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Abstract

Robust Treatment Planning with Conformal Arc Informed Volumetric Modulated Arc Therapy (CAVMAT)

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Objectives: Radiosurgery of multiple brain metastases is often performed with VMAT, which may utilize highly modulated MLC trajectories and may struggle to block between targets, leading to unnecessary healthy tissue dose. Some institutions have also reported difficulties in achieving a beam configuration for these cases that is optimal for all metastasis locations and geometries. Our aim is to develop a treatment planning technique which uses less modulated MLC trajectories and spares healthy tissue, while remaining robust to configuration and delivery errors.

Methods: A Conformal Arc Informed VMAT (CAVMAT) planning technique was developed, combining intuitive MLC motions of dynamic conformal arcs with the flexibility of inverse optimization. Targets are assigned to subgroups which maximize MLC blocking between targets and field weights are optimized to limit MU variation. Inverse optimization is performed to improve dose and conformity to each target. 20 VMAT plans were replanned with the CAVMAT technique and the V6Gy, V12Gy, V16Gy of healthy tissue was evaluated, as well as conformity index. 10 VMAT and CAVMAT plans were calculated at DLG values of 0.4mm, 0.8mm, and 1.2mm to assess configuration error. V6Gy, V12Gy ,and V16Gy metrics were evaluated again and the maximum, mean, and minimum dose to each target was recorded. Linear accelerator log files were collected to assess MLC positional error due to treatment delivery. Gamma analysis was performed on the VMAT and CAVMAT plans using a 1%/1mm passing criteria to assess the quality of treatment delivery.

Results: CAVMAT produced less modulated MLC trajectories compared with VMAT and effectively conformed to targets while sparing healthy tissue. The CAVMAT technique reduced V6Gy by 13.68 ± 18.97%, V12Gy by 11.40 ± 19.44%, and V16Gy by 6.38 ± 19.11%, sparing healthy tissue. CAVMAT improved conformity by 3.81 ± 7.57% (1.40 ± 0.19 to 1.34 ± 0.15) and delivered comparable target dose. VMAT was found to be roughly twice as sensitive to changes in DLG. For a varying DLG, the 10 VMAT plans demonstrated a sensitivity of 22.12 ± 12.16 %/mm, 21.61 ± 12.85 %/mm, and 28.28 ± 21.58 %/mm, to changes in V6Gy, V12Gy, and V16Gy, respectively. In comparison, the CAVMAT plans produced a reduced sensitivity of 13.46 ± 11.46 %/mm, 13.08 ± 10.51 %/mm, and 14.38 ± 11.30 %/mm, respectively. The VMAT plans demonstrated an average sensitivity to changes in target maximum, mean, and minimum dose of 6.45 ± 3.87 %/mm, 6.56 ± 3.80 %/mm, and 6.91 ± 3.98 %/mm, compared to a CAVMAT sensitivity of 2.16 ±

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2.07 %/mm, 2.33 ± 1.95 %/mm, and 3.33 ± 2.66 %/mm, respectively. Log file analysis demonstrated no significant difference between the MLC positional error in VMAT and CAVMAT, illustrating that both VMAT and CAVMAT plans can be effectively delivered. Gamma analysis was high for both VMAT and CAVMAT, but demonstrated superior dose agreement for the CAVMAT plans. For a strict criterion of 1%/1mm, the average VMAT gamma analysis passing rate was 94.53 ± 4.42% compared to 99.28 ± 1.74% for CAVMAT.

Conclusions: CAVMAT is capable of producing effective plans while reducing the volume of healthy tissue receiving low doses. CAVMAT is also less sensitive to the selection of DLG value. Our results indicate that for radiosurgery of multiple brain metastases, the dosimetric effect of uncertainties in beam configuration are of greater importance than dosimetric uncertainties from treatment delivery.