DOI Number: 10.5958/0974-1283.2019.00125.7

Automatic Exposure Control in Chest Radiography

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ABSTRACT

Recent advances in medical imaging technologies have led to the increased use of automatic exposure control (AEC) in digital X-ray equipment. This study is an attempt to measure the dose of exposure based on AEC use and to evaluate the image quality in chest radiography where AEC is used most frequently. We measured the dose of radiation using three (3) units of digital radiation generators for diagnosis in conditions that are frequently used in chest radiography (110kVp, 115kVp, 120kVp, 125kVp). We placed the dosimeter in front of a chest phantom while varying the distance of FID to 110 cm, 140 cm, and 180 cm depending on whether or not AEC was used. The CNR and SNR of the images obtained by setting the lung to signal, 5 regions of Interest (ROIs), and 5 places of media sternum to noise, were measured using the Image J Program. To determine the dose difference based on AEC use, we conducted a t-test, which revealed a significant difference. When AEC was used at FID 110 cm, a high dose of 11.98% appeared. When AEC was used at FID 140cm, a high dose of 8.64% appeared. When AEC was used at FID 180 cm, a high dose of 6.74% appeared. In the t-test for the difference in CNR and SNR based on AEC use, no significant difference was detected. As the distance of FID increased, high values of CNR and SNR were measured.The results of this study show that there is no difference between CNR and SNR regardless of the use of AEC, and the dose was high when using AEC. Therefore, chest X - ray examination should not be based on AEC only. Under appropriate radiological settings, it is possible to reduce unnecessary radiation exposure to the patient.

Keywords: *Automatic exposure control, Chest radiography, Exposure doses, CNR, SNR*

Mathematics Subject Classification: *92C55, 92C50.*

Journal of Economic Literature (JEL) Classification : *I19*

Introduction

In the medical field, radiology equipment and facilities are evolving rapidly due to advances in science[1,2]. Advances in computer technology facilitate dose determination for radiation based on factors such as the examination area of the patient, body shape, and the status of adult or child. However, in reality, it is impossible to determine the most appropriate conditions for patient examination. Several medical institutions introduced Automatic Exposure Control (AEC), first introduced by Morgan in 1942. AEC is a device that allows automatic adjustment of the appropriate radiation dose for the concentration of the image using an ionization chamber[3]. Even when it is an identical examination or identical area in normal radiology, examination conditions are tailored to the patient. However, in many hospitals, it is impossible to consider the patient's body shape or condition each time the examination is performed. Therefore, AEC is used to automatically set the required test conditions, most commonly used in chest radiography[4–8]. The use of AEC has expanded the area of diagnosis by facilitating the examination of the mediastinal region that was not possible in the analog system, despite the poor reliability[3,7]. In the case of AEC, three ionization chambers are used. If the position of the ionization chamber and the position of the patient do not coincide with each other, an error occurs in the calculation of the radiation dose, resulting in an increase in the exposure dose. To correct this situation, equipment companies

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install AEC inside an Image Detector (Table Detector, Stand Buck), although many medical institutions do not use this equipment[3]. The purpose of this study is to analyze the radiation doses based on AEC use in chest radiography in order to provide directions for improved AEC use and to provide basic data for AEC study.

Materials and Method

Measuring Instrument: We used a Global 1 Platform (R-150-800, GE Healthcare, USA), FDR AcSelerate (R-150-1000, Fuji film, Japan), and DRX-Evolution (R-150-800, Carestream, USA), digital radiation generators for diagnosis of A hospital that is located in S city of Korea (Fig1, 2, 3). As the phantom for image acquisition and dose measurement, a human-body shaped multi-purpose Chest Phantom N1 "LUNGMAN" (Kyoto Kagaku, Japan) was used (Fig4). Dose measurement was performed using Unforce Thin X RAD Dosimeter (Raysafe, Sweden), (Fig 5).

Figure 1: Global 1 Platform

Figure 2: FDR AcSelerate

Figure 3: DRX-Evolution

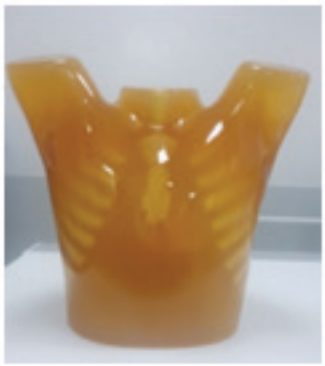

Figure 4: Chest Phantom N1

Figure 5: Unforce Thin X RAD

Experimental Method: To acquire images for dose analysis, a chest phantom was placed in front of the detector, and AEC mode was selected while varying the distance between the detector and the tube, the distance of FID to 180 cm, 140 cm, and 110 cm, under conditions commonly used in chest radiography (110kVp, 115kVp, 120kVp, 125kVp). In order to compare exposure doses based on AEC use, images were acquired under the same chest examination conditions without selecting AEC mode, and the dose was analyzed. Radiation doses were measured by placing the dosimeter in front of the chest phantom.

Image Evaluation: For image evaluation, Signal-to-Noise Ratio (SNR) and Contrast-to-Noise Ratio (CNR) of the images obtained using a chest phantom were measured by setting the lung part to signal, 5 places of ROI, and 5 places of medial sternum to noise using the Image J Program. The obtained images were evaluated with SNR and CNR based on whether or not AEC was used and the variation of FID distance (180 cm, 140 cm, and 110 cm), (Fig 6).

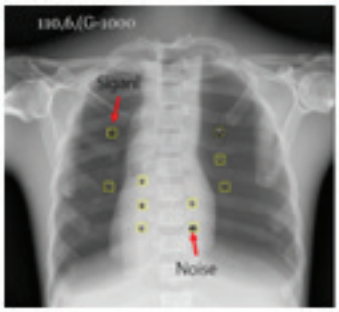

Figure 6: Image Evaluation Point

For measurement values of ROI, we obtained the minimum, maximum, average, and standard deviation values respectively, and based on these values measured SNR and CNR[9].

Results

Dose Based on AEC Use: To determine dose difference based on AEC use, an independent t-test was carried out. When AEC was used, the average dose was measured as 182.33μGy at FID 110 cm, 143.67μGy at 140 cm, and 128.17μGy at 180 cm. In the absence of AEC, the average dose was 162.83μGy at FID 110 cm, 132.25μGy at 140 cm, and 120.08μGy at 180 cm. The dose difference was statistically significant based on AEC use: It was 11.98% higher when using AEC at FID 110 cm ($p < 0.01$). When using AEC at FID 140cm. the dose difference based on AEC use was 8.64% higher, which was statistically significant again ($p<0.01$). When using AEC at FID 180cm, the dose difference based on AEC use was 6.74% higher, which was a statistically significant difference ($p<0.05$). The dose difference based on AEC use was measured higher as FID was closer (Table 1).

Table 1: Dose Based on AEC Use

Distance	AEC Use	N	M(SD)	t-value
110cm	Use	12	182.33(61.364)	3.768**
	Not Use	12	162.83(47.551)	
140cm	Use	12	143.67(56.269)	3.921**
	Not Use	12	132.25(51.879)	
180cm	Use	12	128.17(53.349)	2.386*
	Not Use	12	120.08(46.424)	
N=Number of Samples, M= Mean, SD=Standard Deviation				

CNR Based on AEC Use: To determine dose difference based on AEC use, an independent t-test was carried out as shown in table 2. CNR based on AEC use was measured as 5.59 when AEC was used at FID 110 cm, and it was measured as 5.57 when AEC was not used, and there was no statistically significant difference. CNR based on AEC use was 5.96 when AEC was used at FID 140cm. CNR was 5.95 when AEC was not used, and there was no significant statistical difference. CNR based on AEC use was 6.44 when AEC was used at FID 180cm, and it was 6.45 when AEC was not used, and there was no statistically significant difference. As FID increased, CNR value remained elevated. There was no difference in CNR value between the times when AEC was used and when AEC was not used (Table 2).

Table 2: CNR Based on AEC Use

Distance	AEC Use	N	M(SD)	t-value
110cm	Use	12	5.59(.087)	1.362
	Not Use	12	5.57(.077)	
140cm	Use	12	5.96(.167)	.581
	Not Use	12	5.95(.162)	
180cm	Use	12	6.44(.103)	.804
	Not Use	12	6.45(.117)	
N=Number of Samples M= Mean SD=Standard Deviation				

SNR Based on AEC Use: To determine dose difference based on AEC use, an independent t-test was carried out as shown in table 3. SNR based on AEC use was 7.50 when AEC was used at FID 110 cm, and it declined slightly to 7.48 when AEC was not used, without any statistically significant difference. SNR based on AEC use was 7.92 when AEC was used at FID 140cm, and it was 7.91 when AEC was not used, and no statistically significant difference was noted. SNR based on AEC use was 8.48 when AEC was used at FID 180cm, and it was 8.44 when AEC was not used, suggesting lac of ant statistically significant difference. As FID increased, the SNR value increased. No difference in SNR value was observed with or without AEC(Table 3).

Table 3: SNR Based on AEC Use

Distance	AEC Use	N	M(SD)	t-value
110cm	Use	12	7.50(.128)	1.362
	Not Use	12	7.48(.134)	
140cm	Use	12	7.92(.266)	.581
	Not Use	12	7.91(.267)	
180cm	Use	12	8.48(.172)	.804
	Not Use	12	8.44(.155)	
N=Number of Samples M= Mean SD=Standard Deviation				

Discussion and Conclusion

The International Commission on Radiological Protection states that all medical exposures should be justified just like occupational exposures. As Low As Reasonably Achievable (ALARA) exposures are recommended according to the principle of optimization. The principle of justification should remain as low as reasonably achievable based on the frequency of individual radiation exposure, and the economic and social factors determining the exposure of individuals and groups[10]. As medical exposures increase, the principle of optimization is further emphasized. In the case of medical radiation, the patient should be evaluated under appropriate examination conditions based on the patient's body shape and condition. In a report entitled "Reduction of patient dose in X-ray chest radiography based on AEC use," Jung et al. stated that the dose variation depended on the position of the ionization chamber that is an AEC sensor[4]. They also reported that the function of AEC, which is widely used in chest radiography, should not be unconditionally relied on, and that the position of the sensor in ionization chamber must match the position of the examination area in order to minimize and optimize exposure. Our results of the patient dosage based on AEC use varied depending on the distance. At a distance of 110 cm, the doses were 182.33μGy and 162.83μGy, respectively. At a distance of 140cm, the doses were 143.67μGy and 132.25μGy, respectively, and at a distance of 180 cm, the doses were 128.17μGy and 120.08μGy, respectively. Therefore, it was possible to identify a higher dose under AEC compared with the lack of AEC. Lee et al. reported that as sensitivity increased, the dose of exposure decreased, and better image quality was obtained[7,11]. In the present study, image evaluation based on whether or not AEC was used showed CNR was 5.59 and 5.57, respectively at a distance of 110 cm. At a distance of 140cm, CNR was 5.96 and 5.95, respectively, and at a distance of 180 cm, CNR turned out to be 6.44 and 6.45, respectively. Similarly, SNR was 7.50 and 7.48, respectively, at a distance of 110 cm. At a distance of 140cm, SNR was 7.92 and 7.91, respectively, and at 180cm, SNR scored 8.48 and 8.44, respectively. Therefore, in the cases of both CNR and SNR, similar images were obtained regardless of whether AEC was used or not. The results were similar to those reported by Lee et al. Hence, it is believed that the findings of this investigation will facilitate the determination of the use of AEC depending on patient characteristics using diagnostic radiation generators with AEC of each medical institution. It is also expected that our findings will lead to reduced exposure of patients and the radiation workers by providing quality imaging data and accurate dose information. Ultimately, our findings will contribute to the reducing the exposure dosages for the entire nation.

The study facilitated the determination of dose generation when using AEC. CNR and SNR did not show any difference in terms of image quality regardless of AEC use. We also identified that quality images can be obtained in chest X-ray examination when FID was 180 cm. Therefore, it appears that needless radiation exposure to patients can be reduced by manually setting appropriate examination conditions instead of relying exclusively on AEC.

Acknowledgment

This paper was funded by 2017 Academic Research Support Project of Hanseo University.

Ethical Clearance: Not required

Source of Funding: Self

Conflict of Interest: Nil

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