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Study on the Dose and Exposure Characteristics of the Automatic Optimization Parameter Mode in Mammography

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Abstract

Background/Objectives*: The purpose of study was to provide useful information on the choice of the AOP mode of units that can improve the quality of breast images and reduce exposure dose by analyzing the dose and exposure characteristics of the AOP mode used in the mammography unit of the digital system.*

Methods/Statistical analysis*: The equipment used in the experiment is GE's Senographe Pristna and Hologic's Selenia Dimensions. The phantom used Polymethylmethacrylate phantoms and ACR phantom for the evaluation each according to the automatic exposure control of parameters mode for each equipment to evaluate the average dose. Statistical analysis was performed using one-way ANOVA, and post-hoc was performed using the Tukey method. The statistically significant range was set to ($p<0.05$).*

Findings*: In the dose evaluation, GE's Senographe Pristna showed that AGD and ESE were lower in the Dose- mode and, while Hologic's Selenia Dimensions showed that Auto Time mode was lower in AGD and ESE than the Auto Filter mode in dose evaluation. When compared on the whole, both AGD and ESE showed the lowest dose in the Dose-mode, but no statistical difference was found ($p>0.05$). In the image evaluation, all the scene modes used in the experiment showed different high and low evaluation scores for each item in the evaluation criteria range, but the Dose-mode is believed to provide high-quality images in diagnosing diseases of the breast, as well as mitigating exposure dose since the Dose-mode was the highest in the calcification detection that is considered crucial in mammography.*

Improvements/Applications*: These results showed that AOP modes applied to mammography units in digital systems can improve the quality of breast images and reduce exposure dose. It is also posited that the results of this study will be used as a baseline data for establishing optimized guidelines for image quality improvement*

and dose reduction in future mammography examinations.

Keywords: *digital mammography, automatic optimization parameter, image quality, average glandular dose, entrance skin exposure, polymethylmethacrylate.*

1. INTRODUCTION

Breast cancer accounts for 25.2% of the globe's total female cancer and represents the highest occurrence of female cancer, showing a steady increase to this day[1]. The number of breast cancer patients in South Korea has increased dramatically since the 1990s, and recently the occurrence frequency has more than doubled, making it the second most deadly cancer among female cancers after thyroid cancer[2]. It is unclear why breast cancer has increased, but it is reported that high fat and high calorie intake attributable to Westernized dietary changes, obesity, late marriage, low birth rates, fast first period, late menopause, and avoiding breastfeeding are the factors that contribute to the increase in the total period of exposure to estrogen[3]. The prognostic factor for cancer has not been found among approximately 70% of breast cancer patients so it is difficult to identify effective measures to treat the disease, and eventually the importance of early diagnosis came to the fore[4].

Mammography examination is the most effective inspection method for this diagnosis of breast cancer, and is mainly used to detect potential signs of breast cancer, such as changes in breast tissue, calcification, or tumors[5, 6]. However, quality control and optimization of images and management of minimized doses are particularly crucial in digital mammography examinations because of women who have an annual mammography are exposed to radiation throughout their lives[7].

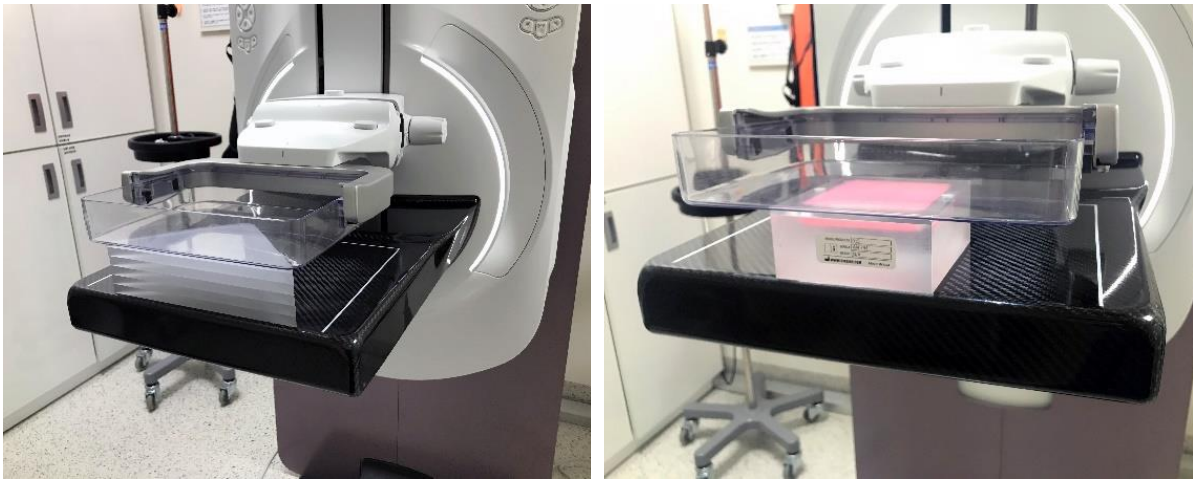
Digital mammography units used in medical institutions in recent years include various inspection methods for image quality and optimized dose management which have been developed. A typical function of this automatic control system is the automatic exposure control of parameters (AOP) mode, used separately between the functions of standard mode, contrast mode, and dose mode. The AOP mode is a function that measures breast thickness and density to control irradiated radiation and to automatically optimize key parameters related to exposure[8]. The AOP mode recommends that the users choose and use the three functional modes according to the purpose of the examination. However, because of the lack of training and information on AOP mode, the use of the standard mode is limited in contrast mode and dose mode by the main use of the standard mode in actual clinical practice.

Thus, there is a need and purpose of study to provide useful information on the choice of the AOP mode of units that can improve the quality of breast images and reduce exposure dose by analyzing the dose and exposure characteristics of the AOP mode used in the mammography unit of the digital system.

2. MATERIALS AND METHODS

2.1. *Experimental Equipment*

The equipment used in the experiment is GE's Senographe Pristna (GE Healthcare, Milwaukee, WI, USA) and Hologic's Selenia Dimensions (Hologic, Bedford, MA, USA). Polymethylmethacrylate (PMMA) phantoms was used to analyze the dose changes according to the AOP mode, and ACR phantom was used for image evaluation as shown figure 1.



(a) **(b)**

Figure 1. Phantoms and mammography system (a) PMMA phantom, (b) ACR phantom

2.2. *Classification of the AOP modes*

The AOP mode is referred to by different names for different equipment companies, but GE is divided into STD+ mode, STD mode, Dose- mode, and Hologic is divided into auto filter mode and auto time mode.

2.3. *Dose Evaluation*

The PMMA phantom used for dose evaluation was changed to 35 mm, 45 mm, 55 mm, and 65 mm in thickness, respectively, taking five shots each according to the AOP mode for each equipment to evaluate the average dose.

2.4. *Image Evaluation*

The ACR phantom used for image evaluation, and was acquisitioned from the cranio-caudal view. And three breast imaging radiologists compared phantom images using the ACR phantom image evaluation, a method of image quality evaluation among the items of quality control of special medical equipment as shown in figure 2.

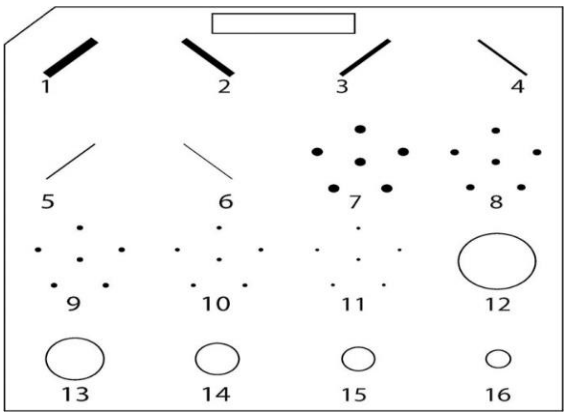


Figure 2. Mammography accreditation phantom image

2.5. *Image Evaluation Criteria*

According to Article 4, Clause 1 of criteria for examination of the diagnostic radiation generator, more than four of six fibers, three of five small calcification groups, and three of five masses, a total of 10 or more imitation lesion of a total of 16 imitation lesions can be accepted for quality control[9]. However, if each element fails to exceed the standard even if the total score exceeds 10, it will be decided on disqualification. The image analysis method of the ACR phantom gives 0.5 points if fiber can be observed more than one-half the length and the location and direction are on the right track. When observing calcification, it gives 0.5 points if two or three are observed in place. If the round limb of the mass is in place but does not appear round, gives 0.5 points.

2.6. *Statistical Analysis*

The measured data were presented as average and standard deviation using SPSS version 25 (SPSS Inc, Chicago, IL, USA) program. Statistical analysis was performed using one-way ANOVA, and post-hoc was performed using the Tukey method. The statistically significant range was set to ($p<0.05$).

3. RESULTS

The average glandular draw (AGD) according to the scene modes was shown to be average of 1.79 ± 0.43, STD- mode was the lowest with 1.22, the Auto Filter mode was measured the highest, and there were no statistically significant differences ($p>0.05$) as shown in table 1.

Entrance Skin Exposure (ESE) averaged 6.77 ± 1.63, STD-mode was the lowest with 4.6, STD+ mode was measured the highest, and there was no statistically significant difference ($p>0.05$).

Table 1: Comparison of conditions according to the mammography units by manufacturer

Type	AGD	ESE	kVp	mAs
STD[a]	1.55	5.84	34.00	43.27
STD+[b]	2.20	8.36	34.00	62.81
Dose-[c]	1.22	4.60	34.00	33.57
Auto Filter[d]	2.23	8.35	29.25	179.80
Auto Time[e]	1.78	6.70	28.00	163.08
M±SD	1.79±0.43	6.77±1.63	31.85±2.98	96.5±69.46
f, p	f=1.024, p=0.427	f=0.534, p=0.713	f=36.051, p<0.001	f=4.761, f=0.011
Post-hoc	n/a	n/a	d.e<a.b.c	c.a.b.e<a.b.e.d

The result of image evaluation of fiber according to the scene modes was shown to average of 4.7 ±0.26, STD-mode was the lowest with 4.3, STD+ mode and auto filter mode were measured the highest with 4.9, and

there were statistically significant differences ($p<0.05$) as shown in table 2.

The result of image evaluation of Specks was shown to average of 3.9 ± 0.98, Auto Time mode was the lowest with 3.1, STD- mode was measured the highest with 5.5, and there was no statistically significant difference ($p>0.05$).

The result of image evaluation of masses was shown to average of 12.6 ± 0.84, Auto Time mode and STD-mode were the lowest with 4.0, and the STD+ mode was the highest with 4.2. This was shown that there were statistically significant differences ($p<0.05$), and Tukey's post mortem results were all homogenous subset ($p>0.05$).

The result of image evaluation of imitation lesions was shown to average of 3.9 ± 0.98, Auto Time mode was the lowest with 11.6, STD-mode was the highest with 13.9, and there was no statistically significant difference ($p>0.05$).

Table 2: Comparison of image evaluation according to the mammography units by manufacturer

	Fiber	Specks	Masses	Lesions
STD[a]	4.6	3.7	4.1	12.4
STD+[b]	4.9	3.8	4.2	12.9
Dose-[c]	4.3	5.5	4.0	13.9
Auto Filter[d]	4.9	3.2	4.1	12.3
Auto Time[e]	4.5	3.1	4.0	11.6
M±SD	4.7±0.26	3.9±0.98	4.1±0.08	12.6±0.84
f, p	f=4.896, p=0.006	f=1.067, p=0.399	f=3.533, p=0.025	f=0.734, p=0.580
Post-hoc	c.e.a<e.a.b.d	n/a	c.e.a.d.b	n/a

4. DISCUSSION

The discovery of X-rays has allowed humankind to achieve its dream of life extension through early diagnosis and treatment of diseases, and it is being applied and used in various areas, including the economy, science, society and education with the development of technology[10]. However, as X-rays are a kind of radiation and there is a risk of exposure, they should be maintained in optimal condition so that unintended doses do not occur through periodic management of the X-ray generator[11]. In particular, females in South Korea are subject to radiation exposure during their lives as they are found to have a disease in their breasts or are subject to a regular examination in the case of a national health examination[12]. Additionally, mammography is basically acquiring four images by shooting the cranicaudal (CC) view and mediolateral oblique (MLO) view on both breasts, and should be concerned in managing exposure dose as radiation-sensitive organs such as lymph nodes and thyroid gland are around the breast [13, 14].

According to Ko and others, most digital mammography systems have been reported to improve the quality of images and lower the dose compared to the existing systems by using the AOP function in conjunction with the AEC system. [13] However, even with mammography units comprising the AOP modes,

only standard modes were used primarily through users' lack of knowledge or experiential conventions in actual clinical practice. Thus, the purpose of this study was to provide useful information and basic data on the choice of the AOP mode in units that can improve the quality of breast images and reduce exposure dose by analyzing the dose and exposure characteristics of the AOP mode used in mammography units in digital systems.

In the analysis, GE showed that AGD and ESE were lower in the Dose- mode and, while Hologic showed that Auto Time mode was lower in AGD and ESE than the Auto Filter mode in dose evaluation. When compared on the whole, both AGD and ESE showed the lowest dose in the Dose-mode, but no statistical difference was found ($p>0.05$). These results were the same as the argument that using the Dose-mode of the AOP modes can maintain the quality of the images and reduce the dose, and the Auto Time mode is superior in terms of dose compared to the Auto Filter mode in the previous study of Kamal et al.[15, 16].

It can be observed as a differentiated study that presented a wider range of comparative data than the results of the previous study since this study compared the equipment of the two companies, while it was evaluated on only one type of equipment in the previous study.

In the image evaluation, all the scene modes used in the experiment showed different high and low evaluation scores for each item in the evaluation criteria range, but the Dose-mode is believed to provide high-quality images in diagnosing diseases of the breast, as well as mitigating exposure dose since the Dose-mode was the highest in the calcification detection that is considered crucial in mammography. The limitations of this study are that we decided to differ from the actual dose measured by experimenting with phantom, not with the human body, and have differences by the dependence of the evaluator in image evaluation.

5. CONCLUSION

The results of the comparative analysis of dose and exposure characteristics by company according to the AOP mode in the use of a mammography device in a digital system are shown as follow.

First, AGD and ESE appeared to have lower Dose- mode than STD+ mode in dose evaluation according to the scene modes.

Second, the image evaluation according to the scene modes showed high STD+ in fiber and mass, and the most important diagnostic items of mammography, Specks and Imitation Lesions, showed high in the Dose-mode.These results showed that AOP modes applied to mammography units in digital systems can improve the quality of breast images and reduce exposure dose. It is also posited that the results of this study will be used as a baseline data for establishing optimized guidelines for image quality improvement and dose reduction in future mammography examinations.

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