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Dosimetric Optimization in LINAC-based Stereotactic Radiosurgery via Dynamic Conformal Arcs & High-Definition MLCs for Multiple Targets in Geographic Proximity

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Purpose

For multiple brain tumors in close proximity to each other, simultaneous treatment via a single isocenter has gained popularity in LINAC-based stereotactic radiosurgery (SRS) system equipped with field-shaping capability by non-coplanar dynamic conformal arcs (DCA). By expanding on an institutional template of a set number of arcs as provided in Brainlab Element Treatment Planning System (TPS) (Version 3.x), this study aims to optimize dosimetric outcomes by exploring different techniques to minimize excessive radiation dose to normal brain tissue either within or outside lesion-bearing area.

Materials and Methods

Three target lesions near each other (operationally defined as overlapping of the respective 50% isodose surfaces if each lesion were planned independently with its own isocenter) were contoured based on brain MRI images of an index patient. The intended prescription dose for each PTV was 22.5 Gy based on their relatively small tumor sizes (0.02, 0.23 and 0.35 cc, respectively). Brainlab Element TPS was used to generate SRS treatment plans with a single isocenter using Varian TrueBeam STx machine with HD MLC (0.25 cm width). Three dosimetric approaches were explored based on a template for 7 non-coplanar DCA arcs with 6MV FFF photon beams. Plan A was generated by treating 3 separate PTVs around each of the 3 tumors respectively. Plan B was generated using the same template but with all 3 tumors joined as a single PTV. Plan C was generated with the same template as Plan A but with an auxiliary contour as an avoidance object implemented (without encroaching upon any PTV) to reduce excessive dose deposited in the overlapping area amongst the 3 tumors.

The degree of normal tissue sparing was assessed based on the volume brain tissue (excluding PTV) receiving the perceived necrosis threshold of 12.0 Gy (V12.0). Whereas Conformity Index (CI) and Gradient Index (GI) for overlapping lesions could not be determined readily for Plans A & C, the normal brain volumes receiving more than 100% and 50% of the prescribed dose were used as surrogate measures for dose conformity (V100%) and fall-off (V50%), respectively. Total monitor units (MU) of each SRS technique were also compared.

Results

	Plan A	Plan B	Plan C
V12.0 (cc)	3.51	4.05	3.86
V100% (cc)	0.52	0.66	0.42
V50% (cc)	3.90	4.49	4.37
MU	10526	3633	19901

Plan B results in the lowest MU that minimizes treatment delivery time, but at the expense of the worst brain sparing with the least conformity and the furthest dose-off. Plan A has the best dose fall-off and the lowest volume prone for necrosis, while Plan C provides the best conformity to individual target lesions but with the highest MU.

Conclusion

By utilizing either individual PTVs separately or a single combined PTV and by adding an auxiliary contour as an avoidance object, one may optimize dosimetric outcomes for closely located target lesions tailored to the specific treatment goals of the planner with regards to tumor dose coverage vs. normal tissue sparing.