

# Variations in breast doses for an automatic mammography unit

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## PURPOSE

To assess variations of glandular doses for a group of patients when different dose modes are selected for a specific system.

## MATERIALS AND METHODS

All measurements were obtained with a Senographe DMR mammography unit (GE Medical Systems). Automatic exposure control with either contrast or standard mode was routinely used in patient examinations. Entrance surface air kerma (ESAK) values were estimated from the postexposure mAs and from the recorded data. Subsequently the mean glandular dose (MGD) for each view was calculated using the conversion factors assuming 50% glandular and 50% adipose tissue composition.

## RESULTS

The average MGD for the right craniocaudal view for all beam qualities was 1.65 mGy, and 46.7 mm was the average compressed breast thickness for this view. Average MGDs were 1.61, 1.76, and 1.35 mGy for Mo-Mo, Mo-Rh, and Rh-Rh anode filter selections, respectively. Conversely, 2.18 and 1.47 of breast doses were measured for contrast and standard dose modes at the most often used (Mo-Mo) anode filter selection.

## CONCLUSION

Breast dose measurement techniques with the standard phantom or on real patients are easy to implement for the mammography users. Obtaining ESAK versus breast thickness relationship is useful for retrospective dose evaluation; better correlation can be established (67% vs. 52%) if they are generated separately for each dose modes.

*Key words:* • mean glandular dose • entrance surface air kerma • automatic exposure control

Mammography is considered to be the most effective method for early detection of breast cancer (1). The use of ionizing radiation, however, carries the risk of radiation-induced carcinogenesis; thus assessment of the breast dose is important. The standard phantom or a real patient can be used for dosimetric purposes (2–4).

In the phantom method, a 45-mm thick polymethyl-methacrylate (PMMA) phantom is assumed to represent a standard breast 50 mm thick. The entrance surface air kerma (ESAK) is measured free in air (without backscatter) at a point corresponding to the entrance surface of the phantom. Mean glandular dose (MGD) for standard breast is calculated using the conversion factors derived from the Monte Carlo calculations (5). In the second method, doses on real patients are estimated for each breast by using the post exposure mAs, tube voltage, and x-ray beam quality specific tube output factor (mGy/mAs). The conversion between incident air kerma and MGD can be made on the basis of these conversion factors. Either a mammographic ion chamber or thermoluminescence dosimeters can be used for the ESAK measurements.

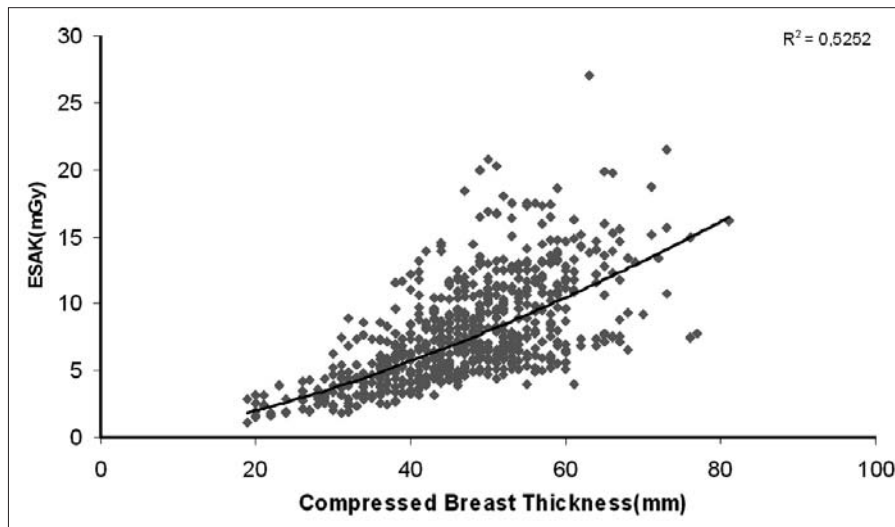
Although the standard phantom measurements are easy to implement and useful for comparing doses between different mammographic systems and quality control purposes, they do not provide complete information about doses received by the patients (6). Instead, a survey of actual patient doses is needed to assess the characteristics of the patient population and the risk of radiation-induced cancer. In situations where dose measurements cannot be provided continuously, however, previously obtained data from a representative selection of patients can be used (3). A high correlation coefficient has been found between compressed breast thickness and MGD (7, 8). Therefore MGD can be estimated retrospectively from the known thickness of the patient breast.

Some X-ray manufacturers now offer mammographic systems with the ability to select automatic beam quality tailored to each patient with the potential for reducing dose and increasing contrast for different breasts. This wide selection of dose controls causes large variations in ESAK values at specific breast thicknesses, and errors may be introduced to the retrospective assessment of breast doses.

The objective of this study was to assess variations of glandular doses for a group of patients when different dose modes were selected for a specific system. We compared ESAK with compressed breast thickness for different dose controls to assess if accuracy of dose assessment can be improved. Phantom experiments were also carried out for this purpose, and tissue equivalent slabs with different glandularity and thickness were exposed at different dose modes.

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**Figure 1.** Entrance surface air kerma (ESAK, [mGy]) versus compressed breast thickness (mm) for right craniocaudal view (for all patients).

### Material and methods

All measurements were obtained with a Senographe DMR mammography unit (GE Medical Systems, Milwaukee, Wisconsin, USA). The most commonly used anode-filter combinations were molybdenum-molybdenum (Mo-Mo), Mo-rhodium (Mo-Rh), and Rh-Rh. Although manual selection of kVp and target-filter is possible, the automatic optimization parameter (AOP) mode of the system together with the automatic exposure control (AEC) provided automatic selection of target material, filter, kV, and mAs. This feature of the system enables the operator to make a selection of one of the dose modes. Contrast, standard, and dose modes are user selectable, and a gradual reduction of the dose is carried out from contrast to dose mode. In the contrast mode, the system automatically sets the minimum kVp and Mo/Mo combination up to 5–6 cm of breast thickness and rarely switches to Mo/Rh combination. In the case of standard or dose modes selection, depending upon the thickness and composition of the breast, Mo/Rh or Rh/Rh combinations are used by the system.

The AOP technique with either contrast or standard mode was routinely used in the patient examinations during this work. To lower the radiation dose to the breast, standard mode was used for 577, and contrast mode was selected for 109 patients. Because of poor image quality produced, dose mode was used only for 15 patients.

The postexposure mAs, breast thicknesses, tube potential, target-filter

combination, and AEC settings were recorded for craniocaudal (CC) views of left and right breasts of 702 patients. Data for lateral views were also recorded, but only the results of right CC view are presented in this paper.

The tube output was measured with a mammographic ion chamber (Radcal Model 9010, 6M, MDH Radcal, Monrovia, California, USA) for each beam quality used for the postexposure method and repeated every three months. High purity (99.9%) aluminum foils (Standart Imaging) were used to perform the half-value layer test. Assessment of kVp was carried out with a noninvasive kVmeter (Radcal 4082). Radiation exposure performance was monitored during the survey. The radiation output (mGy/mAs) was checked routinely. The system was stable within 4% of the initial value. Kodak single emulsion MIN-RM film (Eastman Kodak Company, Rochester, New York,

USA) was used in patient studies, in conjunction with Kodak MIN R single-screen cassette.

ESAK values were estimated from the postexposure mAs and from the recorded data. Subsequently the MGD for each view was calculated using the conversion factors, assuming 50% glandular and 50% adipose tissue composition. A linear regression analysis with the least squares method was used to determine the correlation between compressed breast thicknesses and ESAK values. Tissue equivalent materials (CIRS, Norfolk, Virginia, USA) with a range of simulated relative glandular content (30%, 50%, and 70%) and thicknesses (20–70 mm) were exposed at dose, standard, and contrast modes.

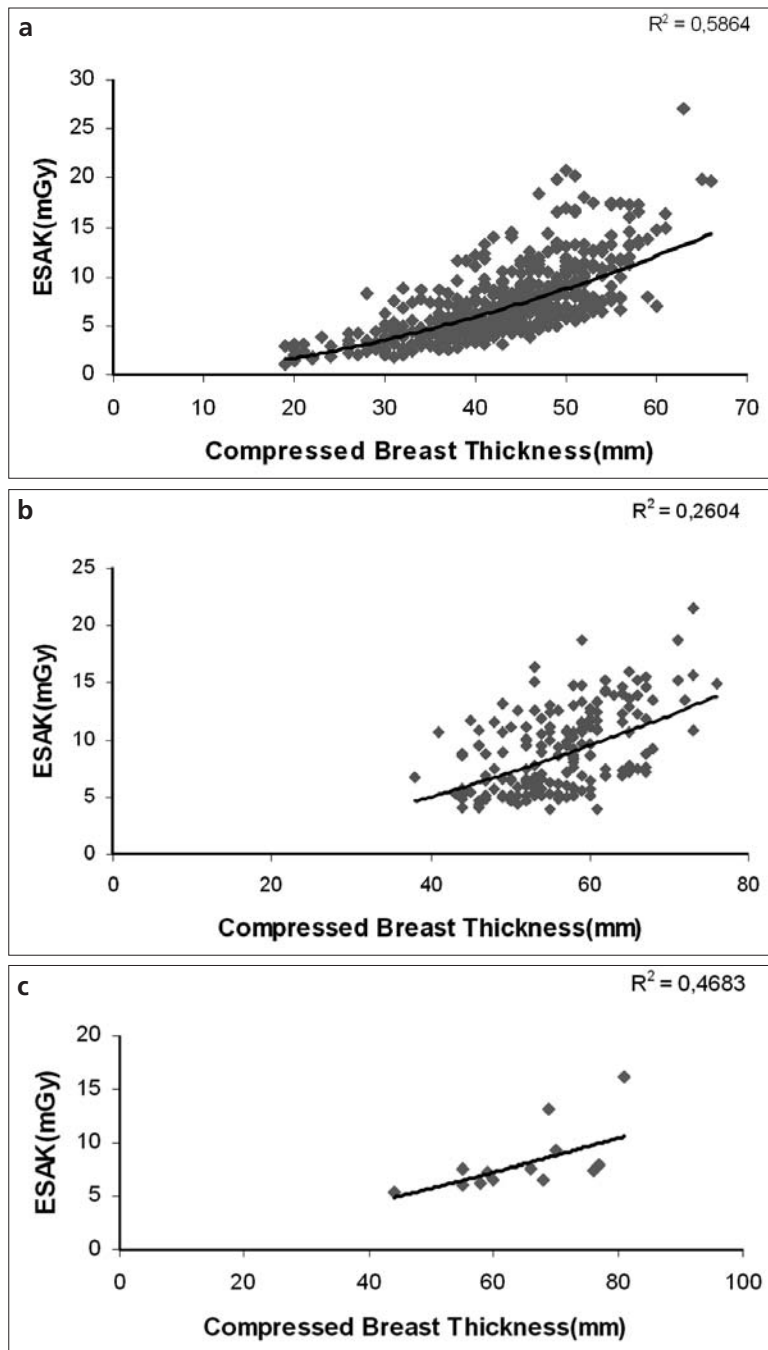
### Results

The average MGD for right CC view for all beam qualities was 1.65 mGy (0.46–4.1), and 46.7 mm was the average compressed breast thickness for this view. The average MGD for the compressed breast thicknesses of 45, 55, and 65 mm were 1.66, 1.92, and 1.95 mGy respectively. Table shows the average MGD and breast thickness for each dose mode. Since more than one target-filter combination can be used for each dose mode, MGD values are given separately for each combination.

In Fig. 1, the ESAK values (obtained from postexposure mAs) against compressed breast thickness for right CC view of 702 patients is shown. Similar data, but specific to each target-filter combination, are illustrated in Figs. 2 a–c. The same data are shown in Figs. 3 a, b for the Mo-Mo combination, but separately for contrast and standard dose modes. Correlation improved

**Table.** Average mean glandular dose (MGD) in mGy and mean compressed breast thickness (t) for each dose mode and beam quality (numbers of patients are given in parenthesis)

	Mo-Mo	Mo-Rh	Rh-Rh
Contrast	2.18 (101)	2.57 (8)	---
Standard	1.47 (402)	1.76 (168)	1.46 (7)
Dose	---	1.09 (9)	1.23 (6)
Average	1.61	1.76	1.35
Mean t (mm)	42.38	56.10	64.60



**Figure 2.** a-c. Entrance surface air kerma (ESAK, [mGy]) versus compressed breast thickness (mm) for Mo-Mo (a), Mo-Rh (b), and Rh-Rh (c) anode-filter combinations.

from 0.52 to 0.67 when this relationship was established for a specific dose mode. The target-filter combination usually switched to Mo-Rh for breast thickness >50 mm. The majority of the exposures were in the standard mode for this combination; therefore, the correlation is same with Fig. 2b. Our statistic for Rh-Rh combination is quite low, but the correlations for standard and dose modes were 0.34

and 0.70, respectively, for Rh-Rh (data not shown).

Slabs with different glandularity and thickness were exposed at three dose modes to support the patient studies. As shown in Fig. 4, use of different modes increases data scatter at ESAK vs. breast thickness relationship. Considerable dose increase at 5-cm thickness is evident for contrast mode at each beam quality.

## Discussion

Our patient dose measurements, average glandular dose values, and breast thicknesses were within the range reported in other surveys (9–15). Dose in contrast mode is higher, as expected. Although the dose mode is not the preferred choice of our radiologists, the benefit of Rh-Rh combination is ensured for thick breasts even at standard mode.

The relationship between ESAK (or MGD) and breast thickness ( $t$ ) may be quite useful in retrospective dose assessment of individuals. However, the variations of tube output and film processing conditions, errors in measurement of compressed breast thickness, and differences in breast composition cause a broad dose range for specific breast thickness. This range may become even wider, depending on selection of different dose modes; these cause considerable change in tube output because of the use of different target-filter combinations.

To see if the target-filter combination caused any further scattering on ESAK- $t$  relationship, the data in Fig. 1 were separately drawn for Mo-Mo and Mo-Rh combinations (Figs. 2 a-c). Correlation improved for Mo-Mo, and less scatter was seen, particularly for thin breasts; however, correlation degraded for Mo-Rh selection. It is difficult to evaluate Rh-Rh behavior due to the small number of cases.

To see the effect of dose mode on this relationship, information in Fig. 2a was redrawn for contrast and standard modes. As seen in Figs 3 a, b, the correlation improves, particularly for contrast mode. Establishment of ESAK- $t$  relationship for different dose modes enables better estimation of breast dose for specific thickness. Spread of data mainly occurs for thick breasts, probably reflecting the large variation in breast composition.

In the phantom experiment, Fig. 4 clearly indicates considerable data scatter on ESAK- $t$  relationship occurs in all three dose modes. Another important factor increasing the scatter, particularly for thick breasts is the variation of breast composition. If Figs. 4 a-c are compared, the relationship at each dose mode does not show remarkable change with glandularity. However, variation is observed between contrast and standard modes because of the

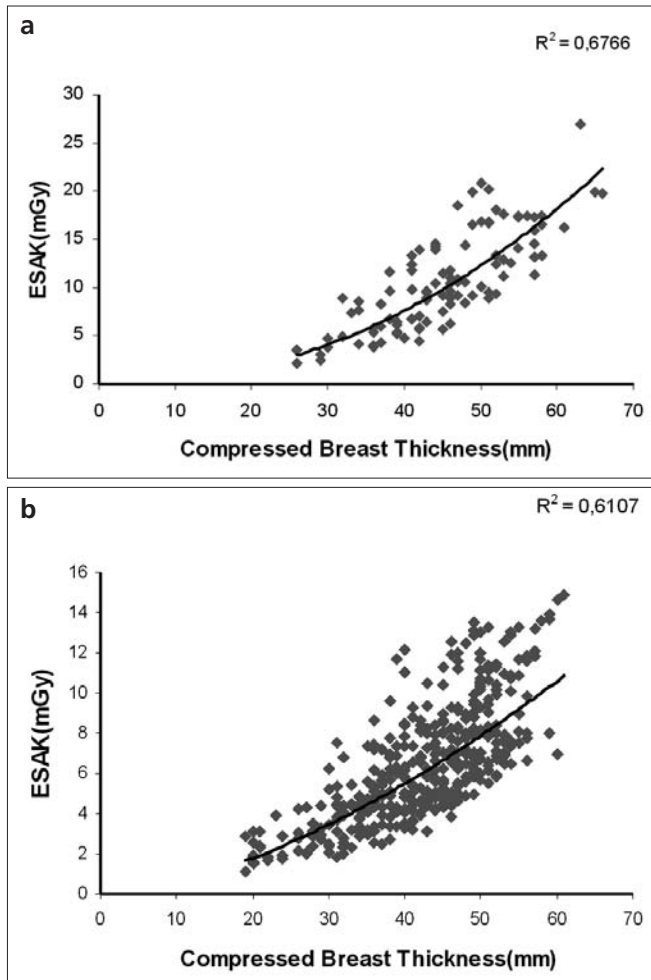


Figure 3. a, b. Entrance surface air kerma (ESAK, [mGy]) versus compressed breast thickness (mm) for Mo-Mo combination. (a) contrast mode, (b) standard mode.

changes in target-filter combination with changes in thickness. Mo-Mo was selected for up to 4 cm thickness. Dose variation was negligible between the standard and contrast modes (less than 10%) for 30% and 50% glandularity. The dose was slightly higher in contrast mode for 70% glandularity. There were considerable dose variations between two modes at approximately 5-cm thickness because of use of the Mo-Rh combination. The dose almost doubled for 50% and 70% glandularity when contrast mode was used. The difference was not so great for 6-cm thickness; the maximum dose increase was 1.5 times as great for dense breasts using contrast mode as standard mode. Considering dose mode, lower doses and less variation between the glandularity are observed.

The main objective of this work was to obtain statistically reliable breast

dose data for a specific mammography system. Breast dose measurement techniques with either the standard phantom or on real patients are easy to implement for the mammography users. However, if there is a lack of expertise and local resources, previously generated data relating mean glandular dose to compressed breast thickness may be an alternative technique for retrospective dose assessments. Automatic selection of beam quality and availability of user selectable dose controls may cause remarkable dose differences for specific breast thick-

ness. This selection becomes most important for breast thickness of approximately 5 cm.

Obtaining a measure of the relationship of ESAC and breast thickness is quite useful for retrospective dose evaluation. Better correlation can be established (67% vs. 52%) if they are generated separately for each dose mode. If there is a need to generate a mean glandular dose-thickness relationship for a system with automatic dose control, the effect of the factors causing data scattering should be minimized.

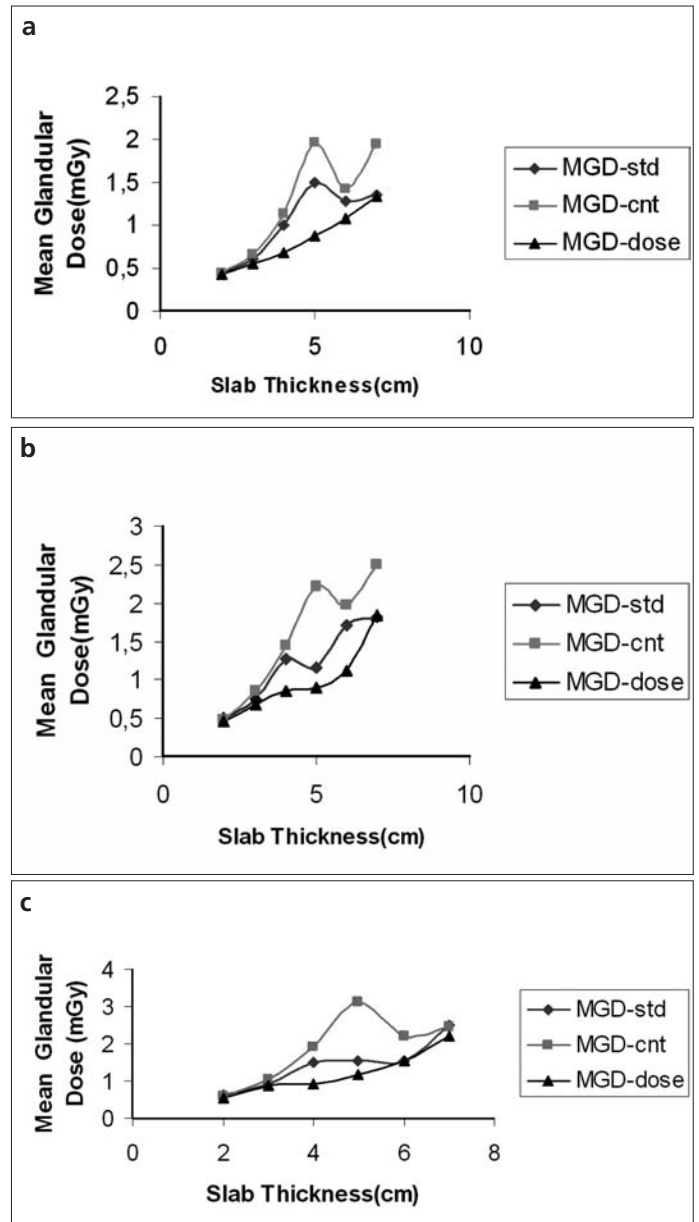


Figure 4. a-c. Mean glandular dose (MGD [mGy]) versus slab thickness (cm) for different glandularities using 3 different dose modes. (a) 30-70, (b) 50-50, (c) 70-30. (std: standard, cnt: contrast)

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