

Inter-fraction Variability of High-Risk Clinical Target Volume (HR-CTV) and Organs at Risk (OARs) in Cervical Cancer High-Dose-Rate (HDR) Brachytherapy

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INTRODUCTION

High-dose-rate (HDR) tandem-and-ring cervical brachytherapy is a resource-intensive process requiring repeated MRI-based contouring and treatment planning. This study retrospectively evaluated anatomical variations during treatment to identify patient subgroups that would benefit from adaptive planning at each fraction versus those who may be safely treated using the initial HR-CTV contour while maintaining adequate target coverage and organ-at-risk (OAR) sparing.

METHODS AND MATERIALS

Forty cervical cancer patients treated between 2019 and 2024 were analyzed. All patients received 45 Gy external beam radiation therapy followed by five HDR brachytherapy fractions (5–7 Gy). Patients were categorized based on initial HR-CTV contour:

- Group A (small, 15–26 cc)
- Group B (medium, 27–42 cc)
- Group C (large, 43–55 cc)

HR-CTV and OAR segmentations were extracted from anonymized MRI DICOM-RT datasets using 3D Slicer. Inter-fraction percent volume changes were computed relative to the first fraction. Image registration was performed using Velocity, with the first fraction defined as the reference and subsequent fractions as secondary images. Spatial overlap of HR-CTV contours was quantified using the Dice Similarity Coefficient (DSC). Treatment variations in source dwell positions and Point A coordinates were used to classify fractions as Replan or No Replan. Statistical comparisons between groups were performed using a two-sided unpaired t-test.

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RESULTS

Variations in HR-CTV between fractions became smaller as the target size increased. Patients with small HR-CTV exhibited the greatest fluctuations, with an average absolute percentage change of $16.3 \pm 12.9\%$. The HR-CTV DSC showed significant difference ($p < 0.05$) between the Replan and No-Replan groups for the entire cohort and for patients with medium HR-CTVs. Analysis of OARs showed that bladder volume also differed significantly between the two groups for the entire cohort and for patients with small HR-CTV.

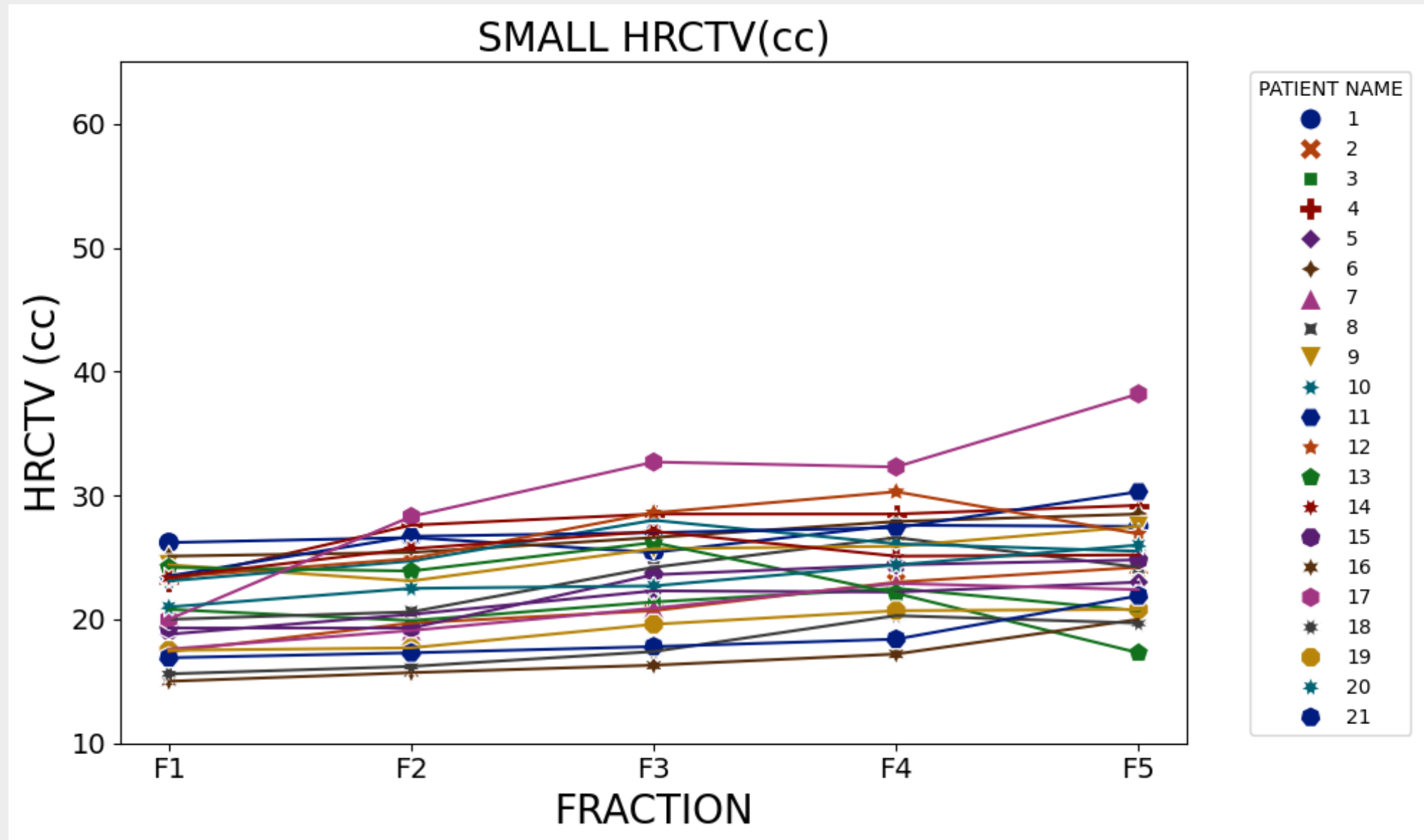


Figure 1: HR-CTV (Small)

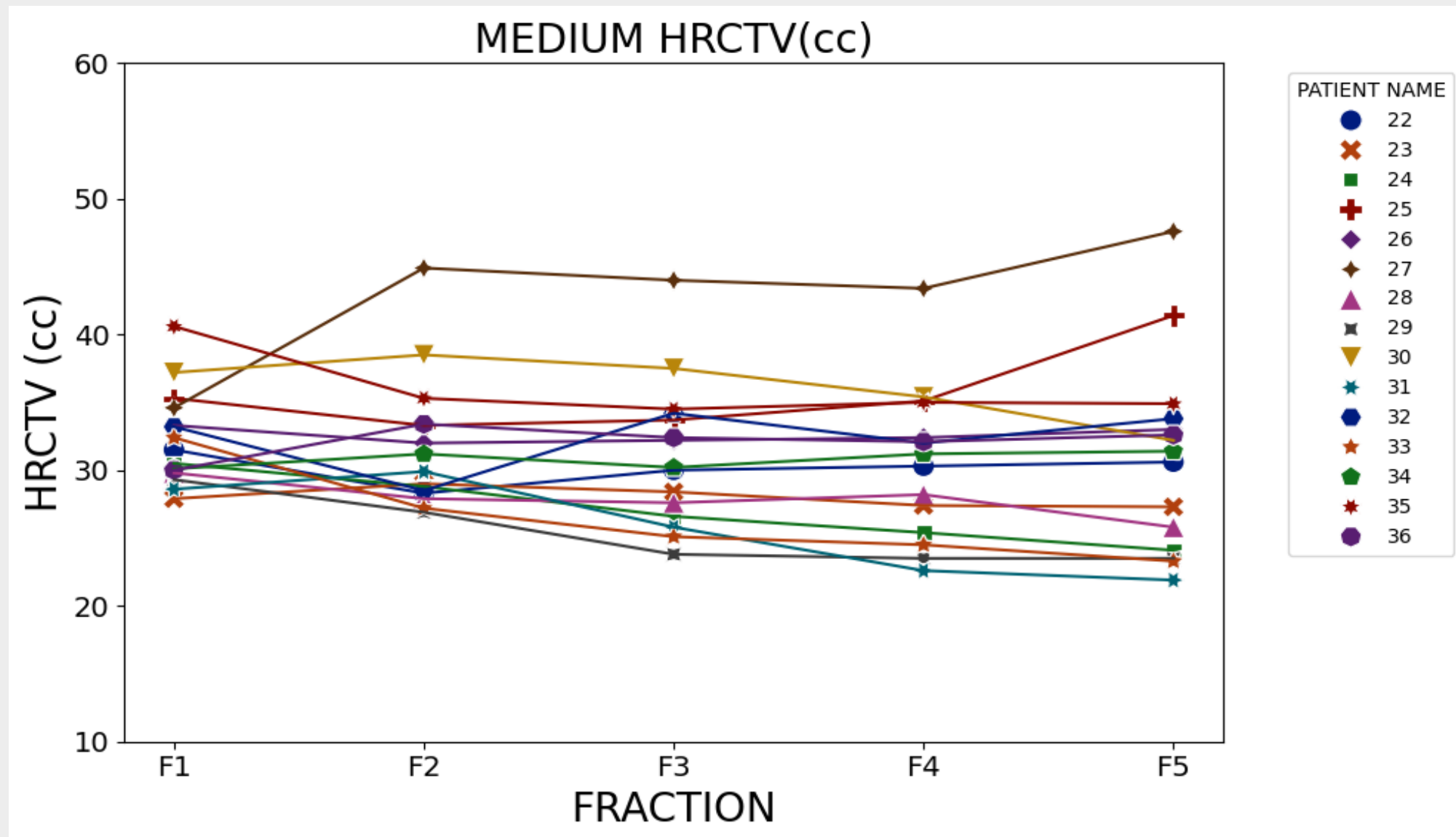


Figure 3: HR-CTV (Medium)

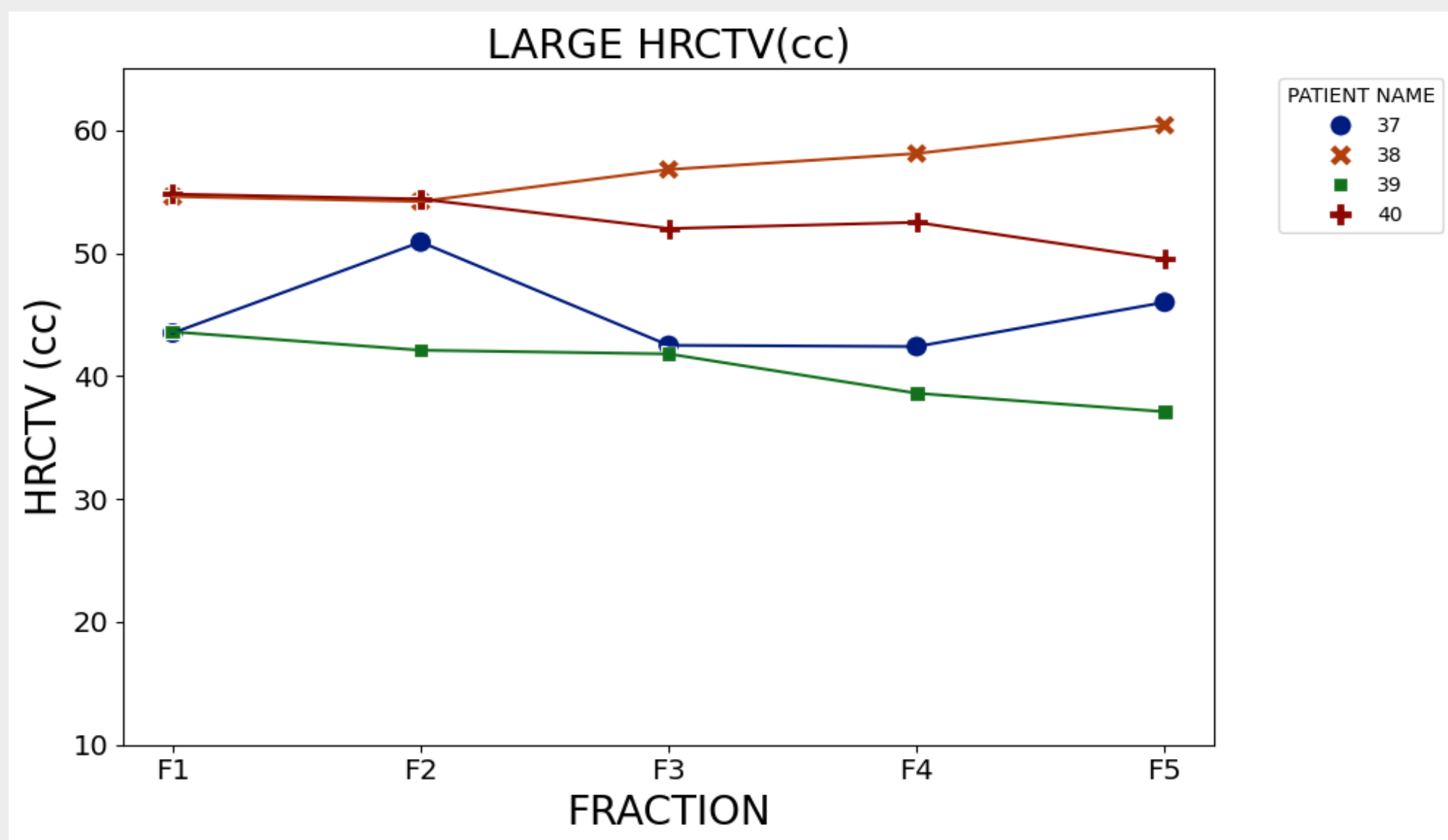


Figure 5: HR-CTV (Large)

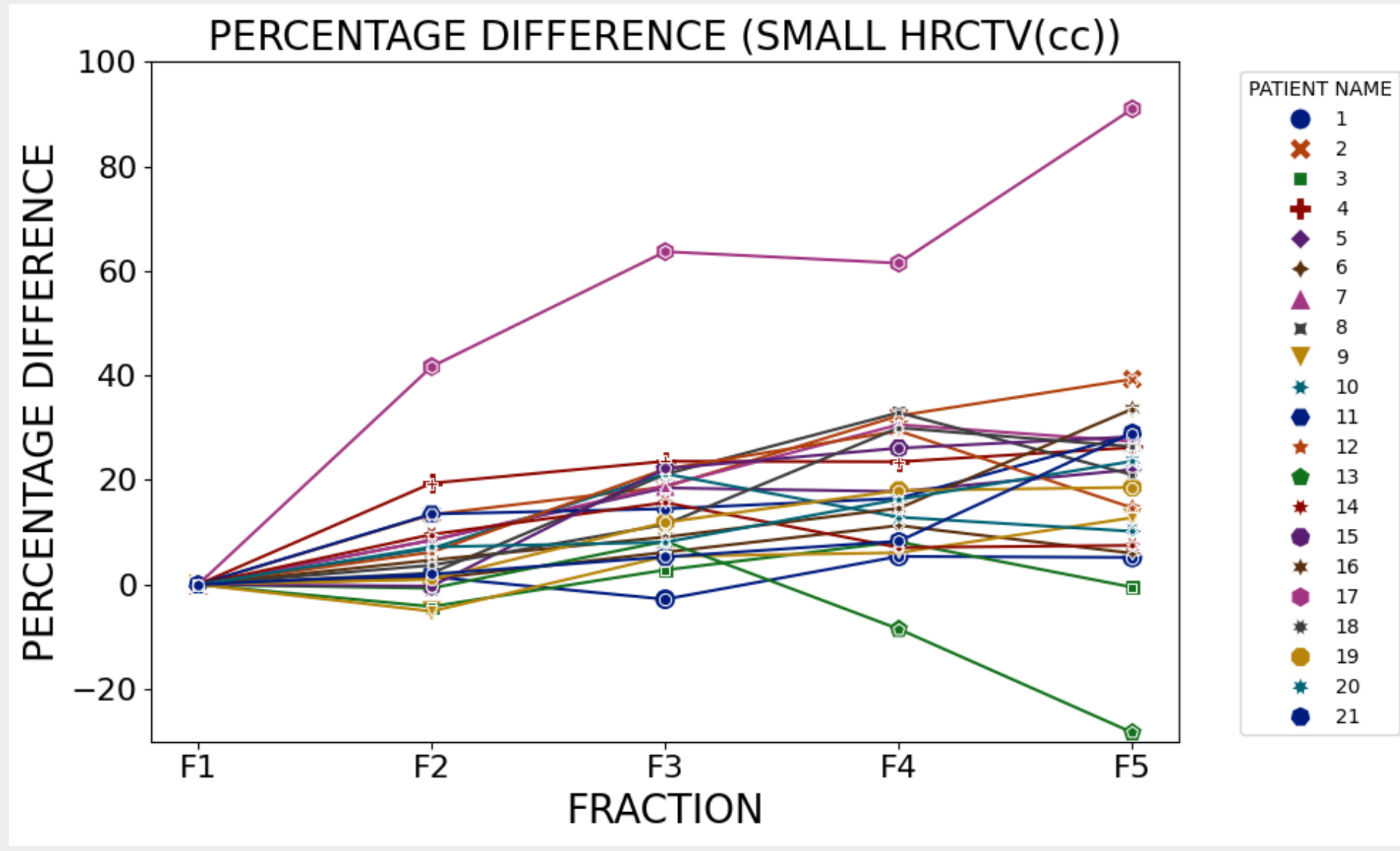


Figure 2: Percentage Difference (Small)

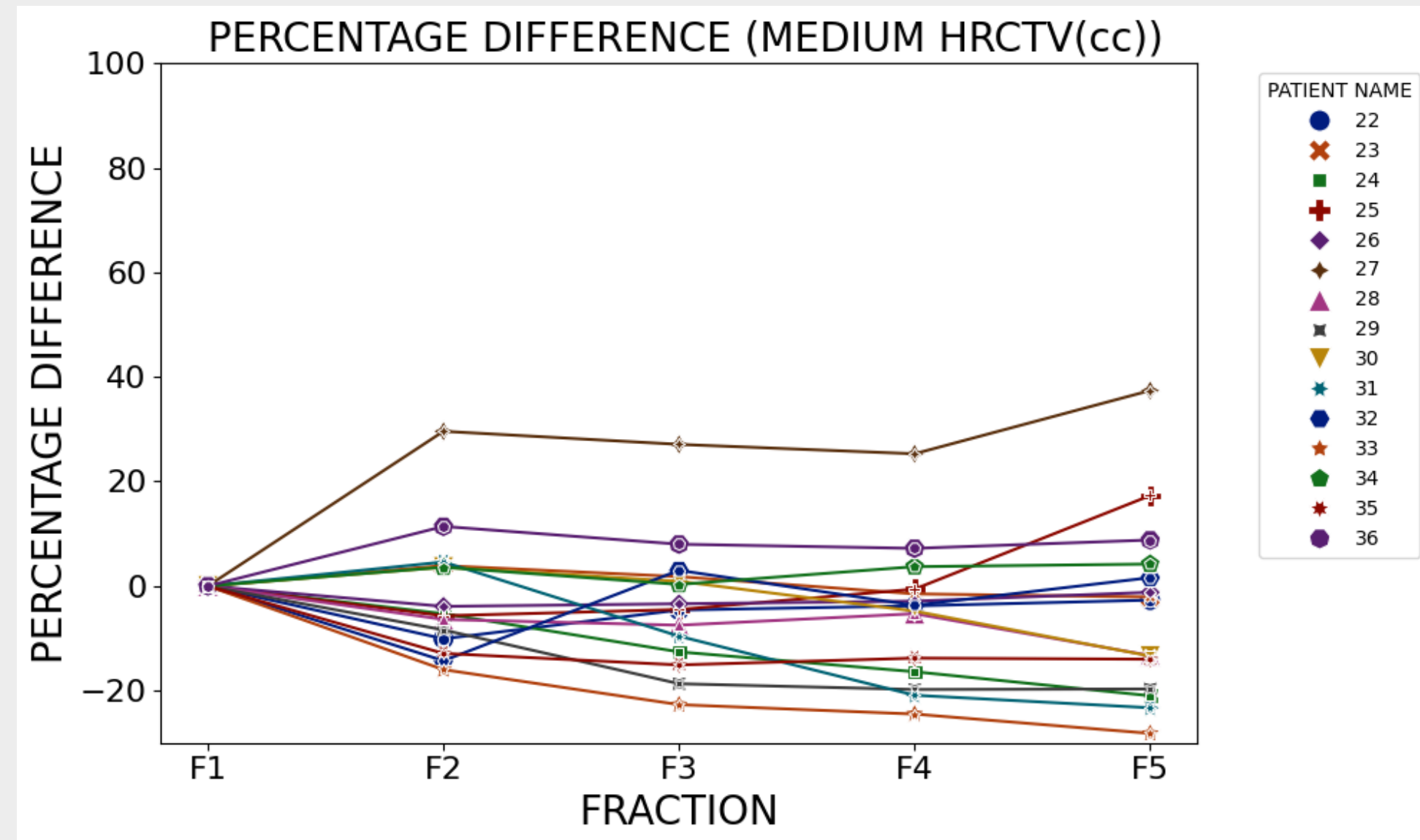


Figure 4: Percentage Difference (Medium)

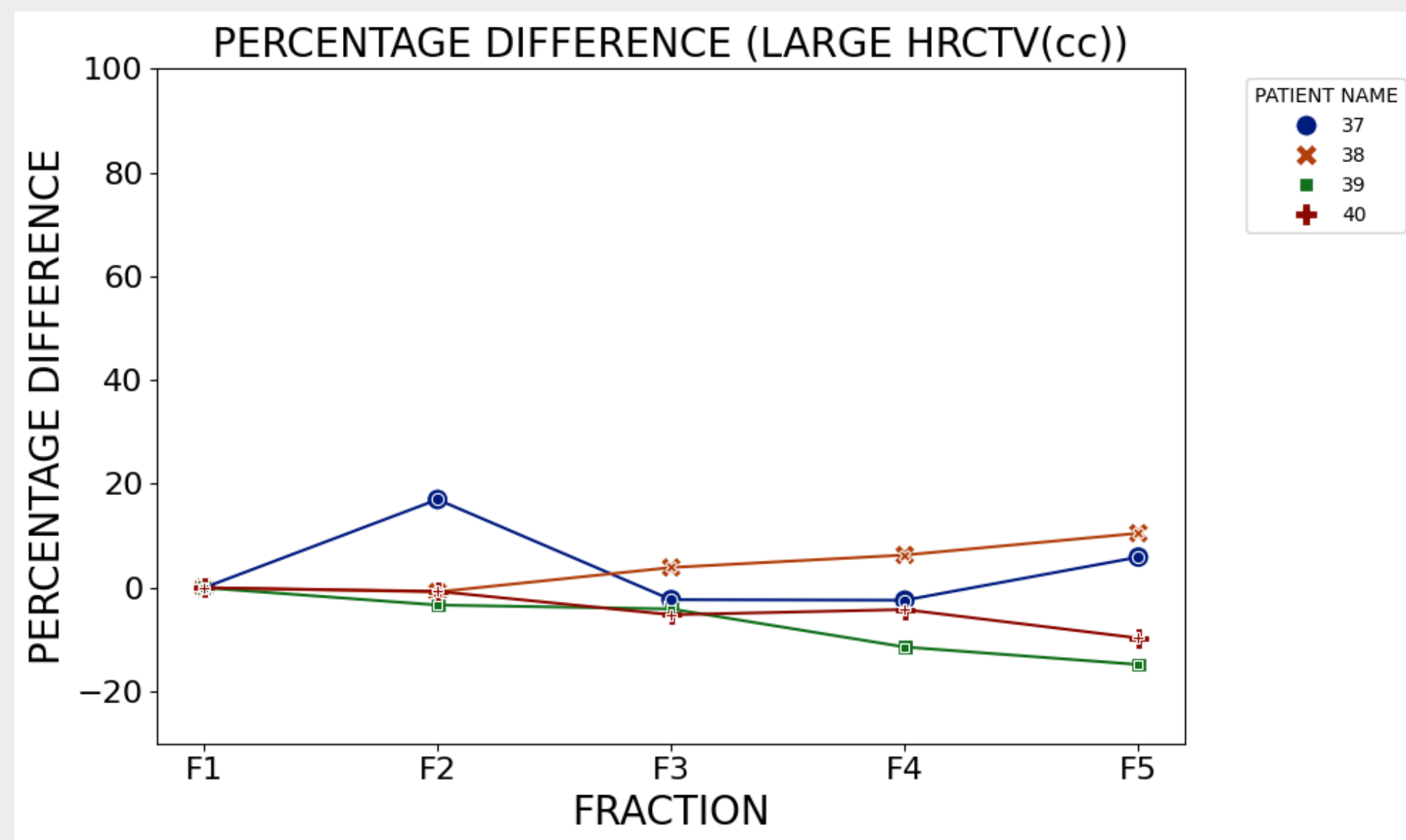


Figure 6: Percentage Difference (Large)

Table 2. Unpaired T-Test Results for Replan vs. No-Replan

	All	Small	Medium	Large
HRCTV DSC.	0.029*	0.130	0.001*	0.506
% Change in HRCTV	0.085	0.160	0.922	0.460
% Change in Bladder Vol.	0.042*	0.037*	0.541	0.145
% Change in Rectum Vol.	0.133	0.092	0.949	0.687
% Change in Sigmoid Vol.	0.076	0.201	0.118	0.380

* indicates $P < 0.05$

Table 1. % Change in HR-CTV

HR-CTV Size	Small	Medium	Large
No. of Patients	21	15	4
Volume (cc)	15-26	27-42	43-55
Mean	16.3%	9.8%	5.7%
Standard Deviation	12.9%	8.5%	1.8%
Minimum	1.6%	0.5%	4.6%
Maximum	64.5%	29.9%	8.4%

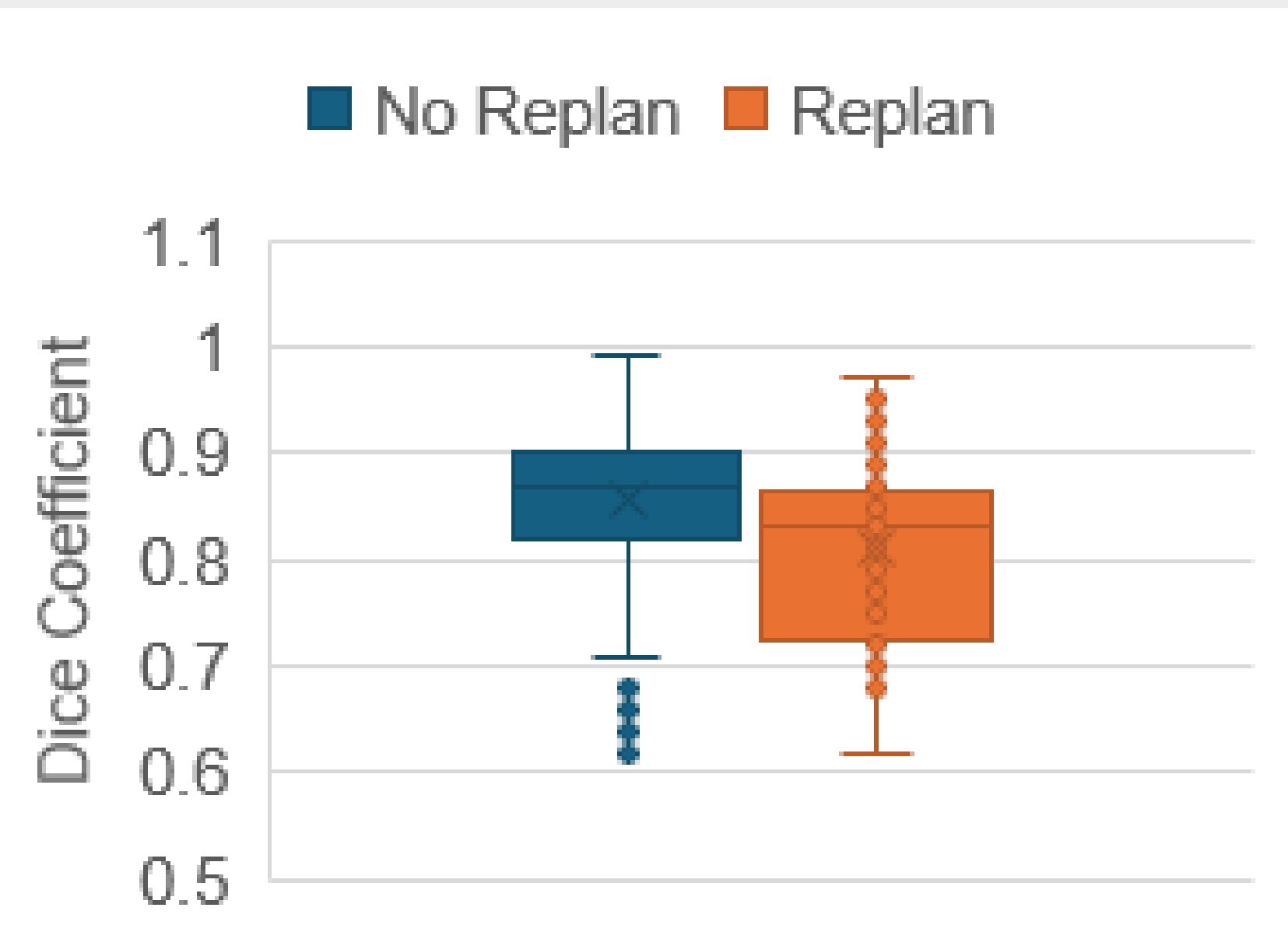


Figure 7. HR-CTV DSC (All Patients)

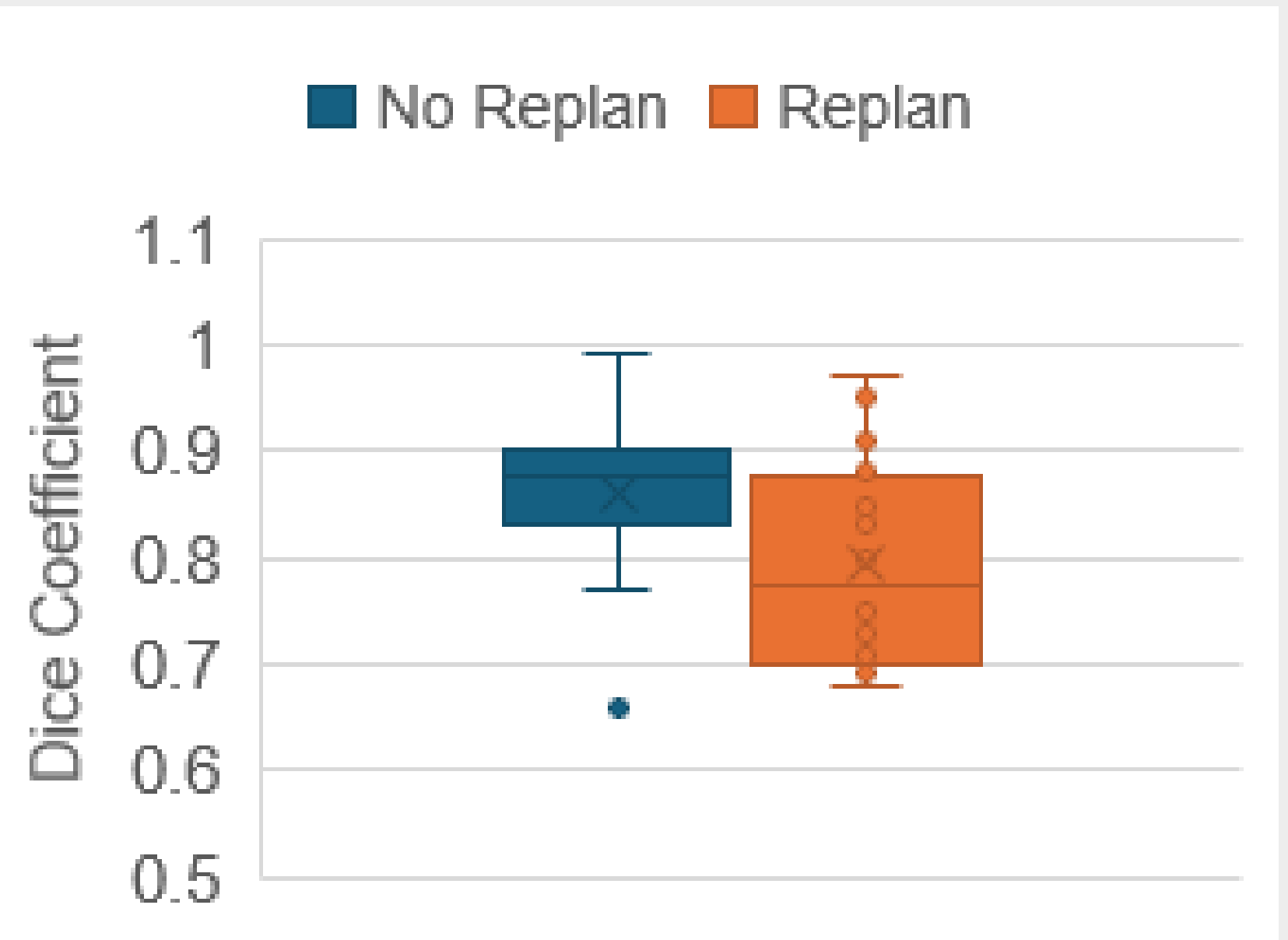


Figure 8. HR-CTV DSC (Medium Target Patient)

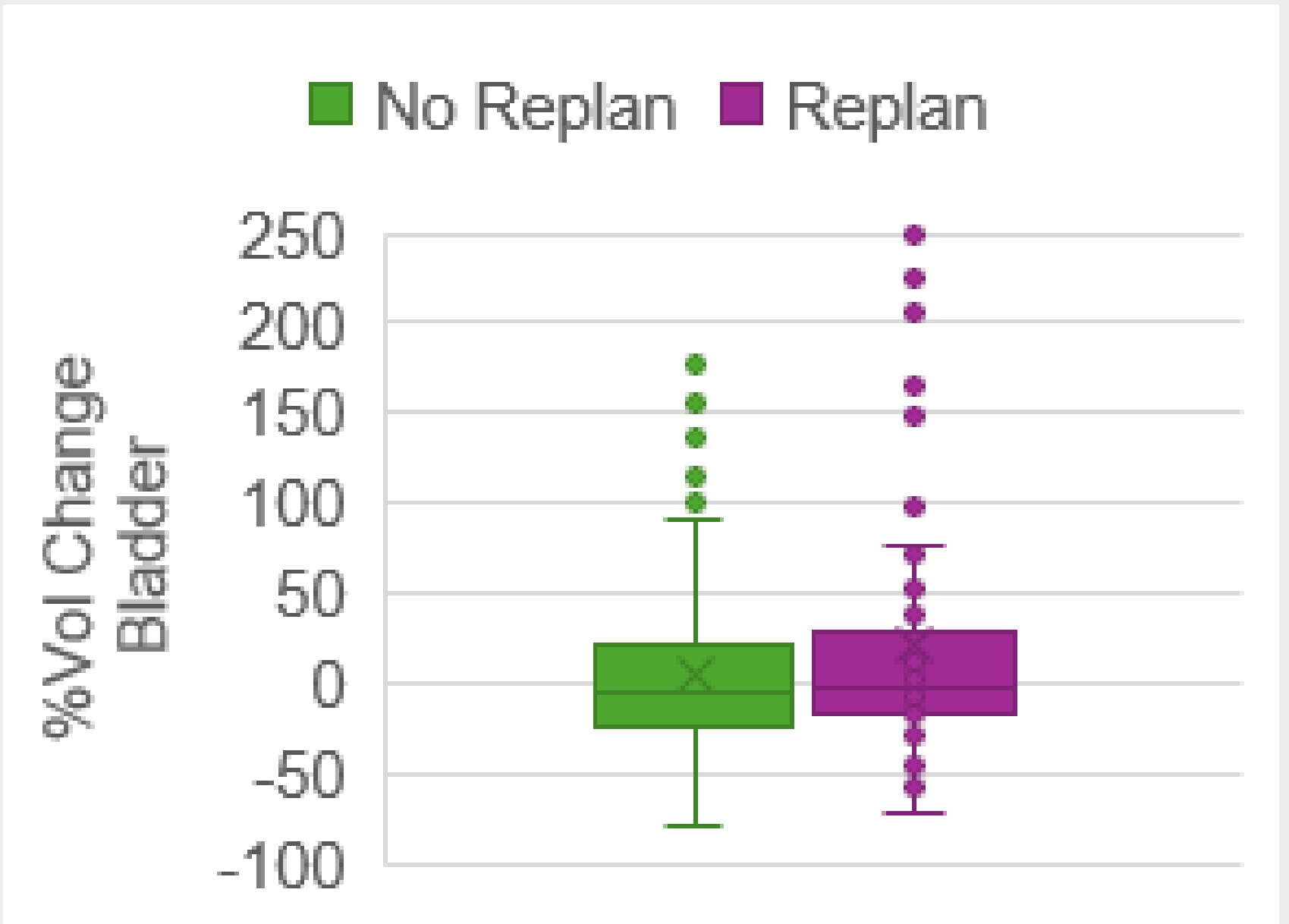


Figure 9. % Change in Bladder Vol. (All Patients)



Figure 10. % Change in Bladder Vol. (Small Target Patients)

CONCLUSIONS

Patients with small HR-CTVs demonstrated the greatest inter-fraction variability and sensitivity to organ motion and filling, making them the most likely to benefit from adaptive treatment planning. Patients with medium HR-CTVs may require selective adaptive evaluation, whereas large HR-CTVs exhibited minimal variability, suggesting that reuse of the initial HR-CTV contour may be feasible.