

SRS Commissioning and QA Test Cases – TG-119 Equivalent for SRS

GEOFF BARAN, MS

REBECCA CULCASI MS, JAY BURMEISTER PhD, MICHAEL DOMINELLO DO



Wayne State University
Karmanos Cancer Center
Detroit, Michigan



Disclosures

- Sun Nuclear
 - Travel support
 - Loaned StereoPHAN, SRS MapCHECK & SNC Patient Software for measurements and analysis

Outline

1

Overview of linac-based SRS commissioning

2

Proposed TG-119 update for SRS

3

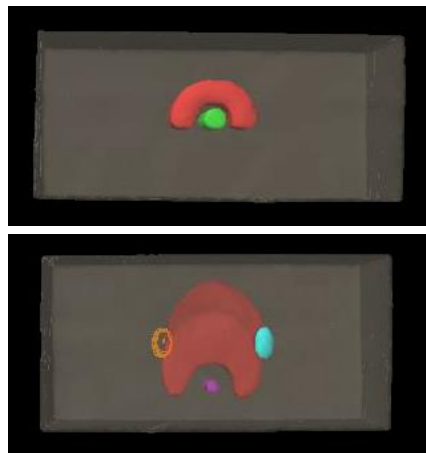
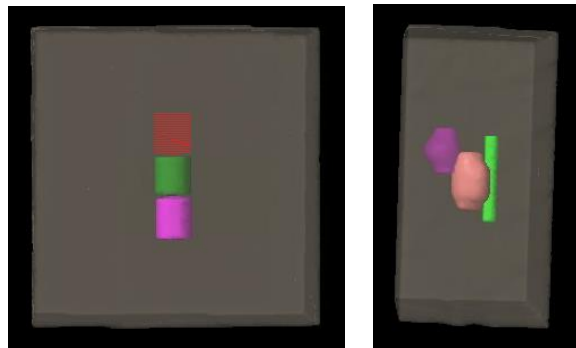
Our initial experience with QA test cases

4

Future work

Summary of TG-119

- Original need for TG-119: IMRT Commissioning
 - **2003 “Guidance Document” on IMRT** [Ezzell et al, Med Phys. 30, 2089-2115 (2003)] – “This complex but promising treatment modality is rapidly proliferating in both academic and community practice settings”
 - **2008:** 250 HN RPC irradiations, 28% failed to meet passing criteria of 7% / 4 mm [Ibbott et al, IJROBP. 71, S71-S75 (2008)]
- **Goal:** Provide degree of agreement that should be expected using confidence limits



IMRT commissioning: Multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119

Gary A. Ezzell

Department of Radiation Oncology, Mayo Clinic Scottsdale, 5777 East Mayo Boulevard, MCSB Concourse, Phoenix, Arizona 89054

Jay W. Burmeister

Wayne State University School of Medicine, Karmanos Cancer Center, 4100 John R Street, Detroit, Michigan 48201

Nesrin Dogan

Department of Radiation Oncology, Virginia Commonwealth University, 401 College Street B-129, Richmond, Virginia 23298

Thomas J. LoSasso and James G. Mechalakos

Department of Medical Physics, Memorial Sloan-Kettering Cancer Center, 1275 York Avenue, New York, New York 10065

Dimitris Mihailidis

Department of Radiation Oncology and Medical Physics, Charleston Radiation Therapy Cons, 3100 MacCorkle Avenue Southeast, Charleston, West Virginia 25304

Andrea Molineu

RPC, UT MD Anderson Cancer Center, 1515 Holcombe Boulevard, Houston, Texas 77030

Jatinder R. Palta

Department of Radiation Oncology, University of Florida Health Science Center, 2000 Archer Road, Gainesville, Florida 32610-0385

Chester R. Ramsey

Thompson Cancer Survival Center, 1915 White Avenue, Knoxville, Tennessee 37916

Bill J. Salter

Department of Radiation Oncology, University of Utah, 1950 Circle of Hope Drive, Salt Lake City, Utah 84112

Jie Shi

Sun Nuclear Corp., 425-A Pineda Court, Melbourne, Florida 32940

Ping Xia

Department of Radiation Oncology, University of California, San Francisco, California 94143-1708

Ning J. Yue

Department of Radiation Oncology, The Cancer Institute of New Jersey, 195 Little Albany Street, New Brunswick, New Jersey 08901

Ying Xiao^{a)}

Department of Radiation Oncology, Thomas Jefferson University Hospital, 111 South 11th Street, Philadelphia, Pennsylvania 19107

(Received 15 May 2009; revised 4 September 2009; accepted for publication 5 September 2009; published 27 October 2009)

Is there a similar need for linac-based SRS?

1. Rapid increase in the use of SRS in the United States
2. IROC SRS Anthropomorphic Phantom Results
3. Increase in the use of non-historical SRS treatment techniques
4. Uncertainties for small field SRS treatments as compared to fractionated larger field treatments
 - Measurement Uncertainty: e.g. small field size OF (detector used / correction factors, detector positioning, jaw / MLC uncertainty)
 - Planning / Dose Calculation Uncertainty: e.g. contouring (segmentation resolution, use of multi-modality imaging); calc. grid size
 - Dose Delivery Uncertainty: e.g. tolerance for couch, gantry, and collimator angle; jaw tracking
5. Single fractions (or ≤ 5)

Linac-Based Radiosurgery

INCREASING

- 1980s –Alternative to Gamma Knife with only a **few** academic facilities in the USA treating cases
- 1995 – Stereotactic Radiosurgery (AAPM Report No. 54)
- 1995 – Radiosurgery Patterns of Practice (Larson et al. Surgical Neurology, 44(5), 414-420)
 - **37** facilities in United States (28 linac-based / 9 Gamma Knife) responded to survey
- 2003 – Linac Based Radiosurgery and Stereotactic Radiotherapy (Thomas Mackie)
 - **160** dedicated radiosurgery units
- 2016 – Changing practice patterns of GK versus linear accelerator-based radiosurgery for brain metastases in the US (Park et al. Journal of Neurosurgery, 124(4), 1018-1024)
 - Proportion of patients undergoing linac SRS increased from **3.2% in 2003 to 30.8% in 2011**
- 2019 – Distribution of dedicated stereotactic radiosurgery systems in the United States (Dean et al. Applied Radiation Oncology, March 2019)
 - **428** SRS systems in the United States (14 centers had 2 types of SRS systems)

IROC SRS Anthropomorphic Phantom Results

- Analysis of results from an anthropomorphic stereotactic radiosurgery phantom [AAPM Annual Meeting: Amador et al., 2011]
 - 634 irradiations (509 with linear accelerators) by 321 institutions
 - 54% of accelerator institutions met all guidelines (84% if minimum dose to target is removed)
- IROC Houston and MDAPL SRS anthropomorphic phantom results from 2013-2016 [AAPM Annual Meeting: Molineu et al., Med Phys. 43, 3665 (2016).]
 - Results of institutions participating in NCI sponsored SRS clinical trials
 - 5% agreement for TLD results and 85% passing rate for 5%/3mm gamma analysis
 - 211 linac irradiations results in passing rate of 79% (compared to 96% for Gamma Knife)
- In addition...
 - 3 mm sufficient?
 - Patient vs. phantom?
 - Single case type sufficient for validation?

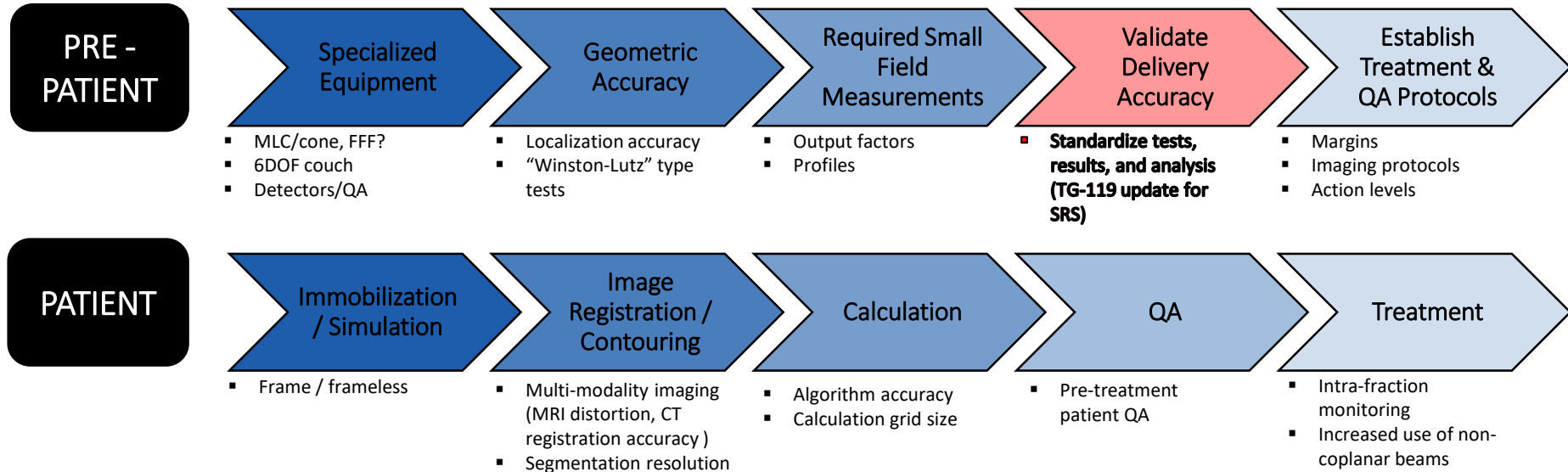
We have already encountered SRS related events

- Quality and safety considerations in stereotactic radiosurgery and stereotactic body radiation therapy: executive summary [Solberg et al, Practical Radiation Oncology, 2(1) (2012), 2-9]
 - Summarized SRS related treatment events
 - **2004-2005:** 77 patients in Florida (calibration error on radiosurgery linac)
 - **2006-2007:** 145 patients in France (measurement of output factors)
 - Discrepancies of up to 15% in output ratios
 - **2004-2009:** 76 patients in Missouri (measurement of output factors)
 - Patients given an average dose exceeding the prescribed dose by 50%

What to make of all of this?

Words to describe SRS commissioning...

- Challenging, time-consuming, uncertain, non-standardized, tedious, overwhelming



SRS Commissioning - Geometric Accuracy

- If using on-board imaging for final target position – evaluate agreement between imaging and radiation isocenters with “Winston-Lutz” type measurements prior to dosimetric measurements
- Maximize agreement between mechanical and imaging isocenter to minimize potential patient couch shifts
- Repeat measurements to develop site-dependent action tolerances [$< 0.5\text{mm}$ (ave) and $< 1\text{mm}$ (max)]
- Track daily/weekly QA results to evaluate any systematic drift

1

13 Collimator Angles at Couch 0° and Gantry 0°

2

13 Gantry Angles at Couch 0° and Collimator 0°

3

23 Couch Angles at Collimator 0° and Gantry 0°

4

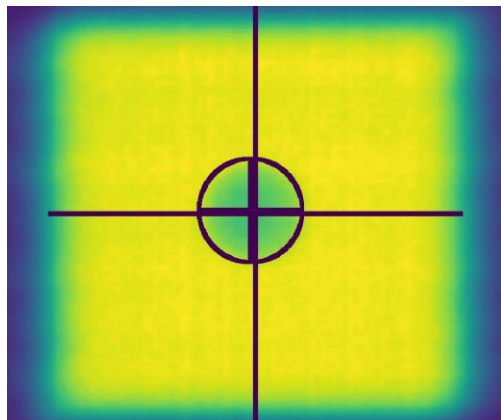
Combination of gantry, couch, and collimator based on realistic fields (used as QA check daily prior to treatment) for 8 positions total

5

Single isocenter, multi-target evaluation

SRS Commissioning - Geometric Accuracy

WHAT WE USED: Sun Nuclear StereoPHAN with Winston Lutz Inserts



Full Planar Offset Summary								
Gantry	Couch	Collimator	S0	S1	S2	S3	S4	S5
0	0	0	0.4977	0.5343	0.5214	0.3251	0.5764	0.6221
0	0	90	0.2367	0.5034	0.4697	0.4449	0.4274	0.5937
0	0	270	0.3096	0.888	0.5183	0.523	0.3631	0.4084
0	90	0	0.2092	0.6382	0.3379	0.5887	0.6131	0.675
0	270	0	0.2231	0.5348	0.2543	0.1465	0.5548	0.3974
90	0	90	0.3216	0.1984	0.4186	0.1971	0.3767	0.3652
180	0	90	0.3794	0.3745	0.1056	0.3353	0.3853	0.09827
270	0	90	0.1845	0.1717	0.1722	0.4618	0.2415	0.3756
Score			PASS	PASS	PASS	PASS	PASS	PASS

SRS Commissioning – Small Field Measurements

- Prior to performing commissioning measurements on test cases need to prepare TPS dose calculation algorithm to handle small fields
- Suggested document to follow: IAEA-AAPM Technical Reports Series No.483
- Major requirement is the accurate measurement of small field output factors which is extremely challenging in itself
 - For small fields, OFs change rapidly with field size such that measurement uncertainties become increasingly significant
 - Field size is defined as the FWHM of a lateral beam profile measured at a depth sufficient to eliminate electron contamination as opposed to collimator setting
 - Need to be aware of detector conditions (size, perturbation of charged particle fluence due to detector), change in energy spectrum for small fields as compared to reference field → output factor no longer the ratio of detector readings

$$\Omega_{Q_{\text{clin}}, Q_{\text{ref}}}^{f_{\text{clin}}, f_{\text{ref}}} = \frac{D_{W, Q_{\text{clin}}}^{f_{\text{clin}}}}{D_{W, Q_{\text{ref}}}^{f_{\text{ref}}}} \quad \Omega_{Q_{\text{clin}}, Q_{\text{ref}}}^{f_{\text{clin}}, f_{\text{ref}}} = \frac{M_{Q_{\text{clin}}}^{f_{\text{clin}}}}{M_{Q_{\text{ref}}}^{f_{\text{ref}}}} k_{Q_{\text{clin}}, Q_{\text{ref}}}^{f_{\text{clin}}, f_{\text{ref}}} \quad k_{Q_{\text{clin}}, Q_{\text{ref}}}^{f_{\text{clin}}, f_{\text{ref}}} = \frac{D_{W, Q_{\text{clin}}}^{f_{\text{clin}}} / \bar{D}_{\text{det}, Q_{\text{clin}}}^{f_{\text{clin}}}}{D_{W, Q_{\text{ref}}}^{f_{\text{ref}}} / \bar{D}_{\text{det}, Q_{\text{ref}}}^{f_{\text{ref}}}} \quad \Omega_{Q_{\text{clin}}, Q_{\text{ref}}}^{f_{\text{clin}}, f_{\text{ref}}} = \left[\Omega_{Q_{\text{clin}}, Q_{\text{int}}}^{f_{\text{clin}}, f_{\text{int}}} \right]_{\text{det}} \left[\Omega_{Q_{\text{int}}, Q_{\text{ref}}}^{f_{\text{int}}, f_{\text{ref}}} \right]_{\text{IC}}$$

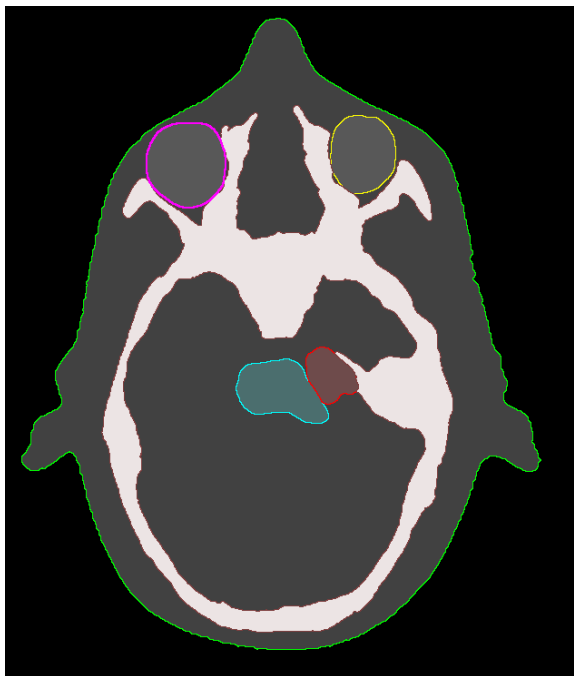
SRS Commissioning – Dosimetric & Delivery Validation

Proposed TG-119 update for dosimetric SRS commissioning using a linear accelerator

1. Required equipment for point, film, and per-field measurements
2. Calibration for point measurements
3. Introduction to standardized case structure sets, planning goals, and delivery requirements
4. Example results

Phantoms

Anthropomorphic head provided for all plan calculations and evaluations for each structure set test group



Phantom with “skull-like” geometry (cylindrical, spherical) required for check of dosimetric accuracy

- Allow for ion chamber point and film/array planar measurements



Chamber Measurements

STANDARD IMAGING EXRADIN MODEL A16 CHAMBER

- Volume = 0.007 cc (keep size of chamber small over gradient regions)
- Cylindrical symmetry (directional independence)
- Issues: sensitivity of chamber, leakage, potential ion recombination / polarity effects, known to under-respond when jaw size is less than 2 cm

UNCERTAINTY ON CT

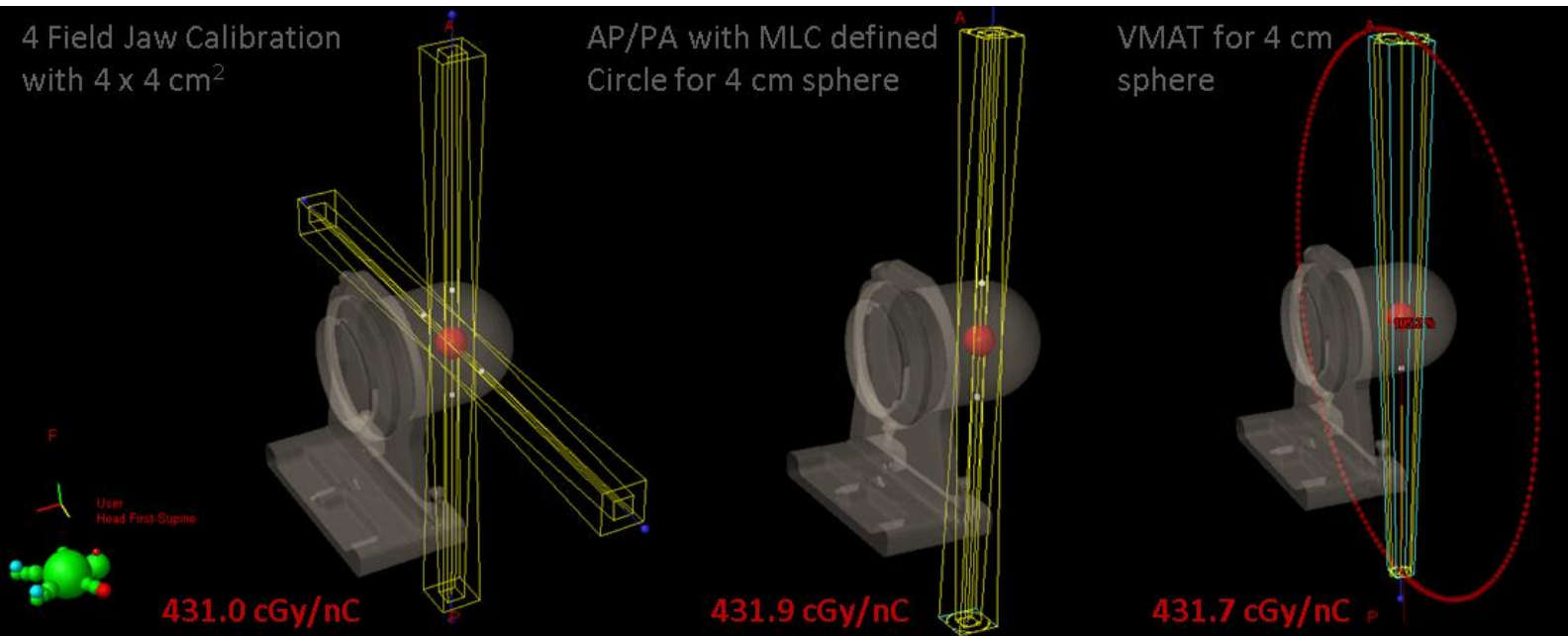
- Contour very small segment on CT, use mean doses, minimize variation between minimum and maximum dose within the contoured volume to less than 5%; also used point dose based on distance to effective POM

	Equivalent Square Field Size (cm)												
Ion Chamber	8.0	6.0	4.0	3.0	2.5	2.0	1.5	1.2	1.0	0.8	0.6	0.5	0.4
Exradin A16 micro	1.000	1.000	1.000	1.000	1.001	1.003	1.008	1.017	1.027	1.043	-	-	-

*Adapted from Table 26 of IAEA Technical Reports Series No. 483: Dosimetry of Small Static Fields Used in External Beam Radiotherapy. Field output correction factors for fields collimated by an MLC or SRS CONE at 6MV WFF and FFF machines as a function of the equivalent square field size.

Calibration

- Performed three different calibrations of increasing complexity towards an actual SRS VMAT plan
- Prior to each day's measurement performed AP/PA calibration
 - Monitored temperature and pressure over course of long deliveries



No significant difference

Planar Measurements

DIODE ARRAY MEASUREMENTS: Sun Nuclear's StereoPHAN with SRS MapCHECK

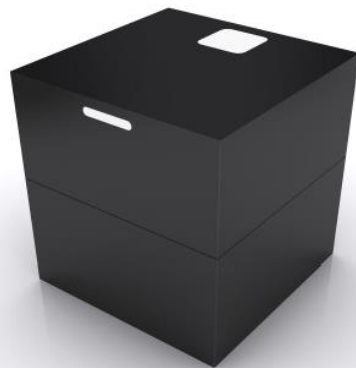
- Per-arc and composite basis
- 1013 detectors with $0.48 \times 0.48 \text{ mm}^2$ active area,
- 2.47 mm spacing across entire array for total field size of $77 \times 77 \text{ mm}^2$
- Sensitivity: 15 nC / Gy (compared to A16 which was $\sim 0.25 \text{ nC / Gy}$)
- Dose-rate dependence: $\pm 1.5\%$ over range of 100 MU/min to 2400 MU / min

FILM MEASUREMENTS: Gafchromic EBT-XD

- Composite basis
- Max dose was ensured to be less than 40 Gy for a given film plane (optimum dose range as specified by the manufacturer)

Dose calculation planes were the same for film and array

Per field and composite planar distributions evaluated at 1% / 1 mm, 2% / 1 mm, and 3% / 1 mm (Global)



Standardized Cases – 1. Small Sphere

SETUP: Single-isocenter placed at center of 1.0 cm diameter sphere

PRESCRIPTION: 24 Gy

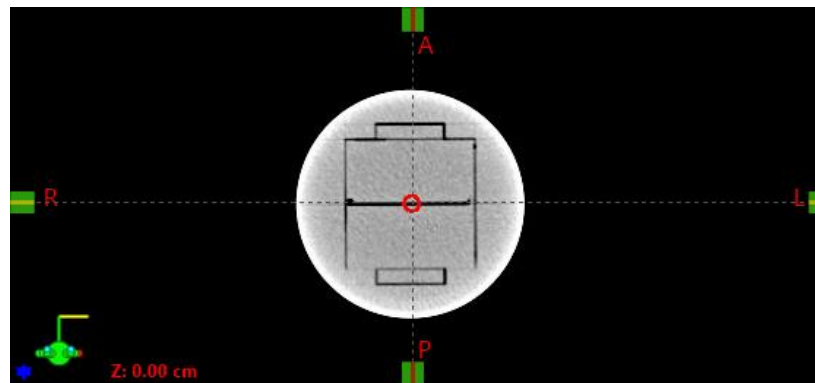
FIELD ARRANGEMENTS:

- A. Single VMAT arc at 0° couch angle
- B. Two VMAT arcs at 0°, 90/270° couch angles
- C. 4 VMAT arcs at 0°, 45°, 315°, & 90/270° degree couch angles

MEASUREMENTS:

- A. 1 IC, 1 Film, 1 SRS MapCHECK = 3
- B. 2 IC, 1 Film, 3 SRS MapCHECK = 6
- C. 4 IC, 1 Film, 5 SRS MapCHECK = 10

Planning Parameter	Plan Goal (Gy)
PTV	$V_{100\%} > 99\%$
Brain – PTV	$V_{12} < 5 \text{ cc}$
	$V_{10} < 10 \text{ cc}$



Standardized Cases – 2. Irregular Target

SETUP: Single-isocenter placed at center of irregular clinical target of dimensions 2.3 cm x 2.2 cm x 1.4 cm

PRESCRIPTION: 18 Gy

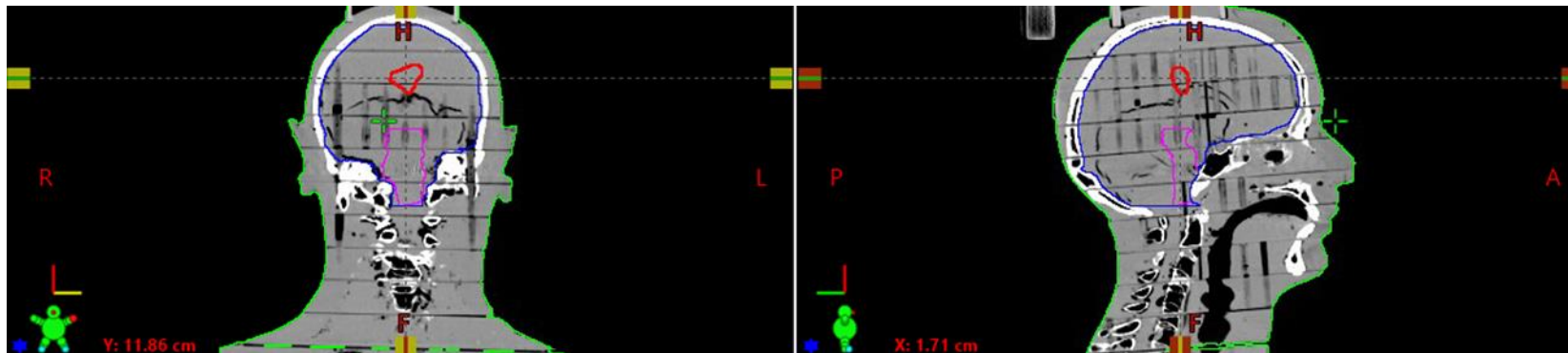
FIELD ARRANGEMENTS:

2 coplanar VMAT arcs at 0°

MEASUREMENTS:

2 IC, 1 Film, 3 SRS MapCHECK = 6

Planning Parameter	Plan Goal (Gy)
PTV	$V_{100\%} > 99\%$
Brain – PTV	$V_{12} < 5 \text{ cc}$
	$V_{10} < 10 \text{ cc}$



Standardized Cases – 3. Irregular Target OA

SETUP: Case 2, but isocenter placed 4.5 cm from target center

PRESCRIPTION: 18 Gy

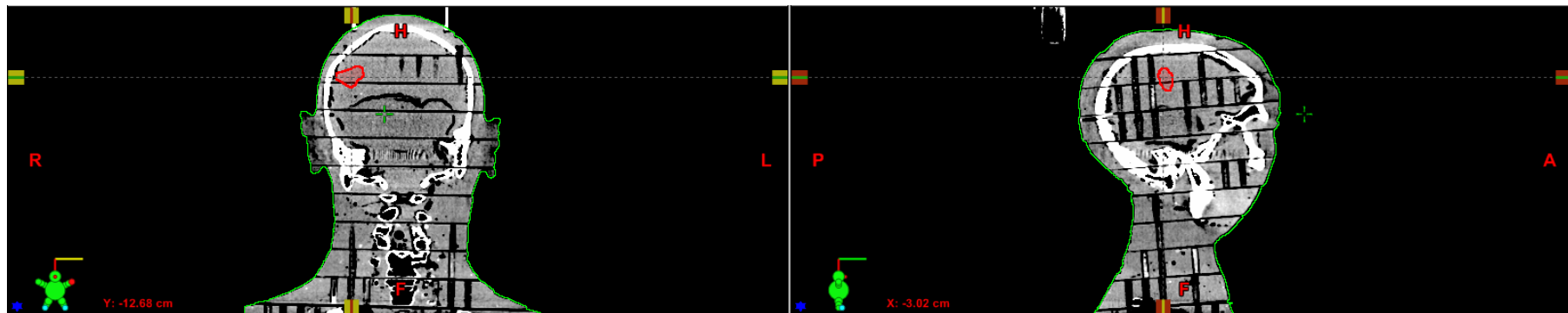
FIELD ARRANGEMENTS:

- A. Two coplanar VMAT arcs at 0°
- B. 4 VMAT arcs at 0°, 45°, 315°, & 90/270° degree couch angles

MEASUREMENTS:

- A. 2 IC, 1 Film, 3 SRS MapCHECK = 6
- B. 4 IC, 1 Film, 5 SRS MapCHECK = 10

Planning Parameter	Plan Goal (Gy)
PTV	$V_{100\%} > 99\%$
Brain – PTV	$V_{12} < 5 \text{ cc}$
	$V_{10} < 10 \text{ cc}$



Standardized Cases – 4. Multi-Target

SETUP: Single-isocenter placed at center of mass of multiple targets (1 irregularly shaped target and 4 mets)

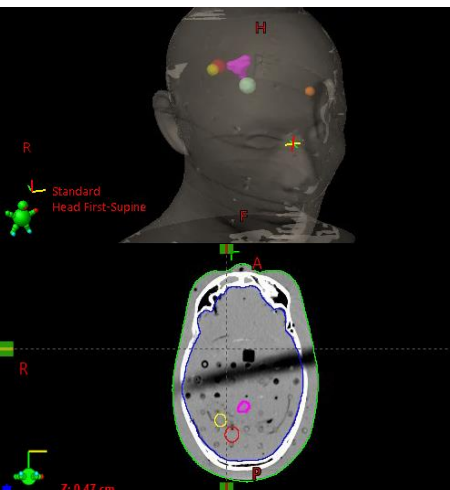
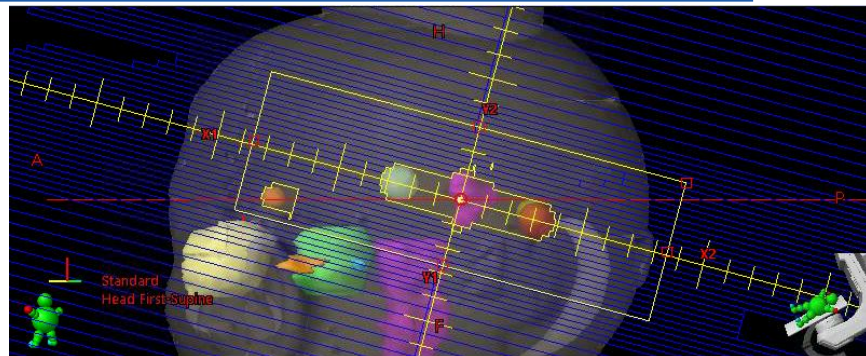
PRESCRIPTION: Doses indicated in table below; normalized such that minimum dose to a single target is at least 99% of rxn dose

FIELD ARRANGEMENTS:

4 VMAT arcs at 0°, 45°, 315°, 90/270° couch angles

MEASUREMENTS:

[4 Ion Chamber, 1 Film, 5 SRS MapCHECK per target] x 5 targets = 50



	Cavity	Met 1	Met 2	Met 3	Met 4
Volume (cc)	2.81	0.43	1.67	0.81	2.01
Dimensions	2.3 x 2.2 x 1.4cm ³	0.9 cm sphere diameter	1.5 cm sphere diameter	1.2 cm sphere diameter	1.6 cm sphere diameter
Off-Axis (cm)	1.3	7.5	3.7	2.9	4.5
Prescription	18 Gy	24 Gy	24 Gy	24 Gy	24 Gy

Standardized Cases – 5. Abutting Targets

SETUP: Single-isocenter placed at center of mass of 3.74 cc lesion adjacent to brainstem (2.4 cm x 1.5 cm x 2.0 cm) and 1.11 cc lesion adjacent to optic nerve (1.9 cm x 0.9 cm x 1.3 cm)

PRESCRIPTION: 13 Gy to lesion adjacent to brainstem, and 12 Gy to lesion adjacent to optic nerve

FIELD ARRANGEMENTS:

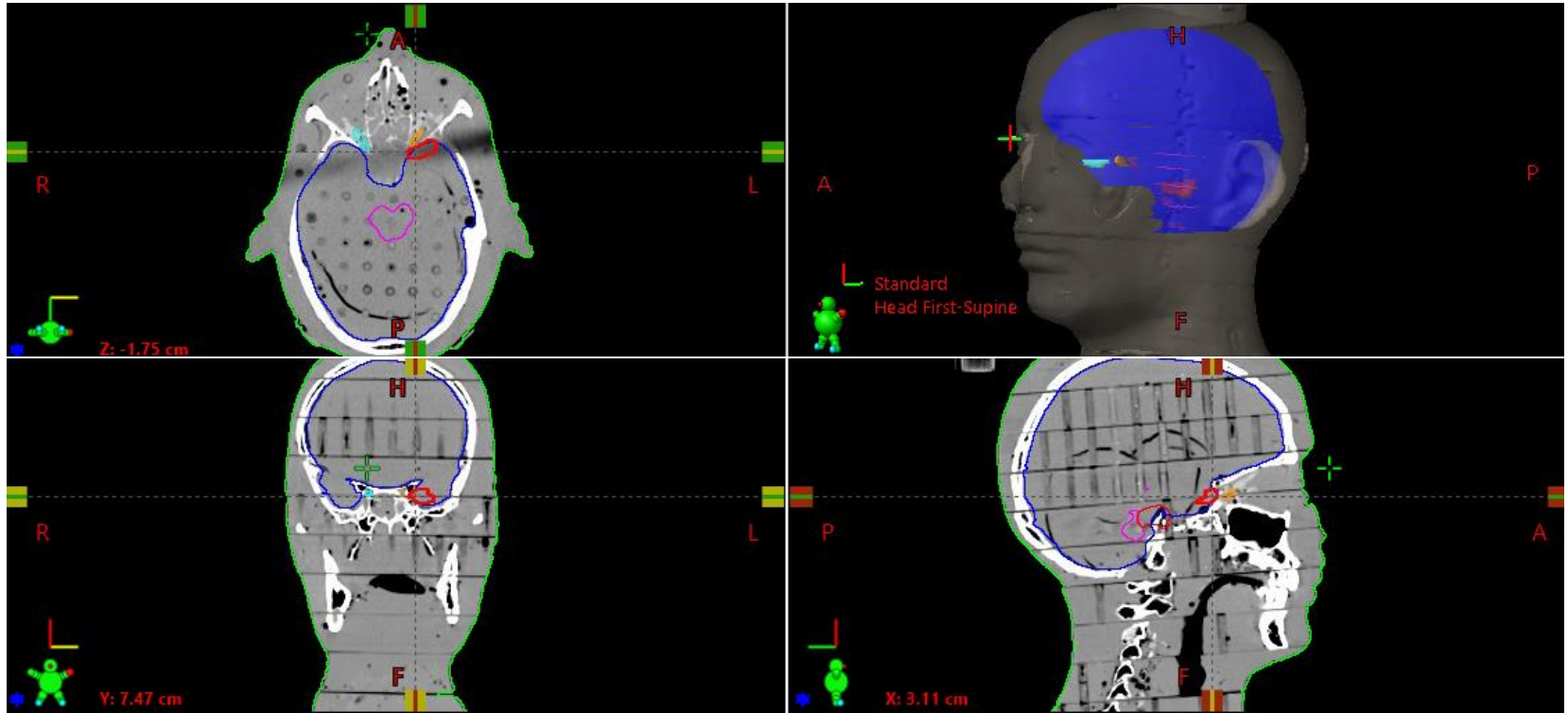
Two VMAT arcs at 0, 90/270° couch angles

MEASUREMENTS:

[2 IC, 1 Film, 3 SRS MapCHECK] x [2 targets + 2 OARs] = 24

Planning Parameter	Plan Goal (Gy)
PTV: $V_{100\%} > 95\%$	$V_{100\%} > 95\%$
Brain – PTV	$V_{12\text{Gy}} < 5 \text{ cc}$
	$V_{10\text{Gy}} < 10 \text{ cc}$
Brainstem	$D_{\text{max}} < 15 \text{ Gy}$
	$V_{10\text{Gy}} < 0.5 \text{ cc}$
Optic Nerve	$D_{\text{max}} < 10\text{-}12 \text{ Gy}$
	$V_{8\text{Gy}} < 0.2 \text{ cc}$

Standardized Cases – 5. Abutting Targets



Results – Small Sphere Chamber

Plan Type	Couch Angle	Ratio (Meas/TPS)	MU	(Max – Min) Dose	Mean Dose
1 Field	0	99.9%	6096	2.1%	141.4%
2 Field	0	100.0%	4971	3.6%	109.6%
	90	103.1%	2512	1.4%	31.1%
4 Field	0	99.8%	3051	1.7%	69.6%
	45	99.7%	1523	0.9%	20.5%
	90	102.1%	1586	2.7%	27.2%
	315	99.1%	1566	1.9%	31.8%

Results – Cavity Chamber

Plan Type	Couch	Ratio (Meas/TPS)	MU	(Max – Min) Dose	Mean Dose
Cavity					
2 Field	0	102.1%	5005	7.0%	102.2%
	90	104.3%	2645	2.6%	43.4%
Cavity O/A					
2 Field	0	100.9%	5476	3.5%	112.1%
	90	103.9%	2746	2.2%	36.4%
4 Field	0	103.4%	2994	2.7%	55.9%
	90	102.7%	1617	1.8%	28.6%
	45	107.9%	1615	2.0%	22.9%
	315	102.5%	1543	1.6%	28.1%

Results – Multi-Met Chamber / Abutting

Plan Type	Ratio (Meas/TPS)	Per Field - Ratio (Meas/TPS) Range	(Max – Min) Dose	Mean Dose
Cavity	99.9%	98.4-100.6%	3.5%	102.9%
Met 1	98.7%	94.2-101.5%	4.7%	151.7%
Met 2	100.9%	96.6-104.0%	3.8%	206.6%
Met 3	99.6%	97.3-100.4%	5.0%	171.4%
Met 4	104.0%	100.7-105.4%	3.8%	179.3%

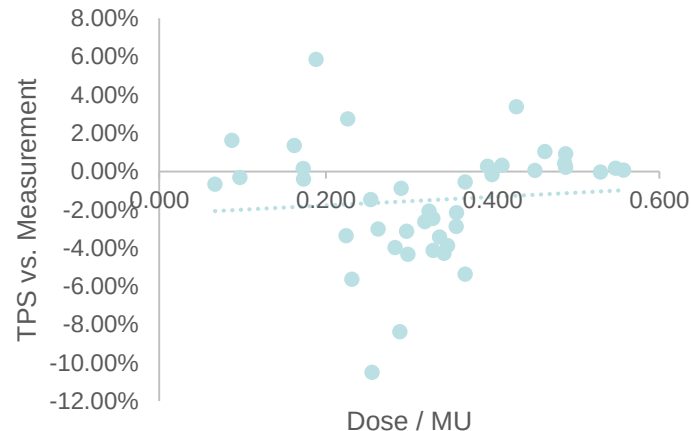
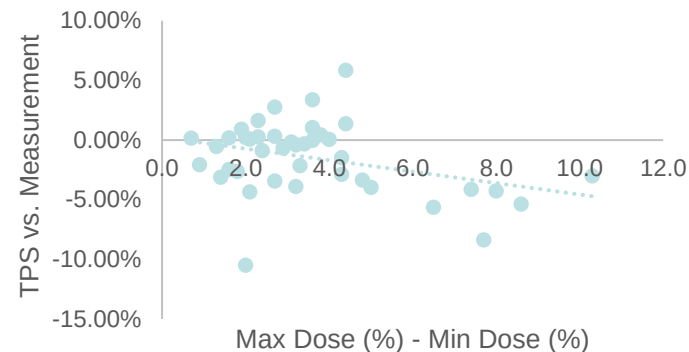
ROI	Ratio (Meas/TPS)	(Max – Min) Dose	Mean Dose
PTV Adjacent to Brainstem	105.0%	9.3%	165.6%
Brainstem	110.9%	4.5%	14.8%
PTV Adjacent to Optic Nerve	105.1%	6.9%	173.1%
Optic Nerve	99.5%	7.1%	42.5%

Ion Chamber Results Summary

- TG-119 equivalent analysis for cumulative ion chamber measurements in high-dose target region
 - Mean Difference = 1.5%
 - Standard Deviation = 3.0%
 - 95% Confidence Limit $\sim$ 7.4%
- Small sphere chamber measurements– Jaw size for plan is $\sim$ 1.6 cm such that should A16 output factor correction factor be applied ($\sim$ 1.007)
- Uncertainty in evaluating chamber position's active volume
 - Too small for CT or CBCT – should slightly larger chamber be used?
 - Dose gradients too significant? – use single point from TPS as opposed to contoured volume?

Ion Chamber Results Summary

- Point measurement vs. Contoured Volume
 - Mean Percentage Difference = 0.15% [-4.33% to 6.11%]
- Measurement as function of gradient
 - No significant findings
- Measurement as function of Dose/MU
 - No significant findings
- Couch position
 - 0 degrees – 1.016
 - 90 degrees – 1.019
 - 45 / 315 degrees = 1.011



Results - Film

Case	Plan	1% / 1mm	2% / 1mm	3% / 1mm
Sphere	Single	99.9%	100.0%	100.0%
Sphere	2 Field	100.0%	100.0%	100.0%
Sphere	4 Field	100.0%	100.0%	100.0%
Cavity	2 Field	98.6%	99.9%	100.0%
Cavity O/A	2 Field	98.7%	99.8%	100.0%
Cavity O/A	4 Field	98.4%	99.9%	100%
Multi-Met	4 Field - Cavity	91.2%	97.5%	99.4%
Multi-Met	4 Field - Met 1	98.2%	100.0%	100.0%
Multi-Met	4 Field - Met 2	93.4%	100.0%	100.0%
Multi-Met	4 Field - Met 3	83.5%	93.4%	98.4%
Multi-Met	4 Field - Met 4	92.3%	97.9%	99.7%
Clinical	2 Field - Brainstem Target	92.9%	96.1%	97.1%
Clinical	2 Field - Optic Nerve Target	60.8%	75.0%	86.9%

*Gamma pass rates are for relative dose normalized by measured and TPS maximum dose in distribution

Results – SRS MapCHECK

Case	Plan	1% / 1mm	2% / 1mm	3% / 1mm
Sphere	Single	100.0%	100.0%	100.0%
Sphere	2 Field	100.0% (99.3-100.0%)	100.0% (99.3-100.0%)	100.0% (100.0%)
Sphere	4 Field	100.0% (99.3-100.0%)	100.0% (99.3-100.0%)	100.0% (100.0%)
Cavity	2 Field	96.7% (95.2-96.1%)	97.9% (97.0-99.4%)	99.1% (97.9-99.4%)
Cavity O/A	2 Field	99.4% (81.2-98.8%)	100.0% (91.0-99.4%)	100.0% (96.3-100.0%)
Cavity O/A	4 Field	99.7% (79.8-97.0%)	100% (89.9-100%)	100% (95.2-100%)
Multi-Met	4 Field - Cavity	63.7% (52.9-93.5%)	85.4% (59.9-99.4%)	98.8% (74.8-100.0%)
Multi-Met	4 Field - Met 1	65.7% (52.1-89.0%)	97.8% (69.8-99.5%)	100.0% (87.5-100.0%)
Multi-Met	4 Field - Met 2	85.3% (76.7-97.8%)	99.4% (86.3-100.0%)	100.0% (95.4-100.0%)
Multi-Met	4 Field - Met 3	73.5% (62.1-88.1%)	97.1% (76.9-99.7%)	100.0% (97.9-100.0%)
Multi-Met	4 Field - Met 4	63.2% (4.8-90.4%)	85.8% (4.9-98.6%)	99.7% (5.1-99.6%)
Clinical	2 Field - Brainstem Target	95.9% (90-92.9%)	99.2% (96.4-99.5%)	99.5% (99.4-99.5%)
Clinical	2 Field - Optic Nerve Target	97.0% (89.9-90.0%)	99.5% (95.3-98.9%)	99.7% (98.1-99.5%)

*Gamma pass rates are for absolute dose, shifted distributions, result includes range of per field measurements in parenthesis

Film and SRS MapCHECK Results

- At 3%/1 mm only single composite film or SRS MapCHECK measurement had result less than 95% passing rate
 - 2 field plan with target abutting optic nerve (86.9%) – going to be repeated
- Low passing rates for per-field SRS MapCHECK measurements were typically for fields contributing minimal dose to the target
- Passing rates for film and SRS MapCHECK decreased for increase in plan complexity
 - For targets further away from isocenter for multi-target plan
 - For targets abutting organs-at-risk with increased plan modulation and dose-gradients

Future Work

- Streamline the process for adapted version of TG-119 for SRS
 - Minimize the time required to do all measurements / what measurements are truly necessary
 - Too much information may be overwhelming if needing to optimize TPS
- Decide on best detector for point measurement
 - Is A16 volume too small (localization error contributing to dose uncertainty)?
- Repeat measurements
- Compare film and SRS MapCHECK measurements to check delivery reproducibility

In Summary

- SRS commissioning is challenging and for confidence, commissioning steps should be handled separately prior to final end-to-end evaluations
- There is a need for standardized SRS test cases similar to the original need for IMRT
 - Fair planning comparison studies
 - Provide confidence intervals for point and planar measurements
 - Determine what gamma analysis parameters are best practice for SRS QA
- A set of SRS test cases has been established that provide a set of increasingly complex clinical scenarios likely to be encountered
 - Small targets
 - Single-isocenter, multi-target treatments with different target sizes and prescriptions
 - Abutting OARs
- Must improve measurement guidelines to reduce uncertainty