Impact of Beam Energy and Field Arrangement on VMAT TBI Plan Quality

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ABSTRACT

Purpose: To assess how different treatment planning techniques affect dose homogeneity and OAR sparing in VMAT total-body irradiation (TBI) plans.

Methods: VMAT TBI treatments for five patients were retrospectively replanned. For all cases, the upper body was planned using three VMAT isocenters (head, chest, and pelvis). The legs were planned with two 3D-CRT AP/PA isocenters (upper and lower leg), which served as a base dose for the VMAT optimization. Multiple VMAT plan variants were generated, varying the beam energies and number of arcs per isocenter. For the energy comparison, all VMAT plans used four full arcs per isocenter with beam energies of 6 MV only, 10 MV only, or an equal combination of 6 and 10 MV. To evaluate the effect of changing the number of fields, 6 MV plans with two or four full arcs per isocenter were generated. All plans were normalized so that 100% of the prescription dose covered 85% of the PTV_Body volume. Plans were evaluated by comparing V110% and OAR dose metrics.

Results: For patients with smaller chest and abdominal separation, beam energy had a negligible effect on V110%. However, for the patient with the largest separation (>55 cm laterally), incorporating 10 MV beams reduced V110% from 17.3% (6 MV) to 15.1% (6 and 10 MV) and 14.3% (10 MV). The effect of energy on OAR doses was variable, with no single energy consistently benefiting all OARs. Increasing the number of arcs per VMAT isocenter considerably improved plan quality. The average V110% decreased from 24.7% (two arcs) to 9.4% (four arcs). Similarly, the lung mean dose decreased from 77.4% to 69.7%.

Conclusion: Increasing the number of arcs in VMAT TBI plans improves dose homogeneity and OAR sparing. Patients with lateral separation exceeding approximately 55 cm may benefit from adding 10 MV beams to reduce V110%.

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INTRODUCTION

VMAT allows for total-body irradiation (TBI) treatments that deliver a more homogeneous dose and spare organs at risk (OARs) such as the lungs, kidneys, and lenses more effectively. However, VMAT TBI treatment planning requires optimization of multiple isocenters on a full-body CT scan, making it computationally demanding. Therefore, it is challenging to achieve acceptable target coverage, hotspots, and OAR doses if planning time is limited. As VMAT TBI becomes more widely adopted, this planning complexity places a significant burden on clinical staff. This study addresses that challenge by providing guidance to help planners develop clinically acceptable plans more efficiently. To that end, the effect of beam energy and number of arcs on VMAT TBI dose distributions was investigated.

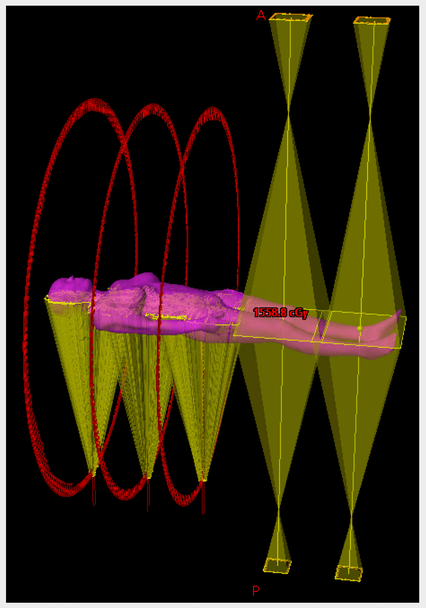

Figure 1. The field arrangement for VMAT TBI plans, with three VMAT upper body isocenters and two lower body AP/PA isocenters.

METHODS AND MATERIALS

VMAT TBI treatments for five patients were retrospectively replanned. For all cases, the upper body was planned using three VMAT isocenters (head, chest, and pelvis), as shown in Figure 1. The legs were planned with two 3D-CRT AP/PA isocenters (upper and lower leg), which served as a base dose for the VMAT optimization.

Multiple VMAT plan variants were generated with different beam energies and number of arcs per isocenter. The leg plans for each patient were the same in all variants, and all plans were generated using the same optimization objectives and number of iterations. For the energy comparison, all VMAT plans used four full arcs per isocenter with beam energies of 6 MV only, 10 MV only, or an equal combination of 6 and 10 MV. To evaluate the effect of changing the number of fields, 6 MV plans with two or four full arcs per isocenter were generated.

All plans were normalized so that 100% of the prescription dose covered 85% of the PTV_Body volume. Plans were evaluated by comparing V110% (to evaluate homogeneity) and OAR dose metrics.

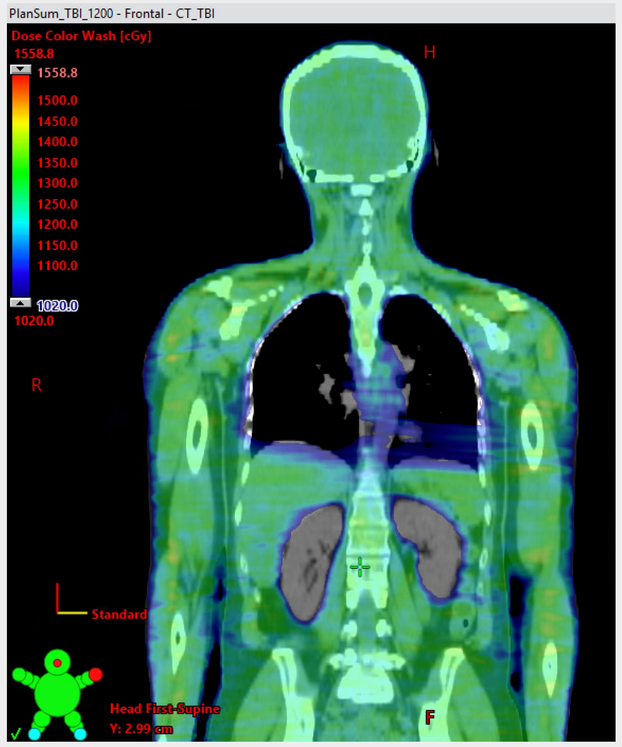

Figure 2. Dose distribution for a VMAT TBI plan, highlighting the sparing of lungs and kidneys.

RESULTS

As shown in Figure 3, for patients with smaller chest and abdominal separation (Patients 1-4: less than 50 cm lateral separation at the chest), beam energy had a negligible effect on V110% (percentage of the PTV_Body volume receiving at least 110% of the prescription dose). However, for the patient with the largest separation (Patient 5: greater than 55 cm laterally), incorporating 10 MV beams reduced V110% from 17.3% (6 MV only) to 15.1% (mixed 6 and 10 MV) and 14.3% (10 MV only). The effect of energy on OAR doses was variable, with no single energy consistently benefiting all OARs.

Increasing the number of arcs per VMAT isocenter considerably improved plan quality, as shown in Figure 4. The average V110% decreased from 24.7% (two arcs) to 9.4% (four arcs) across all patients. Similarly, the lung mean dose decreased from 77.4% to 69.7%. Kidney mean dose decreased from 81.9% to 75.3%.

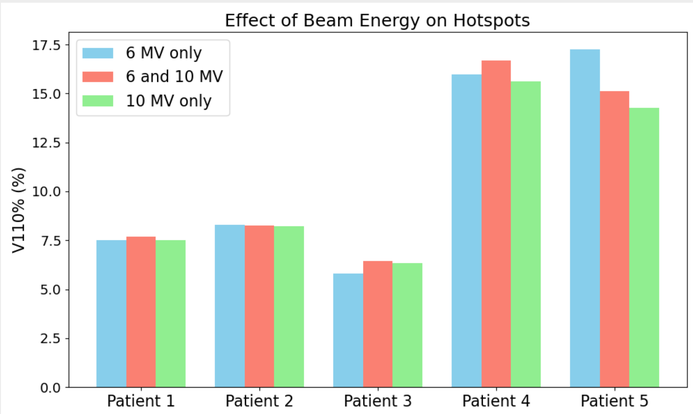

Figure 3. Effect of beam energy on the volume receiving at least 110% of the prescription dose. Patients are in order of increasing lateral separation.

DISCUSSION

The dose distribution of VMAT TBI plans (Figure 2) demonstrates much better dose homogeneity and sparing of OARs than conventional 2D TBI treatments. However, this comes at the cost of much more time and effort required for planning. Applying the results of this work may help planners achieve a better-quality plan in less time.

These results demonstrate that increasing the number of arcs clearly improves overall plan quality. The effect of energy is minimal for smaller patients, but the largest patient (>55 cm lateral separation at the chest) achieved a more homogeneous dose when 10 MV beams were included.

Therefore, to reduce the time required for planning, it may be prudent to begin with four arcs per isocenter, and to include some 10 MV beams if the patient is relatively large.

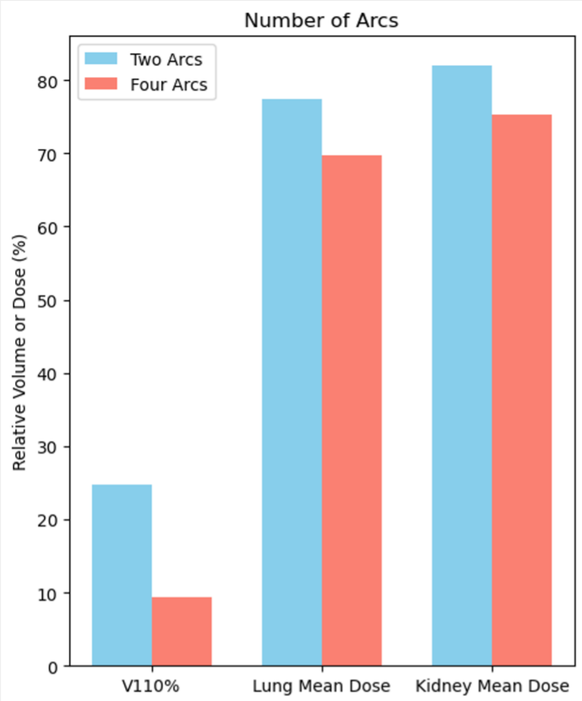

Figure 4. Effect of number of arcs on V110% and lung and kidney mean dose (as a percentage of the prescription dose). These are presented as an average across all patients used in this study.

CONCLUSIONS

Increasing the number of arcs in VMAT TBI plans improves dose homogeneity and OAR sparing. Patients with lateral separation exceeding approximately 55 cm may benefit from adding 10 MV beams to reduce V110%.

REFERENCES

The script described in the following publication was used to aid in plan generation:

Simiele, E. A., et al. (2025). A Single Automated VMAT Planning Framework for TBI, CSI and TMLI: Streamlining Workflow and Enhancing Plan Quality. *International Journal of Radiation Oncology, Biology, Physics*, *123*(1), S245.

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