



## Quality control in breast tomosynthesis

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### ABSTRACT

In Brazil, breast cancer is the most common and the leading cause of death among women, with estimated 57,000 new cases in 2014. The mammography (2D) plays an important role in the early detection of breast cancer, but in some cases can be difficult to detect malignant lesions due overlap of breast tissues. The Digital Breasts Tomosynthesis (DBT: 3D) reduces the effects of overlap, providing improved characterization of mammographic findings. However, the dose may double as compared with mammography. This study presents results of Contrast to Noise Ratio (CNR) and image quality evaluation on Siemens mammography equipment Mammomat Inspiration with tomosynthesis. The CNR was determined with Polymethylmethacrylate (PMMA) layers of 20 to 70 mm thick and an aluminum foils of 0,2 mm thickness and area of 10 mm<sup>2</sup>. Image quality was assessed with the ACR Breast Simulator. In the evaluation of image quality, the detectability of fibers and masses was identical in 2D and 3D systems. Displaying fibers were 4,5 and 4 mass in both modes. In 2D mode were identified 3,5 microcalcifications groups, and 3D showed 3 groups. The Mean Glandular Dose (MGD) for the simulator in 2D mode was 1,17 mGy and 2,35 mGy for the 3D mode. The result reinforces the importance of quality control in the process of obtaining the images and obtained in accordance CNR values, ensuring image quality and compatible dose in 2D and 3D processes.

*Keywords: Breast cancer, Quality control, Breast tomosynthesis.*

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## 1. INTRODUCTION

In Brazil, breast cancer is the most common and the leading cause of death among women, with estimated 57,000 new cases in 2014 (INCA, 2013; FACINA, 2014). Currently, the mammogram (2D) plays an important role in the early detection of breast cancer (SVAHN, *et al.*, 2014). The amount of fibroglandular tissue present in the breast is directly related to mammographic density. When there are high densities in the image, there may be a difficulty in detecting malignant lesions because there are overlapping tissues (SOUZA, *et al.*, 2012). Thus, it is necessary to use an imaging technique that can detect lesions, malignant or not, which are not displayed on a mammogram. The Digital Breast tomosynthesis (DBT: 3D) reduces the effects of overlapping breast tissue and can provide a better characterization of mammographic findings and reducing the need for additional supplementary views (URBAN *et al.*, 2012).

The DBT image acquisition is very similar to the method of digital mammography, the difference is that the x-ray tube rotates around the breast that remains compressed. A number of acquired projections are reconstructed through algorithms (BOUWMAN *et al.*, 2013). The recent introduction of DBT in clinical practice requires Quality Control procedure (QC) and dose measurements (NHSBSP, 2013).

This study aims to implement a QC in DTB equipment, and thus provide a routine clinical practice with acceptable doses for the patient and the professional. The work was performed in a radiology clinic located in the region of Curitiba.

The QC tests in tomosynthesis used in this evaluation were based on those used by the National Health Service Breast Screening Programme (NHSBSP), European Reference Organization for Quality Assured Breast Screening and Diagnostic Service (EUREF), American Association of Physicists in Medicine (AAPM) and the Federal Ordinance 453/98.

## **2. MATERIALS AND METHODS**

The QC tests in modes 2D and 3D were performed in a mammography unit Siemens Mammomat Inspiration.

The determination of the Contrast to Noise Ratio (CNR) for each specific set of exposure parameters was performed using aluminum (Al) and polymethylmethacrylate (PMMA) plates. The Al foils were used (type Al 1145) with a 99,9% purity, with a square area of 10 mm and a thickness of 0,2 mm associated with PMMA plates for the simulation of different breast thicknesses between 20 and 70 mm.

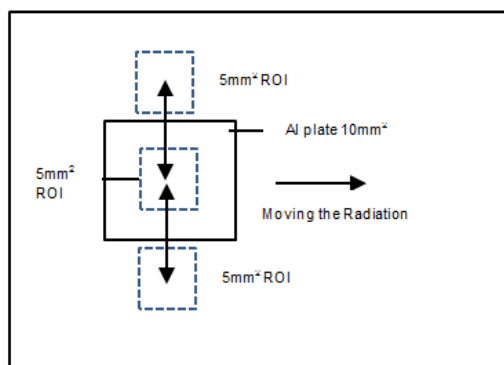
The image quality was evaluated with Breast Simulator recommended by the American College of Radiology (ACR) and the Brazilian College of Radiology (BCR), model 450, which simulates a compressed breast of approximately 4,5 cm thick, and has inside, fiber details, masses and microcalcifications.

### **2.1. Contrast Ratio Noise**

The performance evaluation of CNR in 2D mode was performed by exposure of PMMA plates varying the thicknesses of 20 to 70 mm. The aluminum foil was placed on the right side of the midline of the breast support tray and 6 cm from the chest wall edge. In all measurements, the Al foil was placed on top of a PMMA layer 20 mm thick.

In a first step the exposure was performed using the Automatic Exposure Control (AEC) using target / filter of W/R. After identifying the peak kilovoltage exposure factors (kVp), current versus time product (mAs) for each thickness of PMMA, the exposure factors were reproduced in manual mode.

After the acquisition, the images were evaluated in raw data using a Region of Interest (ROI) of about 5mm x 5mm positioned in the center of Al, and two in the bottom region of the chest wall edge and nipple located below and above the Al foil region respectively as shown in Figure 1.

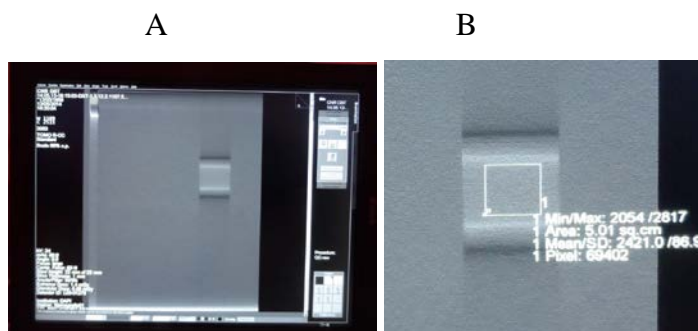
**Figure 1:** Representation of ROI to calculate the positions CNR

Font: EUREF 2013 (modified).

The obtained data, as Pixel Average Value (PAV) and standard deviation (SD) were recorded to calculate the CNR, using the analysis tools provided by mammography manufacturer. For the 3D method, the CNR was evaluated with the same methodology used for 2D and ROIs were evaluated in the first image reconstructed tomosynthesis in craniocaudal incidence (CC) for each PMMA thickness (EUREF, 2013).

The Figures 2A and 2B shows the images used for the calculation of CNR in tomosynthesis a In Figure 2A the image containing all the data display in the lower left corner of the image; in the Figure 2B the data of one ROI measurement, containing PAV and SD of data.

**Figure 2:** Image of DTB with PMMA plate and Al; A) the image containing all the data display in the lower left corner of the image; B) data of the ROI containing the PAV and SD of data



The CNR is defined as the ratio of the difference between the PAV and the bottom contrasting details of a ROI, by the SD and deep structure. For each exposure techniques acquired in 2D and 3D modes, PAVS and SDs of the average pixel values were used to calculate the CNR of each thickness PMMA exposed, according of equation 1.

**Equation 1:** Equation used to calculate the CNR

$$\text{CNR} = \frac{\text{PAV (PMMA)} - \text{PAV (Al)}}{\sqrt{\frac{\text{SD (PMMA)}^2 + \text{SD (Al)}^2}{2}}}$$

Where PAV (PMMA) and PAV (Al) represent the average values of pixels in the regions of Al and PMMA of images. The SD (PMMA) and SD (Al) are the standard deviation measured in ROIs of PMMA and Al and are average values of pixels in the same regions. It should be remembered that the SD is defined as the positive square root of the variance (YOUNG *et al.*, 2006). It is known that the SD is the distance from an arbitrary value for the average value of the variable being generally represented by Equation 2 (BRASIL, 2014).

**Equation 2:** Equation used to calculate deviation standard

$$SD = (X - \bar{X})$$

Where  $\bar{X}$  is the average value of the variable and X is any value. The variance aims to analyze the degree of variability of certain situations in which determines more specifically the possible variations, in order not to compromise the results of the analysis. The variance is measured by Equation 3 (BRASIL, 2014).

**Equation 3:** Equation used to calculate variance

$$S^2 = \frac{\sum_i^N (X - \bar{X})^2}{N-1}$$

Where  $S^2$  is the symbol used for the variance, the measure amounts to square the value of each deviation from the mean and then sum all results (numerator of the equation). Finally, the value of the sum is divided by N-1, which corresponds to the total number minus 1. Rises to the squared to eliminate negative signs of some deviations. Thus the SD of the PMMA is defined as the positive square root of the variance, according of the equation 2 (YOUNG *et al.*, 2006, BRASIL, 2014); the variance being obtained with the Excel software.

## 2.2. ACR Mammography simulator

For the evaluation of image quality the ACR phantom was positioned exactly in the center of the image detector, near of the chest wall edge, exposed using the AEC with W/Rh target filter combination. In this case we used the combo mode equipment (2D + 3D), which provided data for the image of 2D and 3D. The images were evaluated on a BARCO console monitor with a resolution of 3M Pixel. Regarding the tomosynthesis images, the first reconstructed image was selected, because in this slice, the simulator elements have a maximum resolution and are in focus. All data about the exposure parameters used and results of the evaluation of the images were recorded.

According to the Federal Ordinance 453/98, mammography systems must be able to identify the image of a fiber of 0,75 mm, one microcalcification group of 0,32 mm and a mass of 0,75 mm in the ACR phantom. The reference level for Mean Glandular Dose (MGD) is 3 mGy for ACR phantom (MS, 1998).

In QC tests performed in the mammography equipment with a calibrated detector PTW dosimeter DIADOS E (PTW manufacturer, Freiburg, Germany) with semiconductor T60005-1233, it was found that the MGD provided by the software mammography differ in average 1,5% of that estimated from the measurement of the surface air kerma. Thus, the MGD values presented in this work in 2D mode are values from the measurement of surface air kerma, and in 3D mode refer to the MGD of values obtained directly from the mammography unit dosimeter during the phantom exposure.

### 3. RESULTS

#### 3.1. CNR

Table 1 presents of CNR results for 2D mode.

**Table 1:** Results found for CNR in 2D mode

PMMA (mm)	CNR 2D						
	kVp	mAs	Target/Filter	MGD (mGy)	MGD* (mGy)	CNR	CNR NHSBSP**
<b>20</b>	24	80	W/Rh	0,7	< 1,0	14,6	4,2 / 6,2
<b>30</b>	26	100	W/Rh	0,9	< 1,5	13,7	4,2 / 6,2
<b>40</b>	27	140	W/Rh	1,2	< 2,0	11,2	4,2 / 6,2
<b>45</b>	28	160	W/Rh	1,4	< 2,5	11,4	4,2 / 6,2
<b>50</b>	28	200	W/Rh	1,7	< 3,0	11,5	4,2 / 6,2
<b>60</b>	29	280	W/Rh	2,3	< 4,5	9,6	4,2 / 6,2
<b>70</b>	30	450	W/Rh	3,4	< 6,5	9,9	4,2 / 6,2

\*Acceptable values; \*\*CNR of reference values as NHSBSP.

The 3D results can be seen in Table 2. For The 3D values were calculated for the first re-constructed image in DBT.

**Table 2:** Results found for CNR in 3D mode

PMMA (mm)	CNR 3D						
	kVp	mAs	Alvo/Filtro	MGD (mGy)	MGD* (mGy)	CNR	CNR NHSBSP**
<b>20</b>	24	80	W/Rh	1,0	< 1,0	14,8	2,87
<b>30</b>	26	100	W/Rh	1,3	< 1,5	13,6	2,40
<b>40</b>	27	140	W/Rh	1,8	< 2,0	11,7	2,06
<b>45</b>	28	160	W/Rh	2,1	< 2,5	9,4	1,87
<b>50</b>	28	200	W/Rh	2,4	< 3,0	8,6	1,72
<b>60</b>	29	280	W/Rh	3,3	< 4,5	7,0	1,46
<b>70</b>	30	450	W/Rh	5,1	< 6,5	5,6	1,36

\*Acceptable values; \*\*CNR reference values for breast tomosynthesis as NHSBSP 2013.

### 3.2. ACR simulator

The simulated structures were analyzed in visual recognition function on the 3M pixel monitor of the workstation of the mammography unit console. In Table 3, the exposure parameters used for 2D and 3D are presented. The MGD values and the score obtained for both methods as well as the reference values set by Federal Ordinance 453/98. With the images obtained by the simulator exposure was possible to score the fibers groups, masses and calcifications for both systems.

**Table 3:** Values obtained by the simulator exposures for 2D and 3D modes

ACR Simulator						
Modo	kVp	mAs	MGD /Ref* (mGy)	Fibers/Ref.*	Masses/Ref.*	Micro/Ref.*
<b>2D</b>	27	93,8	1,2/3,00	4,5/4	4/3	3,5/3
<b>3D</b>	27	187,5	2,4/3,00	4,5/4	4/3	3/3

\* Reference to the 2D mode with the minimum values expected by the Federal Ordinance 453/98.

## 4. DISCUSSION

### 4.1. CNR

The CNR is the test indicated as ideal parameter to evaluate the image quality in 2D (YOUNG, 2006). In the case of measurements realized for CNR in focal planes in the DTB reconstruction, DBT it is expected that such measurements are highly dependent on the degree of leveling and inherent dimensioning of the reconstruction algorithm. Any interpretation of the absolute values of CNR regarding image quality needs to be interpreted with caution (NHSBSP, 2013).

It is known that the details of an image will be visible if the required CNR is maintained by having a relatively low noise level. Among the factors that influence the CNR are: the radiation spectrum, the pixel size, the dose to the detector and the characteristics of the study object (JAKUBIAK, 2013). However, by comparing the calculated CNR values with the literature (NHSBSP, 2013), which is within the limits, it was identified differences in the results obtained.



This difference may be associated with the factors that influence the CNR, among which are: the type of detector, the test dose pattern and the unit performance.

The values of the CNR are equivalent to the dose received at the detector at the time of exposure. Even with values above used as a reference, it is observed that the CNR kept relatively low noise level and the values obtained are consistent with the expected image quality. By comparing with the results of image quality test, using the ACR Breast Simulator, the system was sensitive enough to register filamentary structures, good image definition to show microcalcifications and large capacity to record image of tumor masses, as recommended by Federal Ordinance 453/98, that's mean that, for the 3D system the score cannot be less than required for the 2D system.

#### **4.2. ACR simulator**

As shown in Table 2, it is possible to see that the test result with ACR breast simulator is within the standards recommended by the ACR and Federal Ordinance 453/98.

For the total of identified fibers, both 2D systems as in 3D outweigh the references of Ordinance 453/98. These linear low contrast objects with different diameters simulate fibrous tissue extensions, which, when exposed, allow the measurement of the sensitivity of the image production system to record filamentary structures within the breast (INCA, 2007).

The groups of masses did not occurred significantly differences when the results of 2D and 3D systems are compared, but it is possible to note, though, a result that is higher than the set defined by the Federal Ordinance 453/98. The ability to record the image of the tumor masses is a very realistic measure of the 2D image quality.

As for microcalcifications groups you can see that the 2D system overcomes the 3D, but the latter remains within the standards. This is due the 2D system has better image definition (INCA, 2007). Although the radiologists using for the breasts evaluation monitors of 5M pixel, these results are relevant, since in Core biopsies and vacuum biopsy, the monitors of 3M pixel of mammography workstation console that are used for visualization of lesions during procedures.

As for registered MGD, can be seen that the 3D mode offered twice the dose compared to 2D, but the values are still below the reference values for the measured thickness.

When comparing the CNR values, MGD and image quality can be seen that a well-tuned system can produce adequate image quality with low dose. What guarantees the patients treated in these devices, the safety of a procedure where the benefit outweighs the risks.

Other tests related to the effectiveness of the clinical dose of DBT system are still in progress and their results are under review.

## **5. CONCLUSION**

The CNR values obtained are compatible with the expected image quality, as to the results with the test breast simulator, the system was sensitive enough to register filamentary structures, excellent image definition to show microcalcifications and large capacity registering image tumor masses, that is, the CNR was adequate to keep a relatively low noise level.

When comparing systems, the MGD values for ACR simulator in 2D mode was 1,2 mGy and 2,4 mGy for 3D, which reinforces compliance obtained in CNR values, ensuring image quality and dose compatible in 2D and 3D processes.

The tests were adequate for the purpose of this study, and the results are within the limits established for those image acquisition parameters. The image quality in 2D and 3D mode meet the limits of conformity. With the results obtained with the ACR simulator and the MGD evaluation for all measured thicknesses, it was demonstrated that when performing tomosynthesis mammography in Siemens Mammomat Inspiration, image quality meets the quality requirements without exceeding the dose limits considered acceptable for each breast thickness measured.

Thus, we can say that the equipment provides an acceptable dose with appropriate image quality for diagnosis.

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