BJRS

BRAZILIAN JOURNAL
OF
RADIATION SCIENCES
10-03B (2022) 01-08

Dosimetry in CR mammography using radiochromic film

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ABSTRACT

Radiochromic film and phantoms made of PMMA were used to estimate the dose that a patient's mammary tissue receives during mammographic screening. X-ray interacts with PMMA in a similar way with breast tissue. Measurement of dose deposited in the tissue is important to verify that the dose is within the recommended limits and hence to minimize the undesirable effects of radiation and as well as optimize the radiation dose that patients receive. This work aims to estimate the absorbed dose in the breast tissue when using CR technology for screening mammography. For the measurements were used PMMA plates as breast phantom and radiochromic film as dosimeter. The doses, on the upper, lower surface and between the plates of the phantom, were estimated from the film calibrations curve.

Keywords: **Dosimetry, mammography, CR technology, breast phantom.**

ISSN: 2319-0612
DOI: https://doi.org/10.15392/2319-0612.2022.2013
Submitted: 2022-02-13
Accepted: 2022-07-28

1. INTRODUCTION

Breast cancer affects mainly the female population and that rarely occurs in men. The estimate made by the *Instituto Nacional do Câncer* indicated the incidence of 66 thousand new cases for the year 2021 in Brazil [1]. In the world, the statistics of new cases exceeds 2 million for the year 2020, according to the International Agency for Research on Cancer [2].

The main tool for the diagnosis of breast cancer is the screening mammography. The mammography equipment with CR (Computed Radiography) technology is the most common in Brazil [3]. This imaging technique allows identification of tissue lesions, which, when identified at an early stage, increases the probability of the treatment being successful and less aggressive [1]. The principal limitations in the diagnosis with this radiographic technique are the reduced size of the lesions in the initial stage and the superposition of the tissues in the digital image [4].

The mammographic system must be periodically evaluated to ensure the optimization of the technique and the dose deposited in the tissues [5]. Dose evaluation is usually performed with breast phantoms made of PMMA (polymethylmethacrylate) that allow to recreate, with a certain degree of similarity, the interaction of the breast tissues with X-ray [6].

The radiochromic film Gafchromic XR QA2 offers a practical alternative to estimate the dose deposited in tissues, evaluating the degree of darkening of its sensitive surface when it is exposed to X-ray [7]. The use of radiochromic film is also common due to its several advantageous features for dosimetry and presents greater sensitivity for doses from 1 mGy to 200 mGy in the energy range from 20 kVp to 200 kVp [8].

The dose estimation can be performed from the calibration curve that correlates the response of the film (darkness degree) with the dose measured with an ionization chamber under the same exposure conditions [9].

The sensitivity of the radiochromic film allows its use in the energy range usually used in digital mammography [10, 11] and its thin structure allows the dose measurement between PMMA plates.

The objective of the present paper was to estimate the dose deposited in breast tissue, when screening mammography is performed with CR technology. PMMA plates were used as breast phantom, radiochromic film and an ionization chamber to estimate the dose due to exposure in a mammography equipment with CR technology.

2. MATERIALS AND METHODS

VMI Graph Mammo AF mammography equipment was used for dosimetry measurements. This equipment has a CR technology and a Mo/Mo target/filter combination.

Six individual plates of transparent PMMA with semicircular format were used as a breast phantom. Figure 1 shows the breast phantom diagram and the dimensions of the plates. In total, the six plates form the phantom of 50 mm thickness.

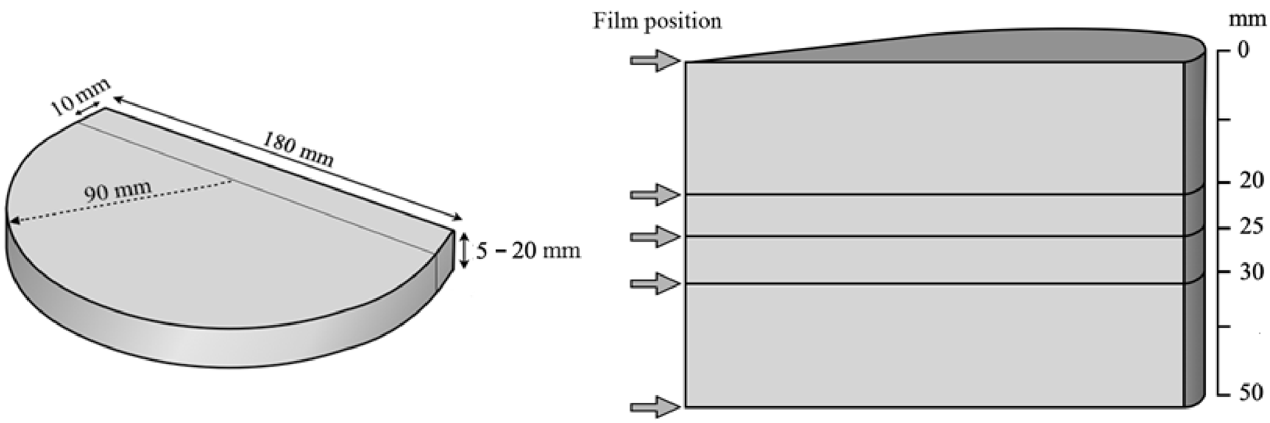

Figure 1: *Breast phantom: the dimensions of the individual plates (left) and the diagram of the 50 mm phantom (right), where the arrows indicate the position of the radiochromic films.*

For the dosimetry tests, strips of Gafchromic XR QA2 film were prepared. The first group of strips was exposed to known doses in the range of 0 to 58 mGy, with beams of RQR-M2 quality, which correspond at a voltage of 28kVp and a half value layer of 0.31mmAl. The known doses were measured with an ionization chamber, model 10X6-6M Accu -Gold+ manufactured by Radcal.

The second group of strips were successively positioned on the upper and lower surface of the phantom (to the thickness of 0 and 50 mm) and between its plates (to the thickness of 20, 25 and 30 mm of PMMA), and the mammography equipment was configured in manual mode to expose the films with the same X-ray beam quality.

All radiochromic film strips were digitized using a commercial scanner, 24 hours before and after exposure, to determine the background value and the darkening intensity, respectively. The scanner was configured to obtain 300 dpi images in RGB (Red Green Blue) mode. In the images, the channel that presents highest sensitivity is the red channel; the images filtered in this channel were processed with the ImageJ software. Figure 2 shows the processed images of the films used in the dosimetry tests.

Figure 2: *Processed images of the radiochromic film strips used with the breast* phantom.

Regions of interest (ROIs) of 10 mm^2 area were selected in the center of the images of each film strip to obtain the optical densities (OD) from the averages of the darkening intensities.

The optical densities values, of the films that were exposed at known doses, were correlated with the doses measured with the ionization chamber to determine the calibration curve. Finally, this curve was used to estimate the doses that correspond to the films positioned in the breast phantom.

3. RESULTS AND DISCUSSION

The calibration curve for radiochromic film that correlates the optical density with doses is shown in Figure 3.

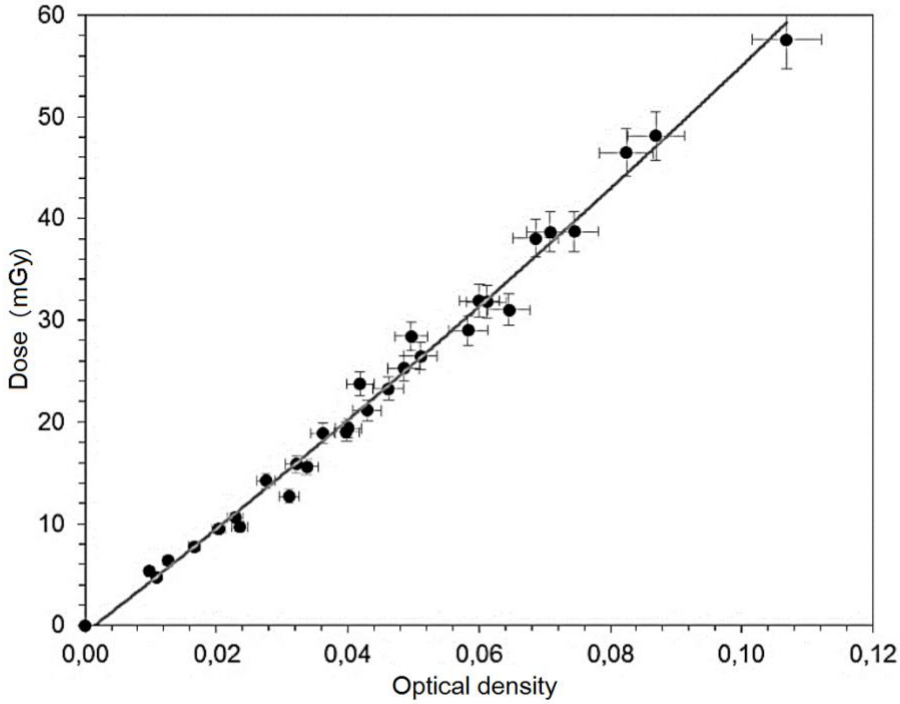

Figure 3: *Radiochromic film calibration curve with known doses from 0 to 58 mGy.*

Equation 1 describes the relationship between the dose and the optical density, where *D* is the dose, *OD* is the optical density, and the coefficients are *a*, *b* and *c*.

$$D = a + b.(OD)+c.(OD)^2 \quad (1)$$

Table 1: *Coefficients values that describe the calibration curve.*

Coefficient	**Value**
a	-0.72±0.80
b	499.81±34.75
c	575.90±334.92
Coeff. of correlation	0.9904

Using the calibration curve, dose values were estimated for each film positioned in the breast phantom. Table 2 shows these dose values.

Table 2: *Estimated dose values from the calibration curve.*

Film position (mm)	Dose (mGy)
0	10.5±0.1
20	3.5±0.2
25	2.8±0.2
30	1.5±0.4
50	<1

According to the estimated dose values for the breast phantom, the maximum dose was 10.5 mGy, which corresponds to the film positioned on the upper surface of the phantom, from that value the dose values for the other film positions decrease due to the attenuation of the intensity of X-ray caused by PMMA plates. At the average thickness of the breast phantom, the dose value was 2.8 mGy, and at the lower surface, the dose value is less than 1 mGy, which is outside the sensitivity range of the radiochromic film.

This dose values, for the upper and lower surfaces and in the middle of the breast phantom, can be compared with the skin entry dose of an equivalent breast 60 mm thick, the dose deposited in the glandular tissue and the dose at the exit of the breast, respectively. The intensity of the X-ray beam through the breast tissue will form the digital mammography image.

4. CONCLUSION

Due to the difficulty of performing dosimetry measurements directly in the breast tissue, dosimetry with radiochromic film and the use of breast phantoms are a practical alternative to estimate the dose that a patient receives during a screening mammography.

The dose values presented in this paper are below the recommended limits for this imaging technique and can also be used for the quality control of mammography equipment, seeking to optimize the dose.

ACKNOWLEDGMENT

Thanks to the *Fundação de Amparo a Pesquisa do Estado de Minas Gerais* for the support to carry out this research.

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