

Spatial Dose Distribution and Exposure Dose during Mammography

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Abstract

This during the breast mammography X-ray test, a glass dosimeter and spatial dose measuring meter was used to measure and evaluate the exposure dose and spatial dose distribution of each organs by exposure dose and scattered ray in order to obtain the optimal image for diagnosis and minimize the exposure dose. The usage dose of tube voltage and tube current amount was larger among the young age group, whereas the transmission dose, the glandular dose, etc. were larger among the old age group (<0.001). The influence of dose inequality phenomenon was confirmed since the exposure dose and spatial scattered dose by the scattered ray has increased as they got closer to the X-ray tube cathode and toward the direction of X-ray irradiation. Such results are expected to be presented as data for anticipating the exposure dose of patients and determining a test method during a breast cancer test in the future and also utilized widely as basic important data for reducing the medical exposure dose.

Keywords: Exposure Dose, Glass Dosimeter, Mammography, Minimize, X-Ray

1. Introduction

Due to South Korea's rapid economic growth and westernization of lifestyle, the number of risk factors for breast cancer has rapidly increased every year. Since 2001, breast cancer has had the highest incidence rate for woman cancer¹. The breast cancer view test has been known as a way of early detection for breast cancer, which could not be touched. Even those women who do not have any relevant symptoms have a growing interest in the mammography treatment due to the introduction of universal health insurance system and the free support for health screening by the government. As a result, there has been a growing desire to receive the mammography

treatment and also the number hereof has been on the rise every year^{2,3}.

The mammography treatment has the attribute that the X-ray absorption difference of its surrounding tissues such as lesions, breast tissue, fatty tissue, etc. is small and fine calcification should be depicted. To improve the detection rate of breast lesions, small focuses are used and the use of small focuses cause the exposure dose to be increased by increasing the exposure time^{1,4}.

It has been reported that the radiation dose received by patients during breast test might cause more harmful effects due to radiation exposure than the benefits of early detection⁵.

International Committee Radiation Protection (ICRP)

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had recommended in the 60 proposal of recommendation that the tissue weighted coefficient of breast shall be 0.05. However, it later raised its previous recommendation in the 103 proposal of recommendation that the tissue weighted coefficient of breast shall be 0.12. Breast is an organ only for women; thus, this upwardness of tissue weighted coefficient can be regarded as a meaningful case. In other words, this amended recommendation allowed us to think that the risk level as to the incidence rate of breast cancer by radiation exposure^{6,7}.

Glass dosimeter allows for repeated reading of radiation exposure dose and accumulative dose measurement since the fluorescence center generated by irradiation is not destroyed by repeated measurement. Also, the measurable dose range is 10 μ Gy to 500 Gy; thus, the measurement range is wide. Since the fading effects are small and the direction and energy dependability are outstanding, glass dosimeter tends to be used as a measurement device for medical exposure dose⁸⁻¹¹.

The exposure by diagnostic radiation is gradually on the rise and it accounts for the largest proportion among the artificial radiations¹⁰. It is required to have a study on exposure dose related to the diagnosis of those organs such as breast, colon, lung and stomach whose tissue weighted coefficient is relatively high in order to minimize the impact of diagnostic radiation on human body.

As for the studies related to breast exposure dose, the exposure dose evaluation in accordance with exposure method¹, the study on absorbed dose within breast tissue using simulation², the study on the status of breast mammography¹², the study on the scattered dose for thyroid during breast test³, the study on the absorbed dose in accordance with imaging conditions during a breast cancer test⁴, etc. were undertaken. However, these studies have been undertaken based on the dose evaluation by the device based on the irradiation dose measuring meter or automatic exposure device. Furthermore, there has been no study on exposure dose by using the glass dosimeter, which is the dosimeter for human tissue equivalent materials.

This study was conducted for the purpose of minimizing the exposure dose and providing preliminary data for obtaining an optimal image by measuring and evaluating the exposure dose and spatial dose distribution using the glass dosimeter as focusing on the patients and radiation related workers in the mammography examination, whose radiation tissue weighted coefficient recommendation was amended upward.

2. Subjects and Method of Study

2.1 Materials and Equipment

As for radiation generator, Siemens' Mammomat Inspiration System was utilized. To measure the exposure dose of examinees, Human Body Phantom for the face and body (Model PBU-31, Kyoto Kagaku, Japan) that consisted of human body equivalent material and Dose Ace (Model GD-352M and FGD-1000, Asahi Techno Glass Cooperation, Shizuoka, Japan) that was a glass dosimeter were utilized.



Figure 1. Radiation Generator and Phantom.

As for the measurement of spatial dose distribution, Ionization Chamber (Model 20 $\times$ 5 - 1,800cc, Monrovia, California, USA) and Electrometer (Radiation Monitor Controller Model 2026), which had completed the calibration, were utilized.



Figure 2. Ionization Chamber and Electrometer.

2.2 Measurement of Exposure Dose during Breast Mammography Examination

As for the exposure dose during breast mammography, its entire treatment data was analyzed by summing tube voltage, irradiation dose, incident dose and glandular

dose, which were utilized from the positions of R - CC, L - CC, R - MLO and L - MLO in which a test was to be conducted generally for the 235 patients who had visited G hospital in G region from July 1 to 31, 2013.

2.3 Measurement of Scattered Exposure Dose using Glass Dosimeter

As for the calibration of glass dosimeter, it was measured by conducting the calibration with the glass element that had been irradiated for 6 mGy by using ^{137}Cs radioactive standard at the Japanese Agency of Radiative Standards.

Taking into account the characteristics of the elements, the background value was measured to be 10-20 μGy after undergoing the cooling process after heating the annealing process at 400°C for one hour before irradiation. And the mean value and the standard deviation were calculated by repeating to decode the dose integration value 10 times through the reader as for the dose value irradiated at the elements after undergoing the cooling process after heating at 70°C for one hour as for the pre-heating after conducting the panorama scanning. The exposure dose value was derived by subtracting the background value from the calculated value [9, 13].

As for the measurement of exposure dose distribution at the mammography examination, the exposure dose distribution for each part was measured by placing the glass dose element at the location of crystalline lens both eyes, thyroid, both breast parts, heart and gonad. In addition, to reduce the measurement error, breast mammography examination was repeated 3 times.

2.4 Measurement of Spatial Scattered Dose

To examine the spatial scattered ray distribution, the table of radiation generator was placed to be horizontal and the subject was placed by designing the distance between the X-ray tube and the detector to be 100 cm. As for the location of ionization chamber, it was measured from the 7 direction after excluding the immeasurable areas from the internal structure of test room in the interval of 45 degrees at the distance of 100 cm from the center of table (Figure 3). To increase the reliability as to the measurement data at the time of measurement, the data was analyzed by using the mean value after measuring 3 times at each location^{13,14}.

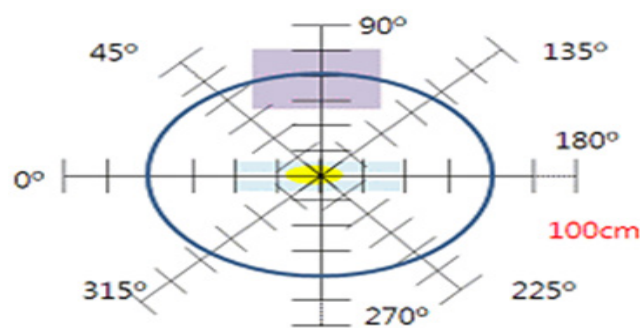


Figure 3. Schematics Measurement Points.

2.5 Statistical Processing and Analysis

As for the data analysis, SPSSWIN (Ver 13.0) statistical program was used. As for the verification of significance as to the mean value of exposure dose and image quality evaluation measurement of the control and experimental groups, t-test and ANOVA were conducted. The significance level of all statistics was decided to be $p < 0.05$.

3. Result and Discussion

3.1 Imaging Conditions and Exposure Dose Distribution during Mammography Examination

As for the irradiation conditions used during the mammography examination, the imaging equipment such as tube voltage and tube current amount were analyzed for each age group by using AEC (Automatic Emission Controller) that was the automatic dose controller. The overall average of tube voltage of examinees was 28.95 ± 1.36 . It was 29.13 ± 1.36 in the age group of 40 years old or younger, whereas it was 29 ± 1.11 in the age group between 41 and 50 years old and 28.82 ± 1.18 in the age group between 61 and 70 years old. Thus, it was found that a relatively high degree of tube voltage was used among the young age groups.

The overall average of tube current amount of examinees was 74.49 ± 23.47 . It was 97.26 ± 27.66 in the age group of 40 years old or younger, whereas it was 84.48 ± 26.35 in the age group between 41 and 50 years old and 63.77 ± 21.52 in the age group between 61 and 70 years old. It was found to be 53.84 ± 17.04 in the age group of 70 years old or older. Thus, it was found that a relatively

high degree of tube current amount was used among the young age groups (<0.001).

Table 1. Distribution of dose in mammography examination

Age	Pt. No.	Exposure factor		Dose(mGy)		P
		kVp	mAs	Entrans°	Glandular	
<41	18	29.13 ± 1.17	97.26 ± 27.66	2.89° ± 1.15	1.07 ± 0.26	<0.001
41-50	78	29 ± 1.11	84.48 ± 26.35	2.86 ± 1.14	1.07 ± 0.26	
51-60	76	29.04 ± 1.40	73.09 ± 24.79	2.86 ± 1.14	1.08 ± 0.31	
61-70	43	28.85 ± 1.18	63.77 ± 21.52	2.93 ± 1.04	1.09 ± 0.30	
70<	20	28.95 ± 1.96	53.84 ± 17.04	3.24 ± 1.3	1.36 ± 1.54	
Aver-age	235	28.95 ± 1.36	74.49 ± 23.47	2.94 ± 0.09	1.13 ± 0.56	

As for the breast transmission dose during a mammography examination, the overall average of examinees was 2.94 ± 0.09 . It was 2.89 ± 1.15 in the age group of 40 years old or younger, whereas it was 2.86 ± 1.14 in the age group between 41 and 50 years old and 2.93 ± 1.04 in the age group between 61 and 70 years old. It was found to be 3.24 ± 1.3 in the age group of 70 years old or older. Thus, it was found that a relatively high degree of breast transmission dose was used among the old age groups (<0.001).

As for the glandular dose during a mammography examination, the overall average of examinees was 1.13 ± 0.56 . It was 1.07 ± 0.26 in the age group of 40 years old or younger, whereas it was 1.08 ± 0.31 in the age group between 41 and 50 years old and 1.09 ± 0.30 in the age group between 61 and 70 years old. It was found to be 1.36 ± 1.54 in the age group of 70 years old or older. Thus, it was found that a relatively high degree of breast transmission dose was used among the old age groups (<0.001).

It is believed that the results thereof indicates that an optimal image is obtained among the young age groups by using a high degree of tube voltage and tube current amount since a younger person has a higher degree of tissue absorption rate. Also, it believed that the

dose was measured to be relatively high since the breast transmission dose and glandular dose has a lower degree of tissue absorption rate among older people.

The above results are expected to be used as important data for determining the imaging conditions in accordance with age during a breast mammography examination.

3.2 Scattered Exposure Dose during Mammography Examination

Mammography examination is the part to obtain images by using low tube voltage and high dose exposure conditions in a simple imaging using X-ray. And it is a test requiring more attention than a test for other parts since it includes breast, heart, gonad and crystalline of eyes whose radioactive sensitivity is relatively higher as for the organs to be exposed to X-ray during test.

As for the X-ray irradiation intensity and determination of dose in this experiment, the experiment was undertaken at the positions of R - CC, L - CC, R - MLO and L - MLO under the conditions of 28kVp and 60mAs that were determined to be the minimal exposure dose while the amount of diagnostic information was at the optimal state by acquiring an image for each irradiation condition after referring to the irradiation conditions used in clinics.

The exposure dose was calculated by summing the 4 positions to acquire the required images for the diagnosis during a breast mammography examination. As for the exposure dose distribution for each organ, the crystalline of left eye that was relatively close from the cathode of X-ray tube was measured to be $308 \pm 1.15 \mu\text{Gy}$, whereas the crystalline of right eye was measured to be $107 \pm 0.94 \mu\text{Gy}$, thyroid was measured to be $105 \pm 0.79 \mu\text{Gy}$, right chest was measured to be $80 \pm 0.65 \mu\text{Gy}$, left chest was measured to be $44 \pm 0.36 \mu\text{Gy}$, heart was measured to be $28 \pm 0.17 \mu\text{Gy}$ and genital area that was in the farthest place from the X-ray tube (Table 2).

From the measurement results, it was possible to confirm that the exposure by the X-ray scattered ray during a breast cancer diagnostic examination using X-ray becomes large when it gets closer to the cathode of X-ray tube. The results thereof were similar to the results of the studies of Cho¹⁴ and Kim¹⁶. Such diagnostic radiography using X-ray has more benefits than risks in accordance with the exposure for testers; thus, it is imperative to ensure the legitimacy and achieve the defense optimization against radiation for patients^{15,16}.

To achieve the optimization during a diagnostic radiography, it is required to have a lot of interests and action will as to the reduction of exposure dose and radiation defense for workers related to radiation.

To this end, it is believed that it is necessary for the workers hereof to wear lead glasses and thyroid protectors during a test in order to minimize the exposure dose of testers during a breast cancer test.

Table 2. Distribution of dose in emammography examination

Part	Dose (μGy)	SD
Rt. Lens	308	1.15
Lt. Lens	107	0.94
Thyroid	105	0.79
Rt. Brest	80	0.65
Lt. Brest	44	0.36
Heart	28	0.17
Reproductive system	21	0.16

3.3 Spatial Dose Distribution in Accordance with Direction during Mammography Examination

When measuring the spatial dose distribution during a mammography test, it was found to be $35.33 \pm 5.51 \mu\text{Gy}$ in the direction of 0 degree of (Figure 3.), whereas it was $7.67 \pm 1.53 \mu\text{Gy}$ in the direction of 90 degrees, $40.67 \pm 8.08 \mu\text{Gy}$ in the direction of 180 degrees, $91.67 \pm 20.23 \mu\text{Gy}$ in the direction of 225 degrees and $368.00 \pm 41.87 \mu\text{Gy}$ in the direction of 270 degrees (Table 3). The reason why the smallest dose was measured in the direction of 90 degrees was that the irradiation part of X-ray tube was pointed toward the opposite direction and the spatial measurement dose was low by means of the shield of X-ray tube itself. The reason why a relatively large amount of spatial dose was measured in the directions of 270 degrees and 225 degrees was that they were the irradiation part of X-ray tube and they were the closest directions to the cathode. These study results are similar to the results of the studies of Cho¹⁴ and Kim¹⁵. It is believed that these findings were obtained as a result of the Heel Effect, which is the dose inequal distribution phenomenon that is the attribute of X-ray tube (Figure 4). It would be also possible to overcome the density non-uniform phenomenon by thickness for diagnostic radiography if such dose inequal phenomenon was utilized appropriately.

Table 3. The distribution of scatter ray on the measurement point

Direction	Dose(μGy)	SD
0	35.33	5.51
45	29.00	9.54
90	7.67	1.53
135	32.33	8.33
180	40.67	8.08
225	91.67	20.23
270	368.00	41.87
315	47.33	7.09

In case of conducting a mammography examination from the above results, testing those organs sensitive to radiation by placing them far away from X-ray tube can minimize the impact on human body since it reduces the effective dose of organs whose tissue weighted coefficient is high even when irradiating the same radiation dose. Thus, it is believed that it would be necessary for relevant workers to have a lot of interests and efforts to minimize the impact on human body.

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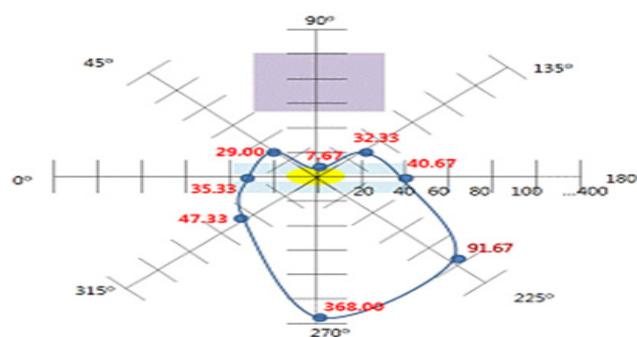


Figure 4. The distribution of scatter ray on the distance.

In addition, it is imperative for the relevant associations and organization that utilize radiation to make a lot of efforts to ensure the legitimacy and achieve the optimization for radiation defense of patients by minimizing exposure

dose by radiography through providing periodic training as to exposure dose and image quality to workers related to radiography.

As for the limitations of this study, the measurement of exposure dose during the breast mammography examination could not analyze the accumulated data for each hospital and equipment nationwide. In other words, this study was conducted at one specific hospital during the specific period; therefore, there should exist some uncertainties in terms of objective evaluation. Thus, it is believed that it will be imperative to conduct the study thereof extensively in order to evaluate more objective related exposure dose during a breast mammography examination in the future.

4. Conclusion

During the breast mammography X-ray test, a glass dosimeter and spatial dose measuring meter was used to measure and evaluate the exposure dose and spatial dose distribution of each organs by exposure dose and scattered ray in order to obtain the optimal image for diagnosis and minimize the exposure dose.

The usage dose of tube voltage and tube current amount was larger among the young age group, whereas the transmission dose, the glandular dose, etc. were larger among the old age group (<0.001).

The influence of dose inequality phenomenon was confirmed since the exposure dose and spatial scattered dose by the scattered ray has increased as they got closer to the X-ray tube cathode and toward the direction of X-ray irradiation.

Such results are expected to be presented as data for anticipating the exposure dose of patients and determining a test method during a breast cancer test in the future and also utilized widely as basic important data for reducing the medical exposure dose.

5. Acknowledgement

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