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Robustness of VMAT TBI Plans Against Interfractional Variations Under Different Placements of Upper Limbs

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ABSTRACT

Purpose: To quantify the impact of interfractional variations on the dosimetric quality of VMAT TBI plans, primarily caused by potentially inconsistent upper limb placement at treatment; and to determine a clinically optimal setup for plan robustness against such variations.

Methods: Changes in DVH endpoints are calculated for three VMAT TBI patients with different upper limb placements during simulation by deforming the planning CT to per-fraction CBCT. The upper limb placements are: 1. elbows flexed with palms on abdomen, 2. posterolateral to torso, 3. anterolateral to torso with palms resting on legs, respectively.

Results: Non-negligible changes in both PTV coverage and dose to the OARs were found with interfractional motion.

Conclusion: Inconsistent upper limb positioning impacts the dosimetric quality of VMAT TBI treatments. Among the three cases evaluated, positioning the arms anterolateral to the torso with the palms resting on the legs was associated with the greatest dosimetric robustness.

INTRODUCTION

Volumetric Modulated Arc Therapy (VMAT) Total Body Irradiation (TBI) promises greater organs-at-risk (OARs) sparing[1] while delivering a whole body myeloablative dose to patients receiving bone marrow transplant. First pioneered on helical tomotherapy units[2], modern VMAT TBI is increasingly delivered on conventional C-arm linacs. The improved conformality of VMAT TBI plans also increases their sensitivity to interfractional variations. In particular, inconsistent upper limb positioning during treatment may impact target coverage and dose to the OARs. This study aims to determine a clinically optimal upper limb placement for plan robustness against interfractional variations in upper limb positions.

METHODS AND MATERIALS

A retrospectively study was performed on three patients, each treated with myeloablative VMAT TBI at 12Gy prescription dose in eight fractions. Placements of the upper limbs during simulations are: 1. elbows flexed with palms on abdomen, 2. posterolateral to torso, 3. anterolateral to torso with palms resting on legs. The planning CT and the associated structure set were deformed to the extended CBCT from each fraction in Varian Velocity. Doses from each fraction were recalculated on the deformed structure sets with preset plan parameters. Fractional doses were accumulated on the original planning CT by applying the inverse deformations. DVH endpoints were calculated with accumulated fractional doses and compared with the original plan.

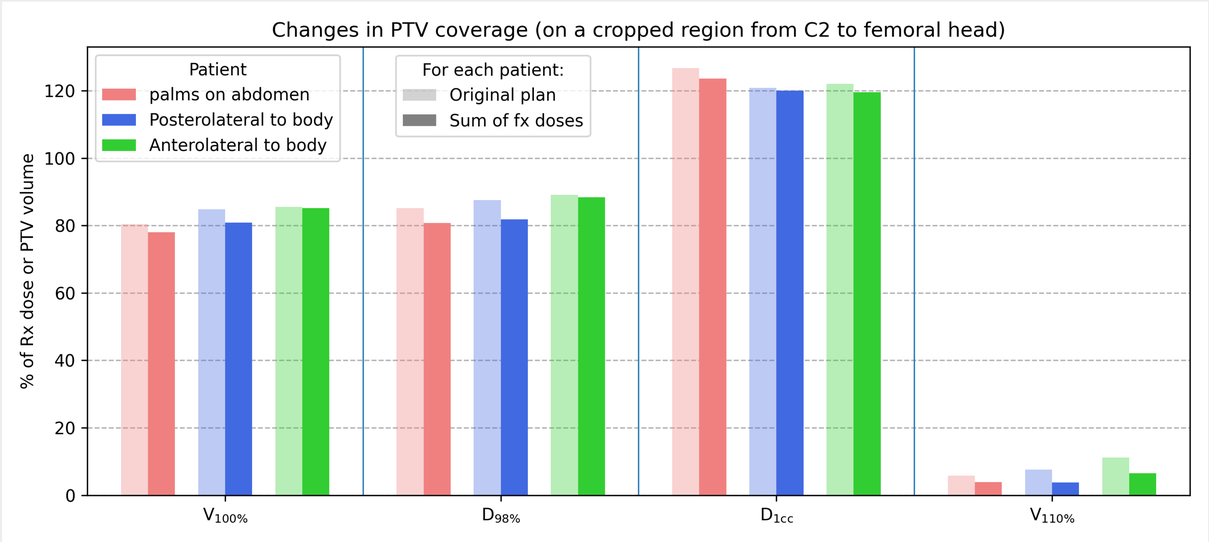
RESULTS

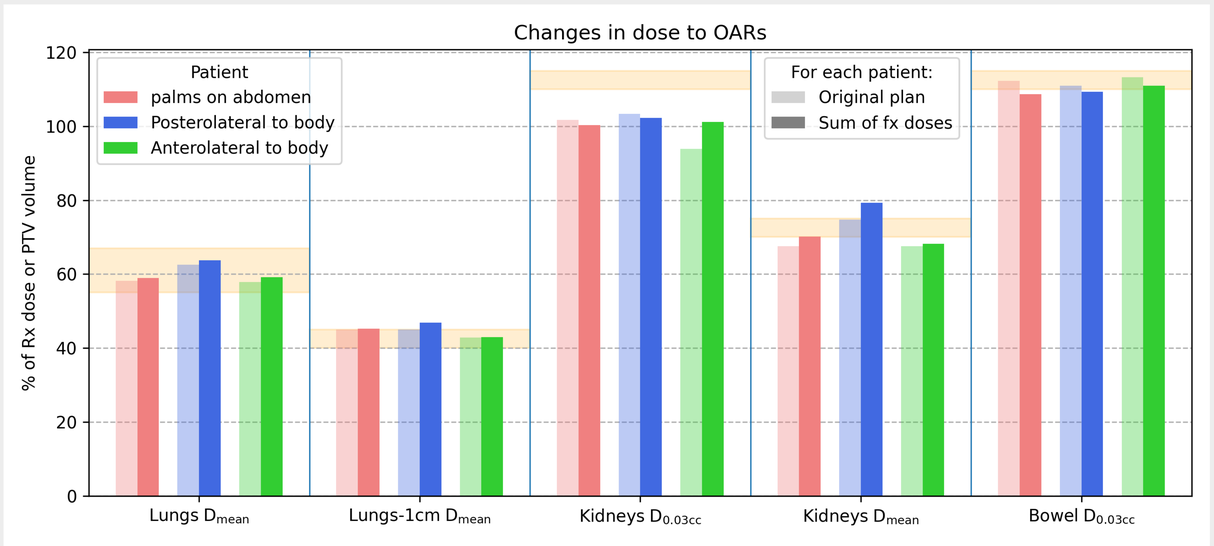
Non-negligible changes in both PTV (cropped from C2 to femoral heads) coverage and dose to the OARs were found.

For Patient 1, D98% of cropped_PTV dropped from 85.2% to 80.83%, while mean dose to kidneys increased from 67.6% to 70.2%.

For Patient 2, D98% and V100% of cropped_PTV dropped from 87.6% to 81.8% and 84.8% to 80.9%, respectively; while mean dose to lungs-1cm increased from 45.0% to 46.9% and mean dose to the kidneys from 74.7% to 79.3%.

For Patient 3, no significant change in PTV coverage was found while mean dose to the lungs marginally increased from 57.9% to 59.2%.





DISCUSSION

Upper-limb positioning for VMAT TBI requires balancing patient comfort, setup reproducibility, treatment-planning geometry, and compatibility with immobilization and motion-monitoring devices. The anterolateral position with the palms resting on the legs was well tolerated, reproducible with Vac-Lok immobilization, and associated with smaller observed changes in target coverage and lung and kidney dose than the other two evaluated setups.

Errors in the deformable registration contribute to uncertainties on the calculated DVH endpoints. A larger patient cohort is needed to establish statistical significance in follow-up studies.

Despite the limitations, this study provided valuable insight in the early implementation of our clinical VMAT TBI program. Future studies aim to establish institutional guidelines regarding the threshold for acceptable upper limb mismatch between planning CT and online CBCT.

CONCLUSIONS

Inconsistent upper limb positioning impacts the dosimetric quality of VMAT TBI treatments. Among the three cases evaluated, positioning the arms anterolateral to the torso with the palms resting on the legs was associated with the greatest dosimetric robustness.

Patient 1

Patient 2

Patient 3

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