

Cross-Treatment Knowledge Transfer: Generalizability of A Deep Learning Autosegmentation Model Trained on External Beam Radiotherapy Contours for Brachytherapy

Patricia Oliva, BSc¹, Shrimanti Ghosh, PhD², Brenda Rose, BSc¹, Jasmine Mehdwan³, Jihyun Yun, PhD¹, Pierre Boulanger, PhD⁴,
Kumaradevan Punithakumar, PhD², Fleur Huang, MD¹, Geetha Menon, PhD¹

¹Department of Oncology, University of Alberta, ²Department of Radiology & Diagnostic Imaging, University of Alberta,
³Department of Physics, University of Alberta, ⁴Department of Computing Science, University of Alberta

INTRODUCTION

- Locally advanced cervical cancer radiotherapy (LACC-RT) includes external beam radiotherapy (EBRT; CT-planned) followed by brachytherapy (BT; MRI or CT-planned).
- In our practice, LACC-BT workflow includes 2 insertions (1 week apart), each delivering 2 HDR fractions (Fxs; >12 hours apart) → 4 Fxs total (Fig. 1)
- Organs-at-risk (OARs: bladder, rectum, sigmoid, bowel) contouring:
 - Fxs1&3 (MRI planned): Autosegmentation model available
 - Fxs2&4 (CT verified): Manually contoured to evaluate dosimetric differences from MRI-based plan (Fxs1&3).

Aim: To evaluate the generalizability of a deep learning (DL)-model, trained exclusively with EBRT OAR contours on CT, for autosegmentation in CT-based LACC-BT.

Innovation: This novel exploratory work investigates the scalability of an in-house built DL-autocontouring model across CT-based treatment applications, aiming to ascertain the following:

- Can knowledge transfer occur from an OAR autosegmentation model developed with EBRT contours for application to BT?
- Is this a practical solution for centres with limited BT-data until sufficient contours are available for training an at-BT model?

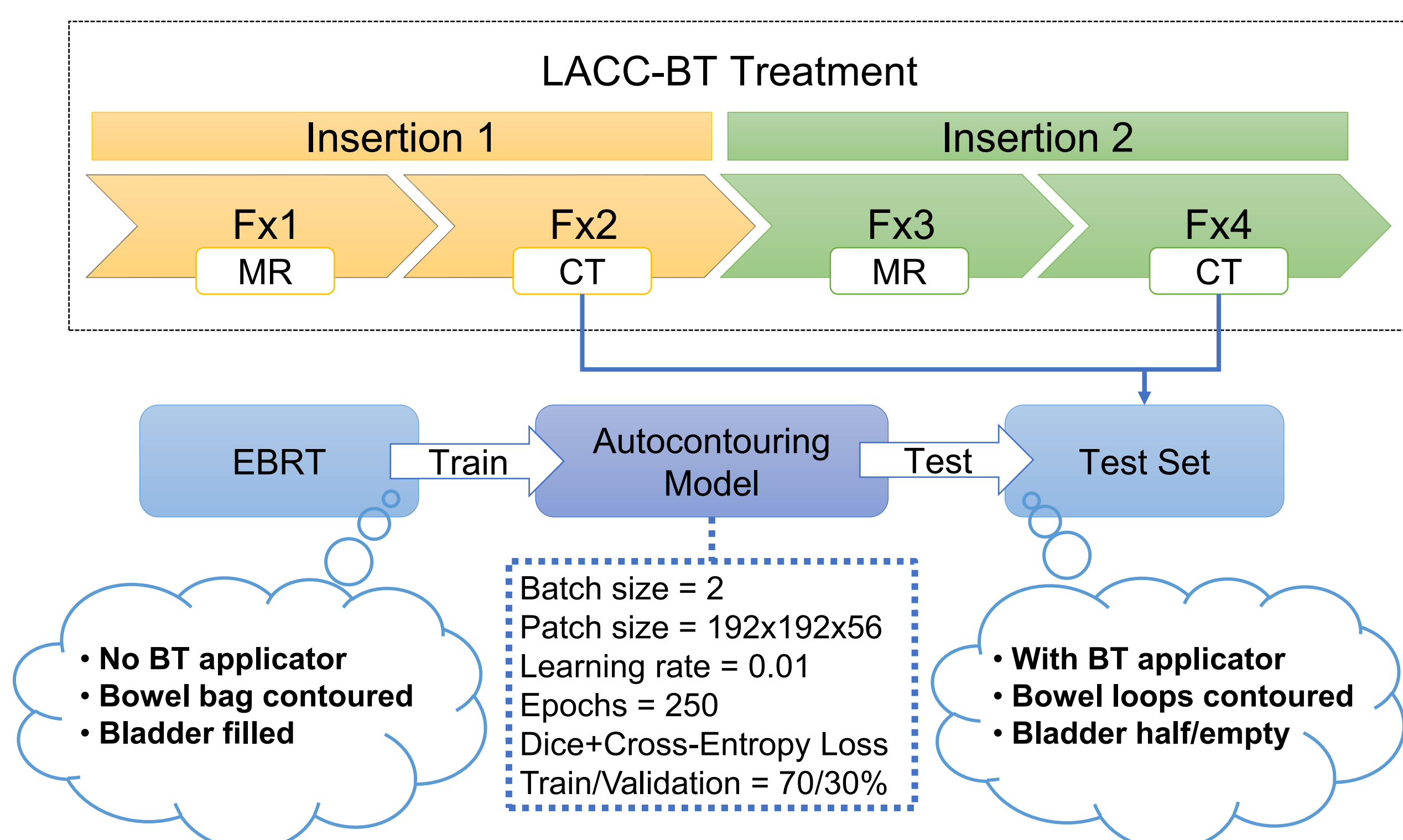


Fig. 1: LACC-BT workflow and overall model schematic. EBRT OAR contours were used to train the nnU-Net-based autocontouring model (hyperparameters shown), which was tested on Fxs2&4 BT CTs. Key differences in the EBRT and BT scans are summarized.

METHODS AND MATERIALS

Dataset Details

- 50 LACC-RT patients
 - Training & validation: 50 EBRT CTs (no BT applicator)
 - Testing: 68 BT CTs (with applicator; n=38 Fx2, n=30 Fx4)
- Manual OAR contours by 3 physicians [1] → Ground Truth (GT)

Model Development

- nnU-Net-based framework [2] (Fig. 1)
- Training time = 1.6 hours (NVIDIA H100 80GB GPU)

Comparison of GT vs Model Contours

- Geometric evaluation
 - Dice Coefficient (Dice), volume similarity, Hausdorff distance, and precision obtained; Dice reported here for brevity.
- Dosimetric implications
 - Clinically delivered MRI-based plans from Fxs1&3 were projected on the predicted contours for Fxs2&4.
 - OAR D2cc differences ($\Delta D2cc$; GT-Model) recorded.

RESULTS

Fxs2&4 OAR at-BT contouring times:

- Model prediction = **4.4 sec/case**
- Manual = ~ 0.5 - 1 hours

Geometric Evaluation

- Mean $\pm$ SD Dice values (Fig. 2):
 - Bladder 0.65 $\pm$ 0.23, rectum 0.68 $\pm$ 0.14, sigmoid 0.50 $\pm$ 0.21, and bowel 0.26 $\pm$ 0.16
- Dice did not differ significantly between BT Fxs2&4 ($p>0.5$).
- Similar trend seen for other geometric metrics.

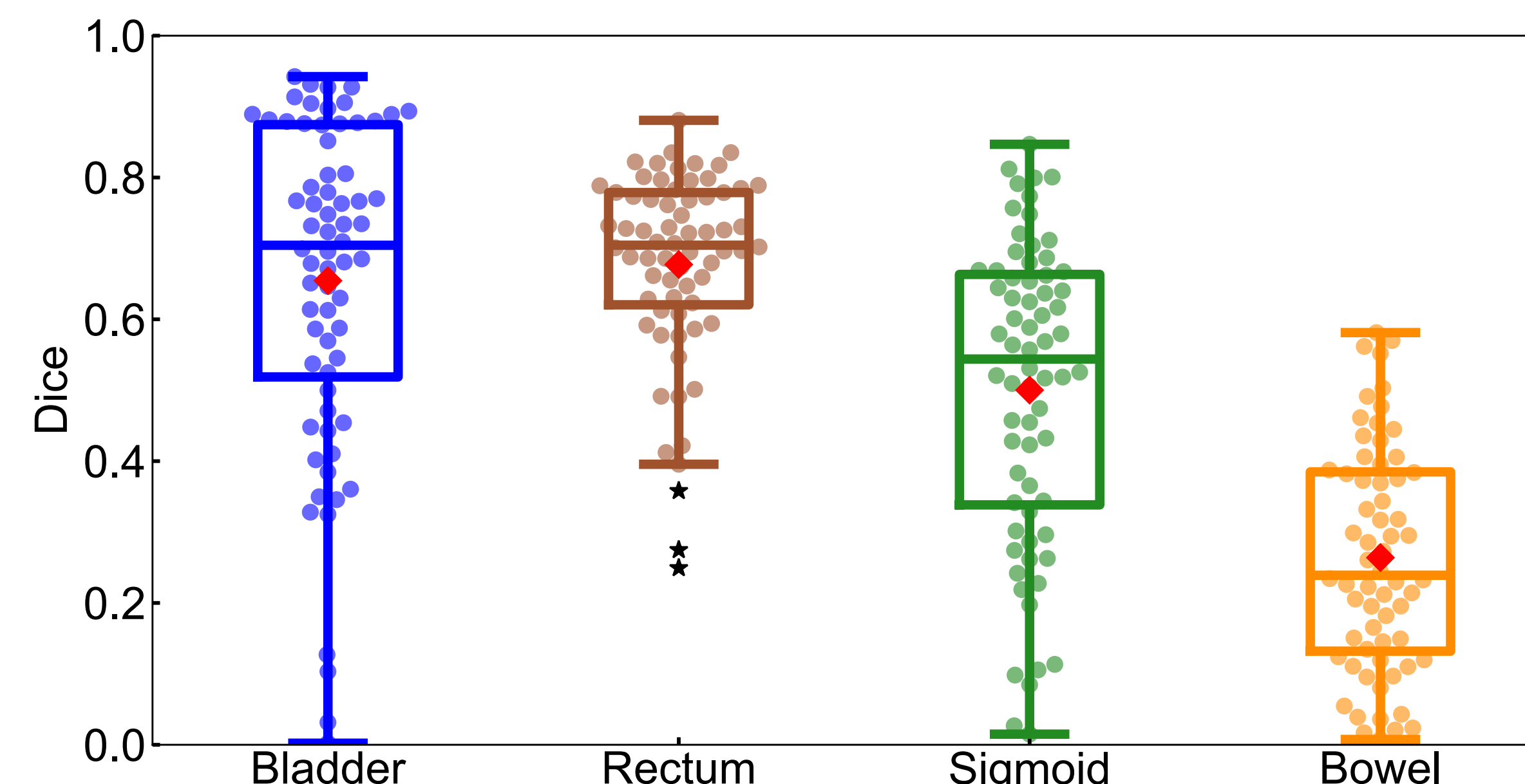


Fig. 2: Boxplot of Dice vs OAR. Means are red diamonds; outliers are black stars. A Dice value closer to 1 corresponds to better overlap between GT and Model contours.

Dosimetric Differences

- Mean $\Delta D2cc$ (Gy EQD2) (Fig. 3):
 - Low for bladder -0.1 $\pm$ 0.4, rectum -1.7 $\pm$ 2.5, and sigmoid 0.1 $\pm$ 0.5, but higher for bowel -6.7 $\pm$ 9.6

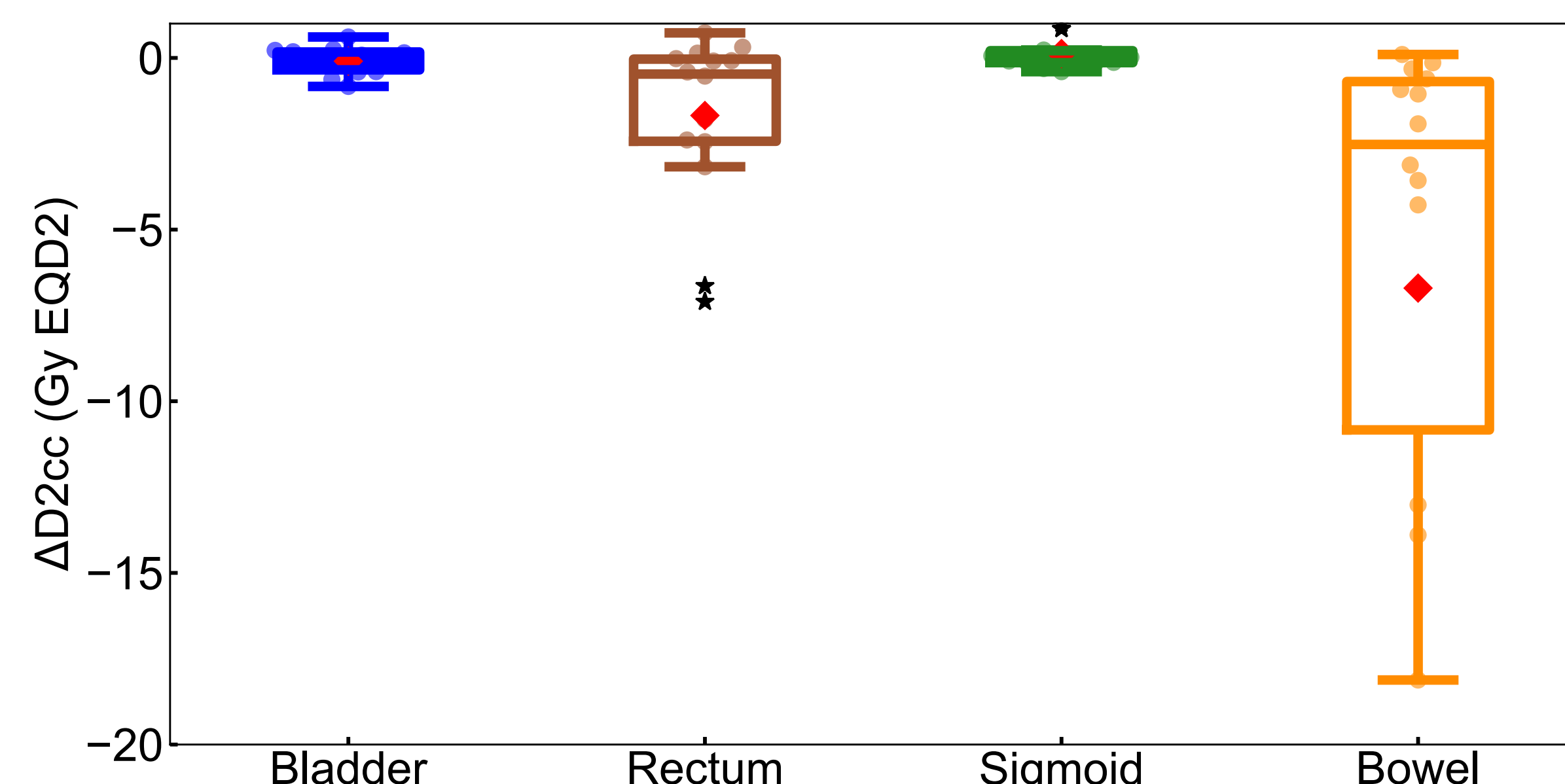


Fig. 3: Boxplot of $\Delta D2cc$ vs OAR. Means are red diamonds; outliers are black stars.

Moderate metrics expected due to:

- Variations in EBRT vs BT practices (Fig. 4)
 - Bladder: Full vs half-full to empty
 - Bowel: Bag vs loops contoured
- Impact of applicator-induced anatomic displacement, domain shift, and small training dataset

↑ Dice & ↓ $\Delta D2cc$
Better agreement GT and Model contours

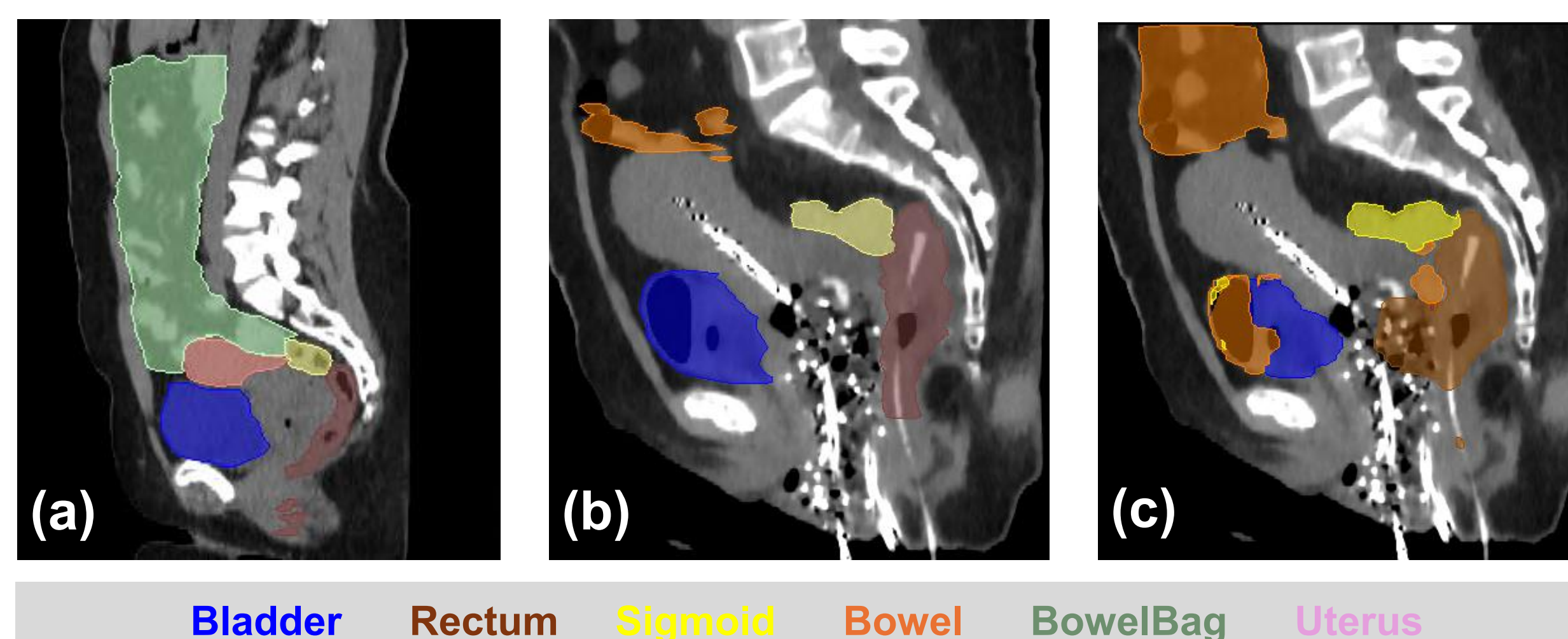


Fig. 4: Comparison of (a) EBRT, (b) GT BT, and (c) Model BT contours for one case, with Dice for bladder of 0.79, rectum, 0.71, sigmoid 0.23, and bowel 0.55. Note the differences in (a) EBRT vs (b) BT practice: bowel bag vs loop contoured and applicator presence (and consequent shift in uterus location).

DISCUSSION

Reasonable scalability for most BT OARs

- Evaluation metrics were similar for bladder, rectum, sigmoid.
- Lower $\Delta D2cc$ indicative of geometric inaccuracies being located outside of high-dose regions as seen for:
 - Low Dice bladder and sigmoid cases (Fig. 2 vs Fig. 3)
 - Few bowel cases: median $\Delta D2cc$ = -2.5 Gy EQD2 (Fig. 4a)

Limited applicability for bowel

- Larger volumes predicted
 - Mean increase of 752.1 $\pm$ 375.9 cc
 - Bowel bag contours in EBRT (Fig. 3a) vs loops in BT (Fig. 3b)
- Location predicted caudally
 - Overlapping with tandem (Fig. 4b) → high bowel $\Delta D2cc$ s
 - Bowel sits lower in EBRT (Fig. 3a) vs BT (Fig. 3b)

Practicality as a starting contour

- Predicted contours → clinically useful starting point for physicians to review and adjust
- Faster approach to evaluate next-day post-implant OAR dosimetry.

Limitations and future work

- Small training datasets → higher risk of overfitting
- Future model refinement with a larger EBRT training dataset
- Validation with CT-based LACC-BT contours to improve scalability

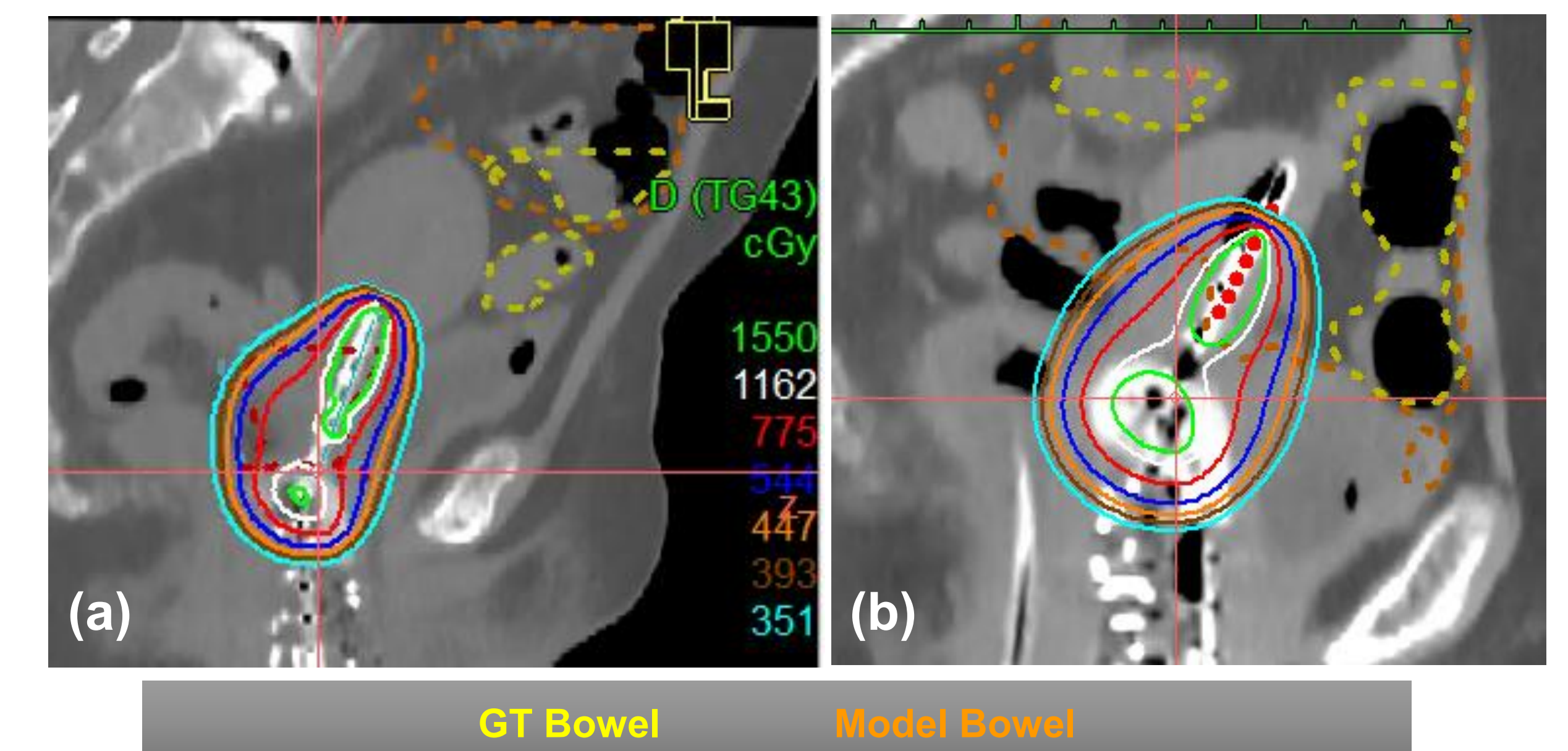


Fig. 5: GT (yellow) vs Model (orange) bowel contours for a low (a) and high (b) $\Delta D2cc$ case. EBRT practice is manifested in Model contours. Planning aim=775 cGy/Fx to target.

CONCLUSIONS

- The Model, trained on EBRT contours, provides reasonable performance for use in BT (except for bowel), supporting knowledge transfer across techniques.
- This may be a potential approach in data-limited settings until adequate data is acquired for developing a task-specific model.

REFERENCES

- EMBRACE II Study, <https://www.embracestudy.dk>
- Isensee *et al.*, Nat. Methods 2021, doi: 10.1038/s41592-020-01008-z

ACKNOWLEDGMENTS

This research has been funded by the Alberta Women's Health Foundation through the Women and Children's Health Research Institute and by the Government of Alberta through the Women in STEM Scholarship.

women & children's
health research institute

AWHF
alberta women's health foundation