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What knowledge- based dose prediction models tell us about ovoid vs. ring based brachytherapy applicators

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INTRODUCTION

- There is currently a lack of patient-specific tools to guide brachytherapy planning and applicator choice
- Little data comparing tandem-and-ring (T&R) to tandem-and-ovoids (T&O) standard applicators [1-3]
- Knowledge-based dose prediction models have been produced for T&O, but have yet to be extended to other applicators, and could provide additional insight [4]

AIM

- To develop and validate applicator-specific knowledge-based models for intracavitary brachytherapy dose prediction
- To use knowledge-based predictions and clinical data to determine the dosimetric differences of two common intracavitary applicators

MATERIALS AND METHODS

- Knowledge-based models use target-OAR distances to predict OAR dose-volume histograms (DVHs) (see Figure 1) [4]
- Individual models developed for T&R and T&O applicators
- Model training on 80 T&O (75 T&R) cases and validation on 32 T&O (38 T&R) cases, where a case = single brachytherapy fraction
- Model performance quantified using $\Delta D_{2cc}=D_{2cc,actual}-D_{2cc,predicted}$
- Standard deviation ($\sigma(\Delta D_{2cc})$) represents model precision
- Estimation of dose difference of two applicators by applying T&O (T&R) model to T&R (T&O) cases
- Model-predicted applicator differences were compared to clinically achieved D_{2cc} for these cases

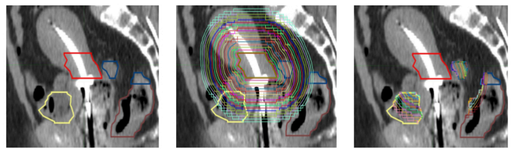

Figure 1: Post-processing required for knowledge-based dose predictions.
1. Target and OARs are contoured (example T&O CT sagittal slice on left)
2. Shells are generated around target (middle), and represent distance from target
3. Dose is extracted from each shell where it overlaps with each OAR (right), and used to generate DVH dose prediction models. More details about algorithm in [4].

RESULTS

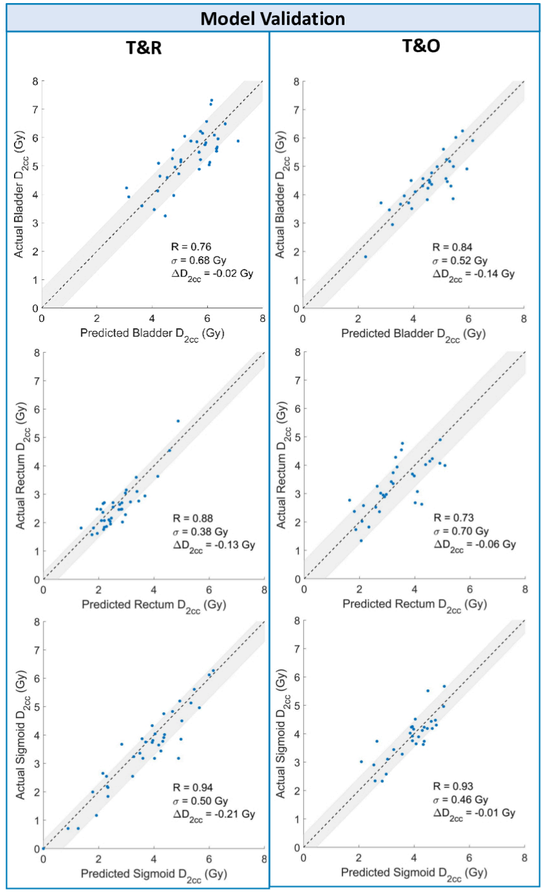

Figure 2: Validation of both tandem-and-ring (T&R) and tandem-and-ovoid (T&O) models demonstrated good agreement between actual and predicted D_{2cc} values for all OARs.

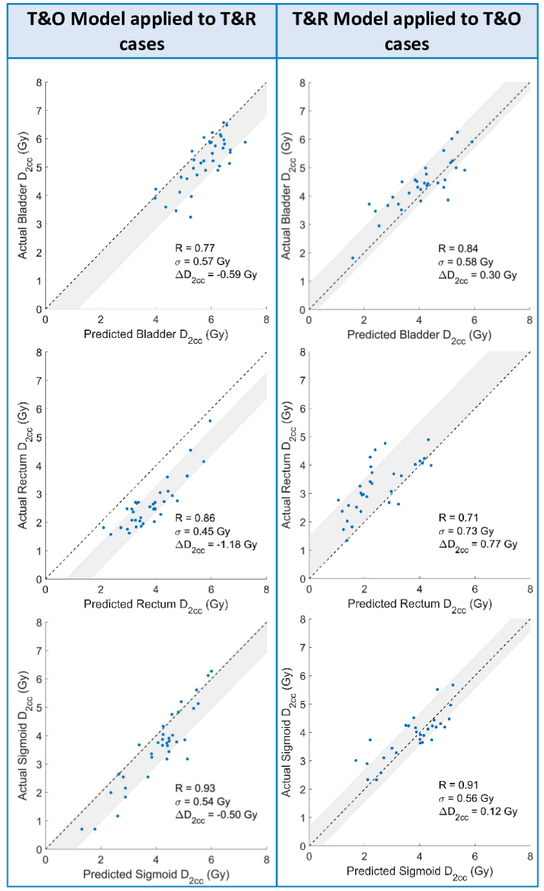

Figure 3: Knowledge-based models suggest that greater organ sparing can be achieved with T&R relative to T&O. Mean ΔD_{2cc} indicate lower OAR doses for T&R compared to T&O for all OARs.

σ = standard deviation over ΔD_{2cc}, where ΔD_{2cc} = Actual D_{2cc}– Predicted D_{2cc}, (also shown by the grey band).
Pearson correlation coefficients (R) and mean ΔD_{2cc} are also presented.

RESULTS

Data Set		Model D_{2cc} Prediction Precision		
		σ (Bladder)	σ (Rectum)	σ (Sigmoid)
T&R Model	Training	0.53 Gy	0.41 Gy	0.54 Gy
	Validation	0.66 Gy	0.39 Gy	0.50 Gy
T&O Model	Training	0.61 Gy	0.57 Gy	0.52 Gy
	Validation	0.52 Gy	0.70 Gy	0.46 Gy

Table 1: Model performance was similar between training and validation datasets, and between applicators.

Table 2: OAR dose differences between T&O and T&R applicators, converted to Gy EQD2 for comparison to prior studies. Both clinical data and models indicate higher organ dose for T&O.

	T&O Clinical Data	T&R Clinical Data	Clinical Data	T&O model	T&R model	EMBRACE I[3]
OAR EQD2	Mean D_{2cc} [Range]	Mean D_{2cc} [Range]	Mean δD_{2cc}	Mean δD_{2cc}	Mean δD_{2cc}	Mean δD_{2cc}
Bladder	77.1 [50.0–108.3]	74.4 [51.9–112.1]	2.7*	7.8**	5.7*	7.7
Rectum	66.0 [48.6-102.07]	55.4 [46.8–78.6]	10.6**	8.1**	8.1**	3.2
Sigmoid	68.8 [39.6-99.6]	61.4 [43.2-81.7]	7.4**	4.6*	1.8	-

δD_{2cc} = T&O D_{2cc} – T&R D_{2cc} , *p<0.05, **p<0.01 (paired t-test)

CONCLUSION

- Accurate knowledge-based dose prediction models were developed for two common intracavitary applicators
- Separate models are necessary due to the dosimetric differences of the two applicators
- Models could be beneficial for standardizing and improving the quality of brachytherapy plans by providing patient-specific quality control and dosimetric targets.
- Both models and clinical data suggest that significant OAR sparing can be achieved with T&R over T&O applicators, particularly for the rectum.

REFERENCES

1. D. Levin et. al., Medical Dosimetry, 2008, doi.org/10.1016/j.meddos.2008.06.003
2. F. Biltekin et. al., Journal of Contemporary Brachytherapy, 2020, doi.org/10.5114/jcb.2020.92699
3. M. Serban et.al., International of Radiation Oncology Biology Physics, 2020, doi.org/10.1016/j.ijrobp.2019.12.019
4. T. I. Yusufaly et. al, Brachytherapy, 2020, doi.org/10.1016/j.brachy.2020.04.008

RELATED WORK

- Knowledge-Based Three-Dimensional Dose Prediction for Tandem-And-Ovoid Brachytherapy, K Cortes*, A Simon, K. Kallis, J Mayadev, S Meyers, K Moore, UC San Diego (presentation Track 3 7/14/2020 3.30 pm- 5.30 pm)
- Can knowledge-based dose prediction models inform brachytherapy needle decision –making for cervical cancer?, K. Kallis, D. Brown, D. Scanderbeg, K. Kisling, B. Covele, C. Yashar, J. Einck, L. Mell, L. A. Simon, Jyoti Mayadev, K.L. Moore, S.M. Meyers, UC San Diego (ePoster)
- ORBIT-RT: A Real-Time, Open Platform for Knowledge-Based Quality Control of Radiotherapy Treatment Planning, B Covele*, K Puri, K Kallis, K Moore, UC San Diego (ePoster)