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Accuracy of the Empirical Estimate of AGD of Patients Exposed to Conventional Mammographical Exams

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Abstract: The appropriate dosimetric indicator of the radiation dose received by patients on mammography exams is the Average Glandular Dose (PGD). This work aims to estimate the clinical AGDs using the parametric equations of Matsumoto et al. (2003) and determine the degree of accuracy compared to the estimates of Dance et al. (2000). To fulfill the objective, kVp data were collected, mAs, compressed breast thickness, age and anode/filter combination of 50 patients who underwent conventional mammography exams. The results were compared with the curves proposed by Dance et al., where it was observed that the values estimated by the equations of Matsumoto et al. (2003) they underestimate the doses with respect to the curve that marks the achievable value and is well below the curve that marks the acceptable values; however, a systematic variation is observed with the reference AGDs, which is due to the correction due to glandularity that Matsumoto's empirical estimates do not consider. With these results it can be inferred that the equations of Matsumoto et al. (2003) are viable to estimate the AGD imparted by mammographers using the Mo/Mo anode/filter combination.

Key words: patients dosimetry, mammography

1. Introduction

Mammography is the radiological examination mostly used for the early detection of breast cancer, since the range of energies used (25 keV-30 keV) makes it possible to distinguish carcinogenic tissue from the fibroglandular and adipose tissue of which the breast is composed [1].

The dose associated with exposure on mammography exams is the Average Glandular Dose (AGD) or Mean Glandular Dose (DGM), which is defined as the average dose in the glandular tissue within the breast and for stochastic effects the International Commission for Radiological Protection (ICRP) recommends AGD as the appropriate dosimetric indicator [7].

The bibliographic collection concerning the estimation of the AGD is broad, that is, there are international protocols such as, for example, the protocols of the International Atomic Energy Agency (IAEA), of the European guidelines (EUREF) [4], and those of the American Association of Medical Physics (AAPM) and several other protocols [5, 7], adapted to these that introduce some modifications for clinical and reference dose estimates.

The best-known expressions for the calculation of AGD are those shown in Eq. (1) and Eq. (2), which use correction factors for beam quality and glandularity of the breast.

$$AGD = k_i.c.s \tag{1}$$

$$AGD = k_i.g.c.s \tag{2}$$

The IAEA uses Eq. (1) to estimate the AGD where, k_i is the kerma incident in air without backscattering at the inlet surface (KASE) of a PMMA phantom that simulates a standard thickness breast. The c factor converts the KASE to AGD for breasts with a 50%/50% composition of glandular/adipose tissue, the s factor

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compensates for the variation of the AGD due to the influence of the anode/filter combination.

The European protocol uses Eq. (2) to estimate the AGD where “Ki”, the s factor is defined in the same way as Eq. (1), however the g factor of this equation is defined as the “c” factor of The IAEA equation, then a new factor c is defined in the European protocol, which corrects the expression for different breast glandularity including the 50% glandular/50% adipose composition.

The factors “c” and “g” were determined by simulation using the Monte Carlo method [3], which depend on breast thickness, glandularity percentage and Half Value Layer (HVL). The results show that the variation of the factor c is in the range of 0.779 and 1.329 with which the author suggests including this factor in the equation for the determination of the AGD. The European protocol for quality control in mammography is based on this work [3].

To avoid KASE measurements in the determination of clinical doses, many authors have proposed the use of parametric equations developed by Monte Carlo simulations, in particular the equation used in this work is the Matsumoto equation [2, 6, 9].

Parametric equations of Matsumoto [6] have been determined, for the anode/filter combinations corresponding to Mo/Mo, Mo/Rh and Rh/Rh, they will be used in clinical dosimetry, knowing the exposure factors: kVp, mAs, breast thickness compressed (EMC). The equations for Mo/Mo and Mo/Rh are presented in Table 1.

Table 1 Parametric equations presented by Matsumoto [6].

Parameter	***Mo/Mo***	***Mo/Rh***
Effective Energy (keV)	Eeff = 0,1325V+ 11,80	Eeff = 0,1435V+ 12,20
Output Exposure (mR/)	XmAs = 2,1329 $Eeff^2$ - 57,78Eeff + 392,71	XmAs = 1,1919 $Eeff^2$ - 31,924Eeff + 212,23
Conversion factor DGM (mGy)	DgN = (0,3962 Eeff - 4,3178)10^{-3}	DgN = (0,3495 Eeff - 3,5479)10^{-3}

To determine the AGD with the above equations, the Eq. (3) is used.

$$AGD = mAs \bullet XmAs \bullet DgN \bullet SSDcf \qquad (3)$$

Being the correction factor for breast thickness:

$$SSDcf = \left(\frac{DFP}{(DFP-EMC)}\right)^2 \qquad (4)$$

In these equations, the exposure factors are replaced: (mAs), the potential in KV used (V), the Focal Point - Film distance (DFP) and the thickness of the compressed breast (EMC).

After the analysis of the related bibliography, this work intends to compare the values obtained in the determination of the Average Glandular Dose with the Matsumoto equations and the Dance’s theoretical curves [3].

2. Materials and Methods

The work is based on the verification of the results obtained using the equations of Ref. [6] in the estimation of the Average Glandular Dose. To do this, exposure data were taken from 50 patients who underwent a mammogram examination in a conventional mammogram of a private service. These data were entered into the equations in Table 1 and later compared with the Dance’s theoretical curves [3], which are accepted by various protocols for the estimation of the Average Glandular Dose.

2.1 Mammography Quality Control

Before collecting the data, the equipment quality controls were carried out to ensure: the repeatability and reproducibility of the potential, time and exposure and the linearity of the exposure with the load, determination of the HVL and the reference AGD, using a detector Solid state UNFORS MAM with a measurement uncertainty of ±5 μGy and the ACR breast phantom (Fig. 1), using the Quality Control

Fig. 1 ACR phantom exposure to then determine KASE.

Manual of conventional mammography TECDOC 1517 [7]. The equipment is a conventional GENERAL ELECTRIC mammograph, Senographe 800 T model, whose available filter anode combinations are Mo/Mo and Mo/Rh.

2.2 Data Collection and Determination of Dosimetric Parameters

A spreadsheet was prepared to collect the exposure data of the patients where the following parameters were recorded: compressed breast thickness (EMC), potential (kV), load (mAs) and anode/filter combination at each exposure, which were extracted of the patients' radiographic films. These data were loaded into Excel spreadsheets programmed with the equations in Table 1 and with Eq. (2) for the estimation of the average glandular doses.

The estimation of the AGD with the Matsumoto equations [6] was performed by replacing the data collected in the equations shown in Table 1, in addition the AGD was determined for each projection, and for each patient. These values were plotted with the theoretical curves of Dance [3], Fig. 2, in such a way to compare the estimated values by means of the Matsumoto equations [6] with the tolerance values and the attainable values depending on the breast thickness.

3. Results and Discussion

From the data collection, EMC measurements from 3.1 cm to 10.1 cm were obtained, which were classified into three categories: small: less than 4.5 cm; medium: between 4.6 and 5.5 cm and large from 5.6 cm onwards. It was observed that most of the patients monitored are in the category of large breasts and that there is a difference in the EMC measurement of the same breast when it is irradiated in different projections.

In all the sampled cases, projections corresponding to the Caudal Skull (CC) and the Oblique Mid Lateral (MLO) were performed in each breast. The letters L and R in the titles correspond to breasts of the Left and Right side, respectively.

With the exposure parameters of the patients, the doses in each breast of each patient were calculated. The doses in categories were averaged, then compared with the achievable and acceptable values for compressed breast thicknesses reported by Dance's theoretical curve [3].

Table 2 Average measures of AGD, classified by breast thickness and projection.

	DOSE (mGy)			
EMC (cm)	Projection CCR	Projection CCL	Projection MLOR	Projection MLOL
< 4.5	0,87	0,95	0,792	1,22
4.5 – 5.5	1,60	1,46	1,75	1,38
> 5.5	2,32	2,32	3,204	2,99

Using the dose measurements, carried out by previous research [10], the work done by Dance [3], shows the variation between the AGD values reported with the glandularity factor for 50% glandular/50% adipose breasts and the AGD values calculated with the correction factors of different glandularities concluding that for large breasts, the use of the glandularity correction factor increases the estimate of the AGD by 30% and for small breasts decreases by 11%.

In this work it is observed that for a CCR projection, the AGD reported for 5 cm of EMC is 1.6 mGy, while in the work presented by Ramos & Villareal [8], who used the Equations of [6], reports a AGD of 1.2 mGy for the Mo/Mo combination.

The graphs that relate the average glandular dose as a function of compressed breast thickness for the Matsumoto parametric equations [6], are shown in Fig. 2, where a comparison is made between the methodology applied in this work and the acceptable value curves and attainable reported by Dance [3], plotted so that the average glandular dose depends on the equivalent breast thickness and not on PMMA blocks.

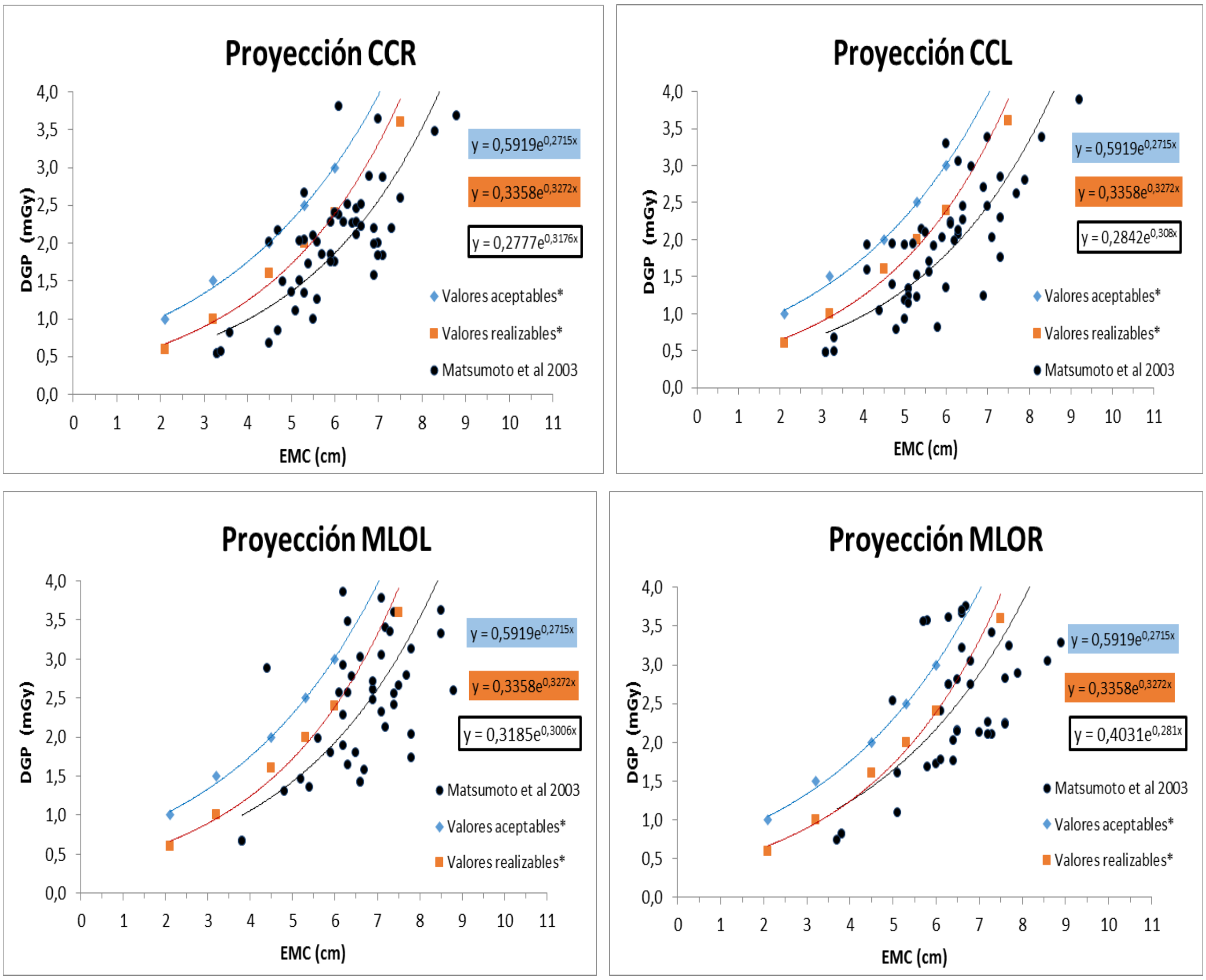

Fig. 2 AGD vs EMC distributions applying Matsumoto methodology [6], compared to Dance's theoretical curves [3].

It is observed that the results obtained are below the Dance curves, which indicates that we report values below those attainable (reported by most authors) and well below acceptable values (tolerable dose limit for a given breast thickness).

The graphs show that there is a majority of data whose EMC > 5.5 cm, which indicates that the women evaluated do not have the characteristic of a standard breast. In addition, the study reveals that there is an asymmetry between both breasts in most cases and that, for an oblique Mid-Lateral projection, the thickness of compressed breast is greater, so the reported dose is also greater.

4. Conclusion

It was possible to apply the Matsumoto methodology [6] with the data collected and estimate Average Glandular Dose values, which were compared with the theoretical curves of Dance [3] and making a graphic comparison of the theoretical curves of Dance [3] and The trend curve of the data obtained in this work, shows that our results follow the same trend as the theoretical curves, which reaffirms the hypothesis that the Matsumoto equations [6] can be used for clinical dosimetry.

We also show that the Average Glandular Dose values obtained in this work are below the attainable values and well below the acceptable values for each breast thickness, which indicates that the doses received by the monitored patients are below of the accepted limit for the thickness of compressed breast that corresponds to them.

All patients underwent mammograms on both breasts and with Skull Caudal and Oblique Mid Lateral projections, this indicates that the total dose received by a standard breast patient is, on average, 6.2 mGy.

It is recommended that the dose values should be monitored periodically, performing a strict quality control to the mammographer, mainly to the Automatic Exposure Control, which will guarantee the correct selection of kV and mAs, so that the clinical doses are below the established limits and the proper medical diagnosis is maintained.

In addition, it was evidenced that there are women who perform mammograms from 33 years of age and up to 71 years of age. In these cases, the methodology described in the European Protocol could not be applied, due to the “c” factor introduced by Dance, since it is dependent on the age of the patients, so the equations in Table 1 could be used for determination of clinical doses in these cases.

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