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Dose distribution and dosimetry parameters calculation of MED3633 palladium-103 source in water phantom using MCNP

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Background: Palladium-103 (^{103}Pd) is a brachytherapy source for cancer treatment. The Monte Carlo codes are usually applied for dose distribution and effect of shieldings. Monte Carlo calculation of dose distribution in water phantom due to a MED3633 ^{103}Pd source is presented in this work. ***Materials and Methods:*** The dose distribution around the ^{103}Pd Model MED3633 located in the center of 30×30×30 cm^3 water phantom cube was calculated using MCNP code by the Monte Carlo method. The percentage depth dose (PDD) variation along the different axis parallel and perpendicular to the source was also calculated. Then, the isodose curves for 100%, 75%, 50% and 25% PDD and dosimetry parameters of TG-43 protocol were determined. ***Results:*** The results show that the Monte Carlo Method could calculate dose deposition in high gradient region, near the source, accurately. The isodose curves and dosimetric characteristics obtained for MED3633 ^{103}Pd source are in good agreement with published results. ***Conclusion:*** The isodose curves of the MED3633 ^{103}Pd source have been derived form dose calculation by MCNP code. The calculated dosimetry parameters for the source agree quite well with their Monte Carlo calculated and experimental measurement values. *Iran. J. Radiat. Res., 2006; 4 (1): 15-19*

Keywords: *^{103}Pd source; dose distribution; isodose curves; MCNP code.*

INTRODUCTION

^{103}Pd brachytherapy sources for prostate and breast cancer therapy are usually used (1-3). Radiation oncologists at Toronto Sunnybrook regional cancer centre in Canada (3) have done the first breast cancer treatment in the world using small beads of ^{103}Pd successfully. To calculate the effect of source shield or applicators and dose distribution usually the Monte Carlo codes such as MCNP, EGS4 or GEANT4 are applied.

Theoretical and experimental dosimetric studies have been supplied useful information on the dependence of the brachytherapy source geometry and material (4-7). To define dose distribution function, the radial dose variation, and the dose calculation close to the source in brachytherapy the Monte Carlo method are used. Rivard presented a discretized approach to determining TG-43 brachytherapy dosimetry parameters using Monte Carlo calculations for the MED3633 ^{103}Pd source (7). In addition, Meigooni *et al.* have determined dosimetric characteristics for brachyseed™ ^{103}Pd, model Pd-1 source theoretically and experimentally (5). Corriveau *et al.* discussed morbidity effect of the time gap between supplemental beam radiation and ^{103}Pd prostate brachytherapy (8).

In the present work, to calculate relative dose in water phantom, MCNP4C code is used (9). Then, the isodose curves and dosimetric characteristics for MED3633 ^{103}Pd source have been determined.

MATERIALS AND METHODS

The ^{103}Pd Source

The internal construction and dimensions of the ^{103}Pd source Model MED3633 is illustrated in figure 1. The source contains four resin spheres, each 0.5 mm in diameter, capsulated inside a titanium cylinder nominally of 4.5 mm length and 0.8 mm external diameter. Two 0.5 mm diameter spheres of gold-copper mixture were placed in

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the middle of the source, separating the radioactive spheres into two groups of two spheres. These gold-copper spheres therefore serve as radiographic markers for visualization during and after the prostate seed implantation process, constituting the "mid-markers" design. The photons spectrum emitted per decay of ^{103}Pd and their intensities are listed in table 1 (7). The source photons' with energies less than 5 keV, and source beta electrons are ignored, due to their negligible chance of penetrating the titanium capsule.

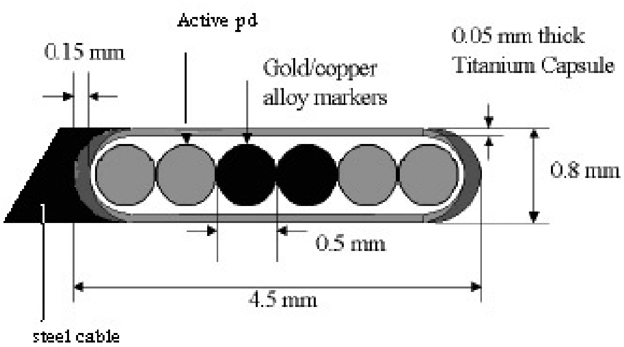

Figure 1. Schematic diagram of the MED3633 ^{103}Pd source.

Method of dose calculation in water phantom

The dose distribution has been calculated around the ^{103}Pd located in the center of 30×30×30 cm^3 water phantom cube (figure 2) by using tally F6:p of MCNP code (9). In order to use variance reduction techniques of MCNP, we have applied F6:p tally in our calculations. The tally in the sphere of 0.1 mm diameter cell was evaluated as dose in the point center of the sphere.

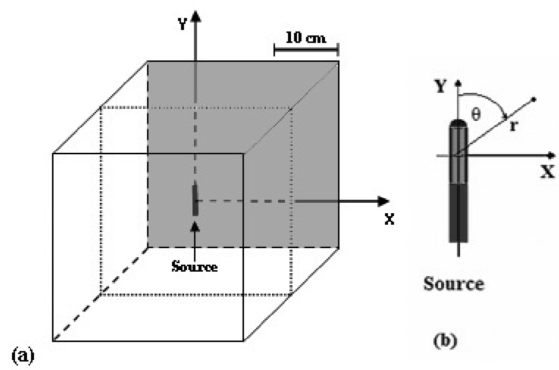

Figure 2. a) Scheme of water phantom and ^{103}Pd source located in the centre of cube, b) the source in large size.

Table 1. The photon spectrum of ^{103}Pd source, used in the simulation.

Photon Energy (keV)	Photons per disintegration (%)	Photon Energy (keV)	Photons per disintegration (%)	Photon Energy (keV)	Photons per disintegration (%)
20.074	22.4	23.312	1.94	294.95	0.0028
20.216	42.3	39.755	0.0683	357.46	0.0221
20.717	10.4	62.51	0.00104	497.054	0.00401

RESULTS AND DISCUSSION

Monte Carlo dose calculation

The relative dose curves along the X-axis with 0.1 mm step and along the Y-axis with 0.1 mm step was calculated. Dose at X=2 mm, Y=0 mm point was selected 100 as reference point in percentage depth dose (PDD) scale. Figure 3 shows the PDD variation along the X=1 and 2.5 mm which the effect of source shield is clear in this figure. PDD along Y=0 and 1.5 mm are shown in figure 4. Then, the isodose points by interpolate from relative dose curves were found. The isodose curves for 100%, 75%, 50% and 25% is shown in figure 5. It can be seen easily that D=D(r,θ), dose distribution depends to r and θ, distance from the center of source and polar angle, respectively. The results for computation of model dependent parameters in the next section are used.

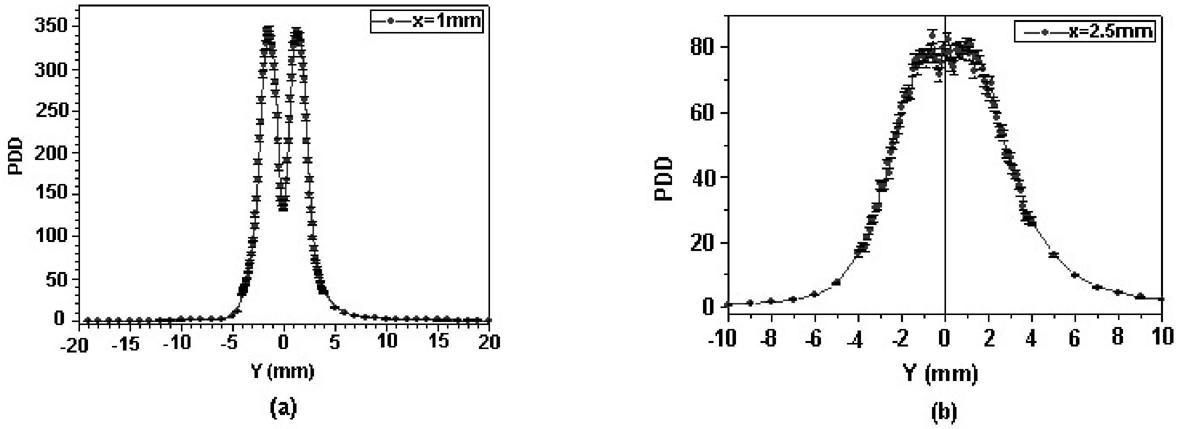

Figure 3. PDD variation along the X=1 and 2.5mm.

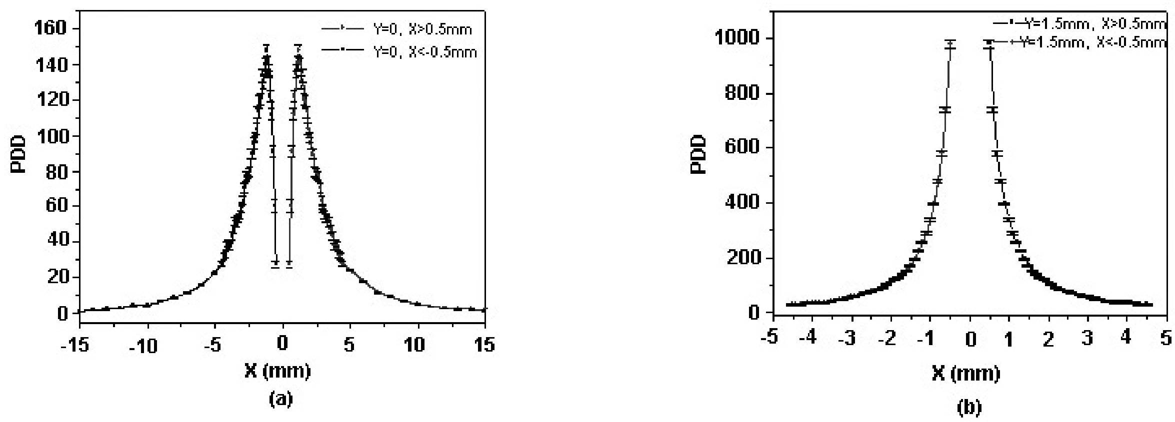

Figure 4. (a) PDD along Y=0 mm and (b) PDD along Y=1.5 mm.

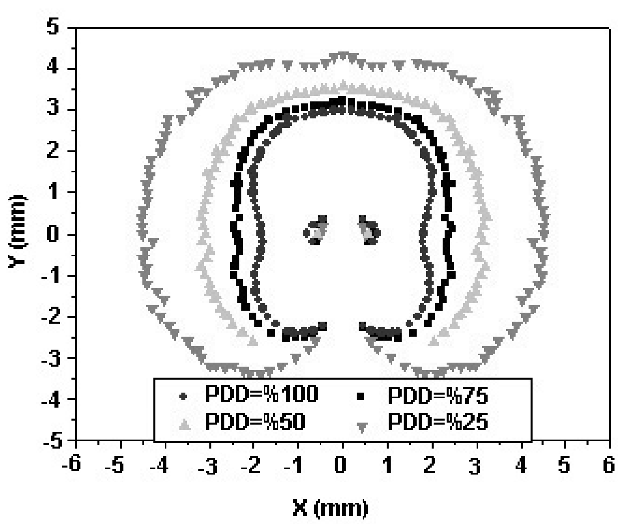

Figure 5. The isodose curves calculated by MCNP (the reference Point: X=2 mm, Y=0 mm).

Determination of dosimetry parameters

Radial dose function, and the dose rate constant and anisotropy function are others obtained dosimetry important parameters, which have been determined to compare our result with those. According to TG43 protocol (7, 10) the absorbed dose can be expressed as:

$$\dot{D}(r,\theta) = S_k \Lambda \frac{G(r,\theta)}{G(r_0,\theta_0)} g(r) F(r,\theta) \qquad (1)$$

where S_k is the air kerma strength, Λ is the dose rate constant, $G(r,\theta)$ is the geometry factor, $F(r,\theta)$ is the anisotropy function, $g(r)$ is radial dose function, t is time, and (r_0, θ_0) is the reference point. To use our simulated data in treatment planning programs based on TG43 formalism, we have extracted the dosimetry parameters from our simulation expressed as following equation:

$$\Lambda = \frac{\dot{D}(r_0,\theta_0)}{S_k} \quad (2)$$

$$g(r) = \frac{\dot{D}(r,\theta_0)}{\dot{D}(r_0,\theta_0)}\ \frac{G(r_0,\theta_0)}{G(r,\theta_0)} \quad (3)$$

$$F(r,\theta) = \frac{\dot{D}(r,\theta)}{\dot{D}(r,\theta_0)}\ \frac{G(r,\theta_0)}{G(r,\theta)} \quad (4)$$

Upon comparison of g(r) for the ^{103}Pd source measured or calculated by various investigators [4, 6, 7], in table 2, it is evident that there has been relatively good agreement over all radial distances. Also, the values of dose rate constant Λ obtained by different authors are listed in table 3 which is in accordance with other results. Figure 6 also shows a comparison of F(1 cm, θ) obtained in this study and the results published by Rivard [4].

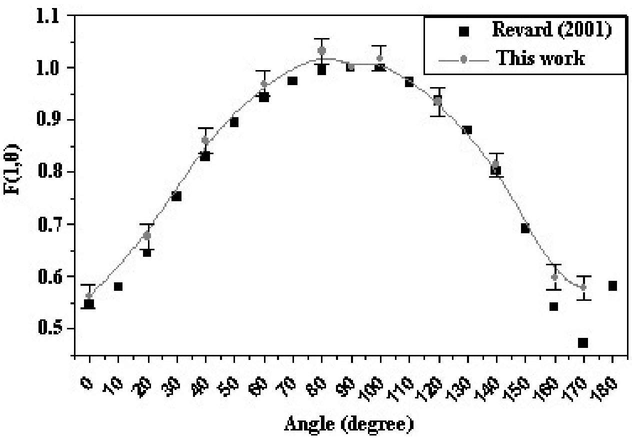

Figure 6. Comparison of the results obtained for F(1 cm, θ) in this study with the result reported by Rivard [4].

CONCLUSION

The isodose curves of the MED3633 ^{103}Pd source have been derived form dose calculation by MCNP code. The results show that by the Monte Carlo method dose deposition in high gradient region, near the source, could be calculated accurately. The calculated dosimetry parameters for the

Table 2. Computational and experimentally obtained g(r) values against r, reported by various investigators.

r (cm)	TLD by Wallace *et al.* (1999)	Diode by Li *et al.* (2000)	MCPT code by Li *et al.* (2000)	MCNP code by Rivard (2001)	MCNP code This work
0.50	1.275	1.345	1.243	1.243	1.251
0.75	1.132	-	1.125	1.120	1.122
1.50	0.769	0.772	0.770	0.780	0.780
2.00	0.580	0.551	0.583	0.603	0.587
3.00	0.318	0.362	0.325	0.347	0.339

Table 3. The values of dose rate constant reported by different authors.

TLD by Wallace *et al.* (1999)	Diode by Li *et al.* (2000)	MCPT code by Li *et al.* (2000)	MCNP code by Rivard (2001)	MCNP code This work
Λ =0.70	Λ =0.721	Λ =0.677	Λ =0.672	Λ =0.669

source agree quite well with their Monte Carlo calculated and experimental measurement values. This study demonstrated a useful approach using MCNP code for dose calculation applicable to many other fields.

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