Intensity Variation Study of the Radiation Field in a Mammographic System Using Termoluminescent Dosemeters

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Abstract
This study presents the results of the intensity variation of the radiation field in a mammographic system using termoluminescent dosemeter (TLD 900). These TLDs were calibrated and characterized in an industrial X-ray system used for instruments calibration, in the energy range used in mammography. These TLDs were distributed in a matrix of nineteen lines and five columns, covering an area of 18 cm x 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.

Keywords: Mammography, Radiation Field Mapping, Quality Control, TL Dosemetry

1. Introduction

Mammography is the breast radiography, which allows premature breast cancer detection, by the fact that it is capable to show very small injuries in an initial stage[1]. However, in order to obtain a good image 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 generated by them. This control must be done using a special ionizing chamber, specific for mammography, which also must be calibrated.

In Brazil, there are just a few laboratories have mammography qualities established in their systems. One of these laboratories is the Calibration Laboratory of IPEN (LCI), which calibrated about 40 mammography ionizing chambers in the period of 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 [2] and the International Atomic Energy Agency (IAEA) code of practice, Technical Report Series No. 457 [3].

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

Figure 1. Mammography system Philips VMI Graph Mammo AF

The radiation field variation study was made using termoluminescent dosemeters (TLD 900). These dosemeters 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 $CaSO_4$ rods were irradiated in the industrial system, 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 rods, with the variation coefficient of (2.39 $\pm$ 0.09) % and calibration coefficient varying from 0.00182 mGy/nC to 0.00205 mGy/nC. In the second group were 12 rods, with a variation coefficient of (3.42 $\pm$ 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 rod was converted into dose, in mGy, and the results were normalized for 28 kV.

After the TLDs characterization, it were selected the 95 rods that presented variation coefficient less than 3.3 % to make the mammography radiation field mapping.

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

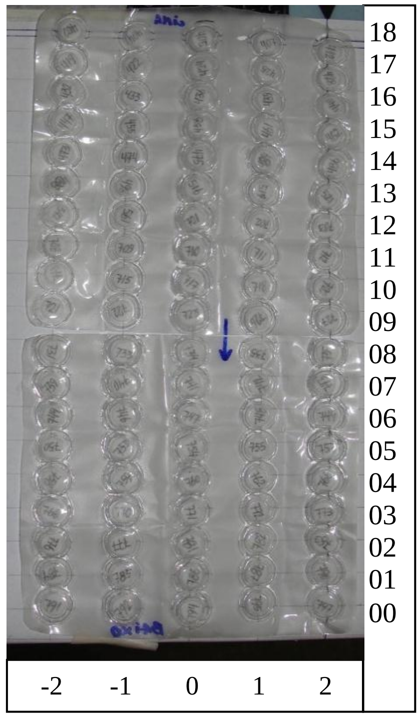

Figure 2. TLDs distribution matrix used in the mammography system mapping.

The number zero in the bottom of the figure 2 indicates the center of the breast support. The variation of the radiation field intensity was made from -4 cm to 4 cm (the distance between the columns is 2 cm), from the left to the right, according to the figure above. The region studied was narrow because there were not enough TLD rods to cover the entire breast support surface and it was decided to study the center of the support and the regions near to it.

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

This procedure was made three times. The mean measurement for each rod 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 figure 3.

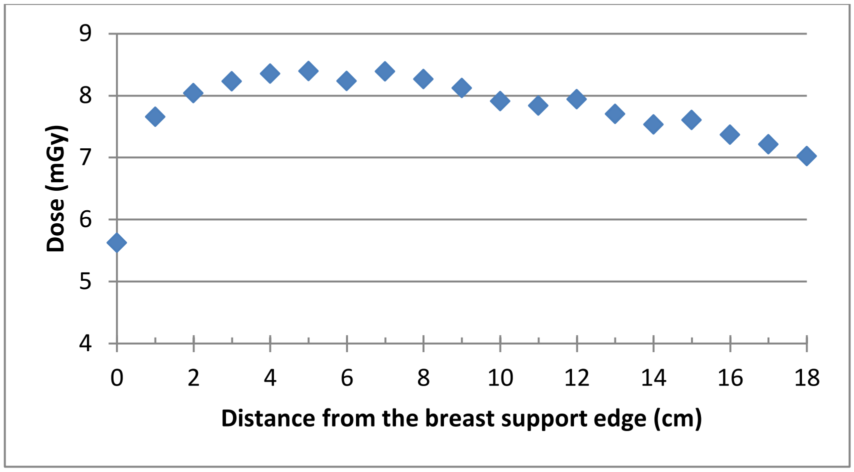

Figure 3. Variation of the radiation intensity along the breast support. In the distance zero the attenuation caused by the beam collimation reduces the patient chest dose.

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.

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

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

The second group showed the lowest variation (around 0.9 %). According to brazilian and international recommendation the mammography ionizing chamber, in a quality control test, must be placed 6 cm away from the breast support edge. Considering that this chamber has around 4.38 cm diameter, 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 figure 4.

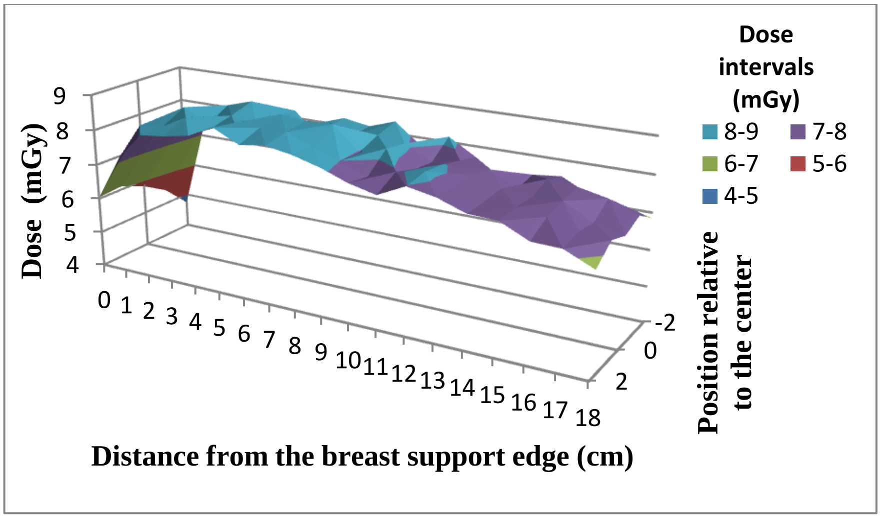

Figure 4. Variation of the radiation intensity along the breast support in a surface graph. It is possible to observe a variation not only in terms of the length but also in terms of the width.

It is possible to observe the behavior of the radiation field intensity not only in the length but also in the width. It was detected a lower dose 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) maintain almost homogenous and gradually decreases in the third region (from 8 cm to 18 cm).

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

4. Conclusions

From the 300 TLDs tested only 95 presented an appropriate behavior to be used to mapping the mammography system radiation field. These TLDs were calibrated in the mammography qualities in an industrial system that is used to calibrate ionizing chambers.

The mapping result showed not only a variation in the radiation field in the length, caused by the heel effect, but also in the width. A further investigation in this case may not be so important, since this variation was detected only in the region where the ionizing chamber will not be placed. Although, if this system were used in medical procedures, this variation could cause a considerable difference in the patient image, so a correction for this would be necessary.

After this study, the calibrated TLDs will be used in patient dose tests in mammography procedures.

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