Efficient Brain SRS Planning: Two –Arc HyperArc Strategy Maintains Dosimetric Quality While Reducing Treatment Time

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Introduction

Stereotactic radiosurgery (SRS) is a standard treatment approach for single brain metastases, requiring precise dose conformity to the target and steep dose fall-off to spare healthy tissue. Hyper-Arc in Eclipse automates the selection of non–coplanar arcs based on the patient protection zone.

Patients with brain metastasis exhibit significant involuntary movements, and reducing treatment time can greatly improve outcomes and patient quality of life. Strategically reducing the number of arcs may decrease treatment time but may affect plan quality.

Purpose

This study evaluates the dosimetric planning impact and efficiency of selecting two -arc versus multi-arc HyperArc plans.

Methods

Patient Selection

A cohort of ten patients with a single brain metastasis previously treated with 16-24Gy in 1 fraction with SRS were included in this retrospective study from the University of Miami's database. These patients did not receive Whole Brain Radiation Therapy or SRS to the same region.

Treatment Planning

Prior single brain metastasis treatments were replanned using the Hyper-Arc template in the Eclipse treatment planning system V18, and the Non-Coplanar Arcs were reduced to 2. The photon beam energy was kept the same at 10X FFF; the GTV volume included in this study ranged from 0.1 cc to 10 cc. All treatment plans used the same optimization cost function and Acuros XB algorithms to calculate the dose.

Data Analysis

To compare dosimetric quality and plan efficiency, each treatment plan was evaluated based on dose coverage, organ-at-risk (OAR) sparing, Conformity Index (CI), Paddick Conformity Index (PCI), Gradient Index (GI), V12Gy (volume receiving ≤12 Gy), and beam-on time (BoT). Low-dose coverage was evaluated, and statistical analysis was performed by calculating the mean and standard deviation, and using the Wilcoxon Signed-rank test. A p-value <0.05 was considered statistically significant.

Results

Figure 1. Distribution of beam-on time for multi-arc versus two-arc treatment plans. Box plots display the median, interquartile range, and overall spread of the data.

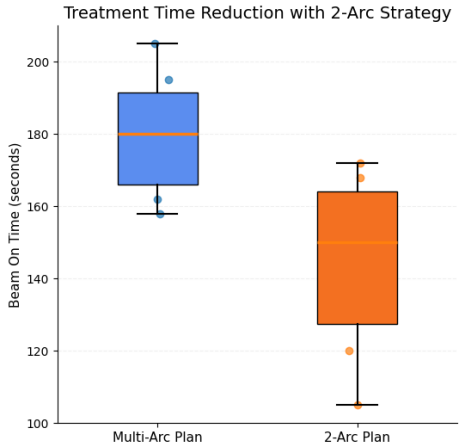

Table 1. Comparison of dosimetric parameters, plan quality indices, organ-at-risk doses, and delivery efficiency between the clinical multi-arc plan and two experimental two-arc plans for one of the cases in this study cohort.

Plan Parameter Comparison

Energy (MeV)	10XFFF
Dose (cGy)	1800
GTV Volume (cc)	1.9

Category	Metric	Units	Clinical Plan (Multi-Arc)	Experimental Plan (2-Arc) a	Difference (Δ%)	Experimental Plan (2-Arc) b*	Difference (Δ%)
Target Coverage	V100% (Coverage)	%	99.00	99.00	0.00	99.00	0.00
	Dmax (Maximum Dose)	%	135.21	130.09	5.12	133.27	1.94
Quality Indices	RTOG Conformity Index (CI)	-	1.04	1.04	0.00	1.03	0.01
	Paddick CI	-	0.89	0.89	0.00	0.90	-0.01
	Gradient Index (GI)	-	3.00	3.39	-0.39	3.10	-0.10
	ICRU Homogeneity Index (HI)	-	0.27	0.21	0.06	0.26	0.01
Organs At Risk	Brainstem (Dmax)	cGy	84.60	118.70	-34.10	4.20	80.40
	Optic Chiasm (Dmax)	cGy	83.40	93.60	-10.20	3.20	80.20
	Normal Brain (V12Gy)	cm3	1.75	1.94	-0.19	1.84	-0.09
	Normal Brain (Dmean)	cGy	34.70	39.60	-4.90	36.80	-2.10
Efficiency	Total Monitor Units (MU)	MU	4456.30	4261.10	195.20	4186.40	269.90
	MLC modulation (from Mobius)						
	Estimated Beam-on Time	seconds	118.71	107.24	11.47	104.97	13.74
	Number of Couch Kicks	#	3	2		2	
	Fields Arrangement		Half Axial+45+315	Half Axial+45		Half Axial+90	
	Isocenter Placement		Right	Right		Right	

Figure 2. Calculated dose distribution for the multiple-arc plan (top row) vs 2-arc plan (bottom row) for one of the single brain cases studied.

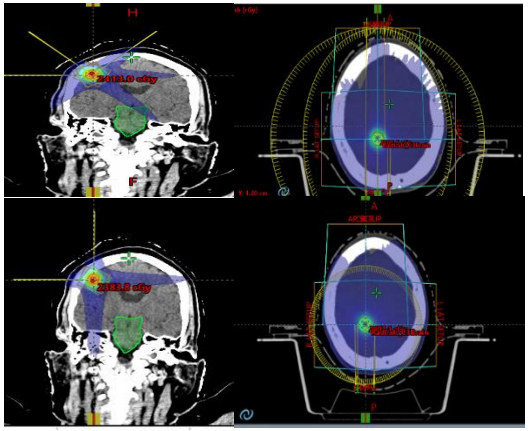

Table 2. Statistical comparison of plan quality and efficiency metrics between multi-arc and two-arc approaches.

Statistical Comparison Summary

Metric	Multi-Arc (mean)	Multi-Arc (+/- SD)	Two-Arc (mean)	Two-Arc (+/- SD)	Mean Difference (two arc - multi arc)	Wilcoxin p-value	Interpretation
CI	1.14	0.15	1.14	0.16	0.00	0.78	Equivalent
PCI	0.82	0.08	0.82	0.08	0.00	0.59	Equivalent
GI	3.57	0.74	3.67	0.71	0.10	0.01	Clinically negligible increase
V12Gy (cc)	2.30	2.04	2.43	2.17	0.13	0.01	Clinically negligible increase
Beam on time (secs)	174.7	22.5	146.0	23.8	-28.7	0.0	Statistically Significant

Conclusion

Two-arc HyperArc plans maintained equivalent target coverage and conformity compared with multi-arc plans. The small increases in GI and V12Gy were statistically significant but clinically negligible. The reduction in beam-on time is substantial, highlighting improved treatment efficiency without compromising plan quality.

Two-arc HyperArc planning is a feasible approach for single brain metastases, guaranteeing an equivalent, clinically acceptable plan with reduced beam-on time (BoT). In the cohort study, a reduction in BoT was observed across all cases for the 2-arcs approach. The average BoT for the multiarc plans was 19% higher than the corresponding value for the 2-arcs cohort. Time saved with the 2-arc approach ranges from 13 to 52 seconds.

References

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