# Monte Carlo Assisted Study of the microSelectron $^{192}$Ir Brachytherapy Source

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## Introduction

Gynecological cancer accounts for around 6% of all cancers diagnosed and about 13% of those diagnosed in the U.S. for women. Traditionally and currently, low dose rate (LDR) $^{137}$Cs is used continuously over 48 hours to give 30 Gy to the tumor. Applicators consisting of a tandem and two ovoids are placed in the vaginal and uterine cavities, radiographic films are taken to ensure proper placement, and the sources are afterloaded.

Selectron afterloaded $^{137}$Cs used by M.D. Anderson will be discontinued by the vendor by 2009, therefore another method of intracavitary brachytherapy (ICBT) treatment for cervical cancer is needed. Pulsed dose rate (PDR) $^{192}$Ir has been proposed as a good candidate because it radiobiologically mimics LDR treatments. The term 'pulsed dose rate' means that the source is placed in the applicator for only a certain amount of time each hour over a period of several hours.

One of the advantages of PDR over conventional LDR is the potential for computer-optimized dose distributions by modulating the dwell time of the stepping source. The dwell times can be optimized to give the desired tumor dose while sparing other critical structures such as the bladder and rectum. Another major advantage of PDR treatment lies in the fact that the source is only in the patient for a short time each hour. For the rest of the hour, nursing staff or family can enter the treatment room, because the source has been retracted into a lead safe.

The ovoids used in the applicator consist of a set of shields which are designed to reduce the dose to the patient's bladder and rectum during treatment. Most brachytherapy treatment planning systems do not take into account the effect of the applicator and shields in their calculations. Instead, some institutions apply a standard Factor to the calculated doses To account for the effect of the Shields. These shields can be easily incorporated into a Monte Carlo model in order to show their effects, including the shielding effects to ICRU points A,B, rectum, and bladder. Point A indicates dose to the cervix, while point B represents the dose to the obturator nodes.

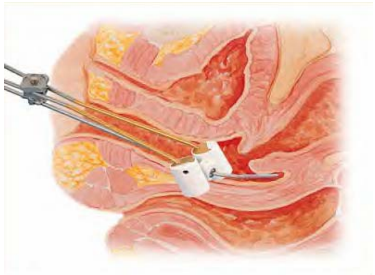

*Figure 1. Intracavitary placement of applicators for PDR treatment*

## Purpose

The purpose of this project was to develop a Monte Carlo input file to simulate $^{192}$Ir treatment and show the effects of the applicator to the ICRU points A, B, rectum, and bladder.

## Materials and Methods

***Verification of single $^{192}$Ir source***

MCNPX version 2.5d (Hendricks et al 2003) was the Monte Carlo code used to model the PDR source investigated in this study. The single microSelectron source was modeled in a similar manner to the one used by Daskalov (Daskalov et al 1998) for comparison purposes. Cylindrical mesh tallies using $10^8$ histories were used to create a standard away and along table.

***Dwell positions in a single ovoid***

Radiochromic film was calibrated for the experiment using a known dose delivered by a Cobalt 60 teletherapy unit. A high impact polystyrene phantom was created to hold the ovoid and three pieces of film in place around the ovoid. The three pieces of film represented the dose found anteriorly (bladder), posteriorly (rectum), and medially (cervix) to the ovoid.

Two separate experiments were conducted; one involving a single dwell position in the ovoid and the other involving four dwell positions. The film was irradiated for comparison with the Monte Carlo model.

The ovoid was modeled in Monte Carlo according to vendor schematics which were verified by independent measurements. Dose grids were tallied which simulated the pieces of film irradiated in the experiment.

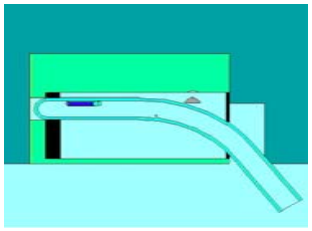

*Figure 2. MCNPX model of ovoid with single dwell position; shields are shown in black*

***Dose to ICRU points***

Treatment plans from 10 patients having undergone $^{137}$Cs treatments were recreated in MCNPX using $^{192}$Ir sources. Two Monte Carlo models were created involving both ovoids and the tandem. One model was created without applicator shields, and the other one with shields as was done in a previous study (Gifford 2004). The doses to ICRU points A, B, rectum, and bladder were tallied and compared.

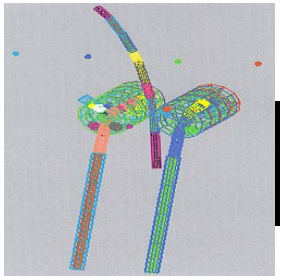

*Figure 3. microSelectron PDR applicator and ICRU dose points modeled in MCNPX*

## Results

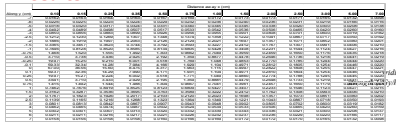

*Figure 4. Monte Carlo generated data for a single Iridium-192 source in water: Dose rate per unit air kerma strength (cGy/hr/U)*

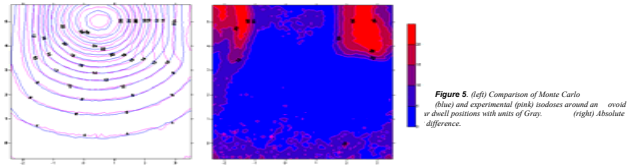

*Figure 5. (left) Comparison of Monte Carlo (blue) and experimental (pink) isodoses around an ovoid w dwell positions with units of Gray. (right) Absolute difference.*

| | Bladder (cGy) | | | Rectum (cGy) | | |
|---|---|---|---|---|---|---|
| Case | Unshielded | Shielded | % diff | Unshielded | Shielded | % diff |
| 1 | 1691 | 1690 | 0.1 | 1512 | 1091 | 27.8 |
| 2 | 1456 | 1224 | 15.9 | 1413 | 1057 | 25.2 |
| 3 | 974 | 830 | 14.8 | 1165 | 772 | 33.7 |
| 4 | 1724 | 1662 | 3.6 | 1370 | 883 | 35.5 |
| 5 | 870 | 721 | 17.1 | 1218 | 828 | 32 |
| 6 | 950 | 838 | 11.8 | 1132 | 890 | 21.4 |
| 7 | 874 | 738 | 15.6 | 1033 | 795 | 23 |
| 8 | 686 | 588 | 14.3 | 967 | 712 | 26.4 |
| 9 | 1200 | 1063 | 11.4 | 1479 | 986 | 33.3 |
| 10 | 1412 | 1101 | 22 | 1332 | 852 | 36 |

*Figure 6. Comparison of shielded and unshielded Monte Carlo calculated doses to ICRU points bladder and rectum.*

## Discussion

Monte Carlo calculations for the single source agreed with published data within 3% for all points. Comparisons between experimental and Monte Carlo data for the source(s) in the single ovoid showed errors in the high gradient regions and low dose regions for all three film positions, however, these differences were also observed between repeated experiments. These errors most likely arise from slight rotations of the ovoid within the phantom and the positioning error of the source on the PDR unit.

Comparison of the Monte Carlo shielded and unshielded tallies revealed that the doses to points A and B were not significantly affected by the presence of the shields. The effect to the bladder and rectum varied between patient cases with an average shielding effect of 12.7% to the bladder and 29.4% to the rectum. More patient cases are needed for statistically significant results.

Treatment plans created using the PDR sources were very similar to plans using the LDR sources. The shape of the isodose contours can be mimicked, and the dose to the ICRU reference points can be matched.

## References

1) Daskalov, G. M., Loffler, E., and Williamson, J. F., "Monte Carlo-aided dosimetry of a new high dose-rate brachytherapy source," Med. Phys. 25, 2200-2208 (1998).
2) Gifford, K., "A 3D CT-assisted Monte Carlo evaluation of intracavitary brachytherapy implants" Ph.D. dissertation: University of Texas Graduate School of Biomedical Sciences, 2004.
3) Hendricks, J., Waters, L., Hamilton, B., "MCNPX Introductory Workshop," Decisions Applications Group D-10, Los Alamos National Laboratory & HQC Professional Services, Inc., LA-UR-01-5285, 2003.