Hybrid direct aperture optimization for VMAT, dynamic trajectory radiotherapy (DTRT) and dynamic mixed beam radiotherapy (DYMBER)

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Purpose

To develop a hybrid direct aperture optimization able to generate treatment plans for volumetric modulated arc therapy (VMAT), dynamic trajectory radiotherapy (DTRT) [1] and dynamic mixed beam radiotherapy (DYMBER) [2].

Methods

Both DTRT and DYMBER utilize additional degrees of freedom (DoFs) compared to VMAT (illustrated in Figure 1 for DYMBER). DTRT applies dynamic trajectories for photon beams with additional dynamic table and collimator rotation compared to VMAT arcs. DYMBER combines photon dynamic trajectories with intensity and energy modulated electron beams collimated with the photon MLC. Both DTRT and DYMBER are non-coplanar treatment techniques.

To generate plans for these treatment techniques, we developed a hybrid column generation and simulated annealing algorithm. The column generation algorithm iteratively adds the next promising aperture, either a photon aperture to a predetermined dynamic trajectory or an electron aperture. After each iteration, a combination of gradient descent based MU-weight optimization and simulated annealing based aperture-shape fine-tuning is performed.

Deliverable VMAT, DTRT and DYMBER plans are generated with the developed in-house optimizer for two head and neck cases to investigate whether the optimizer can dosimetrically exploit the additional freedom of DTRT and DYMBER compared to VMAT.

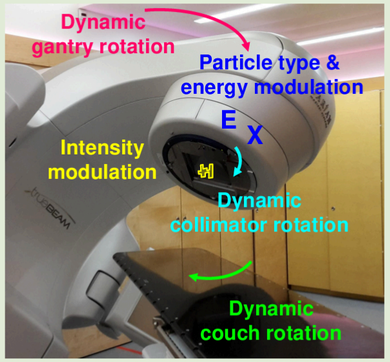

Figure 1: The degrees of freedom exploited by DYMBER.

Results

DVHs and dose distributions of the plans are compared in Figures 2 and 3. The following dosimetric results are averaged over both cases.

- Compared to VMAT, D2% of serial OARs is reduced relative to the prescribed dose by 1.1% and 6% for DTRT and DYMBER, respectively and the mean dose of parallel OARs is reduced relative to the prescribed dose by 2.2% and 3.6% for DTRT and DYMBER.
- Dose homogeneity in the target (D2% / D98%) is on average 1.14, 1.13, 1.13 for VMAT, DTRT and DYMBER, respectively.

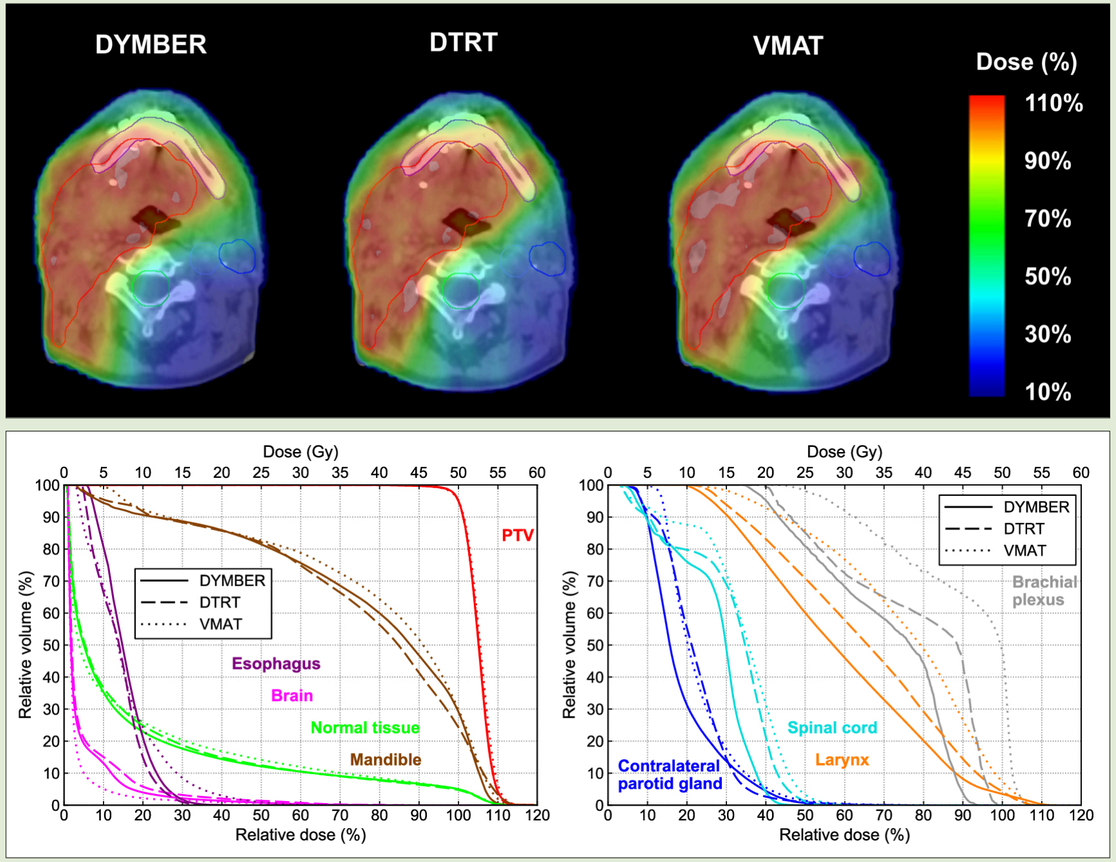

Figure 2: Comparison of dose distributions (top) and DVHs (bottom) of the VMAT, DTRT and DYMBER plans for the first head and neck case.

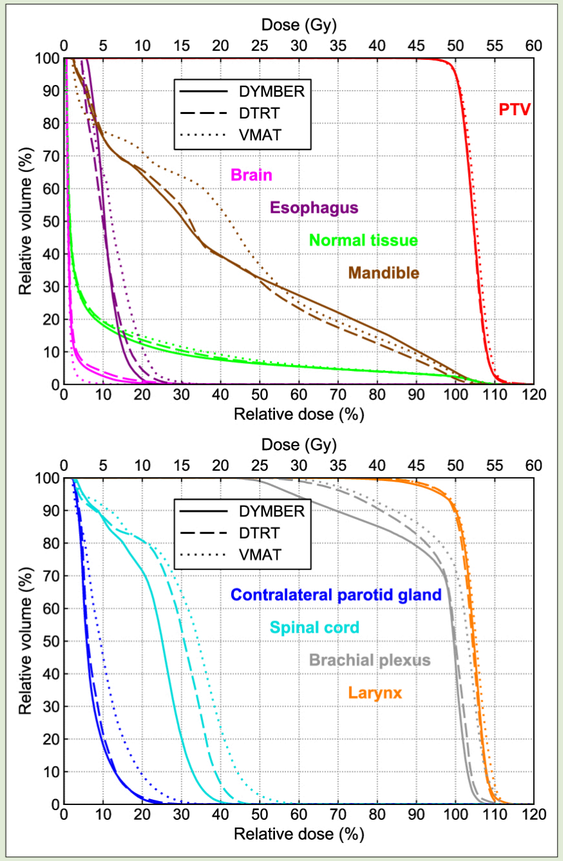

Figure 3: Comparison of DVHs of the VMAT, DTRT and DYMBER plans for the second head and neck case.

Conclusion

A hybrid DAO applicable to VMAT, DTRT and DYMBER is successfully developed. It is shown that the optimizer can take dosimetric advantages out of the additional degrees of freedom provided by DTRT and DYMBER compared to VMAT.

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References

[1] M. K. Fix et al., “Part 1: Optimization and evaluation of dynamic trajectory radiotherapy”, Med. Phys. 45(9), 2018

[2] S. Mueller et al., “Part 2: Dynamic mixed beam radiotherapy (DYMBER): Photon dynamic trajectories combined with modulated electron beams”, Med. Phys. 45(9), 2018

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