Enabling daily proton dose calculation using deep-learning quality improved cone-beam computed tomography for head-and-neck cancer

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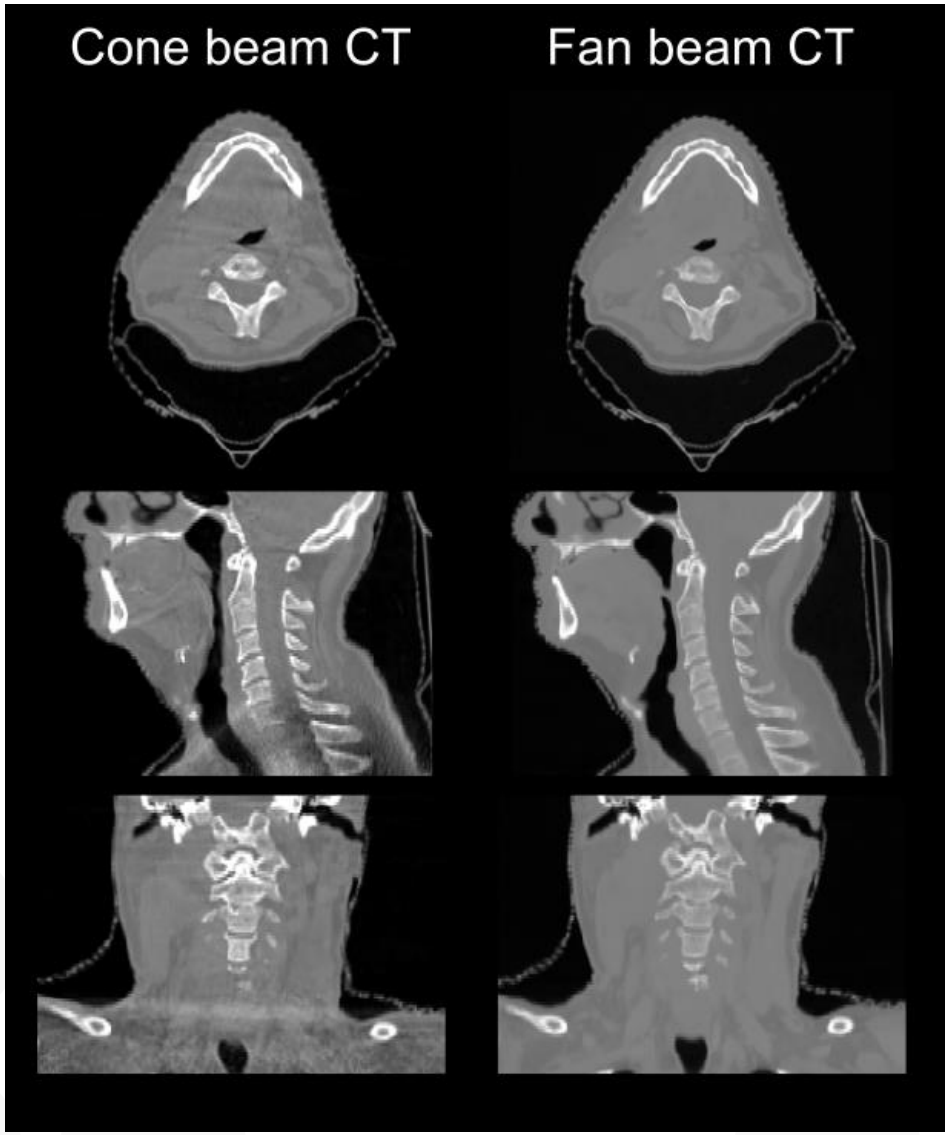
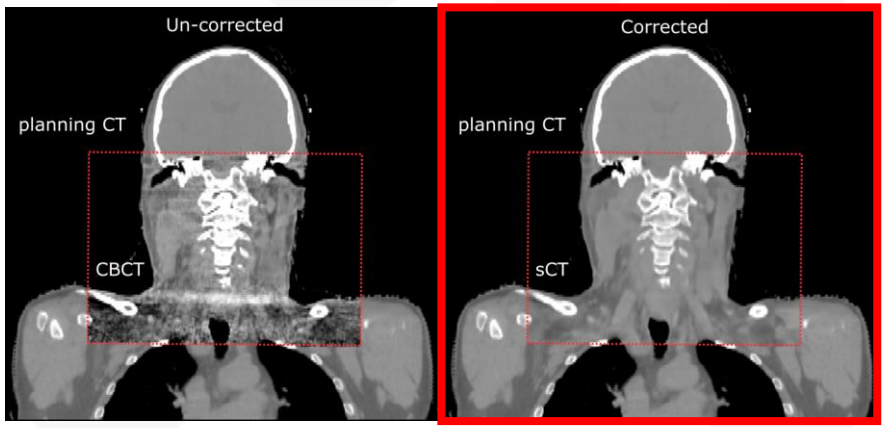
Background

- Proton therapy: sensitive to range estimation uncertainties
  - CT number inaccuracies
  - Interfractional motions
- Ideally: adaptive proton therapy workflow (offline)
  - Based on daily cone-beam CT (CBCT)
- CBCT suffer from artifacts and poor image quality
  - Often insufficient for proton dose calculations
- Deep learning model for synthetic CT generation from CBCT to enable daily re-calculations

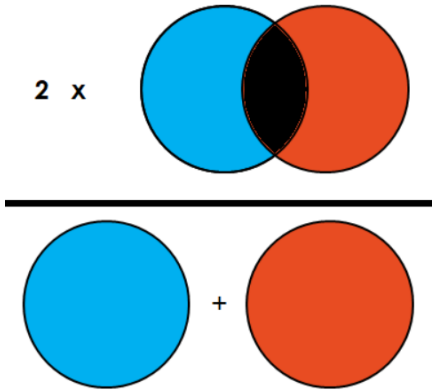


Methods and materials

- A total of 102 head-and-neck cancer patients used to train (82) and evaluate (20) our deep learning model
  - 467 CT scans and 2781 CBCT scans (training)
- Model: 3D Cycle-consistent contrastive unpaired translation (CycleCUT)
- Stitched the sCT onto pCT to obtain a full field-of-view (FOV)
  - Full FOV sCT is the final output of the model
- Compared to a same-day repeat CT deformed to the CBCT anatomy **(gt-rCT)**
- Deformably propagated structures from pCT and re-calculated proton plan



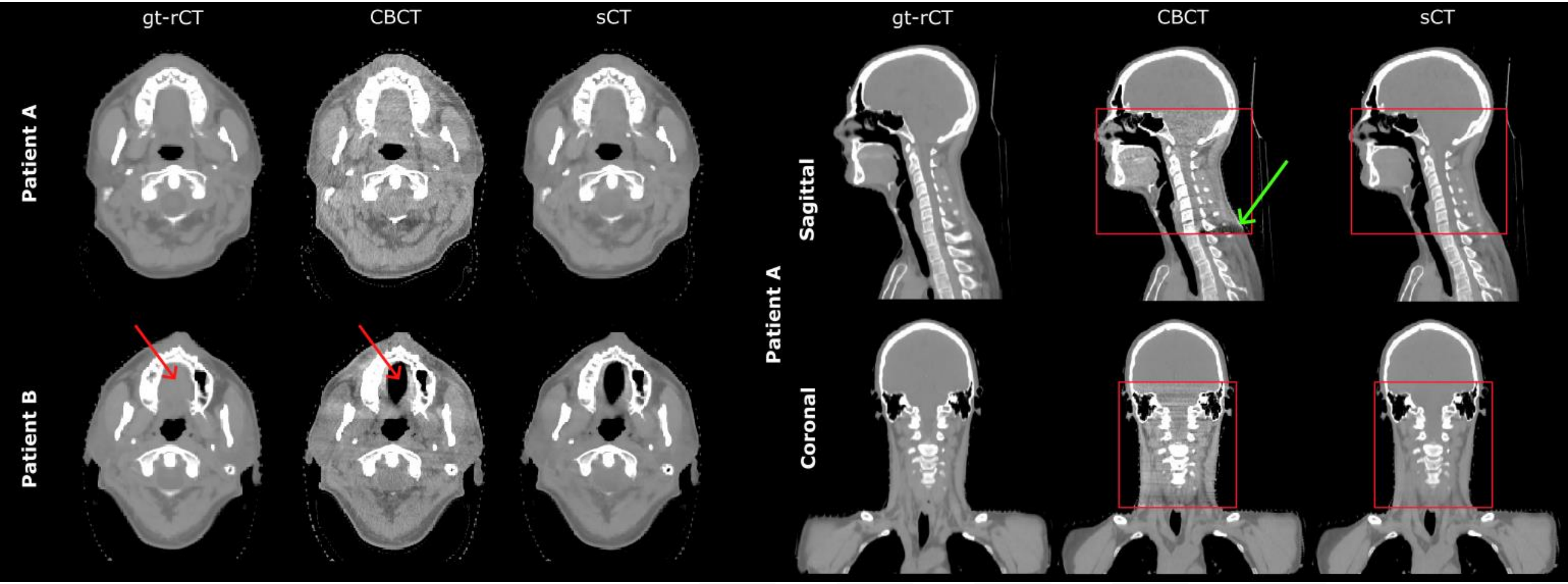
Evaluation: metrics



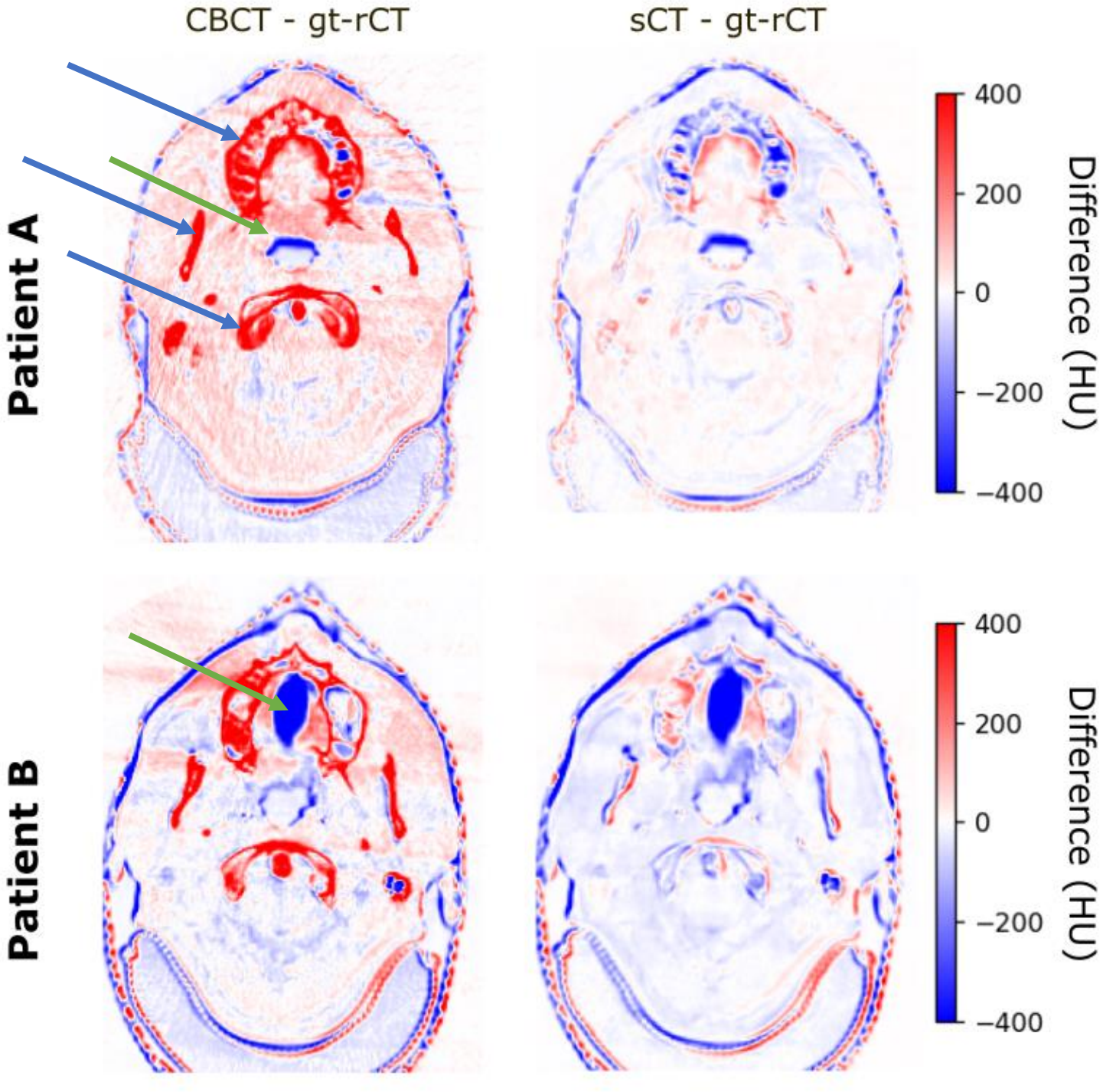
- CT numbers and **dose**
- Dose:
  1. Overlap of isodose lines (25%, 50%, 75%, 90%), evaluated by Dice score
  2. Difference in dose-volume-histogram (DVH) parameters for the target and organs-at-risk
  3. Gamma analysis (global evaluation, lower dose cut-off of 10% of the maximum dose in gt-rCT)
     - Four criteria: 1%/2mm, 2%/2mm, 2%/3mm, 3%/3mm

Results

Patient A: Good anatomical correspondence
Patient B: Less optimal anatomical correspondence



Results



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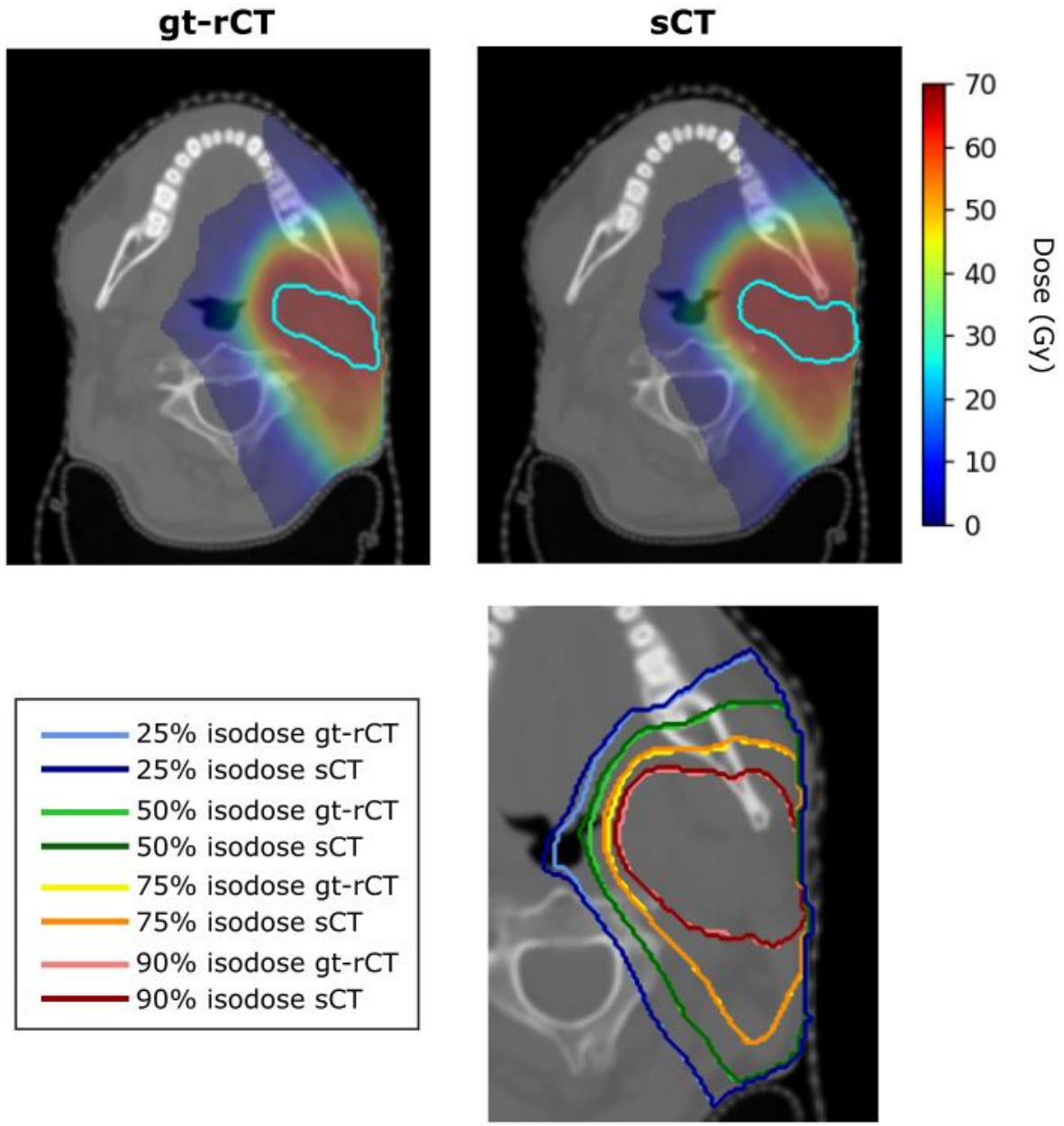
Results

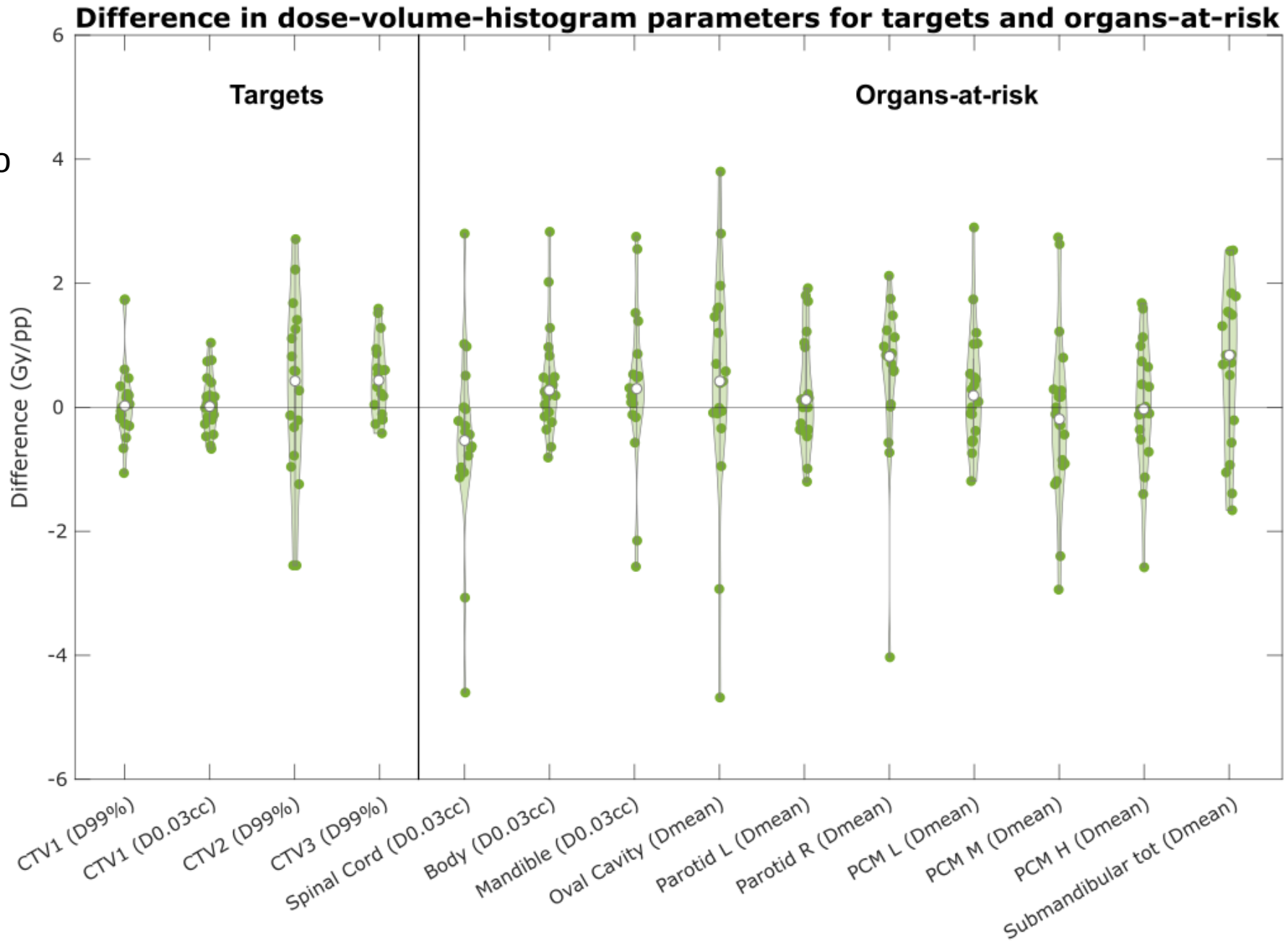
Dice score between isodose lines on ground truth and synthetic CT			
25% isodose	50% isodose	75% isodose	90% isodose
0.98 [0.98; 0.99]	0.98 [0.97; 0.98]	0.97 [0.95; 0.97]	0.95 [0.91; 0.96]

Example



Results

- Medians in vicinity of zero
- D_{max} in dose gradient (SC)
- $pCT_{deformed}$ contour:
  - Different structures for sCT/gt-rCT
  - Mean difference: **3.6 Gy**
- $gt\text{-}rCT_{rigid}$ contour:
  - Same structures for sCT/gt-rCT
  - Difference: **0.6 Gy**



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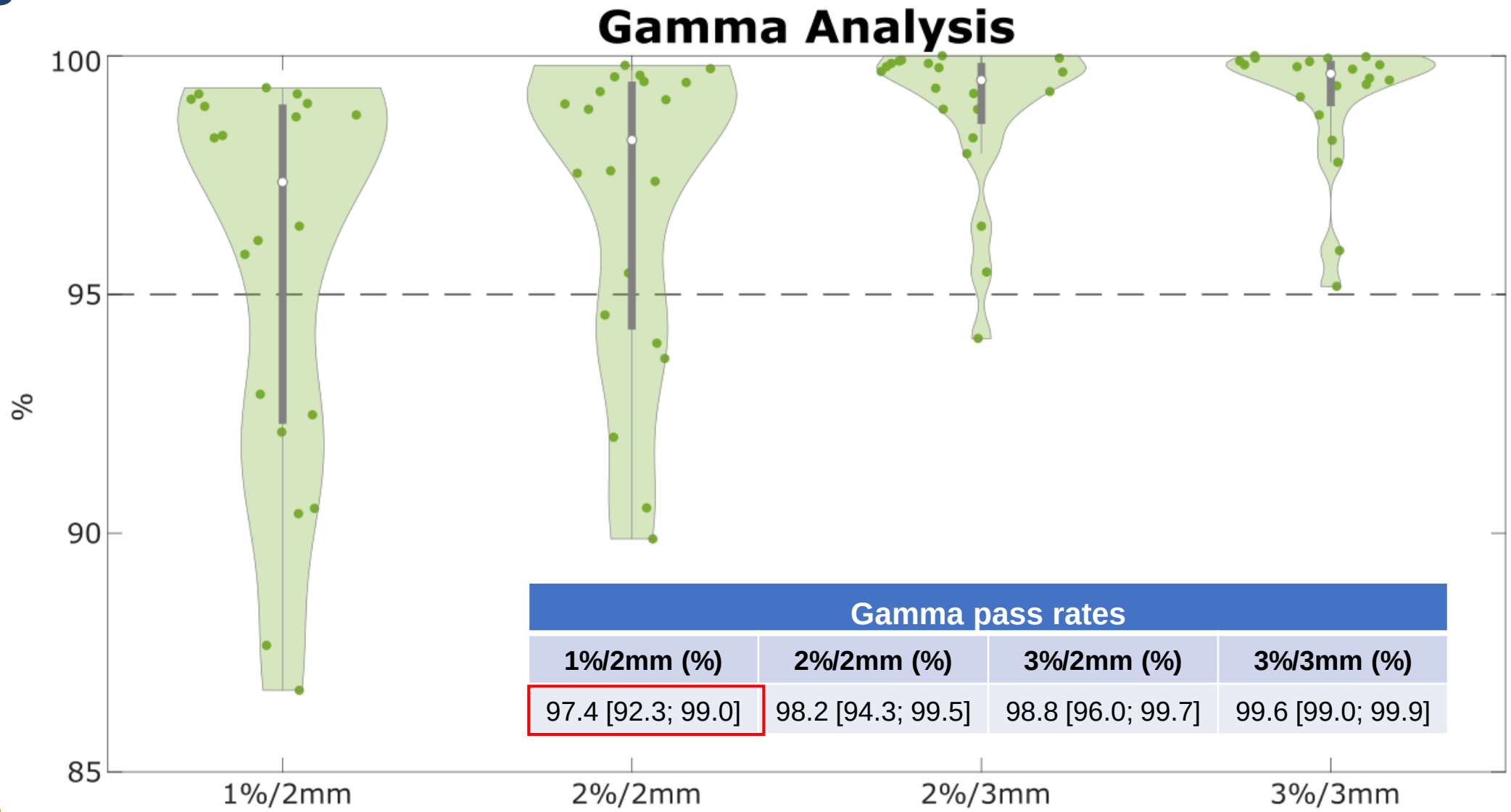
Results



Gamma pass rates			
1%/2mm (%)	2%/2mm (%)	3%/2mm (%)	3%/3mm (%)
97.4 [92.3; 99.0]	98.2 [94.3; 99.5]	98.8 [96.0; 99.7]	99.6 [99.0; 99.9]

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Conclusion

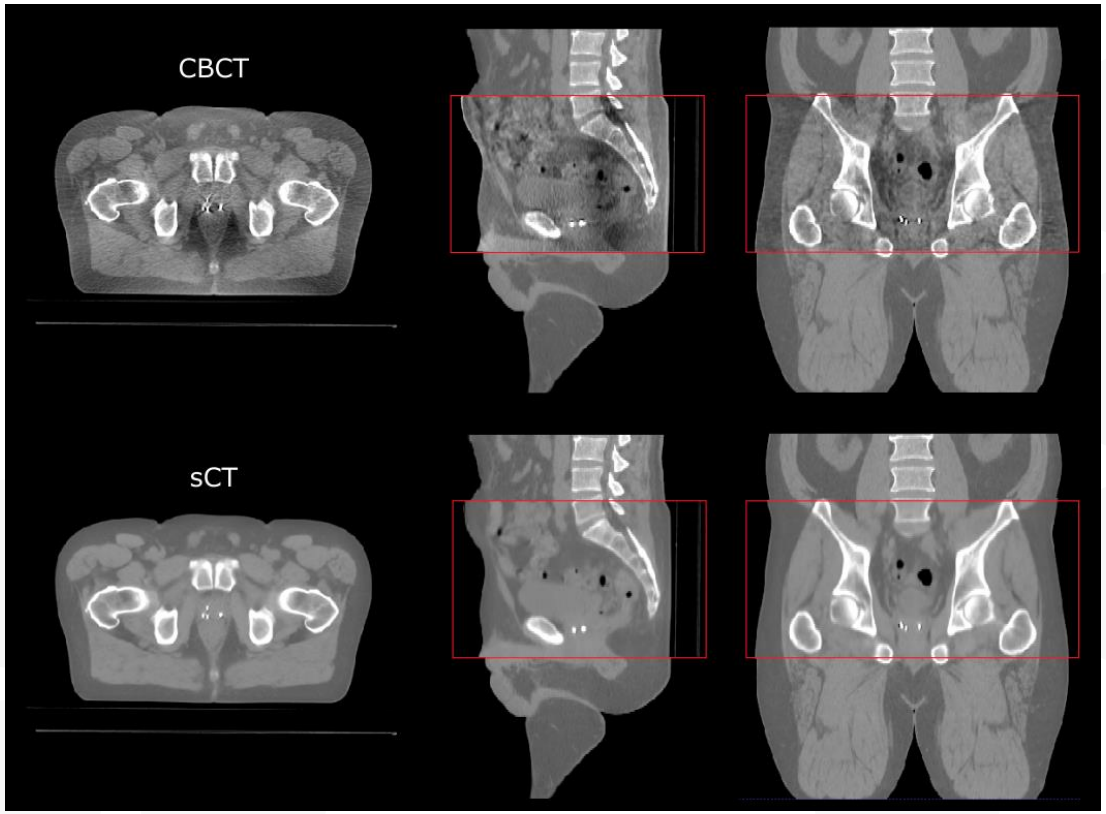
- Seems to work well
- Recently started using this clinically with promising results

Next step

- Compare our in-house method to sCT generation from **Velocity®** (Varian Medical Systems, Palo Alto, CA, USA) and **RayStation** (RaySearch Laboratories AB, Stockholm, Sweden).

- Evaluate the model re-trained for prostate cancer patients

Thank you!



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