Original Article

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Optimization of Image Quality and Patient Dose in Digital Radiography of the Chest

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ABSTRACT

BACKGROUND AND OBJECTIVE: Digital systems have been replacing with screen-film analogue systems in diagnostic radiology departments, rapidly. Despite the differences in the properties of new x-ray imaging detectors, the same radiographic protocols that had been used for radiographic film-screen are used for digital imaging systems, without any review yet. In this study, the image quality and the patient dose in digital imaging of the chest are evaluated and optimized.

METHODS: Two digital radiography machines, Shimadzu RDA Speed and Siemens G2107 have been used in this experimental research. Imaging and dose measurement are carried out at different source to phantom distances and kilo-voltages. For measurement of the image quality, a contrast-detail radiography (CDRAD) phantom is used. For evaluation of optimization, the Inverse Image Quality Figure per patient dose squared (IQF_{inv}/E^2) is used.

FINDINGS: Evaluation of measured data for optimization shows that for both of these two digital radiography machines, despite of increasing in patent dose, with reducing of kilo-voltage, the IQF_{inv}/E^2 is increased. The maximum values of this parameter for Imam Khomeini and Bu Ali Hospitals are measured 0.0180 and 0.0083, respectively.

CONCLUSION: The results of this study indicate that despite the traditional notion of using higher kilo-voltages for chest radiography, with increasing kilo-voltage, the ratio of image quality per patient dose is reduced. So, for optimization of chest radiography, as much as possible the kilo-voltage should be reduced based on the size of patient and clinical purpose.

KEY WORDS: *Digital Radiography, Chest radiography, Contrast-Detail Phantom, Optimization*

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Introduction

In diagnostic radiography, one of the optimization principles is applied that a patient's exposure should be sufficient for the medical purpose and that any unnecessary exposure should be avoided. In other hand, diagnostic x-ray imaging protocols can be modified with respect patient dose and image quality (1). To diagnose correctly in radiography, and based on this to choice appropriate treatment method, and also to prevention of unwanted patient's exposure, optimization of image quality and patient dose in radiography is very important.

With developing digital technology and computers, different digital x-ray imaging modalities such as storage phosphor-based computed radiography (CR) and Flat-Panel (FP) detectors and data collection methods have been developed to replace screen-film radiography (2-4). Due to greater dynamic and exposure range, feasibility of post-processing of images, cost savings, easier access to images and the ability to archaving and comunication using Picture Archive and Communication System (PACS), digital radiography have been considered. It has been shown that picture quality in FP digital systems have improved respect to CR and film-screens or analog systems (5, 6).

Contrast-Detail (C-D) curve evaluation is one of the best methods to compose concept contrast and detail of objects that use Contrast-Detail Radiography (CDRAD) phantoms usually (7). The curves on C-D diagrams indicate the transition from objects that can be seen to those that can't, and these curves are derived subjectively by simple inspection. It is reasonable to expect some inter observer variability in the development of C-D curves, but as a quick subjective evaluation of an imaging system, they are quite useful. One of the methods for analyzing these curves is the use of the Receiver Operating Characteristics (ROC) curves that can be done with a human observer or with an automated software.

At first, image quality evaluation has been performed with simple CDRAD preliminary phantom, but they were able to display the possibility of reducing the patient dose without lose of image quality in the FP system respect to CR (8). Today, advanced CDRAD phantoms are available with software that image quality evaluations became very simple. Of course, there are various special methods to consider radiological image quality (9). When the anatomical structures are considered, Visual Grading Analysis (VGA) with and without reference images, are preferred methods for evaluation of image quality. Although in chest x-ray imaging, patients receive a little dose, but this method is most needed in clinical practice, thus the collective dose of imaging method is high (1,5,10,11). Since, still all of the analog radiology devices have not been replaced with digital in some radiography center completely yet, and only in some radiography centers both devices are used together, so still the radiological conditions selection of operators, not institutionalized. It was seen a tendency to apply further radiological conditions in digital imaging, and also there is no authority except manufacturer's recommendations in this regard (1,12). So, in this study, using image quality phantom and related software, optimal imaging conditions on digital radiography for chest imaging were evaluated.

Methods

This experimental research was conducted after obtaining permission from the Ethics Committee of Babol University of Medical Sciences with the code MUBABOL.REC.1393.5. In this research, two digital radiography machines, Shimadzu RDA Speed and Siemens G2107 have been used. These radiography machines were converted from analogue to digital. Quality control examinations were performed in according to National Diagnostic Reference Level (NDRL), before to apply this study.

The examinations were included dosimetry and image quality factors on these digital radiography machines. Based on the examination results, the outputs of both devices were obtained in terms of microgray (μGy) at a distance of one meter for different kVps. A type of 2 Artinis (Artinis Medical Systems, The Netherlands) Contrast-Detail in Radiography phantom (CDRAD) was obtained for image quality assessment.

This phantom is constructed from a polymethylmethacrylate (PMMA) plate with dimension of 26.5 × 26.5 ×1 cm^3 and a 15 × 15 array of cells with cylindrical holes of exact diameter and depth. In this phantom, three first rows have one hole in the middle of squares, but in another 12 rows there are two identical holes per square (the first in the center and the second in a randomly selected corner) containing logarithmically varied holes in depth and diameter (both ranging from 0.3 to 8.0 mm). Then these images imported in the CDRAD phantom dedicated software. The CDRAD phantom can be used as a tool in the process of dose-reduction when

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introducing FP detectors. Figure 1 is a representation of CDRAD phantom and its FP radiographical image.

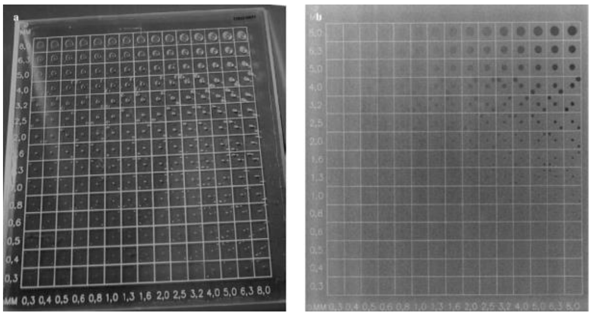

Figure 1. a) Contrast-Detail Radiography(CDRAD) phantom, b) Radiographic image of the phantom

CDRAD analyzer software ver. 1.1 Artinis was performed to automated asses of detail image quality and find any hole location on the phantom plate. Some of the study in this field fulfilled by automated and manual with several observers. But in this study only automatic method is used. The results expressed in Inverse Image Quality Figure(IQF_{inv}) as:

$$IQF_{inv} = \sum_{i=1}^{15} \frac{100}{Diameter_i * Depth_i}$$

$Diameter_i$ and $Depth_i$ show visible hole of column i. To understanding different imaging condition, IQFinv compared with E (μSv) of the same image. With these DR systems, entrance skin dose (ESD) of the patients is obtained in different exposures. ESD is calculated from the output of the DR systems multiply into back scatter factor (BSF) on the patient's skin. BSF coefficients in different kVps were taken from an international code of dosimetry in diagnostic radiology Technical Reports Series, Tecdoc 457 (13). Then, with PCXMC software, effective dose (ED) is estimated from ESD in different imaging conditions (Figure 2). In this software, with applying Monte Carlo simulation, equivalent dose of various organs and total body ED can be calculated.

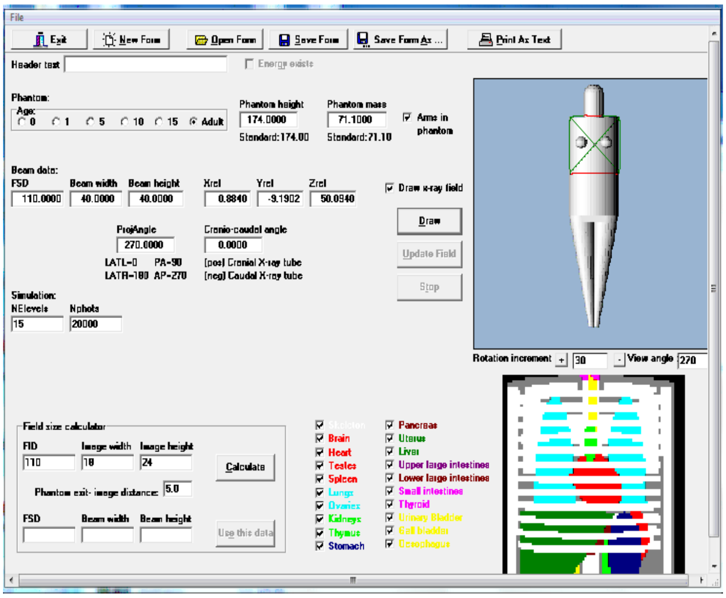

Figure 2. PCXMC software demo for effective dose calculation in chest X-ray imaging

Results

The results of measuring the output of the devices, ESD, ED and image quality factor are presented at different source to detector distances. Depending on the type of device in each center, a kilo-voltage of 55 to 90 was applied, and source to detector distance was 110, 150, and 180 centimeters. The data showed that in all imaging conditions, with increasing radiographic conditions, IQF_{inv} and IQF_{inv}/E^2 are decreasing. Also, with an increase in kV, the ED, which represents the ED of the patient, has also increased (table 1,2).

Table 1. The ESD, ED and image quality factor at different imaging conditions for different source to detector distance for Shimadzu RDA Speed device

Source to detector distance	kVp	ESD@10mAs(μGy)	ED (μSv)	IQF_{inv}	IQF_{inv}/E^2
180 cm	60	120	21	8.12	0.0180
	65	145	29	8.28	0.0098
	70	170	36	8.04	0.0062
150 cm	60	170	26	8.59	0.0130
	65	200	37	8.28	0.0060
	70	240	48	8.61	0.0037
	80	350	80	8.67	0.0013
	90	460	117	7.27	0.0005
110 cm	60	350	54	8.56	0.0029
	70	470	94	8.29	0.0009

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Table 2. The ESD, ED and image quality factor at different imaging conditions and different source to detector distance for Siemens G2107 Speed device

Source to detector distance	kVp	ESD@10mAs(μGy)	ED (μSv)	IQF_{inv}	IQF_{inv}/E^2
180 cm	55	175	29	7.01	0.0083
	65	230	46	6.60	0.0031
	75	350	80	6.50	0.0010
	90	540	147	6.58	0.0003
110 cm	55	450	62	6.06	0.0016
	65	740	124	6.80	0.0004
	70	900	180	7.10	0.0002

Figure 3 shows an example of phantom image and an output analyzed curve of Artinis software. In this figure, points represent scores that corrected with standards proposed by the CDRAD phantom manufacturer, IQF_{inv} value and eventuated CD curve. Also, an example of IQF_{inv}/E^2 diagrams in kVp at different Source to detector distances are shown in Figure 4,5.

In these diagrams, the IQF_{inv} and IQF_{inv}/E^2 decreasing trend with increasing radiographic conditions is seen in all imaging conditions.

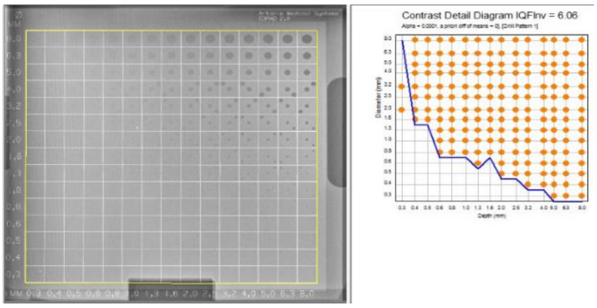

Figure 3. An example of CDRAD phantom image and an output analyzed curve of the software

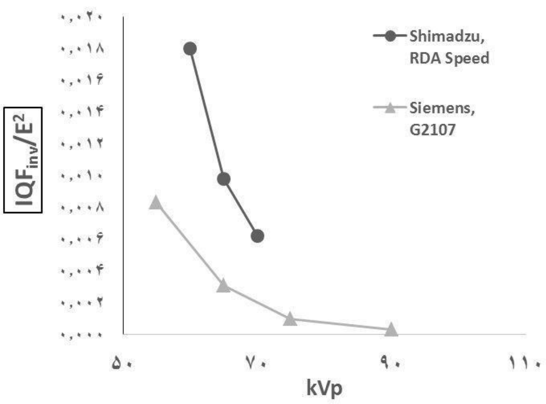

Figure 4. IQFinv/E2 in terms of kVp for Shimadzu RDA Speed and Siemens G2107 (source to detector distance=180 cm)

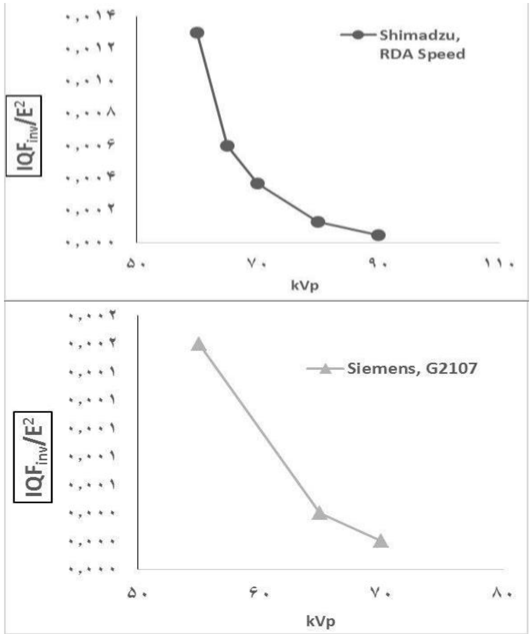

Figure 5. IQF_{inv}/E^2 in terms of kVp for Shimadzu RDA Speed (source to detector distance=150 cm) and for Siemens G2107 (source to detector distance=110 cm)

Discussion

The results of this study; tables 1, 2 and diagrams 1, 2 shows, for all of the imaging conditions with growing the imaging parameters, IQF_{inv} and IQF_{inv}/E^2 are decreasing. This is consistent with the findings of Compagnone's study (2). Also, the results of this study shows with an increase in kV, the ED, which represents the ED of the patient, has also increased. These findings are adapted with results of Paydar *et al* study (12). Although the evaluation of image quality with CDRAD provides valuable data, but with the lack of anatomical noise, limited clinical imaging data is obtained (14).

Alos, although many reports have indicated that dose reduction, while increasing the image quality in digital systems, but others expressed it in contrast to

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that reports (15-17). Limited dynamic range of screen-film systems need to apply more chest imaging conditions inevitably. Whilst, lower tube voltages can be used in digital systems. Although, technical appropriate imaging conditions to be revised (2). On the other hand the digital systems have wide dynamic range that makes a high range of patient dose changes without any damages on the images.

Radiological procedures must be optimized for As Low as Reasonably Achievable (ALARA) principles. Compagnone et al study was shown that with improved image quality in low tube voltages, there are a good correlation between human observations and computer software findings (2). CR images obtained by the voltage 95 kVp and 85 kVp have a little better quality images were obtained at higher voltages and ED, 4 and 13% lower than the ED in 125 kVp.

The cause of this phenomenon is the combination of the effect of change in the detector response with photon energies and the increase of the signal's contrast in the lower kilo-voltages of the tube. Therefore, the chest digital X-ray imaging protocols can be optimized with lower kV, with a slight increase in mA, and, of course, reduced radiation dose in the same image quality or even better. It is shown that DR systems can be give better image quality than CR systems. For changing from screen-film imaging system to digital once, it is need to train the radiology staff and evaluate patient exposure dose exactly (16). The study of Paydar et al showed that at three hospitals in Tehran, the same radiology machine worked with wide range conditions and ESD, while, ED for was higher than NDRL (12). Therefore, the need to educate radiation workers in the form of retraining and optimization of imaging conditions should be part of the educational. The analysis of parameters that influence image quality in digital systems can conclude: Contrast, which is one of the important parameters to consider when selecting the tube voltage for imaging of various tissues, can be easily applied and displayed. On the other hand, it is notable considering that the application of radiographic conditions (voltage and current selection) in the radiology departments we are examining with other studies. As Asadinezhad and Seo et al shown, in addition to the types and organs of imaging, our users tend to apply higher mAs than higher kVp (10, 15).

This issue, which goes back to all types of imaging, whether analog or digital, can be considered as a separate topic. According to the results of this study, digital radiography centers could be suggested that, based on the expected clinical image quality, as much as possible the kilo-voltage should be reduced while preserving the image quality, the lowest ED given to the patient.

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