2026 JULY 19–22 VANCOUVER, BC
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# Proof-of-concept variably shielded HDR applicator: design, dosimetric characterization, and TPS integration

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## INTRODUCTION

As HDR Brachytherapy has the potential to increase in popularity due to changes in reimbursement models, the potential of new treatment sites for the modality can be increased through increased organ-at-risk sparing via integrated shielding. In this work, we present the design and characterization of an HDR applicator with modular shielding.

The applicator was designed to allow for shielding placement to occur after the pre-treatment imaging of the applicator. CBCT imaging of the applicator (Figure 1) demonstrates imaging artifacts created by the shielding, potentially obscuring relevant patient landmarks used to assure the proper placement of the applicator prior to treatment.

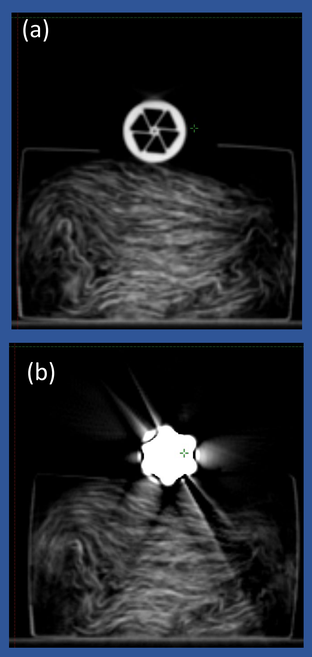


Fig. 1 CBCT imaging of designed cylinder both without placement of modular shielding (a) and with tungsten shielding in plan (b). The modular design of the shielding allows for its removal during imagine occurring prior to treatment to assure proper placement.

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## METHODS

A 3cm dia. cylinder applicator is 3D printed as a proof-of-concept. Within this applicator are 6 triangular channels for the placement of 1.5mm dia tungsten (welding) rods. The shielding is designed to be removed during patient imaging and placed prior to treatment. The channels are offset from a central opening for the placement of an interstitial needle to act as source path. An Elekta micro-selectron afterloader and Ir-192 source are utilized to establish the angular attenuation patten on radiochromic films placed at four depths and axially, perpendicular to a single dwell position (fig. 3). Additional measurements are collected via ionization chamber to confirm output rate. Collected data is complied to create a TG-43 parameter set to commission a virtual source that models the custom shielding configuration of the applicator.

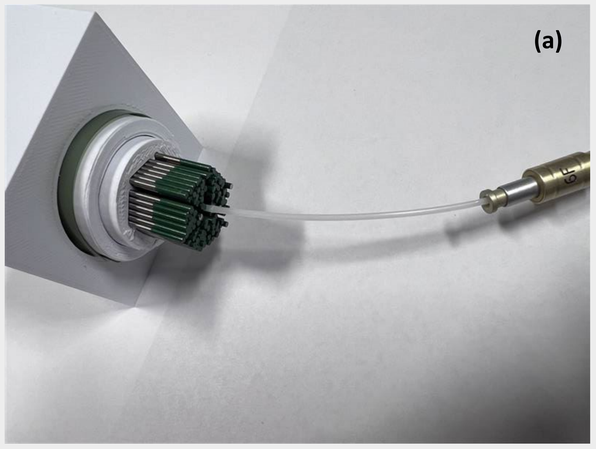
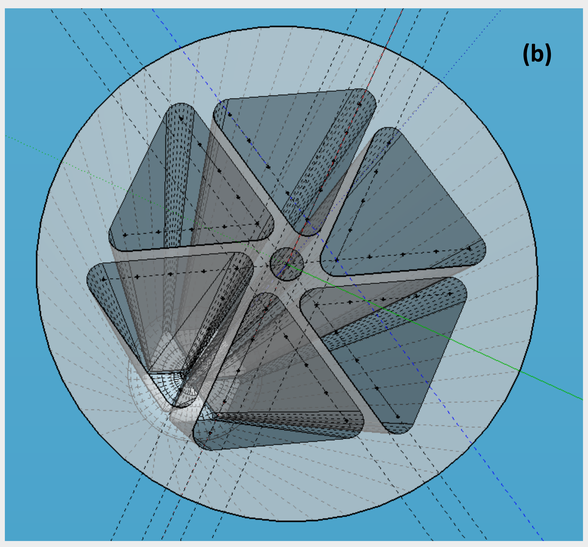



Fig. 2 Applicator in place during film testing will modular tungsten shielding (a). A 5F needle is used within the centra channel for source placement. The 6 sections for shielding placement (b) surround the centra catheter channel and are rotationally offset to aid in obscuring a direct line-of-site exposure through the sub-section sepia.




## RESULTS

The internal shielding is seen to attenuate between 3 HVL and 1 TVL for Ir-192. Shielding configurations studied included 50%, 66% and 83% shielding of the cylinder's radial angle. The dose was demonstrated to be able to be modeled in Varian's BrachyVision TPS (Fig 4) as well as within a simplified spreadsheet. Testing of the applicator within a mock clinical setting also demonstrated that the device was able to be imaged prior to the accurate and reproducible placement of shielding. Additional scatter dose was seen to escape between shielded sections and can be modeled in TG43 parameters within the TPS.

Fig. 3 Axial radiochromic film measurement of a single dwell within a 3cm dia. Cylinder with a 60 deg section remaining unshielded. Within this image is visible additional scatter dose revealed corresponding to sections of reduced shielding (sections of plastic sepia)

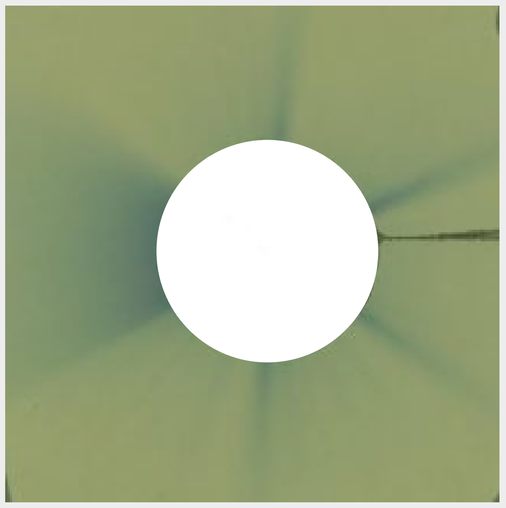
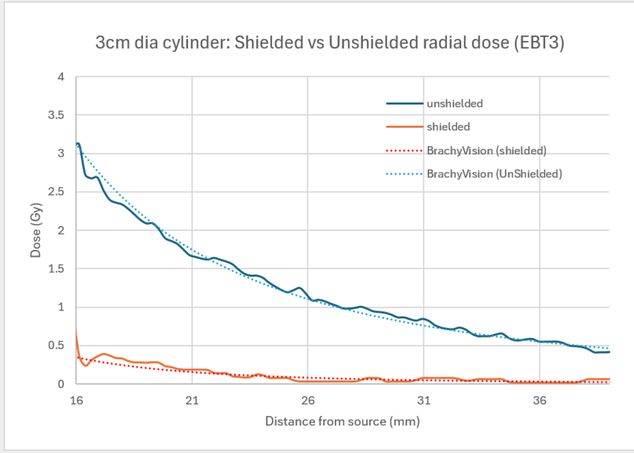


Fig. 4 Dose fall-off with depth within a tissue equivalent phantom for shielded and unshielded sections measured with radiochromic film. Comparisions with predicted doses calculated within BrachyVision demonstrate the feasibility of predicting dose distributions in shielded applicators.




## DISCUSSION

The modular tungsten shielding present in the cylinder was able to selectively shield sections and be removable for imaging prior to treatment. While the weight of the shielding (700g) maybe an issue of patient comfort, this weight can be offloaded via stabilization board & clamp system. The commissioning workload of clinical implementation will require separate TG43 models for specific shielding configurations as well as for dwell positions within the configurations, as azimuthal difference based on position will begin to be seed for dwells near the ends of the shielding.

Ideally, TG186 outlined model based dosimetry maybe the only clinically viable future for practical shielded applicator use within a clinical environment. Pre-loaded digital models of shielding and configuration geometries can be created to accurately predict dose distributions within patient CT sets through the use of Monte Carlo or Lattice-Boltzmann calculations.

Scattering occurring between modules can likely be address through a fine tuning of applicator geometries. An offset configuration of shielded ring sections or and increased angle of rotation for the applicator presented can likely address the 'spokes' of dose that are exhibited.

## CONCLUSIONS

This work demonstrated the feasibility of HDR applicators to possess clinically viable internal shielding. Physicians have expressed interest in the potential of this applicator for use in the treatment of rectal carcinoma. Future Monte Carlo simulations and applicator modeling can hope to bridge the gap between the work demonstrated here and clinical implementation. While the rapid prototyping and affordability was a key component in this stage of development, a more robust means of predicting semi-shielded dose distributions will rely on the reproducibility and ease-of-use of future applicators to be developed.

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