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Dosimetrically-motivated beam-angle optimization for partial-arc non-coplanar VMAT

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Purpose: To develop a beam-angle optimization method for non-coplanar VMAT (NC-VMAT) with table-angle and gantry-angle range determined by iterative beam elimination based on 4-π fluence map optimization (FMO).

Methods: FMO is carried out for beam directions covering the 4-π space around the PTV every 10° gantry-angle and 10° table-angle. A gantry-table contribution map is generated from the fractional contribution of each beam to PTV dose. The map is thresholded to eliminate 25% of the beams with the lowest contribution. Pseudo-arcs are formed by adjacent beams with the same table-angle. Subsequently, FMO is applied to the remaining beams and pseudo-arcs are trimmed by eliminating the 25% lowest-contributing beams at the start and stop (edges) of all pseudo-arcs. Pseudo-arcs spanning less than 55° gantry-angle range are rejected. FMO, trimming, and small-arc rejection are repeated iteratively until reaching a user-defined total gantry-angle range. The resulting pseudo-arcs are converted into dynamic-arcs and subject to hybrid direct aperture optimization (HDAO), yielding a mechanically deliverable NC-VMAT plan.

The method was applied to a clinically-motivated locally recurrent nasopharyngeal carcinoma case (NPC, 25x2 Gy). A HDAO-optimized coplanar-VMAT plan with the same total gantry-angle range was created for comparison.

Results: The desired total gantry-angle range of 720° was reached in 4 iterations yielding a NC-VMAT plan with seven partial-arcs with table angles between -40° and 60° and gantry-angle range from 60° to 130°. The cost function values after HDAO and dose re-normalization were 0.045 for NC-VMAT and 0.066 for coplanar-VMAT. Target coverage was similar for both techniques. Dmax to optic nerves, lenses, optic chiasm, brainstem PRV, and spinal cord PRV were 0.7-6.2 Gy lower for NC-VMAT than for coplanar-VMAT.

Conclusion: A dosimetrically-motivated beam-angle optimization method was developed using iterative 4-π FMO and beam elimination. A NC-VMAT plan was optimized for an NPC case using HDAO to obtain a mechanically deliverable plan achieving better OAR-sparing than coplanar-VMAT.

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