

Theme: Physics

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Planning Strategies for Real-time Gated Proton Therapy in Prostate Cancer

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Objectives

Real-Time Gated Proton Therapy (RGPT) uses continuous X-ray tracking of implanted fiducials to manage intrafraction motion. This study compares planning strategies to identify which best maintains target coverage and organ-at-risk (OAR) sparing during inter-beam isocenter shifts common in RGPT workflows.

Methods

A representative prostate case with fiducials was replanned using four robust IMPT strategies: Multifield Optimization (MFO), Single Field Optimization (SFO), Hybrid (SFO for prostate, MFO for seminal vesicles), and MFO with inter-beam robustness (*Inter-beam*). To simulate RGPT, inter-beam prostate motion was modeled with shifts of 3, 6 and 9mm. Dose distributions were evaluated for target coverage ($D_{98\%}$) and OAR doses/hotspots ($D_{1\%}$ for rectum and bladder) under nominal and shifted conditions.

Results

The SFO and *Inter-beam* plans showed the highest robustness. Both techniques tolerated inter-beam shifts up to 6mm only, with target coverage and OAR parameter variations remaining $< \pm 1\%$ across all tested scenarios, and with minor deviations seen at 9 mm. The Hybrid and MFO plans degraded earlier; Hybrid at 6 mm and MFO from 3 mm onward, showing loss of target coverage in the $D_{98\%}$ region (up to -12%) and increased $D_{1\%}$ hotspot doses (up to $+8\%$) for targets and OARs, for 6mm shifts.

Conclusions

Inter-beam positional shifts in RGPT can degrade dose coverage in MFO plans lacking inter-beam robustness. SFO and Inter-beam robustness strategies preserved target and OAR dosimetry under RGPT-like inter-beam shifts and are recommended for workflows involving per-field isocenter adjustments, especially in hypo-fractionated or SBRT treatments with limited dose averaging opportunities over the treatment course.

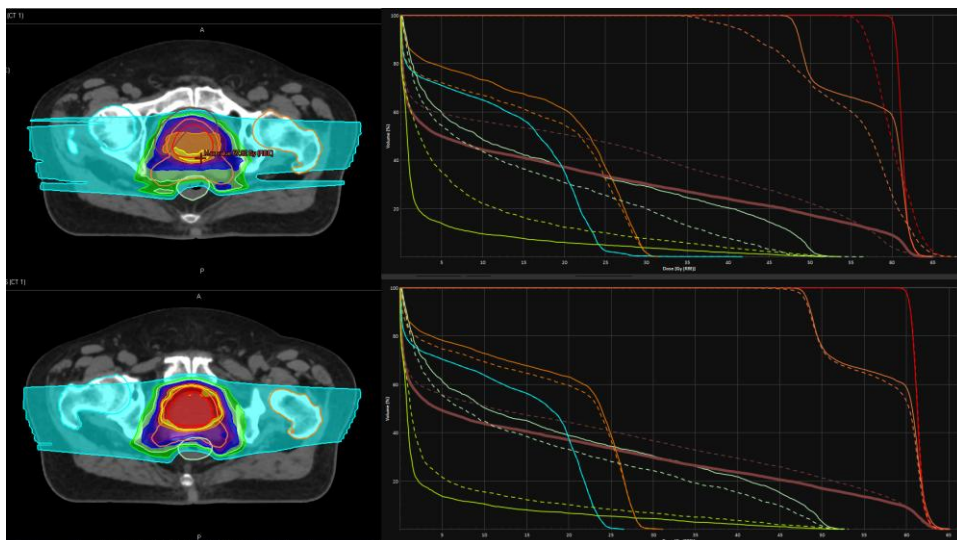


Fig.1. An example of a dose perturbation in an MFO plan (top row) and an SFO plan (bottom row) due to a 6mm inter-beam shift in the superior direction.