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Determination of TG-43 dosimetric parameters for I-125, Ir-192, and Co-60 brachytherapy sources using the Monte Carlo simulation

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HIGHLIGHTS

- Dose rate constant was obtained for I-125, Ir-192 and Co-60 brachytherapy sources using MCNP5 code.
- Radial dose function parameter $g(r)$ was obtained for I-125, Ir-192, and Co-60 using MCNP5 code.
- Anisotropy function $F(r, \theta)$ was obtained for I-125, Ir-192, and Co-60 using MCNP5 code.
- All calculated parameters for I-125, Ir-192 and Co-60 brachytherapy sources were in consistent with reference studies.

ABSTRACT

It is important to have accurate information regarding the dose distribution for treatment planning and to accurately deposit that dose in the tissue surrounding the brachytherapy source. However, the practical measurement of dose distribution for various reasons is associated with several problems. In this study, 6711 I-125, Micro Selectron mHDR-v2r Ir-192, and Flexisource Co-60 sources were simulated using the MCNP5 Monte Carlo method. To simulate the sources, the exact geometric characteristics of each source, the material used in them, and the energy spectrum of each source were entered as input to the program, and finally, the dosimetric parameters including dose rate constant, radial dose function, and anisotropy function were calculated for considered seeds according to AAPM, TG-43 protocol recommendation. Results obtained for dosimetric parameters of dose rate constant, radial dose function, and anisotropy function for I-125, Ir-192, and Co-60 sources agreed with other studies. According to the good agreement obtained between the parameters of TG43 and other studies, now these datasets can be used as input in the treatment planning systems and to validate their calculations.

KEYWORDS
Brachytherapy
Dosimetric parameters
TG-43 protocol
Monte Carlo simulation
MCNP5 code

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1 Introduction

Brachytherapy is a form of internal radiation therapy in which a radioactive source is placed within or near the target. This proximity allows the dose to be concentrated while minimizing exposure to surrounding healthy tissue (DeMarco et al., 1998; Cross et al., 2003).

This method plays an important role in the treatment of cancers related to different organs such as the head and neck, brain, prostate, cervix, vagina, and breast, in which it is possible to enter or implant the radioactive sources (Huh et al., 2007; Mostaar et al., 2003). Therefore, accurate information about the dose distributions is an important factor in treatment planning. As a result, to control and destroy cancer cells as well as minimize damage to the surrounding healthy tissues, dosimetric calculations must be performed with great precision. On the other hand, the practical measurement of the dose often faces several challenges such as the lack of clarity of the dose report due to the large size of common dosimeters, the energy dependence of these dosimeters, lack of tissue equivalent material in detectors, etc. (Williamson et al., 1998). One way to calculate the parameters, approved by the AAPM, is to calculate the dose distribution in water using the Monte Carlo method.

In 1998, The American Association of Physicists in Medicine (AAPM) noted that before the use of different sources in brachytherapy, their dosimetric parameters were determined by Monte Carlo calculations at least once in daily medical applications (Rivard et al., 2004). Therefore, in the present study, the mentioned parameters for I-125, Ir-192, and Co-60 sources were calculated using the MCNP5 code.

Ir-192 is a convenient source for use in brachytherapy.

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This source is made in the form of thin flexible wires that can be cut to any length (IAEA, 2000; Kacperek, 2000). The malleability and flexibility of this source provide the possibility to be produced in different dimensions and thicknesses.

Additionally, I-125 is a suitable material for permanent implantation in radiotherapy (Urie et al., 1984). The advantage of I-125 is that it requires less shielding due a lower photon energy compared the gold source.

Co-60 can also be used for brachytherapy. The main advantage of Co-60 is its high specific activity rate allowing it to be constructed with small dimensions for some specific applicators.

The purpose of this study is to obtain the dosimetric parameters for the 6711 I-125, Micro Selectron mHDR-v2r Ir-192, and Flexisource Co-60 sources using the MCNP5 code. The advantage and innovation of this research compared to similar research are that we perform the calculations of dosimetric parameters for three sources at the same time and therefore it can provide a suitable source for the validation of these sources for researchers.

2 Materials and methods

In this study, two high dose rate model sources, Flex source Co-60 and Micro Selectron mHDR-v2r Ir-192, as well as a low dose rate source 6711 I-125 were simulated using Monte Carlo code. Dose distributions in this work were simulated with the MCNP5 radiation transport code published by Los Alamos National Laboratory (MCNP5, 2008). In the simulation process, the exact geometric characteristics of the sources, the materials used in each part of the seeds, and the energy spectrum of the particles emitted by the sources should be exactly modeled.

The first source studied in the present study is the 6711 I-125 source, which is shown in Fig. 1. In the design process, there is a silver cylindrical marker with a density of 10.5 g.cm^{-3}, a length of 2.8 mm, and a radius of 0.2 mm covered with a combination of silver iodide (AgI) with a density of 6.2 g.cm^{-3} and a thickness of 2 μm. The seed is placed in a titanium capsule with a density of 4.54 g.cm^{-3} and its ends are bounded on both sides by a hemisphere. The average energy of the I-125 source is equal to 280 keV, and its half-life is about 60 d (Rivard, 2009). Also, the photon spectrum of the 6711 I-125 source used in this study according to TG-43 and AAPM reports is shown in Table 1 (Rivard et al., 2004).

The second source used is the Micro Selectron mHDR-v2r Ir-192 its primary material includes enriched iridium and has dimensions of 3.5 mm in length and 0.6 mm in diameter with an effective density of 22.42 g.cm^{-3}. This radioisotope is covered with a layer of air with a specific thickness on each side, and the inside of the tube is made of AISI 316L stainless steel with a density of 3.03 g.cm^{-3} with a diameter of about 0.9 mm. One end of the tube is blocked by laser welding and the other end is connected to a steel cable of an AISI 304L stainless steel with a density of 4.88 g.cm^{-3}. The cable length is considered to be 2 mm in the Monte Carlo simulation, which is practically longer and is also called a guidewire. The diameter of this cable is 0.7 mm and as shown in Fig. 2, its starting point is 1.185 mm away from the source. The average energy of this source is 380 keV and the energy spectrum of the emitting photons is given in Table 2 (López et al., 2011).

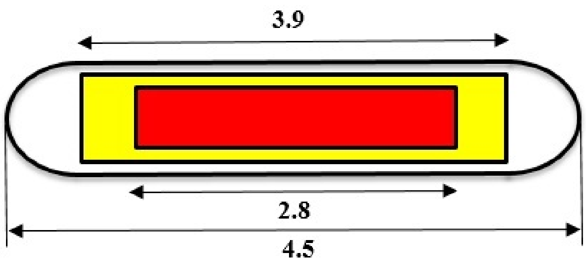

Figure 1: Simulation of 6711 I-125 sources in MCNP5 code (values are written in mm. The diameter of the central core, the chamber containing the air, and the titanium chamber are 0.4, 0.66, and 0.8 mm, respectively)

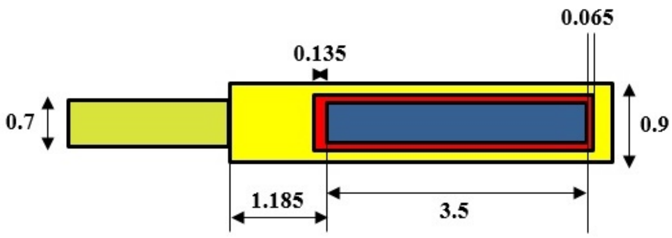

Figure 2: Simulation of Ir-192 source in MCNP5 code (values are written in mm. The internal and external diameters of the source are 0.6 and 0.7 mm).

Table 1: Photon spectrum of I-125 source according to TG-43 and AAPM report.

Photon energy (keV)	Intensity (%)
27.202	40.6
27.472	75.7
30.98	20.2
31.71	4.39
35.492	6.68

Table 2: Photon spectrum of Ir-192 source.

Photon energy (keV)	Intensity (%)
9.44	1.47
11.07	1.24
61.49	1.2
63	2.07
65.12	2.65
66.83	4.53
75.75	1.03
205.8	3.3
295.96	28.67
308.46	0.3
316.51	82.81
468.07	47.83
484.58	3.18
588.58	4.52
604.41	8.23
612.47	5.31

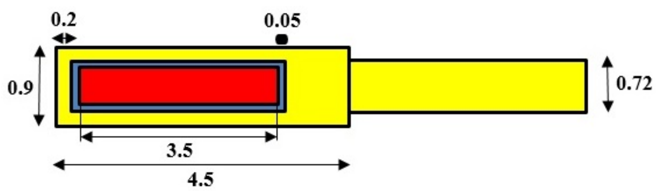

Figure 3: Simulation of Co-60 source in MCNP5 code (values are written in mm. The internal and external diameters of the source are 0.5 and 0.6 mm).

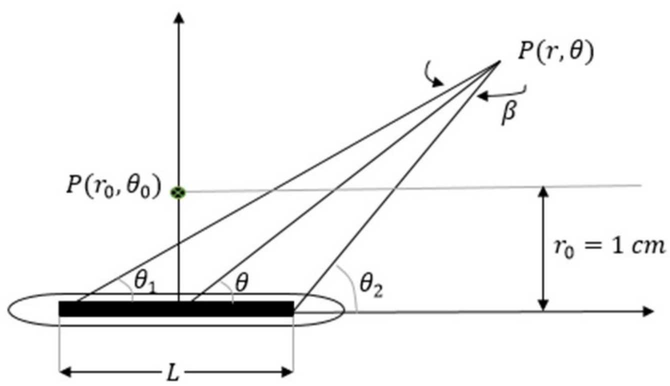

Figure 4: The coordinate system and the parameters used for brachytherapy dosimetry calculations.

Table 3: Photon spectrum of Co-60 source.

Photon energy (keV)	Intensity (%)
347.14	0.0075
826.10	0.0076
1173.23	99.85
1332.49	99.9826
2158.57	0.0012
2505.69	0.000002

Finally, the design and dimensions of the simulated Flexisource Co-60 source are shown in Fig. 3. This seed consists of an active cylindrical metal core of Co-60 with a density of 8.95 g.cm^{-3}, a length of 3.5 mm, and a diameter of 0.5 mm surrounded by a layer of air with a thickness of 0.5 mm. The set is covered with AISI 316L stainless steel with a diameter of 0.9 mm. Also in the present study, we have considered a cable with a length of 5 mm of AISI 316L with an effective density of 3.81 g.cm^{-3} and a diameter of 0.72 mm at the end of the seed. The average energy of this source is 1.525 MeV and its half-life is about 5.26 years. The long half-life of Co-60 makes it a concern for use in brachytherapy. To remedy this, physicians use temporary implants which are removed when the prescribed dose has been reached. The range of energy used in this simulation is given in Table 3 (Vijande et al., 2012). Finally, the physical details and distances of the three sources are shown in Table 4.

AAPM has introduced a dose calculation method to calculate the distribution of 2D doses around symmetrical cylindrical sources. For each source, the dose distribution can be expressed in terms of a polar coordinate system where the origin corresponds to the source center at a distance r from the center to the desired point and angle relative to the longitudinal axis of the source. The point $p(r_0, \theta_0)$ is the reference point on the vertical semicircle of the source at a distance of one centimeter from the source ($r_0 = 1$ cm, $\theta_0 = \pi/2$). The general, 2D dose rate formula from the 1995 TG-43 protocol is given in Eq. (1) (Rivard et al., 2004). Besides, the coordinate system and the parameters used for brachytherapy dosimetry calculations are introduced in Fig. 4.

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

In Eq. (1), $G_L(r, \theta)$, $g_L(r)$, and $F(r, \theta)$ are the geometry function, radial dose function, and anisotropy function, respectively. The geometry function $G_L(r, \theta)$ is normalized to a point 1 cm from the source center along a perpendicular bisector. Its purpose is to quantify the effect of the spatial arrangement of radioactive material on the dose distribution.

The radial dose function, $g(r)$, indicates the effects of photon scattering, the attenuation in water, and dose fall-off on the transverse plane ($\theta_0 = \pi/2$). The radial dose function is defined according to Eq. (2) (Rivard et al., 2004):

$$g(r) = \frac{\dot{D}(r, \theta_0)}{\dot{D}(r_0, \theta_0)} \frac{G_L(r_0, \theta_0)}{G_L(r, \theta_0)} \tag{2}$$

where $\dot{D}(r, \theta_0)$ and $G_L(r, \theta_0)$ are dose rate and geometry function, respectively.

The 2D anisotropy function, $F(r, \theta)$, expresses the angular changes of the dose rate related to seeds at each distance and depends on the intrinsic filtration, the initial filtration of the primary photons passing through the capsule containing the source, and the rate of photon absorption and scattering in the surrounding medium. The 2D anisotropy function is defined according to (Rivard et al., 2004):

$$F(r, \theta) = \frac{\dot{D}(r, \theta)}{\dot{D}(r, \theta_0)} \frac{G_L(r, \theta_0)}{G_L(r, \theta)} \tag{3}$$

The air-Kerma strength (S_K) expresses the intensity of the source used in brachytherapy (K) which should be located on the transverse plane in free space and at a certain distance (d) from the center of the source by the Eq. (4). S_K is represented by the air-Kerma unit (U), where 1 U=1 μGym^2.h^{-1}=1 cGycm^2.h^{-1} (Rivard et al., 2004):

$$S_K = \dot{K}_\delta(d) d^2 \tag{4}$$

Dose rate constant, Λ, is the ratio of dose rate in the water at a distance of 1 cm from the source geometric center on the transverse plane and S_K obtained from Eq. 3. Its unit is cGy.h^{-1}/cGy.m^2.h^{-1}=cGy.h^{-1}.U^{-1} (Nath, 1995):

$$\Lambda = \frac{\dot{D}(r_0, \theta_0)}{S_K} \tag{5}$$

To calculate the absorbed dose rate in cGy.s^{-1}, the following general rule can be applied to each seed (Alizadeh

Table 4: Physical details and distances of sources.

Source	Density (g.cm^{-3})	Average energy (MeV)	Half-life (Days)	Length (mm)	Diameter (mm)
I-125	10.5	0.28	60	2.8	0.4
Ir-192	22.42	0.38	74	3.5	0.6
Co-60	8.95	1.525	1920	3.5	0.5

Table 5: Results of the dose rate constant parameter for 6711 I-125 source, micro Selectron mHDR-v2r Ir-192 source, and Flexisource Co-60 sources and comparison with Dolan, López, Vijande's results.

The source under study	Λ (cGy.H^{-1}U^{-1}) This Work	Comparative Article		Difference (%)
I-125 6711	0.949 ± 0.001	(Dolan et al., 2006)	0.942	0.8
Ir-192 mHDR-v2r	1.109 ± 0.001	(López et al., 2011)	1.112	0.3
Co-60 Flexisource	1.083 ± 0.001	(Vijande et al., 2012)	1.085	0.18

et al., 2015):

$$\begin{aligned}&\text{Dose rate (cGy.s}^{-1}) = \\ &\text{MC output (MeV.g}^{-1}\text{ per photon)} \\ &\times 10^6 \text{ eV.MeV}^{-1} \times 1.602\times 10^{-19}\text{ J.eV}^{-1} \\ &\times 10^3 \text{ g.kg}^{-1} \text{ amount of decay per s (Ci)} \\ &\times 3.7\times 10^{10}\text{ Bq.Ci}^{-1} \\ &\times \#\text{ photon.dis}^{-1} \times 1 \text{ dis.s}^{-1}\text{Bq}^{-1}\end{aligned} \tag{6}$$

According to Eq. (5), to calculate the dose rate constant, two parameters of absorption dose and kerma strength must be calculated for these seeds. For this purpose, according to Eq. (4), the air-kerma strength was calculated first at a distance of one meter and perpendicular to the seed axis ($\theta_0 = 90$). The source was then placed in a vacuum sphere with the center of the coordinate system in the center of the core and the air-kerma was calculated inside the volume enclosed by spherical shells with a radius of 99.5 and 100.5 cm and a cone with a vertex angle of 10° (between two cones with vertex angles of 85 and −85°) using the F6 tally. (The desired cell is approximately located at a distance of one meter and at an angle perpendicular to the source plane) (Rivard, 2009). Thereafter the air-kerma rate can be achieved by multiplying the air-kerma value by the amount of activity of the source and the number of photons in each decay as well as a constant value given in equation 6. In the second step, to calculate the value of the dose rate at the reference point ($r_0 = 1cm, \theta_0 = 90°$) we consider a water sphere with a radius of 15 cm and place the radioactive seed in the center of this sphere. To measure the absorbed dose, a volume enclosed by spherical shells with a radius of 0.95 and 1.05 cm and a cone with a vertex angle of 10° is assumed and calculated using the F6 tally (Sadeghi et al., 2008b), and finally, the dose rate was obtained using the Eq. (6) (Sadeghi and Hosseini, 2010). It is important to mention that due to the low source energy and the short range of the secondary electrons produced by the photons emitted through this source, the transfer of secondary electrons was not simulated and the Kerma was considered equal to the dose (assuming an electronic equilibrium). Now according to Eq. (5), the dose rate constant value is calculated for the I-125 Ir-192 and Co-60 sources.

To obtain the radial dose function according to Eq. (2), the value of the absorption dose rate and the $G_L(r,\theta)$ must be calculated using the Monte Carlo simulation. For this purpose, a brachytherapy seed was placed in the center of the sphere with a radius of 15 cm. To calculate the dose rate at different distances (and at a reference angle of 90°) we assumed a sphere of water and used concentric rings with different thicknesses and conical shells with angles of +85° and −85° and obtained different values of absorbed dose using F6 tally (Saidi et al., 2010). Conical shells were selected to create 90-degree angles at different distances. The $G_L(r,\theta)$ was also determined by the F4 tally at different distances (and at the reference angle of 90°). To exactly determine the $G_L(r,\theta)$, all the materials used in the seed and its surroundings were assumed to be a vacuum and there was no absorption and scattering in the seed and the ambiance. The value of $g(r)$ was measured at different distances and at a reference angle of 90° (Sadeghi et al., 2008a).

Finally, to measure the anisotropy function according to Eq. (3), the value of the dose rate and the $G_L(r,\theta)$ must be calculated at different distances and angles. For this purpose, the brachytherapy seed was placed in the center of the hypothetical sphere (with a density of 0) with a radius of 15 cm.

In the simulation, a high number of particles (about 10^7 photons) was used to achieve a standard deviation of less than 0.2% except along the longitudinal axis where 1% was reached.

The dosimetric parameters obtained for I-125, Ir-192, and Co-60 sources were then compared with the Dolan (Dolan et al., 2006), López (López et al., 2011), and Vijande's (Vijande et al., 2012) works and verified the validation of the present simulation.

3 Results

The Λ parameters for I-125, Ir-192, and Co-60 sources are respectively listed in Table 5, and they are compared with the values obtained in Dolan, López, and Vijande's publications to the validation of the simulation performed.

Also, the radial dose function parameter $g(r)$ for these three sources was obtained in two steps by calculating the absorbed dose and $G_L(r,\theta)$ using Monte Carlo simulation, according to Eq. (2) and using two F6 tally and F4 tally. The parameter $g(r)$ measured for the I-125, Ir-192, and Co-60 sources at various distances with a known reference angle of 90° are shown in Figs. 5, 6, and 7 respectively and are compared with the Dolan, López, and Vijande's works.

The $F(r,\theta)$ anisotropy function was also obtained for the validation of seeds. This function was measured for the I-125 source at distances of 0.5, 1, 2, 3, 4, and 5 cm and angles of 0, 10, 20, 30, 40, 50, 60, 70, 80, and 90°, for the Ir-192 source at distances of 1, 5, 10, and 15 cm and angles of 30, 60, 120, and 150°, and the Co-60 source at distances of 0.5, 1, 2, 3, 4, and 5 cm and angles of 0, 5, 10, 20, 30, 40, 50, 60, 70, 80, and 90°, and the results were presented in Figs. 8 to 23, respectively, to compare with Dolan, López, and Vijande's works.

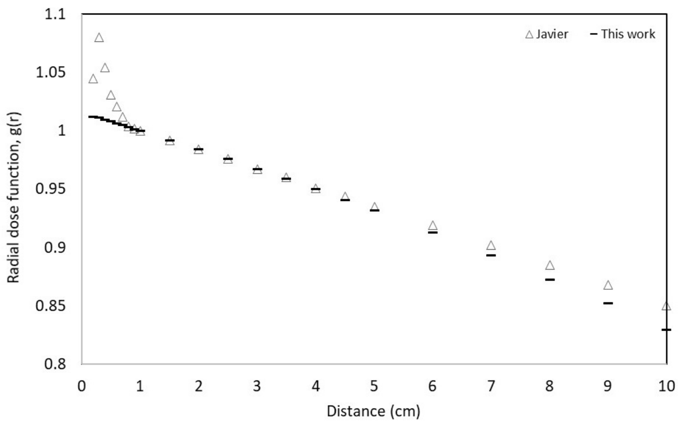

Figure 7: The curve of the radial dose function for Flexisource Co-60 source and comparison with Vijande's (Vijande et al., 2012) results.

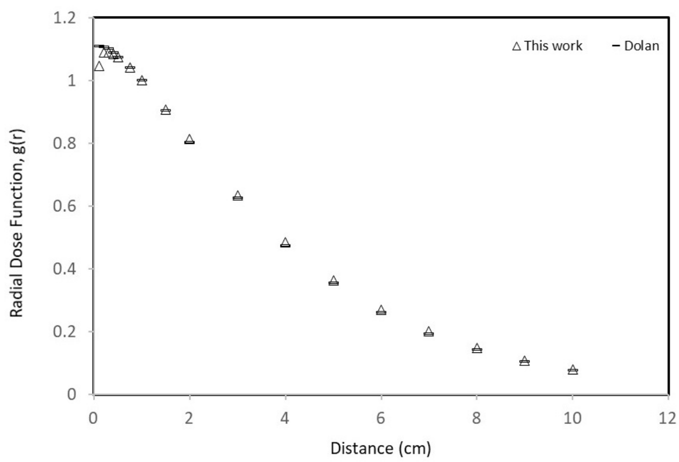

Figure 5: The curve of the radial dose function of 6711 I-125 source, calculated with MCNP5 code and comparison with Dolan's (Dolan et al., 2006) results.

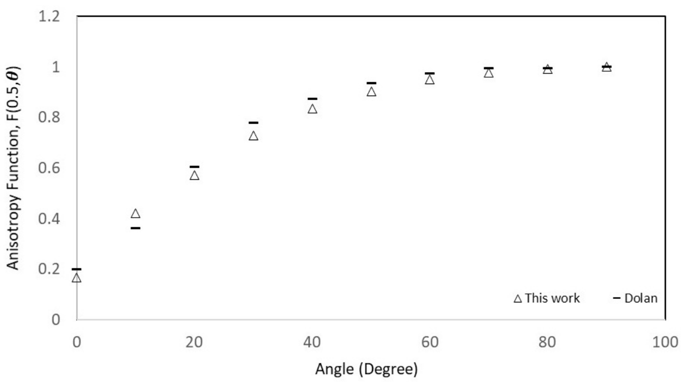

Figure 8: Anisotropy function for 6711 I-125 sources, calculated with MCNP5 code at a distance of 0.5 cm and different angles and comparison with the Dolan's (Dolan et al., 2006) results.

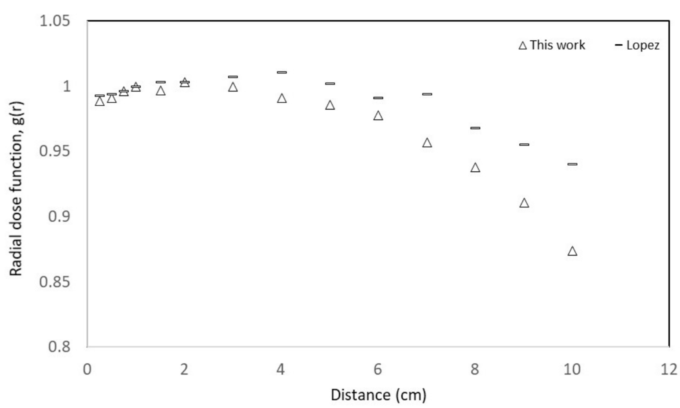

Figure 6: The curve of the radial dose function for micro Selectron mHDR-v2r Ir-192 source and comparison with López's (López et al., 2011) results.

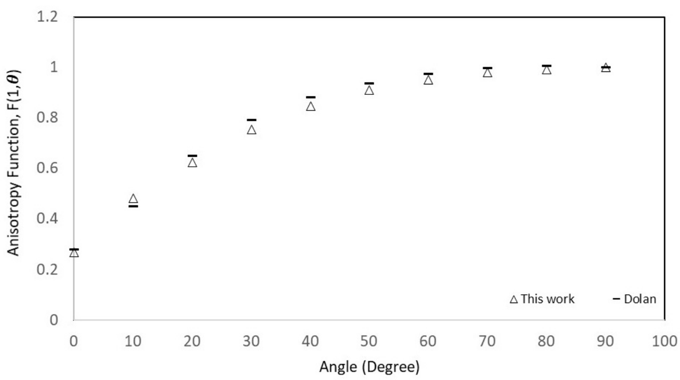

Figure 9: Anisotropy function for 6711 I-125 sources, calculated with MCNP5 code at a distance of 1 cm and different angles and comparison with the Dolan's (Dolan et al., 2006) results.

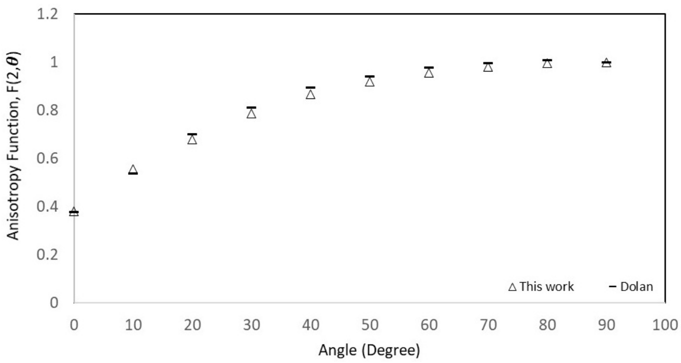

Figure 10: Anisotropy function for 6711 I-125 sources, calculated with MCNP5 code at a distance of 2 cm and different angles and comparison with the Dolan's (Dolan et al., 2006) results.

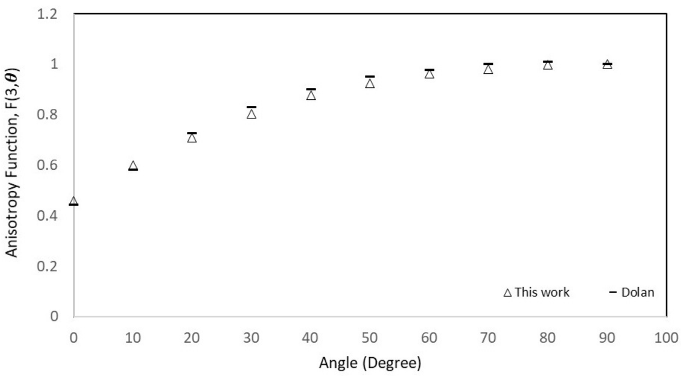

Figure 11: Anisotropy function for 6711 I-125 sources, calculated with MCNP5 code at a distance of 3 cm and different angles and comparison with the Dolan's (Dolan et al., 2006) results.

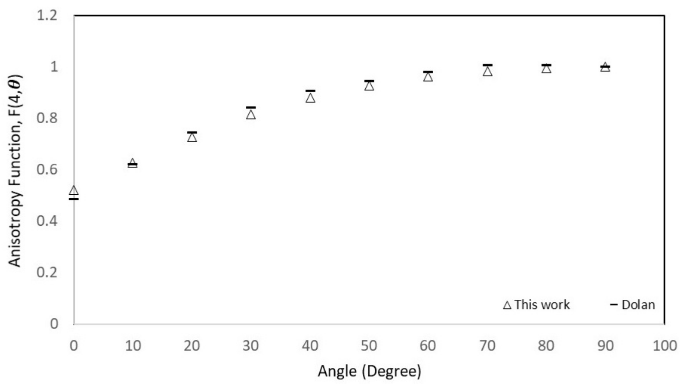

Figure 12: Anisotropy function for 6711 I-125 sources, calculated with MCNP5 code at a distance of 4 cm and different angles and comparison with the Dolan's (Dolan et al., 2006) results.

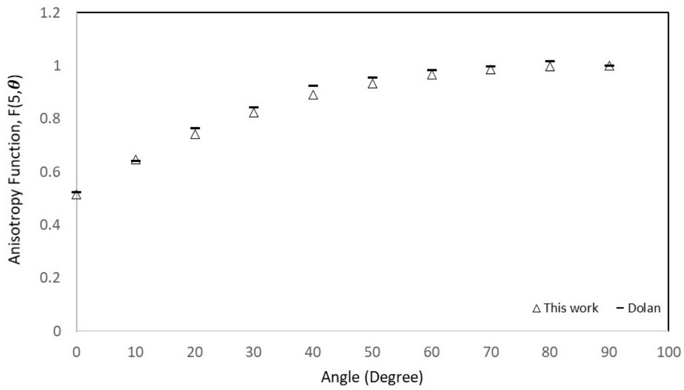

Figure 13: Anisotropy function for 6711 I-125 sources, calculated with MCNP5 code at a distance of 5 cm and different angles and comparison with the Dolan's (Dolan et al., 2006) results.

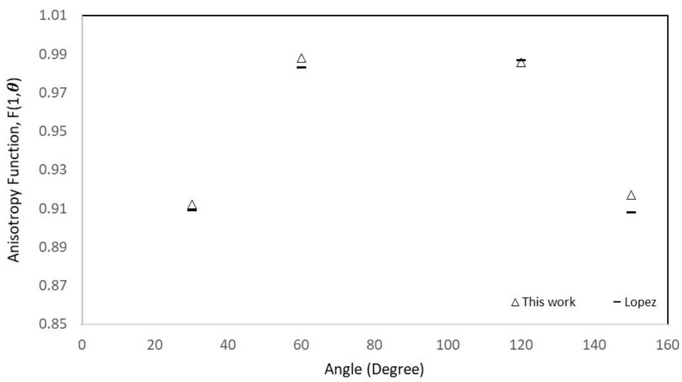

Figure 14: Anisotropy function for micro Selectron mHDR-v2r Ir-192 source, calculated with MCNP5 code at a distance of 1 cm and different angles and comparison with López's (López et al., 2011) results.

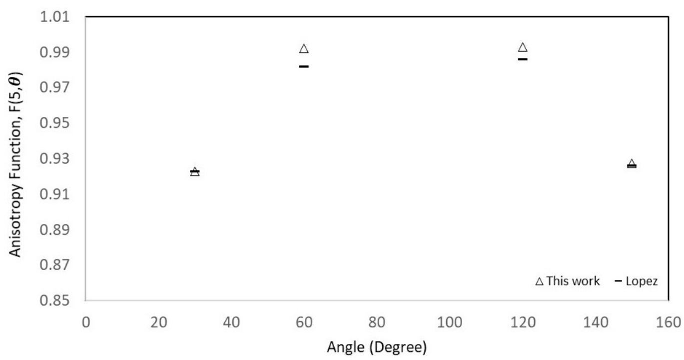

Figure 15: Anisotropy function for micro Selectron mHDR-v2r Ir-192 source, calculated with MCNP5 code at a distance of 5 cm and different angles and comparison with López's (López et al., 2011) results.

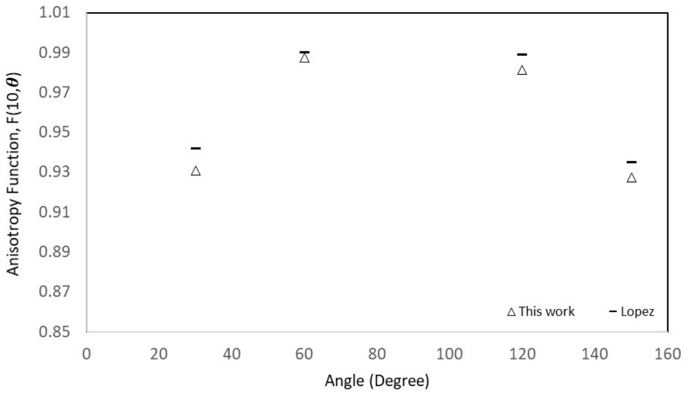

Figure 16: Anisotropy function for micro Selectron mHDR-v2r Ir-192 source, calculated with MCNP5 code at a distance of 10 cm and different angles and comparison with López's (López et al., 2011) results.

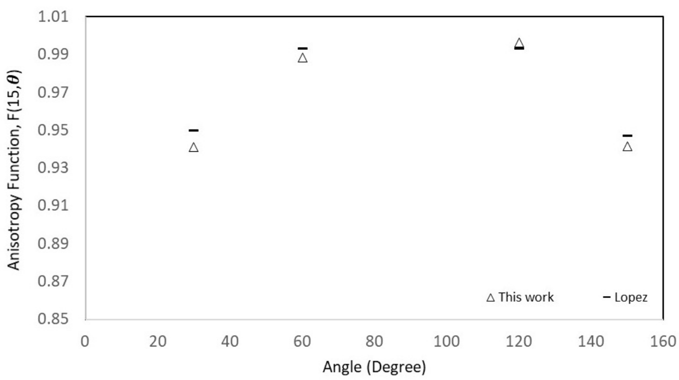

Figure 17: Anisotropy function for micro Selectron mHDR-v2r Ir-192 source, calculated with MCNP5 code at a distance of 15 cm and different angles and comparison with López's (López et al., 2011) results.

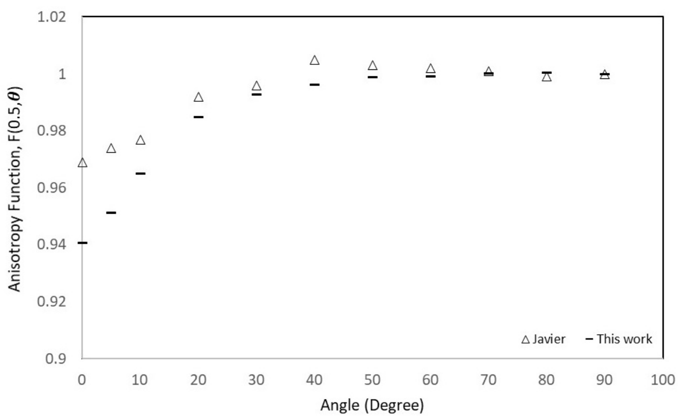

Figure 18: Anisotropy function for Flexisource Co-60 source, calculated with MCNP5 code at a distance of 0.5 cm and different angles and comparison with Vijande's (Vijande et al., 2012) results.

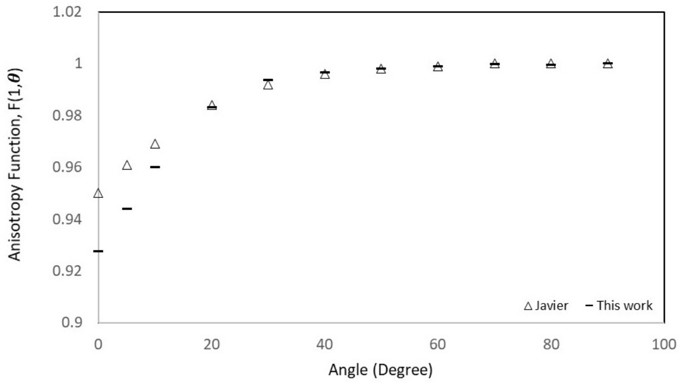

Figure 19: Anisotropy function for Flexisource Co-60 source, calculated with MCNP5 code at a distance of 1 cm and different angles and comparison with Vijande's (Vijande et al., 2012) results.

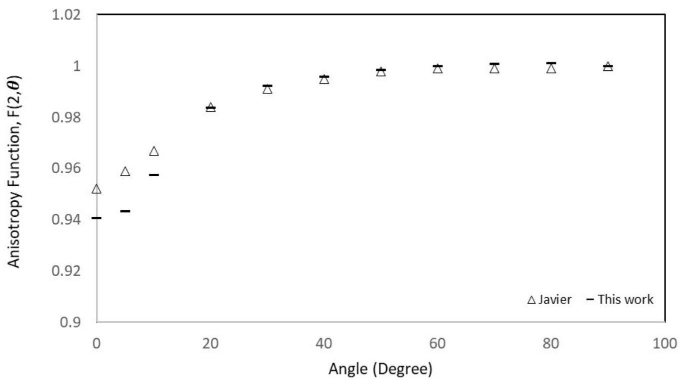

Figure 20: Anisotropy function for Flexisource Co-60 source, calculated with MCNP5 code at a distance of 2 cm and different angles and comparison with Vijande's (Vijande et al., 2012) results.

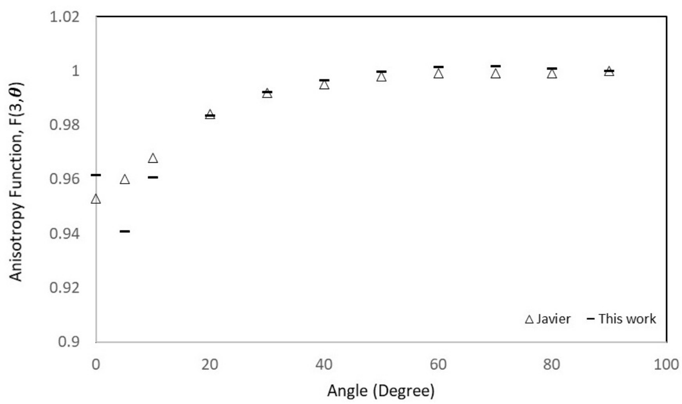

Figure 21: Anisotropy function for Flexisource Co-60 source, calculated with MCNP5 code at a distance of 3 cm and different angles and comparison with Vijande's (Vijande et al., 2012) results.

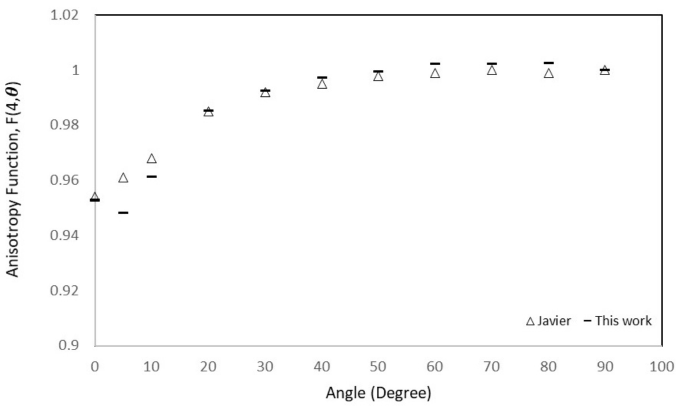

Figure 22: Anisotropy function for Flexisource Co-60 source, calculated with MCNP5 code at a distance of 4 cm and different angles and comparison with Vijande's (Vijande et al., 2012) results.

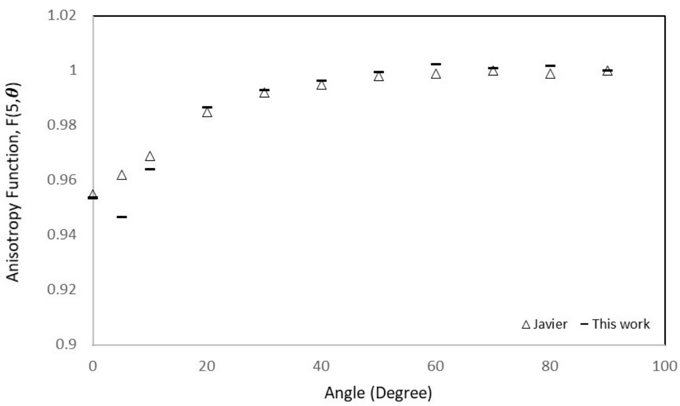

Figure 23: Anisotropy function for Flexisource Co-60 source, calculated with MCNP5 code at a distance of 5 cm and different angles and comparison with Vijande's (Vijande et al., 2012) results.

4 Discussion

According to Table 5, the dose rate constant value for 6711 I-125 seed, Micro Selectron mHDR-v2r Ir-192 seed, and Flexisource Co-60 seed were 0.949 ± 0.001, 1.109 ± 0.001 and 1.083 ± 0.001 cGy.h^{-1}/cGy.m^2.h^{-1} respectively, which was inconsistent with Dolan (Dolan et al., 2006), López (López et al., 2011), and Vijande's (Vijande et al., 2012) articles (differences of 0.8%, 0.3%, and 0.18%, respectively).

Figures 5, 6, and 7 demonstrated the comparison of the data related to the Radial dose function g(r) with the data obtained from the above-mentioned studies. In model 6711 I-125 seed, as shown in Fig. 5, the main difference between the measured values and Dolan's data occurred at a short distance from the source (0.1 cm) (about 5%). Moreover, with increasing distance from the source, the difference became less prominent leading to a good agreement with Dolan's data. In addition, for the Micro Selectron mHDR-v2r Ir-192 seed, as shown in Fig. 6, the difference in the value of $g(r)$ between the calculations in the present study and Lópezs article, indicated an acceptable agreement at distances less than 3 cm (difference less than 0.7%). However, the discrepancies increase with increasing distance from the source up to a maximum difference of approximately 7% at 10 cm from the source. Comparing the $g(r)$ parameter between the present study and Vijande's article, as shown in Fig. 7, it can be concluded that for Flexisource Co-60 seed the difference at short (less than 0.5 cm) and large distances (more than 8 cm) from the source was between 1 and 6%; however, at distances between 0.5 to 8 cm, there was a considerable agreement between the two diagrams. Thus, for all three seeds, although there was no significant difference in the parameter $g(r)$, the observable differences can be attributed to small differences in the dimensions and structure of the source, the spectra used, the inequality of electrons and photons cutoff energy, etc.

According to the diagrams of the anisotropy function for 6711 I-125 seed (Figs. 8 to 13), it can be concluded that elevating the angular distance from the source provides a higher agreement between the present study and the Dolan's study. This indicated that the impact of the factors causing the difference in the absorbed dose between the present study results and Dolan's publication (cited in the comparative section of the radial dose function) became lesser with increasing angular distance. On the other hand, as shown in Figs. 14 to 17, examining the parameter $F(r, \theta)$ on the Micro Selectron mHDR-v2r Ir-192 seed showed that except in rare cases (where the difference in values with Lópezs study is exceeds 1%), the differences in the majority of conditions were below 1%. Finally, by comparing the parameter $F(r, \theta)$ for the Flexisource Co-60 seed to the present study and Vijande's article (as shown in Figs. 18 to 23), it can be inferred that the differences are completely acceptable for most angles at different distances (differences below 1%) except in some places at low angles (with differences 1% to 2%). Therefore, in the case of Co-60 seed, it was also observed that the amount of difference decreases with increasing angular distance from the source.

5 Conclusions

Experimental challenges can lead to inaccurate determination of the dosimetric parameters necessary to accurately compute the dose for brachytherapy treatments. The Monte Carlo MCNP5 code was utilized for the 6711 I-125, MicroSelectron mHDR-v2r Ir-192, and Flexisource Co-60 source models in order to correctly compute their dosimetric parameters. The dose rate constant for the three I-125, Ir-192, and Co-60 seeds were 0.949, 1.1087, and 1.15 cGy.h^{-1}/cGy.m^2.h^{-1} respectively, which were inconsistent with the Dolan's article. Furthermore, a comparison of the $g(r)$ and $F(r, \theta)$ parameters for the three sources with the data of the mentioned studies demonstrated an acceptable consistency, so that these datasets can be used as input in the treatment planning systems and to validate its calculations.

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Conflict of Interest

The authors declare no potential conflict of interest regarding the publication of this work.

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