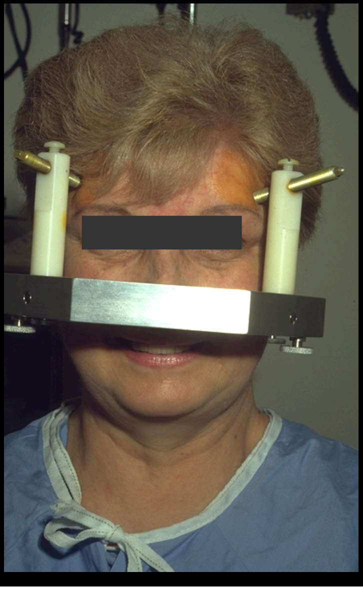
Radiocirugía intracraneal SRS: Actualización desde el punto de vista físico y aseguramiento de la calidad

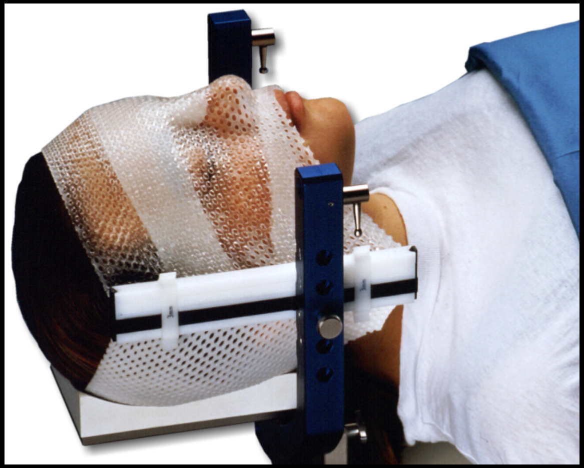
William Parker

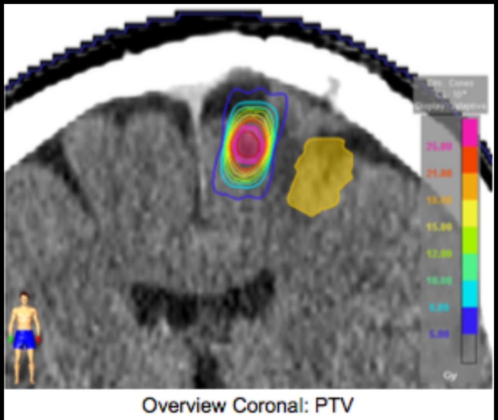
Centre universitaire de santé McGill
McGill University Health Centre

Radiocirugía Estereostática

- Fracción única
- Dosis alta (12-25 Gy) y ablativa
- Históricamente con inmovilización invasiva (cuadro)
- En el presente utilizan sistemas de imagen y mascaras termoplásticas
- Radioterapia Estereostática: dosis convencionales pero inmovilización SRS, misma precisión







Radiocirugía Estereostática

- Las dosis totales prescritas son del orden de 10 - 50 Gy

- Los GTV de planificación son pequeños, con volúmenes típicos que varían de 1 a 35 cm^3.

- Los requisitos de precisión posicional y numérica en administración de dosis son ± 1 mm y ± 5% respectivamente. No hay PTV.

- Caída brusca de dosis (80% a 20% en ~ 3 mm)

- Dosis baja en la piel (para evitar la depilación) y dosis baja en el cristalino (para evitar la formación de cataratas).

- Dosis baja o insignificante de dispersión y fuga a órganos radio-sensibles (para evitar efectos somáticos y genéticos posteriores)

Dose Delivery

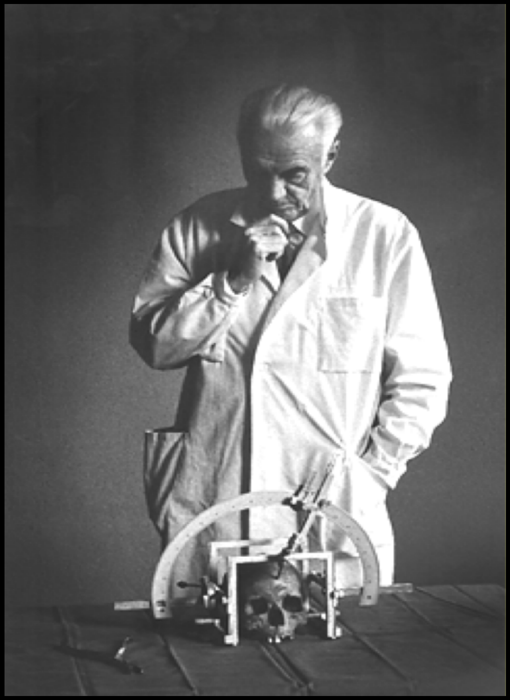
- The accuracy of the absorbed dose (beam calibration) to the target shall be uncertain by less than 5%, in accord with AAPM Report 21.
- The dose delivery to the simulated radio-opaque target shall be aligned to within 1 mm for all gantry, collimator, and PSA angles.
- The tertiary collimator system shall reproducibly collimate the beam with a variation in the full-width at half maximum of 2 mm.
- The dose gradient in the beam penumbra (from 80% to 20%) shall be greater than or equal to -60%/3 mm.

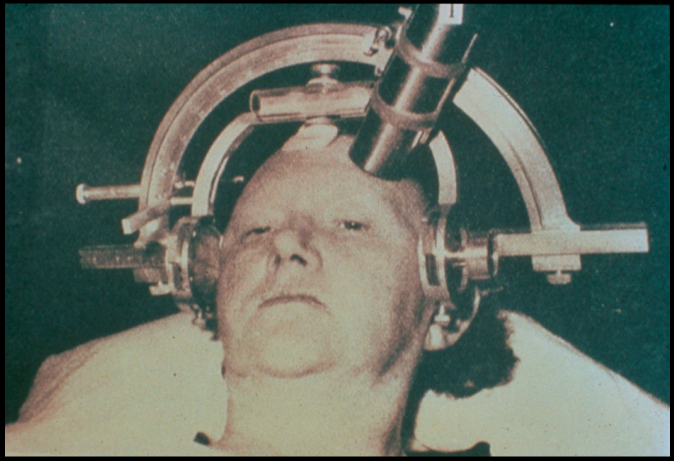
TABLE II. Achievable Uncertainties in SRS

Stereotactic Frame	1.0 mm
Isocentric Alignment	1.0 mm
CT Image Resolution	1.7 mm
Tissue Motion	1.0 mm
Angio (Point Identification)	0.3 mm
Standard Deviation of Position Uncertainty (by Quadrature)	2.4 mm

Podgorsak, IAEA, 2007
AAPM Report 54, 1995

Dr. Lars Leksell (1951)

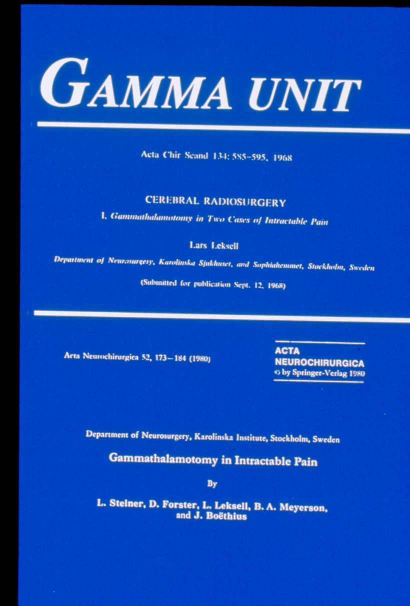




Using 200 kV x-rays

Radiocirugía: concepto de ablación de una lesión mediante radiación en un solo procedimiento, como la cirugía.

1968: Leksell Gamma Knife



GAMMA UNIT

Acta Chir Scand 134: 585–595, 1968

CEREBRAL RADIOSURGERY

I. *Gammathalamotomy in Two Cases of Intractable Pain*

Lars Leksell

Department of Neurosurgery, Karolinska Sjukhuset, and Sophiahemmet, Stockholm, Sweden

(Submitted for publication Sept. 12, 1968)

Acta Neurochirurgica 52, 173–184 (1980)

ACTA NEUROCHIRURGICA
© by Springer-Verlag 1980

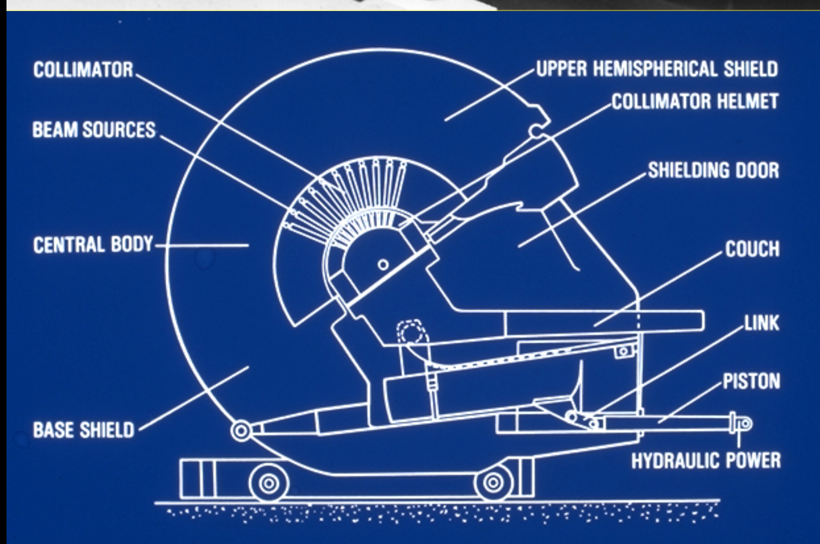
Department of Neurosurgery, Karolinska Institute, Stockholm, Sweden

Gammathalamotomy in Intractable Pain

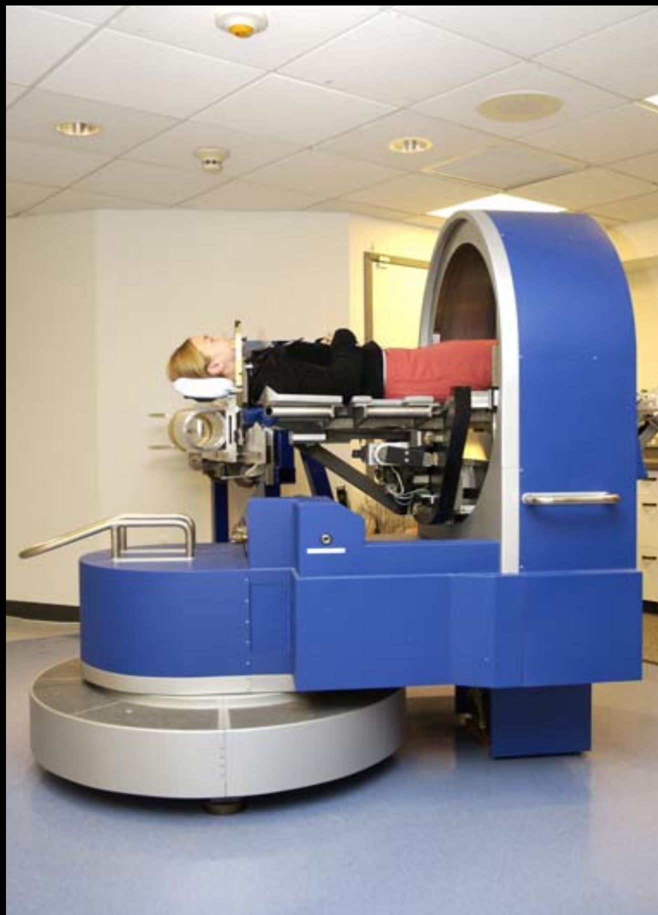
By

L. Steiner, D. Forster, L. Leksell, B. A. Meyerson, and J. Boëthius

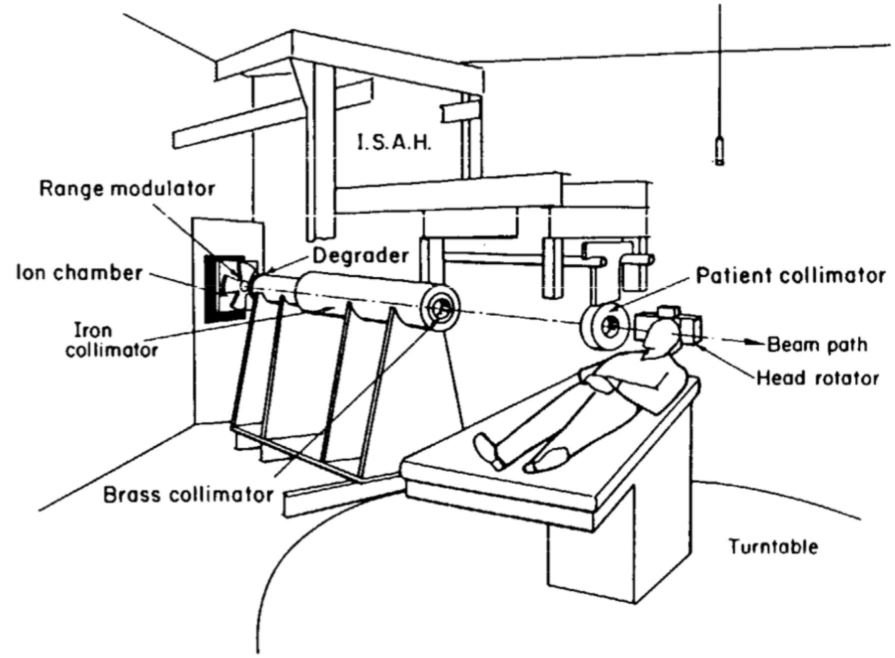
201 cobalt-60 sources
4 helmet sizes
dedicated operation

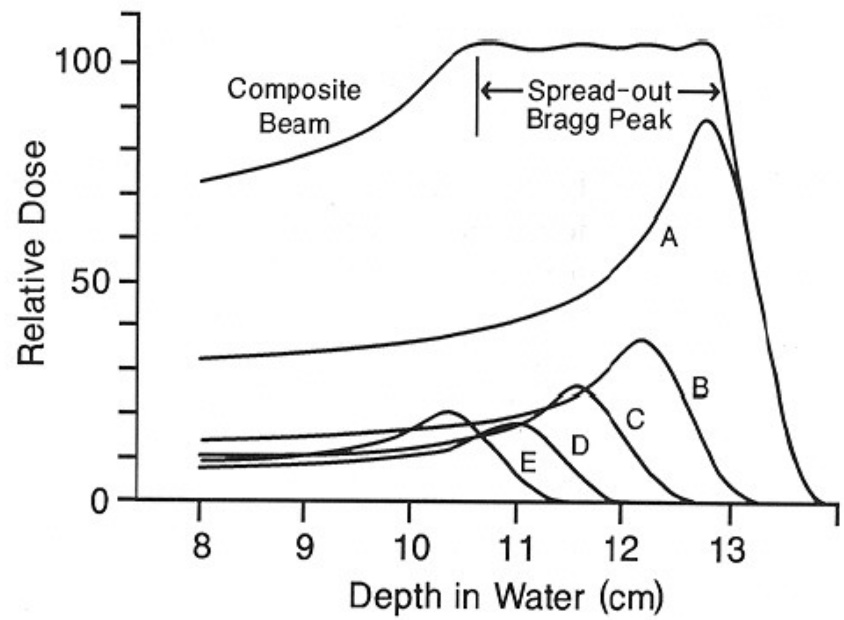


1960's: Proton beams



- 1958: B. Larsson, L. Leksell; Stockholm
- 1962: J.H. Lawrence; Berkeley, CA
- 1968: R.N. Kjellberg; Boston, MA





1980’s - Linac based SRS

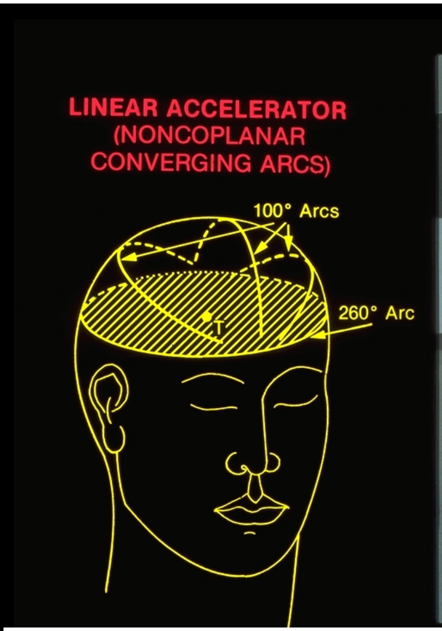
1974: Proposed by B. Larsson; Stockholm
1984: Betti and Derechinsky; Buenos Aires
1985: Colombo, Benedetti et al.; Vicenza, Italy
1985: Hartmann, Schlegel et al.; Heidelberg, Germany
1986: Podgorsak, Souhami et al.; Montreal, Canada
1988: Lutz, Winston et al.; Boston, MA

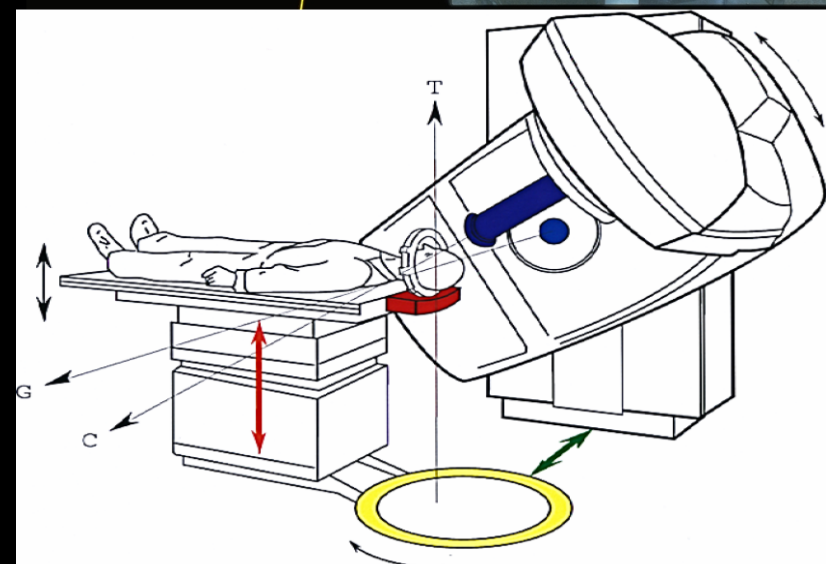
isocentros simples o múltiples

Varios arcos para cada isocentro

- conos (a 4 cm)
- rotación gantry 100-260°
- mesa fija para cada arco

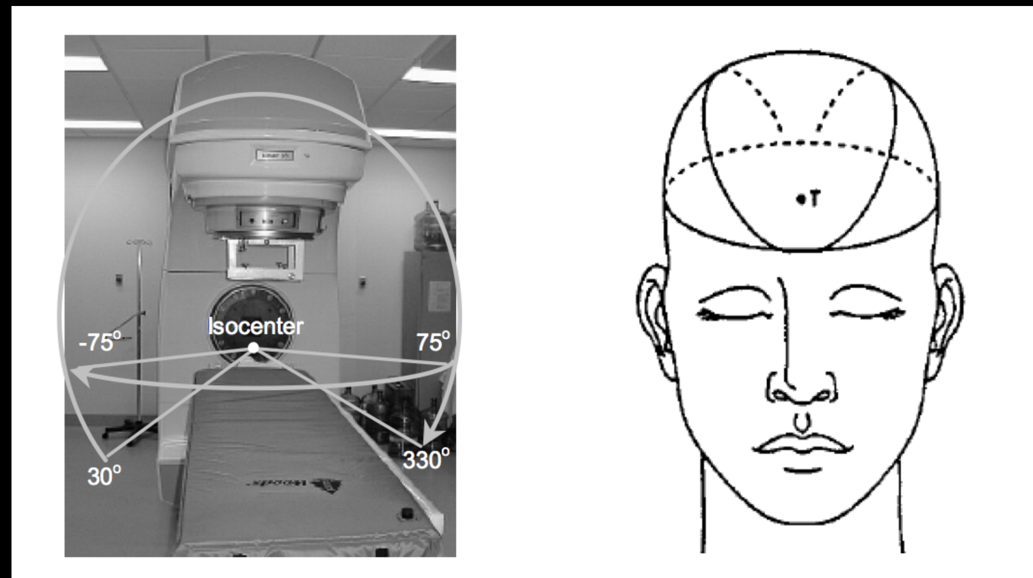
- distribuciones de dosis esféricas

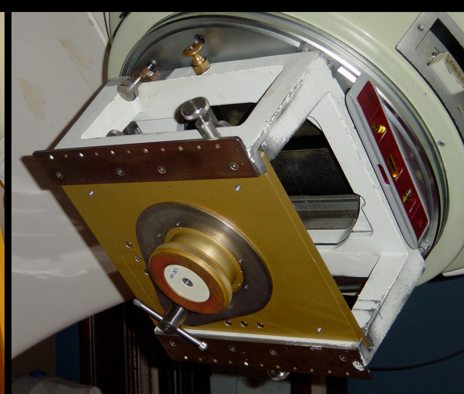


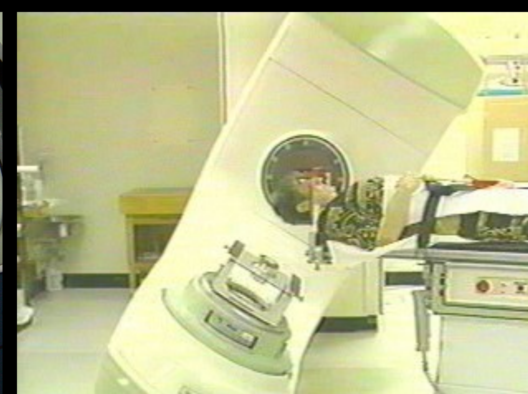


1986: Dynamic rotation SRS (McGill)

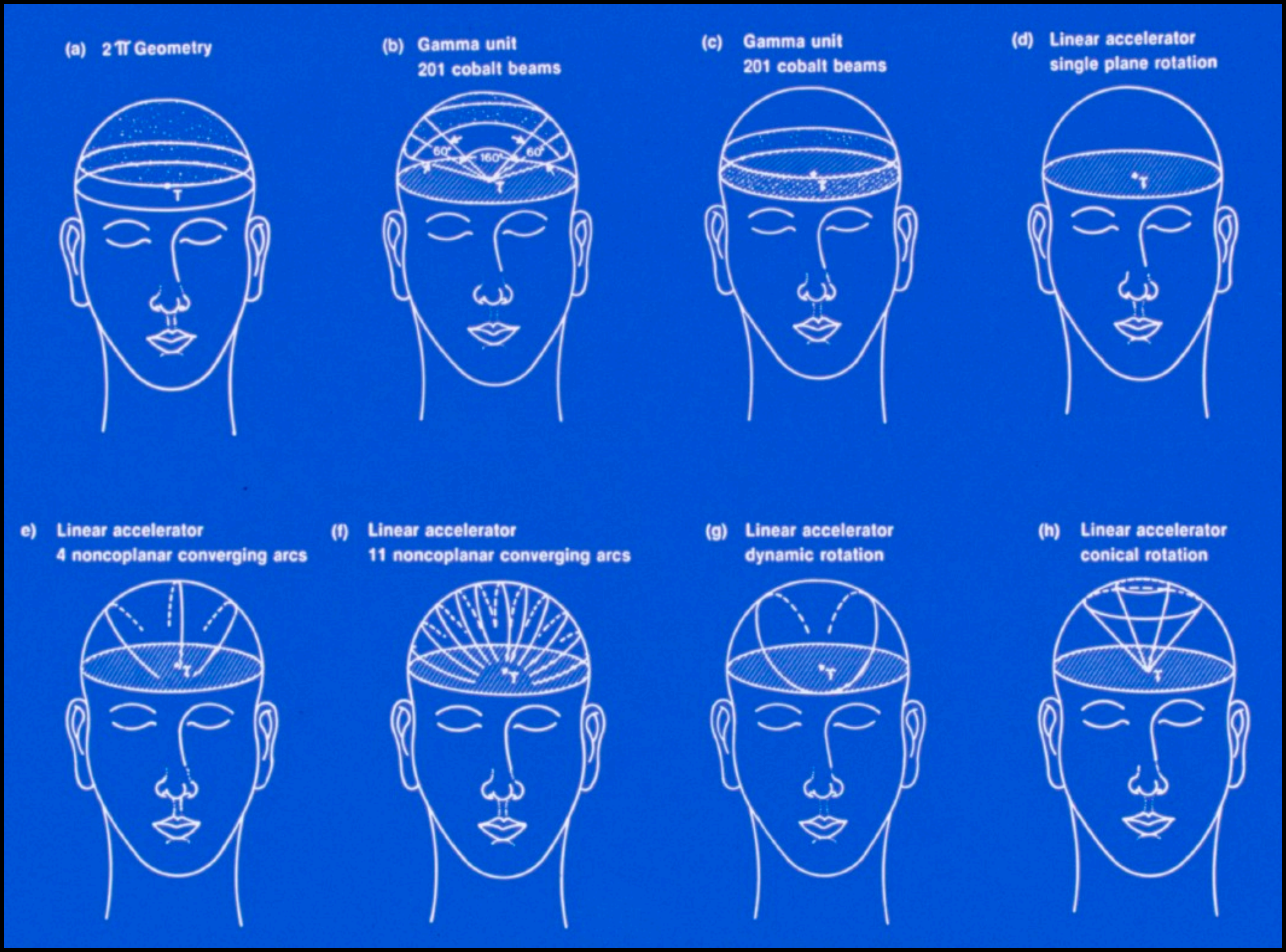
- isocentros simples o múltiples
- arco único no coplanario
- conos (0.5-4 cm)
- rotación del gantry (300 grados)
- rotación simultánea de la camilla (150 grados)
- distribución esférica de dosis
- tiempo de tratamiento de 15 minutos a 2 horas







Geometrias SRS



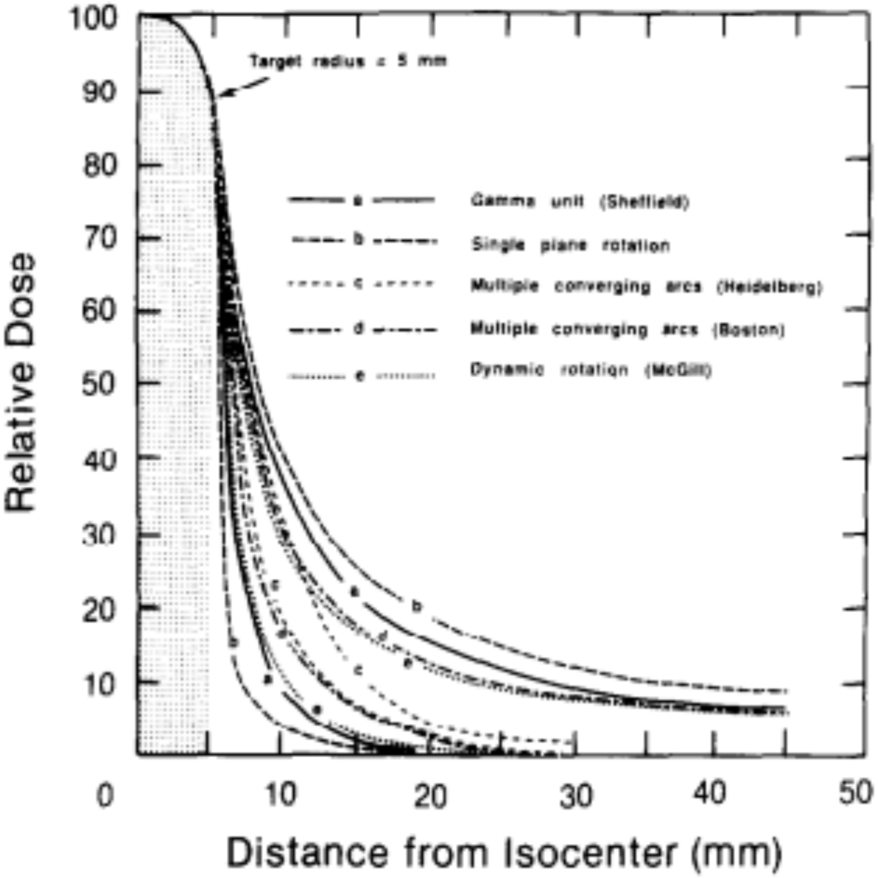
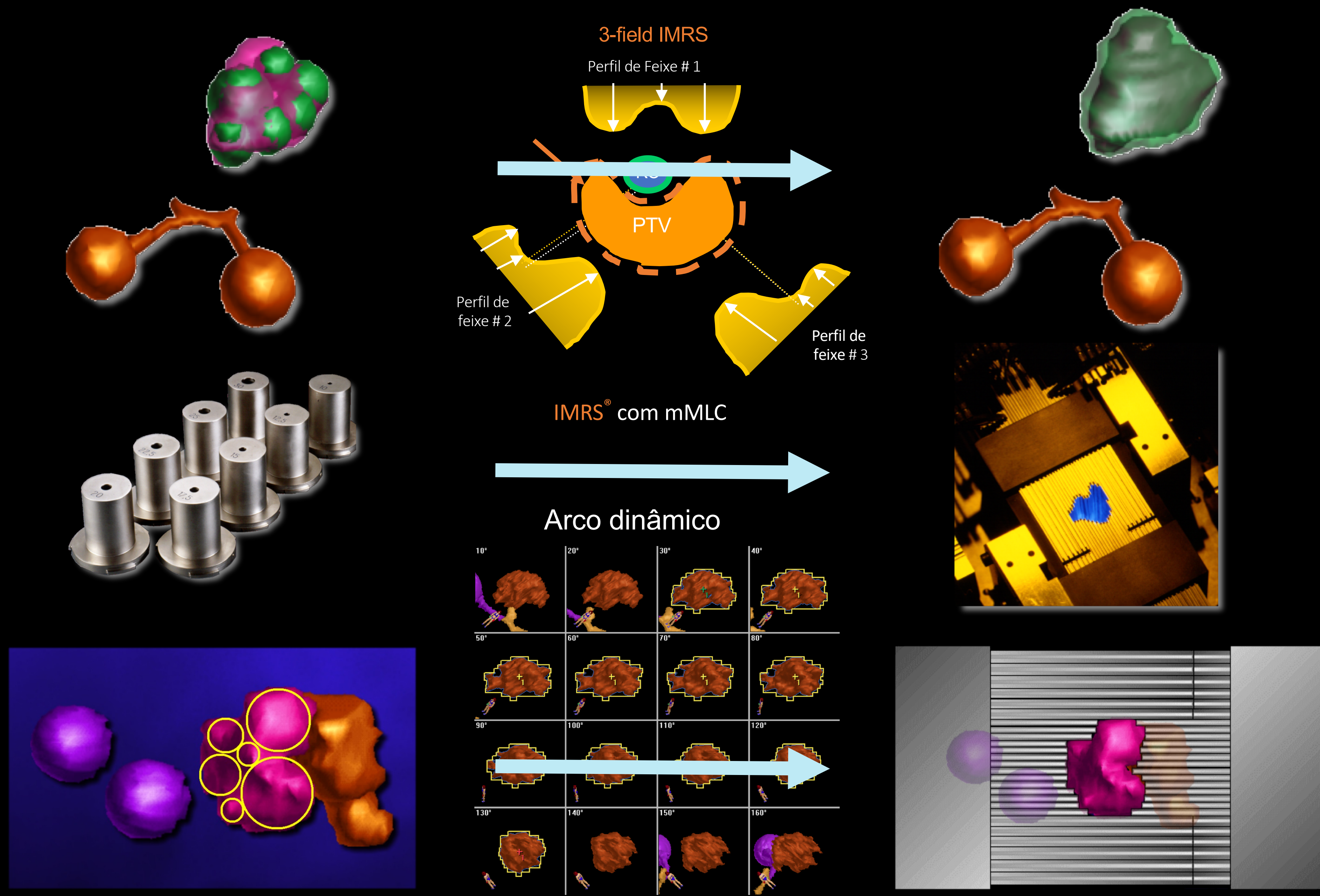


Table 1. Steepest dose fall-offs outside the target volume for various radiosurgical techniques

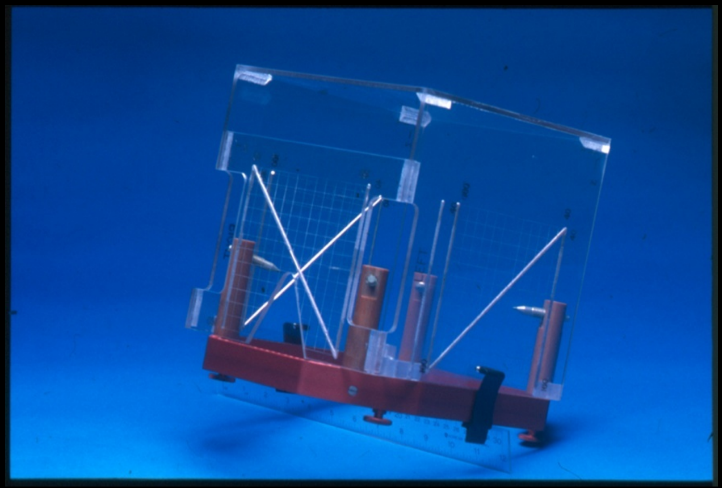
Radiosurgical technique	Distance in mm for dose to fall from		
	90% to 50%	90% to 20%	90% to 10%
Sheffield Gamma unit (22)	2.0	3.5	5.0
Single plane rotation	2.0	2.5	3.0
Multiple converging arcs (Heidelberg)	2.3	4.6	7.3
Multiple converging arcs (Boston)	2.1	4.0	7.6
Dynamic rotation (McGill)	2.0	3.8	5.0

Note: The 90% isodose surface coincides with the spherical target volume with a diameter of 1 cm. The dose fall-offs for the Gamma unit were obtained from Walton *et al.* (22), for the 10 MV linear accelerator techniques they were calculated with the algorithm of Pike *et al.* (19).

Evolución SRS (1990-2000)



Evolución SRS(2000+)

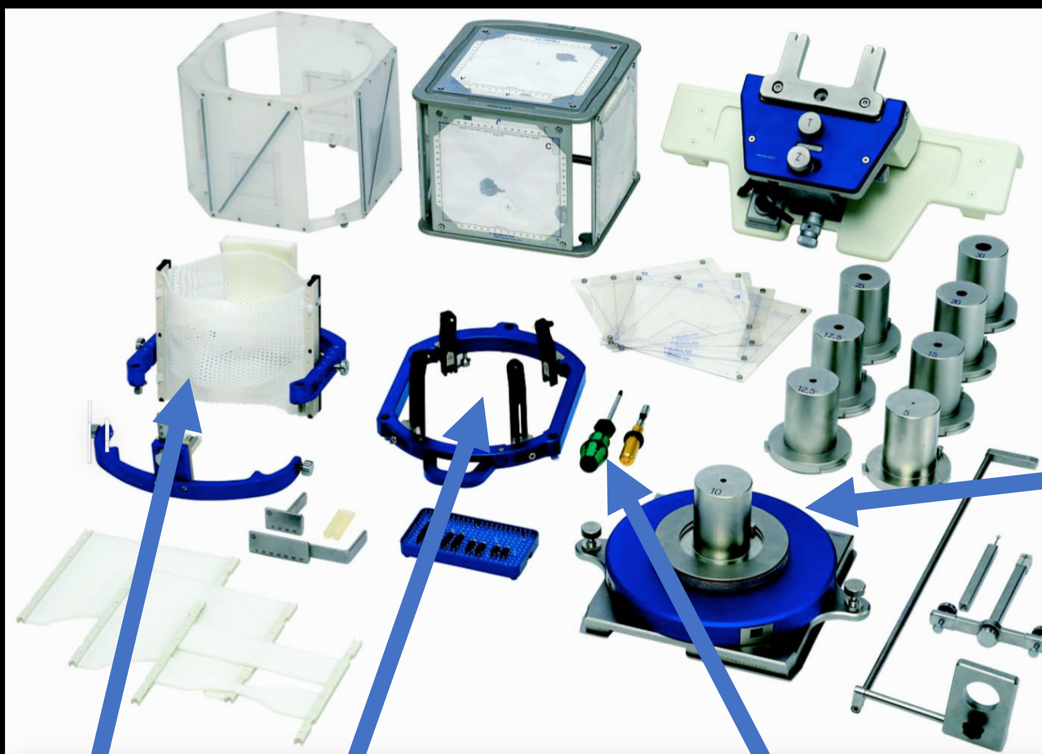


Equipo para SRS – accelerador

CT localizer

localizer box

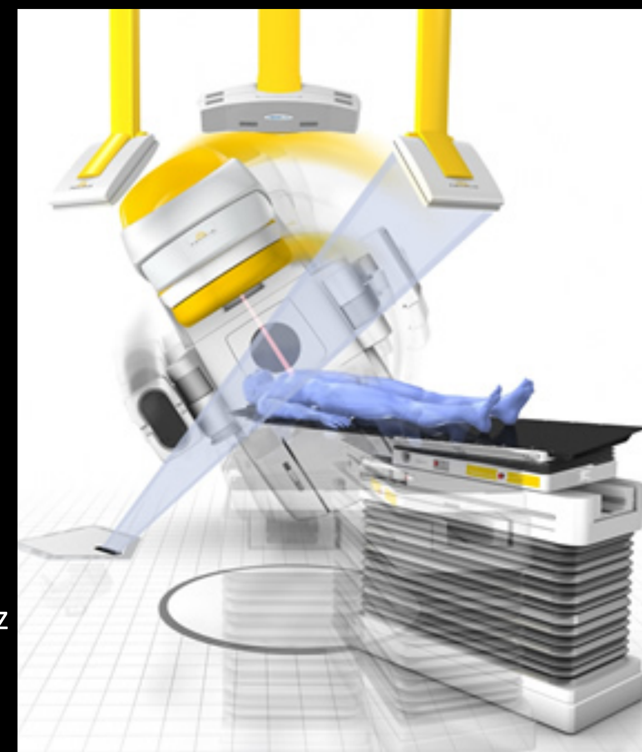
Couch adapter



Cones

Cone attachment

Winston-Lutz tool



Mask and frame

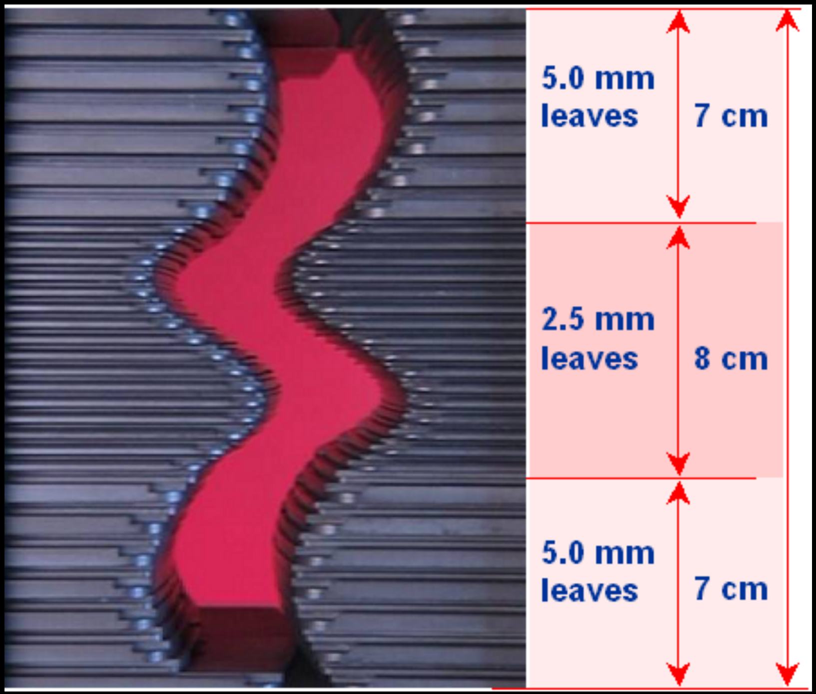
Pins and frame

Screwdrivers

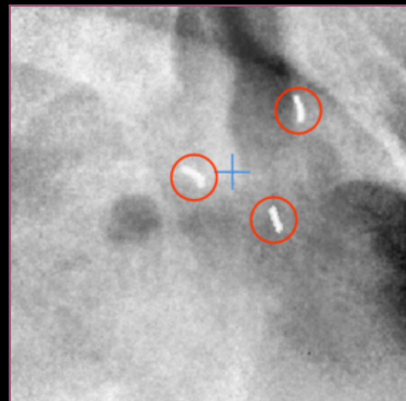
Linac – sistemas de colimación SRS

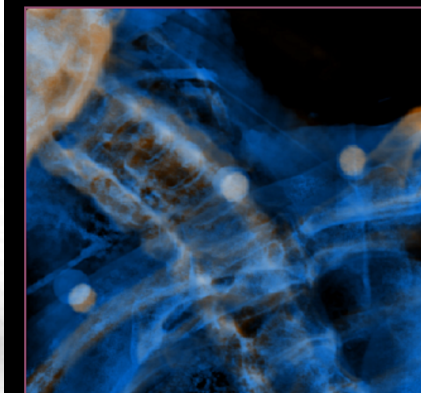
Stereo cones 4 mm- 40 mm

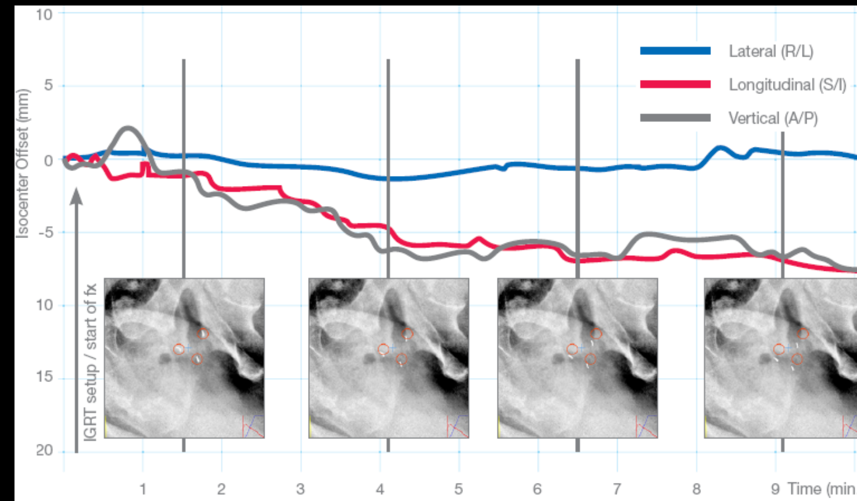
High definition collimator Varian HD120



IGRS? Image guided radiosurgery

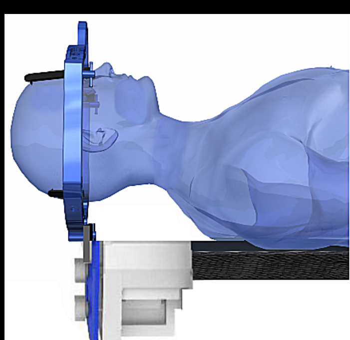


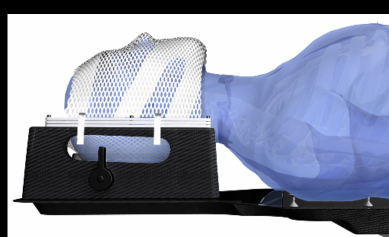




Imágenes antes y durante et tratamiento

“frame” o cuadro remplazado por imágenes y mascara thermoplastica

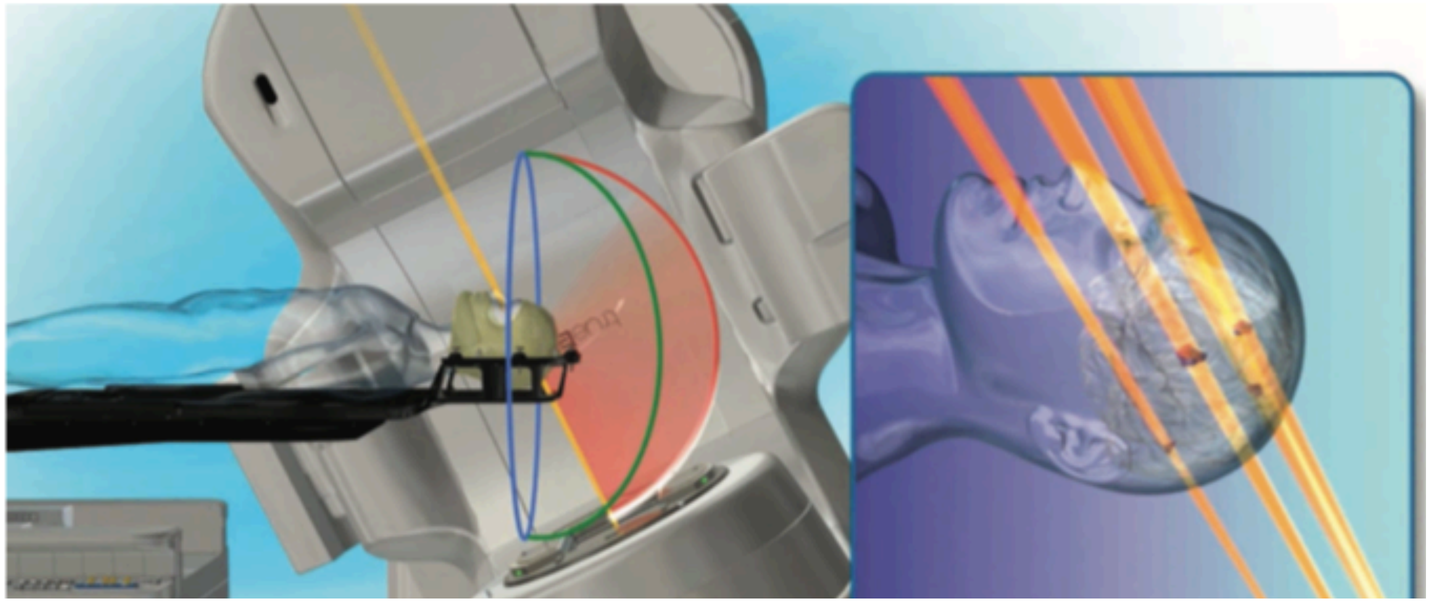


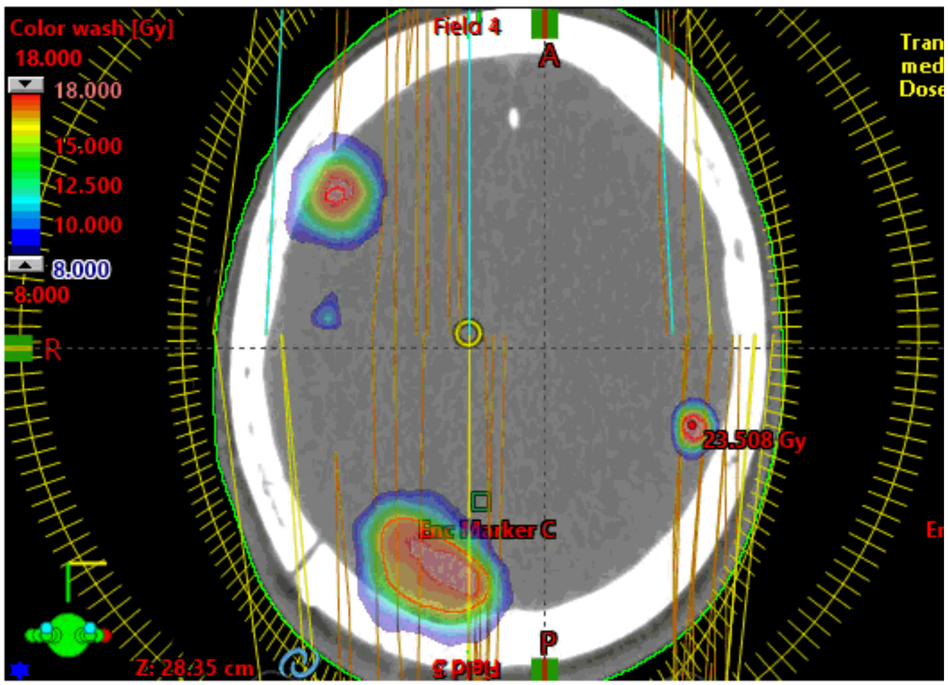


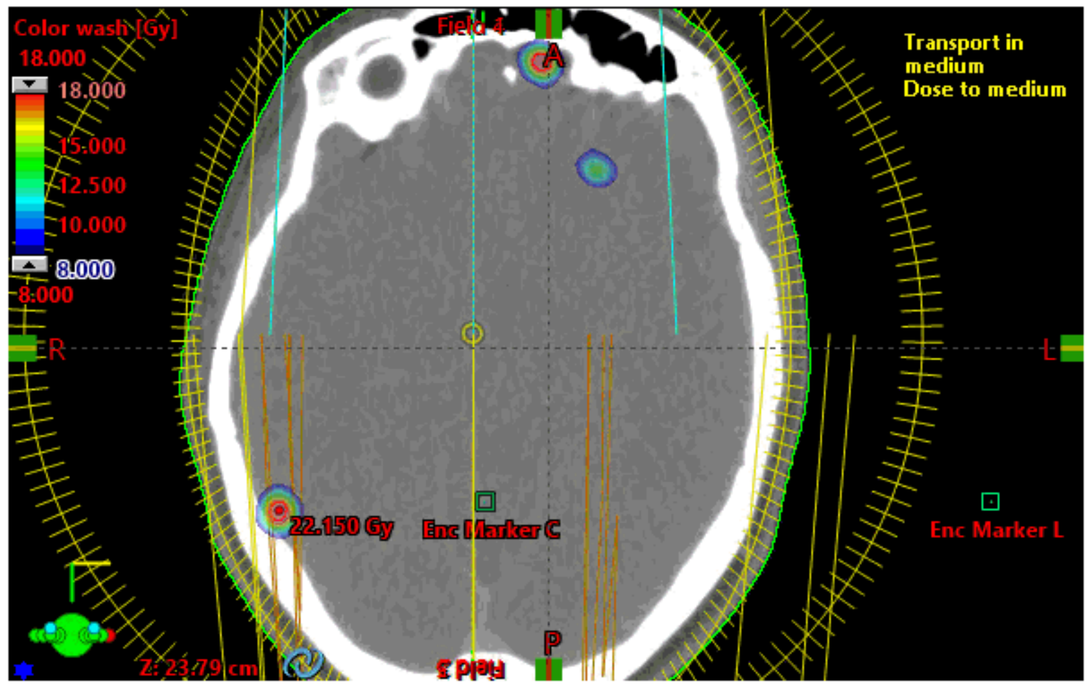
SRS y
VMAT

HyperArc high-definition radiotherapy

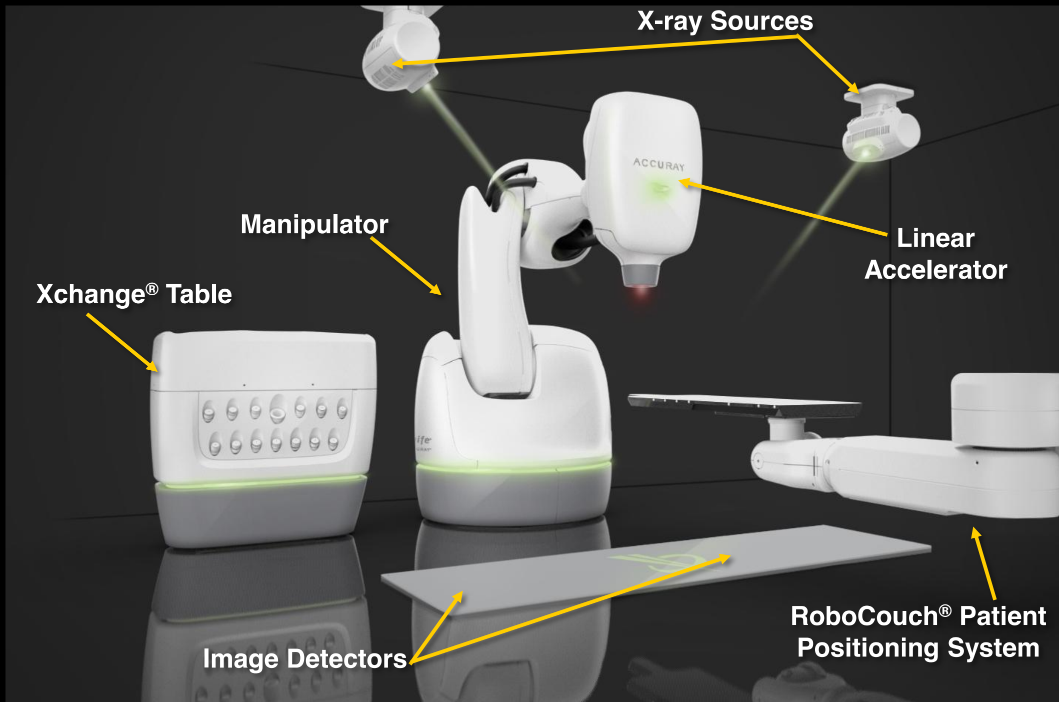
Deliver high-precision SRS

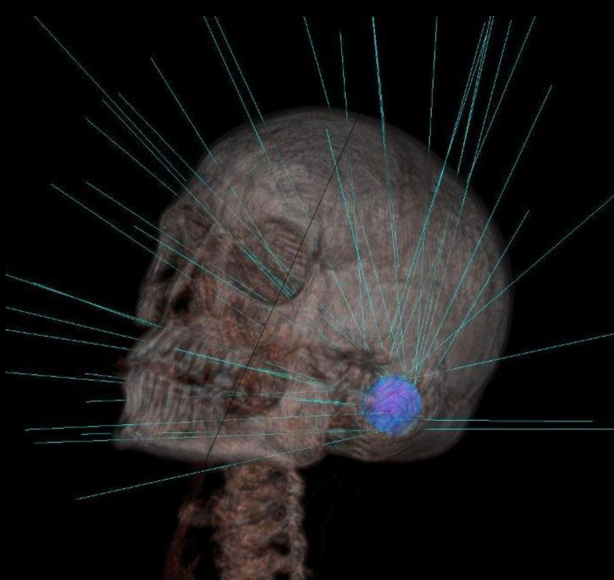


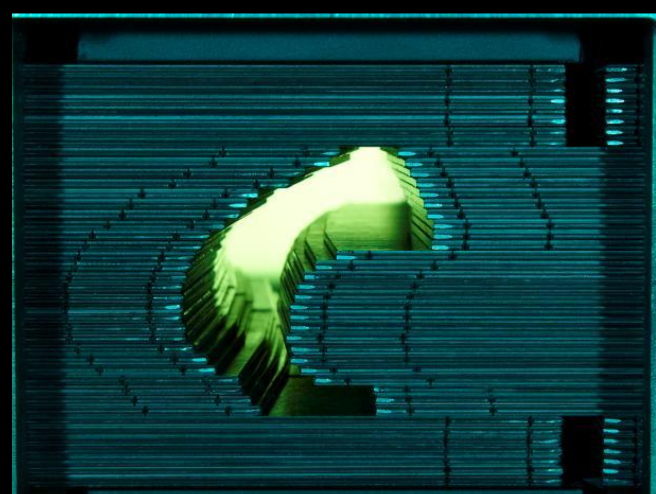


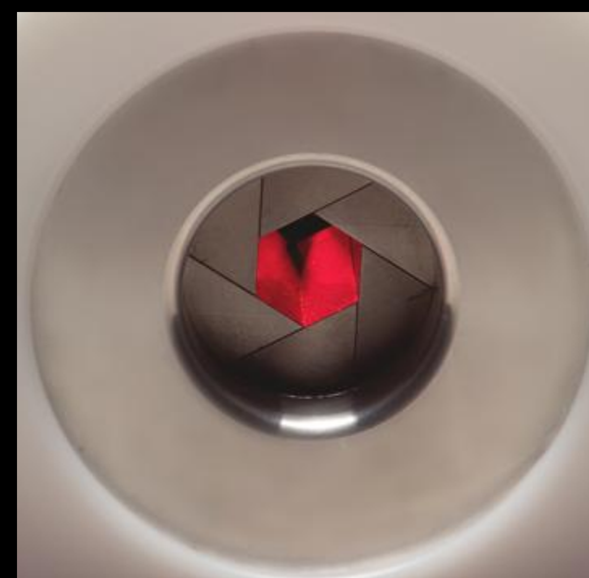


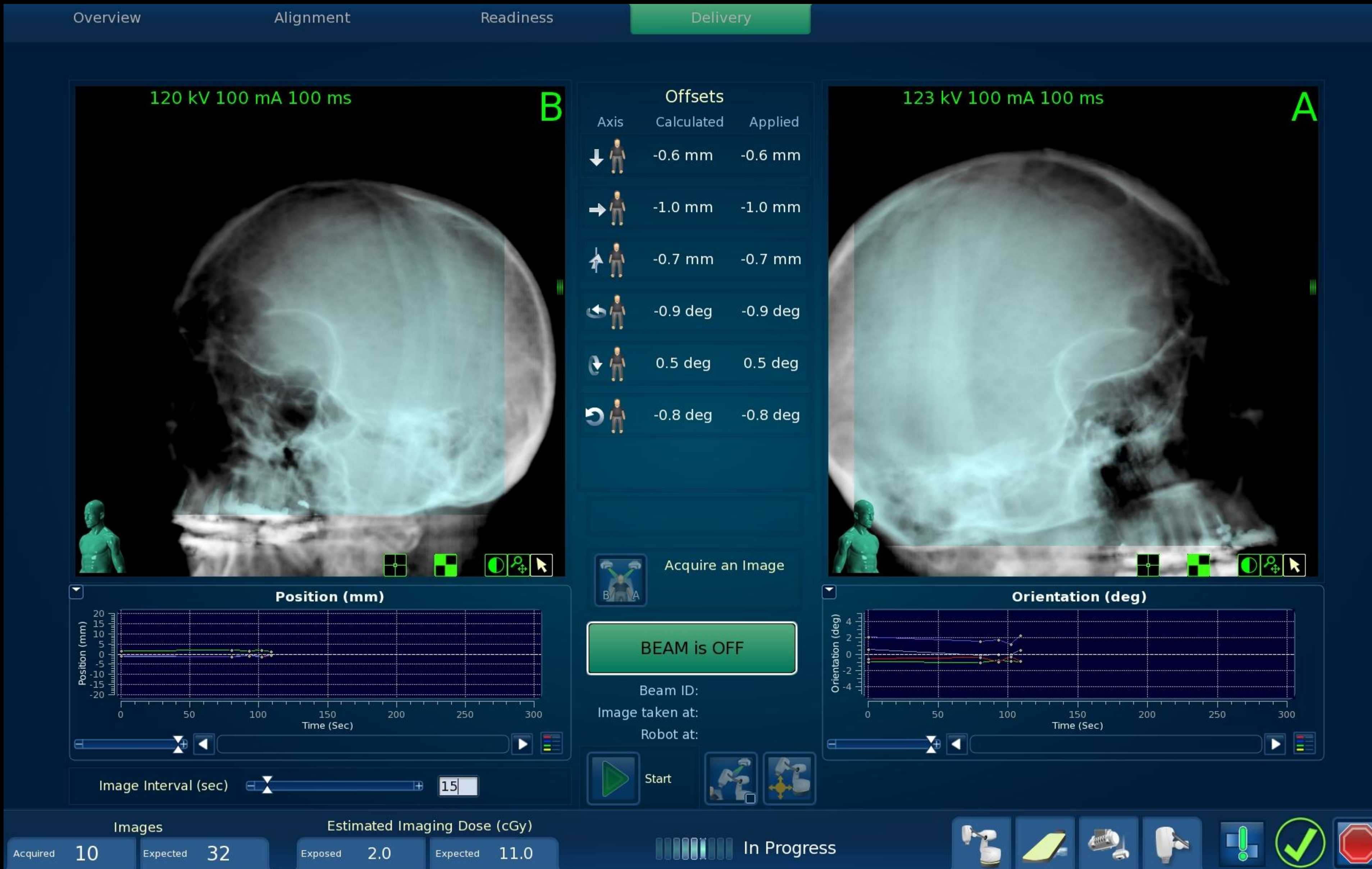
Robot - Cyberknife



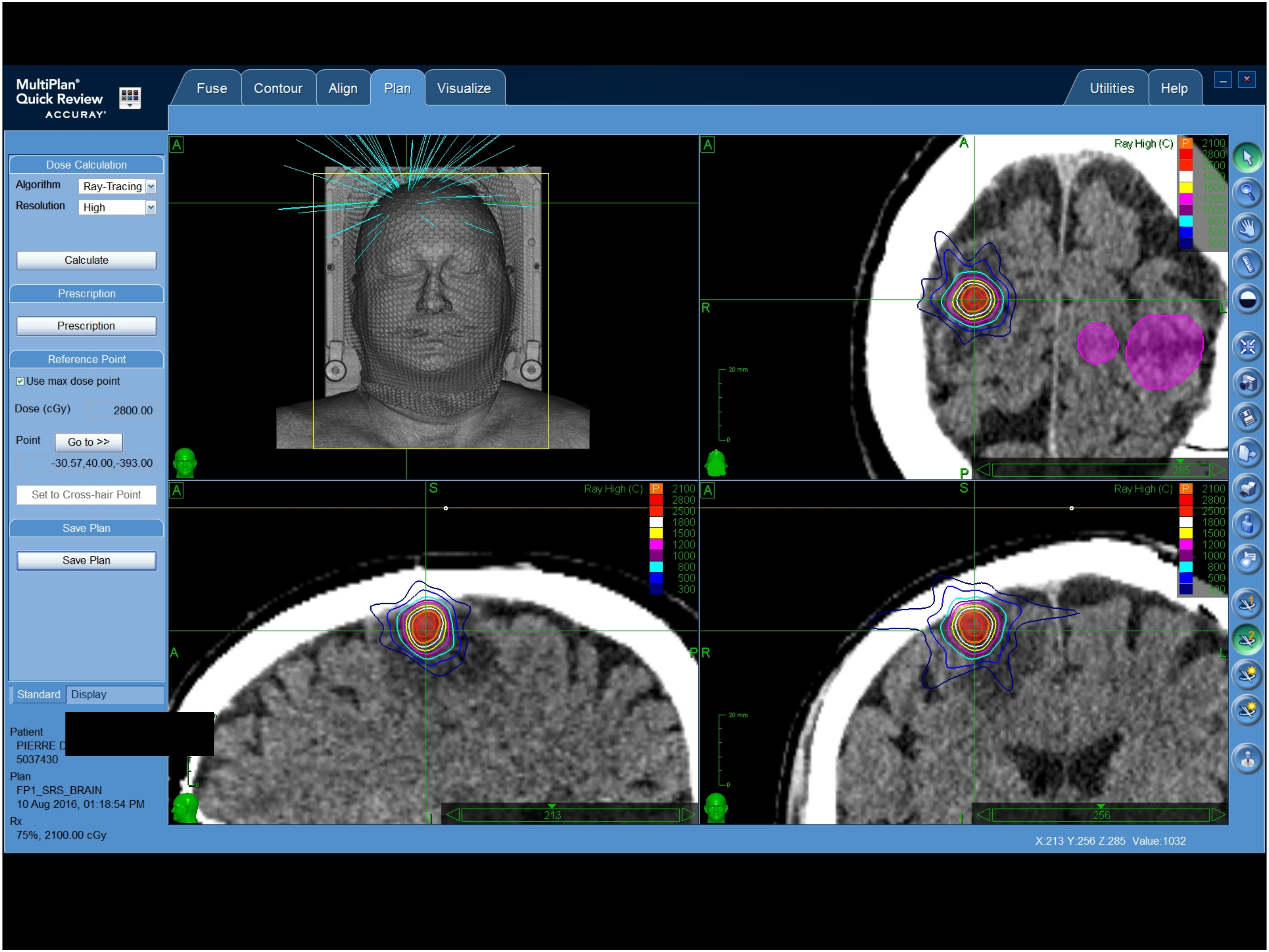


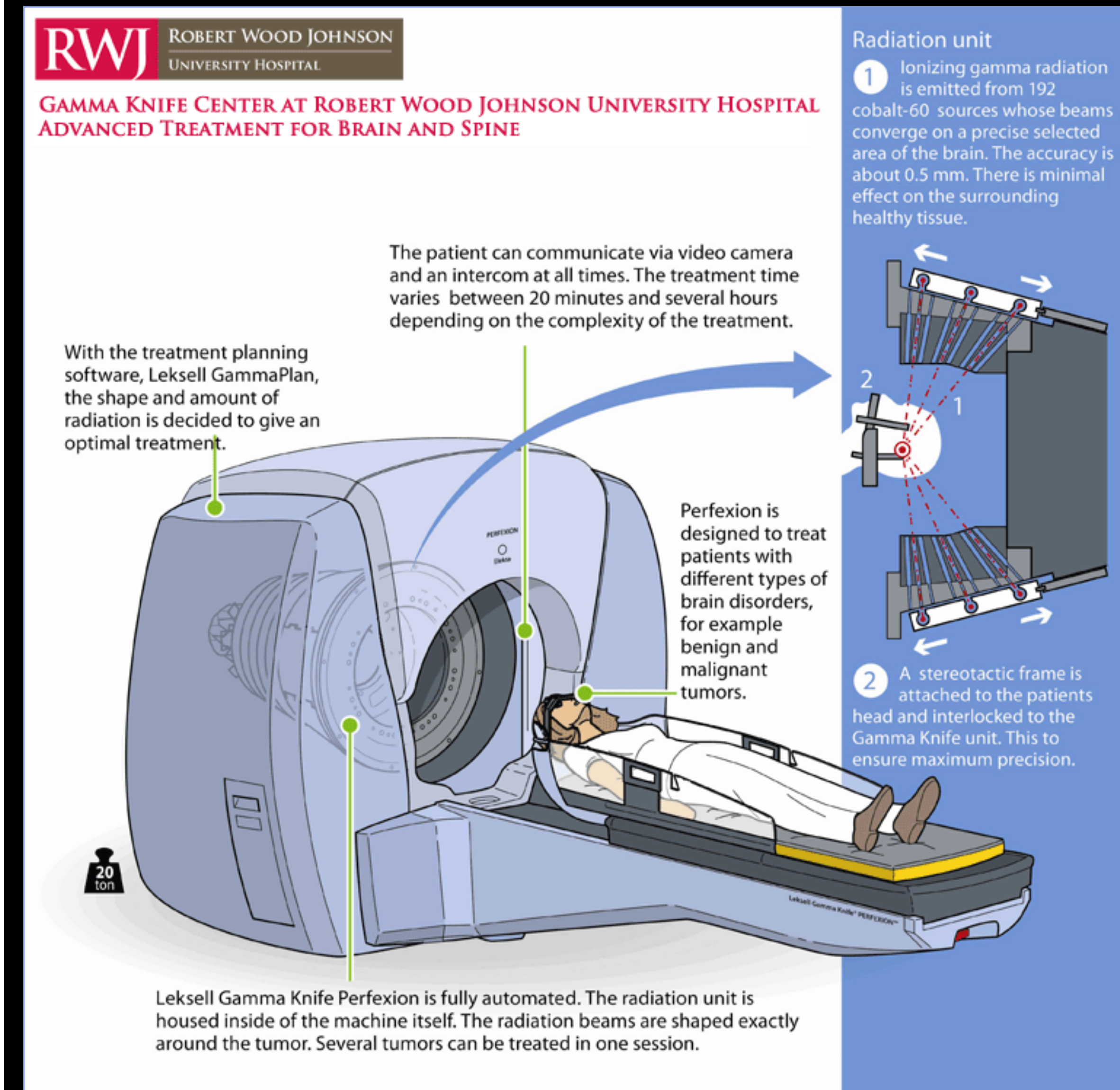
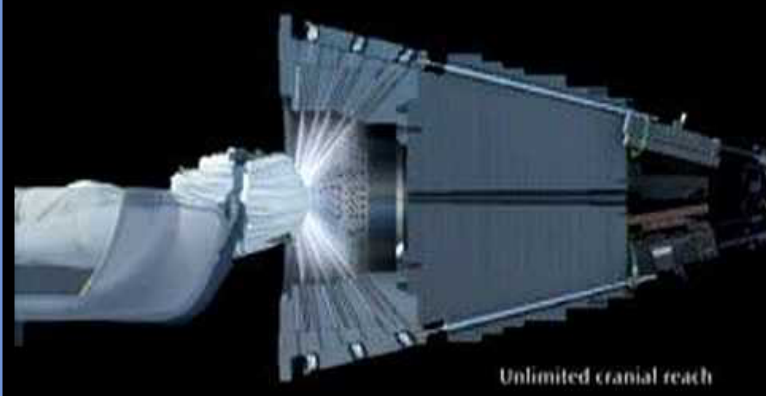
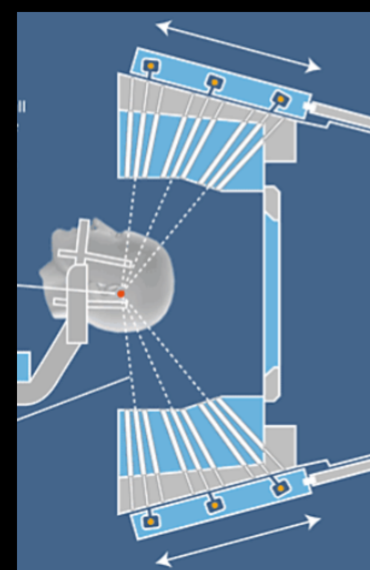


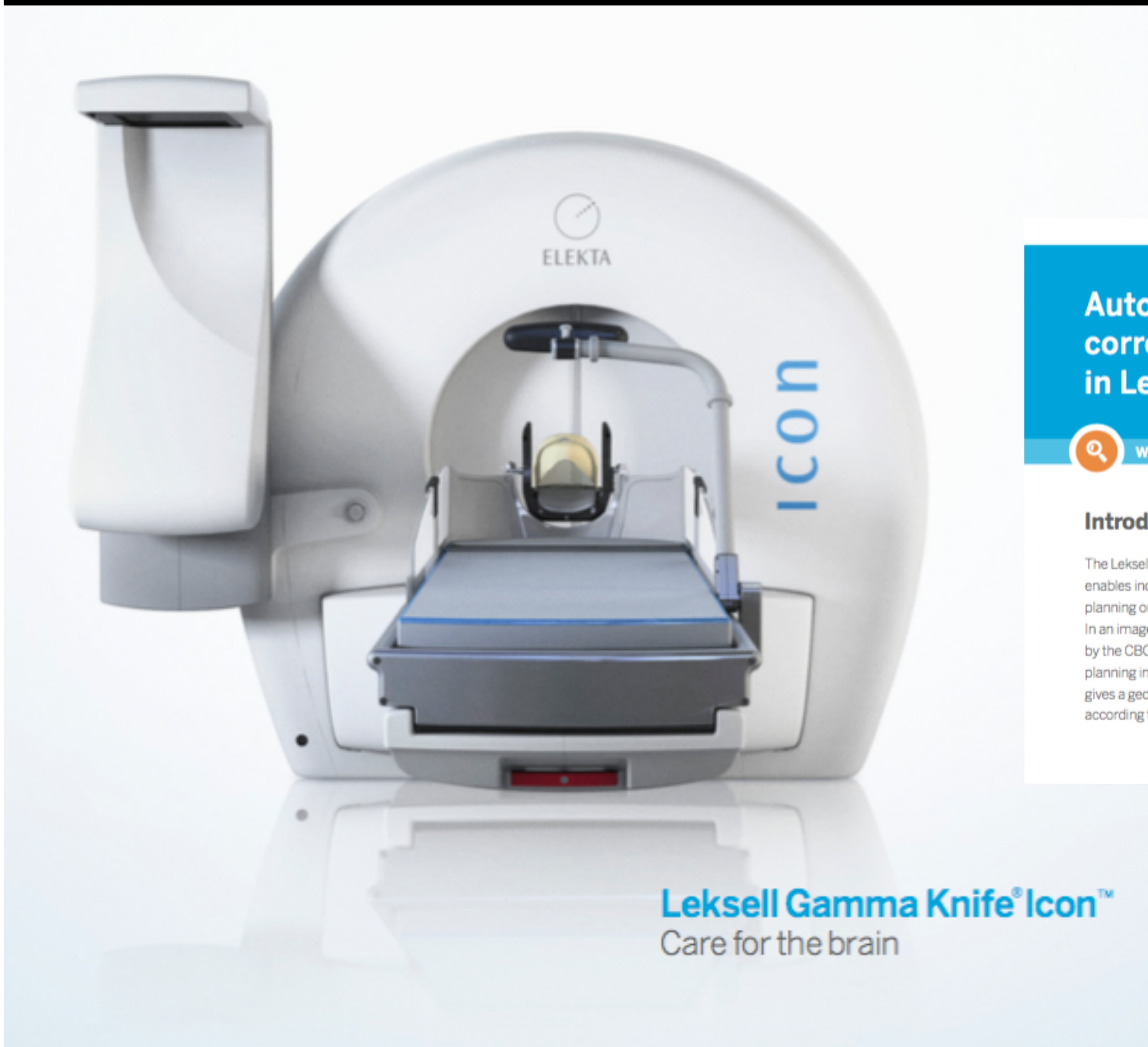


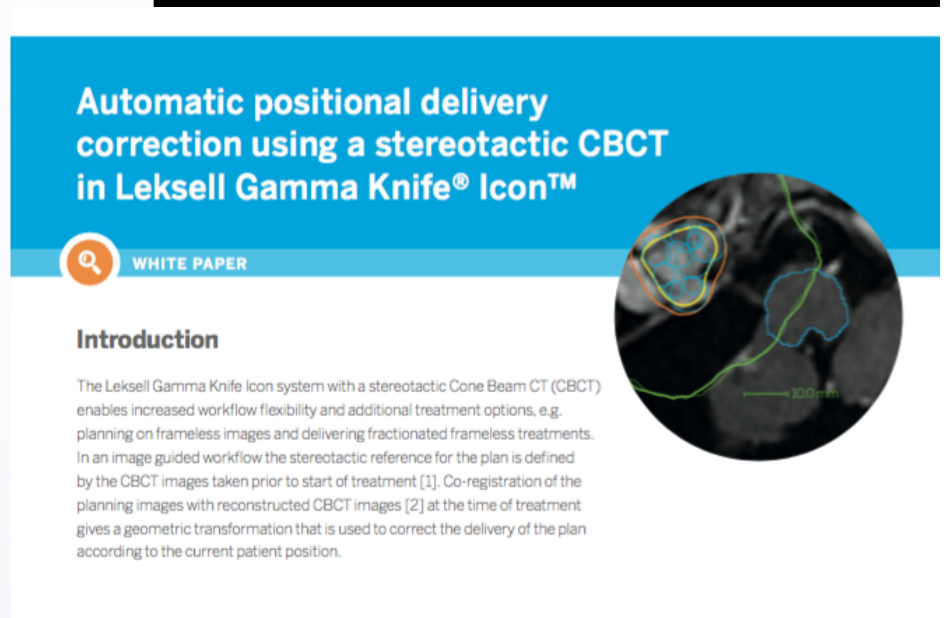


Overview
Alignment
Readiness
Delivery
120 kV 100 mA 100 ms
B
Offsets
Axis
Calculated
Applied
-0.6 mm
-0.6 mm
-1.0 mm
-1.0 mm
-0.7 mm
-0.7 mm
-0.9 deg
-0.9 deg
0.5 deg
0.5 deg
-0.8 deg
-0.8 deg
123 kV 100 mA 100 ms
A
Acquire an Image
Position (mm)
Position (mm)
Time (Sec)
Orientation (deg)
Orientation (deg)
Time (Sec)
BEAM is OFF
Beam ID:
Image taken at:
Robot at:
Start
Image Interval (sec)
15
Images
Acquired
10
Expected
32
Estimated Imaging Dose (cGy)
Exposed
2.0
Expected
11.0
In Progress


MultiPlan® Quick Review
ACCURAY
Fuse
Contour
Align
Plan
Visualize
Utilities
Help
Dose Calculation
Algorithm Ray-Tracing
Resolution High
Calculate
Prescription
Prescription
Reference Point
Use max dose point
Dose (cGy) 2800.00
Point Go to >>
-30.57,40.00,-393.00
Set to Cross-hair Point
Save Plan
Save Plan
Standard Display
Patient
PIERRE [redacted]
5037430
Plan
FP1_SRS_BRAIN
10 Aug 2016, 01:18:54 PM
Rx
75%, 2100.00 cGy
Ray High (C)
P 2100 2800 2500 1800 1500 1200 1000 800 500 300
20 mm
213
256
285
X:213 Y:256 Z:285 Value:1032


RWJ Robert Wood Johnson University Hospital
Gamma Knife Center at Robert Wood Johnson University Hospital
Advanced Treatment for Brain and Spine
Radiation unit
1 Ionizing gamma radiation is emitted from 192 cobalt-60 sources whose beams converge on a precise selected area of the brain. The accuracy is about 0.5 mm. There is minimal effect on the surrounding healthy tissue.
2 A stereotactic frame is attached to the patients head and interlocked to the Gamma Knife unit. This to ensure maximum precision.
The patient can communicate via video camera and an intercom at all times. The treatment time varies between 20 minutes and several hours depending on the complexity of the treatment.
With the treatment planning software, Leksell GammaPlan, the shape and amount of radiation is decided to give an optimal treatment.
Perfexion is designed to treat patients with different types of brain disorders, for example benign and malignant tumors.
20 ton
Leksell Gamma Knife Perfexion is fully automated. The radiation unit is housed inside of the machine itself. The radiation beams are shaped exactly around the tumor. Several tumors can be treated in one session.

Unlimited cranial reach






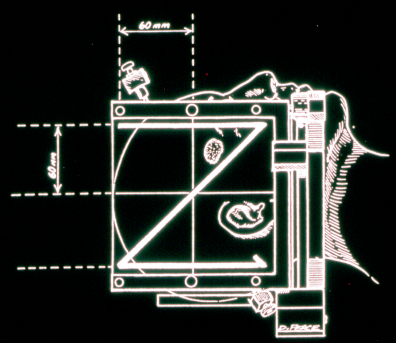
Automatic positional delivery correction using a stereotactic CBCT in Leksell Gamma Knife® Icon™

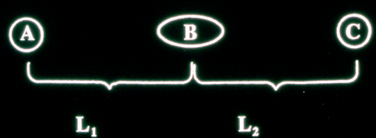
WHITE PAPER

Introduction

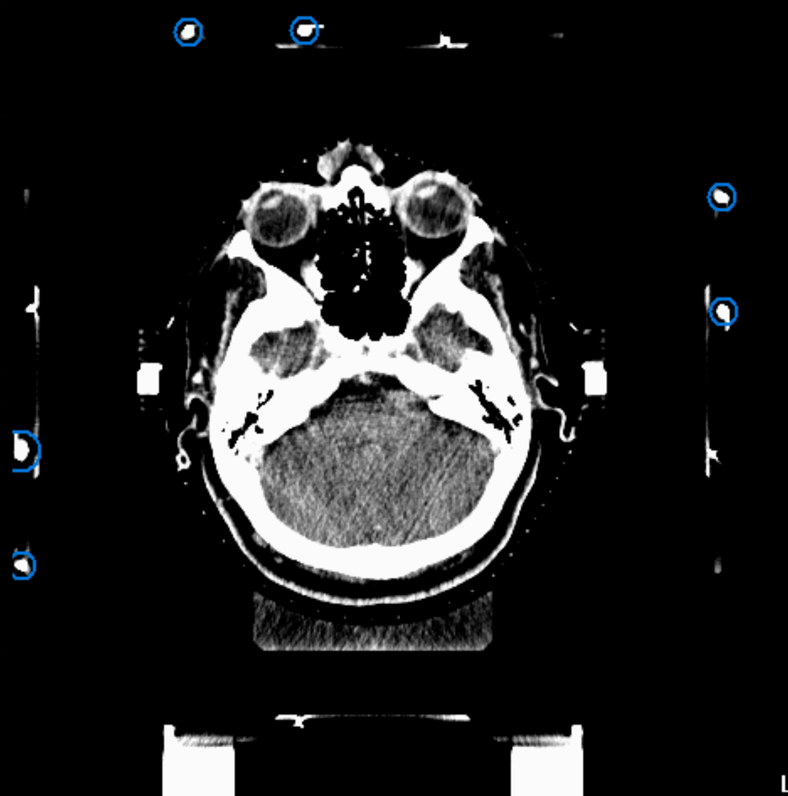
The Leksell Gamma Knife Icon system with a stereotactic Cone Beam CT (CBCT) enables increased workflow flexibility and additional treatment options, e.g. planning on frameless images and delivering fractionated frameless treatments. In an image guided workflow the stereotactic reference for the plan is defined by the CBCT images taken prior to start of treatment [1]. Co-registration of the planning images with reconstructed CBCT images [2] at the time of treatment gives a geometric transformation that is used to correct the delivery of the plan according to the current patient position.

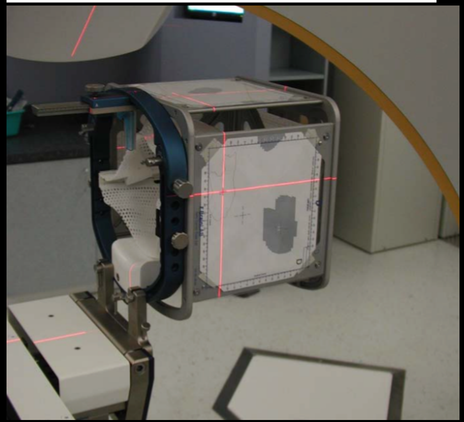
Localización



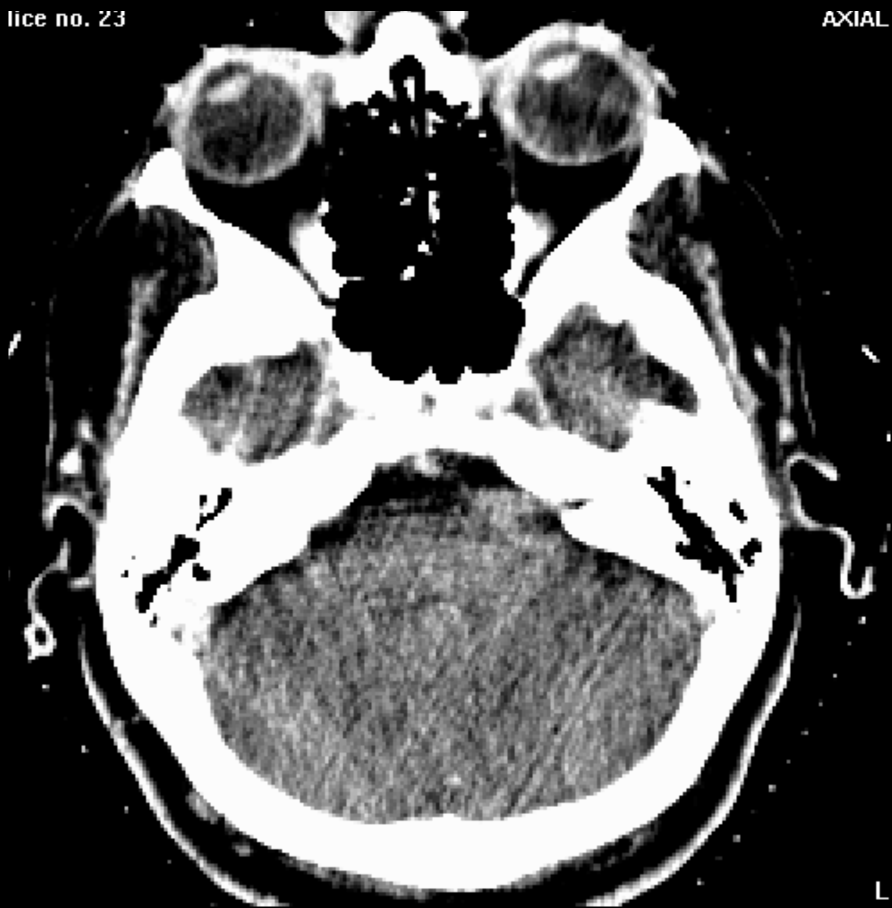


$$Z = BAR * \frac{L2}{L1 + L2}$$





Imagenes de planificacion

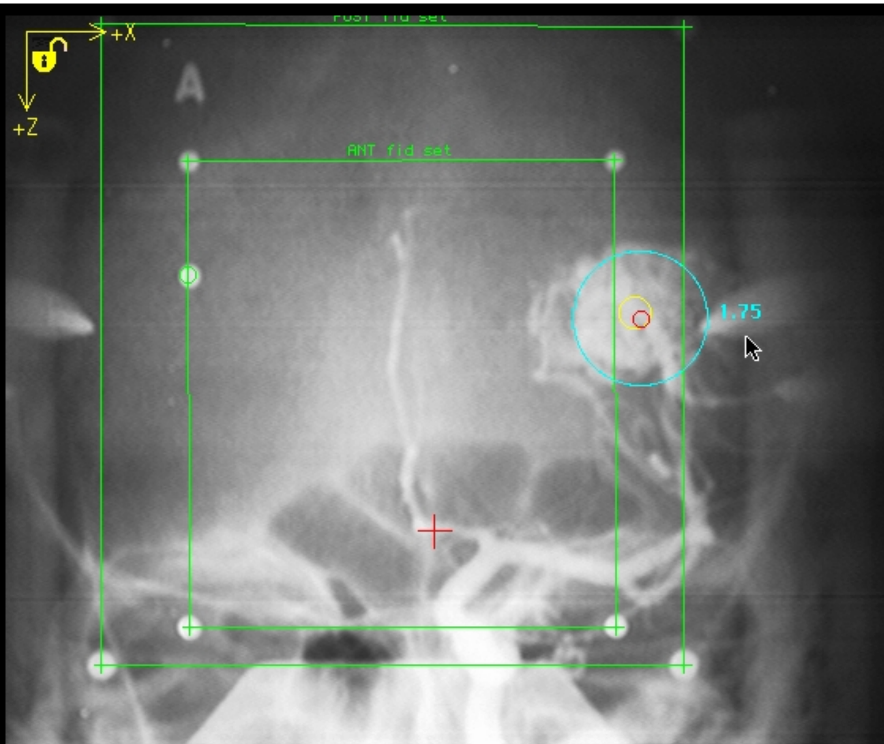


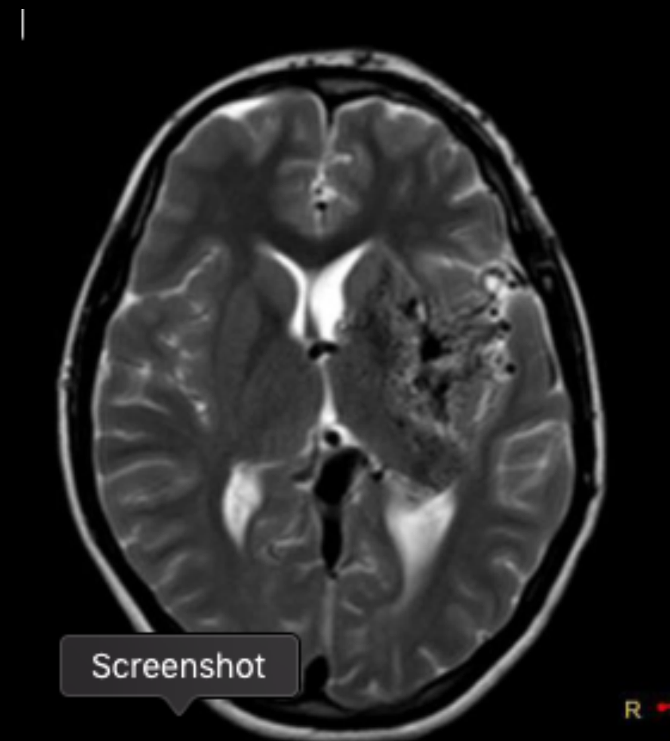
CT

MRI

Localization Method	Average Error In Treatment (mm)
Computed Tomography	1.3 ± 0.6
Plane Film Angiography	0.6 ± 0.2

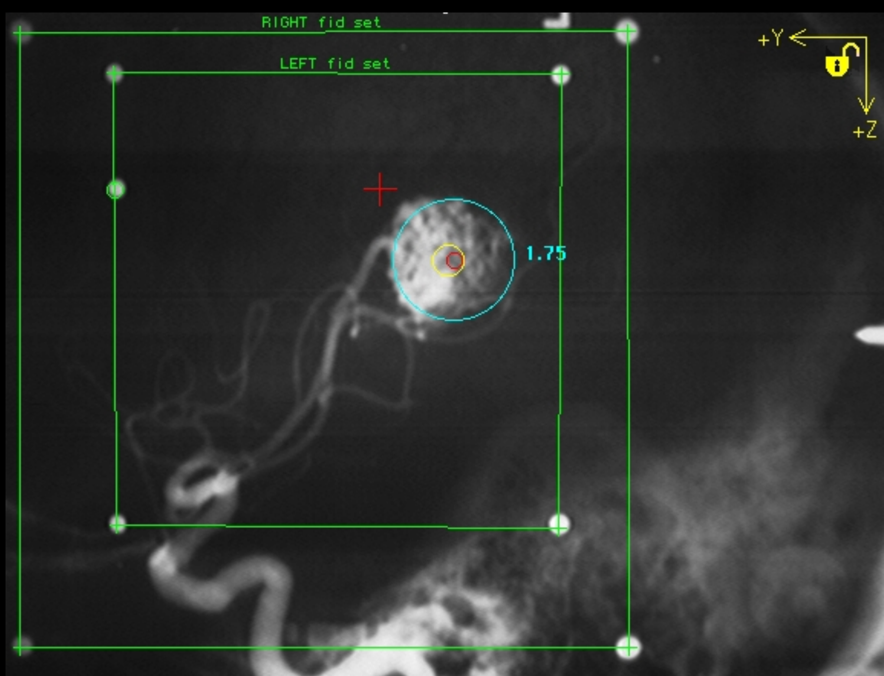
AAPM Report 54, 1995



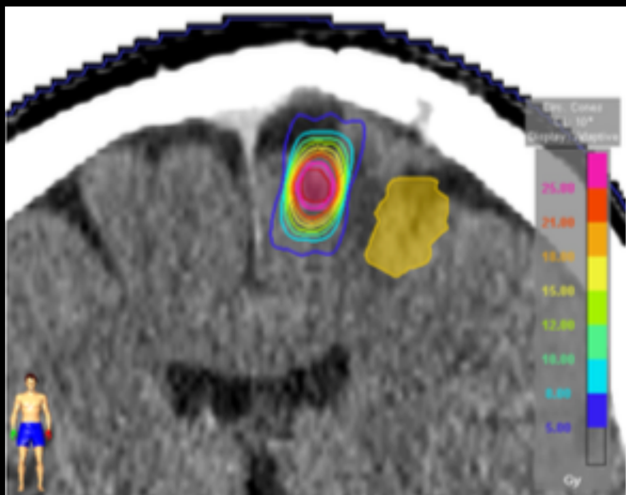


Angiografia

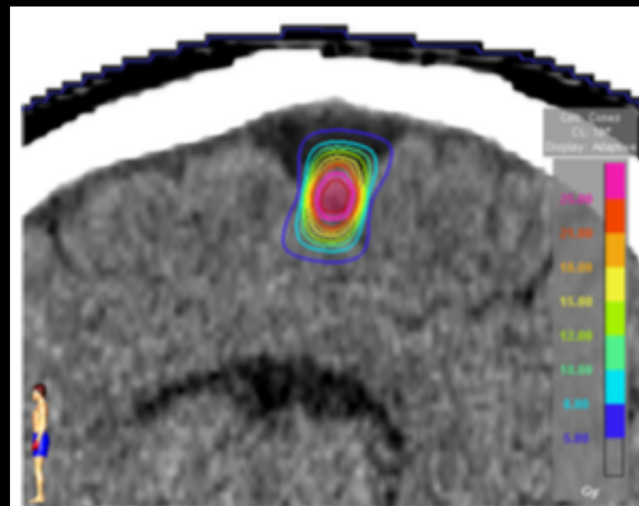
MRI (MRA)



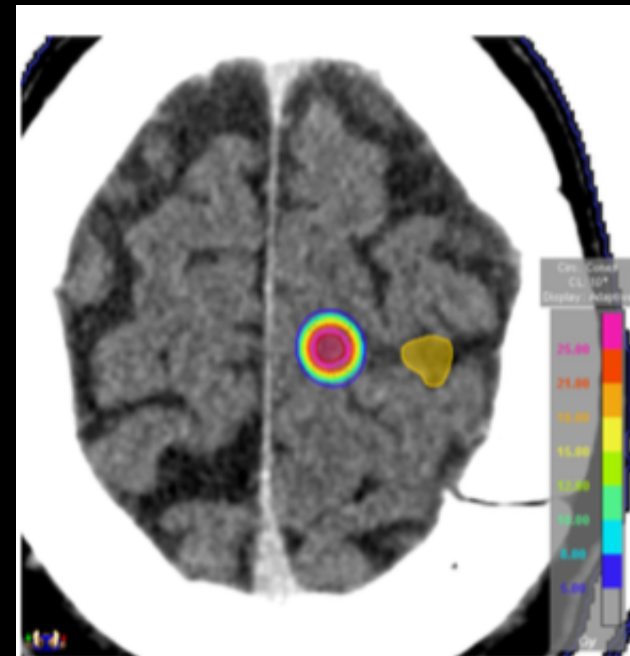
Planificación del tratamiento



Overview Coronal: PTV



Overview Sagittal: PTV



Overview Axial: PTV

Export ID : Name	Table Angle [°]	Gantry Start [°]	Gantry Stop [°]	Rot. Dir.	Coll. Angle [°]	Diam. [mm]	X1 [mm]	X2 [mm]	Y1 [mm]	Y2 [mm]	MU
1 : CARC T65	65.0	50.0	150.0	cw	0.0	10.0	10	10	10	10	888 (1x888.0)
2 : CARC T45	45.0	150.0	50.0	ccw	0.0	10.0	10	10	10	10	912 (1x912.0)
3 : CARC T295	295.0	310.0	210.0	ccw	0.0	10.0	10	10	10	10	905 (1x905.0)
4 : CARC T270	270.0	210.0	310.0	cw	0.0	10.0	10	10	10	10	886 (1x886.0)

PTV en Radiocirurgia?

- **CTV = GTV ? (OK…?)**
- **PTV = CTV ????**
- **Radiocirugía nació antes que el PTV!!!!**
- Práctica tradicional con cuadro
  - AAPM Report 54:
    - Incertitud intracraniana de 2-4 mm globalmente
  - Siempre hay incertezas
  - No se utiliza PTV

Isocenter accuracy: ± **0.5 mm**

Stereotactic target localization accuracy: ± **0.8 mm**

Stereotactic target irradiation accuracy: ± **0.2 mm**

Overall accuracy: $\sqrt{0.5^2 + 0.8^2 + 0.2^2}$ mm = ± 1.0 mm

Consideraciones en SRS

- Conocemos bien las incertitudes en SRS? O de la localización de el GTV?
- Caída de dosis mas alta es bueno?
- V_{12Gy} para cerebro es relevante?
- Cuando tratamos múltiples metástasis? Cuales índices a utilizar?
- Margen de PTV = 0? Con IGRT también?
- Los índices incluyen el tejido normal dentro de el PTV?
- As dosis do RTOG 90-05 son relevantes hoy?

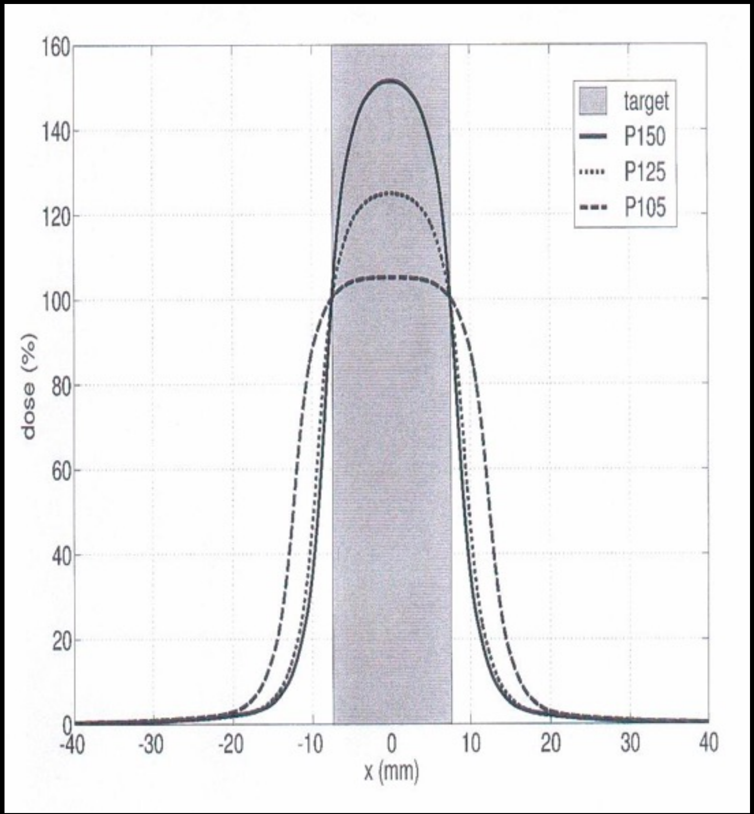
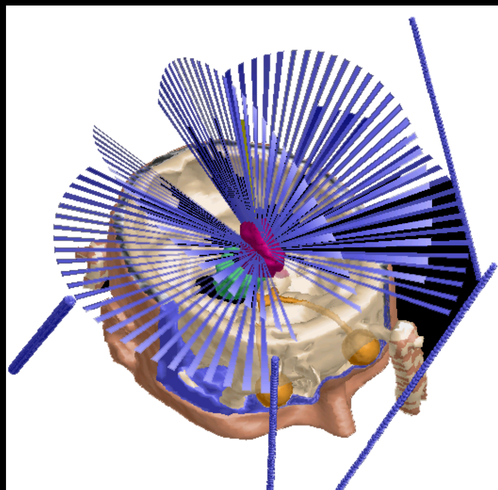


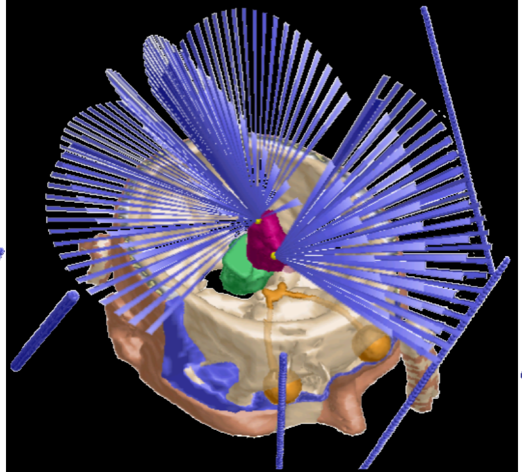
TABLE II. Achievable Uncertainties in SRS

Stereotactic Frame	1.0 mm
Isocentric Alignment	1.0 mm
CT Image Resolution	1.7 mm
Tissue Motion	1.0 mm
Angio (Point Identification)	0.3 mm
Standard Deviation of Position Uncertainty (by Quadrature)	2.4 mm

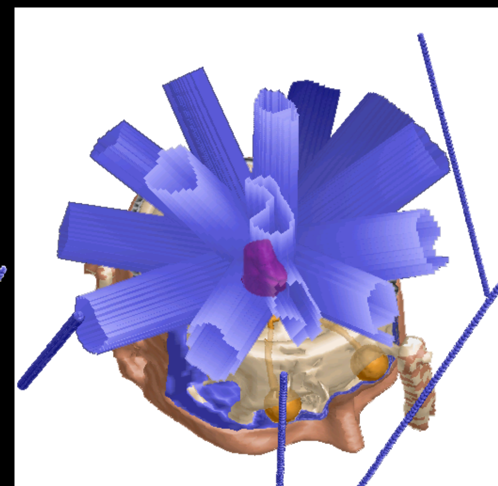
AAPM Report 54, 1995



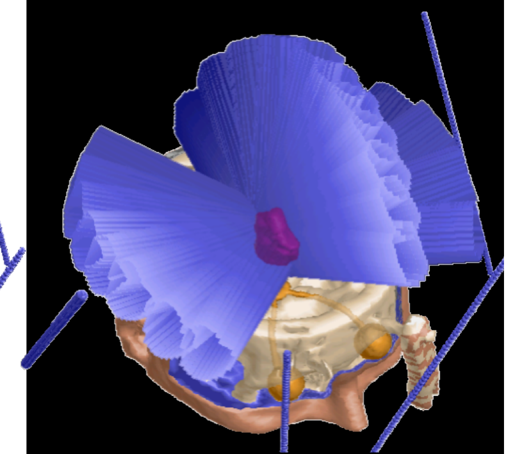
Circular Arc



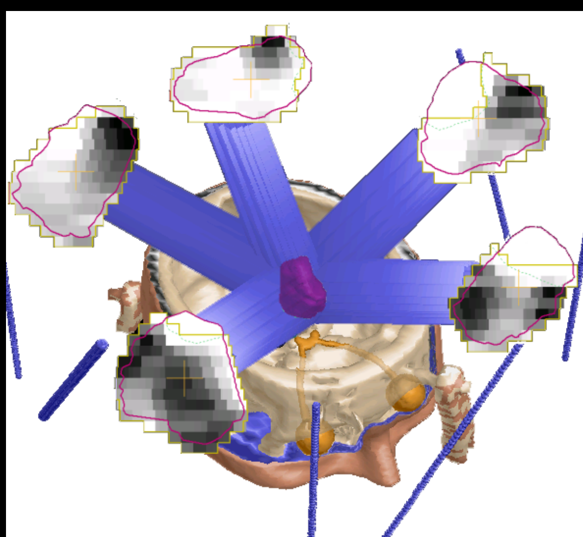
Circular Arc multiple isocenter



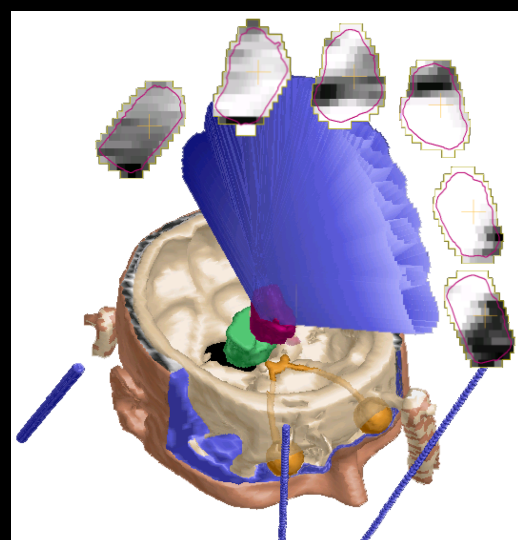
Conformal Shaped Beams



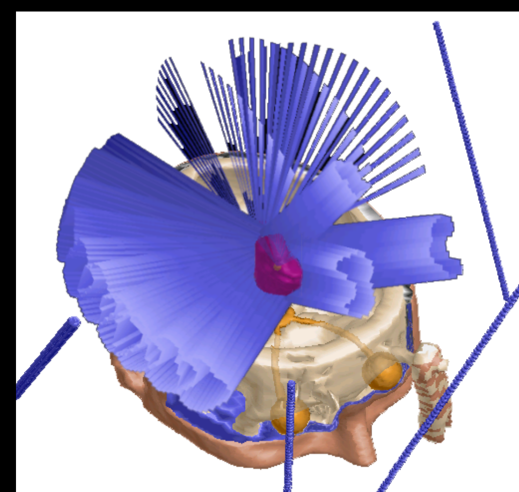
Conformal Arcs



Intensity Modulated
SRS/SRT

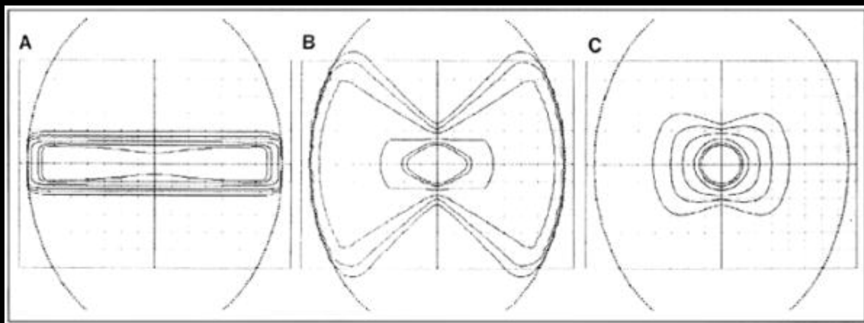


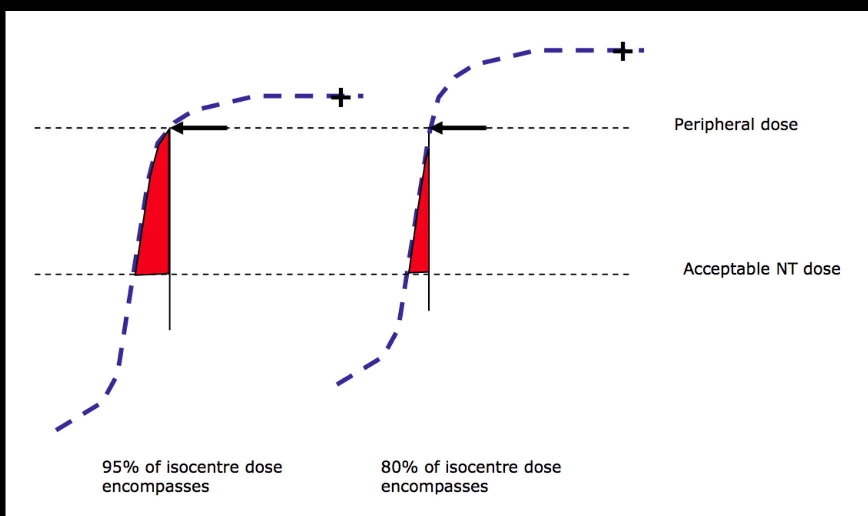
Intensity Modulated Arcs

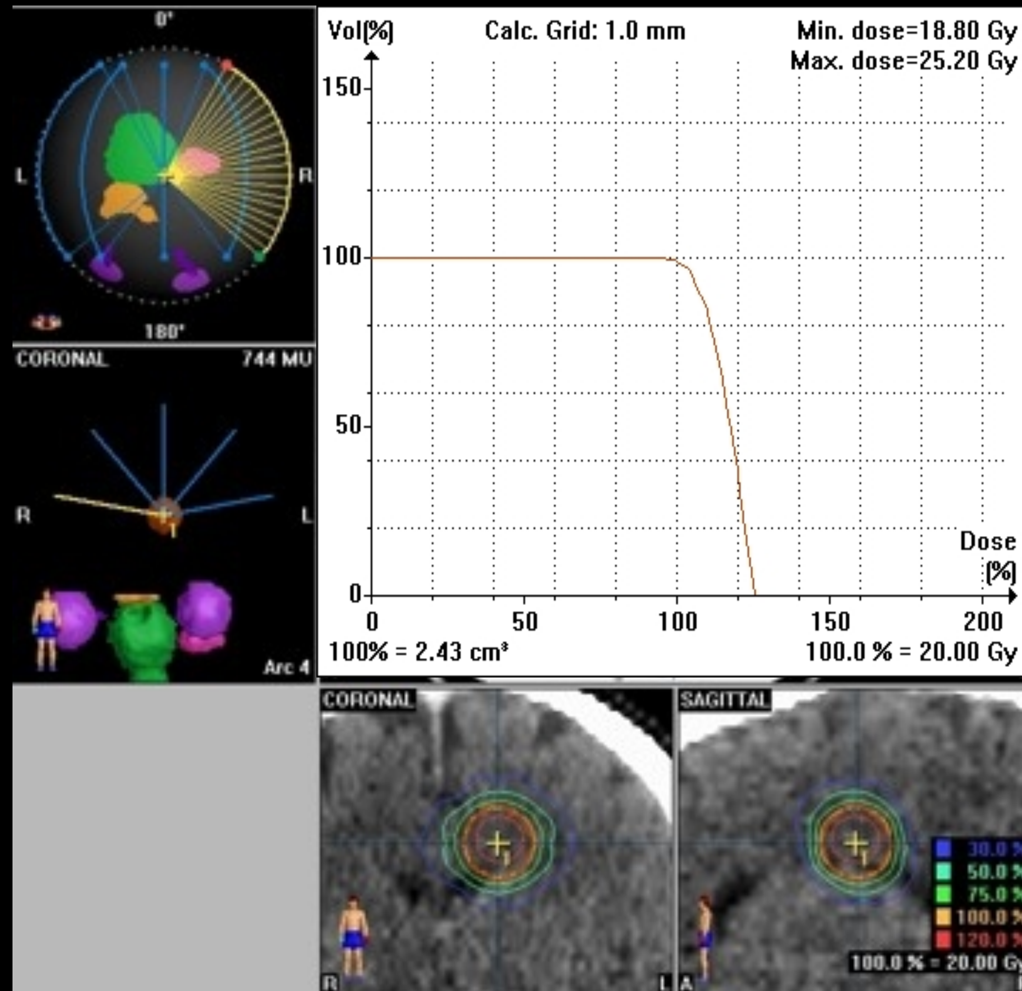


Composite SRS

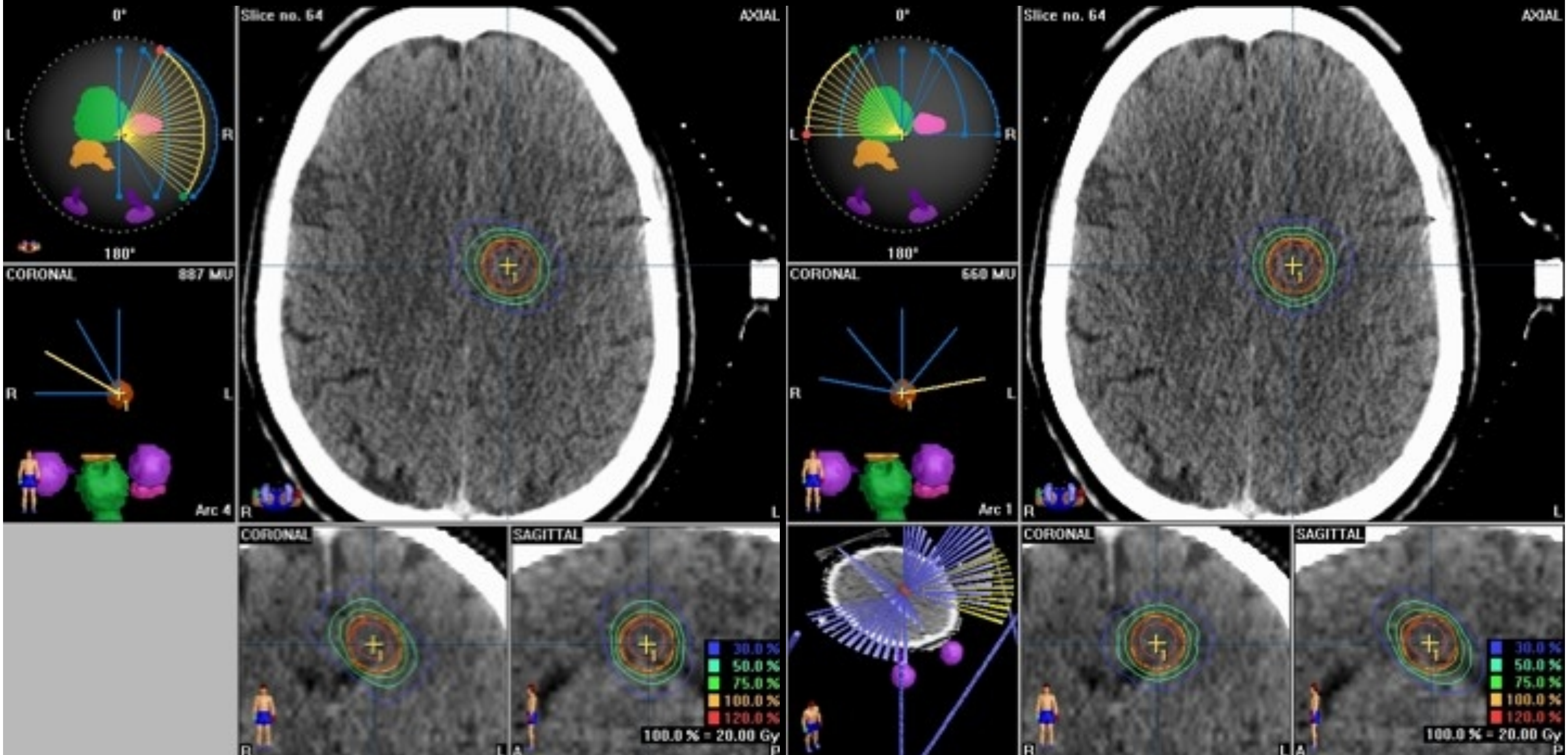
Isocentro unico - Colimador circular



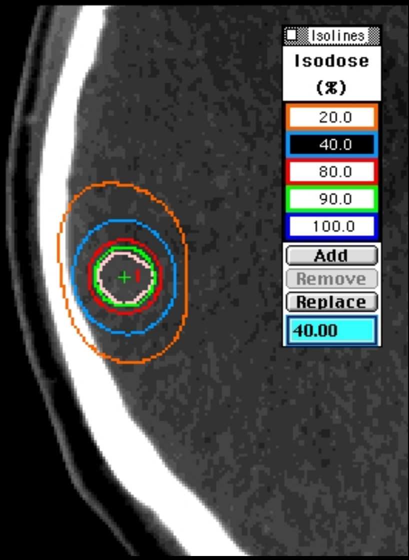


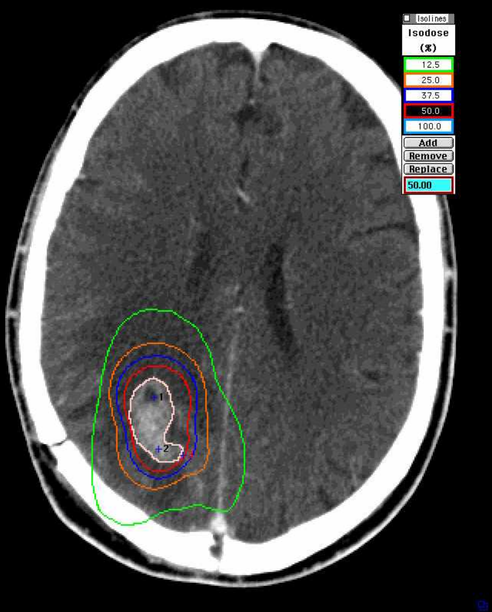


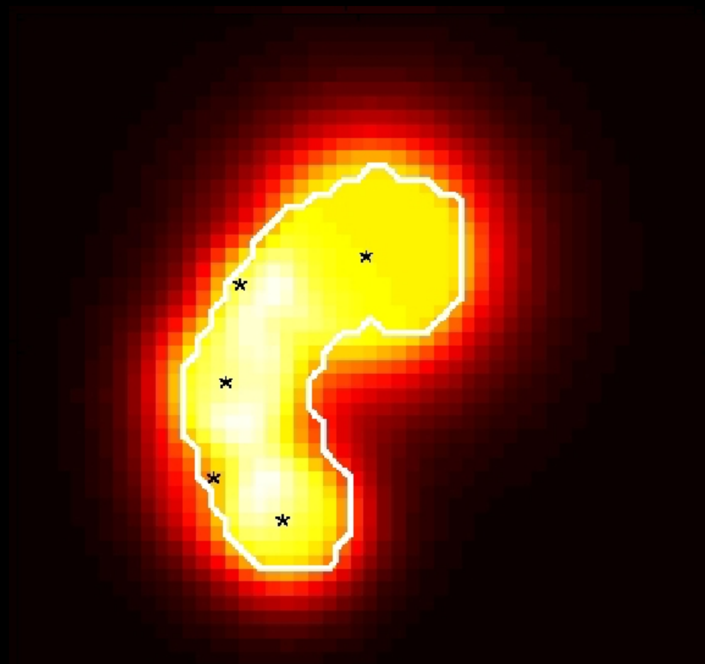
Combinaciones de arcos

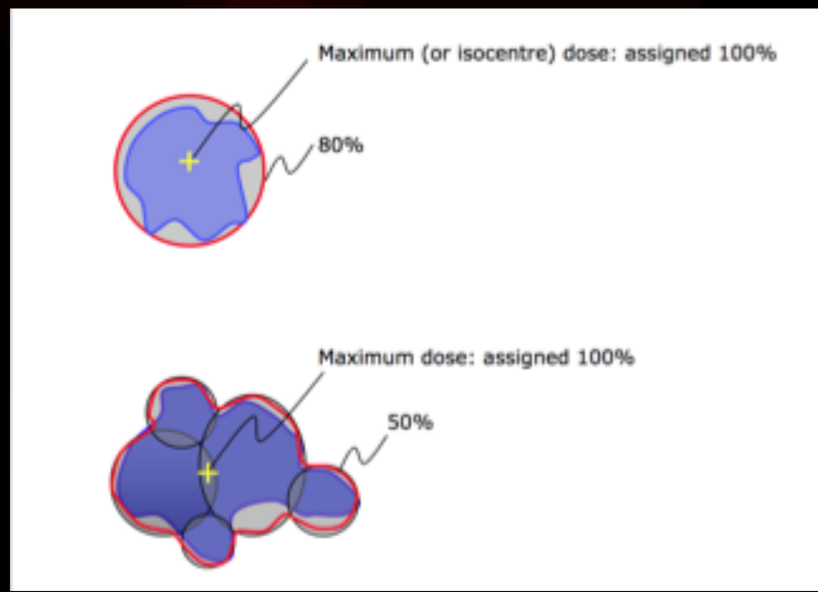


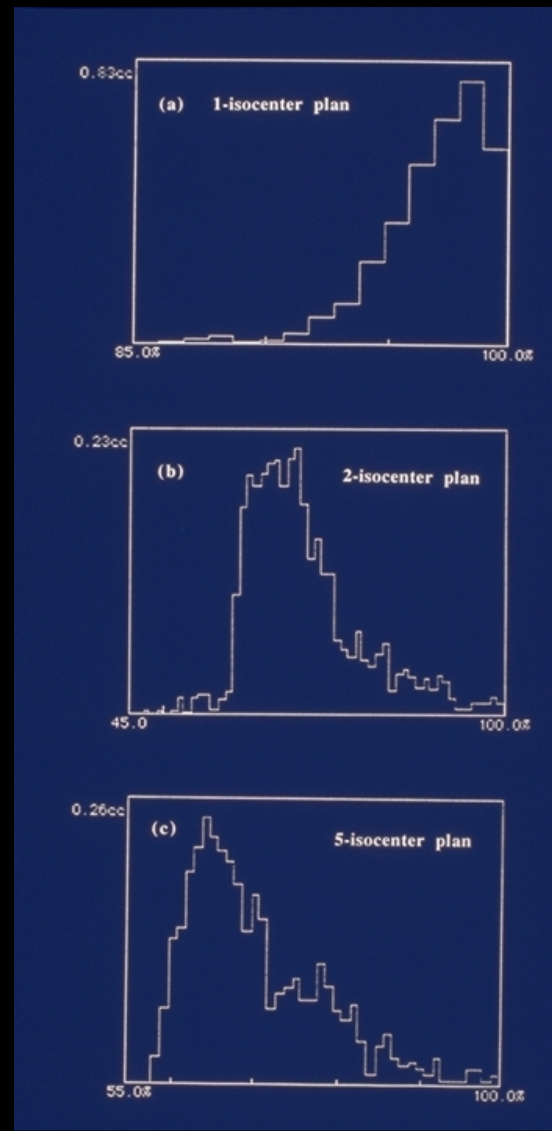
Lesiones irregulares con “disparos” esféricos







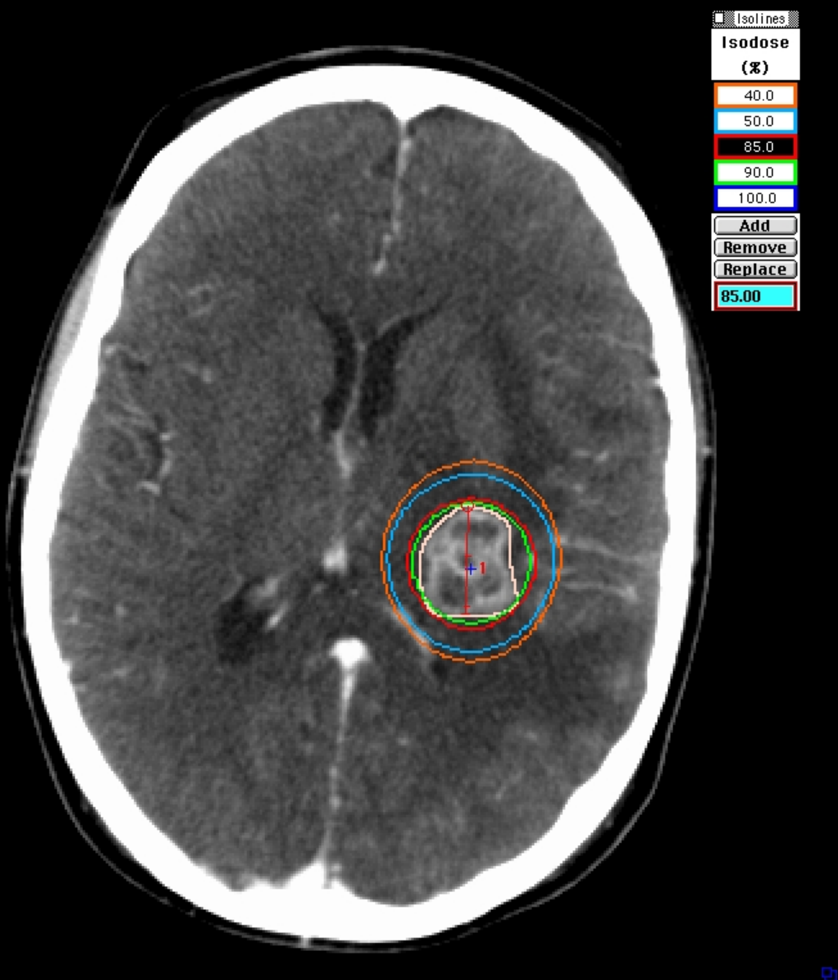


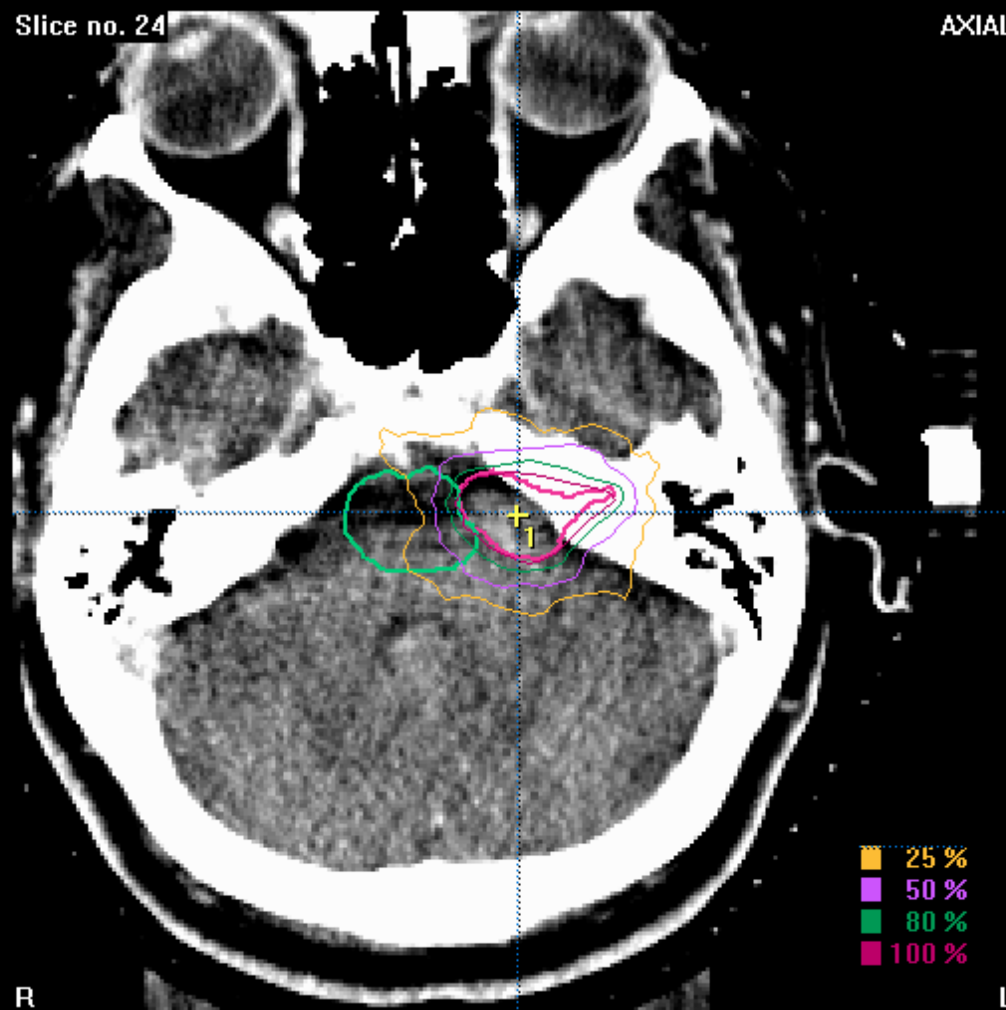


Distribución de dosis: isocentro único

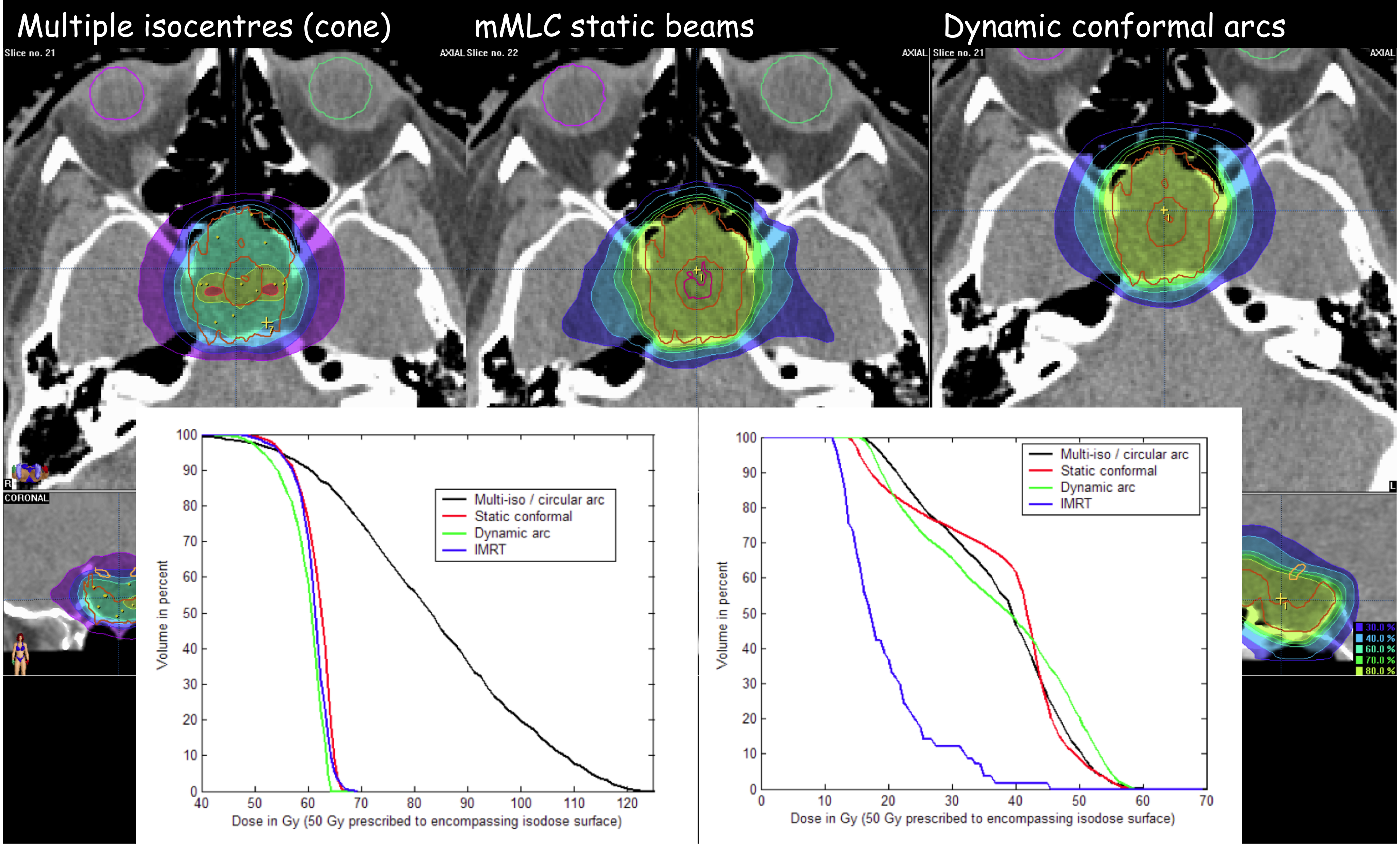
Arco

mMLC





Comparación de técnicas (ejemplo)



Cual técnica utilizar? Si tenemos opción!

Cones	Dynamic arc	IMRT
GTV pequeño GTV esférico Caída de dose periferica mas rápida	GTV pequeño a talla mediana GTV múltiples GTV con talla irregular En vez de “Sphere packing”	GTV grandes GTV con talla irregular GTV múltiples GTV muy cerca (al lado de) OAR critico

Planificación

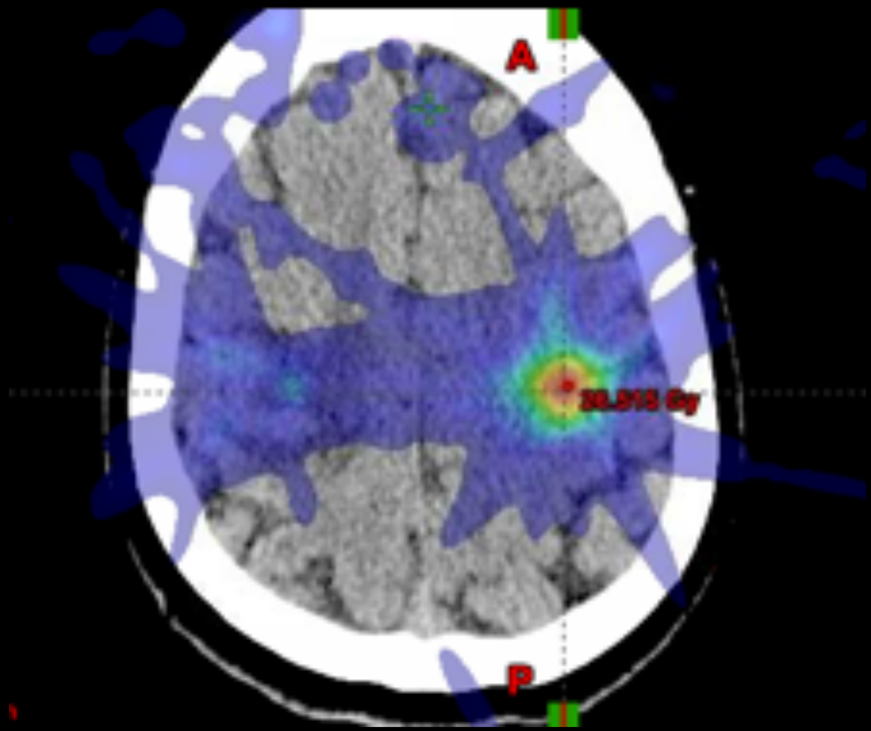
¿Qué resulta en una buena distribución de isodosis?

Características del haz físico (física básica)

- Haz penumbra
- PDD y perfil
- Colimación
- Transmisión

Características del blanco (preocupaciones de planificación del tratamiento)

- Forma GTV
- Tamaño GTV
- Proximidad a estructuras críticas (OAR)
- Cantidad de cerebro normal

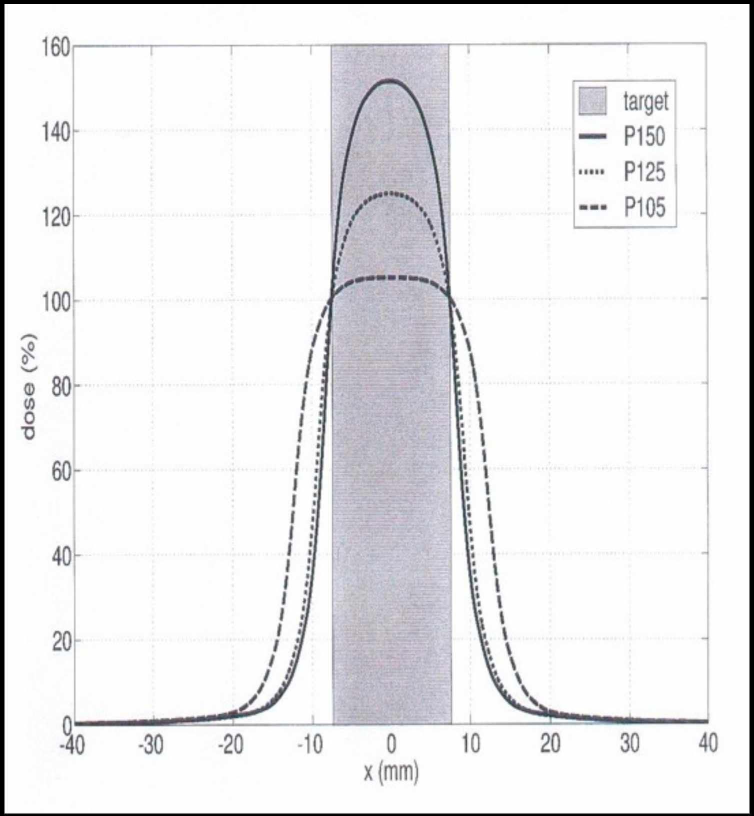


Prescripción en SRS / SBRT

- prescripción a una isodosis relativa à dosis máxima
  - prescripción a 75% - 90% (linac – 1 isocentro)
  - prescripción a 50% (Gamma Knife)
  - prescripción a 50% (neuralgia do trigênio)

- ICRU 90:
  - Mismas recomendaciones de ICRU 83
    - D98%, D50%, D2%

- SRT: prescripción a un nivel de cobertura también possible
  - Cobertura de 95% do PTV con la dosis prescrita



Evaluación del plan

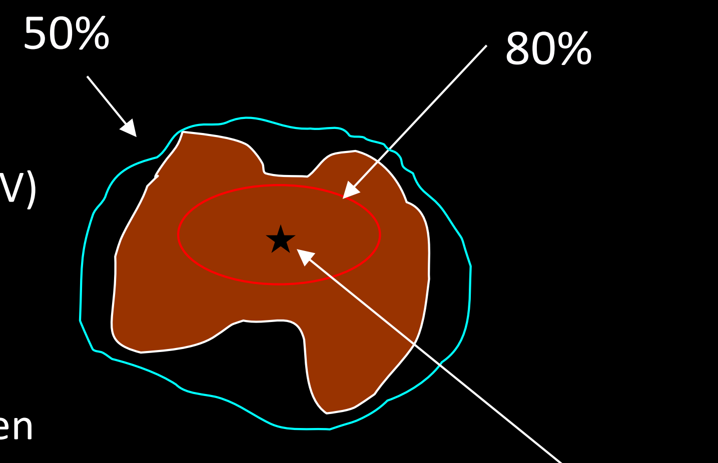
MDPD = max dose / Rx dose

Relación entre la dosis máxima y la dosis de prescripción
Homogeneidad dentro del nivel de dosis de prescripción (GTV)
RTOG recomienda que MDPD <2

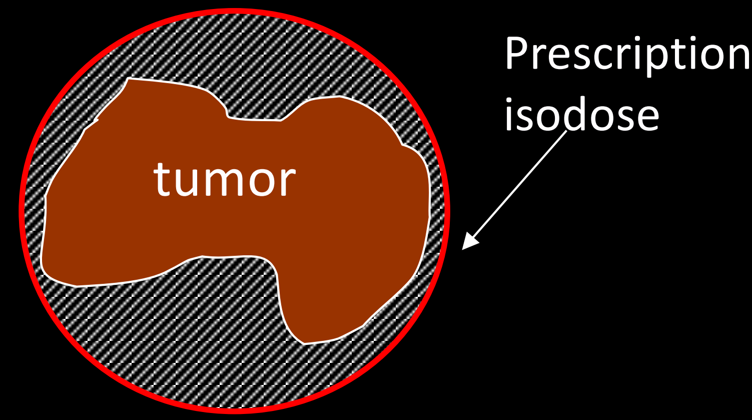
PITV = V_{Rx}/V_{GTV}

Relación de volumen de la isodosis de prescripción al volumen tumoral
Indicación conformidad con el volumen tumoral
RTOG recomienda que PITV <2

Limitaciones
MDPD solo indica calidad de plan adentro del GTV PITV solo compara volúmenes y no considera información espacial



MDPD = 100/50 = 2.0

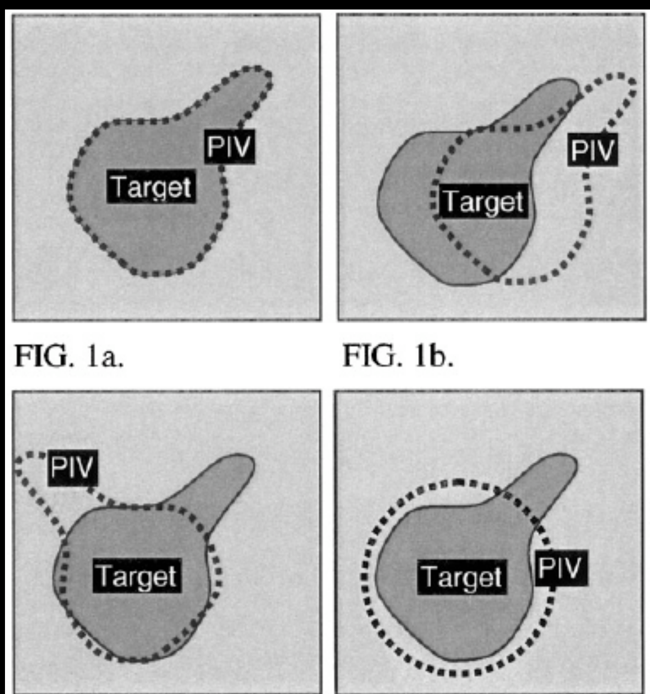


PITV ~ 2.0

Evaluación del plan

Índices de conformidad

$$CI_{Paddick} = \frac{TV_{PI}}{PI} \times \frac{TV_{PI}}{TV} = \frac{TV_{PI}^{\ 2}}{PI \times TV}$$



$$CDI = \frac{NT_{PI} + (TV - TV_{PI})}{0.5(S_{TV} + S_{PI})}$$

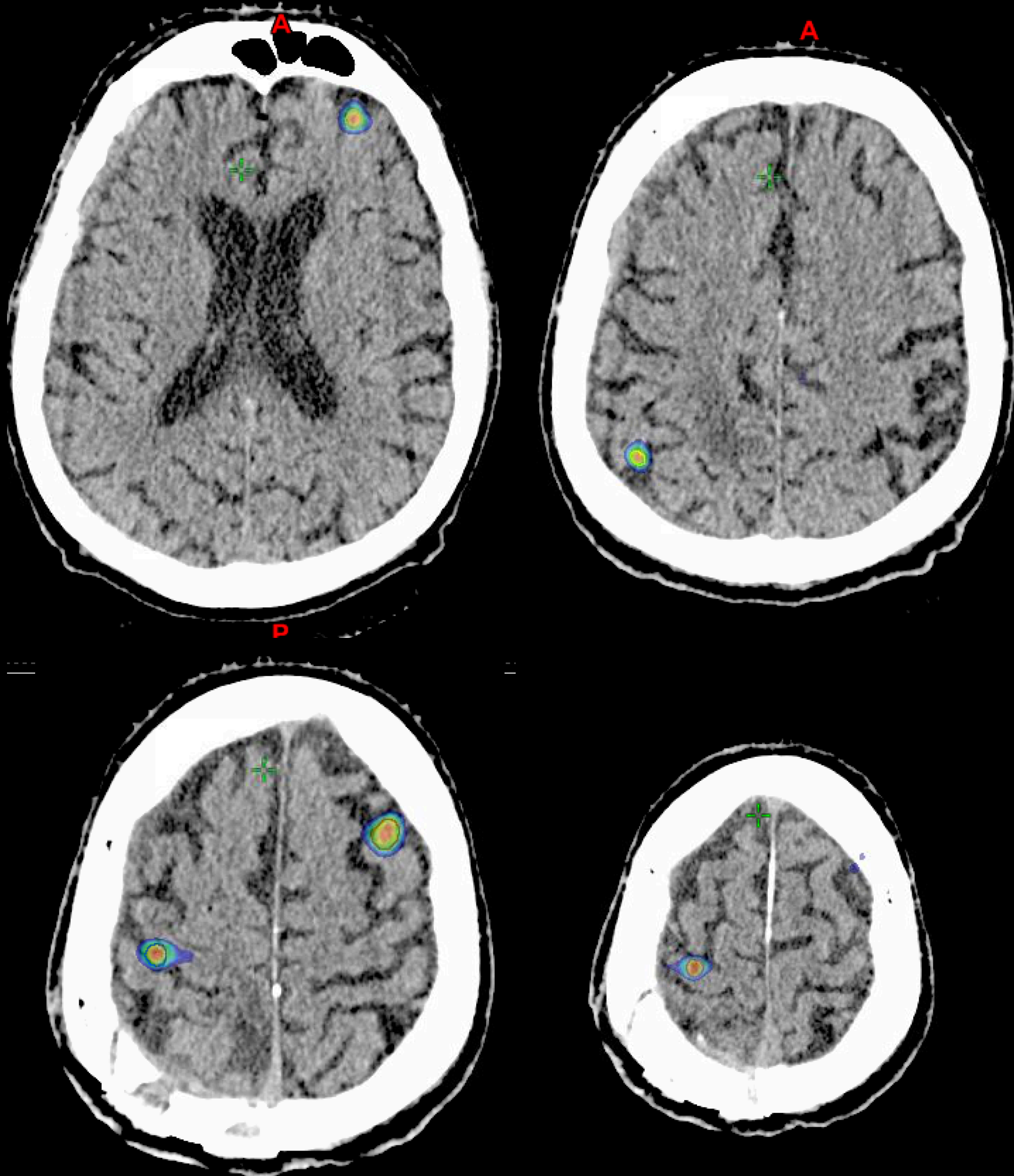
$$CGIg = 100 - \{100 \bullet [(R_{eff\,50\%} - R_{eff\,100\%}) - 0.3cm]\}$$

$$CGIc = (1/PITV) \times 100$$

$$CGI = \frac{CGIc + CGIg}{2}$$

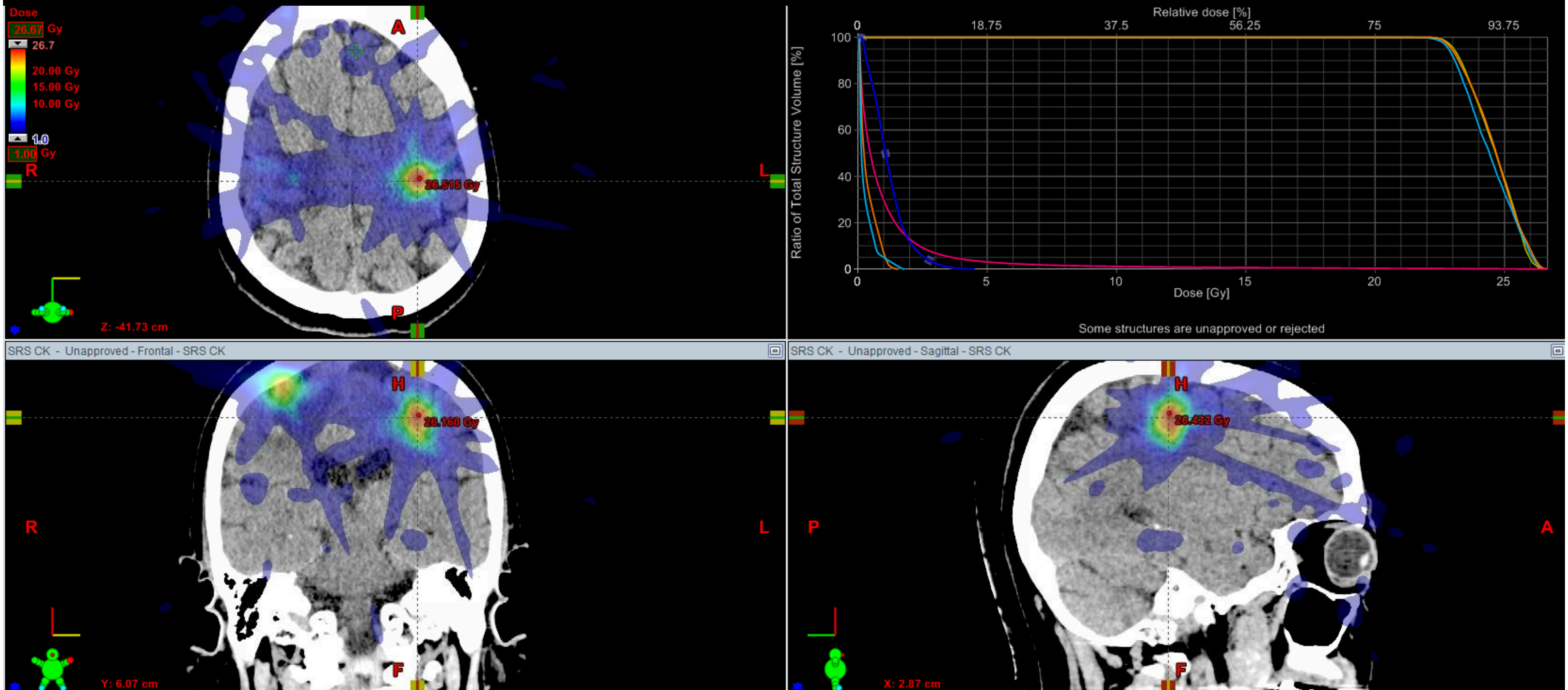
Pero son indicadores del resultado clínico?

V12Gy utilizado para cerebro



SRS
3 metastasis
20 Gy cada

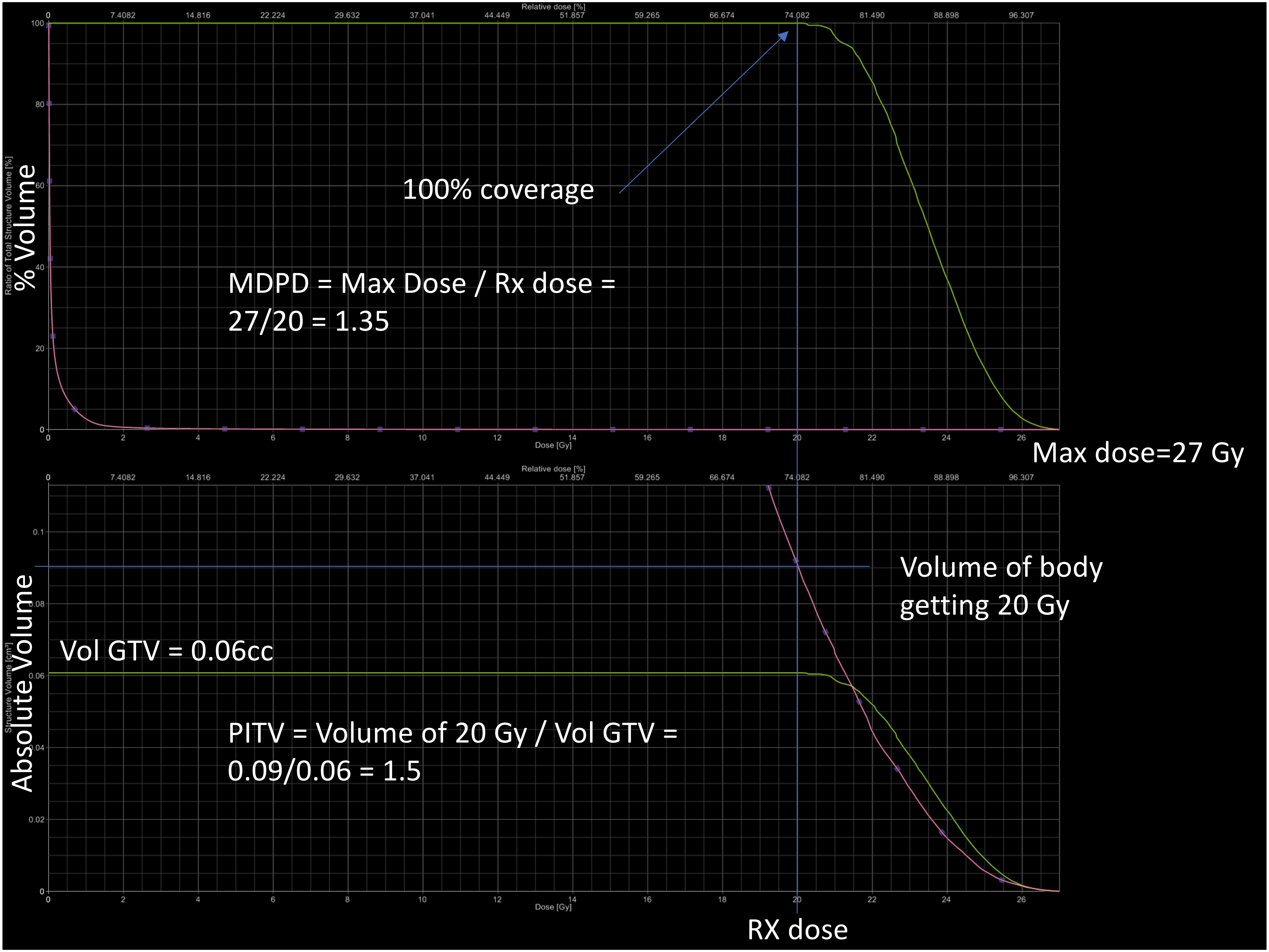
Evaluación del plan



Inspección visual

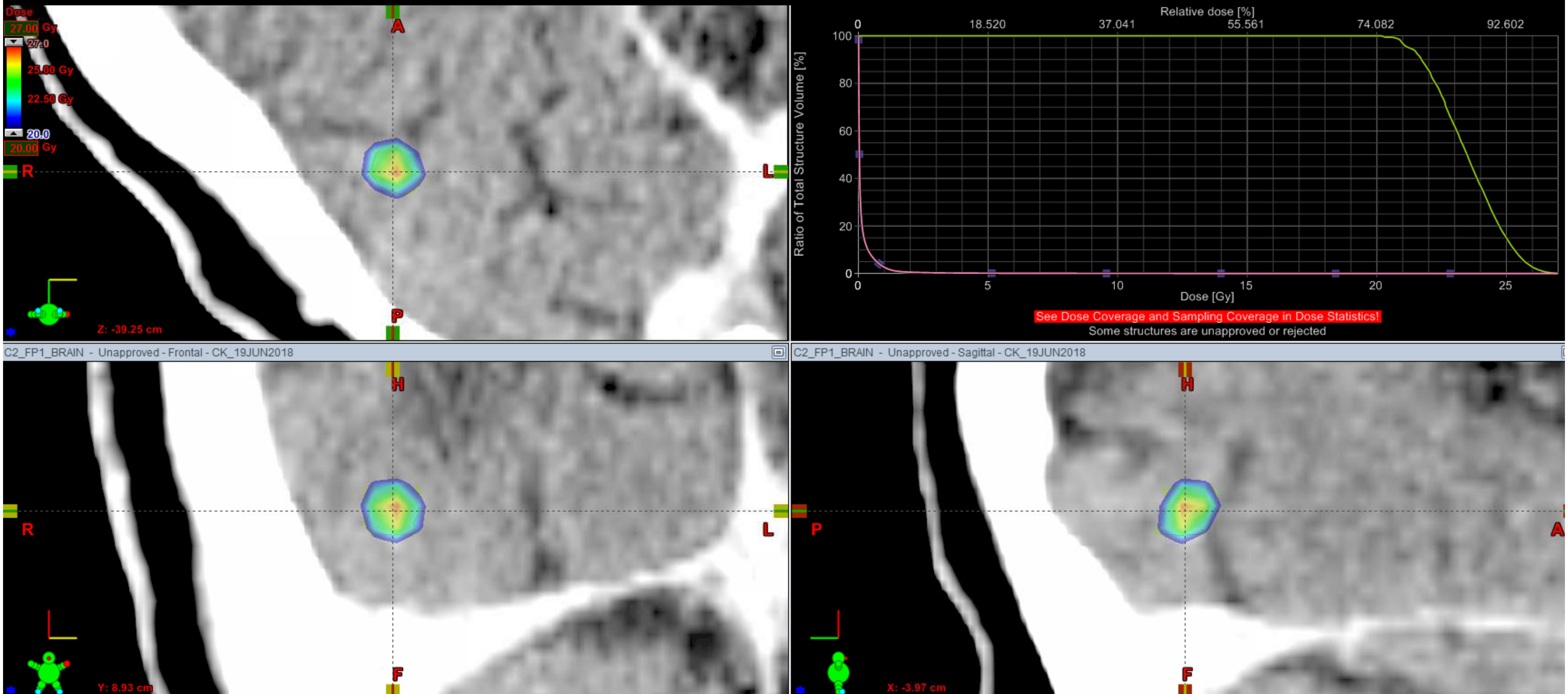
DVH – calculación de MDPD y PITV

V_{12Gy} y V_{3Gy} (visual)

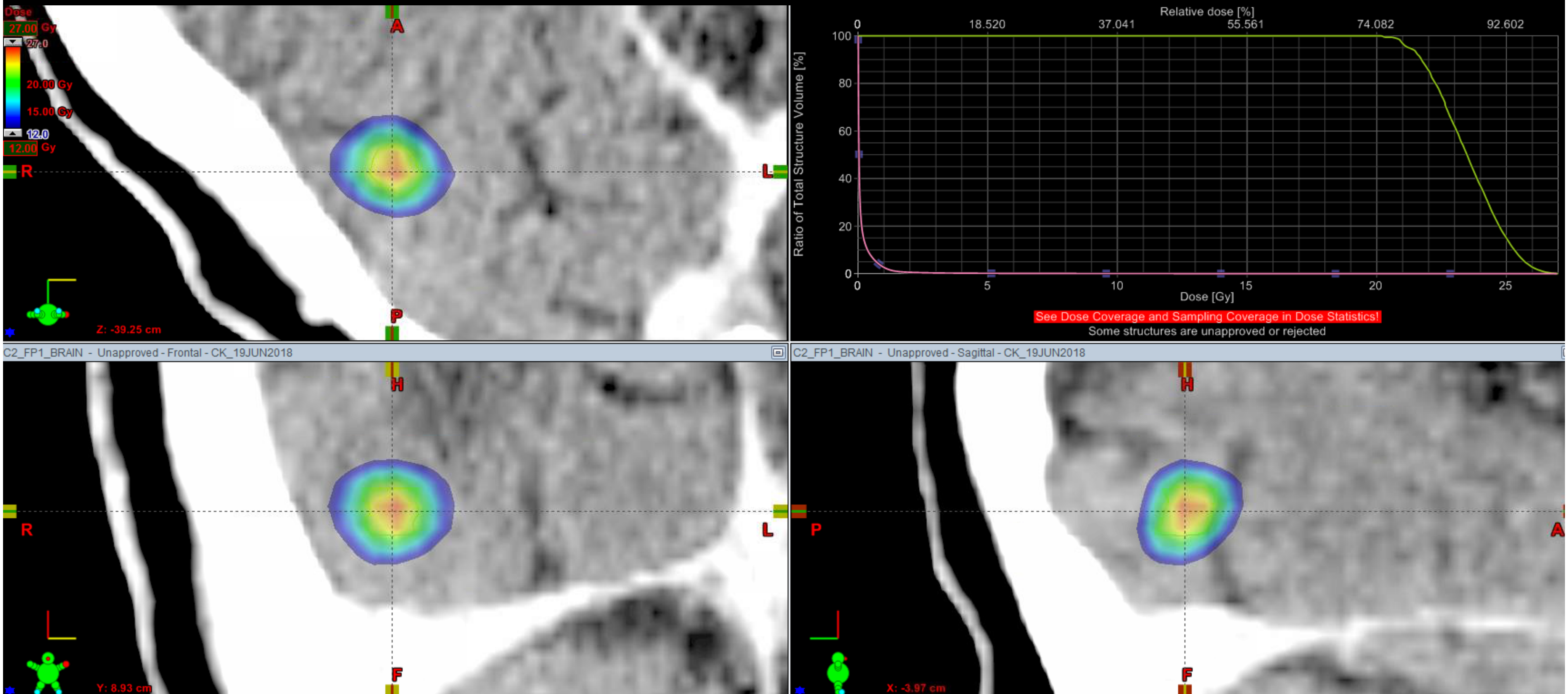


100% coverage
MDPD = Max Dose / Rx dose =
27/20 = 1.35
% Volume
Ratio of Total Structure Volume [%]
Relative dose [%]
Dose [Gy]
Max dose=27 Gy
Volume of body
getting 20 Gy
Vol GTV = 0.06cc
PITV = Volume of 20 Gy / Vol GTV =
0.09/0.06 = 1.5
Absolute Volume
Structure Volume [cm³]
RX dose

20 Gy para PITV



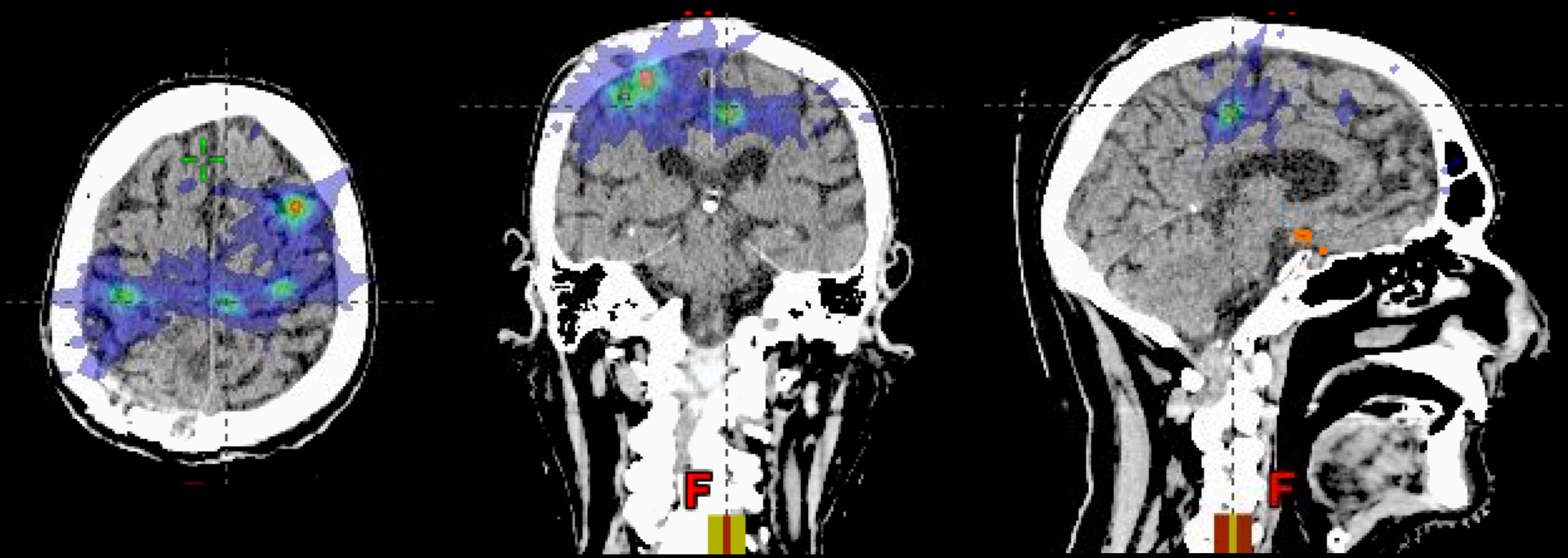
12 Gy isodose contour V_{12Gy}



V_{12Gy} menos de 10 cc por una lesion, menos que 20 cc para multiples

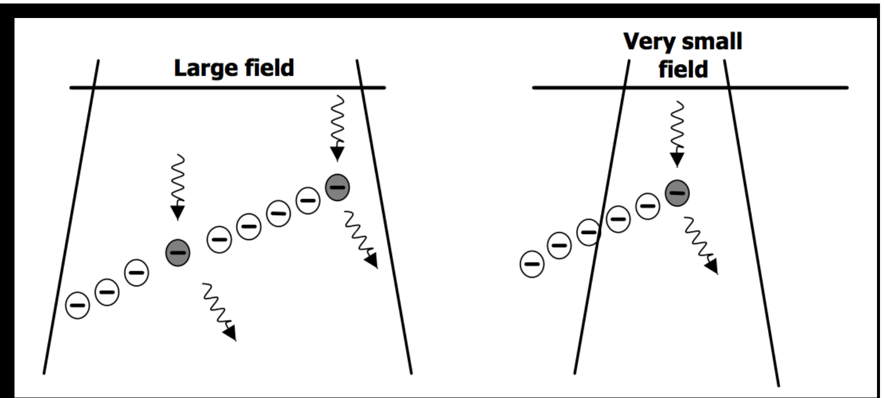
Este caso – 12.3 cc

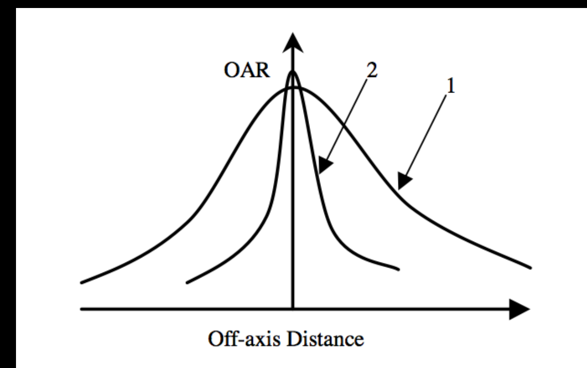
SRS "low dose spill" – 3 Gy

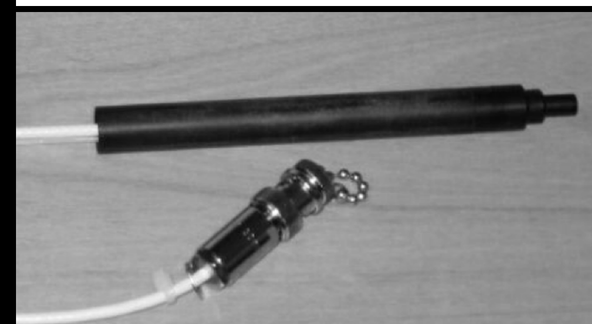


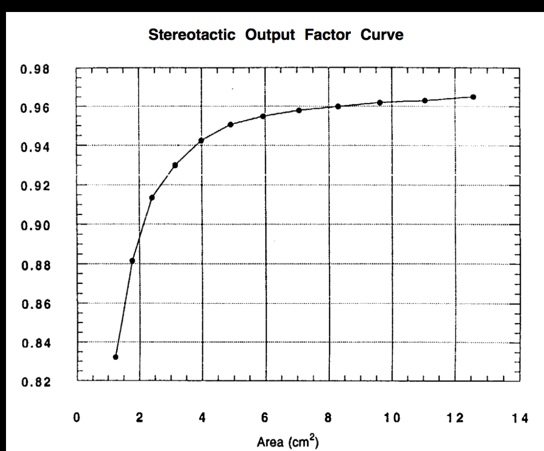
Medidas fisicas!

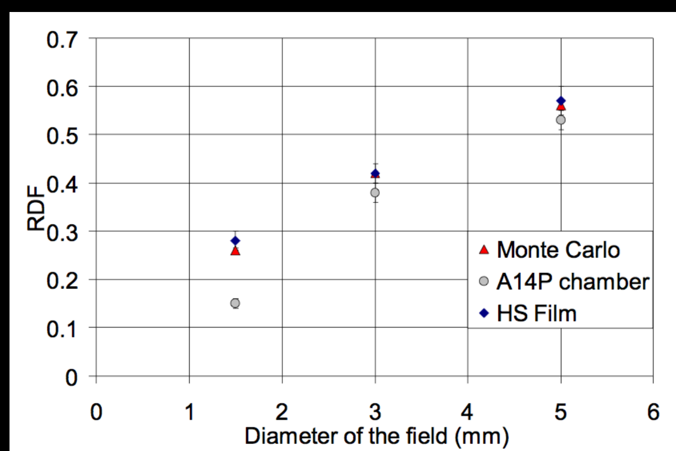
- Campos pequeños
- Tamaño de detectores
- Precisión de posición del detector
- Desequilibrio electrónico

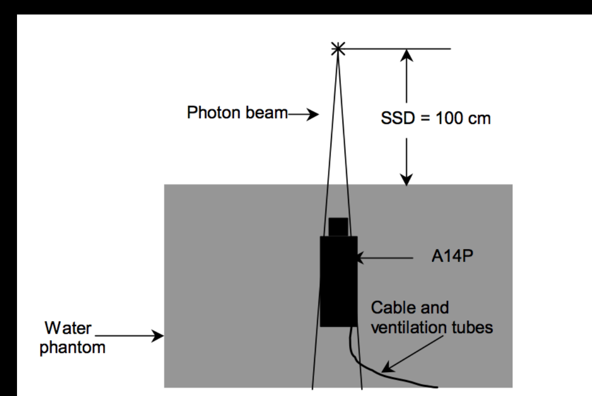












Calibración del haz

AMERICAN ASSOCIATION of PHYSICISTS IN MEDICINE

Search

MEDICAL PHYSICS

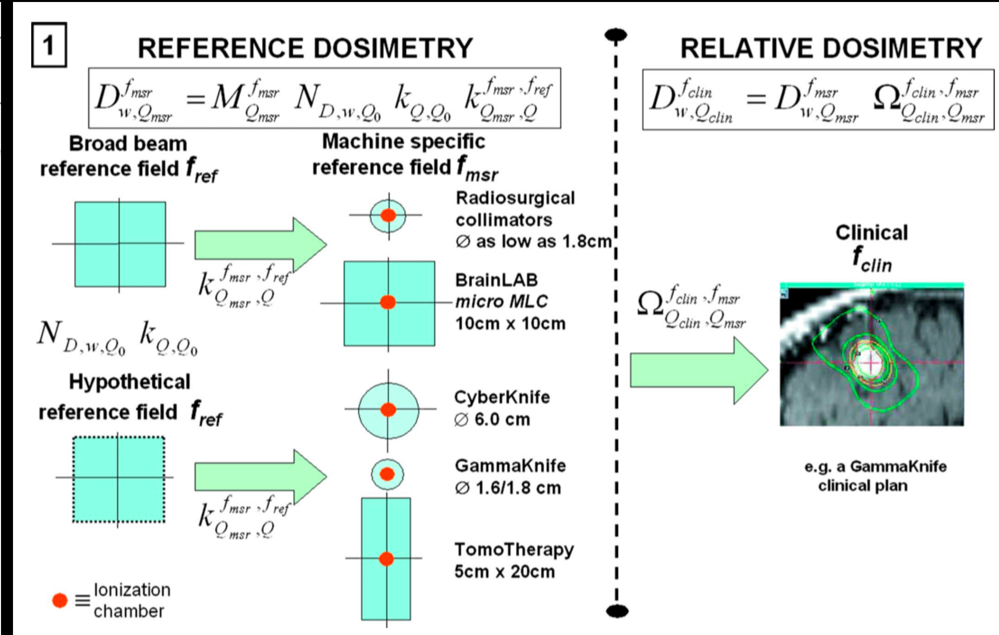
The International Journal of Medical Physics Research and Practice

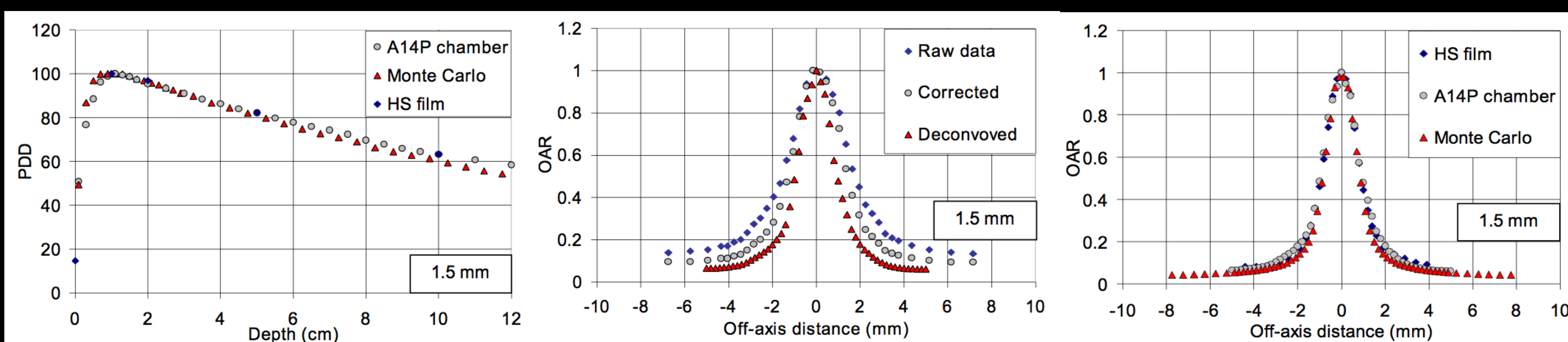
AAPM Scientific Report | Free Access

Dosimetry of small static fields used in external photon beam radiotherapy: Summary of TRS-483, the IAEA–AAPM international Code of Practice for reference and relative dose determination

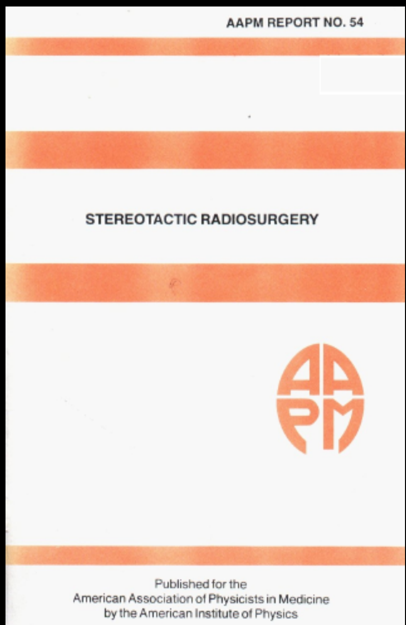
Hugo Palmans, Pedro Andreo, M. Saiful Huq, Jan Seuntjens, Karen E. Christaki, Ahmed Meghzifene

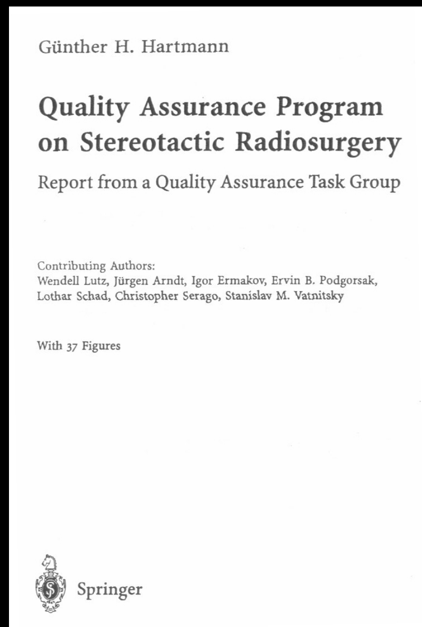
First published: 24 September 2018 | https://doi.org/10.1002/mp.13208 | Cited by: 11





Control de calidad





- Programas basados en directrices nacionales o internacionales de GC (ej. AAPM, OIEA)
- Las nuevas tecnologías requieren nuevas directrices
- Auditorias externas (IROC Houston)

Table 1a: Quality Control Tests for Linac-based SRS/T

Designator	Test	Performance	
		Tolerance	Action
Patient Specific*			
PSL1**	Patient monitoring system	Functional	
PSL2**	Machine interlocks (as appropriate)	Functional	
PSL3	Collision tests	Functional	
PSL4	Imaging parameter check	Appropriate	
PSL5	MU calculation (independent check)	3%	
PSL6**	Couch/Pedestal Locking	Functional	
PSL7**	Cone alignment (if appropriate)	0.5 mm	0.75 mm
PSL8	Field shape check (if appropriate)	0.5 mm	0.75 mm
PSL9	Target coordinate check	0.75 mm	1 mm
PSL10**	Laser check	0.75 mm	1 mm
PSL11	Head Frame motion	1 mm	1 mm
PSL12	Checklist use	Documented	
Quarterly			
QSL1	Isocentre wobble diameter (gantry)	0.5 mm	0.75 mm
QSL2	Isocentre wobble diameter (couch)	0.5 mm	0.75 mm
QSL3	Couch and gantry axis coincidence	0.5 mm	0.75 mm
QSL4	Collimator wobble diameter	0.5 mm	0.75 mm
QSL5	Records	Complete	
Annually			
ASL1	Acceptance functional tests	Functional	
ASL2	Percentage depth dose	2%	2%
ASL3	CT localization performance	1.5 mm	1.5 mm
ASL4	MRI localization performance	2 mm	2 mm
ASL5	Angiography localization performance	1 mm	1 mm
ASL6	Dose profiles (FWHM)	1 mm	1 mm
ASL7	Dose delivery test	2%	5%
ASL8	Output factors	2%	3%
ASL9	Radiation/mechanical isocentre coincidence	0.5 mm	0.5 mm
ASL10	Known target test (CT-based)	1 mm	1.5 mm

*Patient specific tests are to be carried out for every SRS patient subject to the note (**) below. For SRT the minimum frequencies are different. Tests PSL1, PSL2, PSL6, PSL7, and PSL12 are for every fraction, tests PSL3, PSL4 and PSL5 before the first fraction and tests PSL8, PSL8, PSL9 on a weekly basis. Test PSL11 is not applicable in SRT provided a suitable PTV margin is being used in the treatment planning process. It can also be omitted for SRS if it is determined during commissioning that head frame slippage is well below the suggested tolerance for the given frame. Test PSL12 can also be omitted if a record and verify system is used for the dose delivery.

CK QA

Daily

- DL1: Daily systems safety check
- DL2: Visual check of beam laser & standard floor mark
- DL3: Accelerator output
- DL4: AQA (cycle through fixed, IRIS and MLC)
  - Film analysis
- DL5: Modified picket fence test

Monthly

- ML1: Energy Constancy Ratio (TPR)
- ML2: Accelerator Output
- ML3: E2E (cycled through each clinically used Tracking system)
  - For film analysis - see HERE
- ML4: Non-isocentric Patient Specific QA (DQA) (cycled through each clinically used Tracking system) see link HERE
- ML5: Incise IRIS QA
- ML6: Garden Fence MLC Test
- ML7: Imaging (Low contrast detail visibility & spatial resolution test) --- To start June 2018 (baselined May2018)
- ML8: Review records

Quarterly

- QL1-2: Beam symmetry and profile constancy (compared to baseline not TPS)
- QL3: Imaging alignment center (isocrystal)
  - refer to PEG (make sure each option below has been updated correctly)
  - refer to Chp3 Pg15-16 of the Physics Essential Guide
  - see I:\PHYSICS\Glen Commissioning\Cyberknife\Manuals\CK - PhysicsGuide_10.6
  - or refer to PEG uploaded to DepDocs here

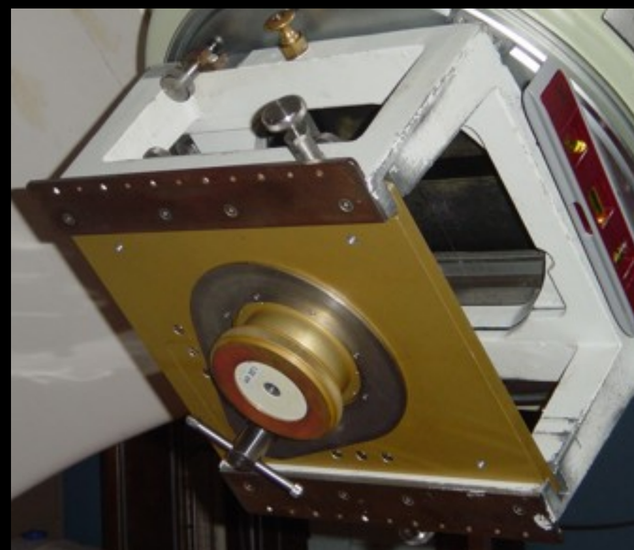
Annual

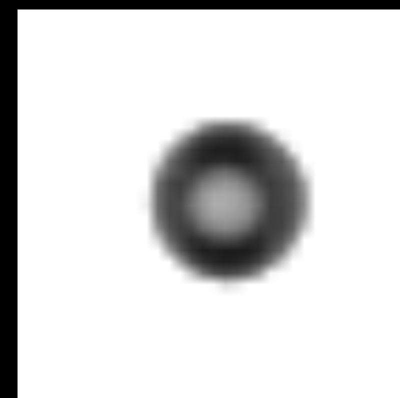
- AL1: Reference dosimetry (TG51)
- AL2: TPR or PDD & Output factors
- AL3: Radial profile constancy
- AL4: Dose output linearity
- AL5: Laser/Radiation coincidence
- AL6: Verification of 2nd order path calibration
- AL7: Synchrony with 20deg phase lag
- AL8: Incise MLC transmission
- AL9: Incise MLC transmission (between leaves)
- AL10: Incise MLC transmission (between abutting leaves)
- AL11: Incise MLC leaf alignment with jaws
- AL12: Imager test -- Exposure parameters (kVp, mA and timer accuracy, exposure linearity, exposure reproducibility)
- AL13: Imager test -- Imaging characteristics (Quantitative assessment of contrast, noise, and spatial resolution of amorphous silicon detector)
- AL15: Independent review and update of QA references

Post PMI

Control de calidad - QA

Laser Winston-Lutz o semejante



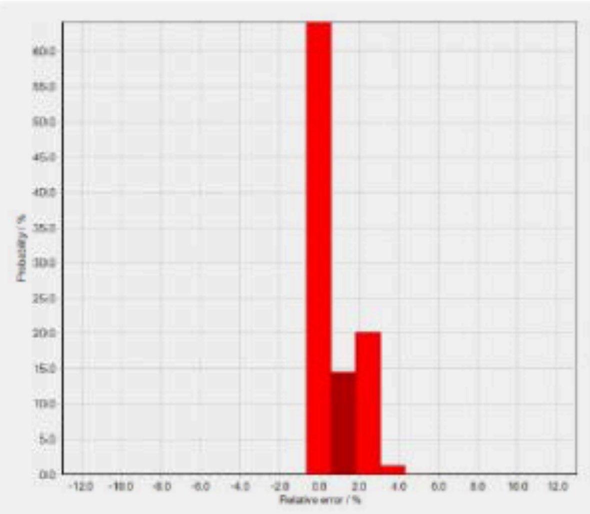


Verificación independiente de MU

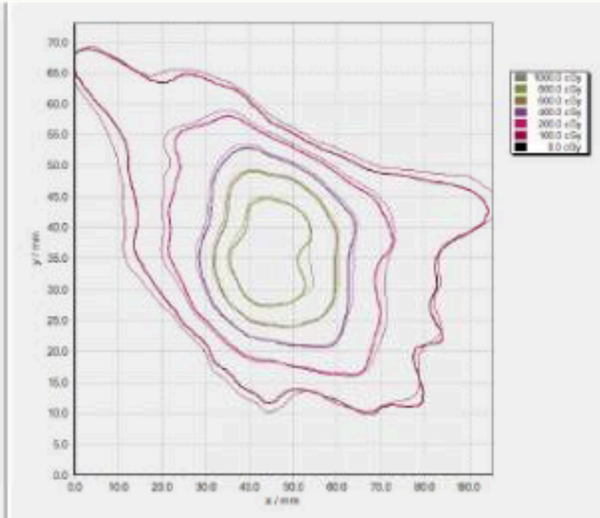
Medida en fantoma

Patient	N/A, N/A
Id	N/A - 25/09/2015 - page 1
Site	none
Facility	N/A
Plan	1.2.840.114358.6.1.20150925083709.486523267646_0993627_QA_FI
Physicist	N/A

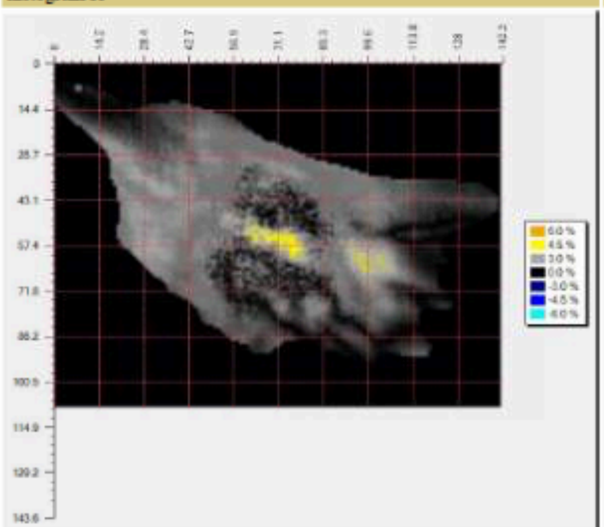
Charts 'Gamma' map



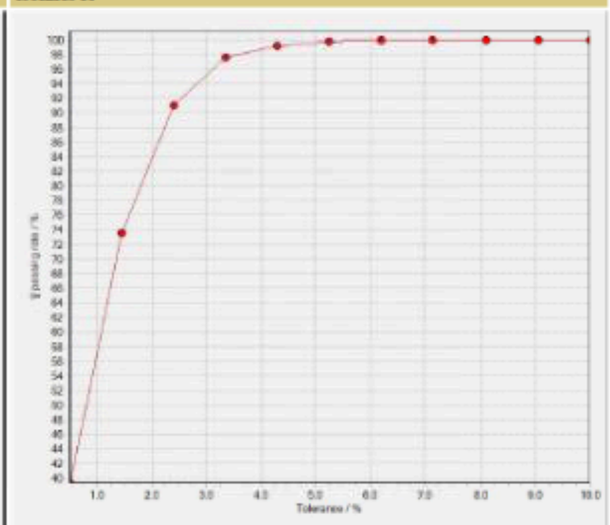
histogram R



isolines R

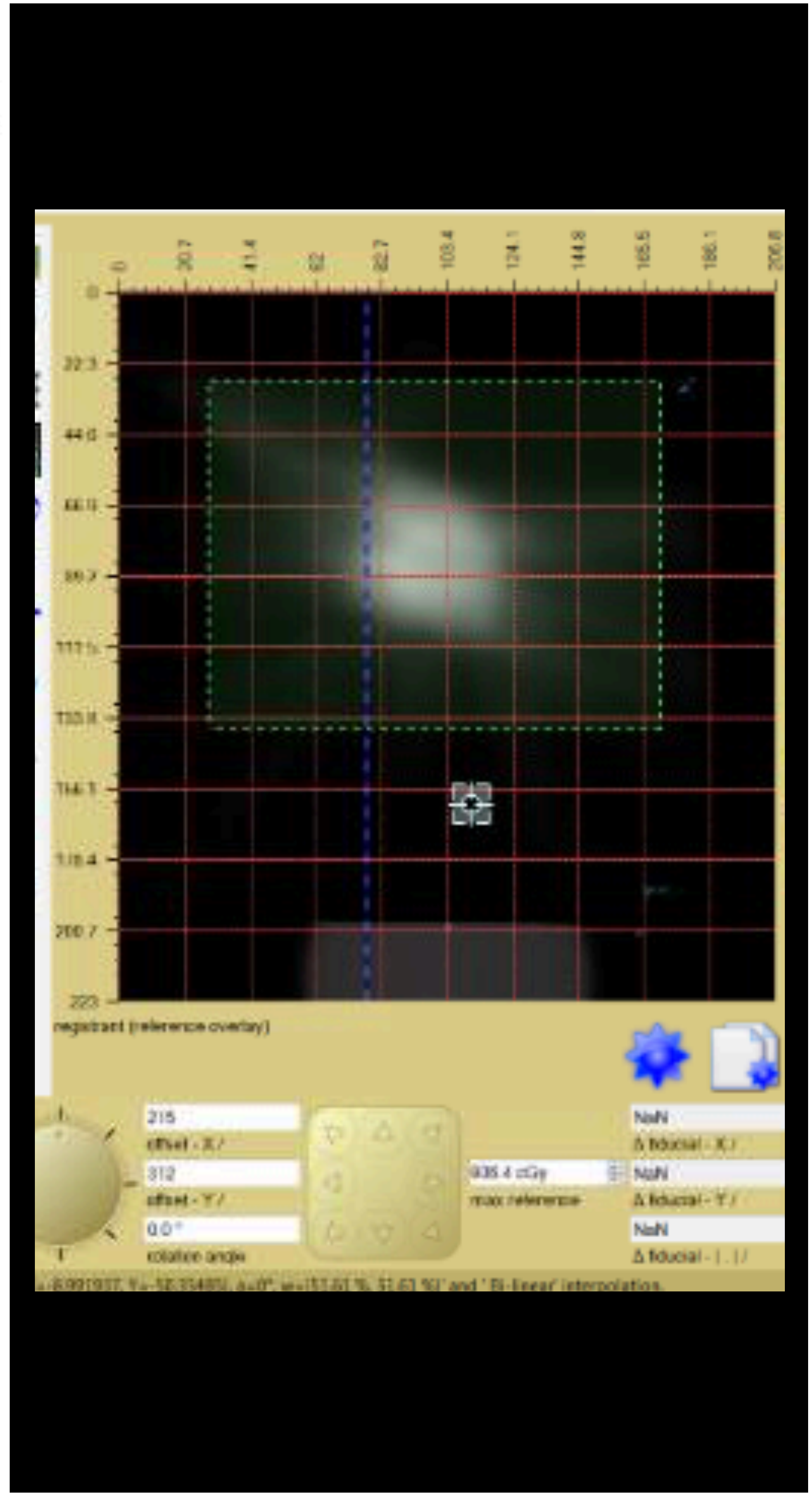


isomap R



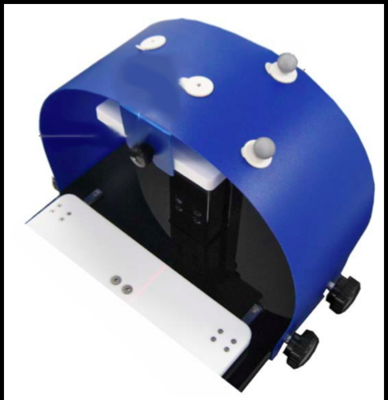
Passing rate R vs. tolerance

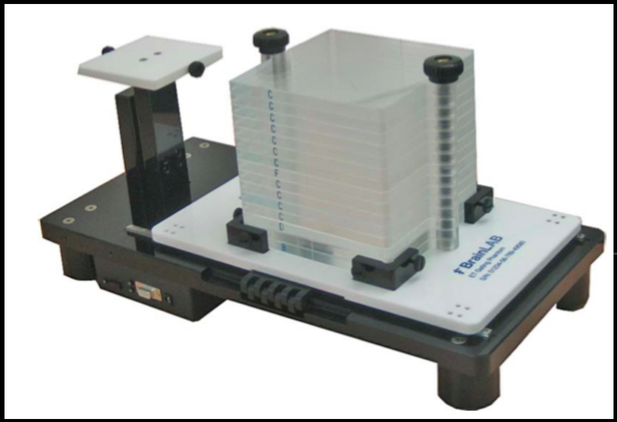
	Gamma	Differential Delta	Distance to agreement
Criterion	3.0 %, 1.0 mm	|2.0 %|	2.0 %, 2.0 mm
Passing rate R	96.6 %	77.0 %	99.7 %
Failing rates R	-3.4,+0.0 %	-22.5,+0.6 %	-0.3,+0.0 %
Mean R	1.7 %	1.3 %	0.2 %
Std dev R	0.9 %	1.2 %	1.2 %

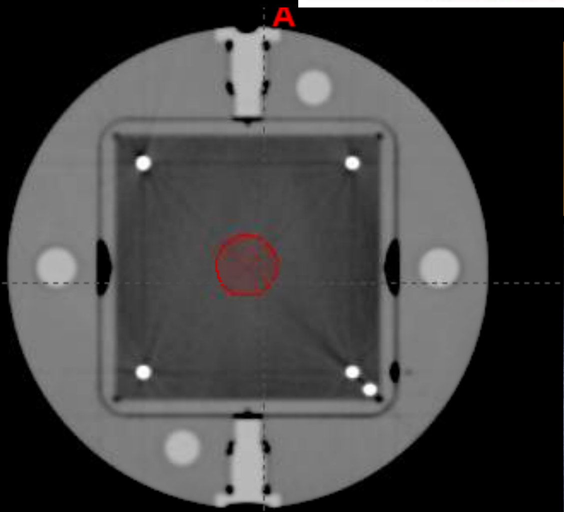


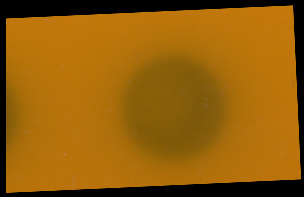
End to End Test

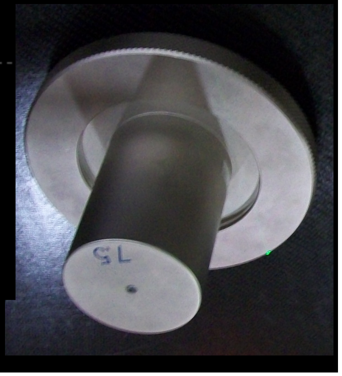
- Objetivo oculto colocado dentro de un fantoma
- Fantoma también contiene marcadores incrustados para el posicionamiento
- Película colocada detrás del objetivo
- Planificar y administrar un tratamiento al objetivo oculto
- Estimaciones de la incertidumbre de extremo a extremo
- Método utilizado para determinar la incertidumbre debida a la resolución del corte del CT











Tiempo de puesta en marcha

	Charged Particle	Linac	Gamma Unit
Total dose to normal brain	+++	+	+
Field edge sharpness	+++	+	+
Radiobiological effectiveness: target versus normal tissue	+++	+	+
Treatment planning flexibility	++	+++	+
Treatment planning complexity	−	++	++
Small target dosimetry	++	++	++
Large target dosimetry	+++	++	+/−
Cost to build/purchase	−	+++	+
Installation	−	++	+
Staffing requirement	−	++	+++
Cost of operation	−	++	+++
Ease of use	−	+	++

[a] Summary comparison of technical features and costs for the gamma knife, linac, and charged-particle beams for radiosurgery. −, disadvantageous; +, not disadvantageous; ++, advantageous; +++, most advantageous.

Table 4. Summary Comparison of Technical Features and Costs[a]

Luxton, Neurosurgery, 1995

TABLE I. Time Estimates for Commissioning a Radiosurgery Program. *Estimated Project Times (weeks)*

TASK	TIME
Stereotactic Equipment Evaluation	2 wks
Treatment Planning System	
a) Evaluate commercial package	1 wk
b) Develop treatment planning	2 yrs
Dosimetry Measurements	2 wks
Treatment Delivery Hardware	
a) Setup commercial package	3 wks
b) Adapt a prefabricated system	12 wks
c) Design & fabricate	28 wks
Final System Test	2 wks
Routine QA	0.5 days/month
Plan and Treat a Radiosurgery Case	8-12 hr/patient (Depending on Complexity)
TIME ESTIMATES FOR FOUR OPTIONS:	
Commercial Package	10 wks
Adapt a Prefabricated System and Write Software	2.3 yrs
Fabricate Hardware/Buy Software	0.7 yrs
Design and Fabricate Hardware/ Write Software	2.7 yrs

AAPM, Report 54

Hoy en día, depende del Sistema, algunos son tan integrados que un equipo experimentado puede lanzar un programa rápidamente (semanas).

Gracias, preguntas?