Determination of Confidence Limits for Linac-Based SRS Point, Composite and Per-Field Measurements From a Clinically Comprehensive SRS Test Suite

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JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING EASTERN TIME [GMT-4] Improving Health QUALITY. Increasing Global IMPACT

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PURPOSE

To showcase the potential multi-institutional use of a standardized set of SRS test cases by establishing single-institution confidence limits (CLs) for point, composite and per-field measurements for evaluating linac-based SRS commissioning delivery accuracy.

METHOD

Five test cases with increasing complexity were created to validate delivery accuracy in SRS commissioning similar to the TG-119 test suite for IMRT commissioning. Standardized structure sets, planning goals, and delivery requirements were specified for each case including a small sphere target, irregular target, irregular target placed off-axis, multi-target, and abutting targets. All cases were calculated on an anthropomorphic head phantom.

All plans consisted of a single-isocenter placed at the target center or geometric center of multiple targets. Planning goals for all cases included constraints for the target and brain minus PTV, along with brainstem and optic nerve for the most challenging case. A variety of intracranial situations with increasing complexity are explored to extensively test the planning and delivery system's capabilities.

The delivered plans were chosen based on the clinical relevancy of their delivery and the added information they provide as the cases increase in complexity. All cases were calculated and measured using SunNuclear's StereoPHAN with Standard Imaging's A16 microchamber for point measurements, Gafchromic EBT-XD film for composite measurements, and SRS MapCHECK's diode array for composite and per-field measurements. Composite and per-field measurements were evaluated with 3%/1mm gamma criterion and 10% dose threshold. Confidence limits were established to provide information to fine-tune and understand the limitations of our SRS planning and delivery system. All plans were calculated with AAA algorithm, but could be tested with other algorithms such as Acuros XB or others with potentially higher accuracy.

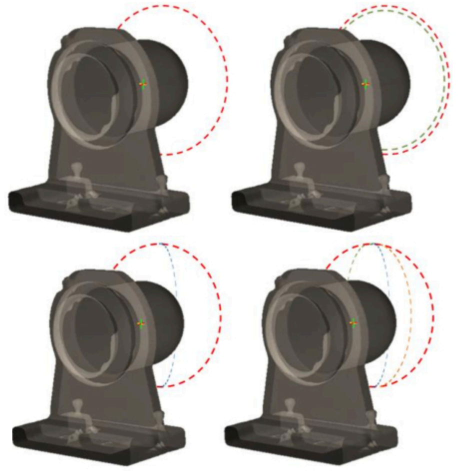

Figure 1. Various VMAT field arrangements including (A) a single arc, (B) two non-coplanar arcs, (C) full arc and vertex half arc, and (D) four non-coplanar arcs were tested to generate clinically appropriate treatment plans.

RESULTS

Table 1. Ion chamber results summarized.

Case	Field Orientation	Target	Avg. Meas. / TPS (%)	Per-Field Range (%)
Small Sphere Target	A	Sphere	99.2	98.9-99.5
	B	Sphere	98.8	98.4-99.3
	C	Sphere	99.8	99.0-101.8
	D	Sphere	98.9	98.1-101.0
Irregular Target	B	Cavity	103.9	102.5-105.4
Irregular Target Off-Axis	B	Cavity	101.8	100.0-103.5
	D	Cavity	103.4	101.1-109.0
Multi-Target	D	Cavity	98.5	95.3-106.2
		Met 1	97.0	89.9-101.5
		Met 2	100.0	94.6-103.5
		Met 3	98.2	94.8-99.8
		Met 4	102.7	99.8-106.3
Clinical	C	AN/BS	106.4	104.4-110.0
		Target/ON	105.4	103.7-106.7
Average			101.0%	
Standard Deviation			2.9%	
95% Confidence Limit			6.7%	
95% Confidence Limit (SE)			2.6%	

Table 2. Planar dose (film and diode array) results summarized.

Case	Field Orientation	Target	Film Gamma Pass Rate		MapCHECK Gamma Pass Rate	
			2%/1mm	3%/1mm	2% / 1mm	3% / 1mm
Small Sphere Target	A	Sphere	100.0%	100.0%	100.00%	100.00%
	B	Sphere	100.0%	100.0%	100.00%	100.00%
	C	Sphere	100.0%	100.0%	100% (99.3-100%)	100.00%
	D	Sphere	100.0%	100.0%	100% (99.3-100%)	100.00%
Irregular Target	B	Cavity	99.8%	100.0%	98.3% (97.7-99.1%)	99.4% (98.8-99.4%)
Irregular Target Off-Axis	B	Cavity	100.0%	100.0%	100.0% (97.6-99.7%)	100.0% (99.2-100.0%)
	D	Cavity	99.9%	100.0%	96.8% (94.0-97.4%)	97.7% (96.5-98.7%)
Multi-Target	D	Cavity	97.5%	99.4%	85.4% (59.9-99.4%)	98.8% (74.8-100.0%)
		Met 1	100.0%	100.0%	97.8% (69.8-99.5%)	100.0% (87.5-100.0%)
		Met 2	98.9%	100.0%	99.4% (86.3-100.0%)	100.0% (95.4-100.0%)
		Met 3	93.4%	98.4%	97.1% (76.9-99.7%)	100.0% (97.9-100.0%)
		Met 4	97.9%	99.7%	86.2% (4.9-98.6%)	99.7% (5.1-100%)
Clinical	C	AN/BS	96.1%	97.1%	99.2% (96.4-99.5%)	99.5% (99.4-99.5%)
		Target/ON	75.0%	86.9%	99.5% (95.3-98.9%)	99.7% (98.1-99.5%)
Average			97.0%	98.7%	97.1%	99.6%
Standard Deviation			1.8%	0.9%	1.3%	0.2%
95% Confidence Limit			16.0%	8.1%	12.5%	1.7%
95% Confidence Limit (SE)			6.4%	3.1%	5.5%	0.7%

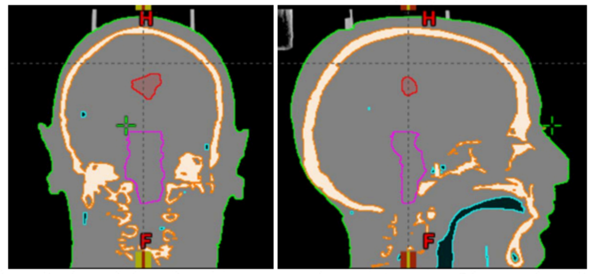

Figure 2. Irregular target structure: Coronal and sagittal views of the centrally located cavity.

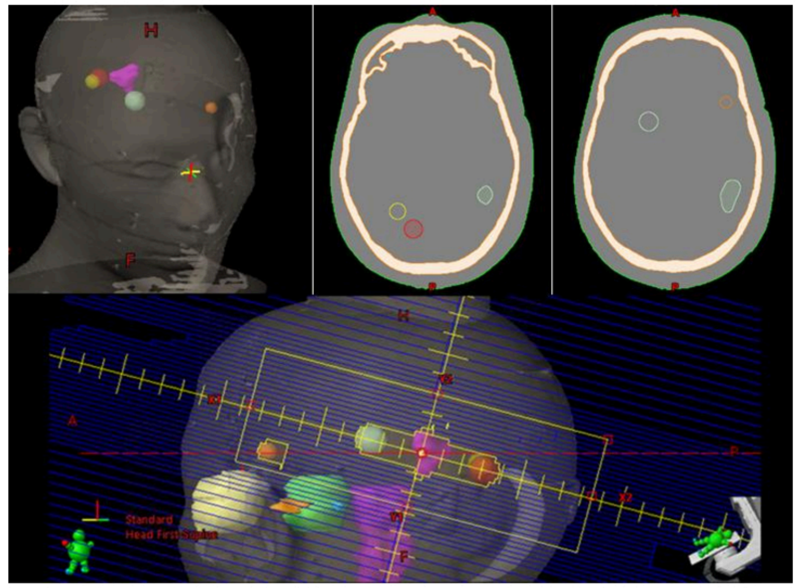

Figure 3. Multi-target structures: 3D representation and coronal views of the centrally located cavity in addition to the four spherical metastases. The beams eye view representation is shown to depict the collimator angle chosen to maintain use of the HD-MLCs throughout the duration of the arc.

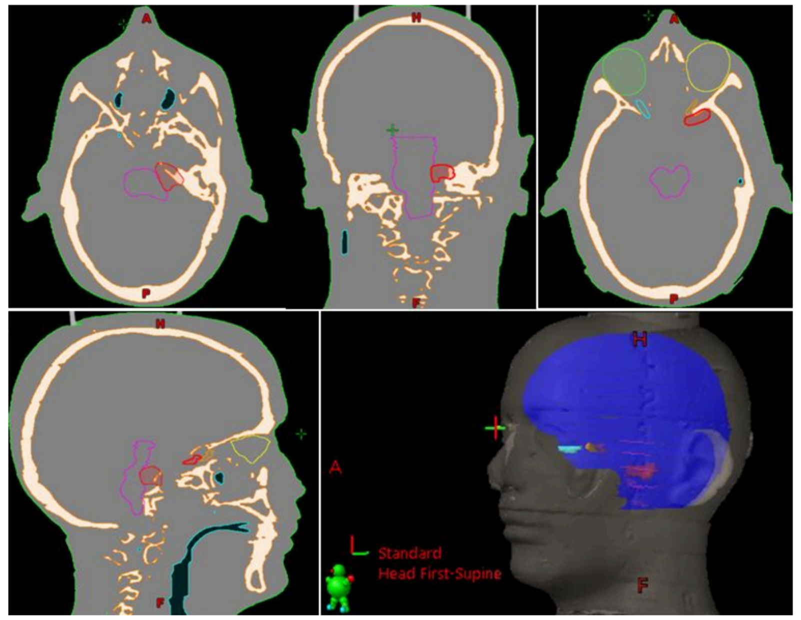

Figure 4. Axial, coronal, and sagittal views, in addition to the 3D representation of the lesions abutting brainstem and optic nerve.

CONCLUSIONS

We have performed comprehensive dosimetric measurements on a standardized set of SRS optimization problems to establish CLs to fine-tune and understand the limitations of our SRS planning and delivery system.

Figures 2-4 represent the structure sets that were established to perform the SRS commissioning procedures on. The results in Table 1 summarize the ion chamber readings acquired for the different field orientations for each case. Table 2 summarizes the planar dose distribution results that were obtained.

Overall, the average measured A16 reading to TPS value ratio was 101.0% ± 2.6%. The planar dose measurements had excellent composite passing rates for a gamma criterion of 3%/1mm. The only clinical case with a pass rate below 97% was the target abutting the optic nerve.

We have performed comprehensive dosimetric measurements on a standardized set of SRS optimization problems to establish CLs to fine-tune and understand the limitations of our SRS planning and delivery system. This standardized approach to linac-based SRS commissioning provides a mechanism for the medical physics community to evaluate the implementation and delivery accuracy of SRS systems, similar to TG-119 for IMRT.

This study established a standardized approach to SRS commissioning through the creation of a set of representative clinical treatment cases that pose a range of optimization problems for evaluating the plan quality and dosimetric accuracy within the commissioning process for linac-based SRS. The standardized structure sets, planning goals, and delivery requirements were specified for each of the cases including a small sphere target, irregular target, irregular target placed off-axis, multi-target, and abutting targets. The rapid widespread implementation of this SRS technique, complexity associated with dosimetry and delivery, and high profile treatment deviations that have already resulted from its use, highlight the importance of such a benchmark test suite. The cases presented here provide a novel benchmark for institutions to evaluate their linac-based SRS program prior to clinical implementation, similar to that provided by AAPM TG-119 for IMRT commissioning.

ACKNOWLEDGEMENTS

We would like to thank SunNuclear for their support with this project including the use of StereoPHAN and SRS MapCHECK.

SUN NUCLEAR corporation

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