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2016 J. Phys.: Conf. Ser. 733 012092

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The influence of different ^{192}Ir sources geometries to the energy deposition

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Abstract. In this paper, various simplifications of the HDR source Varian VariSource Classic model, in which ^{192}Ir as a radionuclide is used, were compared. These simplifications were carried out by Monte Carlo simulations, using the MCNPX 2.7.0 code. The different sources were compared through a distribution of energy deposition in a water phantom. Our results indicated that small simplifications will present no influence on the source response, and the removal of the entire capsule surrounding the radionuclide will present a difference of just 0.53% in the final response.

1. Introduction

In 1869, radioactivity was discovered by Henry Becquerel and in 1898 the Curies discovered radium. With these new horizons of science, in 1901 brachytherapy was first applied by a doctor, using a small amount of radium for the treatment of epithelial lesions. At this time, the Curie Institute in Paris and the St Luke's Hospital and Memorial Hospital in New York pioneered the application of techniques in radiotherapy.

Unlike External Beam Radiotherapy (EBRT), where the tumor receives high dose x-rays from an external place, brachytherapy consists in putting a radioactive source in the tumor, or near it, to kill the cancer cells. The source can be in the format of wires or seeds, containing sealed radioactive material. With it, we can reduce the exposure of healthy tissue to high doses of radiation [1]. This study will use sources of ^{192}Ir , considered a HDR (high-dose rate) source. The source to be studied is a Varian VariSource Classic, using the N-particle transport MCNPX 2.7.0 Monte Code [2].

The purpose of the paper is to evaluate the quantity of radiation that is released if we simplify the source's shield in a Monte Carlo simulation. With this, we may determine whether the geometry can be simplified without any changes in the energy deposited to its surroundings.

2. Materials and Methods

In this paper, various simplifications of the HDR source Varian VariSource Classic model were compared. These simplifications were carried out using the the Monte Carlo MCNPX 2.7.0 code [2]. The different sources were compared through the energy deposition in a water phantom.



The evaluated source was the Classic model of HDR Varian VariSource, which uses ^{192}Ir as a radionuclide. Produced and distributed by Varian Oncology Systems, the active part presents a density of 22.7 g/cm^3 , 10.0 mm in length and a diameter of 0.34 mm. The source's activity is considered evenly distributed. The active core is wrapped with nitinol with a density of 6.45 g/cm^3 , made of titanium and nickel, with a length of 15 mm and a total diameter of 0.59 mm.

The distal tip of the capsule has rounded edges with a radius of curvature of 0.295 mm. The source is fixed in a stainless steel cable with a diameter of 0.59 mm. As the part of the cable near the source is straight, 2 mm of the cable was simulated. The complete geometry of this source is shown in Figure 1.



Figure 1. Design of the source HDR Varian VariSource Classic.

The evaluation consisted in 6 simplifications of this source: (1) replacing the rounded edges for rectangular edges; (2) replacing the superior edge for a rectangular edge; (3) removal of the stainless steel cable; (4) the inferior part of the source's shield was taken; (5) the components of nitinol were taken (6) the source's shield was taken completely. The description of each one of the simplifications is described next.

2.1. Configurations of the source of ^{192}Ir evaluated in this paper

The first simplification consisted in removing the rounded edges of the distal tip of the source and changing it to a rectangular form without any changes in the length and diameter. This configuration is shown in figure 2.



Figure 2. Design of the first simplification of the HDR source Varian VariSource Classic: removal of the rounded edges.

In the second simplification, the distal tip of the original source, the rounded form was replaced with a triangular form, with an opening angle of 40° and no changes in the total length of the source. This configuration is shown in figure 3.



Figure 3. Design of the second simplification of the HDR source Varian VariSource Classic: replacement of the rounded tip for a triangular one.

The third simplification consisted in the removal of the source's cable, but keeping the original diameter and length. This configuration is shown in figure 4.



Figure 4. Design of the third simplification of the HDR source Varian VariSource Classic: removal of the stainless steel cable.

In the fourth simplification, the portion of the capsule that stood between the active part of the source and the portion simulated of the cable in the original source was removed. This thereby reduced the length of the source in relation to the original one by 4 mm, and kept the same diameter of the original source. This configuration is shown in figure 5.



Figure 5. Design of the fourth simplification of the HDR source Varian VariSource Classic: removal of the portion of the capsule that stood between the active part of the source and the cable.

The fifth simplification consisted in the removal of the portion of nitinol between the rounded edges and the active core in the proximal tip and the removal of the portion of nitinol between the active core and the cable in the distal, removing the portion of the cable simulated in the original source. Therefore, the length of the source was reduced by 10.295 mm, but the diameter was kept the same. This configuration is shown in figure 6.



Figure 6. Design of the fifth simplification of the HDR source Varian VariSource Classic: removal the portion of nitinol.

In the sixth simplification, the entire capsule surrounding the radionuclide was removed, and, as a consequence, the source was just the radioactive material. It had 10 mm of length and 0.34 mm of diameter. This configuration is shown in figure 7.



Figure 7. Design of the sixth simplification of the HDR source Varian VariSource Classic: removal of the entire capsule surrounding the radionuclide.

To proceed with the analyses, each seed was placed inside a spherical phantom, composed of water. This geometrical arrangement allowed the evaluation of the angular anisotropy of the irradiation field and the maximum energy deposition.

The anisotropic distribution is in 10° increments, from 0° to 180° . The center of the sphere passes through the center of the ^{192}Ir source. The energy deposition was computed in each of the segments, enclosed by the 10° segments.

With this study, we may determine the influence of each geometrical simplification on the simulated phantom.

3. Results and Discussion

The energy deposition, for each geometrical simplification and angle, are listed in table 1.

As seen from table 1, there were not any differences from the original source (source with no simplifications) for the smaller simplifications, and 0.53% for the source with no capsule surrounding it. This variation may be considered small, in relation to other sources of errors, that may occur during brachytherapy treatments [3].

This shows that making small simplifications that could be time consuming, such as choosing the type of source, may be simplified, with no differences on the final responses.

Table 1. Energy deposition for all the geometrical differences evaluated in this work, for all the wedges. S1 means source 1 (the original source) and S2 to S6 simplifications 2 to 6.

Wedge	Energy deposition ($\times 10^{-3}$ MeV)					
	S1	S2	S3	S4	S5	S6
1	1.283	1.283	1.283	1.284	1.284	1.290
2	1.306	1.306	1.306	1.306	1.306	1.306
3	1.326	1.326	1.326	1.326	1.326	1.327
4	1.332	1.332	1.332	1.332	1.332	1.340
5	1.340	1.340	1.339	1.338	1.339	1.347
6	1.340	1.340	1.340	1.339	1.339	1.344
7	1.350	1.350	1.350	1.351	1.350	1.353
8	1.348	1.348	1.347	1.348	1.348	1.358
9	1.345	1.344	1.345	1.344	1.344	1.355
10	1.342	1.342	1.342	1.342	1.342	1.349
11	1.351	1.352	1.352	1.351	1.351	1.353
12	1.344	1.345	1.344	1.344	1.345	1.355
13	1.338	1.338	1.338	1.338	1.338	1.348
14	1.333	1.333	1.333	1.333	1.334	1.347
15	1.322	1.322	1.322	1.322	1.323	1.333
16	1.313	1.313	1.313	1.313	1.314	1.323
17	1.299	1.299	1.299	1.300	1.300	1.309
18	1.286	1.286	1.286	1.287	1.287	1.290
Mean Value	1.328	1.328	1.328	1.328	1.328	1.335
Difference from the original source	-	0%	0%	0.01%	0.01%	0.53%

4. Conclusion

In this study, we evaluated the effect of geometrical simplifications on the simulation of a ^{192}Ir source. Our results indicated that small simplifications will present no influence on the source response, and the removal of the entire capsule surrounding the radionuclide will present a difference of just 0.53% on the final response. This variation may be considered small, in relation to other sources of errors, that may occur during brachytherapy treatments. Therefore, this indicates that one may simplify some parts of the source geometry, with no influence on the final response.

Acknowledgments

The authors received support from the Brazilian agencies: CAPES (Grant Pro-Estratégia no. 1999/2012), CNPq (Grants no. 304789/2011-9 and 157593/2015-0) and Project INCT for Radiation Metrology in Medicine. The authors would like to thank Dr. Å. Carlson Tedgren (Linköping University, Sweden) for providing the energy spectra of the ^{60}Co beam.

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