Journal of Engineering and Applied Sciences 12 (24): 7685-7688, 2017
ISSN: 1816-949X

A Study on the Utility of Automatic Exposure Control Function in a Diagnostic Digital Radiography System

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Abstract: Diagnostic Digital Radiography (DR) systems may result in an excessive exposure of radiation, since, there are no limitations about exposure levels to acquire the required medical images. This study aimed to understand the proper dose of diagnostic DR equipment and to investigate SI when DICOM image was captured and exposure level when it was tested according to automatic exposure control and manual modes. Four diagnostic DR systems and a chest phantom were used. DICOM images were captured in the chest PA test and their exposure levels were 5 times measured using a dosimeter, establishing AEC and manual modes, respectively, during the chest PA test. The SI for captured DICOM images was recorded by establishing an ROI with image J. The statistical analysis was performed utilizing the Mann-Whitney test. Measurements of the diagnostic DR system yielded SI values that differed by manufacturers and ROIs of DICOM images while AEC and manual modes of the same manufacturer's equipment did not. The exposure level in the AEC mode compared to the manual mode was measured to be lower by 5.7% in S company's equipment by 49% for the P company by 2.1% for the G company and by 187.2% for the C company one. The differences among the four DR systems was statistically significant ($p<0.05$). It is suggested to use radiographic tests of outstanding image quality flexibly with lower doses in consideration of the equipment characteristics and patient's physical conditions, recognizing that excellent medical images can be captured with lower doses in the DR system by the manual mode than by AEC. Since, the AEC function in the diagnostic DR system may not capture the medical image at lowest exposure levels, manual modes that take patient's physical conditions into account are thought to contribute in the reduction of doses.

Key words: AEC (Automatic Exposure Control), manual, SI (Signal Intensity), EI (Exposure Index), exposure dose, condition

INTRODUCTION

X-ray tests which is the basic tools for the diagnosis and treatment of disease can acquire images digitally and the exposure level for an image capture tends to be increasingly low. Radiation to be used in the medical practices should follow ALARA, a defensive principle recommended by ICRP, to acquire an excellent quality image with the lowest dose.

The factors that affect the image quality of radiography using the DR system vary according to the X-ray tubes to generate X-rays, detectors to capture the medical image, software for processing, up to the monitors. The DR system can be weakened during the process of X-rays passing from the object to the X-ray tube and it can acquire black and white digital images by the detector according to the X-ray level (Park *et al*., 2015; Woon *et al*., 2015).

The diagnostic DR system has been improved from early models to realize superior medical images with lower dose levels. Since, a variety of elements in film and screen types are influential factors including test condition, film type, film development temperature and time, the know-how and skillful techniques of the radiological technologists is essential. Moreover, kVp and mAsin the generating device are important to realize a high quality image.

However, the image-taking conditions of the DR system have not been restricted, due to the detectorand the dynamic range which is the characteristic of software for improvement of the DR system and the impact of kVp and mAsin the image is less than that of the film and screen type sytem (Lee *et al*., 2013).

In addition, no correlation has been established between the radiation dose and the "concentration" of the image. AEC which is widely used as the main function in the DR system can control the contrast with post-processing after an image capture (Yang *et al*., 2013).

The AEC function in the DR system utilized to control the radiation dose automatically upon the radiation exposure in the detector is sufficient for an

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image capture. The goal of the generating device for diagnosis is to capture the best image, maintaining the initial capacity and lowering exposure levels to the patient. Hence, this study aimed to lower unnecessary exposure during radiation tests and to acquire an excellent medical image by comparing the exposure levels in AEC and manual modes which are superior in a diagnostic DR system. It is time to consider studies that investigate whether the radiation dose be kept low while acquiring a high-quality image atan appropriate exposure level.

MATERIALS AND METHODS

Test equipment: The tests were performed with four DR systems made by S, P, G and C companies that equip the medical institutions, chest phantom (RSD Phantom, Belarus) of a human model and a dosimeterby Unfors Thin X-Rad (Unfors, Sweden) as seen in Fig. 1.

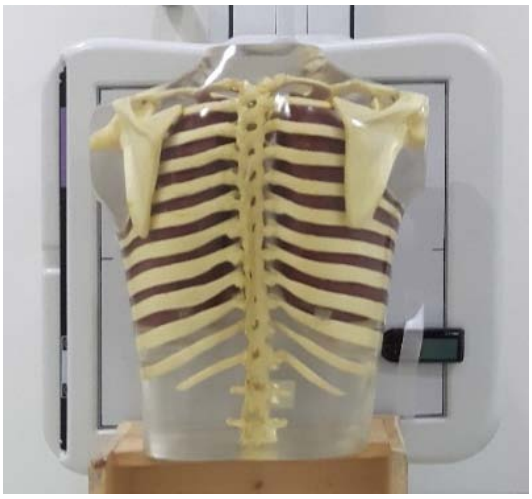

Fig. 1: Chest phantom

Test methods: For reproducibility and a consistency of the image, the tests were performed with a human model chest phantom which was balanced both to the left and right while maintaining A posteroanterior (PA) Position attached on a wall bucky for position stability. A high kilovoltage which is widely used in clinical practice was used to capture the DICOM image. The test conditions to capture the DICOM image were both the AEC mode to control exposure dose automatically and the manual mode to control it by hand. The exposure dose during the image capture was measured simultaneously.

In the AEC mode, DICOM images of the chest phantom were captured 5 times by each DR system with the test conditions including chest PA, Source Image of the receptor Distance (SID) at 180 cm, a radiation field of 17×17 inches and a tube voltage of 125 kVp. With respect to the manual mode, DICOM images in the chest phantom were also captured 5 time by each DR system with the test conditions including chest PA, a SID of 180 cm, a radiation field of 17×17 inches, a tube voltage of 125 kVp and a tube current of 3 mAs. During the capture process of each DICOM image, the Unfors ThinX Rad dosimeter was positioned under the right side of the DR detector and the exposure dose was measured as seen in Fig. 1.

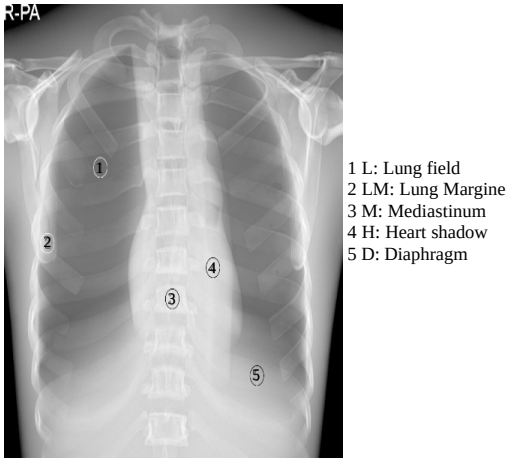

Fig. 2: Image of a chest phantom

Image analysis: DICOM files transmitted by Picture Archiving and Communication System (PACS) were analyzed by image J (Version 1.49) which is a program for value and image analyses developed by National Institutes of Health (NIH). The ROI was set from each DICOM image by image J and its SI was measured after establishing 5 points including L (Lung field), LM (Lung field Margine), M (Mediastinum), HS (Heart Shadow) and D (Diaphragm) as displayed in Fig. 2 which refers to the image evaluation points by the Japanese Tuberculosis Association. A Mann-Whitney test was calculated using SPSS Version 22 for windows to compare the SI of the DICOM image with the results of exposure levelsata significance level of $p<0.05$.

RESULTS AND DISCUSSION

SI (Signal Intensity): The measured values of SI in the AEC mode by the diagnostic DR system were 5.663, 1.719, 3.747 and 3.471 μGy for the S, P, G and C companies, respectively as in the lung field; 9.642, 2.846, 4.435 and 2.283 μGy for the lung field margin, 12.329, 3.360, 5.042 and 746 μGy in the mediastinum; 12.089, 3.317, 4.918 and

Table 1: Measurement values of SI by areas upon DR and AEC systems

Regionhttp	S	P	C	G
Lung field	5.663	1.719	3.471	3.747
Lung field margin	9.642	2.846	2.283	4.435
Mediastinum	12.329	3.360	746.000	5.042
Heart shadow	12.089	3.317	1.136	4.918
Diaphragm	9.477	2.613	2.136	4.526

Table 2: Measurement values of SI by areas upon DR and manual systems

Regionhttp	S	P	C	G
Lung field	5.823	1.718	3.470	3.788
Lung field margin	9.283	2.579	2.347	4.507
Mediastinum	12.386	3.334	723.000	5.079
Heart shadow	12.304	3.255	1.167	5.046
Diaphragm	9.717	2.545	2.209	4.545

Table 3: Exposure dose by dr system and aecunit: μGy

Manufacture	S	P	C	G
Exposure dose	103.4±1.34	64.4±0.2	345.2±0.84	107.7±0.27

Table 4: Exposure dose by dr system and and manual unit: μGy

Manufacture	S	P	C	G
Exposure dose	109.6±1.67	126.2±0.18	120.2±0.84	105.5±1.60

1.136 μGy for the heart shadow and 9.477, 2.613, 4.526 and 2.136 μGy for the diaphragm. The measured values of SI by each area ROI are displayed in Table 1.

The measured values of SI in the manual mode by the diagnostic DR system were 5.823, 1.718, 3.788 and 3.470 μGy for the S, P, G and C companies for the lung field; 9.283, 2.579, 4.507 and 2.347 μGy for the lung field margin, 12.386, 3.334, 5.079 and 723 μGy for the mediastinum; 12.304, 3.255, 4.046 and 1.167 μGy for the heart shadow and 9.417, 2.545, 4.545 and 2.209 μGy for the diaphragm (Table 2). In the same diagnostic DR system, SI values by areas were slightly different: AEC and manual modes ranged at 0.6-3.9, 0.3-10.4, 0.7-2.5 and 0.1-3.3%, for the four companies, respectively.

Exposure dose: The exposure dose using AEC in each DR system was determined to be 103.4, 64.4, 345.2 and 107.7 μGy for the S, P, C and G companies, respectively (Table 3).

In the manual mode of each DR system, the exposure dose were measured to be 109.6, 126.2, 120.2 and 105.5 μGy in S, P, C and G companies, respectively (Table 4). For the AEC mode, the values were lower by 5.7% for the S company equipment, 49% in the P company while higher by 2.1% in the G company and 187.2% in the C company. The exposure levels betweeb AEC and the manual mode in the same DR system were statistically significant for all four types of equipment ($p<0.05$).

The manufacturers of the DR systems provide the Index of Air Kerma (μGy) in the actual detectors where the radiological image is formed which is called as Exposure Index (EI) (Shepard *et al*., 2009). This is a method to exchange the information on the exposure measured in the detector with the technologists who directly operate the equipment. This represents an indirect index of digital image quality as a supplement and it shows the exposure dose measured in the detector as the ratio of image signal versus the noise level (Seibert and Morin, 2011). Therefore, EI cannot determine accurate effective dose for the patient but it is aminimum standard for radiological technologists to recognize the optimization of that dose (Kim, 2010). Checking EI when using AEC functions may lower unnecessary exposure level to the patient. The operator must select the exposure condition to capture an optimum-quality image with the least dose for the patient in radiological tests.

However, setting the optimum radiation dose and change of Air Kerma upon dose increase should be taken into account, since, Air Kerma cannot always be measured and automatic exposing devices arepreferred to manual ones in actual clinical practices (Yang *et al*., 2013).

The DR system's hardware and algorithms to produce an image are environmental factors to that influencet the image and exposure dose significantly, however, they cannot be controlled by the radiological technologists. Exposure levels can be lowered to control kVp and mAs considering the patient's physical condition in the test. The operator of the diagnostic DR system may think about capturingan optimum image with an optimum dose using ACE functions during the test, yet, some diagnostic DR systems in the AEC mode show higher exposure levels than in the manual mode. Nevertheless, once these DR systems pass the performance standards of the Korea Institute for Accreditation of Medical Imaging, they will be no problem for clinical use which does away with worries about unnecessarily increased radiation. The lack of effort to lower effort for the radiation dose by radiological technologists may cause excessive exposure to the patients in the diagnostic DR system.

There were fewe differences of the DICOM image SI for areas measured by image J in term of the signals between AEC and manual modes. However, it was confirmed that SI in the same area was measured to be different depending on the manufacturers. This was because of the detector characteristics and different post-processing algorithms of raw data. The final captured images of the DR system were DICOM ones that carried unique characteristics of the manufacturers. The AEC mode is mainly used in the clinical practice due to the convenience of the test, however, SI values of G and C companies in the AEC mode were higher by 2.1 and 187.2%, respectively, than those in the manual mode which is considered an unnecessary excessive exposure. So, the AEC mode may not be the best way to capture an

optimal medical image with an appropriate dose. Manufacturers are required to improve AEC function to capture excellent imagesat low doses.

Radiological technologists should be well aware of the DR system's characteristics of the DR with regard to the changes of digital imaging devices and their use while resetting optimum radiation conditions to minimize the exposure to the patients without compromising image quality. In addition, they should use it cautiously with a better understanding of AEC and the training about the management of doses should include multiple aspects. When performing quality control of the DR system, the dose measurement items must be included to understand the changes of the dose to the patient by various variables of the device and such a quality control measure ought to be performed regularly (Kim *et al*., 2013).

The image quality evaluation is the important factor in diagnostic radiology. Quantitative evaluation methods of noise are Signal to Noise Ratio (SNR), Contrast to Noise Ratio (CNR), Noise Power Spectrum (NPS) and so on (Choi *et al*., 2016). Contrast, resolution, etc. have also been used as evaluation tools of the DR image. However, they are insufficient as tools to assess image quality as well as their diagnostic value. It is suggested that a standardized phantom compliant with the DR system should be developed and its regular evaluation for the image should be performed continuously.

CONCLUSION

In comparison with the SI values in both AEC and manual modes in the same diagnostic DR system, there was no significant difference between them. It was found that some DR systems showed higher exposure doses in the AEC mode than in the manual mode. The former which is provided by all DR systems is convenient in clinical practice while it may not achievean optimum dose to capture an excellent image. Radiological technologists in clinical practice must recognize the fact that better medical images can be acquired with lower dose levels in the manual mode than in the AEC mode of the diagnostic DR system. They should also use the test methods flexibly to acquire excellent images with lower doses according to ALARA principles while considering the characteristics of the diagnostic DR system in conjunction with the patient's physical conditions. Also, the manufacturers should improve and develop their equipment continuously to acquire excellent images with low exposure doses by performance enhancements and post-processing improvements of AEC functions which are widely used in clinical practice.

ACKNOWLEDGEMENT

This study was supported by the 2015 Academic Research Support Project of Hanseo University.

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