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Quality control of the breast ca treatments on HDR brachytherapy with TLD-100

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An anthropomorphic Phantom, a female trunk, was built with a natural bone structure and experimental material coated, glycerin and water-based material called JJT to build soft tissue equivalent to the muscle of human tissue, and a polymer (styrofoam) to build the lung as critical organ to simulate the treatment of breast cancer, with high dose rate brachytherapy (HDR) and sources of Ir-192. The treatments were planned and calculated for the critical organ: Lung, and injury of 2 cm in diameter in breast with MicroSelectron HDR system and the software Plato Brachytherapy V 14.1 of the Nucletron (Netherlands) which uses the standard protocol of radiotherapy for brachytherapy treatments. The dose experimentally measured with dosimeters TLD-100 LIF: Mg; Ti, which were previously calibrated, were placed in the same positions and bodies mentioned above, with less than 5% uncertainty. The reading dosimeters was carried out in a Harshaw TLD 4500.The results obtained for calculated treatments, using the standard simulator, and the experimental with TLD-100, show a high concordance, as they are on average a ± 1.1% making process becomes in a quality control of this type of treatments.

Keywords: TLD-100; anthropomorphic phantom; brachytherapy HDR; breast.

PACS: 87.53. Jw; 87.66.Xa; 87.66.Sq

1. Introduction

In the use of ionizing radiation in medicine, (radiotherapy, diagnostic radiology, nuclear medicine), is indispensable knowledge of the absorbed dose given to the patient and their determination should be very rigorous, so the International Commission of Radiological Units (ICRU) in its report 59 [2, 5] recommends an accuracy of $\pm 5\%$ in the administration of the absorbed dose in the target volume if the main objective is the elimination of the primary tumor with the least possible damage to nearby healthy tissue, as is the radiation therapy. It is necessary to know the physical characteristics of the sources of ionizing radiation used in certain treatments, with which defines the conditions for using certain dosimetry system [3]. In this work, of interstitial brachytherapy, thermoluminescent dosimeters TLD-100 were used for presenting the following features: rods shape, size of 1.1 mm diameter and 6 mm in length, high precision, good environmental stability and human tissue equivalence, a wide sensitivity range good spatial resolution [1], which is vital for this type of dosimetry given the appearance of high-dose gradients in the implementation of treatments of high-dose brachytherapy in breast tumors. The objective of this work is to build an anthropomorphic phantom that allows ensuring the quality of the interstitial breast treatments, *i.e.*, control and estimation of the dose prescribed, using high dose rate and detectors TLD-100. The paper is organized as follows. In Sec. 2 and in the subsections therein, the general methodology is presented. The construction of the anthropomorphic phantom, based on the natural bone structure and material JJT, also present the planning of the treatments. The calibrations of the dosimeters (TLD-100) are presented in Sec. 3, with emphasis on the Co- 60. Results and discussion are presented in Sec. 4. The conclusions are presented in section Sec. 5.

2. Methodology

Build an anthropomorphic phantom, requires that the material used is equivalent, biologically, to human muscle tissue, in our case the Simulator was built using a natural bone structure corresponding to the chest of a 42-year-old woman, average age of patients treated at the Instituto Nacional de Cancerología (INC), Colombia. The phantom is shown in Figs. 1 and 2.

2.1. Construction of the anthropomorphic phantom

The experimental material, used in construction breast and lining of the chest is according to the specifications of the ICRU 44. [5], constituent elements of our anthropological

FIGURE 1. Natural bony structure of the torax used in the construction of the antropomorphic phantom.

FIGURE 2. Antropological phantom with the respective breast implant for the treatment of high dose rate.

phantom as shown in Fig. 2 , was subjected to a physical, chemical, and radiological analysis by J. Vásquez *et al*. [4], whose results show that JJT material is suited to be used as replacement tissue and the construction of anthropological phantom.

2.2. Calibration of TLD- 100 Crystals with the energy of Co-60

With the energy of Co 60, the crystals were irradiated with a dose of 50 cGy in a Theratron 780, using a field of reference of size 10×10 cm^2, and sensitizing with five irradiations, without performing readings interspersed with an anneling from 1 hour to 400°C followed by two hours at 100°C, at intervals of 12 hours irradiation [6]. To carry out this heat treatment was used oven Lindberg/Blue UP150. In order to calculate the dose is proceeded according to:

$$D = MN_{\text{cal}}K_{\text{chip}}K_{\text{lin}}K_{\text{SSD}}K_{\text{field}} \qquad (1)$$

where D is the dose read on the crystals, M is the reading in coulomb (C) of the crystals. This process was held with the

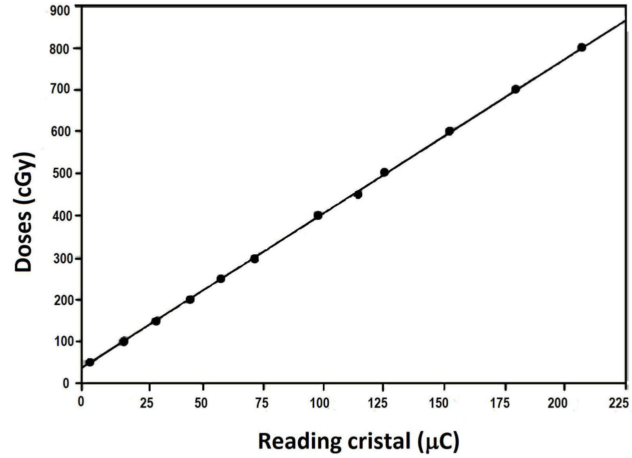

FIGURE 3. Calibration of TLD-100 with Co 60(average energy 1.25 MeV).

reader Harshaw TLD 4500, manufactured by Bicron using for this purpose the planchet heating equipment. During the process a preheat temperature of 50°C was used, from which the data acquisition is performed, at a rate of 10°Cs until reaching a maximum temperature of 300°C, followed by annealing at 300°C . To eliminate the contribution due to infrared heating and reducing the effects of moisture during the process, all readings were carried out on a atmosphere of high purity N_2. N_{cal} is the conversion factor for units of Coulomb (C) in dose units (Gy); K_{chip} is the ratio between the average reading of crystals and individual reading of each crystal, K_{lin} is the correction factor for the nonlinear response of the Crystal with the dose, K_{SSD} is the correction factor due to the distance source -surface; K_{field} is the correction factor due to the size of the field. Calculated performance shows a high correlation with that used in the calculation Prowess of the Instituto Nacional de Cancerología (INC) program and the calculated time to deposit the dose of 50 cGy was 0.59 minutes the date of calibration. The next process was radiate, with specific dosage, groups of 4 crystals, obtaining an average reading for each group of crystals. The Fig. 3 shows the curve obtained according to the readings of the TL signals of the crystals, with a squared correlation coefficient r^2 = 0.999 and given by the equation:

$$D_L = 34\,\text{cGy} + 3.7\frac{\text{cGy}}{\mu C}L(\mu C). \qquad (2)$$

Where D_L is the calculated dose and L is the reading of the Crystal.

2.3. Calibration of the TLD with the energy of Ir - 192 (0.38 MeV)

Connected a 6F endobronchial catheter to the HDR unit so that through it the source Ir-192 will be moved and thus to determine their point of positioning which was verified with an X-ray image. The crystals were placed in groups of four with a buildup of 2 mm material thickness JJT, on the transverse axis of the source at a distance of 10 cm [7]. Supplied

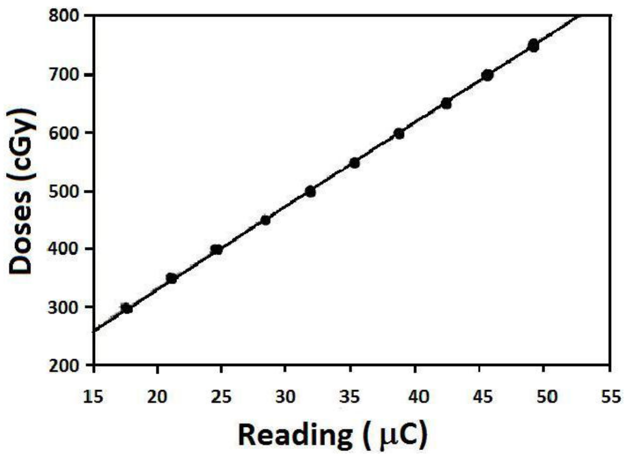

FIGURE 4. Calibration of TLD-100 with Ir 192 (average energy 0.38 MeV).

doses varied in the range of 300 to 750 cGy, obtaining the curve shown in Fig. 4, with a quadratic correlation coefficient r^2 = 0.998 and equation given by:

$$D_L = 44.2\,\text{cGy} + 14.4\frac{\text{cGy}}{\mu C}L(\mu C). \qquad (3)$$

Where D_L is the calculated dose and L is the reading of the crystal.

2.4. Treatments Planning

It was implanted in the anthropomorphic phantom the system consisting of two external fixing strips of 80 mm in length and 3.5 mm thick, each one, and twelve needles vector of stainless steel 120 mm in length, as shown in Fig. 2. Is verified the correct location of the implant using fluoroscopy. Catheters were introduced with fictitious sources in the prescription points, located between the two central needles and 5 mm deep level below it in order to determine the placement points of the crystals where the dose is measured, as shown of red color in Fig. 5.

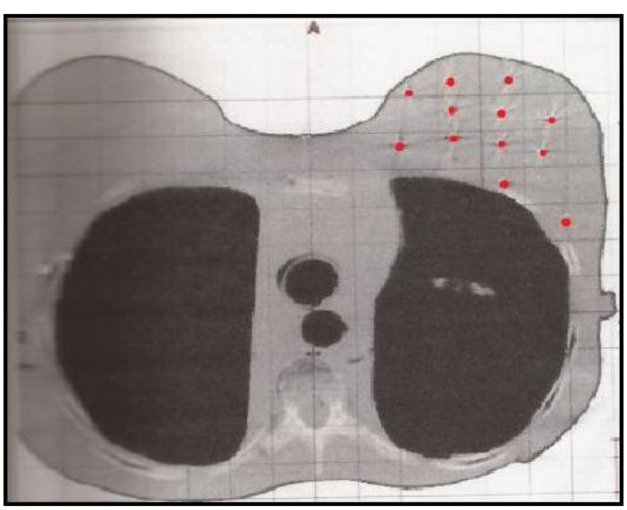

FIGURE 5. Computed axial tomography used for the location of the crystals in the anthropomorphic phantom.

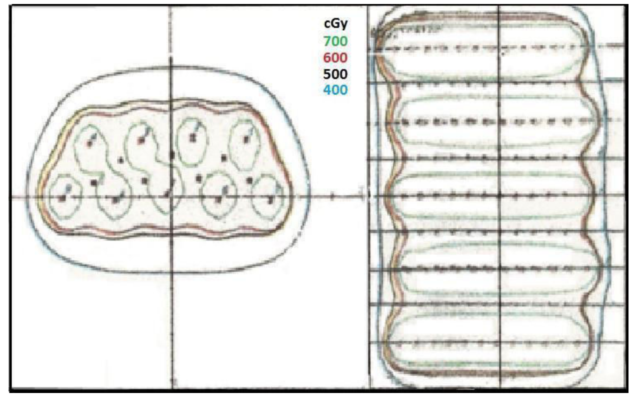

FIGURE 6. Isodose curves for interstitial breast treatments with nine needles for vector doses between 400 to 700 cGy

Treatments made planning for a range of doses between 400-700 cGy, for a tumor volume 5.56 cm^3 and taking into account the spatial coordinates of each of the needles, so calculate with the planning system, Plato Brachytherapy [8], the isodose curves which are shown in Fig 6.

3. Results and discussions

Figure 4 which represents the calibration of the TL crystals with source Ir - 192 shows that the crystals have a linear behavior in the dose range of 300-750 cGy, Which is in good agreement with the works done by S.W.S McKeever *et al* and J.L Muñiz [12, 13], the background radiation present may be related to factors such as high relative humidity (70%) and room temperature (30°C), where the calibration was done. The validation of the method used in the earlier results was made with a group of dosimeters whose values are shown in Table I, where D_{system} is the calculated dose with the planning system Plato Brachytherapy. According to Table I the maximum difference between the measured dose with the TLD-100 and the calculated dose with the planning system is

TABLE I. Validation of the method of calibration of dosimeters TLD-100 with Ir-192.

D_{system}(cGy)	D_L(cGy)	$\frac{D_L}{D_{\text{system}}}$
300	296.9	0.986
350	345.5	0.987
400	396.6	0.991
450	444.5	0.987
500	491.4	0.987
550	542.9	0.992
600	595.8	0.993
650	645.5	0.99
700	692.0	0.988
750	745.1	0.993

TABLE II. Comparison of the calculated dose with the planning system and measures with TLD - 100 in the treatment of breast.

D_{system}(cGy)	D_{TLD}(cGy)	$\frac{D_{TLD}}{D_{\text{system}}}$
700	673	0.961
650	637	0.980
600	584	0.973
500	487	0.974
400	393	0.982

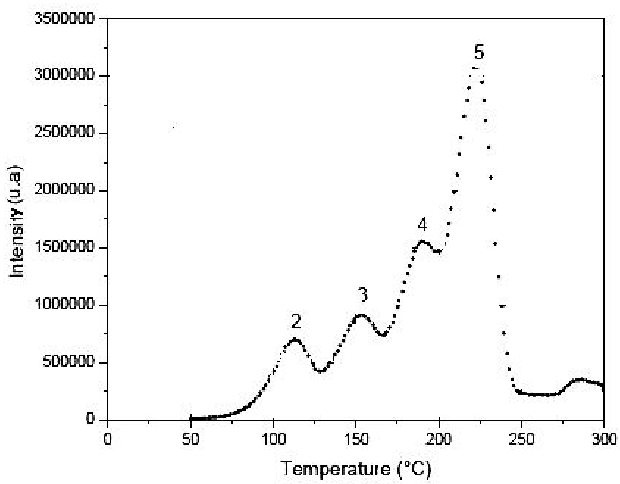

FIGURE 7. Glow Curve of TLD - 100 at a heating rate of 1°C/s between 50 and 300°C

1.4 %, results that are within the range of validity for this type of procedure [9].

The Table II compares the calculated doses with the planning system and the measures with the TLD -100 in the treatments prescribed breast between the center two needles of the deep level and 5 mm below the same. Table II shows that the maximum difference between the dose measurement with the TLD - 100 and calculated by the planning system differs by 4%, which is consistent with the expressed in the ARCAL XXX for this type of treatment [9].

As the dosimeters were reused, it was observed that its sensitivity varied, this is due to surface effects, since it can be given several mechanisms affecting TL sensitivity. The most important are the changes in light transmission due to contamination, scratches and gaseous absorption can also alter the intrinsic efficiency or lead to no radiation-induced signals. Another possible cause may be largely the spatial distribution of the concentration of traps. As defects are dependent on the level of impurities in parts per million and, to a lesser extent, on their heating and thermal history, it is very difficult to set the properties of a TL material. This leads to batch effects. For optimum precision calibrations must be performed for each individual dosimeter. [1, 10]. Dosimeters irradiated permanently keep all information provided, resulting in a gradual loss of dormant thermoluminescence signal. This should be corrected prior to the assessment being adopted heat treatments.

Figure 7 shows the glow curve of one of TLD - 100 (LiF: Mg, Ti) used, the reading was made at a heating rate of 1°C/s, in the temperature interval [50-300]°C. To observe a better definition of the peaks of the crystal was done a simplified analysis with the WinREMS program which is able to solve a complex curve of thermoluminescence and adjust the experimental points using the kinetic theory of first order [13] the result of this analysis is the clearly defined the peaks 2, 3, 4 and 5.

The use of pre- irradiation annealing to eliminate almost completely the picks 2 and 3, significantly increases the peaks 4 and 5, therefore, to eliminates post- irradiation fading in TLD -100. The correlation between peaks 2, 3 and peak 5 led Cameron *et al* [1]to suggest that peaks 2 and 3 are associated with (Mg^{2+}) dipoles while suggesting that peak 5 is a higher order cluster of three dipoles (trimer). More recently, it has been suggested that the trimer is spatially correlated with (Ti^{+3}) ions to form an even larger trapping-recombination complex [14].

4. Conclusions

In this work of quality control of the treatments of breast Ca with HDR dosimetry using TLD - 100 were simulated ten cases for prescribed dose. The results of the dose measures show great similarity with to those calculated with the planning system Plato BRACHYTHERAPY V. 14.1 because they present a maximum difference of 4% , which makes it a good quality control system for treatments of HDR interstitial brachytherapy which allows us to affirm that the prescribed doses are given correctly to the patients and do not exceed the dose of tolerance for breast [9, 11]. The calibration curve of crystals in material JJT, with the average energy of the Ir - 192, with a buildup of 2 mm and distance source crystal 10 cm, show good results to determine the dose in the range of 0 to 1000 cGy, implying that the dosimetry technique is effective provided that thermal processes for this type of dosimetry are followed [9].

Acknowledgments

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