Optimization of a Multi-Isocentric VMAT TBI Technique Incorporating 10FFF and Evaluation of Target and OAR Dose Constraints

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Introduction

- Achieving adequate target coverage while limiting dose to critical organs in TBI (total body irradiation) remains challenging, particularly in larger patients
- Lung sparing is of particular importance due to the risk of radiation-induced pulmonary toxicity; however, patient size and body geometry can significantly affect achievable dosimetric outcomes.

Purpose: To improve lung-sparing for multi-isocentric TBI in adult-sized patients while preserving target coverage, and to determine mean lung dose (MLD) and target maximum dose (PTV D_{1cc}) as a function of body dimensions.

Methods

1. Planning parameters (arc number, collimator angle, and beam energy) were investigated to improve lung sparing while maintaining coverage.
2. An optimal plan template was developed.
3. After establishing an optimal technique, 11 TBI CT datasets were retrospectively analyzed.
4. For each patient, a chest-isocenter plan was generated in Eclipse using the developed planning and optimization templates.
    a. Heating and cooling structures were added as needed throughout the optimization process.
    b. The optimization was considered plateaued when two or more further optimizations did not yield improvements in plan parameters.
5. Once plan optimization plateaued, normalization was employed to achieve 100% prescription coverage of 90% of the target volume.
6. Correlations of MLD with maximum body width, lung volume, and lung-to-body-width ratio were analyzed. PTV D_{1cc} with bodily width was also investigated.

Results

- The optimal plan template consisted of:
    a. 4 arcs, two with ~0° collimator (6 MV and 10 FFF), and two with ~90° collimator (6 MV and 10 FFF).
    b. The optimization template developed included the following structures: PTV (cropped 3 mm from the lung), lung, lung + 3 mm, lung – 3 mm, lung – 5 mm, lung – 1 cm, and the 2.5 cm flash structure.
    c. Heating and cooling structures were added as needed throughout the optimization process.
- Using 10 MV FFF improved plan quality (Figure 1). Use of 10 MV did not yield the same impact.
- Patient maximum lateral body widths ranged from 29.3-63.5 cm; lung volume to maximum lateral body width ratios ranged from 21.0-95.9 cc/cm.
- MLD was not correlated with maximum body width, lung volume, or lung-to-body-width ratio.
- MLD increased over 67% for maximum body width >43 cm (Figure 2).
- PTV D_{1cc} ranged from 117-144% (Figure 3) and correlated with bodily width (R^2=0.8).

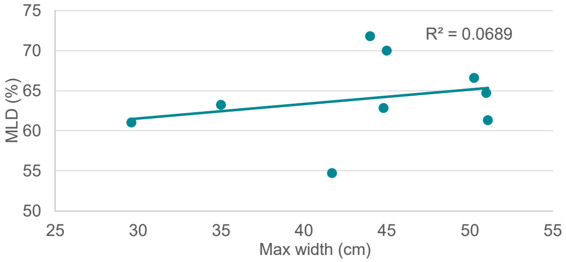

Figure 2. *Mean lung dose (MLD) versus maximum body width.*

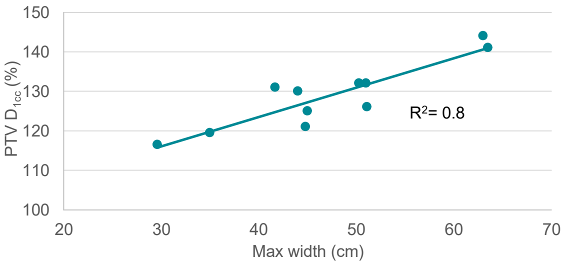

Figure 3. *PTV $D1_{cc}$ versus maximum body width.*

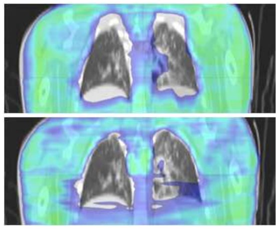

Figure 1*. Example of dosimetry with 6 MV beams only (top) and with mixture of 6 MV and 10 FFF beams (bottom). Both plans yielded MLD of ~ 70 %; however, the plan with 10FFF is more conformal around the lungs, permitting more coverage for the same lung sparing.*

Discussion

- Figure 1 displays the improved plan quality achievable by incorporating 10FFF.
- Figure 2 reveals that MLD can be larger than 67% for patients with maximum body width greater than 43 cm.
    - This finding is significant because current dosimetric goals for multi-isocentric TBI include MLD < 67%[1,2], without providing additional guidance for larger patients.
    - Figure 3 displays that PTV D_{1cc} is correlated with maximum lateral body width, again suggesting that current literature recommendations (PTV D_{1cc} < 120%)[1] are not comprehensive for larger patients.

Conclusion

- A planning and optimization template was developed to enhance lung sparing for a given target coverage in multi-isocentric TBI for adult-sized patients. Incorporating 10FFF energy arcs improved both MLD and PTV D_{1cc} metrics.
- Some bodily widths >43 cm exhibited MLD >67%. Furthermore, PTV D_{1cc} increased linearly with body width. The results suggest that the current dosimetric goals in the literature (MLD < 67%, PTV D_{1cc} < 120%) may not be realistic for larger patients.

References

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