

Principios físicos de la Radiocirugía

Conos y micro multiláminas. Auditoria externa

Curso de Actualización en Protección Radiológica

Córdoba, 7 al 9 de Abril 2016

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Córdoba, ARGENTINA



INSTITUTO DE RADIOTERAPIA
FUNDACIÓN MARIE CURIE

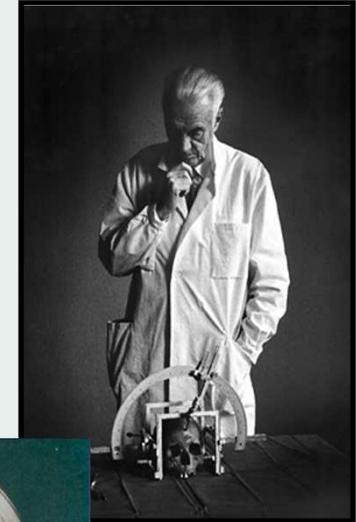
Características generales de la SRS

- Procedimiento de “características especiales” incluye radioterapia y neurocirugía
 - Aproximación multidisciplinaria
 - Radioterapeuta
 - Neurocirujano
 - Físico Medico
 - Procedimiento de única fracción o 5 fracciones máximo
- La dosis total prescrita esta en el orden de 10-50Gy
- Los **blancos** de tratamiento son **pequeños**, por lo general de 1cm³ a 35cm³
- Los requerimientos de exactitud de posición y entrega de dosis son de **1mm** y **5%** respectivamente



Historia

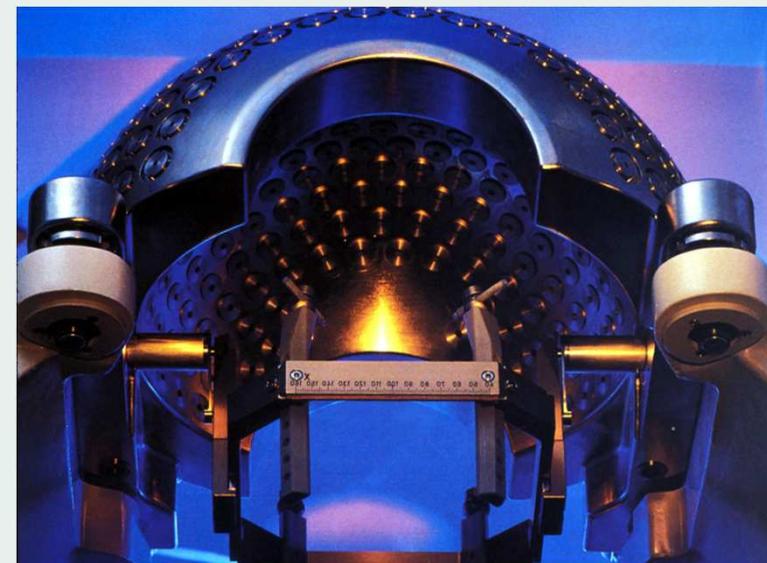
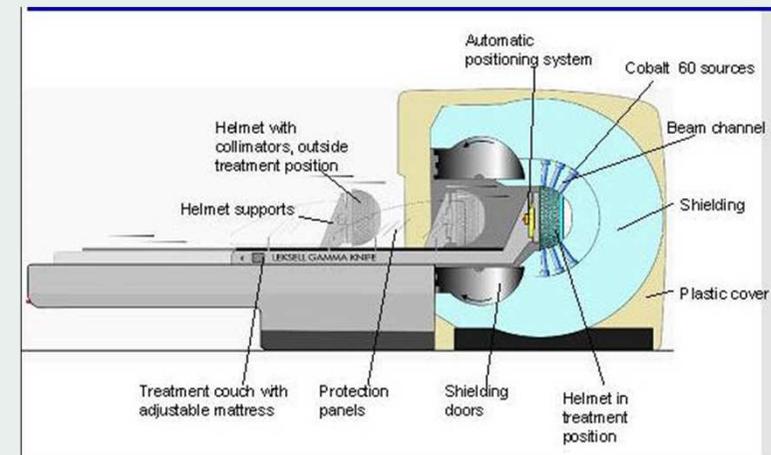
- Dr. Lars Leksell (1951) introduce **Radiocirugía** como el concepto de ablación de una lesión utilizando radiación en un procedimiento único como la cirugía
- Inicialmente utiliza un tubo de RX de 200kV
- 1968 desarrolla el “Gamma knife”
 - 179 fuentes de Co-60
 - Cavidad esférica de 60º x 160º



Gamma knife



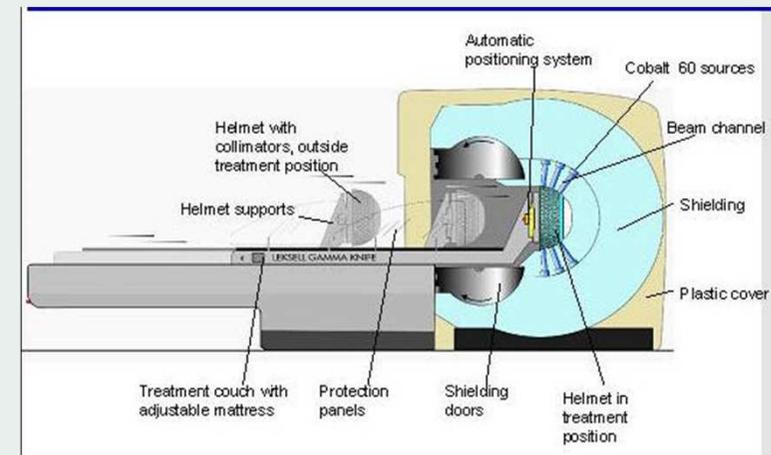
- Unidad que contiene 201 fuentes de Co-60 ubicadas en una hemiesfera y focalizadas en un punto focal común
- Exactitud isocentro < **0.5mm**
- Sistema colimadores de 4mm, 8mm, 14mm y 18mm (corresponde al diámetro de la isodosis del 50% medida en un fantoma de 16cm diámetro)
- Para blancos esféricos 1 isocentro



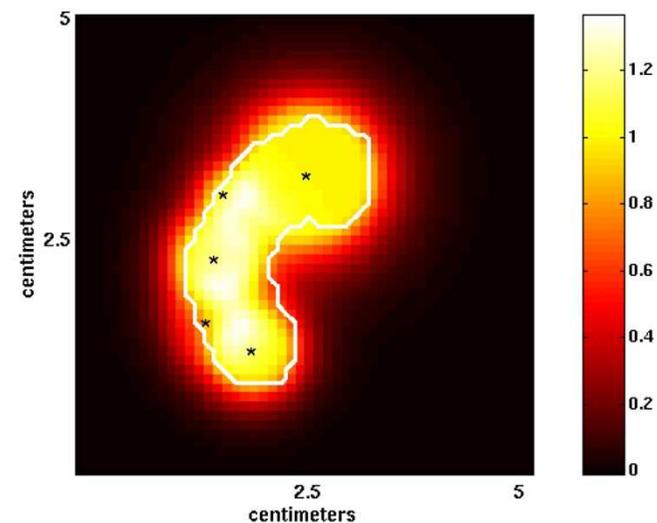
Gamma knife



- Unidad que contiene 201 fuentes de Co-60 ubicadas en una hemiesfera y focalizadas en un punto focal común
- Exactitud isocentro < 0.5mm
- Sistema colimadores de 4mm, 8mm, 14mm y 18mm (corresponde al diámetro de la isodosis del 50% medida en un fantoma de 16cm diámetro)
- Para **blancos irregulares** se utilizan múltiples disparos.



5 Shots



Nuevos conceptos

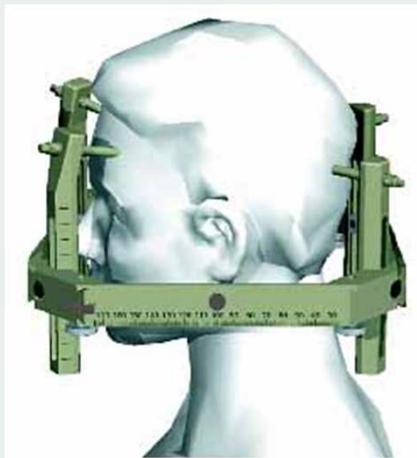
- **Conformidad:** Cociente entre volumen de la superficie de isodosis de prescripción (PI) y el volumen del blanco (TV)
- **Homogeneidad:** Cociente entre la dosis máxima (MD) y la dosis de prescripción (PD)
- **Gradiente dosis:** Cociente entre volumen de tratamiento (TV) y el volumen encerrado por la curva del isodosis del 50% ($V_{50\%}$)

	Conformidad (PI/TV)	Homogeneidad (MD/PD)	Gradiente (TV/ $V_{50\%}$)
Valor referencia	1 – 2	≤ 2	≥ 0.3
Desviación menor (aceptable)	> 0.9 y < 1 / > 2 y < 2.5	> 2 y ≤ 2.5	
Desviación mayor (inaceptable)	< 0.9 y ≥ 2.5	> 2.5	

Radiocirugía estereotáxica (SRS) – Radioterapia estereotáxica (SRT)

La Radiocirugía y la Radioterapia estereotáxica utiliza un **sistema estereotáxico** y **haces de radiación de alta energía** para la irradiación de un volumen.

- (1) Definir **exactamente la forma y localización** de un volumen en un sistema de referencia estereotáxico mediante imágenes.
- (2) Planificación y **entrega** de un plan de tratamiento.



SRS y SRT produce una **dosis de radiación** en el volumen de tratamiento con alto gradiente de caída de dosis fuera del mismo.

SRS - SRT

Definir exactamente la forma y localización de un volumen...
Entregar el plan de tratamiento prescripto...

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

+ otras fuentes

Stereotactic Radiosurgery, AAPM Report No. 54, 1995

Sistema de
Equipo de
tratamiento

Equipo de
adquisición de
imágenes

The screenshot shows a Yahoo! Finance page with a search bar and navigation links. The main content is a press release from BrainLAB dated Friday, June 15, 2006. The headline reads: "Specific Mechanical Component/Software Incompatibility Resulted in 1.25 mm Shift in Target Area Alignment in Radiosurgery Treatment". The text describes a mechanical component/software incompatibility that caused a 1.25 mm shift in target area alignment during radiosurgery treatment at two hospitals in the US. It mentions that seven hospitals worldwide have purchased this configuration, with six in clinical use (two in the US, four in France). The article notes that the shift was discovered during a custom-made test performed in addition to normal commissioning tests, and that the shift falls within accepted safety margins.



SRS - SRT

La **exactitud de la dosis absorbida requerida** en el volumen de tratamiento debe tener una incerteza menor al **5%**

D. 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.

Podgorsak, IAEA, 2007
AAPM Report 54, 1995



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USA TODAY ■ Home ■ News ■ Travel ■ Money ■ Sports ■ Life ■ Tech ■

News » **Health & Behavior** ■ Swine Flu ■ Your Health: Kim Painter ■ Weight Loss Challenge

Radiotherapy error could affect hundreds

Posted 6/14/2007 10:17 PM | Comment | Recommend

By Marco Chown Oved, Associated Press Writer

E-mail | Save | Print | **RSS**

The screenshot displays the BrainLAB iPlan RT Dose 4.1 software interface, which is used for radiation therapy treatment planning. The interface is divided into several main sections:

- Overview (Top Left):** Shows a 3D wireframe model of a patient's head and neck, with a target volume highlighted in orange.
- Slices (Top Right):** Displays a 2D axial slice of the target volume, showing its position relative to the patient's anatomy. The target is labeled "Group 1" and "Conf. Beam 1".
- Irradiation Plan (Bottom Left):** Shows a top-down view of the target volume, with a green beam line indicating the direction of the radiation beam.
- Plan Content (Bottom Right):** Displays a cross-sectional view of the target volume, showing the dose distribution. A color scale on the right indicates the dose percentage, ranging from 0.0% (blue) to 100.0% (red). The target volume is labeled "CT #1 (Axial) Slice 49 / 85".

On the right side of the interface, there is a **Navigator** panel with the following information:

- QA IMRS - DOSIS CAMARA 2
- ID: QA IMRS
- Contornos
- Treatment Planning (highlighted)
- Physician's Review
- Go to... Next

Below the Navigator panel is the **Functions** and **Prescription** panel, which includes:

- 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

At the bottom of the interface, there are four tabs: Overview, Slices, Irradiation Plan, and Plan Content. The BrainLAB logo and version number "iPlan RT Dose 4.1" are visible in the bottom right corner.

Group: Group 1
Name: Conf. Beam 2

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!)

CT #1 (Axial)
Slice 49 / 85

Pencil Beam
Display: Adaptive

100.0% 0
100.00 G_{1mm}

Overview Slices Irradiation Plan Plan Content

BrainLAB
iPlan RT Dose 4.1

Group: Group 1
Name: Conf. Beam 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

Group: Group 1
Name: Conf. Arc 1

Gantry: 210°

CT #1 (Axial)
Slice 49 / 85

Pencil Beam: 50
PB: 10"
Display: Adaptive

100.0% 0
100.00 0mm

Overview | Slices | Irradiation Plan | Arc BEVs | 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

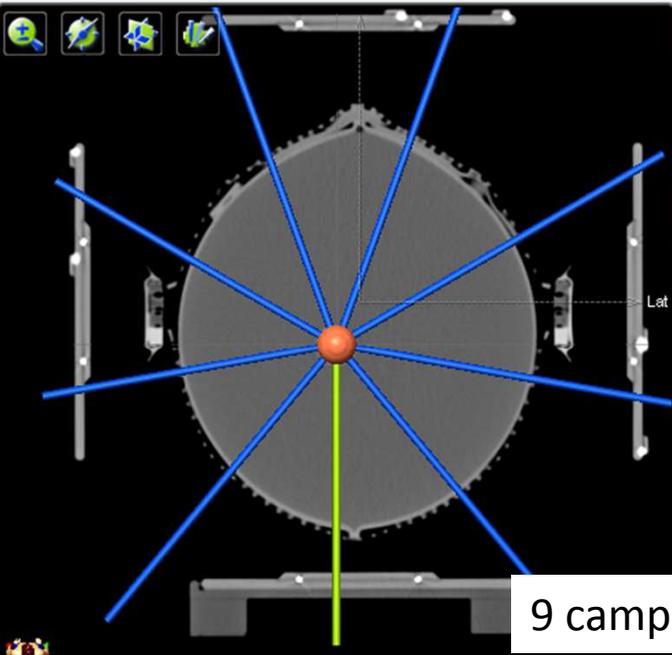
Properties

Plan Templates

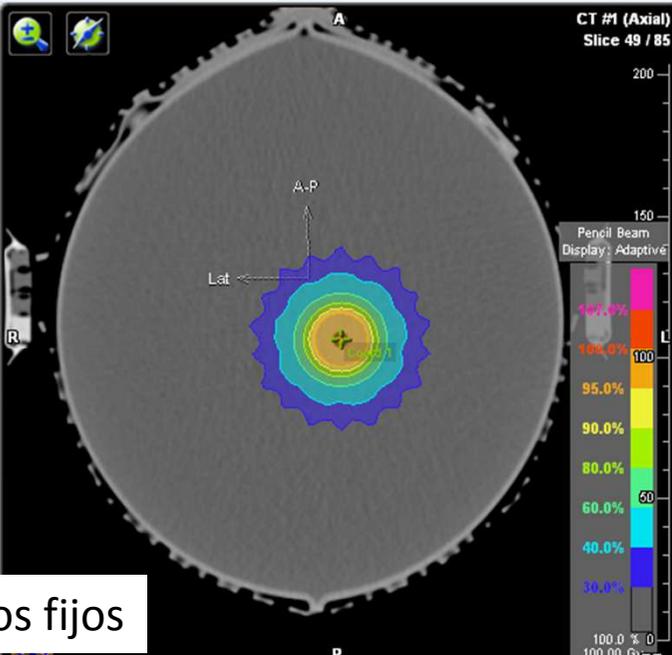
Save as new Manage

Shape Export

Create Varian MLC file(s)



9 campos fijos



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

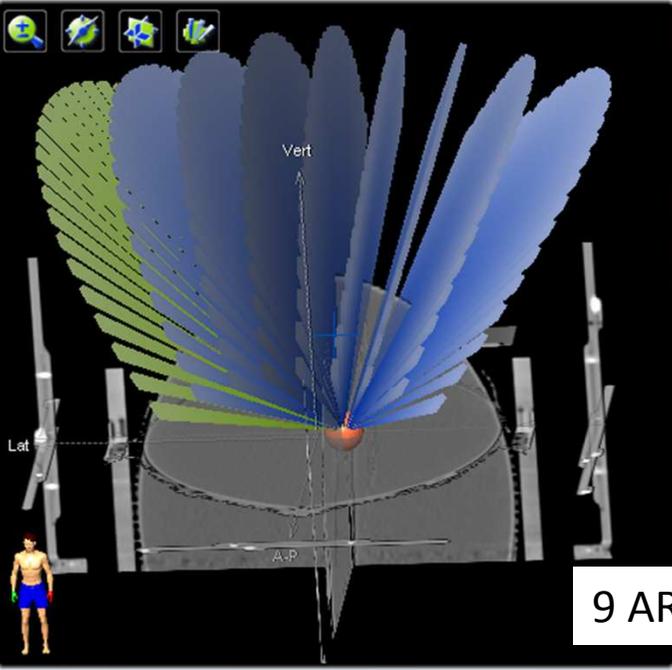
Properties

Plan Templates

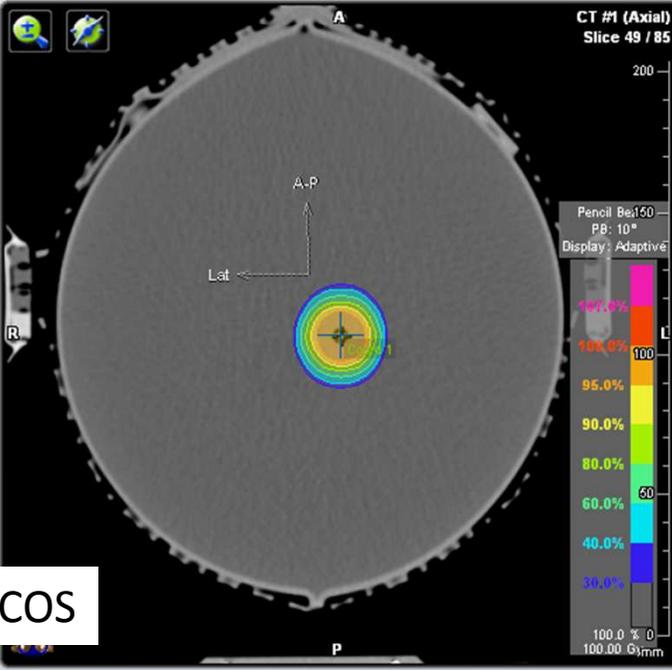
Save as new Manage

Shape Export

Create Varian MLC file(s)

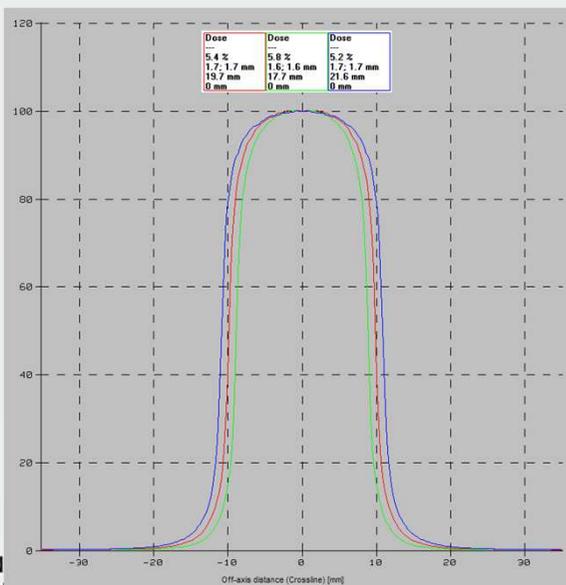


9 ARCOS



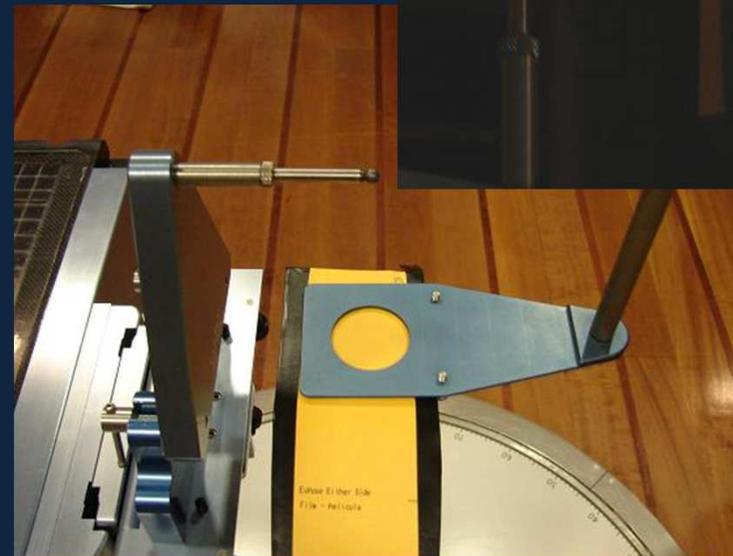
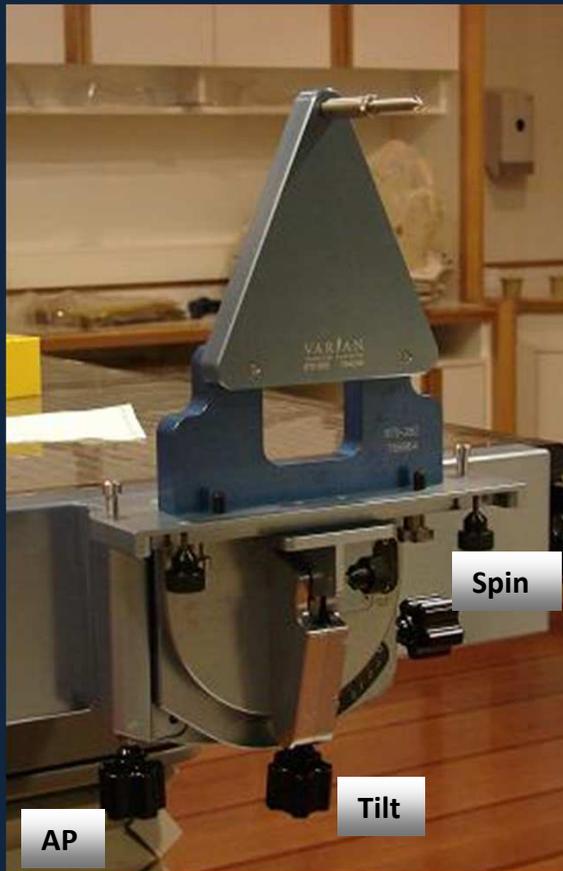
Radiocirugía con Linac + conos

- Conjunto de colimadores cónicos de 5-40mm de diámetro
- Proyección de haz circular
- Ajuste sobre soporte en colimador



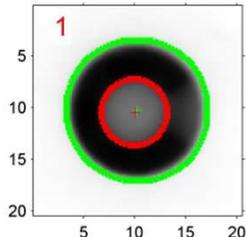
Precisión mecánica

- Control de calidad de sistema óptico
- Verificación de isocentro de **gantry** (Conos)

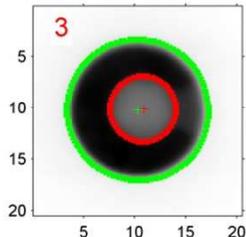


Precisión mecánica

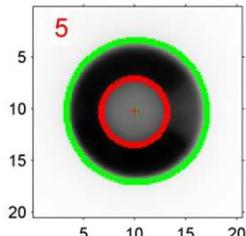
Ball Centroid: Row = 62.22, Column = 59.38
 Cone Centroid: Row = 60.87, Column = 60.66
 Distance = 1.86 pixels, 0.35 mm



Delta X = -1.28 pixels, -0.24 mm
 Delta Y = 1.35 pixels, 0.25 mm
 Ball Centroid: Row = 60.20, Column = 64.43
 Cone Centroid: Row = 60.58, Column = 61.11
 Distance = 3.34 pixels, 0.62 mm

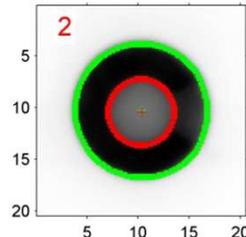


Delta X = 3.32 pixels, 0.62 mm
 Delta Y = -0.38 pixels, -0.07 mm
 Ball Centroid: Row = 60.64, Column = 59.42
 Cone Centroid: Row = 60.63, Column = 60.49
 Distance = 1.07 pixels, 0.20 mm

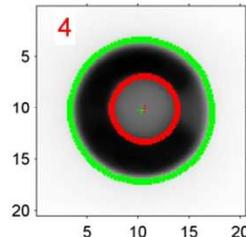


Delta X = -1.07 pixels, -0.20 mm
 Delta Y = 0.01 pixels, 0.00 mm

Ball Centroid: Row = 61.96, Column = 61.32
 Cone Centroid: Row = 61.07, Column = 61.16
 Distance = 0.90 pixels, 0.17 mm



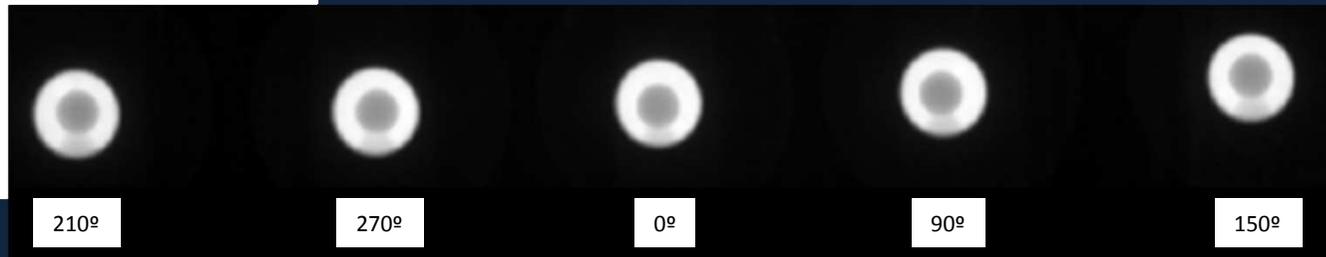
Delta X = 0.16 pixels, 0.03 mm
 Delta Y = 0.88 pixels, 0.16 mm
 Ball Centroid: Row = 59.57, Column = 63.07
 Cone Centroid: Row = 61.04, Column = 61.16
 Distance = 2.42 pixels, 0.45 mm



Delta X = 1.91 pixels, 0.36 mm
 Delta Y = -1.48 pixels, -0.27 mm

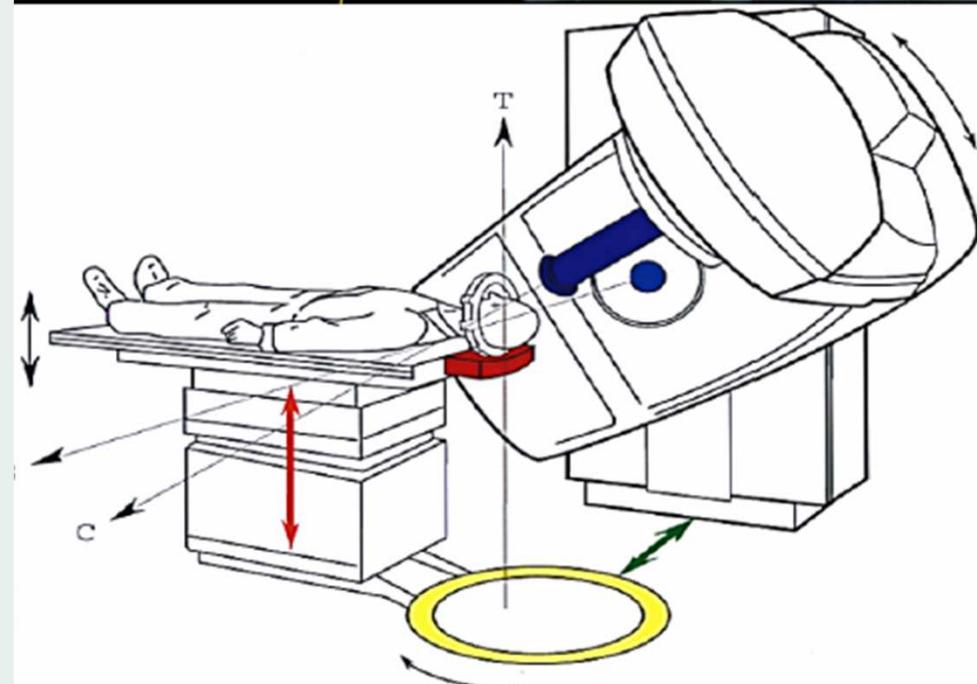
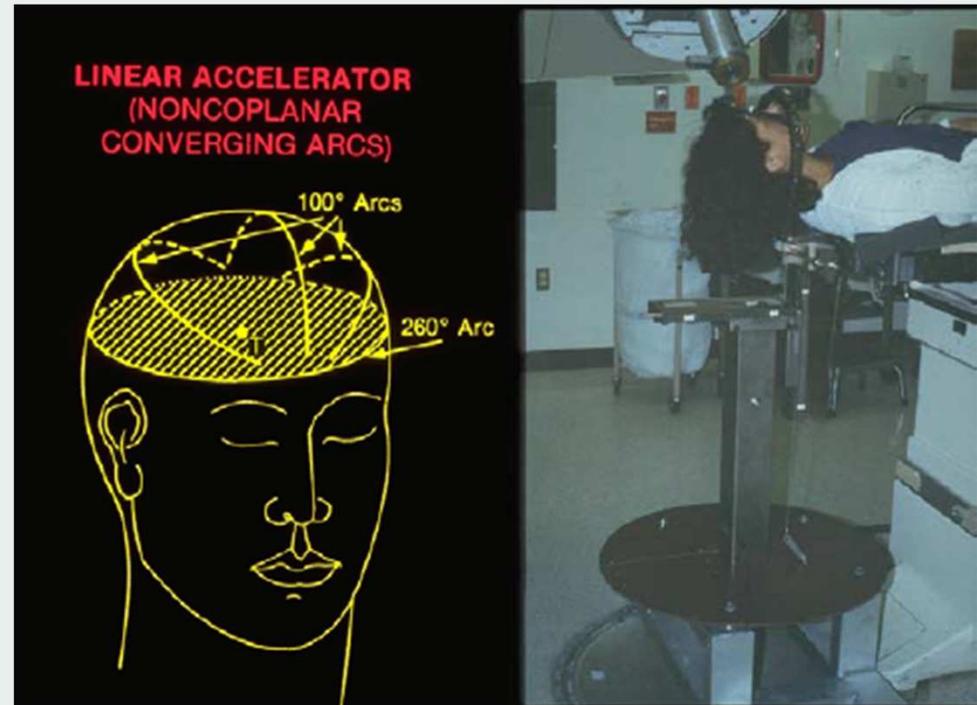
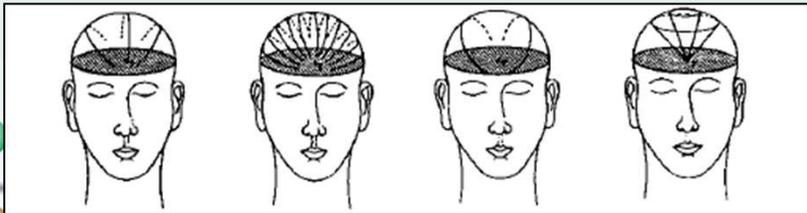
Angulo gantry	210°	270°	0°	90°	150°
ΔGT (mm)	0.25	0.03	0.62	0.36	0.20
ΔAB (mm)	0.24	0.15	0.07	0.27	0.0
Vector (mm)	0.35	0.15	0.62	0.45	0.20

AAPM TG42 Tolerancia = 1mm



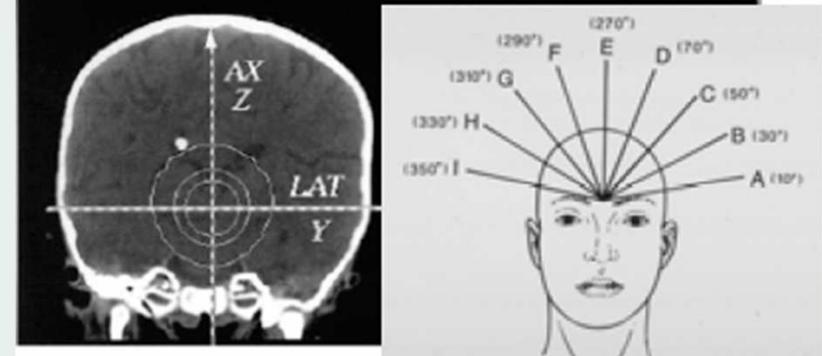
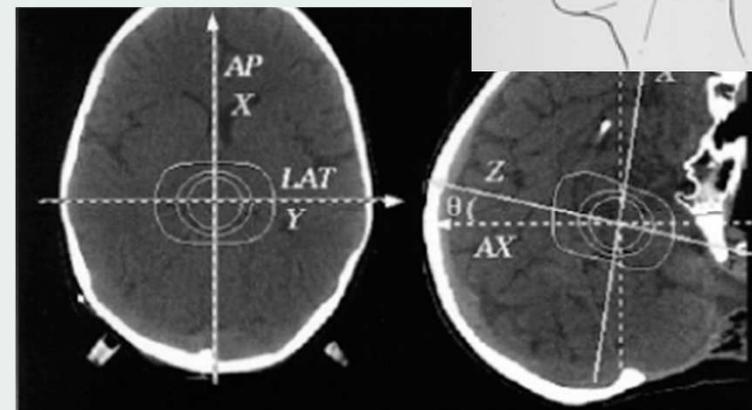
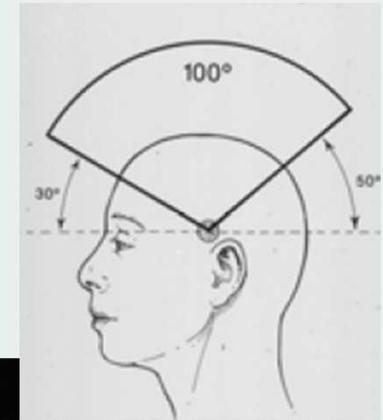
Radiocirugía con Linac + conos

- **Isocentro único o múltiples**
- **Múltiples arcos por isocentro**
 - Arcos de 100° a 160°
 - Angulo de mesa fijo para cada arco
 - Distribuciones de dosis esféricas para cada irradiación



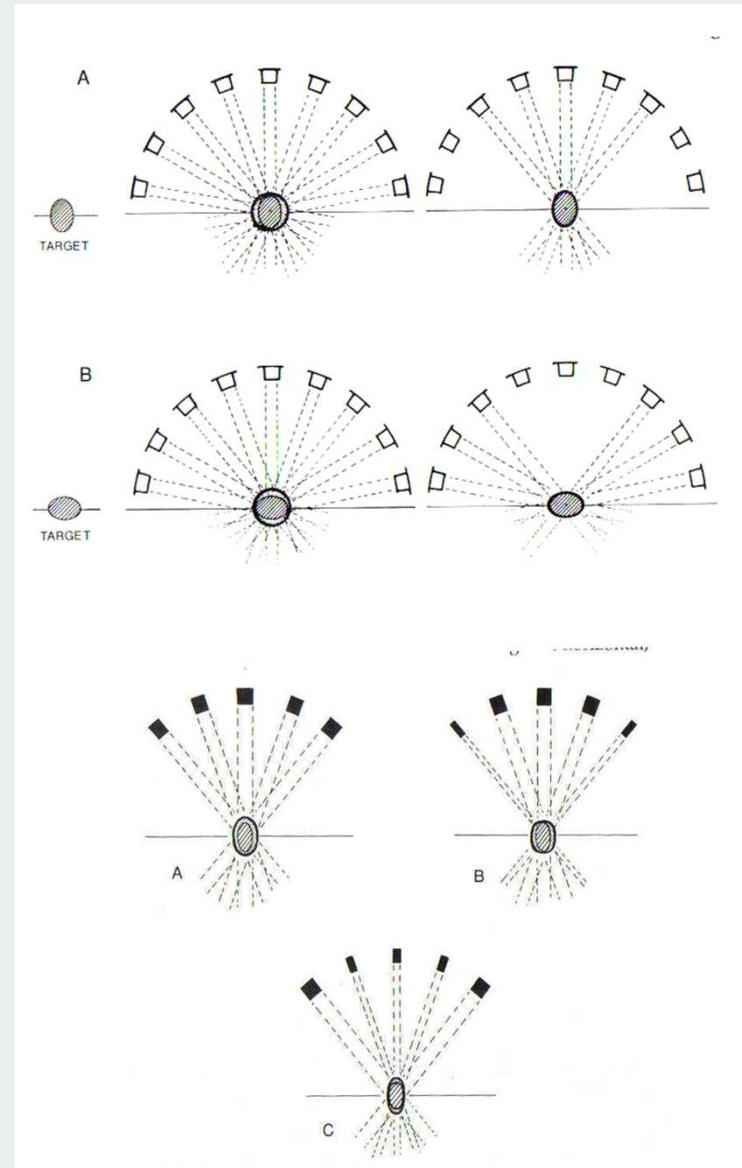
Conceptos básicos de planificación con conos

- **9 set de arcos** (Técnica Universidad de Florida)
- Distribución de dosis esférica
- Diámetro distribución similar al diámetro del colimador
- Arcos sagitales igualmente espaciados
- Arcos de 100
- Rotación de mesa 20
- **Distribución similar puede ser obtenida con 5 set de arcos**



Conceptos básicos de planificación con conos

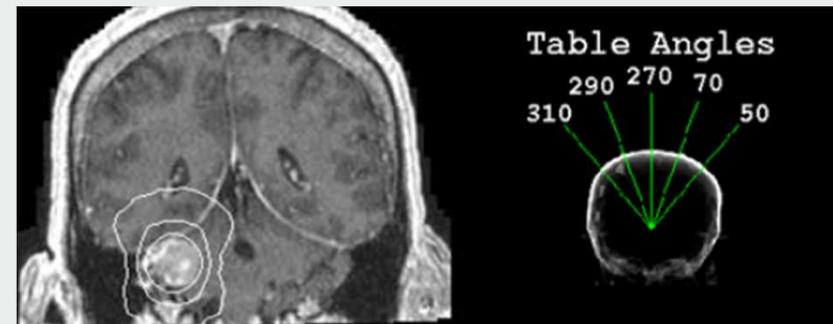
- **Blancos elipsoidales** pueden obtenerse a partir de la plantilla básica modificando
 - Tamaño de colimador
 - Angulo de inicio de arcos
 - Angulo de parada de arcos
 - Eliminación de arcos



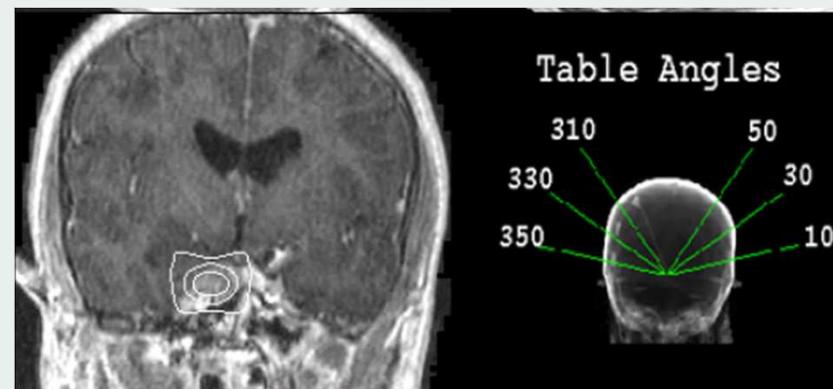
Conceptos básicos de planificación con conos

- **Blancos elipsoidales** pueden obtenerse a partir de la plantilla básica modificando
 - Tamaño de colimador
 - Angulo de inicio de arcos
 - Angulo de parada de arcos
 - Eliminación de arcos
 - Elongación SUP-INF (1)
 - Incremento LATERAL (2)

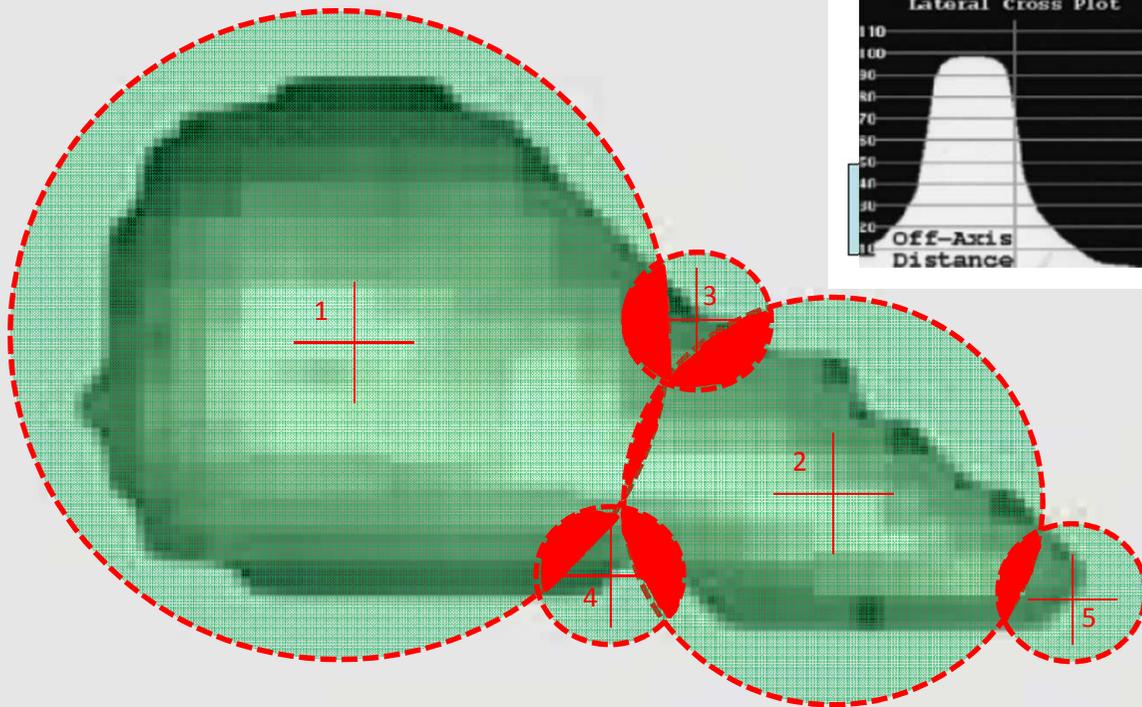
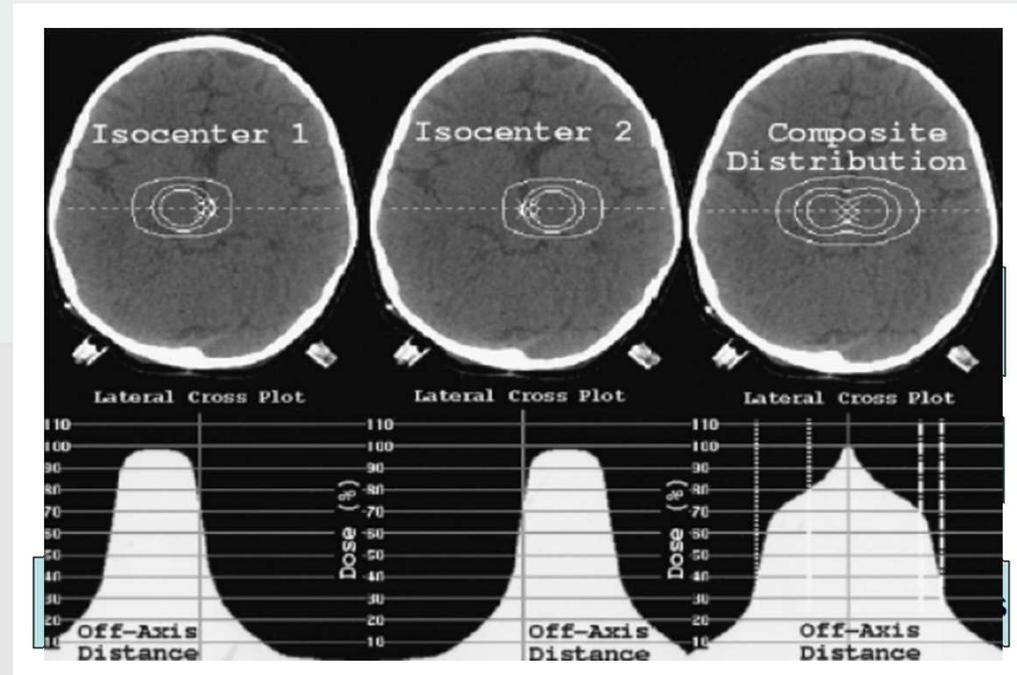
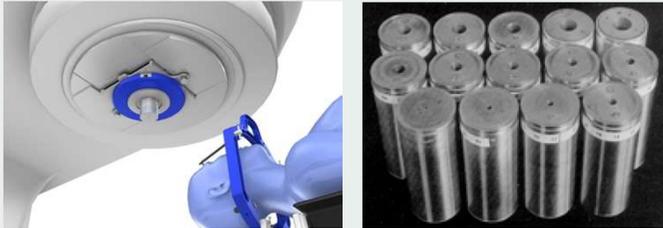
1.



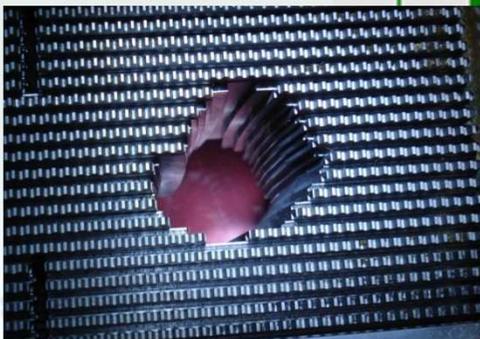
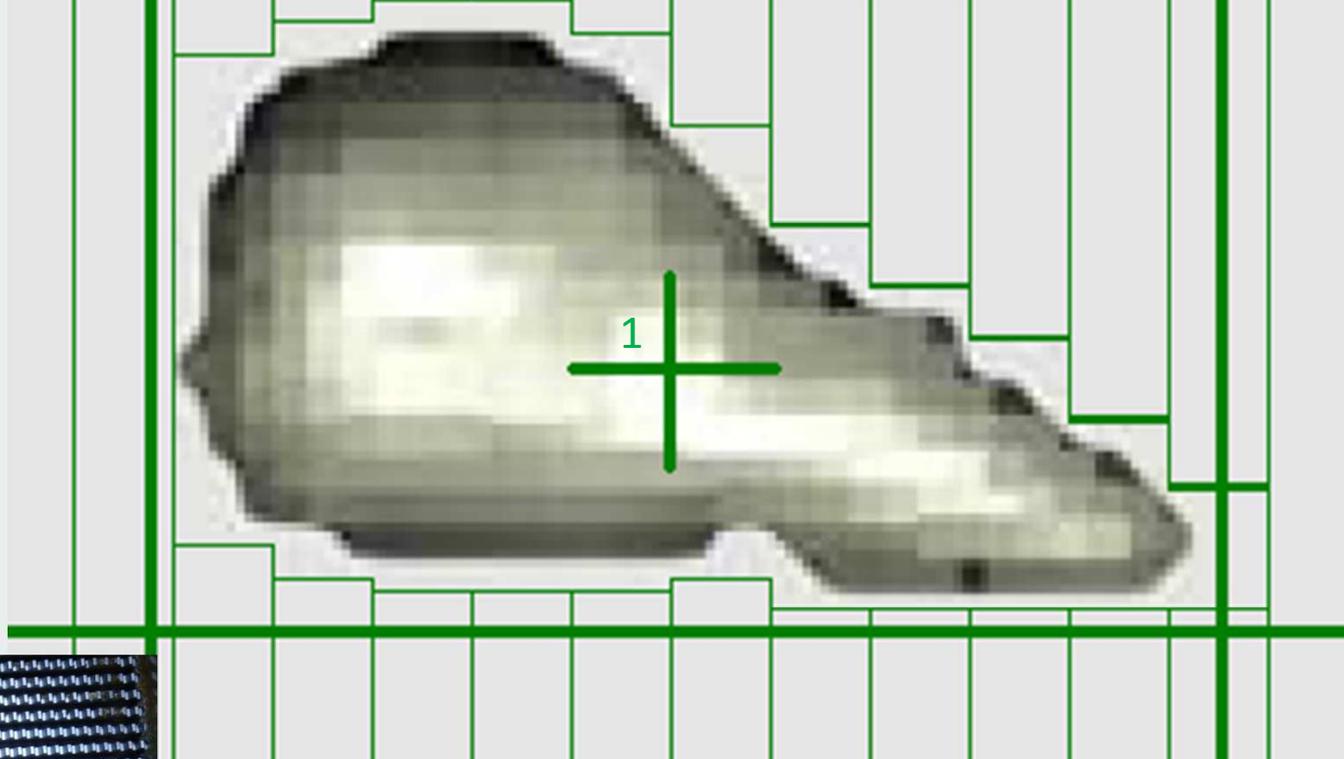
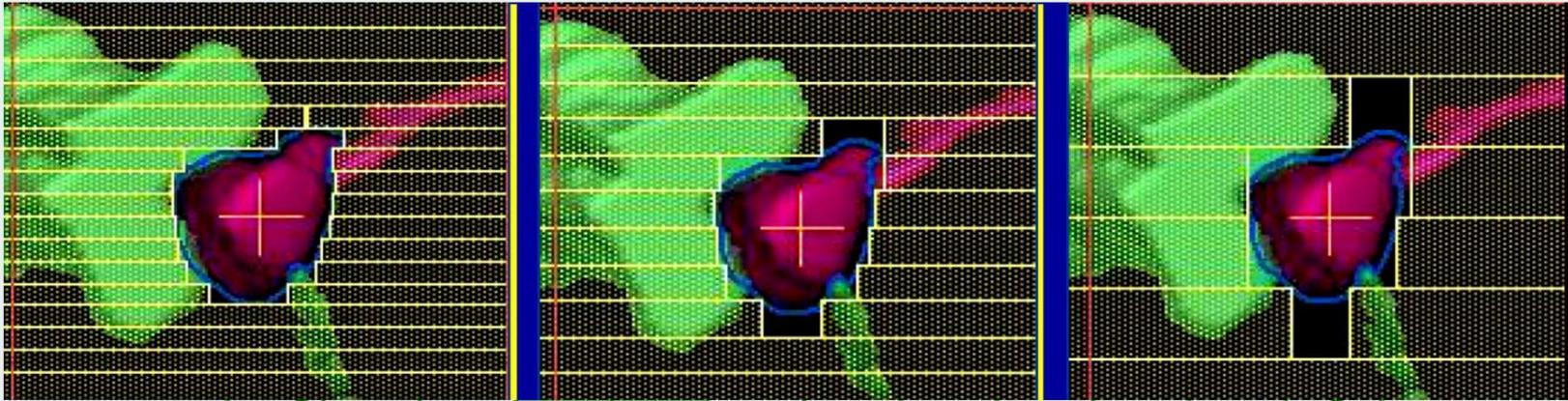
2.



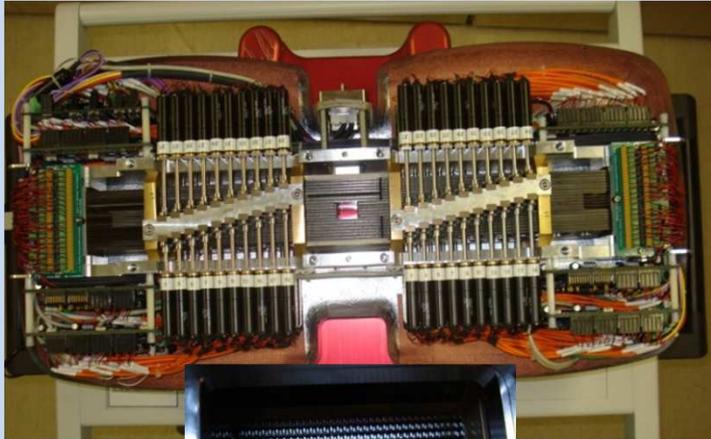
Conceptos básicos de planificación con conos



- Coloque isocentro 1 en la parte mayor del tumor y utilice set de 5 arcos
- Coloque isocentros adicionales cubriendo el blanco
- Verifique distancia entre isocentros ($0.55 \times \sum d_s$)
- Verifique distribución de dosis



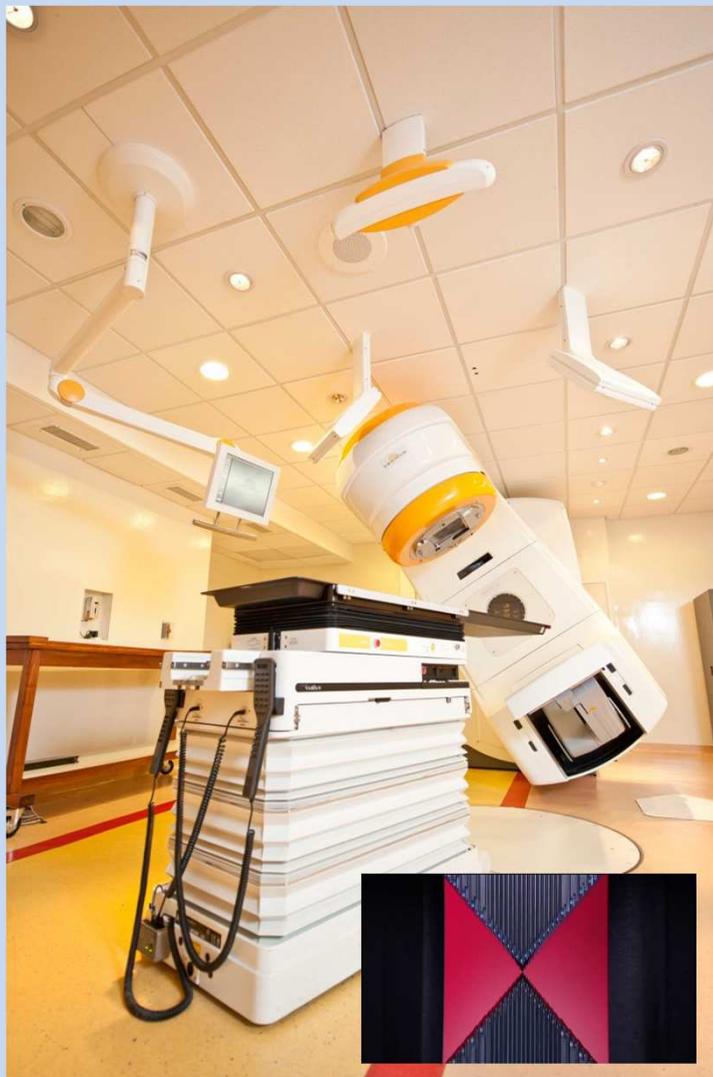
Aumento en el ancho de lamina =>
aumento del volumen de tejido sano



Micro MLC (mMLC)

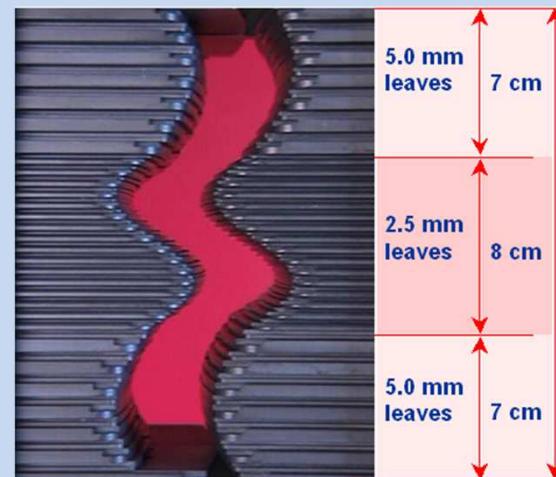
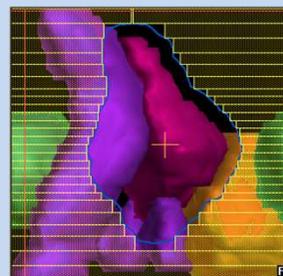
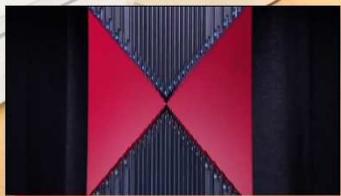
- Sistema sujeto al colimador
- MODULEAF, Siemens
 - 80 laminas (tungsteno)
 - Peso **40Kg** (montaje con carro)
 - Ancho de laminas en isocentro **2.5 mm**
 - Exactitud de posicionamiento **0.5 mm**
 - Penumbra 2.5 – 3.5mm
 - Transmisión < 2.5%
 - Tamaño de campo máximo **12 x 10 cm²**





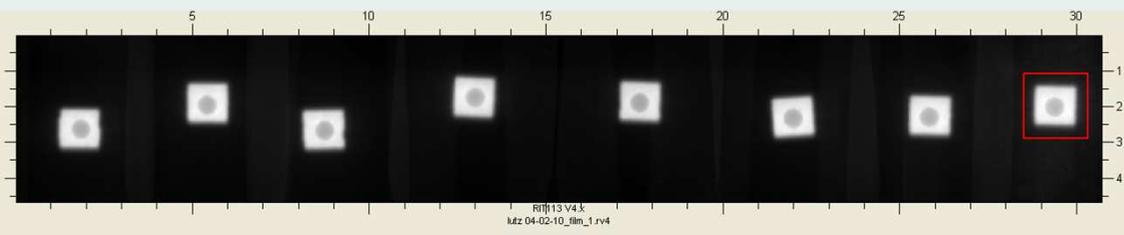
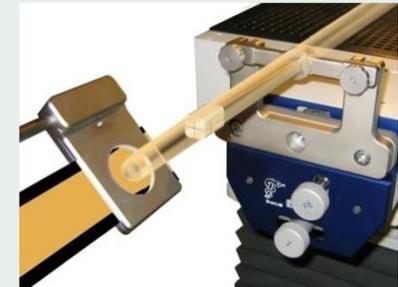
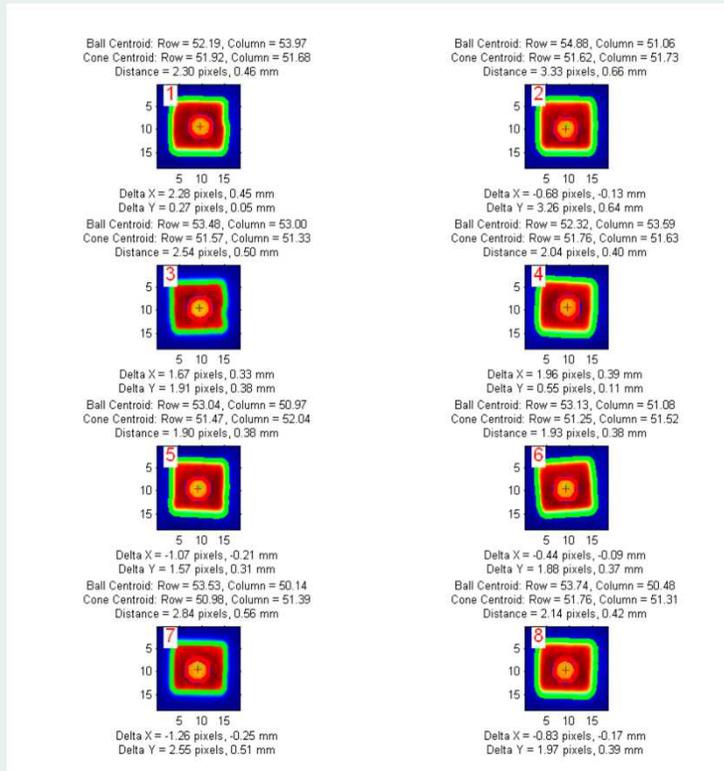
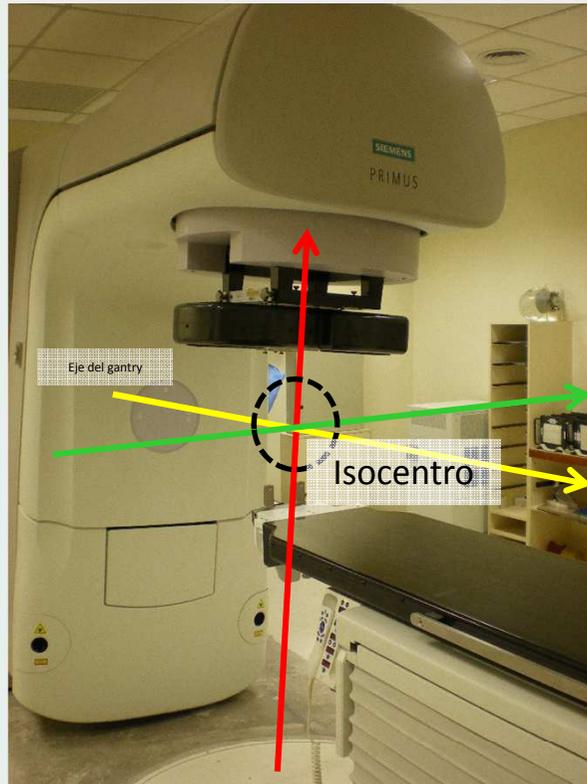
HD MLC – Novalis TX

- **120** laminas (tungsteno)
- Integrado
- Ancho de laminas en isocentro
 - **2.5 mm – 8cm**
 - **5 mm**
- Exactitud de posicionamiento **0.5 mm**
- Penumbra <2mm
- Transmisión < 1.5%
- Tamaño de campo máximo **22 x 40 cm²**



Exactitud isocéntrica

Test Winston - Lutz

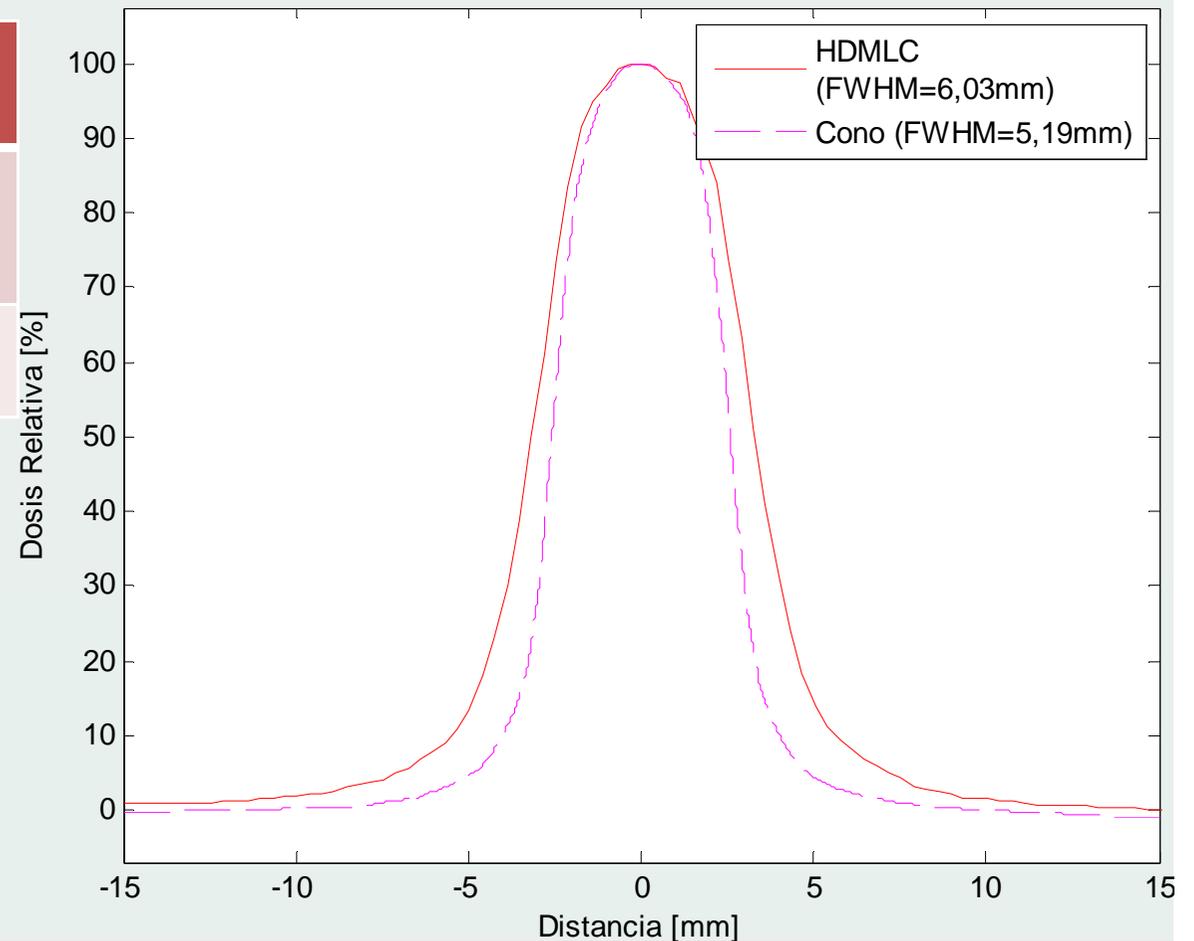


Comparación Sistema HDMLC vs. CONOS



Perfiles - Comparación Sistemas de Colimación - Campo 5mm x 5mm

HDMLC Campo 5 x 5 mm ²	CONO 5 mm
Penumbra	Penumbra
1,9 mm	1,4 mm

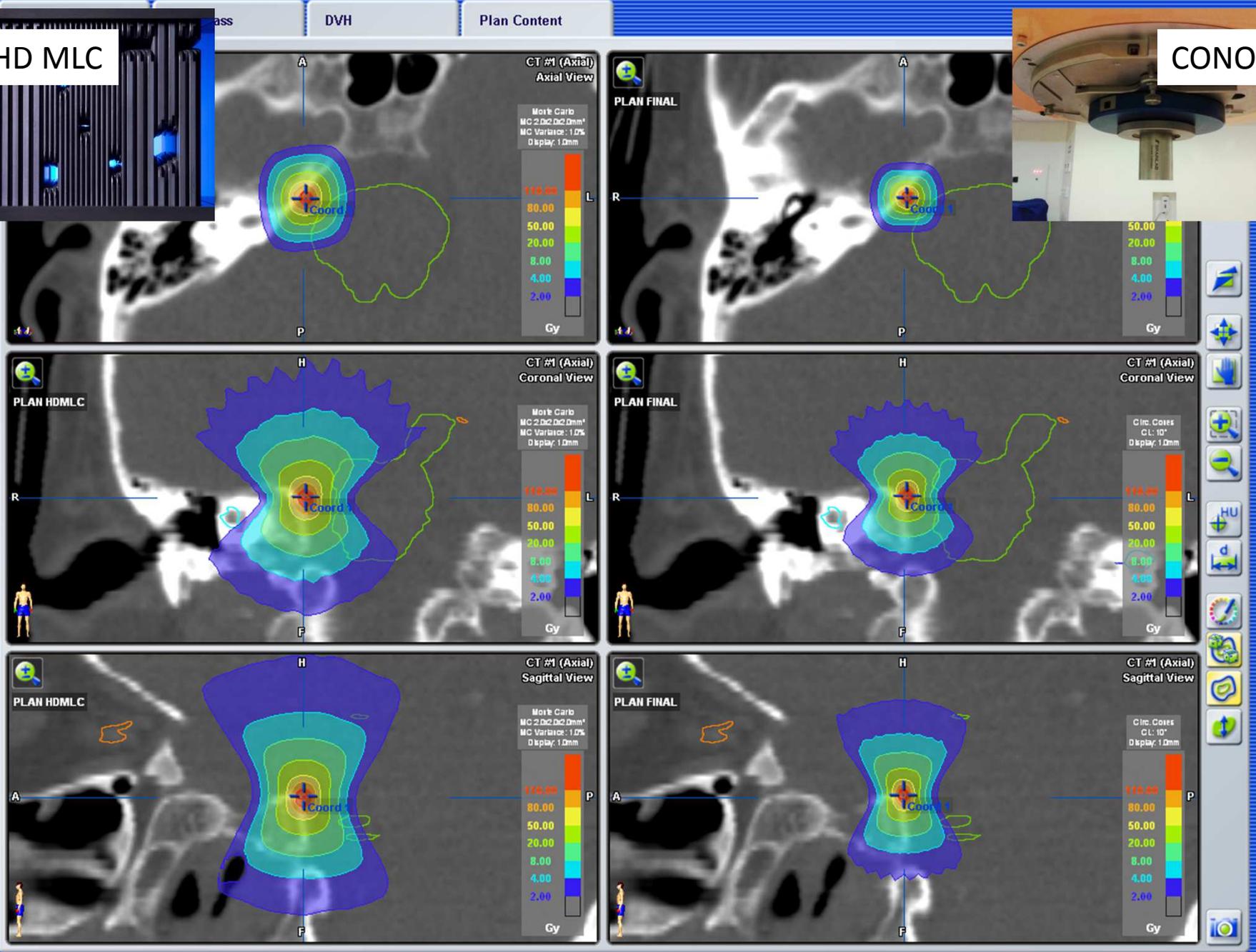




HD MLC



CONO



Close

Dual Reconst

Spy Glass

DVH

Plan Content



Outer plan: PLAN HDMLC
Inner plan: PLAN FINAL

CT #1 (Axial)
Slice 116 / 180

R

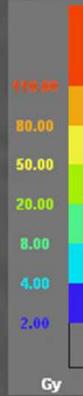
A

HD MLC

Coord 1

CONO

Monte Carlo
MC: 2.0x2.0x2.0mm³
MC Variance: 1.0%
Display: 1.0mm



P

Close

Dual Reconst

Spy Glass

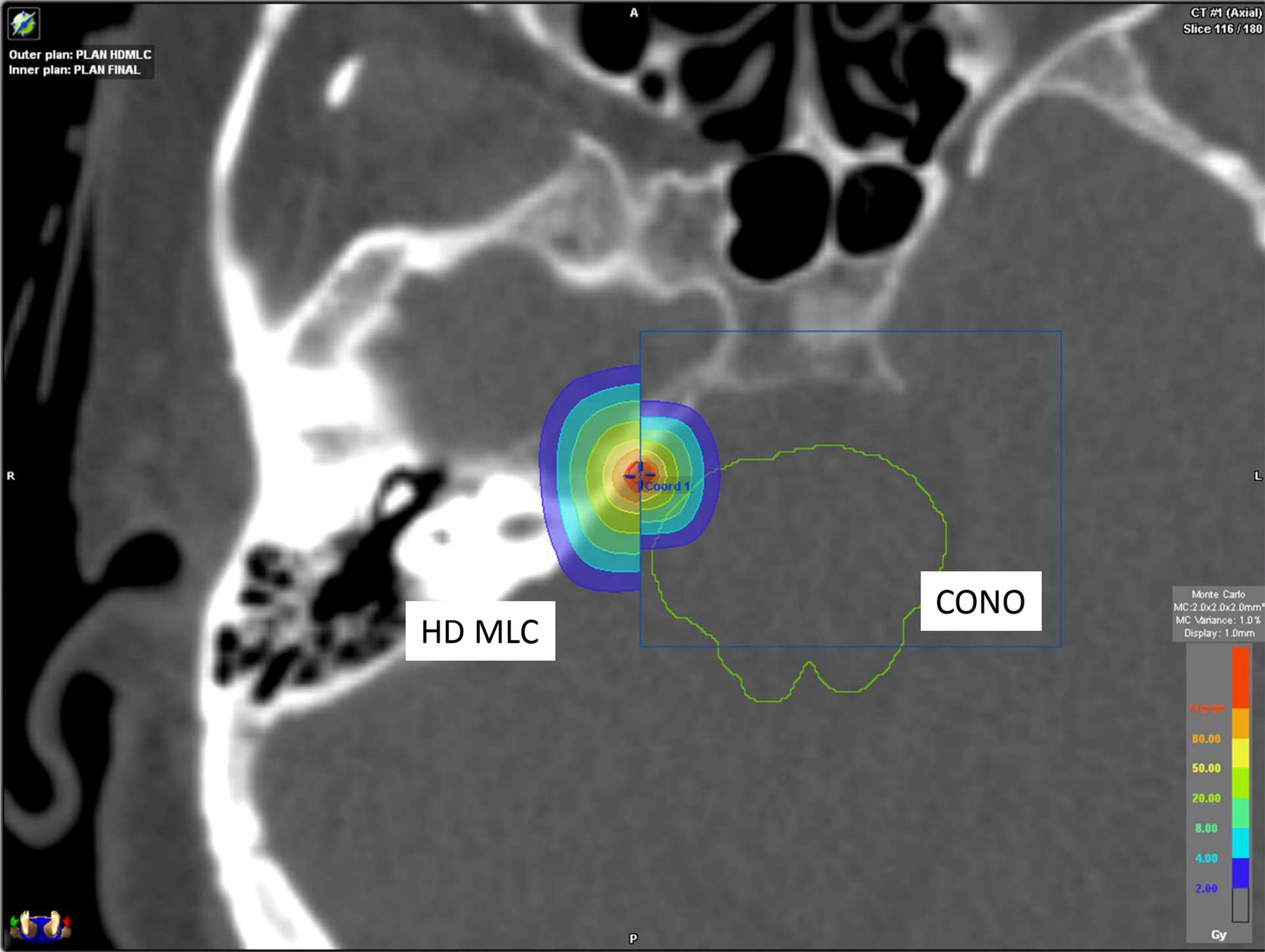
DVH

Plan Content

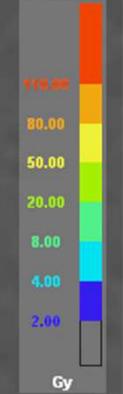


Outer plan: PLAN HDMLC
Inner plan: PLAN FINAL

CT #1 (Axial)
Slice 116 / 180



Monte Carlo
MC: 2.0x2.0x2.0mm³
MC Variance: 1.0%
Display: 1.0mm



Close

Dual Reconst

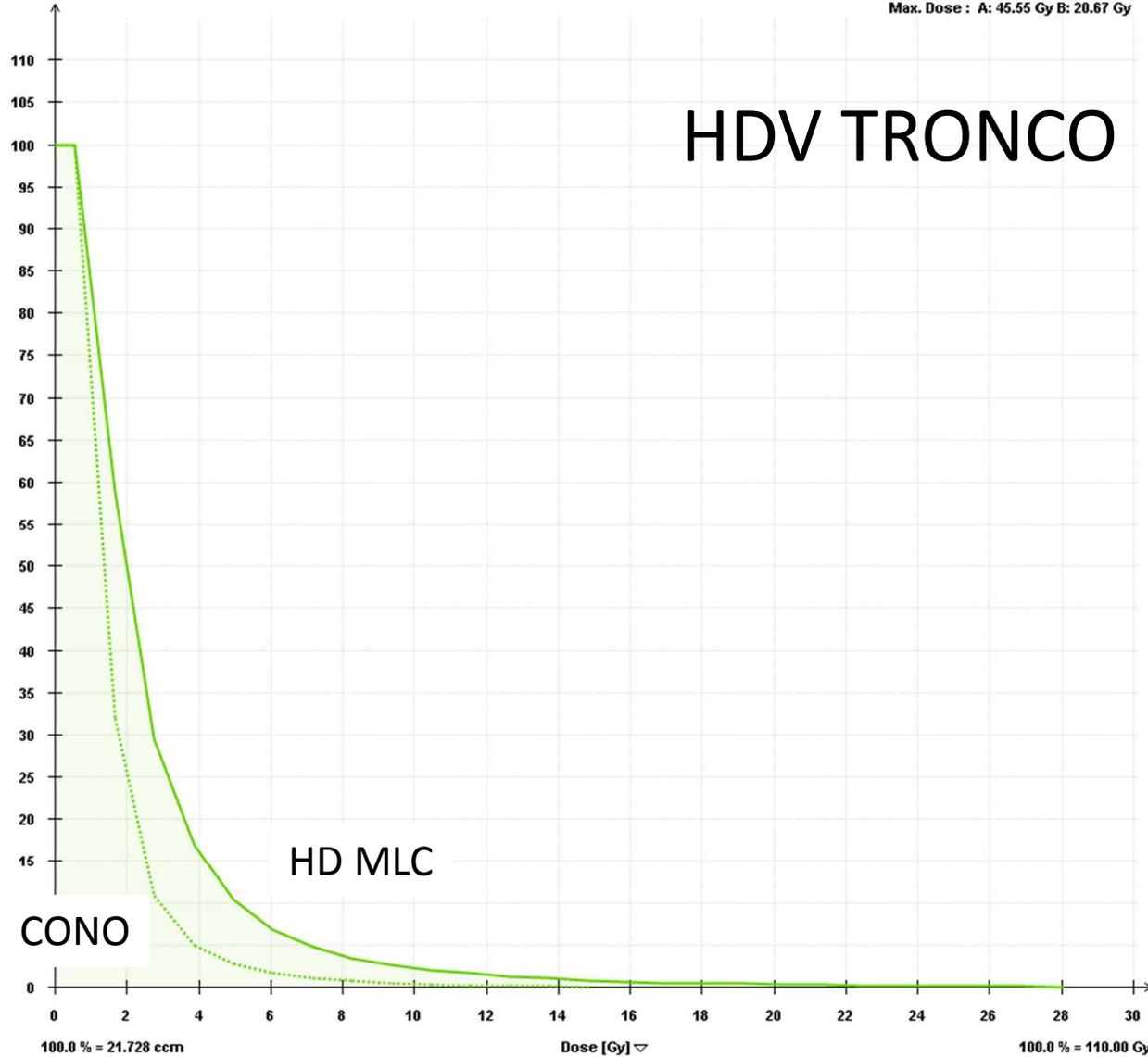
Spy Glass

DVH

Plan Content

A (solid): PLAN HDMLC
Volume [%] ▾

Min. Dose : A: 0.12 Gy B: 0.00 Gy
Mean Dose : A: 2.08 Gy B: 1.00 Gy
Max. Dose : A: 45.55 Gy B: 20.67 Gy



CONO

HD MLC

HDV TRONCO

100.0 % = 21.728 cm
Gridsize : 1.00 mm

Dose [Gy] ▾
Monte Carlo : 1.0%;2.0x2.0x2.0mm³

100.0 % = 110.00 Gy

Objects

Select single / multiple Item(s) or Group ▾

1 CTV	PTV
Coclea der	Other
Tronco	Other
Via Optica	Other
Tissue	
Normal Tissue	

Display Options

- Normal Tissue Graph
- Differential DVH
- Interpolate Graph
- Show Constraints

Calculation

Grid Size: mm

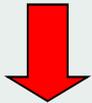
- Finer for Small Objects

Recalc

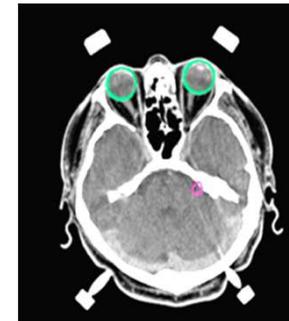
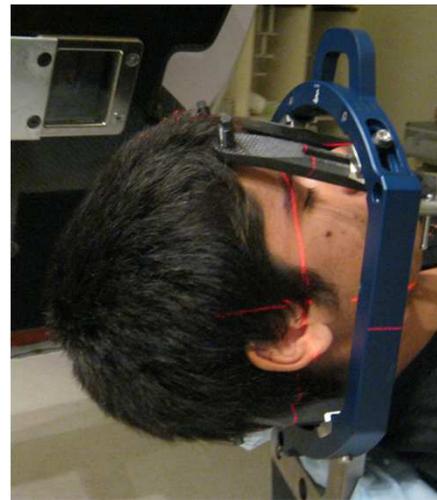
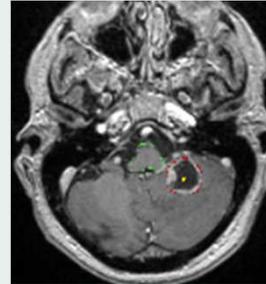
Export to Clipboard

Close

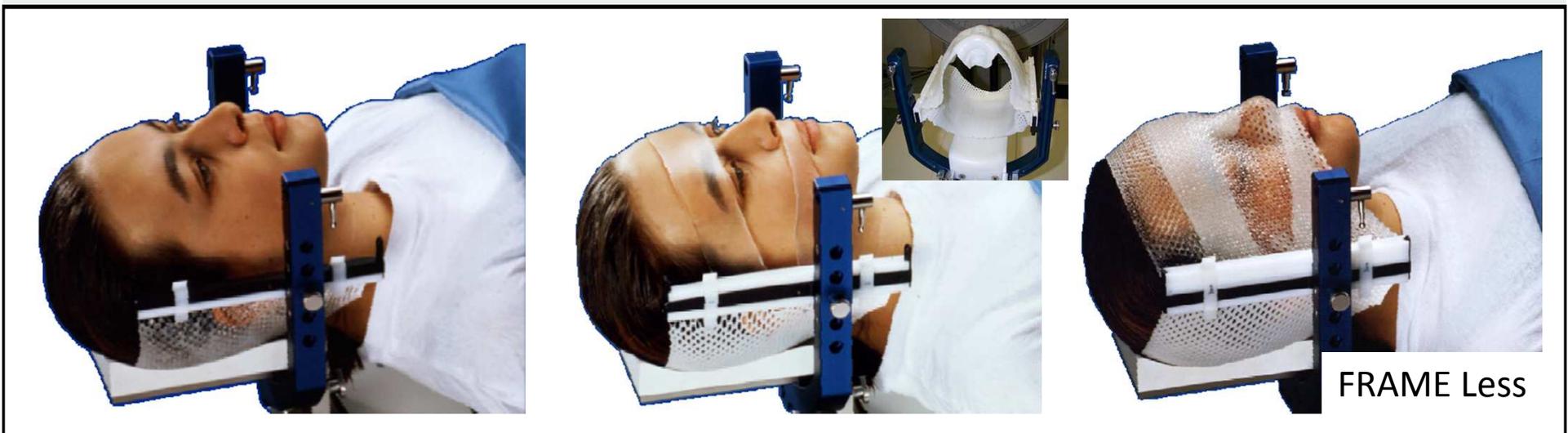
Imágenes de Resonancia



Preparación del paciente



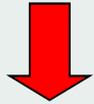
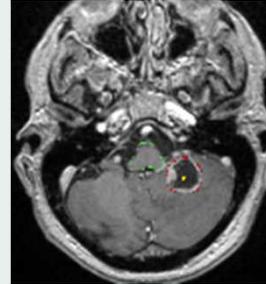
FRAME



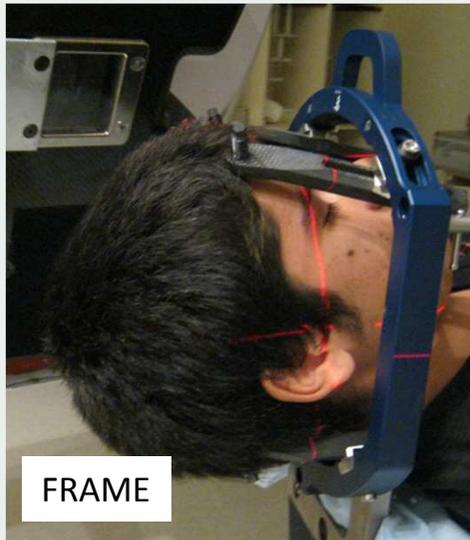
FRAME Less

Procedimiento

Imágenes de Resonancia



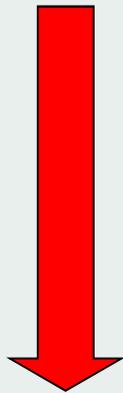
Preparación del paciente



FRAME



FRAME Less



Imágenes estereotácicas (TAC)

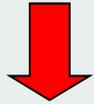
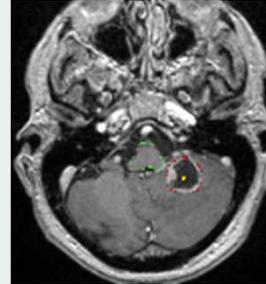


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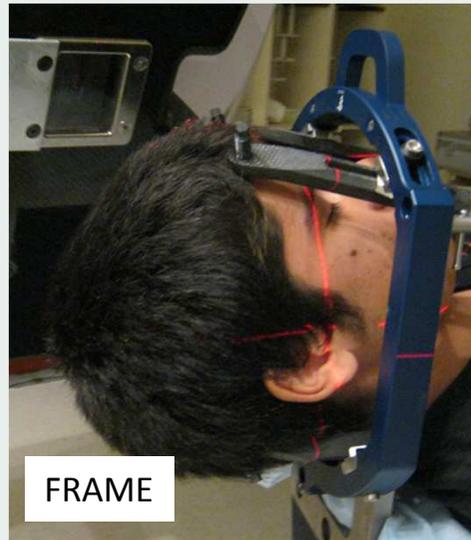


Procedimiento

Imágenes de Resonancia



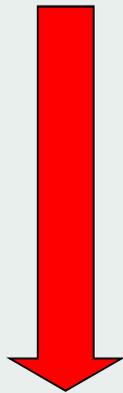
Preparación del paciente



FRAME



FRAME Less



Imágenes estereotácicas (TAC)

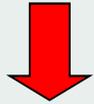
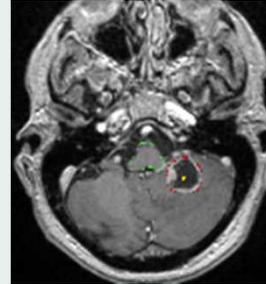


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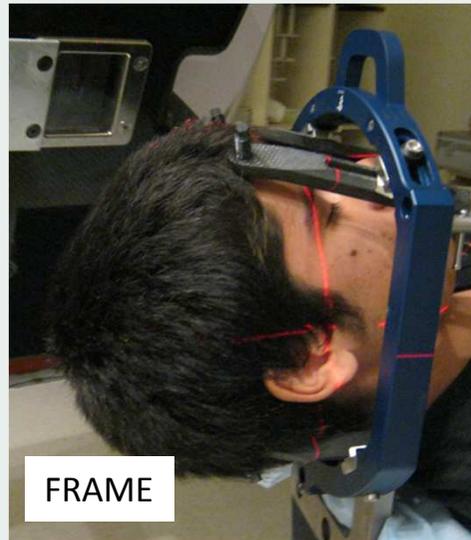


Procedimiento

Imágenes de Resonancia



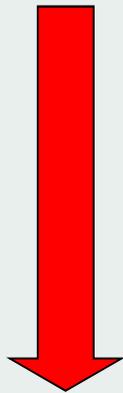
Preparación del paciente



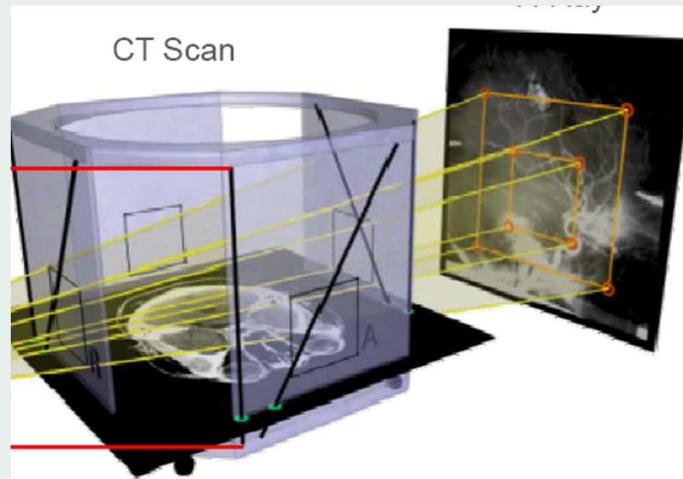
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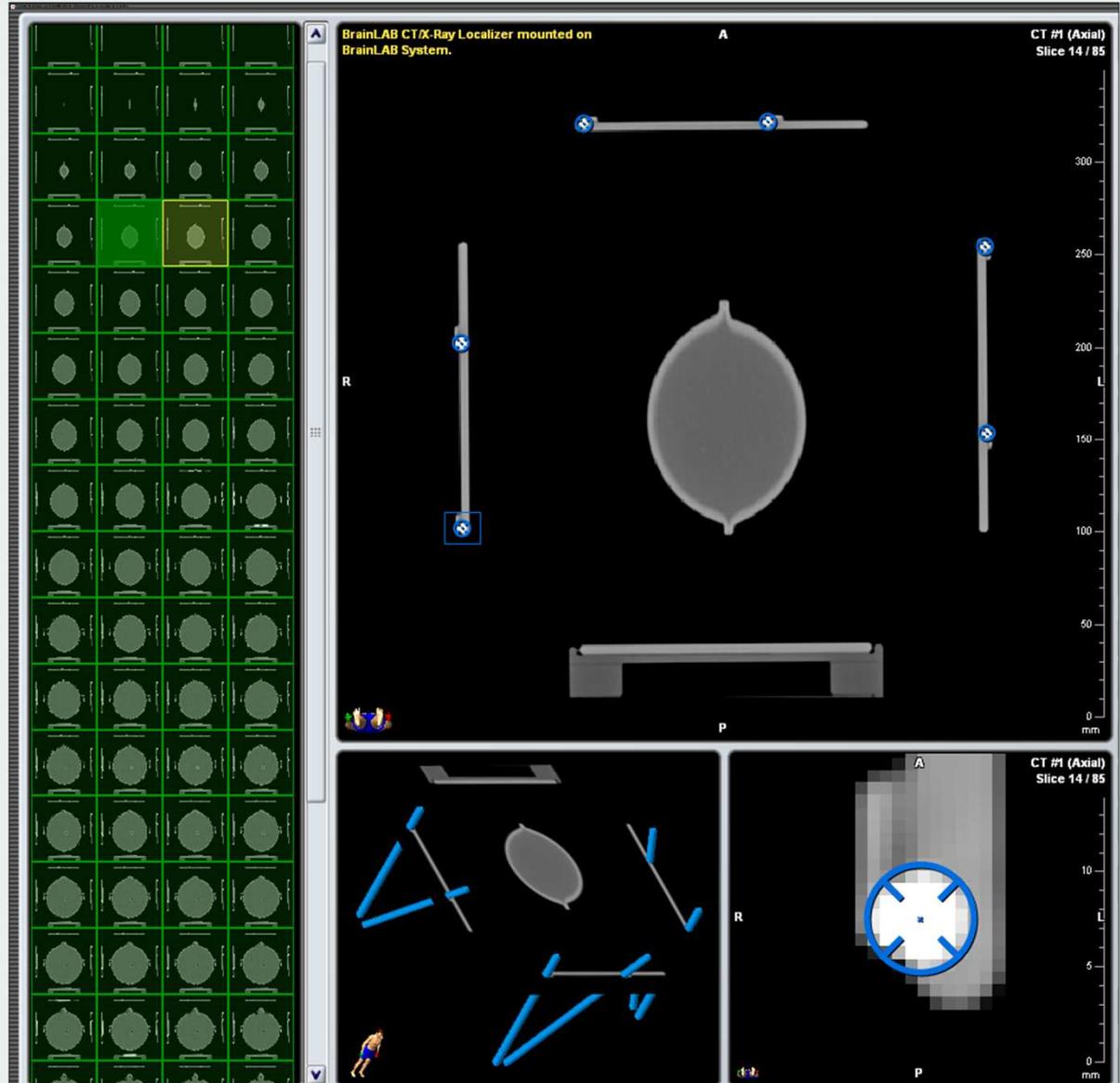
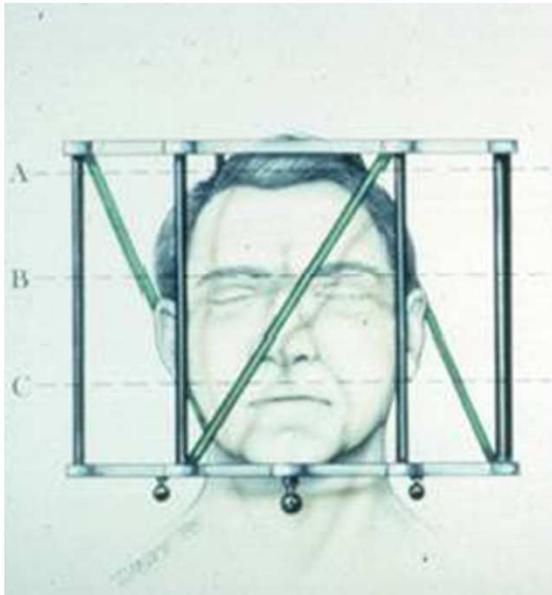
FRAME Less



Imágenes estereotáxicas (angiografía)

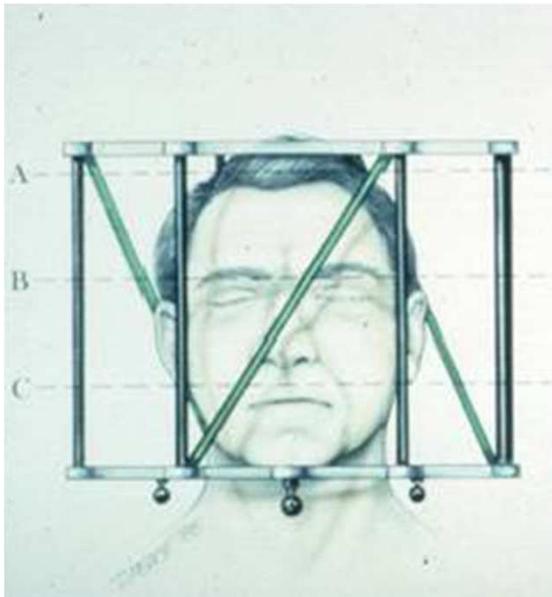


Imágenes estereotáxicas: marco localizador

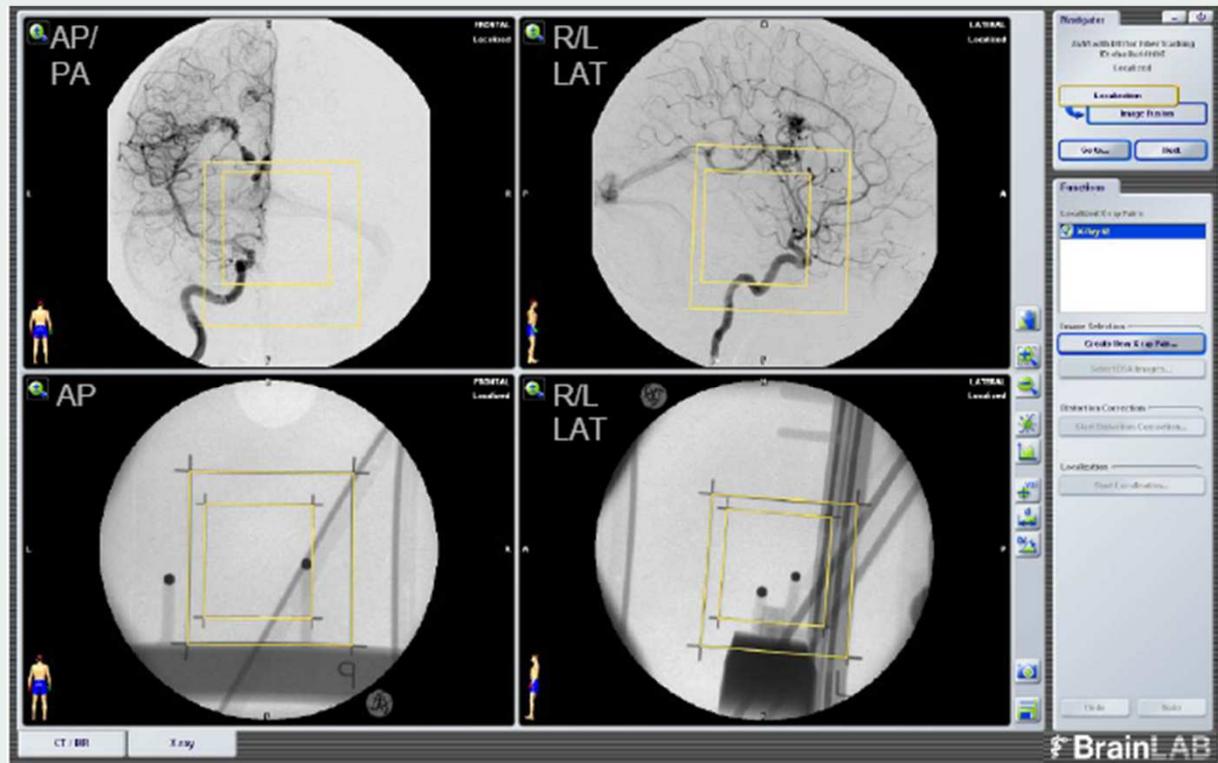


TAC

Imágenes estereotáxicas: marco localizador

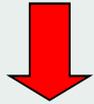


Angiografía

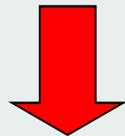


Procedimiento

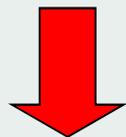
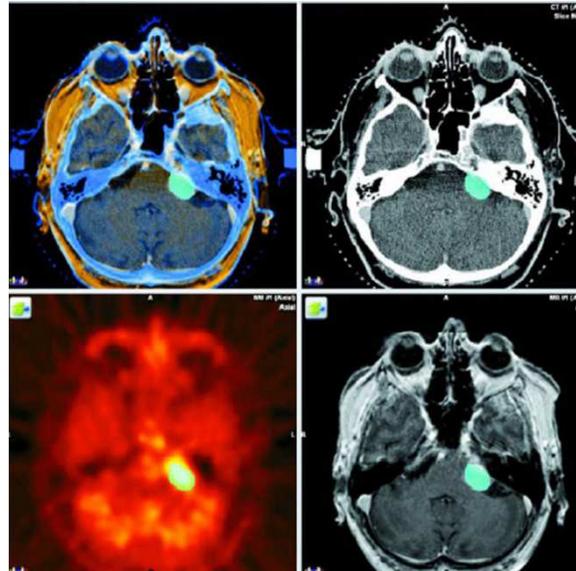
Imágenes de Resonancia



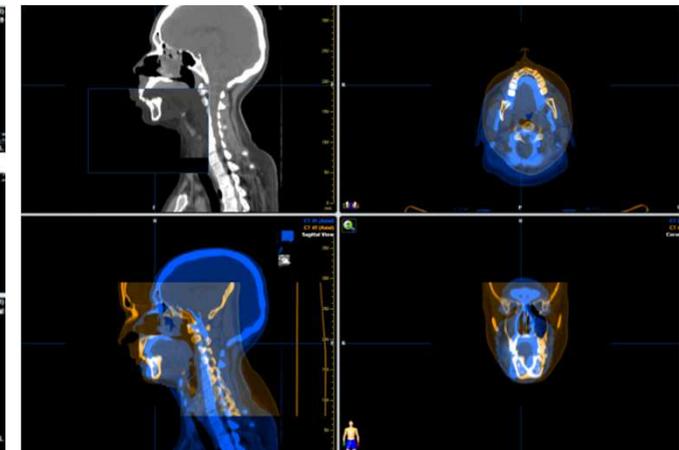
Preparación del paciente



Imágenes estereotáxicas



Fusión de Imágenes automática

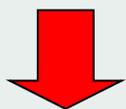


TAC – RNM – SPECT - PET



INSTITUTO DE RADIOTERAPIA
FUNDACIÓN MARIE CURIE

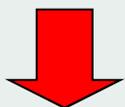
Preparación del
paciente



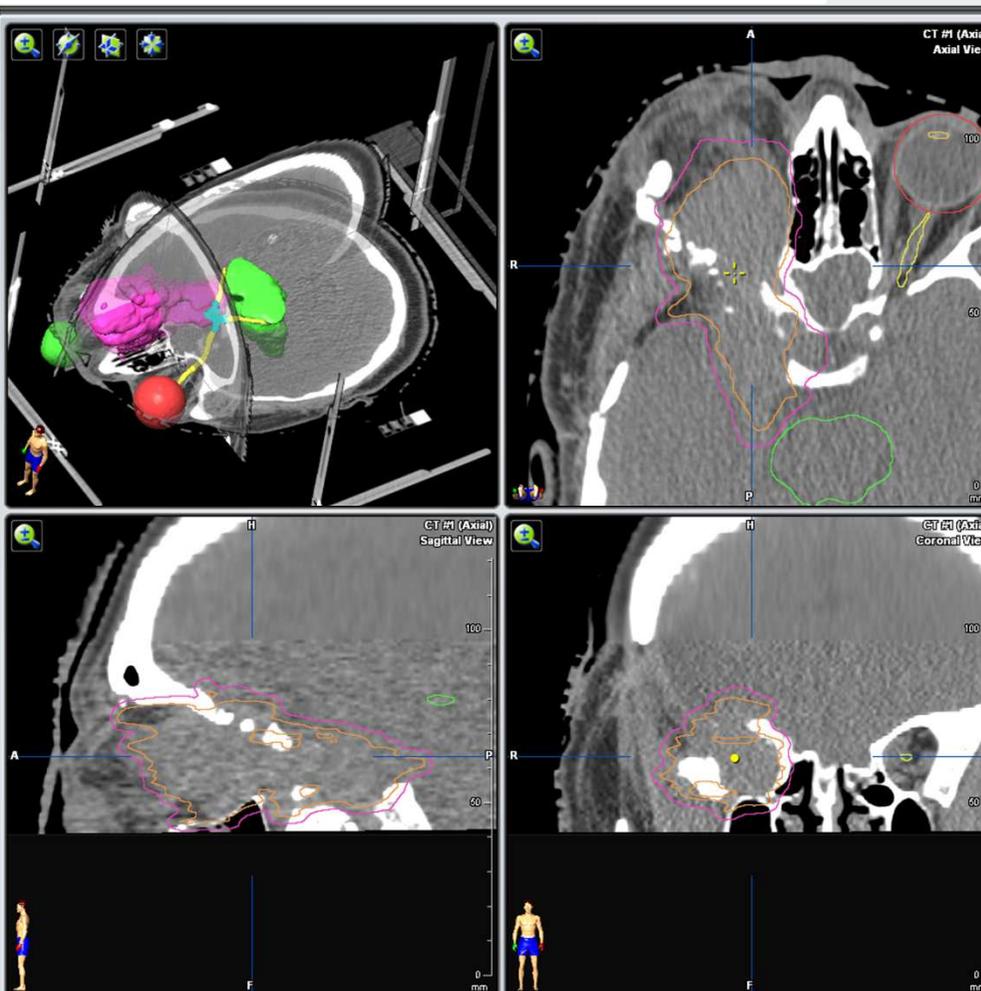
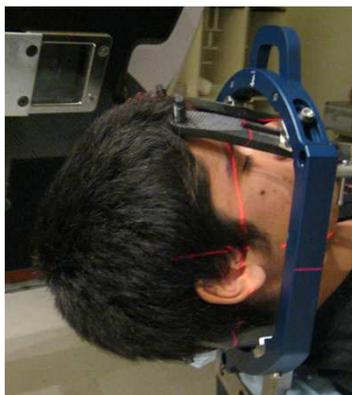
Imágenes
estereotáxicas



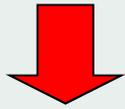
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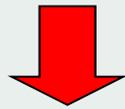
Definición volúmenes



Preparación paciente

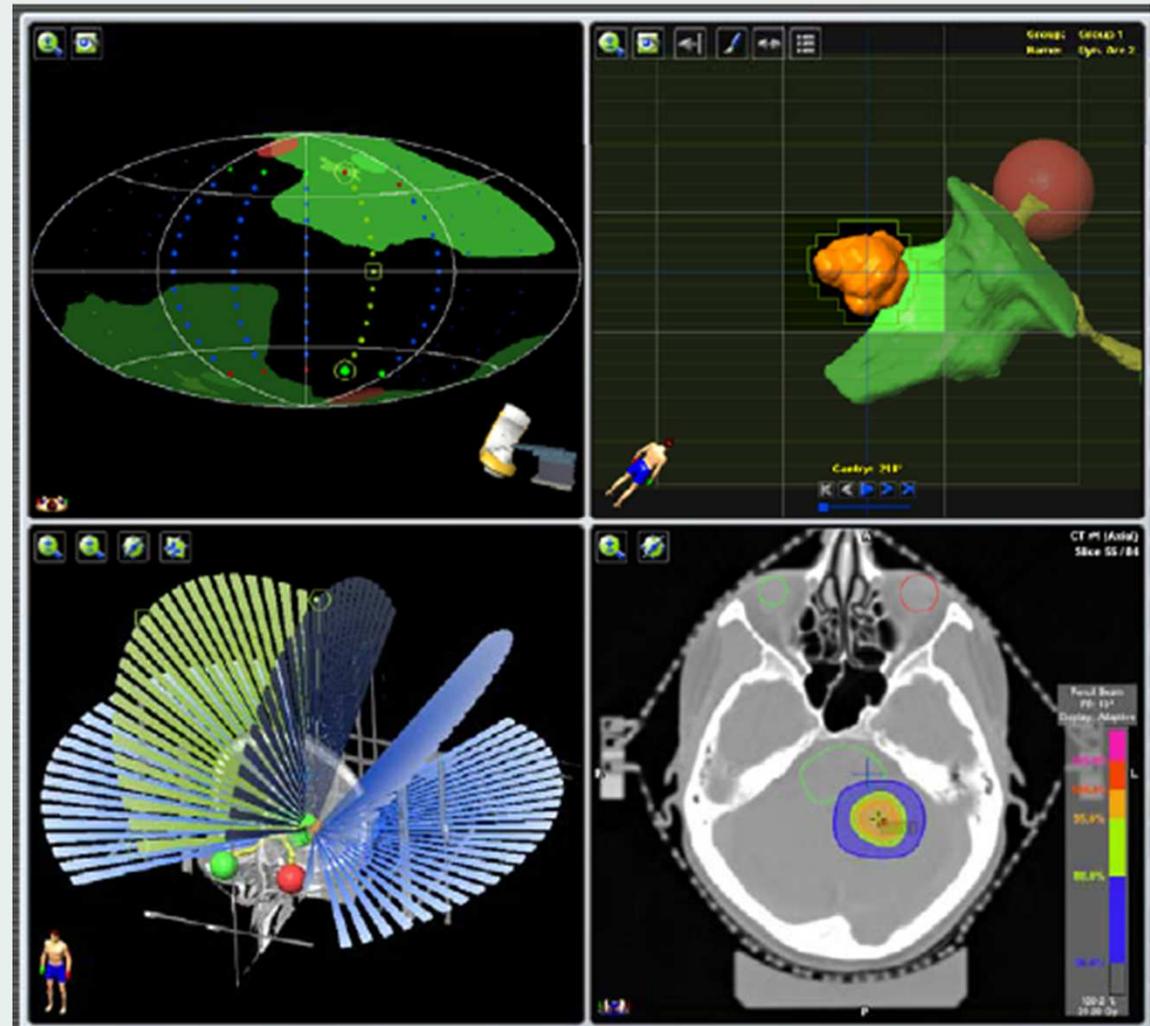
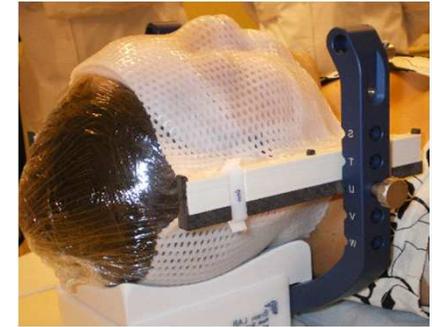
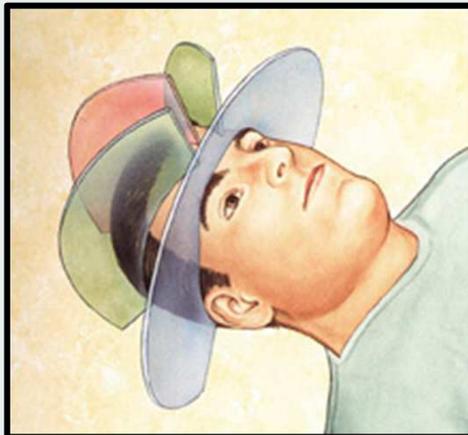


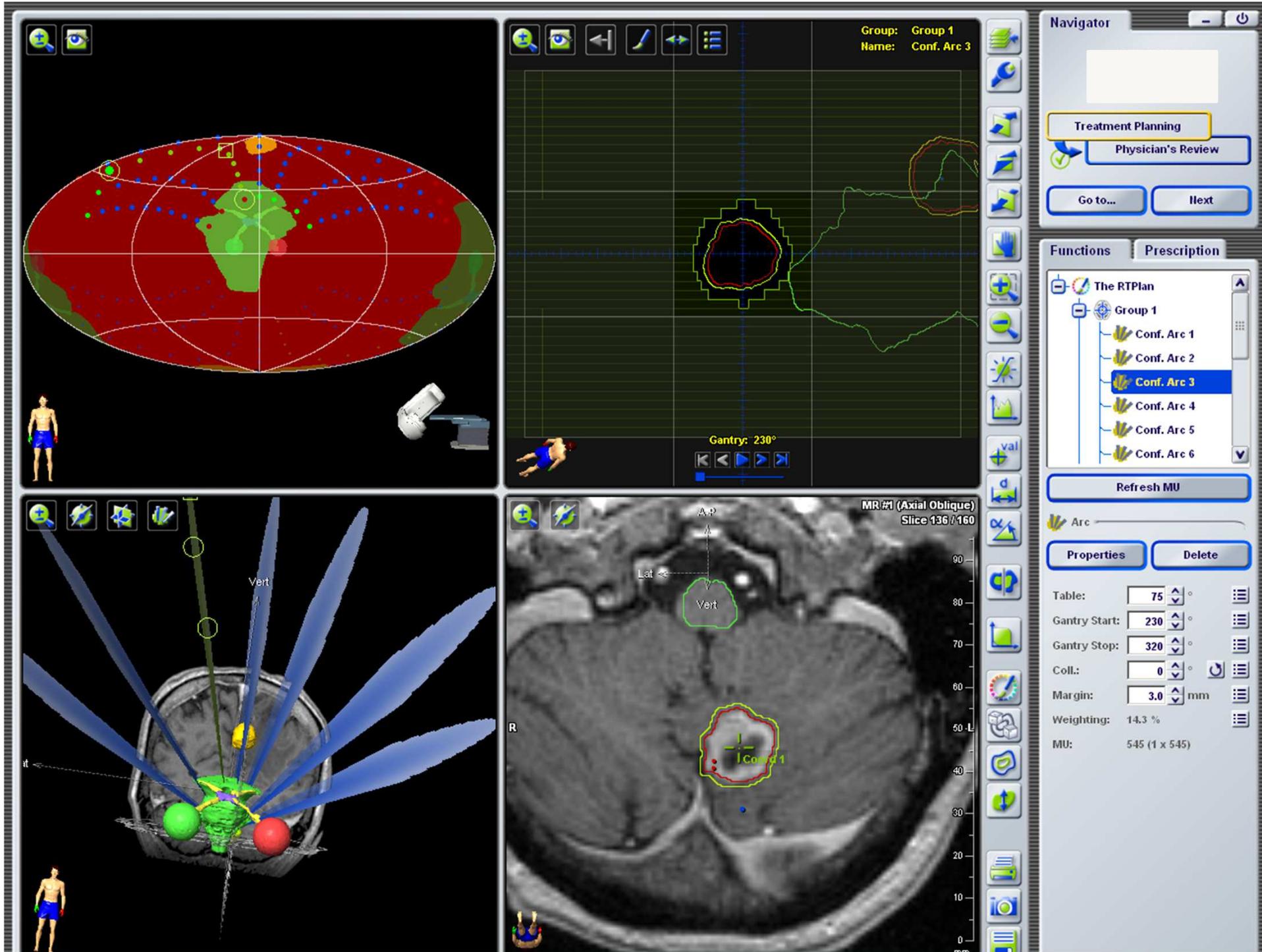
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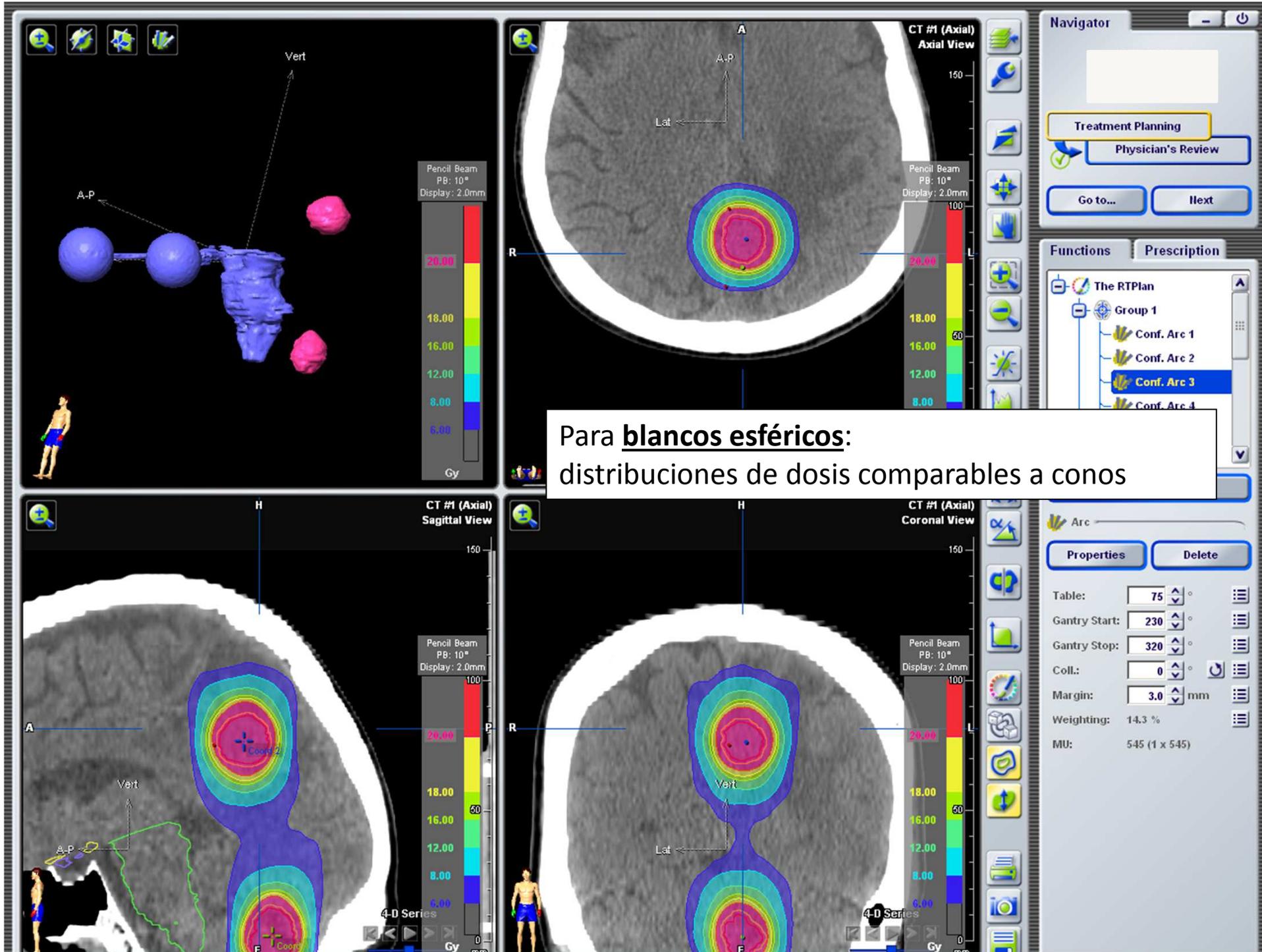


PLANIFICACION

1. Arcos conformados







Preparación paciente

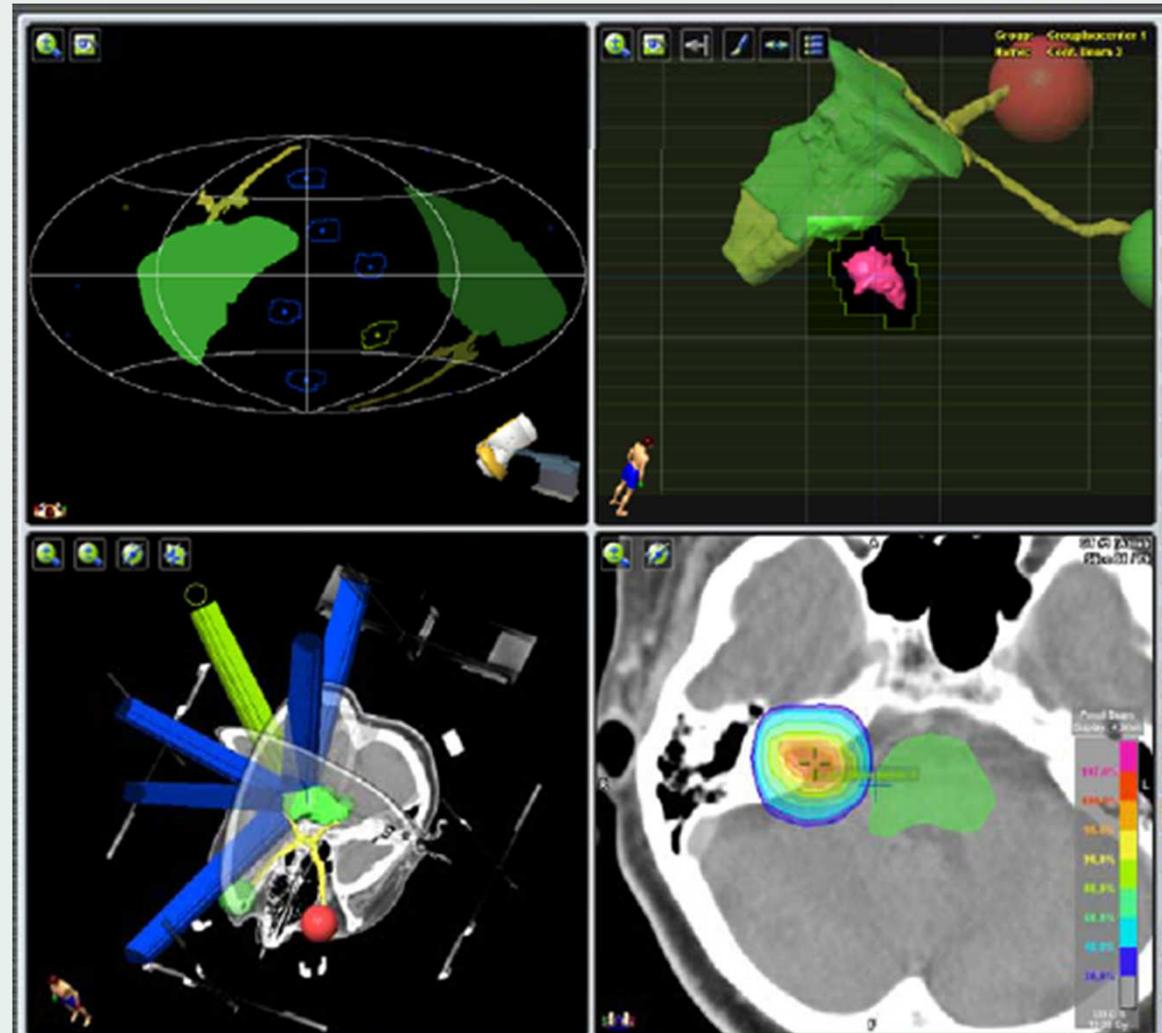
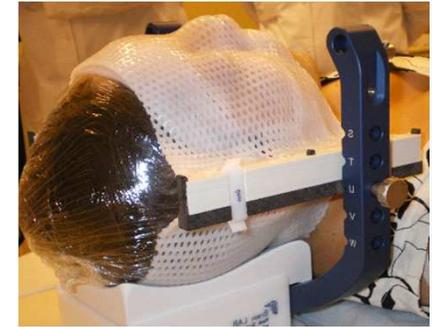
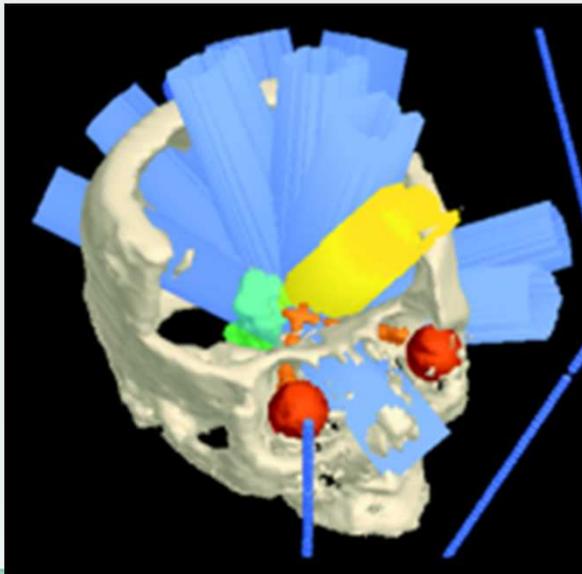


...



PLANIFICACION

2. Campos conformados



Preparación paciente

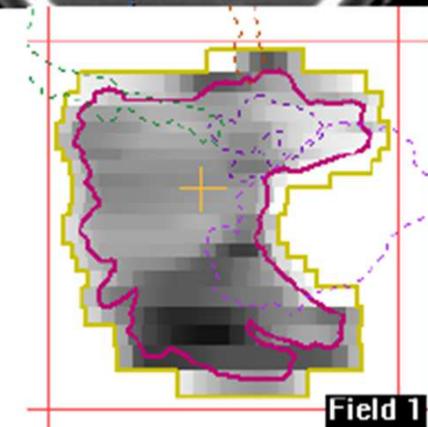
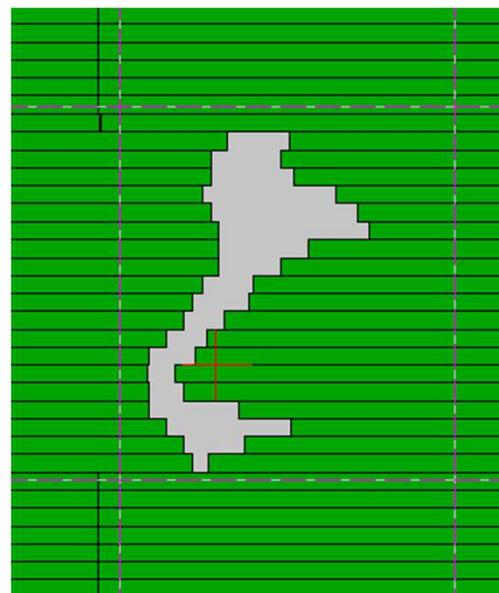
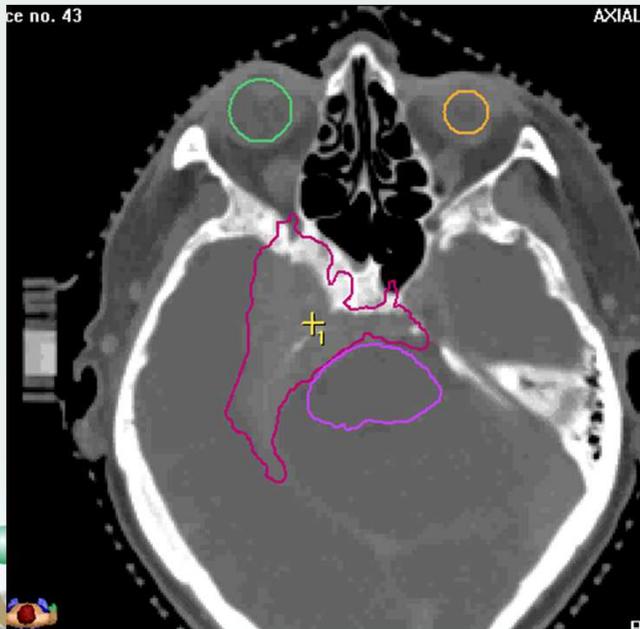
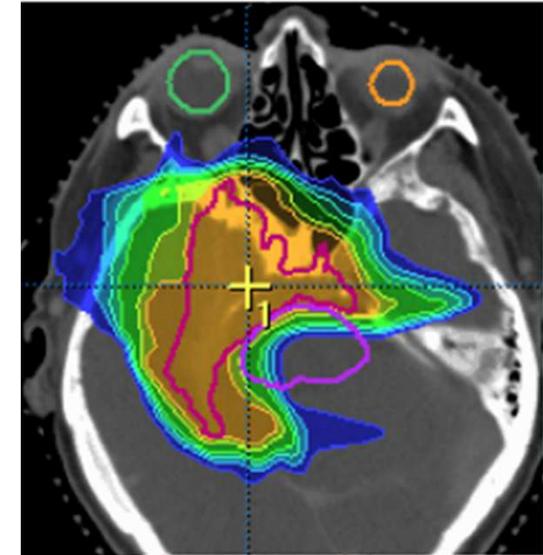
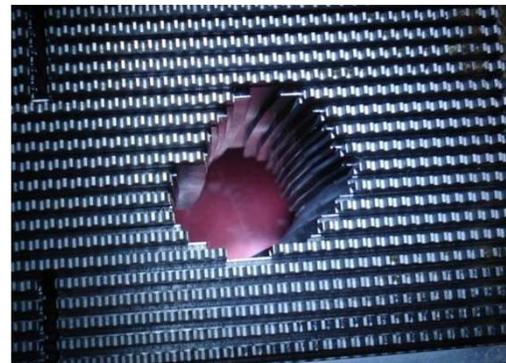
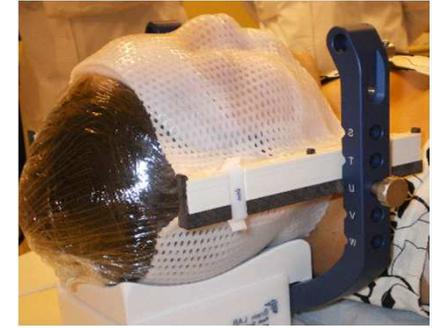


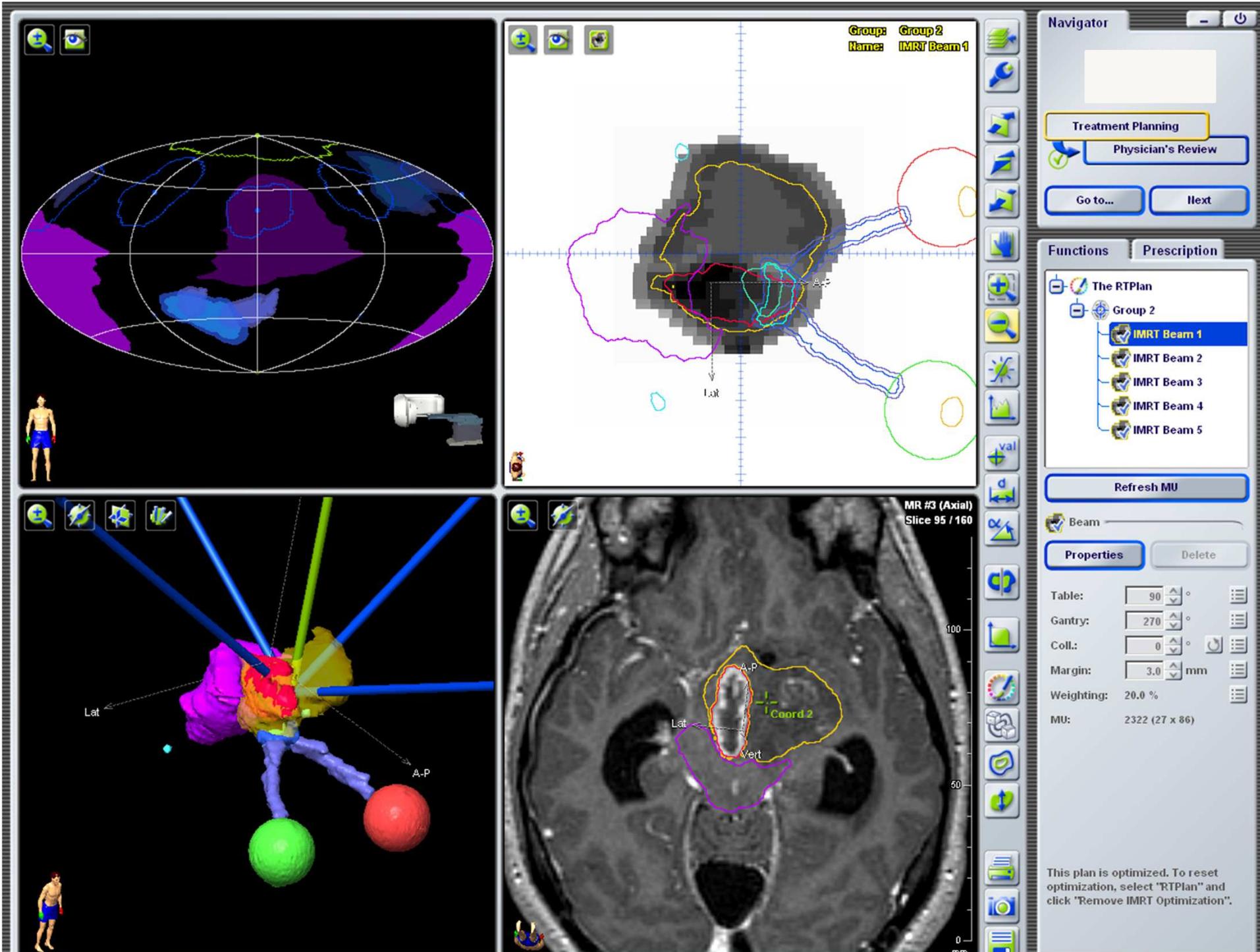
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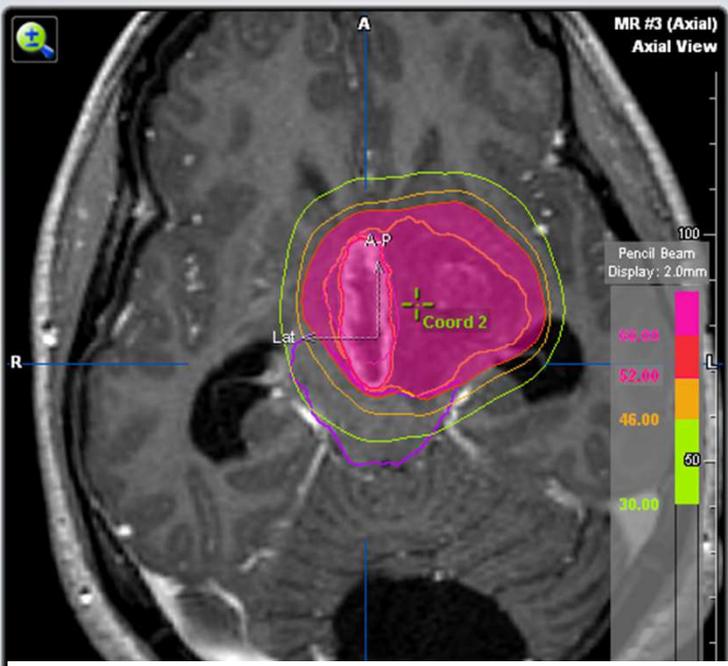
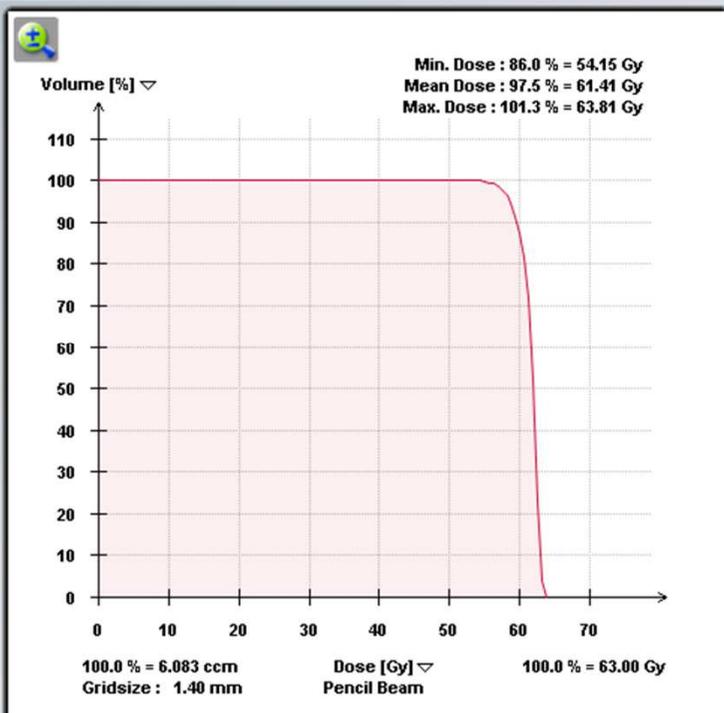


PLANIFICACION

3. Modulación de Intensidad estereotáxica (IMRS)







Navigator

Physician's Review
 Physicist's Verification

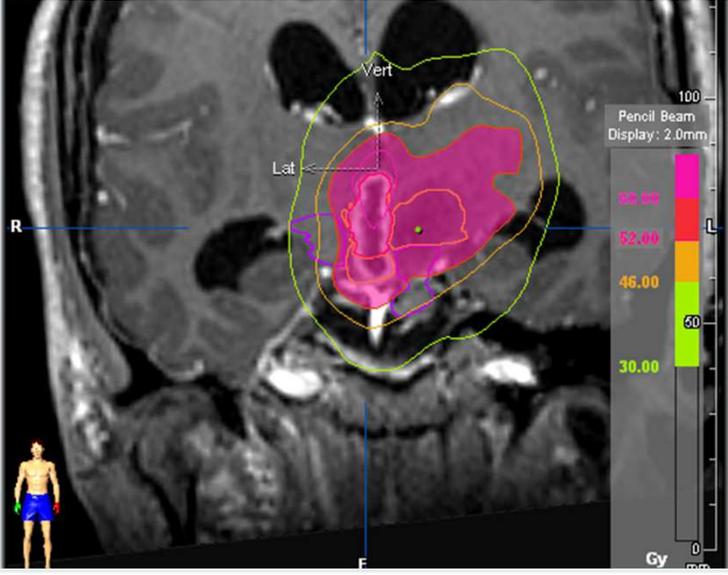
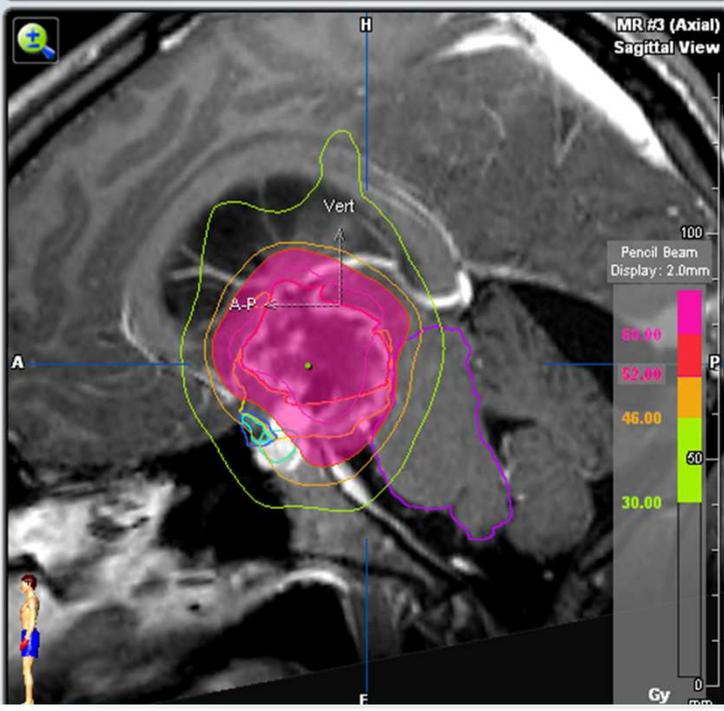
Go to... Next

Functions POI

Chiasm EXT-PTV	OAR 1
Optic Nerve Union EXT	OAR 1
Optic Nerve Union	OAR 1
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

Para **blancos irregulares**:

- Se requiere solo 1 isocentro
- Mejor conformación y homogeneidad que conos



Navigator

Physician's Review
 Physicist's Verification

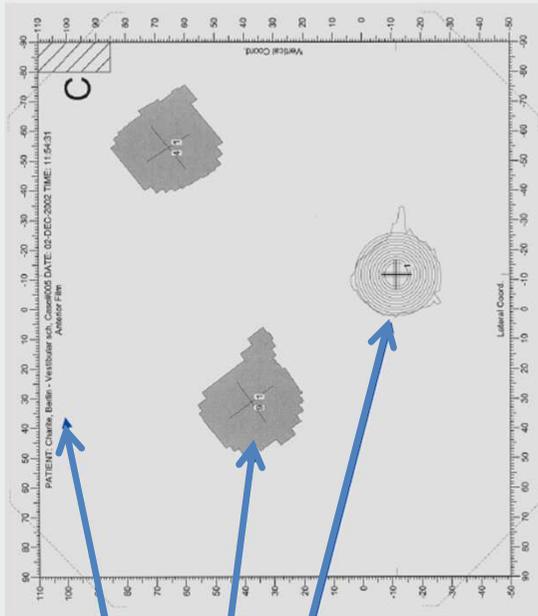
Go to... Next

Functions POI

Chiasm EXT-PTV	OAR 1
Optic Nerve Union EXT	OAR 1
Optic Nerve Union	OAR 1
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

Transferencia de coordenadas

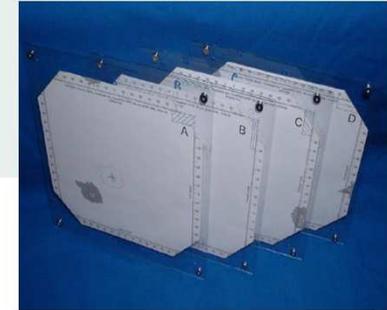
PLAN TPS -> equipo de tratamiento



Identificación del paciente

Proyecciones de formas de campo

Marcas de ISOCENTRO para LASER



Transferencia de coordenadas

PLAN TPS -> equipo de tratamiento



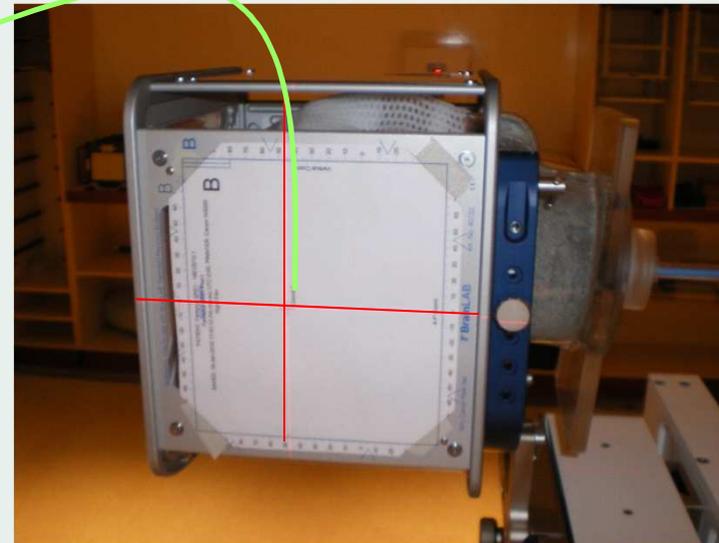
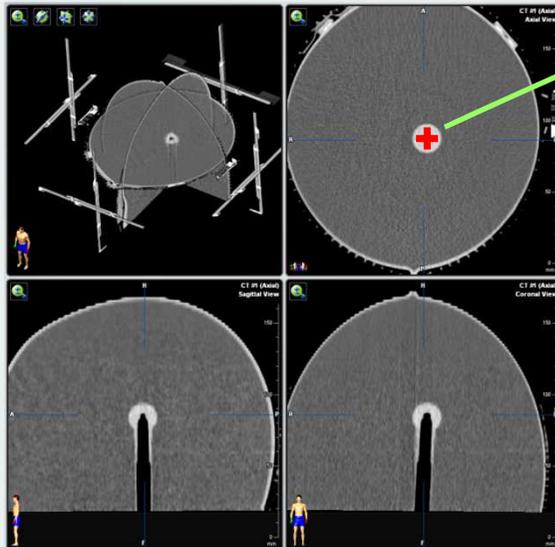
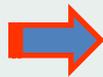
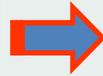
Control de calidad

- Isocentro del equipo (Test Winston-Lutz)
- Transferencia de coordenadas al equipo de tratamiento



Verificación del proceso de localización

- Sistema con plantillas + LASER -



Control de calidad

- Isocentro del equipo (Test Winston-Lutz)
- Transferencia de coordenadas al equipo de tratamiento
- **Dosimetría**
 - Adquisición de datos del equipo de tratamiento
 - Modelado de maquina de tratamiento
 - Dosis calculada versus medida
 - IMRS requiere un control paciente especifico

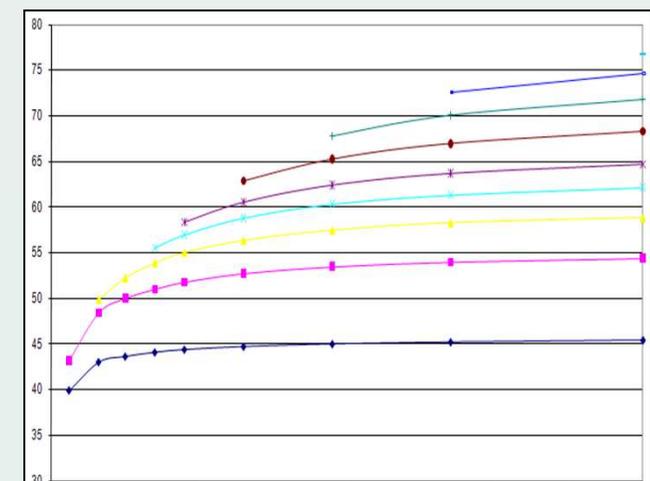
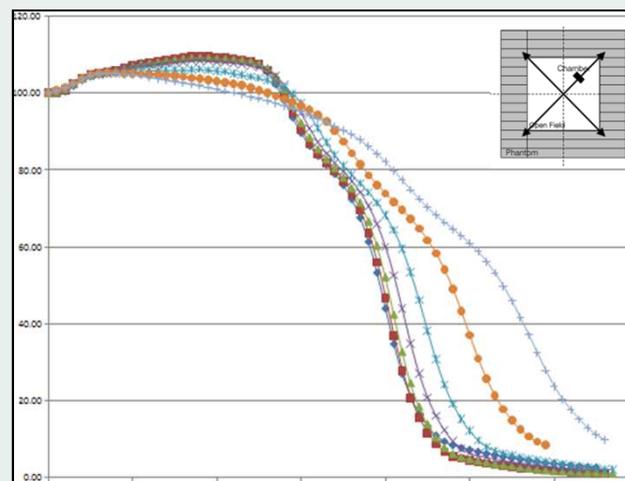
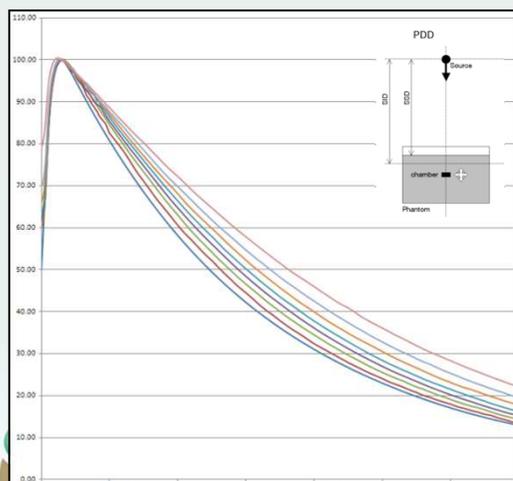


Dosimetría

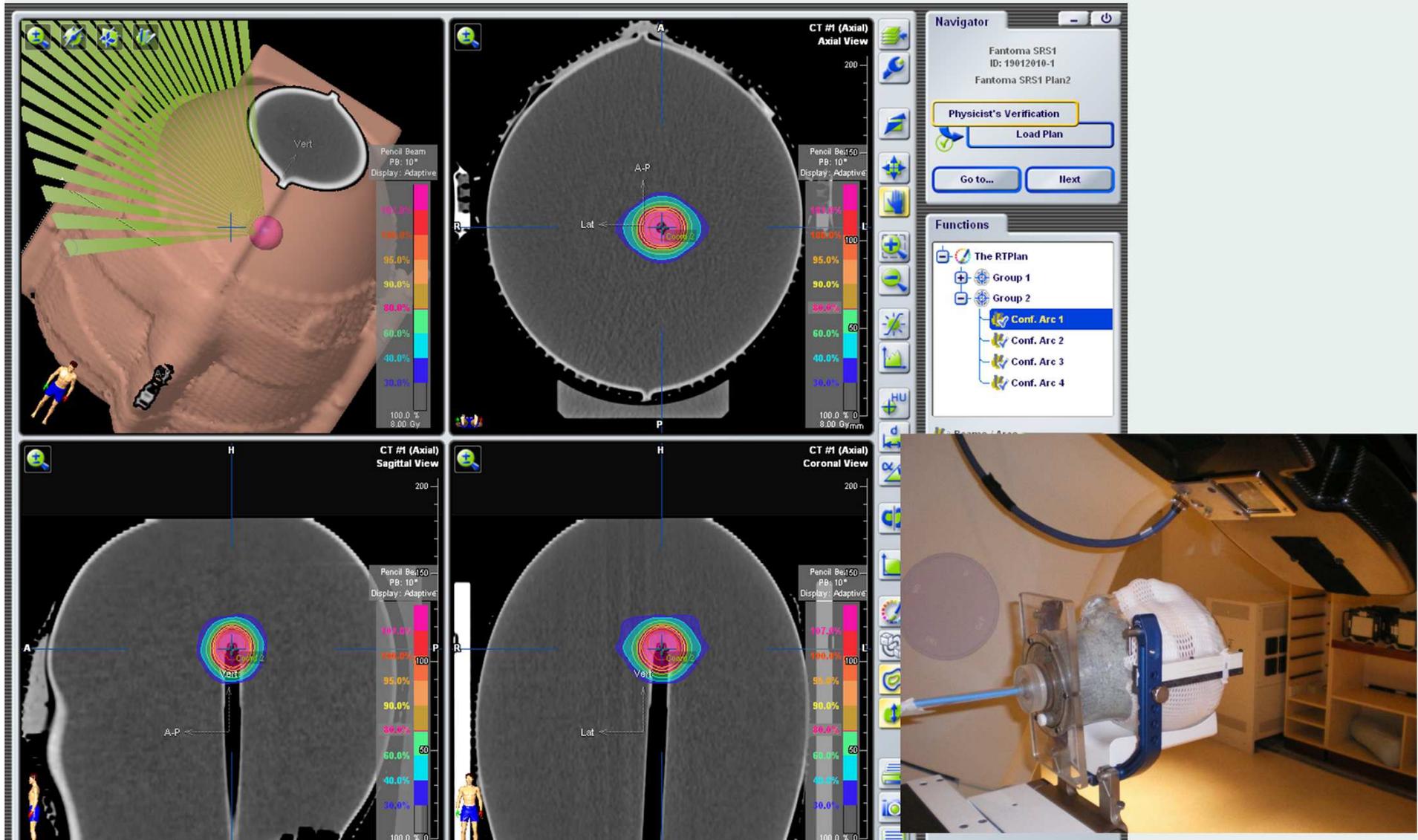


Adquisición de datos dosimétricos del haz de tratamiento
Comisionamiento del Sistema de planificación

- Medición de parámetros del haz
 - *Dosis en profundidad (PDD)*
 - *Perfiles de dosis*
 - *Factores de campo*
 - *Transmisión*
 - ***Dosis ABSOLUTA***



Verificación del calculo de dosis



Verificación del calculo de dosis

- IMRS – Control paciente específico
 - Verificación de dosis absoluta plan total
 - Verificación de dosis relativa por campo
 - Verificación de dosis relativa del plan



VERIFICACION DOSIS IMRT PEBUS F4481A.002 Pagina 1 de 2

Control de Calidad específico Paciente IMRT

Paciente: _____ ID (KonRAD) _____

I. Rendimiento en condición de referencia

Centro: _____ Fecha: _____ Dosis a 100%: _____

Exista: d. [cm] SSD D. [cm] L_{ref} N_{ref} D_{ref} Δ%

II. Dosis absoluta en FANTOMA PLANO (según CÓDIGO DE TRATAMIENTO)

Campo	Nombre	L _{ap} (cm) en referencia
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		

Dosis Medida calculada (KonRAD) = _____ Δ% = _____

Tiempo inicial: _____ Tiempo final: _____

III. Dosis relativa en FANTOMA PLANO por campo

FILM	Campo	AGNIO PTV 725	Imagen N°	QA RIT
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				

IV. Dosis relativa en FANTOMA Cosis Total

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

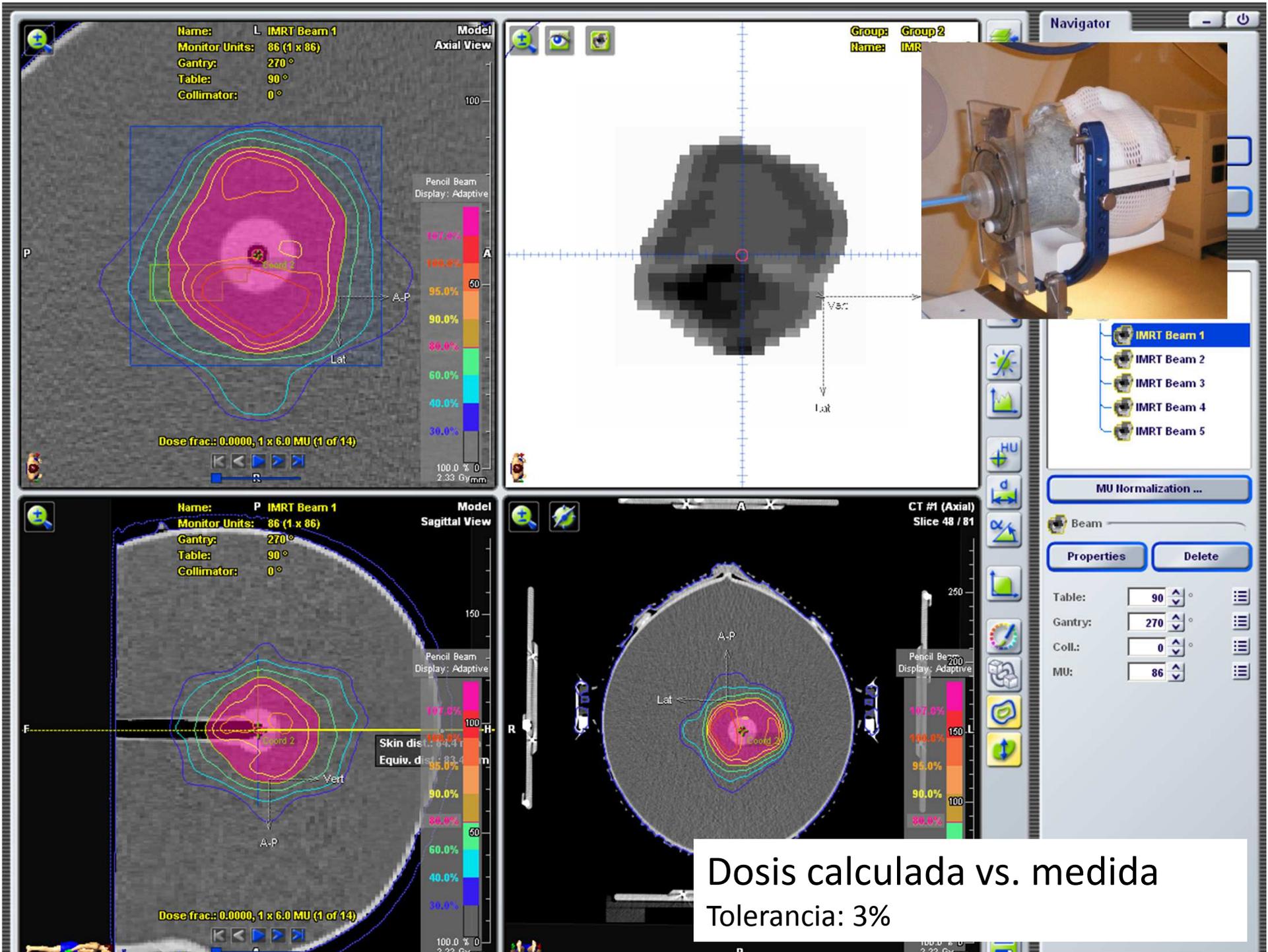
Film: _____ Imagen N° _____ QA RIT _____

X_w _____ X_w _____ X_w _____ X_w _____

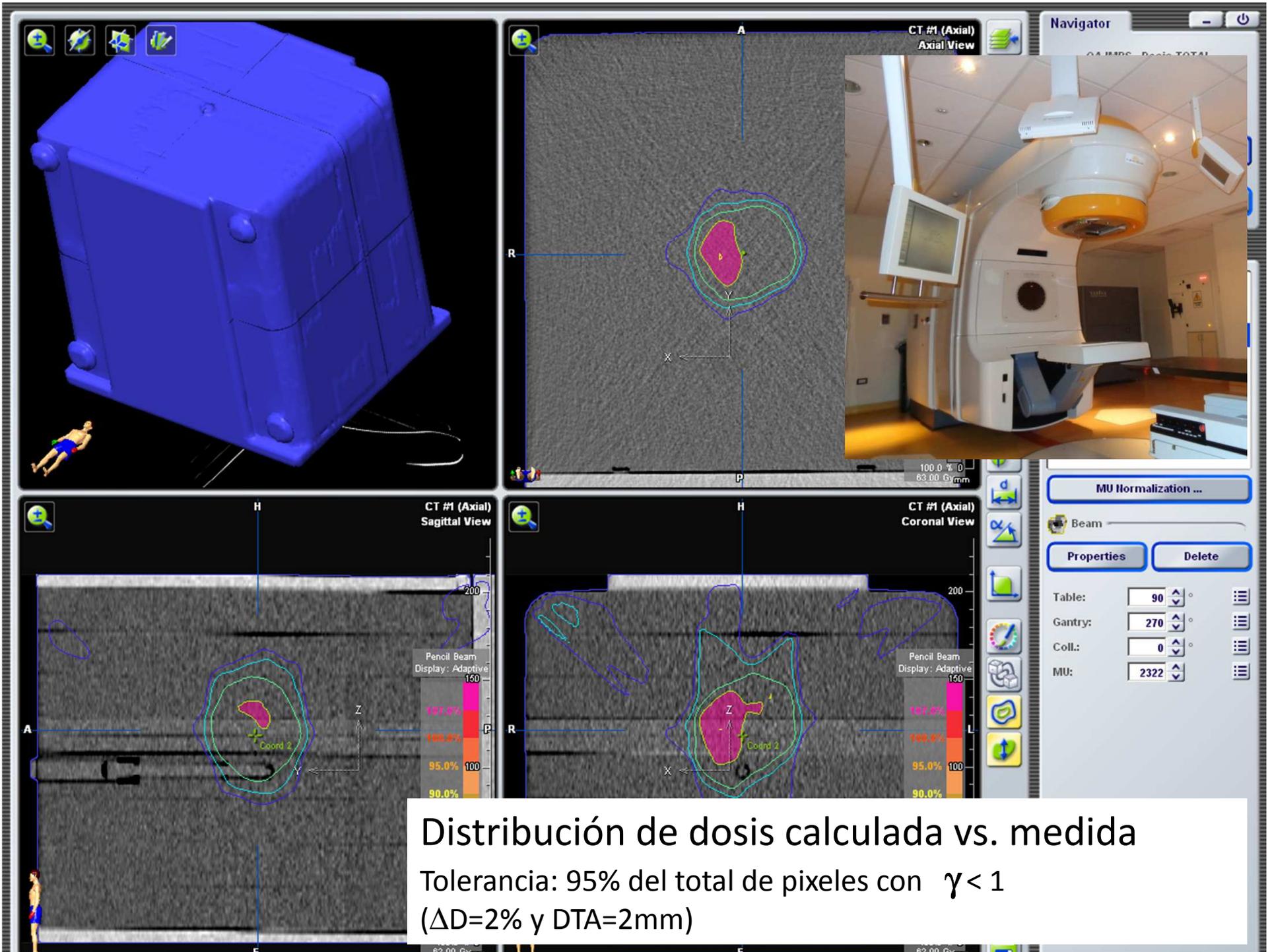
La Medida por: _____ Minuto: _____ Segundo: _____

Verificado por: _____ Minuto: _____ Segundo: _____

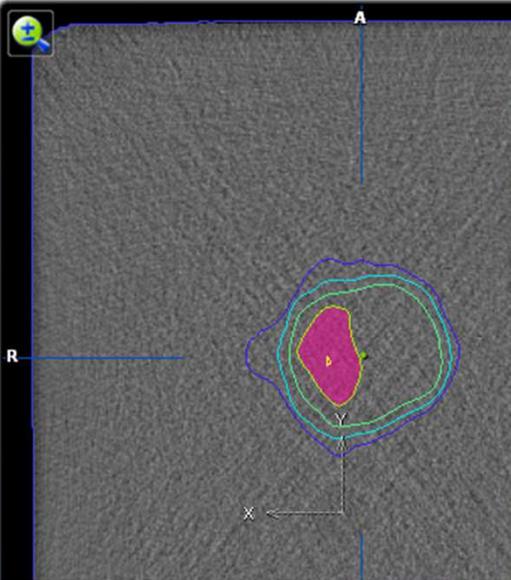




Dosis calculada vs. medida
Tolerancia: 3%



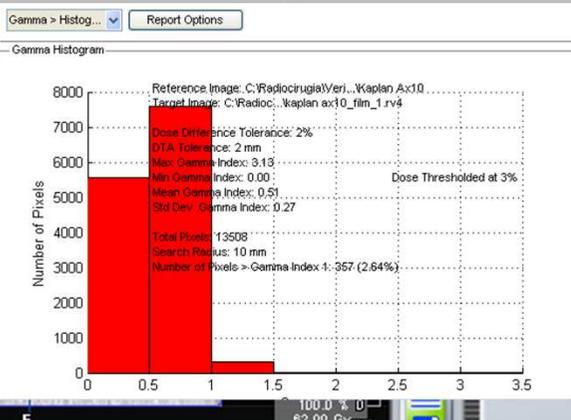
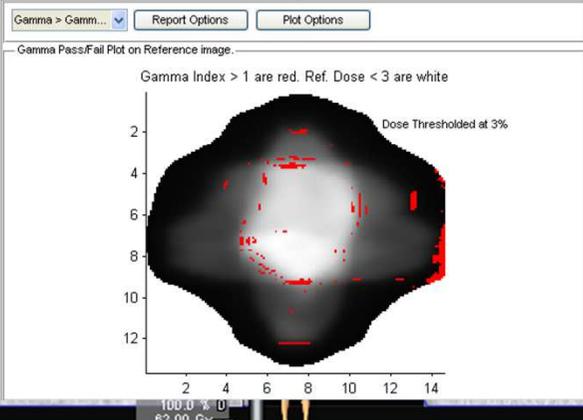
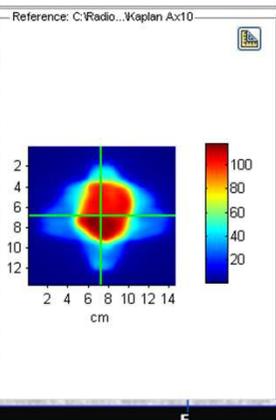
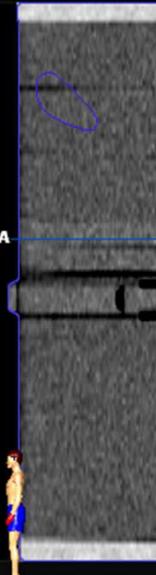
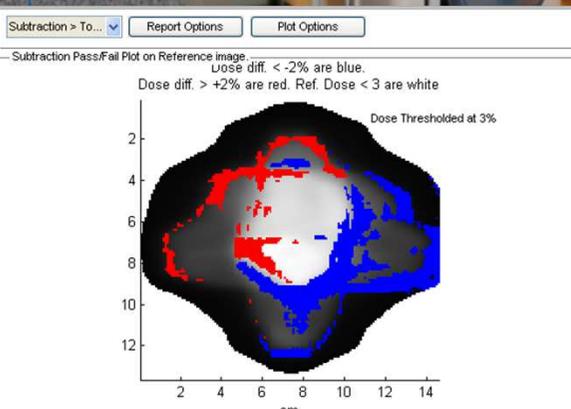
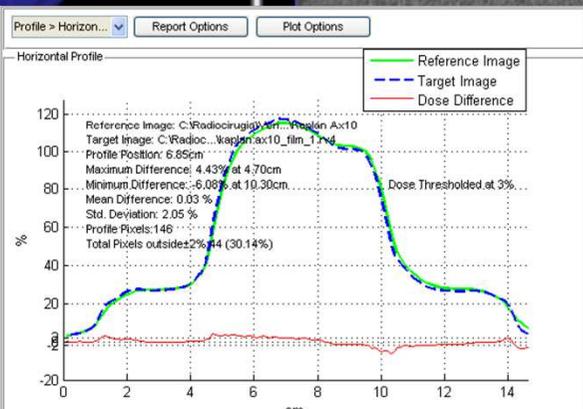
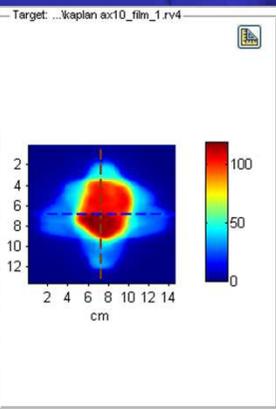
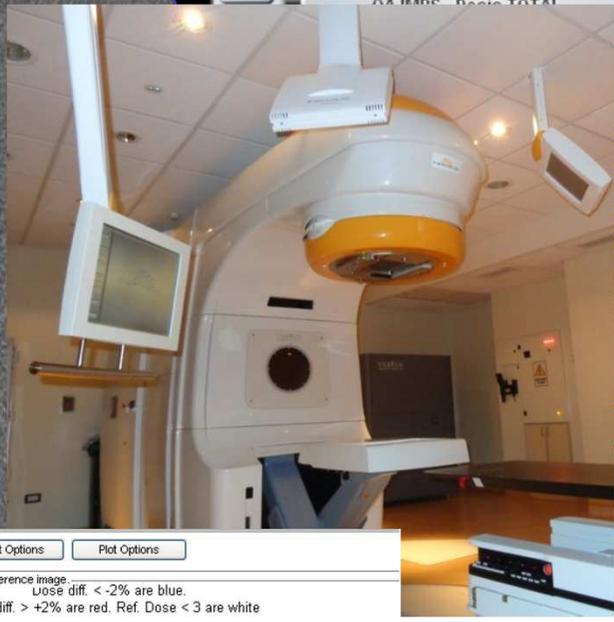
Distribución de dosis calculada vs. medida
 Tolerancia: 95% del total de píxeles con $\gamma < 1$
 ($\Delta D=2\%$ y $DTA=2\text{mm}$)



CT #1 (Axial)
Axial View

Navigator

CA-MPS Basic TOTAL



U Normalization ...

Delete

- 90
- 270
- 0
- 2322

- **Porque una preocupación especifica sobre seguridad en SRS/SBRT?**

- Pequeños errores en la localización del blanco
 - Subdosificación del blanco
 - Sobredosificación de los OAR
- Errores en determinación de dosis asociados a dosimetría de pequeños campos
- Ajustadas tolerancias (aprox. 1mm)
- Alto impacto en 1fx por errores de calibración
- Uso específico de accesorios y seteo especial de equipos
- Incidencias no convencionales
- Errores no limitados a una tecnología específica
- **Etc....**



Causados por fallas de equipos y fallas humanas (> 60%) - NRC

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

Quality and safety in stereotactic radiosurgery and stereotactic body radiation therapy: can more be done?

Timothy D. Solberg, Ph.D. and Paul M. Medin, Ph.D.

Jour. of Radiosurgery and SBRT, Vol. 1, pp. 13-19
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1. Error de calibración de unidad

- 77 pacientes en Florida durante 2004-2005
 - Sin verificación independiente.
- 145 pacientes en Toulouse, Francia 2006-2207
 - 32% a 12 meses de neuropatías trigeminales en 32 pacientes tratados por neurinomas del acústico (Gourmelon et al.)
- 76 pacientes en Springfield, Missouri 2004-2009

Friday, April 08, 2005

Major Radiation Overdoses at Florida Cancer Center

In the typical fashion of releasing bad news when most people are not focusing on the news, on Friday, April 2 [H. Lee Moffitt Cancer Center & Research Institute](#) released information that [77 patients received 50% higher radiation doses than prescribed](#). Whoa!

Dosimetric stereotactic radiosurgical accident: Study of 33 patients treated for brain metastases.

09:55 EDT 7th August 2014 | BioPortfolio

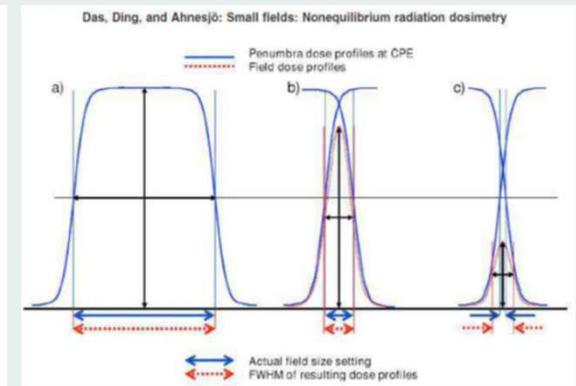
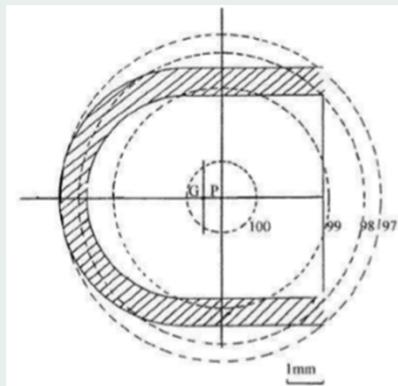
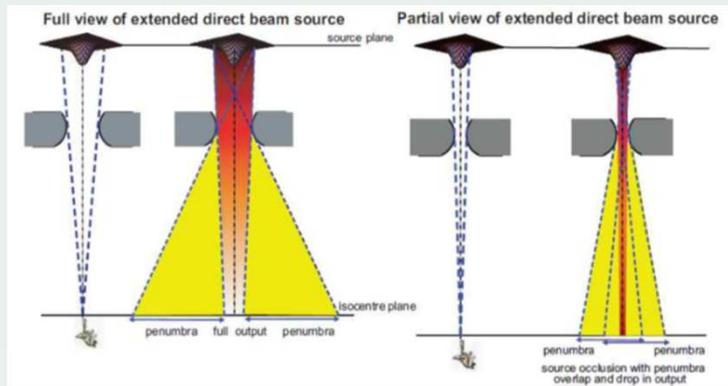
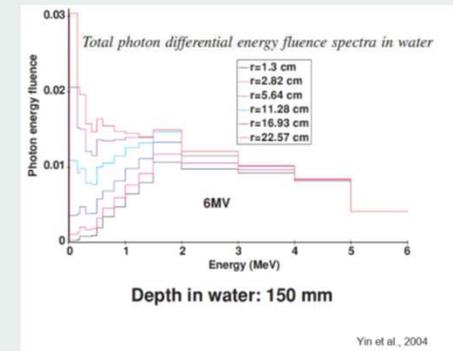
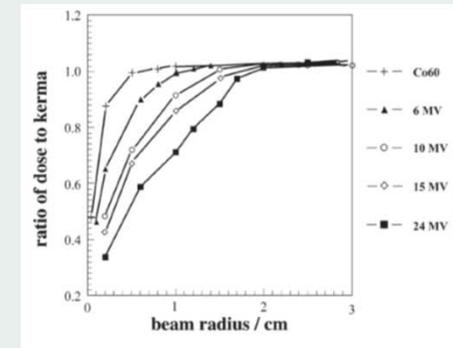
Home » Citations » Neuro-Chirurgie » Dosimetric stereotactic radiosurgical accident: Study of 33 patients treated for brain metastases.



INSTITUTO DE RADIOTERAPIA
FUNDACIÓN MARIE CURIE

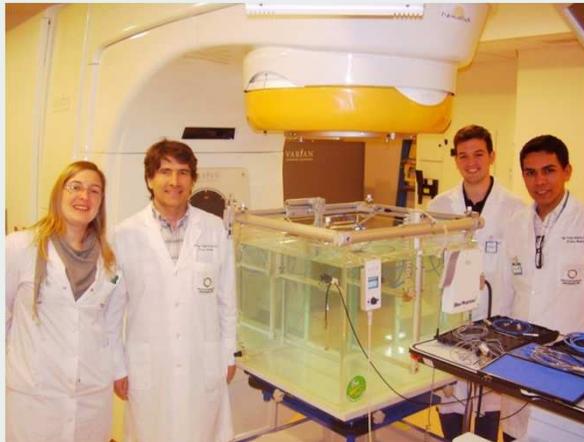
1. Dosimetría de campos pequeños!!

- Falta de equilibrio electrónico lateral
 - Rango e- secundarios comparable con tamaño del haz
- Efecto de endurecimiento del haz
 - Reducción de dispersión por disminución de campo
- Efecto de oclusión parcial de la fuente
- Tamaño del detector
- Definición del tamaño del campo



1. Dosimetría de campos pequeños!! REQUIERE

- Personal **altamente** capacitado
- Equipamiento **especifico**

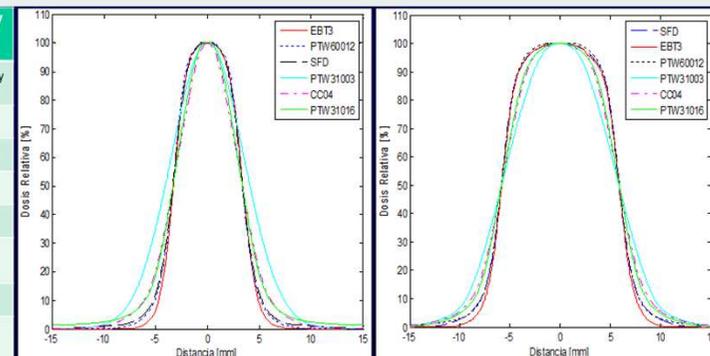


MLC Field Size [mm]	Jaw Field Size [mm]										
	8x8	12x12	22x22	32x32	42x42	60x60	80x80	100x100	140x140	220x220	254x254
5x5	0.514	0.531	0.541	0.544	0.546	0.548	0.551	0.553	0.556	0.563	0.586
10x10	0.586	0.672	0.689	0.694	0.696	0.700	0.703	0.705	0.708	0.717	0.720
20x20	0.586	0.691	0.803	0.813	0.820	0.824	0.827	0.830	0.833	0.841	0.844
30x30	0.586	0.691	0.809	0.854	0.866	0.879	0.884	0.886	0.890	0.898	0.901
40x40	0.586	0.691	0.809	0.859	0.887	0.905	0.915	0.921	0.925	0.932	0.934
60x60	0.586	0.691	0.809	0.859	0.890	0.932	0.952	0.962	0.971	0.980	0.980
80x80	0.586	0.691	0.809	0.859	0.890	0.932	0.970	0.985	0.998	1.008	1.010
100x100	0.586	0.691	0.809	0.859	0.890	0.932	0.970	1.000	1.018	1.029	1.031
140x140	0.586	0.691	0.809	0.859	0.890	0.932	0.970	1.000	1.031	1.060	1.061
220x220	0.586	0.691	0.809	0.859	0.890	0.932	0.970	1.000	1.031	1.093	1.100
254x254	0.586	0.691	0.809	0.859	0.890	0.932	0.970	1.000	1.031	1.093	1.108

Detector type	Promedio (diode SFD3G + diode PTW60012)	Field size = 5x5
Detector type	Promedio (diode SFD3G + diode PTW60012 + IC PinPoint 31016)	Field sizes 10x10 and 20x20
Detector type	Promedio (diode SFD3G + diode PTW60012 + IC PinPoint 31016 + IC CC04)	Field size = 30x30
Detector type	IC CC04	Field size > 30x30mm
SSD [mm]	1000	
Norm. Depth [mm]	100	



Detector	Type	Volume	Diameter / Reader
EBT3	Gafchromic film	-	VIDAR Dosimetry Pro RED
TLD	TLD700	1x1x1 mm ³	Harshaw 4500
PTW 31013	Ion chamber	0.3 cm ³	5,5 mm
IBA CC04	Ion chamber	0.04 cm ³	3,6 mm
PTW 30013	Ion chamber	0.6 cm ³	6,1 mm
PTW 31016 (PinPoint)	Ion chamber	0.016 cm ³	2,9 mm
PTW 60012	Diode unshielded	-	1 mm
IBA SFD	Diode unshielded	-	0,6 mm



2. Error accesorio de localización

- Francia, España y USA

3. Error en el setting de colimadores de backup

- AVM (1) en Francia
- Neuralgia del trigémino (3) en Evanston, IL, USA
 - 80-85Gy al 100%, cono 4-5mm

THE RADIATION BOOM

A Pinpoint Beam Strays Invisibly, Harming Instead of Healing

By WALT BOGDANICH and KRISTINA REBELD
Published: December 28, 2010

The initial accident report offered few details, except to say that an unidentified hospital had administered radiation overdoses to three patients during identical medical procedures.

[Enlarge This Image](#)



Marci Faber is nearly comatose after a treatment mistake.

It was not until many months later that the full import of what had happened in the hospital last year began to surface in urgent nationwide warnings, which advised doctors to be extra vigilant when using a particular device that delivers high-intensity, pinpoint radiation to vulnerable parts of the body.



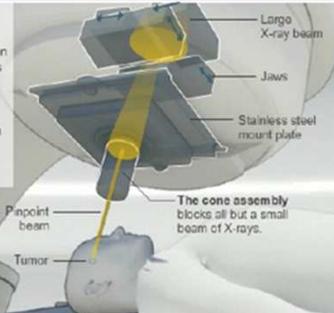
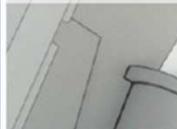
The New York Times

Health

Proper Setup

Radiation is beamed through an opening controlled by two pairs of movable metal jaws.

The opening is supposed to constrain the X-ray beam to an area smaller than the cone's diameter.

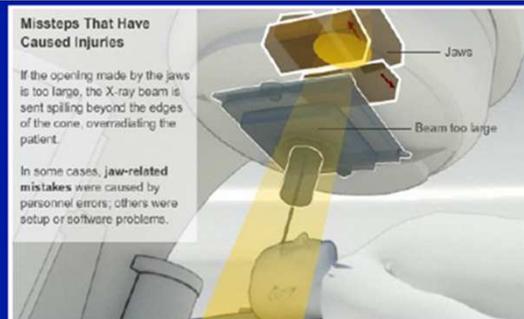


Mike Grondahl, Bill Marsh, Graham Roberts and Xosha O.V. / The New York Times | [Send Feedback](#)
Sources: Manufacturers and interviews with medical physicists.

Misteps That Have Caused Injuries

If the opening made by the jaws is too large, the X-ray beam is sent spilling beyond the edges of the cone, overradiating the patient.

In some cases, jaw-related mistakes were caused by personnel errors; others were setup or software problems.



Vika Grondahl, Bill Marsh, Graham Roberts and Xosha O.V. / The New York Times | [Send Feedback](#)
Sources: Manufacturers and interviews with medical physicists.



INSTITUTO DE RADIOTERAPIA
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- **Errores no limitados a una tecnología en particular**
 - Desde 2005 se reportaron 13 eventos erróneos Gamma Knife (NRC), 7 de los cuales se refirieron a error en la localización y 3 dosis incorrecta

U.S. Nuclear Regulatory Commission
Protecting People and the Environment

NUCLEAR REACTORS | NUCLEAR MATERIALS | RADIOACTIVE WASTE | NUCLEAR SECURITY | PUBLIC MEETINGS & INVOLVEMENT | NRC LIBRARY | ABOUT NRC

Home > Electronic Reading Room > Document Collections > Reports Associated with Events > Event Notification Reports > 2007 > October 29

Event Notification Report for October 29, 2007

U.S. Nuclear Regulatory Commission

Event Text

GAMMA KNIFE TREATMENT TO WRONG SIDE OF BRAIN

"On October 24, 2007, a medical event occurred at Leksell Gamma Knife facility which resulted in the total dose delivered differing from the prescribed dose by more than 20%.

"1. Licensee's name: Karmanos Cancer Center.

"2. Name of prescribing physician: [DELETED]

"3. Brief description of the event:

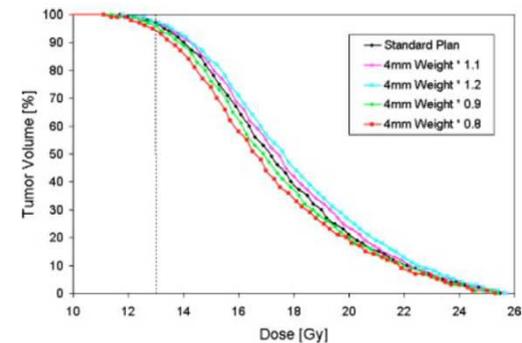
"Due to a left - right reversal of the treatment planning MRI images, the patient's left side was targeted and treated rather than the right side. The error resulted in an 18 mm shift of isocenter across midline of the brain. The collimator diameter selected for the treatment was 18 mm, thus resulting in some overlap of the delivered 50% isodose volume with the correct intended target lesion volume. The event resulted in approximately 7% of the lesion volume receiving the prescribed dose of 18 Gy to the 50% isodose, rather than the preferred 95% of the lesion volume.

<http://www.nrc.gov/reading-rm/doc-collections/event-status/event/2007/20071029en.html>

JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS, VOLUME 4, NUMBER 4, FALL 2003

Technical note: The effect of the 4-mm-collimator output factor on gamma knife dose distributions

John P. Gibbons,* Dimitris Mihailidis, Curtis Worthington, Hassaan Alkhatib, Raleigh Boulware, Robert Clark, Burke Dial, and William Neglia
Gamma Knife Center of the Carolinas, Columbia, South Carolina 29203



INSTITUTO DE RADIOTERAPIA
FUNDACIÓN MARIE CURIE

- 4. Selección incorrecta de cono
- 5. Error de orientación del paciente
- 6. Error de planificación
 - Restricción dosis volumen
 - Dosis en piel



Accessory Verification 2.0.0.3

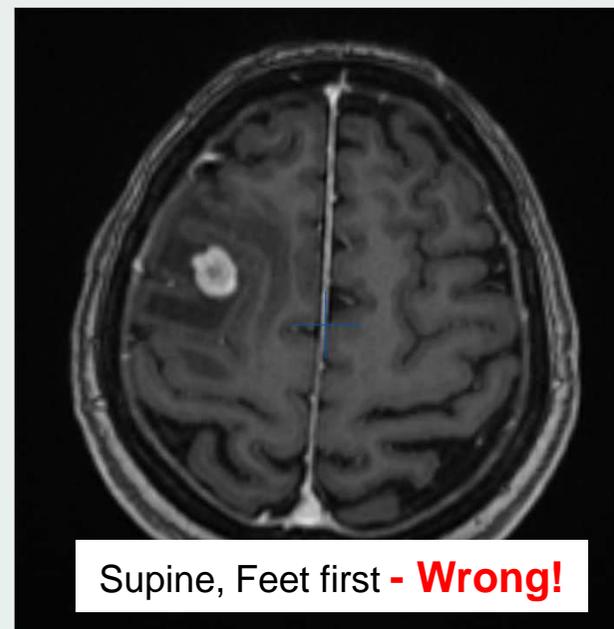
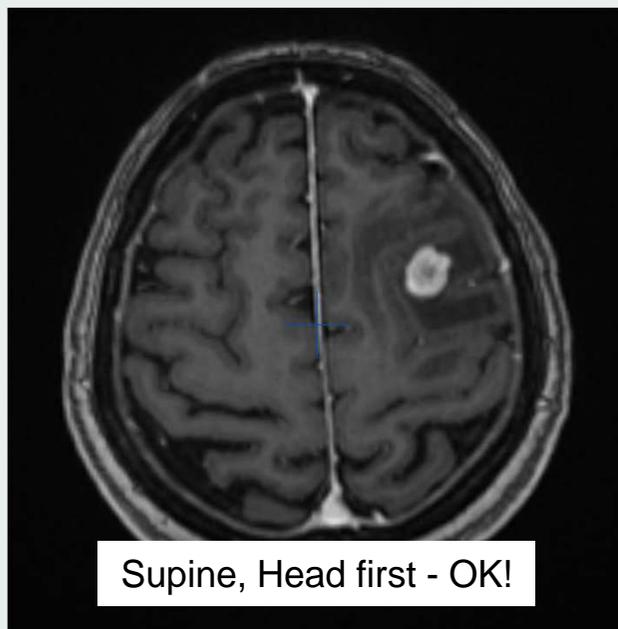
Code **5mm CC (3269)**

To continue,
1. Scan label "1" on Interface Mount, then
2. Scan label "2" on the Conical Collimator within 5 seconds of scanning label "1".

Connected to Treatment Console and Barcode Reader



4. Selección incorrecta de cono
5. **Error de orientación del paciente**
6. Error de planificación
 - Restricción dosis volumen
 - Dosis en piel

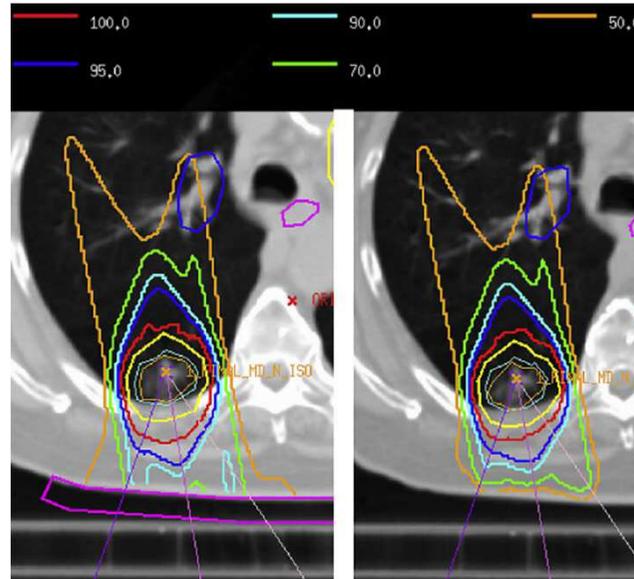


4. Selección incorrecta de cono
5. Error de orientación del paciente
6. Error de planificación
 - Restricción dosis volumen
 - Dosis en piel

Serial Tissue	Volume (mL)	Volume Max (Gy)	Max Point Dose (Gy)	Endpoint (≥Grade 3)
SINGLE-FRACTION TREATMENT				
Optic pathway	<0.2	8	10	Neuritis
Cochlea			12	Hearing loss
Brainstem	<1	10	15	Cranial neuropathy
Spinal cord	<0.25	10	14	Myelitis
Spinal cord			<0.25	10
			<1.2	7
Ipsilateral brachial plexus	<3	14.4	16	Neuropathy
Heart/pericardium	<15	16	22	Pericarditis
Great vessels	<10	31	37	Aneurysm
Trachea and ipsilateral bronchus*	<4	8.8	22	Stenosis/fistula
Skin	<10			
Stomach	<10			
Duodenum*	<5			
Jejunum/ileum*	<5			
Colon*	<20	11	22	Colitis/nstura
Rectum*	<20	11	22	Proctitis/fistula
Bladder wall	<15	8.7	22	Cystitis/fistula
Penile bulb	<3	14	34	Impotence
Femoral heads (right and left)	<10	14		Necrosis
Renal hilum/vascular trunk	<2/3 volume	10.6		Malignant hypertension
Spinal cord			<0.25	22.5 (4.5 Gy/fx)
			<1.2	13.5 (2.7 Gy/fx)
Spinal cord			14	30 (6 Gy/fx)
Ipsilateral brachial plexus	<3	30 (6 Gy/fx)	32 (6.4 Gy/fx)	Neuropathy
Heart/pericardium	<15	32 (6.4 Gy/fx)	38 (7.6 Gy/fx)	Pericarditis
Great vessels	<10	47 (9.4 Gy/fx)	53 (10.6 Gy/fx)	Aneurysm
Trachea and ipsilateral bronchus*	<4	18 (3.6 Gy/fx)	38 (7.6 Gy/fx)	Stenosis/fistula
Skin	<10			
Stomach	<10			
Duodenum*	<5			
Jejunum/ileum*	<5			
Colon*	<20	25 (5 Gy/fx)	38 (7.6 Gy/fx)	Colitis/nstura
Rectum*	<20	25 (5 Gy/fx)	38 (7.6 Gy/fx)	proctitis/fistula
Bladder wall	<15	18.3 (3.65 Gy/fx)	38 (7.6 Gy/fx)	cystitis/fistula
Penile bulb	<3	30 (6 Gy/fx)	50 (10 Gy/fx)	Impotence
Femoral heads (right and left)	<10	30 (6 Gy/fx)		Necrosis
Renal hilum/vascular trunk	<2/3 volume	23 (4.6 Gy/fx)		Malignant hypertension
Parallel Tissue	Critical Volume (mL)	Critical Volume Dose Max (Gy)	Endpoint (≥Grade 3)	
Lung (right and left)	1,500	7	Basic lung function	
Lung (right and left)	1,000	7.4	Pneumonitis	
Liver	700	9.1	Basic liver function	
Renal cortex (right and left)	200	8.4	Basic renal function	
Parallel Tissue	Critical Volume (mL)	Critical Volume Dose Max (Gy)	Endpoint (≥Grade 3)	
Lung (right and left)	1,500	12.5 (2.5 Gy/fx)	Basic lung function	
Lung (right and left)	1000	13.5 (2.7 Gy/fx)	Pneumonitis	
Liver	700	21 (4.2 Gy/fx)	Basic liver function	
Renal cortex (right and left)	200	17.5 (3.5 Gy/fx)	Basic renal function	



4. Selección incorrecta de cono
5. Error de orientación del paciente
- 6. Error de planificación**
 - Restricción dosis volumen
 - Dosis en piel



Factores asociados a toxicidad

- Planes con 3 haces
- Sistema de inmovilización
- Distancia piel-tumor <5cm
- D_{\max} piel > 50% de $D_{\text{prescripta}}$



7. Utilización de datos dosimétricos extrapolados
8. Grilla de calculo de dosis
9. Algoritmo de calculo de dosis



Brainlab AG
Kapellenstraße 12 • 85622 Feldkirchen • Germany

phone: +49 89 99 15 68 0
fax: +49 89 99 15 68 33

FIELD SAFETY NOTICE / PRODUCT NOTIFICATION

Subject: Software accuracy limitations for very small Multi-Leaf-Collimator (MLC) field sizes

Product Reference: All Brainlab BrainSCAN and iPlan RT treatment planning software versions

Date of Notification: March 9, 2012

Individual Notifying: Markus Hofmann, MDR & Vigilance Manager

Brainlab Identifier: 12-01-13.FIP.1

Type of action: Advice regarding use of device.

Brainlab has become aware of events where the accuracy of the Brainlab Radiotherapy treatment planning software was not within clinically desirable limits for very small Multi-Leaf-Collimator (MLC) field sizes.



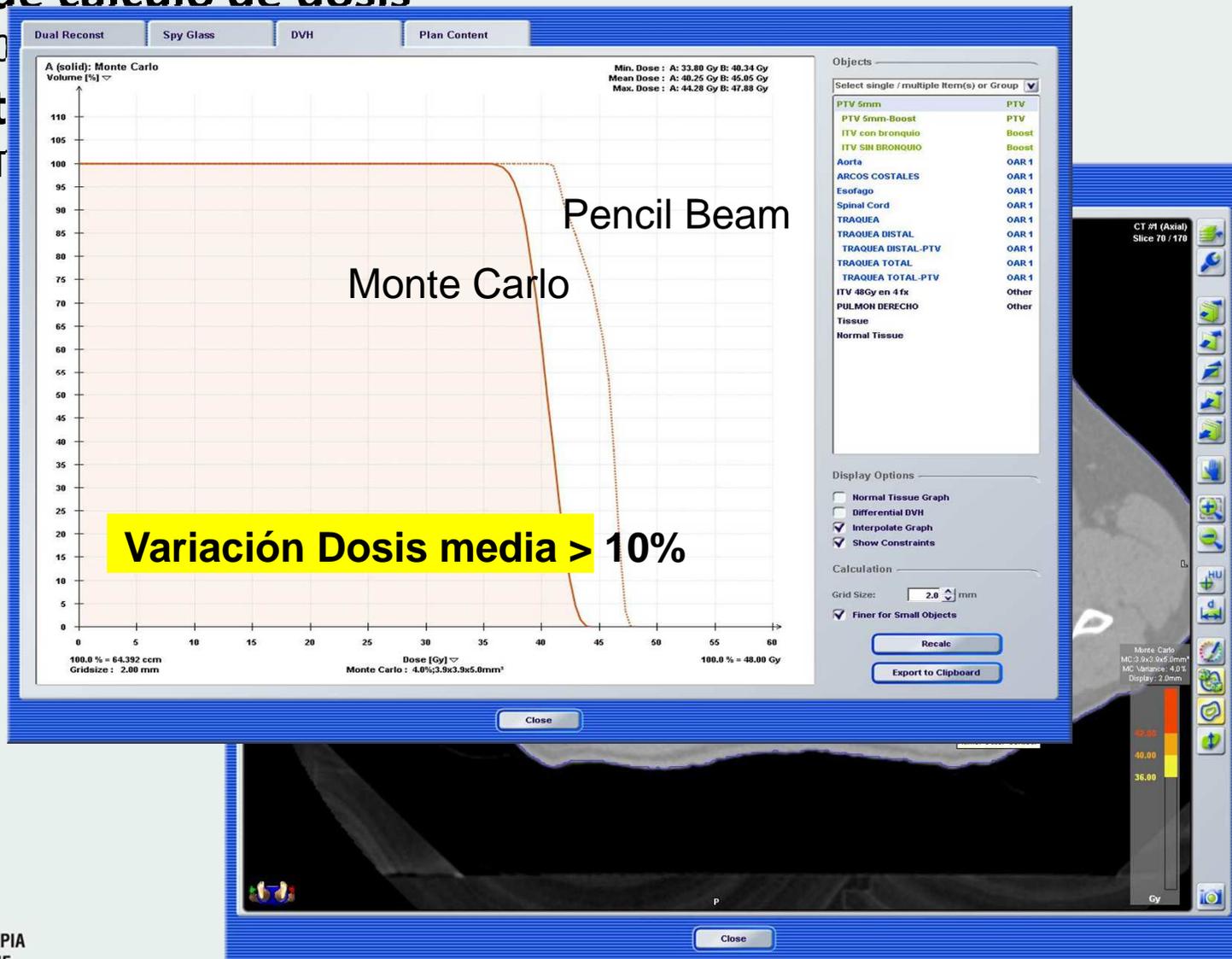
7. Utilización de datos dosimétricos extrapolados

8. Grilla de calculo de dosis

- TG10

9. Algorit

• SBRT



Porque hay accidentes en SRS/SBRT?

- Falta de entrenamiento, competencia o experiencia
- Personal inadecuado y/o formación inadecuada
- Fatiga o estrés
- Mal diseño y documentación de procedimientos
- Complejidad y sofisticación de nuevas tecnologías
- Exceso de confianza en procedimientos automáticos
- Infraestructura y ambiente de trabajo inadecuado
- Cambios en el proceso

Quality and safety in stereotactic radiosurgery and stereotactic body radiation therapy: can more be done?

Timothy D. Solberg, Ph.D. and Paul M. Medin, Ph.D.

Jour. of Radiosurgery and SBRT, Vol. 1, pp. 13-19
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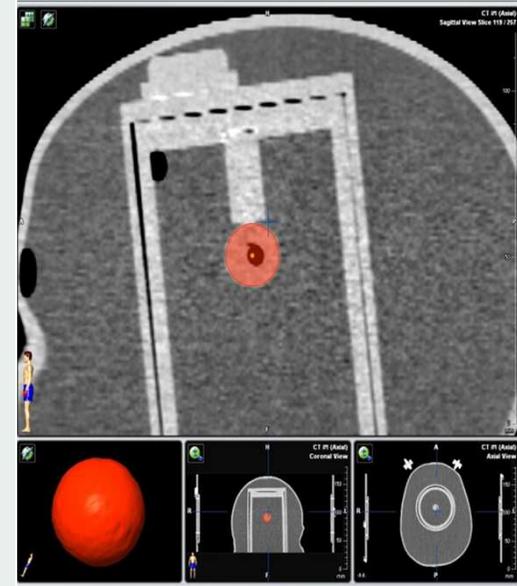
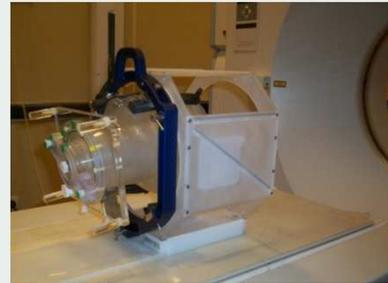
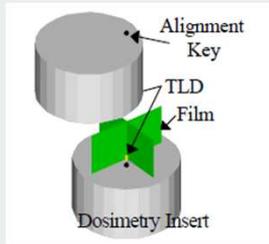
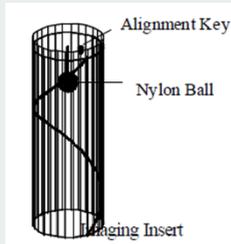
Control de calidad

- Isocentro del equipo (Test Winston-Lutz)
- Transferencia de coordenadas al equipo de tratamiento
- Dosimetría
 - Adquisición de datos del equipo de tratamiento
 - Modelado de maquina de tratamiento
 - Dosis calculada versus medida
 - IMRS requiere un control paciente especifico
- **AUDITORIA externa**



RPC Test - Head phantom

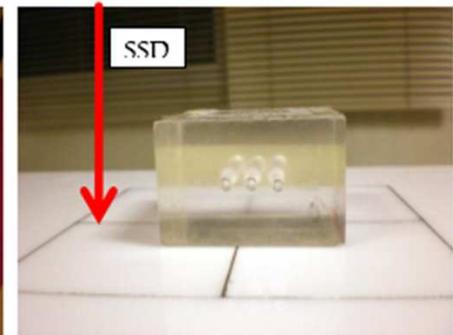
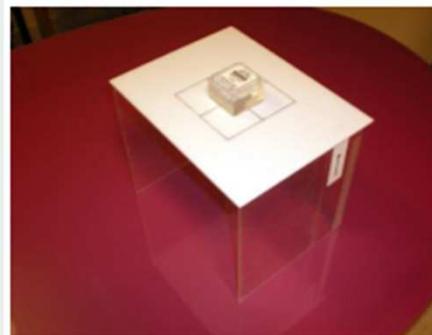
<http://rpc.mdanderson.org>



Posición en TAC

TAC

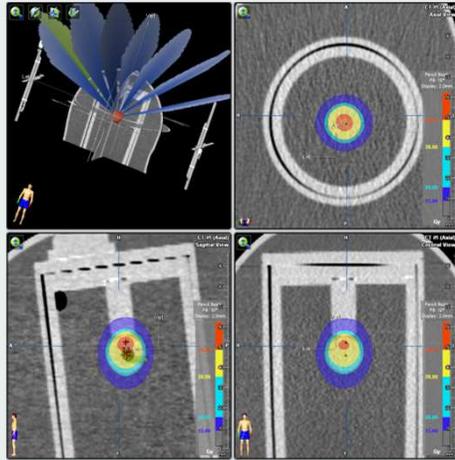
Irradiación TLD de referencia



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FUNDACIÓN MARIE CURIE

RPC Test - Head phantom

<http://rpc.mdanderson.org>



THE UNIVERSITY OF TEXAS #2766 Instituto De Radioterapia Oncologica

Dose to TLD Capsules (Gy)		Average Dose (Gy)	Institution Dose	Ratio
Upper	Lower	(Dose to Center)	(Gy)	Measured/Institution
29.6	28.5	29.0	29.7	0.98

Measured Along	FieldSize (86.7% Isodose Line)			Offset (86.7%) Line*
	Measured (cm)	Institution (cm)	Measured - Institution	
Sagittal-Axial line	2.17	2.05	0.12	0.07
Axial - Coronal Line	2.21	2.12	0.09	0.06
Sagittal - Coronal Line	2.28	2.32	-0.04	0.09

Treated Volume (cm ³)**	5.70	5.28	
-------------------------------------	------	------	--

Date of Report:
 Institution:
 Physician:
 Radiation Machine:
 Stereotactic System:
 Date of Irradiation:

Description of Procedure:
 An anthropomorphic head phantom, imaged, and irradiated with dosimetry capsules provide point dose information. The dose profiles allow measurement of the dose along the principal axes in addition to an evaluation of the dose distribution presented in summary below and 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 (RDS/Institution)	0.98	0.95 - 1.05
Treated Volume ^(b) : (Measured/Institution)	1.08	0.75 - 1.25 ^(c)
Ratio of Measured Treated Volume to Target Volume ^(d)	1.59	1.00 - 2.00
Minimum Dose to Target (Minimum Dose/Prescription Dose) ^(e)	1.03	> 0.90

Prescription dose stated by the institution is 86.7% of the maximum dose.

(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 Analysis By: Gunn Sutedja
 Film Analysis By: Trang Nguyen
 Report Checked by: Susan A. Smith

Marilyn Stovall / 8/24/2000
 Marilyn Stovall, Ph.D. / Date



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Algunas conclusiones...

- La utilización de conos permite la realización de tratamiento con arcos
- La utilización de microMLC permite la realización de tratamientos en arcos (estáticos o dinámicos), tratamientos conformados e IMRS (depende del TPS)
- Una auditoria externa nos permite el control del proceso global de radiocirugía
- Una auditoria externa nos ayuda a controlar los parámetros principales asociados al proceso de la radiocirugía
 - Precisión mecánica
 - Precisión dosimétrica

