Intensity Modulated HDR GYN Brachytherapy

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INTRODUCTION

Currently, high dose rate (HDR) gynecological (GYN) cervix brachytherapy is performed using tandem and ring applicators in combination with Iridium-192 (or Cobalt-60) as the radiation source. Because of the high photon energies of these sources, localized shielding is ineffective resulting in high doses to the bladder, sigmoid and rectum.

AIM

The purpose of this study is to investigate lower energy brachytherapy sources such as Se-75 and Yb-169 in combination with a shielded ring applicator and compare the results to unshielded Ir-192 for GYN cervix brachytherapy. By using thin amounts of gold with these middle energy sources, it is possible to modulate the dose distribution around the cervix to avoid the critical structures, which would enable better medical outcomes.

METHOD

Monte Carlo simulations were performed using MCNP6 to evaluate the dose distribution in a typical GYN cervix geometry using a standard ring applicator. The geometry was modeled based off the ICRU 38 reference points. Comparative dose calculations were made for the currently used high energy Ir-192 source and middle energy Se-75 and Yb-169 sources with a ring partially surrounded by gold, a high-density shielding material. The ring consists of a 13 mm radius by 0.5 mm diameter toroidal active element encapsulated in titanium 0.1 mm thick. A 75 degree conical opening of the ring was used. Calculations were made using various thicknesses of shielding for each of the isotopes.

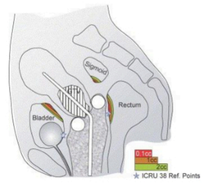


Figure 1: ICRU 38 reference points and volume constraints for GYN cervix brachytherapy

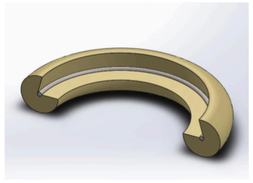


Figure 2: GYN ring applicator 26 mm in diameter and shielded with about 3 mm of gold.

RESULTS

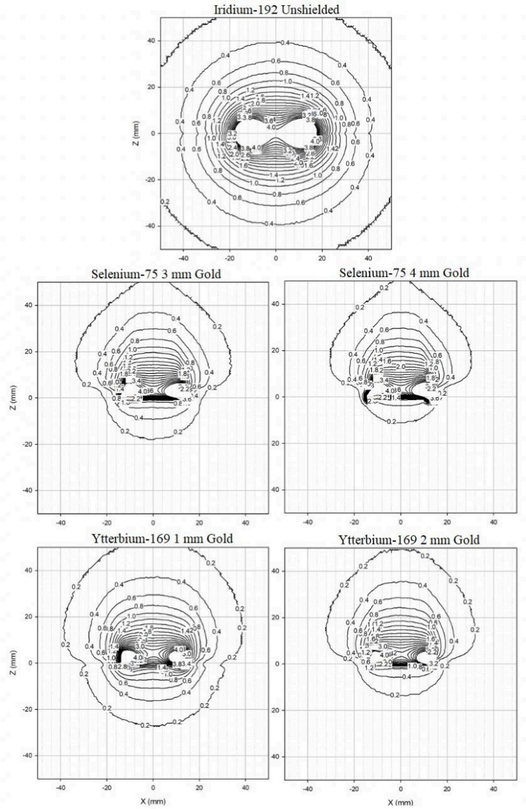


Figure 3: Comparative dose distributions of the XZ plane from the MCNP6 simulations, which includes the axis of a 26 mm diameter GYN ring applicator. The dose rate is measured in Gy/min. Results are shown for the unshielded ring applicator in combination with Ir-192, the same applicator surrounded by 3 and 4 mm of gold for Se-75, and 1 and 2 mm of gold for Yb-169. The prescription dose was delivered to a depth of 10 mm on the z axis. The Ir-192 was normalized to 10 Ci, Se-75 to 19.98 Ci, and Yb-169 to 27.79 Ci.

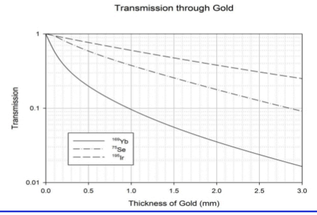
		Dose Relative to Unshielded Ir-192			
Isotope	Shielding Thickness (mm)	Target	Bladder	Sigmoid	Rectum
Ir-192	0	1.00	1.00	1.00	1.00
	3	0.99	0.68	0.54	0.30
Se-75	0	1.00	1.06	1.07	1.04
	2	0.98	0.66	0.51	0.21
	3	0.98	0.55	0.40	0.10
	4	0.98	0.48	0.33	0.06
Yb-169	0	1.00	1.08	1.03	0.98
	1	0.91	0.73	0.52	0.22
	2	0.89	0.52	0.36	0.08

Table 1: Comparison of dose relative to Ir-192 with no shielding to the target, bladder, sigmoid, and rectum. All simulations were with a 26 mm diameter ring applicator. The shielding is in mm of gold. Various simulations were calculated for Ir-192 with 0 and 3 mm of gold, Se-75 with 0, 2, 3, and 4 mm of gold, and Yb-169 with 0, 1, and 2 mm of gold normalized to 10, 19.98, and 27.79 Ci respectively and to a depth of 10 mm on the z axis.

The Monte Carlo results show significant dose reduction to the bladder, sigmoid, and rectum when using small thicknesses of shielding. Se-75 has a TVL of about 3 mm. When 3 mm of gold shielding was used, there was a dose reduction of 45% to the bladder, 60% to the sigmoid, and 90% to the rectum. Increasing the shielding to 4 mm of gold increased the dose reduction to 52% to the bladder, 67% to the sigmoid, and 94% to the rectum.

Yb-169 has a TVL of about 1 mm. When 1 mm of gold shielding is used, there was a dose reduction of 27% to the bladder, 48% to the sigmoid, and 78% to the rectum. When this shielding was increased to 2 mm, the dose reduction was 48% to the bladder, 64% to the sigmoid, and 92% to the rectum.

While some dose reduction is possible with Ir-192, the amount of gold required to reach its TVL would not be acceptable for GYN brachytherapy.



CONCLUSIONS

The results show it is possible to modulate the dose distribution of Yb-169 and Se-75 using small amounts of gold, to deliver the prescription dose to the target and protect surrounding critical structures. The use of a partially shielded ring applicator would also allow for better treatment planning as oncologists would be able to increase dose to the cervix without overexposing the bladder, sigmoid, and rectum. The isodose curves show much greater control as the dose can be pulled away from the critical structures when using the shielded applicator whereas the dose would otherwise be isotropic as in the Ir-192 dose distribution.

Future work includes varying the angle of the collimator opening of the applicator directed toward the cervix to have even greater control of the dose. Different collimators can be used to treat a variety of tumor sizes and the shielding designs can be optimized to accommodate individual patients.

Future work also includes experimentally verifying the results from the MCNP6 calculations using Gafchromic EBT3 film dosimetry.

Overall, the partially shielded ring applicator in combination with middle energy sources show promising results for improving HDR GYN brachytherapy by achieving the desired dose to the cervix and providing the ability to increase the dose to the cervix without exceeding acceptable limits of dose to the bladder, sigmoid, and rectum.

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REFERENCES

International Commission on Radiation Units and Measurements. ICRU report 38: dose and volume specification for reporting intracavitary therapy in gynaecology. Bethesda, MD:ICRU; 1985.

Viswanathan AN, Beriwal S, De Los Santos JF, et al. American Brachytherapy Society consensus guidelines for locally advanced carcinoma of the cervix. Part II: high-dose-rate brachytherapy. *Brachytherapy*. 2012;11(1):47-52.

Pötter R, Haie-Meder C, Van Limbergen E, et al. Recommendations from gynaecological (GYN) GEC ESTRO working group (II): concepts and terms in 3D image-based treatment planning in cervix cancer brachytherapy-3D dose volume parameters and aspects of 3D image-based anatomy, radiation physics, radiobiology. *Radiother Oncol*. 2006;78(1):67-77.

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