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Dosimetric Evaluation of Prostate SBRT Using Deformable Image Registration

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Purpose:

Adaptive radiotherapy is designed to improve target coverage and reduce normal tissues doses compared with non-adaptive delivery. While in prostate SBRT differences between adaptive and non-adaptive plans are often modest, certain fractions exhibit clinically significant under-coverage. This study quantified the cumulative dosimetric impact of these under-covered fractions by accumulating fraction doses on daily anatomy using deformable image registration to the reference planning CT.

Varian Ethos ART system

INTRODUCTION

Prostate stereotactic body radiotherapy (SBRT) employs high fractional doses with tight planning target volume (PTV) margins, making accurate target localization essential. Daily anatomical variations in prostate position, bladder filling, and rectal distension can compromise target coverage when non-adaptive treatment plans are delivered. Online adaptive radiotherapy (ART) addresses these changes through daily plan modification; however, previous studies have shown that differences between adaptive and non-adaptive prostate SBRT plans are often modest for most fractions. Nevertheless, a small subset of fractions may exhibit substantial target under-coverage that could potentially impact the cumulative delivered dose. The clinical significance of these isolated events remains uncertain. This study aimed to estimate the dosimetric consequences of marked non-adaptive under-coverage by accumulating delivered doses across the treatment course using deformable image registration, thereby evaluating whether isolated under-dosed fractions translate into meaningful reductions in cumulative prostate dose.

METHODS AND MATERIALS

From a retrospective institutional prostate SBRT cohort delivered on a Varian Ethos platform (250 fractions), nine fractions with pronounced non-adaptive under-coverage were identified, showing notable inter-fraction variability in a subset of patients. Three patients had D95%<50%, four patients had one fraction each with D95% between 50–80%, and one patient had two fractions with D95% between 75–80%. For each affected patient, the full treatment course was exported, and fraction doses were mapped to the reference planning CT using deformable image registration to estimate cumulative dose. Delivered prostate doses were compared with the planned target volume to quantify deviations

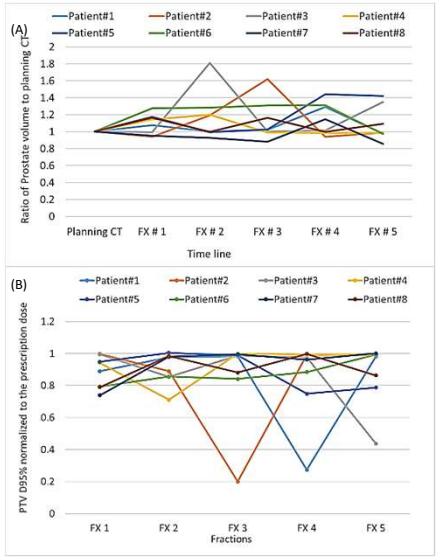

Figure 1. Prostate volume normalized to the planning CT volume (A) and corresponding PTV D95% (B) across treatment fractions for the eight-patient cohort.

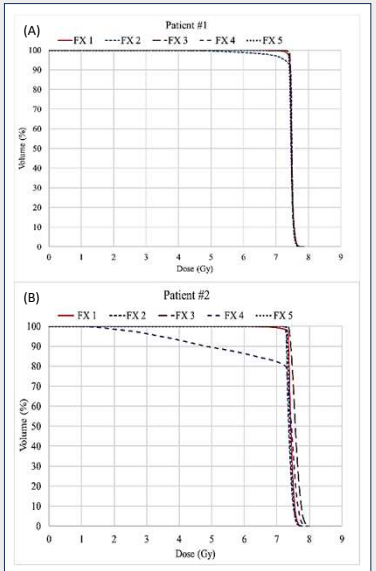

Figure 2. Per-fraction PTV DVHs demonstrating the variability in target coverage across the treatment course for Patient 1 (A) and Patient 2 (B).

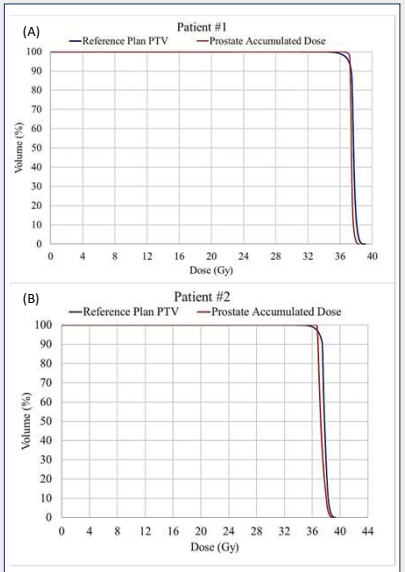

Figure 3. Accumulated prostate dose following deformable dose registration compared with the planned PTV dose for Patient 1 (A) and Patient 2 (B)

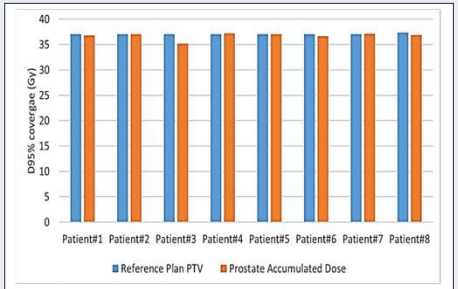

Figure 4. Histogram summarizing the differences in D95% between the accumulated prostate dose and the planned PTV dose across the study cohort.

RESULTS

Deformable dose accumulation demonstrated that, despite large per-fraction variations and occasional substantial under-coverage, cumulative prostate dose remained close to the reference prescription, with differences of ≤1Gy (<3%). In one patient, accumulated D95% appeared reduced to ~81% due to Ethos automatically shifting the treatment isocenter to follow the prostate center of mass. Recalculating that fraction after correcting for this shift in Eclipse restored the cumulative course dose to the prescribed 37Gy. It should be noted that if multiple fractions exhibited severe under-coverage, larger cumulative deviations could occur

CONCLUSIONS

In the studied cases, cumulative prostate dose was largely preserved despite isolated non-adaptive under-coverage. These findings highlight the potential utility of adaptive workflows and suggest that incorporating an option to switch to adaptive planning only when clinically warranted could optimize treatment efficiency while maintaining dose fidelity

CONTACT

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