

DETERMINATION OF PERSONALIZED MEAN GLANDULAR DOSE USING ESTIMATES OF THE GLANDULAR TISSUE DISTRIBUTION IN A CLINICAL SETTING

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ABSTRACT

Introduction: The effect due to the glandular tissue distribution is not considered in the currently used mammography dosimetry methods. The effect in mean glandular dose (MGD) is solely dependent on the particular glandular tissue distribution for a patient.

Objective: Develop a methodology for personalized calculations of mean glandular dose (MGD) conversion coefficients in a clinical setting incorporating estimates of the glandular tissue distribution for each patient using information and resources commonly available in clinical practice.

Methods: 20 patients with craniocaudal (CC) and mediolateral oblique (MLO) views were studied. Distributions of glandular tissue were estimated visually by a radiologist. MGD coefficients were calculated using three independent methods: (1) Monte Carlo simulations with traditional geometry, (2) Monte Carlo simulations with heterogeneously-layered breast (HLB) geometry, and (3) individual glandular tissue distribution correction factor (k_{dist}).

Results: Differences of up to 19% were found between the dose coefficients calculated using the traditional geometry (1) with respect to those calculated using the HLB geometry (2). These differences are due solely to the individual distributions of glandular tissue. The use of the correction factor k_{dist} (3) has results comparable to those from Monte Carlo (2) with a 4.2% median difference.

Conclusion: The use of k_{dist} and radiologist assessment of the glandular tissue distribution provides reasonable estimates of the patient-based MGD coefficients in the absence of breast density map and Monte Carlo techniques. The use of the methods presented in this work is recommended particularly in MGD calculations for highly heterogeneous breasts.

Keywords: mammography dosimetry, mean glandular dose, glandular tissue distribution.

I. INTRODUCTION

Conventional mammography dosimetry uses the normalized mean glandular dose (D_{gN}) as a conversion coefficient that relates mean glandular dose (MGD) with incident air kerma. The D_{gN} corresponds to the multiplication of all the relevant dose conversion factors and coefficients used in the formalism developed by Dance [1, 2] ($D_{\text{gN}} = g \cdot c \cdot s$). These coefficients are calculated using Monte Carlo techniques.

The breast geometrical model used consists of a homogeneous mix of glandular and adipose tissues wrapped in a layer of adipose tissue. This approximation overlooks the effects on the value of MGD due to the heterogeneous distribution of the glandular tissues.

In a previous work, the HLB (heterogeneously-layered breast) geometry was introduced to calculate personalized MGD [6]. In this geometry the compressed breast is modeled as a series of layers with different glandularity.

In the present study, a method to calculate personalized dose conversion coefficients is introduced. This method incorporates the glandular tissue information as modeled by the HLB geometry using information and resources commonly available in clinical practice.

II. MATERIALS AND METHODS

A group of 20 patients with craniocaudal (CC) and mediolateral oblique (MLO) views was used for this study. The patients had compressed breast thicknesses in the 4 cm to 7 cm range.

In this work, the method used to incorporate the glandular tissue distribution in the calculation of normalized mean glandular dose is based in the Heterogeneously-Layered Breast (HLB) geometry.

The HLB geometry consists of a simplified breast geometry used for imaging dosimetry that incorporates the anatomical structures of the breast as a series of layers with variable composition. The breast core is wrapped by a 3.5 mm thick adipose tissue layer and a 1.5 mm thick layer, as shown in Figure 1.

The breast core is divided into three layers, each of which can have different glandular percent value. This allows incorporation of individual estimates of glandular tissue distributions in the calculation of the D_{gN-HLB} .

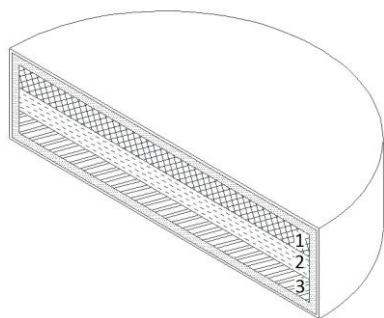


Figure 1. Heterogeneously-layered breast (HLB) model. Each of the shaded areas corresponds to a breast core layer with different glandular composition.

The glandular tissue distribution for the patients in this study was estimated visually by a radiologist. The mammogram was divided into three sections and an estimation of the glandularity for each section was performed by the radiologist.

The dose conversion coefficients for each case were obtained using three approaches:

- 1) Monte Carlo simulations using traditional geometry
- 2) Monte Carlo simulations using the individual HLB geometries
- 3) Use of patient-based glandular tissue distribution correction (k_{dist}) applied to the tabulated values

1- Calculation of normalized mean glandular dose using traditional geometry

The first approach corresponds to the currently used dosimetry method, based on the work of Dance [1, 2]. The D_{gN} resulting from this method does not include the effect of the glandular tissue distribution.

For each image, a set of monoenergetic Monte Carlo simulations (MCNP5, Los Alamos, USA) was developed. These simulations used the corresponding homogeneous core breast geometry. The whole breast glandular percentage used corresponded to the average of the glandularities of each breast section as estimated by the radiologist for each case.

Using the readings for a CC view it is possible to estimate the glandular tissue distribution for the corresponding MLO compression and vice versa. The breast geometry used to estimate the D_{gN} for a CC image used the compressed breast thickness (CBT) for the corresponding MLO image.

The elemental composition of the different glandular percentages was based on the materials reported by Hammerstein *et al.* [3]

The simulation geometry followed the descriptions from Dance [1] and included the antiscatter grid and the mammographic screen. The source to image detector distance was 60 cm for all cases. All simulations were performed in air. The density and elemental compositions of the materials used were taken from NIST [5]. All simulations used 1×10^7 particles. The source energies were between 0 keV and 30 keV with 0.5 keV steps.

The results from the monoenergetic simulations were used with a Rh anode, 25 μ mRh filter, 30 kVp spectrum with 0.39 mmAl half-value layer. This spectrum was generated using software based on Rosado-Méndez [8].

The D_{gN} for each case was obtained from the results of these simulations and compared to the tabulated results from Dance.

2- Calculation of normalized mean glandular dose using HLB geometry

The second approach incorporates the glandular tissue distribution in the calculation of the personalized MGD conversion coefficient (D_{gN-HLB}) and therefore is the preferred method to be used in mammography dosimetry. This method makes use of the HLB geometry instead of the traditional homogeneous breast core geometry. All the other details of the Monte Carlo simulation remain the same as in the previous section.

The HLB geometry was developed for each patient image using the glandular tissue distribution estimated by the radiologist for each breast section.

3- Calculation of normalized mean glandular dose using clinically available information

In this approach, a patient-based glandular tissue distribution correction (k_{dist}) is applied to the tabulated values from Dance [1, 2] and the personalized MGD conversion coefficient ($D_{gN-dist}$) is estimated. The main advantage of this approach is that it does not require the use of Monte Carlo techniques and can therefore be implemented in typical clinical settings.

The *glandular tissue distribution index* (I_{dist}), has been introduced in a previous work [7] as a means to summarize the glandular tissue distribution used to create the corresponding patient HLB geometry and is calculated by:

$$I_{dist} = \frac{G_1 - G_3}{G_2} \quad (1)$$

where G_1 , G_2 and G_3 correspond to the glandular percentage of each layer in the corresponding HLB geometry.

Patient-based glandular tissue distribution coefficients (k_{dist}) were estimated using I_{dist} for all cases using Equation 2. In this work $m=25.7$ and $b=0.170$ were used, as obtained in a previous study [7]. The resulting k_{dist} were applied to the corresponding values tabulated by Dance [1, 2] as shown in Equation (3).

$$k_{\text{dist}} = \frac{m \cdot I_{\text{dist}} + b}{100} + 1 \quad (2)$$

$$D_{\text{gN-dist}} = k_{\text{dist}} \cdot D_{\text{gN-Dance}} \quad (3)$$

The patient-based dose conversion coefficients obtained with the first approach were compared to the corresponding dose conversion coefficients according to the values tabulated by Dance [1, 2].

The results from approaches 1 and 2 were compared to study the effect of the glandular tissue distribution in the calculation of the dose conversion coefficients.

Finally, the results from approaches 2 and 3 were compared to evaluate the application of the k_{dist} approach (3) in a clinical setting.

III. RESULTS AND DISCUSSIONS

An average percent difference of 1.6 % was found between the tabulated values from Dance and the dose conversion coefficients calculated using Monte Carlo techniques and traditional geometry. The purpose of this comparison was to validate the Monte Carlo methods used in this project against those used to obtain the currently accepted values.

The percent difference between the dose conversion coefficients calculated using Monte Carlo techniques and traditional geometry (1) with respect to those calculated using the corresponding HLB geometry (2) was found to be as high as 19% for the most heterogeneous breasts.

The magnitude of the difference is dependent on the individual distribution of glandular tissue. In particular, for the cases with $I_{\text{dist}} > 0.5$ the median percent difference was 16%. This subgroup corresponds to the most heterogeneous distributions in the patients studied in this work. All the differences observed in this comparison correspond to the effect of the glandular tissue distribution within the breast.

It must be noted that the differences were found in a group of patients where all cases had around 33% whole breast glandularity. Greater differences are expected in the full range of glandularities and in particular for highly heterogeneous breasts.

The median difference between the dose conversion coefficients calculated using the corresponding k_{dist} correction (3) and those calculated with Monte Carlo techniques (2) was 4.2%. The maximum percent difference in this comparison was 11%.

Although the use of Monte Carlo techniques, along with an objective method to estimate the glandular tissue

distribution [4, 9] remains the preferred approach to estimate the glandular tissue distribution, our results suggest that the k_{dist} correction may be used to calculate estimates of the patient-based dose conversion coefficients with information and resources available in typical clinical settings.

The current investigation was limited by the small number of patients included, as well as a limited range of glandularities and CBTs studied. A study with a larger and more varied group of patients could provide more definite evidence on the accuracy of the k_{dist} approach.

IV. CONCLUSIONS

A method to estimate $D_{\text{gN-HLB}}$ using resources and information available in clinical settings was presented.

The method is based on a correction (k_{dist}) to the currently available tabulated values of Dance and requires a radiologist assessment of the distribution of the glandular tissue.

The drawback of needing an additional reading from the radiologist, or a trained specialist, may be lessened by using these techniques solely for those cases with highly heterogeneous tissue distributions.

Further work with a larger patient group is needed to determine the accuracy of this approach, but the results from this study suggest that the use of k_{dist} may provide a reasonable estimate of the patient-oriented MGD coefficients.

The main advantage of this method is that it can be used in situations where computational resources may be limited, as is the case in most developing countries.

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VI. REFERENCIAS BIBLIOGRÁFICAS

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