

Dosimetric Impact and Robustness of Daily Online Adaptive Radiotherapy for Focal-Boosted Prostate Stereotactic Body Radiation Therapy

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ABSTRACT

Purpose/Objectives: To evaluate dosimetric trends and robustness of online adaptive radiation therapy for focal-boosted prostate SBRT.

Materials/Methods Plan adaptation frequency, dosimetric impact, and robustness with respect to bladder volume and hydrogel spacer use were evaluated in 62 prostate cancer patients on a prospective phase II clinical trial (NCT06067269). Treatments were delivered on ViewRay MRIdian or Varian Ethos. Plans were optimized to meet clinical trial dosimetric constraints, prioritizing OAR sparing, followed by PTV/CTV coverage, then dominant intraprostatic lesion (DIL) GTV coverage. The initial plan was recalculated on daily anatomy (predicted plan) and compared to the reoptimized adapted plan

Results:

- Among 310 fractions, 77% failed at least one planning objectives: 41% failed PTV/CTV coverage criteria, 62% failed OAR constraint, and 26% failed both.
- Plan adaptation demonstrated improved PTV/CTV coverage while reducing OAR hotspots and low dose wash, with stable GTV coverage.
- Hydrogel spacer was associated with significantly improved rectal sparing ($p < 0.05$) for initial and adaptive planning, however under daily anatomical variation, predicted rectal dosimetry was similarly high between spacer and non-spacer cohorts.
- Predicted fractions strongly exhibited bladder volume dependence for bladder V20Gy compliance, whereas adapted fractions showed uniformly high bladder compliance across all bladder-volume quartiles.

Conclusion: Online adaptive radiotherapy improved target coverage and OAR sparing on a per-fraction basis for SIB dose-painted SBRT. Adaptive planning is robust to bladder-volume variation and provides additional dosimetric benefit when combined with rectal hydrogel spacer use

INTRODUCTION

Innovation/Impact: Stereotactic body radiation therapy (SBRT) dose escalation to the whole prostate has the potential to improve treatment outcomes, however at the cost of increased toxicity. Alternatively, focal dose escalation to the dominant intraprostatic lesion(s) (DILs) has garnered interest to improve control rates while minimizing treatment toxicity. **The incorporation of prostate focal boosting reduces prostate dose homogeneity with increasing dose to the DIL, increasing plan complexity and raises risk of OAR hotspots and treatment-related toxicity. Online adaptive radiation therapy can potentially minimize these risks by reoptimizing plans according to the daily on-table treatment anatomy.** This study aims to investigate the dosimetric impact of online adaptive radiation therapy for prostate cancer patients undergoing focal-boosted prostate SBRT (CTV: 38Gy; PTV: 36.25 Gy; GTV (DIL): 50Gy in 5 fractions).

METHODS AND MATERIALS

- 62 prostate patients (HEATWAVE trial NCT06067269)**
 - DIL identified on multi-parametric MRI and PSMA-PET
- 0.35T MR-Guided (n = 59) or CT-Guided Radiation Therapy (n = 3)**
 - 36.25Gy/5Fx to prostate and proximal seminal vesicles (CTV)
 - 2mm isotropic PTV margins
 - 50Gy/5Fx to DIL (GTV)
 - mpMRI/PSMA PET-defined
- Organs-at-risks (OARS):** bladder, rectum, femurs, urethra
- Adaptive Radiation Therapy (ART)**
 - ART initiated at discretion of treating physician
 - CTV and OARS recontoured
 - Reoptimized plan compared to non-reoptimized initial predicted plan forward calculated on daily anatomy

RESULTS

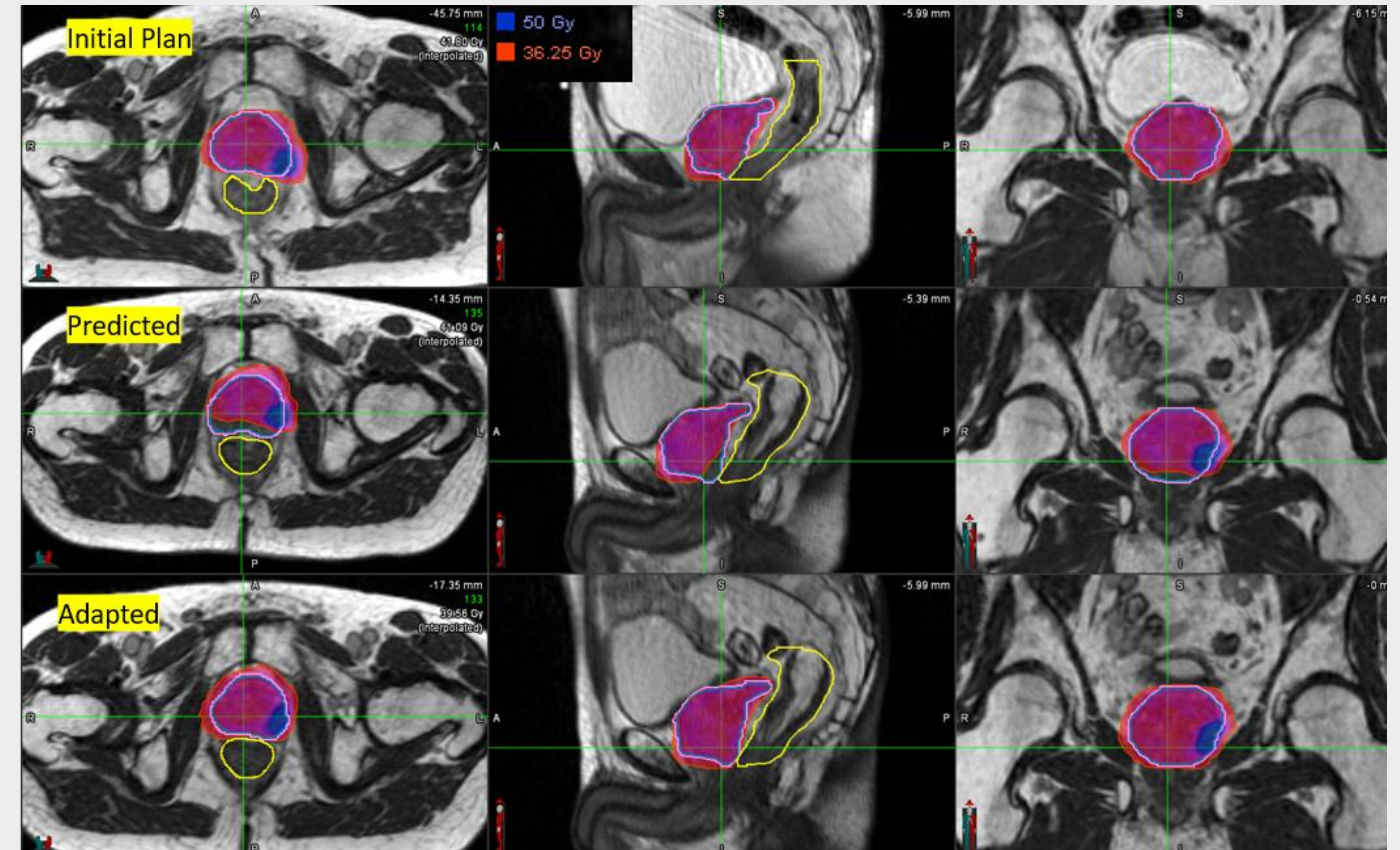


Figure 1. Large daily rectal deformation reduced CTV coverage (V38Gy: initial 98.98% vs predicted 89.08%) and increased urethra dose (D0.03cc: initial 41.12Gy vs predicted 42.26 Gy). Plan adaptation was able to recover CTV V38Gy to 99.12% and reduce urethra D0.03cc to 41.04Gy.

Planning Constraints (Predicted vs Adapted)

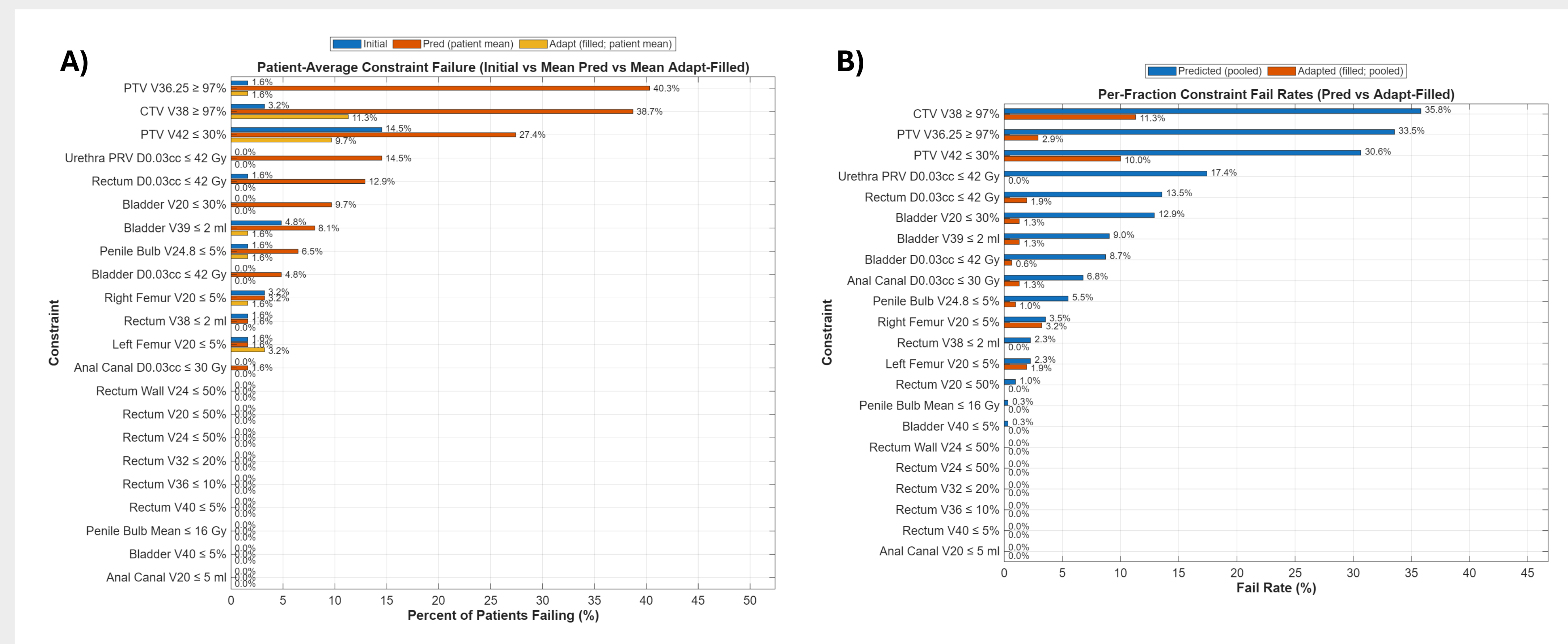


Figure 2. Plan adaptation was selected for 96% of fractions. A) shows the constraint failure rate for the initial, average predicted plan, and average adapted plan; B) shows constraint failure for predicted and adapted fractions. CTV V38Gy, PTV V36.25Gy, Urethra D0.03cc, Rectum D0.03cc, and Bladder V20 were the most common predicted clinically failed constraint.

Hydrogel Spacer Effect

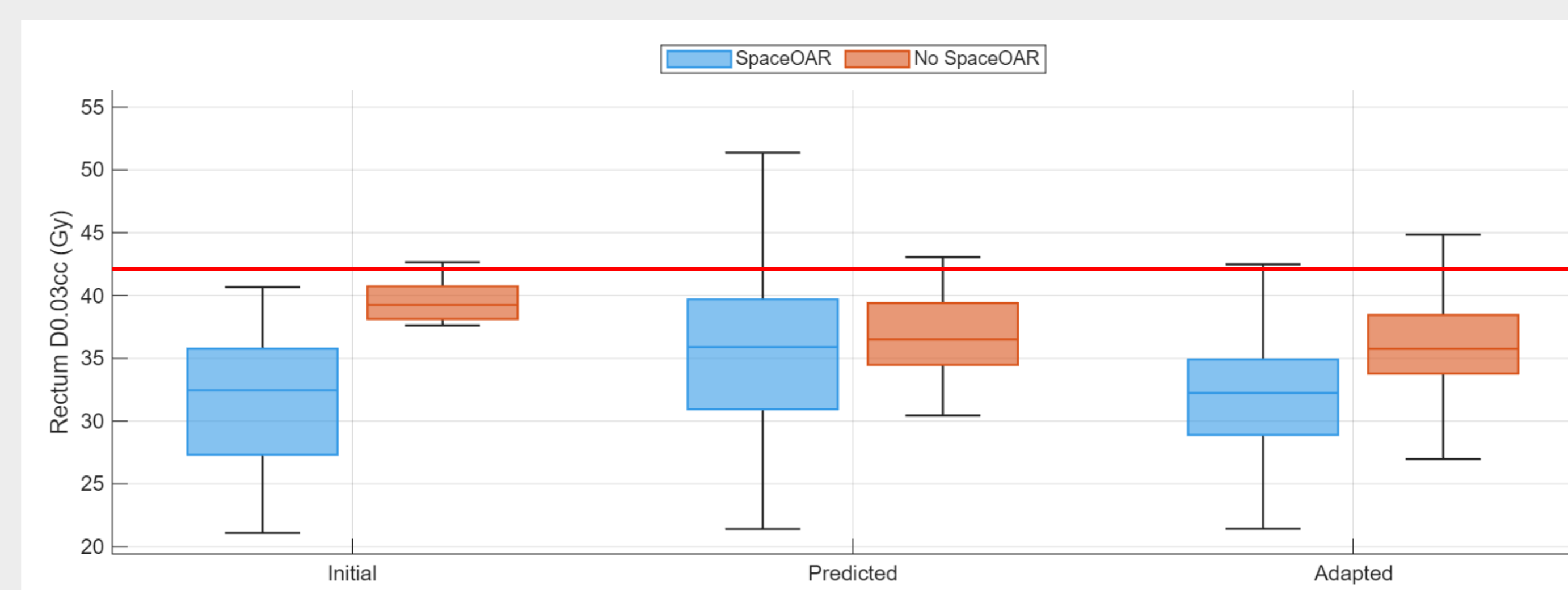


Figure 3. Boxplots of Rectum D0.03cc ≤ 42Gy for initial, predicted fractions, and adapted fractions between cohort of patients with hydrogel spacer (56 patients (280 fractions)) and no hydrogel spacer (6 patients (30 fractions)). Adaptive replanning ensured comparable constraint compliance irrespective of spacer use, while spacer continued to confer lower absolute rectum doses

Bladder Volume Variation Effect

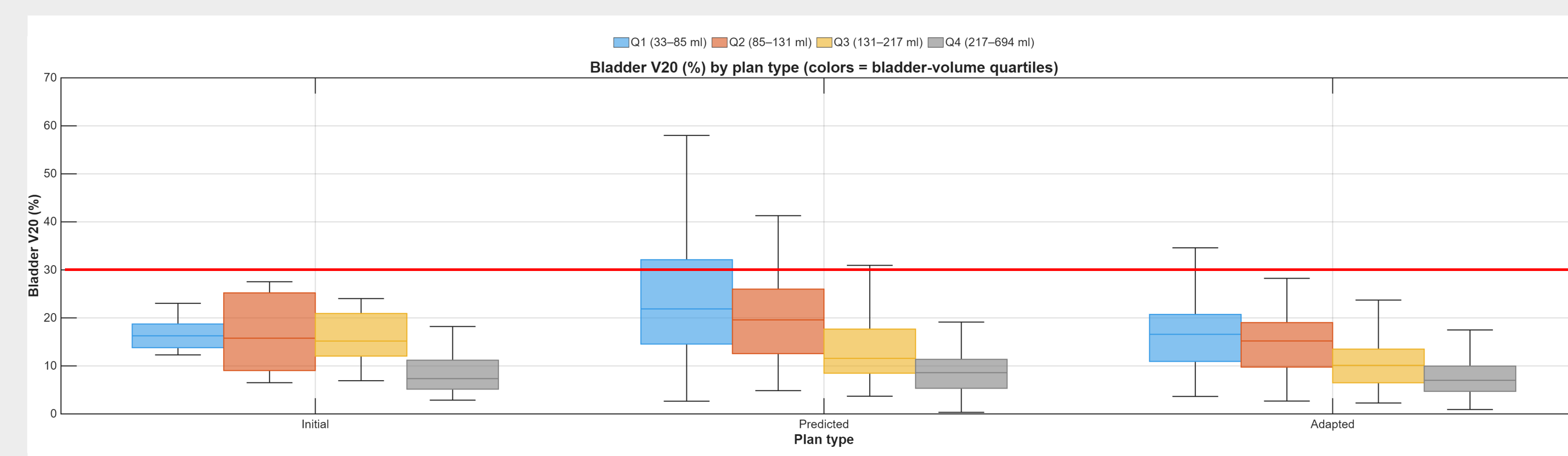


Figure 4. Boxplots of Bladder V20Gy ≤ 30% for initial, predicted fractions and adapted fractions between bladder-volume percentiles demonstrated over the course of simulation and treatment. Paired fraction-level analysis using McNemar’s test demonstrated that adaptation recovered 38 predicted failures while introducing only 2 new failures ($p = 1.5 \times 10^{-9}$), indicating a robust reduction in bladder-volume sensitivity and improved constraint compliance with adaptation