Old Template

New Template

Improving Treatment Plan Quality using Optimization Templates for Prostate HDR with DIL Boost

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Summary

Prostate HDR brachytherapy with DIL boost requires rapid intraoperative treatment planning, where maintaining high plan quality while minimizing planner variability is critical. The incorporation of ring structures into the inverse planning template improved dose conformity while maintaining target coverage and OAR sparing, providing a robust and standardized planning approach. This template-based workflow has the potential to reduce planning variability, improve efficiency during time-sensitive procedures, and establish a foundation for automated plan quality benchmarking and future optimization strategies.

INTRODUCTION

Prostate High Dose-Rate (HDR) Brachytherapy with Dominant Intraprostatic Lesion (DIL) boost is well tolerated for high-risk patients. Ultrasound-guided prostate HDR is a time-sensitive procedure with treatment planning subject to variability, especially for small glands and glands with large DILs. We aim to benchmark and improve the quality, consistency, and efficiency of treatment planning by optimizing the inverse planning dose–objective template. We present the enhanced template and its performance across a range of clinical cases.

METHODS

Thirty-five plans were reviewed retrospectively, each receiving 15Gy to the prostate and 18Gy to the DIL. Two optimization templates (VEGO, Vitesse TPS, Varian) were evaluated: the current clinical template and a modified template incorporating a ring structure around the Prostate+2mm and DIL+4mm volumes.

Plans were generated using both templates without manual intervention and benchmarked against clinically delivered plans using coverage, organ-at-risk (OAR) and conformality index (COIN) metrics.

COIN (conformal index) = C1 x C2
where C1 = PTV volume enclosed by Rx dose/PTV volume and
C2 = PTV volume enclosed by Rx dose/Rx dose volume

Old Template

	Region	Coverage	Priority	Portion		< > =	Dose	
☑	Prostate	Volume	1.00	90.00	%	>	105.00	%
☑	Prostate	Volume	1.00	100.00	%	>	97.00	%
☑	Prostate	Volume	1.00	35.00	%	<	150.00	%
☑	Urethra	Volume	1.00	0.00	cm³	<	120.00	%
☑	Urethra	Volume	1.00	20.00	%	<	110.00	%
☑	Rectum	Volume	1.00	0.00	cm³	<	100.00	%
☑	Rectum	Volume	1.00	1.00	cm³	<	80.00	%
☑	Normal Tissue	Volume	1.00	1.00	cm³	<	150.00	%
☑	DIL1	Volume	1.00	100.00	%	>	120.00	%
☐	DIL1	Volume	1.00	80.00	%	>	24.00	Gy
☑	DIL2	Volume	1.00	100.00	%	>	120.00	%
☑	DIL2	Volume	1.00	70.00	%	>	24.00	Gy

New Template

	Region	Coverage	Priority	Portion		< > =	Dose	
☑	Prostate	Volume	2.00	95.00	%	>	100.00	%
☑	Prostate	Volume	2.00	100.00	%	>	95.00	%
☑	Prostate	Volume	1.00	40.00	%	<	150.00	%
☑	Urethra	Volume	1.00	0.00	cm³	<	119.00	%
☑	Urethra	Volume	1.20	20.00	%	<	109.00	%
☑	Rectum	Volume	1.00	0.00	cm³	<	100.00	%
☑	Rectum	Volume	1.00	1.00	cm³	<	80.00	%
☑	DIL1	Volume	1.00	100.00	%	>	120.00	%
☑	Prostate+8mm	Volume	1.00	8.00	%	<	100.00	%
☑	Prostate+8mm	Volume	1.00	2.00	%	<	120.00	%
☑	Prostate+8mm	Volume	1.00	0.00	%	<	150.00	%

Figure 1: (Top) Default template with coverage constraints for DIL and Prostate and OAR constraints for rectum, urethra. (bottom) Template 2 consists of ring structures cropped 2mm from the prostate and 4mm from the DILs to help with high dose conformality.

RESULTS

Prostate volumes ranged from 11cc to 55cc (median 25.3 cc). All plans met target coverage (PTV D90%≥95-115%; DIL D90%≥120%) requirements.

The modified template demonstrated statistically significant improvement in conformity index (mean COIN 0.68, range 0.60-0.76) versus the default template (mean COIN 0.67, range 0.54-0.77, p = 0.03) and clinical plans (mean COIN 0.66, range 0.49-0.76, p = 0), with the largest improvements at lower prostate volumes. There was no significant increase in OAR doses between the clinical plans and the new template.

The new template was at least as efficient as the original one in generating clinically acceptable plans meeting all the constraints without any manual changes (63%). A linear fit was created for COIN v prostate volume to provide a preliminary predictive model.

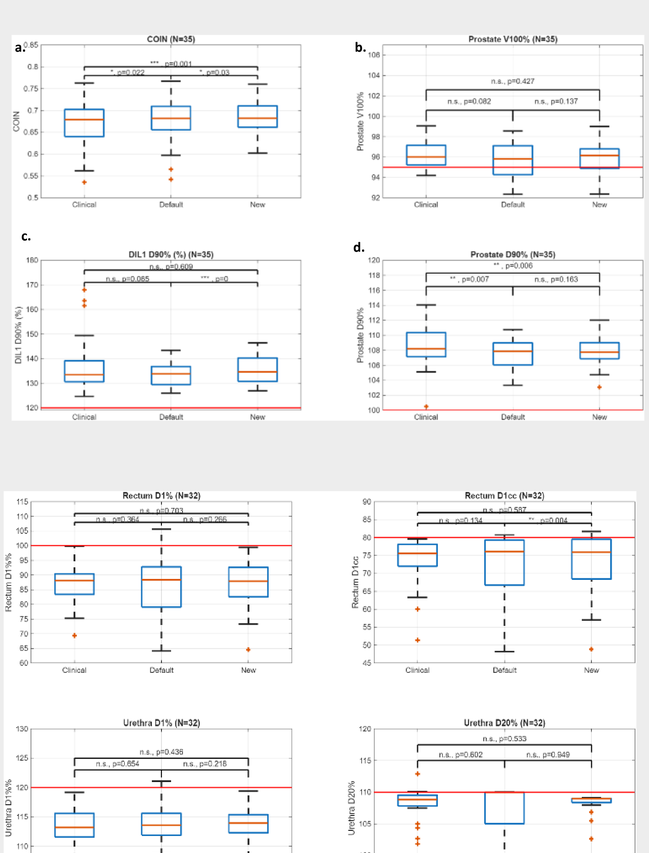

Figure 2: (top) COIN across all plans and optimization techniques. There is statistically significant improvement in COIN between clinical and New Template, and Default and New Template (two-tailed, paired t-test, alpha = 0.05). b) Prostate V100% shows no statistical difference between clinical and new template. c) and d) DIL coverage and Prostate D90% met for all plans. (Bottom): OAR constraints across all three optimization techniques. The red lines indicate the clinical constraints. While rectum constraints were slightly higher for the New template, they weren't significantly different from the clinical plans.

RESULTS

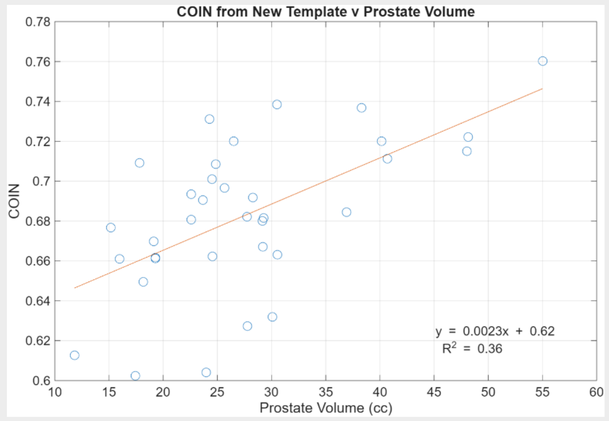

Figure 3: Weak linear correlation between COIN and prostate volume (cc). This serves as a preliminary model for COIN prediction based on prostate size. More data points to be added for better predictive power.

DISCUSSION

The modified optimization template consistently improved dose conformity without compromising target coverage or OAR constraints, supporting the use of ring structures as a simple strategy to enhance inverse planning.

The benefits were most pronounced for smaller prostates, where plan optimization is typically more challenging. Standardizing optimization templates may reduce inter-planner variability and improve efficiency during time-sensitive intraoperative HDR procedures.

Future work will validate the predictive COIN model in a larger patient cohort and explore its use for automated plan quality benchmarking.

CONCLUSION

This template-based approach establishes a robust baseline for high-quality prostate HDR brachytherapy with DIL Boost, ensuring standardization across planners. The inclusion of a ring structure in the optimization process offers improved conformality while maintaining acceptable target coverage and OAR sparing.

REFERENCES

1. Panetta JV, Veltchev I, Horwitz E, Hallman M, Wong K, Price RA, Ma CMC. Overview of treatment plan quality in a high dose rate prostate brachytherapy workflow. *Brachytherapy*. 2024;23(6):698-704. doi:10.1016/j.brachy.2024.08.255.

CONTACT

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