Prostate HDR Treatment End-to-End Testing with In-house Fabricated 16mm EBT4 Radiochromic Film Discs

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Nadia M. Vassell, MS, Charlotte Read, MS, Mario Serrano-Sosa, PhD, Sunshine Osterman, PhD, and Andrew Lukban, MS
Mount Sinai Heath System, New York, NY

INTRODUCTION

End-to-end testing of prostate HDR treatments can be accurately performed using a custom 3D-printed phantom and clinical treatment catheters. This work builds upon our previously reported OSLD-based methodology, with key modifications to instead utilize EBT4 film for dosimetric evaluation.

MATERIAL & METHODS

A 3D-printed treatment grid assembly was developed to enable reproducible positioning of 16mm radiochromic film discs between simulation and irradiation. The design replicates a clinical prostate HDR grid and incorporates fixed locations for film disc placement at two locations representing bladder and rectum.
The phantom was submerged in water and CT simulated using dummy film discs that were replaced with calibrated film prior to treatment. Film centers were identified using CT re-slicing and optimized window/level settings. Novel integrated air-ring markers within the phantom facilitated accurate localization of the film plane for dose point selection.
EBT4 film was calibrated using a 6MV linear accelerator. The end-to-end testing workflow consisted of: (1) CT simulation with dummy discs and fourteen 240mm sharp plastic catheters, (2) catheter digitization and treatment planning with dose optimization (3) irradiation in water, and (4) flatbed film scanning followed by analysis using freely available software.

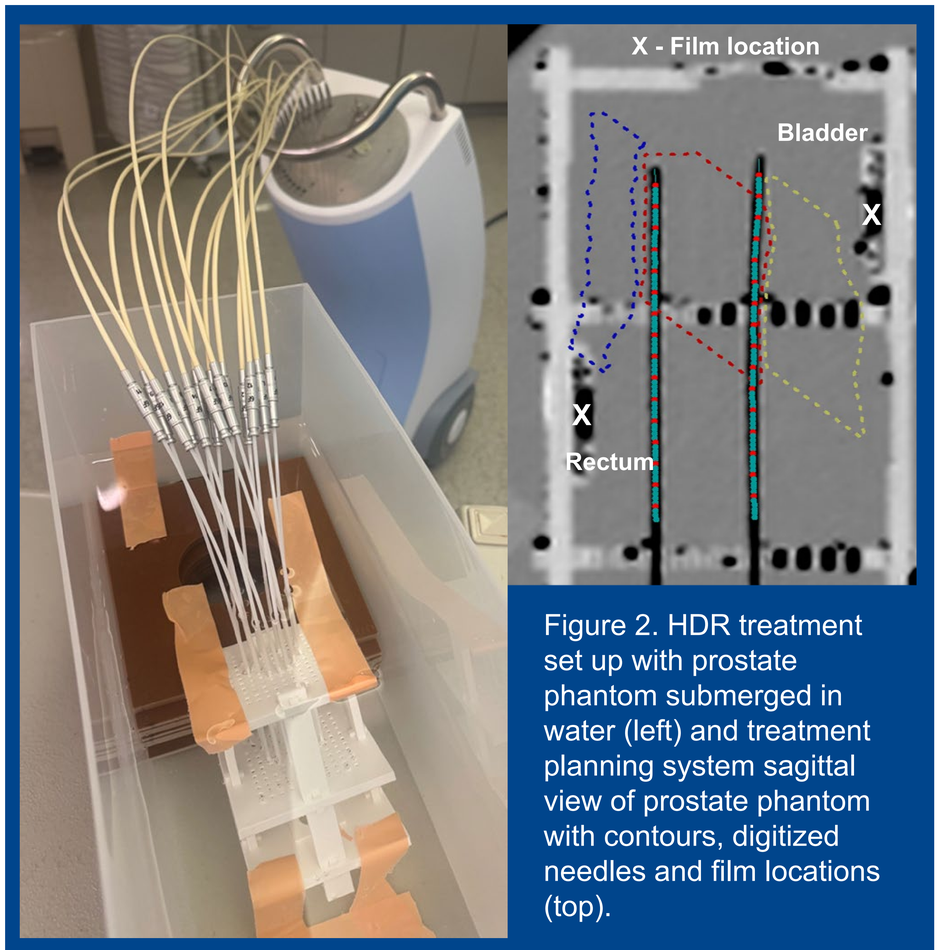


Figure 2. HDR treatment set up with prostate phantom submerged in water (left) and treatment planning system sagittal view of prostate phantom with contours, digitized needles and film locations (top).

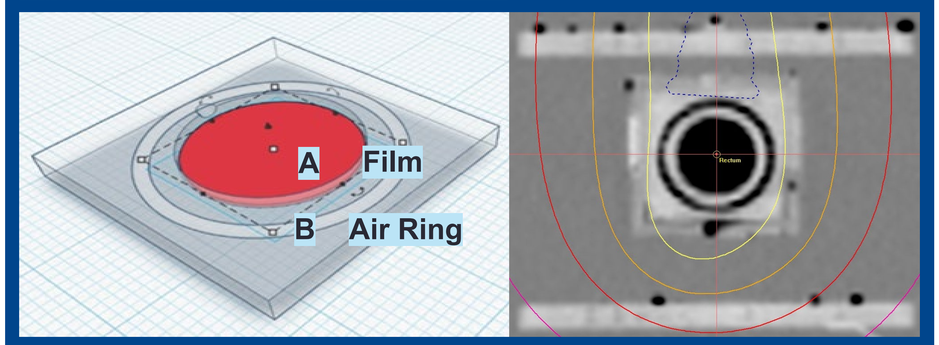
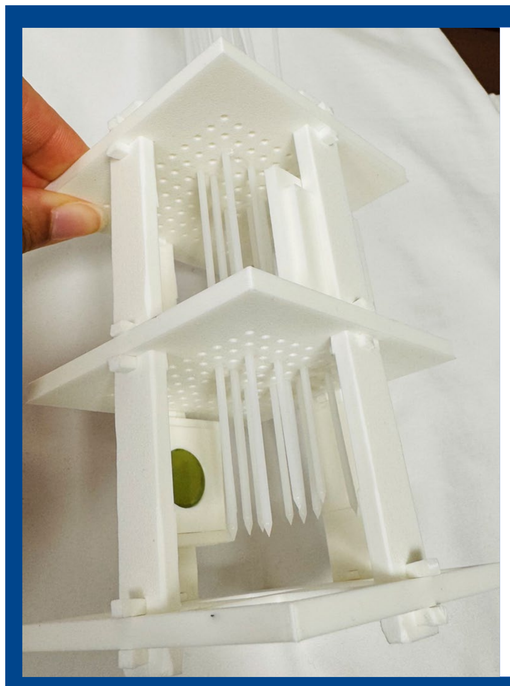


Figure 3. CAD designed film holder showing film location (A) and air ring (B) (left) and treatment planning system axial view of rectum film holder with isodose distribution (right).



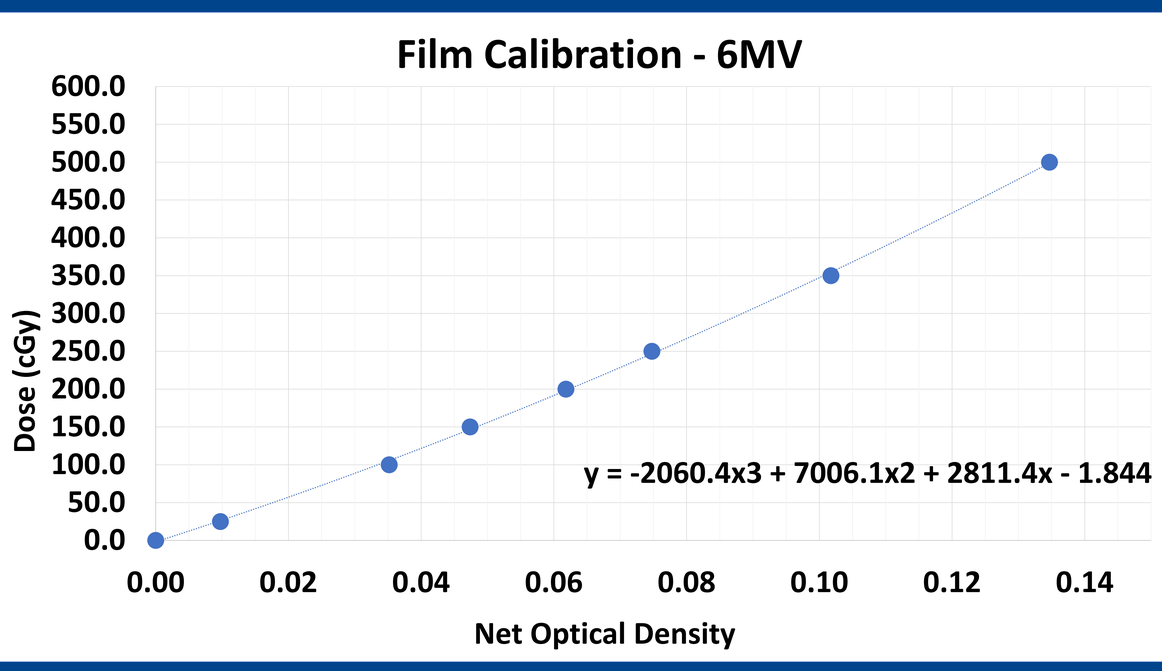


Figure 1. 3D printed prostate jig with 16mm EBT4 film discs (left) and EBT4 film calibration using 6MV linac (right).

RESULTS

With accurate localization of the radiochromic film disc centers in the treatment planning system and application of film calibration corrections, agreement between planned and measured dose was less than 4%.

Percent Error at Film Location

Bladder	Rectum
0.51%	3.64%

Details

Film Location	Reading	Expected dose [cGy]	Net OD	Predicted dose [cGy]	Percent error (%)
Bladder	22373	330.33	0.096	332.01	0.51
Rectum	21281	278.13	0.085	288.24	3.64

Table 1. Film dose verification results for two 16mm radiochromic film discs located on prostate end-to-end phantom

DISCUSSION

The 16mm EBT4 film discs are difficult to visualize on CT imaging. As a result, we re-designed a novel 3D-printed phantom incorporating an integrated air-ring marker to reliably facilitate accurate localization of the film plane for dose point selection. The treatment plan was also optimized to minimize steep dose gradients across the film plane.
This innovation preserves the geometric and dosimetric rigor of the original workflow while enabling continued comprehensive end-to-end verification of HDR prostate treatments.
Agreement between planned and measured dose was well within expected difference validating our redefined film approach.

CONCLUSION

End-to-end testing that closely replicates clinical prostate HDR treatments was accurately performed using a custom 3D-printed phantom, treatment catheters, and EBT4 film. This clinically realistic workflow updates our previous OSLD-based methodology and provides accurate dosimetric verification. Incorporation of a novel air-ring design facilitated precise film localization, with planned and measured doses agreeing within 4%.