STEREOTACTIC RADIOSURGERY
-
CONCEPTS AND IMPLEMENTATION

ICTP School on Medical Physics for Radiation Therapy
Dosimetry and Treatment Planning for Basic and Advanced Applications
March 27 – April 7, 2017
Miramare, Trieste, Italy

Yakov Pipman, D.Sc

OUTLINE

Stereotactic Radiosurgery Concepts – targets and dose distributions

Some History

Commissioning and Quality Control

Image Fusion and Target delineation

Dose delivery methods

SRS treatment process

Stereotactic Radiosurgery

"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)

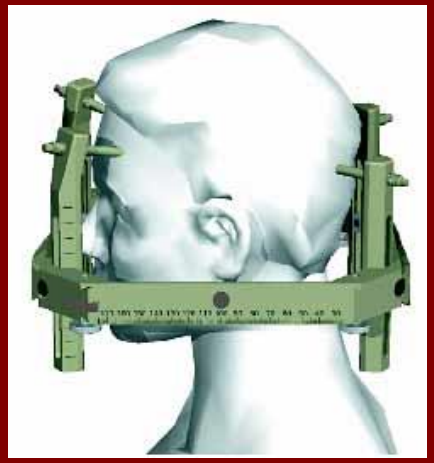
Historical Development of Stereotactic Ablative Radiotherapy
Timothy D. Solberg, Robert L. Siddon, and Brian Kavanagh

Stereotactic Radiosurgery (SRS) – Stereotactic Radiotherapy (SRT)

SRS and SRT use a stereotactic system and high energy beams to irradiate a volume.

(1) Requires an image based volume defined and indexed to a stereotactic coordinate system.

(2) Planning and treatment delivery indexed to the same coordinate system.



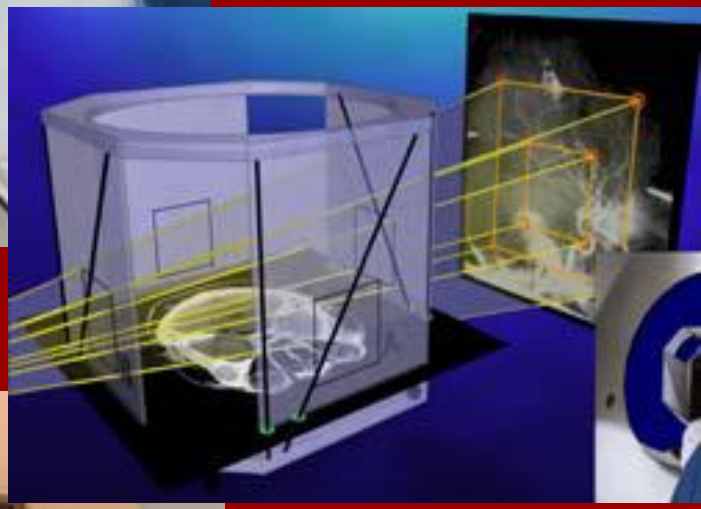
SRS and SRT produce a sharp dose gradient outside the treatment volume.

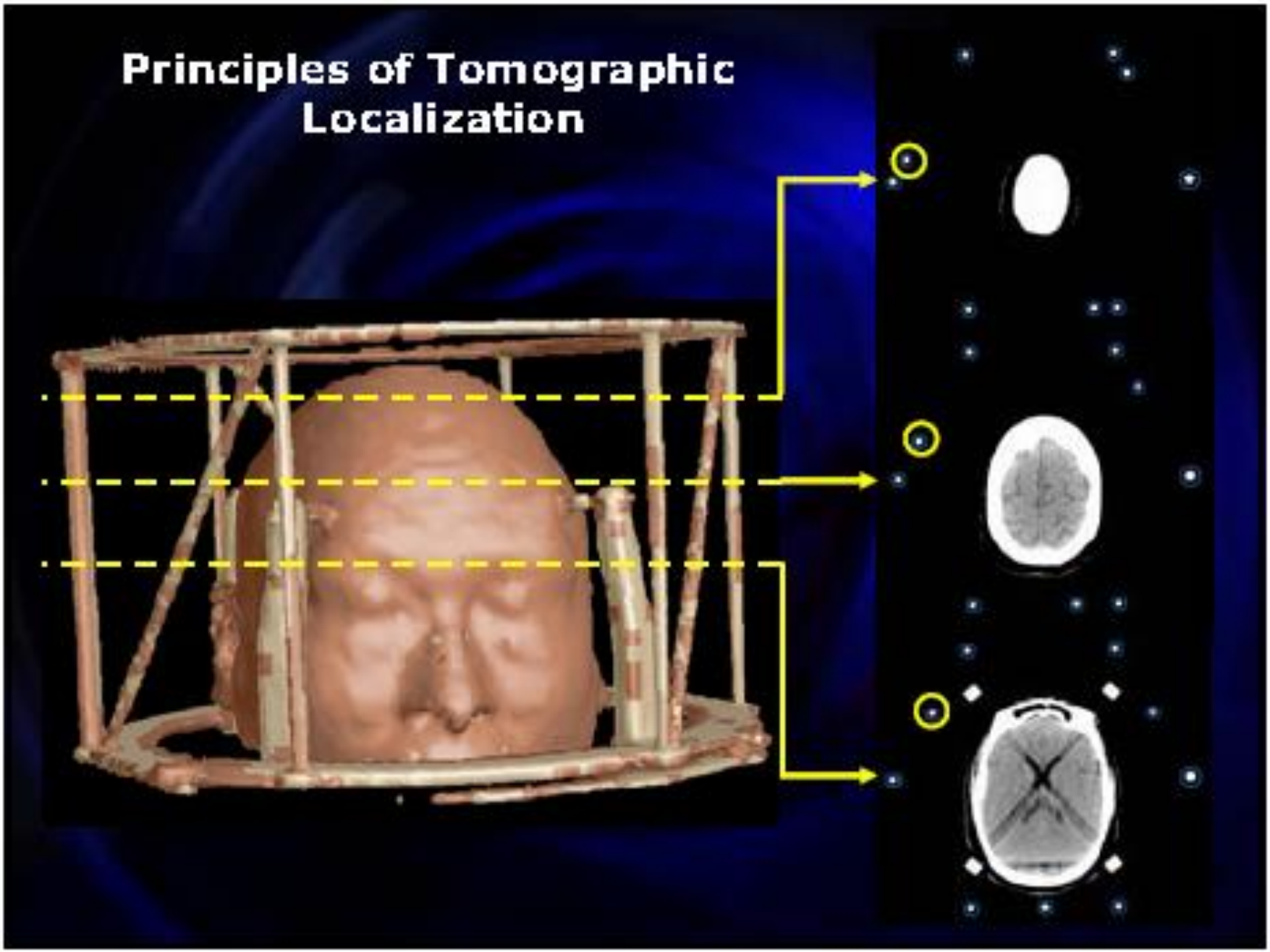
Stereotactic Localization

A localizer head frame, rigidly attached to the cranium, defines a precise and rigid frame of reference.

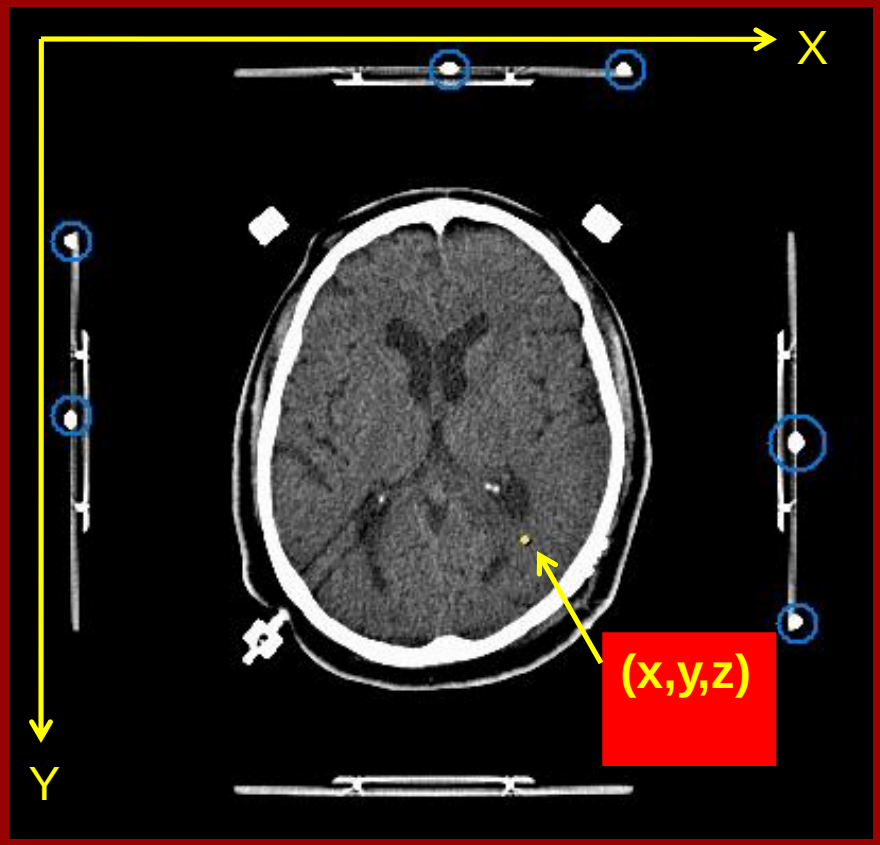
All points within that space can be referenced to a unique coordinate system.

All structures and points can be identified in all the imaging studies that include the localization frame, which is uniquely and rigidly attached to the base frame.

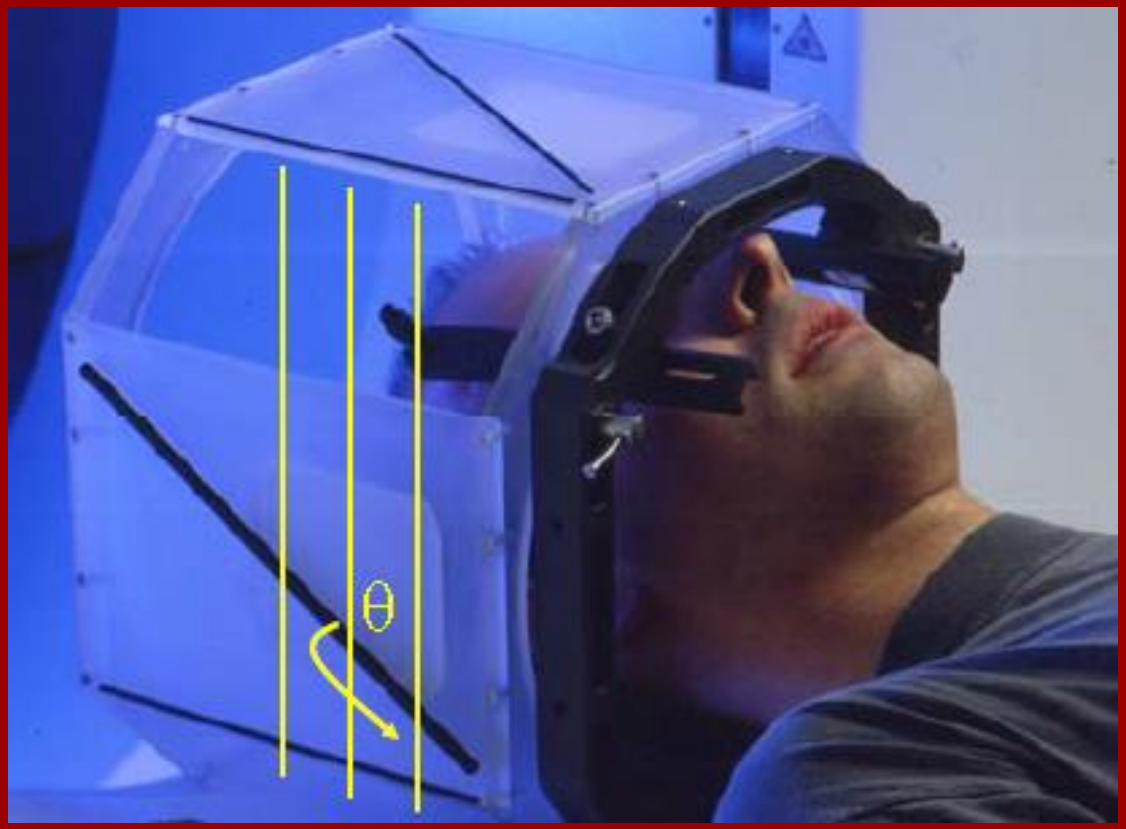



Principles of Tomographic Localization

Localization of points



The “z” coordinate

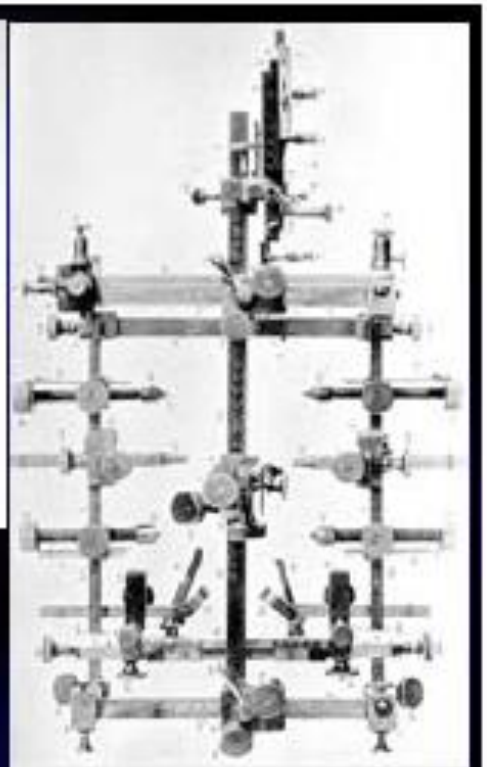


SRS treatment strategy

Position the point or volume to be treated at the point of convergence or intersection of all the beams

History

Original stereotactic frame

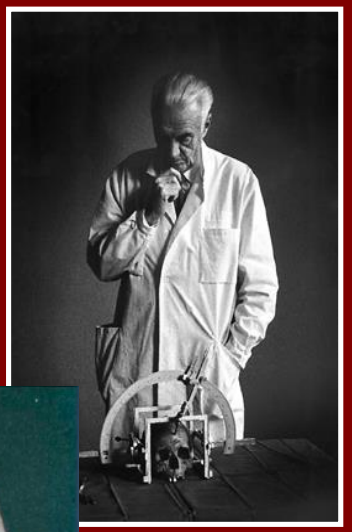


Clarke RH, Horsley VA, On a method of investigating the deep ganglia and tracts of the central nervous system (cerebellum). Br Med J 1799-1800, 1906.

Horsley VA, Clarke RH, The structure and functions of the cerebellum examined by a new method. Brain 31:45-124, 1908.

History

- Dr. Lars Leksell (1951) introduced the concept of Radiosurgery as the ablation of a lesion by radiation in a single procedure, similar to surgery
- Initially used a 200kV x-ray tube
- In 1968 developed the “Gamma knife”
  - 179 Co-60 sources
  - A spherical cavity covering 60º x 160º



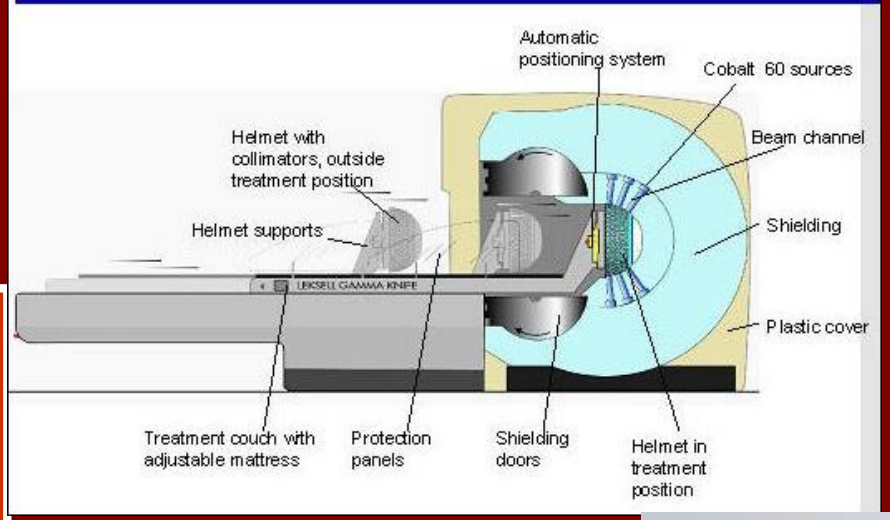
Gamma Knife

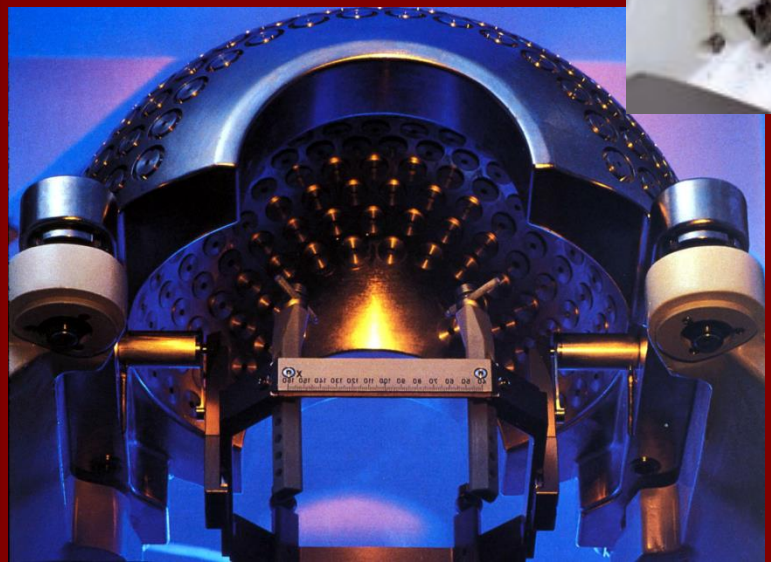
201 Co-60 sources arranged hemispherically around a common ‘focal’ point

The isocenter precision <0.5mm

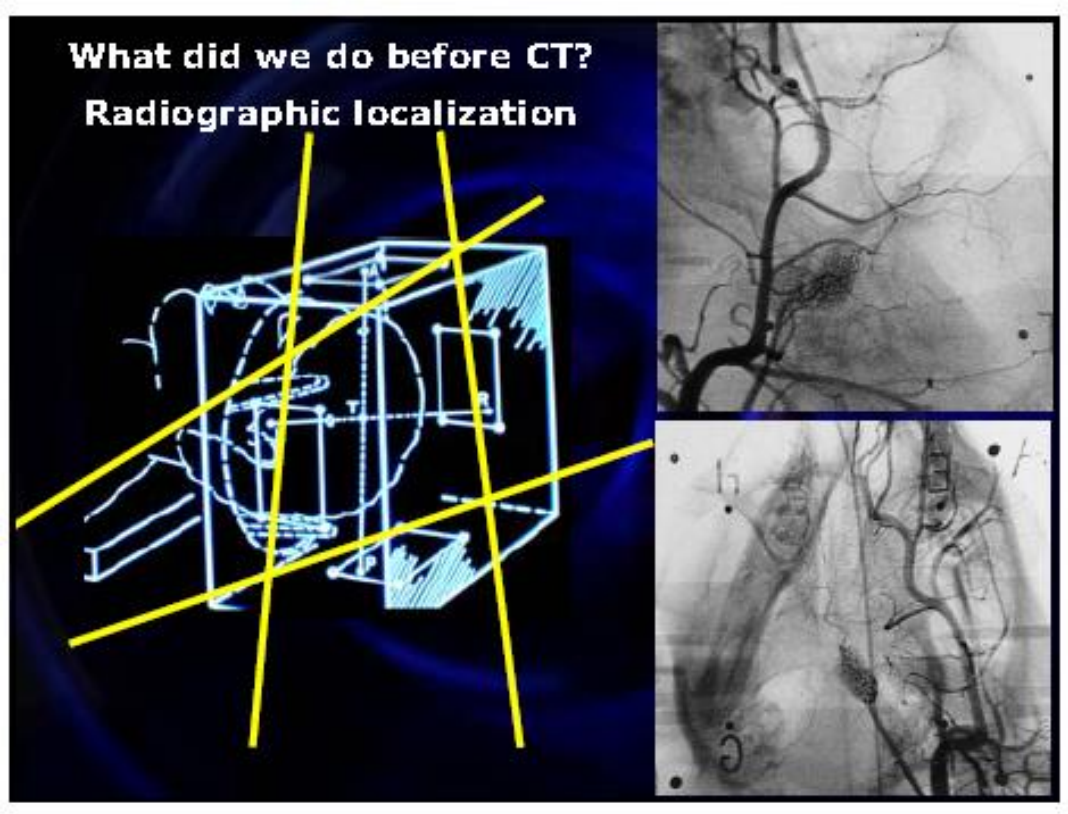
A system of collimators (4, 8, 14 and 18mm) (diameter of 50% isodose level on a 16cm phantom)

Used for spherical targets in one isocenter

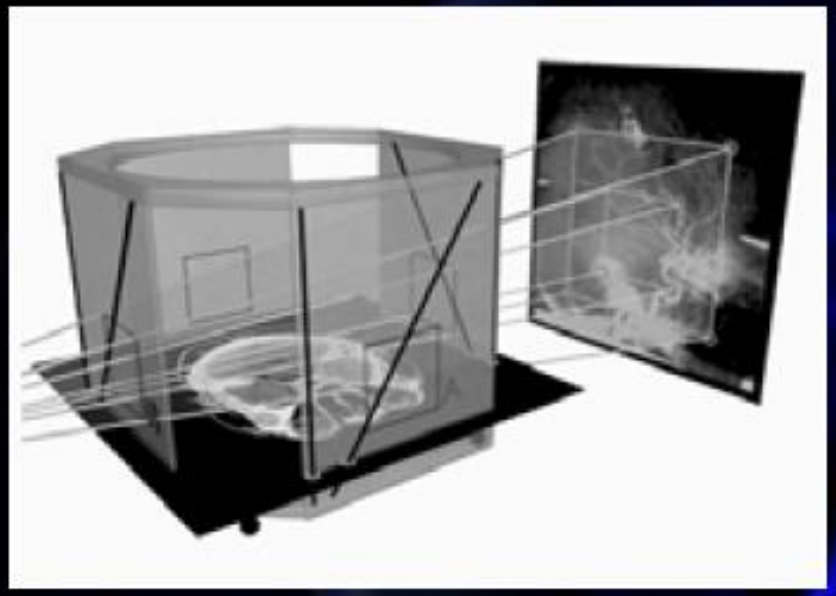


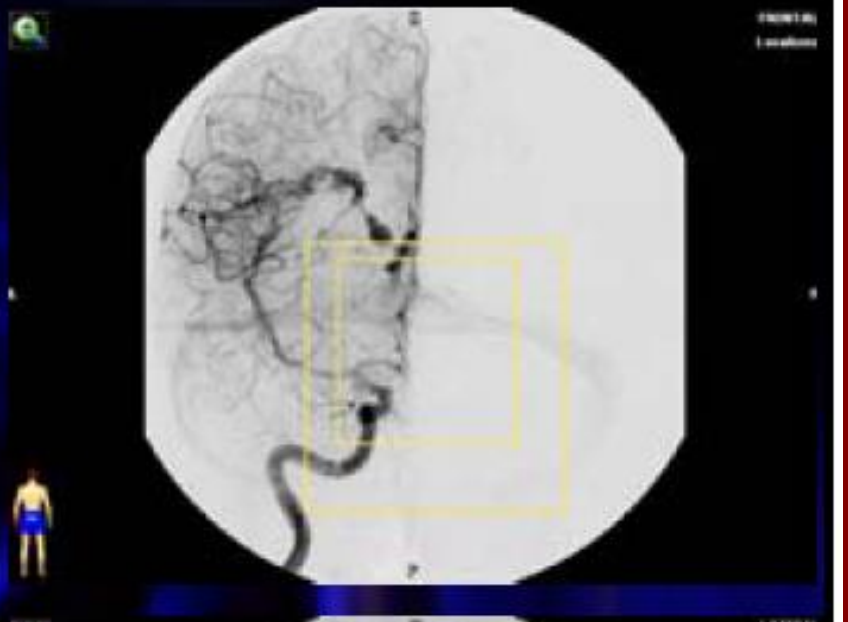


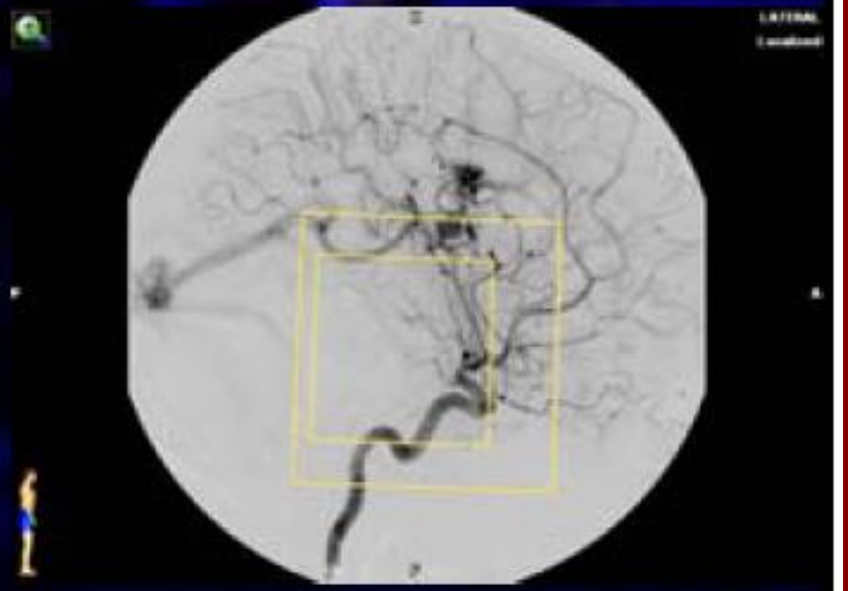
Initial application for treatment of artero-venous malformations (AVM)



DSA



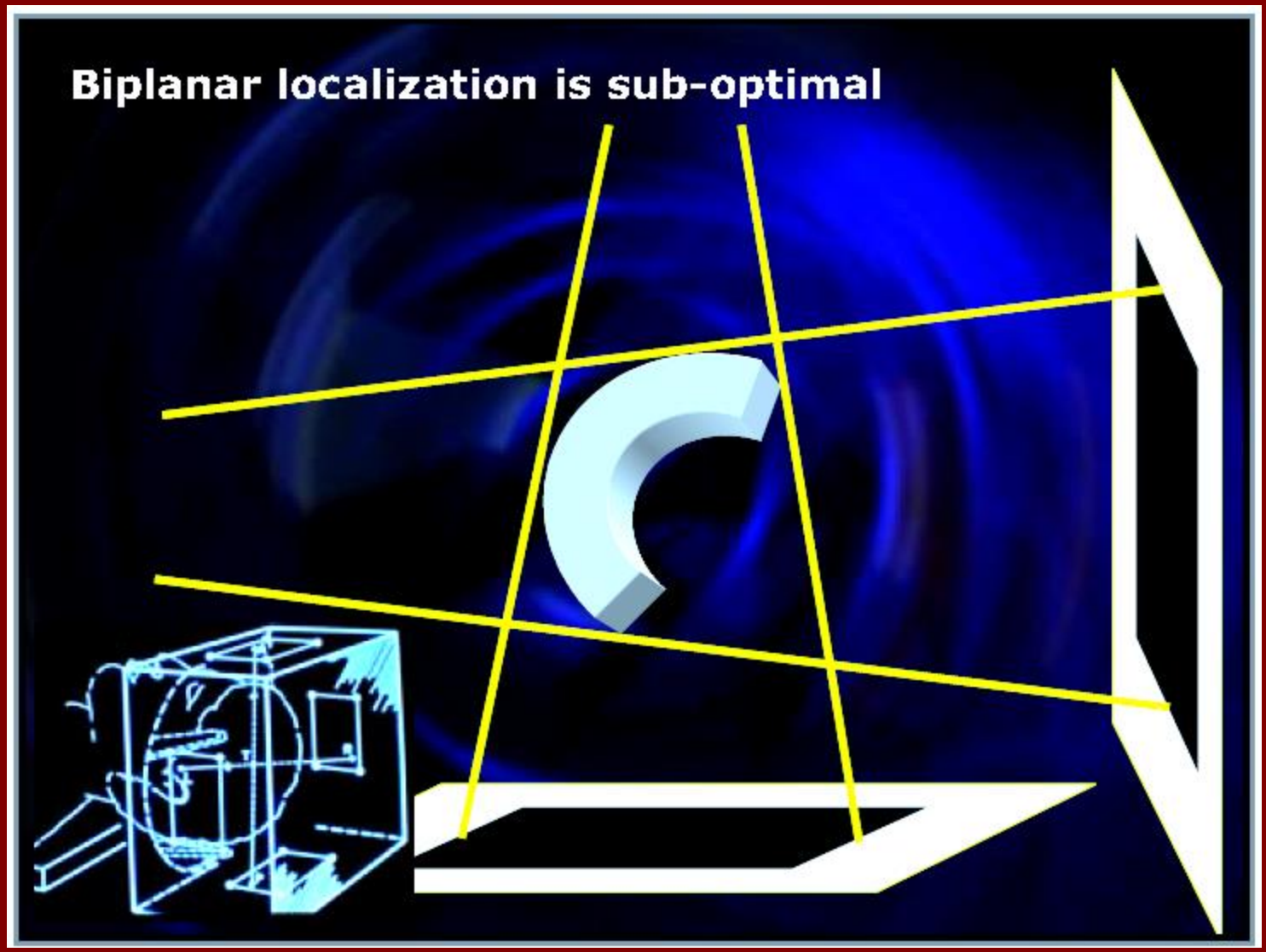




Radiographic localization requires a reference frame

Images are registered, not fused. There is no such thing as "frameless" 2D angio localization, and you cannot "fuse" 2D angios.

Incomplete information



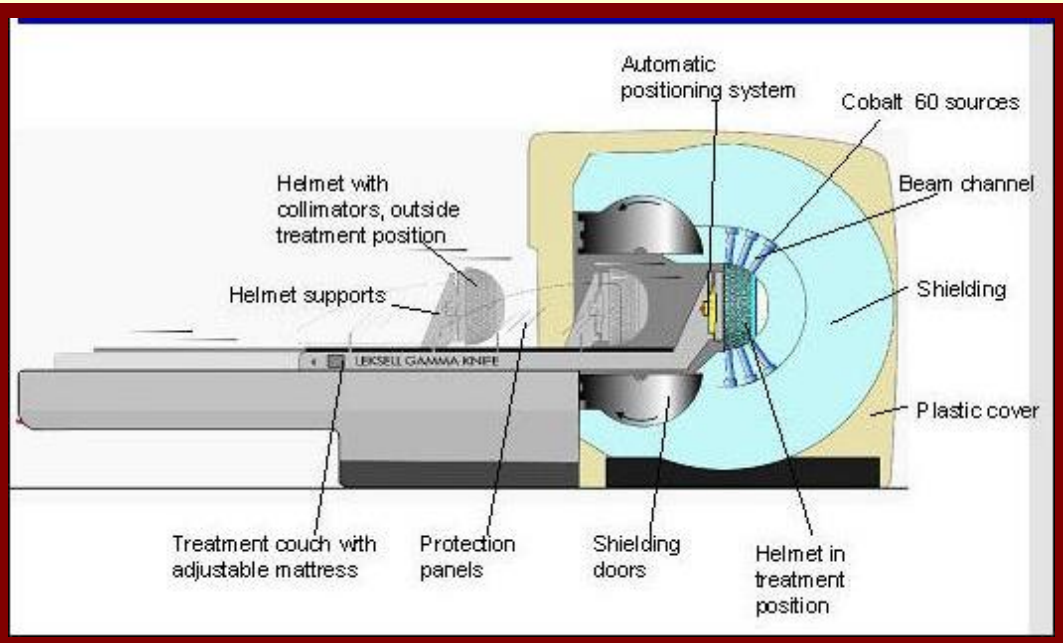
Laser-Angiographic Target Localizer (LATL)

Used for Angiography to register the nidus to a CT data set

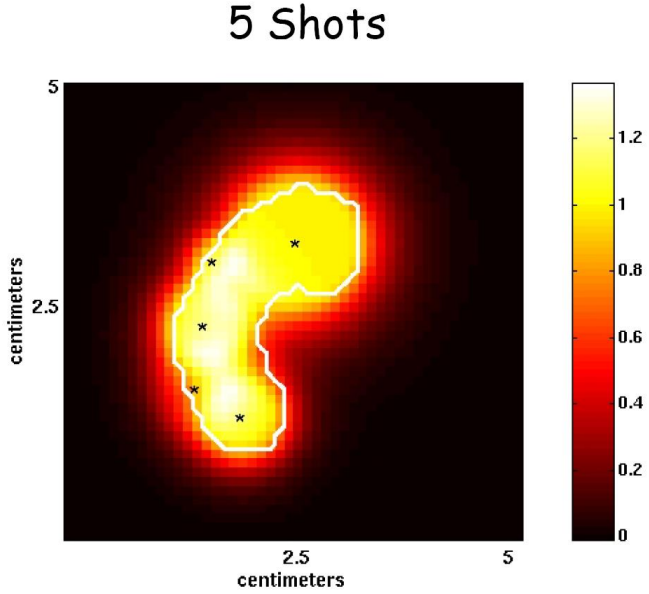
FIDUCIAL MARKER BOX:


Gamma-Knife

Gamma knife



- **Irregular target volumes require multiple 'shots'**



X-Knife

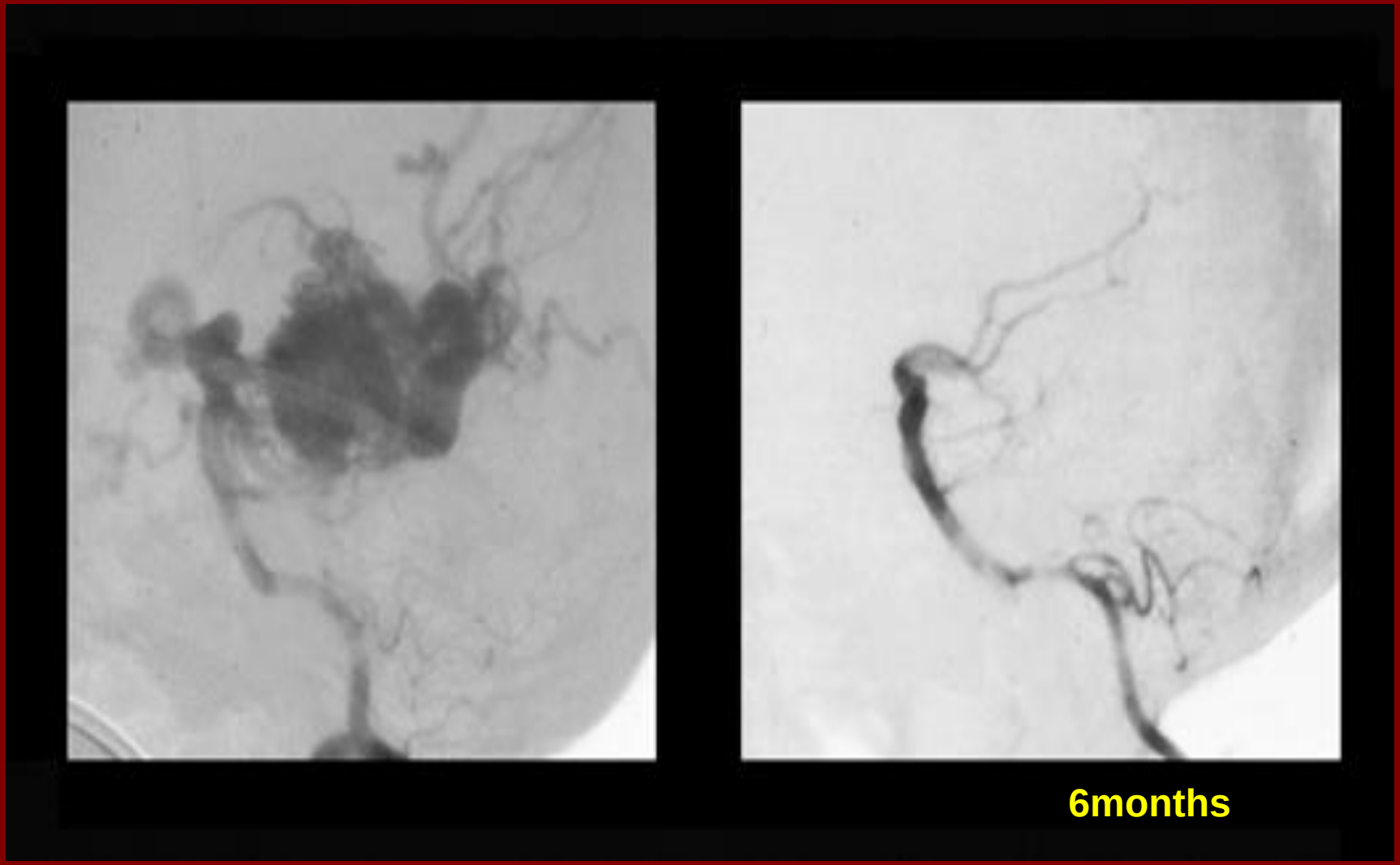
- Collimator sizes: 5 to 45 mm in 2.5 mm steps
- Conformal SRT: with jaws/circles; mMLC; IMRT.
- Extra-cranial: head and neck; body localization, spine localization, other targets

Gamma Knife

- Collimator sizes: 4,8,14,18 mm
- Conformal is only attained through multiple isocenters
- No extra-cranial targets possible

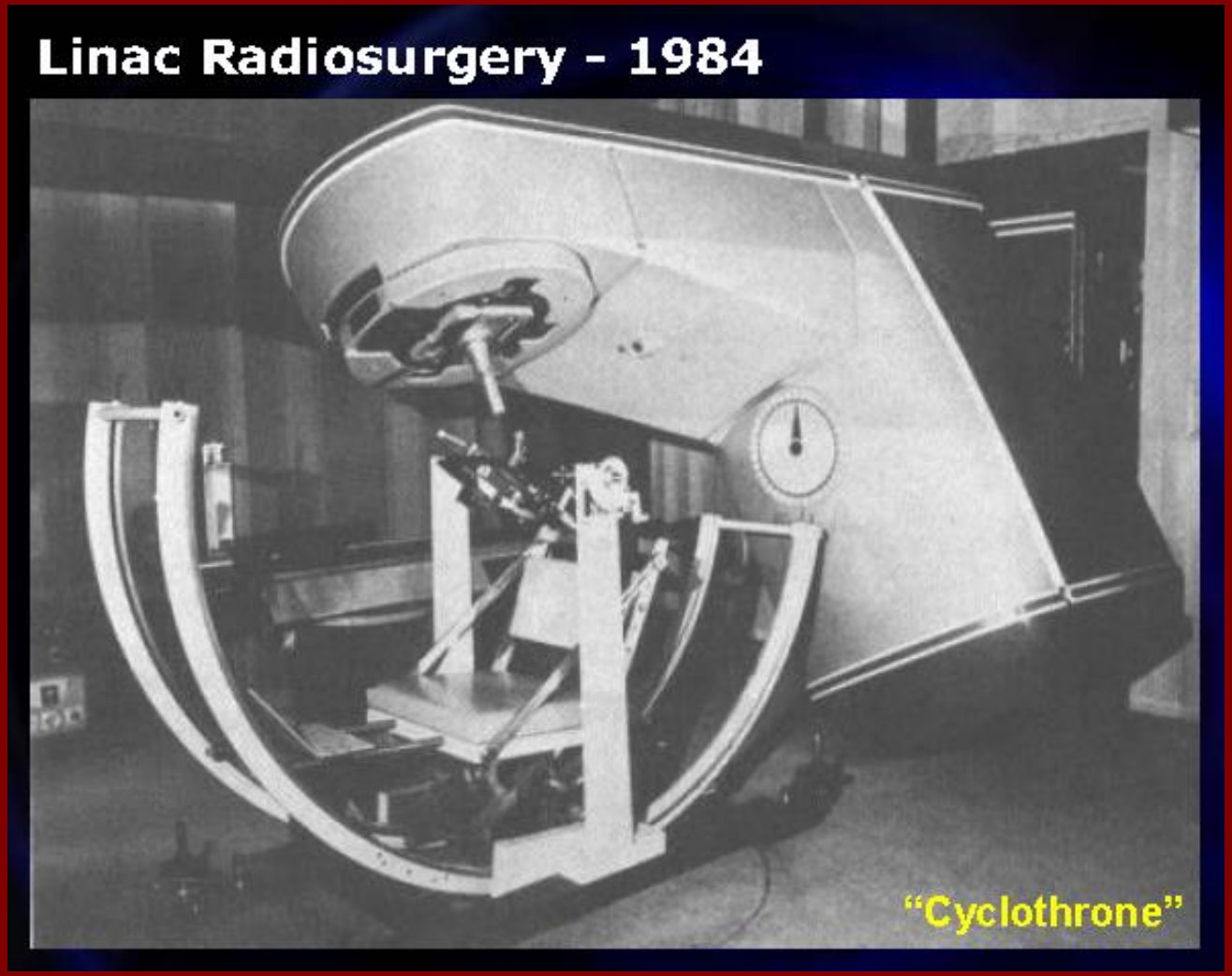
Radiosurgery AVM

Pre-Radiosurgery **Post-Radiosurgery**



6months

History



First linac- based SRS system. Betti et al., Buenos Aires, Argentina

Ref: Historical Development of Stereotactic Ablative Radiotherapy, by Timothy D. Solberg, Robert L. Siddon, and Brian Kavanagh. In S. S. Lo et al. (eds.), Stereotactic Body Radiation Therapy, Medical Radiology. Radiation Oncology,

DOI: 10.1007/174_2012_540, Springer-Verlag Berlin Heidelberg 2012

Radiation delivery techniques

Arcs with circular collimators

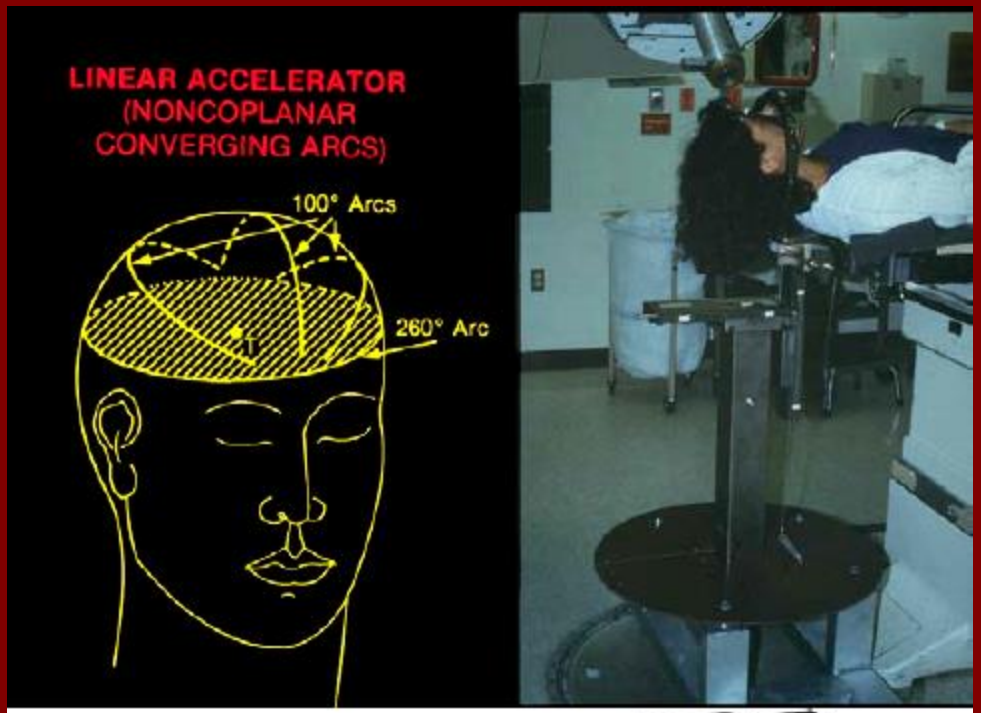
Conformal beams

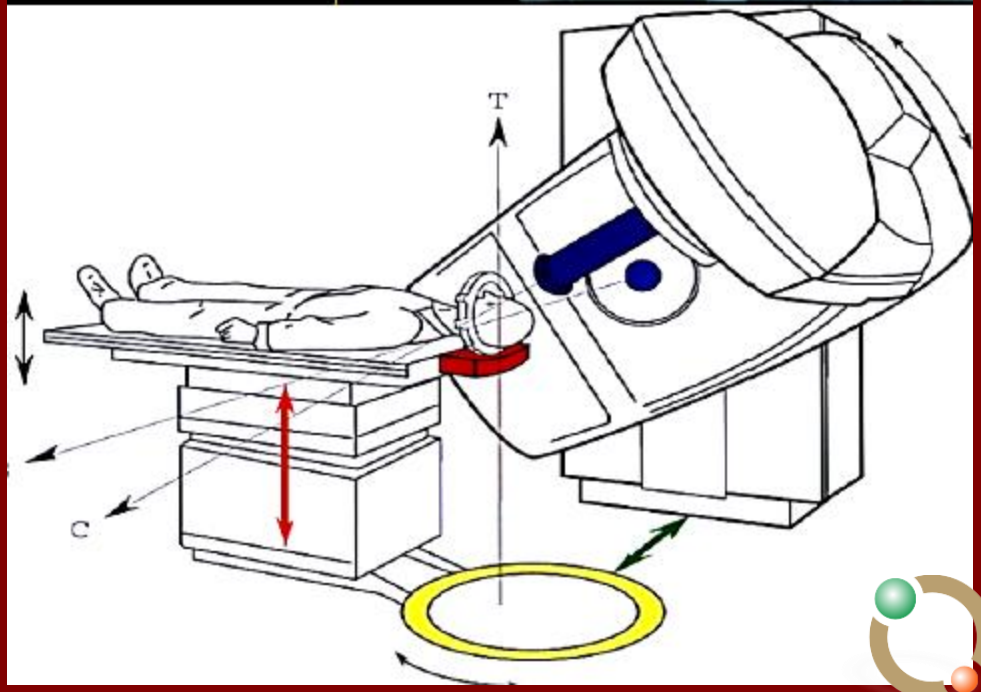
Arcs with Conformal Dynamic beams

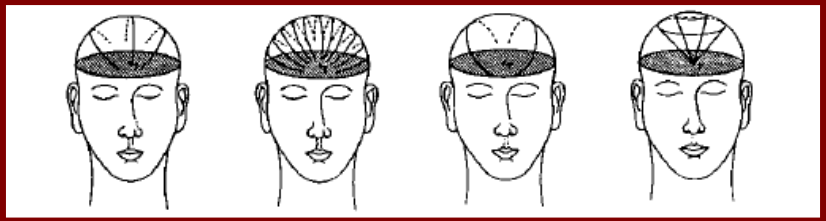
IMRT

Linac SRS with cones

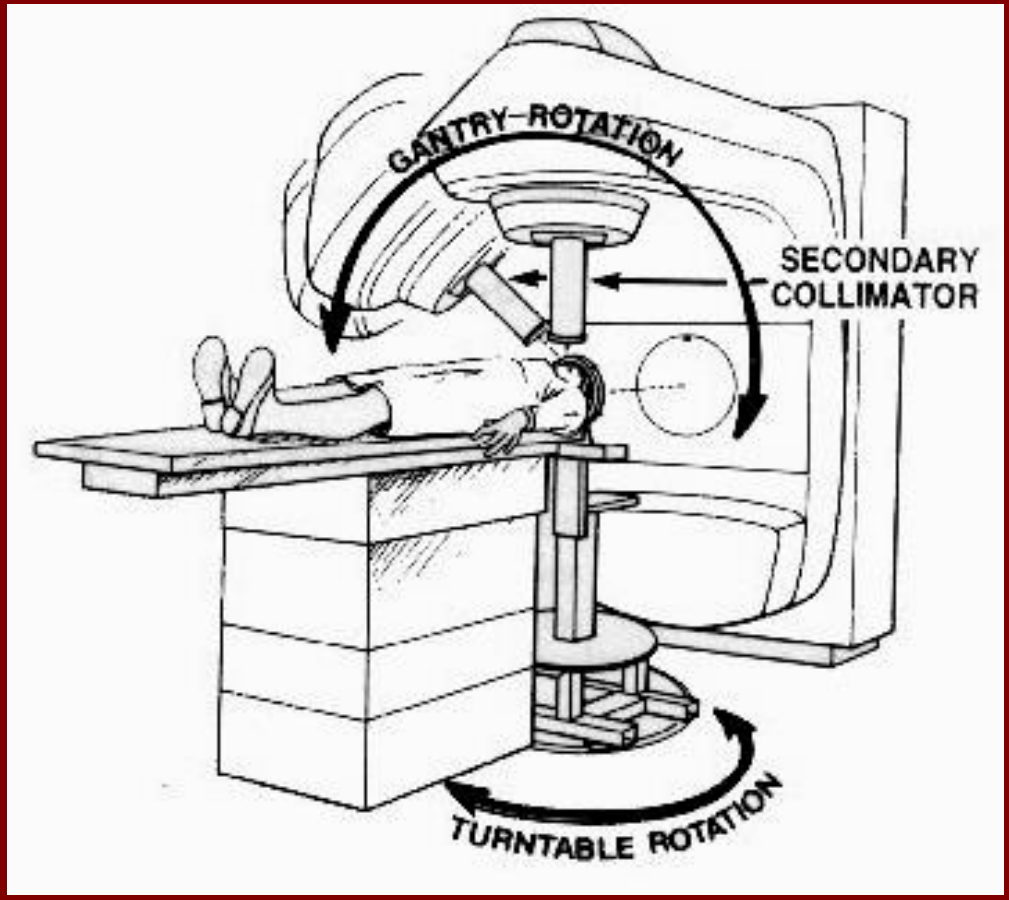
- One or more isocenters
- Multiple arcs per isocenter
  - Arcs of 100º to 160º
  - Fixed couch angle for each arc
  - Spherical dose distributions for each irradiación

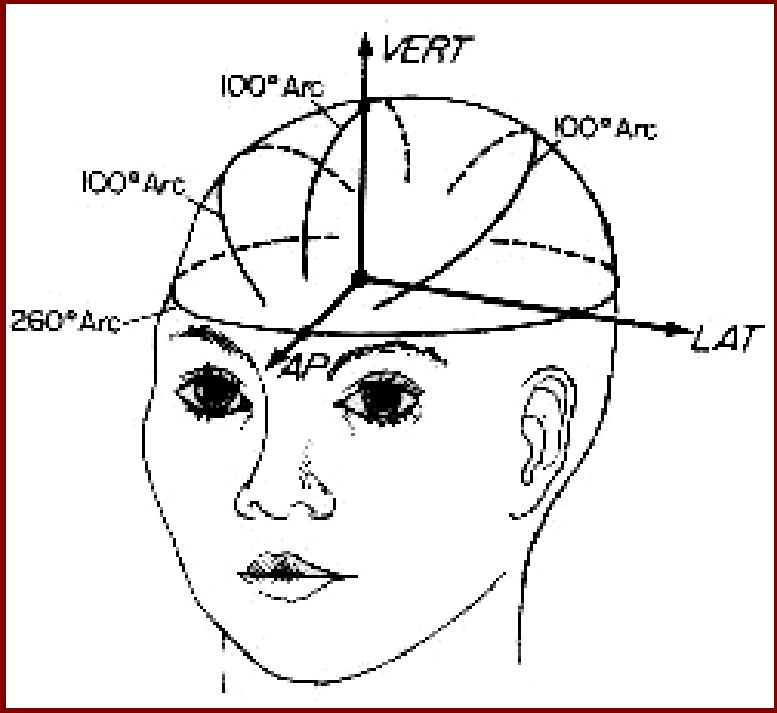






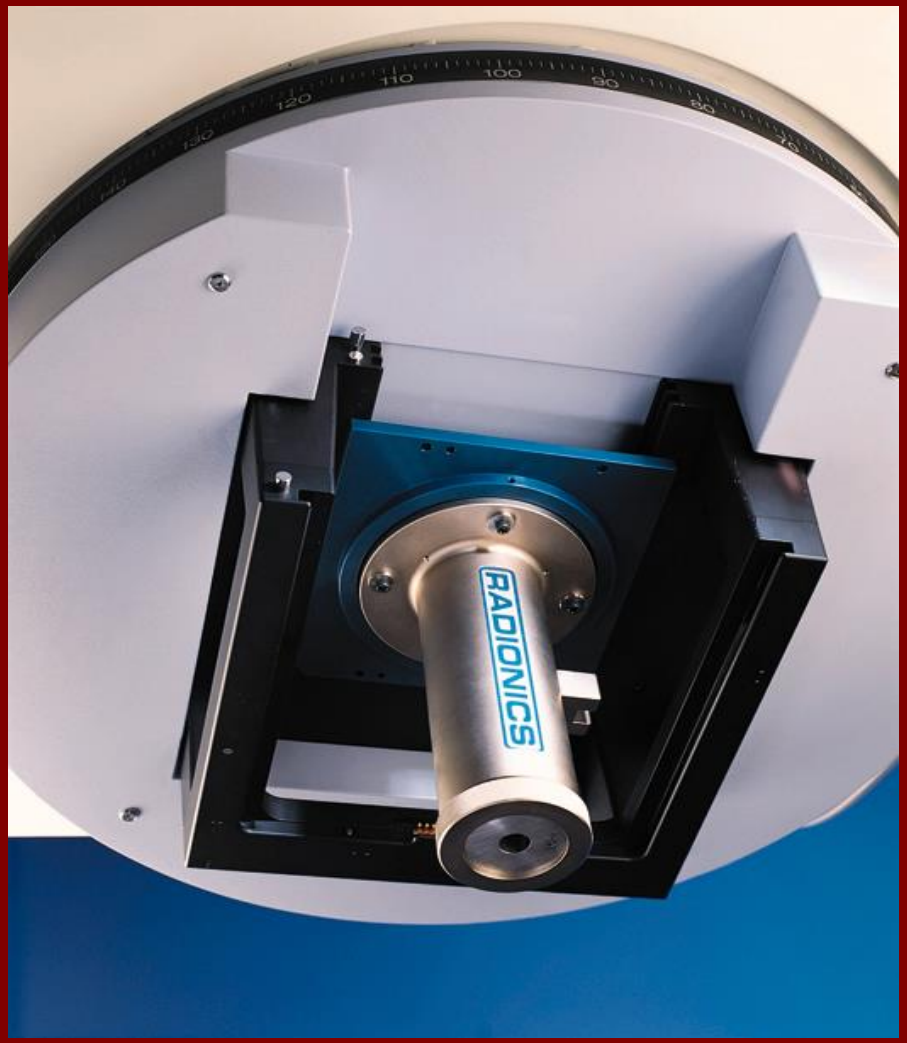
Arcs with circular cross sections are obtained by rotating the source (linac gantry) in various planes in the patient, corresponding to various couch angles.

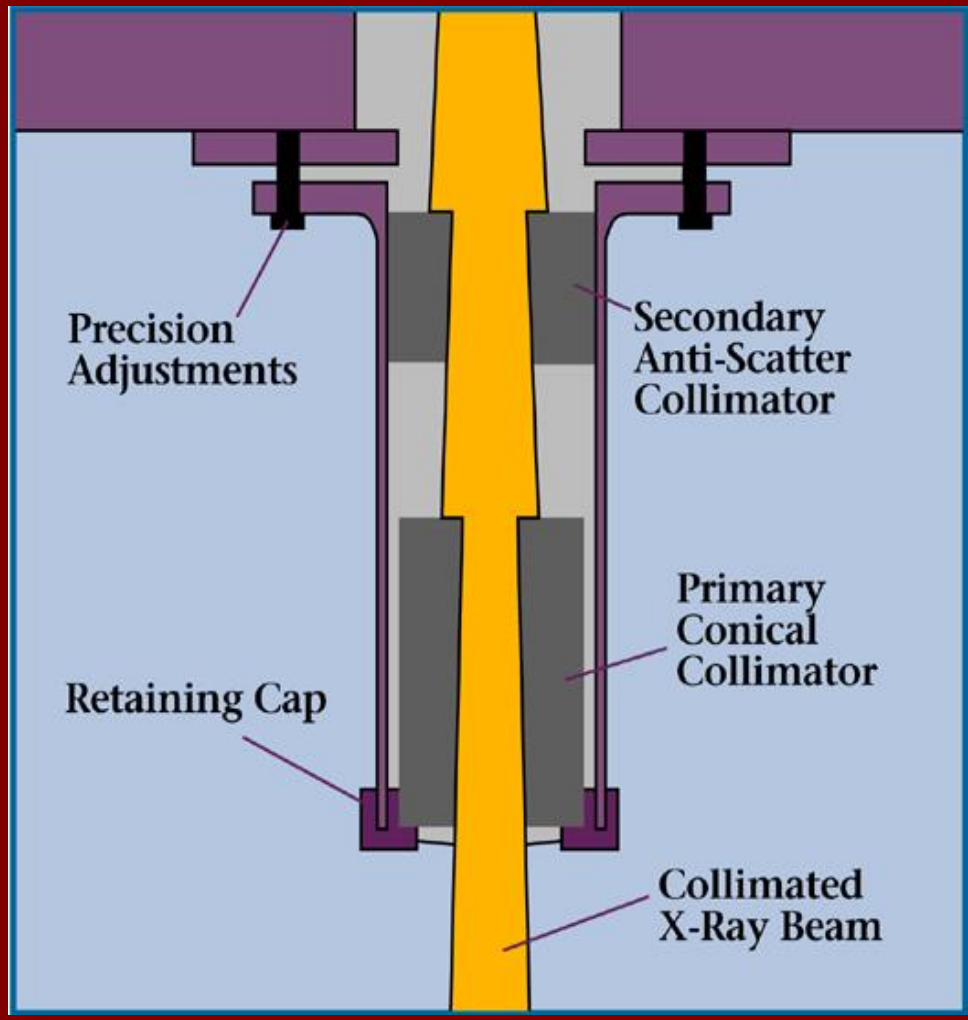




Tertiary Collimation Cone

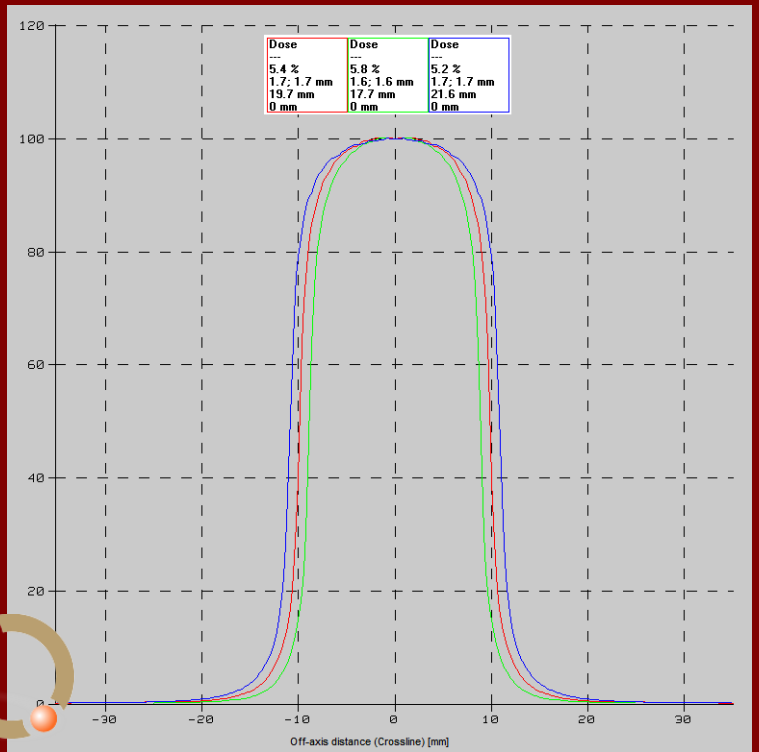
Collimation





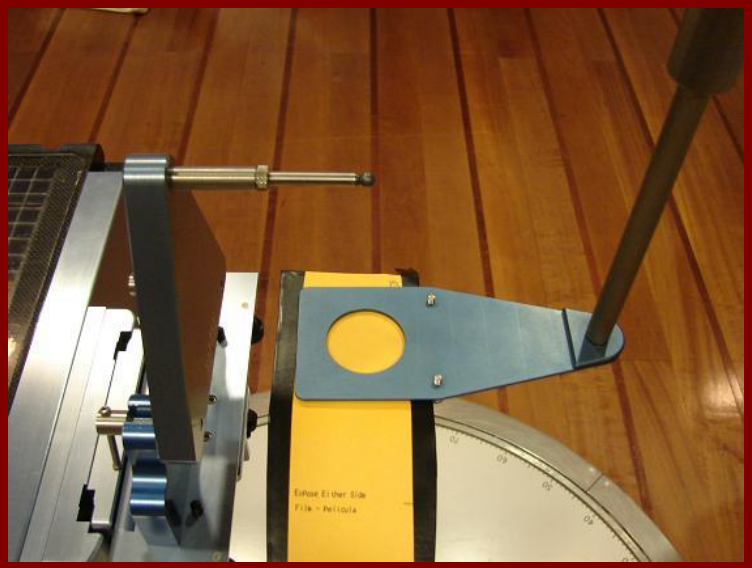
Linac SRS on Linac + cones

- 5-40mm diameter cone set
- Circular beam projection
- Collimator mounted assembly



Verification of gantry isocenter with cones

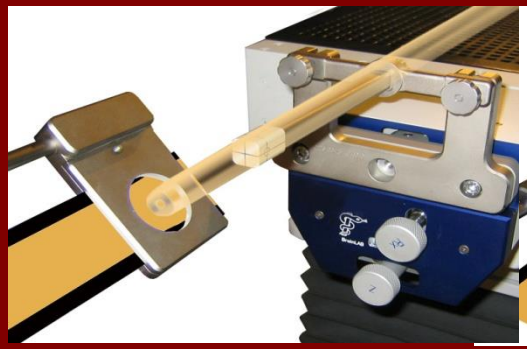
Laser alignment

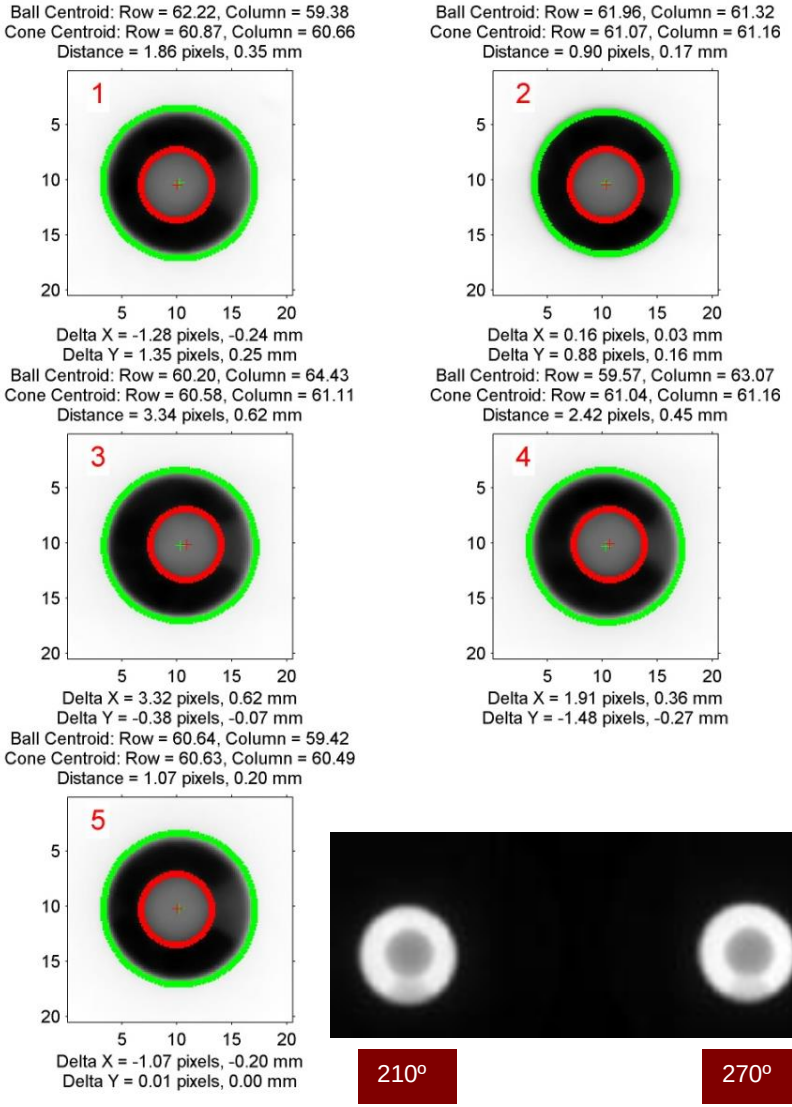


Stereotactic Set-up QA

Winston Lutz Quality Assurance

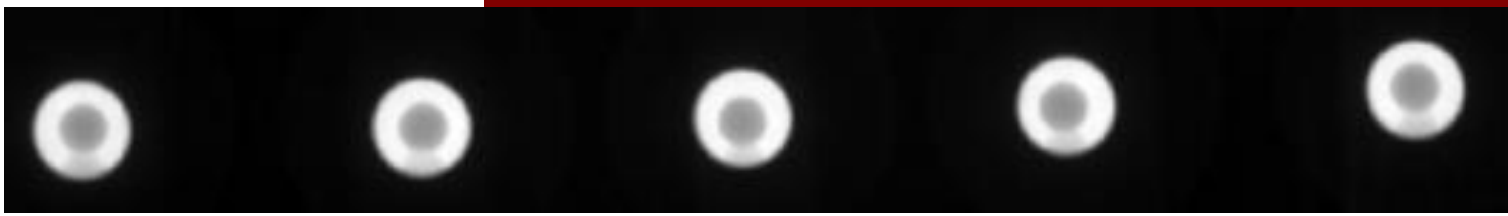
- **Phantom Pointer verifies laser accuracy prior to SRS**
- **Embossed laser lines for easy alignment with wall lasers**
- **Integrated tungsten sphere for film verification**
- **Irradiation of film at different gantry angles**
- **Shadow in field center verifies accuracy**



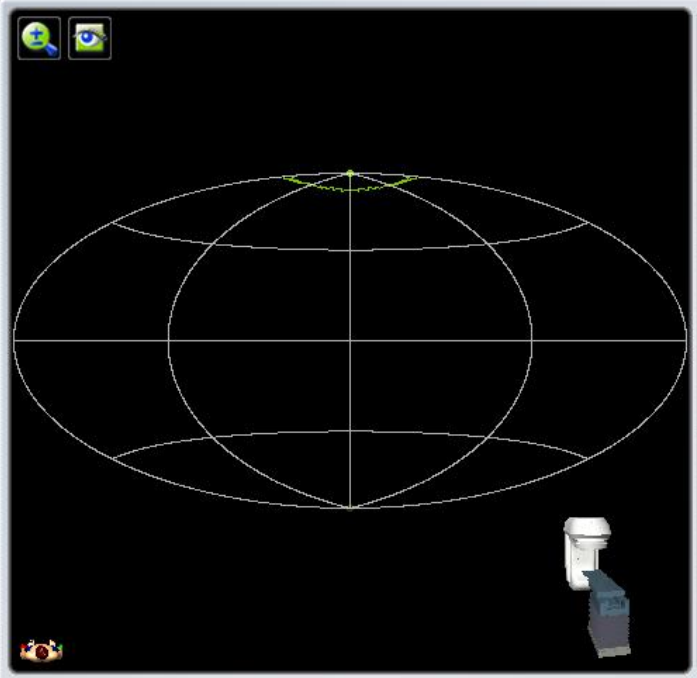


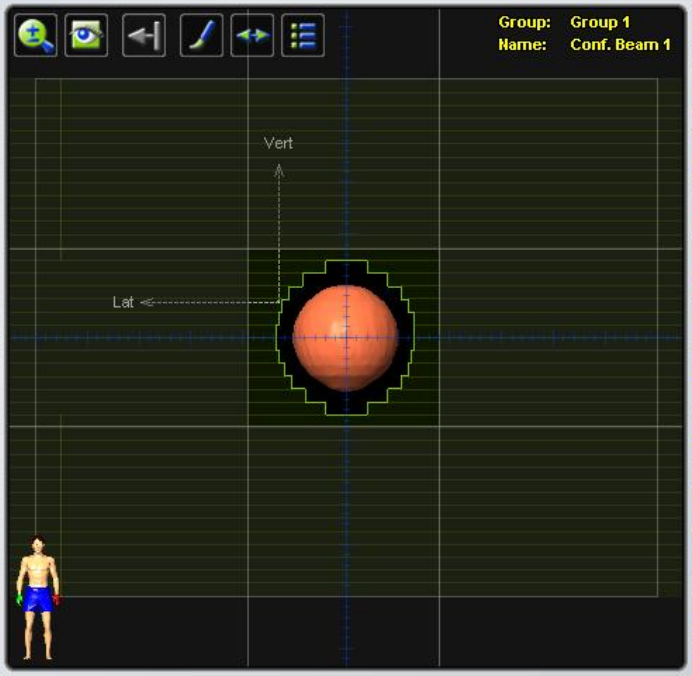
Gantry	210º	270º	0º	90º	150º
ΔGT (mm)	0.25	0.03	0.62	0.36	0.20
ΔAB (mm)	0.24	0.15	0.07	0.27	0.0
Vector (mm)	0.35	0.15	0.62	0.45	0.20

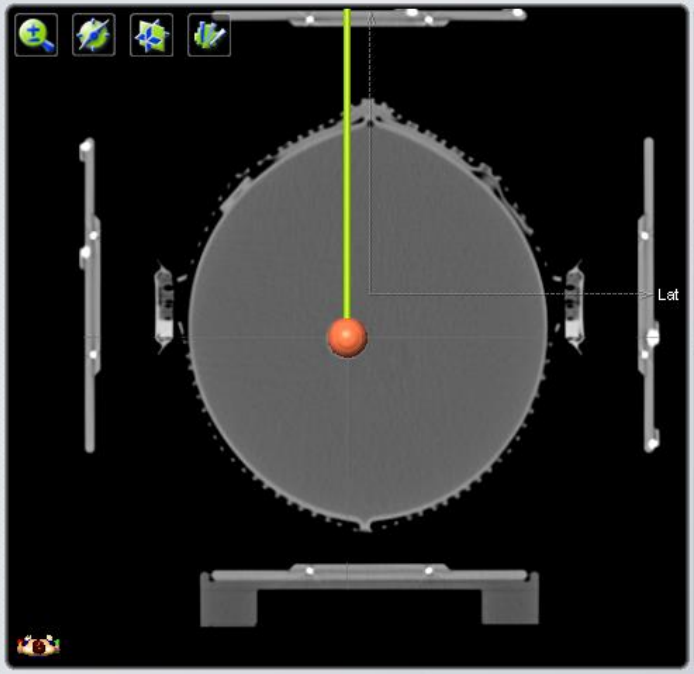
AAPM TG42: Tolerance = 1mm

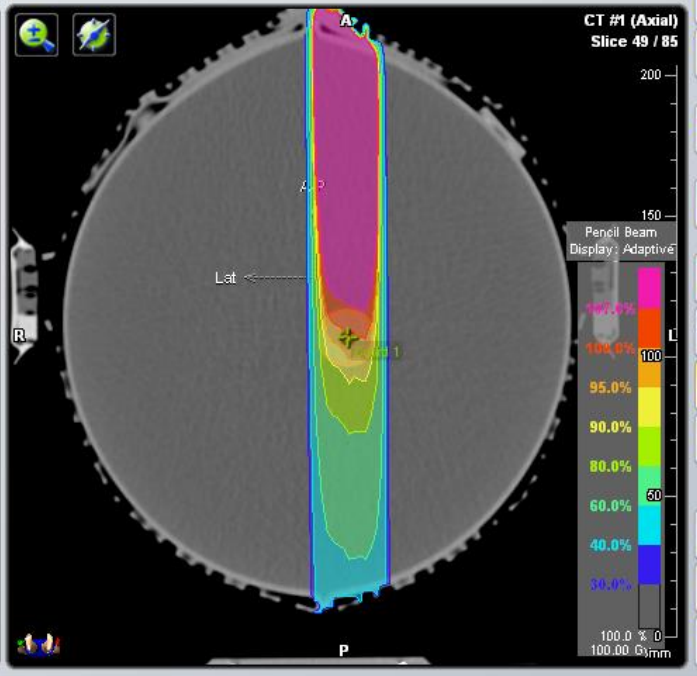


210º 270º 0º 90º 150º









Navigator

QA IMRS - DOSIS CAMARA 2
ID: QA IMRS
Contornos

Treatment Planning

Physician's Review

Go to... | Next

Functions | Prescription

- The RTPlan
  - Group 1
    - Conf. Beam 1

Refresh MU

Treatment Group

Position | Find

Properties | Delete

Coord 1:

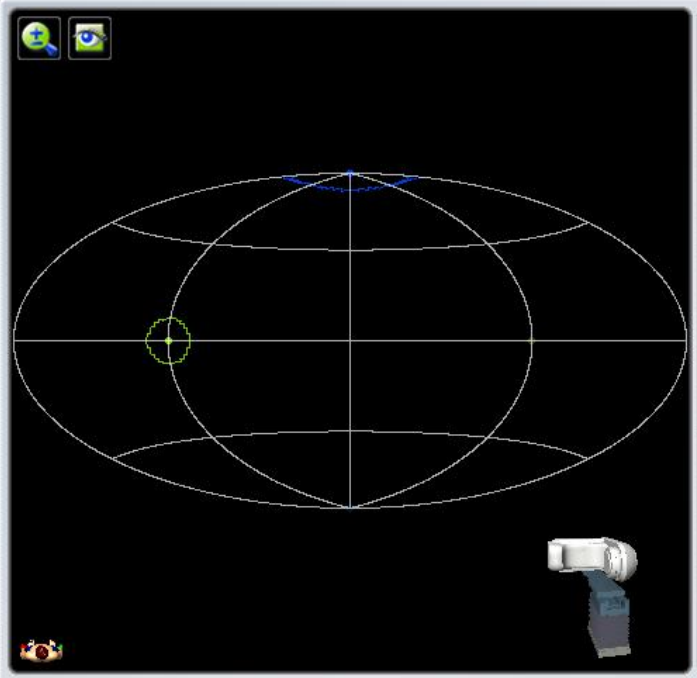
A-P	-21.7	mm
Lateral	-11.6	mm
Vertical	-5.4	mm
Weighting:	100.0 %	

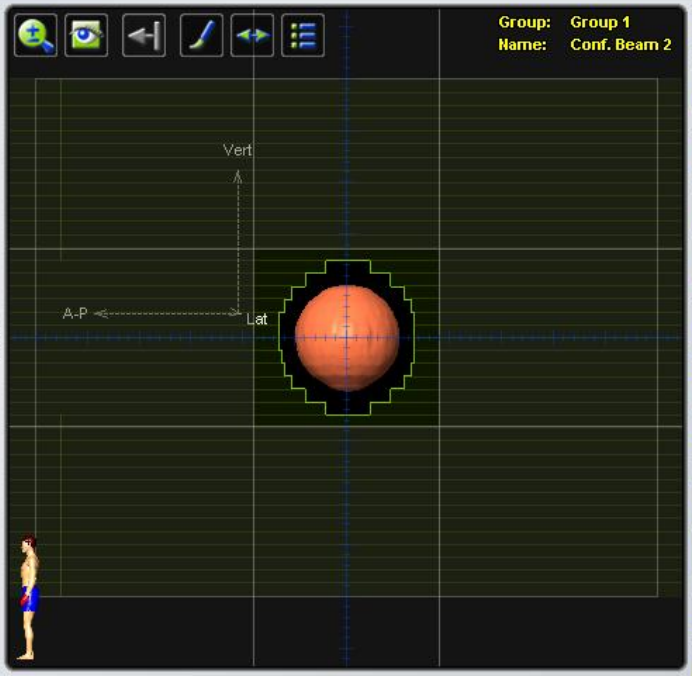
Beams / Arcs

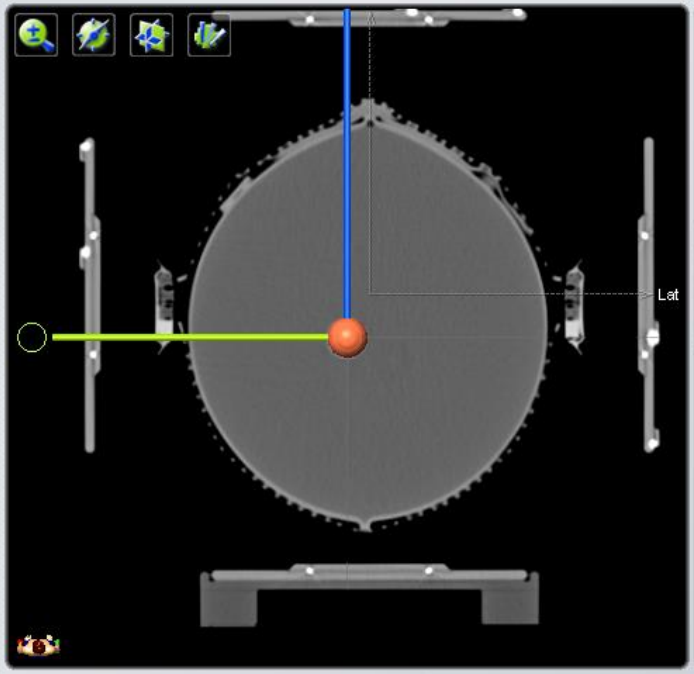
Add

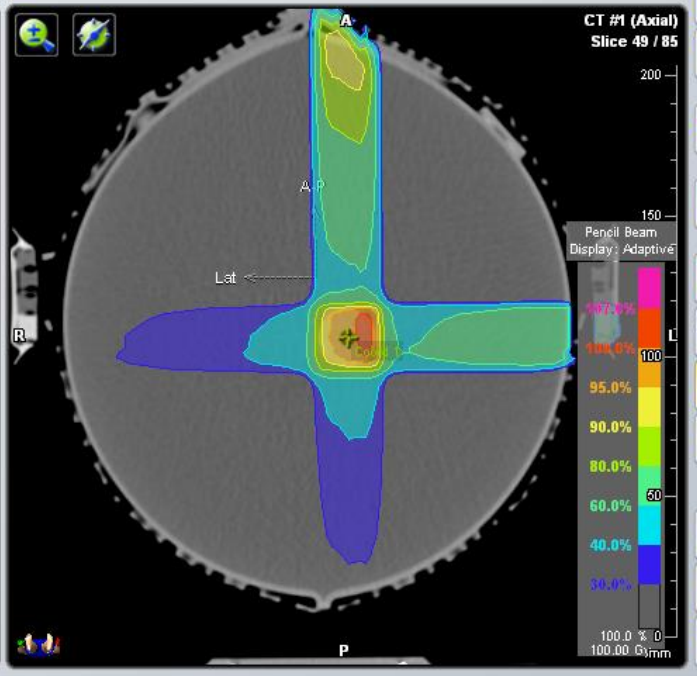
Overview | Slices | Irradiation Plan | Plan Content

BrainLAB
iPlan RT Dose 4.1









Navigator

QA IMRS - DOSIS CAMARA 2
ID: QA IMRS
Contornos

Treatment Planning

Physician's Review

Go to... | Next

Functions | Prescription

- The RTPlan
  - Group 1
    - Conf. Beam 1
    - Conf. Beam 2

Refresh MU

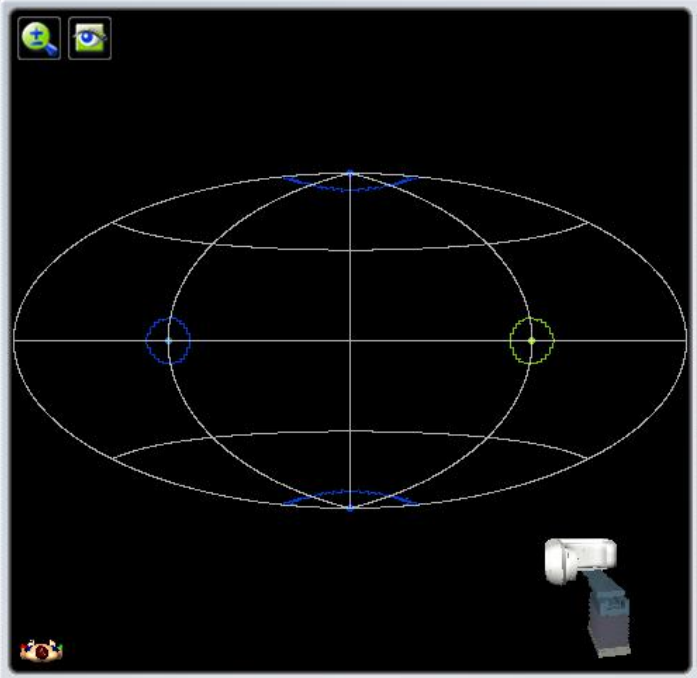
Beam

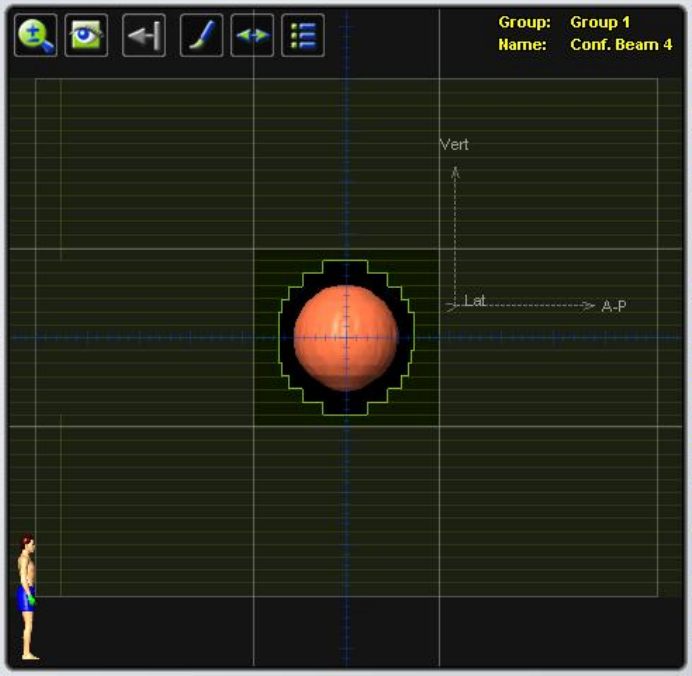
Properties | Delete

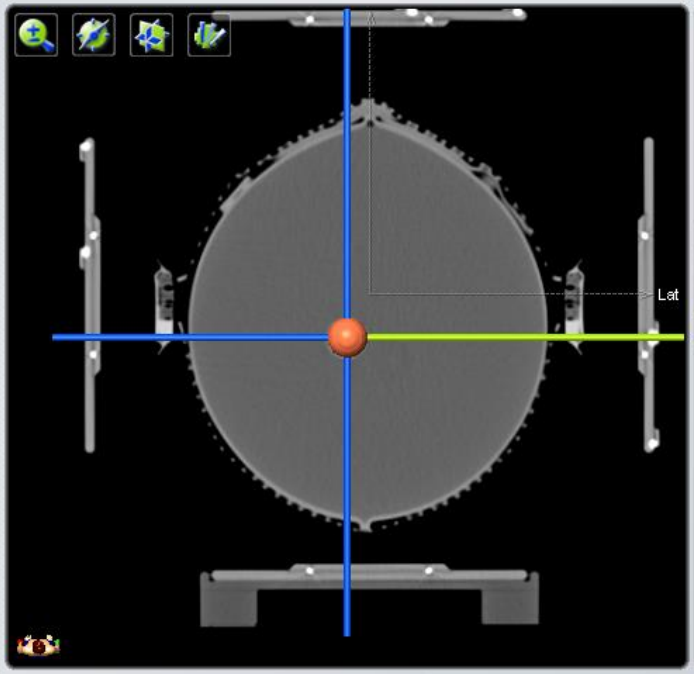
Table:	0	°
Gantry:	90	°
Coll.:	0	°
Margin:	3.0	mm
Weighting:	50.0 %	
MU:	6753 (1 x 6753)!	

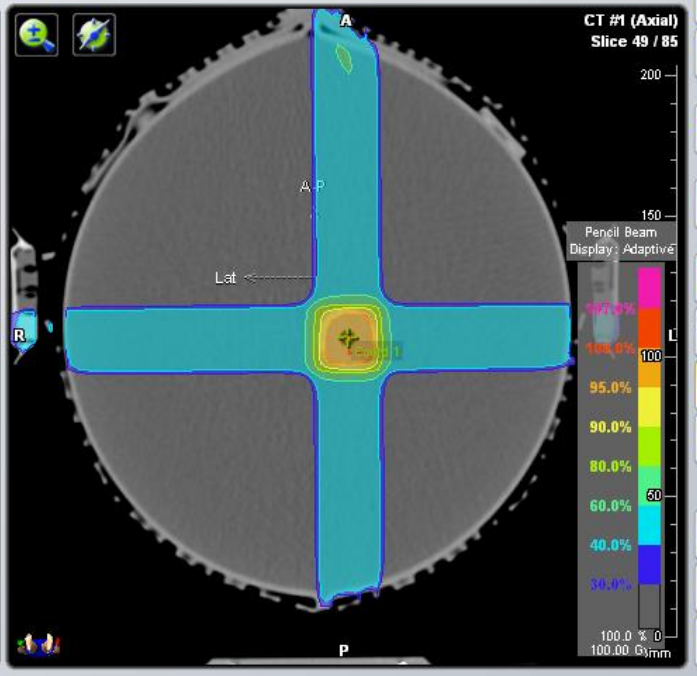
Overview | Slices | Irradiation Plan | Plan Content

BrainLAB
iPlan RT Dose 4.1









Navigator

QA IMRS - DOSIS CAMARA 2
ID: QA IMRS
Contornos

Treatment Planning
Physician's Review
Go to... Next

Functions | Prescription

- The RTPlan
  - Group 1
    - Conf. Beam 1
    - Conf. Beam 2
    - Conf. Beam 3
    - Conf. Beam 4

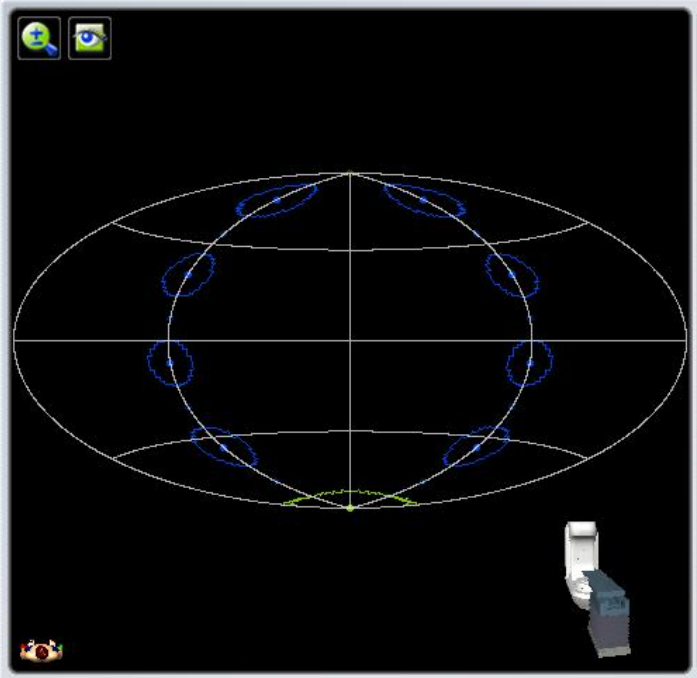
Refresh MU

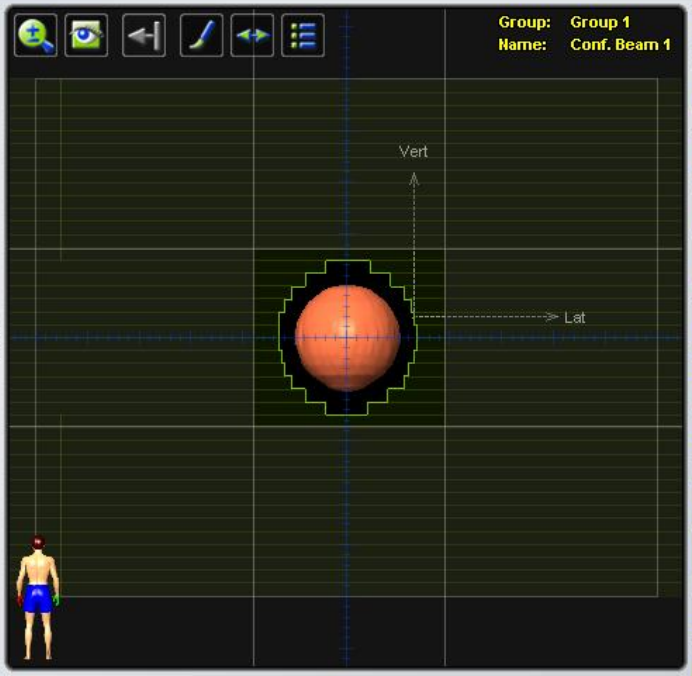
Beam
Properties Delete

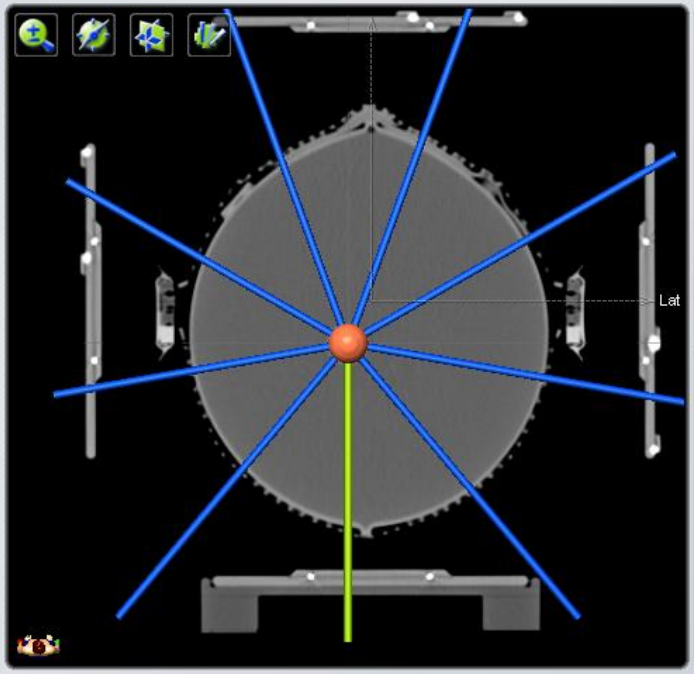
Table:	0	°
Gantry:	270	°
Coll.:	0	°
Margin:	3.0	mm
Weighting:	25.0 %	
MU:	3706 (1 x 3706)!	

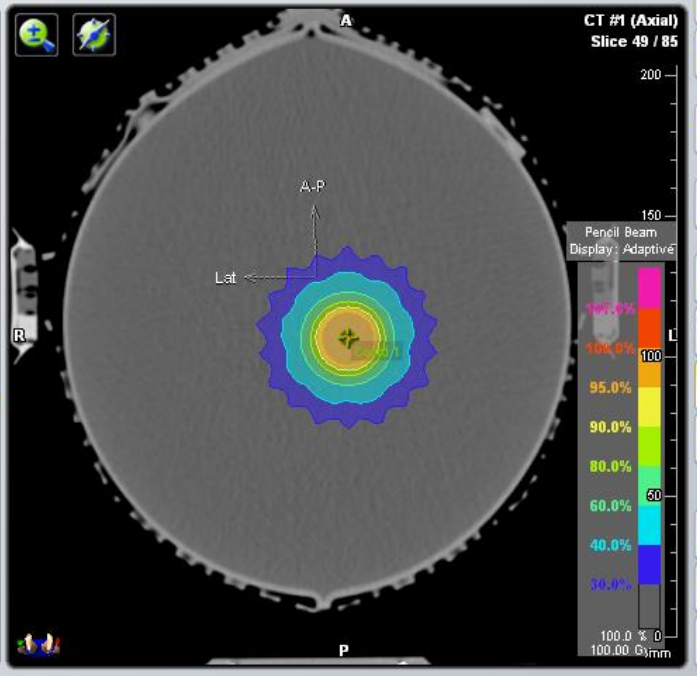
Overview | Slices | Irradiation Plan | Plan Content

BrainLAB
iPlan RT Dose 4.1









Navigator

QA IMRS - DOSIS CAMARA 2
ID: QA IMRS
Contornos

Treatment Planning
Physician's Review
Go to...
Next

Functions | Prescription

- Group 1
  - Conf. Beam 1
  - Conf. Beam 2
  - Conf. Beam 3
  - Conf. Beam 4
  - Conf. Beam 5
  - Conf. Beam 6
  - Conf. Beam 7

Refresh MU

Treatment Group

Position | Find
Properties | Delete

Coord 1:

A-P	-21.7	mm
Lateral	-11.6	mm
Vertical	-5.4	mm

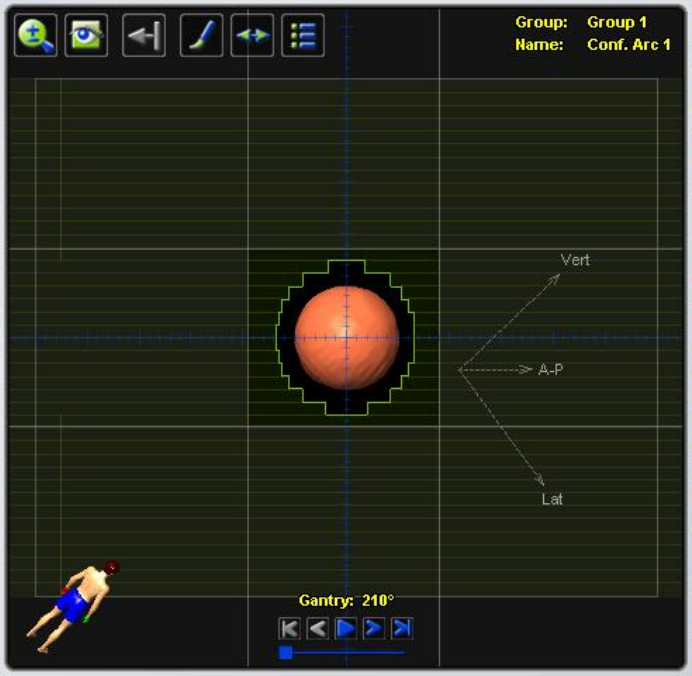
Weighting: 100.0 %

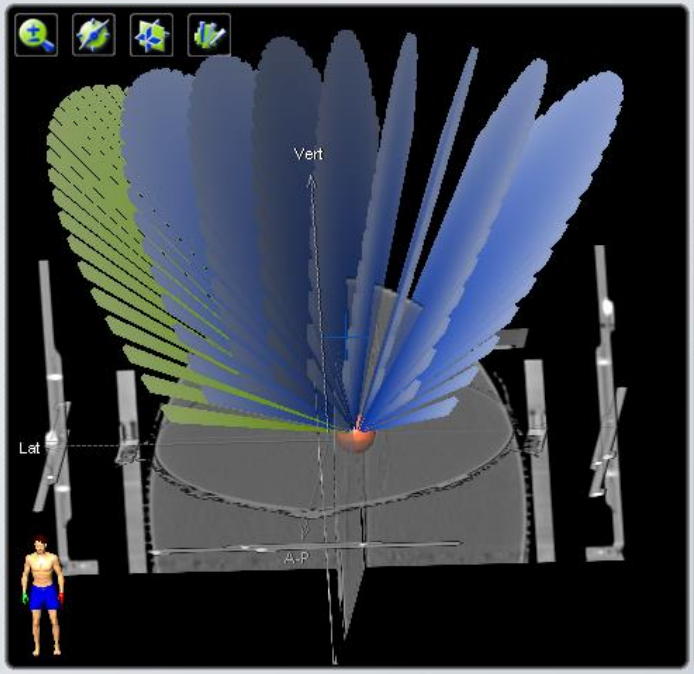
Beams / Arcs

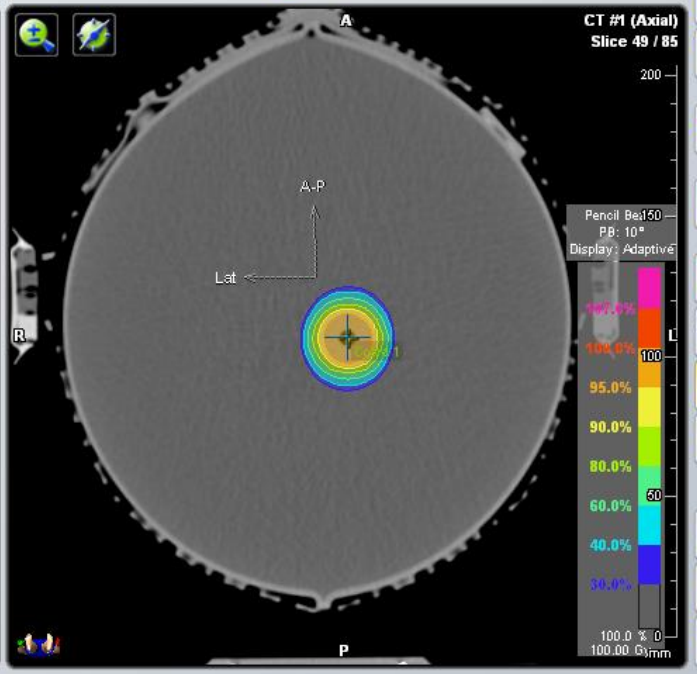
Add

Overview | Slices | Irradiation Plan | Plan Content

BrainLAB
iPlan RT Dose 4.1







Navigator

QA IMRS - DOSIS CAMARA 2
ID: QA IMRS
Contornos

Treatment Planning
Physician's Review
Go to... | Next

Functions | Prescription

- The RTPlan
  - Group 1
    - Conf. Arc 1
    - Conf. Arc 2
    - Conf. Arc 3
    - Conf. Arc 4
    - Conf. Arc 5
    - Conf. Arc 6

Refresh MU

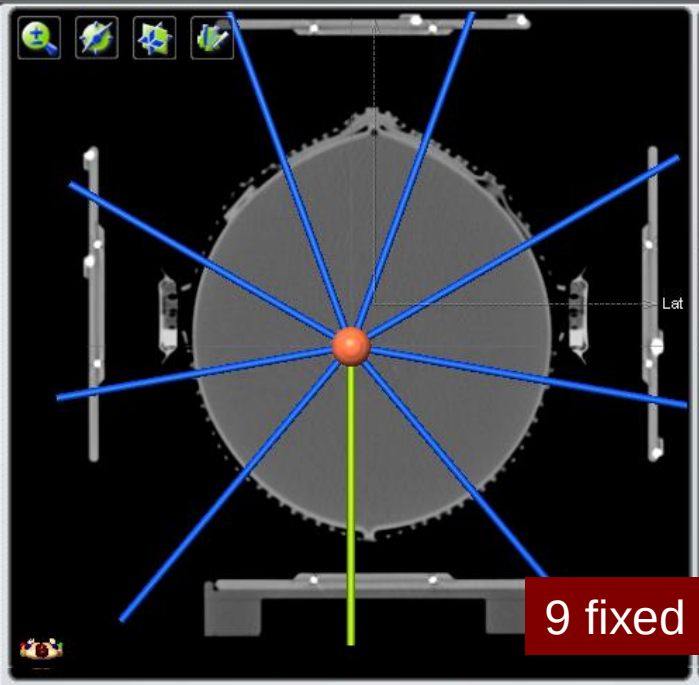
Plan
Add Treatment Group
Properties

Plan Templates
Save as new | Manage

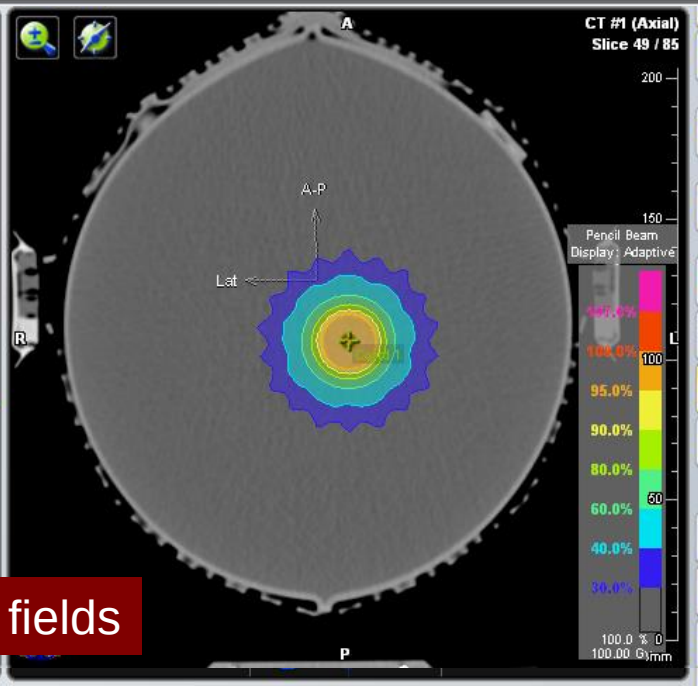
Shape Export
Create Varian MLC file(s)

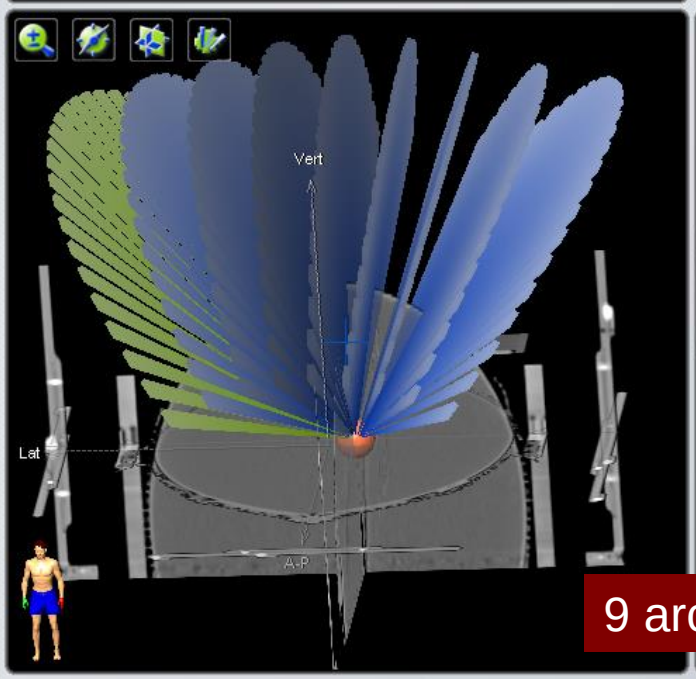
Overview | Slices | Irradiation Plan | Arc BEVs | Plan Content

BrainLAB
iPlan RT Dose 4.1

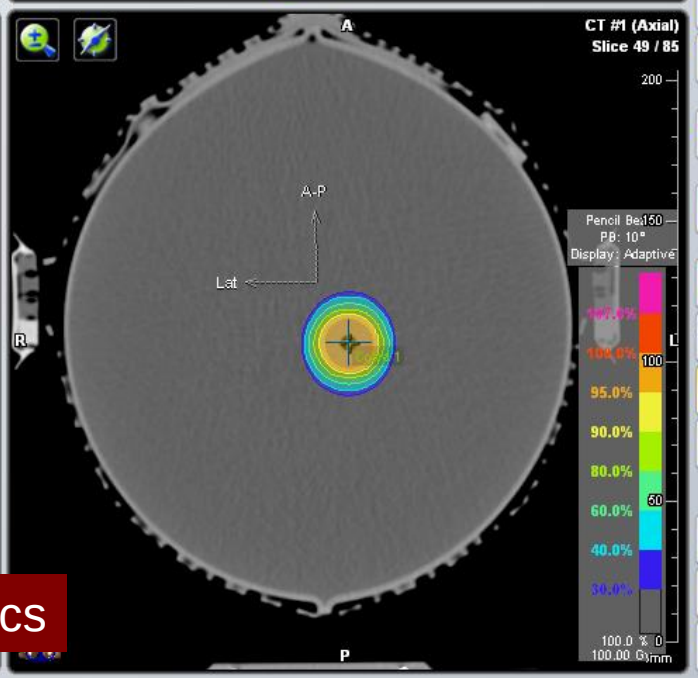


9 fixed fields





9 arcs



Treatment Group

Position | Find

Properties | Delete

Coord 1:

A-P -21.7 mm

Lateral -11.6 mm

Vertical -5.4 mm

Weighting: 100.0 %

Beams / Arcs

Add

Refresh MU

Plan

Add Treatment Group

Properties

Plan Templates

Save as new | Manage

Shape Export

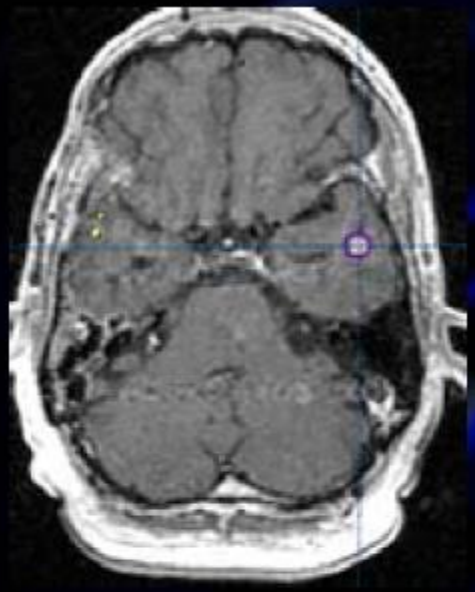
Create Varian MLC file(s)

Overview | Slices | Irradiation Plan | Arc BEVs | Plan Content

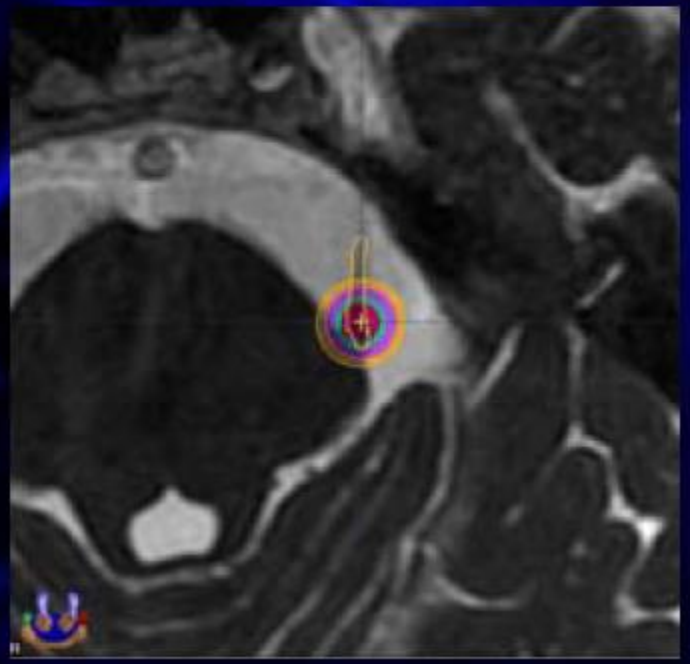
BrainLAB
iPlan RT Dose 4.1

Circular Arc

When to use it?



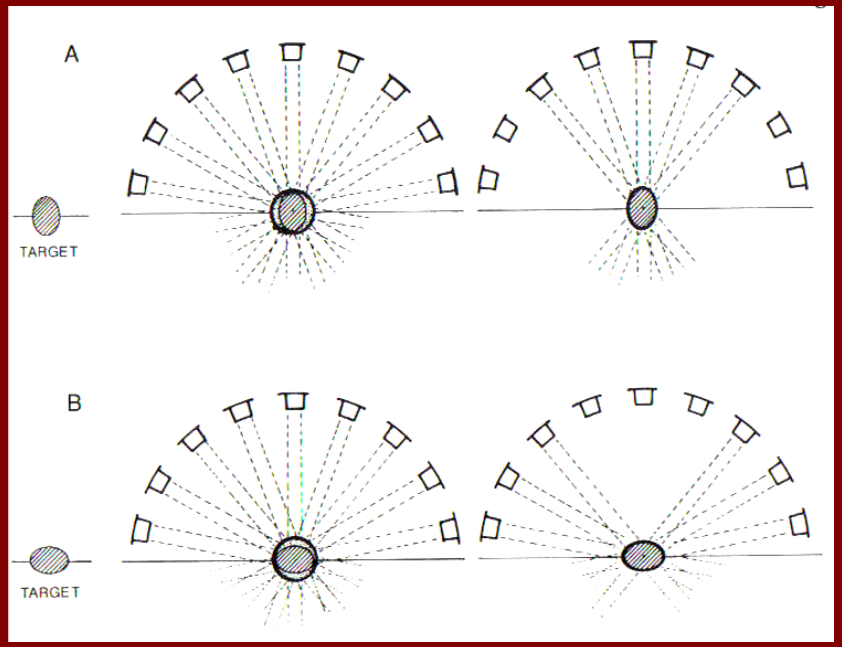
Small, spherical Metastases

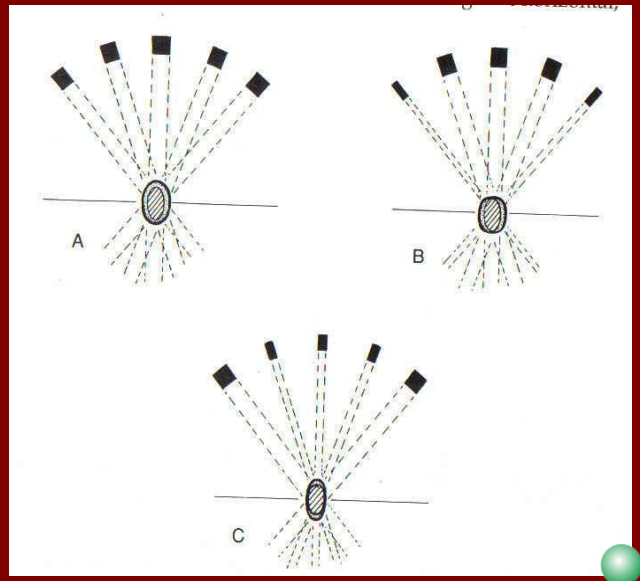


Trigeminal Neuralgia

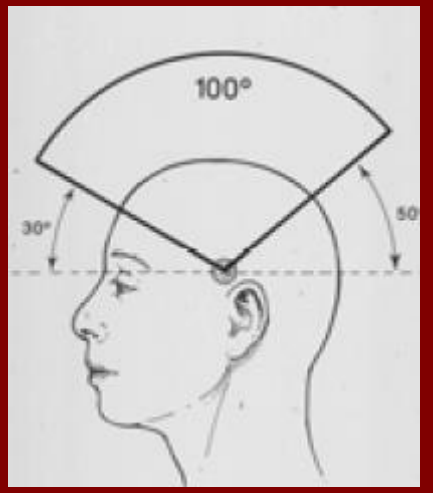
Planning strategies for SRS with arcs

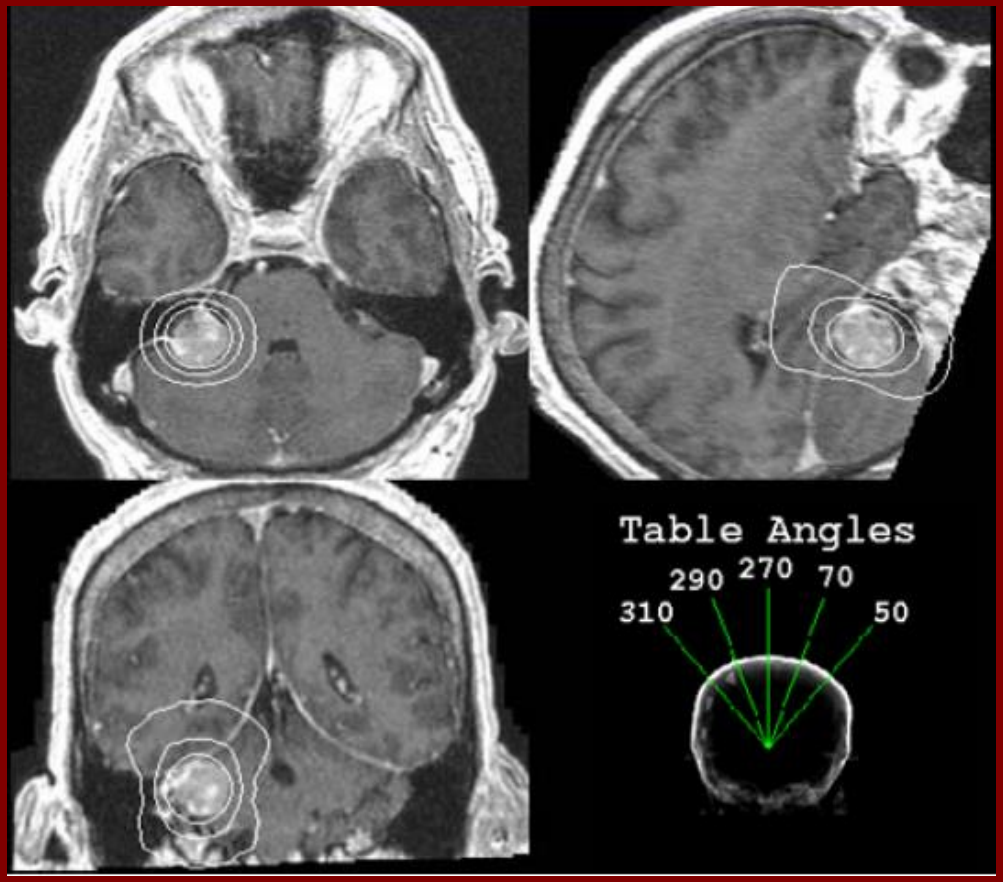
- **Spherical targets:**
  - **Use up to 9 arcs with collimator diameter corresponding to the target diameter**
- **Elliptical targets:**
  - **If the major axis is in the coronal plane, eliminate perpendicular arcs, or use different cone sizes**

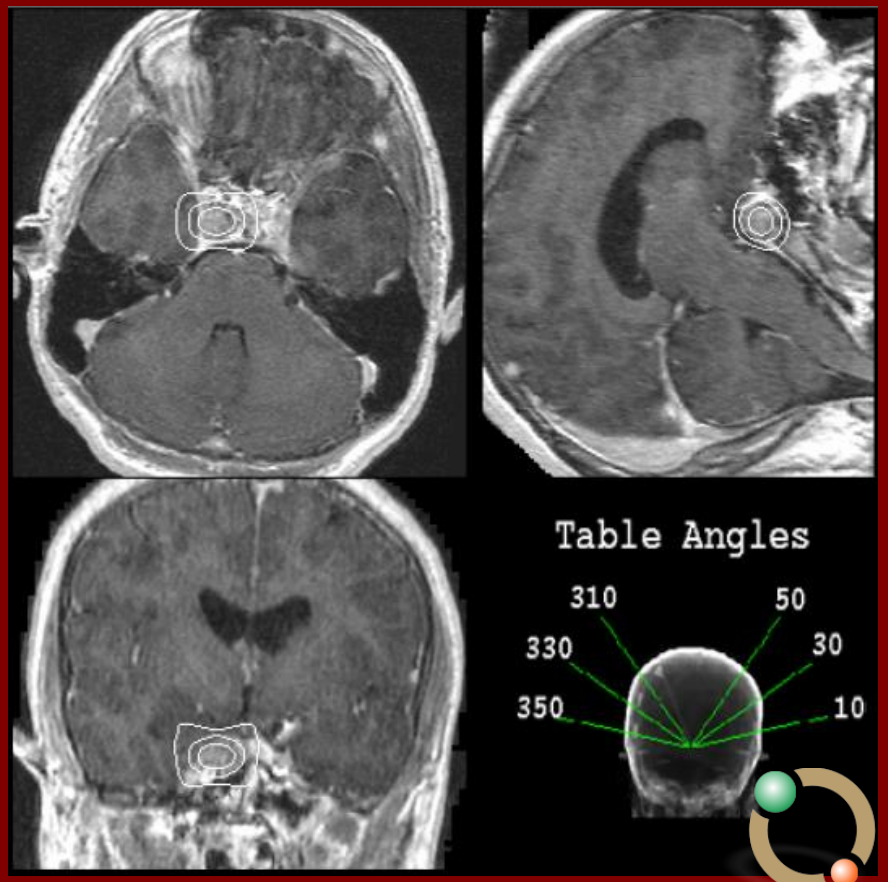




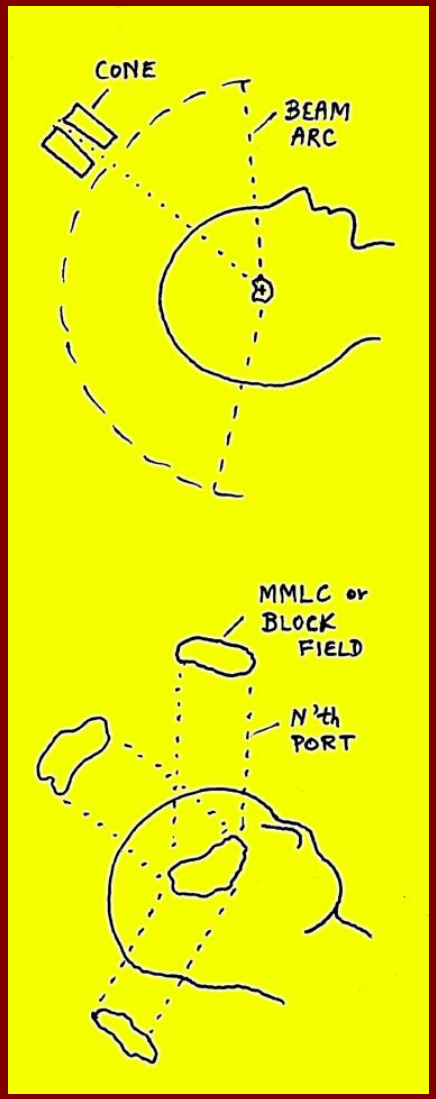
Circular collimators





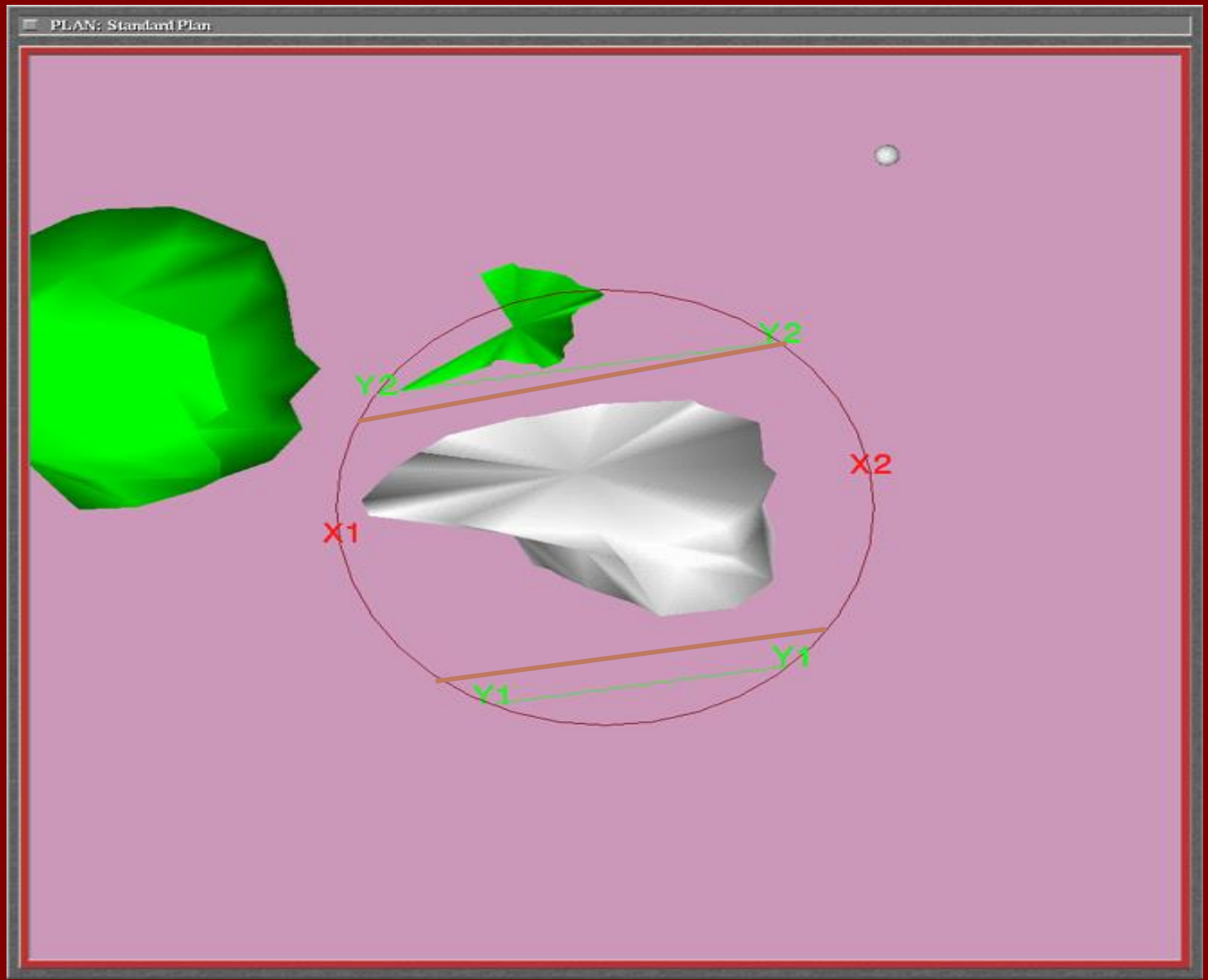


Considerations according to the type of target

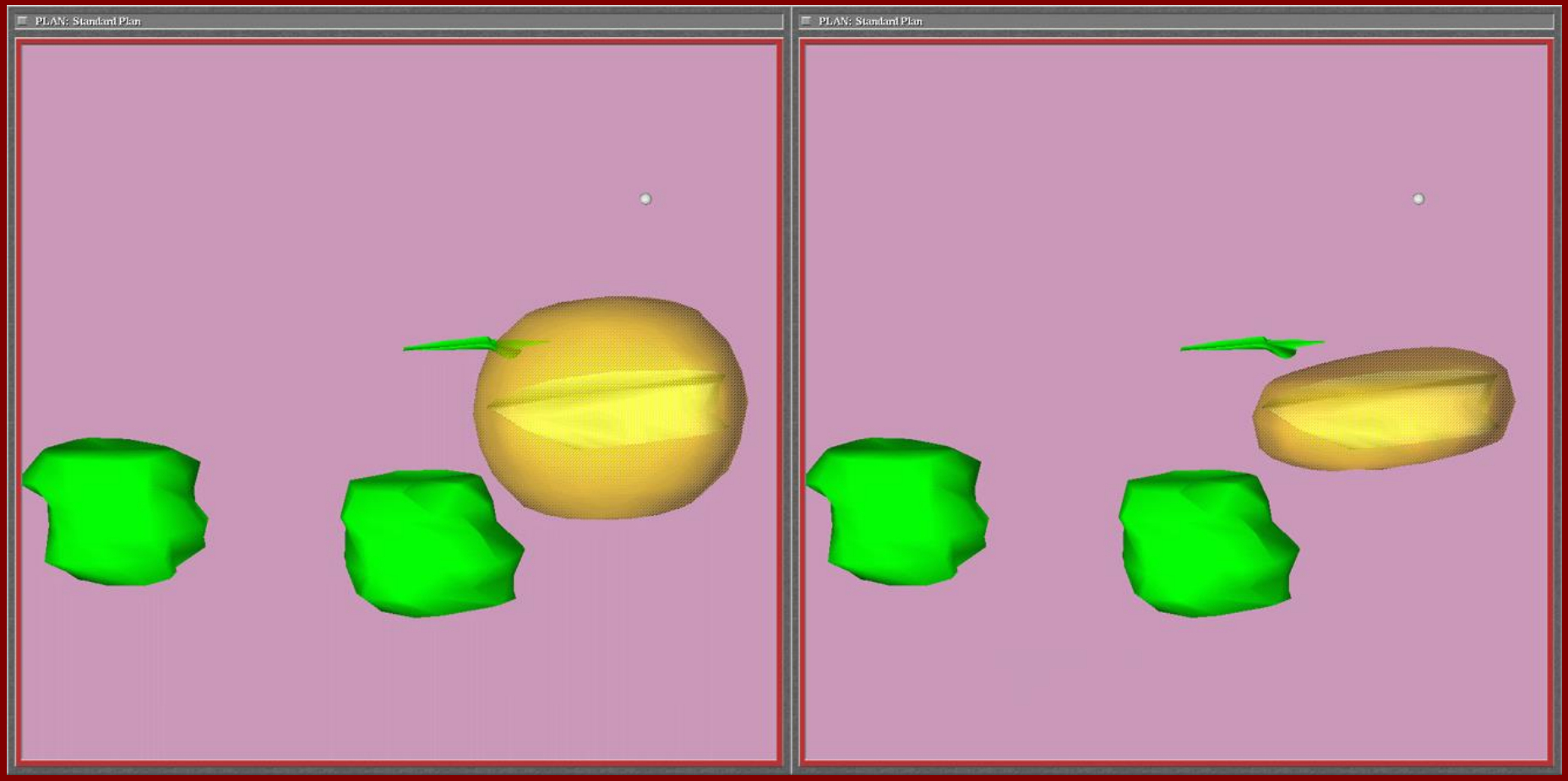


- < 3-4 cm
  - *Circular Cones + Arcs Best*
  - *Sharp Penumbra avoids OAR*
  - *Precise Geometry*
  - *Low Integral Dose to Brain*
- 3-6 cm
  - (a) XJaws = Jaws and Cones and Arcs
  - Simple
  - Low Integral Dose to Brain
  - Optimal Conformal Index
  - (b) MMLC Okay
  - Exact Conformation not an issue.

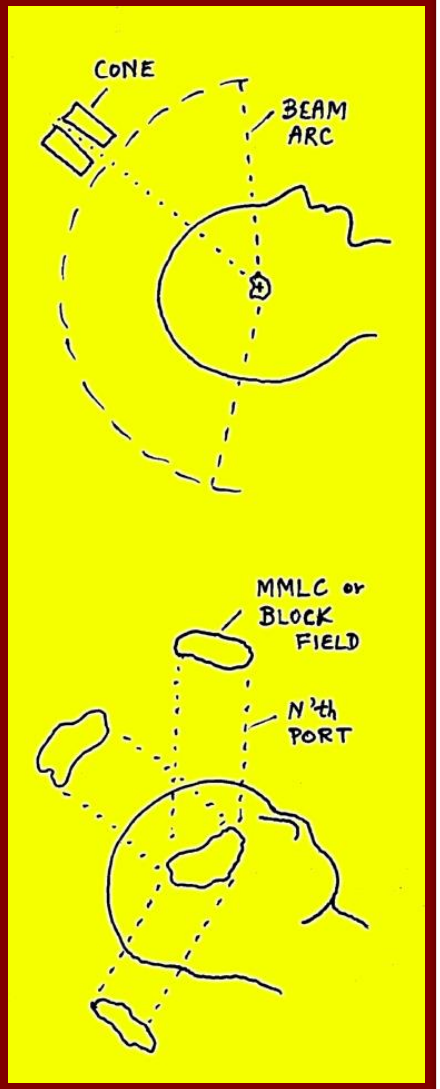
Conformal Arc BEV



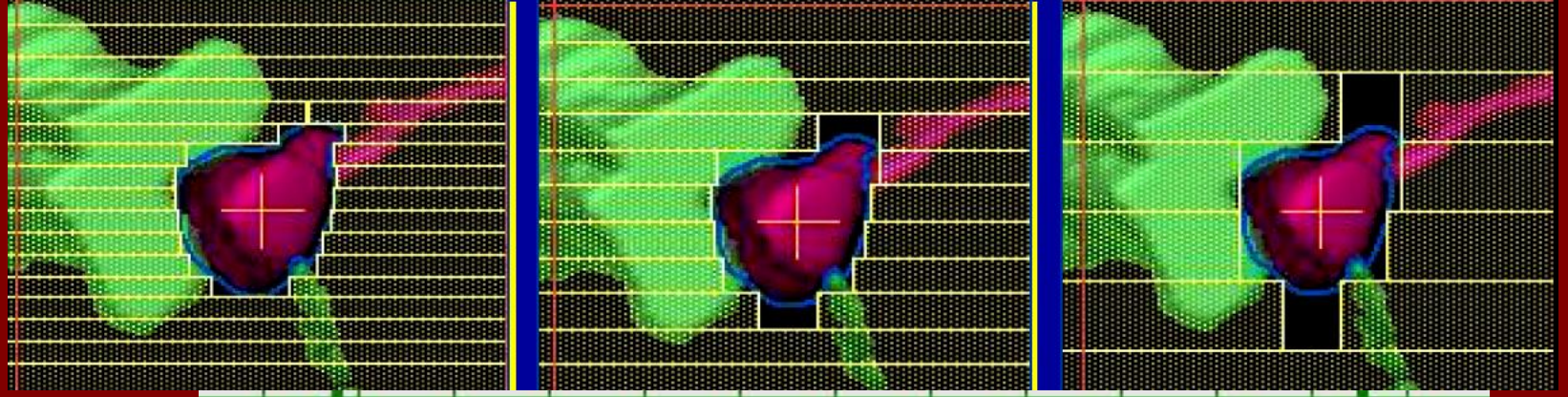
Standard Arc Conformal Arc

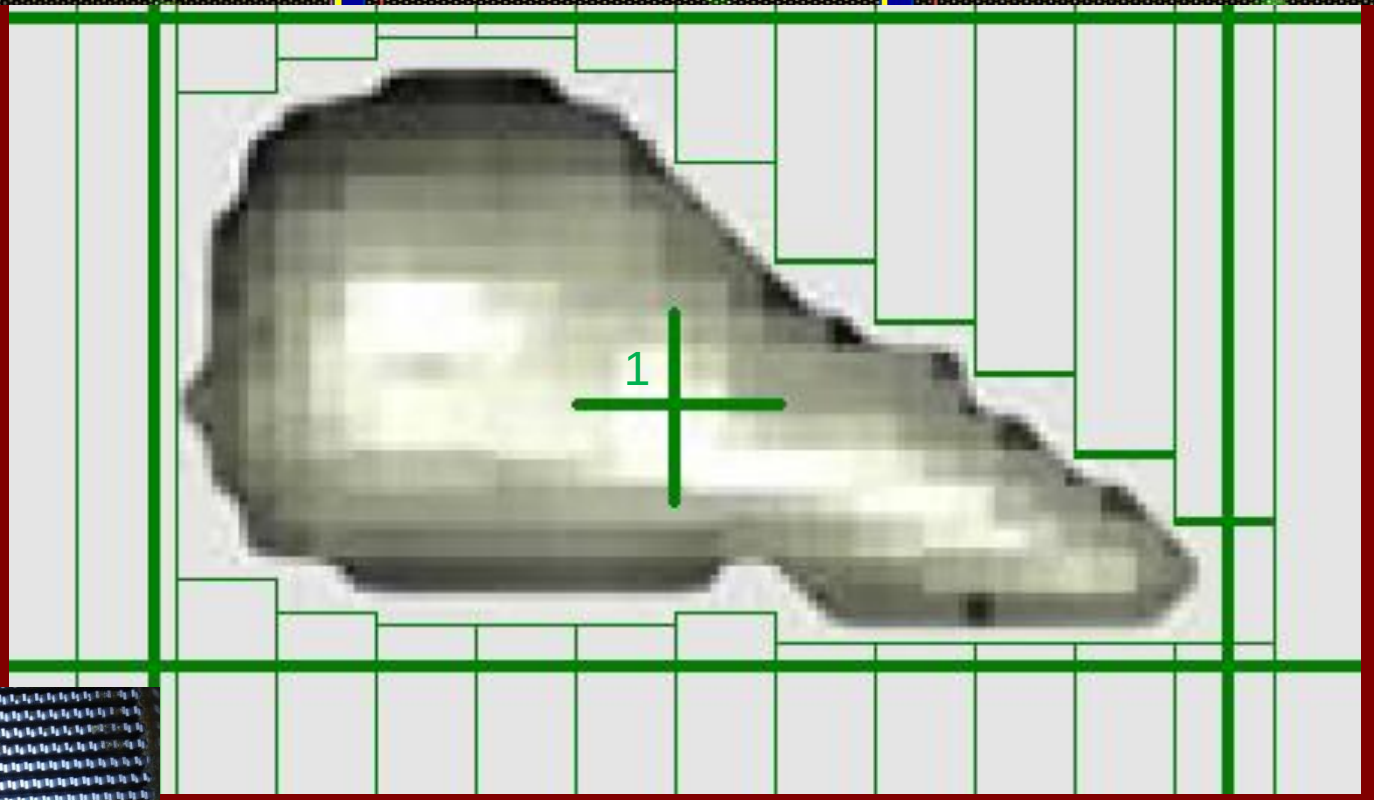


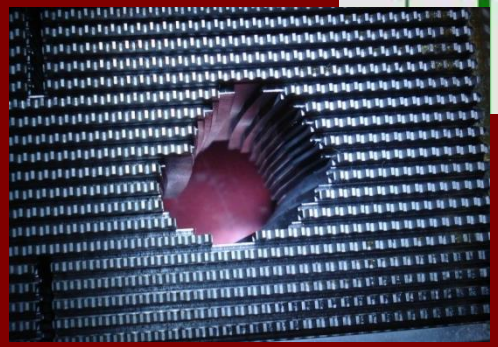
Considerations according to the type of target



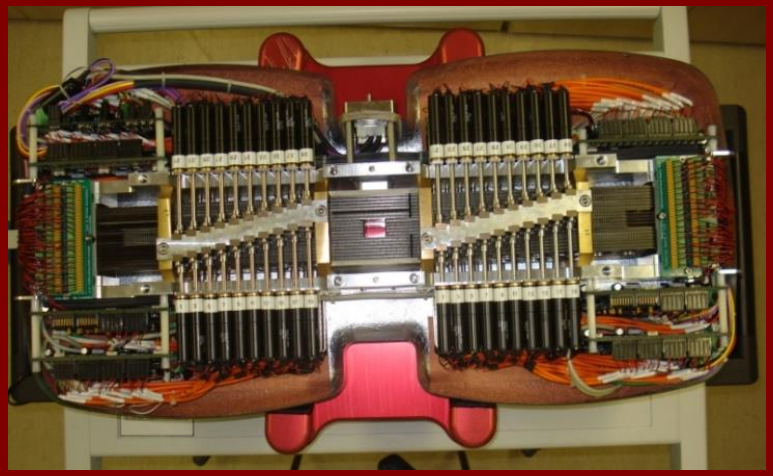
- < 3-4 cm
  - *Circular Cones + Arcs Best*
  - *Sharp Penumbra avoids OAR*
  - *Precise Geometry*
  - *Low Integral Dose to Brain*
- 3-6 cm
  - (a) XJaws = Jaws and Cones and Arcs
  - Simple
  - Low Integral Dose to Brain
  - Optimal Conformal Index
  - (b) MMLC Okay
  - Conformation not the issue.
- **> 6 cm**
  - **Penumbra Increases, not very effective to use Cones and Arcs**
  - **Better N ≥ 6 Non-Coplanar Static Fields**
  - **Need XPlan, OAR, Beam Model**
  - **MMLC necessary.**
  - **2 π Access Reduces IMRT Need.**







Larger leaf width => increase in normal tissue irradiated

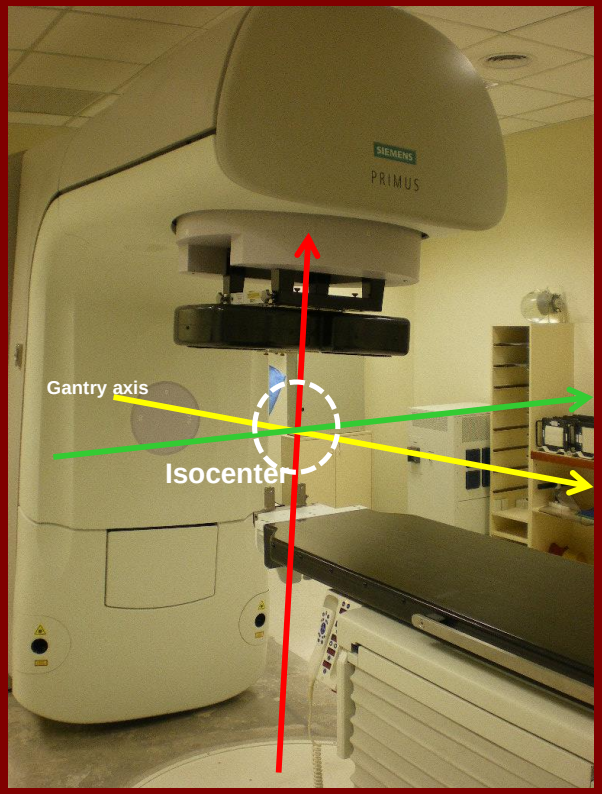


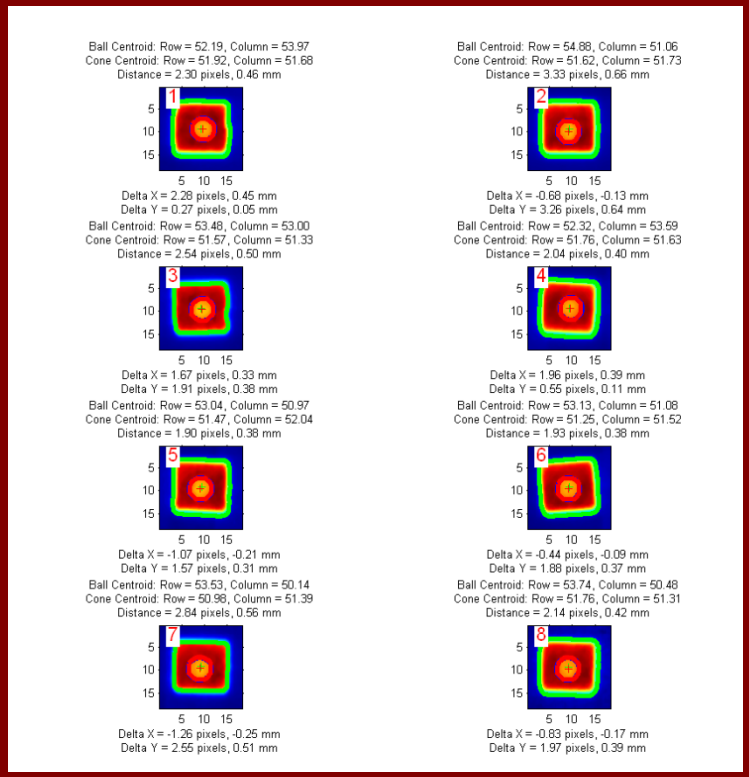
Micro MLC (mMLC)

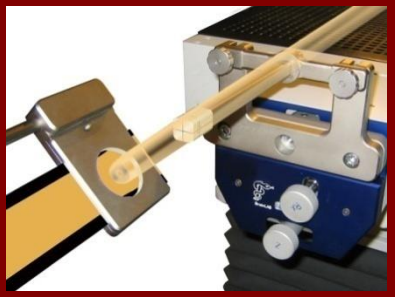
- **Add-on system attached to the regular collimator**
- **MODULEAF, Siemens**
  - **80 leaf**
  - **40Kg (require special mount to move around)**
  - **Leaf width at isocenter - 2.5 mm**
  - **Positioning precision - 0.5 mm**
  - **Penumbra 2.5 – 3.5mm**
  - **Transmission < 2.5%**
  - **Maximum field size 12 x 10 cm^2**

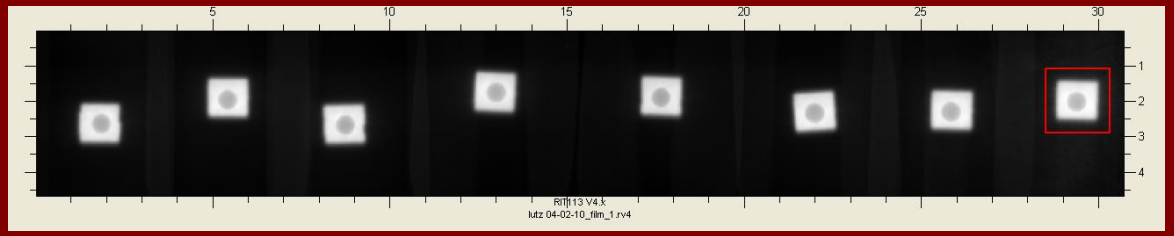
Isocenter precision

Winston - Lutz test



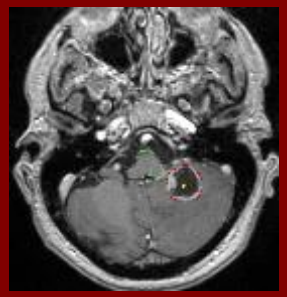






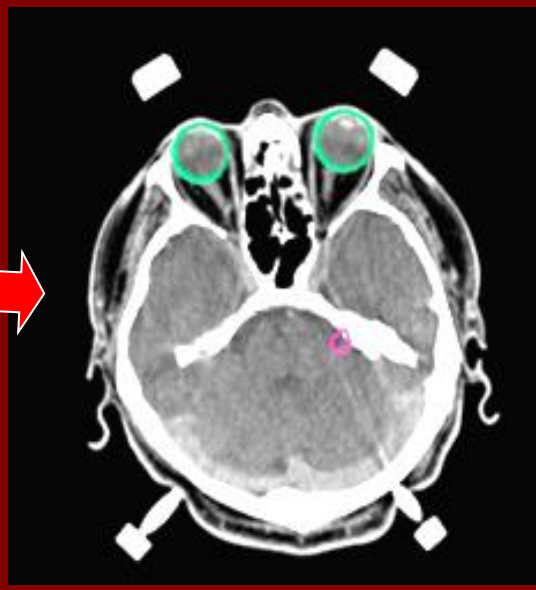
Procedure

MRI images

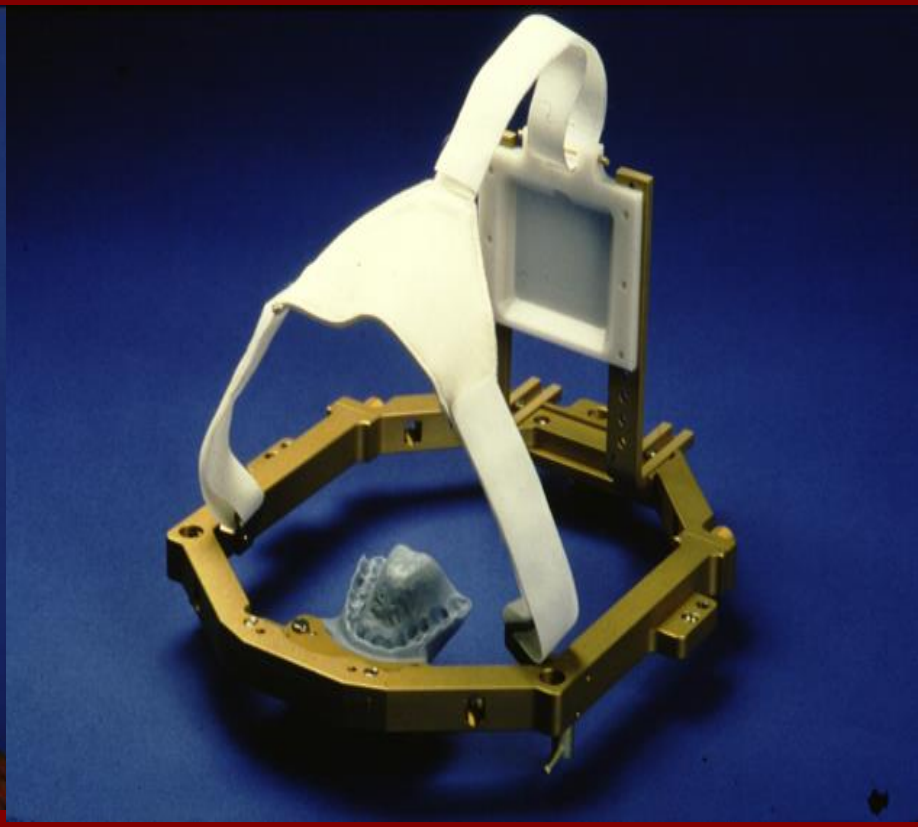


Patient preparation

Placement of Head Ring for SRS



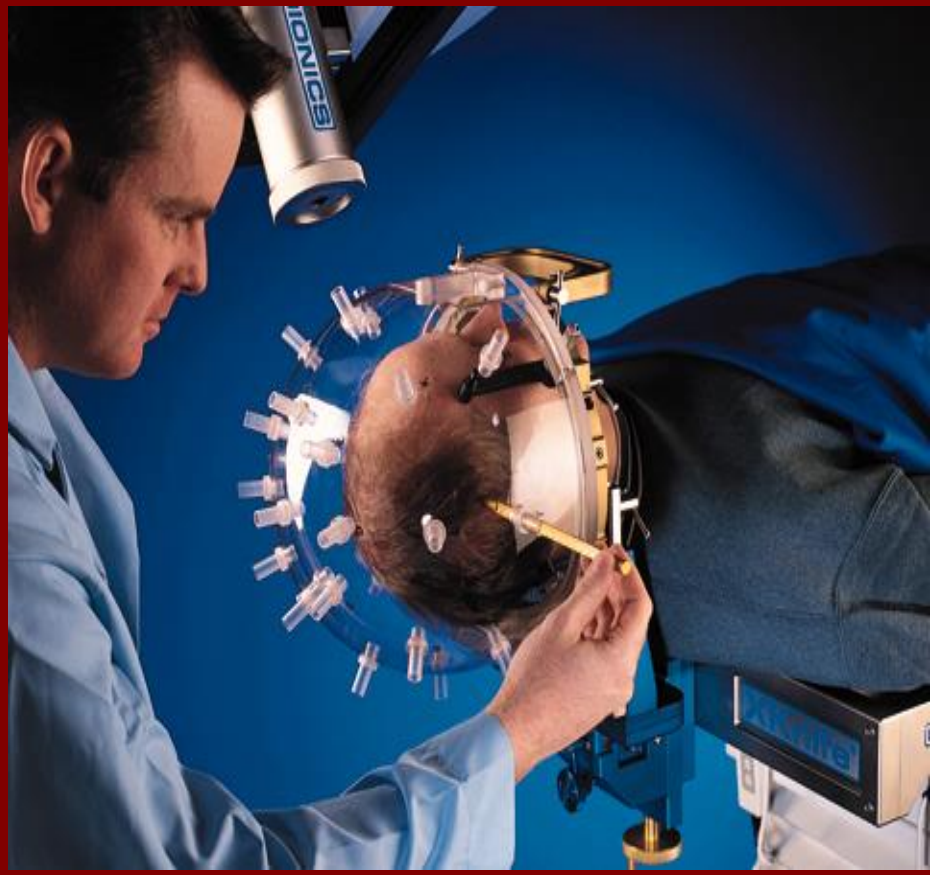
Relocatable Head Frame (Gill-Thomas-Cosman) for fractionated SRT



SRS with GTC relocatable head frame

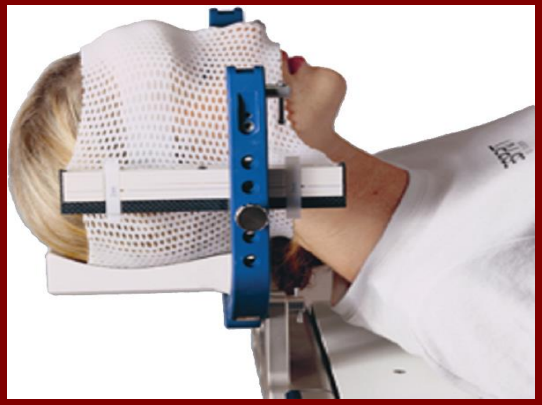
Daily reproducibility of the head frame position

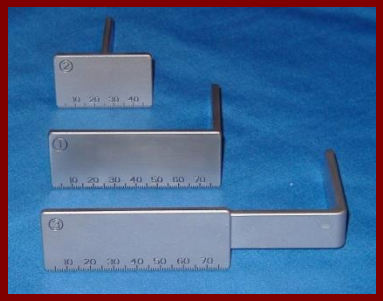
DEPTH CONFIRMATION HELMET: **Mounts on stereotactic base ring; allows for 25 'helmet to scalp' measurements which are repeated following frame attachment, removal, replacement, and for SRT prior to each treatment (accuracy +/-1.5 mm)**



Patient Immobilization (SRT)

- 3 piece Mask System
- Extends treatment area to T1
- Set-up errors from 1.7 to 0.9 mm
- Indexed bite plates
- Carbon fiber
- Tilt compensation for set-up
- Suitable for elderly patients & children



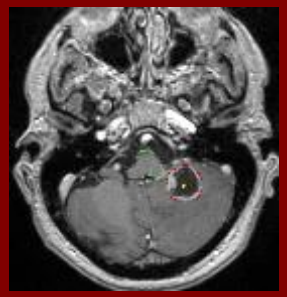


Patient positioning accuracy in a thermoplastic mask with upper jaw support.
J. Ahlswede et al. AAPM Annual Meeting 2001 Poster Display

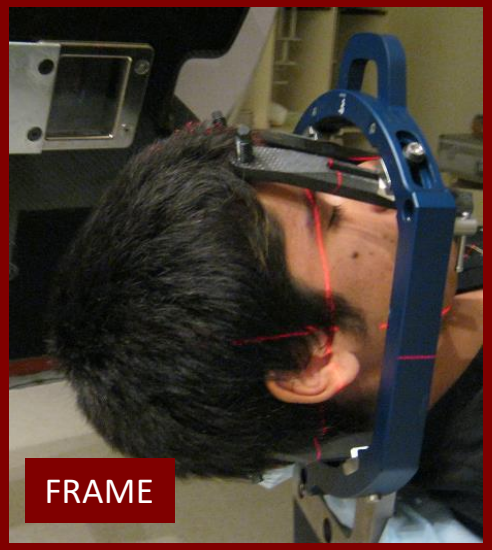
Frameless Immobilization

CT angiography

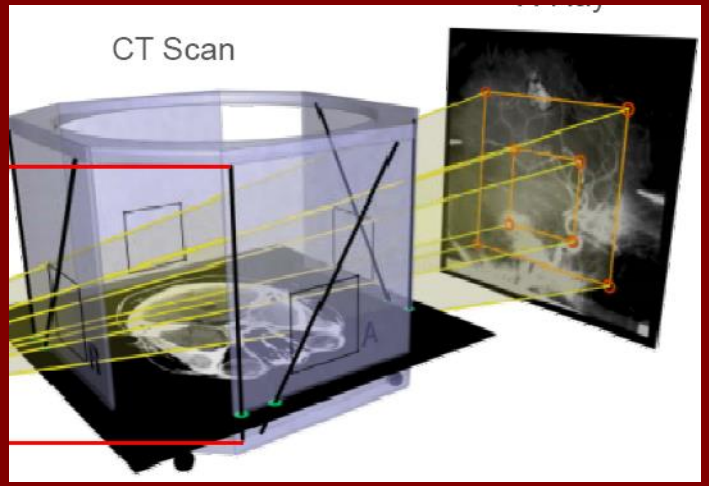
MRI



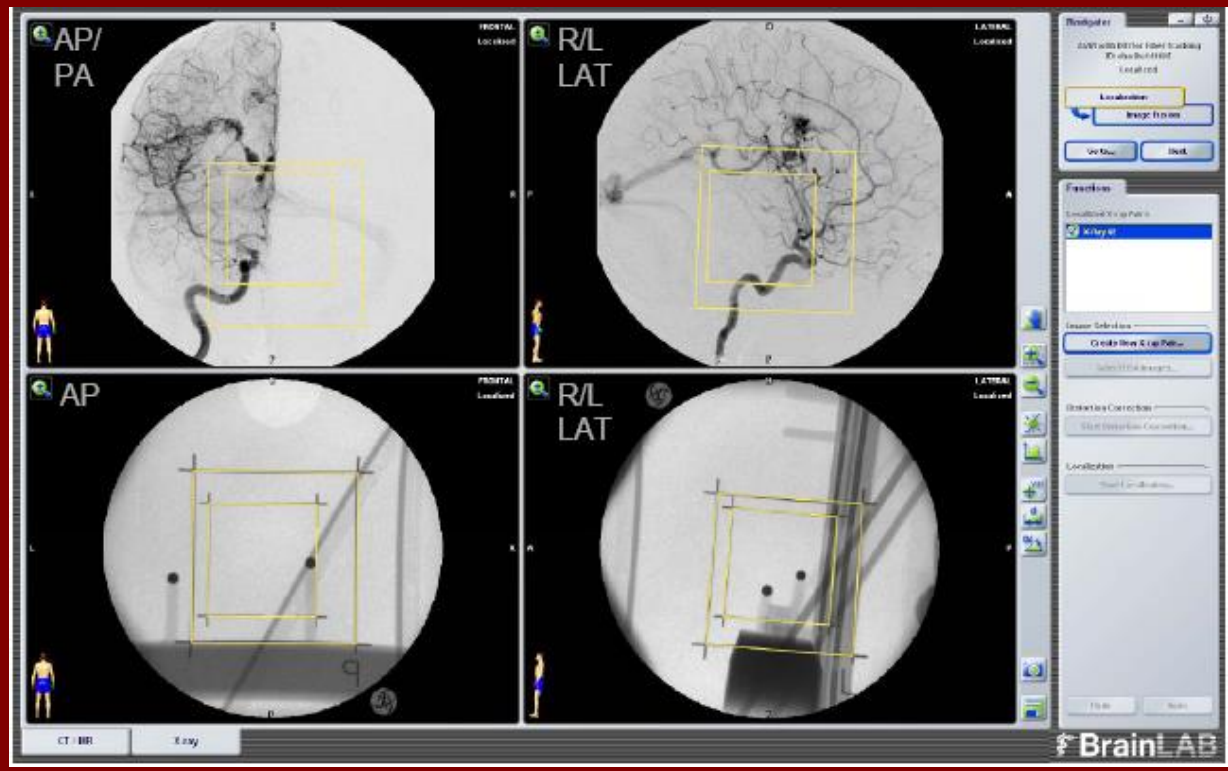
Patient setup



CT angiography

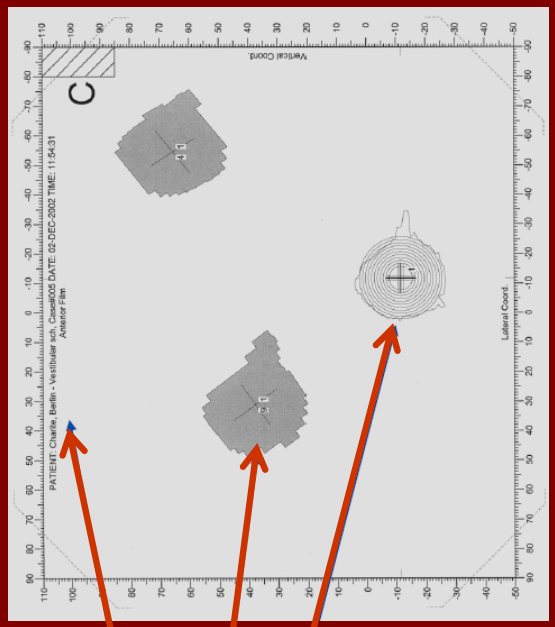


Angiography Localizer frames for Stereotactic Imaging



Transfer of Coordinates

TPS plan -> Treatment unit



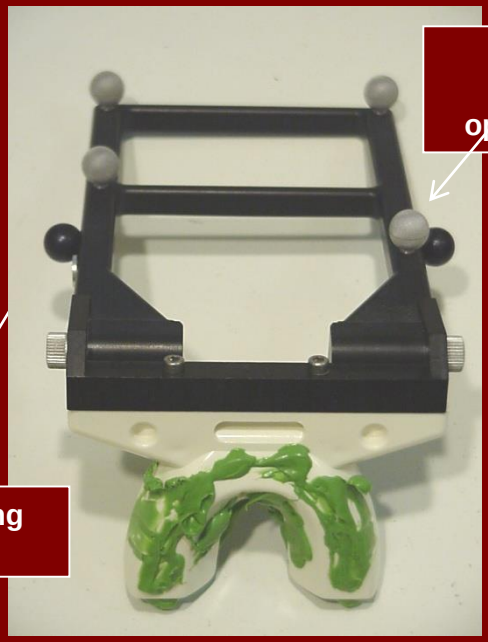
Patient identifier

Field shape projection

Laser isocenter alignment

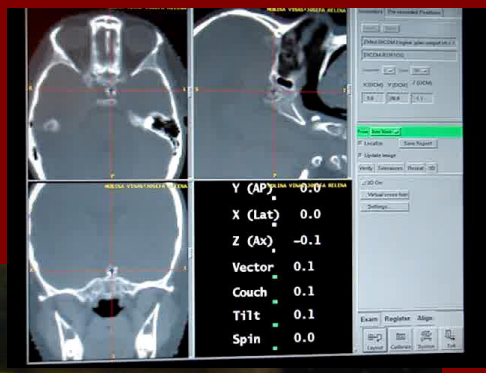
Optical tracking of Stereotactic position space

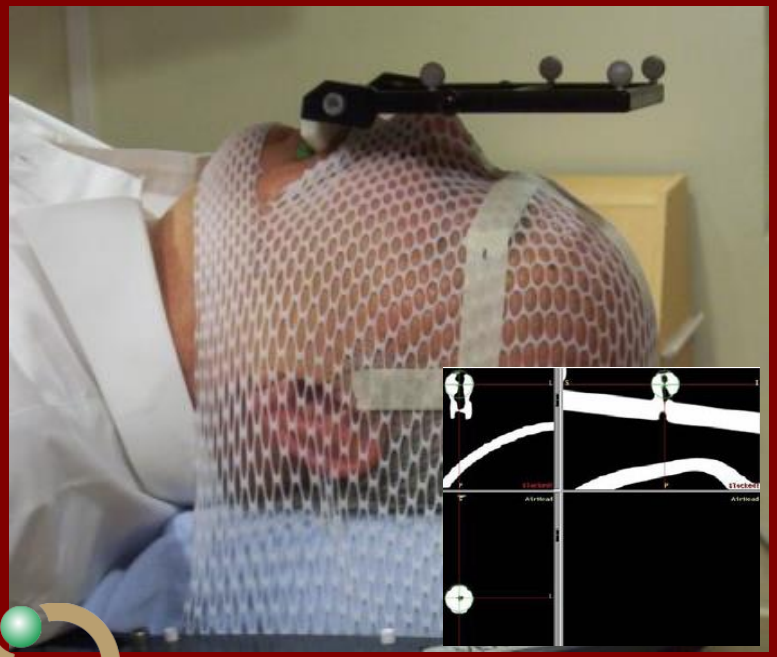
The CT images of the spheres are used to transfer the coordinate space to the treatment room



Reflecting spheres for optical tracking

CT localizing spheres





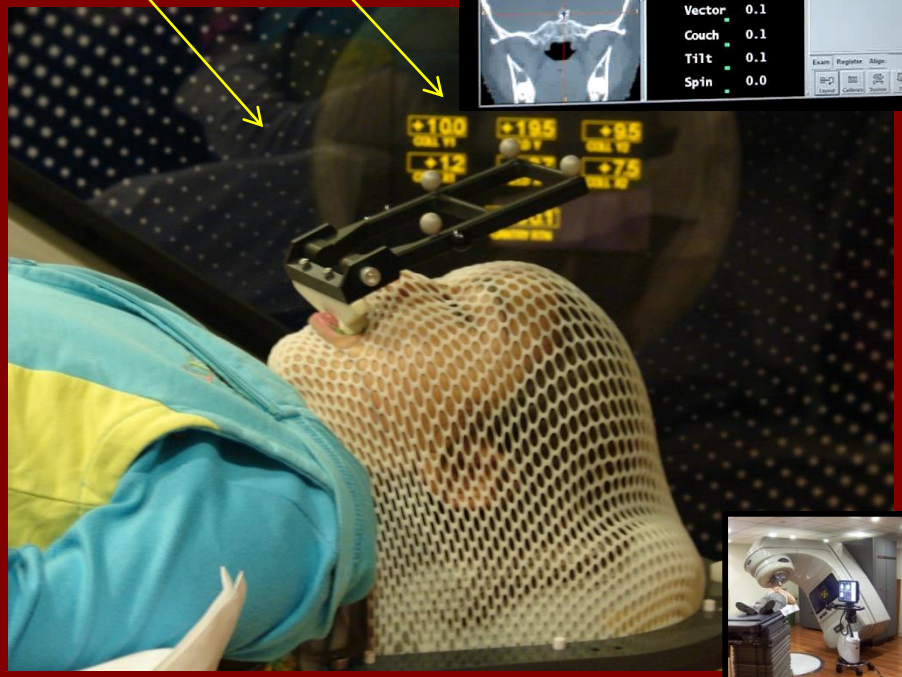
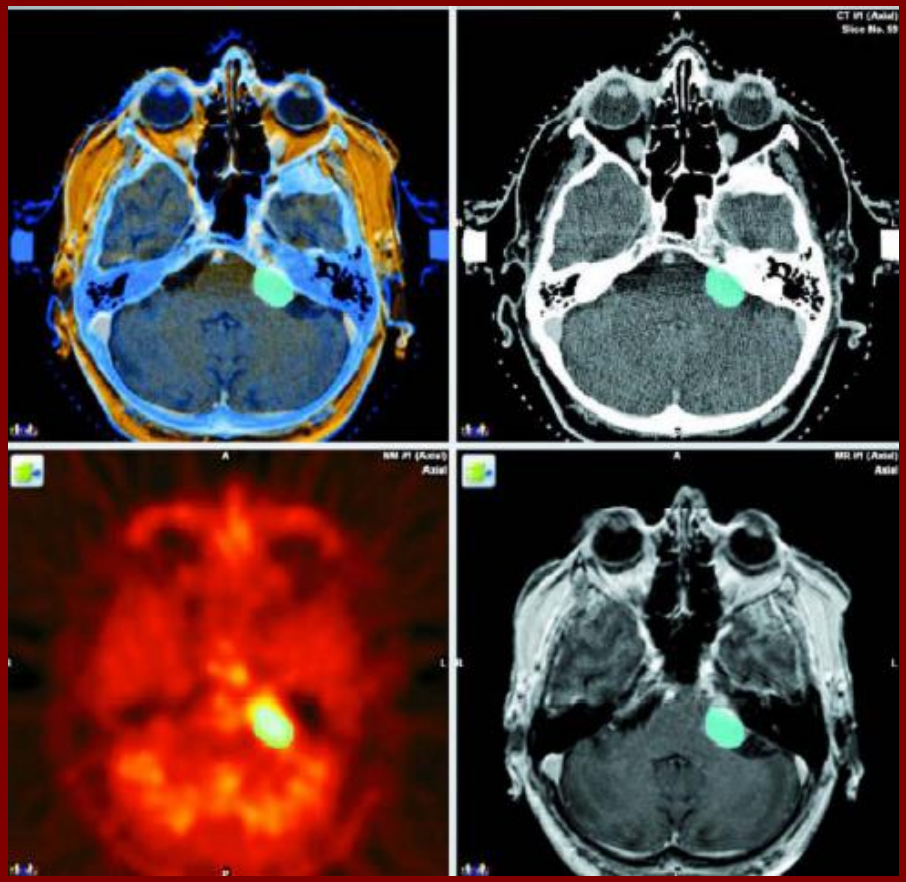
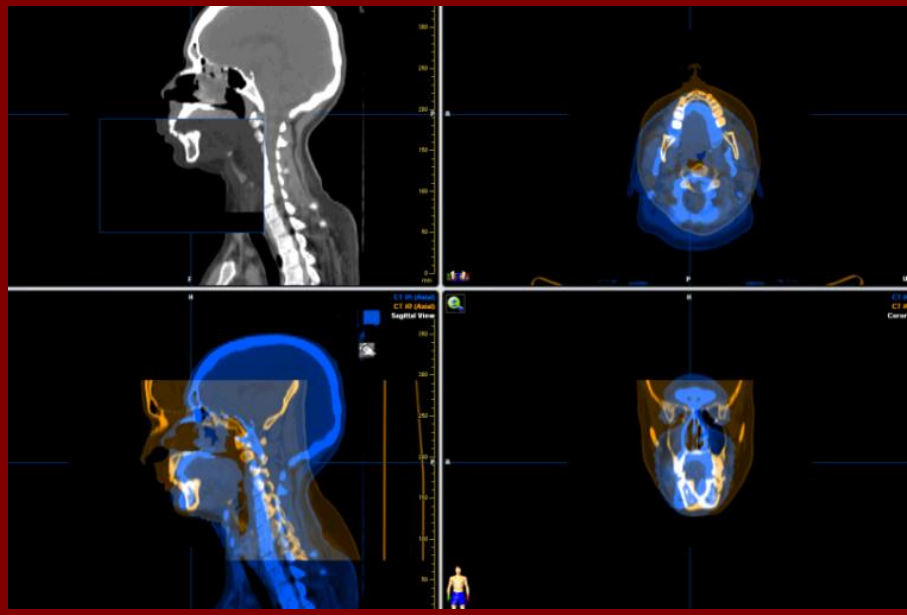
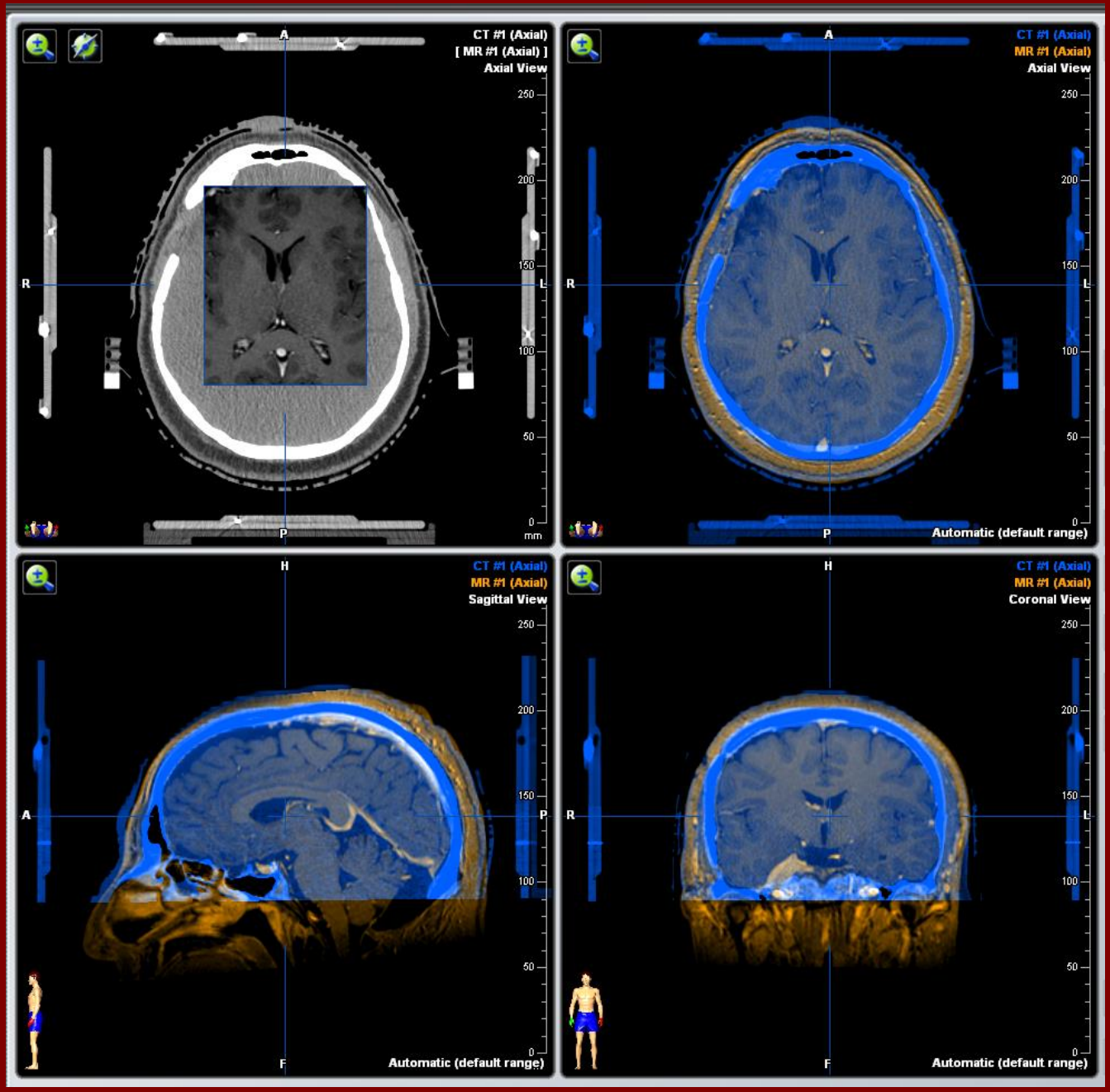


Image fusion or Registration





CT – MR – SPECT - PET


CT #1 (Axial)
[MR #1 (Axial)]
Axial View
A
R
L
P
250
200
150
100
50
0
mm
CT #1 (Axial)
MR #1 (Axial)
Axial View
Automatic (default range)
CT #1 (Axial)
MR #1 (Axial)
Sagittal View
H
A
P
F
Automatic (default range)
CT #1 (Axial)
MR #1 (Axial)
Coronal View
Automatic (default range)

Patient setup

Stereo Images

Image fusion

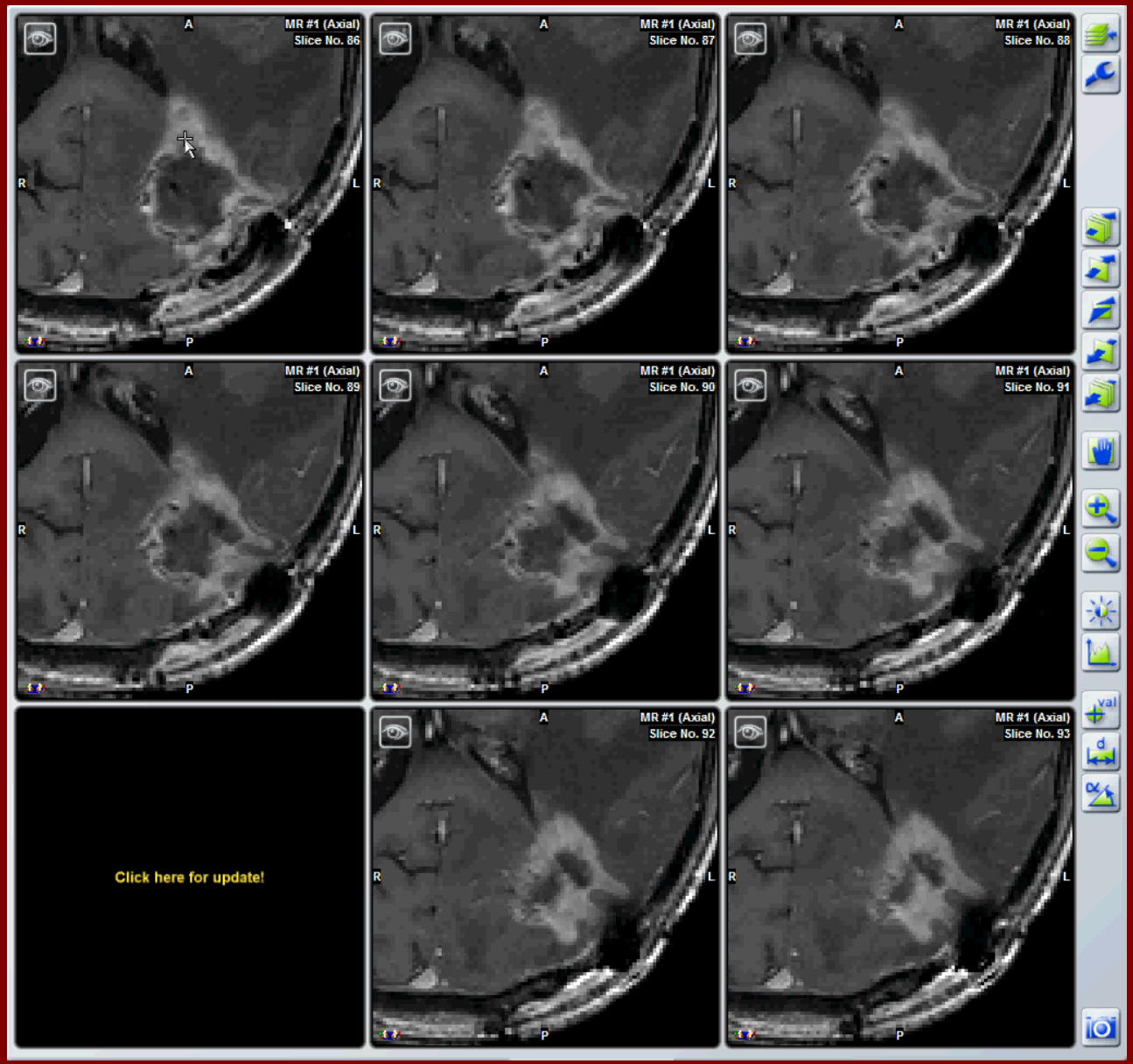
Volume definitions

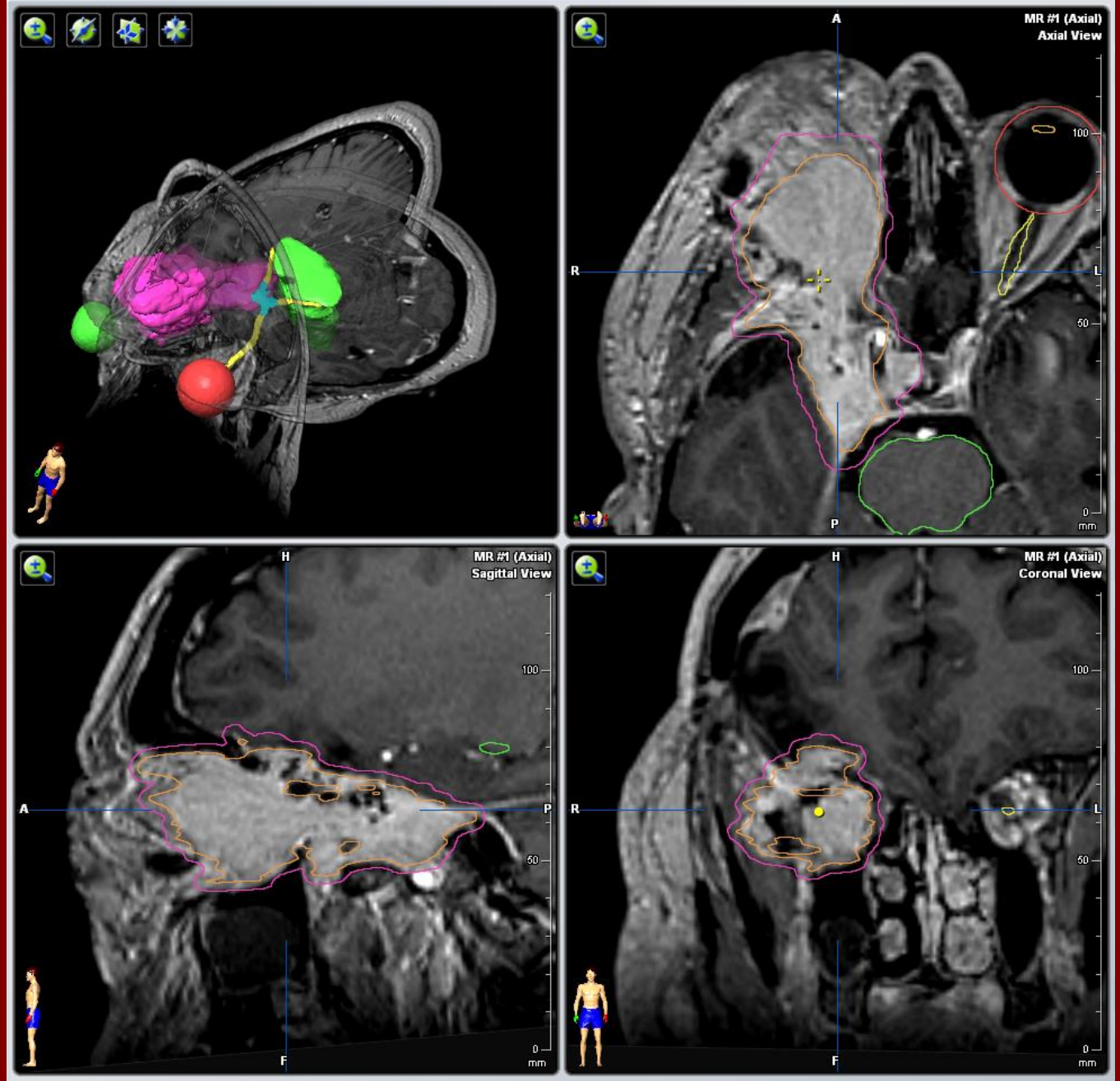
Patient setup

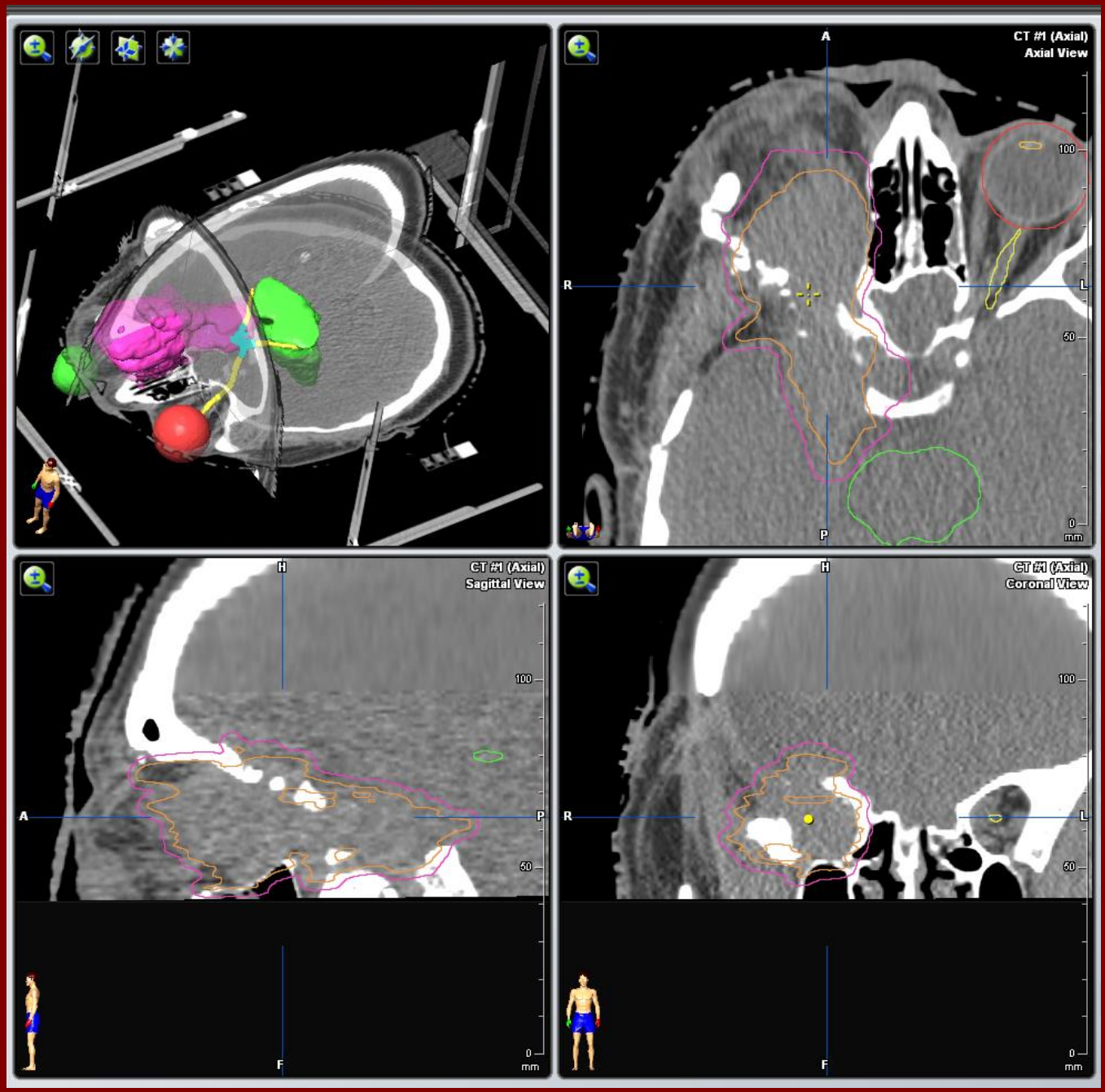
Stereo Images

Image fusion

Volume definitions




MR #1 (Axial)
Axial View
A
R
L
P
100
50
0
mm
MR #1 (Axial)
Sagittal View
H
A
P
F
MR #1 (Axial)
Coronal View
H
R
L
F

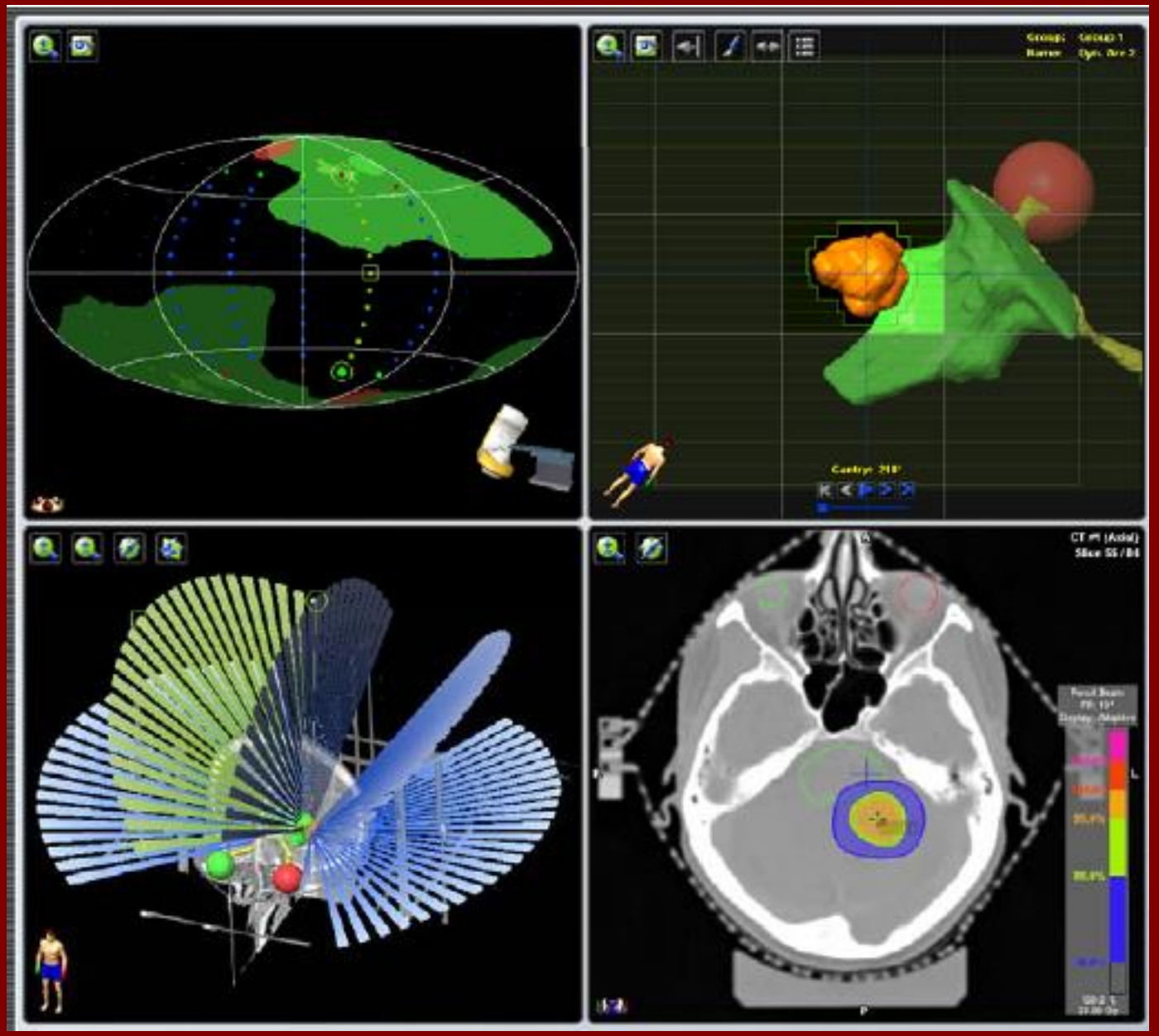

CT #1 (Axial)
Axial View
A
R
L
P
100
50
0
mm
CT #1 (Axial)
Sagittal View
H
A
P
F
CT #1 (Axial)
Coronal View
H
R
L
F

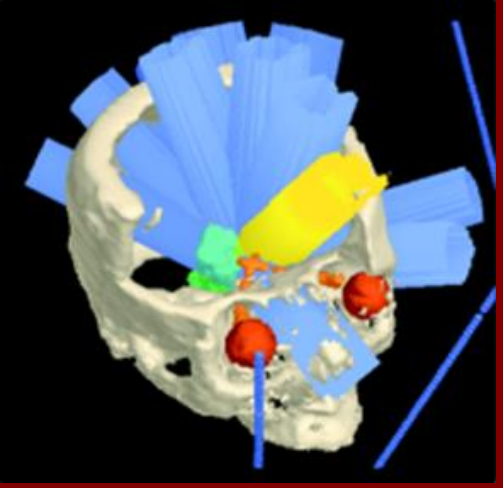
Uncertainties achievable in SRS

CT slice *Thickness*	1 mm	3 mm
Stereotactic Frame	1 mm	1 mm
Isocenter Alignment	1 mm	1 mm
CT Image resolution	1.7 mm	3.2 mm
Tissue Motion	1.0 mm	1 mm
Angio (Point identification)	0.3 mm	0.3 mm
Std. Dev. of Pos. Uncertainty	2.4 mm	3.7 mm

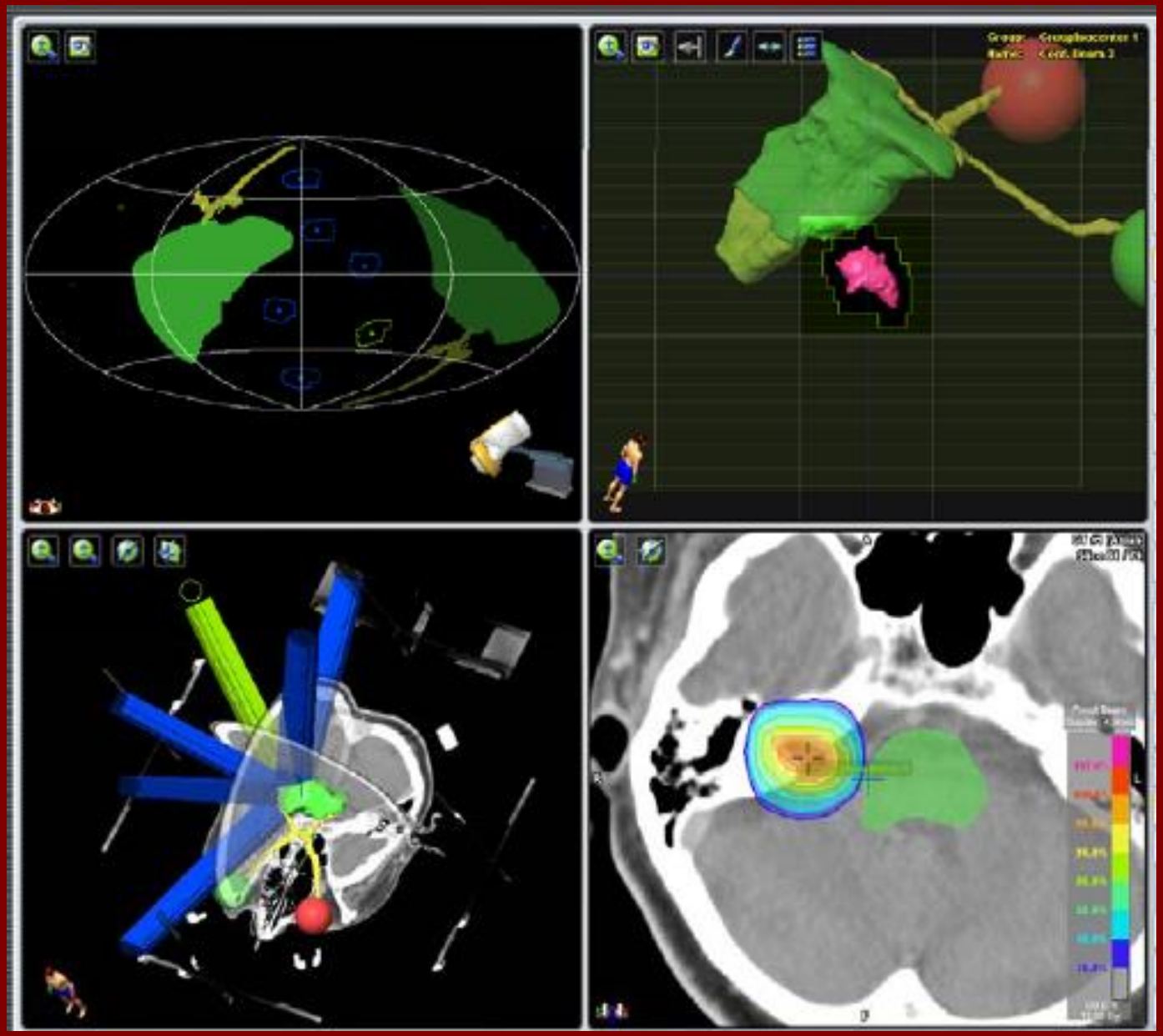
AAPM Report No 54:Stereotatic Radiosurgery

PLANING WITH CONFORMAL ARCS

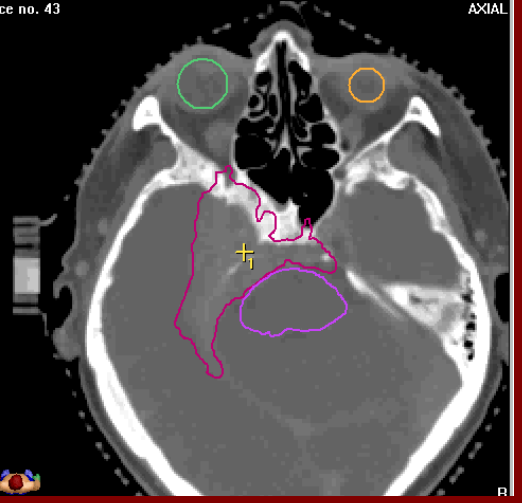


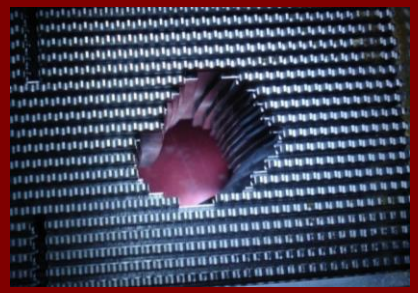


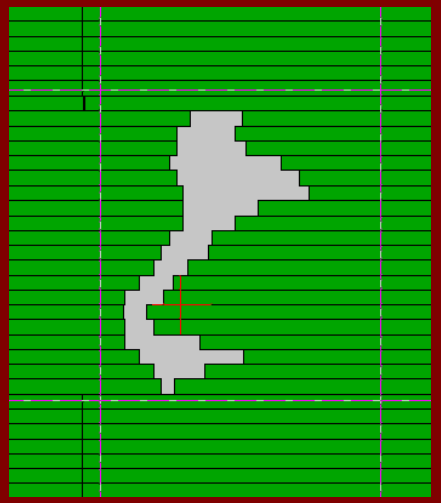
PLANING WITH CONFORMAL FIXED FIELDS

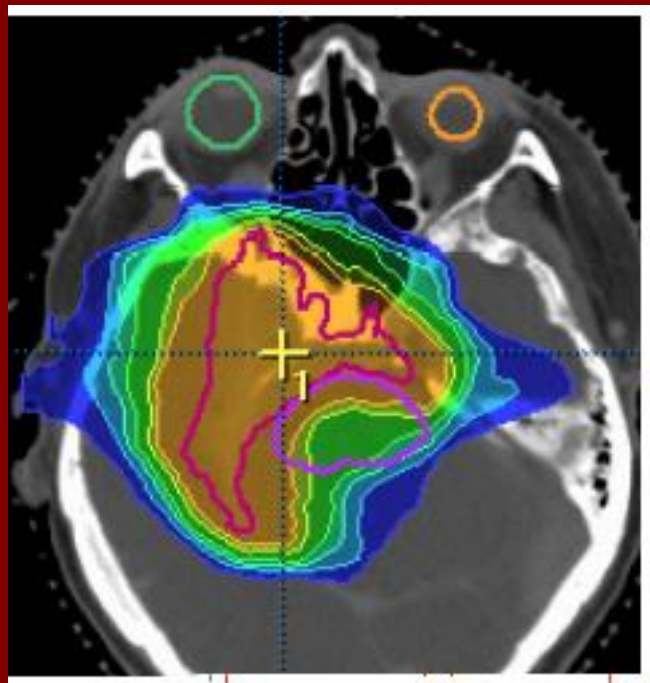


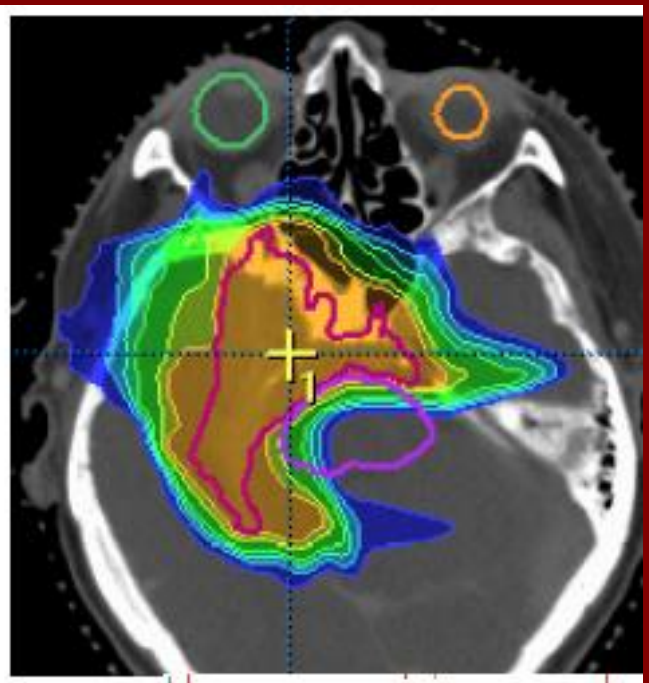
PLANING with Intensity Modulated Radio Surgery (IMRS)

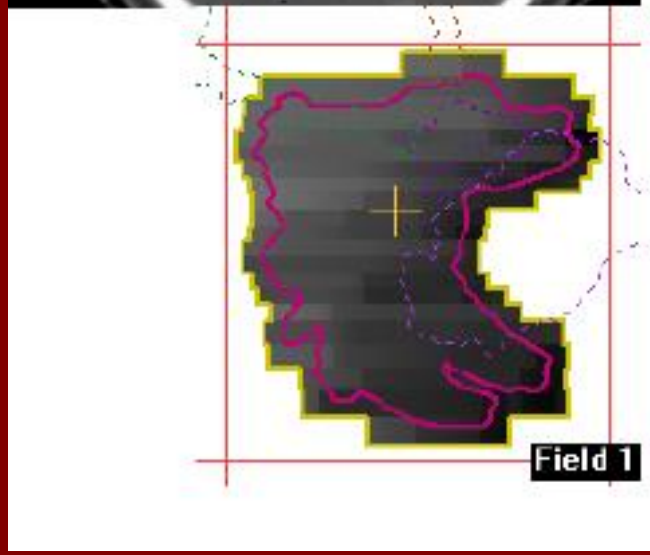


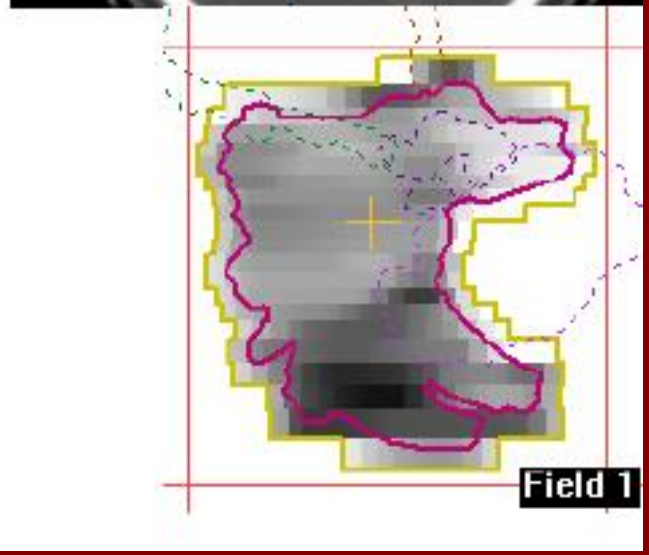


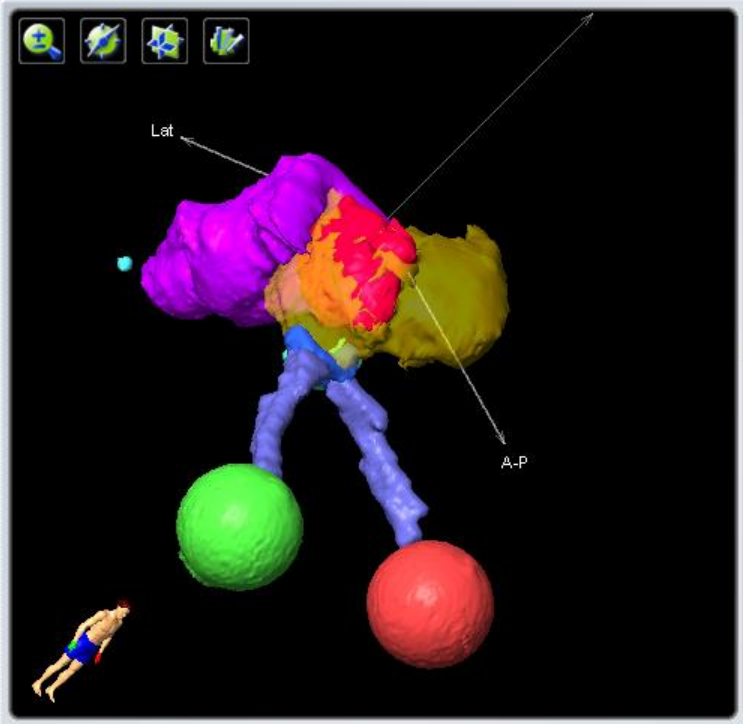


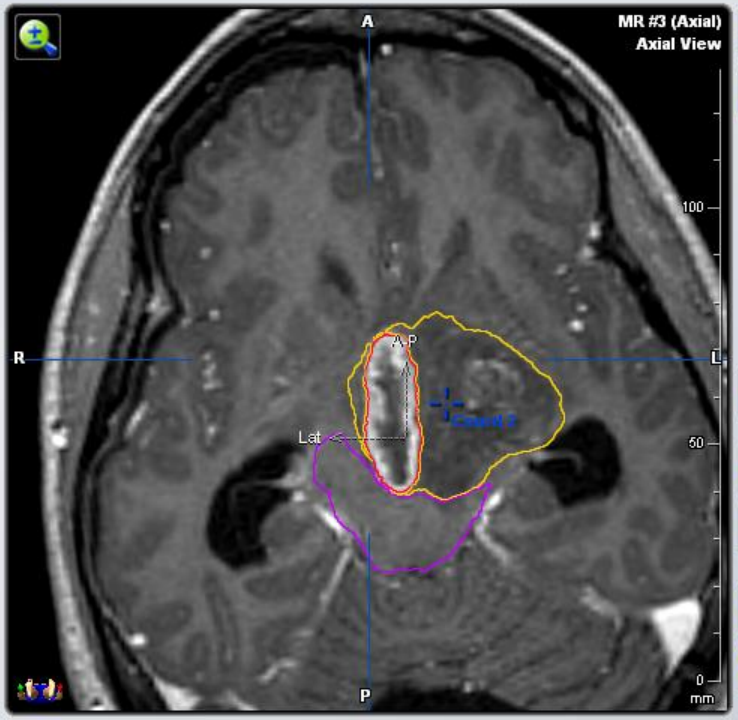


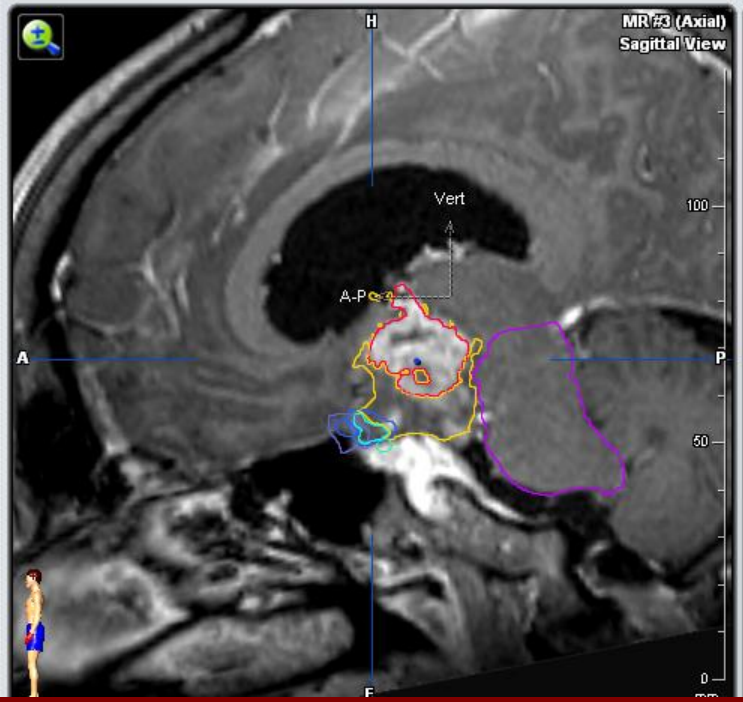


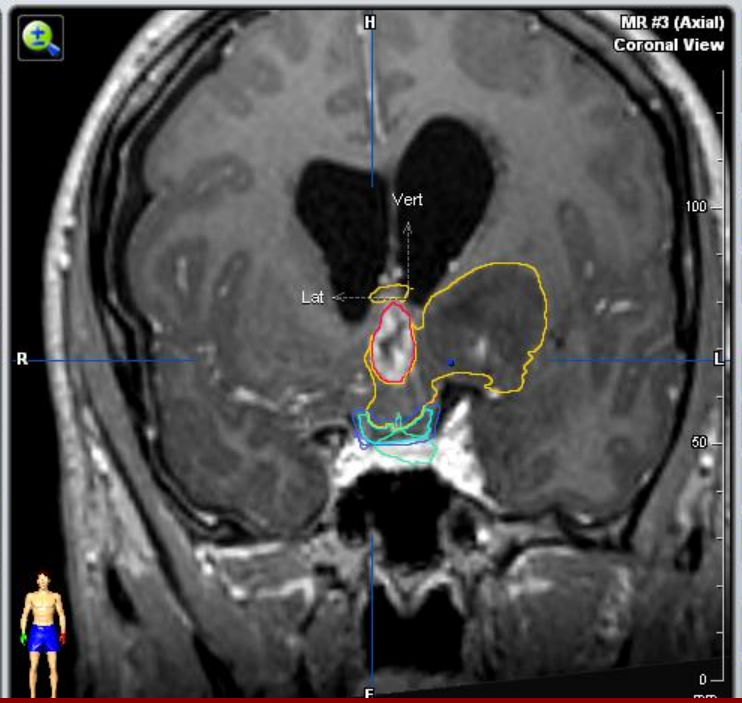












Navigator

Object Creation

Treatment Planning

Go to...

Next

Object

Cochlea, Left

Cochlea, Right

Eye, Left

Eye, Right

GTV1 60Gy

GTV2 54-60Gy

Inner Ear, Left

New...

Remove

Auto Segmentation...

Brush Size

Contours

Outlining

Brush

Eraser

SmartBrush

Draw Sphere

SmartShaper...

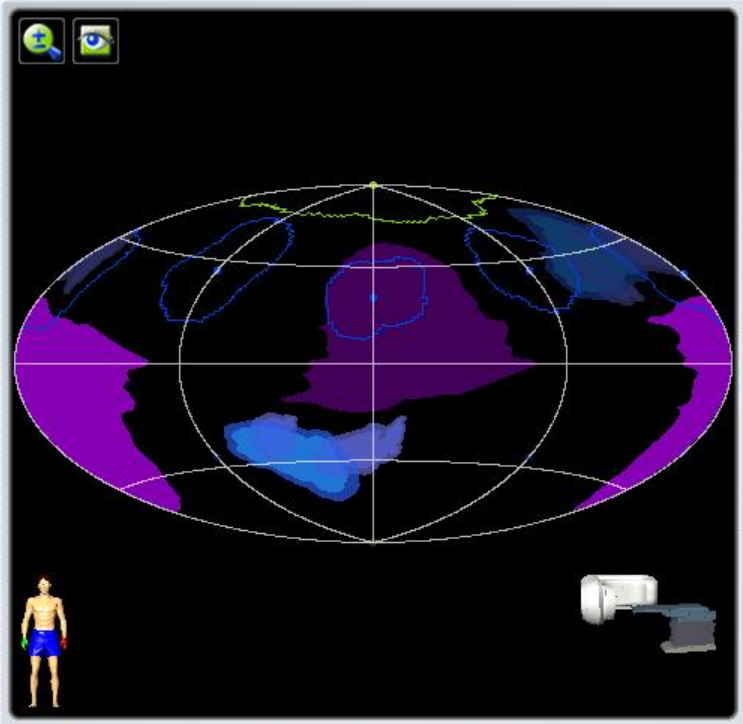
Auto Fill

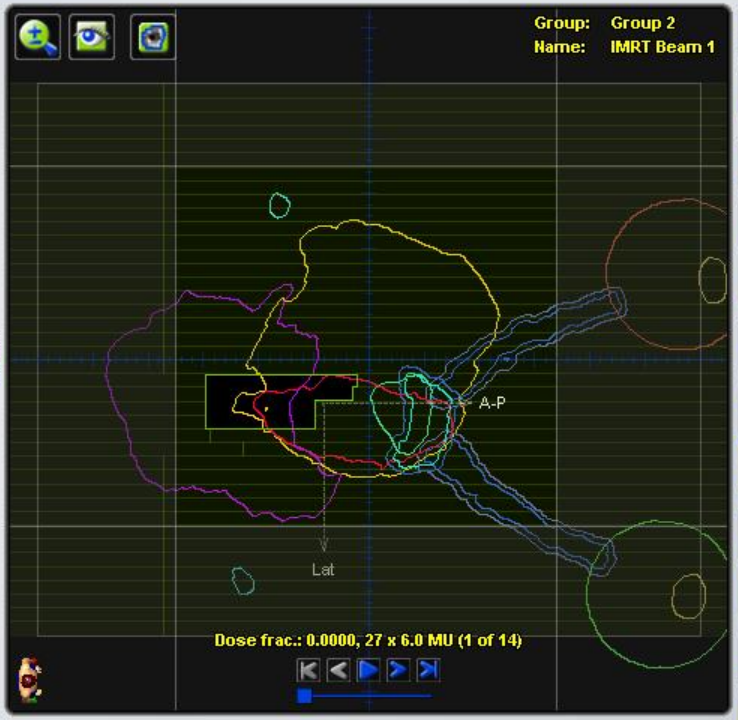
Interpolation

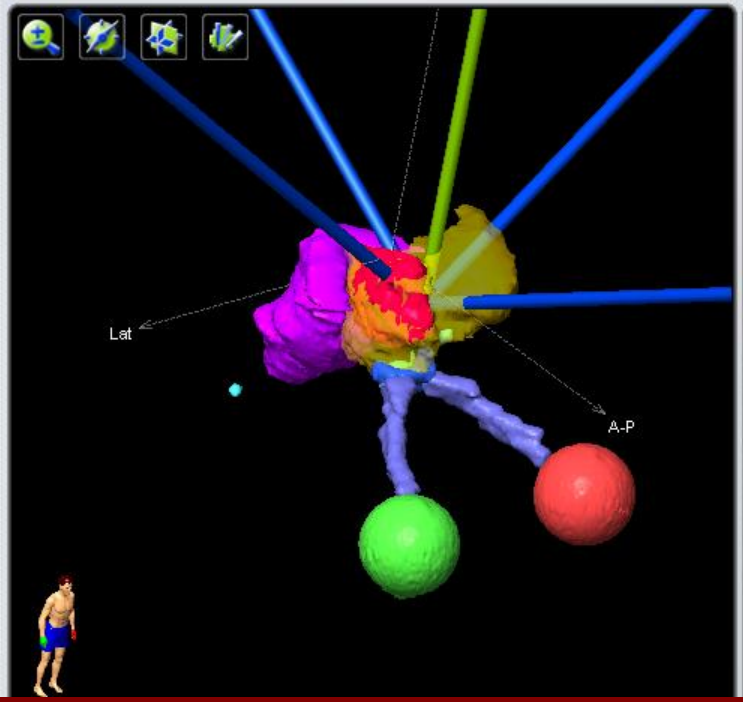
Advanced Manipulation...

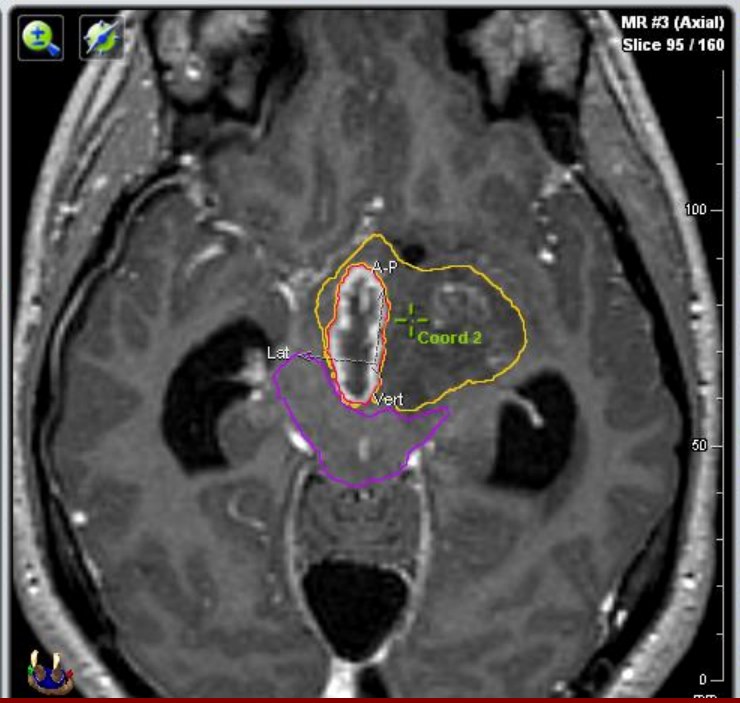
Role Reassignment...

Undo









Navigator

Treatment Planning

Physician's Review

Go to... Next

Functions Prescription

The RTPlan
Group 2
IMRT Beam 1
IMRT Beam 2
IMRT Beam 3
IMRT Beam 4
IMRT Beam 5

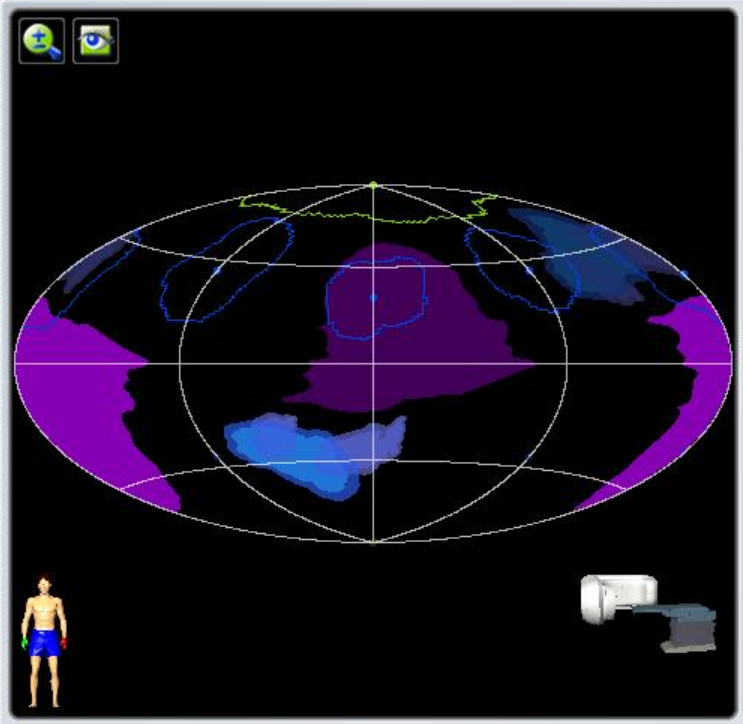
Refresh MU

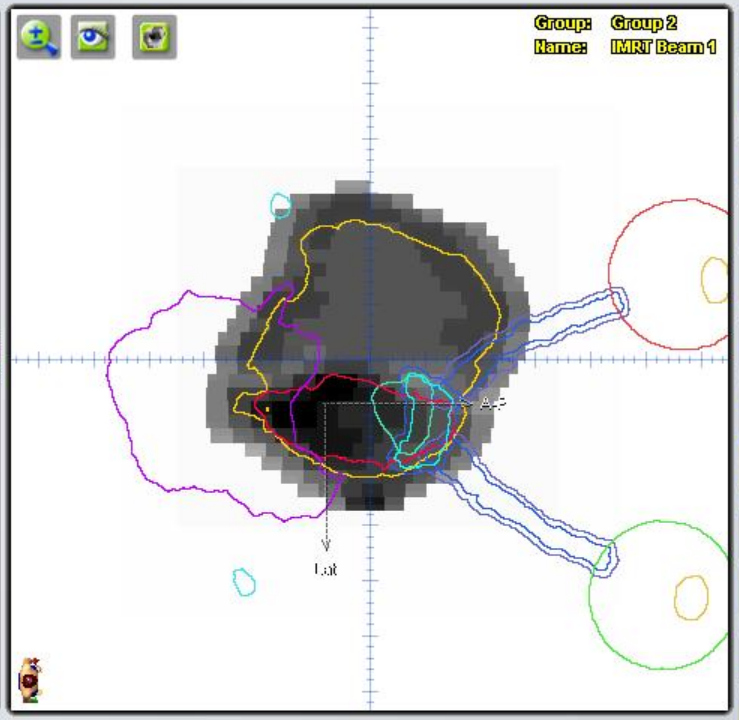
Beam

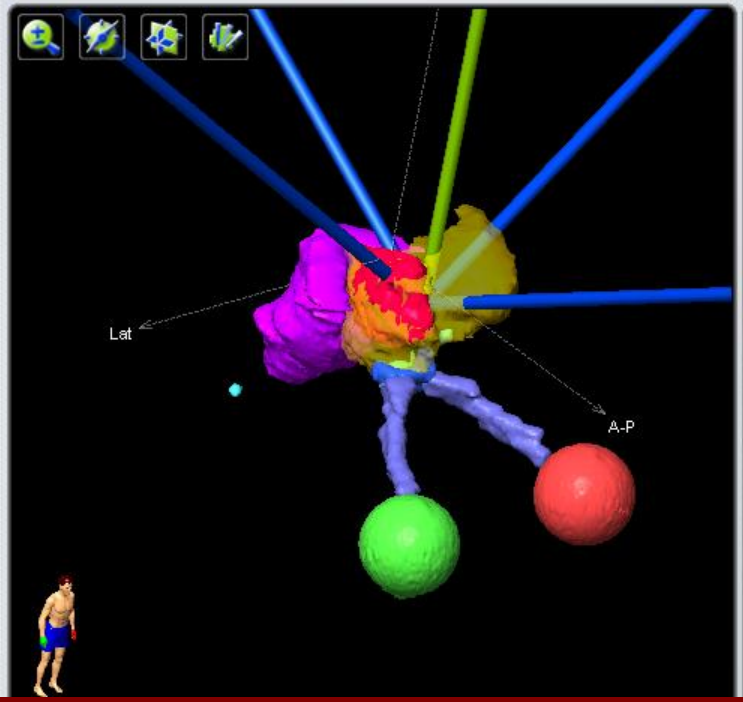
Properties Delete

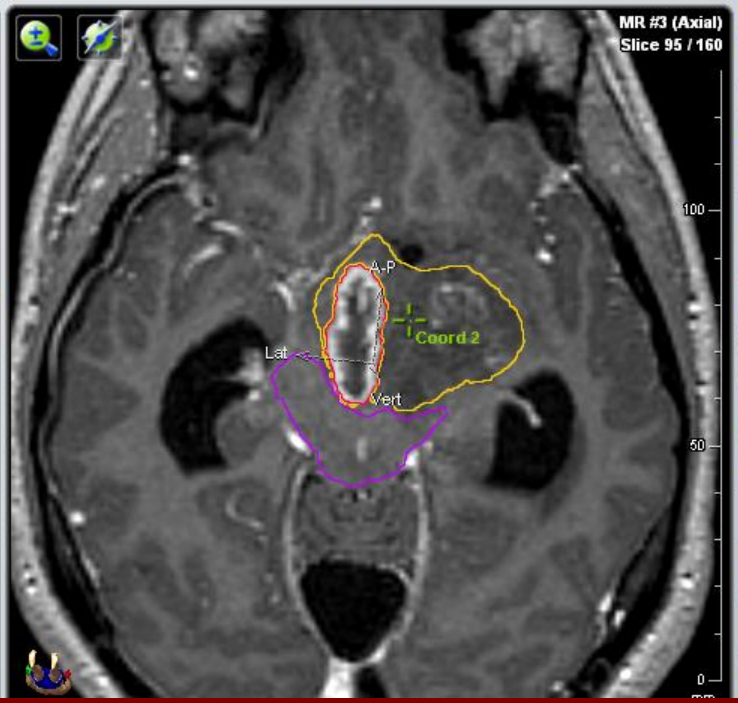
Table:	90	°
Gantry:	270	°
Coll.:	0	°
Margin:	3.0	mm
Weighting:	20.0 %	
MU:	2322 (27 x 86)	

This plan is optimized. T... optimization, select "RT... and click "Remove IMRT Op...mization".









Navigator

Treatment Planning

Physician's Review

Go to... Next

Functions Prescription

- The RTPlan
  - Group 2
    - IMRT Beam 1
    - IMRT Beam 2
    - IMRT Beam 3
    - IMRT Beam 4
    - IMRT Beam 5

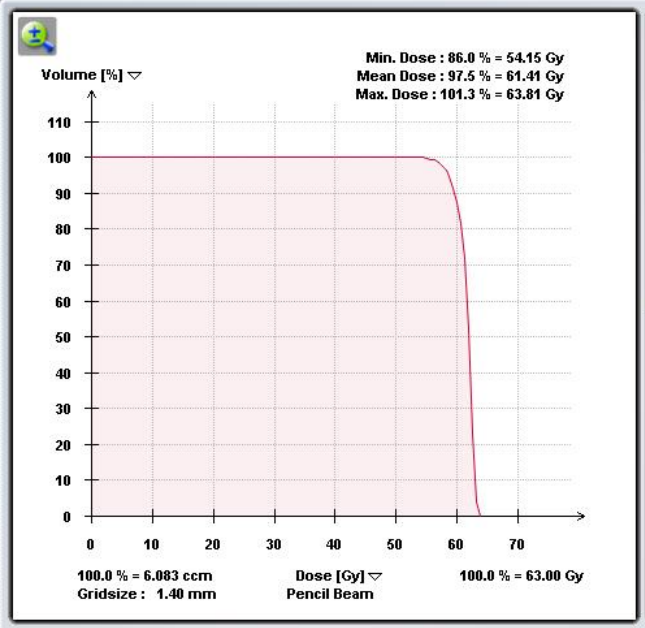
Refresh MU

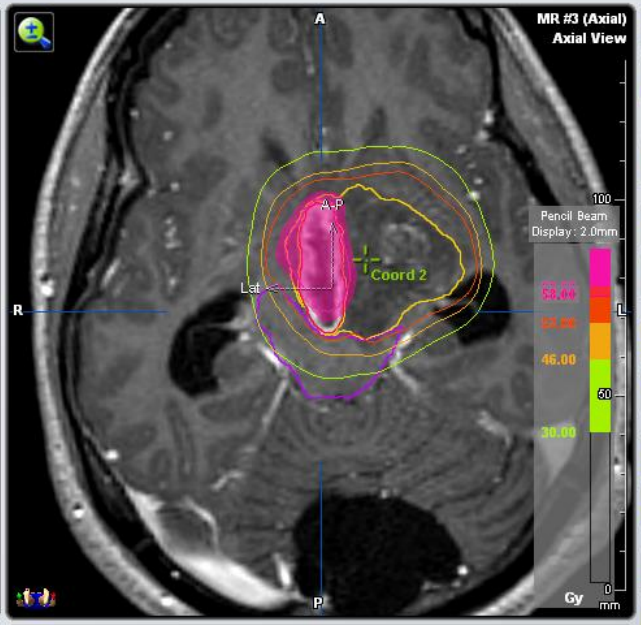
Beam

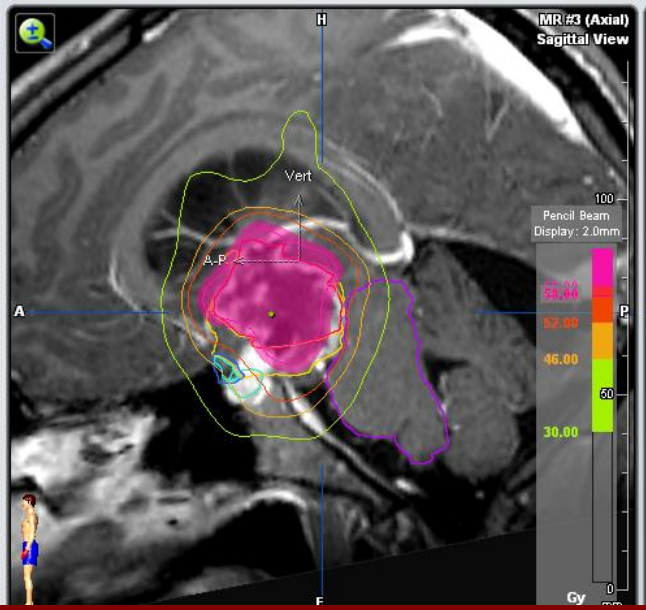
Properties Delete

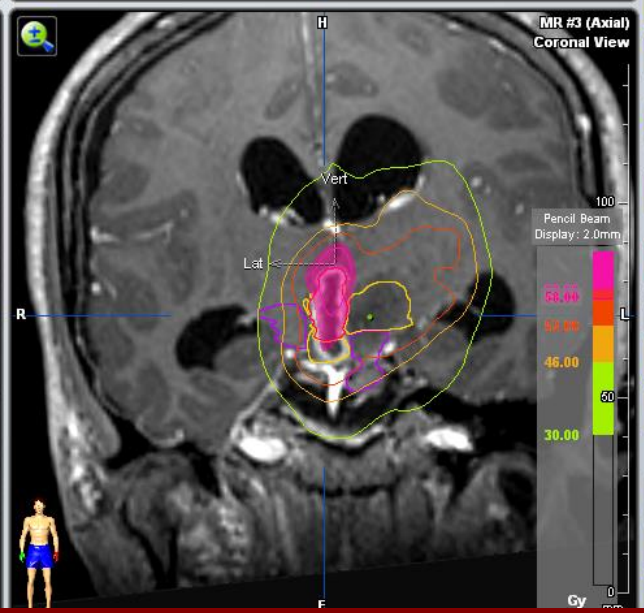
Table:	90	°
Gantry:	270	°
Coll.:	0	°
Margin:	3.0	mm
Weighting:	20.0 %	
MU:	2322 (27 x 86)	

This plan is optimized. T... optimization, select "RT... and click "Remove IMRT Op...mization".

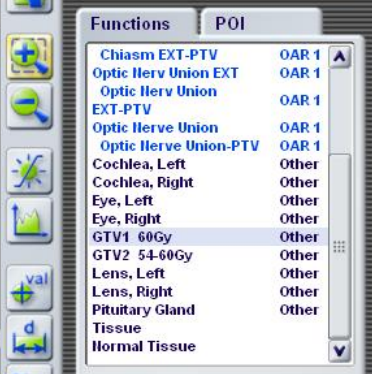

Min. Dose : 86.0 % = 54.15 Gy
Mean Dose : 97.5 % = 61.41 Gy
Max. Dose : 101.3 % = 63.81 Gy
Volume [%]
110
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
100.0 % = 6.083 ccm
Gridsize : 1.40 mm
Dose [Gy]
Pencil Beam
100.0 % = 63.00 Gy


MR #3 (Axial)
Axial View
A
P
R
L
A-P
Lat
Coord 2
Pencil Beam
Display: 2.0mm
100
60
46.00
30.00
Gy
mm


MR #3 (Axial)
Sagittal View
H
A
P
Vert
A-P
Pencil Beam
Display: 2.0mm
100
60
52.00
46.00
30.00
Gy
mm

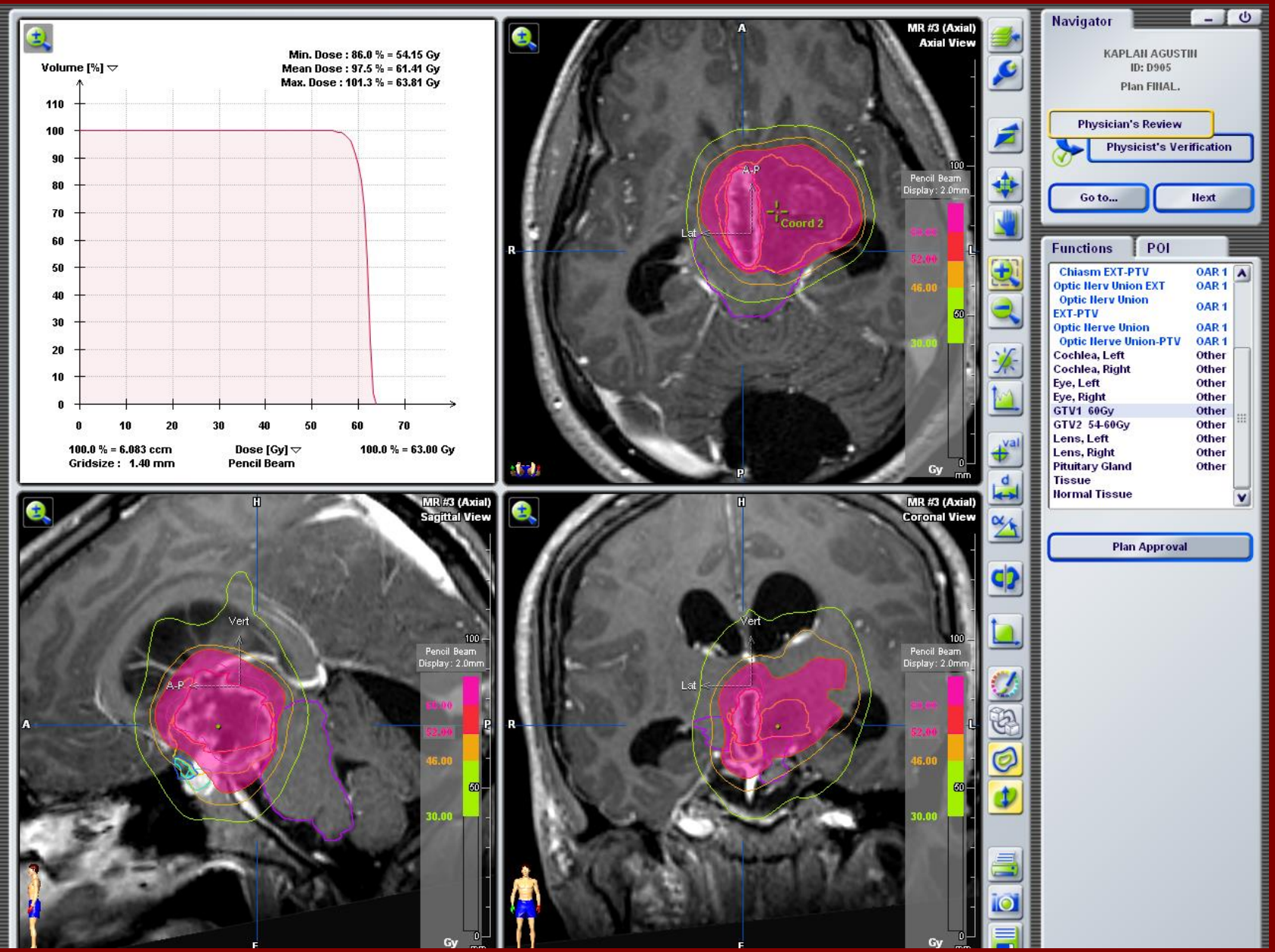

MR #3 (Axial)
Coronal View
H
R
L
Vert
Lat
Pencil Beam
Display: 2.0mm
100
60
46.00
30.00
Gy
mm


Navigator
KAPLAN AGUSTIN
ID: D905
Plan FINAL.
Physician's Review
Physicist's Verification
Go to...
Next


Functions
POI
Chiasm EXT-PTV OAR 1
Optic Nerv Union EXT OAR 1
Optic Nerv Union EXT-PTV OAR 1
Optic Nerve Union OAR 1
Optic Nerve Union-PTV OAR 1
Cochlea, Left Other
Cochlea, Right Other
Eye, Left Other
Eye, Right Other
GTV1 60Gy Other
GTV2 54-60Gy Other
Lens, Left Other
Lens, Right Other
Pituitary Gland Other
Tissue
Normal Tissue


Plan Approval

Single isocenter for irregular targets with better conformality and homogeneity than cones

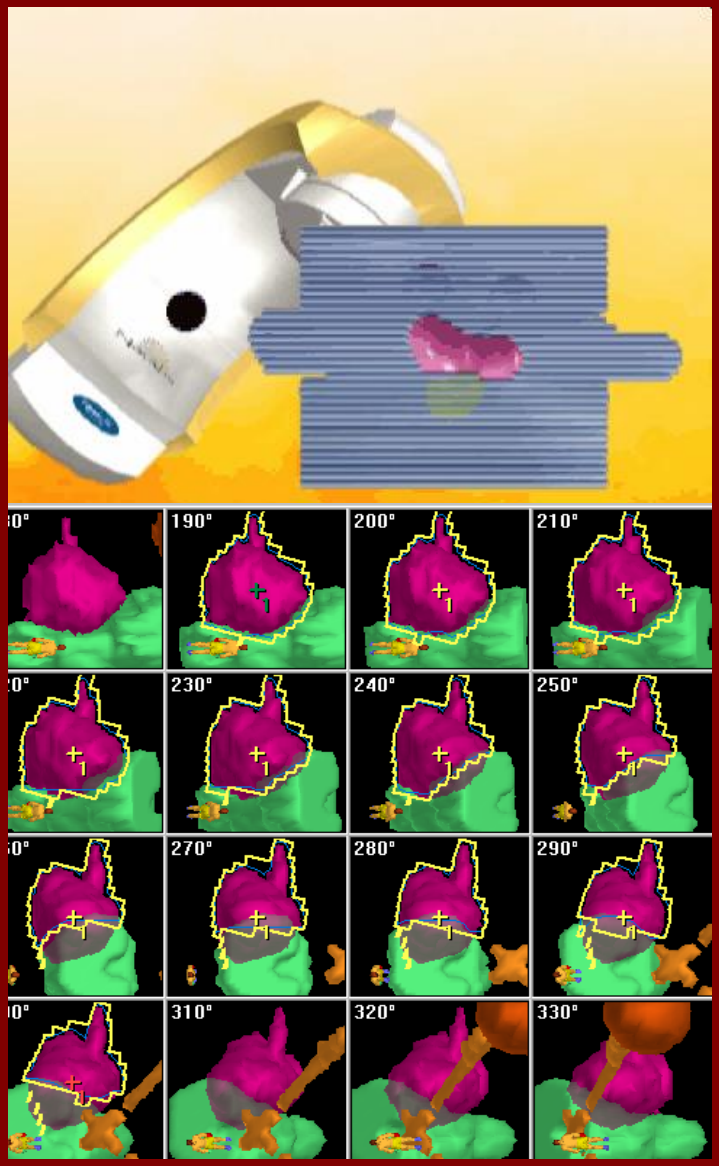


Dynamic Conformal Arc

- **Automatic leaf adaptation to tumor contour**
- **Straight-forward arc optimization with collision map**
- **MLC control must be synchronized with gantry rotation**

Advantages

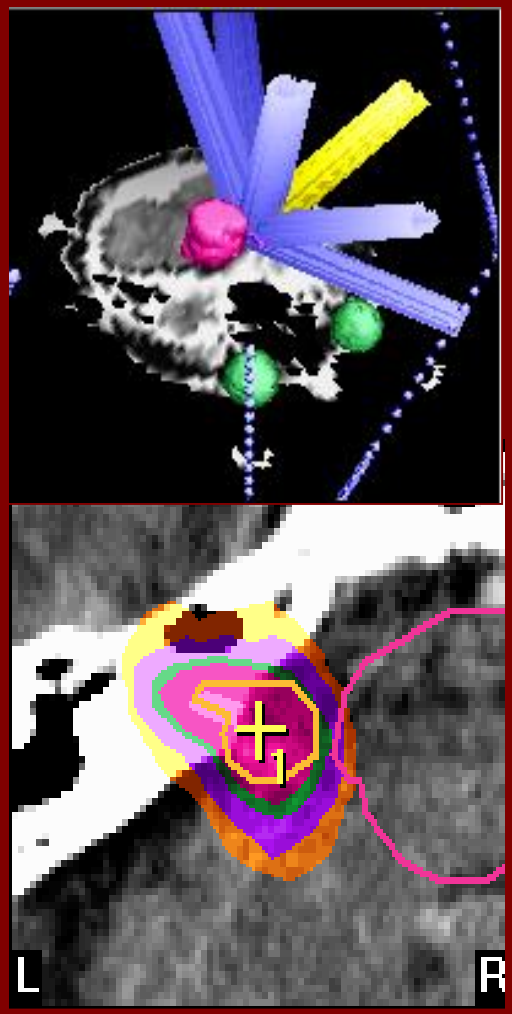
- **Fast, semi-automatic single isocenter treatment planning**
- **Critical structures are easier to avoid for most beam angles**
- **Most conformal and homogeneous dose distribution with reduced irradiation of normal tissue**



<DPF, NSUH-LIJ >

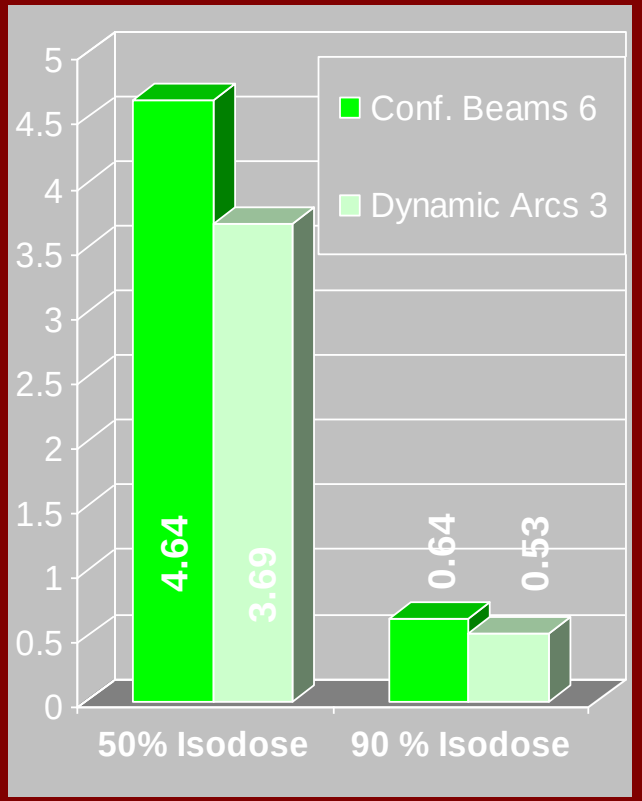
Comparison of plans

Conformal mMLC Plan
1 Isocenter -6 Static Fields



Dynamic Conformal Arc Plan
1 Isocenter - 3 Dynamic Arcs

Volume of irradiated Normal Tissue (cm^3)

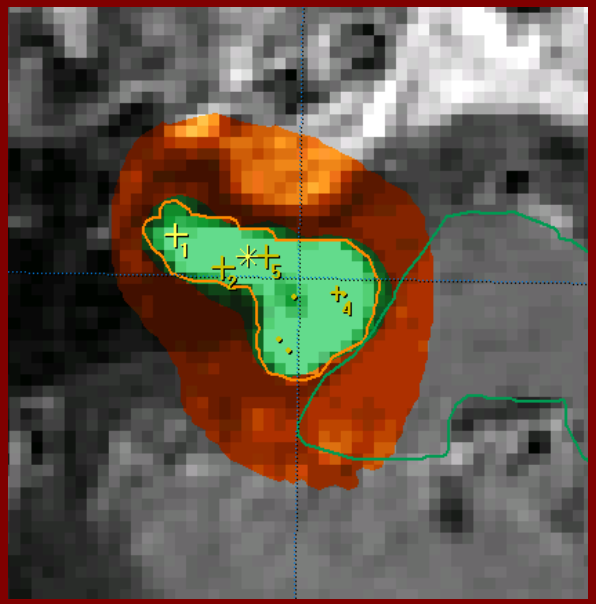


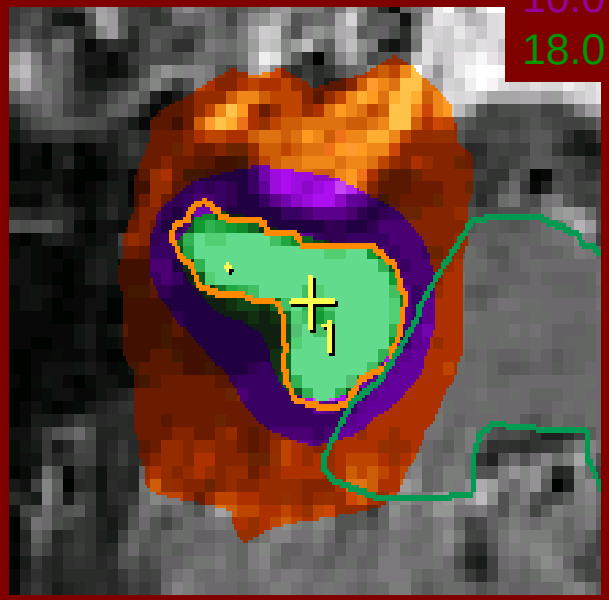
Courtesy of Universitätsklinkum Charité, Berlin

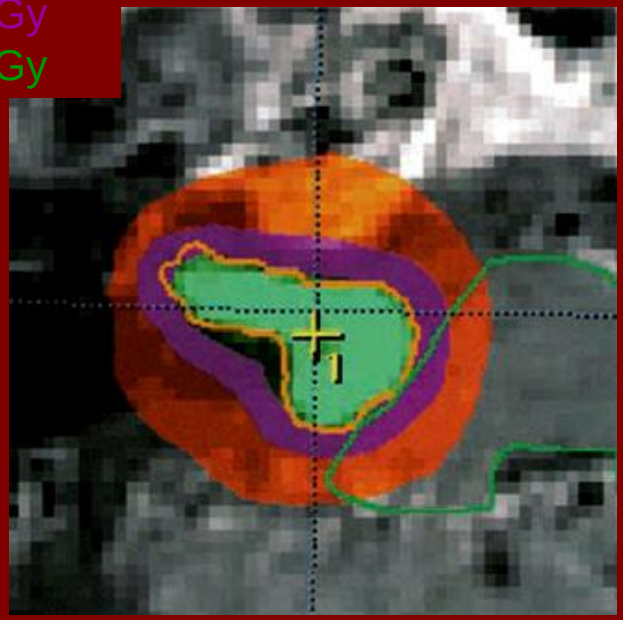
Comparacion
Acoustic Neuroma

7.2 Gy
18.0 Gy

4.0 Gy
10.0 Gy
18.0 Gy







Circular Arc,
8 Isocenters

Conformal Beam,
19 Beams (1 isocenter)

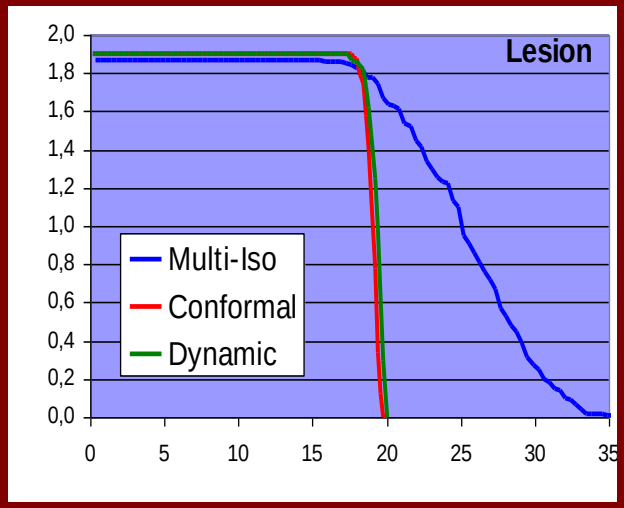
Dynamic Conformal
Arc, 5 Arcs (1 isocenter)

Improved normal tissue sparing
Tight margin around target

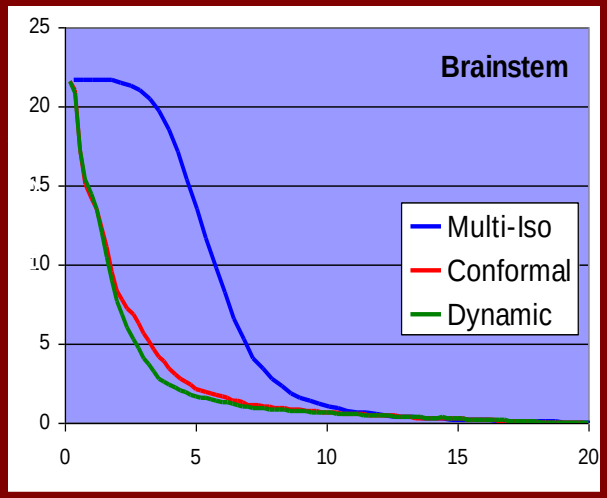
Dynamic Arc Radiosurgery Field Shaping: A Comparison with Static Field Conformal and non-coplanar circular arcs. T. Solberg *et al.* Int. J. Radiation Oncology Biol Physics. Vol 49, No. 5, pp1481–1491, 2001

Comparison
Acoustic Neuroma

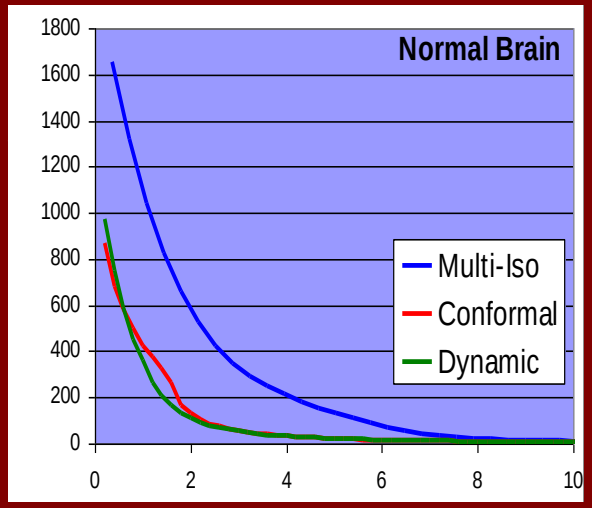
Homogenous Dose Distribution
Greater sparing of normal tissue and structures at risk



Dose (cGy)



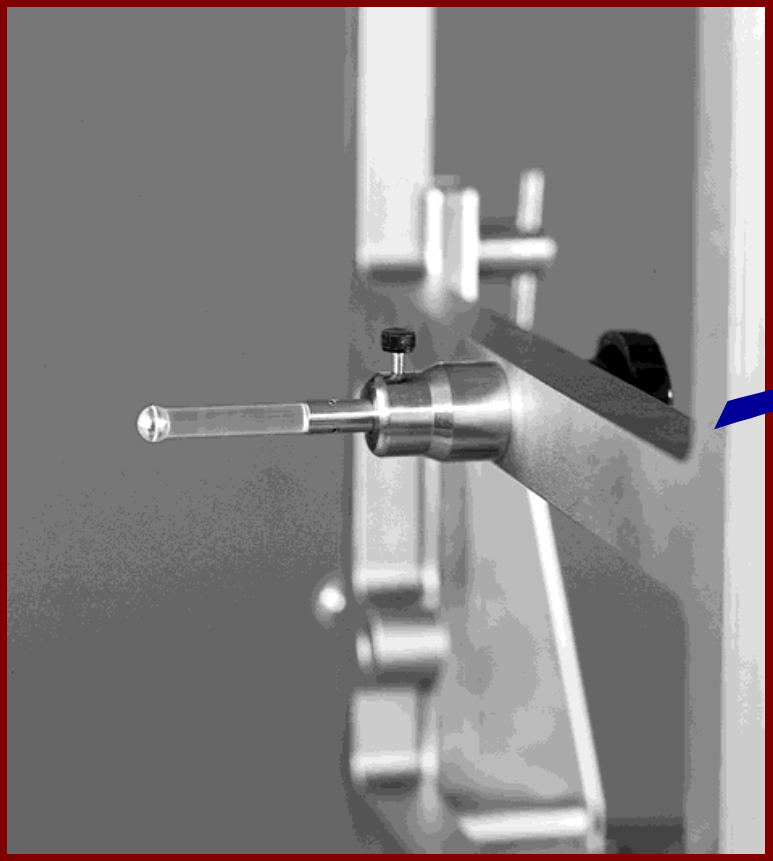
Dose (cGy)

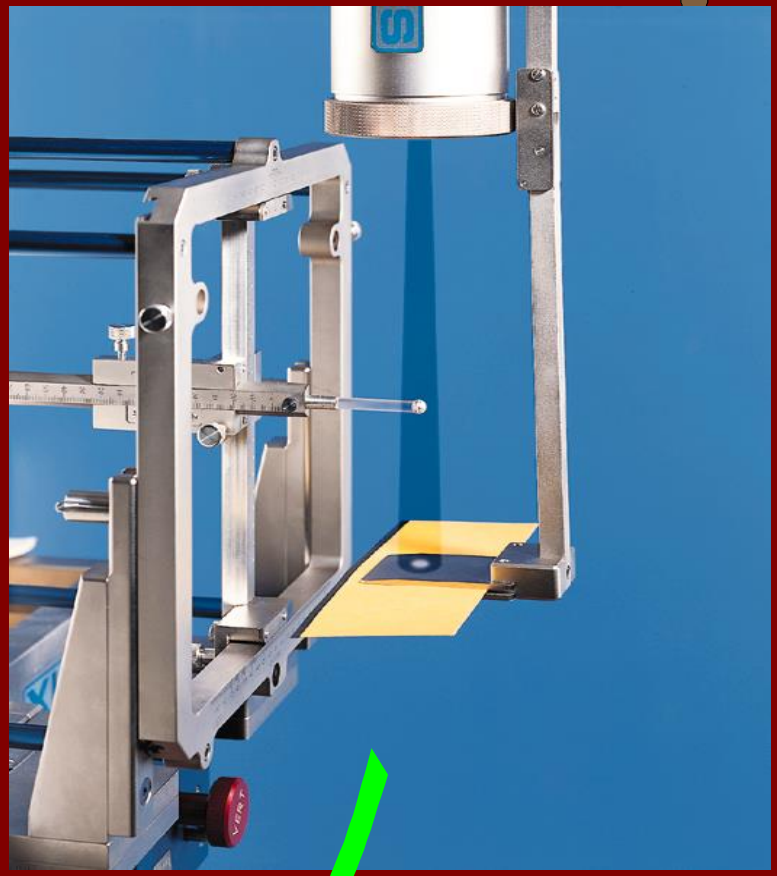


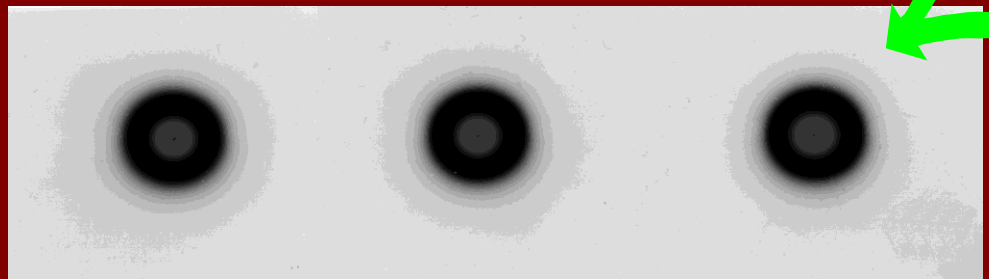
Dose (cGy)

Dynamic Arc Radiosurgery Field Shaping: A Comparison with Static Field Conformal and non-coplanar circular arcs. T. Solberg *et al.* Int. J. Radiation Oncology Biol Physics. Vol 49, No. 5, pp1481–1491, 2001

QA of Isocenter

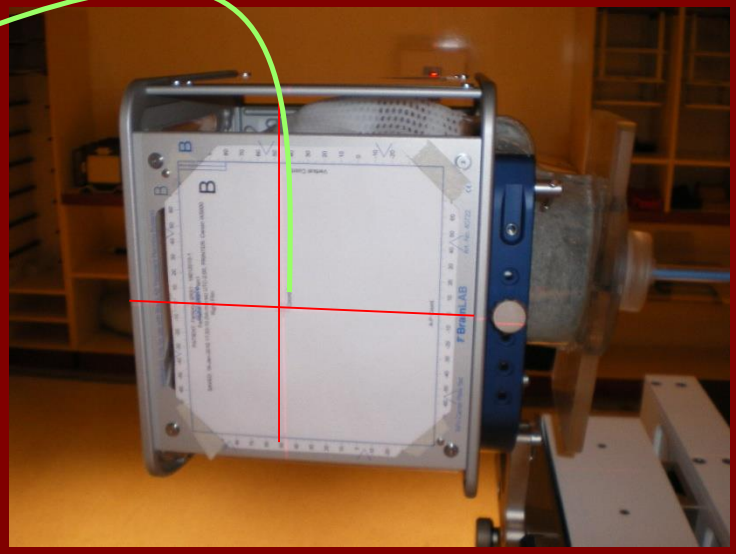






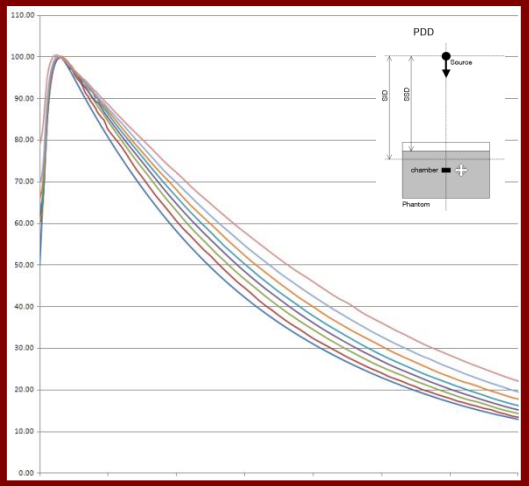
Coordinate verification

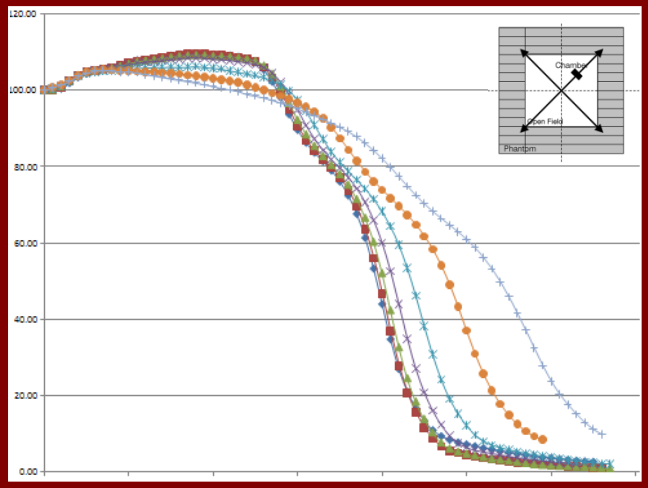
- Templates and Laser -

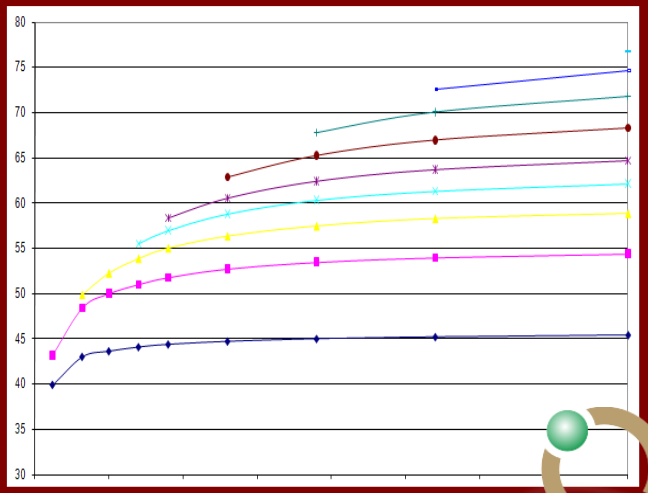


Beam dosimetry of small fields and treatment planning commisioning

- **Beam parameters**
  - ***PDD***
  - ***Profiles***
  - ***Field size dependent output factors***
  - ***Transmission***
  - ***Absolute dose***





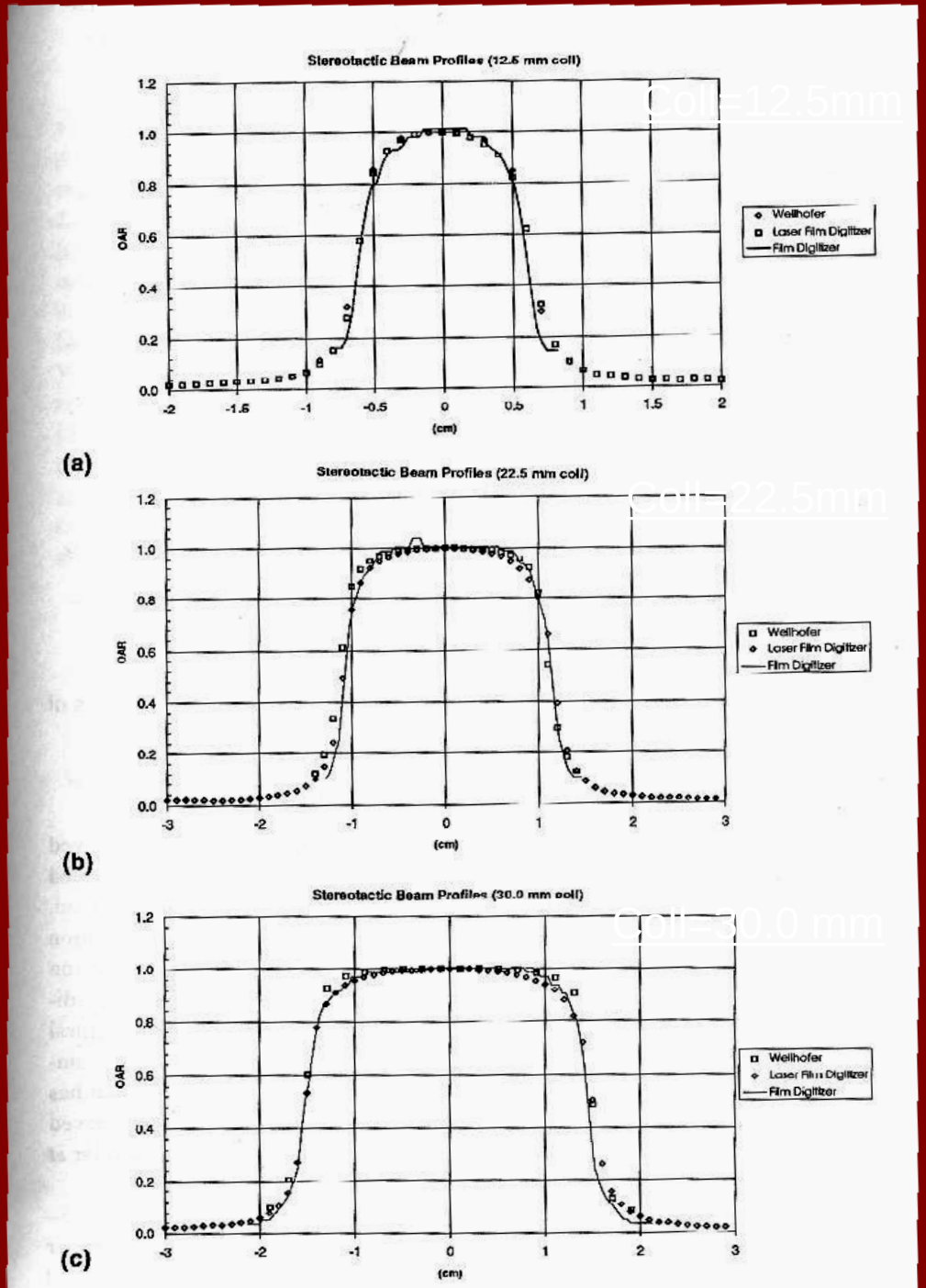


Beam Dose Measurements

- **Issues with small field dosimetry:**
  - **Detector size vs. Small field dimensions**
  - **Lack of lateral charged particle equilibrium**
  - **Large dose gradients in SRS penumbra**
- **Equipment:**
  - **Water tank, polystyrene slabs, ion chamber, diodes, TLD's and Film**
  - **Very small Detector diameter required to reproduce a penumbra of ~1mm**

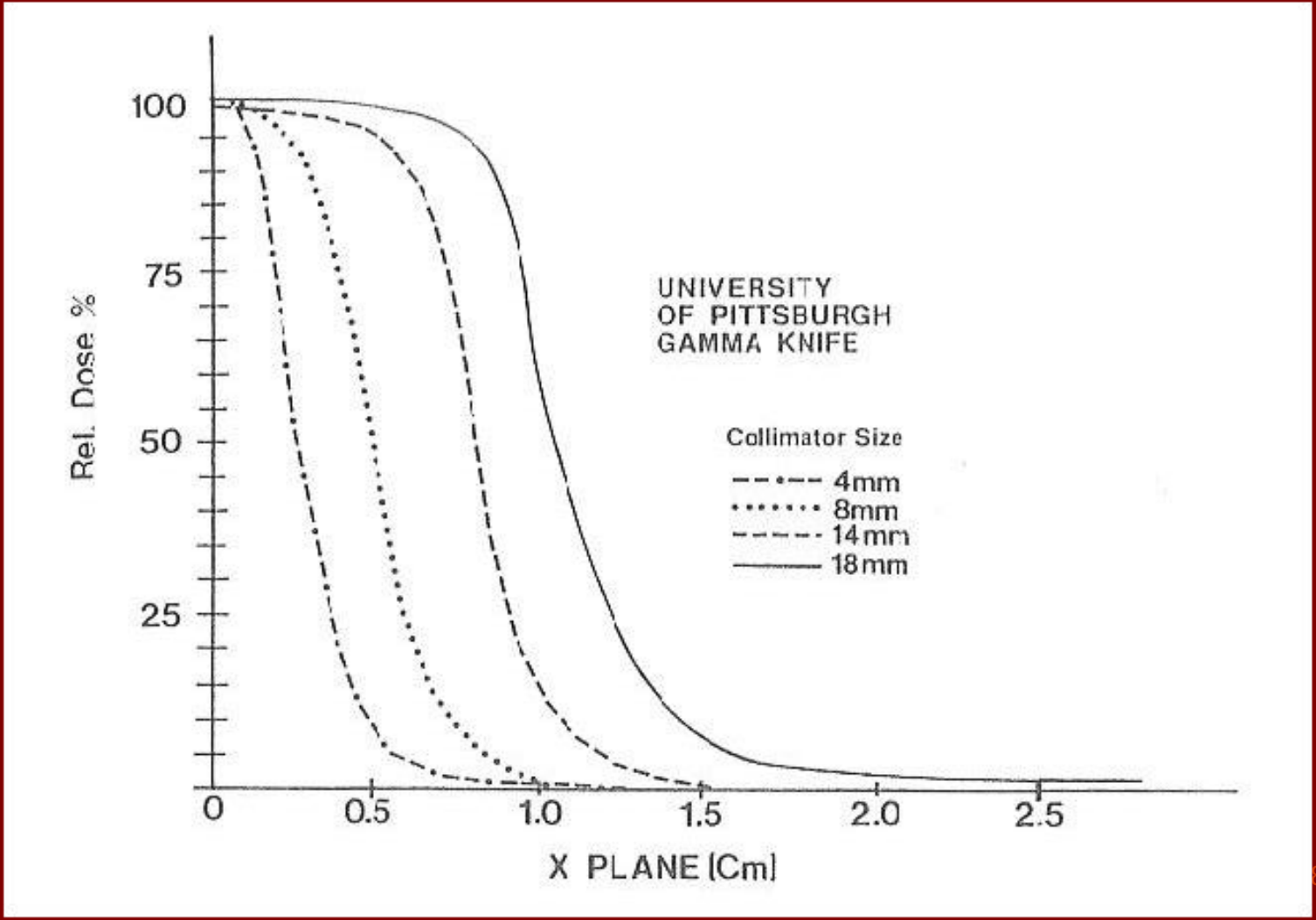
Small Field Dosimetry: Overview of AAPM TG-155 - Indra Das- AAPM AM 2015
http://amos3.aapm.org/abstracts/pdf/99-28443-359478-110238.pdf

Beam Profiles

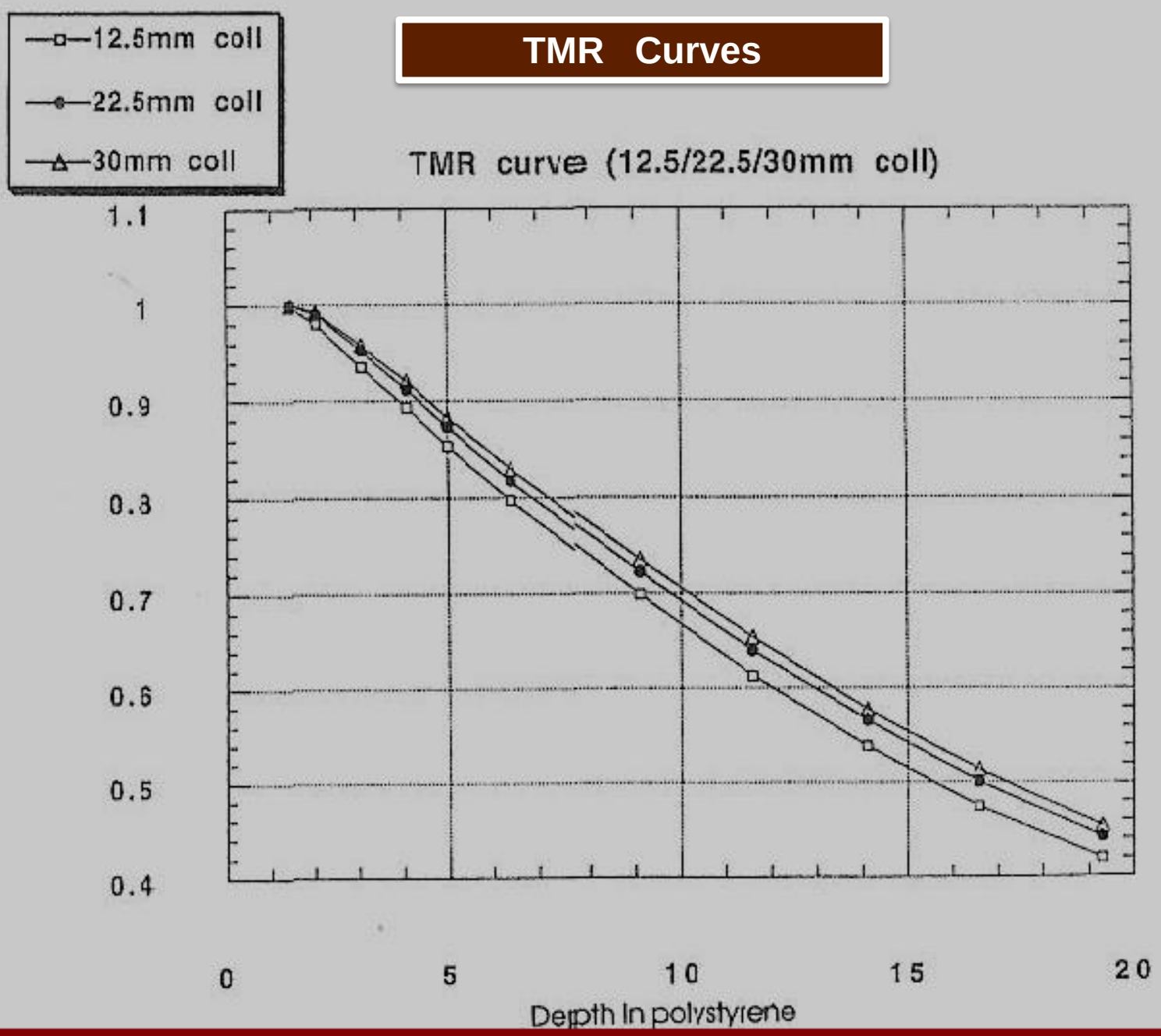


- **Welhofer**
  - **Laser Film Digitizer (Lumisys)**
  - **Film Digitizer**

Gamma Knife - Beam profiles

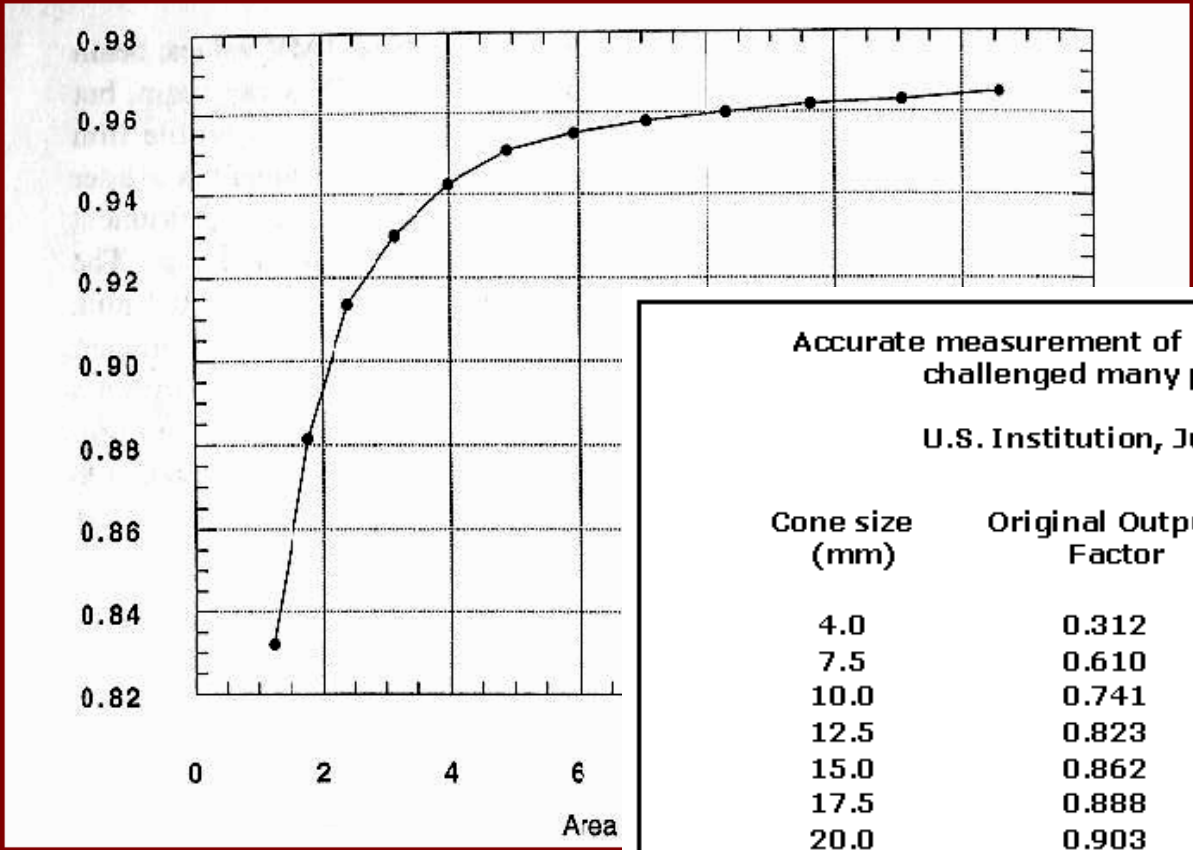


TMR Curves


12.5mm coll
22.5mm coll
30mm coll
TMR curve (12.5/22.5/30mm coll)
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0
5
10
15
20
Depth in polystyrene

Stereotatic Output Factor Curve
($S_t = S_c \ S_p$)
@ Isocenter, d_{max}

6 MV Coll. Diam.:12.5mm to 20.0mm

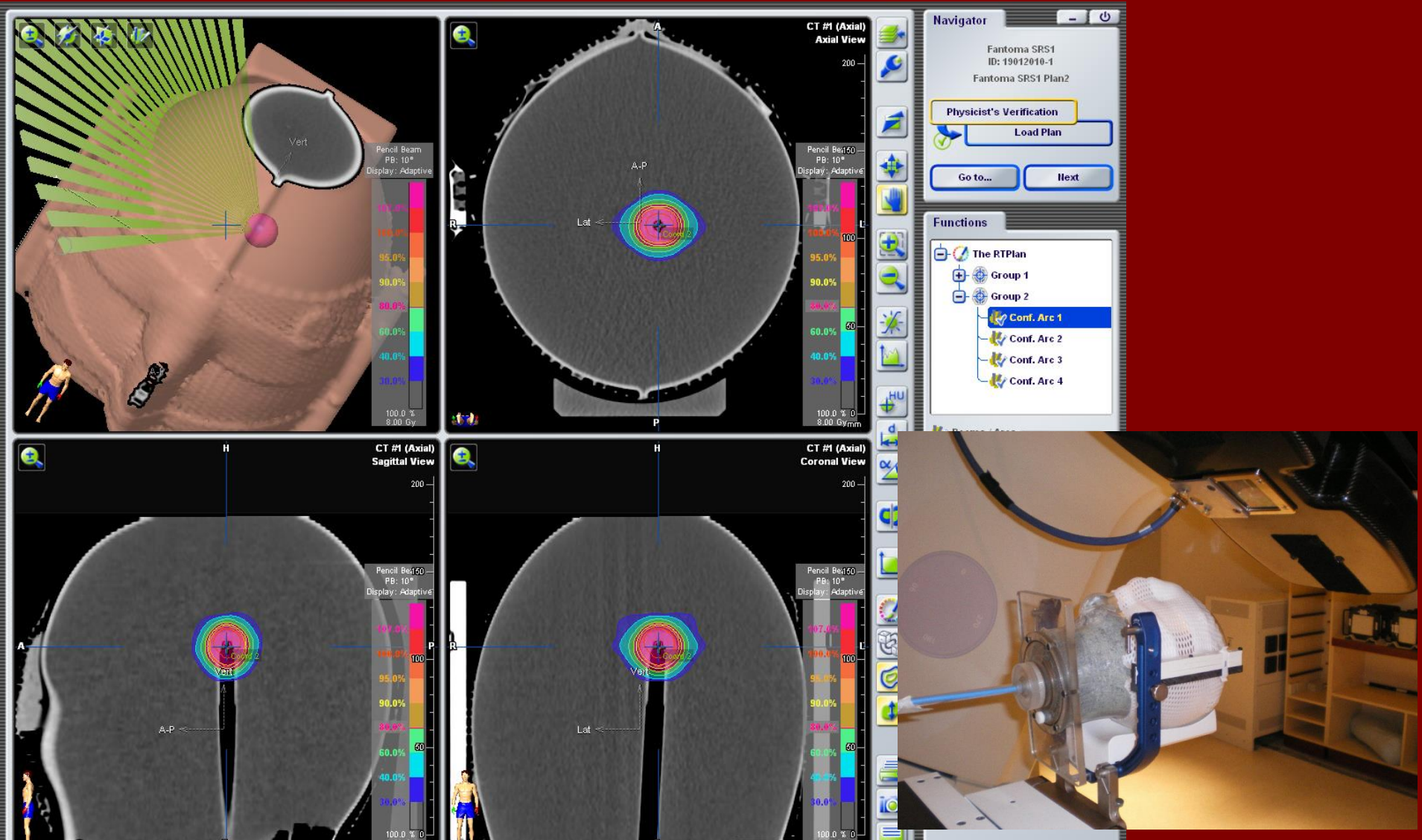


Accurate measurement of output factors has challenged many physicists

U.S. Institution, July, 2010

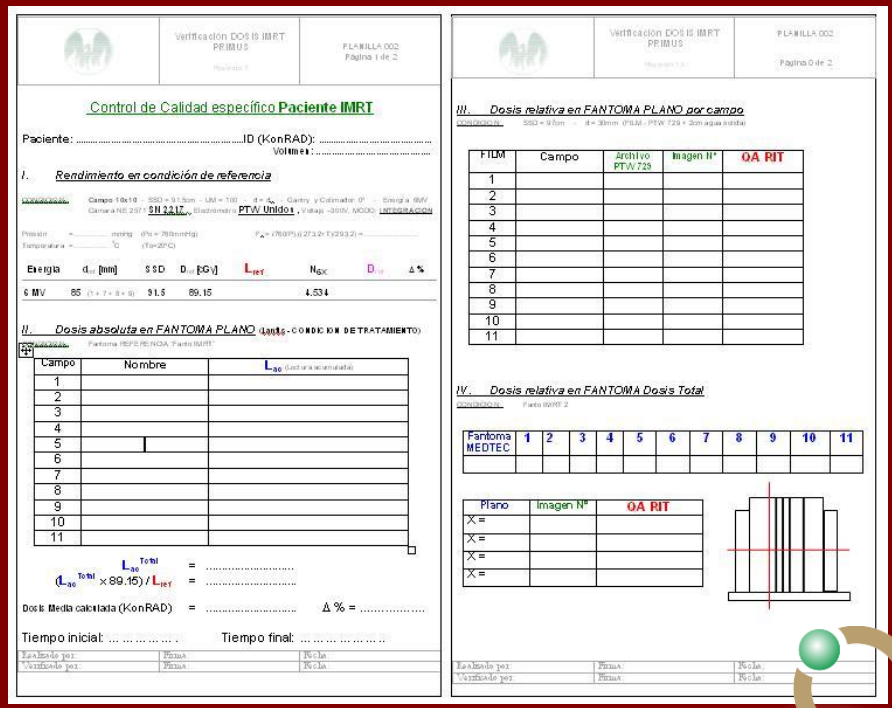
Cone size (mm)	Original Output Factor	Re-measured Output Factor
4.0	0.312	0.699
7.5	0.610	0.797
10.0	0.741	0.835
12.5	0.823	0.871
15.0	0.862	0.890
17.5	0.888	0.904
20.0	0.903	0.913
25.0	0.920	0.930
30.0	0.928	0.940

Verification of dose calculations



Verification of dose calculations

- **IMRS – Patient specific dose measurements**
  - **Absolute total plan dose**
  - **Relative doses per field**
  - **Relative plan dose distribution**



Verificación DOSIS IMRT PRIMUS

PLANILLA 002

Página 1 de 2

Control de Calidad específico **Paciente IMRT**

Paciente: ..... ID (KonRAD): .....

Volumen: .....

I. *Rendimiento en condición de referencia*

Energía	d_{ref} [mm]	SSD	D_{ref} [cGy]	L_{ref}	N_{gK}	D_{ref}	Δ %
6 MV	85	91.5	89.15		4.534		

II. *Dosis absoluta en FANTOMA PLANO* (Lado - CONDICIÓN DE TRATAMIENTO)

Campo	Nombre	L_{ao} (Lectura acumulada)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		

L_{ao}^{Total} = ...

$(L_{ao}^{Total} \times 89.15) / L_{ref}$ = ...

Dosis Media calculada (KonRAD) = ... Δ % = ...

Tiempo inicial: ..... Tiempo final: .....

Realizado por:	Firma:	Fecha:
Verificado por:	Firma:	Fecha:

Verificación DOSIS IMRT PRIMUS

PLANILLA 002

Página 2 de 2

III. *Dosis relativa en FANTOMA PLANO por campo*

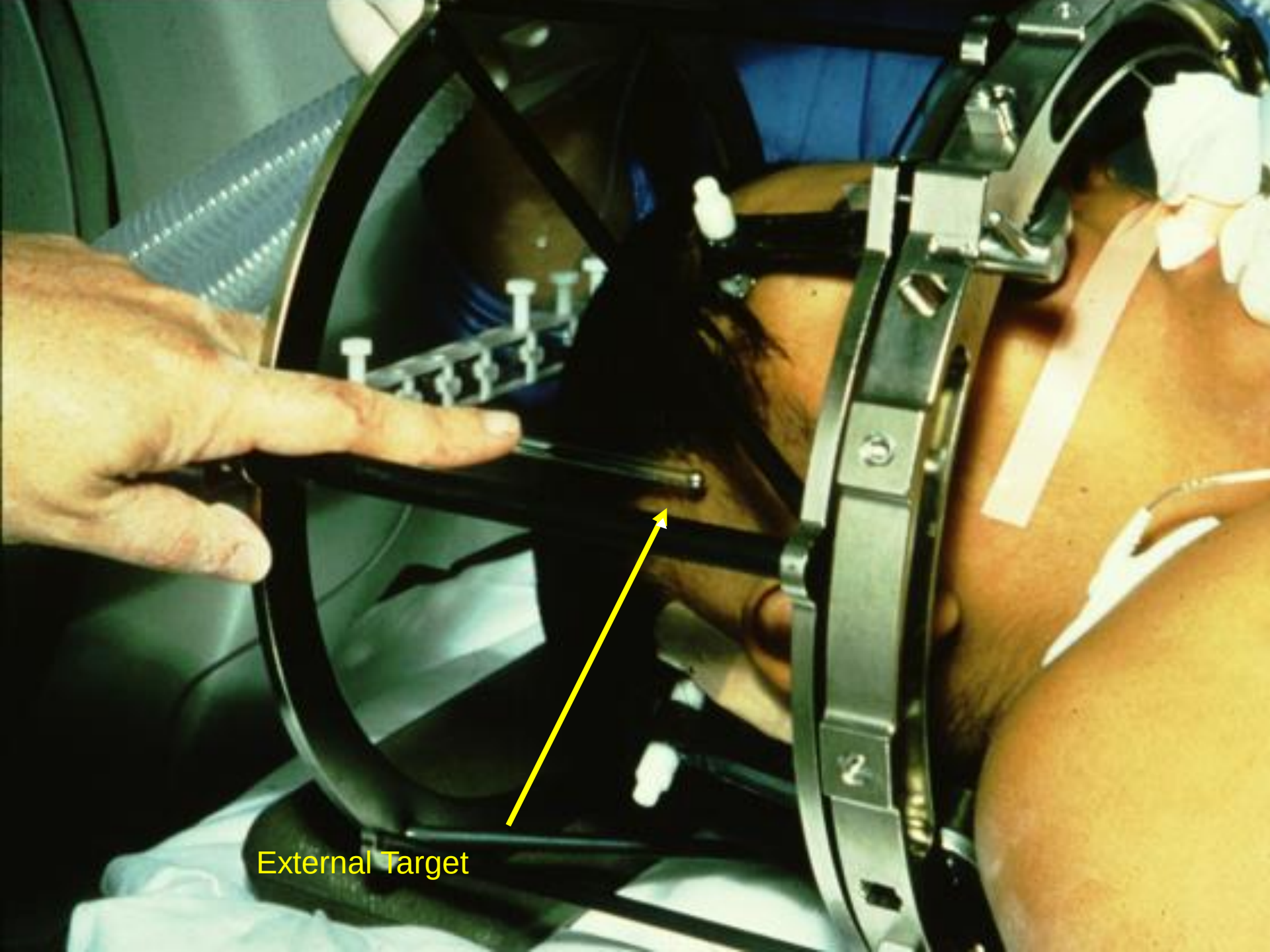
FTDM	Campo	Archivo PTW 729	Imagen N°	QA RIT
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				

IV. *Dosis relativa en FANTOMA Dosis Total*

Fantoma MEDTEC	1	2	3	4	5	6	7	8	9	10	11

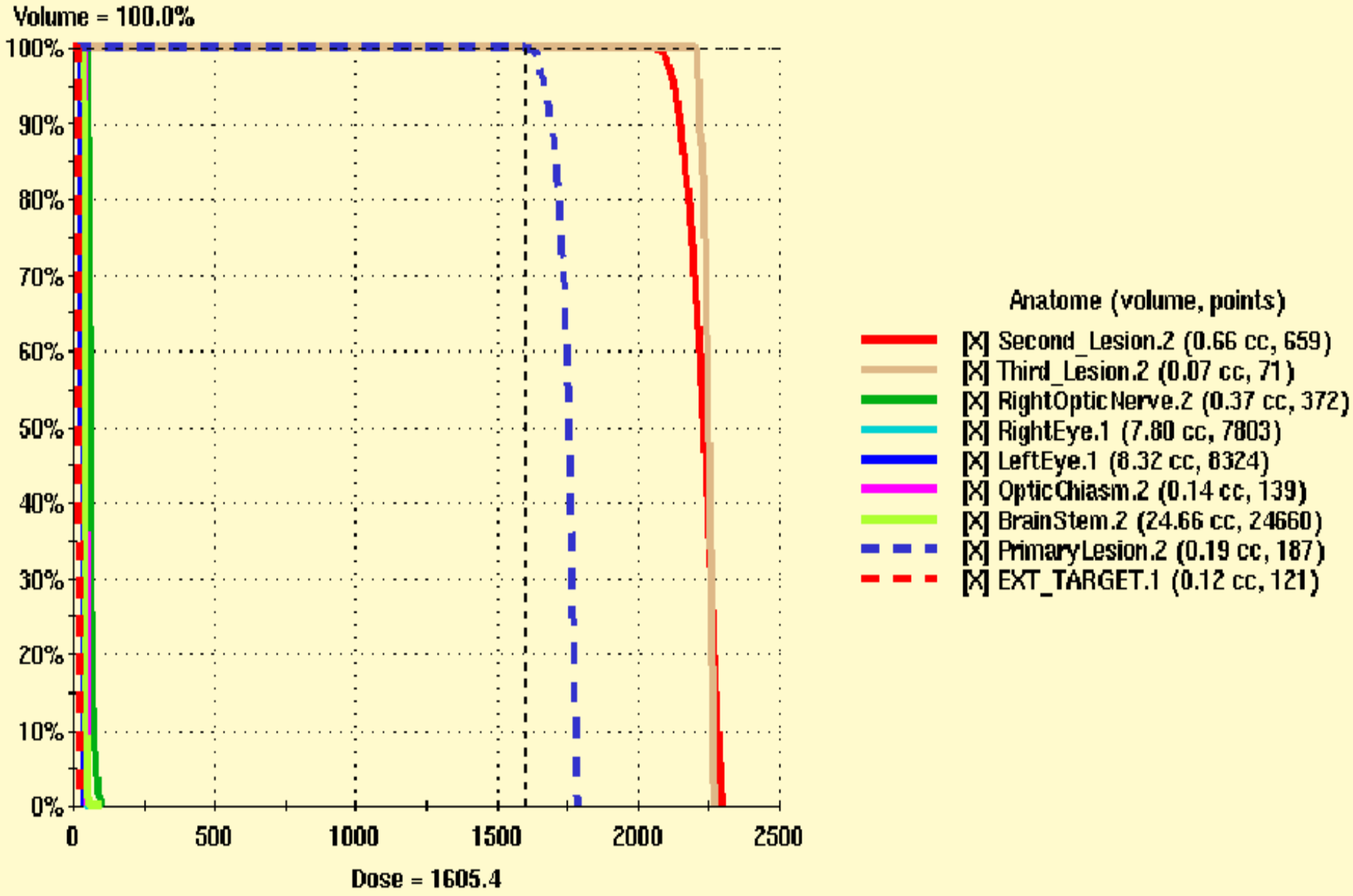
Plano	Imagen N°	QA RIT
X =		
X =		
X =		
X =		

Realizado por:	Firma:	Fecha:
Verificado por:	Firma:	Fecha:


External Target

Dose Evaluation Tools

- Volume Dose
- Surface Dose
- Dose Summary
- Slice Dose
- Dose Volume Histograms


Volume = 100.0%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
500
1000
1500
2000
2500
Dose = 1605.4
Anatome (volume, points)
[X] Second_Lesion.2 (0.66 cc, 659)
[X] Third_Lesion.2 (0.07 cc, 71)
[X] RightOpticNerve.2 (0.37 cc, 372)
[X] RightEye.1 (7.80 cc, 7803)
[X] LeftEye.1 (8.32 cc, 8324)
[X] OpticChiasm.2 (0.14 cc, 139)
[X] BrainStem.2 (24.66 cc, 24660)
[X] PrimaryLesion.2 (0.19 cc, 187)
[X] EXT_TARGET.1 (0.12 cc, 121)

Plan quality indices

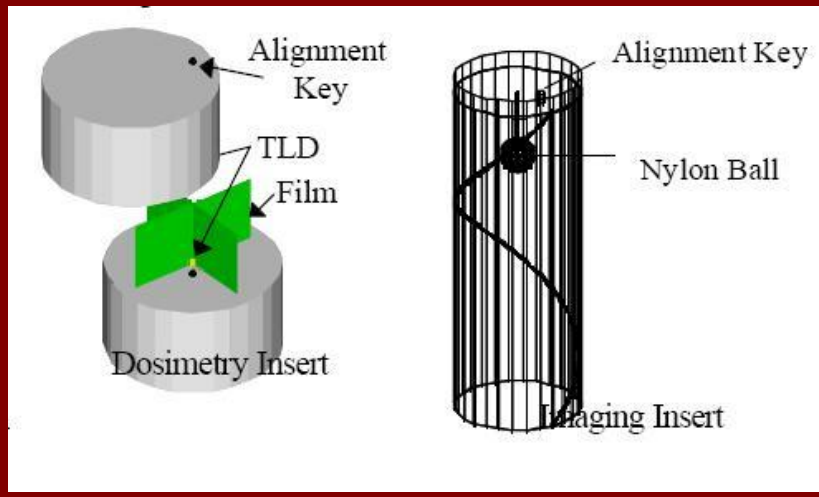
Conformity (CI): Ratio of the prescription isodose volume V(p)to the target Volume V(T)

Homogeneity (HI) Ratio of maximum dose D(max) to Prescription Dose D(p)

- **Dose gradient :** Ratio of V(T) to Volume of the 50% isodose ($V_{50\%}$)

	Conformity	Homogeneity	Gradient
Reference value	1 – 2	HI ≤ 2	≥ 0.3
Minor deviation (acceptable)	0.9< CI < 1 o 2 < CI < 2.5	2 < HI ≤ 2.5	
Major deviation (unacceptable)	CI < 0.9 o CI ≥ 2.5	HI > 2.5	

Total system verification – external audit



- *Plan according to "RTOG Quality Assurance Guidelines"*
- *Phantom*
  - *Target F = 19mm*
  - *Gafchromic film in two orthogonal planes*
  - *2 TLD-100at the target center*
  - http://rpc.mdanderson.org/rpc

IROC IMAGING AND RADIATION ONCOLOGY CORE Global Leaders in Clinical Trial Quality Assurance MD Anderson IROC Houston Quality Assurance Center

Report

THE UNIVERSITY OF TEXAS MD ANDERSON CANCER CENTER

Preliminary studies suggest that the precision of the TLD is ±3%, and the localization precision from the film is ±1 mm.

Summary of results:

	Ratio	Criteria [a]
Dose to the center of the target (RPC/Institution)	0.98	0.95 - 1.05
Treated Volume [b]: (Measured/Institution)	0.78	0.75 - 1.25 [c]
Ratio of Measured Treated Volume to Target Volume [d]	1.17	1.00 - 2.00
Minimum Dose to Target (Minimum Dose/Prescription Dose)[e]	0.91	> 0.90

(a) Criteria are adapted from the RTOG QA guidelines. Int. J. Onc. Biol. Phys. 27, 1231-39, 1993.
(b) The treated volume is assumed to be an ellipsoid with diameters taken from the "Film Results" table.
(c) Average discrepancy of approximately 2 mm on each diameter.
(d) The target is the 1.9 cm. sphere.
(e) Minimum dose is taken from the 3 dose profiles.

TLD and Film Analysis by: Paola Alvarez, MS

TLD Results:

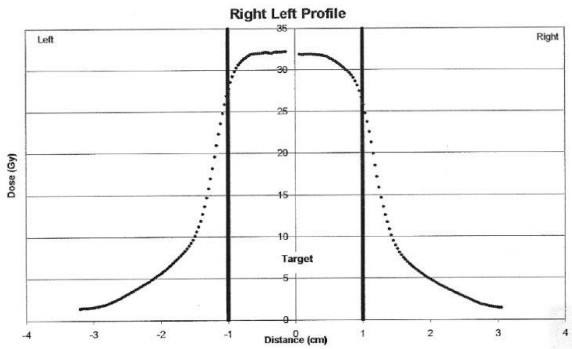
Dose to TLD Capsules (Gy) Upper	Lower	Average Dose (Gy) (Dose to Center)	Institution Dose (Gy)	Ratio Measured/Institution
30.5	29.4	30.0	30.5	0.982

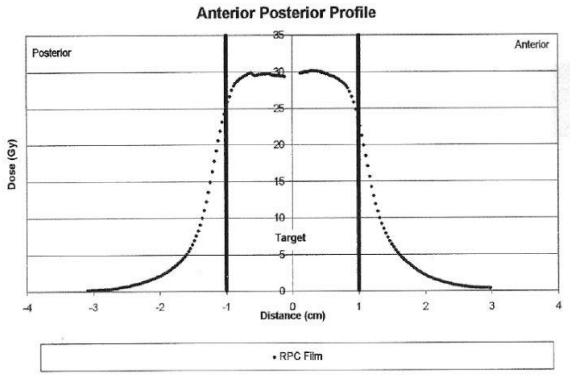
Film Results:

Measured Along	Field Size (80% Isodose Line) Measured (cm)	Institution (cm)	Measured - Institution	Offset (80% Line)* (cm)
Right/Left Profile (x)	2.1	2.2	-0.1	0.0
Anterior/Posterior Profile (y)	2.0	2.1	-0.2	0.0
Superior/Inferior Profile (z)	1.9	2.2	-0.3	-0.1

Treated Volume (cm^3)**	4.19	5.40

* Offset is the distance between the center of the specified isodose line and the center of the physical target.
** Treated Volume= $(\pi \cdot x \cdot y \cdot z)/6$





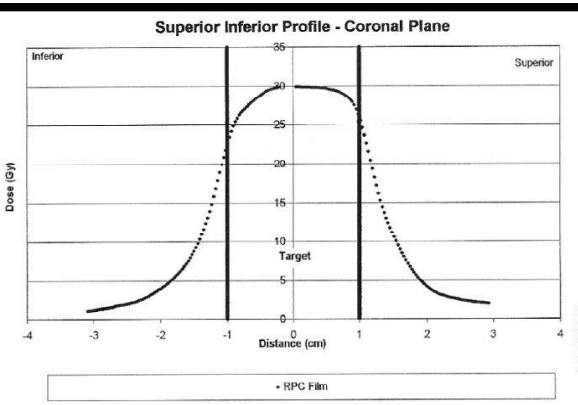


Table 1. List of radiosurgery events reported to the NRC during the period 2005-2010

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

from: **Quality and safety in stereotactic radiosurgery and stereotactic body radiation therapy: can more be done? Timothy D. Solberg, and Paul M. Medin**
Jour. of Radiosurgery and SBRT, Vol. 1, pp. 13-19

LESSONS FROM RECENT ACCIDENTS IN RADIATION THERAPY IN FRANCE

S. Derreumaux*, C. Etard, C. Huet, F. Trompier, I. Clairand, J-F. Bottollier-Depois, B. Aubert and P. Gourmelon
Institut de Radioprotection et de Sûreté Nucléaire, Direction de la Radioprotection de l'Homme, IRSN, BP 17, F-92262 Fontenay-aux-Roses Cedex, France
Radiation Protection Dosimetry (2008), Vol. 131, No. 1, pp. 130–135

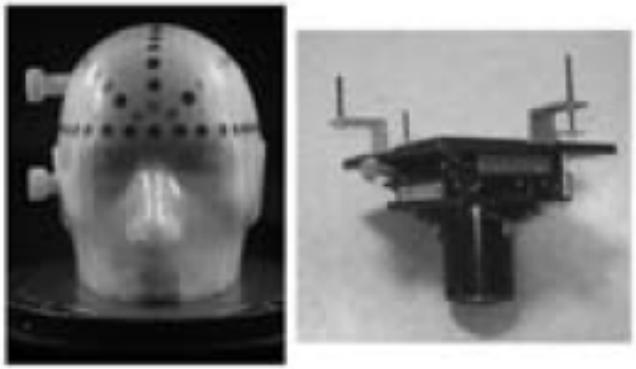


Figure 2. Stereotactic radiotherapy treatment delivery with successive beam entrance positions as a function of accelerator and table rotation angles (left). The plate used in the centre (Case 2) to hold the cylindrical additional collimator (right).

Single fraction SRS for AVM, November, 2004

Prescription dose not reported; plan/treatment used multiple isocenters, with collimators from 10 -30 mm

Jaws set to 40 x 40 cm^2 instead of 40 x 40 mm^2. Physicist told therapist "40 x 40"

Some areas of normal brain received in more than dose to intended target

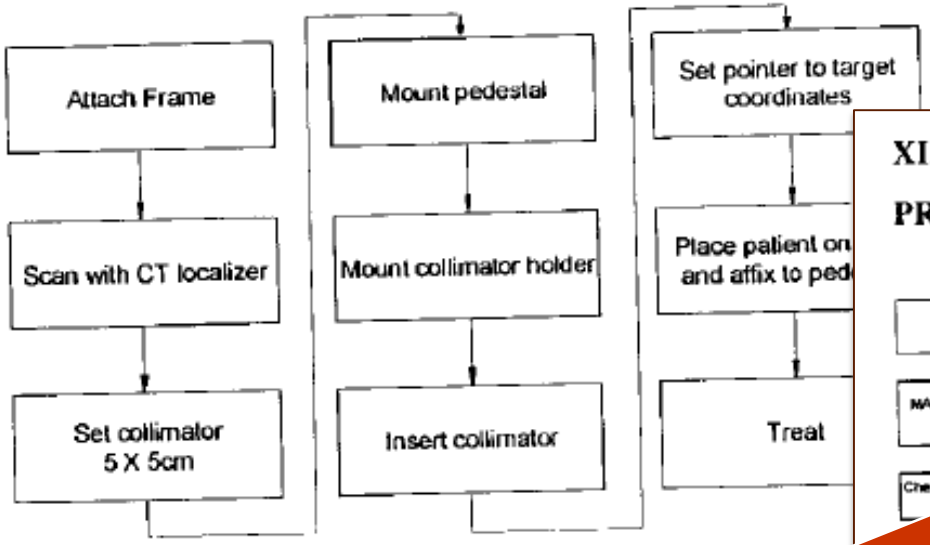
Severe complications: "fibrosis and oseo-tracheal fistula that required surgical operation." Patient died several days later as a result of a "brutal haemorrhage."

A written checklist system, and/or a proper R/V system can minimize events like this

AAPM Report 54 (1995) Task Group #42 - Stereotactic Radiosurgery

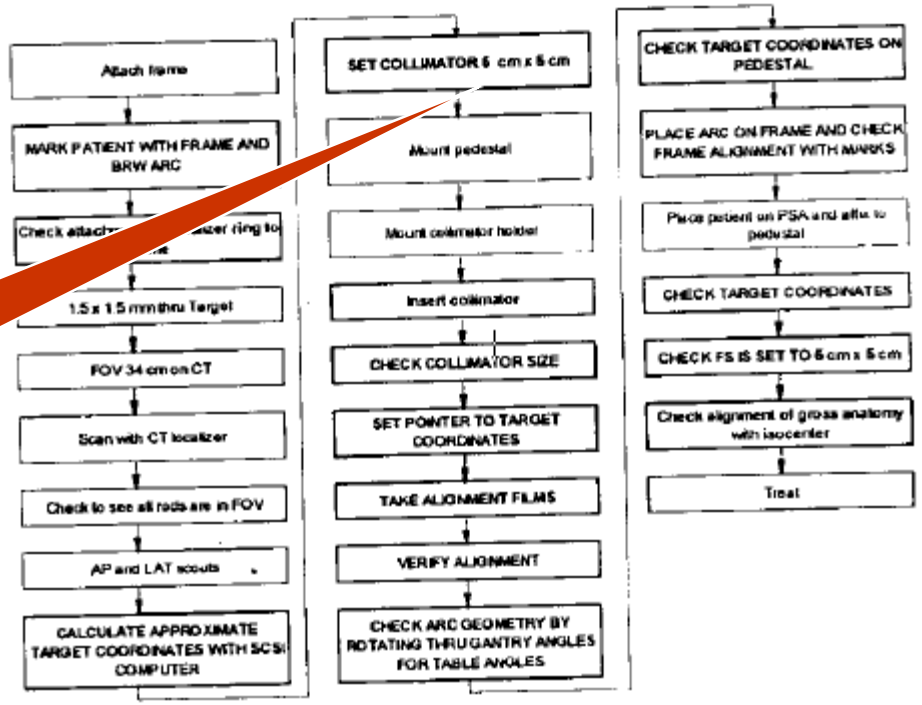
XI. APPENDIX I

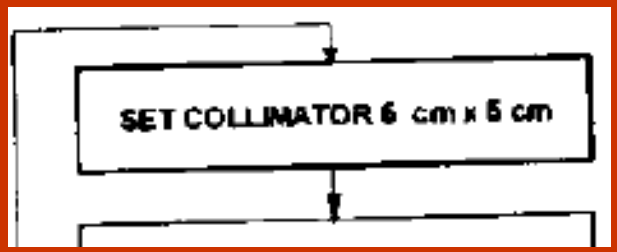
PROBABLE RISK ANALYSIS FLOWCHART: EXAMPLE 1



XII. APPENDIX II

PROBABLE RISK ANALYSIS FLOWCHART: EXAMPLE 2





RADIOSURGERY PROCEDURE CHECK LIST

Patient Name:	Date:

ISOCENTER NAME :					
EXTERNAL TARGET	**AP**	**LAT**	VERT	SIGNATURE	
Phantom Base Measurements			+2.4 =		
Plan-32 Calculation					
External test target acceptable:					
TRUE TARGET (ISO)	AP	LAT	VERT		
Floor Stand (target) coord.					
Floor Stand Redont Check					
Collimator size					
Collimator Inserted					
Jaw 5 x 5, Collimator:270°					
Target Simulator	AP	LAT	VERT		
Coordinates			+15.4 =		
Target Simulator Film Acceptabble	Exposure	Gantry	Couch		
	1	130°	180°		
	2	65°	180°		
	3	295°	180°		
	4	230°	180°		
	5	130°	270°		
	6	67°	270°		
	7	230°	90°		
	8	297°	90°		
Anti-collision switches in place					
Couch Disabled					

LONG ISLAND JEWISH MEDICAL CENTER
DEPARTMENT OF RADIATION ONCOLOGY
RADIOSURGERY PROCEDURE CHECK LIST

Patient Name:	ID:	Date:

ISOCENTER NAME :

EXTERNAL TARGET	AP(Y)	LAT(X)	VERT(Z)	SIGNATURES	
Phantom Base Measurements			+2.4 =		
Radionics Calculation (mm)					
Treatment Planning System(mm)					
External test target acceptable:	Yes		No		

TRUE TARGET (ISO)	AP(Y)	LAT(X)	VERT (Z)		
Rectilinear Phantom Pointer(RLPP)					
RLPP(target) Coordinates (mm)					
RLPP read out check (mm)					

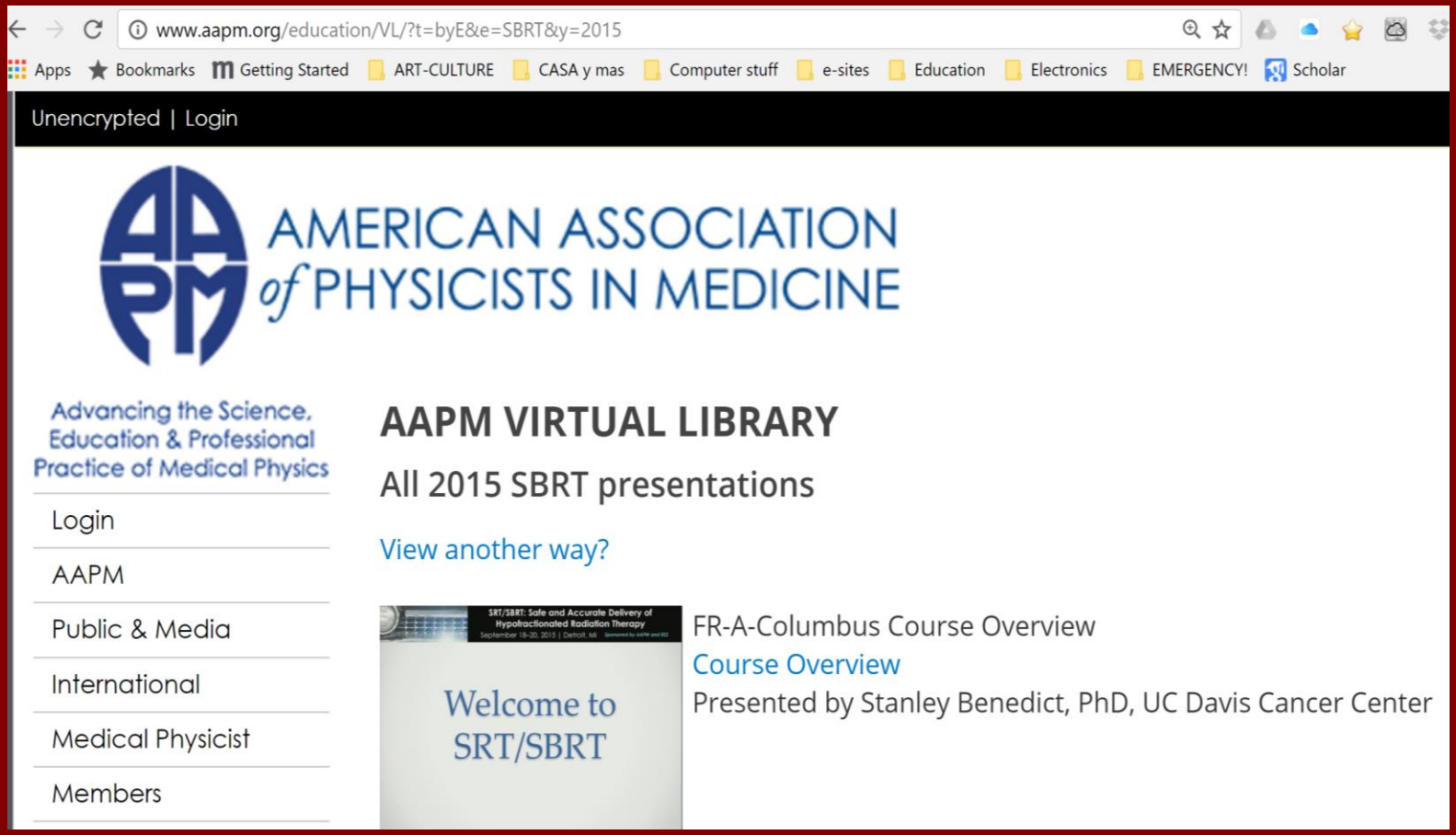
Collimator (cone) size planed	mm (diameter)		
Collimator Inserted	mm (diameter)		
Jaw 5 x 5,Collimator: 0°	Yes	No	

Laser Target Localizer Frame (LTLF)	AP(Y)	LAT(X)	VERT(Z)		
LTLF Coordinates (mm)					

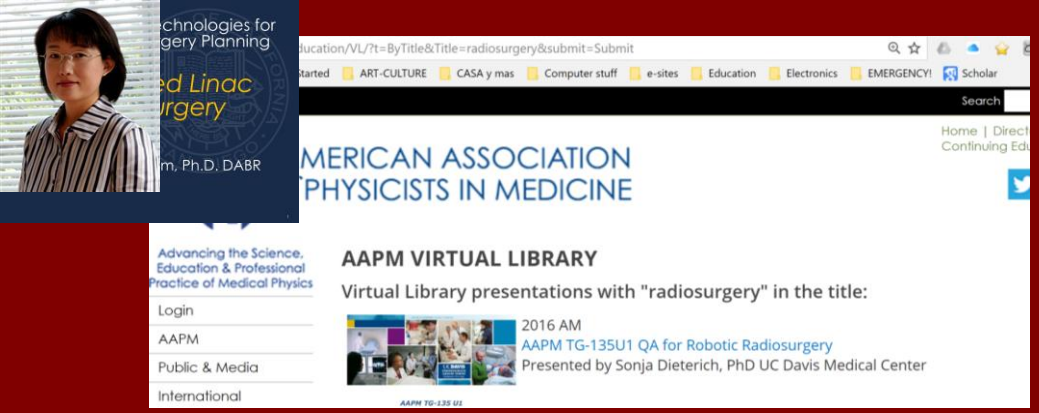
Target Simulator Film Acceptable	Exposure	Gantry	Couch		
	1	0°	90°		
Yes No	2	270°	0°		
	3	90°	0°		
	4	0°	270°		

Couch Marion Disabled	Yes	No		

Depth Confirmation Helmet Check	Point	Helmet Port	Depth (mm)		
	1				
	2				
	3				
	4				
	5				
	6				



http://www.aapm.org/education/VL/?t=byE&e=SBRT&y=2015



Strategies and Technologies for Cranial Radiosurgery Planning: MLC-Based Linac - Grace Gwe-Ya Kim- AAPM AM 2015
http://amos3.aapm.org/abstracts/pdf/99-28341-359478-110407.pdf

Strategies and Technologies for Cranial Radiosurgery Planning: Gamma Knife - D. Schlesinger, -AAPM AM 2015
http://amos3.aapm.org/abstracts/pdf/99-28342-359478-110662-163112814.pdf

Overview of CyberKnife Radiosurgery - M Descovich - AAPM AM 2014
http://amos3.aapm.org/abstracts/pdf/90-25583-333462-107361.pdf

Clinical Applications of Surface Imaging: Frameless (Maskless, Bite-blockless) Intracranial Radiosurgery - G Kim –AAPM AM 2013


תודה
Dankie
Gracias
Спасибо
شكراً
Merci
Takk
Köszönjük
Terima kasih
Grazie
Dziękujemy
Dėkojame
Ďakujeme
Vielen Dank
Paldies
Kiitos
Täname teid
谢谢
Thank You
Tak
感謝您
Obrigado
Teşekkür Ederiz
감사합니다
Σας ευχαριστούμε
ขอบคุณ
Bedankt
Děkujeme vám
ありがとうございます
Tack