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Average Absorbed Breast Dose (2ABD) to Mean Glandular Dose (MGD) Conversion Function for Digital Breast Tomosynthesis: A New Approach

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ABSTRACT

Background: In this work a new method for the Mean Glandular Dose evaluation in digital breast tomosynthesis (DBT) is presented.

Methods: Starting from the experimental-based dosimetric index, 2ABD, which represents the average absorbed breast dose, the mean glandular dose MGD2ABD was calculated using a conversion function of glandularity f(G), obtained through the use of Monte Carlo simulations.

Results: f(G) was computed for a 4.5 cm thick breast: from its value MGD2ABD for different compressed breast thicknesses and glandularities was obtained. The comparison between MGD2ABD estimates and the dosimetric index provided in the current dosimetry protocols, following the Dance's approach, MGD_{Dance}, showed a good agreement (<10%) for all the analyzed breast thicknesses and glandularities.

Conclusion: The strength of the proposed method can be considered an accurate mean glandular dose assessment starting from few and accessible parameters, reported in the header DICOM of each DBT exam.

Introduction

Breast cancer screening procedures are routinely performed in many countries to detect the most commonly diagnosed cancer among women. Early detection of cancer seems to reduce the breast cancer mortality with better survival rates.[1] Digital Mammography (DM) is the main X-ray technique used to detect breast masses and microcalcifications. Technological advancements have highly improved the DM technique over the years and today the best upgrade is represented by the Digital Breast Tomosynthesis (DBT)[2,3], recently introduced in clinical routine worldwide. DBT reduces the intrinsic tissues superimposition which characterizes the DM acquisitions: tissue overlapping can lead to lower sensitivity and specificity.[4]

The breast is mainly composed of adipose and glandular tissue. The latter is considered the radiosensitive tissue-at-risk. X-ray radiation dose absorbed by the glandular tissue must be accurately assessed to quantify the radio-induced cancer risk. International dosimetry protocols[5–7] suggest the formalism proposed by Dance[8–12] which provides c, g, s and T conversion factors from incident air kerma on the upper surface of the compressed breast to a mean glandular dose (named MGD_{Dance} in this paper): c, g, s and T factors are computed via Monte Carlo (MC) calculations. These factors depend on beam quality, patient age, breast thickness and DBT scan angle; therefore, in order to compute MGD_{Dance},

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mathematical interpolation from tabulate values are often required.

Recently a similar dosimetric index (Average Absorbed Breast Dose, 2ABD), based on experimental phantom measurements, has been described, which calculates the average absorbed breast dose in DM or DBT procedures.[13–15] It can be easily calculated for a specific anode/filter combination by knowing the exposure and geometric parameters reported in the DICOM header of each exam. Specifically, tube voltage, tube load, breast thickness, focus-to-surface distance and tube yield are needed to calculate 2ABD, which can be used in any clinical condition, i.e. for any employed mammographic device and for any analyzed breast thickness.

2ABD represents the average absorbed dose to the breast without considering its glandularity: nevertheless, the amount of glandular tissue within the breast (named glandularity) must be considered for a glandular dose assessment because different values of glandularity lead to different glandular dose estimates.

The mean glandular dose cannot be measured experimentally, and computer-based methods are used to compute challenging quantities. The Monte Carlo methods simulate radiation-matter interactions using artificially generated random variables to solve the mathematical problem under investigation, which is the radiation dose delivered to the gland. In this work, a function of glandularity has been introduced by Monte Carlo simulations, to convert 2ABD in the Mean Glandular Dose MGD_{2ABD}. MGD_{2ABD} values are finally compared with MGD_{Dance} estimates provided by the current formalism.

Methods

2ABD Method

Recently a new dose index for DM and DBT procedures, named 2ABD, has been presented and described[14,15]. 2ABD allows the calculation of the value of the average breast dose in a simple way: it is easily computed for each anode/filter combination starting from the knowledge of tube voltage kVp, tube load mAs, breast thickness T, focus-to-surface distance FSD and tube yield Y_{tb}. kVp, mAs and T are characteristics of each DM or DBT exam and can be easily found in the DICOM header; FSD is a specific (and well known) characteristic of the mammographic device and, finally, Y_{tb} can be measured once a time and periodically verified for all the employed devices. A complete description of the method is out of the scope of the present work and can be found in the previous publications[14,15] for both DM and DBT modalities.

2ABD can be calculated by the following equation:

$$2ABD \sim \frac{1}{T}\int_0^T k_{a,i} C e^{-mx} dx \quad (1)$$

where $k_{a,i}$ is the incident air kerma on the breast/phantom surface; C ~ 0.77 is a conversion factor from $k_{a,i}$ to dose in phantom and m is a parameter which quantifies the beam attenuation in the breast/phantom, expressed as:

$$m = \frac{a}{kVp^b} \quad (2)$$

where a and b are fitting parameters (depending on the anode/filter combination, W/Al in our case), whose values are a = 20.32 ± 1.97 kVp/cm and b = 1.04 ± 0.03 respectively. The incident air kerma $k_{a,i}$ can be calculated by the following equation

$$k_{a,i} = \varepsilon \cdot (\alpha \cdot kVp^2 + \beta \cdot kVp + \gamma) \cdot mAs \cdot \frac{Y_{tb}\ FSD}{(FSD(-T)^2} \quad (3)$$

where ε is a coefficient whose value is ε=6.6033× 〚10〛^4 mAs·cm²/mGy and Y_{tb} (FSD) represents the yield (mGy/mAs) of the X-ray tube involved. Y_{tb} (FSD) must be evaluated for a specific tube voltage (32 kVp in our case) as described in Traino et al.[15] Finally, α, β, and γ are fitting parameters depending on the particular anode/filter combination. For the W/Al DBT anode/filter combination, the obtained values of α, β, and γ are α = (5.70 ± 0.86) × 10^{-5} mGy/(kVp²·mAs), β = (3.77 ± 0.56) × 10^{-3} mGy/(kVp·mAs) and γ = (-8.44 ± 0.89) × 10^{-2} mGy/mAs, respectively. It is important to underline that these coefficients (α, β, and γ, a and b) can be used for all the mammographic devices whose anode/filter combination is W/Al.

To simulate the breast in experimental measurements, a homogeneous phantom with planar dimensions of 16 × 16 cm² and variable thickness was employed. The phantom is composed of polystyrene (C_8H_8) with an admixture of 2.1 ± 0.2 % (mean ± standard deviation) of TiO_2 and its density (very similar to the breast glandular tissue) is 1.04 ± 0.04 g/cm³.

The Monte-Carlo model

Absorbed glandular dose estimates cannot be evaluated experimentally and MC simulations represent fundamental tools to assess the mean glandular dose by means of dedicated conversion factors obtained through the simulation of both MGD and $k_{a,i}$ values. The MC code used in this work has been validated following AAPM TG 195 protocol[16] which defines the required geometry assumptions and the computational methods to adopt for obtaining MGD values. The validation procedure concerns the comparison between specified scoring data reported in the TG 195 protocol and those obtained using the MC code;

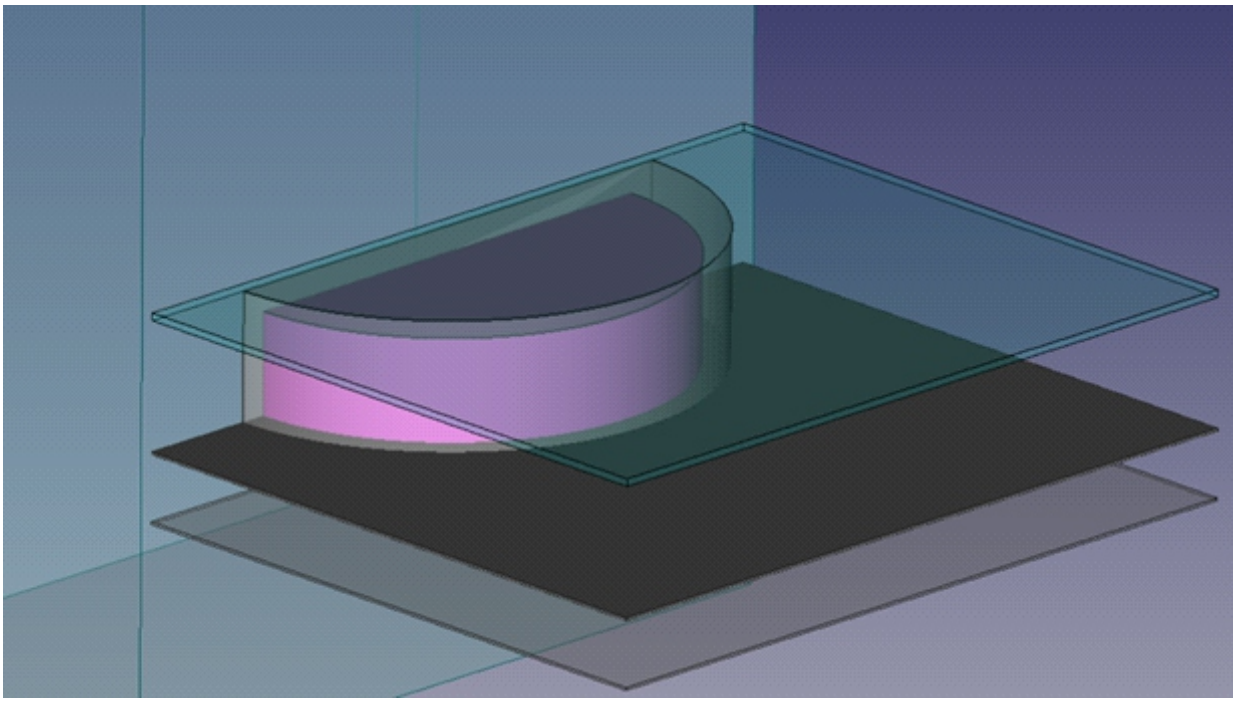

Figure 1. Representation of the digital breast phantom adopted for MC simulations. The breast tissue (in pink colour), in which the mean glandular dose estimates are computed, is surrounded by the 1.45 mm thick skin envelope; for visual purposes, the skin thickness is emphasized in this image. Compressed breast thickness is varied in the range 3-7 cm. Compression paddles (upper and lower) and the detector surface are represented.

MGD values (in mGy/photon) and energy deposit (in eV/photon) for a specified volume of interest have been compared for both monoenergetic and polychromatic beams, showing a maximum discrepancy of 0.35% for the MGD values and of 0.53% for the energy deposit. For the validation procedure, a publication of Dance et al. (2011)[11] has been used for the comparison of the t-factors (i.e. the ratio between MGD values obtained at zero projection angles during the tomosynthesis investigation), with a maximum and a mean discrepancy respectively of 0.44% and 0.25% for all the analyzed data. A detailed description of the validation procedure has been fully described in the publication of Sarno et al.[17], whose method we follow.

Glandular dose estimates are evaluated in terms of the MGD as historically defined by Wu and Boone through MC calculations in a homogeneous digital breast phantom.[18–20] The MC model involved in this work relies on a GEANT4-based MC code, which adopts a semi-cylindrical cross section breast phantom with radius of 10 cm with a homogeneous compound of glandular and adipose tissues forming a certain glandularity. Breast tissue is surrounded by a skin envelope of 1.45 mm thick (Figure 1), in line with the experimental findings derived from clinical breast CT (bCT) scans[21], using the dedicated elemental composition provided by Boone.[20] This may be the principal aspect of novelty in MC dosimetry, in which the previously used skin depth was 5 mm adipose tissue.

The effect of skin thickness on breast dosimetry has been investigated by many authors[22,23] and efforts in MC calculations have been made to obtain new dose conversion factors with the updated skin model.[17,24,25]

The MC code was designed to obtain mean glandular dose estimates, named MGD_{MC} in this work, using the methods already described in the literature.[17,24–27] MC calculations were employed to reproduce the experimental setup described in Traino et al.[15], using W/Al spectra and a 15 degrees scan angle with 15 DBT projections. Moreover, incident air kerma estimates $k_{a,i,MC}$ were computed following the formalism provided by Sarno and colleagues.[27] The number of histories launched in the MC calculations, 10^8 for the MGD scoring for each DBT projection angle and 10^9 for the air kerma scoring, were chosen to reduce the uncertainties under 0.2%.[28]

From 2ABD to $MGD2_{ABD}$

The experimental-based 2ABD method was developed in a homogeneous phantom, with 2ABD representing the mean absorbed dose in a homogenous phantom.

In the above-mentioned preliminary study,[15] it was found that the used phantom represented a good approximation of a homogenous breast whose glandularity was 1 (100% of tissue is glandular). Specifically, 2ABD matched MGD_{Dance} within an accuracy of ~ 6 % for a phantom whose thickness was T=3 cm. The discrepancy between 2ABD and

MGD_{Dance} decreased if T increased and increased if the glandularity decreased.

In this work, a new approach to relating the 2ABD to a glandular dose MGD_{2ABD} is proposed. Specifically, the Mean Glandular Dose MGD_{2ABD} was calculated starting from 2ABD, obtained by:

$$MGD_{2ABD}=2ABD \cdot f(G) \quad (4)$$

where f(G) is a function which depends on the glandularity G of the breast. f(G) is evaluated with MC simulations of MGD_{MC} performed considering the 1.45 mm thick skin envelope with a dedicated composition[20], instead of 5 mm thick skin layer made by adipose tissue, as mentioned in the current protocols.[5–7]

To compare MGD_{MC} calculated by MC simulations and 2ABD evaluated by experimental measurements, both quantities must be normalized to the respective $k_{a,i}$, as fully described in Tucciariello et al.[26,29]:

$$\left[\frac{MGD}{k_{a,i}}\right]_{MC} = \left[\frac{2ABD}{k_{a,i}}\right]_{meas} \cdot f(G) \quad (5)$$

Eq. (5) has been used to obtain a simple reliable function f(G) using a reference breast model of 4.5 cm of thickness.

Results

Starting from MC simulations, the function f(G) was evaluated by Eq. (5) for a 4.5 compressed breast thickness, varying the glandularity G in the range 0.01-1, where 0.01 means a nearly full adipose and 1 means a full glandular breast. In Figure 2, the conversion function f(G) is shown. The conversion function can be expressed as a 2nd order polynomial function:

$$f(G) = A_0 + A_1 \cdot G + A_2 \cdot G^2 \quad (6)$$

where A_0=1.389±0.001,A_1=-0.555±0.004 and A_2=0.115±0.004 are the fitting parameters (R^2 = 0.99).

f(G) can be used to convert 2ABD in MGD_{2ABD} values for all the analyzed breast thicknesses. Figure 3 shows the mean glandular dose values obtained converting the 2ABD estimates through f(G). Typical kVp and mAs used in DBT modality are indicated for each breast thickness. The effect of the glandularity is also reported in the figure 2.

The measure-based MGD_{2ABD} values have been compared with MGD_{MC} values obtained with MC simulations, which consider the exact breast thicknesses and glandularities, as defined in the previous paragraph and in line with the current state-of-the-art dosimetry in the literature.[17,24,30] The comparison allows estimating the reliability of this method and the approximation observed involving the f(G) function versus a MC-based dosimetry. Results are reported in Table 1 for breast thicknesses T ranging from 3 to 7 cm and normalized glandularities in the range 0.01-1 with increments of 0.1. The results show a good agreement for all the analyzed breast thicknesses and glandularities, where a maximum error of 12.4% is found for a 3 cm thick breast with the lower glandularity. The agreement can be considered fairly good for all T and G (except T=3 cm and G≤0.2).

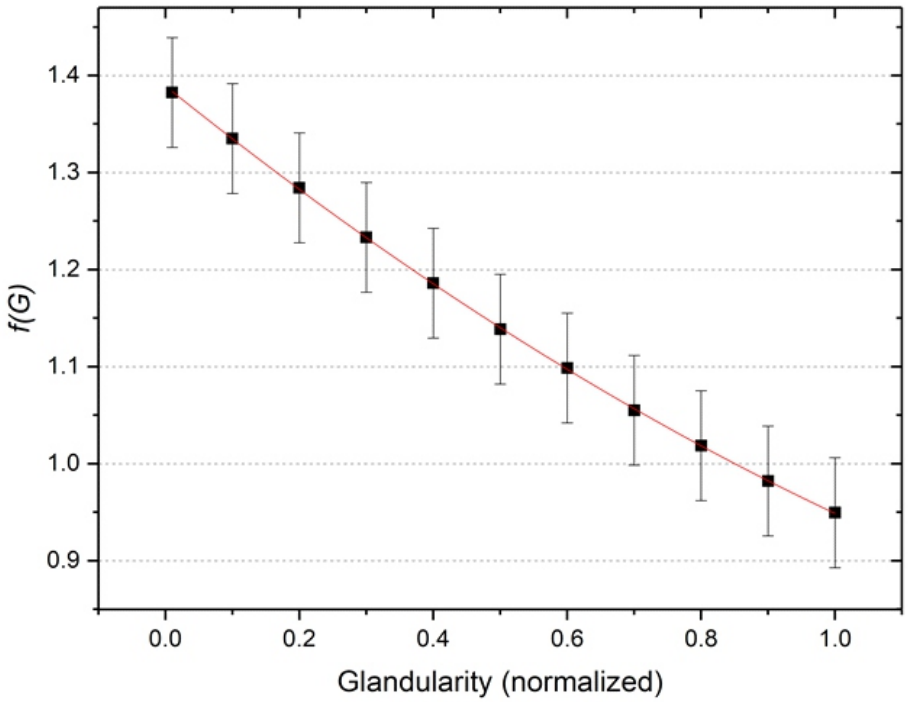

Figure 2. f(G) for normalized glandularities ranging from 0.01 to 1. Error bars are mainly affected by the uncertainties on the experimental-based 2ABD quantities (~20%), while uncertainties related to MC-based MGD_{MC} quantities are negligible (less than 0.2%). Both MGD_{MC} and 2ABD are normalized for their respective incident air kerma (Eq. (5)). Data refer to a 4.5 thick breast with a 30 kVp DBT investigation.

Table 1. Comparison between the MGD_{2ABD} values obtained by converting the 2ABD estimates, and MGD_{MC} values obtained with dedicated Monte Carlo simulations using the formalism described in the text. Both MGD2ABD and MGD_{MC} are normalized for the respective incident air kerma. Data provided by MC calculations are in good agreement with Sarno et al.[25]

T (cm)	kilovoltage (kVp)	G (normalized)	$\left[\frac{MGD}{k_{a,i}}\right]_{MC}$	$\left[\frac{MGD_{2ABD}}{k_{a,i}}\right]_{meas}$	Discrepancies
3	28	0.01	0.459	0.5 ± 0.1	8.9%
		0.10	0.445	0.5 ± 0.1	12.4%
		0.20	0.430	0.4 ± 0.1	-7.0%
		0.30	0.416	0.4 ± 0.1	-3.8%
		0.40	0.402	0.41 ± 0.09	2.0%
		0.50	0.388	0.40 ± 0.09	3.1%
		0.60	0.375	0.38 ± 0.09	1.3%
		0.70	0.363	0.37 ± 0.08	1.9%
		0.80	0.351	0.35 ± 0.08	-0.3%
		0.90	0.340	0.34 ± 0.08	0.0%
		1.00	0.330	0.33 ± 0.08	0.0%
4	29	0.01	0.396	0.41 ± 0.09	3.5%
		0.10	0.382	0.39 ± 0.09	2.1%
		0.20	0.368	0.38 ± 0.08	3.3%
		0.30	0.354	0.36 ± 0.08	1.7%
		0.40	0.340	0.35 ± 0.08	2.9%
		0.50	0.328	0.34 ± 0.07	3.7%
		0.60	0.315	0.32 ± 0.07	1.6%
		0.70	0.304	0.31 ± 0.07	2.0%
		0.80	0.293	0.30 ± 0.07	2.4%
		0.90	0.283	0.29 ± 0.06	2.5%
		1.00	0.273	0.28 ± 0.06	2.6%
5	31	0.01	0.363	0.36 ± 0.08	-0.8%
		0.10	0.350	0.35 ± 0.07	0.0%
		0.20	0.336	0.33 ± 0.07	-1.8%
		0.30	0.322	0.32 ± 0.07	-0.6%
		0.40	0.309	0.31 ± 0.06	0.3%
		0.50	0.297	0.30 ± 0.06	1.0%
		0.60	0.286	0.28 ± 0.06	-2.1%
		0.70	0.275	0.27 ± 0.06	-1.8%
		0.80	0.265	0.26 ± 0.06	-1.9%
		0.90	0.255	0.26 ± 0.05	2.0%
		1.00	0.246	0.25 ± 0.05	1.6%
6	33	0.01	0.336	0.32 ± 0.07	-4.8%
		0.10	0.324	0.31 ± 0.06	-4.3%
		0.20	0.311	0.30 ± 0.06	-3.5%
		0.30	0.298	0.29 ± 0.06	-2.7%
		0.40	0.286	0.28 ± 0.06	-2.1%
		0.50	0.274	0.27 ± 0.05	-1.5%
		0.60	0.264	0.26 ± 0.05	-1.5%
		0.70	0.253	0.25 ± 0.05	-1.2%
		0.80	0.244	0.24 ± 0.05	-1.6%
		0.90	0.235	0.23 ± 0.05	-2.1%
		1.00	0.227	0.22 ± 0.05	-3.1%
7	35	0.01	0.315	0.30 ± 0.06	-4.8%
		0.10	0.303	0.29 ± 0.06	-4.3%
		0.20	0.291	0.28 ± 0.06	-3.8%
		0.30	0.279	0.27 ± 0.05	-3.2%
		0.40	0.267	0.26 ± 0.05	-2.6%
		0.50	0.257	0.25 ± 0.05	-2.7%
		0.60	0.246	0.24 ± 0.05	-2.4%
		0.70	0.237	0.23 ± 0.05	-3.0%
		0.80	0.228	0.22 ± 0.04	-3.5%
		0.90	0.219	0.21 ± 0.04	-4.1%
		1.00	0.212	0.20 ± 0.04	-5.7%

Moreover, in order to test the approach presented in this work, a comparison between MGD_{2ABD} and MGD_{Dance} values provided in the current dosimetry protocols based on the Dance's approach was performed for normalized glandularities ranging from 0.2 to 1 with steps of 0.2.[5–7] It should be noted that c and g Dance's coefficients have been interpolated in order to match the exact glandularity to perform the comparison. The results are reported in

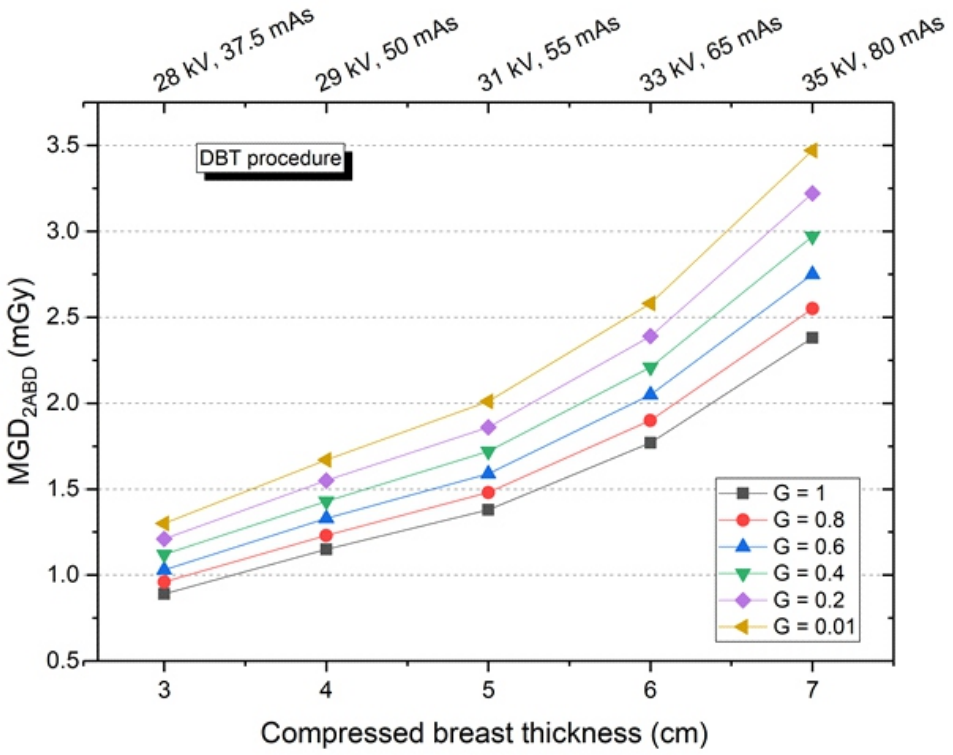

Figure 3. Mean glandular dose values obtained converting the 2ABD estimates. kV and mAs are typical parameters automatically selected by the DBT unit for the specified breast thickness.

Table 2. Comparison between MGD_{2ABD} and the MGD_{Dance} calculated using the Dance's approach for different breast thicknesses and glandularities.

G (normalized)	Phantom thickness (cm)	Tube load (mAs)	Tube voltage (kVp)	MGD_{2ABD} (mGy)	MGD_{Dance} (mGy)	Relative difference (%)
1	3	37.5	28	0.9 ± 0.2	1.0 ± 0.2	-10.0%
	4	50	29	1.2 ± 0.2	1.2 ± 0.2	0.0%
	5	55	31	1.4 ± 0.3	1.5 ± 0.3	-6.7%
	6	65	33	1.8 ± 0.3	1.9 ± 0.4	-5.3%
	7	80	35	2.4 ± 0.4	2.6 ± 0.3	-7.7%
0.80	3	37.5	28	1.0 ± 0.2	1.1 ± 0.2	-9.1%
	4	50	29	1.3 ± 0.2	1.3 ± 0.3	0.0%
	5	55	31	1.5 ± 0.3	1.6 ± 0.3	-6.3%
	6	65	33	2.0 ± 0.3	2.0 ± 0.4	0.0%
	7	80	35	2.6 ± 0.5	2.8 ± 0.6	-7.1%
0.60	3	37.5	28	1.1 ± 0.2	1.1 ± 0.2	0.0%
	4	50	29	1.4 ± 0.3	1.4 ± 0.3	0.0%
	5	55	31	1.7 ± 0.3	1.7 ± 0.3	0.0%
	6	65	33	2.1 ± 0.4	2.2 ± 0.4	-4.5%
	7	80	35	2.9 ± 0.5	3.0 ± 0.6	-3.3%
0.40	3	37.5	28	1.2 ± 0.2	1.2 ± 0.2	0.0%
	4	50	29	1.5 ± 0.3	1.5 ± 0.3	0.0%
	5	55	31	1.8 ± 0.3	1.8 ± 0.4	0.0%
	6	65	33	2.4 ± 0.4	2.4 ± 0.5	0.0%
	7	80	35	3.2 ± 0.5	3.3 ± 0.7	-3.0%
0.20	3	37.5	28	1.3 ± 0.3	1.3 ± 0.3	0.0%
	4	50	29	1.7 ± 0.3	1.6 ± 0.3	6.2%
	5	55	31	2.0 ± 0.3	2.0 ± 0.4	0.0%
	6	65	33	2.6 ± 0.4	2.6 ± 0.5	0.0%
	7	80	35	3.5 ± 0.6	3.6 ± 0.7	-2.8%

Table 2.

There is a good agreement between the MGD_{Dance} and MGD_{2ABD} with a mean discrepancy among all data provided in Table 2 of -2.4% and a maximum relative percentage difference of -10.8% occurring with a 3 cm thick and 100% glandular breast (G=1). It should be stressed that in this work, the 1.45 mm thick skin model has been used, probably affecting the comparison mainly for low breast thicknesses with the MGD_{Dance} coefficients, which are obtained using a

5 mm thick adipose skin. Indeed, in the 5 mm skin case, the breast tissue volume, i.e. the scoring volume for MC calculations, is thinner compared to the case of 1.45 mm thick skin layer, where the breast tissue is thicker; this implies different dose estimates because MC dose estimates are not performed in the skin tissue.

Discussion

Currently two similar methods for the mean glandular dose evaluation in DM or DBT are employed, both based on MC calculations: the Dance[8–12] and the Wu and Boone methods.[18–20] The method introduced by Dance is the most widely used in the international dosimetry protocols.[5–7] It allows obtaining a reliable dosimetric index related to the ionizing radiation risk through the conversion of the incident air kerma $k_{a,i}$ in a mean glandular dose MGD_{Dance}. MGD_{Dance} estimates are based on dedicated correction factors tabulated as a function of the beam quality, patient age, projections angle and breast thickness: interpolation is often required for an accurate evaluation of MGD_{Dance} and the dependence of glandularity on the age of the patient is sometimes questionable.

In this work, another method for evaluating the mean glandular dose absorbed by the patient's breast during the DBT examinations was presented. In previous works[14,15], a simple approach based on experimental measurements has been introduced to individually evaluate the average absorbed dose in DM and DBT procedures. This method is based on the evaluation of a new dosimetric index, named 2ABD (Eq. 1), which quantifies the average dose absorbed in a homogenous phantom simulating a 100% glandular breast (G=1). The glandular dose is highly dependent on the glandularity of the breast, which results in wide variations among women, often not related to their age.

In order to extend this last method to any glandularity, in this work a new approach for relating the Average Absorbed Breast Dose 2ABD to a glandular dose MGD_{2ABD} was proposed. Using a validated GEANT4-based MC code, 2ABD was converted in a MGD_{2ABD} by a 2nd order polinomial function f(G) which depends only on different glandularities G. Following the geometrical assumptions of the breast model involved in international dosimetry protocols, a skin envelope was used to surround the sensitive volume (breast tissue) for the MC calculations. Based on the new results published in the literature obtained using bCT investigations, a skin layer of 1.45 mm of thickness and dedicated composition was used.[17,20,24,25]

f(G), obtained for a 4.5 thick breast (Figure 2), converted the mean dose $_{2ABD}$ in a mean glandular dose MGD_{2ABD} for different breast thicknesses and glandularities. A comparison between the measure-based MGD_{2ABD} and the MC-based MGD_{MC} values showed a maximum discrepancy of 12.4% for a 3 cm thick breast with the 0.1 glandularity. The agreement between MGD_{2ABD} and MGD_{MC} can be considered fairly good for all T and G except T=3 cm and G≤0.2.

Moreover, in order to compare the presented method to that currently involved in the dosimetry protocols, MGD_{2ABD} values were compared with MGD_{Dance} values. In this case, a maximum relative percentage difference of -10.0% was obtained for a 100% glandular (G=1) and 3 cm thick breast. In this work, MC simulations were performed using a 1.45 mm thick skin, probably affecting the comparison with MGD_{Dance} estimates (obtained considering a 5 mm thick adipose skin) especially for small compressed breast thicknesses.

The method presented in this paper allows the evaluation of the average glandular dose in a simple way. Few (and very easily accessible) parameters are required: tube voltage kVp, tube load mAs, breast thickness T, focus-to-surface distance FSD, tube yield Y_{tb} and finally the breast glandularity G. Some of these parameters (kVp, mAs and T) are characteristics of each DBT examination and can be easily found in the DICOM header of the images; FSD is typical of the specific employed mammographic device and Y_{tb} is calculated once and periodically verified. Therefore, if the glandularity of the breast is known, the evaluation of MGD_{2ABD} using the f(G) conversion function can be done for each patient. Thanks to its simplicity, the MGD_{2ABD} based method could be easily implemented in any mammographic device. The proposed method is based on the above-presented coefficients α, β, γ, a and b which are strictly related to the form of the X-ray spectra. For this reason, while the method is general, the values of α, β, γ, a and b presented in this paper can be used only for the mammographic devices whose anode-filter combination is W/Al.

Some limitations of the proposed approach should be noted. Specifically, there are some approximations in our 2ABD model. For example, a simple exponential decay relationship was employed to describe the dose distribution with depth, neglecting the polychromatic nature of the X-ray beams.[14,15] Additionally, the absorbed dose distribution was considered homogeneous at each depth of the phantom. On the other hand, even the Monte Carlo simulations included some simplifications in the mammographic hardware modeling (e.g. modelisation of anode inclination, filtration thickness, compression paddle and breast support) which affect the final X-ray spectra and thus the absorbed dose and MGD estimation.

In conclusion, MGD_{2ABD} represents an easily evaluable index related to the risk induced by the exposure to the ionizing radiation, which can be included in the report of each DBT examination, in line with the indications of the 2013/59/Euratom Directive.

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Conflict of Interests

The authors declare that they have no conflict of interests.

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