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The assessment of the automatic exposure control system for mammography x-ray machine

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ABSTRACT

In the U.S., performance assessment on the Automatic Exposure Control system (AEC) is managed according to the Mammography Quality Standards Act (MQSA). However, The AEC is not available in the performance assessment conducted in Korea. Also, there is no study made on the performance of the automatic exposure control system for mammography in Korea. For this reason, this study examined the performance of the automatic exposure control system for mammography that was clinically used in the Incheon area. Result showed that the difference of the mean optical density was 0.79 ~ 2.81. This implies that some devices caused unnecessary x-ray exposure to patients. Furthermore, only 61.5% of the entire experimental device was shown to be satisfactory in terms of change in mean optical density. Moreover, in terms of the subject's thickness, change in radiographic density was shown to be severe among lower X-ray tube voltage while there was severe density change in X-ray image depending on X-ray tube voltage among the subjects with more thickness. Therefore, it is suggested to provide performance management on the AEC for mammography.

***Key words**: AEC, Density, Mammography X-ray machine, MQSA, CR*

1. INTRODUCTION

The number of the cancer patients in Korea increased to 90.6% in the last 10 years, from 101,032 people in 1999 to 192,561 in 2009. When comparing the age-standardized incidence rate during the same period of time, data showed that breast cancer among women increased to about 134%, from 5,744 people to 13,460, showing the biggest incidence in thyroid cancer[1]. Since the incidence of breast cancer radically increased, the number of examinations through mammography tended to increase for early diagnosis. In this instance fast resolution mammography to diagnose micro calcification or breast fibrosis plays a critical role[2].

In order to get high quality result from the mammography, strict regulation and education of professionals on mammography X-ray machine are essential. In the U.S., a quality control certification program by an organization conducting mammography began in the beginning of 1980s under the supervision of the American College of Radiology (ACR) and Food and Drug Administration (FDA). In relation to this, the Mammography Quality Standards Act was established in 1992 to manage the mammography facilities, radiation dose, mammography X-ray machine and professionals in the field. Also, regular quality assessment and certification systems were provided which took effect in 1999.

In Korea, regulations on quality control have been managed such as the regulations on mammography X-ray machine which was included in the Rules of Diagnosis Radiation Equipment Safety Management, revised in January 2001 by the Ministry of Health and Welfare. Nonetheless, the performance assessment of automatic exposure control system, which is practiced in MQSA, is not available in the assessment items in Korea[3],[4].

Automatic exposure control system was introduced by R.H. Morgan in 1942 and its actual use began after 1970. This system is designed to maintain a constant radiographic density by automatically controlling exposure time. In this system, the necessary radiographic density is obtained by converting the x-ray dose that penetrates a subject to an electric signal and blocking the x-ray when this amount of electric signal reaches a certain value. The radiographic density changes depending on the subject's thickness and X-ray tube voltage in the clinical application. Therefore, it is advised to fully understand

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the characteristics of the automatic exposure control system for its effective use[5].

There are methods that use photo-timer and ionization chamber for the automatic exposure control system and in most cases, the ionization chamber is used. For the mammography X-ray machine, the automatic exposure control system is used in general due to the broad scope of breast thickness and density[6]. However, such methods are not managed in Korea and there is no basic study made on the automatic exposure control system for the mammography X-ray machine, which is being used the most in clinical settings.

Thus, this study assessed the performance of the automatic exposure control system for the mammography X-ray machines used in a clinical settings in the Incheon area.

2. METHODS

A total of 13 mammography X-ray machines with an automatic exposure control system, which used the CR and film screen method in 10 hospitals among clinics, general hospitals and university hospitals located in the Incheon area, were examined and assessed.

As recommended in the MQSA, phantom (Model 014A, CIRS Inc.) BR-12 could fully cover the measuring part of the automatic exposure control system which was positioned on the cassette tray and then compressed with a compression paddle. After locating the shooting mode on the automatic exposure control system, the X-ray tube voltage was manually controlled. While changing the X-ray tube voltage to 24, 28 and 32 kV, the thickness of BR-12 phantom in the X-ray tube voltage was changed to 2, 4 and 6 cm, respectively to develop a total of 9 phantom X-ray images from a single mammography X-ray machine (Figure 1). At that time, only a cassette was used to remove the other effects of the density to the cassette. After developing the image, the level of the density was measured to assess the performance. The position and density during the automatic exposure control system remained in the same condition when practiced in each hospital. The standard for the performance assessment implemented the reference suggested by the Korean Radiological Society[3] and MQSA guide[7],[8]. The mean optical density in all changes were based on density ±0.30.

Fig. 1. Arrangement for AEC test

3. RESULT

A total of 13 machines including 3 film-type and 10 CR-type mammography X-ray machines with the automatic exposure control system used in the Incheon area were assessed for their performance. The mean optical density of the 13 machines was shown to be from a minimum of 0.79 and a maximum of 2.81.

The mean optical density of the CR type was shown to be higher in general. Specifically, for film type, the density was 1.10~1.94 and 0.79~2.81 for the CR type. In the mean optical density and experimental condition, the difference between the minimum and maximum density showed a great difference of 0.10~1.14, and only eight devices, respectively, from the two film-type devices and five CR-type devices satisfied the standard of 61.5% when the assessment was made for the devices that satisfied ±0.3 of the standard (Table 1.).

Regarding the density change in the automatic exposure control system when fixing the subjects' thickness and changing the X-ray tube voltage, subjects with more thickness showed severe density change depending on the X-ray tube voltage with densities of 0.10~1.17 with 2 cm thickness, 0.0~1.04 with 4 cm thickness, and 0.02~1.22 with 6 cm thickness. Also when the X-ray tube voltage was fixed and subjects' thickness was changed, the density change depending on subjects' thickness in the automatic exposure control system was shown to be greater among lower X-ray tube voltage, having 0.06~1.96 for 24 kV, 0.05~1.37 for 28 kV, and 0.03~1.31 for 32 kV.

Table 1. MOD of AEC system

Type		MOD	MOD - Min.Density	MON - Max.Density
Film type	A	1.10	0.24	0.30
	B	1.94	0.82	0.78
	C	1.61	0.14	0.17
	av.±SD	1.55±0.43	0.40±0.37	0.41±0.32
CR-type	A	1.03	0.23	0.30
	B	2.42	0.88	0.34
	C	2.81	0.55	0.46
	D	1.68	0.90	1.06
	E	2.81	0.77	0.87
	F	0.86	0.14	0.25
	G	1.53	0.10	0.14
	H	1.76	0.63	1.14
	I	0.79	0.13	0.21
	J	0.82	0.15	0.11
	av.±SD	1.65±0.80	0.45±0.33	0.49±0.39
Total av.±SD		1.63±0.71	0.44±0.32	0.47±0.36

4. CONCLUSION

In Korea, breast cancer incidence is prevalent among those aged between 40 ~ 49 years old and such incidence of breast cancer tends to gradually increase. In the case of U.S. and European countries, such incidence increases along with age. However in Korea, the incidence of breast cancer gradually increases from early 20s and the rate decreases after reaching its peak between 45 and 49 years old. Since the ratio of young patients with breast cancer is relatively higher than western countries, it is important to make accurate diagnosis on the disease[9].

According to the report made by Kwon et al., the breast thickness compressed when having a mammography showed various ranges from 15mm to 62 mm. Along with age, the breast thickness compressed during mammography got thicker[2]. Thus, this study implemented the experiment by changing the thickness of BR-12 phantom from 2~6 cm in consideration of the thickness of the compressed breasts among Korean women.

The automatic exposure control system is the most suitable method to reduce effects of re-shooting caused by failure of radiation exposure at x-ray. Nonetheless, only a performance experiment on general x-ray machines was conducted by Kim et al., in Korea and not a study on mammography X-ray machine that uses the automatic exposure control system[5],[10],[11]. Overseas, an experiment was conducted not with multiple mammography X-ray machines but only one machine; as a consequence, it is hard to determine the real application of the mammography X-ray machine[12].

The reasons of density changes in a mammography X-ray machine with the automatic exposure control system include various thickness changes, long x-ray exposure depending on the X-ray tube voltage, sensitivity change in the sensors of the automatic exposure control system depending on x-ray beam hardening, and effects from various scatter rays[13]. Among such various factors, this study conducted an experiment by reviewing the effects caused by changes in thickness and X-ray tube voltage.

The results showed 0.79 ~ 2.81 difference in the mean optical density among all 13 machines. This implies that a patient can be exposed to unnecessary x-ray. In the experiment, the mean optical density of the CR-type was higher. Since the density was freely controlled from the diagnostic monitor, the users seem to increase the amount of x-ray exposure in general in order to decrease the potential of re-exposure to x-ray caused by insufficient density. Also when the subjects' thickness was fixed and the X-ray tube voltage was changed, the density of the x-ray image was severe along with thickness. However when the X-ray tube voltage was fixed and subjects' thickness was changed, the change in the density was severe among low X-ray tube voltage. Such results seem to be caused by the quality dependency of the mammography X-ray machine, which has low energy-oriented device.

In the density change depending on the device's mean optical density, only 61.5% of the total satisfied the standard, and the maximum density change over the mean optical density reached up to 1.14 in some devices. If the density change of the automatic exposure control system is low, it may generate an error when diagnosing the final image while a very high density damages a patient due to the increased unnecessary x-ray exposure. From such perspective, the performance assessment for the automatic exposure control system of mammography in Korea should be systematically managed.

Since the experiment of this study was conducted in one area, the study results cannot represent the overall performance of the countless mammography X-ray machines in Korea. However, this study helps people understand the general reality on the performance of the automatic exposure control system for the mammography X-ray machines, which have not been studied in Korea. In consideration of the shift from film screen and CR system to digital system, the study conducted an experiment taking into account of the film type. However, this method is being applied in the MQSA, the origin of the management of the mammography X-ray machine. Thus, it does not seem to be an issue. This study serves as foundation to add the automatic exposure control system to the examination items assessed for the performance management of the mammography X-ray machine in Korea.

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