Enhancing efficiency of a treatment planning process for mixed beam radiotherapy towards clinical usability

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Purpose

Our approach for mixed beam radiotherapy (MBRT) is based on utilizing intensity modulated photon and electron apertures collimated by the photon MLC and was shown to be dosimetrically superior than VMAT for superficial targets [1]. This work aims to improve and evaluate computational efficiency of a Monte Carlo (MC) treatment planning process (TPP) [1-2] for MBRT towards clinical usability and to validate the deliverability and dosimetric accuracy of generated plans.

Methods

- To improve computational efficiency, following features are implemented in the original MC-TPP resulting in an efficiency-enhanced MC-TPP: use of pre-calculated pre-patient phase-spaces for beamlet MC dose calculation, setting of statistical uncertainties of MC beamlet dose distributions as high as still sufficiently usable for optimization, sparse representation of MC beamlet dose distributions (i.e. introduction of a dose threshold), merging of voxels distant to the PTV, normal tissue objectives, dynamic stopping criteria for optimization, particle recycling for final MC dose calculation and automatic xml-file generation for plan delivery.
- The impact of these features on computational efficiency and plan quality is evaluated by generating MBRT plans for a bladder and a head and neck case.
- For validation purposes, the efficiency-enhanced MC-TPP is applied to an academic case of a water slab phantom and the generated xml-file is delivered on a TrueBeam (Varian Medical Systems) in the developer mode to a Gafchromic EBT3 film.
- Furthermore, a log-file based dose re-calculation is performed. Both, log-file re-calculation and measurement are compared to the final dose calculation.

Results

From the original MC-TPP to the efficiency-enhanced MC-TPP …

- … the computation times for optimization, beamlet and final dose calculation are reduced from 1 h to 10 min, 8 h to 25 min and 30 min to 5 min, respectively.
- … the utilized RAM-memory space is reduced from 17.5 GB to 7 GB for optimization .

These computational efficiency improvements have no substantial impact on treatment plan quality (Figure 1).

- The film measurement agreed with dose calculation with a passing rate >99% for a 3% / 2 mm gamma analysis with 10% dose threshold (Figure 2).
- The discrepancies between final calculated and log-file re-calculated dose are within statistical uncertainty of <1% (Figure 3).

Conclusion

The computational efficiency of an MC-TPP for MBRT and the deliverability of generated plans are successfully improved and validated. The efficiency-enhanced MC-TPP is deemed to be adequate for clinical use.

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References

[1] S. Mueller et al., “Simultaneous optimization of photons and electrons for mixed beam radiotherapy”, Phys. Med. Biol. 62, (2017).

[2] D. Henzen et al., “Monte Carlo based beam model using a photon MLC for modulated electron radiotherapy”, Med. Phys. 41(2), (2014).

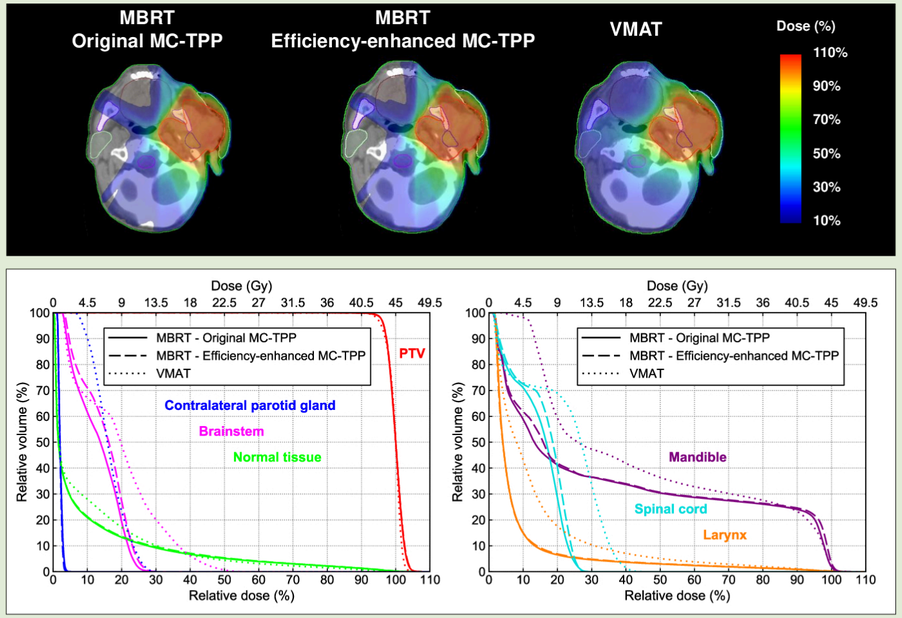

Figure 1: Dose distributions (top) and DVHs (bottom) of the MBRT plans for the head and neck case either generated with the original or with the efficiency-enhanced MC-TPP. Only minor degradations in plan quality are visible. Additionally, the clinical VMAT plan is also shown as a reference for treatment plan quality.

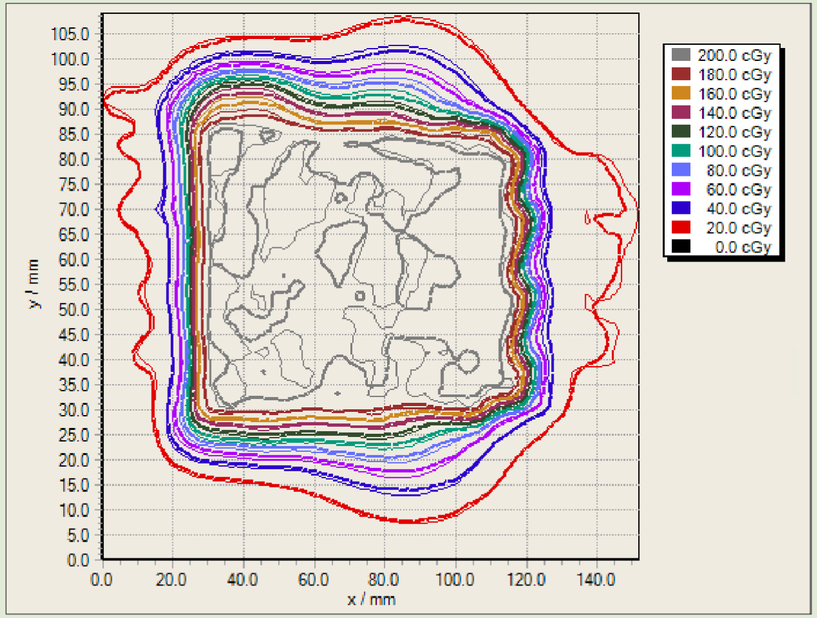

Figure 2: Comparison of measured (thin lines) and final calculated (thick lines) isodose distributions for the MBRT plan created for the academic case. Following beam modalities are part of the plan: 6 MV photons and 6, 9, 12, 15, 18 and 22 MeV electrons.

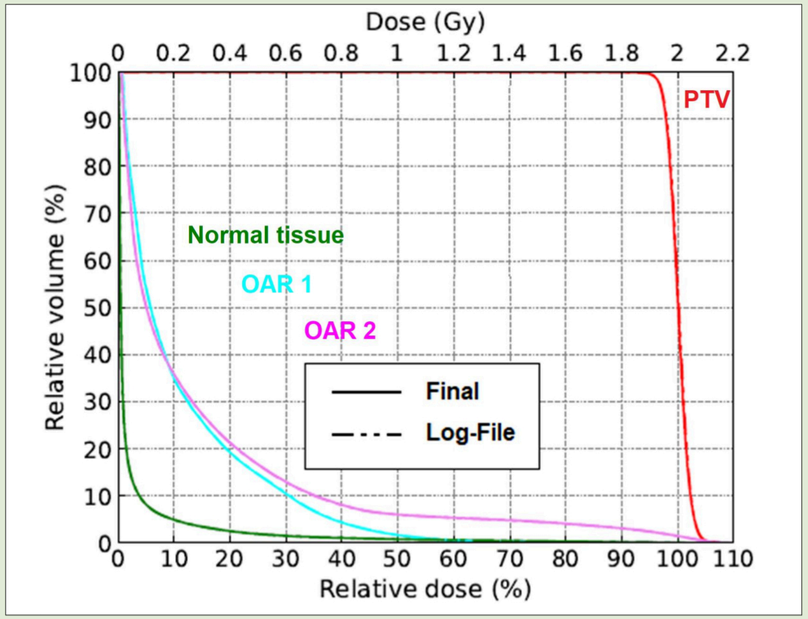

Figure 3: DVH comparison of the final and log-file based dose calculation for the MBRT plan created for the academic case. By eye, the differences between the two calculations are not visible on the figure.