New SRS Technology and Program Implementation

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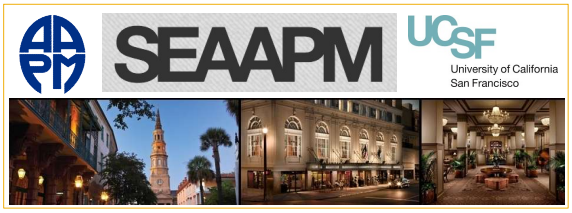
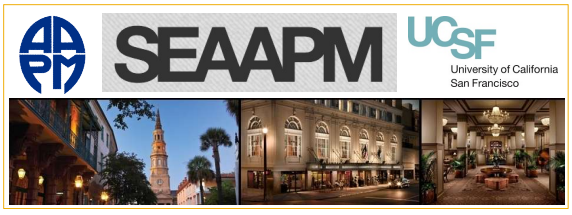


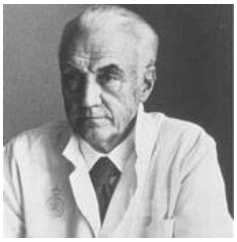
SEAAPM SYMPOSIUM & SCIENTIFIC MEETING FEB. 23-25, 2017

New SRS Technology and Program Implementation

- Evolution of Equipment Delivery Technology
- SRS Program Requirements
- Advances in Image Guidance
- Treatment of Brain Metastases



SEAAPM SYMPOSIUM & SCIENTIFIC MEETING FEB. 23-25, 2017

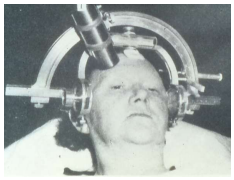


The March of Technology in SRS

"A single high dose of radiation, stereotactically directed to an intra-cranial region of interest. May be from X-ray, gamma ray, protons or heavy particles." - Lars Leksell, 1951

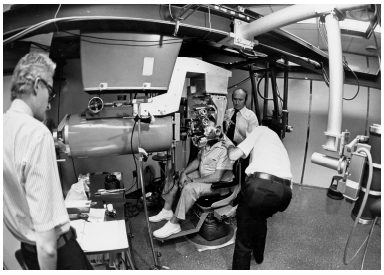
"It is clear, however, that the radiation in the 200 kilovolt range used here should be replaced by radiation of higher energy. This would give better depth dose, especially with the extremely small fields used here, and also a better definition of the beam."

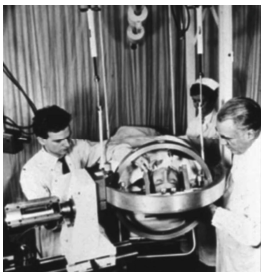
L Leksell, The stereotaxic method and radiosurgery of the brain, Acta Chir Scand. 13;102(4):316-9, 1951.



21 portals, each with a skin dose of 900 R
Total dose to target area 1,650 R
6 mm aperture
74 minute Tx time
Pain began to subside after ~2 weeks
Pain free for 18 years

L Leksell, Stereotaxic radiosurgery in Trigeminal Neuralgia, Acta Chir Scand. 137:311-314, 1971.



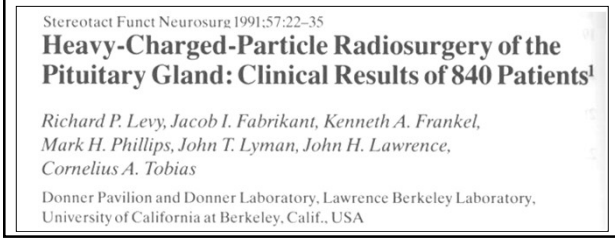


Better Form of Radiation

Larsson B, Leksell L, et al, The high energy proton beam as a neurosurgical tool. Nature 182:1222-3, 1958

Tobias CA, Lawrence JH, et al, Pituitary irradiation with high-energy proton beams. A preliminary report. Cancer Res 18:121-34, 1958

Kjellberg RN et al, Proton-beam therapy in acromegaly. NEJM 278:689-95, 1968.

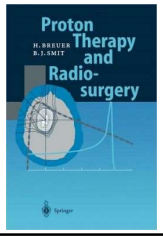


Stereotact Funct Neurosurg 1991;57:22–35

Heavy-Charged-Particle Radiosurgery of the Pituitary Gland: Clinical Results of 840 Patients[1]

Richard P. Levy, Jacob I. Fabrikant, Kenneth A. Frankel, Mark H. Phillips, John T. Lyman, John H. Lawrence, Cornelius A. Tobias

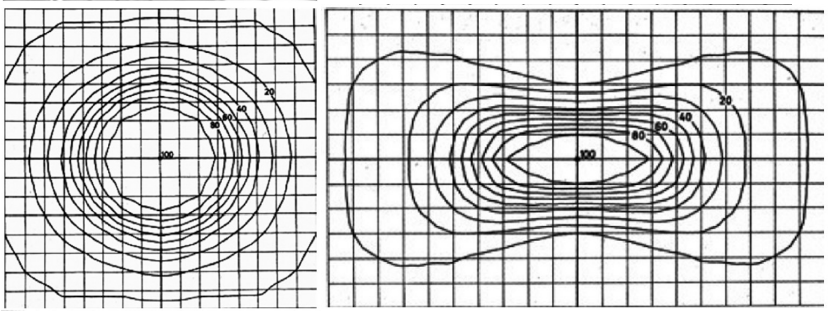
Donner Pavilion and Donner Laboratory, Lawrence Berkeley Laboratory, University of California at Berkeley, Calif., USA



Better Form of Radiation

The 1st Gamma Knife
179 Co-60 sources
3 x 7 and 5 x 7 rectangular collimators
(designed for thalamotomy)

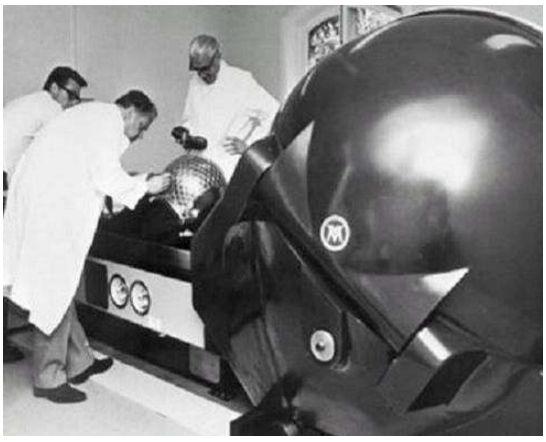
First patient treated Oct. 25, 1967
Young boy with a craniopharyngioma

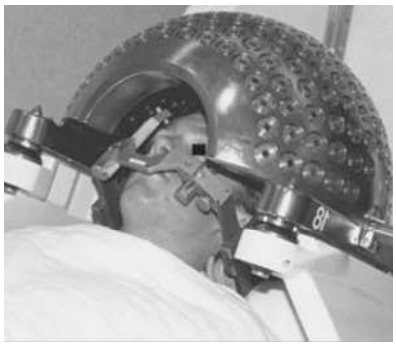


Larsson, Liden & Sarby, Irradiation of small structures through the intact skull, Acta Radiol Ther Phys Biol. 13(6):512-34, 1974.

The Next Gamma Knife

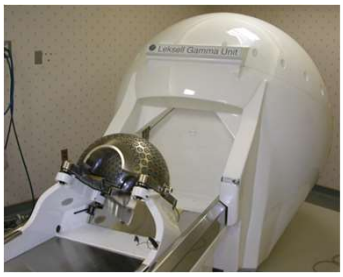
2nd Unit 201 Co-60 sources,
4, 8 and 14 mm circular collimators
1st treatment in 1974 at Karolinska University Hospital
3rd Unit installed in Buenos Aires in 1983 (Hernan Bunge)
4th Unit installed in Sheffield in 1985 (David Forster)





The Commercial Gamma Knives

Model U

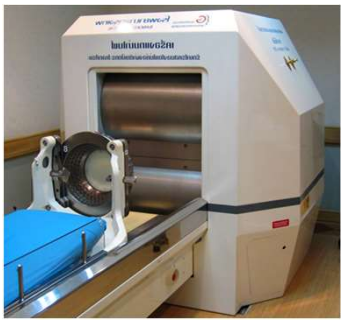


Lunsford LD, Maitz A, Lindner G, First United States 201 source cobalt-60 gamma unit for radiosurgery, Appl Neurophysiol. 50:253-6, 1987.

Overall deviation approximately 0.25 mm

Wu et al, Physics of Gamma Knife Approach on Convergent Beams in Stereotactic Radiosurgery , Int J Radiat Onc Biol Phys. 18:941-949, 1990.

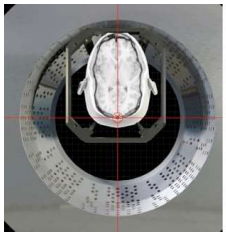
Model B



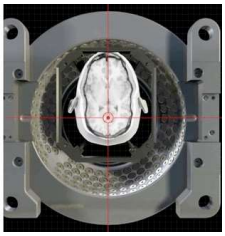
Model 4C

Perfexion

- 8 independent sectors, each with 24 Co-60 sources
- 4, 8, and 16 mm collimators can be combined within each sector
- 6600 Ci nominal activity produces dose rate of > 3 Gy/min
- Larger treatment field of view



Perfexion



Gamma Knife

Linear Accelerators - Better Form of Radiation, but not Accurate

United States Patent [19]
Derechinsky et al.

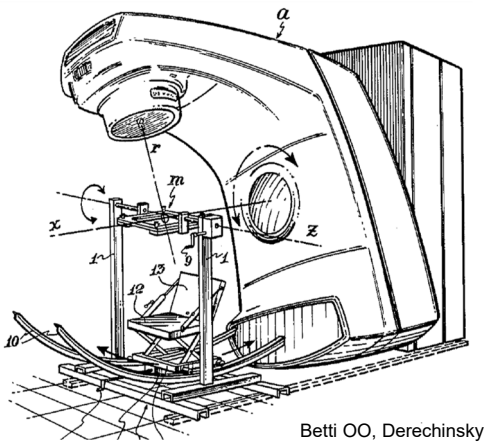
[11] **Patent Number: 4,583,537**
[45] **Date of Patent: Apr. 22, 1986**

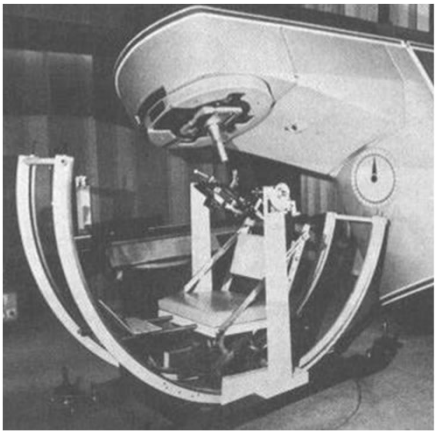
[54] **CONVERGENT MULTIBEAM UNIT FOR RADIATION**

[76] Inventors: **Victor E. Derechinsky; Osvaldo O. Betti,** both of Sarmiento 2172, Buenos Aires, Argentina, 1044

FOREIGN PATENT DOCUMENTS
2724321 12/1977 Fed. Rep. of Germany ... 128/303 B

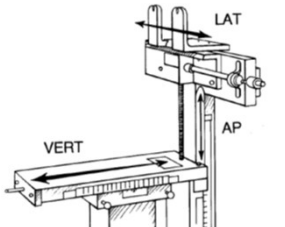
Primary Examiner—Edward M. Coven
Attorney, Agent, or Firm—Berman, Aisenberg & Platt

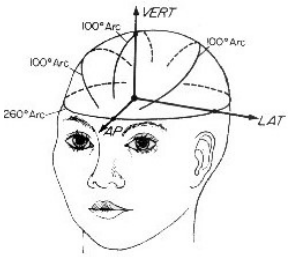


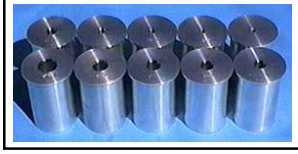


Betti OO, Derechinsky VE, Hyperselective encephalic irradiation with linear accelerator, Acta Neurochir. 33: 385, 1984

Linear Accelerators - Better Form of Radiation, but not Accurate?







Lutz, et al

Friedman and Bova

Radiation Accuracy = 0.5 ± 0.2 mm (n=9)
Lutz W, et al, A system for stereotactic radiosurgery with a linear accelerator, IJROBP 14(2):373-81, 1988

Radiation Accuracy = 0.2 ± 0.1 mm (n=40)
Friedman WA, Bova FJ, The University of Florida radiosurgery system, Surg Neurol. 32(5):334-42, 1989

Modern Linear Accelerators

Assemble the Guidance Documents

TG 42 – Stereotactic Radiosurgery
TG 76 – Management of Motion in Radiation Oncology
TG 68 – Intracranial Stereotactic Positioning Systems
TG 101 – Stereotactic Body Radiotherapy
TG 104 – kV Localization in Therapy
TG 135 – QA for Robotic Radiosurgery
TG 142 – QA of Medical Linear Accelerators
TG 147 – QA for Non-Radiographic Radiotherapy Localization and Positioning Systems
TG 176 – Task Group on Dosimetric Effects of Immobilization Devices
TG 178 – Gamma Stereotactic Radiosurgery Dosimetry and QA
TG 179 – QA for Image-Guided Radiation Therapy Utilizing CT-Based Technologies
ASTRO SRS/SBRT Quality and Safety White Paper
ACR/ASTRO Standards

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 155 – Small Fields / Non-Equilibrium Condition Photon Beam Dosimetry

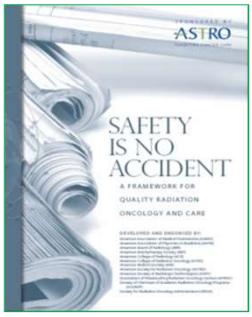
Assemble the Guidance Documents

ACR-ASTRO, 2014

ACR-ASTRO, 2014

AAPM TG-101, 2010

PRO, 2012



ASTRO, 2012

ASTRO SRS/SBRT White Paper

SRS/SBRT as a well thought out program, not an addition / afterthought
- Team approach, plan ahead

SRS/SBRT specific training

SRS/SBRT expertise/competence, including personnel certification
- Follow nationally accepted standards, clinical and physics

SRS/SBRT accreditation / credentialing

Adequate resources:
- Time, equipment, personnel
- Quality management system, including reporting and ongoing quality improvement, and peer review
- Physician and physicist supervision for each procedure

Greatly increased vendor responsibility

Table 1. Essential planning aspects for developing a new SBRT program and/or considering new disease sites.

Recommendation	Duration or Frequency	Reference
Establish clinical program goals, specify disease sites, identify program specialists, develop guidelines for treatment, follow-up and assessment.	**CLINICAL GOALS**	33-34, 36
Identify required resources: expertise, personnel, technology, time.	Initially, and for each new technology and/or disease site	32-33
Perform technology assessment commensurate with clinical goals, identify equipment and processes for simulation, immobilization, image guidance, management of organ motion, treatment delivery.	**APPROPRIATE TECHNOLOGY**	32-33
Perform assessment of staffing levels, develop processes for initial and ongoing training of all program staff.	Initially, and for each new technology and/or disease site	32-35
Develop and use checklists for all aspects of SRS/SBRT processes.	Initially, and for each new technology and/or disease site	34-36
Provide documentation for a culture and environment fostering clear and open communication.	**SAFETY CULTURE**	32
Develop quality assurance processes that encompass all clinical and technical SBRT program aspects, clearly following available guidance, with regard to procedures and tolerances.	Initially, and for each new technology and/or disease site	32-36, 43
Conduct clinical SBRT patient conferences for pre-treatment planning and post-treatment review.	Ongoing	
Develop processes for documentation and reporting, peer review, regular review of processes and procedures, updating clinical guidelines and recommendations, ongoing needs assessment, and continuous quality improvement.	**PEER REVIEW, CONTINUOUS QUALITY IMPROVEMENT**	32-35

SRS/SBRT as a well thought out program, not an addition/afterthought

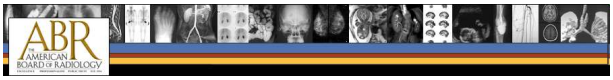
Table 2. Personnel qualifications of a stereotactic program

Recommendation	Duration or Frequency	Reference
All personnel must demonstrate initial attainment of knowledge and competence in their respective discipline through graduation from an approved educational program, board certification and licensure as appropriate.	Initially	32-33
All personnel must receive vendor provided equipment -specific training prior to involvement in an SBRT program.	16 hours per staff member	32, 34
All personnel must receive disease-site-specific training prior to involvement in a stereotactic program.	16 hours per staff member	32, 34
All personnel must maintain their skills by lifelong learning through continuing professional development. For physicians and physicists this is the ABR Maintenance of Certification process.	Ongoing	32, 34-35
There must be adequate resources in place to meet the demands of the stereotactic program with sufficient staff. Staff must have sufficient time to carry out the necessary tasks without undue pressure.	Ongoing	32-33, 37, 39
Job description and list of responsibilities should be clearly delineated in writing for all stereotactic program individuals.	Initially	32-33
Non-radiation oncology specialists can sometimes lend expertise in the area of target delineation for SBRT, given a deep fund of knowledge in the anatomy of various body sites. Examples of such specialists include neurosurgeons, pulmonologists, hepatologists, and oncologic surgeons.		

SRS/SBRT specific training

SRS/SBRT expertise/competence, including personnel certification

Adequate resources



Board Certification is a Minimum Qualification

Table 3. Essential commissioning elements of a stereotactic program.

Recommendation	Duration	Reference
Appropriate resources, specialized equipment, personnel, time, must be evaluated and available prior to initiation of acceptance and commissioning processes and procedures.	8-16 weeks	32-33
Independent assessment of measured beam data should be performed prior to initiating a clinical SBRT program.	1 week	
Independent verification of absolute calibration should be performed prior to initiating a clinical stereotactic program.	<1 week	
Comprehensive treatment planning system commissioning incorporating a full range of stereotactic delivery parameters and techniques, and specifically addressing use of inhomogeneity corrections with specific dose algorithm(s), must be performed prior to initiating a clinical stereotactic program.	4-8 weeks	33
Independent verification of system commissioning, utilizing appropriate specialized phantoms such as those from the Radiological Physics Center, should be performed prior to initiating a clinical stereotactic program and prior to initiating new clinical sites and/or treatment techniques.	2-4 weeks	
Thorough commissioning of simulation devices and processes, including 4D CT if used, must be performed prior to initiating a clinical stereotactic program.	2-4 weeks	33
Management of respiratory motion is an essential element of SBRT simulation, planning and delivery. Measures must be developed to ensure effective and safe operation of these technologies.	2-4 weeks	33-34, 40
Evaluation of individual and end-to-end localization capabilities of the image guidance system must be performed prior to initiating a clinical stereotactic program and prior to initiating new clinical sites and/or treatment techniques.	2 weeks	33-34
End-to-end commissioning procedures, incorporating simulation, treatment planning and dosimetry, image guidance, management of motion, and treatment management systems, must be performed prior to initiating a clinical stereotactic program and prior to initiating new clinical sites and/or treatment techniques. In addition, users may find it useful to deliberately introduce known errors, and evaluate the capabilities of the system and processes in detecting such errors.	2 weeks	33

Thorough commissioning, end-to-end assessment, independent verification

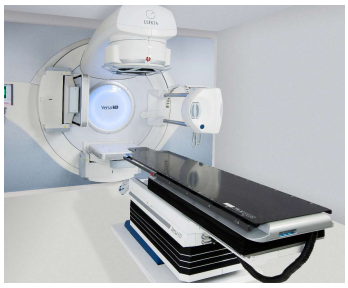
Table 7. Patient-specific quality assurance activities.

Recommendation	Reference
The course of treatment, including dose schedule, normal tissue constraints, CTV/ITV and PTV margins, should follow established national guidelines, with careful consideration of the setup accuracy of the particular system in place at the given institution. Examples of dose constraints used at one institution are provided Reference 61.	33-34, 63
Treatment protocols that spell out responsibilities and detailed procedures ,must be available for all personnel, including therapists, medical physicists and radiation oncologists.	
One or more comprehensive checklists should be used to guide all aspects of the treatment process. Examples of checklists used at several institutions are provided in Appendix 2 and 3. Note: these checklists intended to serve as a template, and should not be adopted in whole or in part. They are institution and technology specific are meant solely for illustration.	34-36
Appropriate program team members, including radiation oncologist(s), medical physicist(s) and radiation therapist(s) must be present as described by their responsibilities during the various aspects of the treatment process.	33-34
All imaging for anatomical definition / contouring purposes should be performed with the patient in the treatment position, and if possible, in the immobilization device to be used for treatment.	33
Patient-specific pre-treatment QA is considered necessary for a safe SBRT program. Prior to initiating treatment for each and every patient, the institution must verify that there is adequate information available to ensure that the process is correct. The QA methods used must verify the integrity of the data transfer from the treatment planning system to the treatment management system and the accuracy of the dose to be delivered.	33
Extra verification steps must be taken in cases where a laterality or adjacency errors could be made. This would include, for example, radiosurgery for trigeminal neuralgia, thalamotomy and pallidotomy, and spine SBRT.	
An independent review of all planning, setup and treatment parameters must be performed prior to initiating treatment.	
A radiation oncologist should be present at the treatment unit before irradiation to confirm localization based on reference images and review and approve the results of image guidance procedures prior to each treatment. A medical physicist must be present at the treatment unit before and during imaging, and through the entirety of each treatment to ensure that all issues of patient position, proper machine settings, and any technical issues of treatment delivery are safely and correctly applied. Procedures for image review and setup correction must be readily available for all personnel.	32-34
All images, corrections, and treatment parameters must be saved and available for subsequent review. If such information is not captured by the treatment machine / treatment management system, then it must be recorded manually.	32

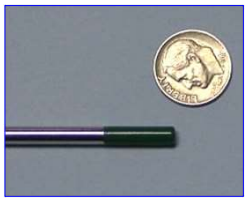
Table 7. Patient-specific quality assurance activities.

Procedure	Performed
Validate target construction, appropriateness of planning directives and normal tissue toxicity risks, establish immobilization, breathing management and image guidance strategy, validate plan and monitor units, ensure adequate image and structure information is provided to support localization method	Prior to first fraction
Validate initial setup instructions, check script against downloaded plan, ensure sufficient documentation, check validity of monitor units, supervise/assist patient positioning, verify delivery of treatment on site	At first fraction
Check validity of script and setup, assist in image guided localization, ensure adequately trained personnel familiar with the individual treatment are present to perform irradiation	Prior to each fraction

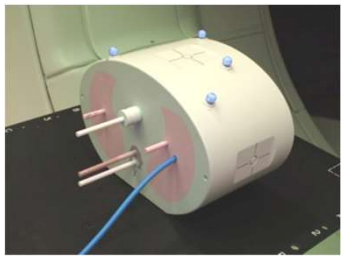
Select the appropriate equipment



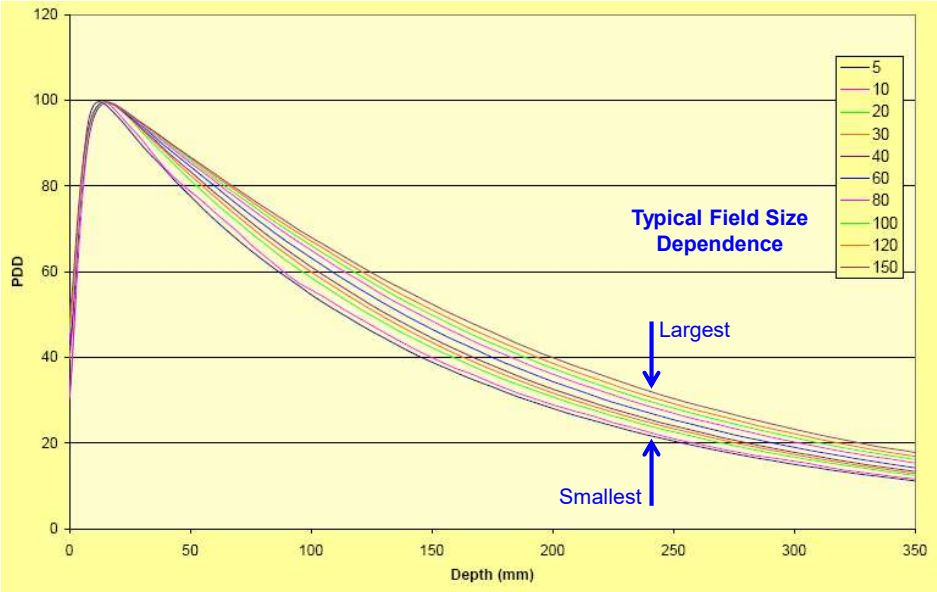
Select the appropriate equipment



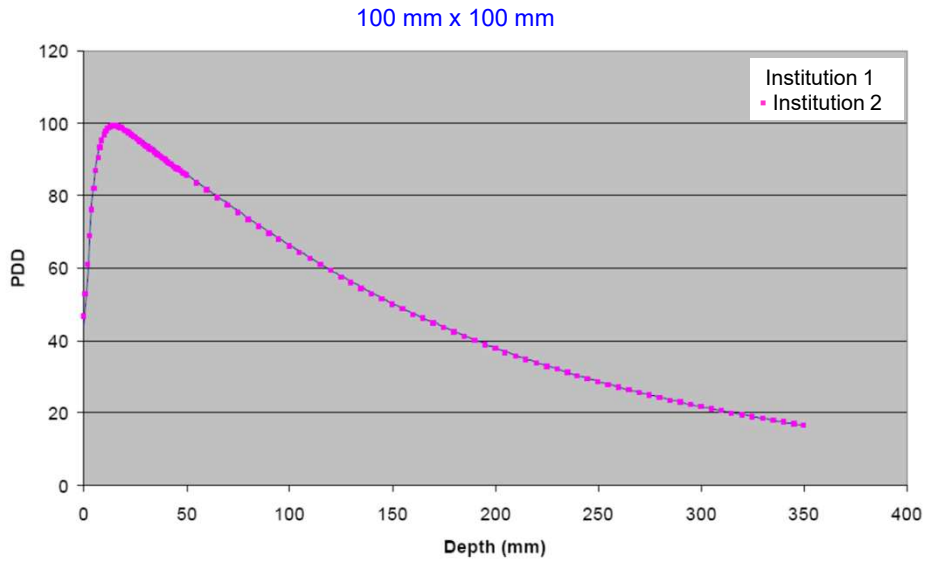


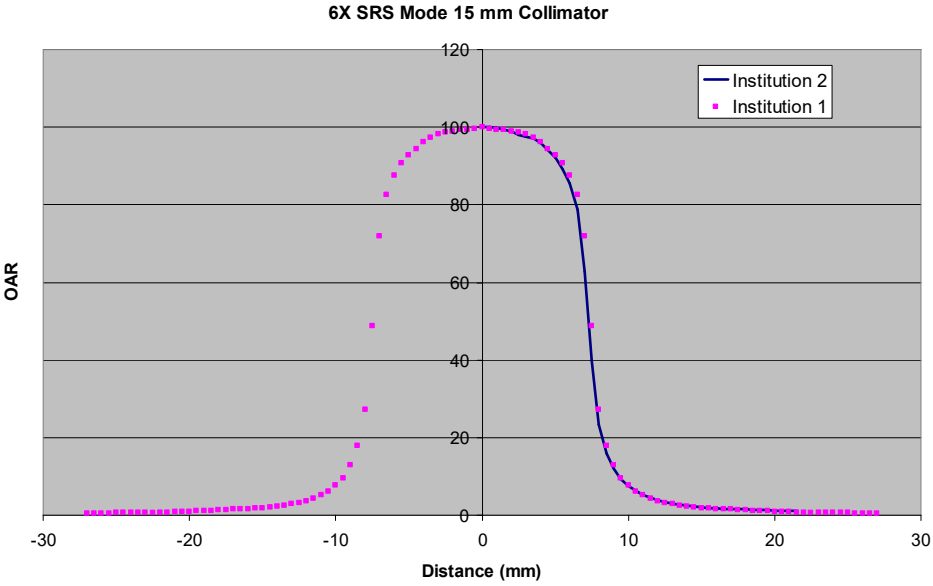
How do small field PDD behave?



Compare beam data with appropriate references



Compare beam data with appropriate references



Compare beam data with appropriate references

Output Factors for MLC

Novalis Tx, 6X, HD-120 MLC

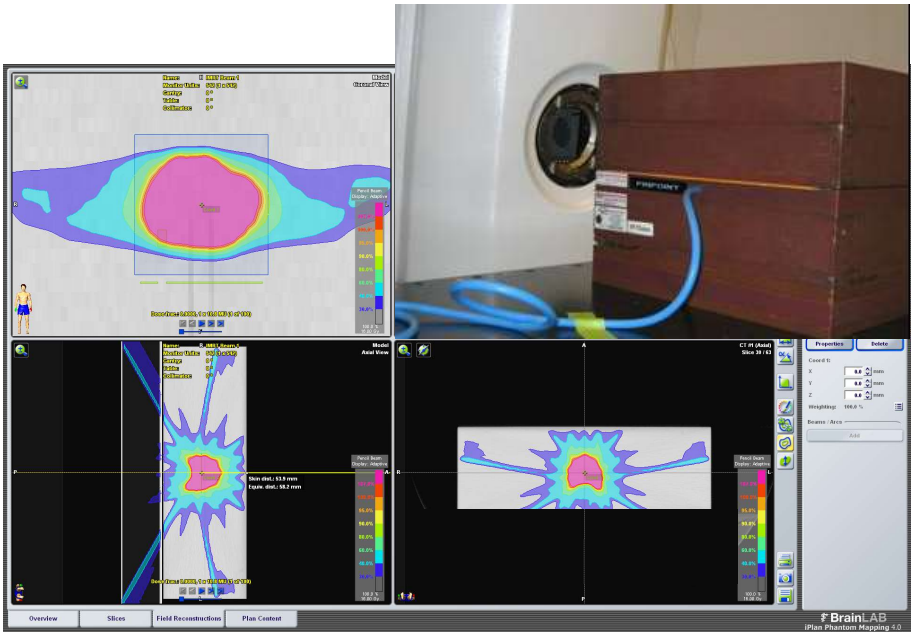
Institution 2

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

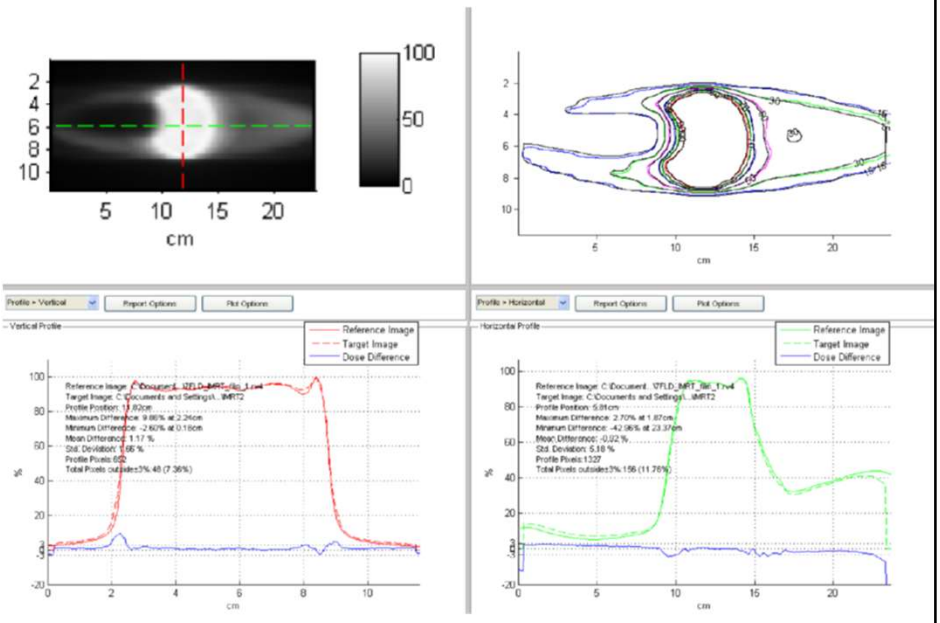
TrueBeam STx, 6X, HD-120 MLC

MLC Field Size [mm^2] \ Jaw Field Size [mm^2]	8	12	22	32	42	60	80
5	0.5870	0.5962	0.5981	0.5985	0.5989	0.6005	0.601
10	0.6723	0.7313	0.7393	0.7400	0.7400	0.7420	0.742
20	0.6719	0.7488	0.8015	0.8082	0.8110	0.8130	0.815
30	0.6719	0.7488	0.8082	0.8367	0.8447	0.8544	0.858
40	0.6719	0.7488	0.8082	0.8429	0.8690	0.8827	0.890
60	0.6719	0.7488	0.8082	0.8420	0.8739	0.9221	0.936
80	0.6719	0.7488	0.8082	0.8420	0.8735	0.9226	0.965
100	0.6719	0.7488	0.8082	0.8420	0.8735	0.9235	0.966
140	0.6719	0.7488	0.8082	0.8420	0.8735	0.9235	0.966
220	0.6719	0.7488	0.8082	0.8420	0.8735	0.9235	0.966
254	0.6719	0.7488	0.8082	0.8420	0.8735	0.9235	0.966

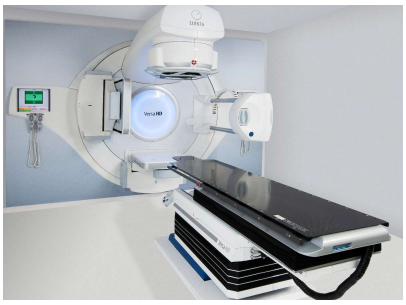
Appropriate TPS commissioning



Appropriate TPS commissioning



Modern Linear Accelerators



What can we do differently with Image guidance and MLC

How accurate are head frames?

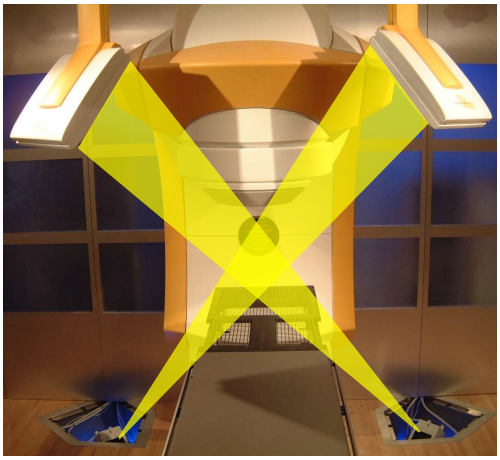
CT Slice Thickness (mm)	Measurement	BRW (mm)	CRW (mm)	Compass (mm)	Leksell (mm)
1	Mean	1.9	1.8	1.2	1.7
	SD	1.0	1.1	0.6	1.0
	Min value	0.1	0.0	0.3	0.2
	Max value	5.0	4.9	3.2	4.9
	95% CI	3.6	3.6	2.2	3.4
	99.9% CI	5.0	5.2	3.1	4.8
4	Mean	2.7	2.6	2.5	2.6
	SD	1.3	1.5	1.2	1.4
	Min value	0.0	0.0	0.4	1.0
	Max value	7.0	7.1	6.4	7.2
	95% CI	4.8	5.1	4.5	4.9
	99.9% CI	6.7	7.2	6.2	6.9
8	Mean	6.6	6.6	5.1	5.4
	SD	3.1	3.0	2.3	2.4
	Min value	0.0	0.3	0.6	0.6
	Max value	11.2	12.0	10.9	10.2
	95% CI	11.7	11.6	8.9	9.4
	99.9% CI	16.2	15.9	12.2	12.8

[a] n = 13,500 independent accuracy measurements. CT, computed tomography; SD, standard deviation; Min, minimum; Max, maximum; N/A, not available; BRW, Brown-Roberts-Wells; CRW, Cosman-Roberts-Wells; CI, confidence interval; AE, angulation effect.

The Application Accuracy of Stereotactic Frames

Maciunas, Robert J. M.D.; Galloway, Robert L. Jr. Ph.D.; Latimer, Jim W. M.D.
Neurosurgery
Issue: Volume 35(4), October 1994, p 682-695

How accurate is image guidance?



BrainLAB ExacTrac 6D
X-ray tubes recessed in floor
Flat panels mounted to ceiling

Accuray CyberKnife
X-ray tubes mounted to ceiling
Flat panels recessed in floor

How accurate is image guidance?

AN ANALYSIS OF THE ACCURACY OF THE CYBERKNIFE: A ROBOTIC FRAMELESS STEREOTACTIC RADIOSURGICAL SYSTEM

Neurosurgery 52:140-147, 2003 DOI: 10.1227/01.NEU.0000039162.72141.18 www.neurosurgery-online.com

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Department of Neurosurgery, Stanford University School of Medicine, Stanford, California

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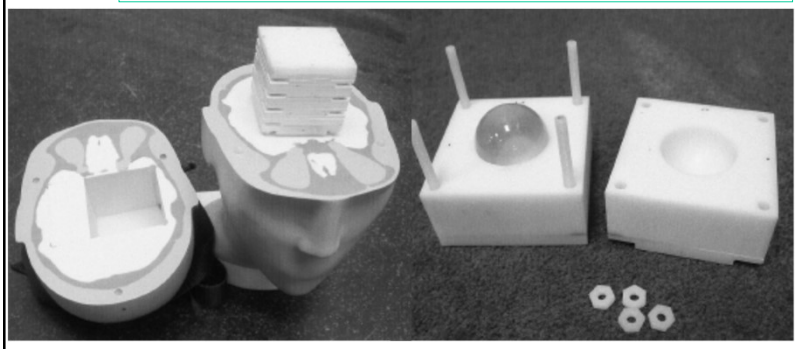
Accuray, Inc., Sunnyvale, California

David P. Martin, M.D.
Department of Neurosurgery, Stanford University School of Medicine, Stanford, California

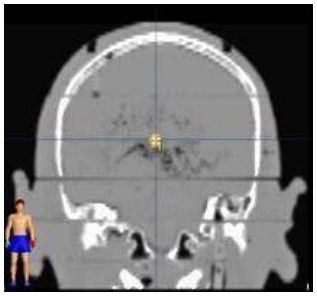
Iris C. Gibbs, M.D.
Department of Radiation Oncology, Stanford University School of Medicine, Stanford, California

M. Peter Heilbrun, M.D.
Department of Neurosurgery, Stanford University School of Medicine, Stanford, California

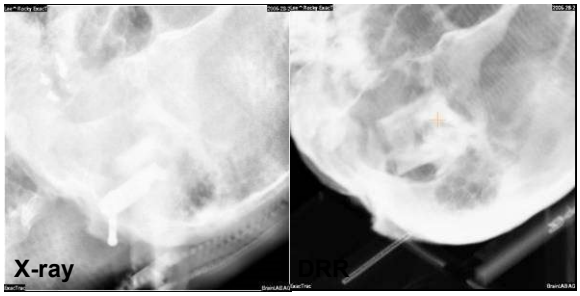


CONCLUSION: The frameless, image-guided, second-generation CyberKnife radiosurgery system has a clinically relevant accuracy of 1.1 ± 0.3 mm when CT slice thicknesses of 1.25 mm are used. CyberKnife precision is comparable to published localization errors in current frame-based radiosurgical systems.

How accurate is image guidance?

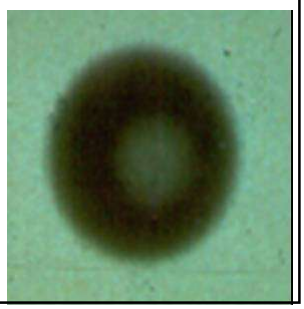


Identify target & plan



Set up in treatment room

Irradiate



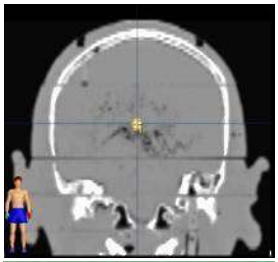
Evaluate

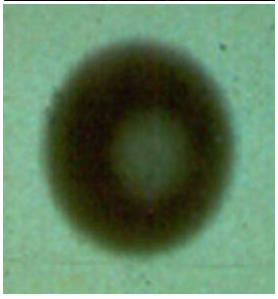
QA FOR RT SUPPLEMENT

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

Int. J. Radiation Oncology Biol. Phys., Vol. 71, No. 1, Supplement, pp. S131–S135, 2008

TIMOTHY D. SOLBERG, PH.D.,* PAUL M. MEDIN, PH.D.,* JOHN MULLINS, B.S.,† AND SICONG LI, D.SC.*





Results of Phantom Data

(mm)	Lat	Long	Vert	3D vector
Average	-0.06	-0.01	0.05	1.11
Standard Deviation	0.56	0.32	0.82	0.42

n = 50; 95% Confidence Level +/- 0.12 mm

QA FOR RT SUPPLEMENT

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

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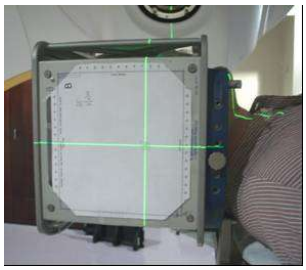
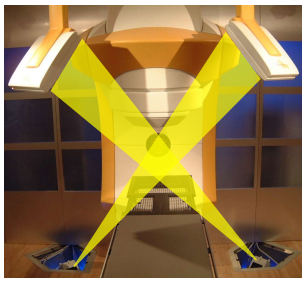


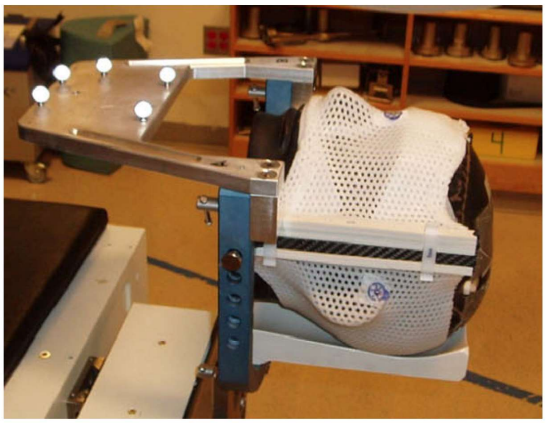


Results of Patient Data

(mm)	Lat	Long	Vert	3D vector
Average	-0.09	0.13	0.23	1.02
Standard Deviation	0.67	0.57	0.76	0.59

A clinical comparison of patient setup and intra-fraction motion using frame-based radiosurgery versus a frameless image-guided radiosurgery system for intracranial lesions Radiotherapy and Oncology 95 (2010) 109–115

Naren Ramakrishna *, Florin Rosca, Scott Friesen, Evrim Tezcanli, Piotr Zygmanszki, Fred Hacker



Phantom Evaluation
0.7 ± 0.3 mm (n=57)

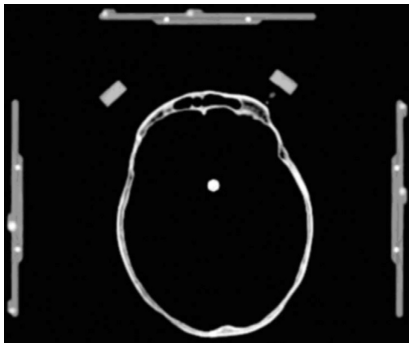
Frame – IGRT comparison
1.0 ± 0.5 mm (n=102)

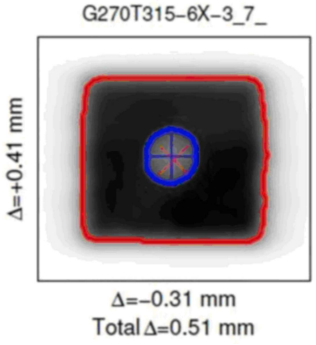
Results: The hidden-target tests demonstrated a mean error magnitude of 0.7 mm (SD = 0.3 mm). For SRS treatments, mean deviation between frame-based and image-guided initial positioning was 1.0 mm (SD = 0.5 mm). Fusion failures were observed among 3 patients resulting in aberrant predicted shifts.

Evaluation of the setup margins for cone beam computed tomography–guided cranial radiosurgery: A phantom study

Juan Francisco Calvo Ortega, M.Sc.,* Wouter Wunderink, Ph.D.,† David Delgado, M.D.,* Sandra Moragues, R.T.T.,* Miquel Pozo, R.T.T.,* and Joan Casals, M.D.*

Medical Dosimetry 41 (2016) 199–204





	Lt-Rt	Ant-Post	Sup-Inf
Offset range (mm)	**-2.1 – 1.2**	**-1.1 – 1.1**	**-0.9 – 1.1**
Std. Dev. (mm)	**0.6**	**0.4**	**0.4**
CTV-PTV Margin (mm)	**1.1**	**0.7**	**0.7**

The Use of Cone Beam Computed Tomography for Image Guided Gamma Knife Stereotactic Radiosurgery: Initial Clinical Evaluation

Winnie Li, MRT(T), MSc,*,† Young-Bin Cho, PhD,*,† Steve Ansell, BSc,* Normand Laperriere, MD,*,† Cynthia Ménard, MD,*,† Barbara-Ann Millar, MD,*,† Gelareh Zadeh, MD, PhD,‡,§ Paul Kongkham, MD, PhD,‡ Mark Bernstein, MD, MHSc,‡ David A. Jaffray, PhD,*,†,‖ and Caroline Chung, MD, MSc, CIP*,†

Int J Radiation Oncol Biol Phys, Vol. 96, No. 1, pp. 214–220, 2016

20 GK patients treated in a Leksell frame

Difference between frame and CBCT localization recorded

Variable	Mean ± SD
Setup error	
Translation (mm)	
LR	−0.19 ± 0.32
AP	0.08 ± 0.29
CC	−0.35 ± 0.50
Vector	0.40 ± 0.66
Rotation (°)	
LR	−0.14 ± 0.25
AP	−0.03 ± 0.19
CC	0.10 ± 0.20
Intrafraction error	
Translation (mm)	
LR	−0.03 ± 0.05
AP	−0.03 ± 0.18
CC	−0.03 ± 0.12
Vector	0.05 ± 0.22
Rotation (°)	
LR	−0.05 ± 0.30
AP	−0.03 ± 0.20
CC	−0.01 ± 0.09

CASE STUDY Strahlenther Onkol

Adaptive fractionated stereotactic Gamma Knife radiotherapy of meningioma using integrated stereotactic cone-beam-CT and adaptive re-planning (a-gkFSRT)

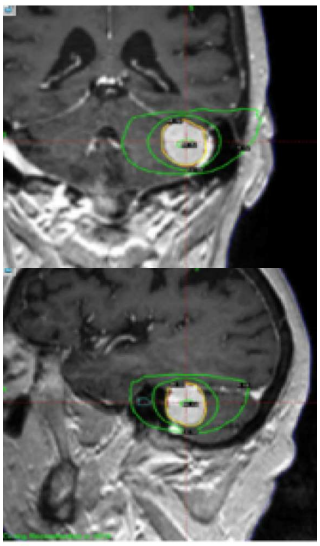
F. Stieler[1] · F. Wenz[1] · Y. Abo-Madyan[1] · B. Schweizer[1] · M. Polednik[1] · C. Herskind[1] · F. A. Giordano[1] · S. Mai[1]

Single acoustic patient

5 x 5 Gy prescribed (to 46% IDL) to preserve acoustic and facial nerve, 23 shots

Imaging time ~1.65 min

Total treatment time including imaging ~20 min

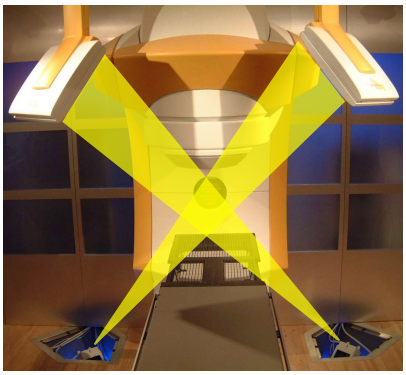


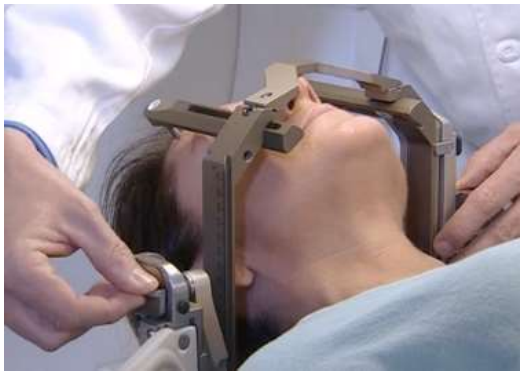
Daily CBCT compared with thermoplastic mask setup:

X:	0.94 ± 0.52 mm
Y:	-0.08 ± 0.08 mm
Z:	-1.13 ± 0.89 mm

Intrafraction movement 0.13 ± 0.04 mm

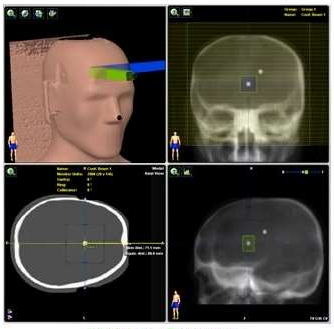
So, IGRT is as Accurate as a Head Frame. Period.



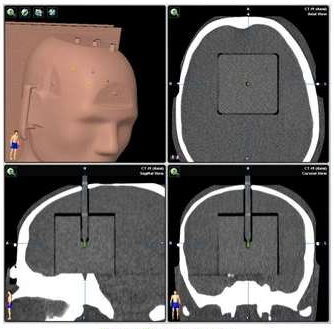


End-to-end testing

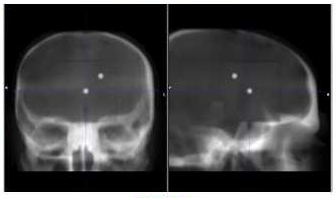
Head Phantom



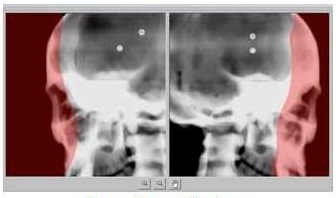
Hidden Targets



Ion Chamber

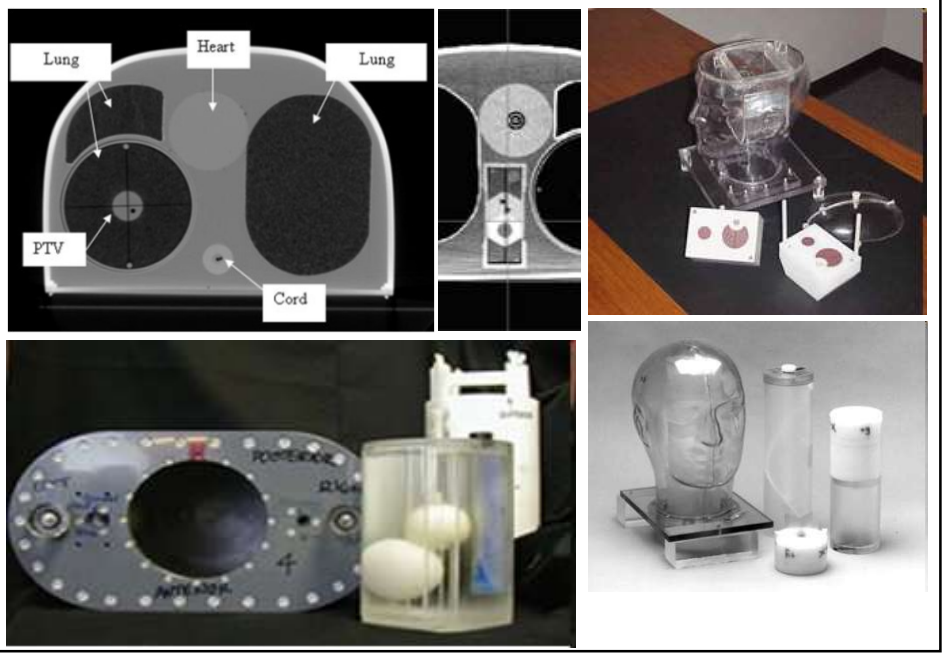


DRRs

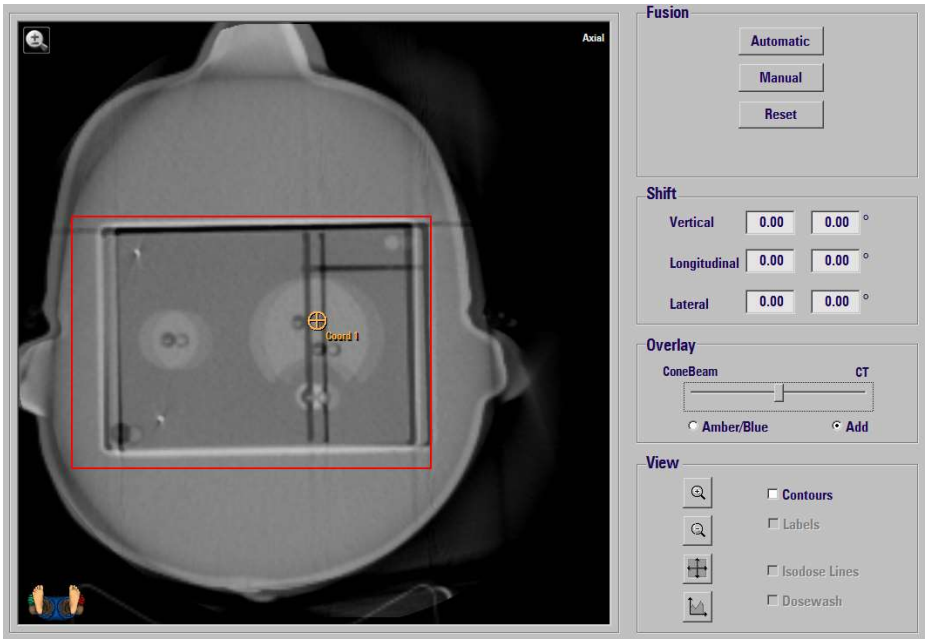


ExacTrac Setup

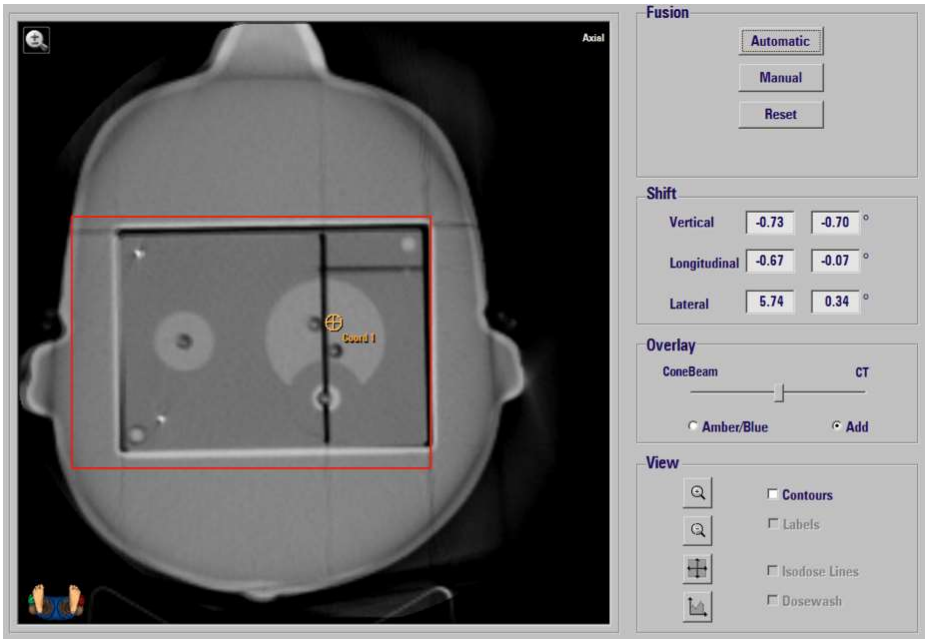
Independent Validation!



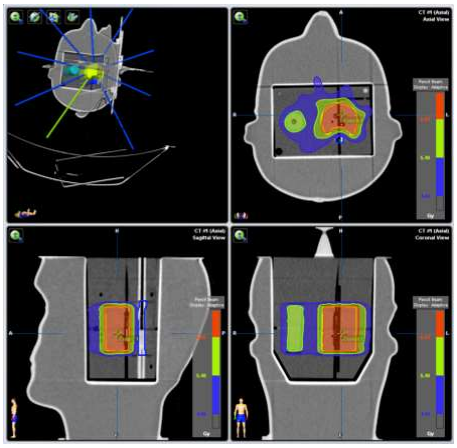
RPC H&N Phantom: End-to-End Testing



RPC H&N Phantom: End-to-End Testing



Independent Validation!



RPC Radiological Physics Center
Excellence through Quality Assurance

8060 El Rio Street, Houston, TX 77054 • Tel (713) 745-8989
rpc@mdanderson.org •http://rpc.mdanderson.org • Fax (713) 794-1364

THE UNIVERSITY OF TEXAS MD Anderson Cancer Center

Report of IMRT Head and Neck Phantom Irradiation

Date of Report:	October 24, 2012
Institution:	UTSW Med Ctr - Radiation Oncology West
Physicist:	Ryan Foster
Radiation Machine:	Mitsubishi, Vero (201902) – 6 MV
Intensity Modulation Device:	Multileaf Collimator
IMRT Technique:	Segmental (step and shoot) MLC
Treatment Planning System:	BrainLab, iPlan (3D/IMRT) – Pencil Beam
Date of Irradiation:	August 21, 2012

Description of Procedure

An anthropomorphic head phantom incorporating a rectangular dosimetry insert was imaged and irradiated to approximately 6.6 Gy using an IMRT technique. The dosimetry insert consisted of one primary PTV containing four TLD capsules, a secondary PTV and an organ at risk (OAR), each containing two TLD capsules. The TLD capsules provided point dose information. Three sheets of GAFChromic™ Dosimetry Media provided dose profiles through the center of primary PTV.

The dosimetric precision of the TLD is 3%, and the spatial precision of the film and densitometer system is 1 mm.

Summary of TLD and film results:

Location	RPC vs. Inst.	Criteria	Acceptable
Primary PTV sup. ant.	0.96	0.93 – 1.07	Yes
Primary PTV inf. ant.	0.97	0.93 – 1.07	Yes
Primary PTV sup. post.	0.99	0.93 – 1.07	Yes
Primary PTV inf. post.	0.98	0.93 – 1.07	Yes
Secondary PTV sup.	0.96	0.93 – 1.07	Yes
Secondary PTV inf.	0.96	0.93 – 1.07	Yes

Film Plane	Gamma Index*	Criteria	Acceptable
Axial	100%	≥85%	Yes
Sagittal	99%	≥85%	Yes

*Percentage of points meeting gamma index criteria of 7% and 7 mm.

The phantom irradiation results listed in the table above **do meet** the criteria established by the RPC in collaboration with the cooperative study groups. Therefore, your institution **has satisfied** the phantom irradiation component of the credentialing process to enter patients into certain protocols that allow the use of IMRT.

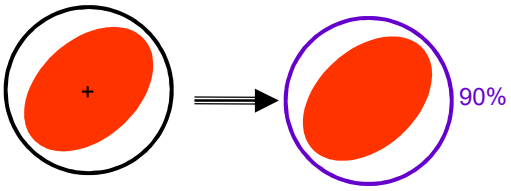
TLD and Film Analysis by: Nadia Hernandez and Andrea Molineu, M.S.

Report Checked by:

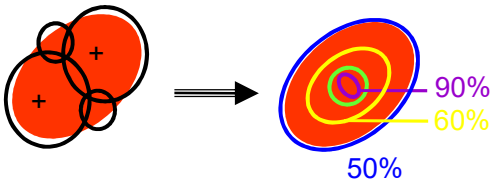
David S. Followill, Ph.D.
Director, Radiological Physics Center

What about Multileaf Collimator? What good is it?

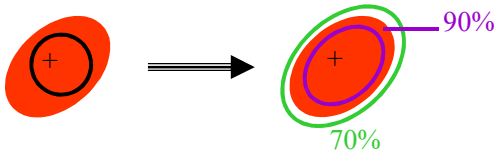
Treatment Approaches with Circular Collimators



Single Isocenter Approach

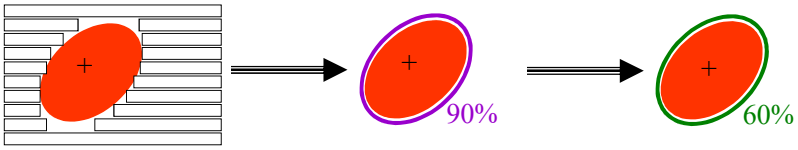


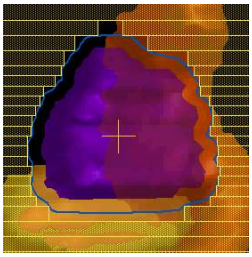
Multiple Isocenter (shot) Approach



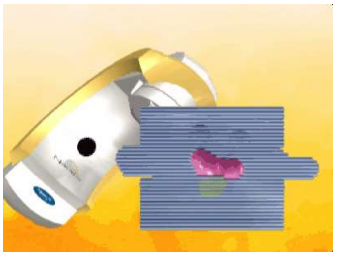
Non-isocentric (robotic) Approach

Treatment Approaches with Multileaf Collimators

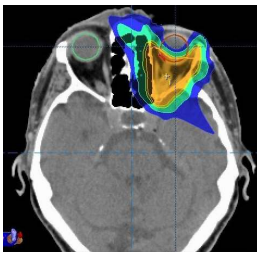




Fixed Beam



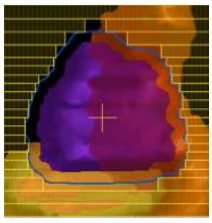
Dynamic Conformal Arc



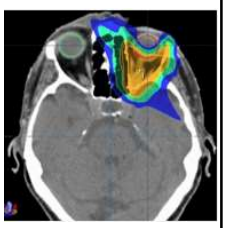
IMRT / VMAT

Treatment Approaches for Multiple Brain Metastases


Circular Collimators


Fixed Beam

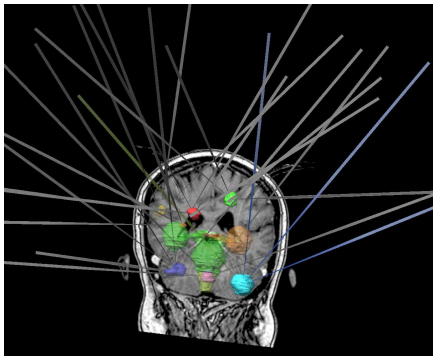

Dynamic Conformal Arc


IMRT / VMAT

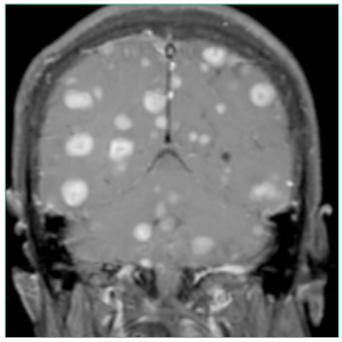
New (Multiple) Isos for each Target

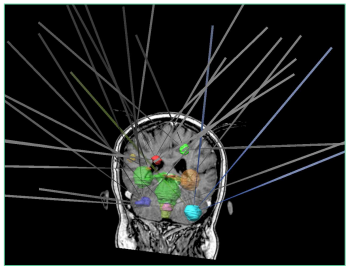
Time consuming to plan and deliver

Very Inefficient!



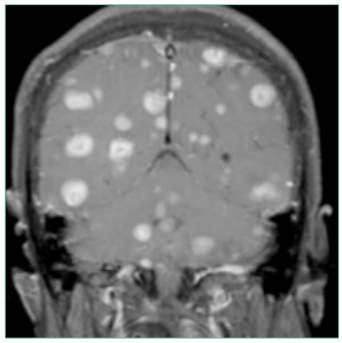
Treatment of Multiple Brain Metastases – Is there Anything Better?

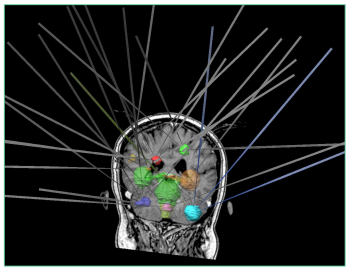




Single isocenter, multiple target MLC approach: "moving Swiss cheese"

Why treat multiple mets with radiosurgery?





Whole Brain +/- SRS Boost: Survival Benefit

Articles

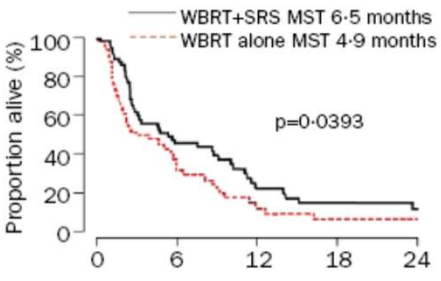
Lancet 2004; **363:** 1665–72

Whole brain radiation therapy with or without stereotactic radiosurgery boost for patients with one to three brain metastases: phase III results of the RTOG 9508 randomised trial

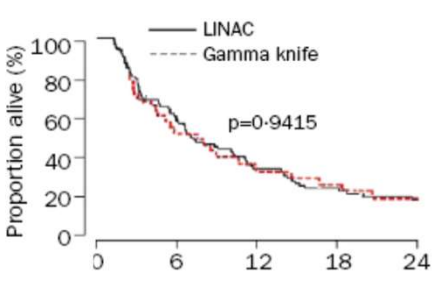
David W Andrews, Charles B Scott, Paul W Sperduto, Adam E Flanders, Laurie E Gaspar, Michael C Schell, Maria Werner-Wasik, William Demas, Janice Ryu, Jean-Paul Bahary, Luis Souhami, Marvin Rotman, Minesh P Mehta, Walter J Curran Jr

Adding SRS to WB improves survival

Survival in patients with single metastasis



Survival by treatment unit



Resection or SRS +/- Whole Brain

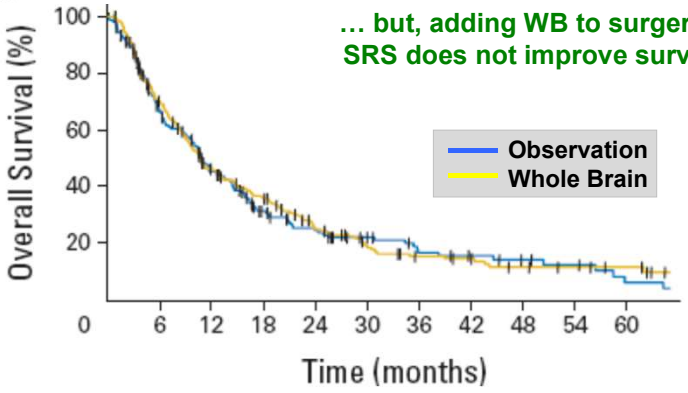
VOLUME 29 · NUMBER 2 · JANUARY 10 2011

JOURNAL OF CLINICAL ONCOLOGY ORIGINAL REPORT

Adjuvant Whole-Brain Radiotherapy Versus Observation After Radiosurgery or Surgical Resection of One to Three Cerebral Metastases: Results of the EORTC 22952-26001 Study

Martin Kocher, Riccardo Soffietti, Ufuk Abacioglu, Salvador Villà, Francois Fauchon, Brigitta G. Baumert, Laura Fariselli, Tzahala Tzuk-Shina, Rolf-Dieter Kortmann, Christian Carrie, Mohamed Ben Hassel, Mauri Kouri, Egils Valeinis, Dirk van den Berge, Sandra Collette, Laurence Collette, and Rolf-Peter Mueller

… but, adding WB to surgery or SRS does not improve survival



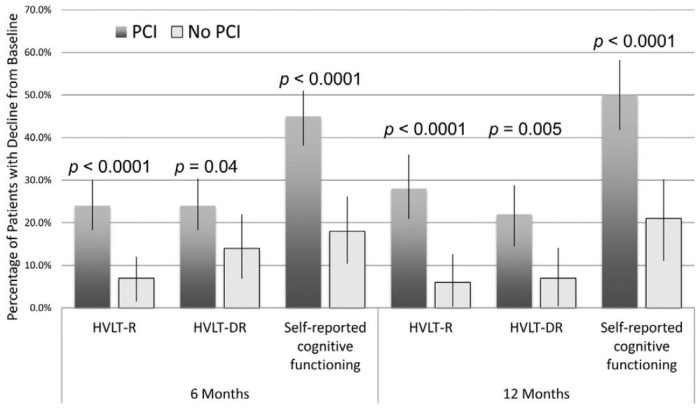
Decline in Tested and Self-Reported Cognitive Functioning After Prophylactic Cranial Irradiation for Lung Cancer: Pooled Secondary Analysis of Radiation Therapy Oncology Group Randomized Trials 0212 and 0214

International Journal of Radiation Oncology biology • physics

Int J Radiation Oncol Biol Phys, Vol. 86, No. 4, pp. 656–664, 2013

Vinai Gondi, MD,*,† Rebecca Paulus, MS,‡ Deborah W. Bruner, RN, PhD, FAAN,§ Christina A. Meyers, PhD,‖ Elizabeth M. Gore, MD,¶ Aaron Wolfson, MD,# Maria Werner-Wasik, MD, Alexander Y. Sun, MD, PhD,†† Hak Choy, MD,‡‡ and Benjamin Movsas, MD§§**

… and, WB results in neurocognitive decline



RTOG 0214: locally advanced NSCLC randomized to PCI or observation;
RTOG 0212: limited-disease small cell randomized to high or standard-dose PCI

Original Investigation

Effect of Radiosurgery Alone vs Radiosurgery With Whole Brain Radiation Therapy on Cognitive Function in Patients With 1 to 3 Brain Metastases

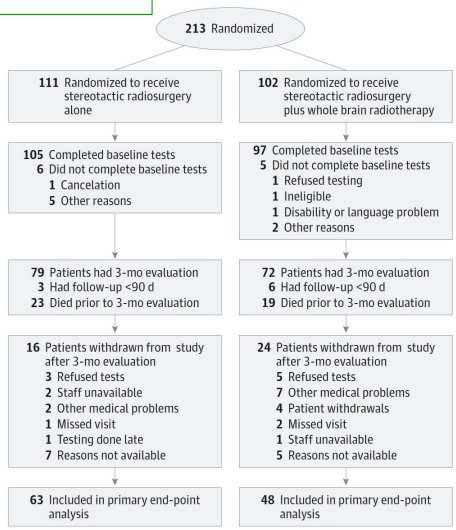
A Randomized Clinical Trial *JAMA*. 2016;316(4):401-409

Paul D. Brown, MD; Kurt Jaeckle, MD; Karla V. Ballman, PhD; Elana Farace, PhD; Jane H. Cerhan, PhD; S. Keith Anderson, MS; Xiomara W. Carrero, BS; Fred G. Barker II, MD; Richard Deming, MD; Stuart H. Burri, MD; Cynthia Ménard, MD; Caroline Chung, MD; Volker W. Stieber, MD; Bruce E. Pollock, MD; Evanthia Galanis, MD; Jan C. Buckner, MD; Anthony L. Asher, MD

213 patients randomized to SRS ±WBRT

Primary endpoint –
- Cognitive decline @ 3 months

Secondary endpoints –
- Local control
- Quality of life
- Overall survival
- Long term cognitive status



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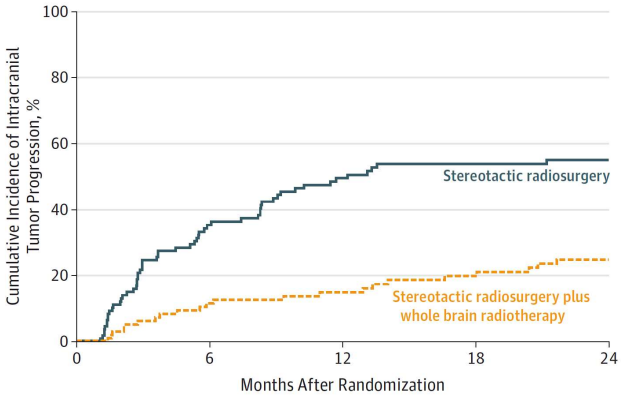
Tumor Control @3 mo

SRS Alone: 75.3%

SRS + WBRT: 93.7%



No. at risk

Stereotactic radiosurgery	111	35	12	5	1
Stereotactic radiosurgery plus whole brain radiotherapy	102	43	24	16	9

Original Investigation

Effect of Radiosurgery Alone vs Radiosurgery With Whole Brain Radiation Therapy on Cognitive Function in Patients With 1 to 3 Brain Metastases

A Randomized Clinical Trial

JAMA. 2016;316(4):401-409

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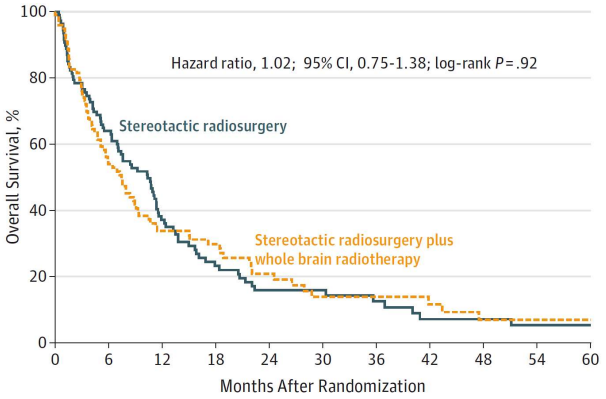
Median overall survival

SRS Alone: 10.4 mo

SRS + WBRT: 7.4 mo



No. at risk

Stereotactic radiosurgery	111	64	35	19	13	10	7	4	4	2	2
Stereotactic radiosurgery plus whole brain radiotherapy	102	50	28	22	13	8	8	5	3	1	1

Table 2. Patients Who Experienced Cognitive Deterioration by 3 Months and Difference Between Groups

	No. (%) of Participants			
	SRS Alone (n = 63)	SRS Plus WBRT (n = 48)	Mean Difference, % (95% CI)	*P* Value[a]
Change from baseline[b]				
HVLT-R				
Immediate recall				
Deterioration	5 (8.2)	14 (30.4)	22.2 (5.4 to 39.1)	.004
No deterioration	56 (91.8)	32 (69.6)		
Delayed recall				
Deterioration	12 (19.7)	24 (51.1)	31.4 (12.1 to 50.7)	<.001
No deterioration	49 (80.3)	23 (48.9)		
Recognition				
Deterioration	14 (22.6)	19 (40.4)	17.8 (−1.5 to 37.2)	.06
No deterioration	48 (77.4)	28 (59.6)		
TMT-A time to complete				
Deterioration	10 (16.7)	14 (30.4)	13.8 (−4.4 to 32.0)	.11
No deterioration	50 (83.3)	32 (69.6)		
TMT-B time to complete				
Deterioration	11 (19.0)	16 (37.2)	18.2 (−1.4 to 37.9)	.07
No deterioration	47 (81.0)	27 (62.8)		
COWAT total				
Deterioration	1 (1.9)	8 (18.6)	16.7 (2.4 to 31.0)	.01
No deterioration	52 (98.1)	35 (81.4)		
GPS total seconds				
Deterioration	17 (29.3)	21 (47.7)	18.4 (−2.4 to 39.3)	.07
No deterioration	41 (70.7)	23 (52.3)		
Outcome for cognitive progression at 3 mo				
Stable	23 (36.5)	4 (8.3)	−28.2 (−44.2 to −12.2)	<.001
Progression	40 (63.5)	44 (91.7)		

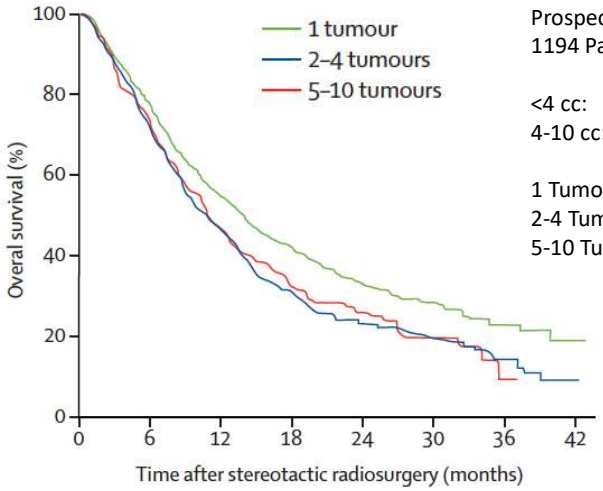
Among patients with 1-3 brain metastases, the use of SRS alone, compared with SRS + WBRT, resulted in less cognitive deterioration at 3 months.

In the absence of a difference in overall survival, these findings suggest that for patients with 1-3 brain metastases amenable to radiosurgery, SRS alone may be a preferred strategy

Brown et al, 2016

Stereotactic radiosurgery for patients with multiple brain metastases (JLGK0901): a multi-institutional prospective observational study *Lancet Oncol* 2014

Masaaki Yamamoto, Toru Serizawa*, Takashi Shuto, Atsuya Akabane, Yoshinori Higuchi, Jun Kawagishi, Kazuhiro Yamanaka, Yasunori Sato, Hidefumi Jokura, Shoji Yomo, Osamu Nagano, Hiroyuki Kenai, Akihito Moriki, Satoshi Suzuki, Yoshihisa Kida, Yoshiyasu Iwai, Motohiro Hayashi, Hiroaki Onishi, Masazumi Gondo, Mitsuya Sato, Tomohide Akimitsu, Kenji Kubo, Yasuhiro Kikuchi, Toru Shibasaki, Tomoaki Goto, Masami Takanashi, Yoshimasa Mori, Kintomo Takakura, Naokatsu Saeki, Etsuo Kunieda, Hidefumi Aoyama, Suketaka Momoshima, Kazuhiro Tsuchiya*

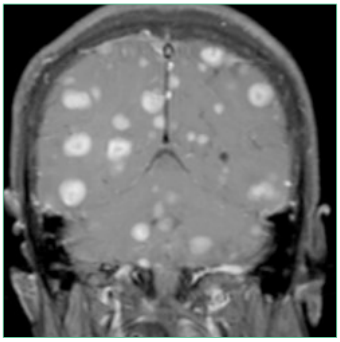


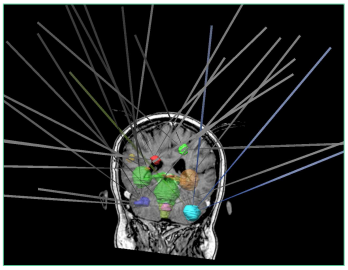
Prospective Observational Study
1194 Patients

<4 cc: 22 Gy
4-10 cc: 20 Gy

1 Tumor (455 patients)	13.9 mo
2-4 Tumors (531 patients)	10.8 mo
5-10 Tumors (208patients)	10.8 mo

So, back to the moving Swiss cheese approach ….





Radiosurgery of multiple brain metastases with single-isocenter dynamic conformal arcs (SIDCA) Radiotherapy and Oncology 112 (2014) 128–132

Yimei Huang*, Karen Chin, Jared R. Robbins, Jinkoo Kim, Haisen Li, Hanan Amro, Indrin J. Chetty, James Gordon, Samuel Ryu

- 6 patients with 3-5 metastases treated with single-isocenter dynamic conformal arcs
- 5 120° arcs (±sub-arcs as needed), adjusted as necessary to minimize overlapping multiple targets
- 99% of each target volume received 100% of the prescription dose
- Compared with multi-isocenter dynamic conformal arc (non-optimized, non-modulated) and with RapidArc (VMAT)

Patient number	No. of lesions	Volume of each lesion (cm^3)	PTV_{total} (cm^3)
1	3	0.40, 0.48, 0.65	1.53
2	3	0.30, 0.44, 0.77	1.51
3	4	0.32, 0.35, 0.50, 1.14	2.31
4	4	0.34, 0.39, 0.66, 0.69	2.09
5	5	0.52, 0.55, 0.59, 1.17, 2.75	5.58
6	5	0.30, 0.37, 0.43, 0.49, 1.25	2.84

Radiosurgery of multiple brain metastases with single-isocenter dynamic conformal arcs (SIDCA) Radiotherapy and Oncology 112 (2014) 128–132

Yimei Huang*, Karen Chin, Jared R. Robbins, Jinkoo Kim, Haisen Li, Hanan Amro, Indrin J. Chetty, James Gordon, Samuel Ryu

	SIDCA	MIDCA	VMAT
RTOG CI	1.36 ± 0.07	1.32 ± 0.05	1.15 ± 0.08
Paddick CI	0.72 ± 0.04	0.75 ± 0.03	0.86 ± 0.05
Gradient Index	3.97 ± 0.50	3.84 ± 0.44	4.34 ± 0.48
Total MUs	16,113 ± 3304	15,613± 3867	8,027 ± 738
Delivery Time (min)	29.5 ± 5.3	44.3 ± 10.8	15.3 ± 0.9
$V_{100\%}$ (cm^3)	3.56 ± 1.98	3.63 ± 1.98	2.94 ± 1.57
$V_{50\%}$ (cm^3)	13.58 ± 5.94	13.40 ± 5.80	12.24 ± 5.06
$V_{10\%}$ (cm^3)	328.14 ± 209.35	260.32 ± 203.85	678.20 ± 419.94

VMAT is more conformal than single or multiple dynamic arc plans

Delivery time for SIDCA is better than MIDCA but not as fast as VMAT

VMAT is much more MU efficient

SIDCA / MIDCA have better “spillage” characteristics: Gradient Index and V10%

Evan M. Thomas, PhD*
Richard A. Popple, PhD*
Xingen Wu, PhD*
Grant M. Clark, MD*
James M. Markert, MD‡
Barton L. Guthrie, MD‡
Yu Yuan, PhD*
Michael C. Dobelbower, MD, PhD*
Sharon A. Spencer, MD*
John B. Fiveash, MD*

Comparison of Plan Quality and Delivery Time Between Volumetric Arc Therapy (RapidArc) and Gamma Knife Radiosurgery for Multiple Cranial Metastases *Neurosurgery 75:409–418, 2014*

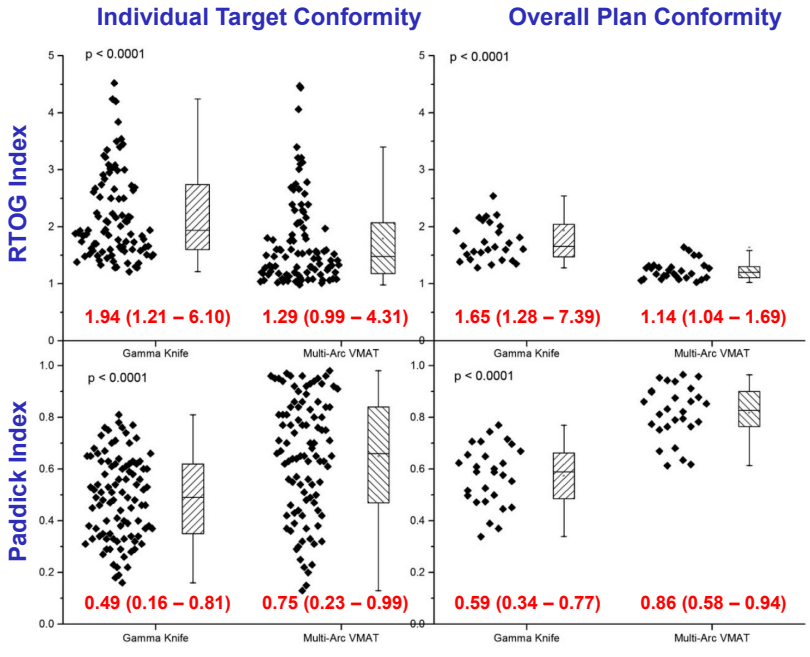
TABLE 1. Case and Target Demographics

Cases/total targets treated	28/112		
Tumors per case	Range, 2-9	Median, 3	Mean, 4.0
Case target volume (cc)	Range, 0.23-19.56	Median, 3.72	Mean, 4.93
Individual target volume (cc)	Range, 0.0027-15.01	Median, 0.14	Mean, 1.22

28 patients with multiple metastases previously treated on GK

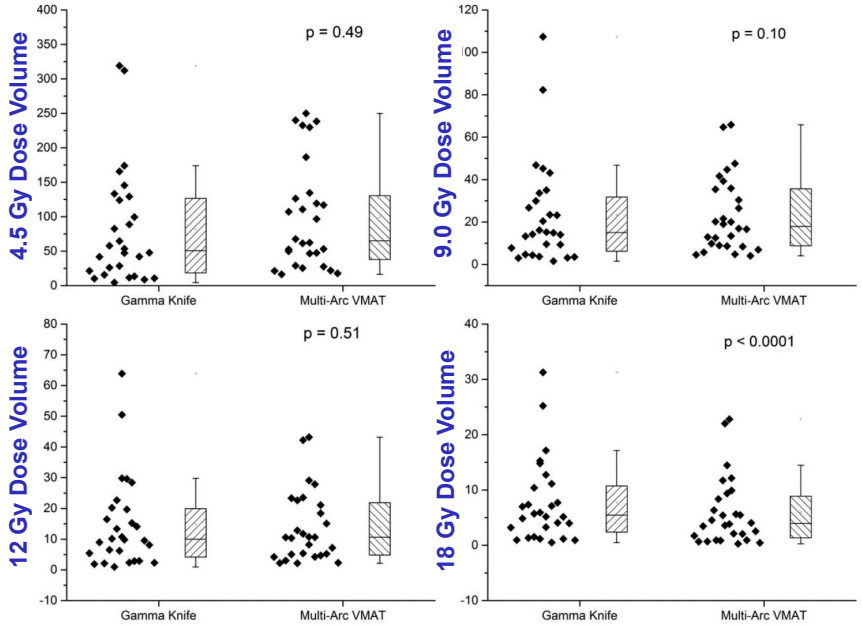
Replanned using single isocenter, single or multi arc VMAT (RapidArc)

Scored RTOG and Paddick conformity indices, V_{12}, V_9 and $V_{4.5}$, beam-on and treatment times



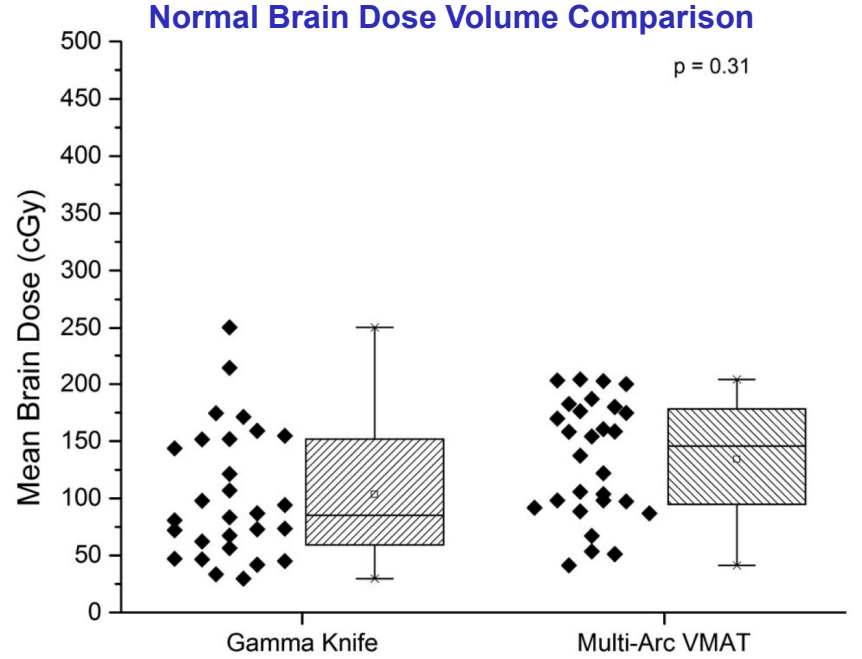
Thomas et al, Neurosurgery, 79:409-418, 2014

Normal Brain Dose Volume Comparison



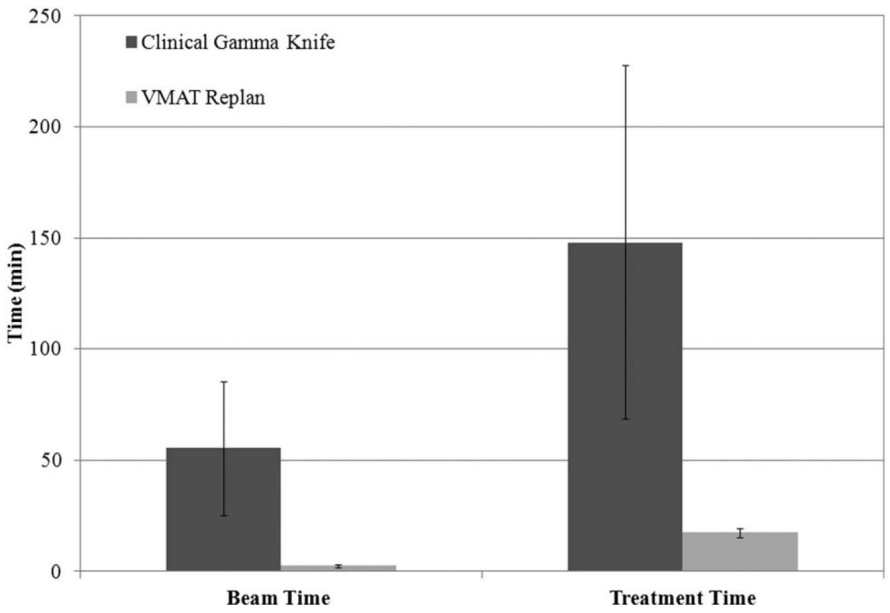
Thomas et al, Neurosurgery, 79:409-418, 2014

Normal Brain Dose Volume Comparison



Thomas et al, Neurosurgery, 79:409-418, 2014

Beam and Treatment Time Comparison



Thomas et al, Neurosurgery, 79:409-418, 2014

Plan Quality and Treatment Efficiency for Radiosurgery to Multiple Brain Metastases: Non-Coplanar RapidArc vs. Gamma Knife

*Haisong Liu[1], David W. Andrews[2], James J. Evans[2], Maria Werner-Wasik[1], Yan Yu[1], Adam Paul Dicker[1] and Wenyin Shi[1]**

Frontiers in Oncology February 2016 | Volume 6 | Article 26

6 patients with 3-4 metastases planned on both GK and single isocenter, multi arc VMAT (RapidArc)

Scored RTOG and Paddick conformity indices, V_{12}, and beam-on and treatment times

	Gamma Knife		RapidArc		
	Mean	Std.	Mean	Std.	*p*
RTOG Index	1.50	0.16	1.19	0.14	<0.001
V12 (patient composite)	10.85	7.2	9.7	5.1	0.63
V6	36.9	16.9	36.3	14.7	0.96
V4.5	86.7	29.8	99	27.3	0.15
V3	160.8	55.7	224	53	0.1
Beam-on time	71.6	15.9	6.4	0.8	<0.01
Est. total tx time	85.9	19.1	19.3	2.6	<0.01

Plan Quality and Treatment Efficiency for Radiosurgery to Multiple Brain Metastases: Non-Coplanar RapidArc vs. Gamma Knife

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Frontiers in Oncology February 2016 | Volume 6 | Article 26

RapidArc Parameters

No. of arcs	Monitor units (MU)	Beam-on time (min)	Est. total tx time (min)
4	7000	5.0	15
6	8300	5.9	18
6	9600	6.9	21
5	10,130	7.2	22
5	8660	6.2	19
5	9750	7.0	21

Plan Quality and Treatment Efficiency for Radiosurgery to Multiple Brain Metastases: Non-Coplanar RapidArc vs. Gamma Knife

*Haisong Liu[1], David W. Andrews[2], James J. Evans[2], Maria Werner-Wasik[1], Yan Yu[1], Adam Paul Dicker[1] and Wenyin Shi[1]**

Frontiers in Oncology February 2016 | Volume 6 | Article 26

Gamma Knife Parameters

Patient no.	No. of targets	Number of shots	Beam-on time (min)	Est. total tx time (min)
1	3	43	83.5	100
2	3	15	72.2	87
3	3	4	47	56
4	3	19	70	84
5	3	26	93	112
6	4	10	64	77

A Systematic Analysis of 2 Monoisocentric Techniques for the Treatment of Multiple Brain Metastases

Ganesh Narayanasamy, PhD[1,2], Sotirios Stathakis, PhD[1], Alonso N. Gutierrez, PhD[1], Evangelos Pappas, PhD[3], Richard Crownover, MD, PhD[1], John R. Floyd II, MD[4], and Niko Papanikolaou, PhD[1]

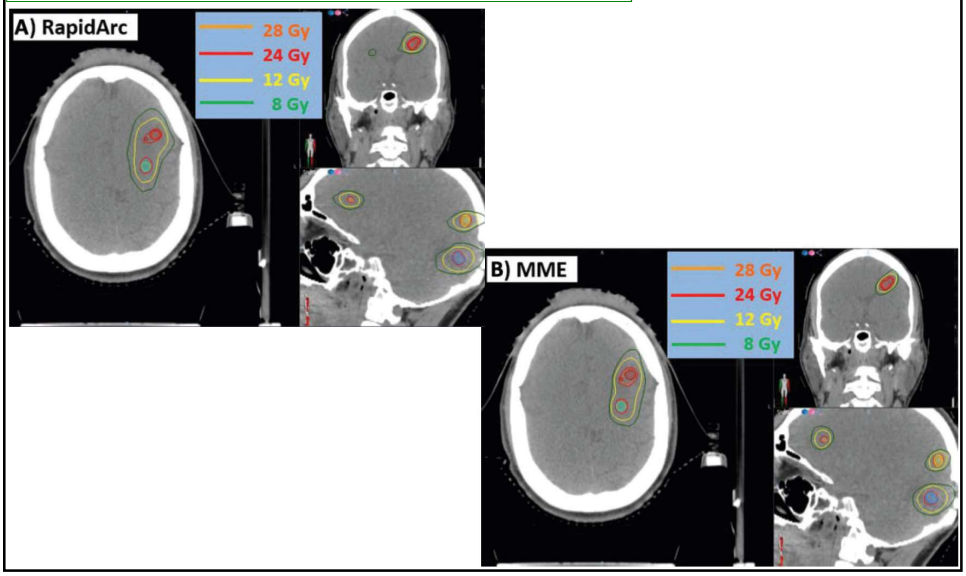
Technology in Cancer Research & Treatment 2016

8 patients with 3-7 metastases planned using the BrainLAB Multiple Metastases Element (MME) software and compared with a 4 arc RapidArc approach following the methodology of Thomas et al.

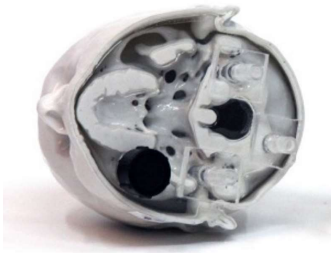
	MultiArc VMAT	MME
	Median (Range)	Median (Range)
Paddick CI	0.67 (0.22 – 0.83)	0.67 (0.22 – 0.83)
Gradient Index	4.7 (3.5 – 5.9)	4.5 (2.6 – 6.0)
V12 (cc)	21.2 (10.6 – 33.5)	22.3 (9.0 – 33.1)
Mean Brain Dose (Gy)	2.8 (1.3 – 3.9)	2.5 (1.3 – 3.1)
MU	9655 ± 1533	7119 ± 1076

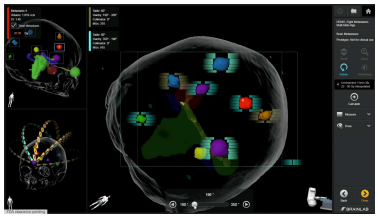
A Systematic Analysis of 2 Monoisocentric Techniques for the Treatment of Multiple Brain Metastases

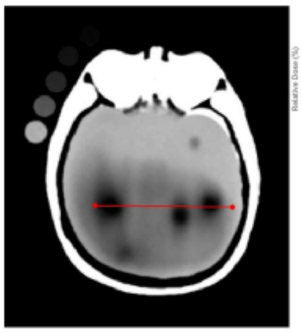
Technology in Cancer Research & Treatment 2016

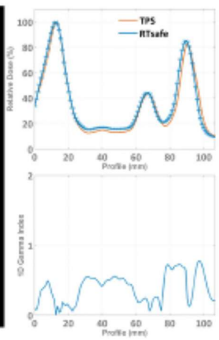


How to Commission / QA this!!!???





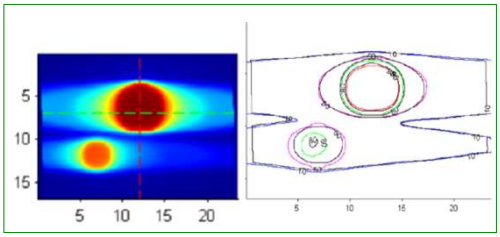




RTsafe

www.rt-safe.com

How to Commission / QA this!!!???



IMT

www.integratedmedicaltechnologies.us

80 Lesions in 49 Patients
Randomized to 1 or 3 mm margin
40 Lesions in Each Arm
All Single Fraction on Novalis

Defining the Optimal Planning Target Volume in Image-Guided Stereotactic Radiosurgery of Brain Metastases: Results of a Randomized Trial

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Int J Radiation Oncol Biol Phys, Vol. 91, No. 1, pp. 100–108, 2015

Characteristic	Lesion margin			
	1 mm		3 mm	
	n	%	n	%
All	40	100.0	40	100.0
Maximum PTV diameter				
<2 cm	30	75.0	26	65.0
≥2 to <3 cm	8	20.0	10	25.0
≥3 to <4 cm	2	5.0	4	10.0
SRS prescription dose, Gy				
15	2	5.0	4	10.0
18	9	22.5	10	25.0
24	29	72.5	26	65.0
Tumor status after SRS				
Local recurrence	2	5.0	1	2.5
Radionecrosis	1	2.5	5	12.5
No changes on imaging suggesting recurrence or radionecrosis	33	82.5	27	67.5
Insufficient information/unknown	4	10.0	7	17.5

"…given the higher risk of RN with a 3-mm margin, a 1 mm GTV expansion is more appropriate."

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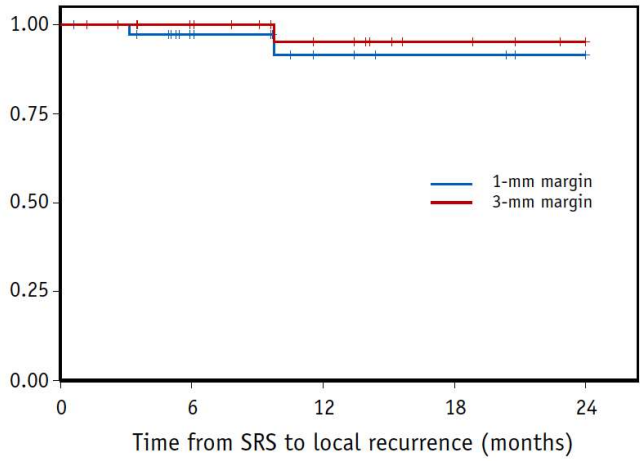

Number at Risk					
1-mm margin	36	23	14	11	7
3-mm margin	33	26	19	12	9

Summary

- Image guidance available on all SRS delivery platforms will hasten the demise of the stereotactic head frame
- With image guidance universally available, practitioners will no longer argue about accuracy
- Multi and single isocenter linac techniques provide equivalent target conformity and normal brain V12
- Use of radiosurgery in the setting of multiple brain metastases will continue to increase

SEAAPM SYMPOSIUM & SCIENTIFIC MEETING FEB. 23-25, 2017

1. The Radiation Isocenter of a Modern Linac SRS System is:

a) Equivalent to Gamma Knife systems
b) Inferior to Gamma Knife systems
c) Superior to Gamma Knife systems
d) Depends on CT slice thickness
e) Depends on the type of head frame used

Answer: Equivalent to Gamma Knife systems.

Refs: Wu et al, Physics of Gamma Knife Approach on Convergent Beams in Stereotactic Radiosurgery , Int J Radiat Onc Biol Phys. 18:941-949, 1990

Lutz W, et al, A system for stereotactic radiosurgery with a linear accelerator, IJROBP 14(2):373-81, 1988

Friedman WA, Bova FJ, The University of Florida radiosurgery system, Surg Neurol. 32(5):334-42, 1989

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2. The ASTRO/AAPM SRS/SBRT Guidelines ….

a) recommend that SBRT should be performed only at accredited centers of excellence
b) focuses primarily on preventing errors
c) require patient-specific measurements prior to treating any patient
d) require patient-specific QA activities prior to treating any patient
e) recommend that SRS/SBRT only be delivered using specialized machines

Answer: The ASTRO/AAPM SRS/SBRT Guidelines require a systematic patient-specific QA process prior to treatment. This does not have to include measurements (though that is recommended). There are many aspects to the QA process besides measurement.

Ref: Solberg TD et al, PRO. 2:2-9,2012

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3. The accuracy of modern image guidance is:

a) Equivalent to stereotactic head frames
b) Inferior to stereotactic head frames
c) Superior to stereotactic head frames
d) Depends on the type of imaging – 2D kV/kV versus CBCT
e) Depends on the type of head frame used

Answer: Equivalent to stereotactic head frames.

Refs: Masciunas et al, The application accuracy of stereotactic frames, Neurosurg. 35, 1994
Chang, et al, An analysis of the accuracy of the CyberKnife….., Neurosurg. 52, 2003
Solberg et al, Quality assurance of immobilization and localization systems….., IJROBP 71, 2008
Ramakrishna et al, A clinical comparison of patient setup and infra-fraction motion…., Rad Oncol 95, 2010

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4. Single isocenter, multiple metastases treatments:

a) Require higher MUs …..
b) Have longer treatment times …..
c) Results in a higher normal brain V_{12} …..
d) Results in a higher mean brain dose …..
e) Produces better clinical outcomes
…..than a multiple isocenter/ multiple target approach

Answer: Results in a (slightly) higher mean brain dose.

Refs: Thomas et al, Comparison of plan quality and delivery time…., Neurosurg. 75, 2014
Narayanasamy et al, A systematic analysis of 2 monoisocentric techniques….., TCRT, 2016
Huang et al, Radiosurgery of multiple brain metastases with single-isocenter….., Rad Oncol 95, 2014

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5. Whole brain radiation therapy:

a) Is necessary when patients present with more than 2 brain metastases
b) Results in improved local control compared with SRS or surgery alone
c) Results in improved survival compared with SRS or surgery alone
d) Results in a lower mean brain dose compared with SRS or surgery alone
e) Has little effect on acute cognitive function

Answer: Results in improved local control, but does not translate to survival.

Refs: Andrews et al, Whole brain radiation therapy with or without…., Lancet 363, 2004
Kocher et al, Adjuvant whole brain radiation therapy….., JCO 29, 2011
Gondi et al Decline in tested and self reported cognitive functioning….. IJROBP 86, 2013
Yamamoto et al, Stereotactic radiosurgery for patients with multiple brain metastases…., Lancet Oncol, 2014
Brown et al, Effect of radiosurgery alone vs. radiosurgery with whole brain…., JAMA 316, 2016

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Thank You

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