PROSTATE DOSE CALCULATIONS FOR PERMANENT IMPLANTS USING THE MCNPX CODE AND THE VOXELS PHANTOM MAX

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Abstract. *This paper presents the modeling of 80, 88 and 100 of ^{125}I seeds, punctual and volumetric inserted into the phantom spherical volume representing the prostate and prostate phantom voxels MAX. Starting values of minimum and maximum activity, 0.27 mCi and 0.38 mCi, respectively, were simulated in the Monte Carlo code MCNPX in order to determine whether the final dose, according to the integration of the equation of decay at time $t = 0$ to $t = \infty$ corresponds to the default value set by the AAPM 64 which is 144 Gy. The results showed that consider sources results in doses exceeding the percentage discrepancy of the default value of 200%, while volumetric consider sources result in doses close to 144 Gy.*

Keywords*: Monte Carlo, Brachytherapy, MAX phantom, AAPM 64.*

1. INTRODUCTION

There are many studies in the area of dosimetry that discuss applications of ^{125}I seeds for the treatment of prostate brachytherapy, these works calculate dosimetric quantities such as anisotropy function (SOLBERG et al., 2002; RODRÍGUEZ, et al. 2005), radial dose function (SOLBERG et al., 2002; DUGGAN, 2004; RODRÍGUEZ, et al., 2005), constant dose rate (RODRÍGUEZ, et al., 2005), air-kerma strength (RODRÍGUEZ, et al., 2005) and the geometry factor (YU et al. 1999; SOLBERG et al., 2002; NATH, 1999). However in the literature were not identified works or articles that relate to the insertion of brachytherapy seeds in voxel phantoms to verify the dose being deposited in the prostate is consistent with the required values for the actual treatment.

The few studies founded, do these calculations for mathematical phantoms (SUSRUT, 2003) and adopt the model sources of ^{125}I as point (JARRETT, 2005).

1.1 The ^{125}I radioisotope.

The decay scheme of ^{125}I results in photon energy of 27.4 keV (1.15 photons/disintegration), 31.4 keV (0.25 photons/disintegration) and 35.5 keV (0.067 photons/disintegration), (YU et al., 1999). Figure 1 shows the decay scheme of 125I (LEGRAND et al., 1975). The half life of ^{125}I is 59.43 days and 90% of the total dose is delivered in 197 days.

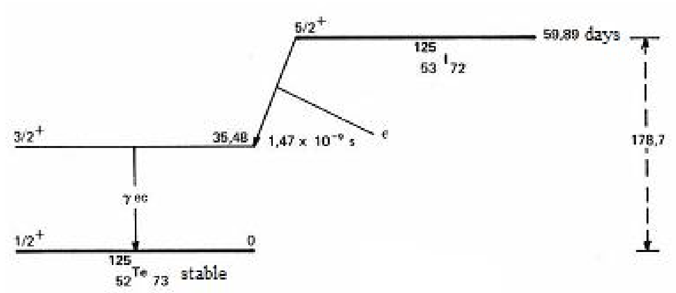

Figure 1. Decay scheme of ^{125}I.

Luse and collaborators (LUSE et al., 1997) compared the dose distributions for a prostate implant of a 35 cm^3, using 88 seeds and 20 needles. When the old formalism was used, the result was that the prostate receiving 160 Gy, however when the parameters of the TG-43 were used in calculating the dose was 144 Gy, which is the percentage difference, 11%. For this reason LUSE et al. recommended that the prescription dose in prostate implants was 144 Gy instead of 160 Gy. Another empirical study, conducted by BICE and collaborators (BICE et al., 1998), which is based on a similar comparative analysis, also concluded that the final dose should be 144 Gy.

2. METHODOLOGY

In the following sections will be presented the methods of insertion of 125I seeds in the spherical phantom that represents the prostate and prostate phantom voxels, MAX, respectively.

2.1 Modeling of ^{125}I seeds in the spherical phantom.

In the code MCNPX was a simulated prostate water with the same mass of the prostate phantom MAX, 21.46 g. The prostate was modeled as a sphere of radius 1.72 cm of water in this sphere were placed 100 seeds of 125I punctual e volumetric (Amersham 6711), providing two independent inputs. The final values of doses will consider the total number of transformations on an infinite period of time.

The seeds were placed along five sections perpendicular to the x axis, with centers fixed in the coordinates of where x_1 = -0,8, x_2 = -0,4, x_3 = 0, x_4 = 0,4, x_5 = 0,8, the visualization from 100 seeds inserted into the prostate phantom of water in the slices at x are shown in Figure 2.

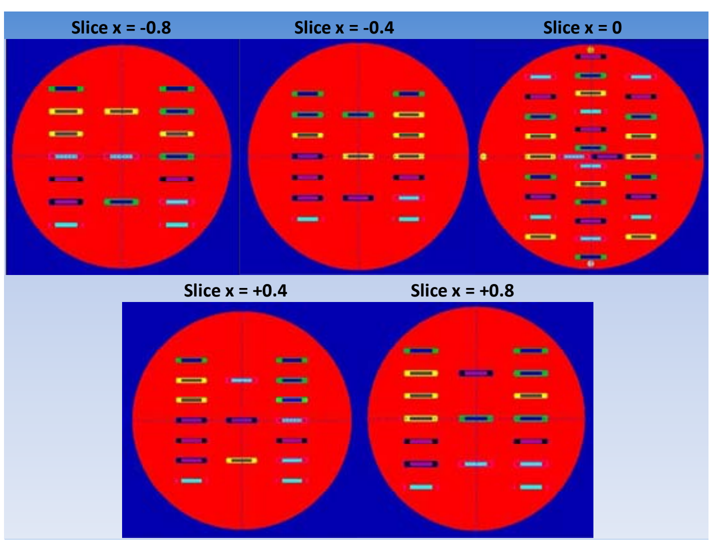

Figure 2. Visualization of the geometry of the input volume with 100 sources using the program Moritz (RIPER, 2008).

2.2 Modeling of ^{125}I seeds in the MAX phantom.

The sources of ^{125}I were distributed proportionally according to the number of voxels present in the selected slice. In Figures 3 and 4, representing the regions selected for the insertion of the maximum d seed, which is 100, the dark gray voxel represents the universe of the prostate, in this phantom voxels, MAX, note the figure that the slice has more voxels, z = 83.60 cm, is the one with more seeds, 21.

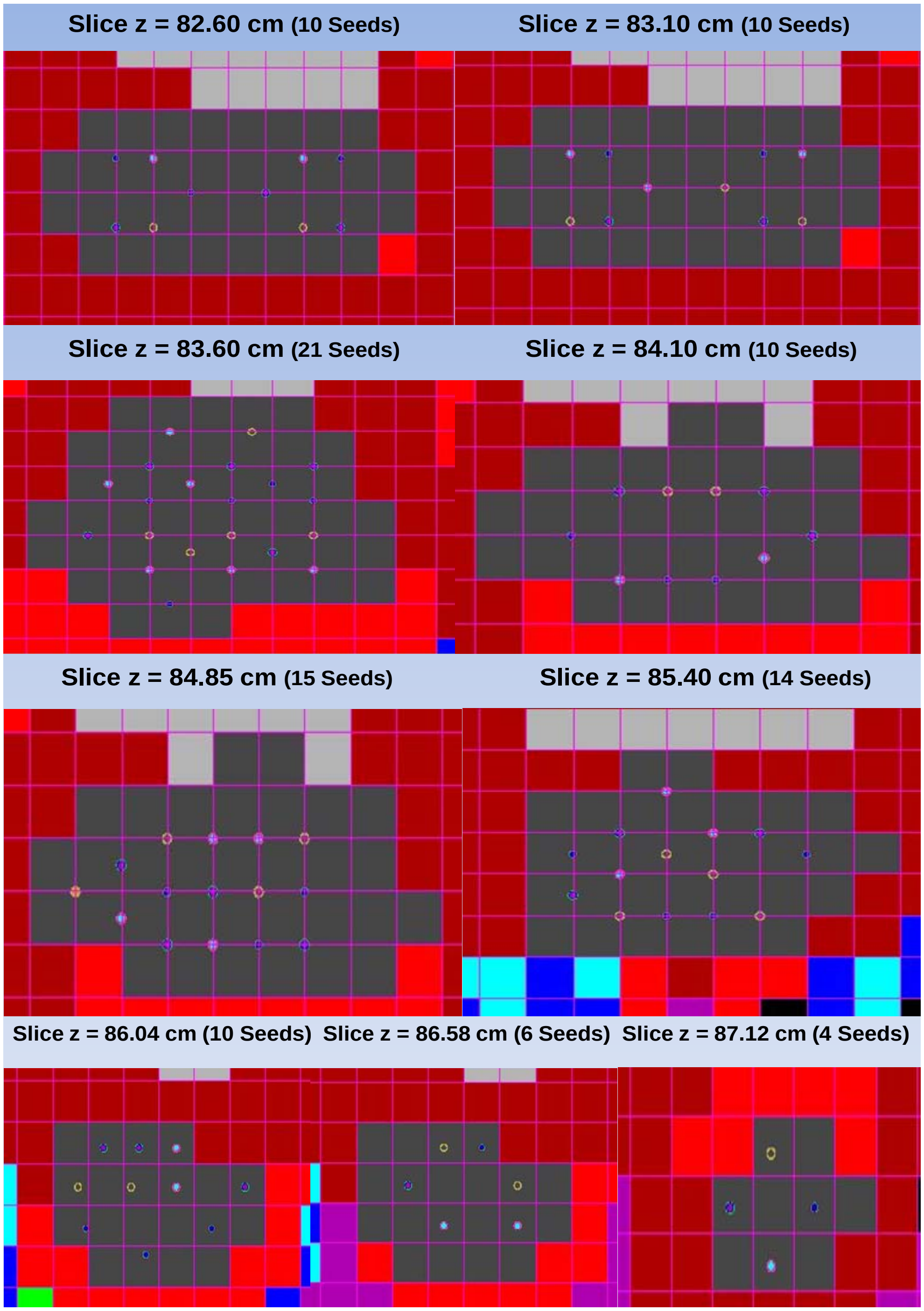

Figure 3. Visualization of the geometry of the input volume with 100 sources using the program Moritz (RIPER, 2008).

2.3 Spheric phantom and the prostate max phantom.

The results of simulations with the MAX05 phantom and prostate of water will be presented, considering the initial activities (minimum and maximum) of 0.27 mCi and 0.38 mCi, respectively. The simulations were performed taking into account the numbers a minimum, average and maximum number of seeds that are commonly used in permanent implants: 80, 88 and 100 seeds, respectively, (PEREIRA JÚNIOR, 2003; AMADEI, 2008). Table 1. shows the total number of transformations for the two initial activities and the three configurations of seeds. In this work, we considered the integration of equation (1) on an infinite time period:

$$\int_0^{\infty} A_0 \,.\, e^{-\lambda.t} \;\Rightarrow\; -\frac{A_0}{\lambda}.\left(\frac{1}{e^{\lambda.\infty}}-\frac{1}{e^{\lambda.0}}\right) \;\Rightarrow\; \frac{A_0}{\lambda} \qquad (1)$$

The solution in Eq (1), A0 / λ, is used to calculate the final dose for the treatment of prostate cancer due to implantation of 125I seeds.

Table 1. Total number of transformations for 80, 88 and 100 seeds points and volumetric for the activities of 0.27 mCi and 0.38 mCi.

Prostate mass	**21,46g**	
Total number of transformations **A_0 = 0,27 mCi**	80 Seeds	**5,92E+15**
	88 Seeds	**6,51E+15**
	100 Seeds	**7,40E+15**
Total number of transformations **A_0 = 0,38 mCi**	80 Seeds	**8,33E+15**
	88 Seeds	**9,17E+15**
	100 Seeds	**1,04E+16**

3. RESULTS

In the following sections will present the results for the spherical phantom that represents the prostate and prostate voxels of the phantom voxels MAX, considering the sources punctual and volumetric, minimum and maximum activity, 0.27 mCi and 0.38 mCi, respectively, numbers and minimum, average and maximum of seeds that are 80, 88 and 100 seeds, respectively.

3.1 Punctual sources.

For point sources inserted in the water phantom and the phantom voxels MAX 10^7 stories were simulated, resulting in an uncertainty of 0.16%. Regarding the results, when compared with the dose recommended by the AAPM 64, (YU et al., 1999), the fact is considered point source generates very discrepant results regarding the stipulated amount, 144 Gy, as they are shown in Figures 4 and 5, taking, for example, one can cite the value of the dose due to 100 seeds off and initial activity of 0.38 mCi, overestimates total dose of treatment in more than 200%. Between the two phantoms doses for the simulator MAX voxels are always smaller than the doses of the water phantom, the difference being less than 10%. This is due to the irregular geometry of the prostate in the voxel phantom, differences between the chemical composition and densities of soft tissue and water.

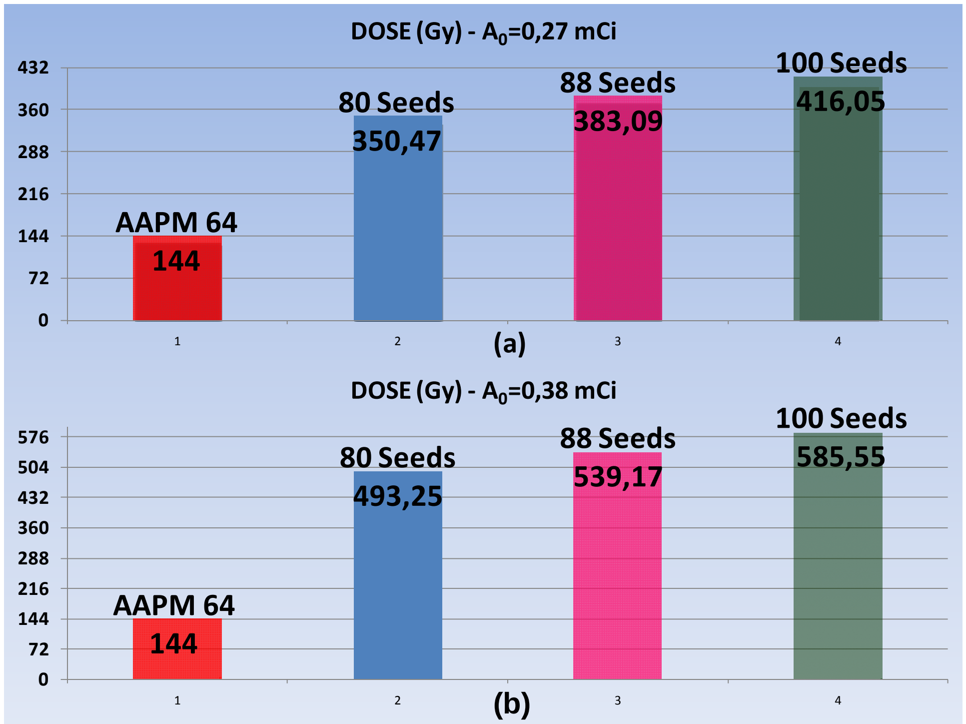

Figure 4. Final doses whereas 80, 88 and 100 seeds points ^{125}I inserted into the water phantom in (a) has dose values considering the initial activity of 0.27 mCi of (b) has the initial activity of 0.38 mCi.

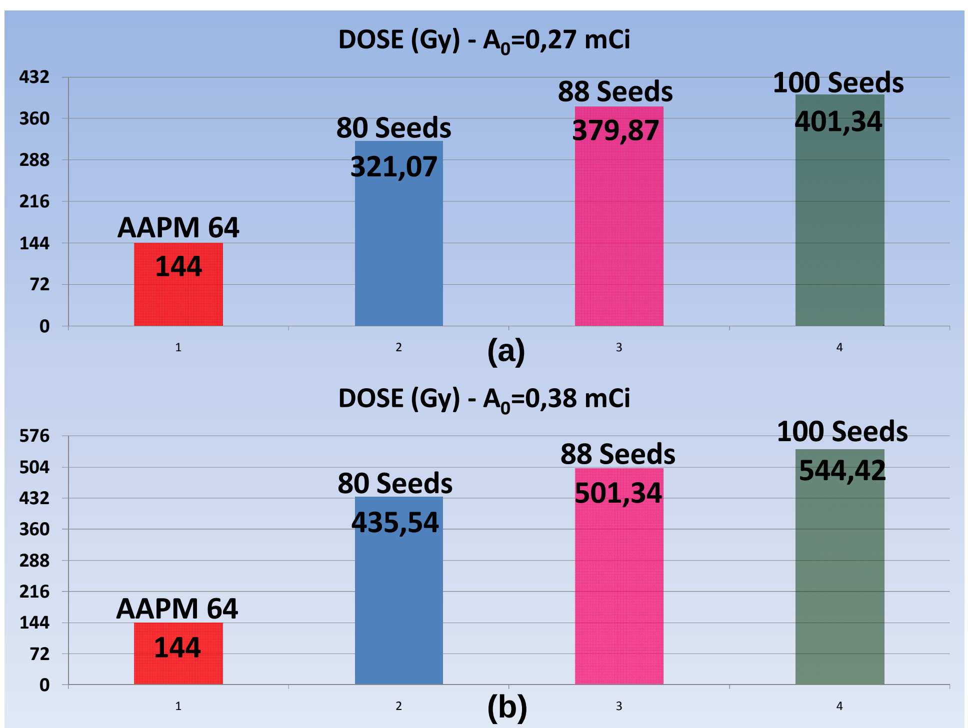

Figure 5. Doses whereas 80, 88 and 100 seeds points ^{125}I inserted into the MAX phantom in (a) has dose values considering the initial activity of 0.27 mCi of (b) has the initial activity of 0.38 mCi.

3.2 Volumetric souces

The volumetric sources simulated with the MCNP were inserted into the water phantom and the phantom voxel MAX. For a total of 10^7 histories the uncertainty generated was 0.16%. Differently of the results presented to point sources, the dose values considering volumetric sources are closer to the value of 144 Gy, recommended by the AAPM 64. Figures 6 and 7 show the total doses in the prostate when the seeds are modeled volumetrically. According to the graphics, it appears that some font settings underestimate the dose of 144 Gy, as is the case with the configuration of 80 seeds placed on the phantom voxel considering the initial activity of 0.27 mCi, resulting in a total dose 127.72 Gy. However, there are settings that overestimate the dose by more than 50%, as is the case with the configuration of 100 seeds inserted in water phantom with initial activity of 0.38 mCi (235.92 Gy).

The results show that the choice of souce configuration must be done with extreme caution, because if the dose is underestimated when there is a chance of brachytherapy treatment is not administered the dose required to excise the tumor and, therefore, the chance of cancer cells reproduce tumor may return. In contrast a dose overestimation can result in unnecessary dose to radiosensitive organs that are close to the prostate.

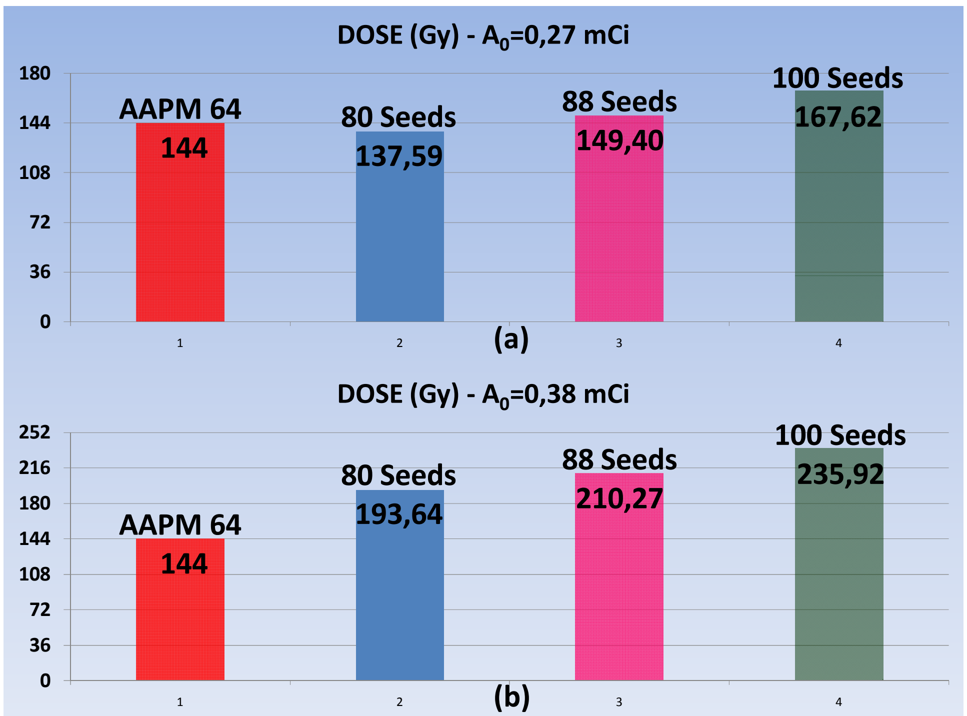

Figure 6. Doses whereas 80, 88 and 100 volumetric seeds of ^{125}I inserted in water phantom, at (a) has dose values considering the initial activity of 0.27 mCi of (b) has the initial activity of 0.38 mCi.

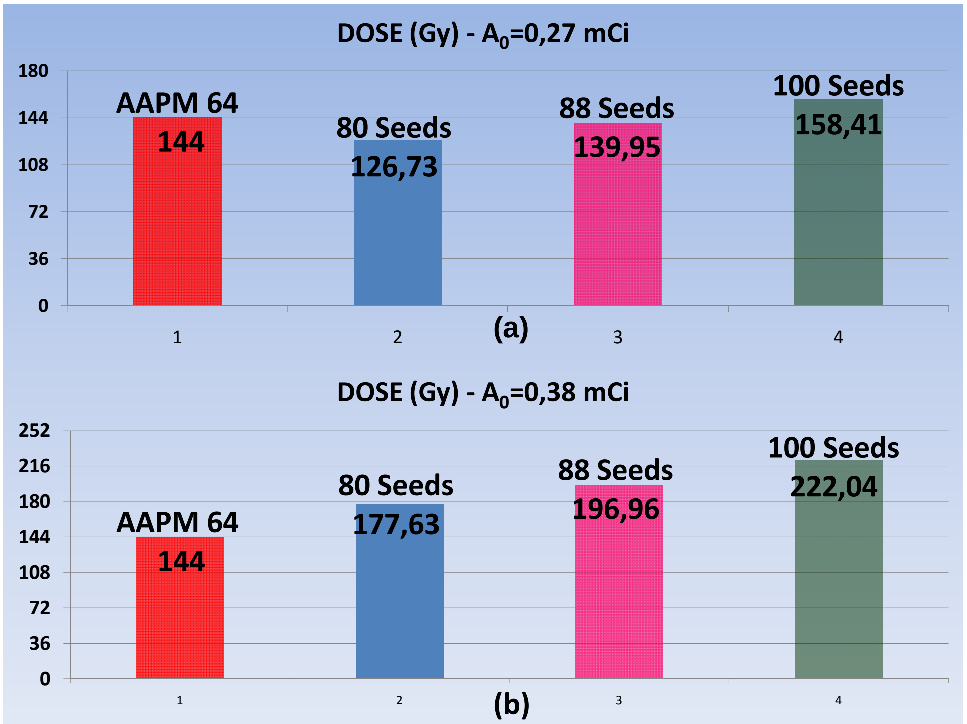

Figure 7. Final doses whereas 80, 88 and 100 volumetric seeds of ^{125}I inserted into the MAX phantom in (a) has dose values considering the initial activity of 0.27 mCi of (b) has the initial activity of 0, 38 mCi.

4. CONCLUSION

The results for the formalism of point sources, both for the spherical phantom, as for prostate for the MAX phantom voxels, are so different from the value recommended by the AAPM 64, some values overestimate the total dose of treatment in more than 200%, this can be explained by the strong attenuation suffered for the low energy photons, average 27.4 keV, by encapsulating the source of ^{125}I, which is made of high density materials such as silver and titanium.

For volumetric sources, when considering initial activity of 0.27 mCi source, the final dose values are next to the default values of the AAPM 64, the best configuration, the 88 seeds, which is the average amount of seeds in an implant , the maximum values of initial activity, 0.38 mCi, always overestimate the value end of the dose by 65%. Between the phantoms two the doses for simulator MAX voxels are always smaller than the doses of the water phantom, is to be sources for volumetric sources, the difference being less than 10%. This is due to the irregular geometry of the prostate in the voxel phantom, differences between the chemical composition and densities of soft tissue and water.

5. ACKNOWLEDGEMENT

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