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Intensity variation study of the radiation field in a mammographic system using thermoluminescent dosimeters TLD-900 ($CaSO_4$:Dy)

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HIGHLIGHTS

- TLD calibration in mammography energy range.
- Determination of the TLDs calibration and variation coefficients.
- Radiation field mapping of a mammography X-ray system.

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ABSTRACT

This study presents the results of the intensity variation of the radiation field in a mammographic system using the thermoluminescent dosimeter TLD-900 ($CaSO_4$:Dy). These TLDs were calibrated and characterized in an industrial X-ray system used for instruments calibration, in the energy range used in mammography. They were distributed in a matrix of 19 lines and five columns, covering an area of 18 cm × 8 cm in the center of the radiation field on the clinical equipment. The results showed a variation of the intensity probably explained by the non-uniformity of the field due to the heel effect.

1. Introduction

Mammography is the gold standard method, which allows premature breast cancer detection, by the fact that it is able to show very small injuries in an initial stage (INCA, 2010). Mammography's role as the most important tool for the early detection of breast cancer has become more universally accepted (Pisano et al., 2004). However, in order to produce images with high resolution it is necessary that the mammography X-ray system be calibrated.

For this reason, a good quality control of these equipments is very important, especially in terms of the radiation dose generated by them. This control must be done using an ionizing chamber, specific for mammography, which also must be calibrated.

In Brazil, there are just a few laboratories which have mammography qualities established in their systems. One of these laboratories is the Laboratório de Calibração de Instrumentos (LCI) of IPEN, which calibrated about 40 mammography ionizing chambers in the period 2009–2010.

In this laboratory the system that is used to calibrate these chambers is an industrial X-Ray equipment, which is provided with a tungsten (W) target. The X-ray mammography qualities were established according to the new international standard IEC 61267 (IEC, 2005) and the International Atomic Energy Agency (IAEA) code of practice, Technical Report Series no. 457 (IAEA, 2007).

In order to obtain an energy range closer to that used in medical procedures and considering that this system does not have a molybdenum target, it became necessary to establish the mammography qualities in one clinical equipment. To know the radiation beam intensity variation caused by the heel effect, it was made a radiation field mapping using the TLDs.

2. Materials and methods

The radiation field mapping was made in a clinical mammography system Philips VMI Graph Mammo AF, which has a

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Fig. 1. Mammography system Philips VMI Graph Mammo AF.

molybdenum target and additional filtration of molybdenum and rhodium (Fig. 1).

The radiation field variation study was made using thermoluminescent dosimeters TLD-900 ($CaSO_4$:Dy). These dosimeters were calibrated in an industrial system Pantak/Seifert, which has a tungsten target and the mammography calibration qualities established on it, with an additional filtration of molybdenum.

Three hundred $CaSO_4$ pellets were irradiated in the industrial system in the calibration laboratory at the Instituto de Pesquisas Energéticas e Nucleares (IPEN), on the mammography reference calibration energy, 28 kV, for the repeatability test. From these, 22 were selected and divided into two groups: in the first group were 10 pellets, with the variation coefficient of (2.39 ± 0.09) % and calibration coefficient varying from 0.00182 mGy/nC to 0.00205 mGy/nC. In the second group were 12 pellets, with a variation coefficient of (3.42 ± 0.11) % and calibration coefficient varying from 0.00180 mGy/nC to 0.00203 mGy/nC.

These two groups were used to determine the TLDs energy dependence. For this, both of them were irradiated in the other mammography radiation qualities (25 kV, 30 kV and 35 kV). The charge, in nC, collected by each pellet was converted into dose, in mGy, and the results were normalized for 28 kV.

After the TLDs characterization, 95 pellets that presented variation coefficient less than 3.3% were selected in order to make the mammography radiation field mapping. The maximum variation adopted in this study was based in earlier studies with $CaSO_4$ (Nunes, 2008; Bravim, 2010).

The TLDs were disposed in a 5×19 matrix. The distance between the pellets was of 2 cm in the width and 1 cm in the length. The distance of 1 cm was used to make the verification of small intensities variation possible. The distribution matrix is shown in Fig. 2.

The number zero in the bottom of Fig. 2 indicates the center of the breast support. The variation of the radiation field intensity was made from −4 cm to 4 cm, from left to right, according to Fig. 2. The region studied was the center of the support and the regions near it.

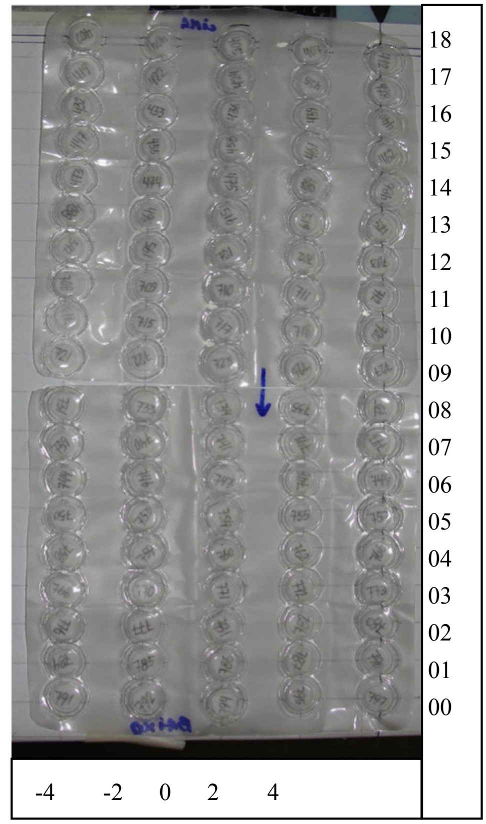

Fig. 2. TLDs distribution matrix used in the mammography system mapping.

The numbers on the right of Fig. 2 indicate the distance, in cm, from the breast support edge, where the number zero indicates the closest position to the patient chest wall.

This procedure was repeated thrice. The mean measurement for each pellet was taken and multiplied by the calibration coefficient to obtain the accumulated dose, in mGy.

3. Results

The results show a clear variation of the radiation beam intensity along the breast support, as shown in Fig. 3.

This variation was expected in a mammography system, due to the heel effect. In order to facilitate this distribution analysis the values in the graph above were divided in three groups: the first group covers the dose variation between 0 cm and 2 cm. The second group goes from 3 cm to 8 cm, and the third from 9 cm to 18 cm. The accumulated dose and variation obtained for each group is shown in Table 1.

It is possible to notice that there is a great variation in the radiation intensity (more than 16%) in the edge of the breast support. This is an important characteristic to protect the patient. The system collimator prevents the radiation to reach patient beyond the chest wall.

The second group showed the lowest variation (around 0.9%). According to Brazilian and International recommendations the mammography ionizing chamber, in a quality control test, must be placed 6 cm away from the breast support edge. Considering the chamber diameter of 4.38 cm, when it is placed at this distance it will take the region in which the radiation field is most homogeneous.

In the third group the dose decreases gradually. This variation can be seen clearly in Fig. 4.

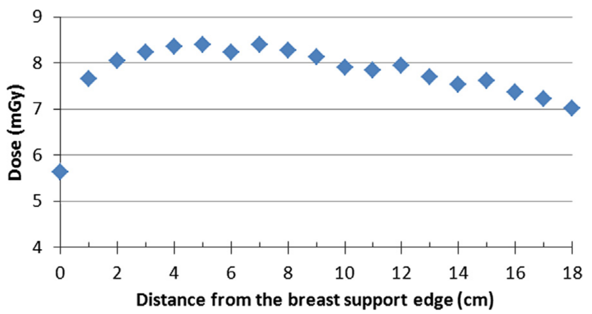

Fig. 3. Variation of the radiation intensity along the breast support. At distance zero the attenuation caused by the beam collimation reduces the patient's chest wall dose.

Table 1
Dose range obtained in the center of the breast support.

Group	Distance (cm)	Accumulated dose (mGy)	Standard variation (mGy)	Percentual variation (%)
1	0–3	7.38	1.20	16.23
2	3–8	8.31	0.08	0.92
3	8–18	7.68	0.38	4.97

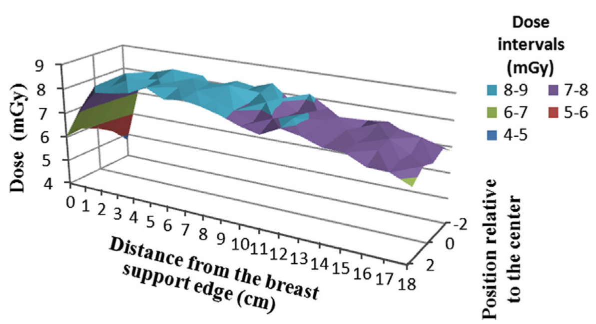

Fig. 4. Variation of the radiation intensity along the breast support in a surface graph.

It is possible to observe the behavior of the radiation field intensity not only in the length but also in the width. A lower dose was detected in the position (0,–2) than in position (0,2). Furthermore, it is easier to notice that the dose, along the length, increases in the first region (from 0 cm to 3 cm); in the second region (from 3 cm to 8 cm) maintains almost homogenous and gradually decreases in the third region (from 8 cm to 18 cm).

The results show how important it is to know very well the behavior of the radiation field in a calibration system.

4. Conclusions

Out of the 300 TLDs tested only 95 presented an appropriate accuracy response to be used to map the mammography system radiation field. A further investigation showed that lot of these TLDs were old and have already been used in other tests. The values of the calibration and variation coefficients of these pellets were not good enough to be used in this test.

The mapping result showed not only a variation in the radiation field in the length, caused by the heel effect, but also a variation in the field width. This does not affect the dose evaluation considering the geometry used in this measurement obtainment. A further study should be done to verify if this intensity variation could be responsible for losses in detecting small structures in the image.

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