Mooooo

Quality Assurance Aspects of Stereotactic Radiosurgery / Fractionated Stereotactic Radiation Therapy

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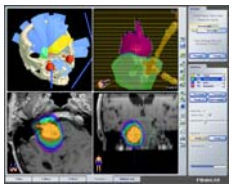
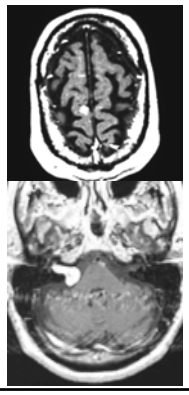
Therapy Educational Course WE-B-224-1

COMP OCPM 2011 JOINT AAPM/COMP MEETING - JULY 31 - AUGUST 4 - VANCOUVER
UT SOUTHWESTERN MEDICAL CENTER

Where to Start? Define Your Program Goals!





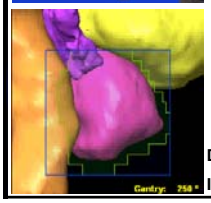
Cranial Only?

Benign?

Where to Start? Define Your Program Goals!

Conformal Techniques - mMLC

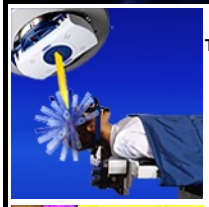
AVM?



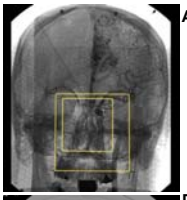
Dynamic Arcs?

IMRT?

Where to Start? Define Your Program Goals!

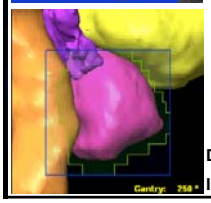


Conformal Techniques - mMLC



AVM?

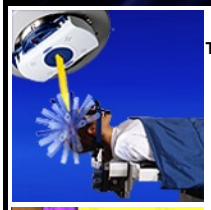
DSA?



Dynamic Arcs?

IMRT?

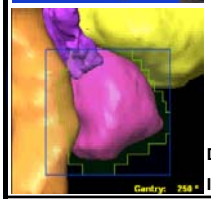
Where to Start? Define Your Program Goals!



Conformal Techniques - mMLC

AVM?

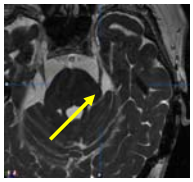
RotationalAngio?



Dynamic Arcs?

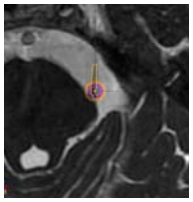
IMRT?

Where to Start? Define Your Program Goals!

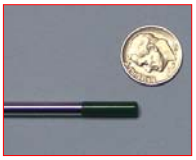


Trigeminal Neuralgia?

Circular Collimators



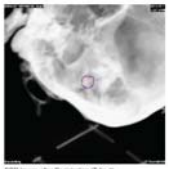
Detectors



Where to Start? Define Your Program Goals!

Frame-based

or Frameless (Image-Guided)



Where to Start? Get the Documentation

AAPM Efforts In Progress

Report 54 (TG 42) – Stereotactic Radiosurgery
TG 68 – Intracranial Stereotactic Positioning Systems
Report 101 (TG 101) – Stereotactic Body Radiotherapy
Report 104 (TG 104) – kV Localization in Therapy
Report 135 (TG 135) – QA for Robotic Radiosurgery

AAPM Efforts In Progress

TG 117 – Use of MRI in Treatment Planning and Stereotactic Procedures
TG 132 – Use of Image Registration and Data Fusion Algorithms and Techniques in Radiotherapy Treatment Planning
TG 147 – QA for Non-Radiographic Radiotherapy Localization and Positioning Systems
TG 155 – Small Fields / Non-Equilibrium Condition Photon Beam Dosimetry
TG 178 – Gamma Stereotactic Radiosurgery Dosimetry and QA
TG 179 – QA for Image-Guided Radiation Therapy Utilizing CT-Based Technologies
TG 194 – Simulation Training for Medical Physicists and Impact on Procedure Outcome

Other Efforts

PRACTICE GUIDELINE FOR THE PERFORMANCE OF STEREOTACTIC RADIOSURGERY

Standards for Quality Control at Canadian Radiation Treatment Centres

Stereotactic Radiosurgery/Radiotherapy

December 2006

International Journal of Radiation Oncology*Biology*Physics

Quality Assurance for Radiation Therapy: The Challenges of Advanced Technology Symposium (2007)

ASTROgram: Tell us what you think: safety considerations for SBRT

ASTRO is taking public comments on the draft *Safety Considerations for SBRT* white paper. This report on SRS and SBRT is part of a series of white papers addressing patient safety and quality assurance issues commissioned by the American Society for Radiation Oncology (ASTRO) under the umbrella of the ASTRO/AAPM/ACR Safety Task Force and is based on the results of a systematic review of literature and complemented by expert opinion. To submit comments on the white paper, please click here. The public comment period will close March 16, 2011. For more information, please go to www.astro.org/Research/CommentForm.

Where to Start? Get the Documentation

Technical Reference Guide

Revision 1.0

7 Monte Carlo: General Beam Data Measurement

7.1 General Information

7.1.1 Contents of This Chapter

Topics Covered

Section	See
Getting Started	page 131
Recommended Equipment	page 133
Coordinate Systems	page 134
Measurements in Air	page 136
Measurements in Water	page 137
Data Correction	page 135

Get the Resources

PRACTICE GUIDELINE FOR THE PERFORMANCE OF STEREOTACTIC BODY RADIATION THERAPY

The medical physicist is responsible for the technical aspects of radiosurgery and must be available for consultation throughout the entire procedure: imaging, treatment planning, and dose delivery. Those responsibilities shall be clearly defined and should include the following:

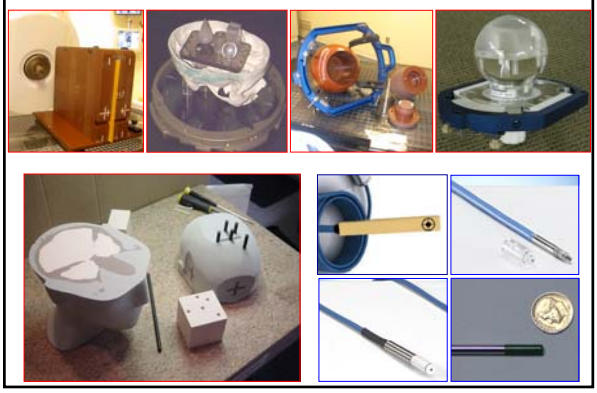
So you will need more staff!!!

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

VII.A.2. Time and personnel considerations

The complexity of SBRT requires an increased level of physicist involvement in every aspect of the process, including the initial commissioning of immobilization and stereotactic localization system, small-field measurements and verifications, and continued quality assurance. Additional physics resources will be needed to implement and maintain an SBRT program for most centers.

Get the right equipment

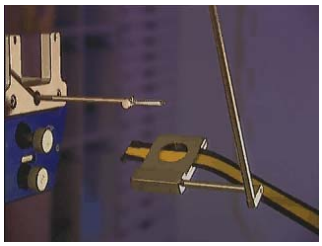


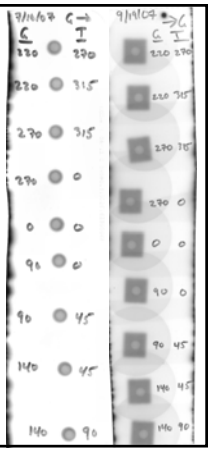
Pick the appropriate device(s)

How well can you hit your target?

There are many aspects to localization

Winston-Lutz Test





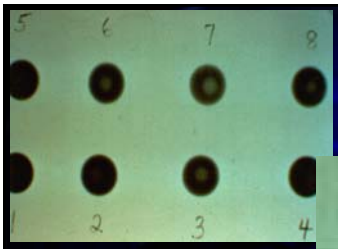
Align lasers based on W-L test
Everything else (e.g., image guidance) follows

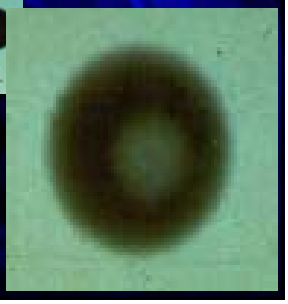
Need to perform daily

Need to perform for cones and MLC

Need to perform after any service

Isocentric Accuracy: The Winston-Lutz Test

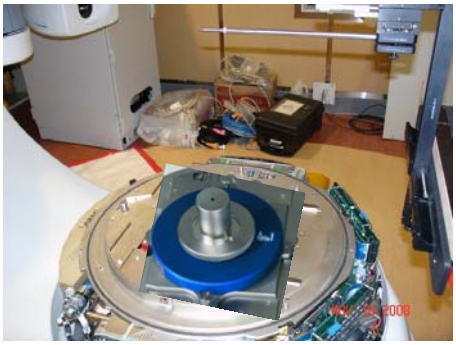




Is the projection of the ball centered within the field?

Good results ≤ 0.5 mm

Winston-Lutz Test

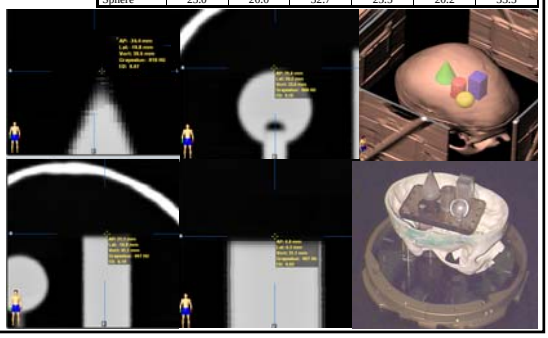


Can be performed in a variety of ways

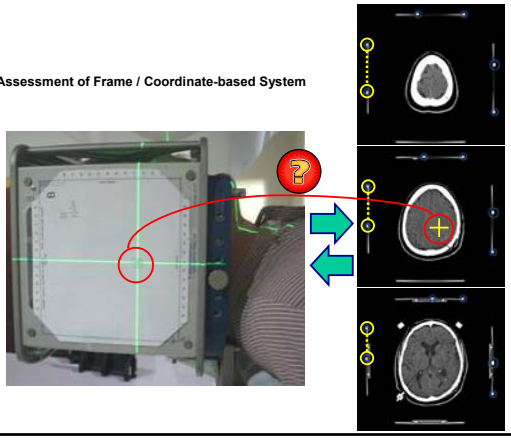
But should be clinically relevant

Assessment of Frame - Coordinate System

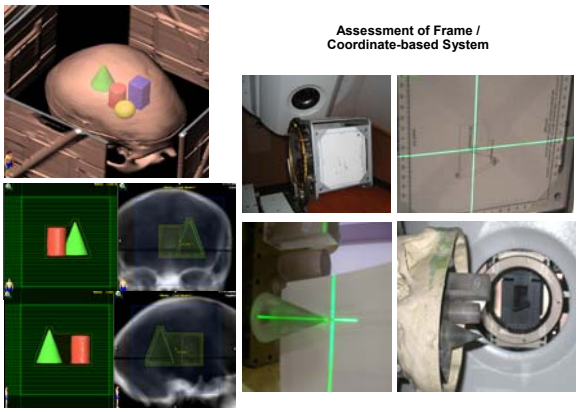
	Phantom Specifications			iPlan Stereotactic Coordinates		
Structure	AP	LAT	VERT	AP	LAT	VERT
Cylinder	0.0	0.0	30.0	1.0	0.4	30.8
Cube	20.0	-17.0	40.0	20.8	-17.1	42.4
Cone	-35.0	-20.0	40.0	-34.6	-19.7	40.8
Sphere	25.0	20.0	32.7	25.5	20.2	33.5

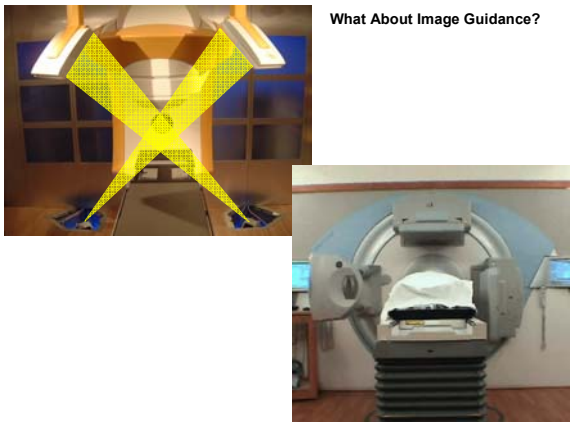


Assessment of Frame / Coordinate-based System



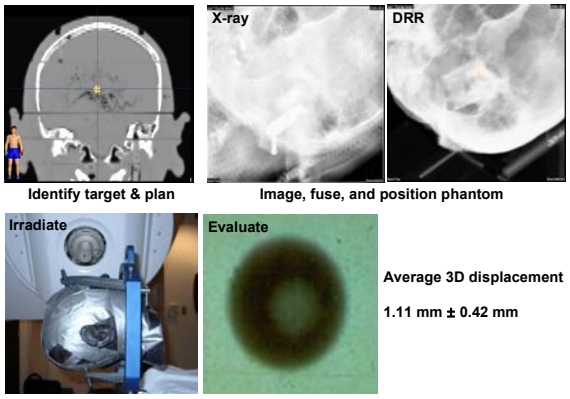
Assessment of Frame / Coordinate-based System





What About Image Guidance?

Image Guided End-to-End Assessment



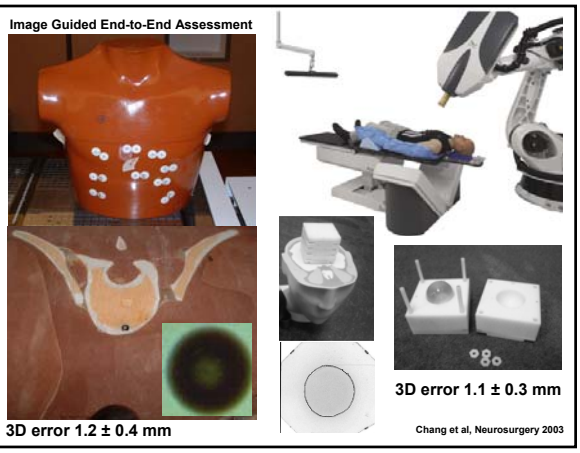
Identify target & plan

Image, fuse, and position phantom

Average 3D displacement

1.11 mm ± 0.42 mm

Image Guided End-to-End Assessment

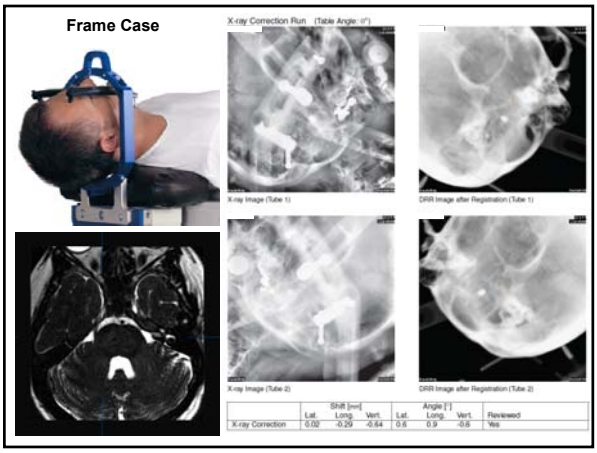


3D error 1.2 ± 0.4 mm

3D error 1.1 ± 0.3 mm

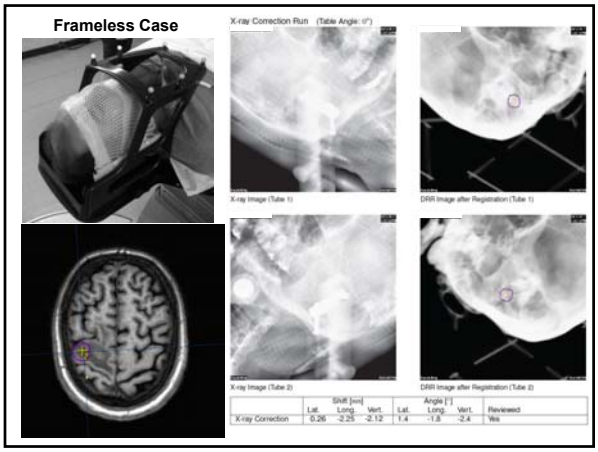
Chang et al, Neurosurgery 2003

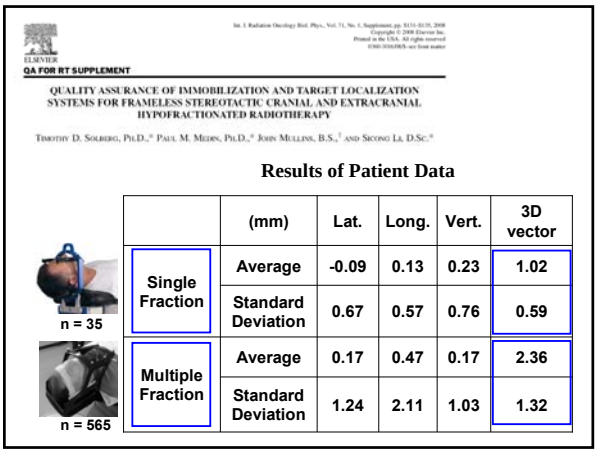
Frame Case



	Shift [mm]			Angle [°]			
	Lat.	Long.	Vert.	Lat.	Long.	Vert.	Reviewed
X-ray Correction	0.02	-0.29	-0.64	0.6	0.9	-0.6	Yes

Frameless Case





ELSEVIER

QA FOR RT SUPPLEMENT

QUALITY ASSURANCE OF IMMOBILIZATION AND TARGET LOCALIZATION SYSTEMS FOR FRAMELESS STEREOTACTIC CRANIAL AND EXTRACRANIAL HYPOFRACTIONATED RADIOTHERAPY

Timothy D. Solberg, Ph.D.,* Paul M. Medin, Ph.D.,* John Mullins, B.S.,† and Siong Lu, D.Sc.*

Results of Patient Data

n = 35

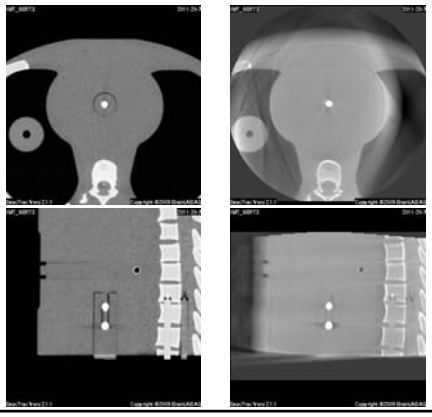
n = 565

	(mm)	Lat.	Long.	Vert.	3D vector
Single Fraction	Average	-0.09	0.13	0.23	1.02
	Standard Deviation	0.67	0.57	0.76	0.59
Multiple Fraction	Average	0.17	0.47	0.17	2.36
	Standard Deviation	1.24	2.11	1.03	1.32

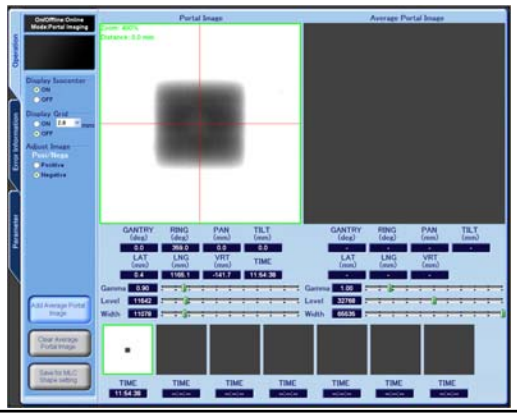
CBCT Localization – Titanium Ball

Axial

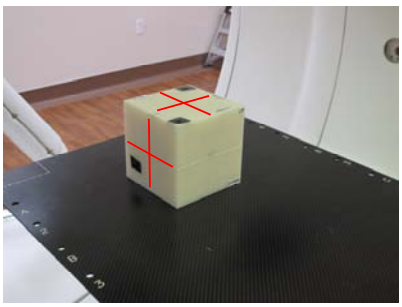
Sagittal



Hidden Target Evaluation: Titanium Ball – AP EPID Image

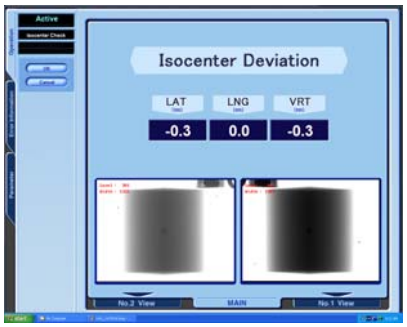


Daily QA of IGRT Systems is Essential



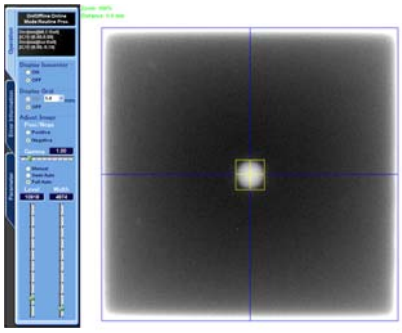
Align to Lasers

Daily QA of IGRT Systems is Essential



Assess Laser-kV coincidence

Daily QA of IGRT Systems is Essential



Assess kV-MV coincidence

Daily QA of IGRT Systems is Essential

GANTRY (deg)	RING (deg)	Measured deviation X(mm)	Y(mm)
270	0	0.0	0.0
0	0	-0.2	0.0
90	0	0.0	0.0
180	0	0.0	0.0
180	20	0.0	0.0
90	20	0.0	0.0
0	20	0.0	0.0
270	20	0.0	0.0
270	340	0.0	0.0
0	340	0.0	0.0
90	340	0.0	0.0
180	340	0.0	-0.2

Assess kV-MV coincidence

Beam data acquisition for SRS / SBRT is challenging and time consuming

Small fields
Sharp gradients

Lots of data to acquire

Cones-Direct Measurement
XLow Standard-Pencil Beam
XLow SRS-Pencil Beam
XHigh Standard-Pencil Beam

XLow Standard-Monte Carlo
XLow SRS-Monte Carlo
XHigh Standard-Monte Carlo

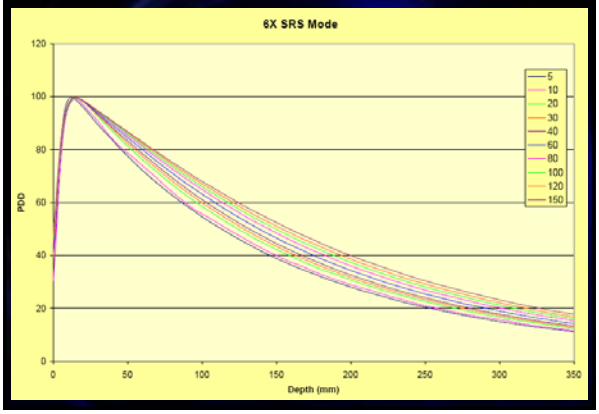
Stereotactic body radiation therapy: The report of AAPM Task Group 101

VI.A. Problems associated with dosimetry of small/ narrow field geometry

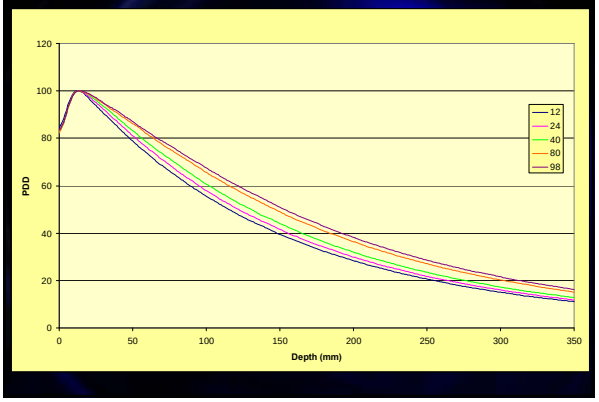
SBRT and IMRT routinely use small fields and beamlets of less than 10 mm in diameter in order to achieve the desired, highly focused and precisely modulated dose distribution. Measurement of small photon beams is complicated by the loss of lateral electronic equilibrium,[215] volume averaging,[217–220] detector-interface artifacts, collimator effects,[221–224] and detector position-orientation effects.[94,220,225]

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 to measure the basic dosimetry data, e.g., the total scatter factor (or relative output factor), tissue-maximum ratio, and off-axis ratios. Even with stereotactic detectors, careful detector-phantom setup, and detailed dose corrections, one might still find more than 10% discrepancies among the measurements of very small fields (<10 mm in diameter).[218,226–228]

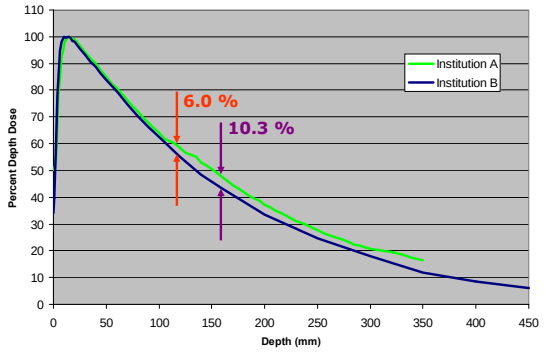
How should the data look?



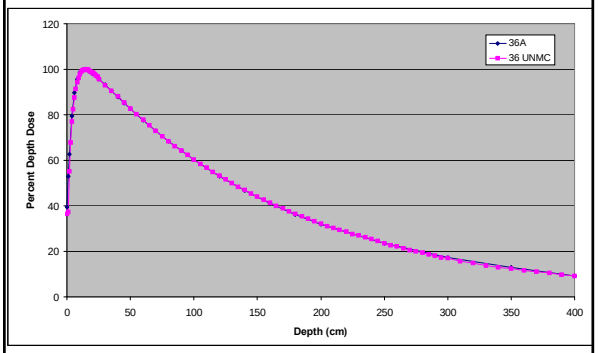
How shouldn't the data look?



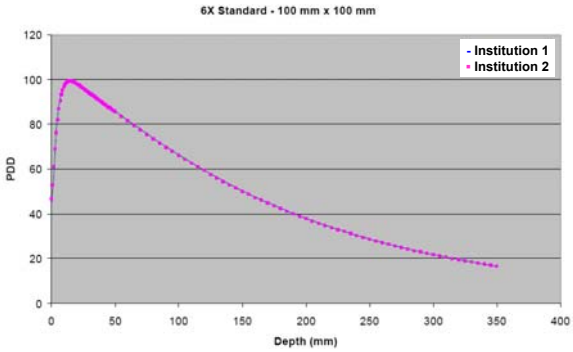
How shouldn't the data look?



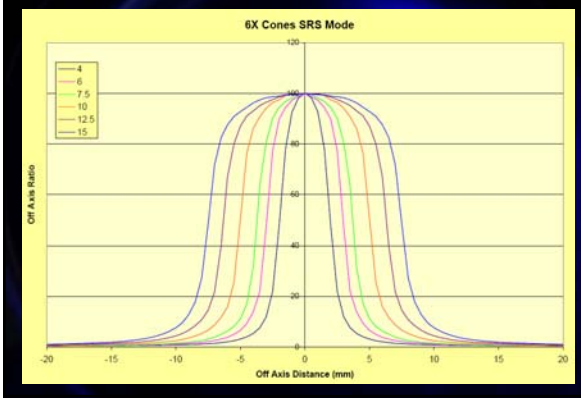
What can you do?
Compare with Other Institutions / Machines



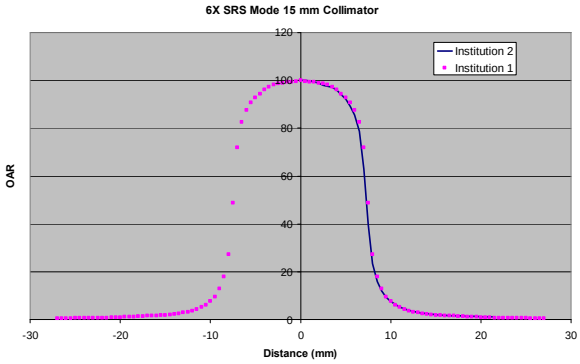
Compare with Other Institutions / Machines
Novalis Tx



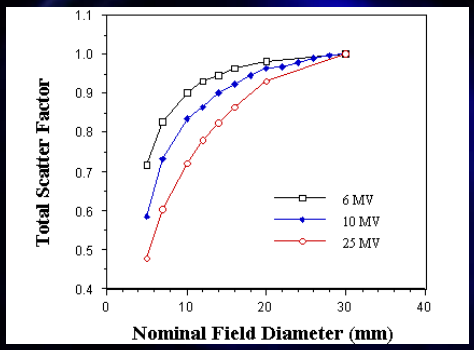
Off Axis Profiles – Cones



Compare with Other Institutions / Machines



Output Factors – difficult to measure, directly proportional to MU and dose



Are we having trouble? Yes!

U.S. Institution, July, 2010

Cone size (mm)	Original Output Factor	Re-measured Output Factor
4.0	0.312	0.699
7.5	0.610	0.797
10.0	0.741	0.835
12.5	0.823	0.871
15.0	0.862	0.890
17.5	0.888	0.904
20.0	0.903	0.913
25.0	0.920	0.930
30.0	0.928	0.940

Million $$$ question: Are the output factors correct? Compare with Other Institutions / Machines

Circular Cones – Device A

	Institution 1	Institution 2	Institution 3
4.0	0.6662	0.6590	0.6669
6.0	0.7681	0.7639	0.7689
7.5	0.8184	0.8159	0.8193
10.0	0.8704	0.8704	0.8713
12.5	0.9022	0.9026	0.9032
15.0	0.9206	0.9223	0.9216

Circular Cones – Device B

Scatter Factors for Circular Collimators

	Collimator Diameter (mm)					
	4	6	7.5	10	12.5	15
Institution 1	0.6611	0.7577	0.8097	0.8625	0.8976	0.9220
Institution 2	0.6632	0.7640	0.8116	0.8670	0.9009	0.9214
Institution 3	0.6668	0.7684	0.8163	0.8736	0.9056	0.9245

Are the output factors correct? Compare with Other Institutions / Machines

MLC Fields (XLow)

Scatter Factors for HD120, 6MV, Standard Mode

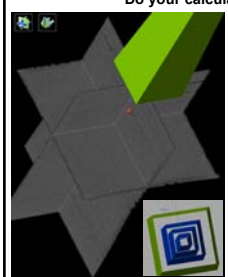
Institution 1

MLC Field Size [mm]	Jaw Field Size [mm] 7	12	22	32	42	60	80	100	140	220	254
5	0.581	0.606	0.610	0.610	0.613	0.615	0.617	0.616	0.620	0.626	0.629
10	0.627	0.712	0.722	0.721	0.724	0.727	0.726	0.729	0.731	0.739	0.741
20	0.627	0.734	0.753	0.799	0.808	0.810	0.811	0.813	0.817	0.823	0.825
30	0.627	0.734	0.801	0.832	0.844	0.855	0.858	0.860	0.863	0.870	0.872
40	0.627	0.734	0.801	0.832	0.868	0.882	0.891	0.896	0.898	0.906	0.908
60	0.627	0.734	0.801	0.832	0.874	0.922	0.937	0.948	0.955	0.962	0.962
80	0.627	0.734	0.801	0.832	0.874	0.922	0.965	0.970	0.991	0.999	1.001
100	0.627	0.734	0.801	0.832	0.874	0.922	0.965	1.000	1.017	1.025	1.029
140	0.627	0.734	0.801	0.832	0.874	0.922	0.965	1.000	1.048	1.068	1.068
220	0.627	0.734	0.801	0.832	0.874	0.922	0.965	1.000	1.048	1.106	1.113
254	0.627	0.734	0.801	0.832	0.874	0.922	0.965	1.000	1.048	1.106	1.122

Institution 2

MLC Field Size [mm]	Jaw Field Size [mm] 7	12	22	32	42	60	80	100	140	220	254
5	0.591	0.614	0.619	0.619	0.623	0.626	0.625	0.629	0.631	0.636	0.639
10	0.621	0.716	0.727	0.728	0.730	0.733	0.733	0.735	0.738	0.743	0.746
20	0.621	0.735	0.794	0.807	0.814	0.816	0.817	0.819	0.822	0.829	0.831
30	0.621	0.735	0.800	0.834	0.845	0.857	0.861	0.861	0.865	0.870	0.871
40	0.621	0.735	0.800	0.834	0.869	0.886	0.894	0.898	0.901	0.907	0.909
60	0.621	0.735	0.800	0.834	0.872	0.923	0.936	0.947	0.954	0.961	0.962
80	0.621	0.735	0.800	0.834	0.872	0.923	0.966	0.980	0.991	1.000	1.002
100	0.621	0.735	0.800	0.834	0.872	0.923	0.966	1.000	1.018	1.027	1.029
140	0.621	0.735	0.800	0.834	0.872	0.923	0.966	1.000	1.052	1.069	1.071
220	0.621	0.735	0.800	0.834	0.872	0.923	0.966	1.000	1.052	1.110	1.116
254	0.621	0.735	0.800	0.834	0.872	0.923	0.966	1.000	1.052	1.110	1.122

Beam data is good? The job is ~ half complete. Dosimetric commissioning: Do your calculations agree with measurement?



Depth (cm)	Measured	iPlan	% diff
FS = 2 x 2 cm²			
2.0	98.32	98.00	0.33
3.0	92.73	93.00	-0.29
4.0	86.96	87.00	-0.05
5.0	81.74	82.00	-0.32
7.5	69.32	69.00	0.46
10.0	59.08	59.00	0.14
12.5	50.36	50.00	0.71
15.0	43.09	43.00	0.21

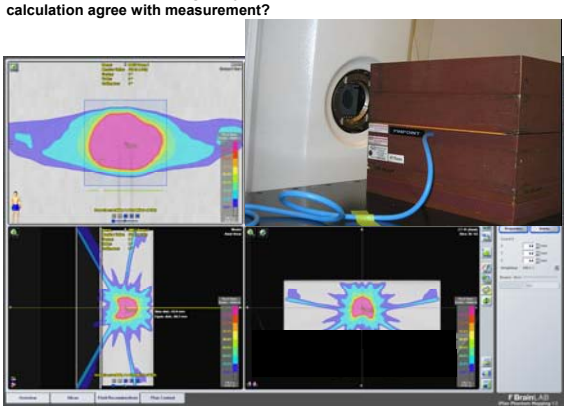
Depth (cm)	Measured	iPlan	% diff
FS = 4 x4 cm²			
2.0	98.79	98.00	0.80
3.0	93.97	94.00	-0.03
4.0	88.80	88.00	0.90
5.0	83.84	84.00	-0.19
7.5	72.03	72.00	0.04
10.0	61.81	62.00	-0.31
12.5	52.99	53.00	-0.02
15.0	45.46	45.00	1.01

Depth (cm)	Measured	iPlan	% diff
FS = 6 x 6 cm²			
2.0	99.00	99.00	0.00
3.0	94.21	95.00	-0.84
4.0	89.97	90.00	-0.03
5.0	85.39	86.00	-0.71
7.5	74.31	75.00	-0.93
10.0	64.17	64.00	0.26
12.5	55.32	56.00	-1.23
15.0	47.72	48.00	-0.59

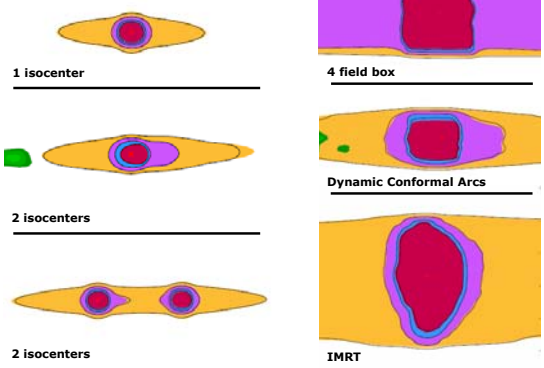
Depth (cm)	Measured	iPlan	% diff
FS = 10 x 10 cm²			
2.0	98.94	99.00	-0.06
3.0	94.93	95.00	-0.07
4.0	90.55	90.00	0.61
5.0	86.20	86.00	0.23
7.5	76.15	76.00	0.20
10.0	66.69	66.00	1.03
12.5	58.26	58.00	0.45
15.0	50.83	51.00	-0.33

Start simple: can your TP system reproduce your measured beam data?

Dosimetric commissioning: Do your calculation agree with measurement?



Comprehensive range of energy, dose, technique, etc.



The beam data / treatment planning system look good (so far). What else should I look for?

End-to-End test incorporating both localization and dosimetry

End-to-End test incorporating both localization and dosimetry

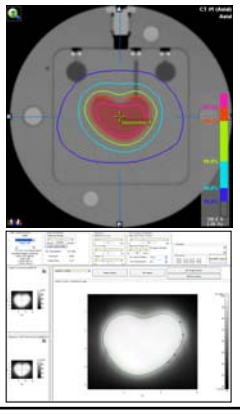


Image-guided dosimetric assessment

Image guided dosimetric assessment

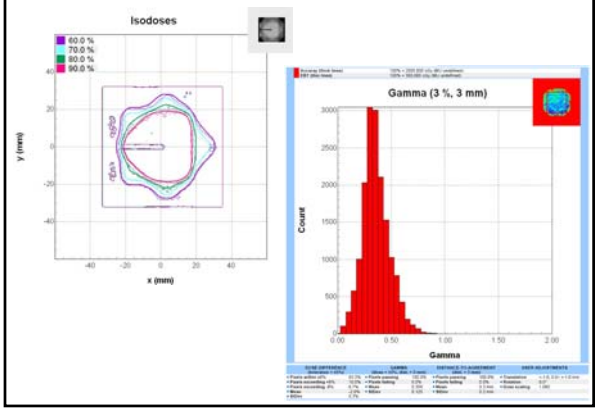


Image guided dosimetric assessment

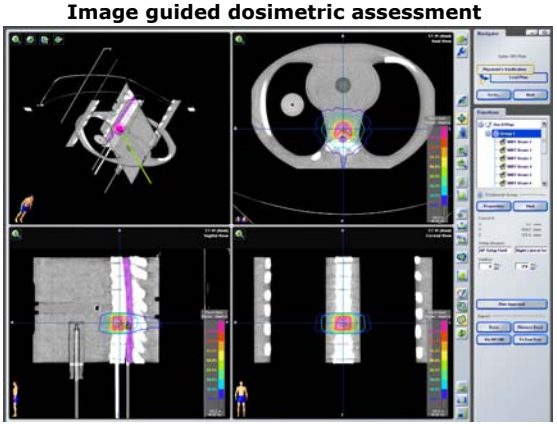
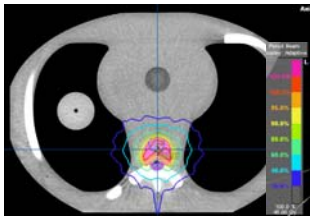
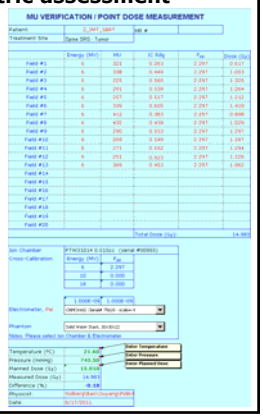
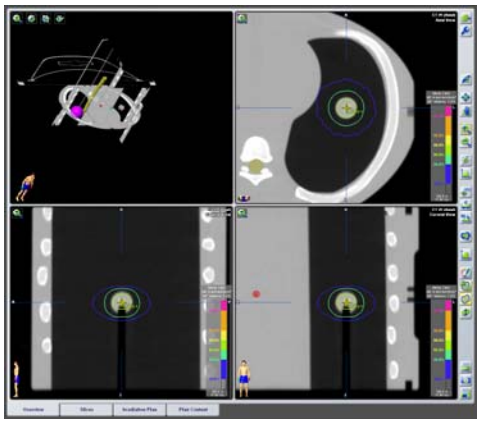


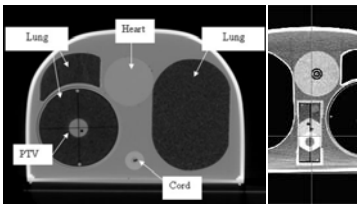
Image guided dosimetric assessment



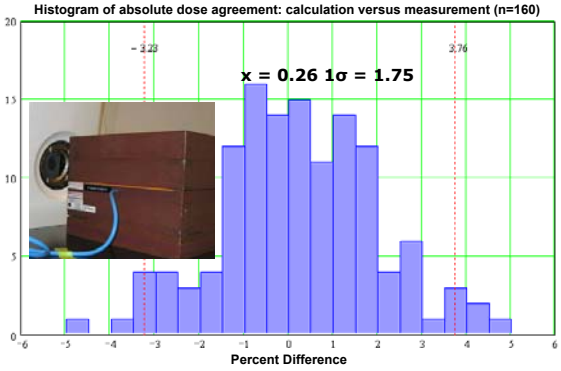




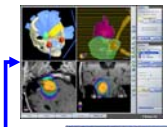
Use ALL the RPC phantoms!!!



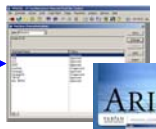
Track your dosimetric results to look for systematic errors and trends



Are your electronic systems configured correctly?



Planning

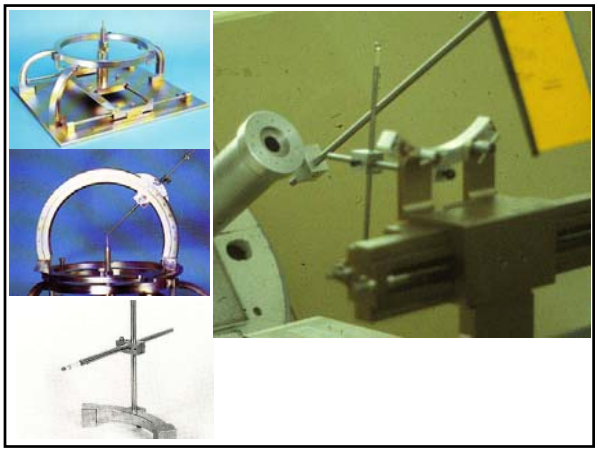


R/V

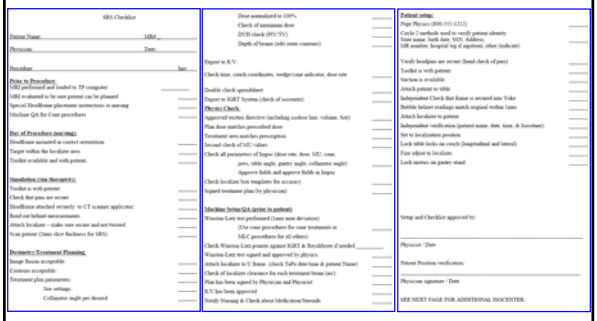
Do all of your commissioning in clinical mode, and through your R/V system

Tx Unit

Patient Specific QA – Dosimetry?????



Patient Specific QA – Checklists!



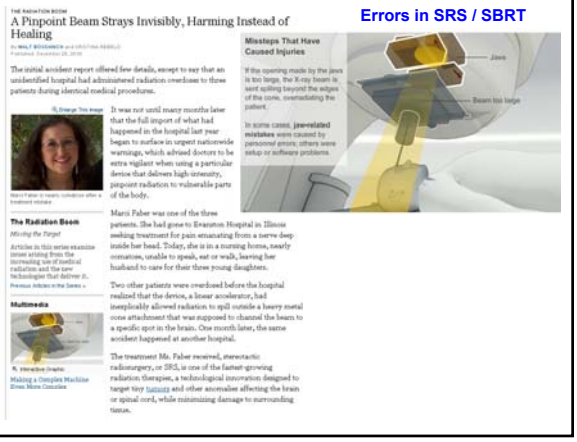
Wrong site errors are common

U.S.NRC

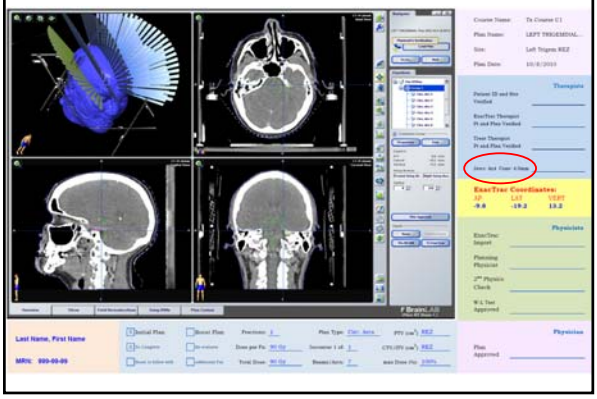
Event Description	Treatment Implication
Patient orientation entered incorrectly at MR Scanner	Wrong location treated
Fiducial box not seated properly during CT imaging	Wrong location treated
Malfunction of automatic positioning mechanism following re-initialization	Wrong location treated
Right trigeminal nerve targeted instead of left	Wrong location treated
Facial nerve targeted instead of trigeminal nerve	Wrong location treated
Mistake in setting isocenter coordinates	Wrong location treated
Head not secured to stereotactic device (2 events)	Wrong location treated
Selected collimators did not match planned	Wrong dose/distribution delivered
Physician mistakenly typed 28 Gy instead of 18 Gy into planning system	Wrong dose delivered
Physicist calculated prescription to 50% isodose instead of 40%	Wrong dose delivered
Microphone dislodged, causing stereotactic device to break	Treatment halted after 2 of 5 fractions
Couch moved during treatment	None; personnel interrupted treatment

Patient Specific QA – Checklists!

Errors in SRS / SBRT



Patient Specific QA – Checklists!



UCLA Radiation Oncology - Radiosurgery Check List

Patient Name: _____ Patient ID #: _____ Date: _____

Step	*Isocenter Operations*	*Isocenter 1*	*Isocenter 2*	*Isocenter 3*	*Isocenter 4*	*Isocenter 5*	*Isocenter 6*
1	Arrange sheet and pad on couch.						
2	Set the couch to 0 & coll to 90.						
3	Take photos of patient (2).						
4a	Set backup jaws to 4.0 x 4.0cm. (2 initials & size).	/	/	/	/	/	/
4b	Install the cone. (2 initials & size).	/	/	/	/	/	/
5	Position isocenter templates on positioning box. 2 init.						
6	Enable linac switches 1, 2, and 4. Unlock microadjusters/table locks.						
7	Fit ring onto patient head frame.						
8	Attach large bolts (2) onto ring.						
9	Assist patient onto couch.						
10	Secure frame to couch mount. Tighten large bolts.						
11	Attach small bolts (2) onto ring.						
12	Secure patient to couch w/ strap.						
13	Attach positioning box to the frame.						
14	Positon positioning box to the isocenter.						
15	Tighten Lat & Long table locks and disable linac switches 1,2,4.						
16	Use microadjusters, reposition box to isocenter, lock microadjusters.						
17	Review of fields by physician.						