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Abstract
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Treatment Planning and Delivery with Organ Motion Mitigation in Ultra-high Single-Dose Ablative Radiation Therapy for Unfavorable Organ-confined Prostate Cancer

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Abstract

Objectives:

Great emphasis on rigorous planning and delivery techniques must be placed when using extreme hypofractionated regimens to fully exploit their potential benefits in optimizing the therapeutic ratio, thus yielding excellent clinical outcomes. The aim of this study was to report the clinical treatment planning implementation for organ-confined linac-based prostate Single-Dose Ablative Radiation Therapy (SDART) using electromagnetic tracking for real-time intrafraction organ motion management (NCT04831983).

Methods:

Since June 2021 twenty patients with localized unfavorable intermediate or selected high-risk prostate tumors were enrolled to receive an ultra-high SDART of 24 Gy (BED 1.5 = 408 Gy). Patients were simulated with empty rectum and bladder filled by a Foley catheter. Fused CT and T2W 3D MRI image sets were used to delineate the target and OARs. The PTV consisted of the CTV with a 2-mm isotropic margin. A high-dose avoidance zone (HDAZ) was created by a 3-mm expansion around the rectum, bladder, and urethra. Patients were planned to a minimum dose defined by the OARs dose constraints with a dose escalation to 24 Gy to the target volume away from the HDAZ. A 10MV FFF beam energy single arc from 140° to 220° was optimized using target penalties with the Monaco Monte Carlo TPS. During the treatment delivery, CBCT matching ensured accurate patient setup alignment and target localization. Real-time 3D prostate motion was tracked with a novel electromagnetic tracking device. Treatment was interrupted when the signals exceeded a 2 mm threshold in any of the three spatial directions and couch position was corrected unless the offset was transient.

Results:

All the predefined planning objectives were fulfilled. The median PTV volume was 68.5 cc [25.6 – 100.6]. The average total monitor units per plan were 6694 ± 520. All the treatment plans were quality assured using a two-dimensional silicon diode array and fulfilled a gamma (2%/2mm) passing rate >95% objective. The mean delivery time lasted 4.5 ± 0.6 minutes. The overall mean treatment time, from procedure inception to beam-off, was 16.0 ± 8.0 minutes. Intrafractional tracking was successfully carried out in all treatment sessions. Adherence to the 2mm target shift tolerance was accomplished and beam interruptions were needed for 14 patients because of target motion beyond limits, with 1.5 interruptions on average for patient [0 – 7]. Overall, the mean value of the target average deviation was -0.21 ± 0.40 mm, 0.37 ± 0.65 mm, and -0.30 ± 0.52 mm in lateral, longitudinal, and vertical directions, respectively. Prostate displacement did not occur in a distinct direction. The prostate was found inside the 2 mm threshold from its initial position in 88% of the treatment time, i.e. in 86% of the time during the setup phase and in 95% during the delivery phase (beam on + interruptions).

Conclusion(s):

The use of an HDAZ during planning limited the volume of rectal mucosa receiving critical doses. The accomplishment of urethral sparing via negative dose painting to minimize genitourinary toxicity is feasible through appropriate imaging procedures and online tracking during treatment delivery. Our preliminary findings offer encouraging perspectives on the feasibility and safety of 24 Gy SDART in organ-confined

prostate cancer.