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INDIRECT MEASUREMENT OF RADIATION DOSE RATE FROM BRACHYTHERAPY 125 IODINE SEEDS BY NUMERICAL METHOD: PRELIMINARY COMPARISONS WITH ANALYTICAL CALCULATIONS

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Abstract: Brachytherapy, using radioactive iodine seeds, is a very important and efficient process of cancer treatment. These seeds are small sealed tubes of titanium, 4,50mm long, with the radioactive material inside. The amount of radiation to be imparted on a tumor has to be precisely evaluated, so any calculation process is welcome, beside the normative ones. In this work it is shown a numerical method to compute the dose rate in the vicinity of the seed, and comparisons of its results is compared with analytical calculations, in order to evaluate the method. These are preliminary results, for a future validation.

Keywords: brachytherapy, 125 iodine, dose rate.

1. INTRODUCTION

Brachytherapy is a very important and efficient process of cancer treatment [1,2]. It consists of to irradiate tumors by inserting on it radioactive sources, instead of traditional methods that irradiate the tumors from outside body. It is call "to treat from inside to outside". One of these sources consists of radioactive iodine seeds, commonly used for prostate or ocular cancer. These seeds are small sealed tubes of titanium, 4,50mm long, 0,80mm external and 0,70mm internal diameter, with a silver rod inside. This silver rod has the 125 iodine adsorbed. Effectively, the 125 iodine is the only radioactive source and fits a scab form, around the silver rod. A sketch of this seed is shown in figure 1.

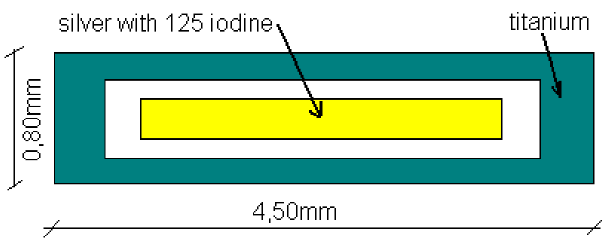

Fig. 1. Longitudinal cut sketch of the cylindrical seed used in brachytherapy.

The IPEN/CNEN, in São Paulo - Brazil, had developed its own prototype of this seed and will begin its national production next year, for internal and external patients [3,4]. The quantity "dose rate" has to be evaluated for any kind of these seeds, whichever the producer [5]. This work uses the numerical method next explained which evaluate the dose rate in desired positions close to the seed, as it was inside the tissue. This is a new algorithm which will be exhaustively tested before to be used effectively, or be validated. In order to evaluate preliminarily this algorithm, its results were compared with analytical calculations, considering sources of punctual form and as an axis segment.

2. SHORT DESCRIPTION OF ALGORITHM

It was used one numerical and two analytical methods or approaches.

The numerical procedure consists of finite differences in a cylindrical coordinate system of reference, centered in the middle of the seed, and the z axis coincident with the longitudinal cylindrical axis. The ρ coordinate (distance from the z axis, in a Cartesian system) was discretized in fifteen points, non-uniformly. The θ coordinate (angle from x axis), was discretized uniformly in seventy-two points. And the z axis was discretized in thirty-six points, non-uniformly.

In the numerical context, the radiation source (125 iodine) is the set of points: 4 and 5 in ρ, 1 to 72 in θ and 14 to 23 in z. Each one of these points was considered as a punctual source of radiation, and used the equation 1, as follow:

$$\overset{\circ}{X}(P) = \Gamma \frac{A}{d^2} \tag{1}$$

$\overset{\circ}{X}$ is the exposition rate; Γ is the radiation constant of the 125 iodine gamma radiation emission; A is the activity of the fraction of source and d is the distance from the source. P is the point of coordinates (ρ_P, θ_P, z_P).

It was considered attenuation from the materials, when radiations beam cross the structures.

One of the analytical methods considers the punctual form of the source and uses the equation 1 but instead of fraction of activity, it was used the total activity of the seed.

The second analytical approach considers the axis segment form of the source. For this geometry, in a point P inside a plane orthogonal to the segment and passing through the middle point of the segment, the dose rate is calculated by integration and gives the following equation:

$$\overset{o}{X}(P) = 2\Gamma \frac{A_\lambda}{d^2}.\text{arctg}\left(\frac{L}{2d}\right) \qquad (2)$$

A_λ is the linear density of activity; L is the length of the axis segment and d is the distance from the source in the median axis of the segment.

For a point inside the axis of the segment, distant R from the closest end side of the segment, the equation is:

$$\overset{o}{X}(P) = \Gamma \frac{A}{R(R+L)}. \qquad (3)$$

3. RESULTS

By equations 1 (punctual), 2 or 3 (segment), and through the numerical method (computation simulation), it was calculated the dose rate in two sets of points, shown in figure 2.

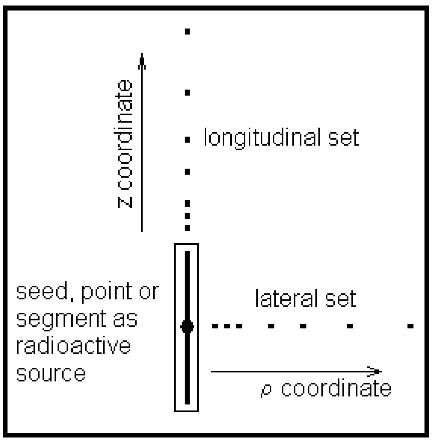

Fig. 2. Two sets of points where dose rate was calculated or simulated

One of these sets contains points distant from the middle of the seed, in an orthogonal or lateral axis. The other set of points are getting far from the seed but through the longitudinal axis. The results are in figures 1 and 2. The θ coordinate is irrelevant for these sets. The activity of the seed was 3,0mCi for every calculation.

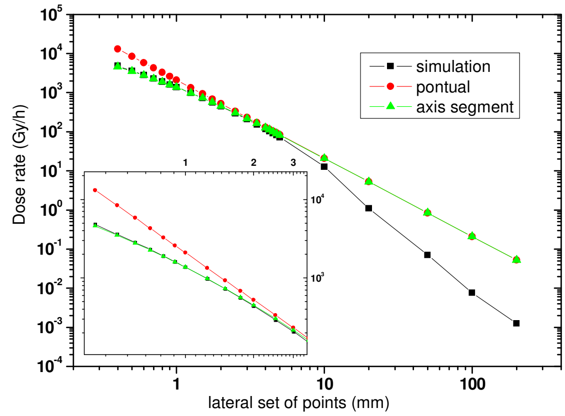

Fig. 3. Dose rate values, in Gy/h, for the points of lateral set.

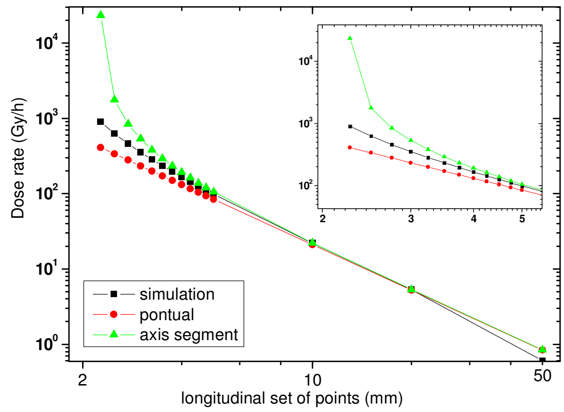

Fig. 4. Dose rate values, in Gy/h, for the points of longitudinal set.

These results show that close to the seed, the three ways of calculation have effective differences, as expected by the shape diversity. In longitudinal set, for distances from 9mm to 2cm, every approach has values very close. In lateral set, the similarity of the approaches happens only from 2 to 8mm. For distances higher then 2cm, in longitudinal set, and higher then 8mm, in lateral set of points, the simulation does not agree with the analytical approaches because there is air attenuation of the radioactive beam.

3. CONCLUSION

It was shown preliminary results of a numerical method to compute radiation dose rate from a brachytherapy seed. The results were compared to analytical calculations of dose rates from punctual and axis segment forms of radioactive sources, made by simple integrations. The results were coherent with expected ones. The work of comparison with experimental results is in progress.

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