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A Monte Carlo investigation of the dose distribution for new I-125 by GEANT4

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Abstract

Brachytherapy is a special type of radiation therapy in which the source of radiation, such as seed(s), is placed near or inside a tumor. In this study, at first we simulated and validated I-125 source (model 6711) seed, as a common source in brachytherapy, according to the TG-43U1 recommendation, by GEANT4 Monte Carlo toolkit. Moreover, we simulated a new I-125 seed contains a cylindrical $Ag+Al_2O_3$ marker and calculated its radial dose and anisotropy function. The source validation show that GEANT4 Monte Carlo toolkit produces accurate results for dosimetric parameters of the I-125 seed with choosing the appropriate physics list. On the other hand, results show a similarity between calculated dosimetric parameters of the I-125 seed (6711) and the new source, with a percentage difference about 5%.

Keywords: **Brachytherapy, Radial dose, Anisotropy function, I-125, GEANT4.**

Introduction

Brachytherapy is a type of internal radiation therapy, which an encapsulated radiation source is positioned within or close to a region inside the patient's body to maximize doses to cancer cells while minimizing damage to normal tissues. Today, the low-energy photon emitting radioisotopes such as I-125, Pd-103, and Cs-131 are widely used in brachytherapy for treatment of different cancer, such as prostate cancer, eye malignant tumors, cervix cancers, and malignant brain tumors. I-125 is the most commonly used form of local treatment brachytherapy with a half-life of 59.431 days. It decays by electron capture to excited state of Te-125. In this study, we simulated I-125 seed model 6711 by GEANT4 Monte Carlo toolkit. The results have been validated by comparing our simulation results with the results of previous studies according to TG-43U1 protocol [1]. In the I-125 seed models, the materials and geometry of the active core varies from company to company. Since $Ag+Al_2O_3$ rod is a good carrier for an Iodine radioisotope and distribution of the source on it is relatively uniform, the $Ag+Al_2O_3$ has been suggested as a good compound for seed marker [2]. Hereby, we studied effect of Ag+Al2O3 marker instead of Ag on the dosimetric parameter results by simulation of this source by GEANT4 toolkit.

Results show the seed with new Ag+Al2O3 carrier body can produce a dose map similar to the conventional I-125 seed.

Materials and methods

As shown in Figure 1-a, the seed consist of a silver cylindrical marker with 0.025 cm radius and 3.2 mm length. I-125 radioisotope is uniformly deposited on the silver marker with the 1 μm thickness. The marker is encapsulated within a titanium tube of 0.47cm length, 0.08cm diameter, and 0.006cm thickness in top and bottom and 0.4mm radius at both semispherical ends. The space between the titanium and marker was filled with air. In a separate simulation, Ag was replaced with $Ag+Al_2O_3$ marker [2] and simulation was repeated and results were compared. Simulations were performed using GEANT4 Monte Carlo toolkit to determine the dosimetric parameters of the I-125 brachytherapy seed in the center of a water phantom. The radial dose function and anisotropy function were calculated by calculation of dose deposition in the specific scoring rings, according to the TG-43U1 [1].

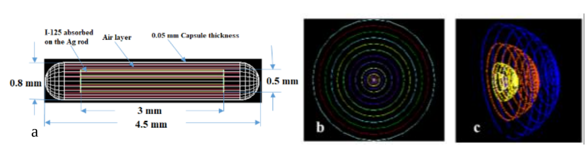

Figure 1. I-125 seed (a), Geometric system used to calculate g(r) (b) and F(r,θ) (c) in the GEANT4

Radial dose function

Values of the radial dose function for source in the water phantom for two simulated seeds were calculated for distances from 0.1 to 10 cm with 0.4 mm thicknesses from the source center by GEANT4 toolkit with emstandard_opt3 physics list (Figure 1-b). These results along some available data are shown in Figure 2. The mean statistical uncertainty for the dose calculation was about 2%. The mean difference between our results and those of Gate [1], Rodrıguez [3], Rivard et al [4], Rivard [5], and Baghani et al. (by MCNP) [6] were about 4%, 3%, 4.6%, 5.8%, and 5%, respectively, which show a good agreement. The mean difference between the new source results, and I-125 seed (6711) was about 1.2%, which show a similarity between them.

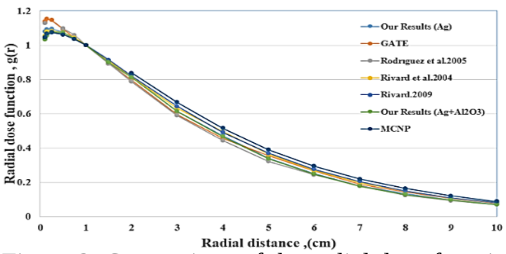

Figure 2. Comparison of the radial dose function

Anisotropy function

The anisotropy function of the seed was calculated at distances of 0.5, 1, and 5 cm from the source center using rings with 0.4 mm thicknesses at different angle relative to the source axis (Figure 1-c), as described by Fardi et al. [1]. Figure 3 shows a comparison of the anisotropy function of the source, which is calculated by GEANT4 toolkit, with the Fardi et al. [1], at three radial distances of 0.5 (Figure 3a), 1 (Figure 3b), and 5 cm (Figure 3c). The mean statistical uncertainty for the dose calculation was about 3%. In this Figures, we also show the results of the anisotropy function of the new seed. The mean difference between GEANT4 results and those of GATE for I-125 seed (6711) is about 1.7%, 2.7%, and 4.8% at 0.5 cm, 1cm, and 5 cm distance, respectively, which show a good agreement between results. Furthermore, the average difference between results of the anisotropy function of the I-125 seed with Ag marker and I-125 seed with Ag+Al2O3 marker seed in our simulation is about 5.2%,5.3% and 3.9% at 0.5cm, 1cm, and 5 cm distance, respectively.

Conclusions

Our results along with comparison with other commercial sources models show the good agreement between simulated I-125 source (model 6711) results and previous researches. This demonstrate the correct source geometry and physics list, which were used in our simulation by GEANT4 toolkit. Furthermore, we determine the dosimetric parameters of a new I-125 seed contains a cylindrical $Ag+Al_2O_3$ marker according to the TG-43U1 recommendation by GEANT4 toolkit. Since model 6711 is considered as a standard source in brachytherapy, similarity between calculated dosimetric parameters of the I-125 seed (model 6711) and the new source, demonstrated that this new seed could be used in the similar cases.

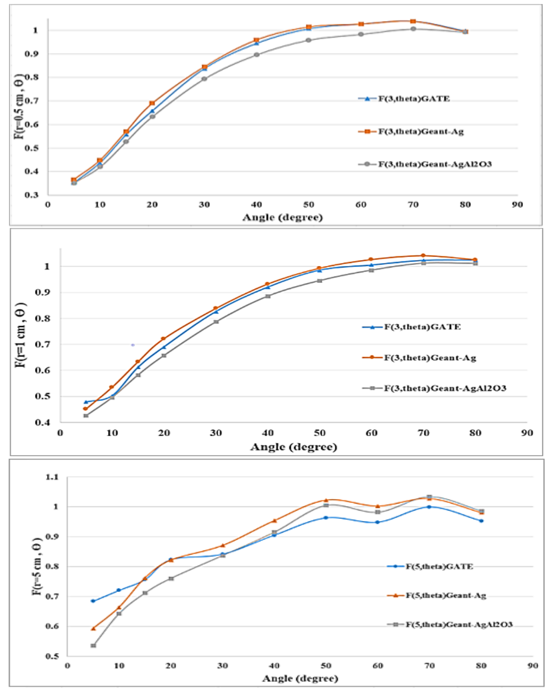

Figure 3. Anisotropy function obtained by GEANT4 results and other results for 0.5 cm (a), 1cm (b), and 5 cm

References

[1] Z. Fardi, P. Taherparvar, *Monte Carlo investigation of the dose distribution for new I-125 Low Dose Rate brachytherapy source in water and in different media*, Pol J Med Phys Eng. 27, 15 (2019).
[2] A. Eslami, M. Shamsaei, *Determination of dosimetric characteristics of a new design I-125 brachytherapy source with an Ag+AL2O3 marker using Monte-Carlo code MCNPX*,RSM.56,550(2014).
[3] E. Rodríguez, E. Alcón, M. Rodriguez, et al, *Dosimetric parameters estimation using PENELOPE Monte Carlo simulation code: Model 6711 a I-125 brachytherapy seed*, Appl. Radiat. Isot. 63, 41 (2005).
[4] M. Rivard, B. Corsey, L. DeWerd, et al, *Update of AAPM Task Group No. 43 Report: a revised AAPM protocol for brachytherapy dose calculations*, Med. Phys. 31, 633-674(2004).
[5] M. Rivard, *Monte Carlo radiation dose simulations and dosimetric comparison of the model 6711 and 9011 I-125 brachytherapy sources*, Med. Phys. 36, 486 (2009).
[6] H. Baghani, V.Lohrabian, M. Aghamiri, M. Robatjazi, *Monte Carlo Determination of Dosimetric Parameters of a New I-125 Brachytherapy Source According to AAPM TG-43 (U1) Protocol*, Arch. Iran. Med. 19, 186 (2016).