MASSEY CANCER CENTER VCU

The Design of a Novel Direction Modulated Brachytherapy (DMBT) Vaginal Cylinder Using GEANT4 Monte Carlo Simulation Code

M. Meftahi [1], W. Song[1]
1 VIRGINIA COMMONWEALTH UNIVERSITY

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INTRODUCTION

Anisotropy of the source is an important factor that affects the dose distribution at the apex in vaginal cylinder brachytherapy (VC BT) . The dose distribution produced by the HDR ^{192}Ir source is inherently anisotropic due to self-absorption by the high-density source core, oblique filtration by the source capsule and asymmetric geometry of the source capsule [1], which prevents it from having a uniform dose coverage at the apex.

This phenomenon more commonly affects single-channel applicators, as these are the most widely used vaginal applicators. Although it can be modified using multichannel applicators through inverse planning to some extent, this modification can cause loss of coverage at the other part of the apex [2-3].

AIM

In this study, we designed a novel DMBT vaginal cylinder applicator using the general-purpose GEANT4 Monte Carlo (MC) Simulation code to address the anisotropy of the source.

METHOD

A Varian ^{192}Ir Gamma Med Plus source was simulated using GEANT4 Monte Carlo simulation code (toolkit 10.05). The source and the extension of the cable were placed across the Y axis for a 2D data acquisition. Dose rate constant was calculated, as explained in the literature [4].

The new DMBT vaginal applicator was designed to be a 30 mm diameter, single lumen vaginal cylinder, made of PPSU plastic. The central part of the applicator which includes the lumen was considered to be a detachable 8 mm diameter PEEK plastic tandem rod. In order to provide directional modulation, a tungsten rod with the similar dimensions was added to simulation. The applicator works in two steps. First, we get a typical dose distribution based on the planning system using the applicator with a detachable PEEK tandem in place. Second, the detachable tandem is replaced with a tungsten tandem to compensate for lack of coverage at the apex utilizing directional radiation beam generated. The same source dwell positioning is used for both steps, fed from Varian's TPS, while the dwell time for the second step is equivalent to three quarter of one fraction of the first step (5 fractions in total) .

For both steps, the applicator is placed at a water phantom 30*30*30 cc, gridded into voxels with a side length of 1 mm. The MATLAB software was used for data analysis.

RESULTS

The **dose rate constant** for Gamma Med Plus was obtained to be 1.122 cGy.h^{-1}.U^{-1} that is in a good agreement with the consensus data of 1.117 cGy.h^{-1}.U^{-1} , with relative error less than 0.5% [5] .

The results from the two-step DMBT applicator is shown in Figures 1 and 2. The **prescription dose line** is shown in **red**. According to the results, this novel DMBT applicator can remove the anisotropy dip at the apex and lift up the prescription isodose line **up to 2 mm** without overdosing the other periphery surfaces, i.e., **only 3-4 % increase** in dose at those surfaces.

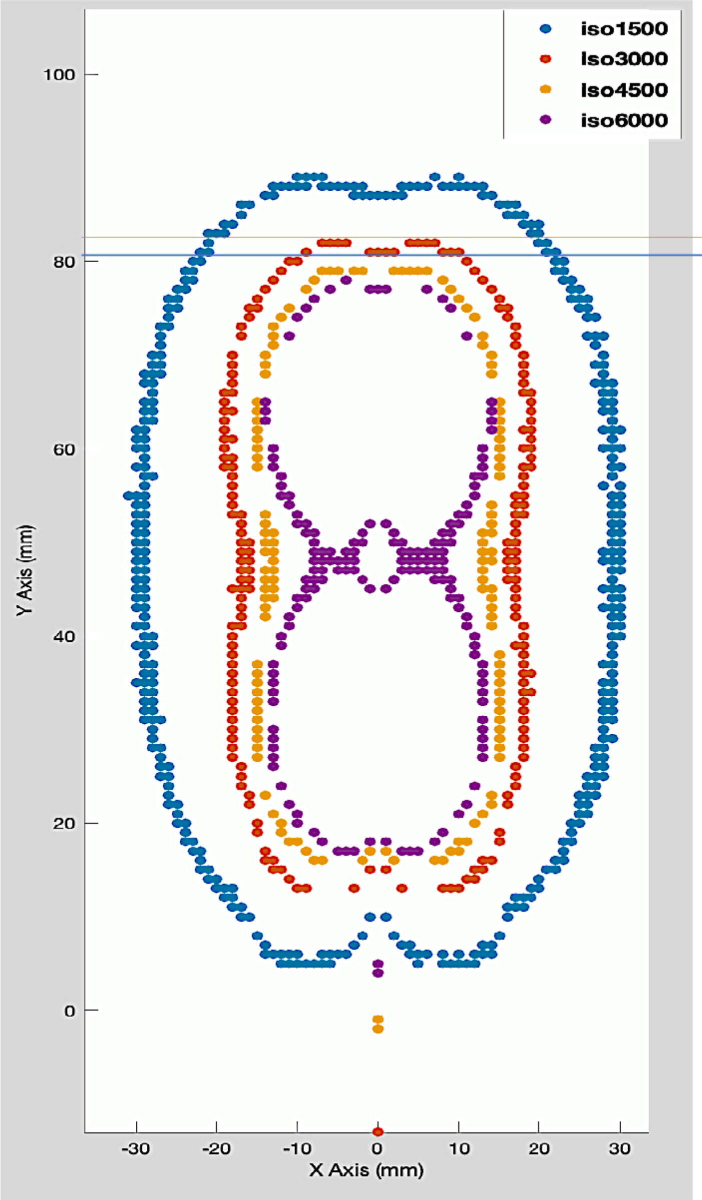

*Figure 1, isodose lines (cGy) obtained from GEANT4 MC simulations considering heterogeneities, for a 30 mm diameter applicator with the **Peek tandem in place***

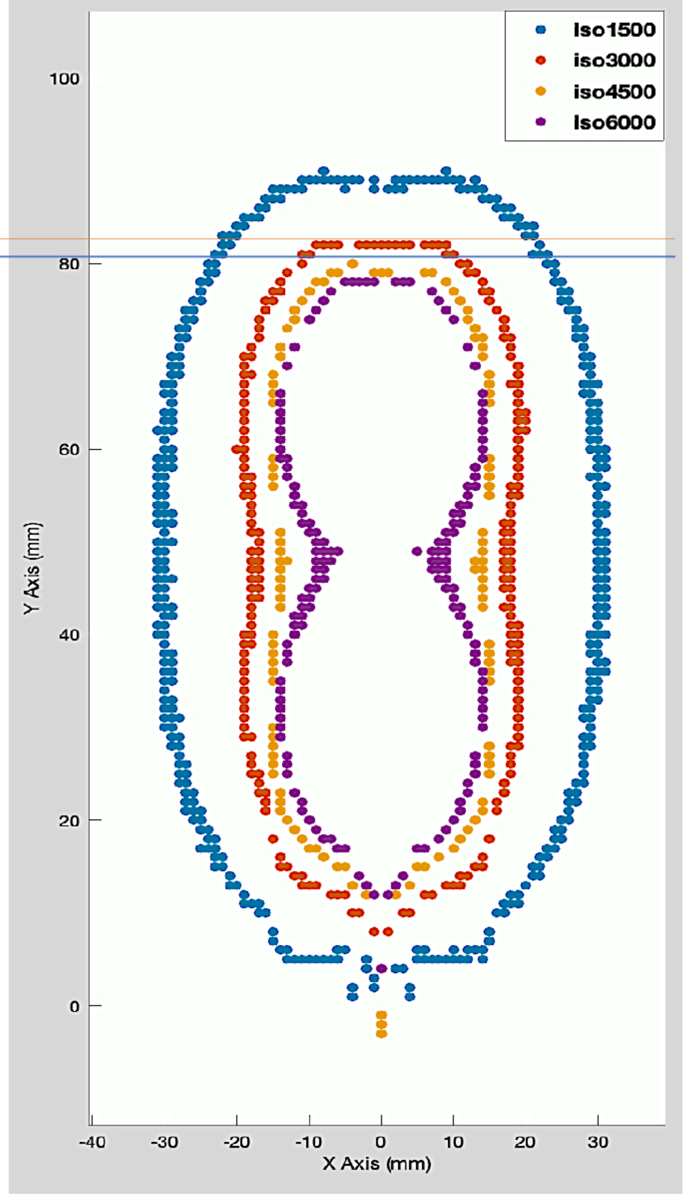

*Figure 2, isodose lines (cGy) obtained from GEANT4 MC simulations considering heterogeneities, for a 30 mm diameter applicator with **the Tungsten tandem in place***

CONCLUSIONS

It is important to generate a radiation dose distribution that best and uniformly conforms to the vaginal cuff region as it is the most common place for post-treatment recurrence, through optimization during treatment planning. The most recent American Brachytherapy Society (ABS) recommendations (released in 2012), define optimization as the manipulation of the HDR BT dwell positions, dwell times, or both at the upper apex or at vaginal cuff as well as the lateral sides of the applicator in order to avoid unacceptably high doses to the vaginal apex and any overlying portions of the small bowel. Delivering radiation dose to the vaginal cuff area that receives uniform prescription dose (Rx) as much as possible is desired. At minimum, considerable cold spots should be avoided during the planning process as the risk of recurrence at the vaginal cuff site is approximately 70% .Due to the nature of the source construction, however, the anisotropy of the source will cause underdosage in the apex area even after the optimization [6].

A novel single-channel DMBT vaginal applicator is proposed in this research to address the anisotropy underdosage effect. Based on the results, this applicator can be a possible solution to compensate for the lack of coverage at the apex due to anisotropy of the source. With the same dwell positions, the dwell times of the source for this compensation was obtained to be a small fraction of the total treatment time, i.e., adding few minutes extra to the overall treatment time. There is a subset of patients who experience recurrence of the disease at the vaginal apex after vaginal BT. Considering an optimization line as ABS recommends and using the new introduced DMBT applicator can assure the sufficient coverage of vaginal apex, without overdosing the lateral periphery.

In conclusion, the novel DMBT cylinder design proposed in this thesis work is a potential solution to remedy the underdosage at the vaginal apex due to source anisotropy. Such design may be of clinical benefit.

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CONTACT INFORMATION

Moeen Meftahi: meftahim@vcu.edu