Evaluation of Patient Doses in Conventional, Computed and Digital Radiography

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Abstract

The transition from conventional screen-film radiography (SFR) to computed radiography (CR) or digital radiography (DR) can involve an increase in patient radiation doses due to the wide dynamic range of the digital imaging systems, which allows overexposure with no adverse effect on image quality. The current study intends to measure and compare the radiation dose to adult patients during (i) chest (CXR) (ii) lumbar spine (LS) (iii) others; in three hospital in Khartoum state , Sudan. Using: (i) conventional (screen-Flim) radiography (ii) computed radiography (iii) digital radiography. Entrance surface doses (ESDs) were calculated from patient exposure parameters using DosCal software for three imaging modalities. A total of 202 patients were studied (115 CXR, 78 LS and 9 others).The mean ESDs were 1.77±0.01 mGy for the AP/LS, 5.39±0.16 mGy for LA/LS and0.07±0.02mGy for the CXR in SFR. The mean ESDs were 2.54±0.05 mGy for the AP/LS, 1.55mGy for LA/LS and 0.11±0.01 for the CXR in CR and The mean ESDs were 1.16±0.44 for the AP/LS, 1.72±0.45mGy for LA/LS,0.06±0.04mGY for the CXR and 0.2±0.13mGy for other in DR. The ratio of ESDs for CR to SFR was +44%, +26% and +57% higher than those for DR to SFR were -34%, -60% and -14% for AP/Ls, LA/Ls and CXR respectively. Patient dose in DR were lower than other two imaging modalities. CR dose values were higher than the other two modalities. LS patient dose values were lower than the majority previous studies in all modalities and so CXR doses too. Radiation dose optimization is highly required.

Keywords: screen-film radiography, computed radiography, digital radiography, patient dose, optimisation

1. Introduction

Since Rontgen's discovery that X-rays can identify bone structures, X-rays have been use for medical imaging. The first medical use was less than a month after his paper on the subject. In 2010, 5 billion medical imaging studies were done worldwide. Radiation exposure from medical imaging in 2006 made up about 50% of total ionizing radiation exposure in the United States. (NCRP report no 160, 2009).
Computed radiography (CR) and digital radiography (DR) are the commonly used terms for digital radiography detectors. CR is the acronym for computed radiography, and DR is an acronym for digital radiography. CR uses a photostimulable storage phosphor that stores the latent image, which is subsequently processed using a stimulating laser beam. It can be easily adapted to a cassette-based system analogous to that used in screen-film (SF) radiography. Historically, the acronym DR has been used to describe a digital X-ray imaging system that reads the transmitted X-ray signal immediately after exposure with the detector in place.
There are several types of detectors that can be classified as DR systems, including: Automated (cassette-less) CR systems, and (ii) some DR systems that are adapted to a cassette-based X-ray system. Thus, the historical nomenclature becomes less relevant as technology advances, since distinct classification into the two broad categories of CR and DR is no longer possible. More appropriate is the distinction between "cassette-based" versus "cassette-less" operation (Markus Korner, 2007).
There are many ways to categorize the current state-of-the-art digital radiography technology. One categorization considers 1) form factor, 2) image acquisition time, and 3) X-ray signal conversion methodology. The concept of "cassette-based" versus "cassette-less" operation is defined using the term form factor. A cassette-based digital detector uses the SF paradigm that allows the use of existing imaging modality infrastructure and provides excellent positioning flexibility. On the other hand, labor-intensive handling of cassettes and the need to wait for the image, often with batch-mode processing, lead to a loss of time efficiency. Cassette-less operation indicates the ability to acquire the X-ray signal, and, without subsequent user intervention, produce an image at a local workstation for review and manipulation (Bansal 2006).
The transition from conventional screen-film to computed or digital radiography can entail an increase in patient radiation doses (Vano, 2007). One of the main causes for the increase is the wide dynamic range of the digital imaging systems, which allows overexposure with no adverse effect on image quality .In addition, the lack of specific training in the new digital techniques for some radiographers and the lack of well-established methods to audit patient doses in digital systems can worsen the problem of patient radiation exposure .The International Commission on Radiological Protection (ICRP) became aware of this risk and launched several specific recommendations to manage patient doses in digital and computed radiology . These recommendations include appropriate training, particularly in aspects of patient dose management, revision of the diagnostic reference levels, and frequent patient dose audits. In addition, the ICRP recommended that the industry promote tools to inform radiologists, radiographers, and medical physicists about exposure parameters and the resultant patient doses (ICRP , 2004). In the literature, many authors reported that the patient doses in CR are higher compared with the DR ad SFR (Peters and Brennan 2000,weatherburn et al 2001, Vano, 2007). In Sudan, recently many departments installed CR or DR system and the number expected to increase gradually. To my knowledge no study was conducted regarding this issue, therefore, this study will provide a base line data in DR , CR dose during chest and spine imaging.

The current study intends to:Measure and optimize the radiation dose to adult patients during (i) chest (ii) spine with: (DR), (SFR), (CR), evaluate of patient doses in (DR), (SFR), (CR), omparison between direct conversion systems and indirect conversion systems reduce the dose for patients, co-patient and staff and its related risks, chose the best diagnostic reference level (DRL) and evaluate the results with the literature.

2. Materials & Methods

This Study intended to compare the radiation doses from imaging of Conventional X-ray (SFR), Computed Radiography (CR) and Digital Radiography (DR) machine during chest and lumbar spine. The data used in this Study was collected from three X-ray centers different modalities Khartoum Teaching Hospital (KTH) as (SFR) Khartoum Advanced Diagnostic Centre (KADC) as (CR) and Modern Medical Center (MMC) as (DR) and by questionnaire and data sheets; the data has been collected from July 2011 to December 2011.

2.1 X-ray machines

In the present study, three different modalities X-ray machines, from different manufacture were used as described in Table 1

Table 1 .Type and main characteristics of X- ray machine

Center	Manufacturer	Manufactu -ring Date	Type	Focal spot (mm)	Total Filtiration (mm Al)	Max KVp	Max mA	Max time (s)	Year install
KTH(A)	Toshiba	August 2003	Fixed (SFR)	1.2/0.6	1.1l	150	640	1.6	2009
KADC	Toshiba	2003	Fixed (CR)	0.5	1.1	150	500	30	2004
MMC	Shimadzu	March 2004	Fixed (DR)	1.2	1.5	125	200	2.2	2007

2.2 Patient samples

A total of 202 patients were examined in three hospitals in Khartoum state. The data were collected using a sheet for all patients in order to maintain consistency of the information. The following parameters were recorded age (year), weight (kg), height (m), body mass index (BMI(kg/m^2)) derived from weight (kg)/ (height (m)) and exposure parameters were recorded.The dose was measured for two main examinations: chest and lumber spine and few others examinations (upper and lower limbs and skull X rays). The examinations were collected according to the availability.

2.3 Imaging technique

Routine X rays examinations consist of two views, the frontal view (referred to as posterior anterior PA) and the lateral (side) view. For chest X rays it is preferred that the patient stand for this exam, particularly when studying collection of fluid in the lungs and during the actual time of exposure, the technologist usually asks the patient to hold his or her breath. It is very important in taking a chest x- ray to ensure there is no motion that could detract from the quality and sharpness of the film image. There is no advance preparation necessary for routine x rays. A hospital gown is used to replace all clothing on the upper body and all jewelry must be removed from the examined organ. Upper limbs radiography is the production of x-ray images of the fingers, hand, wrist, shoulder and elbow. Before the examination, the radiographer explained the procedure to all patients. While lower limbs radiography is the production of x-ray images of the foot, leg, ankle and knee joint. All examinations were performed according to the technique used in each hospital.

2.4 Absorbed Dose calculations

ESD which is defined as the absorbed dose to air at the centre of the beam including backscattered radiation, measured for all patients using mathematical equation in addition to output factor and patient exposure factors. The exposure to the skin of the patient during standard radiographic examination or fluoroscopy can be measured directly or estimated by a calculation to exposure factors used and the equipment specifications from formula below.

$$ESD = OPx\left(\frac{kV}{80}\right)^2 xmAsx\left(\frac{100}{FSD}\right)^2 BSF$$

Where:
(OP) is the output in mGy/ (mA s) of the X-ray tube at 80 kV at a focus distance of 1 m normalized to 10 mA s, (kV) the tube potential,(mA s) the product of the tube current (in mA) and the exposure time(in s), **(FSD)** the focus-to-skin distance (in cm).
(BSF) the backscatter factor, the normalization at 80 kV and 10 mAs was used as the potentials across the X-ray tube and the tube current are highly stabilized at this point. BSF is calculated automatically by the Dose Cal software after all input data are entered manually in the software. The tube output, the patient anthropometrical data and the radiographic parameters (kVp, mA s, FSD and filtration) are initially inserted in the software. The kinds of examination and projection are selected afterwards. ESDs in this study were calculated using DoseCal software. The software was extensively used for patient dose measurements in diagnostic radiology and also produced reliable results (Suliman 2007).

2.5 Image protocol

In X- ray imaging the exposure parameters used are selected according to patient weight and organ size. The Standard (FFD) of 100 cm was used for all routine examination and the chest X- rays FFD of 180 cm are used for geometrical reason.

3. Results

A total of 202 adults patients were examined in three hospitals equipped with different imaging modalities, 68 patients are exposure to computed radiography in Khartoum Advanced Diagnostic Centre (25LS&43chest), 62 patients are exposure to digital radiography in Modern Central Medical (20 LS, 33 chest and 9 others) and 72 patients are exposure to conventional radiography in the Khartoum teaching hospital which has two types of conventional machine A (18LS&27chest) and B (8 LS & 19 chest) (Table 1 and Table 2). The ESD for anterior and posterior lumbar spine to all three hospitals are (KADC) (1.03 and 1.55), (MCM) (0.91 and1.53 and (KEH) in A is (0.27 and 0.67) and in B is (0.98 and1.22), (Tables 4.7, 4.8, 4.9, and 4.10).

Table 2: Exposure factors and number of patients in three modalities:

Hospital &Exam	SFR			CR			DR			
Position	AP/LS	LA/LS	CXR	AP/LS	LA/LS	CXR	AP/LS	LA/LS	CXR	Others
No	26		46	25		43	20		33	9
KVp	83.8±0.5	94.7±0.9	69.8±0.1	69.4±0.0	85.1±1.1	65.4±0.2	85±1.8	94.6±2	78.9±0.6	67.3±5
mAs	8.3±0.1	16±0.0	25.4±0.7	46.1±0.1	46.08±0.1	15.0±0.0	27.1±0.1	36.8±1	9.7±0.2	9.5±0.9

Table 3: patient ESD (mGy) for standard radiographic examinations using SFR, CR and DR.

Examination	SFR	CR	DR	CR vs SFR	DR vs SFR	DR vs SFR
AP/LS	1.77	2.54	1.16	+44%	-34%	-54%
LA/LS	4.27	5.39	1.72	+26%	-60%	-68%
PA chest	0.07	0.11	0.06	+57%	-14%	-45%

4. Discussion

The radiation dose in this study showed wide differences in terms of dose, exposure factors and inter-examiners. CR dose values were higher than the other two modalities. The results of this study confirm the findings of the two reported studies (Weatherburn 2000, Herrmann 2002, G Compagnone, 2006), *i.e.* that Computed Radiograph generally results in higher ESDs than those in conventional radiography and Digital radiography. Table 3 presents the ESDs (mGy) for standard radiographic examinations using SFR, CR, and DR. Wide variation was detected when SFR compared to DR. In this study, itt was found that doses for CR for the entire examination were higher than the doses for the other two modalities. The ratio of ESDs for CR to SFR were +44%%, +26% and +57% higher than those for SFR during AP/LS , LA/LS and PA chest, respectively. The image quality met the criteria of the departments for all investigation. Bragg et al, 1997, have reported a dose increase in CR systems of 33–58% compared with a 400-speed SFR system. The findings of this study are therefore neither completely unexpected nor in contradiction with those of other trials. Therefore the importance of dose optimization during CR imaging must be considered. The radiation dose in this study showed wide differences in terms of dose, exposure factors and inter-examiners. Lumbar spine and chest exposure Patient dose values in DR were lower than other two imaging modalities, Computed radiography dose values were the highest one (Figure1).patient dose values were lower than majority previous studies in all. Radiation dose optimization is (suitable) required.

Table 4 presents a comparison between mean ESD (mGy) in different examination and previous studies using conventional radiography. The dose values for all examinations were below the previous reported studies except the study of Ciraj et al(2004). This variation could be attributed to exposure factors and patient morphologic characteristics and the sensitivity of the detectors. The limited experience with digital technology and the technologist may attempt to avoid noisy images by using mAs settings higher than necessary for good image quality.

Table 4: comparison between mean ESD (mGy) in different examination and previous studies:

Examination	Present study				Osman, 2010	Kepler.k et al (2008)	Hanner (2010)	Ciraj et al (2004)
	SFR A	SFR B	CR	DR				
AP/LS	1.49±0.15	1.77±0.01	2.54±0.05	1.16±0.44	0.61±55	6.4	5	1.6±1.0
LA/LS	1.87±0.97	4.27±0.04	5.39±0.16	1.72±0.45	0.71±38.61	10.7	15	2.2±1.0
PA chest	0.08±0.02	0.07±0.02	0.11±0.01	0.06±0.04	0.23±44.3	0.3	0.2	0.2±0.14

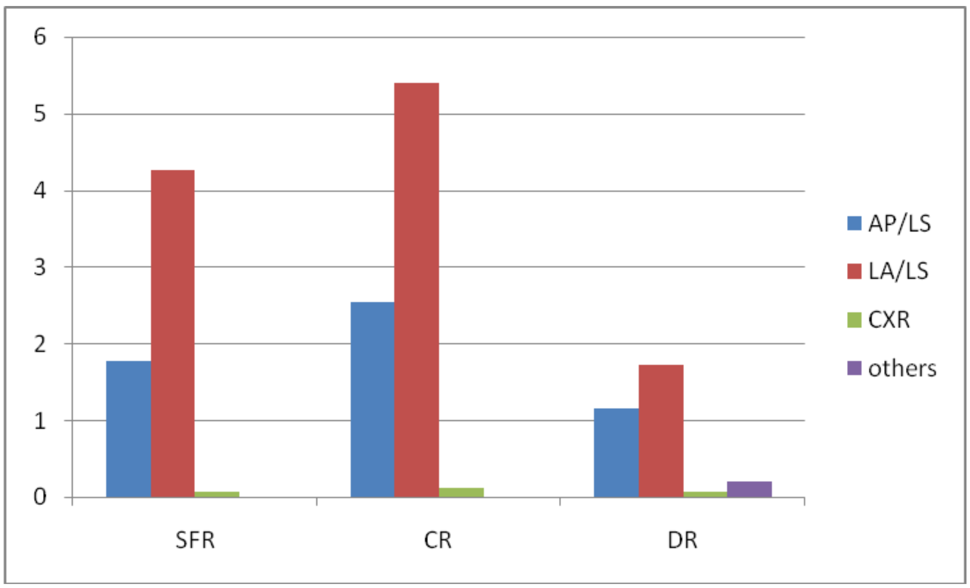

Figure1: correlation between entrance surface doses ESD (mGy) in three modalities.

5. Conclusions

This study compared radiation doses to patients undergoing two standard radiographic examinations (chest and lumber spine) using SFR, CR and DR. The patient radiation doses for lumber spine was higher in computed radiography compared to digital and conventional radiography as reposted in previous studies. The lowest dose was in the conventional radiography. Unlike the previous studies, the dose in chest radiography was higher in conventional radiography compared to other techniques. Recently digital and computed radiography are becoming more popular due to the important advantage of digital imaging is cost and access. The hospitals save money from lower film cost, reduced requirement for storage space, and lesser staff required to run the services and archiving sections. To overcome this limitation in Sudan, training of staff is important in order to get the benefit of digital radiography in patient dose reduction.

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