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Comparison of Multiple Lesion Single Isocenter Treatment Planning Techniques for Stereotactic Radiosurgery

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Abstract
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Abstract

Objective: To compare two planning techniques, volumetric modulated arc therapy (VMAT) and dynamic conformal arcs (DCA), which are in widespread use for stereotactic radiosurgery of multiple brain metastases using a single isocenter in terms of their dosimetric and delivery performance.

Methods: Fourteen patients with 2 to 18 brain metastases (total 103; median 4) previously treated with single fraction SRS were replanned for multiple lesion single isocenter treatments using Varian Eclipse for VMAT and Brainlab's Multiple Metastases Elements (MME) for DCA. Planning target volumes (PTV) were created from MRI-defined gross tumor volumes by applying a 1 mm radial margin. Prescribed doses were 15 Gy to lesions having a largest diameter ⩽ 4cm and ⩾ 3cm, 18 Gy to lesions with a largest diameter < 3 cm and ⩾ 2 cm , and 21 Gy or 24 Gy to lesions having a largest diameter < 2 cm. PTV coverage was at least 99%, but ideally 99.5%. VMAT plans used both coplanar and non-coplanar beam arrangements with one to four couch angles, chosen based on the number and distribution of lesions. MME plans exclusively used non-coplanar arrangements with four to six couch angles. Plans were evaluated using the Paddick conformity index, normal tissue V12Gy, the probability for symptomatic brain necrosis (S-NEC) calculated using logistic regression, and maximum organ-at-risk point doses for brainstem, chiasm, optic nerves, and eyes. The total number of monitor units (MU) was used as a surrogate for delivery efficiency.

Results: All plans were clinically acceptable and achieved the minimum target prescription dose coverage goal of 99%. The median cumulative tumor volume was 3.94 cm3. Conformity was not significantly different between VMAT and MME plans with median conformity indices of 1.38 and 1.46-1.49, respectively. VMAT plans showed a trend towards higher MU with a median difference between 18% and 24% ($p \leqslant 0.09$). OAR maximum point doses were significantly higher in VMAT plans for the brainstem ($p < 0.01$), chiasm ($p \leqslant 0.02$), and optic nerves ($p \leqslant 0.04$) with median differences of 1.78 Gy (-1.25 to 6.50 Gy), 0.73 Gy (-1.70 to 3.96 Gy), and 0.64 Gy (-1.20 to 3.88 Gy), respectively. The volumes of low and intermediate doses were lower with MME compared to VMAT. Normal brain V12Gy favored MME plans especially for small cumulative target volumes, while at larger cumulative volumes the difference between MME and VMAT reduced.

Conclusion: For the treatment of multiple cranial lesions using a single isocenter, MME plans were found to be dosimetrically superior to VMAT plans in most cases, with reduced V12Gy and associated S-NEC. Maximum doses to important OARs showed significant improvement, increasing the ability for subsequent salvage treatments involving radiation. Furthermore, MME plans are in general less complex simplifying quality assurance, increasing efficiency, and patient safety.