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# Autosegmentation via nnU-Net on Post-Brachytherapy-Catheter CT for Prostate HDR Brachytherapy

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## ABSTRACT

**Purpose**: To develop and validate a 3D deep learning autosegmentation model for prostate and OAR contouring on post-brachytherapy-catheter CT images for HDR prostate brachytherapy planning.

**Methods**: A self-configuring U-Net architecture (nnU-Net) was trained on 206 HDR prostate brachytherapy cases. An independent test set of 36 patients was used for evaluation. Structures included the prostate PTV, bladder, rectum, and urethra. Model performance was compared against a commercially available solution originally trained for external beam radiotherapy (EBRT), using clinically approved, physician-drawn contours as ground truth. Evaluation metrics included geometric metrics such as Dice coefficient (DSC), Hausdorff distance (HD95%), and average surface distance (ASD). Clinically relevant dosimetric measures, including PTV V100%, bladder and rectum D1cc, and urethra D0.1cc, were also assessed. Statistical significance was determined using paired Wilcoxon signed-rank tests.

**Results**: The nnU-Net model demonstrated superior geometric accuracy for all structures within slices containing the prostate. For prostate PTV, nnU-Net achieved DSC = 0.91±0.04, HD95% = 3.62±2.23 mm, and ASD = 1.25±0.66 mm, compared to DSC = 0.78±0.07, HD95% = 9.52±4.73 mm, and ASD = 2.97±0.90 mm for the commercial model. Urethra segmentation was only available with nnU-Net (DSC = 0.84±0.09). Segmentations produced by nnU-Net resulted in clinically negligible dosimetric changes, including ΔPTV V100% = -0.25±2.30%, bladder ΔD1cc = 0.13±0.75 Gy, rectum ΔD1cc = 0.34±0.74 Gy, and urethra ΔD0.1cc = -0.03±0.16 Gy. No significant difference in PTV V100% was observed for nnU-Net (p=0.91), while the commercial model showed significant deviations (p < 0.001).

**Conclusion**: A brachytherapy-specific nnU-Net model enables accurate and reliable autosegmentation of the prostate and OARs on post-brachytherapy-catheter CT images. Compared to an EBRT-trained commercial solution, it offers improved geometric performance with minimal dosimetric impact, supporting its clinical feasibility and potential to streamline HDR prostate brachytherapy workflows.

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## INTRODUCTION

This work introduces the first deep learning model specifically trained for HDR prostate brachytherapy on post-brachytherapy-catheter CT images, capable of segmenting the prostate PTV and all clinically relevant OARs, including the urethra.

Unlike prior approaches, this model addresses the unique challenges of HDR prostate planning, such as catheter-induced artifacts and anatomical deformation.

The model achieved high geometric fidelity and clinically negligible dosimetric differences compared to clinically approved contours, demonstrating strong potential to reduce manual contouring time, improve consistency, and streamline planning.

**Table 1.** Characteristics of training and testing datasets.

| | Training | Testing |
|---|---|---|
| **Number of patients** | 206 | 36 |
| **Total 2D CT slices** | 39,001 | 6,664 |
| **Inserted Catheters** | | |
| Minimum | 13 | 14 |
| Mean | 16.8 | 16.9 |
| Maximum | 22 | 22 |
| **Prostate Volume (cm$^3$)** | | |
| Minimum | 21.7 | 22.0 |
| Mean | 42.9 | 42.2 |
| Maximum | 95.4 | 102.9 |

## METHODS AND MATERIALS

Post-catheter CT images were acquired after foley catheter and plastic interstitial needle placement using a 64-slice mobile CT scanner. To increase visualization of the interstitial needles and aid with catheter tip identification, brass stylets were inserted into each needle prior to imaging. Images were acquired with a slice thickness of 1.25 mm and in-plane pixel spacing of 0.7 mm x 0.7 mm. Manual segmentations of the prostate, rectum, bladder, and urethra visualized by the foley catheter were created by two treating physicians and had been clinically approved before retrospective use in this study. A self-configuring U-Net (nnU-Net)[1] was trained on 206 HDR prostate brachytherapy cases and tested on an additional independent test set of 36 patients. Model performance was evaluated against a commercially available DL-based autosegmentation solution integrated within the MIM Maestro platform (ProtégéAI)[2]. Geometric, including dice similarity coefficient (DSC), Hausdorff distance (D95%), and average surface distance (ASD), and dosimetric evaluation metrics were assessed between the autosegmentation methods using the physician contours as ground truth.

## REFERENCES

1. Isensee F, Jaeger PF, Kohl SAA, Petersen J, Maier-Hein KH. nnU-Net: a self-configuring method for deep learning-based biomedical image segmentation. *Nat Methods*. 2021;18(2):203-211. doi:10.1038/s41592-020-01008-z
2. Wan H. *Automated Contouring Using Neural Networks*. MIM; 2024.

## RESULTS

Within axial slices containing the prostate, the nnU-Net model showed high geometric accuracy for the prostate and OARs with clinically negligible dosimetric differences. Autosegmentation results are shown in *Table 2* for the nnU-Net and a commercially available EBRT-trained solution (MIM Contour ProtégéAI). *Figure 1* illustrates typical (median) performance of the nnU-Net model for the prostate PTV, rectum, and bladder. *Figure 2* summarizes dose differences for each structure when comparing clinically approved contours with those generated by the nnU-Net model and ProtégéAI.

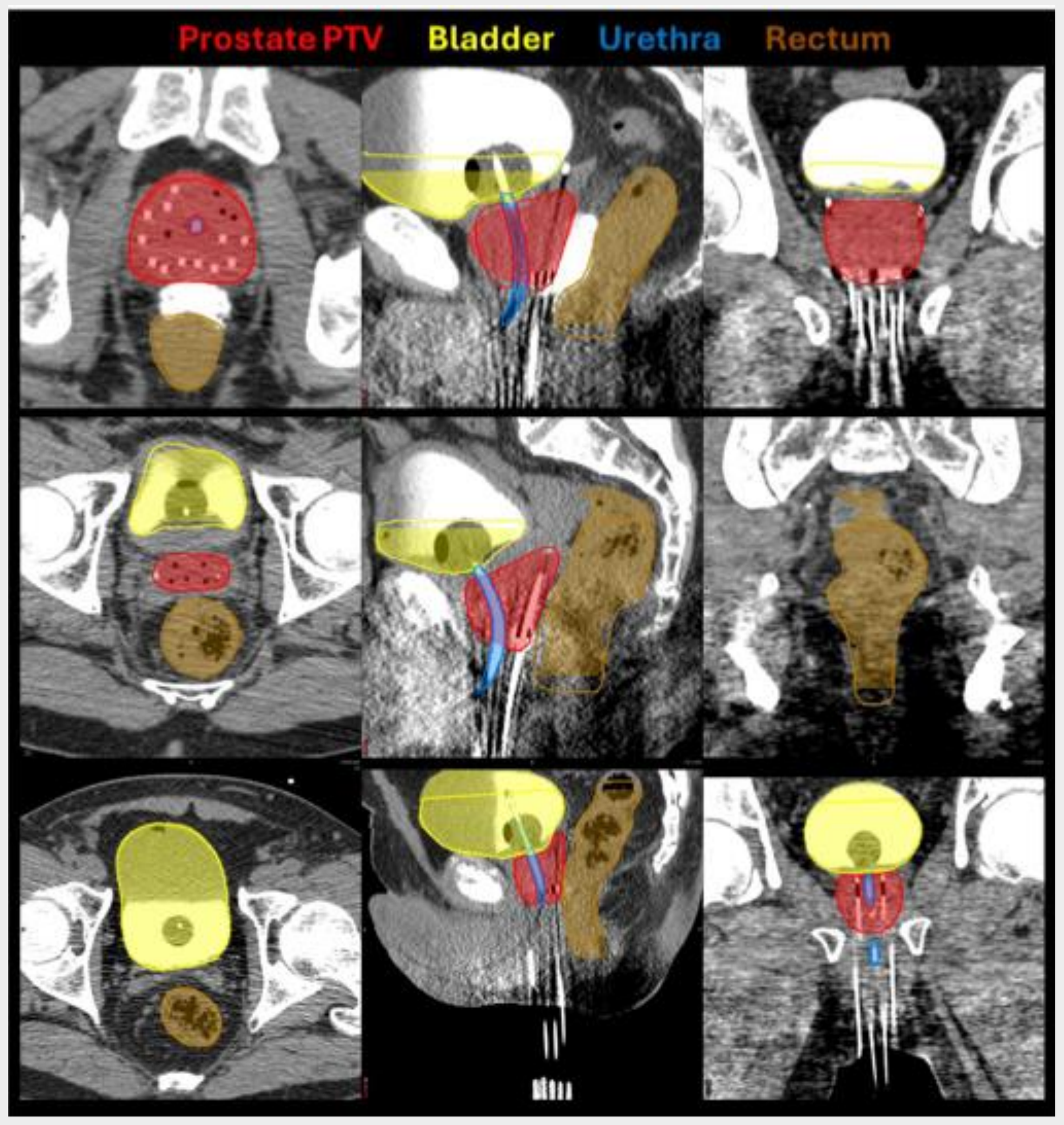


**Figure 1.** Typical segmentations assessed in terms of the median DSC for prostate (top row), rectum (middle row), and bladder (bottom row) are presented for the deep learning technique (thick lines, unfilled) versus clinical contours (thin lines, 40% fill)

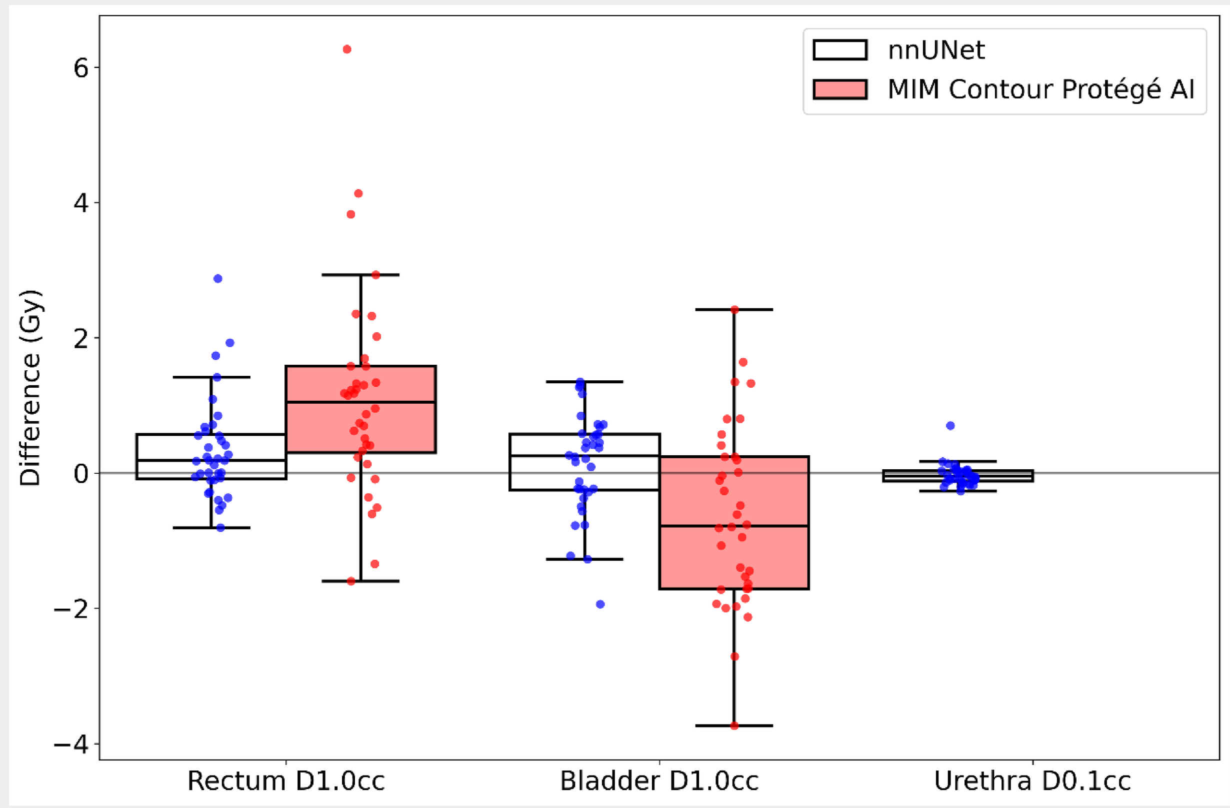


**Figure 2.** The difference in dose (Gy) between the deep learning and physician contours is shown for brachytherapy relevant dosimetric endpoints for rectum, bladder, and urethra

## DISCUSSION

To the best of our knowledge, this work presents the first DL-based segmentation method to automatically contour the prostate PTV and urethra via foley catheter on post-catheter CT images for HDR prostate brachytherapy. In addition, we report the first evaluation of a DL model trained exclusively on prostate brachytherapy CT images to segment the prostate PTV, urethra, bladder, and rectum.

Our DL nnU-Net provided excellent target segmentation accuracy, with a mean DSC of 0.91 ± 0.04, compared with 0.78 ± 0.07 for ProtégéAI. Similarly, the mean ASD was 1.25 ± 0.66 mm for nnU-Net versus 2.97 ± 0.90 mm for ProtégéAI. The nnU-Net outperformed the EBRT focused ProtégéAI model across all evaluation metrics.

An additional advantage of the nnU-Net approach is its ability to segment the urethra, with a mean DSC of 0.84 ± 0.09 and ASD equal to 0.56 ± 0.38 mm, whereas ProtégéAI does not provide urethra segmentation. Our results indicate that significant ($p<0.05$) improvements in performance can be achieved by training a DL network on post-catheter brachytherapy specific images. While EBRT-focused DL architectures may yield acceptable performance for certain OARs such as the rectum, our findings demonstrate that improved and more consistent performance is obtained when networks are trained on brachytherapy specific data.

## CONCLUSIONS

We implemented and evaluated the first DL auto-contouring method for CT-based HDR prostate brachytherapy. The model successfully contoured the prostate PTV, bladder, rectum, and urethra with high accuracy. Dosimetric differences in target coverage were not statistically significant which supports clinical use. DL based auto-contouring may improve contouring consistency, procedural efficiency, and reduce anesthesia time in HDR prostate brachytherapy workflows. While DL models developed for EBRT demonstrated utility for segmenting some OARs, our results show that improved accuracy is achieved using a brachytherapy-specific DL model.

**Table 2.** Auto-contouring results. Prostate PTV, bladder, rectum, and urethra are compared for a network trained on BT planning images (nnU-Net) and a commercial EBRT method (MIM ProtégéAI) versus clinical segmentations. Results are presented as the mean ± standard deviation for a VOI containing the prostate PTV.

| Structure | Model | DSC | HD95% (mm) | ASD (mm) |
|---|---|---|---|---|
| **Prostate PTV** | nnU-Net | 0.91 ± 0.04 | 3.62 ± 2.23 | 1.25 ± 0.66 |
| | ProtégéAI | 0.78 ± 0.07 | 9.52 ± 4.73 | 2.97 ± 0.90 |
| **Bladder** | nnU-Net | 0.85 ±0.19 | 3.73 ± 7.34 | 0.37 ± 0.26 |
| | ProtégéAI | 0.82 ± 0.15 | 6.55 ± 9.39 | 0.81 ± 0.55 |
| **Rectum** | nnU-Net | 0.93 ± 0.04 | 2.08 ± 1.03 | 0.60 ± 0.29 |
| | ProtégéAI | 0.90 ± 0.06 | 3.61 ± 2.70 | 0.90 ± 0.54 |
| **Urethra** | nnU-Net | 0.84 ± 0.09 | 1.83 ± 1.92 | 0.56 ± 0.38 |
| | ProtégéAI | -- | -- | -- |