Evaluation of scriptable SURFACE AREA INFORMED OPTIMIZATION (SAIO) to enhance a vendor automated multi-metastases planning solution

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INTRODUCTION

A Stereotactic Radio Surgery Normal Tissue Objective (SRS NTO) is provided within the HyperArc (HA) planning framework to minimize Intermediate Dose Spill outside the PTV to spare normal brain tissue. Previous work has demonstrated that using surface area information in the design of a plan optimization strategy can generate high-quality multi-met SRS plans without leveraging an SRS NTO or patient-specific Collimator Angle Optimization (CAO).[1]

The plan optimization strategy is the Ask For It (AFI) methodology.[2-4] AFI provides guidance on generating a custom-tailored optimization structure around each PTV dependent on both volume and surface area and further provides custom constraints for the optimization structure to achieve the smallest Intermediate Dose Spill ($R50\%_{Analytic}$).[4] This approach is referred to as Surface Area Informed Optimization (SAIO) and has been explained in detail in previous work.[2]

The purpose of this work is to evaluate the combination of SRS NTO and patient-specific CAO from HyperArc (HA) with Surface Area Informed Optimization (SAIO) objectives and related constraint structures obtained using the Ask For It (AFI) methodology

METHOD

Six example SRS cases were created for this study: three single-target plans (Case A, Case B, and Case C), one 2-target plan (Case D), one 5-target plan (Case E), and one 10-target plan (Case F). All cases were generated using 6xFFF in Eclipse V16.1, and individual PTV volumes ranged from 0.18 cm^3 – 26.53 cm^3. The six cases were each initially planned with HA using SRS NTO and CAO (HA plans).

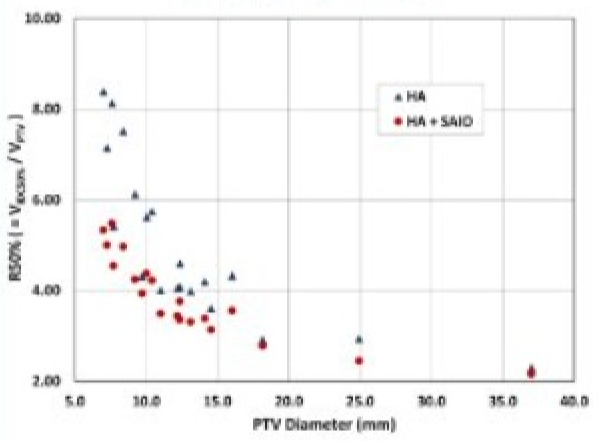
Custom optimization structures were then created for the six example cases using the AFI methodology. The cases were replanned and optimized with HA using the resulting AFI optimization objectives/constraints (HA+SAIO plans). Isocenter locations and collimator settings were duplicated from the HA plans.

The HA and HA+SAIO plans were evaluated for each case with three metrics: R50% to assess intermediate dose spill and CI_{RTOG} and $CI_{Paddick}$ to assess prescription conformality and dose coverage.

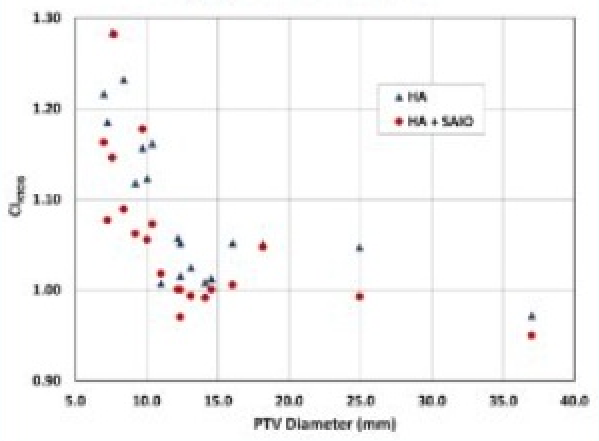
Wilcoxson sign ranked tests were performed to assess statistical relevance of any difference in the metrics.

RESULTS: HA + SAIO demonstrated improvement over HA alone for R50%, CI_{RTOG}, and $CI_{Paddick}$.

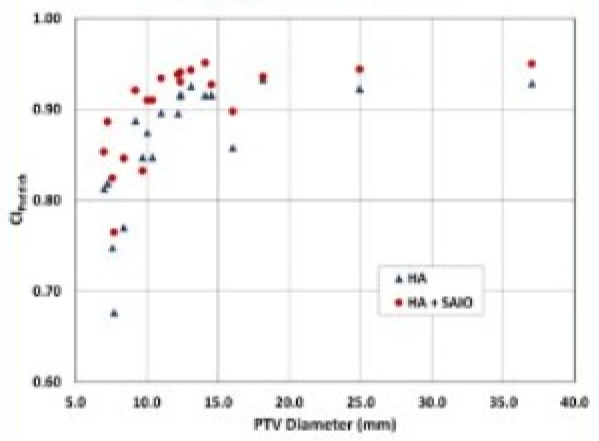
R50% COMPARISON



CI_{RTOG} COMPARISON



$CI_{Paddick}$ COMPARISON



RESULTS TABLE

Case	Target(s)	Method	Mean R50%	Mean CI_{RTOG}	Mean $CI_{Paddick}$
A	1	HA	2.92	1.05	0.93
		HA + SAIO	2.78	1.05	0.94
B	1	HA	4.33	1.16	0.82
		HA + SAIO	3.94	1.18	0.83
C	1	HA	5.42	1.45	0.68
		HA + SAIO	4.54	1.28	0.76
D	2	HA	2.62	1.01	0.93
		HA + SAIO	2.30	0.97	0.95
E	5	HA	3.94	1.02	0.91
		HA + SAIO	3.34	1.00	0.93
F	10	HA	6.18	1.14	0.84
		HA + SAIO	4.43	1.07	0.89
All	All	HA	4.79	1.11	0.87
		HA + SAIO	3.84	1.05	0.90
		p-value	0.00001	0.000004	0.00001

Wilcoxon results show SAIO improves each index with a p-value < 0.000014.

CONCLUSIONS

- The HA + SAIO method showed a statistically significant improvement to HA alone for all three plan quality metrics.
- The addition of SAIO objectives to HA improved multi-met SRS plans in all circumstances.
- The addition of optimization objectives and related structures required for SAIO can be fully automated utilizing the free ESAPI tool and source code on GitHub. https://github.com/eljj/SurfaceAreaInformedOptimization

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