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Binary Collimation for Multiple Brain Metastases Radiosurgery (G, I)

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Purpose: A novel system of algorithms has been developed that allows for automated planning of conformally collimated radiotherapy plans for the treatment of multiple brain metastases with various prescription doses. This study uses simulated annealing to optimize the collimation to subsets of targets at specified incident radiation angles, along with modulation of dose, to achieve prescription target dose coverage and healthy tissue sparing.
Methods: At each discretized location in the treatment (control point), the system aims to optimize the number of targets treated, the rotation angle of the collimator, the collimator leaf positions, and the number of monitor units (MU) delivered. A novel optimization cost function (OF) was designed for this study using a linear-quadratic metric penalty function, with a generic form applied to healthy organ maximum doses and clinical target metrics. This OF is used as a minimization metric in a simulated annealing procedure to define the intra-arc binary collimation (iABC) pattern. In iABC, each target can either be conformally treated or entirely shielded by the MLC at each control point. Seven multiple metastases cases previously treated at the Nova Scotia Health Authority were anonymized and re-planned with iABC using consistent planning methods, and compared to the clinical standard.
Results: Treatment plans generated with iABC used an average of 3044 (37%) fewer MU in the total plan than VMAT ($p = 0.026$). All healthy tissue metrics for all plans and all patients were within clinical acceptability. No statistically significant difference was observed for any normal tissue metrics. Normalized prescription target coverage accuracy for all targets was 4.0% better on average for VMAT plans when compared to iABC ($p = 0.016$), and 14.8% better on average for iABC when compared to DCA ($p = 0.041$).
Conclusion: Intra-arc binary collimation has the potential to improve treatment delivery to multiple metastases treatment plans with multiple unique prescriptions with a statistically significant improvement to target coverage accuracy when compared to conventional DCA. Additionally, this method retains the majority of MU sparing inherent in DCA (37% when compared to VMAT) without a statistical significant difference in normal tissue dose when compared to VMAT.

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