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To Bag or Not to Bag? Comparative Evaluation of Patient Positioning and Motion Management in MR-Guided Prostate SBRT

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ABSTRACT

This study evaluated whether vacuum cradles (VC) are necessary for prostate SBRT on the MR-Linac, where real-time cine-MR tracking and CMM gating already provide robust motion management. Forty patients treated with 40 Gy in 5 fractions were analyzed, half immobilized with a VC and half without. Interfraction setup accuracy, intrafraction motion, and gating performance were extracted from daily MR registrations and system log files. No significant differences were observed in 3D interfraction motion, rotational setup error, or gating duty cycle between groups, and intrafraction motion was comparable aside from a small left-right difference. In a subset with adaptive plan recalculations, CTV and PTV coverage changes were slightly more variable in the VC group, with occasional larger degradations. These findings indicate that prostate SBRT patients can be effectively and efficiently treated on the MR-Linac without a vacuum cradle, maintaining setup accuracy, motion control, and dosimetric robustness while simplifying workflow and improving coil clearance.

INTRODUCTION

Accurate immobilization has traditionally been essential in radiotherapy to minimize setup errors and patient motion, particularly for stereotactic body radiotherapy (SBRT), where large vacuum cradles (VC) are commonly used. Although on-board x-ray imaging reduces systematic misalignment, intrafraction motion remains a concern. MR-guided radiotherapy (MRgRT) enables real-time soft-tissue tracking and automated gating through the Comprehensive Motion Management (CMM) system, further mitigating motion during treatment. This study evaluated whether eliminating the VC affects setup accuracy, adaptive planning dosimetry, and intrafraction motion in CMM-enabled prostate SBRT delivered on the MR-Linac (MRL).

METHODS

A total of 40 patients treated with prostate SBRT were retrospectively analyzed under an IRB-approved protocol (2022-0521). All patients received 40 Gy in 5 fractions to the clinical target volume and were simulated using a standardized setup consisting of a headrest, dual-leg positioner, and A-bar, with half of the cohort additionally immobilized using a large vacuum cradle (VC) and the remaining half treated without VC support. Treatments were delivered on the Elekta Unity 1.5T MR-Linac equipped with the CMM system. For each fraction, daily MR images were acquired for adaptive planning, and rigid registration to the reference image provided translational setup shifts used to quantify interfraction motion.

Treatment plans were generated using the standard Unity adaptive workflow, and from the system log files, an in-house script (UT Southwestern) was used to extract gating duty cycle and the 95th-percentile displacement in the left-right, superior-inferior, and anterior-posterior directions, from which the resultant 3D intrafraction motion was computed. Together, these data enabled a comparative evaluation of immobilization strategy, setup accuracy, and motion characteristics between VC and non-VC cohorts.



Figure 1. Patient setup - with VC (top) and without VC (bottom)

RESULTS

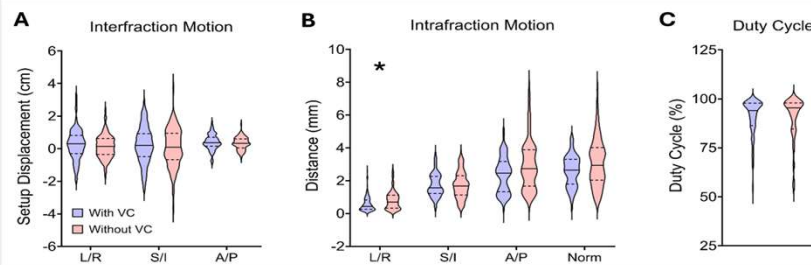


Figure 2. Interfraction motion, intrafraction motion, and duty cycle for patients treated with and without VC.

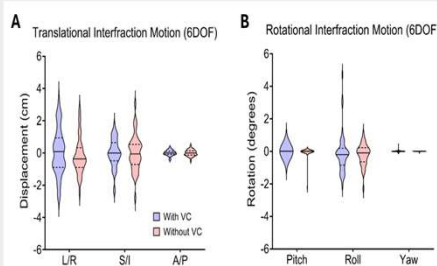


Figure 3. Translational and rotational interfraction motion (6DOF) between reference CT and daily MRI.

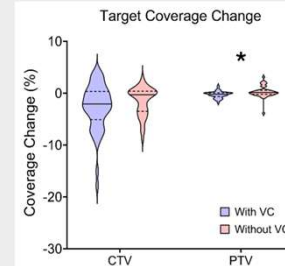


Figure 4. CTV and PTV coverages between the clinically delivered plan and research plan.

DISCUSSION

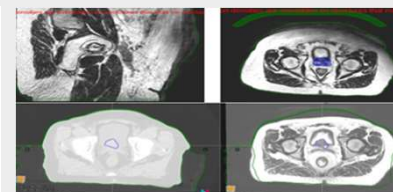


Figure 5. Incorrect external contour due to MR motion artefact (Top), external contour difference between CT sim with VC and MR sim without VC (Bottom).

Patients with larger abdominal girth or heavier breathing showed greater anterior soft-tissue bulging when immobilized with a VC, bringing the skin surface closer to the coils and increasing variability in the anterior external contour. This variability can lead to inaccurate external-contour deformation during ATS and elevate the risk of reduced CTV coverage, underscoring the need for careful anterior contour verification during adaptive workflows when VC is used (Fig. 5).

CONCLUSIONS

Prostate SBRT patients can be effectively positioned and treated on the MRL without a vacuum cradle. Using only a headrest and dual-leg positioner maintains setup accuracy, workflow efficiency, inter- and intrafraction motion control, and patient comfort. VC removal did not compromise treatment quality and may reduce variability in adaptive plan dosimetry.

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