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Can knowledge-based dose prediction models inform brachytherapy needle decision-making for cervical cancer?

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INTRODUCTION

- Interstitial needles are often used in combination with intracavitary applicators, e.g. tandem-and-ring/ ovoids (T&R/T&O), for complex cervical cancer cases [1]
  - Customized dose distributions
  - Increased procedure time and risk of potential complications
- The decision to use needles is not standardized and dependent on physician's expertise

AIM

The purpose of this study is to determine whether knowledge-based models can predict cases where needle supplementation would be required to meet dose objectives for targets and organs-at-risk (OARs).

MATERIALS AND METHODS

- Previously validated dose-prediction models for intracavitary applicators[2,3]
- Prediction of dose volume histogram for OARs based on distance from high-risk clinical target volume (HRCTV)
- D_{2cc} of prediction and clinical dose distribution used as plan quality criteria

Applicator	Model D_{2cc} Prediction Precision		
	Bladder	Rectum	Sigmoid
T&R	0.66 Gy	0.39 Gy	0.50 Gy
T&O	0.52 Gy	0.70 Gy	0.46 Gy

- Intracavitary models applied to hybrid cases with 1-3 implanted needles
- Prediction accuracy was verified by replanning of 70 T&R and 71 T&O hybrid cases without needles, and comparing predicted to re-planned D_{2cc}
- Manual dose optimization[4,5] was guided by predicted D_{2cc} values, and attempted to meet the following dose objectives (in EQD2):

Priority	Parameter	Limit	Aim
1.	HRCTV D90	85 – 90 Gy	Manditory Aim
2.	Bladder D_{2cc} Rectum D_{2cc} Sigmoid D_{2cc}	< 90 Gy < 75 Gy < 75 Gy	Optional Aims
3.	HRCTV V100	> 95 %	

- Deviations in bladder D_{2cc} predictions were found to be greater, and correlated to asymmetry in the shape of the HRCTV
- Therefore, an additional correction was applied for asymmetric cases:
  - "Asymmetry" metric = distance from the center of mass of HRCTV to the tandem (> 4 mm considered asymmetric)
  - Linear regression model was fit to 14 T&R and 37 T&O cases with asymmetric HRCTV and used to refine bladder D_{2cc} predictions

RESULTS

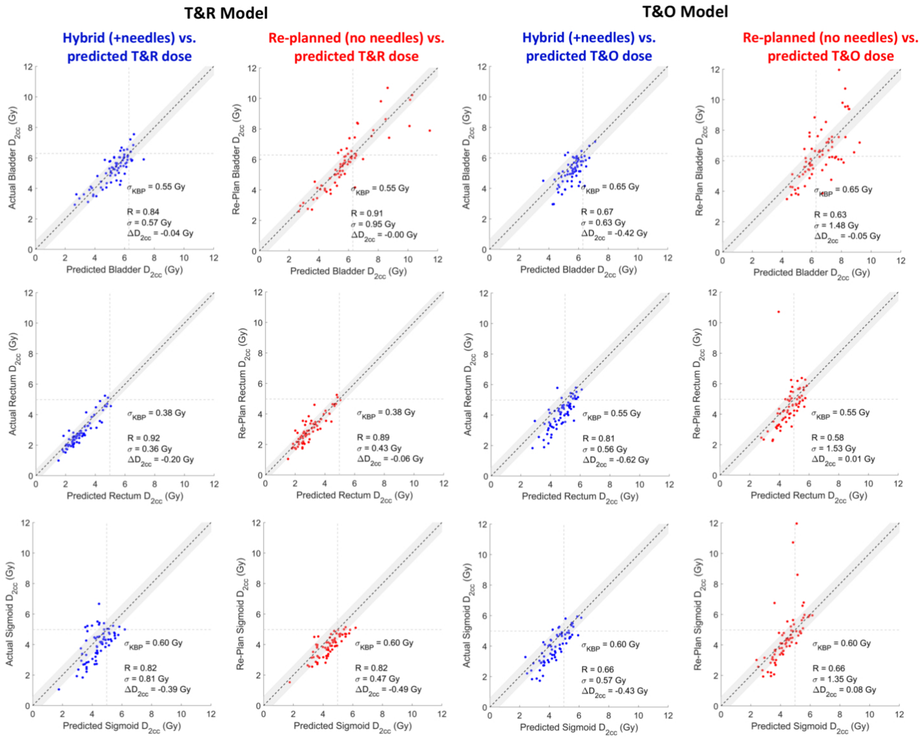

Figure 1: *Actual and re-planned D_{2cc} values compared to the D_{2cc} values predicted from knowledge-based intracavitary models*

Actual D_{2cc} values were obtained from clinical hybrid plans.
Doses obtained when these cases were re-planned without needles, to meet a HRCTV D90 of 85-90 Gy EQD2

Precision of the dose- prediction model
Organ dose limits for a 4 brachytherapy fraction treatment

Parameter	OAR	Result T&R	Result T&O
Re-planned D_{2cc} within precision of model-prediction	Bladder	66 %	46 %
	Rectum	67 %	46 %
	Sigmoid	54 %	45 %
	All OARs	30 %	11 %
Re-planned D_{2cc} < OAR dose limit	Bladder	71 %	56%
	Rectum	96 %	46%
	Sigmoid	91 %	46%
	All OARs	66 %	10%
D_{2cc} prediction met OAR limits, but re-planned D_{2cc} > OAR limit	Bladder	9 %	10 %
	Rectum	4 %	7 %
	Sigmoid	2 %	10 %
	All OARs	9 %	3 %
Cases correctly predicted as hybrid cases (re-plan OARs > limit, i.e. Specificity)	Bladder	70 %	74 %
	Rectum	97 %	79 %
	Sigmoid	94 %	85 %
	All OARs	80 %	50 %
Cases correctly predicted as intracavitary cases (re-plan OARs < limit, i.e. Sensitivity)	Bladder	92 %	71 %
	Rectum	–	72 %
	Sigmoid	67 %	56 %
	All OARs	75%	95 %

Although the models were applied to more complex cases that fall outside of the scope of the model training dataset, model performance was still reasonable.

These cases could have been planned with an intracavitary applicator alone (i.e. no needles), assuming the physician is okay with taking OARs up to the limit.

For < 10 % of cases, the model predicted that an intracavitary applicator alone was sufficient, while the re-plan indicated needles would be required.

Models were ≥ 50 % accurate in identifying when needles were required.

Models were ≥ 75 % accurate in identifying when needles were not required.

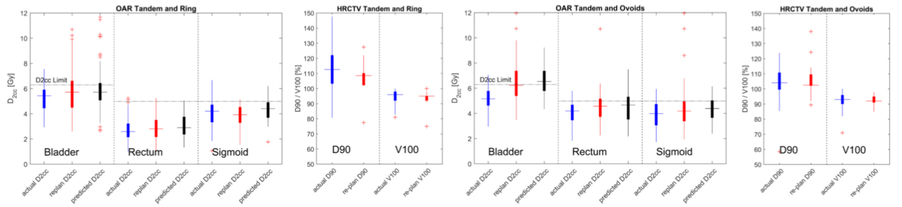

Figure 2: *Comparison of **actual** (+ needles), **re-planned** (no needles) and **predicted** (no needles) doses.*

Organ dose limits for a 4 brachytherapy fx treatment

CONCLUSION

- **Model predicted D_{2cc} values are beneficial for identifying cases that could be treated with intracavitary applicators alone (≥75% accuracy), and cases that require needles (≥50% accuracy)**
- **Needles over-used, particularly for T&R cases**
- **Standardized planning driven by knowledge-based dose predictions could reduce needle usage**

RELATED WORK

- Knowledge-Based Three-Dimensional Dose Prediction for Tandem-And-Ovoid Brachytherapy, K Cortes* et al (oral, 7/14/20 track 3 3.30-5.30 pm)
- What Knowledge-Based Dose Prediction Models Tell Us About Ovoid Vs. Ring Based Brachytherapy Applicators, K Kallis* et al (e-Poster)
- ORBIT-RT: A Real-Time, Open Platform for Knowledge-Based Quality Control of Radiotherapy Treatment Planning, B Covele* et al (e-Poster)

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