Iran. J. Radiat. Res., 2008; 6 (1): 37-42

Monte Carlo and experimental relative dose determination for an Iridium-192 source in water phantom

A.A. Mowlavi[1*], F. Cupardo[2], M. Severgnini[2]

[1] Physics Department, School of Sciences, Sabzevar Tarbiat Moallem University, Sabzevar, Iran
[2] Servizio di Fisica Sanitaria, Ospedali Riuniti di Trieste, Trieste, Italy

Background: Monte Carlo and experimental relative dose determination in a water phantom, due to a high dose rate (HDR) ^{192}Ir source is presented for real energy spectrum and monochromatic at 356 keV. ***Materials and Methods:*** The dose distribution has been calculated around the ^{192}Ir located in the center of 30 cm ×30 cm ×30 cm water phantom using MCNP4C code by Monte Carlo method. Relative dose variation has been measured by using Gafchromic Rtqa along X and Y axis, as well. Percentage depth dose (PDD) variation along the different axis parallel and perpendicular the source were calculated. Finally, F (5cm, θ) dosimetry parameters of TG-43 protocol were determined. ***Results:*** The results showed 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 ^{192}Ir source are in good agreement with experimental results. ***Conclusion:*** The isodose curves of the ^{192}Ir source were derived form dose calculation by MCNP code. Also, Monte Carlo and experimental PDD X=2.5 mm are in good agreement, and the both results y=10 mm, in x∈ [-25mm,25mm] interval were well matched. However, out of this range Monte Carlo result was estimated to be lower. The calculated dosimetry parameters for the source were in agreement with other results. **Iran. J. Radiat. Res., 2008; 6 (1): 37-42**

Keywords: *Brachytherapy, dose distribution, Monte Carlo method, MCNP code, anisotropy function, Gafchromic Rtqa film.*

INTRODUCTION

Theoretical and experimental studies have been applied for dosimetric parameters determination of the brachytherapy sources [1-3]. Usually, Monte Carlo method has been used to define such quantities as the anisotropy dose function, the radial dose function, and the dose calculation close to the source in brachytherapy [4-6].

^{192}Ir source is used widely in brachytherapy to treat localized tumors near body site. Daskalov *et al.* [7] have done dosimetric modeling of the microselectron HDR ^{192}Ir source by the multigroup discrete ordinates method. Recently, Sureka *et al.* calculated the relative dose distribution and effective transmission around a shielded vaginal cylinder with HDR ^{192}Ir source using MCNP4B [8]. In the present study, MCNP4C [9] code was used to calculate relative dose and anisotropy dose function and radial dose function TG-43 dosimetry parameters of microselectron HDR ^{192}Ir in a water phantom and compared with the measured dose by Gafchromic Rtqa film.

MATERIALS AND METHODS

The internal construction and dimensions of Microselectron HDR ^{192}Ir source is illustrated in figure 1. The source has been manufactured by Nucletron Company (The Netherland). The simulated source was a cylinder of about 30% Ir and 70% Pt with 21.704 g/cm^3 density, encased in a stainless steel. It was assumed that the radioactive material to be uniformly distributed within the ^{192}Ir active core. The decay scheme of ^{192}Ir was available on-line in the Nuclear Data

Corresponding author:
Dr. Ali Asghar Mowlavi, Physics Department, School of Sciences, Sabzevar Tarbiat Moallem University, P.O. Box 397, Sabzevar, Iran.
Fax: *+98 571 4411161*
E-mail: *amowlavi@sttu.ac.ir*

[Downloaded from ijrr.com on 2026-09-17]

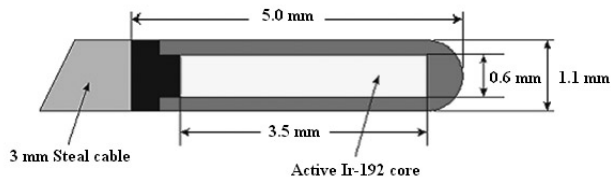

Figure 1. Schematic diagram of the ^{192}Ir source; a cylinder of about 30% Ir and 70% Pt with 21.704 g/cm^3 density, encased in a stainless steel.

Base of the IAEA. Pia *et al.* [5] used the monochromatic spectrum at 356 keV in their simulation with GEANT4 for brachytherapy treatment. Figure 2 shows the real [2] and monochromatic spectra of the source per decay. It was observed that the real spectrum had been important in dose calculation near and far from the source.

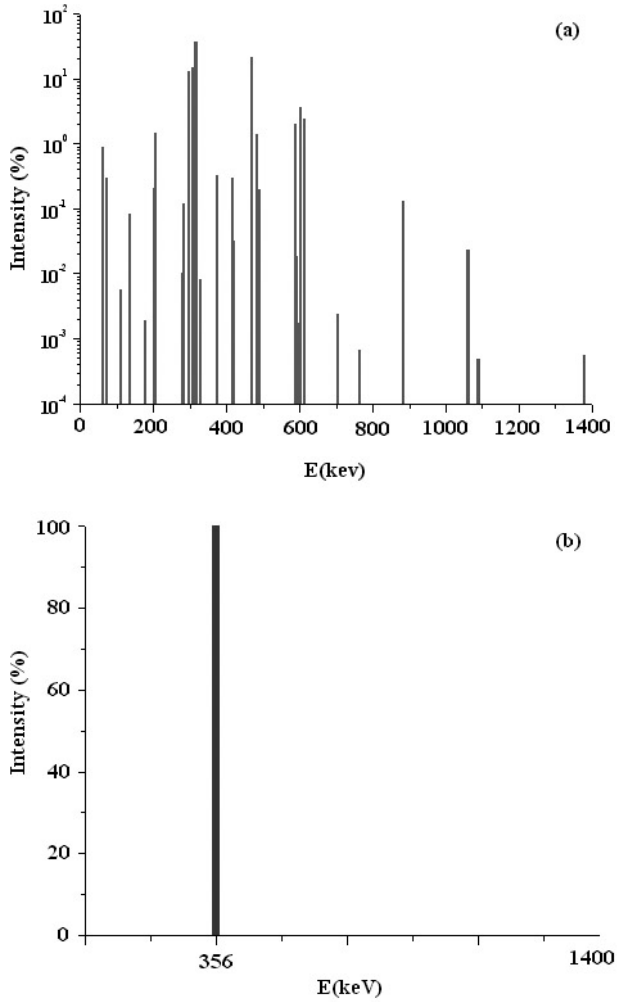

Figure 2. The real spectrum of ^{192}Ir (a), and the monochromatic spectrum at 356 keV (b).

Dose Calculation and Measurment in Water Phantom

Relative dose calculation

The dose distribution was calculated around the ^{192}Ir located in the center of 30 cm ×30 cm ×30 cm water phantom cube (figure 3) by using tally *F8:p of MCNP code. Tally *F8 was evaluated in the point center of a sphere with 0.1 mm diameter cell. First, the relative dose curves were calculated along the X axis with 0.2 mm step and along the Y axis with 0.2 mm step. Dose at X=1.5 mm, Y=0 mm point was selected as the 100% reference point for the percentage depth dose (PDD) scale. Then, the isodose points were by interpolate of PDD curves. Because of source symmetry along the Y axis, dose variation along the X axis had been the same as that of Z axis; so, the isodose curves in XY surface could be extended to isodose surfaces in 3-dimention XYZ space.

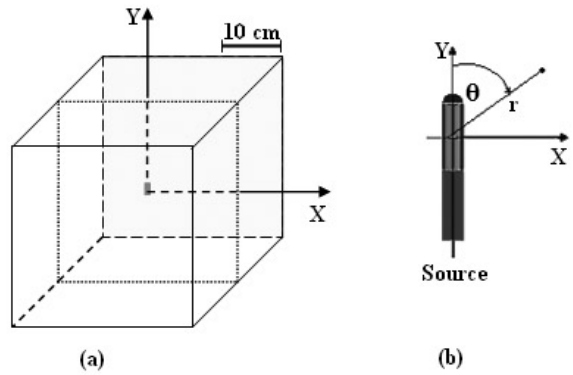

Figure 3. Schematic diagram of water phantom and ^{192}Ir source located in the centre of water cube (a). Representation of the source in a larger size (b).

Dose measurement

The dose measurement was carried out by using Gafchromic Rtqa film (International Specialty Products Company). This kind of film is designed for routine quality systems management of all modalities of radiotherapy with ease and confidence in 0.02 Gy to 8 Gy dynamic ranges. PDD along X=2.5 mm and Y=10 mm was obtained to compare with Monte Carlo results.

Recently, Tsao *et al.* have reported the verification of the dose distributions around ^{192}Ir seed sources at radial distances from 0.5

[Downloaded from ijrr.com on 2026-09-17]

mm to 6 mm using Gafchromic film [10]. They obtained isodose curve plots in the plane containing the source's longitudinal axis and dose rate plots in the radial direction by this technique. Also, Zilio *et al.* have reported valuable results of absolute depth-dose-rate measurements for an ^{192}Ir HDR brachytherapy source in water using MOSFET detectors [11].

RESULTS AND DISCUSSION

Figure 4 shows the PDD variation along the X=0 mm. The effect of source shield is presented clearly in this figure. Figure 5a shows the Monte Carlo and experimental PDD along X=2.5 mm which are in good agreement. Also in figure 5b both results are shown along y=10 mm, in x∈ [-25mm,25mm] interval are well matched; however, out of this range the Monte Carlo result were estimated to be lower. The discrepancy could have been due to the uncertainty in film positioning during the measurement. The isodose curves for 50%, 10%, 3%, and 1% and a typical PLATO result are showed in figure 6. PLATO brachytherapy software module provides image based planning and 3D visualization as a standard feature. In 1995, the Cleveland Clinic Foundation Taussig Cancer Centre initiated a Nucletron Microselectron ^{192}Ir remote afterloading system into the brachytherapy service (Microselectron/PLATO Planning System). This system has been utilizing the PLATO dosimetry planning software, which allowed source dwell-time optimization to minimize

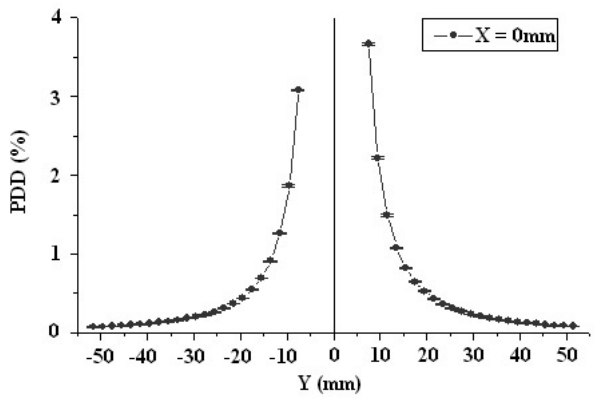

Figure 4. Monte Carlo result of PDD variation along the X=0 mm.

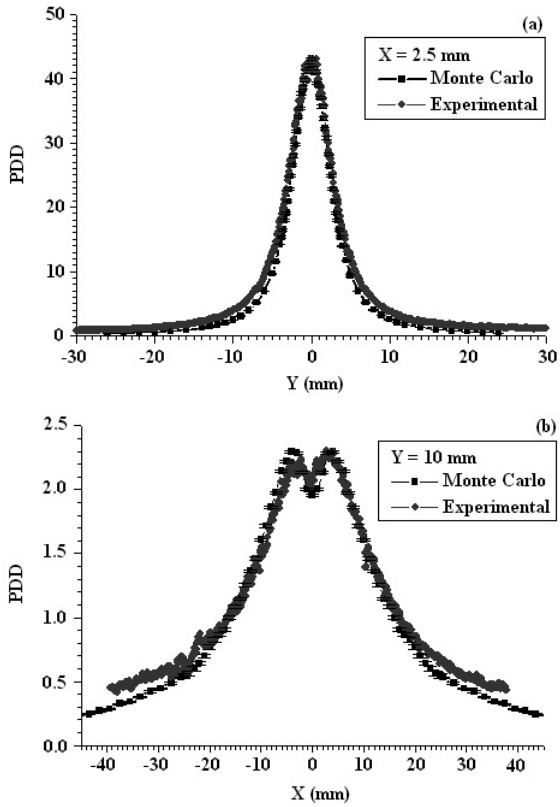

Figure 5. The Monte Carlo and experimental PDD results: (a) along X=2.5 mm and (b) along Y=10 mm.

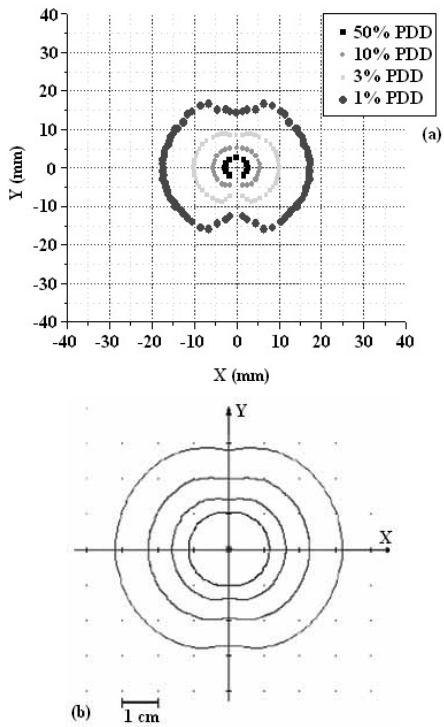

Figure 6. The isodose curves calculated by MCNP (the reference Point: X=1.5mm, Y=0mm) (a), and a typical isodose curves of PLATO (b).

[Downloaded from ijrr.com on 2026-09-17]

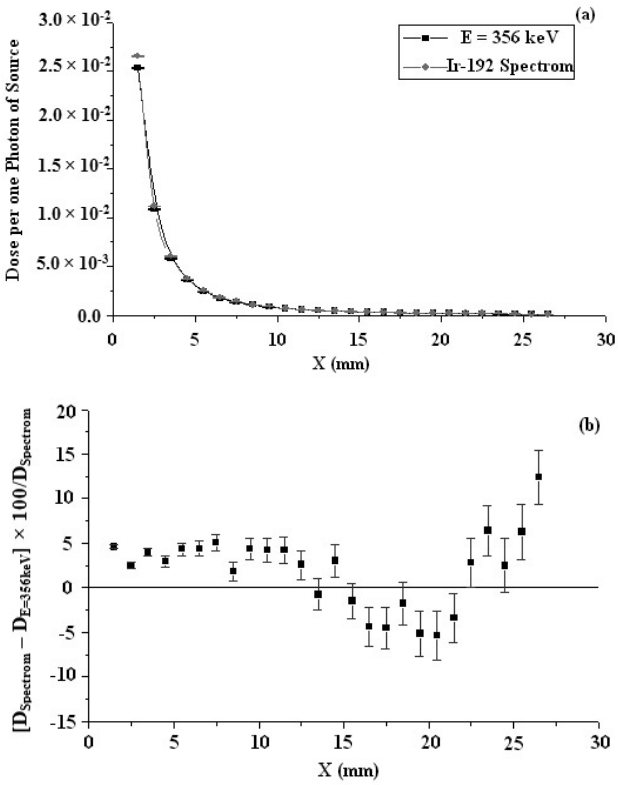

Figure 7. The dose variation (a), and relative deflection dose along the Y=0 mm for the real spectrum of ^{192}Ir and the monochromatic at 356 keV (b).

heterogeneity of dose distribution, a notable advance in the field of interstitial brachytherapy. It can be seen easily D= D(r,θ) that dose distribution has been dependant on r and θ distance from the center of the source and polar angle, respectively. The results could be used for computation of model dependent parameters like anisotropy dose function. As it was mentioned before, Pia *et al.* [5] used the monochromatic spectrum at 356 keV in their simulation; because of energy dependency of attenuation coefficient, dose deposit of monochromatic and real spectrum source was different due to distance from the source. Figure 7 shows the dose variation and relative differences along the y=0 for both spectra. Farther from the source, deflection dose reached to 13%, and closer the source, it was 5% due to absorbing of low energy photons near the source and reaching some high energy photons to far distance of the source. These results showed no simplification on spectrum of the source in simulation process may be due to signification error.

Determination of TG-43 dosimetry parameters

Anisotropy function and radial dose function are dosimetry important parameters which have been determined to compare the results with those obtained by others. According to TG43 protocol [7, 12], the absorbed dose rate can be expressed as:

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

where S_k is the air kerma strength, G(r,θ) is the dose rate constant, Λ is the geometry factor, F(r,θ) 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 the simulated data in treatment planning programs based on TG43 formalism, dosimetry parameters was extracted from simulation in the following expressions:

$$g(r) = \frac{D(r,\theta_0)}{D(r_0,\theta_0)} \frac{G(r_0,\theta_0)}{G(r,\theta_0)} \qquad (2)$$

$$F(r,\theta) = \frac{D(r,\theta)}{D(r,\theta_0)} \frac{G(r,\theta_0)}{G(r,\theta)} \qquad (3)$$

Anisotropy function was an important parameter in comparison with other studies. Figure 8 shows a comparison of F (5 cm, θ) obtained with experimental and Monte Carlo methods by Anctil *et al.* [13], Baltas *et al.* [14], Williamson *et al.* [15] and the results of the present study. A good agreement can be

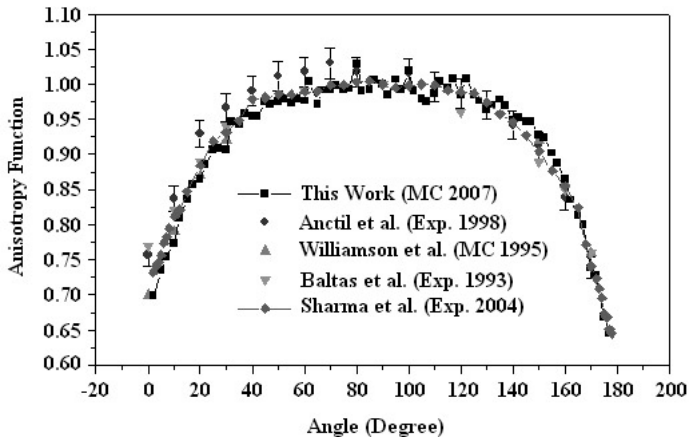

Figure 8. Comparison of F(5 cm, θ) obtained with experimental (Exp.) and Monte Carlo (MC) methods by others.

[Downloaded from ijrr.com on 2026-09-17]

observed between this work and other experimental/Mont Carlo results.

CONCLUSION

Monte Carlo simulation in brachytherapy has been useful to obtain model dependent parameters and to verify PLATO data, since the computational result was more accurate than the analytical PLATO data. Also the results can be used for computing anisotropy dose function. Dose can be calculated accurately by Monte Carlo method near the source because of high gradient dose variation in this region. The present work demonstrates a useful approach using MCNP code in dose calculation that can be applied in many other fields.

ACKNOWLEDGEMENT

The authors would like to thank Prof. G. Furlan, head of the TRIL program at ICTP, Trieste, Italy, for his contribution to this work. Also, A.A. Mowlavi would like to thank the Medical Physicists of Ospedale Maggiore for having a good scientific period with them.

REFERENCES

1. Piermattei A, Fidanzio A, Azario L, Rossu A, Perrone F, Toni MP, Capote R (2003) Experimental and Monte Carlo endovascular dosimerty of a ^{192}Ir source. *Physica Medica, **XIX**: 111- 118.*
2. Ballester F, Hernández C, Pe'rez-Calatayud J, Lliso F (1997) Monte Carlo calculation of dose rate distributions around ^{192}Ir wires. *Med Phys, **24**: 1221-1228.*
3. Kirov AS, Williamson JF, Meigooni AS, Zhu Y (1996) Measurement and calculation of heterogeneity correction factors for an Ir-192 high dose-rate brachytherapy source behind tungsten alloy and steel shields. *Med Phys, **23**: 911-919.*
4. Foppiano F, Agostinelli S, Garelli S, Paoli G, Bevegni M, Pia MG, Franzone P, Scolaro T, Andreucci L (2001) Comparison between PLATO isodose distribution of a ^{192}Ir source and those simulation with GEANT4 toolkit. National Cancer Institute and Phys. Dept. of Genova, Genova, Italy.
5. Pia MG, Foppiano F, Agostinelli S, Garelli S, Paoli G, Nieminen P (2001) The application of GEANT4 simulation code for brachytherapy treatment. 9th International Conference on Calorimetry in High Energy Physics, pp: 1-15, Annecy, France.
6. Angelopoulos A, Baras P, Sakelliou L, Karaiskos P, Sandilos P (2000) Monte Carlo dosimetry of a new ^{192}Ir high dose rate brachytherapy source. *Med Phys, **27**: 2521-2527.*
7. Daskalov GM, Baker RS, Rogers DWO, Williamson JF (2000) Dosimetric modeling of the microselectron high dose rate ^{192}Ir source by the multigroup discrete ordinates method. *Med Phys, **27**: 2307-2319.*
8. Sureka CS, Aruna P, Ganesan S, Sunny CS, Subbaiah KV (2006) Computation of relative dose distribution and effective transmission around a shielded vaginal cylinder with ^{192}Ir HDR source using MCNP4B. *Med Phys, **33**: 1552-1561.*
9. Briesmeister JF (2000) MCNP™- A general Monte Carlo N-particle transport code, Version 4C. Los Alamos National laboratory Report LA-13709-M, USA.
10. Tsao STC, Duckworth TL, Patel NS, Pisch J, Harrison LB (2004) Verification of Ir-192 near source dosimetry using GAFCHROMIC® film. *Med Phys, **31**: 201-207.*
11. Zilio VO, Joneja OP, Popowski Y, Rosenfeld A, Chawla R (2006) Absolute depth-dose-rate measurements for an ^{192}Ir HDR brachytherapy source in water using MOSFET detectors. *Med Phys, **33**: 1532-1539.*
12. Nath R, Anderson LL, Luxton G, Weaver KA, Williamson JF, Meigooni AS (1995) Dosimetry of interstitial brachytherapy sources: Recommendations of the AAPM Radiation Therapy Committee Task Group No. 43. *Med Phys, **22**: 209-234.*
13. Anctil JC, Clark BG, Arsenault CJ (1998) Experimental determination of dosimetry functions of Ir-192 sources. *Med Phys, **25**: 2279-2287.*
14. Baltas D, Kramer R, Löffler E (1993) Measurements of the anisotropy of the new Ir-192 source for the microselectron-HDR. *Activity Special Report **3**: 2.*
15. Williamson JF and Li Z (1995) Monte Carlo aided dosimetry of the microselectron pulsed and high dose-rate Ir-192 sources. *Med Phys, **22**: 809-820.*

[Downloaded from ijrr.com on 2026-09-17]