Key Publications

Small Field QA

Practice Changes

Professional practice changes in radiotherapy physics during the COVID-19 pandemic

J. Bertholet, et al, Bern University Hospital, University of Bern, Switzerland, Physics and Imaging in Radiation Oncology, 2021 Jul; 19: 25–32.

- *"Results: The majority of MPs worked in alternation at home/on-site. Among practice changes, implementation and/or increased use of hypofractionation was the most common (47% of the respondents). Sixteen percent of respondents modified patient-specific quality assurance (QA), 21% reduced machine QA, and 25% moved machine QA to weekends/evenings."*

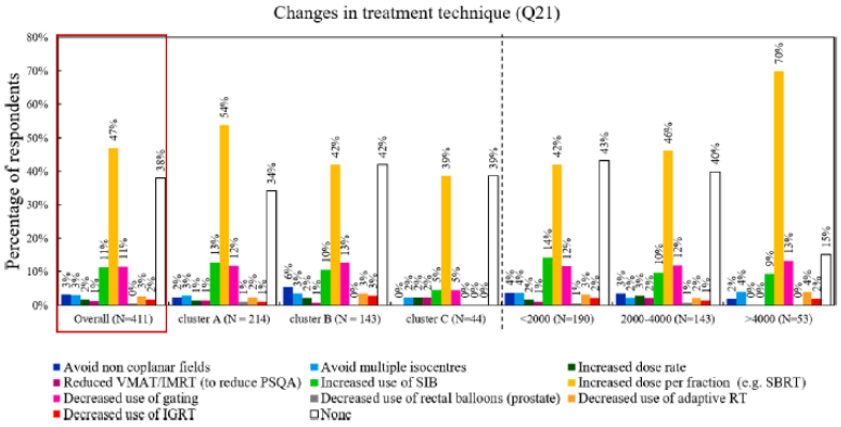


Fig. 1. Changes in treatment technique (Q21) overall (red box), by country cluster (left of the dotted line) and by centre size in patients treated per year (right of the dotted line). Ten responses not associated to any cluster and 25 responses without an answer for the number of patients treated per year are only included in the "Overall" group. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

SRS MapCHECK® Accuracy Studies

Stereotactic radiosurgery commissioning and QA test cases—A TG-119 approach for Stereotactic radiosurgery

R. Culcasi, et al., Karmanos Cancer Institute, Detroit, MI, U.S., Medical Physics. 2021;00:1–12

- Outlines a series of progressively more difficult plans to QA various types of SRS
  - Test 1 – Small spherical target
  - Test 2 – Irregular target
  - Test 3 – Irregular target off-axis
  - Test 4 – Multi-target
  - Test 5 – Abutting OARs
- *"Many drastic errors in SRS commissioning have occurred despite the availability of current AAPM task-group recommendations and independent validation through IROC. When dealing with the large ablative doses used for SRS, such errors can have catastrophic consequences and have the potential to be life-threatening."*
- *"If robust end-to-end testing of the commissioning process and quality assurance procedures were established, these catastrophic errors could have been caught prior to treating these patients."*

Case	Field orientation	Target	Avg. meas./ TPS (%)	Per-field range (%)
Small spherical 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
Abutting OARs	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% (4.6%[a])	

[a]If you exclude last 2 measurements where we believe to have pushed the limits of the machine.

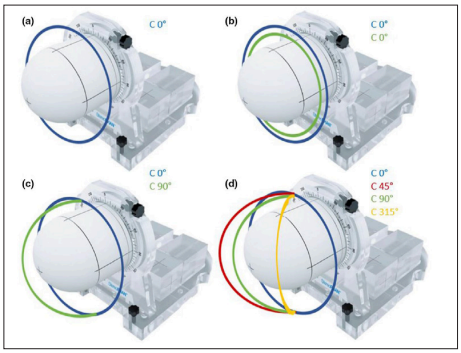


FIGURE 1 VMAT arc orientations utilized for test suite cases. These will be referred to throught the paper as orientations a, b, c and d, respectively

Evaluation of a two-dimensional diode array for patient-specific quality assurance of HyperArc

R. Popple, et al, University of Alabama at Birmingham, Birmingham, AL, U.S., J Appl Clin Med Phy. 2021;1–8

- Summary: validated SRS MapCHECK with 60 plans, 30 of them Single Iso Multi-Met
- *"Conclusion: an advantage of a two-dimensional diode array compared to the film is the efficiency of use and the immediate availability of results after measurement…This study demonstrated that a two-dimensional diode array can obtain results equivalent to the film, resulting in similar gamma analysis outcomes using tolerance limits appropriate for SRS."*

Multi-institution validation of a new high spatial resolution diode array forSRS and SBRT plan pretreatment quality assurance

M Rose, et al, Sun Nuclear Corporation, Med. Phys. 47 (7), July 2020, 3153-3164

- *"The SRS MapCHECK demonstrates near equivalent results to film, validating the SRS MapCHECK as a PSQA/end-to-end test tool, with good sensitivity to common planning, setup, and dosimetry errors in small field dosimetry"*
- *"…devices for which the active detector area is smaller than the typical calculation grid (such as the SRS MapCHECK) can reveal when calculation grid spacing recommendations like MPPG 9a are not being followed."*
- Discusses Nyquist Sampling Theorem and concludes 2.5mm spacing is adequate for SRS QA

4. DISCUSSION

In this study, the following five parameter groups were identified as potential sources for discrepancies between measuring devices and/or calculation:

1. Coarse TPS grid spacing
2. Output factor errors
3. High modulation
4. Low-dose film accuracy
5. Poor CBCT alignment.

Sensitivity and specificity analysis of 2D small field measurement array: Patient-specific quality assurance of small target treatments and spatially fractionated radiotherapy

M. Banos-Capilla, et al., Radiation Oncology Department, Hospital Vithas Consuelo, Valencia, Spain, J Appl Clin Med Phy. 2021;1–16.

- Study on the Sensitivity and Specificity of SRS MapCHECK for SFRT (Spatially Fractionated RT)
- *"The small size of detectors that form the array does not show a convolution-type influence, allowing them to reproduce profiles with high gradient levels in a reliable way."*
- *"Conclusion: …we tested the SRSMapCheck array response under different irradiation conditions, after having characterized the device's sensitivity and specificity. We found that the characteristics of the equipment together with the correction factors applied, let us to reliably perform patient specific QA for a wide range of complex treatments, not only SRS treatments but also focused on treatments that include multiple targets treated at once and high gradient dose plans such as those achieved in SFRT."*
- Recommended using 2%/1mm criteria to detect Gantry errors (all other errors were detectable even with 2/2, but 2/1 is most appropriate for SRS)

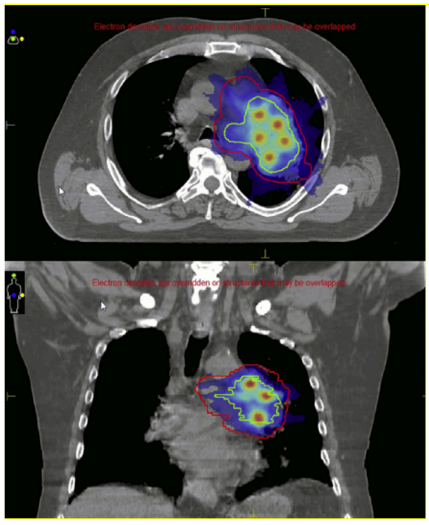


TABLE 3 Summary of sensitivity and specificity obtained from test treatment plans with systematic errors derived from field size and gantry position

N = 99	Fraction of correctly classified plans			Sensitivity			Specificity		
(IC = 95%)	Value	Lower limit	Upper limit	Value	Lower limit	Upper limit	Value	Lower limit	Upper limit
Γ (2%, 2 mm)	0.92	0.84	0.96	0.81	0.65	0.91	1.00	0.92	1.00
Γ (2%, 1 mm)	0.96	0.89	0.99	0.94	0.86	0.98	1.00	0.85	1.00

TABLE 4 Sensitivity, specificity and F1 score results for systematic error tests of the MLC position

MLC position errors	Sensitivity			Specificity			F1-Score
(*N* = 48, IC = 95%)	Value	Lower limit	Upper limit	Value	Lower limit	Upper limit	Value
Γ (2%, 2 mm)	1.00	0.78	1.00	1.00	0.86	1.00	1.00
Γ (2%, 1 mm)	1.00	0.70	1.00	1.00	0.87	1.00	1.00

TABLE 5 Sensitivity, specificity and F1-score results for systematic error tests of the Gantry position

Gantry position errors	Sensitivity			Specificity			F1 score
(*N* = 51, IC = 95%)	Value	Lower limit	Upper limit	Value	Lower limit	Upper limit	Value
Γ (2%, 2 mm)	0.67	0.47	0.84	1.00	0.85	1.00	0.80
Γ (2%, 1 mm)	0.89	0.73	0.96	1.00	0.75	1.00	0.94

Dosimetric characterization of a new two-dimensional diode detector array used for stereotactic radiosurgery quality assurance

K. Yasui, et al., Fujita Health University, Japan, Int. J. Radiat. Res., Vol. 19 No. 2, April 2021

- *"Methods: ….The reproducibility, dose linearity, dose rate dependencies, output factors (OPFs) and angular dependencies were investigated as dosimetric characteristics. The OPFs were measured and compared between AP and PA direction ranging from 0.5 x 0.5 to 7 x 7 cm2."*
- *"Conclusion: Results indicate that the new 2D diode detector is stable and useful for QA and end-to-end testing of SRS due to its excellent dose characteristics, high resolution and ease of handling when combined with the StereoPHAN"*

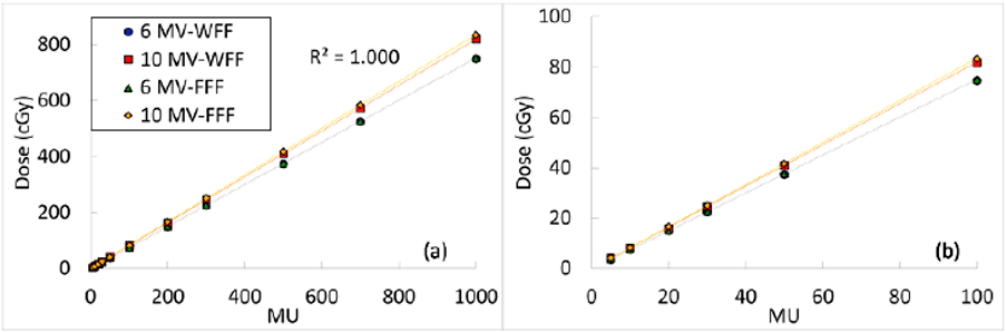


Figure 2. Dose linearities of WFF and FFF beams from 5 to 1000 MU **(a)**. An enlarged low dose area of less than 100 MU **(b)**.

Commissioning of the TrueBeam STx 6 MV FFF Beam in the RayStation Treatment Planning System for SRS and SBRT Treatments

Y. Lee, et al., The University of Arizona, Tucson, AZ, U.S., Int. J. Medical Physics, Clinical Engineering and Radiation Oncology, 2021, 10, 16-37

- Commissioning of TrueBeam/RayStation for SRS/SBRT
- Used 3D Scanner, 1D Scanner, SNC125C, EDGE Detector, Reference Detector, StereoPHAN, MapCHECK 2, and SRS MapCHECK
- Data matched Representative Data within 0.5%
- SRS MapCHECK criteria: 2%/1mm and 1%/1mm

MPPG 5.a. Test 7.4 (clinical tests): Gamma passing rate

SRS (DCAT†)		SRS (VMAT‡)		SBRT (DCAT)		SBRT (VMAT)	
2%/1 mm	1%/1 mm	2%/1 mm	1%/1 mm	2%/1 mm	1%/1 mm	2%/1 mm	1%/1 mm
99.7%	99.3%	96.1%	92.2%	100%	96.8%	98.2%	94.8%

MPPG 5.a. Test 7.5 (end-to-end testing): Ion chamber measurement result

SRS (VMAT)	SRS (CCAT* with a 17.5 mm cone)
0.20%	0.53%

†Dynamic conformal arc therapy; ‡Volumetric modulated arc therapy; *Circular collimator arc therapy.

Commissioning cranial single-isocenter multi-target radiosurgery for the Versa HD

C. Knill, et al., Beaumont Health, Royal Oak, MI, U.S., J Appl Clin Med Phys 2021; 1–7

- Commissioning of VersaHD/Brainlab Elements for SRS/SBRT
- Multi-Met Brainlab Element's plans were validated with microdiamond, film and SRS MapCHECK
- *"Average per-field pass rates measured with the SRSMapcheck in the StereoPHAN were 98.0% with a minimum of 95.5% using a 2%/1 mm/10% threshold."*

Single isocenter SRS using CAVMAT offers improved robustness to commissioning and treatment delivery uncertainty compared to VMAT

E. Cullom, et al., Duke University, Durham, NC, U.S., J Appl Clin Med Phys 2021; 1–8

- Showed that Conformal Arc plans are more robust to DLG changes than standard VMAT plans

A first report of tumour-tracking radiotherapy with helical tomotherapy for lung and liver tumours: A double case report

W. Okada, et al., Takarazuka City Hospital, Takarazuka, Japan, SAGE Open Medical Case Reports, Volume 9: 1–5

- Used 2-dimensional platform
- Rotated SRS MapCHECK/SterePHAN 30 degrees to allow X and Y motion
- *"The point dose accuracy and the gamma passing rates of 2D doses were within the clinically acceptable range. Thus, SMC (SRSMC) is an MQA (Motion QA) tool with accurate dosimetry and spatial resolution."*

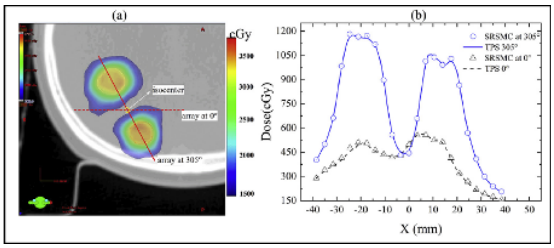
Table 1. Dosimetric error and motion detection accuracy for two cases.

Case no.	Delivery time (s)	Motion parameters		Synchrony® (−)			Synchrony® (+)			Detection accuracy
		A (mm)	P (s)	Dose %diff	Gamma passing rate (%)		Dose %diff	Gamma passing rate (%)		RMS (mm)
					2%/2 mm	1%/1 mm		2%/2 mm	1%/1 mm	
1	496.3	17.6	6.0	−0.43	78.6	56.7	−0.18	100.0	95.0	0.87
2	110.5	10.8	4.0	0.51	99.3	76.4	0.43	100.0	87.8	0.53

A: peak-to-peak amplitude of respiration; P: period; Dose %diff: dose percent difference; RMS: root mean square.

Dosimetric characteristics of a 2D silicon diode array for stereotactic radiotherapy end-to-end patient-specific QA

L Bai, et al, Radiation Physics and Chemistry 173 (2020) 108885



- *"The array, within the StereoPHAN phantom, is shown to be dosimetrically and mechanically accurate for SRT end-to-end patient-specific QA"*
- *"From the characteristics tests in this work, we did not find any volume-averaging effect in high-dose gradients or non-uniform dose regions because of the very small sensitive volume of the SRSMC diodes."*
- *"Any dose profile realistically encountered in megavoltage photon radiotherapy can be adequately sampled, according to the Nyquist sampling theorem, with a sampling step width not exceeding 2.5mm."*

Table 3
Gamma analysis of twenty-seven selected VMAT plans for the SRT end-to-end patient-specific QA using SRSMC.

	Criterion	Brain	Brain			Lung	Total
		Coplanar (n = 7)	Non-coplanar (n = 11)	Single metastasis (n = 6)	Multiple metastases (n = 12)	Coplanar (n = 9)	(n = 27)
GPRs (%)mean (SD)	2%/1 mm	96.4 (1.3)	97.5 (1.5)	97.5 (1.1)	97.0 (1.7)	96.2 (1.9)	96.8 (1.7)
	3%/1 mm	98.8 (0.4)	99.0 (0.9)	99.0 (0.3)	98.9 (0.9)	98.4 (1.4)	98.8 (1.0)
	2%/2 mm	98.5 (0.5)	98.8 (1.1)	98.8 (0.7)	98.6 (1.0)	98.4 (1.1)	98.6 (1.0)
	3%/2 mm	99.4 (0.5)	99.7 (0.4)	99.5 (0.6)	99.7 (0.4)	99.5 (0.6)	99.6 (0.5)

- *"The Gamma Pass Rates of end-to-end patient-specific QA for non-coplanar and multiple metastases were as high as that for coplanar and single-target, and a gamma criterion of 2%/1mm would be suitable for SRT QA when using the diode array."*

Comprehensive evaluation of the high resolution diode array for SRS dosimetry

S. Ahmed, V. Feygelman, et al., Department of Radiation Oncology, Moffitt Cancer Center, Tampa, FL, U.S., J Appl Clin Med Phys 2019; 1-11

- Study of SRS MapCHECK central diode output vs. W2/film, Dose Rate and Angular Dependence
- *"Conclusion: The SRS MapCHECK diode array in the StereoPHAN phantom has sufficient dosimetric accuracy and spatial resolution to be a usefultool for SRS commissioning and quality assurance, including single isocenter multiple met modulated plans."*

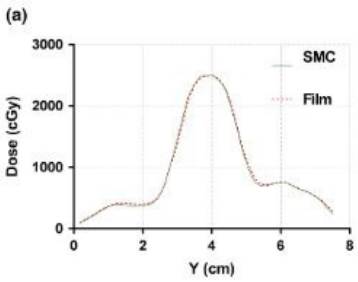


Table 4 Gamma analysis passing rates: SMC vs film.

	γ-Analysis pass rate (%)	
Plan	3%G/1mm	2%G/1mm
6MV_1	97.6	95.9
6MV_2	98.0	95.5
6MV_3	99.8	98.6
6MVFFF_1	99.5	97.5
6MVFFF_2	99.1	97.1
6MVFFF_3	99.6	98.5
Average	98.9	97.2
SD	0.9	1.3
95%CI	98.0-99.9	95.8-98.5

Commissioning and performance testing of the first prototype of AlignRT InBore™, a Halcyon™ AND Ethos™ dedicated surface guided radiation therapy platform

D. Nguyen, et al., Radiotherapy centers of ORLAM group, Macon, FR, et al, Physica Medica 80 (2020) 159–166

- Validates Varian Medical Systems® Halcyon™ System, Ethos™ Therapy, and SGRT using ArcCHECK and SRS MapCHECK

CyberKnife® patient plan verification with the SRS MapCHECK - First clinical experience

S. Peters, et al, Strahlenzentrum, Germany, PO-1385, ESTRO 2020

- Summary: Validation of SRS MapCHECK for Accuray CyberKnife® use with Vertex fields
- *"Conclusion: The SRS MapCHECK allows easy and meaningful verification of patient plans without film, without restrictions of the angle of incidence and with little expenditure of time."*

Validation of SRS MapCHECK for patient specific QA

C. Anson Marcos, et al, University Hospital La Princesa, Spain, PO-1374, ESTRO 2020

- Validation of SRS MapCHECK with Acuros using various methods
- *"The highest average gamma passing rate when using AXB is showed for the configuration QAWater,1.14. Therefore, this configuration was validated for the PSQA workflow."*

	$QA_{1.2}$		$QA_{Water,1.14}$		$QA_{Water,1.2}$		QA_{PMMA}	
	AAA		AXB		AXB		AXB	
	3%/1mm	*2%/1mm*	*3%/1mm*	*2%/1mm*	*3%/1mm*	*2%/1mm*	*3%/1mm*	*2%/1mm*
6WFF	99.9%	98.7%	99.6%	97.3%	98.0%	91.0%	69.3%	60.6%
6FFF	99.6%	98.5%	99.8%	99.3%				
10FFF	99.9%	99.7%	99.7%	99.0%				

Table 1. Average gamma passing rates for different phantom assign material

Determination of dosimetric leaf gap (DLG) for FFF and WFF beams for a high definition MLC

C. Anson Marcos, et al, University Hospital La Princesa, Spain, PO-1414, ESTRO 2020

- SRS MapCHECK used to tune DLG factors on HDMLC
- Results: *"for 6WFF this value had to be increased in 0.5 mm in order to obtain a good agreement between plan and delivered doses."*

		DLG (mm)			Transmission		
		6 WFF	6FFF	10 FFF	6 WFF	6FFF	10 FFF
Sliding MLC gap method	Perpendicular to leaf mov. on-axis	0.6	0.56	0.7	1.18%	1.01%	1.22%
	Perpendicular to leaf mov. off-axis	0.446			1.11%		
	Parallel to leaf movement	0.633	0.61	0.71	1.19%	1.00%	1.21%
	Patient optimization	1.1	0.56	0.7	1.18%	1.01%	1.22%

Table 1. DLG and transmission values.

Evaluation of SRS MapCHECK for Small-Field CyberKnife G4 Patient Specific Quality Control

B. Wilson, J. Szanto, The Ottawa Hospital, Ottawa, ON, CA,, PO-GeP-T-417, AAPM 2020

- *All patient specific QC passed with greater than 99% gamma pass rate at 2% 1mm passing criteria. The smallest cone treatment (5 mm trigeminal neuralgia), passed with 0.2% central axis dose error and (0.2mm, 0.2mm, 0 mm) calculated shift which demonstrates very accurate tolerances of the device. The device was also found to be suitable for the measurement of 60 mm profiles."*
- *"Conclusion: A significant advantage of a two-dimensional diode array compared to the film is the efficiency of use and the immediate availability of results after measurement...This study demonstrated that a two-dimensional diode array can obtain results equivalent to the film, resulting in similar gamma analysis outcomes using tolerance limits appropriate for SRS."*

Characterization and Validation of SRS MapCheck for Patient Specific QA On CyberKnife M6

D Parsons, et al., UT Southwestern Medical Center, Dallas, TX, AAPM 2019

- Validation study of SRS MapCHECK for CyberKnife using MLC, Iris, and Cone CyberKnife configurations
- Results: Criteria 2%/1mm *"The mean gamma pass rates were 95.0%, 98.1% and 94.4% for the MLC, iris and fixed-cone collimators."*
- Conclusion: *"The use of SRS-MC has been characterized and validated for patient specific QA on CyberKnife for a variety of clinical plans. The results show that SRS-MC is well suited for this task."*

Evaluation of a High Spatial Resolution Detector Array for SRS Patient Specific QA in Comparison with GafChromic Films and Diamond Detector

J Duan, et al., Duke University Medical Center, Durham, NC, AAPM 2019

- Comparison study of SRS MapCHECK to film and microdiamond - showed excellent accuracy and efficiency.
- "SRSMC is much more efficient, effective and stable for 2D dose measurement and analysis compared to film dosimetry."

Technical Note: Dosimetric feasibility of lattice radiotherapy for breast cancer using GammaPod

B. Kopchick, et al, The George Washington University, Washington, DC, U.S., Med Phys. 2020 Sep;47(9):3928-3934

- SRS MapCHECK successfully used to perform PSQA on GammaPod Lattice Treatments

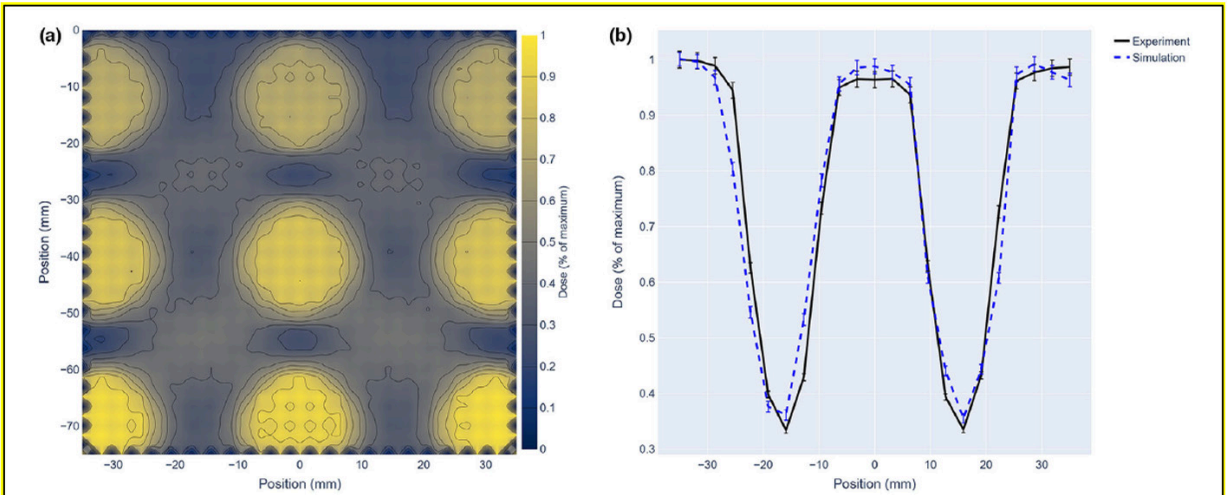


FIG. 6. (a) Dose distribution using the GammaPod's 15 mm collimators as measured from SRS MapCHECK. (b) The corresponding lateral central dose profile from (a) with Monte-Carlo-based simulation of same central dose profile.

Commissioning and acceptance guide for the GammaPod

S. Becker, et al., Department of Radiation Oncology, University of Maryland School of Medicine, Baltimore, MD, U.S., Phys Med Biol. 2019 Oct 21;64(20):205021

- Validation study of SRS MapCHECK to QA GammaPod
- Time Savings - *"the analysis time reduced from 1 hr min to 5 min."*

AAPM Guidelines for QA Devices

Tolerance limits and methodologies for IMRT measurement-based verification QA: Recommendations of AAPM Task Group No. 218

M. Miften, et al., University of Colorado School of Medicine, Aurora, CO, U.S., Medical Physics, 45 (4), April 2018

- SRS MapCHECK and MapCHECK 3 are the only 2D arrays available that meet the TG-218 requirement for angular corrections

> *"We make the following recommendations for IMRT QA verification of the dose distributions (fixed-gantry IMRT and rotational IMRT): IMRT QA measurements should be performed using a TC (true composite) delivery method provided that the QA device has negligible angular dependence or the* ***angular dependence is accurately accounted for in the vendor software."***

Stereotactic body radiation therapy: The report of AAPM Task Group 101

S. Benedict, et al., University of Virginia Health System, Charlottesville, VA, U.S, Medical Physics, Vol. 37, No. 8, August 2010

- SRS MapCHECK better than <1mm criteria called for in TG-101

> *"Recommendation: Due to the small dimensions and steep dose gradients of photon beams used in SRS/SRT and IMRT, an appropriate dosimeter with a spatial resolution of approximately* ***1 mm or better*** *(stereotactic detectors) is required."*

Multi-Met Winston-Lutz Cube for Single Isocenter Multi-Met Treatments

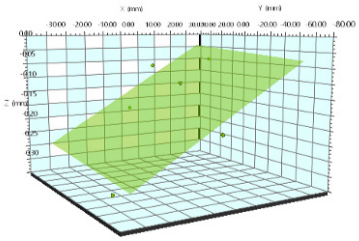
A machine QA tool to verify targeting accuracy of off-isocenter metastases

H. Kudrolli, et al., Sun Nuclear Corporation, Melbourne, FL, U.S., PO-1320, ESTRO 2020

- *"Results: Optimized delivery plans were developed, which allow data acquisition to be completed within 10 minutes"*
- *"By introducing positioning errors of known magnitude, we demonstrated the ability of the tool to identify translational positioning errors to ± 0.1 mm and rotational positioning errors (pitch, roll, and yaw) ± 0.2 degrees."*

POSITIONAL ERROR 6DOF

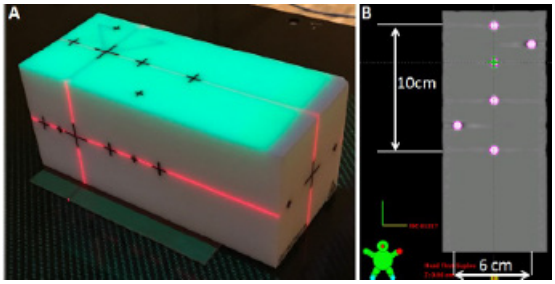
	LATERAL (mm)	LONG (mm)	VERTICAL (mm)	PITCH (deg)	ROLL (deg)	YAW (deg)
DELTA	-0.26	-0.24	-0.07	-0.01	-0.23	0.10
CURRENT	0.71	692.30	-41.43			
CORRECTED	0.97	692.54	-41.36			



Validation of a New Tool for Testing Spatial Accuracy of Off-Axis Beam Apertures Used in Single-Isocenter Stereotactic Treatment of Multiple-Metastases of the Brain

D. Pinkham, et al., Yale School of Medicine, New Haven, CT, U.S., PO-GeP-T-838, AAPM 2020

- Summary: Multi Met Winston-Lutz Cube Validation on Elekta with Agility head
- *"Purpose: A prerequisite for simultaneous SRS treatment of multiple targets is validation of the spatial accuracy of off-axis beam apertures.*
- *"For one of the linacs, the test detected a lateral misalignment of the MLC leaf bank and misalignment of the couch axis from the gantry isocenter. After adjustment of both, the following results were obtained. The mean deviation for all projections was 0.65 mm ±0.3 mm."*
- *"Conclusion: The tool provides for effective and efficient testing for commissioning and QA of a stereotactic program that includes simultaneous treatment of multiple metastasis."*



Development of a Phantom to Verify Targeting Accuracy of Single-Isocenter Multiple Lesion Stereotactic Radiosurgery

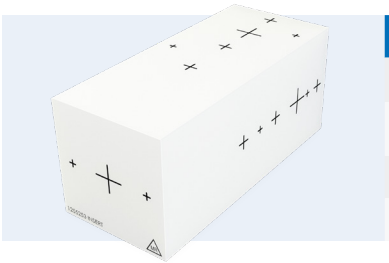
A. Murray, et al., Sun Nuclear Corporation, Melbourne, FL, AAPM 2019

- *"Our results indicate a targeting accuracy within 0.1 mm for off-isocenter targets up to 7 cm of the linac isocenter.…A mathematical matrix deconvolution model is being developed to isolate the source of TDS error."*
- *Conclusion: "This phantom … provides a simple method to verify targeting accuracy for multiple lesions with single isocenter."*

Re-examining TG-142 recommendations in light of modern techniques for linear accelerator based radiosurgery

AM Faught, et al., Department of Radiation Oncology, Duke University Medical Center, Durham, NC, U.S., Med. Phys. 43 (10), October 2016

- "We suggest a careful review by the clinical physicist of routine quality assurance tolerances for angular mechanical checks when using multifocal MVAT for metastatic disease…the stricter angular tolerance ***may necessitate a new method of measurement"***
- Study showed that a 1° collimator error could induce a PTV dose error as great as 33%



	Target Coverage	V100%	D99%
+/- 1.0˚ Coll	Ave errors	5%	6%
	Max errors	33%	20%
+/- 1.0˚ Gantry	Ave errors	2%	4.5%
	Max errors	18%	12%+

In Heterogeneous Patients, Modeling Matters
SunCHECK Patient - PerFRACTION: EPID or Log File-based QA

Assessment of three software systems for the independent calculation of Eclipse HyperArc SRS plans

J. Calvo-Ortega, hospital Quirónsalud Barcelona, Radiation Oncology, Barcelona, Spain, ESTRO 2021, PO-1841

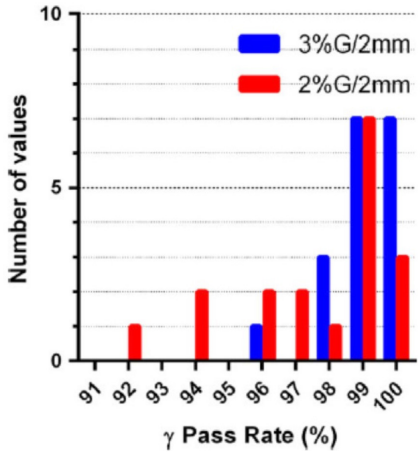
- *"Purpose or Objective: To perform independent dosimetric check of Eclipse HyperArc (HA) SRS plans by using three different software, in the context of patient-specific quality assurance (PSQA)."*
- *"Conclusion: Both DoseCheck and PRIMO (with the 6 MV Varian phase-space file) agree with Eclipse HyperArc calculations for a TrueBeam, with no need for the user to fine-tune the calculation parameters. The Mobius 3D default model, however, would need tuning to match HyperArc dose distributions"*

	ECLIPSE vs Dosecheck		ECLIPSE vs M3D		ECLIPSE vs PRIMO	
Criteria	mean (SD)	AL-TG119	mean (SD)	AL-TG119	mean (SD)	AL-TG119
3% (G) 1 mm	99.7 (1.2)	97.4	94.3 (13.8)	67.2	97.6 (9.8)	78.5
5% (G) 1 mm	100.0 (0.1)	99.8	97.7 (11.4)	75.3	99.6 (2.5)	94.7
2% (G) 2 mm	99.9 (0.6)	98.7	98.5 (5.9)	87.0	99.0 (2.1)	94.9

Validation of a GPU-Based 3D dose calculator for modulated beams

Ahmed et al., USF, Moffitt Cancer Center, Sun Nuclear Corp., J Appl Clin Med Phys (2017)

- Study validating the accuracy of the Sun Nuclear Dose Calculator (SDC)
- Three photon energies were examined: 6, 15 MV, and 10 MV FFF using a set of IMRT and VMAT plans based on four of the five AAPM Practice Guideline 5a
- Compared to Pinnacle 3D Dose, Ion Chamber, ArcCHECK and PDP 3D Dose for TG 244 datasets reveal the accuracy level expected in routine patient-specific testing (>= 95% gamma (3%/2 mm) passing rates)



SDC vs. Pinnacle

Finally, the doses generated by Pinnacle and SDC are quantitatively compared in Table 5. Gamma analysis passing rates are well above 95% for all cases.

		6 MV		10 FFF		15 MV	
TG-244 Patient/Test	Plan	SDC Pass rate (%)	Median ΔD (SDC-TPS, %)	SDC Pass rate (%)	Median ΔD (SDC-TPS, %)	SDC Pass rate (%)	Median ΔD (SDC-TPS, %)
ABDOMEN	VMAT	99.9	-0.02	99.3	0.4	99.8	1.07
	IMRT	100.0	0.5	99.9	0.9	100	1.43
Head&Neck	VMAT	99.8	-0.8	98.7	2.3	97.5	1.5
	WFIMRT	99.8	-0.1	97.7	3.2	96.3	2.0
ANAL	VMAT	99.9	-0.5	98.7	2.0	99.1	1.05
	WFIMRT	99.8	0.0	98.8	2.8	99.7	1.35
LUNG	VMAT	100.0	1.3	98.9	3.8	93.4	4.9
	WFIMRT	99.8	1.8	98.6	3.4	96.3	3.7
	Average	*99.9*	*0.3*	*98.8*	*2.4*	*97.8*	*2.1*
	St. Dev.	*0.1*	*0.9*	*0.6*	*1.2*	*2.3*	*1.4*

A hybrid volumetric dose verification method for single isocenter multiple target cranial SRS

S. Ahmed, et al., Moffitt Cancer Center, Tampa, FL, U.S., Med Phys 2018; Vol 19, Iss 5:1–8

- PerFRACTION calculations for single target, Multi-Met cases were compared to Pinnacle calculations, 3D PDP calculations, ion chamber and film measurements.
- *"Results: Excellent agreement is observed for PF, with the lowest passing rate of 96.1%."*

Table 1: Results for the gamma comparison between PerFraction reconstructed dose and EBT-XD film measurements .

Plan	Plane	PerFRACTION vs. Film	
		3%/1mm	2%/2mm
T3	Oblique 45°	100	100
	Oblique 135°	99.9	99.93
PT3	Oblique 45°	100	100
	Oblique 135°	100	100
PT5	Coronal	99.4	99.1
	Oblique 45°	99.7	99.6
	Oblique 135°	97.3	95.8

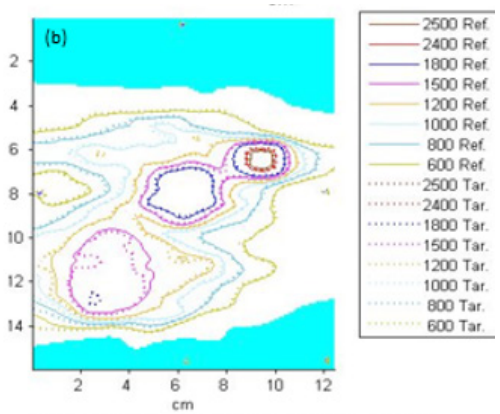


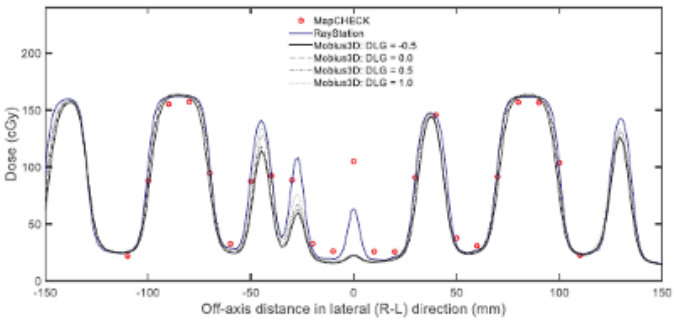
Figure 2: 2%/2mm γ map (a) and isodose overlay (b) for the PT5 oblique (135°).

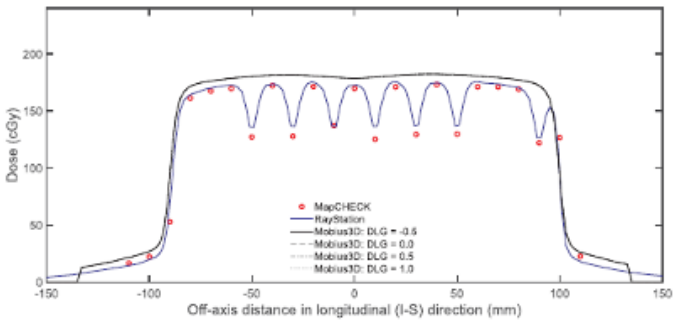
Heterogeneous Studies of Varian Medical Systems® Mobius3D™ Calculations

Detailed evaluation of Mobius3D dose calculation accuracy for volumetric modulated arc therapy

J. Kim, et al., Yonsei University College of Medicine, Seoul, South Korea, Physica Medica 74 (2020) 125–132 126

- *"Results: …The mean percentage of pixels passing gamma from a 3%/1 mm gamma analysis for the MLC test set was 43.5% across the MLC tests."*
- *"Conclusions: It was demonstrated that Mobius3D has dose calculation uncertainties for small fields and MLC tongue-and-groove design is not adequately taken into consideration in Mobius3D."*

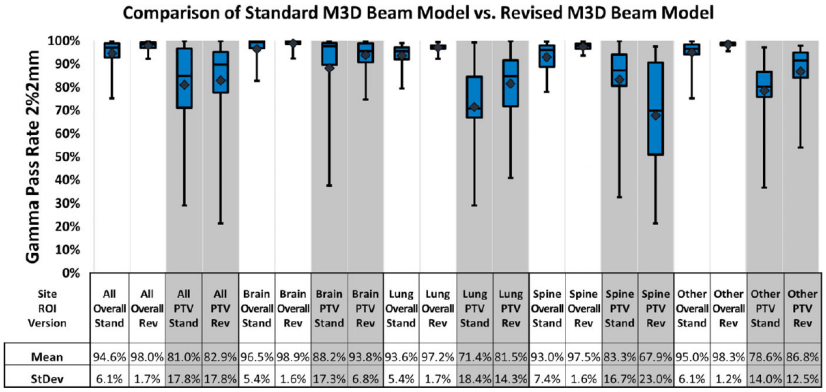




Refinement of MLC modeling improves commercial QA dosimetry system for SRS and SBRT patient-specific QA

Y. Hillman, et al., Karmanos Cancer Institute at McLaren Macomb, Mt. Clemens, MI, U.S., Med. Phys. 45 (4), April 2018.

- Output Factor 0.5 x 0.5 cm^2
  - Plastic Scintillator Detector measured: 0.605
  - Varian Medical Systems® Mobius3D™ calculated: 0.300 – 0.499
  - Varian Medical Systems® Mobius3D™ Output Factor: >17% discrepancy
  - Sun Nuclear DoseCHECK - 1.5% *
    *Validation of a GPU-Based 3D dose calculator for modulated beams



Site ROI Version	All Overall Stand	All Overall Rev	All PTV Stand	All PTV Rev	Brain Overall Stand	Brain Overall Rev	Brain PTV Stand	Brain PTV Rev	Lung Overall Stand	Lung Overall Rev	Lung PTV Stand	Lung PTV Rev	Spine Overall Stand	Spine Overall Rev	Spine PTV Stand	Spine PTV Rev	Other Overall Stand	Other Overall Rev	Other PTV Stand	Other PTV Rev
Mean	94.6%	98.0%	81.0%	82.9%	96.5%	98.9%	88.2%	93.8%	93.6%	97.2%	71.4%	81.5%	93.0%	97.5%	83.3%	67.9%	95.0%	98.3%	78.6%	86.8%
StDev	6.1%	1.7%	17.8%	17.8%	5.4%	1.6%	17.3%	6.8%	5.4%	1.7%	18.4%	14.3%	7.4%	1.6%	16.7%	23.0%	6.1%	1.2%	14.0%	12.5%

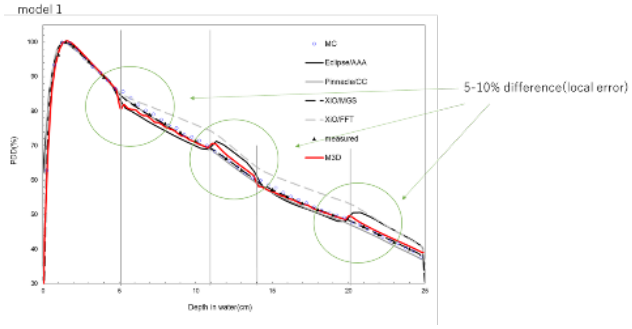
FIG. 3. The results of the standard M3D beam model and the revised beam model indicate that the revised beam model has better agreement with AAA and less deviation for every category except spine PTV. However the revised model still has lower agreement with AAA in PTV (shaded columns) indicating that PTV gamma passing rates may require an action level below the conventional 90% gamma pass rate. [Color figure can be viewed at wileyonlinelibrary.com]

SBRT Cases (qty)	Standard Mobius3D Model	Adjusted Model
Brain PTV (25)	**88.2%**	93.8%
Lung PTV (20)	**71.4%**	81.5%
Spine PTV (20)	83.3%	**67.9%**

Validation of secondary dose calculation system with manufacturer provided reference beam data using heterogeneous phantoms

Y. Nakaguchi, et al., Kumamoto University Hospital, Kumamoto, Japan, Radiol Phys Technol. 2019 Mar;12(1):126-135. doi: 10.1007/s12194-019-00499-6. Epub 2019 Jan 25.

- Conclusion:
  - *"For the planning of the whole neck, the differences in the M3D and the TPS dose profiles led to the inability of the former to calculate a complex dose distribution for VMAT"*
  - *"the M3D system appears to be unsuitable for highly accurate dose calculations in anatomical regions filled with air."*
  - *"the M3D dose measurements differed by 5-10% in the lung and bone regions."*



SunCHECK™ Patient PerFRACTION™ Sensitivity Studies

Can a commercially available EPID dosimetry system detect small daily patient setup errors for cranial IMRT/SRS?

E. Hsieh, S. Dietrich, et al., University of California, Davis, Davis, CA, U.S., PRO Journal, 2017, Vol 7, Issue 4, Pages e283–e290

- Study showing PerFRACTION detects setup errors down to 1mm for SRS, and 3mm for IMRT

> *"PerFRACTION 2D mode successfully detected setup errors outside of tolerance for IMRT (3mm DTA) and SRS (1mm DTA) when an appropriate analysis metric and pass/fail criteria was implemented."*

Sensitivity study of an automated system for daily patient QA using EPID exit dose images

A. Zhuang, A. Olch, University of Southern California, Los Angeles, CA, U.S., J Appl Clin Med Phys 2018: 1-11

- 3D PerFRACTION was able to detect all the delivered perturbations (induced errors). Defining clinical meaningful dose variations as 3% or greater, we can assert that Fraction 0 detected 100% of the errors, as shown in Table 5."
- PerFRACTION found "0" False Positives!
- Portal Dosimetry had 13 False Positives, and 2 False Negatives

Table 2 Induced errors, DD, and/or DTA tolerance used, PerFRACTION-calculated Gamma passing rates, and the sensitivity of PerFRACTION.

Tested items	Induced errors	DD and/or DTA tolerance, or Gamma passing rates	Sensitivity of PerFRACTION
Jaw position	1.5 mm	1.3 mm	0.2 mm
MLC position	1.5 mm	1.1 mm	0.4 mm
Linac output	0.5%, 1.0%, 1.5%	0.5%, 1.2% and 1.6%	0.2%
Collimator rotation	1, 2 and 3°	0.7, 1.7 and 2.5°*	0.5°
Couch shift	1.5 mm	1.7 mm	0.2 mm

Effect of collimator angle on HyperArc stereotactic radiosurgery planning for single and multiple brain metastases

S. Ohira, et al., Osaka University Graduate School of Medicine, Suita, Japan, Medical Dosimetry 45 (2020) 85–91

- Conclusion: For Multi-Met plans, preferred Collimator Optimized results
- PF results: >95% for 2%/2mm, >98% for 3%/3mm

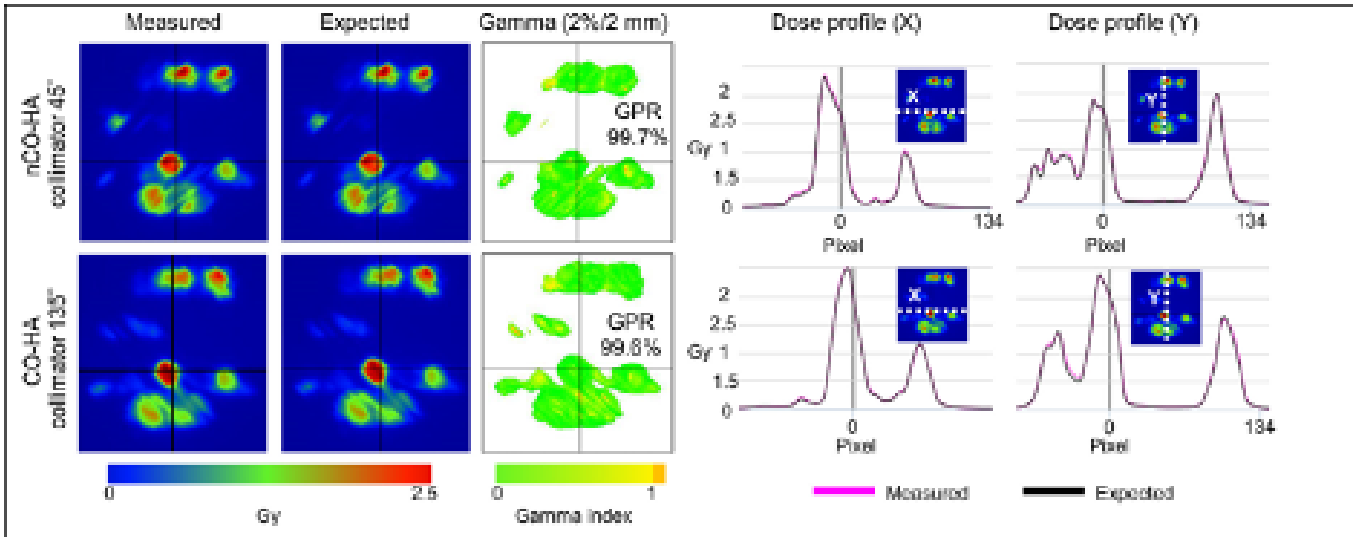


Fig. 5. Measured and expected doses in the nCO-HA and CO-HA plans for patient #26 (1 of the 4 half arc beam) who has 8 brain metastases. (Color version of figure is available online.)

*PDIP is Portal Dosimetry

All EPID Solutions Are Not the Same

Assessing the feasibility of single target radiosurgery quality assurance with portal dosimetry

E. Covington, R. Popple, et al., University of Alabama – Birmingham, South Birmingham, AL, U.S., J Appl Clin Med Phys 2019; 1–6

- Portal dosimetry should not be used for the commissioning and validating of stereotactic beam models."
- Conclusion: *"Portal dosimetry measurements were found to be target size dependent and could deviate up to 8% from film measurements for the smallest targets evaluated. While portal dosimetry provides a quick method to evaluate SRS plans for gross error without the use of a specialized phantom, it does not provide an accurate method for determining the dosimetric accuracy of the plan when compared to film."*

Can an EPID Be Commissioned for Multi-Met SRS Pre-Treatment VMAT QA?

D Raxter, et al., University of Toledo, Toledo, OH, AAPM 2019

- Varian Medical Systems® Portal Dosimetry PDIP algorithm produced poor results even with accurate Output Factors.
- Conclusion:
  - "Despite accurate output factor measurements of fields as small as 1x1 cm2, the algorithm for calculating the EPID predicted response led to failing PD results using the clinical beam model parameters."
  - "Results were not robust when the EPID was compared to film as a reference dosimeter. Ultimately, a more robust QA method for VMAT SRS plans is required."