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Development of a Phantom for Low Dose Mammography

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Abstract

Background/Objectives: Interest in regular mammography has grown as a way for early detection of breast cancer. In this study, we produced a phantom that allows for an evaluation of the image quality of images acquired at different phases using X-rays.

Method/Statistical Analysis: To measure the radiation generated during breast cancer diagnosis using X-rays, the X-ray tube system by Varian was used to measure and analyze at a distance of 40 cm under the conditions of 22kVp, 20 mA, and 710mAs. To reduce errors in measurement, imaging of the breasts was done repeatedly for 10 times.

Findings: In the absorption image, there were 5.0±0.2 fibers, 4.5 specks and 4.5 masses, making the total 14 which is higher than the 10 required to be officially authorized. In the dispersion and phase differential images, there were 5.5±0.0 fibers, 4.5 specks, and 4.5 masses, making the total 14.5 which is higher than the 10 required to be officially authorized. In addition the image quality was better than that of the absorption image. When a dosimeter was used, the radiation exposure was an average of 2425.85±0.33mR. When the absorbed radiation was measured using a glass dosimeter, it was 1,334±1.82μGy. This was different from the value converted using the valid radiation.

Improvements/Applications: In particular, phase differential imaging is expected to be applied to breast cancer tests where most of the tissue is soft, verification tests for foreign objects and forecasting of the progress in the disease.

Keywords: *Low dose, Mammocancer, Rontgen ray, Image Quality, Phantom.*

Introduction

With the increase in fat intake, contemporary people have seen an increase in obesity, a fall in birth rates and nursing rates, a fall in the age of women's first period and an increase in the age at which menopause arrives, leading to more potential to be exposed to the risk factors of breast cancer. As such, there is a clear increase in demand for breast cancer tests[1-2].

In the forecast of cancer incidence and cancer-related deaths in 2018 by the WHO IARC, the cancer burden has been increasing. Breast cancer is forecast to be the most frequently occurring cancer for women, while for Asian men lung cancer is forecast to be ranked first. In other areas, prostate cancer is expected to be ranked first for men. Regardless of a nation's income level, breast cancer has a significantly higher incidence than any other cancer in women[3-7].

In 2003, ICRP presented a Diagnostic Reference Level for radiation by measuring the radiation amount during mammography in the U.S. and U.K and has been recommending that governments have it applied. In Korea, too, efforts to reduce radiation exposure have increased, by evaluating the radiation that patients are exposed to during mammography and having a study jointly conducted by the KFDA and Korea Medical Image Quality Management Center[7-12].

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Interest in regular mammography has grown as a way for early detection of breast cancer. Mammography is offered at many medical institutions across the country. The Ministry of Health and Welfare, too, recommends that women over age 40 undergo a mammography.

Many report that an imaging device for the breasts that has a high contrast and resolution offers the benefits of early detection of breast cancer and increasing the survival rate by over 30% even when cancer is found[13-14]. But ill-managed devices or certain types of imaging devices for the breasts may actually increase the risk of breast cancer.

Despite the growth in demand for check-ups for breast cancer around the world, there is no cost-effective test method for the dense breast tissue, raising the need for a new test method. In recent years, devices that have significantly increased the accuracy in diagnosis of dense breast tissue have appeared. Digital Breast Tomosynthesis, Automated Breast Ultrasound, X-ray phase contrast imaging technology and imaging devices that bring all these together have earned a lot of interest in the market.

Hologic has led the market for diagnosis devices for breast imaging launched in 2011 Selenia Dimension, which is the world's first three dimensional imaging device for the breasts approved by the FDA and KFDA. In recent years, low dose technology has seen progress to produce several tens of slices with radiation exposure on par with existing mammography. In particular, the two dimensional mammography required by FDA is not taken in addition, but the synthesis technology using Tomosynthesis is applied to reduce radiation exposure while realizing a high contrast level for the lesion. The technology is called C-View.

X-ray phase differential imaging technology uses information on dispersion and difference in phases to dramatically show the borders between similar types of substances with similar density[7-12]. In addition, it has the benefit of using less radiation to produce better quality images compared to existing imaging technologies that leverage the difference in absorption rate of X-rays. Because of this trait, the technology is being researched for its application to low dose diagnostic devices for breast cancer[13-15].

In this study, we produced a phantom that allows for an evaluation of the image quality of images acquired at different phases using X-rays. The image quality and practical value of the technology were analyzed to optimize the valid radiation amount in a breast cancer test that has a high sensibility to radiation. The radiation amount and absorption amount for X-ray phase differential imaging was measured to verify the accuracy of the theoretical valid radiation and provide basic data for further research on X-ray phase differential phantoms.

Study Subjects and Methodology

1. **Evaluation of the practical value of the phantom manufactured in the lab:** For the radiation generating device, Hologic LORAD selonia System was used. To acquire images during breast cancer tests and evaluation of such images, the posture used for breast cancer tests at clinical hospitals conducting health check-ups was used. In the postures, R – CC, L – CC. R – MLO, L- MLO, the phantom produced by the researcher was exposed to a radiation of 28kVp 100mAs.

2. **Measuring and analyzing the radiation generated and absorbed during an X-ray test for breast cancer:** To measure the radiation generated during breast cancer diagnosis using X-rays, the X-ray tube system by Varian was used to measure and analyze at a distance of 40cm under the conditions of 22kVp, 20mA, and 710mAs.

The radiation generated was measured using Radcal 2026C device with a 360cc detector equipped. To reduce errors in measurement, imaging of the breasts was done repeatedly for 10 times.

For the measurement of radiation absorbed, the glass dosimeter ACE 100GD model of the Japanese company Chiyoda was used. For the calibration of the glass dosimeter, ^{137}Cs standard radiation from the Japanese Radiation Standard Center was applied, using a glass device receiving 6mGy.

Given the characteristics of the glass device, the annealing process before the radiation consisted of one hour of heating at 400^{o}C, then cooling and measuring of the background value to measure 10-20μGy. After a panorama scan, pre-heating was done at 70^{o}C for one hour. After a cooling period, the radiation value that the glass device was exposed to was read 10 times using the reader to calculate the mean and standard deviation. Using the calculated value, the background value was deducted to conclude the exposure of radiation [9, 13].

Conclusion and Discussion

1. **Evaluation of the image quality when using an in-house produced phantom for breast cancer diagnosis tests:** Diagnostic tests for breast cancer consist of self-diagnosis, clinical diagnosis, imaging tests, ultrasound tests and biopsy. Early detection of breast cancer not only improves the full recovery rate and survival rate, but also helps preserves the breasts and improves the quality of life. Imaging tests of the breasts are essential to the diagnosis of breast cancer and plays an important role in detecting early lesions that cannot be picked up on by diagnosis by touch or by ultrasound tests, such as subtle calcification.

In this study, a phantom was manufactured in the lab to evaluate the image quality and the technology of the X-ray phase differential imaging, as well as verify the data provided by the image.

The phantom was manufactured using a material that is similar to the breast tissue, artificially creating an environment similar to a disease in the breasts. Under the clinical imaging conditions, the X-ray absorbed was as seen in Figure 1, 2. As seen in the figures, in both the phantom made of liquid substances and the phantom made of solid substances, resolution had relatively decreased.

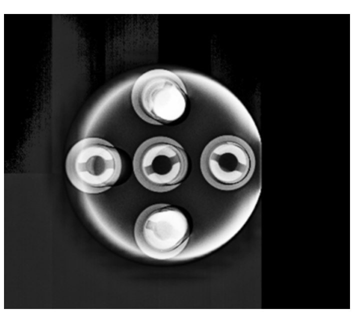

Figure 1. Image acquired from the phantom made of liquid substances

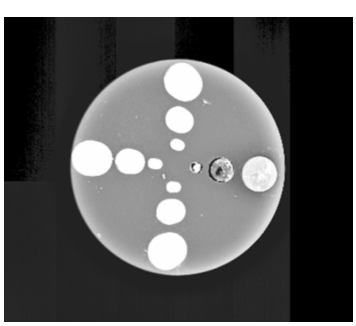

Figure 2. Image acquired from the phantom made of solid substances

To evaluate the resolution of images, the phantom made of solid substances was used to review the absorption image, dispersion image and phase differential image, as seen in Figure 3.

A team consisting of a radiology doctor and five radiologists with more than 10 years of experience conducted qualitative evaluation of the images. In the absorption image, there were 5.0±0.2 fibers, 4.5 specks and 4.5 masses in resolution. The total was 14, which is more than the cutoff rate of 10 for the image to meet the authorized standard. In the dispersed image and phase differential image, there were 5.5±0.0 fibers, 4.5 specks, and 4.5 masses. The total was 14.5 which is more than the cutoff rate of 10 for the image to meet the authorized standard. It was also confirmed that the quality of the image was better than that of the absorption image [Table 1].

Based on these results, the absorption image, dispersion image and phase differential image were analyzed using a phantom made of solid powder. The results were as seen in Figure 4. As seen in the figure, the lead substance has a low valid atomic number, leading to the data decreasing in the absorption image compared to those of the dispersion image and phase differential image. In particular, it was confirmed that the data were superior in the phase differential image.

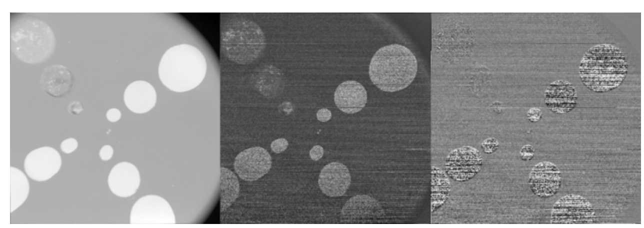

Figure 3. Absorption, dispersion and phase differential in phantoms made of solid substances

Table 1. Evaluation of absorption, dispersion and phase differential in breast cancer imaging tests

	Absorption Image	**Dispersion Image**	**Phase Differential**
Fiber	5.0±0.2	5.5±0.0	5.5±0.0
Specks	4.5±0.0	4.5±0.0	4.5±0.0
Mass	4.5±0.2	4.5±0.2	4.5±0.2
Total	14.0±0.2	14.5±0.1	14.5±0.1

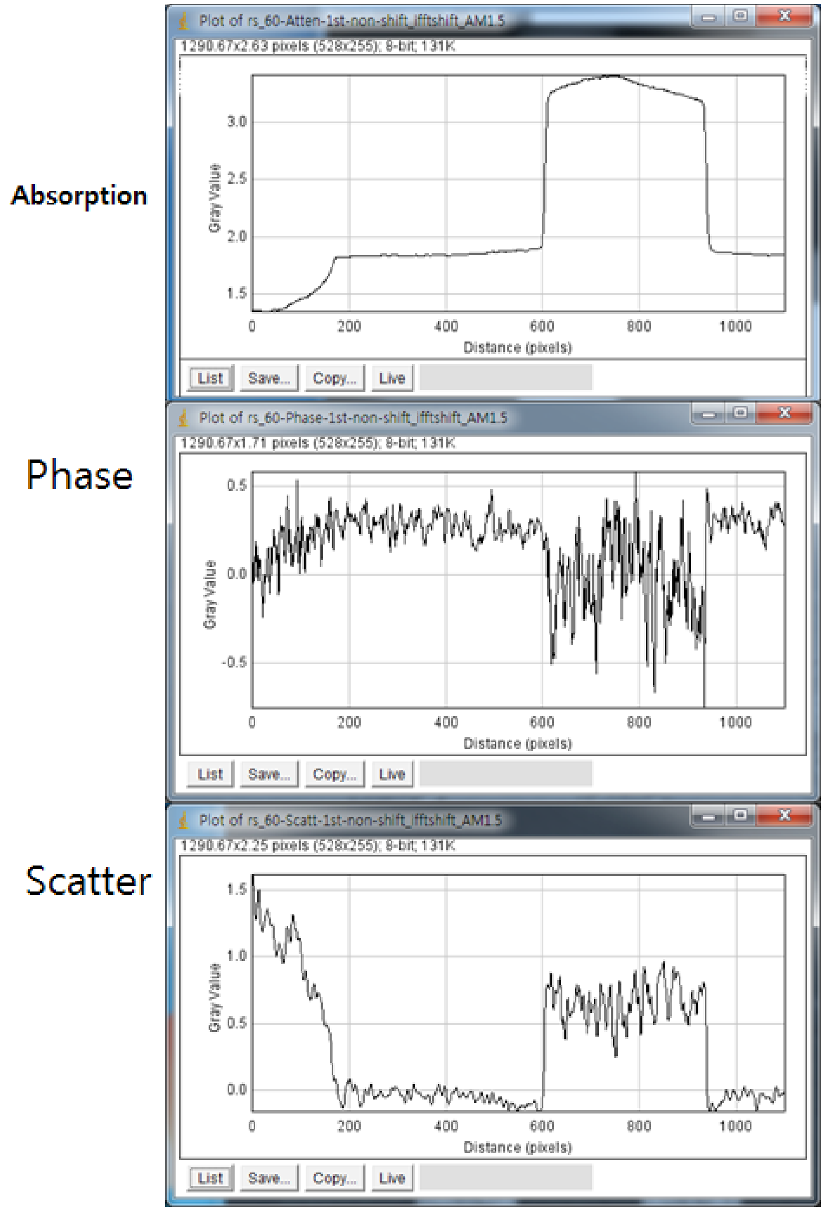

Figure 4. Analysis of the data from the absorption, dispersion and phase differential images using the in-house phantom made of solid substances

2. **Measurement and analysis of the radiation exposed and absorbed during an X-ray diagnostic test for breast cancer:** The mammary tissue in the breasts is relatively sensitive to radiation. As such, it is reported that X-ray diagnostic tests can rather increase the chances of causing cancer rather than giving the benefit of early detecting of breast cancer. For this reason, the measurement of radiation in breast cancer tests and defenses against radiation are very important.

In this study, to measure the radiation during an X-ray diagnostic test for breast cancer, the X-ray rube system by Varian was used to measure at a distance of 40cm under the condition of 22kVp, 20mA, 710mAs. The measurement of radiation amount generated was done using Radical 2026C. To reduce the margin of error in measurement, it was repeated 10 times.

The measurement of the radiation amount absorbed was done using the glass dosimeter ACE 100GD model of the Japanese company Chiyoda. se company Chiyoda was used. For the calibration of the glass dosimeter, ^{137}Cs standard radiation from the Japanese Radiation Standard Center was applied, using a glass device receiving 6mGy. The radiation applied to the glass device was measured 10 times through the reader to calculate the mean and standard deviation.

Table 2. Evaluation of the radiation exposed and absorbed during a diagnostic test for breast cancer

Scan No.	Radiation Exposure [mR±SD]	Radiation Absorbed [μGy±SD]
1	2425.85±0.35	1,324±1.82
2	2425.35±0.33	1,330±1.82
3	2432.85±0.32	1,334±1.82
4	2426.15±0.35	1,335±1.62
5	2418.85±0.31	1,333±1.82
6	2420.35±0.33	1,344±0.82
7	2423.65±0.35	1,338±1.82
8	2425.85±0.43	1,324±1.01
9	2431.35±0.29	1,332±1.23
10	2428.05±0.35	1,336±2.30
Average	2425.85±0.33	1,334±1.82

[Table 2] shows the evaluation of radiation exposure during the phase differential imaging for breast cancer tests. When a radiation measuring device that is highly dependent on direction was used, the mean was 2425.85±0.33mR. From a conservative viewpoint assuming that the energy of the X and r-rays applied to the human body has an energy absorption coefficient ratio of approximately 1.11 when the energy of the X and r-rays are 0.1MeV or higher, the absorbed amount can be calculated as 0.974 ×X[R] = approximately 1.0×X[R] [rad]. When this is converted to an equivalent dose, 1 R becomes 10mSv. Therefore, it is converted into 24.25mSv. This result shows that when the breast tissue's weighted coefficient 0.2 is multiplied, the value becomes 4.85mSv, which is much higher than the average valid radiation of 0.3mSv in a breast cancer X-ray test.

When the radiation absorbed was measured using a glass dosimeter, it was 1,334±1.82 μGy. When this is converted to valid radiation, the radiation's weighted coefficient 1 and the breast tissue's weighted coefficient of 0.2 are multiplied to generate 0.2668 mSv. This is a lower value than the average valid radiation of 0.3 mSv during one breast cancer X-ray test.

The radiation exposure converted to valid radiation amount and the absorbed amount converted to valid radiation amount were different. This difference indicates that in low energy of below 0.1MeV with low radiation, it is difficult to convert the radiation exposure into valid radiation. As such, to evaluate the radiation exposure in low energy, the absorption amount must be used as a base. Follow-up studies would be needed in this field.

From these findings, it was verified that during a diagnostic test for breast cancer, the X-ray dispersion image and phase differential image reduce radiation exposure and improve the image quality. In particular, phase differential imaging is expected to be applied to breast cancer tests where most of the tissue is soft, verification tests for foreign objects and forecasting of the progress in the disease.

Conclusion

In breast cancer tests where there is high sensibility to radiation, optimization of the valid radiation is needed to acquire optimal images. This study used an in-house manufactured phantom to analyze the quality of image resolutions and the practical value of the technology, as well as to compare the radiation exposure and radiation absorption during X-ray phase differential imaging to analyze theoretical valid radiation

In the absorption image, there were 5.0±0.2 fibers, 4.5 specks and 4.5 masses, making the total 14 which is higher than the 10 required to be officially authorized.

In the dispersion and phase differential images, there were 5.5±0.0 fibers, 4.5 specks, and 4.5 masses, making the total 14.5 which is higher than the 10 required to be officially authorized. In addition the image quality was better than that of the absorption image.

When a dosimeter was used, the radiation exposure was an average of 2425.85±0.33mR. When the absorbed radiation was measured using a glass dosimeter, it was 1,334±1.82 μGy. This was different from the value converted using the valid radiation.

To evaluate the low energy radiation exposure, the absorbed radiation must be used as a base. Follow-up studies would be needed on this topic.

Ethical Clearance: Not required

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Conflict of Interest: Nil

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