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Dosimetric Impact of Pelvic Bone Electron Density Assignment In Online Adapt-to-Shape (ATS) MR-Guided Prostate SBRT

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Introduction

Pelvic bone contouring is not routinely required in clinical protocols for prostate stereotactic body radiation therapy (SBRT). In the Elekta Unity online adapt-to-shape (ATS) workflow, anatomical regions that are not explicitly contoured may be assigned a default bulk electron density (ED) corresponding to the external contour. Consequently, pelvic bones that are not delineated may be treated as soft tissue during dose calculation, potentially misrepresenting beam attenuation and scatter within the pelvis. Although the density difference between bone and surrounding soft tissue may influence calculated dose distributions, the clinical significance of this approximation in prostate SBRT remains unclear. Few studies have specifically quantified the dosimetric impact of pelvic bone contouring and ED assignment during online ATS MR-guided prostate SBRT. Here, we evaluate how pelvic bone contouring and ED assignment influence target coverage and dose agreement in the ATS workflow.

Methods and Materials

Ten treated prostate SBRT patients (40 Gy in 5 fractions) were retrospectively analyzed. Planning objectives and dose–volume constraints followed institutional directives based on Zelefsky et al. For each patient, a reference plan was generated by forcing pelvic bone ED to match the external/body ED, emulating the ATS scenario in which pelvic bone inherits the external/body ED when it is not contoured. Plans were normalized such that 95% of the planning target volume (PTV) received 40 Gy. Statistical uncertainty per calculation was set to 0.3%. Each reference plan was copied and recalculated as an evaluation plan using the actual pelvic bone ED (without the forced ED override) while keeping segment shapes and monitor units unchanged. Dosimetric endpoints included V_{40Gy}, $D_{95\%}$, and $D_{99\%}$ for the PTV and clinical target volume (CTV). Agreement between reference and evaluation plan dose distributions was assessed using 3D local gamma analysis with criteria of 2%/2 mm and a 10% dose threshold.

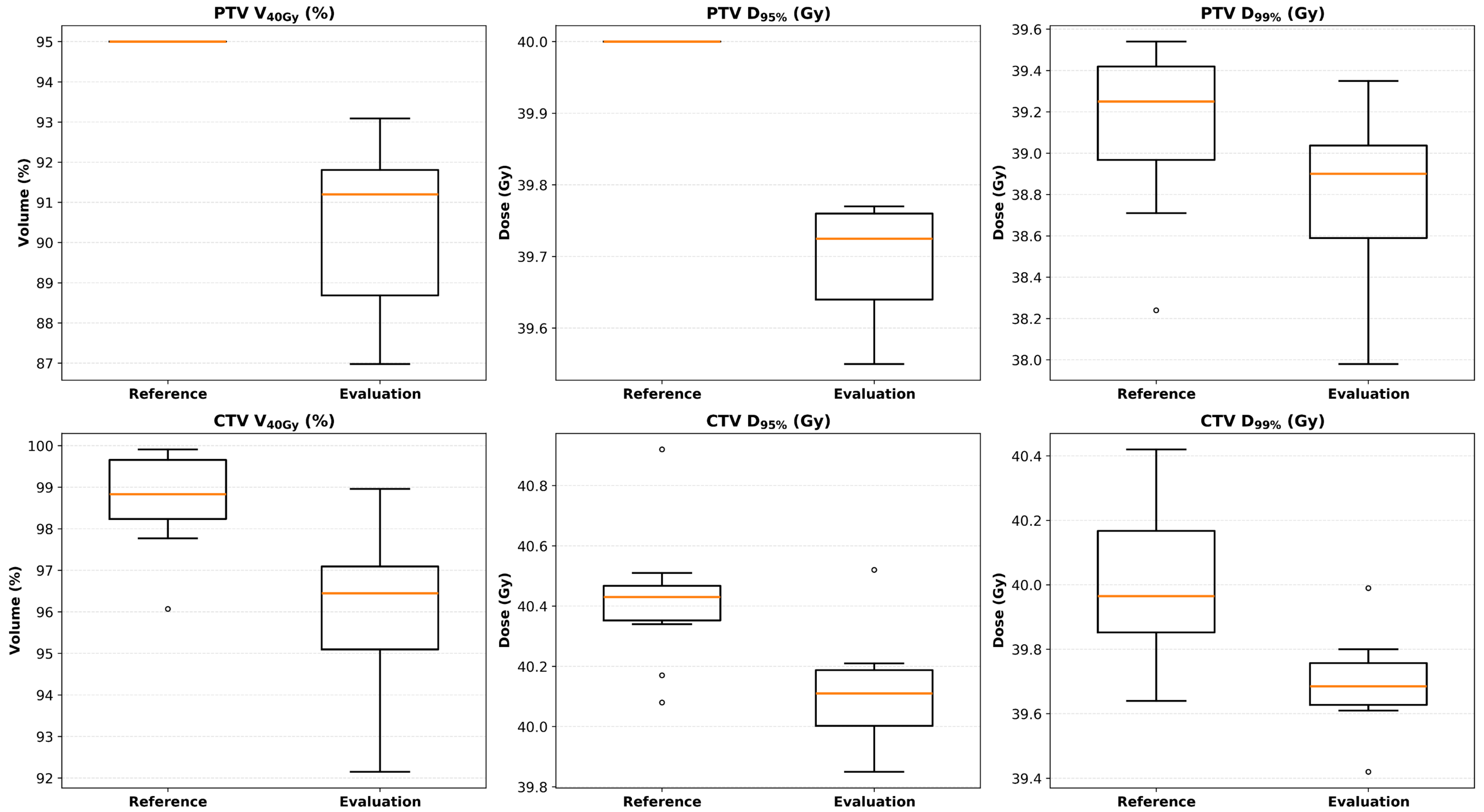

Figure 1. Box plots of V40Gy (%), D95% (Gy), and D99% (Gy) for PTV and CTV in reference (default bulk ED) and evaluation (pelvic bone ED) plans.

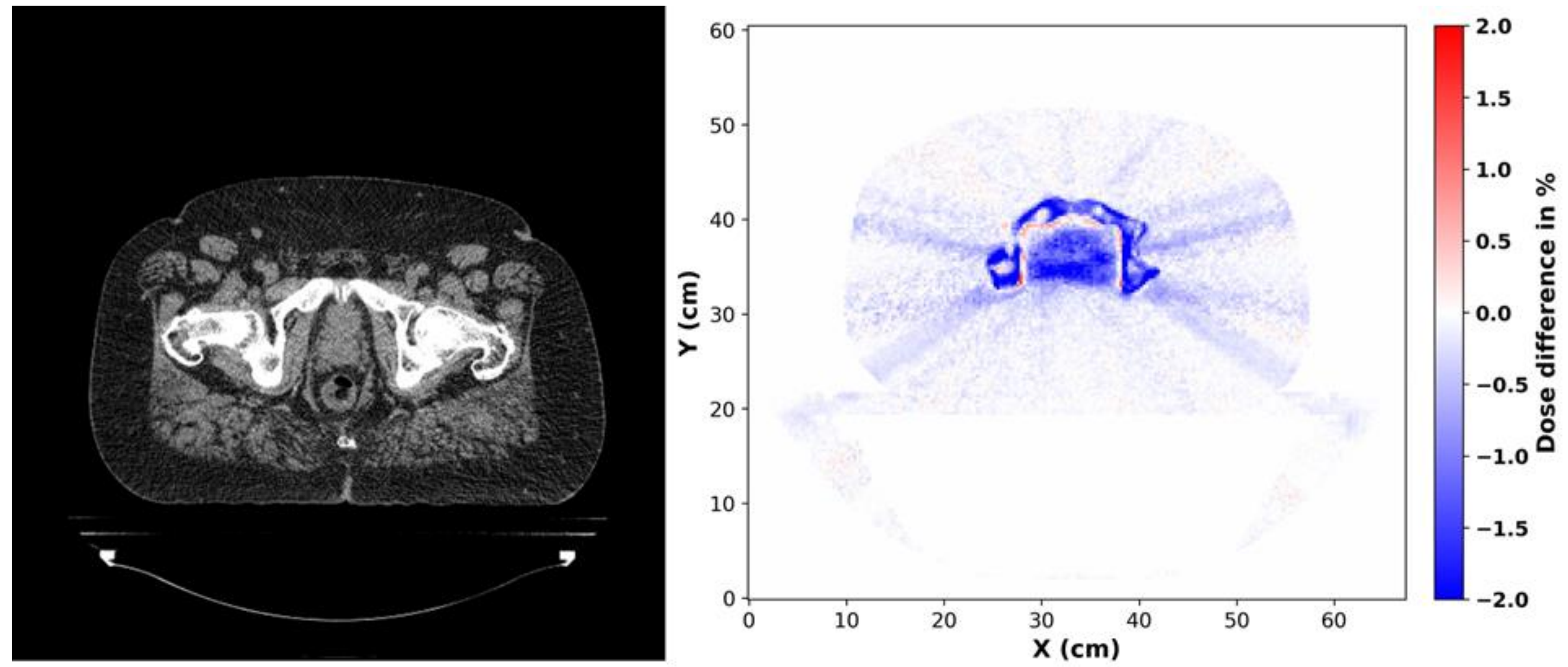

Figure 2. Representative axial slice showing (left) the CT simulation image and (right) the percent dose difference map (evaluation - reference), normalized to the 40 Gy prescription.

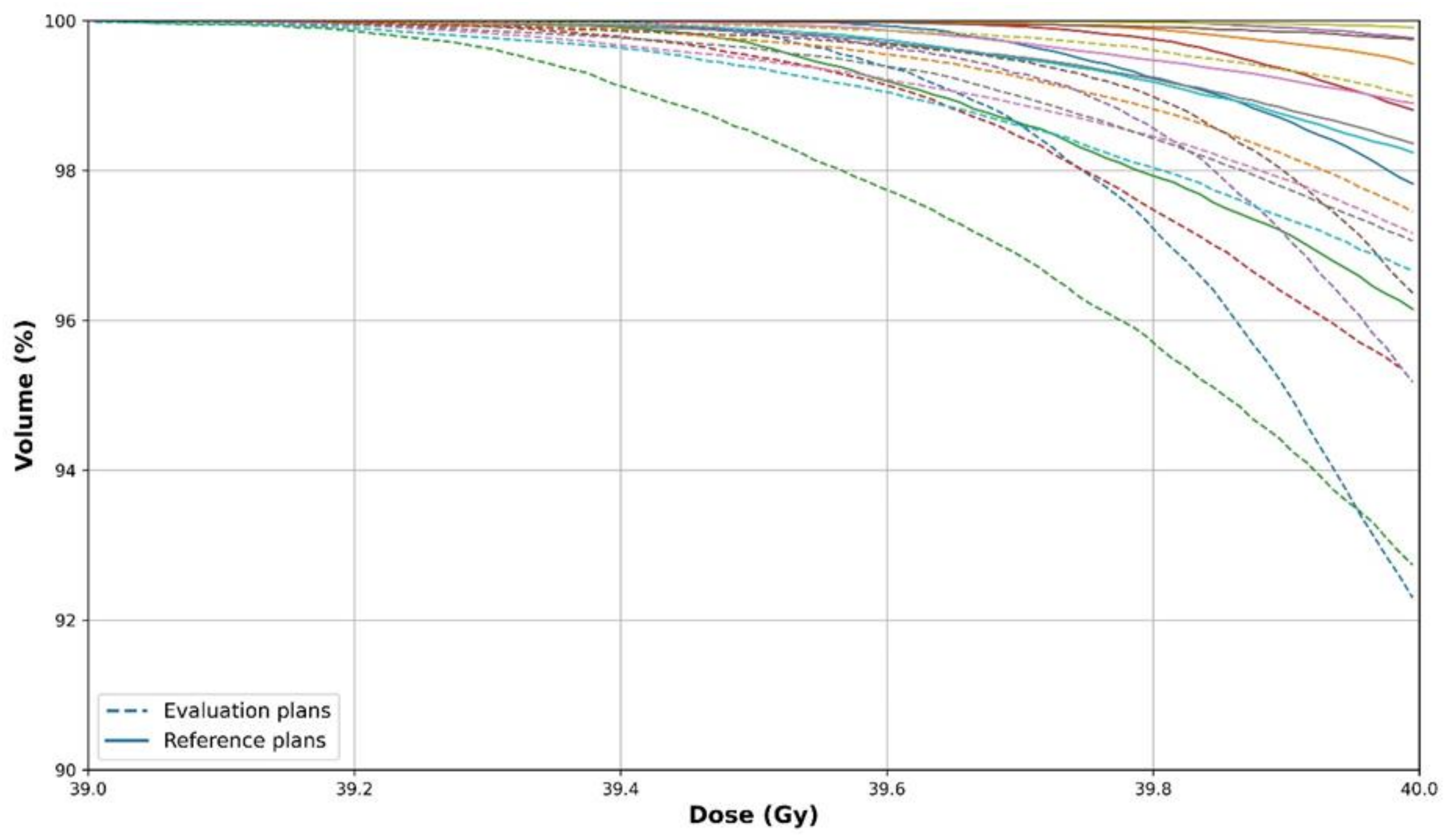

Figure 3. Cumulative DVHs for PTV comparing reference plans (solid; default body bulk ED) and evaluation plans (dashed; pelvic bone ED) across 10 prostate SBRT patients. The plot is zoomed to 39-40 Gy to emphasize differences in near-prescription target coverage.

Results

Evaluation plans exhibited systematic loss of near-prescription coverage relative to reference. PTV V_{40Gy} decreased from 95.00% ± 0.00% to 90.41% ± 2.25% ($p < 0.05$), and CTV V_{40Gy} decreased from 98.69% ± 1.17% to 95.84% ± 2.13% ($p < 0.05$). Mean $D_{95\%}$ and $D_{99\%}$ for both PTV and CTV were reduced by 0.31–0.32 Gy. The mean 3D local gamma passing rate between reference and evaluation plans was 88.34% ± 3.43%.

Discussion

This study demonstrates that assigning pelvic bone the same electron density as the external/body contour systematically overestimates target coverage in the Elekta Unity ATS workflow. When plans were recalculated using the actual pelvic bone electron density while maintaining identical beam segments and monitor units, all evaluated target-dose metrics decreased. The largest differences were observed in prescription-level coverage, with mean PTV V_{40Gy} decreasing by 4.6% and mean CTV V_{40Gy} decreasing by 2.9%. Although reductions in $D_{95\%}$ and $D_{99\%}$ were smaller, averaging approximately 0.31–0.32 Gy, these modest dose shifts produced substantial changes in the volume receiving the prescription dose. Because pelvic bone has a higher electron density than surrounding soft tissue, modeling it as soft tissue may underestimate attenuation and overestimate target dose. These differences are relevant in prostate SBRT, where high fractional doses, tight margins, and steep dose gradients require accurate online plan evaluation.

Conclusions

In ATS MRgRT prostate SBRT, omitting pelvic bone contouring can overestimate target coverage. Contouring pelvic bone and assigning the appropriate ED improves dose calculation accuracy and target coverage evaluation during online adaptation.

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