2017 International Nuclear Atlantic Conference - INAC 2017
Belo Horizonte, MG, Brazil, October 22-27, 2017
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR – ABEN

Agência Brasileira do ISBN
ISBN 978-85-99141-07-6

DEVELOPMENT OF BREAST PHANTOM FOR QUALITY ASSESSMENT OF MAMOGRAPHIC IMAGES

Jêniffer Miranda Arvelos[1], Mabel Bustos Flores[2], Fernando Amaral[1], Margarita Chevalier del Río[3] and Arnaldo Prata Mourão[1,2]

[1]Biomedical Engineering Center
Federal Center for Technological Education of Minas Gerais (CEFET-MG)
Av. Amazonas 5253, Nova Suíssa
30421-169 Belo Horizonte, MG
jenifferarvelos00@gmail.com

[2]Department of Nuclear Engineering
Federal University of Minas Gerais (UFMG)
Avenida Presidente Antônio Carlos, 6627, Pampulha
31270-900 Belo Horizonte, MG

[3]Departmento de Radiologia - Faculdad de Medicina
Universidad Complutense de Madrid (UCM)
Pza. Ramón y Cajal, s/n
28040 – Madrid

ABSTRACT

Diagnosis of breast cancer in young women may be impaired by the tissue composition of breast in this age group, as fibroglandular tissue is present in greater amount in young women and it has higher density than fibrous and fatty tissues which predominate in women older than 40 years old. The higher density of breast tissue makes it difficult to identify nodules in two-dimensional techniques, due to the overlapping of dense layers. Breast phantoms are used in evaluation and quality control of clinical images, and therefore, it is important to develop non-homogeneous phantoms that may better simulate a real breast. Grouped microcalcifications are often the earliest changes associated with malignant neoplasm of breast. In this work, a phantom was developed in the form of a compressed breast using acrylic resin blend. The resin blend used to fulfill the interior of the phantom has similar mammographic density to the one in fibroglandular tissue, representing a dense breast. The lesions were made of acrylic resin blend and calcium compounds that might simulate breast abnormalities, representing nodules, macrocalcifications and microcalcifications of different dimensions and densities. They were distributed into the material representing fibroglandular tissue. The developed phantom has a thickness of 1 cm, and it may be matched with other plates to represent a dense breast of thickness between 5 and 6 cm. The main goal of the project is to evaluate the sensitivity of detection of these calcifications in relation to their density and location in the breast in two-dimensional images generated in mammography equipment. Mammographic images allow the visualization of the changes implemented in the phantom. The developed phantom may be used in evaluation of diagnostic images generated through two-dimensional and three-dimensional images.

Keywords: Breast phantom, microcalcifications, mammography.

1. INTRODUCTION

Breast cancer is the second most frequent cancer in the world, representing the most frequently diagnosed cancer and the highest mortality rate among female population. In 2012, approximately 1.67 million new cases were diagnosed worldwide, accounting for 25% of cancer cases in female patients, with approximately 522,000 deaths [1].

According to the 2016 Cancer Incidence Estimate in Brazil, conducted by the National Cancer Institute José Alencar Gomes da Silva, 57,960 new cases of breast cancer were expected in the country [2]. Breast cancer can affect both females and males, however, males account for a much smaller proportion of the cases. Women, especially middle-aged women, are more frequently affected by breast cancer, therefore biennial mammography for females between the ages of 50 and 69 is the strategy recommended by the Brazilian Ministry of Health for breast cancer screening [2] in asymptomatic patients with normal risk of breast cancer. Two-dimensional mammography plays an important role in the early detection of breast cancer, however, in some cases it may be difficult to detect malignant lesions due to breast tissues overlapping. Mammography is considered to be the most effective technique for identification of breast cancer, however, it has limitations, like any method of imaging diagnosis.

Diagnosis of breast cancer in young women is impaired by the tissue composition of the breast in this age group, since fibroglandular tissue, which is present in greater quantity in the young woman breast, has higher density than the fibrous and fatty tissues that predominate in the breast of women over the age of 40. In mammography, the fatty tissue present in the breast appears in darker shades and the fibroglandular tissue appears in lighter shades, just like tumors and calcifications. This may compromise the early detection of breast cancer, considering that the fatty tissue allows a better visualization of alterations because they have different densities. In the mammography exam, a two-dimensional image is generated, containing superposition of tissue of various depths in the breast.

Another factor that influences the detection of lesions is the breast thickness, given that the thicker breasts generate greater overlapping and greater spread radiation. There are no statistical data related to the incidence of breast cancer in young women in Brazil, but according to a statistical study conducted in the United States, the number of women diagnosed with breast cancer aged between 20 and 45 years in 2014 represented a total of 10.5% of the cases [3].

Phantoms are used in the evaluation and quality control of clinical images, and therefore, there is need to develop non-homogeneous simulators that can better characterize the three-dimensional structure of the human breast. Mammographic images allow visualization of the changes implemented in the phantom. Therefore, the phantoms developed in this study were based in a compressed breast with potential to serve the ground truth for various studies including virtual clinical trials, dosimetry, and comparison of performance across manufacturers and 3D reconstruction techniques. The main goal of the project is the evaluation of the detection sensitivity of these calcifications in relation to their density and localization in the breast in two-dimensional images generated in mammography devices.

2. MATERIALS AND METHODS

2.1. Breast phantom development

The breast phantom developed was made using a widely available commercial autopolymerizing acrylic resin. The resin blend used to fill the interior of the simulating objects has mammographic density similar to the density of the fibroglandular tissue, therefore, the object is a dense breast representation. The developed phantom is a slab in the shape of a central horizontal cut of a compressed breast. The object is 10 cm wide, 18 cm length, and 1cm thick. The final form of the developed physical breast phantom is represented in Fig.1.

Figure 1: Breast phantom plate.

The interior of the plate breast phantom was filled with a blend of acrylic resin to represent mammographic density similar to that of the fibroglandular tissue, and just as in a human dense breast, the material filled most of the phantom. The breast tissue representation does not match the real tissue heterogeneity of a human breast.

Alterations made of acrylic resin blend and structures that could characterize breast anomalies were further included in the breast phantom. These alterations were distributed in the representative material of fibroglandular tissue, representing nodules, macrocalcifications and microcalcifications of different dimensions and densities. Spherical nodules are representative elements of commonly benign lesions, as irregular nodules are representative elements often associated with malignant changes. Grouped microcalcifications are often the earliest alterations associated with malignant neoplasm of the breast. The positioning of the alterations is described in the distribution map shown in the Figure 2.

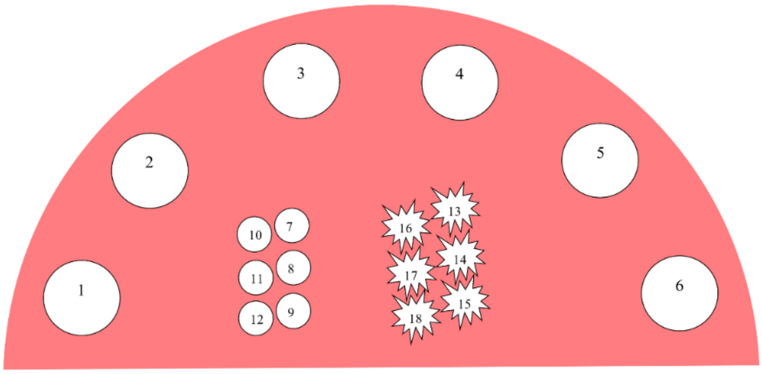

Figure 2: Distribution map of the representative breast lesions.

The simulated microcalcifications clusters were developed by calcium carbonate, resulting in small elements with a big amount of calcium. Each grouping contains about 15 to 30 granules of sizes defined by a range of values. Table 1 lists the size of each microcalcification grouping to its position on the map represented in Figure 1.

Table 1: Dimensions associated with the microcalcifications.

Microcalcifications	1	2	3	4	5	6
Size chart (μm)	106-150	150-177	177-300	300-420	420-590	>590

The nodules occupying positions 7 to 12 are spherical and rigid elements of different diameters made using an acrylic resin blend. Table 2 lists the dimensions of the spherical nodular lesions at their positions inside the phantom.

Table 2: Dimensions associated with the spherical nodules.

Spherical Nodules	7	8	9	10	11	12
Diameter (mm)	~8,5	~6,0	~4,5	~4,0	~3,0	~2,5

The nodules located in positions 13 to 18 are irregular and rigid elements of varied diameters also made using acrylic resin. Table 3 lists the irregular nodules dimensions at the positions defined in the alterations distribution map of Figure 2.

Table 3: Dimensions associated with the irregular nodules.

Irregular Nodules	13	14	15	16	17	18
Diameter (mm)	~16	~11,5	~7,75	~6	~5,5	~4

2.2. Assembly of the simulator object

The developed plate is associated with other polymethylmetacrylate (PMMA) to compose a compressed breast, with thicknesses of 1 and 2 cm. When combined with PMMA plates to represent a dense breast, the set may assume a thickness of 5 cm or 6 cm. To represent a 5 cm thick breast, the resin plate developed is placed between two PMMA plates with a thickness of 2 cm. For the representation of a 6 cm thick breast, the developed resin plate and a PMMA plate of thickness 1 cm are placed between two PMMA objects of 2 cm thickness. All plates used in the study are represented in the Figure 3(*a*). The assembly used in this study consisted of the association of the resin plate positioned between two identical PMMA plates of thickness 2 cm, resulting in the simulation of a compressed dense breast of thickness 5 cm. The final assembly is represented in Fig. 3(*b*).

a. ***b***.

Figure 3: Breast phantom. Plates (*a*) and assembled (*b*).

2.3. Image Acquisition and Validation of Breast Phantom

An image of the phantom was acquired on a Graph Mammo AF mammography device from the VMI brand. A target/filter of molybdenum-molybdenum combination filter was used to verify the properties of the materials used in the development of the phantom on typical beams of mammographic exams. A computed radiography (CR) plate of 18x24 cm, Regius model, was used for image generation. The acquisition parameters were 28 kV and 85 mAs. The image was obtained in DICOM format.

The image was visually evaluated to characterize the overall quality in representing the breast tissue density and common breast lesions, as well as identify artifacts of the building process. The generated image, represented in Figure 4, makes it possible to verify the positioning and mammographic densities of the elements that compose the phantom.

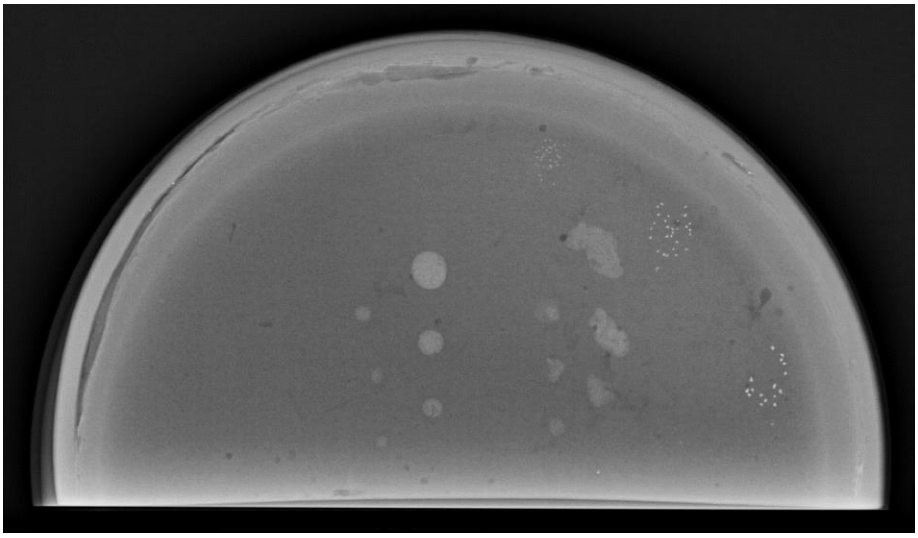

Figure 4: Breast phantom mammogram.

3. RESULTS

The developed breast phantom is shown in Fig. 1. Its shape is similar to a horizontal cut of a human compressed breast. The fibroglandular representative material as well as the various alterations included in the phantom are visualized in the mammogram presented in Fig. 4. Through Fig. 4 is possible to evaluate the characteristics of each alteration.

Figure 5 displays the mammographic appearance of the regular lesions. The spherical nodules observed in the generated image have well defined limits and mammographic density higher than the representative material of the fibroglandular tissue. These spherical elements, therefore, are a good representation of nodular lesions of usually identifiable benign characteristics.

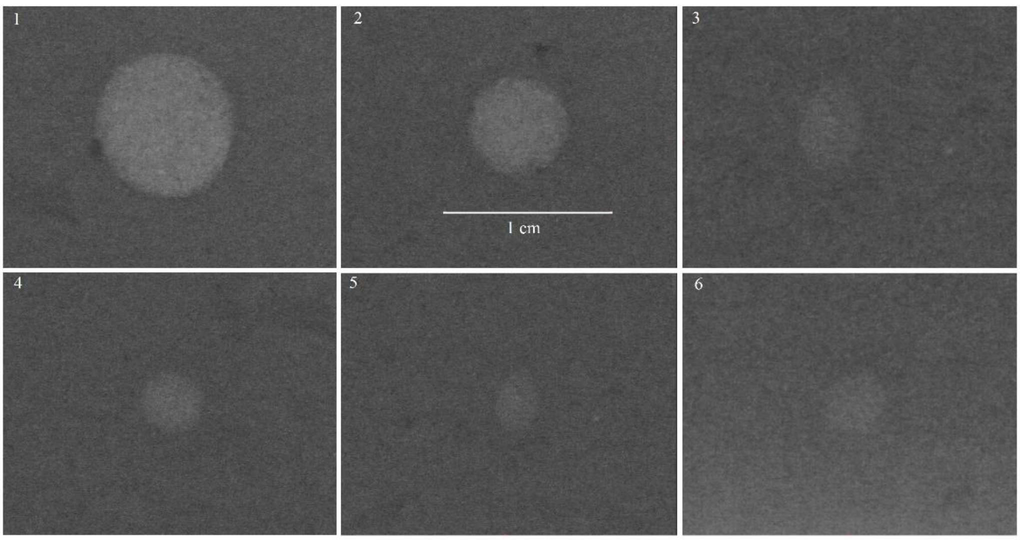

Figure 5: Regular nodules in mammographic image.

Figure 6 displays the mammographic appearance of the irregular lesions. The irregular nodules observed in the generated image have less defined limits when compared to the spherical nodules, and have mammographic density higher than the material used to fill the interior of the object. These irregular elements may be considered a good representation of malignant nodular lesions usually identified in the breast.

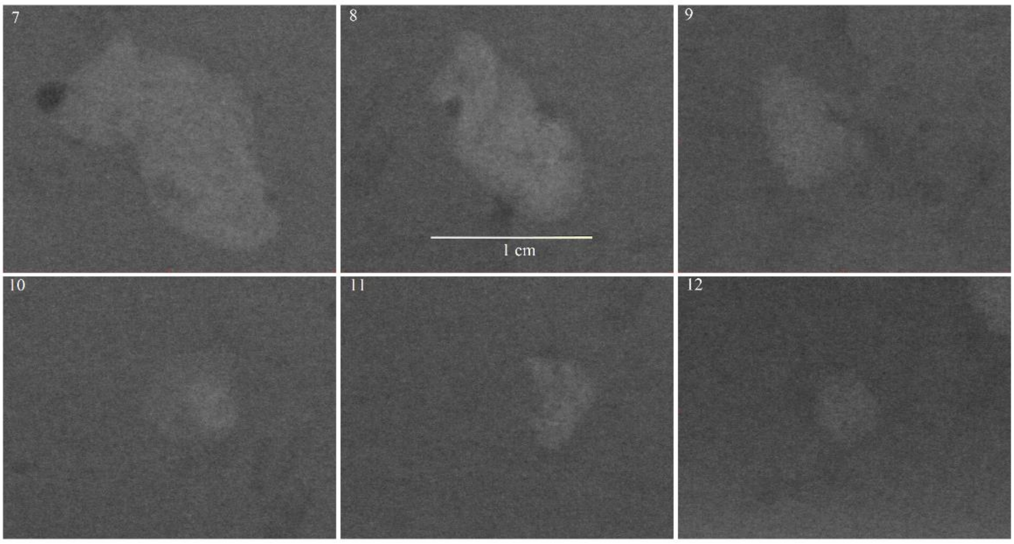

Figure 6: Irregular nodules in mammographic image.

Figure 7 displays the mammographic appearance of the microcalcification clusters. The microcalcifications groupings distributed in the resin plate are representations of changes that were previously identified as possibly malignant. Groupings 15, 16, 17, and 18 are distinguishable in the simulator object image. Groupings 14 and 13 cannot be identified in the generated image and are indistinguishable from the component material of the phantom. The groupings of microcalcifications identifiable in the image lend themselves to the diagnosis.

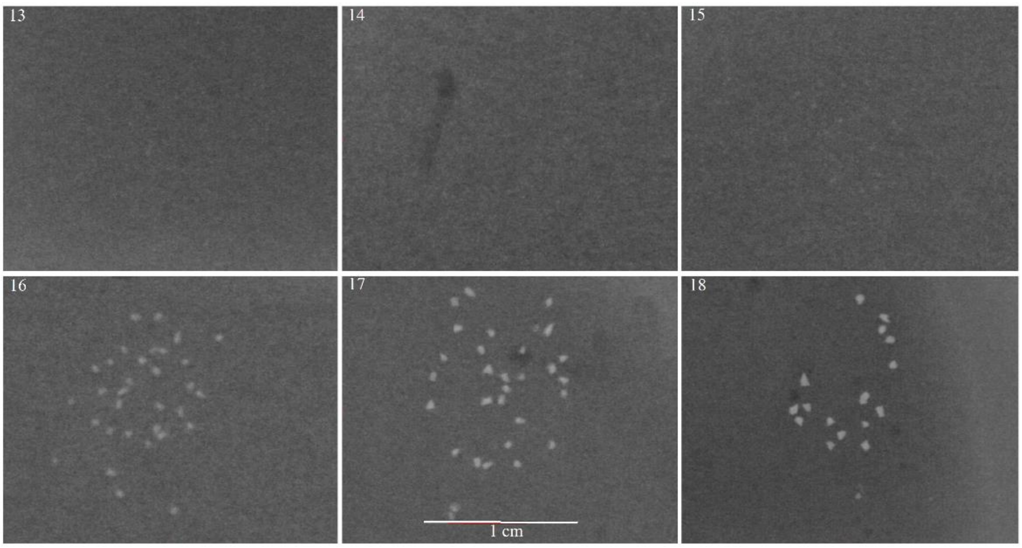

Figure 7: Microcalcifications clusters in mammographic image.

4. CONCLUSION

In this work a breast phantom was developed using acrylic resin blender and PMMA plates. The developed phantom may be used to evaluate diagnostic images generated through two-dimensional and three-dimensional techniques. The radiographic properties of the material used to fill the resin plate and to develop the alterations allowed to build a phantom that presents characteristics similar to a dense breast in which there are nodules and microcalcifications. Analyzing the general panorama of the image, we can see that it is not possible to distinguish microcalcifications with a diameter smaller than 177 μm by using computed mammography (CR). The other groups of microcalcifications are identifiable in the radiographic image, therefore, they lend themselves to the diagnosis. Through this image, it is possible to identify that the developed phantom exhibits some artifacts resulting from the appearance of bubbles generated in the filling of the resin plate used as a representative element of the fibroglandular breast tissue. However, the artifacts did not prevent the identification of the alterations, therefore, do not invalidate the method. It is important to point out that, we were gradually able to significantly reduce the appearance of these artifacts, as we improve the technique of make plate with resin blend.

ACKNOWLEDGMENTS

The authors would like to acknowledge the Foundation for Research Support of the State of Minas Gerais (FAPEMIG) and the National Council for Scientific and Technological Development (CNPq) for the support.

REFERENCES

1. Instituto Nacional de Câncer José Alencar Gomes da Silva, **"**Estimativa|2016: Incidência de câncer no Brasil", Rio de Janeiro: INCA, 2015.
2. Ferlay J, Soerjomataram I, Ervik M, Dikshit R, Eser S, Mathers C, Rebelo M, Parkin DM, Forman D, Bray, F. GLOBOCAN 2012 v1.1, Cancer Incidence and Mortality Worldwide: IARC CancerBase No. 11 [Internet]. Lyon, France: International Agency for Research on Cancer; 2014. Available from:http://globocan.iarc.fr, accessed on 02/04/2017.
3. Surveillance, Epidemiology, and End Results (SEER) Program. SEER*Stat Database: Incidence-SEER 18 Regs Research Data+Hurricane Katrina Impacted Louisiana Cases, Nov. 2012 Sub (2000-2010). Bethesda, MD: National Cancer Institute, Division of Cancer Control and Population Sciences, Surveillance Research Program, Surveillance Systems Branch; 2013. Released April 2013 based on the November 2012 submission.
4. Kiarashi, N., Nolte, A.C., Sturgeon, G.M., Segars, W.P., Ghate, S.V., Nolte, L.W., Samei, E., Lo, J.Y., "Development of realistic physical breast phantoms matched to virtual breast phantoms based on human subject data", *Medical physics*, **vol.42**, pp. 4116-4126 (2015)
5. R. G. Eduardo, A. K. Hilton, "Rastreamento do câncer de mama: aspectos relacionados ao médico", Radiologia Brasileira, vol.37 no.2, São Paulo Mar./Apr. 2004.
6. A.K. Carton, P. Bakic, C. Ullberg, H. Derand, "Maidment AD,Development of a physical 3D anthropomorphic breast phantom" , *Medical Physics.*,**vol.38(2)**, pp.891-6 (2011).
7. Nooshin Kiarashi, Adam C. Nolte, Gregory M. Sturgeon, William P. Segars, Sujata V. Ghate, Loren W. Nolte, Ehsan Samei, and Joseph Y. Lo**, "**Development of realistic physical breast phantoms matched to virtual breast phantoms based on human subject data", *Medical Physics*, **vol.42**, pp.4116 (2015).