

Dosimetry Parameters Determination of ^{169}Yb Brachytherapy Source Model X1267

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Abstract

Monte Carlo calculation of dose distribution in soft tissue phantom and determination of dosimetry parameters, due to a high dose rate ^{169}Yb source have been presented in this work. Dose deposition in high gradient region, near the source, can only be calculated accurately by Monte Carlo method. The results for this material of phantom can be used in treatment planning systems. The calculated dosimetry parameters for the source are in agreement well with the Monte Carlo and experimental results of others published literatures. We have used MCNP4C code for the calculation.

Keywords: ^{169}Yb source, MCNP code, Dose calculation

1. Introduction

Theoretical and experimental dosimetric studies have been supplied useful information on the dependence of the brachytherapy source geometry and materials (Mainegra et al, 2000). Usually, Monte Carlo method has been used to define dose distribution function, the radial dose variation, and the dose calculation close the source in brachytherapy. A number of studies have been performed that allow comparison of dosimetric results for ytterbium prototype seeds before clinical use (Mason et al, 1992; Perera et al, 1994). Monte Carlo calculation was used to characterize the distribution of absorbed dose around some commercially available sources like ^{125}I seeds model 6711 and 6702, ^{192}Ir stainless-steel and platinum-covered 3 mm seeds, ^{169}Yb seed models 5, 6, 8 and X6712, and ^{103}Pd seed by Mainegra et al. (2000). Also, Piermattei et al. have determined dosimetric characteristics for brachyseed ^{169}Yb , model X1267 source experimentally (Piermattei et al, 1995).

^{169}Yb brachytherapy sources are used normally in prostate and breast cancer therapy (Lief, 2005). For calculating the effect of source shield or applicators and dose distribution usually Monte Carlo codes as MCNP, EGS4, GEANT are applied (Selvam et al, 2003). In this present work, we have used MCNP4C code (Briesmeister, 2000) to calculate relative dose in the soft tissue phantom.

2. The ^{169}Yb Source

Ytterbium-169 is a source that it has been proposed as a replacement for iodine-125 in permanent implant brachytherapy. It has a slightly higher initial dose rate of 12.5cGy/hr and also a higher energy of 93keV, thus allowing more favorable dose distributions and negligible tissue self-attenuation compared with both palladium and iodine implants. Its disadvantage as a permanent implant material is the presence of a small (less than three percent) photon peak at 300keV that significantly affects the radiation protection requirements required for its use.

Offsetting that disadvantage is its high specific activity, which translates into the possibility of developing physically small, high-activity sources as a replacement for ^{192}Ir in temporary brachytherapy (Porter et al, 1995).

The internal construction and dimensions of the HDR ^{169}Yb source model X1267 is illustrated in Figure 1 (Piermattei et al, 1995). We have assumed that the radioactive material is uniform distributed within the ^{169}Yb

active core. The photons spectrum emitted per decay of ^{169}Yb and their intensity are shown in Figure 2 (Selvam et al, 2003). The beta rays of the source were ignored due to their negligible chance of penetrating the titanium capsule.

3. Dose calculation in water and soft tissue phantoms

In the present work, the dose distribution has been calculated around the ^{169}Yb source located in the center of 30 cm $\times$ 30 cm $\times$ 30 cm water or soft tissue phantom by using tally F6:p of MCNP code (Briesmeister, 2000). Tally F6 has been evaluated in 0.1 mm diameter sphere cell as dose in point center of the sphere. First, along the X axis with 0.1 mm step and along the Y axis with 0.1 mm step, relative dose curves have been calculated. Dose at X=2 mm, Y=0 mm point is selected 100 as reference point in percentage depth dose (PDD) scale. Then, the isodose points were found by interpolate from relative dose curves.

4. Results and discussion

Figure 3 shows the PDD variation along the Y=0 mm and Y=3 mm which the effect of source shield is clear in this figure. Also, the PDD variation along the X=0.5 mm and X=2 mm are shown in Figure 4. The isodose curves for 100%, 75%, 50% and 25% results in water phantom are shown in Figure 5. As well as, Figure 6 shows the same isodose curves for the soft tissue phantom. It can be seen easily dose distribution depends to r and θ , distance from the center of source and polar angle, respectively. The results can be used for computation of model dependent parameters such as anisotropy dose function.

5. Determination of dosimetry parameters

Radial dose function, the dose rate constant and anisotropy function, are dosimetry important parameters that have been determined to compare our result with which was obtained by others. According to TG43 protocol (Rivard, 2001; Nath et al, 1995), the absorbed dose can be expressed as:

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

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. For the use of our simulated data in treatment planning programs based on TG43 formalism, we have extracted from our simulation the dosimetry parameters that appear in the following expression:

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

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

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

Computational of $g(r)$ value against r for the ^{169}Yb source model X1267 in water and soft tissue phantoms illustrated in Table 1. Moreover, Table 2 and Table 3 show $F(r, \theta)$ for water and soft tissue phantoms against θ obtained in this study.

Upon comparison of $F(1 \text{ cm}, \theta)$ for the ^{169}Yb source measured or calculated by Mainegra et al (2000) and this work in Table 4, it is evident there was relatively good agreement over all radial distances. Also, Figure 7 shows good agreement for $F(1 \text{ cm}, \theta)$ between the result of Piermattei et al (1995) and this study for ^{169}Yb source.

6. Conclusion

Dose deposition in high gradient region, near the source, can only be calculated accurately by Monte Carlo method. The result can be used in treatment planning systems and also for computation of model dependent parameters. The calculated dosimetry parameters for the source are agree quite well with Monte Carlo result of Mainegra et al. (2000), Piermattei et al. (1995) which can be useful in treatment in therapeutic plan. The present work demonstrates a useful approach using MCNP code calculation that can be applied in many other fields.

7. Acknowledgements Conclusion

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References

- Briesmeister, J. F., Editor. (2000). *MCNP- A general Monte Carlo N-Particle transport code*, version 4C. Los Alamos National Laboratory Report LA-13709-M.
- Lief, E. (2005). *Modern Advances in Prostate Brachytherapy*. AAPM Brachytherapy School Seattle.
- Mainegra E, Capote R, López E. (2000). Anisotropy functions for ^{169}Yb brachytherapy seed models 5, 8 and X1267. An EGS4 Monte Carlo study. *Physics in Medicine & biology*, 45, 3693-3705.
- Mason, D., Battista, J., Barnett, R., & Porter, A. T. (1992). Ytterbium 169: Calculated physical property of a new radiation source for brachytherapy. *Medical Physics*, 19, 695-703.
- Nath, R., Anderson, L. L., Luxton, G., Weaver, K. A., Williamson, J. F., & Meigooni, A. S. (1995). Dosimetry of interstitial brachytherapy sources: recommendations of the AAPM Radiation Therapy Committee Task Group No. 43, American Association of Physicists in Medicine. *Medical Physics*, 22(2), 209–234.
- Perera, H., Williamson, J. F., Zuofeng, L., Mishra, V., & Meigooni, A. S. (1994). Dosimetric characteristics, air-kerma strength calibration and verification of Monte Carlo simulation for a new ytterbium-169 brachytherapy source. *International Journal of Radiation Oncology Biology Physics*, 28, 953-970.
- Piermattei, A., Avario, L., Rossi, G., Soriani, A., Arcovito, G., Ragona, R., Gallesi, M., & Taccini, G. (1995). Dosimetry of ^{169}Yb seed model X1267. *Physics in Medicine and Biology*, 40, 1317-1330.
- Porter, A. T., Blasko, J. C., Grimm, P. D., Reddy S. M., & Ragde, H. (1995). Brachytherapy for Prostate Cancer. *Cancer Journal for Clinician*, 45, 165- 178.
- Rivard, M. J. (2001). A discretized approach to determining TG-43 brachytherapy dosimetry parameters: case study using Monte Carlo calculations for the MED3633 ^{103}Pd source. *Applied Radiation and Isotopes*, 55, 775–782.
- Selvam, T. P., Rajan, K. N. G., Sethulakshmi, P., & Bhatt, B. C. (2003). Monte Carlo aided room scatter corrections in the air-kerma strength standardization of ^{169}Yb and ^{60}Co brachytherapy sources. *Physics in Medicine and Biology*, 48(11), N139-N147.

Table 1. Computational of $g(r)$ value against r with MCNP code calculation

Distance along transverse axis (cm)	0.2	0.35	0.5	0.75	1	1.5	2	2.5	3	3.5	4	4.5	5
Water Phantom	1	0.971	0.963	0.945	0.970	0.997	0.989	1.062	1.036	1.124	1.024	1.014	1.067
Soft Tissue Phantom	1	0.967	0.957	0.939	0.972	0.987	1.017	1.055	1.079	1.139	1.074	1.046	0.961

Table 2. Computational of $F(r, \theta)$ value against r with MCNP code calculation in water phantom

θ (deg)	$r(\text{cm})$									
	0.5	1	1.5	2	2.5	3	4	5	6	7
10	0.6487	0.6697	0.6897	0.7140	0.7183	0.7408	0.7831	0.8024	0.8167	0.8271
20	0.7727	0.7895	0.7895	0.8074	0.8006	0.8133	0.8454	0.8487	0.8494	0.8802
30	0.8351	0.8497	0.8574	0.8652	0.8827	0.8826	0.9001	0.9015	0.9034	0.9096
40	0.8791	0.8912	0.9001	0.9193	0.9361	0.9365	0.9377	0.9401	0.9458	0.9548
50	0.9425	0.9471	0.9489	0.9506	0.9543	0.9582	0.9599	0.9641	0.9657	0.9678
60	0.9487	0.9693	0.9623	0.9684	0.9680	0.9712	0.9788	0.9734	0.9703	0.9744
70	0.9737	0.9803	0.9819	0.9899	0.9856	0.9867	0.9872	0.9861	0.9878	0.9891
80	0.9906	0.9931	0.9970	0.9986	0.9975	0.9985	0.9913	0.9940	0.9977	0.9983
90	1	1	1	1	1	1	1	1	1	1

Table 3. Computational of $F(r, \theta)$ value against r with MCNP code calculation in soft tissue phantom

θ (deg)	$r(\text{cm})$									
	0.5	1	1.5	2	2.5	3	4	5	6	7
10	0.6855	0.7011	0.7326	0.7597	0.7837	0.8024	0.8281	0.8383	0.8508	0.8675
20	0.8014	0.8016	0.8122	0.8226	0.8343	0.8488	0.8569	0.8800	0.8993	0.9124
30	0.8599	0.8721	0.8863	0.8974	0.9087	0.9112	0.9139	0.9135	0.9140	0.9270
40	0.8907	0.9086	0.9119	0.9257	0.9381	0.9452	0.9485	0.9501	0.9572	0.9581
50	0.9490	0.9512	0.9547	0.9583	0.9642	0.9687	0.9703	0.9718	0.9720	0.9717
60	0.9547	0.9724	0.9751	0.9784	0.9791	0.9782	0.9764	0.9773	0.9767	0.9759
70	0.9822	0.9847	0.9830	.9894	0.9875	0.9868	0.9869	0.9872	0.9887	0.9893
80	0.9995	0.9986	0.9973	0.9981	0.9987	0.9972	0.9983	0.9997	0.9992	0.9989
90	1	1	1	1	1	1	1	1	1	1

Table 4. Comparison of the results F (1cm, θ) in this study with the result of Mainegra et al (2000)

Distance along transverse axis (cm)	10°	20°	30°	40°	50°	60°	70°	80°
This Work	0.6697	0.7895	0.8497	0.8912	0.9471	0.9693	0.9803	0.9931
Mainegra et. al	0.6387	0.7719	0.8523	0.9080	0.9458	0.9725	0.9901	0.9977

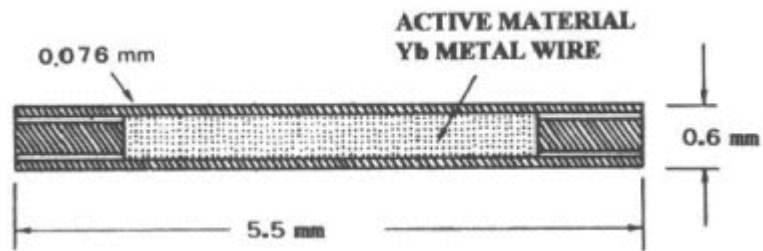


Figure 1. Schematic of the X1276 ^{169}Yb source

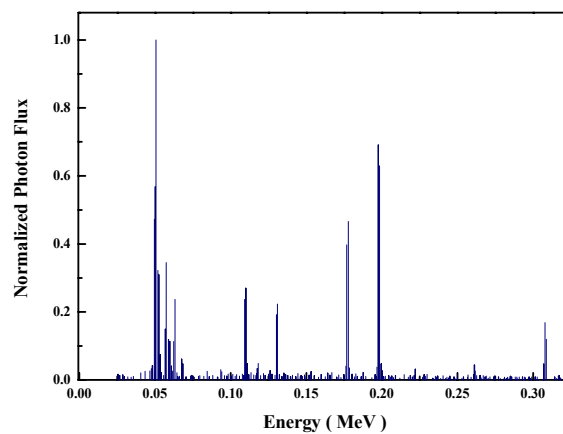


Figure 2. The photon spectrum of ^{169}Yb source is used in our simulation

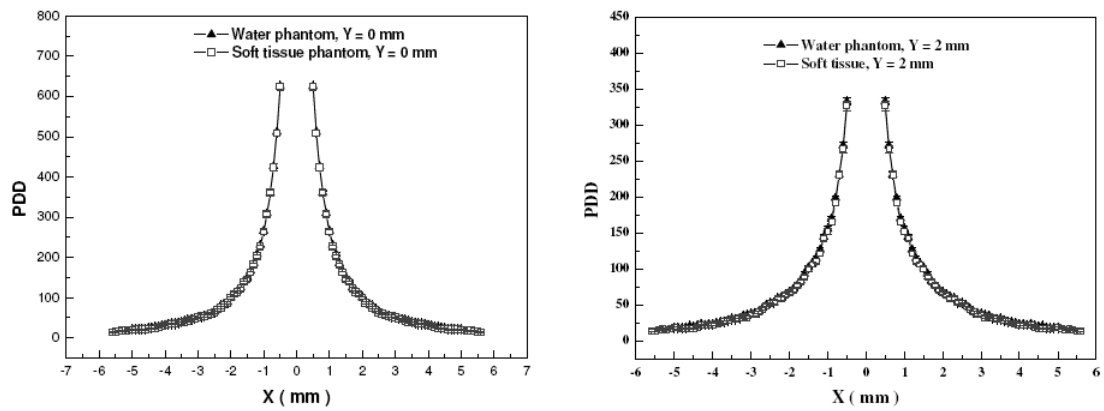


Figure 3. PDD variation along the Y=0 mm and Y=2 mm

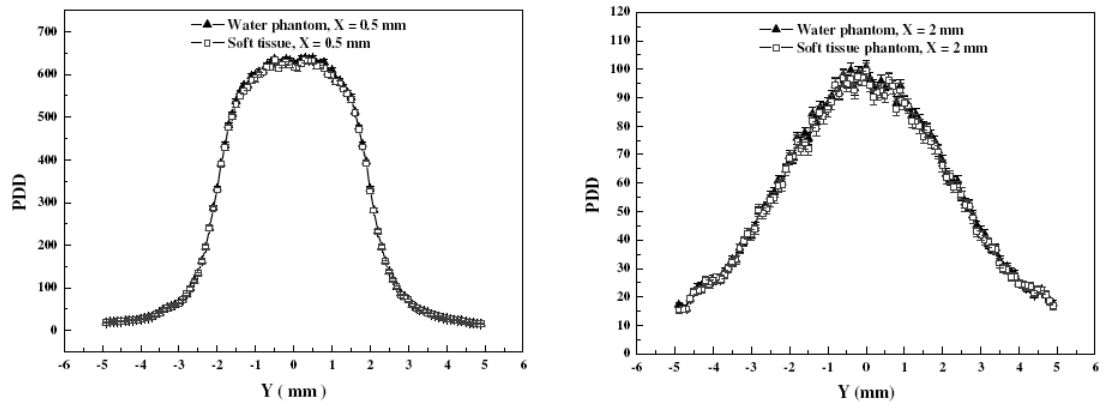


Figure 4. PDD variation along the X=0.5 mm and X=2 mm

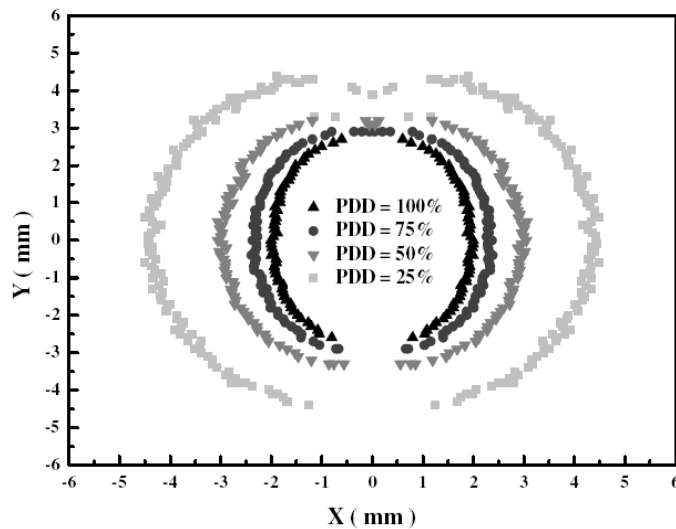


Figure 5. The isodose curves calculated in water phantom (the reference point: X=2 mm, Y=0 mm)

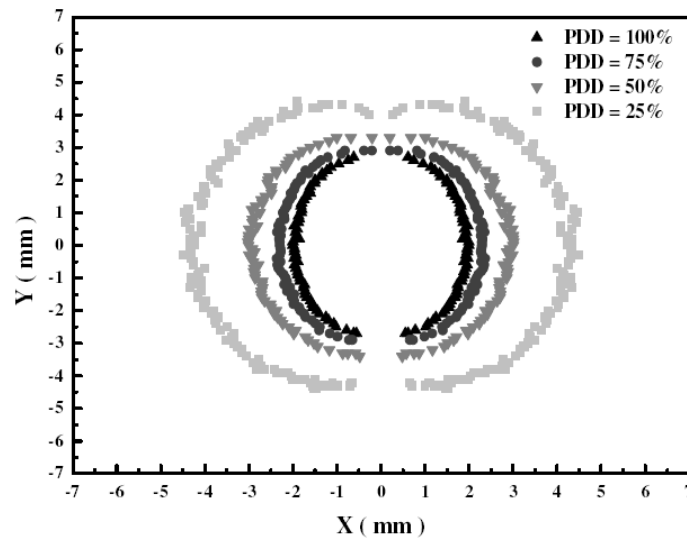


Figure 6. The isodose curves calculated in soft tissue phantom (the reference point: $X=2$ mm, $Y=0$ mm)

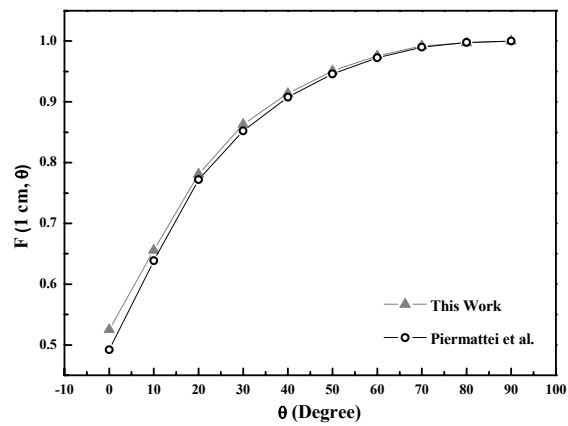


Figure 7. Comparison of the results $F(1\text{ cm}, \theta)$ in this study with the result of Piermattei et al (1995)