

Radiology has earned a vital place in modern medicine where it has become one of the most powerful and indispensable diagnostic tools (Linton, 1995). It has been estimated that about 30%–50% of critical medical decisions are based on x-ray examinations (Tavakoli, SeilanianToosi, & Saadatjou, 2003). For instance, in a questionnaire radiologist members of the Norwegian Medical Association were asked to rate potential causes (fifteen items) of increased investigation volume and unnecessary investigations. The results showed that the highest rated causes of increasing the use of radiological investigations were the new radiological technology, people demands, clinicians' intolerance for uncertainty, expanded clinical indications, and availability (Lysdahl & Hofmann, 2009). This prevalence was accompanied with a quality control (QC) program which ensures a clear image as well as a small dose to the patient. Effective optimization in medical exposures means maintaining the radiation dose as low as reasonably achievable and ensuring that the image quality is sufficient for diagnostic purposes. This optimization could be controlled by a QC program. Without such a program the consequences may be regrettable. Unfortunately, nowadays some government and private hospitals and local health centers ignore the regulations of QC. This ignorance is always justified by the availability of new digital X-ray machines and/or non-availability of inspection devices and

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specialist staff. Hence, the standards and the preparing of the specialist staff were not taken into account.

Initial results of a multinational research study on x-ray QC and patient dose conducted by the International Atomic Energy Agency (IAEA) revealed that up to 50% of x-ray exams performed in less developed countries are of substandard quality (Keen, 2008). Many patients in these countries are being exposed to unnecessary radiation doses due to the need to repeat procedures (World Health Organization. 2008). A study done by al. (Korir et 2007) revealed that radiation doses from non-calibrated x-ray equipment exceeded the International Atomic Energy Agency guidance levels by a factor of one to five. Meanwhile, a patient dose reduction range of *31%–77%* without compromising good image quality was achieved through a quantitative QC assessment of processes involved in producing radiographs (Korir, Wambani et al., 2010). Likewise, the lack of a QC program in Tanzania revealed poor image quality and/or higher doses to patients (Ngoye et al., 2015).

Duhok city which is located in the north of the Kurdistan region of Iraq has 1,300,000 inhabitants. The prevailing X-ray investigation rate was 1855 per 10,000 enrollees per year before 2014. In October 2014 More than 860,000 internally displaced people (IDP) moved out of their war-torn towns and cities to the Kurdistan region and the majority of them are now living in the Duhok governorate. This led to an increase in the population by about 25% and raised the rate of conventional x-ray examinations to more than 2000 per 10,000 enrollees per year according to the Ministry of Health, Iraq (Annual Report, 2010). Despite this, neither patient dose recording nor image quality control in medical X-ray examinations are considered in Duhok hospitals. The aim of this study is to evaluate the patient entrance surface (ESD) dose and effective dose (E) in the government hospitals that did not follow a quality control (QC) program or protocols. In this study the image quality was not under consideration.

2. Material and methods

Four X-ray machines in three major and busy government hospitals were included with an average workload of 140 patients per week for each equipment. These x-ray machines are Siemens Germany (automatic exposure control- AEC) and EcoRay Co Ltd Korea at Azadi, and Shimadzu Kyoto-japan at Emergency hospital while Doban hospital was equipped with EcoRay Co Ltd Korea as demonstrated in Table 1.

X-ray exposure parameters such as kvp, mA, mAs, and focus to skin distance (FSD) were recorded directly from the control panel of each patient and projection. Entrance Surface Dose (ESD) values were measured for 409 patients undergoing five routine radiographic examinations: chest (AP), abdomen (AP), pelvis (AP), skull (AP), and cervical spine (LAT) from the three hospitals.

The entrance surface air kerma was measured using calibrated dosimeter (DOSIMAX- WELLHOFER DOSIMETRIE) placed on the patient table (Focus to Skin Distance) at the center of the entrance surface in the X-ray beam field. The ESD was calculated for all x-ray machines except the digital Siemens through entering parameters of X-ray tube output, backscatter factor and focus to skin distance in equation (1) (Ofori, Antwi et al., 2012).

$$\mathrm{ESD} = \mathrm{BSF} \times \text{Tube Output}\left(\frac{\mathrm{mGy}}{\mathrm{mAs}}\right) \times \left[\frac{100}{\mathrm{FSD}}\right]^2 \times \mathrm{mAs} \quad (1)$$

where Tube Output is the beam output in mGy/mAs measured from the X-ray tube at different kvp settings at distance of 1 m divided by mAs which is the product of the tube current (mA) and the exposure time in seconds. The focus-to-skin distance (FSD/cm) was calculated from the Focus Film Distance (FFD/cm) for all projections by subtracting the standard patient thickness for each projection. The patient thickness of *20* cm for all examinations was used (Kim et al., 2007). The backscatter factor values (BSF) of 1.25 was used for skull and cervical, 1.3 was used for chest and 1.4 was used for abdomen and pelvic examinations (Martin, 2011).

For the digital Siemens, ESD was recorded directly when the tube current exposure time (mAs) value governed by the automatic exposure control unit is displayed. Whereas, the DR x-ray equipment provides the user with an exposure index for each clinical image, which is a calibrated measure of the exposure incident on the detector (AAPM REPORT NO. 116). The risk in medical imaging is quantified using effective dose. However, measurement of effective dose is rather difficult and time consuming. Therefore, energy imparted and entrance surface dose are obtained then converted to effective dose using the appropriate software CALDose_ X, version 5. CALDose_X is a software tool that enables the calculation of the Entrance surface dose (ESD) based on the output of an X-ray tube as well as organ and tissue absorbed doses and effective doses (E) for posture-specific female (FASH) and a male (MASH) adult phantoms, Additionally, CALDose_X determines the risks of cancer incidence and cancer mortality for the examination selected by the user (Kramer, Khoury et al., 2008).

Twenty-four different X-ray examinations with various projections can be simulated using spectra with 2.0–5.0 mm Al filtration between 60 and 150 kvp and different focus-to-detector distances (FDD). Once the organs and tissues are determined, the effective dose is calculated using equation (2):

$$\mathrm{E} = \sum_{\mathrm{T}} \mathrm{wT} \sum_{\mathrm{R}} \mathrm{wR\ DT\ R}\ ,\ \mathrm{E} = \sum_{\mathrm{T}} \mathrm{wT\ HT} \quad (2)$$

where W_T is the tissue weighting factor, and H_T or $W_R\ D_{T,R}$ is the equivalent dose in a tissue or organ. The unit for the effective dose is the same as for absorbed dose, $J\ kg^{-1}$, and it is commonly known as Sievert (*Sv*). Based on CALDose_X, E is then calculated from the average of the sex-specific weighted doses by this expression (3), (Valentin, 2007)

$$\mathrm{E} = \frac{1}{2}[\mathrm{F} + \mathrm{M}]\mathrm{E} = \sum \frac{\mathrm{WT}[\mathrm{HT(Female)} + \mathrm{HT(Male)}]}{2} \quad (3)$$

3. Results

Table 2 presents the relative contributions of different X-ray examinations at the three hospitals. It seems that the majorly performed X-ray examinations were cervical spine AP, and Chest PA

Table 1
Features of X-ray machines in the five examinations used for the study.

Hospital	Manufacturer/country	Type	Max kV	Max mA	Total filtration mm Al	Date of installation
Azadi-Duhok	Siemens- Germany	Digital	150	1000	1.9	May 2011
	EcoRay Co Ltd Korea	Computed Radiography	150	600	2	March 2015
Emergency-Duhok	Shimadzu Kyoto- japan	Computed Radiography	150	630	1.5	October 2013
Doban- Sumial	EcoRay Co Ltd Korea	Computed Radiography	150	600	2	March 2015

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