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Normal Tissue Objective Versus Manual Optimization Rings for Multiple Brain Metastases Stereotactic Radiosurgery

Introduction

Stereotactic radiosurgery (SRS) is a standard treatment for patients with multiple brain metastases, providing highly conformal dose delivery while minimizing irradiation of healthy brain tissue. Limiting normal brain dose is critical, as excess exposure is associated with neurocognitive decline and radiation necrosis. Achieving steep dose gradients and minimizing dose spill are therefore essential components of high quality SRS planning.

The Eclipse Treatment Planning System offers two common approaches to promote normal tissue sparing: manual optimization rings and the automated Normal Tissue Objective (NTO). While both methods are widely used, limited data exists comparing their performance in multi-met brain SRS, where overlapping dose distributions increase planning complexity.

This study compares manual optimization rings and NTO in multiple brain metastases SRS plans to determine whether NTO provides equivalent or superior plan quality.

Methods

This study included ten patients who had previously undergone SRS for three or more brain metastases. Each patient had three separate VMAT plans generated using identical beam geometries to allow direct comparison of optimization techniques while minimizing planner bias.

Optimization Strategies

- Manual rings only
  - 1st ring is 0.5 cm around PTV with no margin
  - 2nd ring is 1 cm cropped 0.5 cm away from PTV
  - 3rd ring is 3 cm cropped 1 cm away from PTV
- NTO only
  - Priority: Equal to PTV objective priority
  - Distance from target border: 0.5 cm
  - Start dose: 100%
  - End dose: 40%
  - Fall-off: 0.15
- Hybrid (rings and NTO both utilized)

Target evaluation metrics included planning target volume (PTV) coverage assessed by D95%, conformity index (CI), gradient measure (GM), maximum plan dose, minimum PTV dose, and total PTV volume (cc). Dose to normal brain (Brain-GTV) was assessed using V12Gy, V10Gy, V5Gy, and mean brain dose (Dmean), as these metrics are clinically relevant predictors of radionecrosis risk in multi-metastases SRS. Plan efficiency was assessed by total monitor units (MU) and comparison of MU ratios between optimization strategies.

Results

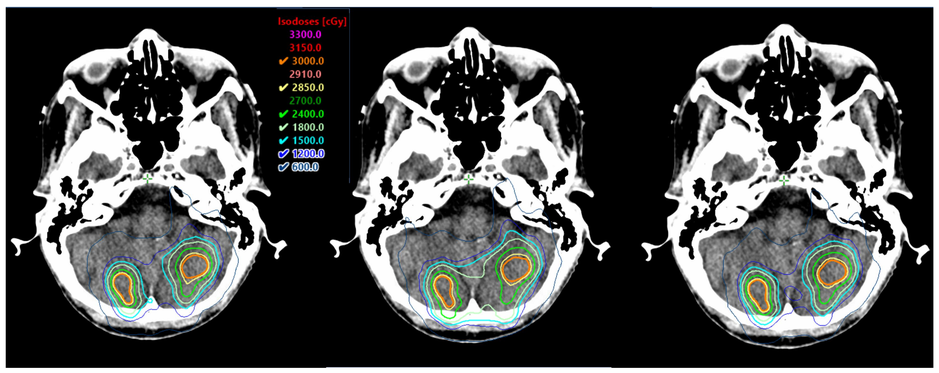

Fig. 1. Axial CT images demonstrating intermediate dose bridging between adjacent lesions in the posterior fossa for (A) manual rings optimization, (B) Normal Tissue Objective (NTO) optimization, and (C) manual rings and NTO both utilized during optimization.

Metric	Variable	Mean	Std Dev	P-value	Significant
Gradient Measure	NTO	1.85	0.85	0.0022	Yes
	Manual Rings	1.39	0.75		
	Hybrid	1.39	0.76		
Brain-GTV Dmean	NTO	1327.12	1245.69	0.6408	No
	Manual Rings	1313.9	1329.9		
	Hybrid	1309.71	1331.1		
Monitor Units	NTO	2069.31	467.41	0.0016	Yes
	Manual Rings	2293.65	380.36		
	Hybrid	2327.92	402.12		
PTV Dmax	NTO	3644.3	633.5	0.0532	No
	Manual Rings	3940.2	523.2		
	Hybrid	3818.8	690.4		

Fig 2. Comparison of dosimetric outcomes (mean ± standard deviation) among NTO, manual optimization ring, and hybrid planning techniques for multi-metastases brain SRS, with statistically significant differences observed in gradient measure and monitor units.

Measure	P-value	Adjusted P-Value		
		NTO vs Manual Rings	NTO vs Hybrid	Manual Rings vs Hybrid
Gradient Measure	0.0022	0.0053	0.0066	1
Monitor Units	0.0016	0.0078	0.0029	1

Fig 3. Post-hoc analysis demonstrating significant differences between NTO and both manual ring and hybrid techniques for gradient measure and monitor units, shown with a P value less than 0.05. There was no significant difference between manual rings and hybrid, with a P value of 1.

Conclusion

The use of Eclipse's Normal Tissue Objective (NTO) demonstrated comparable performance to both the manual optimization rings and hybrid techniques in the treatment of multiple brain metastases SRS. While most dosimetric endpoints showed minimal differences, the manual optimization rings and hybrid planning approaches resulted in significantly improved gradient measure, indicating a sharper fall off. The NTO, however, showed a significantly lower monitor unit value than the manual rings and hybrid approaches.

Despite this, the overall impact on plan quality remained modest. These findings suggest that NTO may serve as an efficient alternative to manual optimization rings, potentially reducing planning time while maintaining clinically acceptable dose distributions. Further investigation with a larger sample size is warranted to better characterize these subtle differences between the optimization strategies.

Limitations

Limitations of this study include a relatively small sample size and small effect sizes observed in some dosimetric metrics, which may limit statistical power and the ability to detect clinically meaningful differences. Additional data are needed to validate these findings.

References

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