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Characterization of the anisotropy function of a new 125I brachytherapy source using thermoluminescent dosimetry

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1. Introduction

Cancer is the disordered increase of cells that take over organs and tissues. When dividing, these cells tend to be uncontrollable and aggressive, so much so that they become tumors, which spread to all regions of the body [1]. In Brazil, prostate cancer is the most common among the male population, occurring mainly in men over 65 years of age.

Cancer treatment involves several techniques, including brachytherapy, which is a technique that allows a more localized dose of the disease, presenting excellent efficiency in relation to teletherapy, as it minimizes the dose received to other tissues and organs as much as possible. neighbors. In brachytherapy, the source is positioned within or close to the cancerous organ and, as an advantage, the effects are concentrated in the areas affected by cancer, in order to minimize the effects on healthy organs.

Sealed radioactive sources of 125I, in the form of seeds, are inserted into the organ with the help of a thin needle that is inserted into the cancerous organ. The radionuclide is used directly in prostate cancer, due to its favorable characteristics for use in brachytherapy. To reduce the price and allow this treatment to reach more patients, IPEN/CNEN is developing sealed sources of 125I. The seed consists of a titanium capsule with an external diameter of 0.8 mm, a wall thickness of 0.05 mm and a length of 4.5 mm. The inner part of the seed contains a silver wire of 0.5 mm in diameter and 3 mm in length, where 125I is adsorved as observed in Fig. 1 [2].

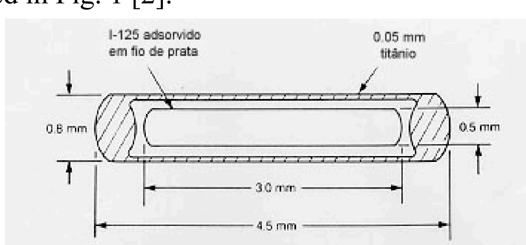

Figure 1: National prototype of the iodine-125 seed produced by IPEN/CNEN.

The objective of this work is to carry out part of the dosimetric characterization of the 125I seed in accordance with the guidelines presented in the interstitial dosimetry protocol Task Group 43 known as TG-43 of the AAPM [3], which provides detailed theoretical and practical recommendations on how to perform calculations dosimeters in water or equivalent material in brachytherapy.

In order to compare the experimentally obtained values of the anisotropy function with the already commercialized seed, the OncoSeed 6711 seed from the company Amersham (GE Healthcare), it has a geometry similar to that being made by IPEN. These seeds are used, or intended to be used, in permanent implant treatments for prostate cancer.

2. Methodology

The experimental practice was based on the collection of experimental measurements to calculate the parameters of the TG - 43 protocol. Thermoluminescent dosimeters (TLDs) which by definition are detectors, in which the radiation dose is calculated through the intensity of light emitted. The crystals used in this work were TLD-100 chips with dimensions of 3.2 x 3.2 x 0.89 mm^3. The thermoluminescence spectra of these crystals were recorded using the Harshaw TLD 3500 reader [4]. To measure the parameters contained in the formalism for calculating the dose rate for 125I seeds expressed by Eq. 1, the selected and calibrated dosimeters were used.

$$\dot{D}(r,\theta) = S_K \cdot \Lambda \cdot \frac{G_L(r,\theta)}{G_L(r_0,\theta_0)} \bullet g_L(r) \cdot F(r,\theta) \qquad (1)$$

The parameters of Eq. 1 were experimentally evaluated to determine the anisotropy function of the 125I seed manufactured at IPEN/CNEN.

The polar coordinate system is spare space used by the TG-43, where r and θ represent the polar coordinates at the point of interest in relation to the origin, located at the geometric center of the source. The point of interest P(r,θ) can be evaluated at any value of the radius, and must have a cylindrical geometry in relation to the longitudinal axis of the seed. The reference point $P(r_0,\theta_0)$, is defined as r_0= 1 cm and θ_0= 90°.

SK (Air Kerma) is the measurement of the intensity of a source applied in brachytherapy, at a distance of 1 m along the axis perpendicular to the position of the source. The value of the Kerma intensity in the air is designated through the product of the rate of kerma in the air at a distance, transported in vacuum, due to the energy of photons greater than the threshold δ, by the squared distance from the source to the geometric center of the volume sensitivity of the measurement system.

The dose rate constant parameter Λ aims to describe the dose rate at the reference point, this constant being influenced by the effects of the internal geometry of the source and the strength of the kerma in the air. The geometry function G (r, θ), geometric factor ignores the photon absorption and scattering parameters in the source structure and verifies an effective inverse square distance law correction based on an approximate model of the radioactive material within the source , representing the dose variation due to the geometry of photon propagation. The radial dose function, g(r), considers the absorption and scattering effects of the dose along the transverse plane of the radioactive source. F(r,θ) is the anisotropy function, it describes the anisotropy around the radioactive source, representing the dose variation as a function of the polar angle θ at a given fixed distance.

TG-43 recommends the use of simulations for comparison and assistance in dosimetric determinations for brachytherapy. In this work, the Monte Carlo method using the MCNP 6 code was used in the experimental stage to determine the estimated time in which the TLDs should be exposed to source. To ensure that the absorbed dose was within the dosimeter response linearity range [5].

In all irradiations, the TLDs were first positioned on the phantom, after positioning all dosimeters, in their respective positions, arranged and angled around the 125I seed, using distances of 1 cm, 2 cm and 3 cm around it. of the seed to acquire the absorbed dose. And an angle of 30° by 30° for a distance of 1 cm, due to limitations in positioning the TLDs, and of 10° by 10° for distances of 2 and 3 cm.

3. Results and Discussion

The anisotropy function, as its name suggests, describes the angular variation of the dose distribution around the source. In other words, the anisotropy function quantifies the dose rate variations around the source. In addition to describing how the dose is attenuated or filtered at different angles in relation to the transverse plane, which affects the spatial distribution of the dose. Measurements of the anisotropy function values were carried out for three distances from the geometric center of the iodine source to the position of the TLD as already described in the methods.

It was observed that all the graphs described below showed an increasing trend in the F(r,θ) function, which was expected due to the increase in the dose rate for angles closer to 90°. However, some inconsistencies in the continuity of function at certain angles were observed, and these inconsistencies may be related to the fact that the seed has a different weld geometry at its ends. Welding performed by a laser system can affect dose rate values for smaller angles, especially those close to the seed tip.

These observations highlight the importance of taking into account the specific characteristics of the seed, including its weld geometry, when interpreting graph results. The variation in dose rate at different angles can be explained by interactions between the seed and the surrounding medium.

The experimental values of the anisotropy functions are compared with the values of the already commercialized Amersham model OncoSeed 6711. The choice of this seed for comparison purposes is justified, as this model has similar characteristics to the seed produced by the Institute of Energy and Nuclear Research. Through figures 2, 3 and 4. The distances compared vary from 1 to 3 cm, with polar angles from 0 to 90°. The anisotropy functions obtained in this work are in good agreement with the values provided by the TG-43, for the comparison range, the average difference found between the values obtained in this work with the TG-43 is approximately.

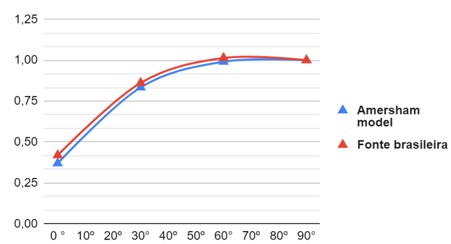

Figure 2: Comparison of the values of the anisotropy functions for a distance of 1 cm.

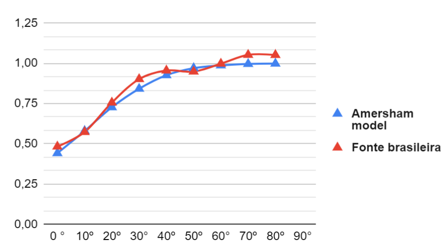

Figure 3: Comparison of anisotropy function values for a distance of 2 cm.

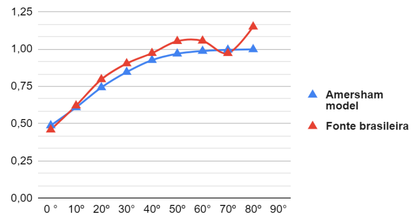

Figure 4: Comparison of anisotropy function values for a distance of 3 cm.

The uncertainties of the anisotropy function are greater for regions close to the transverse axis of the 125I seed, where, due to the internal components of the seed, they result in large dose variations [6]. The variation in this region was expected due to the variation in the geometry of the seed tip between the two models, as presented in this work. In this work, the total combined uncertainty for the anisotropy function is close to 5%.

4. Conclusions

Regarding the dosimetric parameters of the seed developed by IPEN, the analysis revealed a close agreement with the values of model 6711. This result indicates a significant similarity in the dosimetric characteristics between the two models. Such correspondence was anticipated, given that the geometry of the seed investigated in this study was based on model 6711, which already has a substantially established dosimetric characterization.

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