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# Dosimetric Evaluation of the Mean Glandular Dose for Mammography in Korean Women: A Preliminary Report

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The purpose of this study was to evaluate the thickness of the compressed breast in mediolateral oblique (MLO) and craniocaudal (CC) mammograms, to relate these thickness and breast patterns to mean glandular dose (MGD) in Korean women, and to evaluate the suitability of using the American College of Radiology's Recommendations for Korean women from a quality assurance standpoint. The study population consisted of 92 paired MLO and CC mammograms obtained on one mammographic unit. The digital readouts of compressed breast thickness, applied compression force and tube voltage were recorded. Entrance skin exposure was measured by dosimetry. MGD was calculated by multiplying entrance skin exposure by the exposure-to-absorbed dose conversion factor. The range of breast thickness was 1.3 - 6.2 cm in CC mammograms with a mean breast thickness of 3.6 cm, and 1.6 - 6.5 cm in MLO mammograms with a mean breast thickness of 3.9 cm. MGDs in CC and MLO mammograms were 1.77 mSv and 1.88 mSv per view, respectively. Breast composition patterns were divided into 4 groups according to ACR BI-RADS; P1 (n=20), P2 (n=16), P3 (n=48) and P4 (n=8).

The MGDs for these groups were: 1.82, 1.84, 1.84, and 1.91 mSv, respectively. When subjects were subdivided by breast thickness into three groups, namely, below 3 cm, 3 cm to 4.2 cm, aaa and above 4.2 cm, the corresponding MGDs were 1.83, 1.86, and 1.91 mSv.

According to our initial trial, the mean breast thickness and the MGDs of Korean women are lower than recommended by the American College of Radiology, which are commonly used for quality assurance purposes.

**Key Words:** Radiation, mammography, dosimetry, phantom

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## INTRODUCTION

At present, mammography is the most accurate and reliable means of detecting minimal, nonpalpable breast cancer.[1] However, the carcinogenic risk associated with mammography and the absorbed radiation applied to the breast has given rise to concern.

Using risk estimates in the Biological Effects of Ionizing Radiation (BEIR)[2] Report issued by the National Academy of Sciences and a mean glandular dose of 4 mGy resulting from two-views per breast bilateral mammography, one can estimate that the annual mammography of 100,000 women, for 10 consecutive years beginning at age 40, will cause eight lifetime breast cancer deaths.

On the other hand, researchers have shown a 24% mortality reduction from the biennial screening of women in this age group, which would result in a benefit-to-risk ratio of 48.5 lives saved per life lost, or 121.3 years of life saved per year of life lost. An assumed mortality reduction of 36% from annual screening would result in 36.5 lives saved per life lost and 91.3 years of life saved per year of life lost.[3,4]

Thus, the theoretical radiation risk posed by screening mammography is extremely small compared with the established benefit of this life-saving procedure, and should not unduly distract women under the age of 50 who are considering screening.

Breast cancer almost always arises in the glandular breast tissue. As a result, the average radiation dose absorbed by the glandular tissue is the preferred measure of radiation risk associated with mammography.

The average glandular dose cannot be measured directly, but is calculated by making certain assumptions based on experimentally determined entrance exposure in air kerma or entrance surface exposure using so-called conversion factors. The average glandular dose (Dg) is determined using the measured entrance skin exposures (XESE) and tabulated values of normalized average glandular dose (DgN), as follows: Dg=DgN * XESE.[1] Determinations of DgN require accurate estimates of the kilovolt peak, half-value layer (HVL), breast thickness, and breast composition.

Screening mammography programs[5] in the United State prescribe limits on the radiation dose versus the type of glandular tissue in the compressed breast, for example, the Mean Glandular Dose (MGD), may vary between 2 and 3 mGy for 50% adipose and 50% glandular tissue compressed breast of 4.2 to 5.0 cm thickness. Moreover, several organizations have recommended mean glandular doses, for example, the NCRP (National Council on Radiation Protection & Measurement), MQSA (Mammography Quality Standard Act) and ACR (American College of Radiology)(Table 1). However, the recommended mean glandular dose, which is used for quality assurance in Korea, is based on the ACR recommendations, although the breast thickness and breast patterns of Korean women differ from those of American women (Table 1).

The purpose of this study was to evaluate the thickness of the compressed breast in mediolateral oblique (MLO) and craniocaudal (CC) mammograms, to relate these thicknesses and breast patterns to the mean glandular dose (MGD) in Korean women, and to evaluate the suitability of the American College of Radiology's Recommendations[6] in terms of quality assurance for Korean women.

## MATERIALS AND METHODS

The total number of mammograms examined were 92 paired mediolateral oblique (MLO) and craniocaudal (CC) mammograms from 46 patients, and were obtained on one mammographic unit (Senographe-DMR, GE, Milwaukee, Wisconsin, USA) which has dual tract for target/filter combinations. Mammograms of women with breast implants, prior lumpectomy or radiotherapy, or showing post operative chest wall deformity were excluded. For each view, a digital readout of compressed breast thickness, applied compression force (range 26 - 30lbs), milliamperes (mAs) and tube voltage was obtained, in an automatic exposure control (AEC) mode.

Entrance skin exposure was measured by dosimetry (VICTOREEN Mammographic Ion Chamber Model 6000-529). The dosimeter was located just below the compression device, using the same conditions as, used for the digital measurement of compressed breast thickness. We also measured the applied compression force, mAs and tube voltage, and enterance skin exposure (Fig. 1).

The average glandular dose (Dg) was calculated using the measured entrance skin exposures (XESE) and the tabulated values of the normalized average glandular dose (DgN), as follows: Dg= DgN * XESE, using HVL 0.38 mmAl and SID 66

**Table 1.** Recommended Mean Glandular Dose Several Organizations in United States and in Korea

| Organization | For Screen - Film Mammography | For Xero - Mammography | Year |
|---|---|---|---|
| NCRP | < 4 mGy | < 4 mGy | 1985 |
| MQSA | < 3 mGy | | 1994 |
| California State | < 2 mGy | < 3 mGy | 1990 |
| ACR | < 3 mGy | < 4 mGy | 1992 |
| NIH (Korea) | < 3 mGy | | 2001 |

NCRP, National Council on Radiation Protection & Measurement; MQSA, Mammography Quality Standard Act; ACR, American College of Radiology; NIH, National Institute of Health.

cm. DgN was determined using tables, which were computed using Monte Carlo simulations of x-ray photon transport in breast tissue, as described by Wu. et al.[1] Breast patterns were divided into 4 groups, i.e., P1 (n=20), P2 (n=16), P3 (n=48) and P4 (n=8), according to ACR BI-RADS. The 100% gland breast compositions tables devised by Wu, et al. were used to determine DgN, in P1 (100% adipose), in P2 and P3 (50% adipose/50% gland), and in P4.

The relations between MGD and compressed breast thicknesses and breast patterns were investigated on MLO and CC mammograms.

## RESULTS

The study population consisted of 46 patients, aged 41 to 63 years with an average age of 52.3 years.

Breast patterns were divided into 4 subgroups, P1 (n=20), P2 (n=16), P3 (n=48) and P4 (n=8), according to ACR BI-RADS. Breast pattern 3 was the most common breast encountered.

Table 2 shows the relation between mean glandular dose and breast thickness according to breast pattern (Fig. 2). The average breast thicknesses of these subgroups were 1.7, 3.9, 3.9 and 3.8 cm, respectively, the average entrance skin exposures 5.87, 8.42, 8.27, and 8.97 mSv, and the average MGDs 1.82, 1.84, 1.84, and 1.91 mSv.

When the subjects in 'P3' were sub-divided by breast thickness into three subgroups, namely, below 3 cm, 3 cm to 4.2 cm, and above 4.2 cm, the average MGDs of these subgroups were 1.83, 1.86, and 1.91 mSv, respectively (Table 3, Fig. 3).

Breast thicknesses ranged from 1.3 to 6.2 cm in CC mammograms, with an average breast thickness of 3.6 cm, and from 1.6 to 6.5 cm in MLO mammograms with an average breast thickness of 3.9 cm, (Table 4). The average MGDs in CC and MLO mammograms were 1.77 mSv and 1.88 mSv per view, respectively (Table 5).

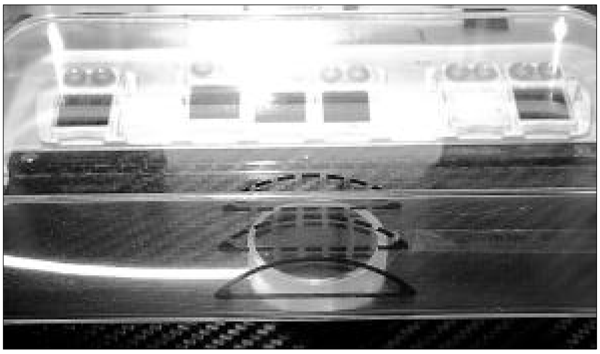

**Fig. 1.** A dosimeter was located just below the compression device, using the same conditions as, used for the digital measurement of compressed breast thickness, applied compression force, mAs and tube voltage, and entrance skin exposure was measured.

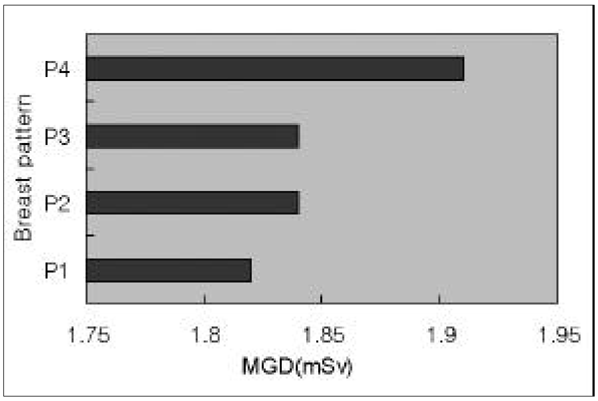


**Fig. 2.** Mean glandular dose by breast pattern.

**Table 2.** The Relation of Mean Glandular Dose to Breast Thickness according to Breast Pattern

| Pattern | Thickness (cm) | XESE (mSv) | DgN | MGD (mSv) | $p$ value |
|---|---|---|---|---|---|
| P1 (n=20) | 1.7 | 5.87 | 310 | 1.82 | .481* |
| P2 (n=16) | 3.9 | 8.42 | 219 | 1.84 | .650* |
| P3 (n=48) | 3.9 | 8.27 | 222 | 1.84 | .481* |
| P4 (n=8) | 3.8 | 8.97 | 213 | 1.91 | .481* |

*Correlation between breast pattern and MGD is significant at the 0.01 level ($p<0.01$).
XESE, Entrance skin exposure dose; MGD, Mean glandular dose; DgN, Computed tabulated values of the normalized average glandular dose.


**Fig. 3.** Mean Glandular Dose by Breast Thickness into Three Group.

## DISCUSSION

X-ray mammography carries a small but significant risk of radiation-induced carcinogenesis, and the determination of the mean glandular dose represents an important aspect of the quality control of mammographic imaging systems. The widespread adoption of a standard phantom for assessing image quality and radiation dose has proven beneficial in mammography. However, the measurement of radiation dose delivered to a standard phantom does not provide complete information of the dose received by a patient. For whereas the ACR phantom and the tables used to

**Table 3.** The Relation of Mean Glandular Dose to Breast Thickness in Breast Pattern 3

| Group by Breast thickness (cm) | XESE (mSv) | DgN | MGD (mSv) | *p* value |
|---|---|---|---|---|
| < 3 | 7.93 | 230 | 1.83 | .898* |
| 3 - 4.2 | 8.67 | 216 | 1.86 | .898* |
| > 4.2 | 8.97 | 213 | 1.91 | .898* |

Note: The study population consisted only who has breast pattern 3 and divided by breast thickness into three groups, namely below 3 cm, 3 cm to 4.2 cm, above 4.2 cm.
*Correlation between three groups and MGD is significant at the 0.01 level ($p < 0.01$).
XESE, Entrance skin exposure dose; MGD, Mean glandular dose.
DgN: Computed tabulated values of the normalized average glandular dose.

**Table 4.** The Average Readout Data* per Film for Mediolateral Oblique and Craniocaudal Views under AEC Mode

| | MLO | CC |
|---|---|---|
| Breast thickness (cm) | 3.9 | 3.6 |
| Compression force (Ibs) | 14.8 | 14.5 |
| MAs | 47 | 46 |
| KVp | 26 | 26 |

*Recorded data on AEC (Automatic exposure control) mode.
MLO, Mediolateral oblique View; CC, Craniocaudal view.

**Table 5.** Mean Glandular Dose of both Mediolateral Oblique and Craniocaudal Views of Mammograms

| | XESE (mSv) | DgN | MGD (mSv) | *p* value |
|---|---|---|---|---|
| MLO | 8.84 | 213 | 1.88 | .977* |
| CC | 8.45 | 209 | 1.77 | .977* |

*Correlation between MLO and CC is significant at the 0.01 level ($p < 0.01$).
XESE, Entrance skin exposure dose; MGD, Mean glandular dose.
DgN, Computed tabulated values of the normalized average glandular dose.
MLO, Mediolateral oblique view; CC, Craniocaudal view.

compute the mean glandular dose assume a breast composition of 50% glandular and 50% adipose tissue, breast compositions obviously vary from woman to woman.

Thick, dense breasts require more exposure and hence a greater dose than adipose containing breasts. For example, for a screen-film mammogram of a medium-sized breast (5-cm thick), the average breast dose to a highly glandular breast is nearly twice that required for a highly adipose breast. Even for thin breasts (3-cm thick), the dose to glandular and adipose breasts differes by 20%.[7] But, in the present study, the mean glandular dose required for breast pattern 2 (P2) and breast pattern 3 (P3) were both 1.84 mSv, what we expected different mean glandular dose initially, despite their having the same mean breast thickness (Table 2, Fig. 2). This result can be explained by the use of the same computational table to determine the mean glandular dose, and by the similar amount of remained parenchymal tissues even though different distribution of parenchymal composition in breast patterns 2 and 3 which was classified by ACR-BIRADS. We found that breasts were thinner on the craniocaudal (CC) view than on the mediolateral oblique (MLO) view (3.6 versus 3.9 cm), despite a slightly lower compressional force in the craniocaudal (CC) view (14.5 lb versus 14.8 lb). These findings are due to the inclusion of pectoral muscle in the mediolateral oblique (MLO) view.[8] Moreover, the breast thickness difference in CC and MLO mammograms' values was statistically significant in 7%.

The mean glandular radiation dose is greatly affected by changes in breast thickness.[9-11] Gentry and DeWerd[9] reported a linear relationship between dose and thickness, and similar findings and relationships were reported by Kruger, et al.[10] Our results also support a relation between mean glandular dose and breast thickness (Table 3, Fig. 3).

Our results may be compared with those of similar recent studies[9,12,13] in the UK[12,13] and in the USA,[9] although it must be emphasized that such comparisons are limited. Burch, et al.[11] examined data from 4,633 women screened at 92 units in the United Kingdom from 1994 to 1995. They found a mean breast thickness of 5.7 cm and 5.2 cm for the MLO and CC views, respectively, which are higher than those of our study. The mean dose per film was 1.93 mGy in the MLO view, which is somewhat higher than the 1.88 mGy of our study, and the mean glandular dose per film was 1.63 mGy for the CC view, which is somewhat less than the 1.77 mGy used in the present study. It is interesting to note that in this UK study the mean glandular dose was 1.63 mGy for a mean breast thickness of 5.2 cm, whereas our present study showed 1.77 mGy for a mean breast thickness of 3.6 cm. This difference can be explained in part by the greater percentage of composed glandular tissue in Korean women,[14] and by application of different target/filter combinations automatically controlled by AEC mode (molybdenum-molybdenum) for smaller breast thickness in Korean women than in the UK study (molybdenum- rhodium, rhodium-rhodium) for large breast, and the use of different conversion factors.[13]

Burch, et al. used factors published by Dance,[15] which are approximately 10% lower than the corresponding factors published by Wu, et al.,[1] which were used in the present study.

Gentry and DeWerd[9] measured the compressed breast thickness and entrance skin exposure using thermoluminescent dosimeters for 4,400 women undergoing film-screen mammography in 170 units in the USA over a two years period (1993-1994). They reported an average thickness of 4.5 cm and a mean glandular dose of 1.5 mGy for the CC view, which is similar to that reported in the UK study by Burch, et al.[12]

As mentioned earlier, an upper limit of 3.0 mGy per film has been established by the ACR[6] as a mean glandular dose for 4.2-cm thick breasts with a 50% glandular composition. The mean glandular dose used in the present study was well below this limit of 3.0 mGy. However, the results of our study support the need to revise the commonly made assumption that the glandular content of the average breast is 50%.

According to this initial trial, the mean breast thickness and the MGD of Korean women are lower than those used in the American College of Radiology's Recommendations.[6] The mean glandular dose uses in the present study was higher than that used in similar studies conducted in the UK and the USA, although our breast thicknesses were lower. We suggest that the higher glandular composition of the Korean breast explains this difference, and assert that a Korean phantom model is needed for quality assurance purposes in Korea.

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