

***Disminución de la dosis en OAR con la nueva tecnología***

***Nuevos protocolos y procedimientos por nuevo equipamiento***

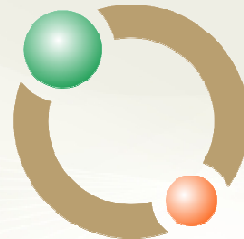
***Influencia de la complejidad – personal - capacitación***

**Daniel Venencia, Físico Medico**

Instituto de Radioterapia, Córdoba, ARGENTINA

**Curso de Actualización en Protección Radiológica**

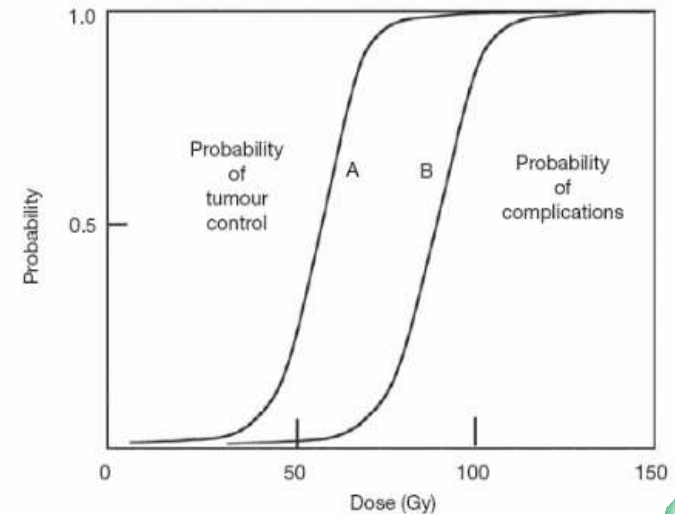
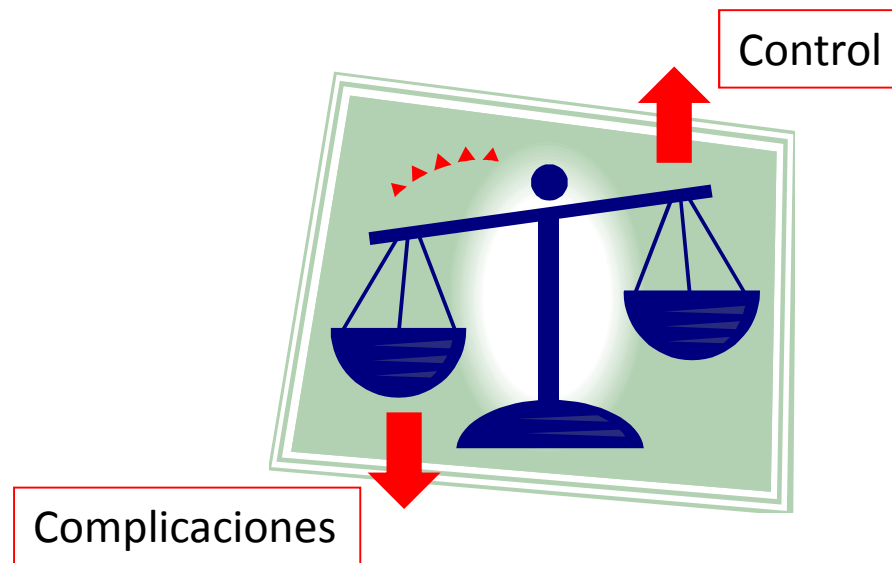
Córdoba, 21 al 23 de Noviembre 2013



**INSTITUTO DE RADIOTERAPIA  
FUNDACIÓN MARIE CURIE**

# Radioterapia

- El objetivo es el de entregar una alta dosis **uniforme** de radiación a un volumen de tratamiento, con el objeto de maximizar el control tumoral, manteniendo la dosis en los tejidos vecinos **tan baja como sea posible** para disminuir la probabilidad o severidad de complicaciones en tejidos normales.



# Radioterapia

## Radioterapia 2D

- Simulación rayos X
- Imagen única de CT en isocentro
- Diseño de campos basado en referencias óseas y juicio medico
- Arreglo simple de campos
- Distribución de dosis limitado a un volumen de tratamiento
- Sin información volumétrica, etc.



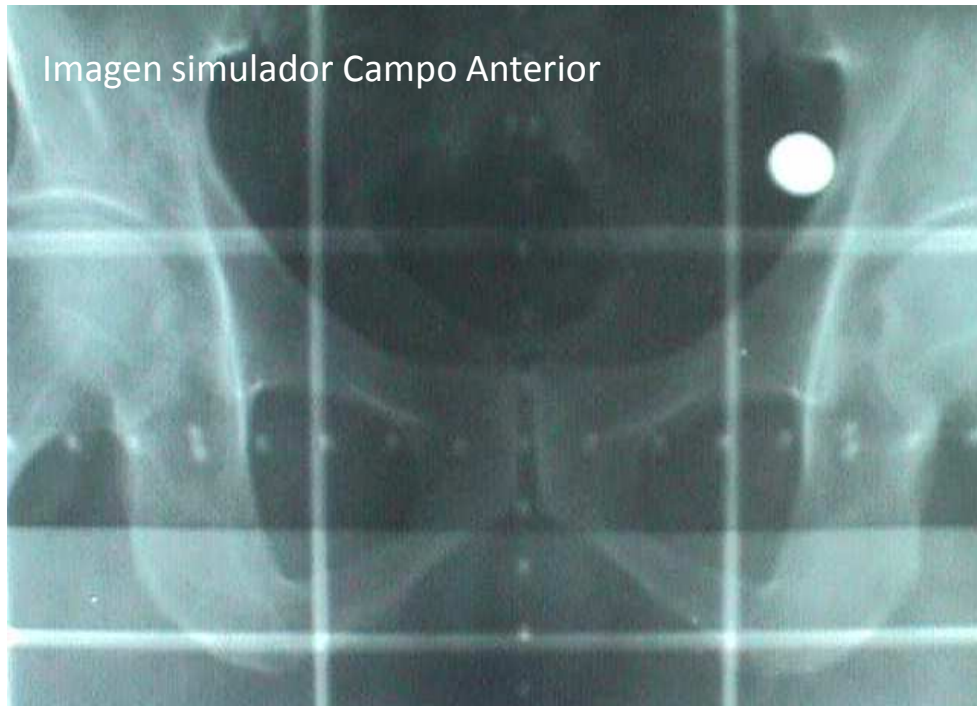
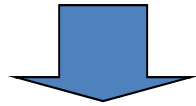
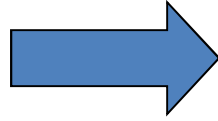


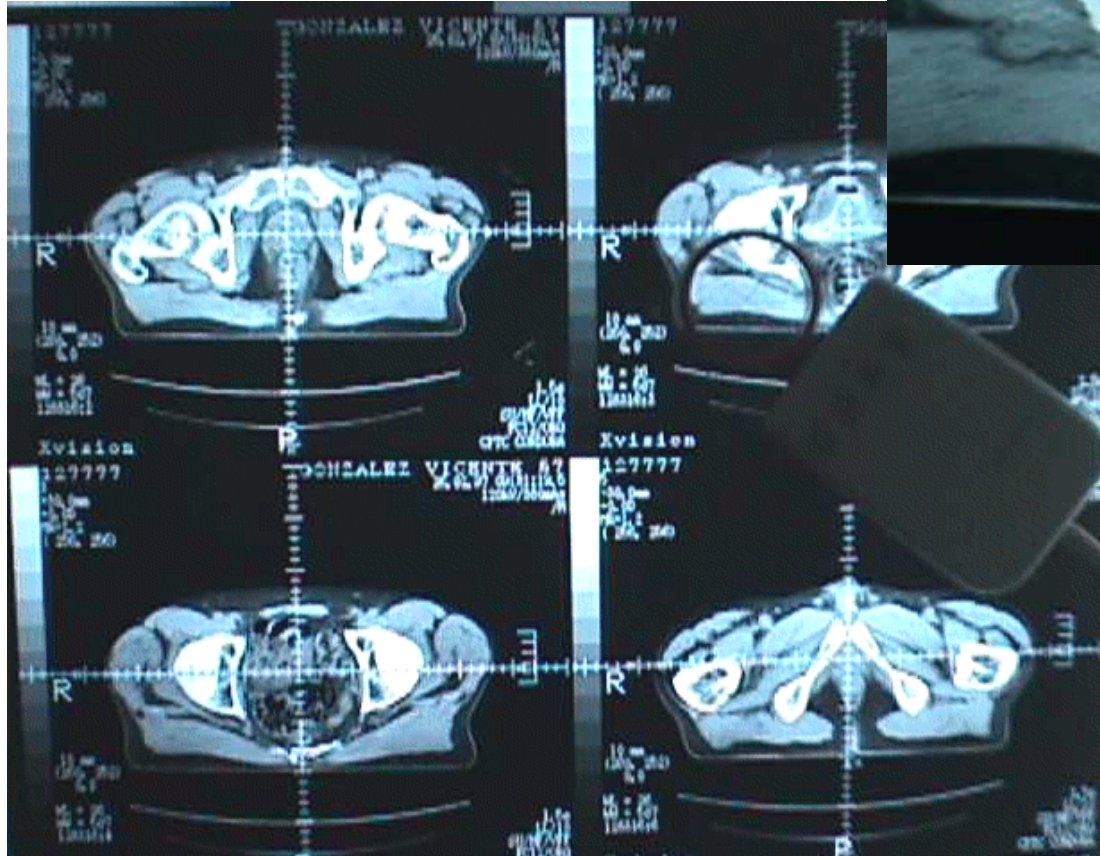
Imagen simulador Campo Anterior



Imagen simulador Campo Lateral



Imagen de TAC para  
**Planificación Computada**



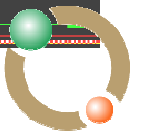
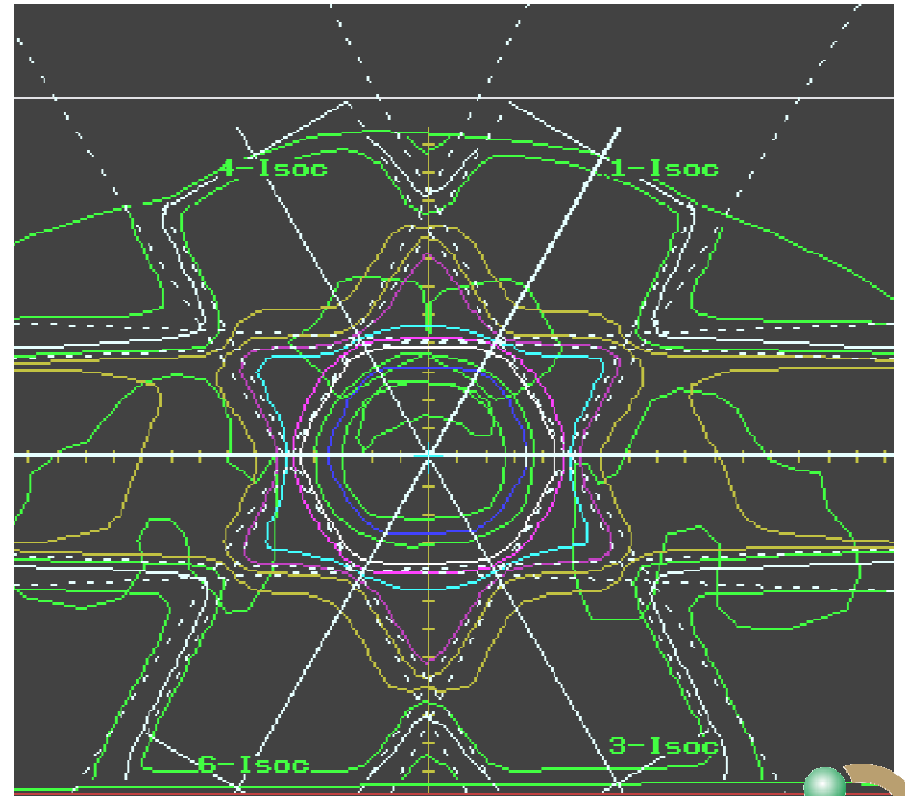
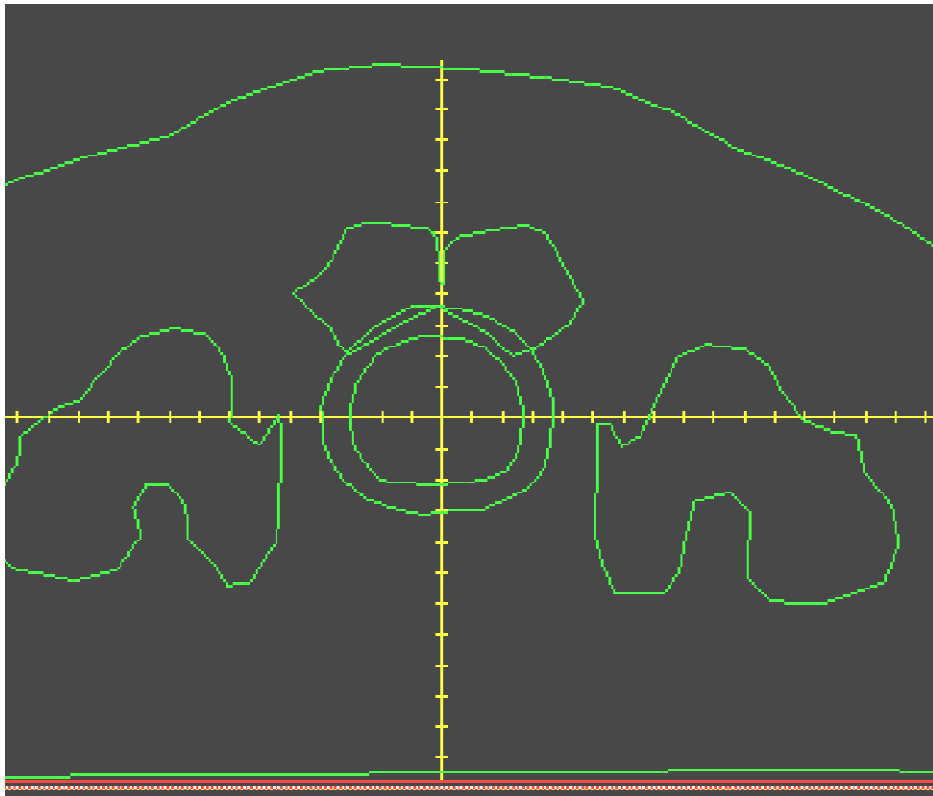
Ingreso de TAC  
al TPS por digitalizador





# Radioterapia convencional

Cálculo de distribución de dosis en 2D (en 1 plano)



# Radioterapia

Avances en tecnología computacional han permitido una transición de una planificación y entrega de tratamiento básico 2D a una aproximación sofisticada como es la radioterapia 3D (3DCRT)

## Radioterapia 2D

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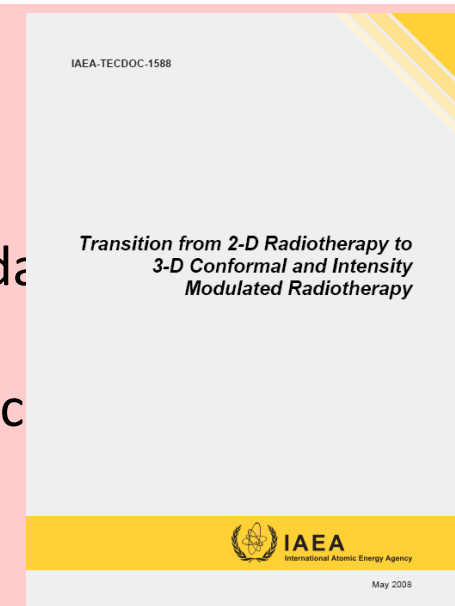


# Radioterapia

Radioterapia conformada 3-D es el termino utilizado para describir el diseño y entrega de planes de tratamiento basados en imágenes 3D con campos individualmente conformados para tratar solamente el volumen blanco.

## Radioterapia 3D

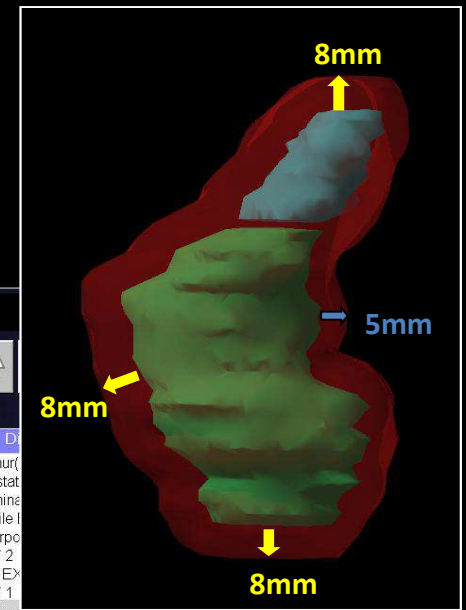
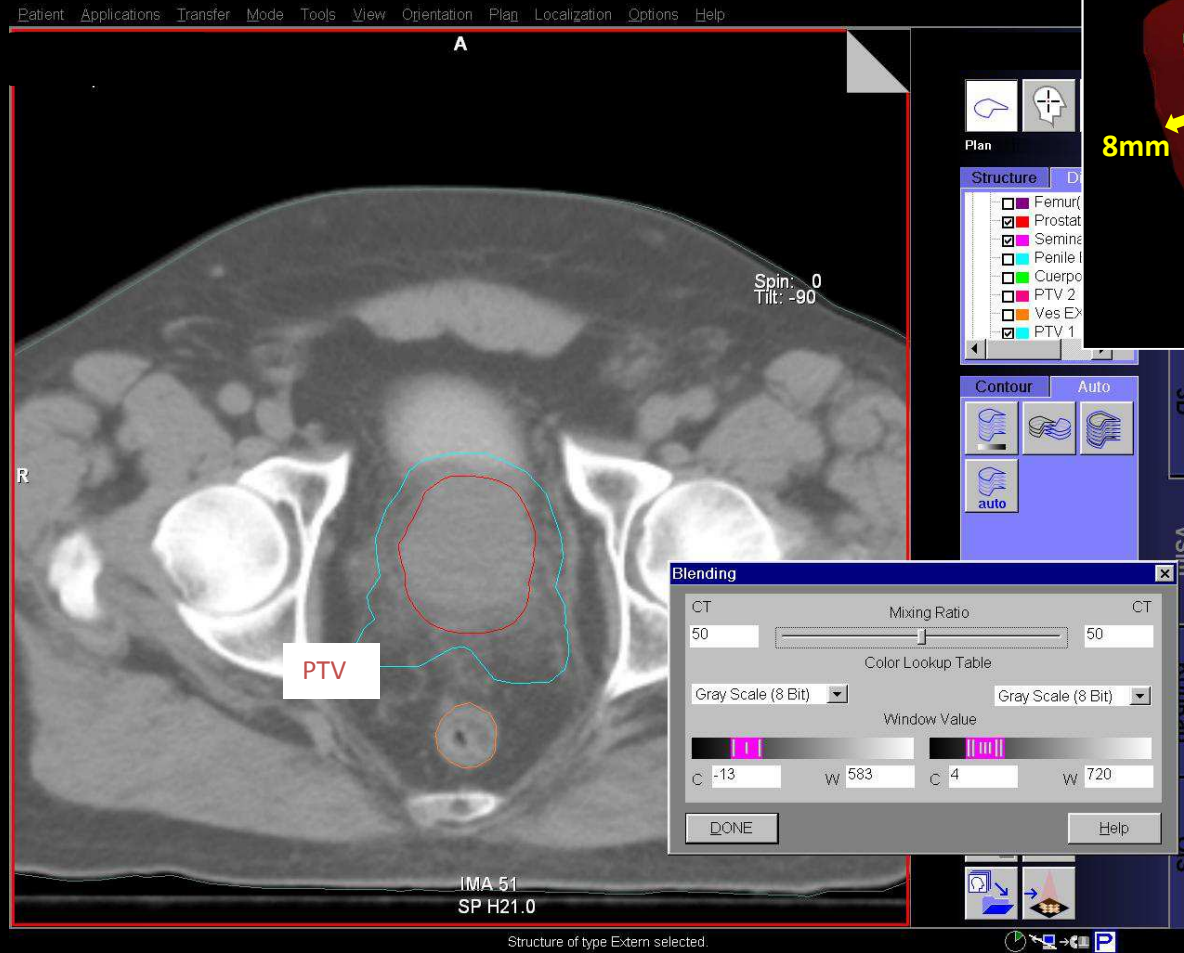
- Simulación por TAC
- Delimitación de volúmenes (ICRU50/62/83)
- Disponibilidad de fusión entre diversas modalidades
- Reconstrucción 3D de volúmenes
- Elección de haces con variadas incidencias (no-coplanares)
- Análisis de HDV (histogramas dosis volumen)
- Posibilidad de optimizar planes, etc.





# Simulación virtual Ca. de Próstata

- TAC
- TAC con contraste (fusión)



## Simulación virtual Ca. de Próstata

- TAC
- TAC con contraste (fusión)
- RNM (fusión)

Patient Applications Transfer Mode Tools View Orientation Plan Simulation Options Help

Plan Date: 6/2/2008

Plan: IMRT PTV1

Beam: Display

- Rectum
- Femur(L)
- Femur(R)
- Prostate
- Seminal Ves
- Penile Bulb
- Cuerpos cav
- PTV 2

Table Angle MLC

Position (x,y,z) in cm

0 0 0

Rel to: Isocentro II

SSD 82.7 (cm)

Tools View Orien...

Y1(cm): 0.00 Y2(cm): 0.00 W 1645 C -202

Table Pos(cm) 0,0,0,0,0,0

Institution: IPRO  
Plan Name: IMRT\_PTV1  
Beam Name: 7.5100  
Machine Name: PRIMUSIEC  
SAD(cm): 100.0  
SSD(cm): 82.7

Gantry: 100.0  
Collimator: 0.0  
Table Rot: 0.0

ALVAREZ RESTOR 01 1946 Sep 15 MFR

ALVAREZ RESTOR 01 1946 Sep 15 MFR

ALVAREZ RESTOR 01 1946 Sep 15 MFR

ALVAREZ RESTOR 01 1946 Sep 15 MFR

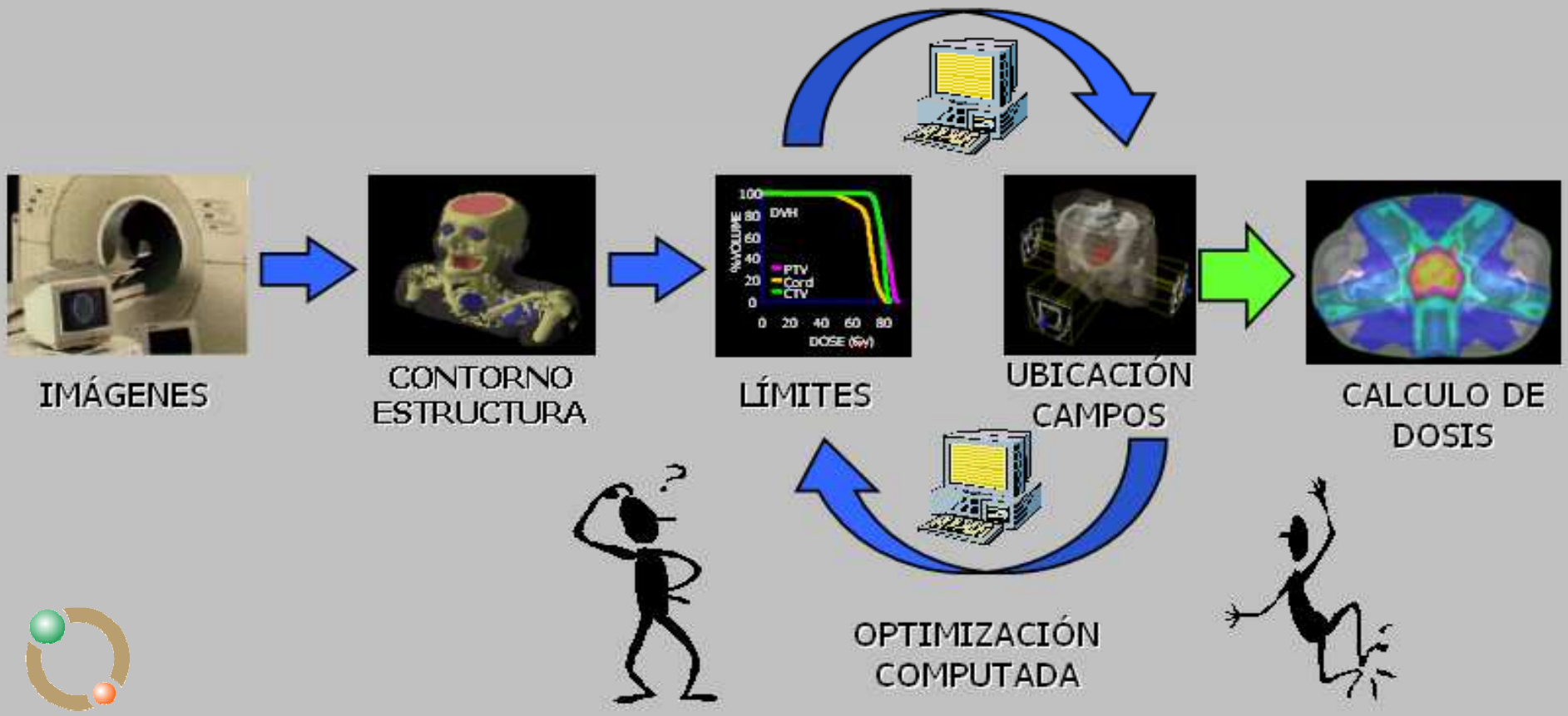
Viewing  
Fliming  
3D  
VSim  
KonRad  
OIS

Simulación virtual



La **Radioterapia por Modulación de Intensidad (IMRT)** utiliza haces de radiación con intensidad no uniformes, las cuales son determinadas por técnicas de optimización computacionales o “planificación inversa”.

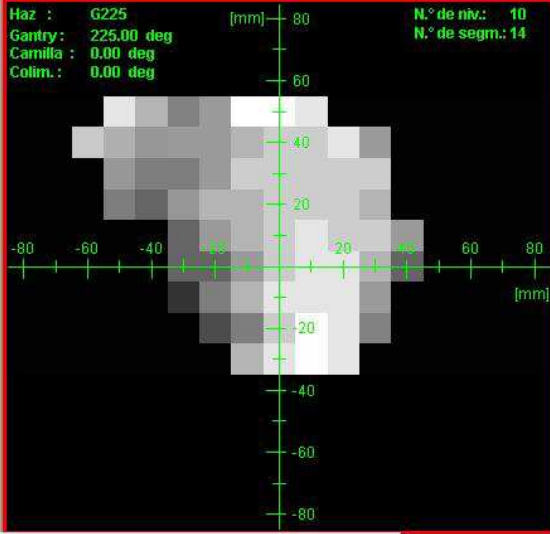
Con **IMRT** es posible obtener distribuciones de dosis cóncavas y un aumento en el gradiente de dosis en los bordes del PTV, permitiendo una mayor conformación de las distribuciones de dosis, lo cual se traduce en una mayor protección de los tejidos sanos





Plan Salida

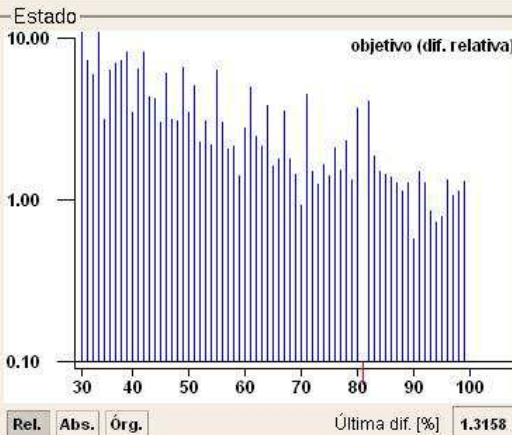
Visualización de la fluencia



TC (sagital/frontal) Fluencia  
 DVH (completo)  Mostrar suma de dosis

Configurar

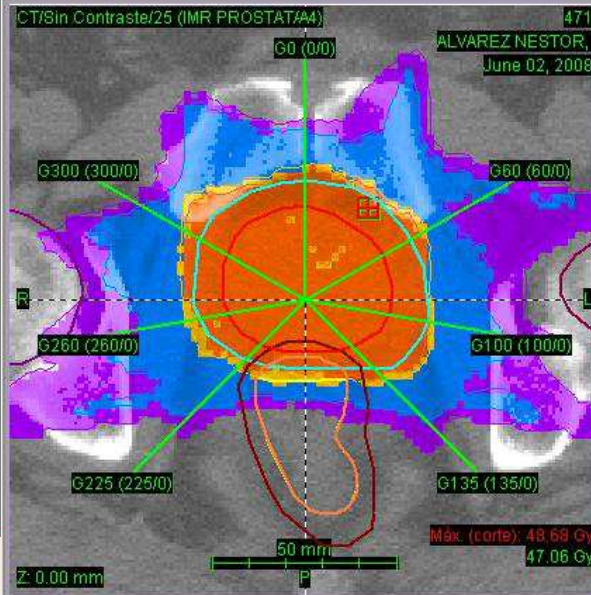
Secuenciador Isodosis Normalización  
 Márgenes



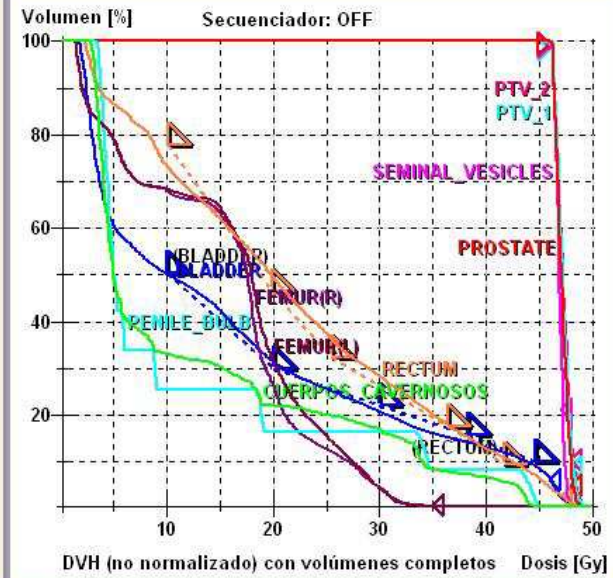
Optimización

Restablecer **Iniciar** Detener

Transversal



Histograma de volúmenes de dosis



Parámetros del órgano

VOI	On/Off	Prioridad Superposición	Tipo de órgano	Máxima dosis [Gy]	Ponderación	Mínima dosis [Gy]	Ponderación	Puntos DVH
PTV_2	<input checked="" type="checkbox"/>	3	1 2 3	48.0	1.0	46.0	15.0	
PTV_1	<input checked="" type="checkbox"/>	4	1 2 3	48.0	5.0	46.0	15.0	
SEMINAL_VESICLES	<input checked="" type="checkbox"/>	2	1 2 3	47.0	1.0	46.0	20.0	
PROSTATE	<input checked="" type="checkbox"/>	1	1 2 3	48.0	1.0	46.0	30.0	

[2] Órganos de riesgo

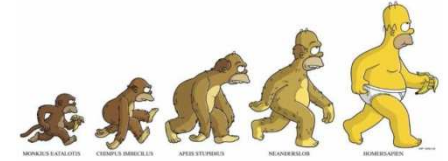
BLADDER	<input type="checkbox"/>	6	1 2 3	46.0	15.0	0.0	0.0	<input type="checkbox"/>
FEMUR(R)	<input type="checkbox"/>	1	1 2 3	35.0	1.0	0.0	0.0	<input type="checkbox"/>
PENILE_BULB	<input type="checkbox"/>	2	1 2 3	46.0	1.0	0.0	0.0	<input type="checkbox"/>
FEMUR(L)	<input type="checkbox"/>	1	1 2 3	35.0	1.0	0.0	0.0	<input type="checkbox"/>
RECTUM	<input type="checkbox"/>	5	1 2 3	47.0	25.0	0.0	0.0	<input type="checkbox"/>

Aceptar

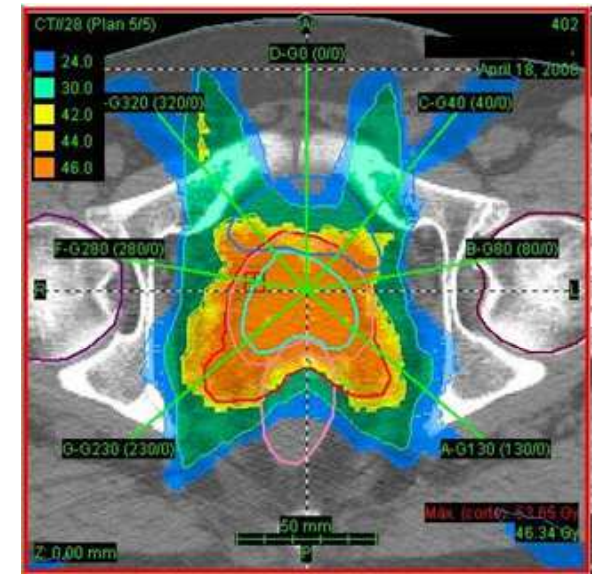
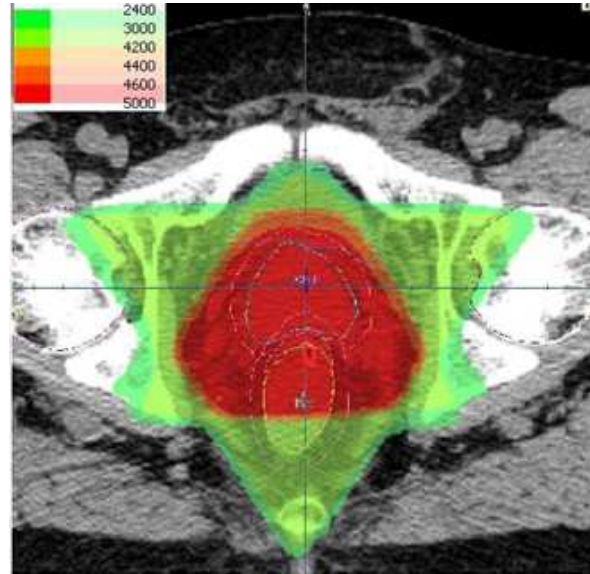
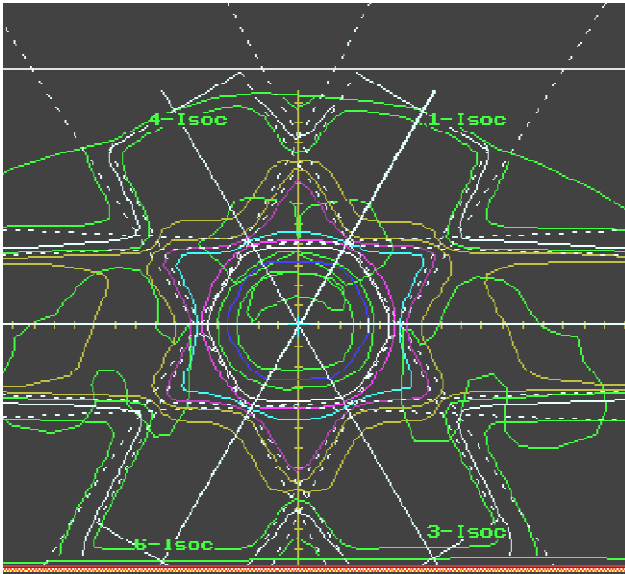
Cancelar

Estado



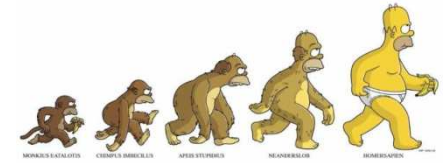


2D → 3D → IMRT →

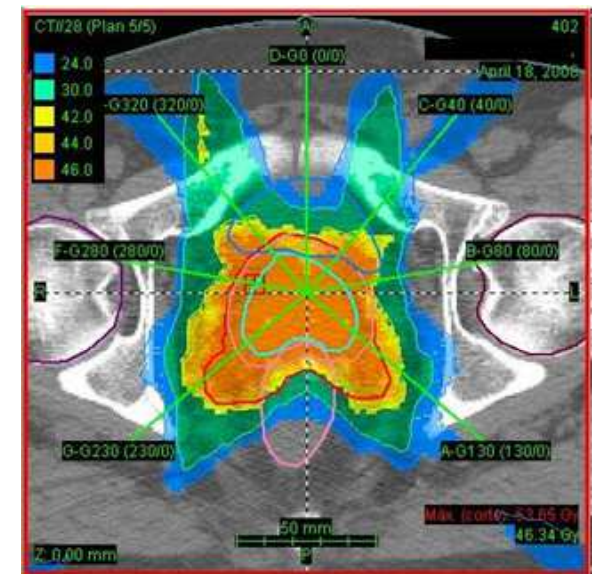
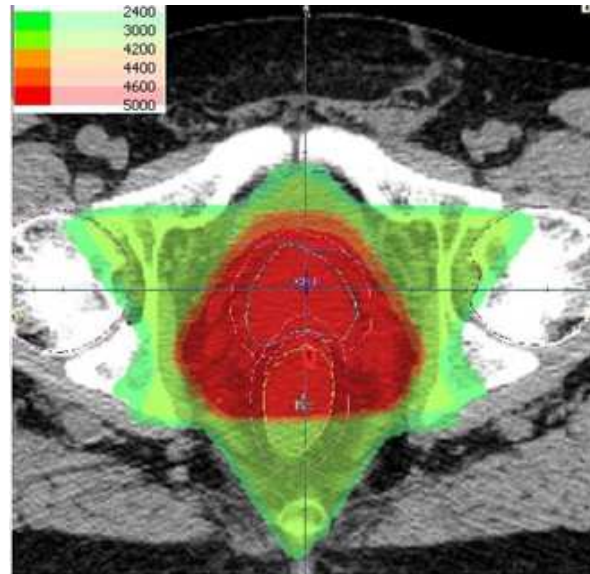
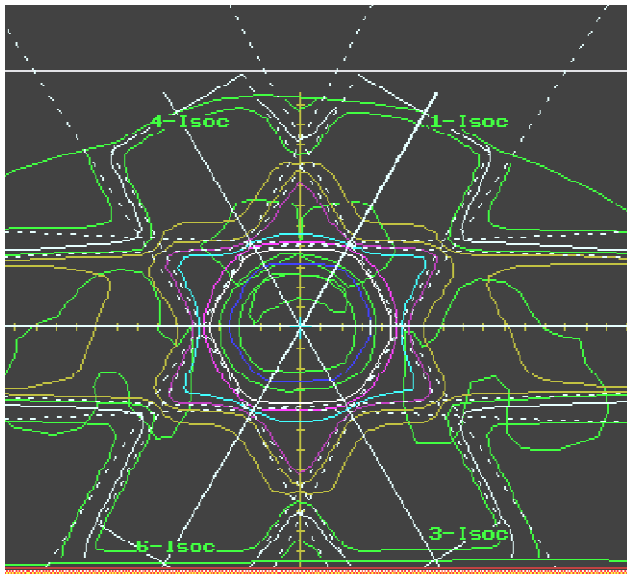


- Disminución de la dosis en los OAR
- Generación de nuevos procedimientos
- Nuevas necesidades de formación – personal - QA





2D → 3D → IMRT →



- Disminución de la dosis en los OAR
- Generación de nuevos procedimientos
- Nuevas necesidades de formación – personal - QA

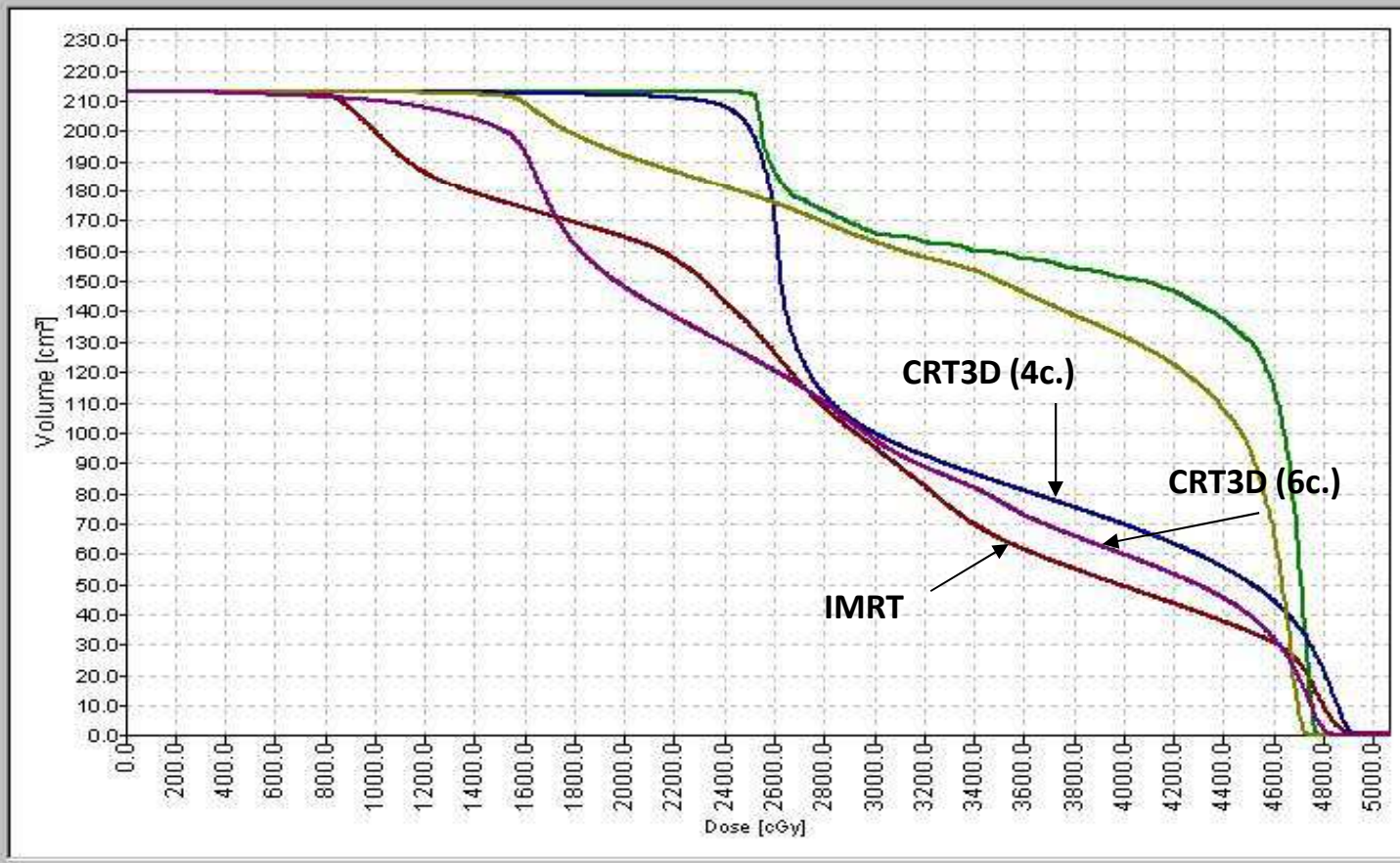
Plan Comparison with Dose Volume Histogram

Patient Volumes:

vejiga

Calculate Export... Print...

	Plan	Structure	Prescr.[cGy]	Treat.[%]	Cov.[%]	Volume [cm <sup>3</sup> ]	Min [cGy]	Max [cGy]	Mean [cGy]	Mo
<input checked="" type="checkbox"/>	IMRT PTV1	vejiga	4600.0	96.0	100.0	212.3	658.9	5055.0	2915.1	4781
<input checked="" type="checkbox"/>	4 CAMPOS ABI	vejiga	4600.0	99.0	100.0	212.3	2434.8	4777.0	4119.3	4714
<input checked="" type="checkbox"/>	4 CAMPOS C/P	vejiga	4600.0	95.0	100.0	212.3	1511.9	4930.5	3405.4	2617
<input checked="" type="checkbox"/>	6 CAMPOS ABI	vejiga	4600.0	99.0	100.0	212.3	906.3	4738.5	3847.8	4678
<input type="checkbox"/>	CRT3D (Bloques)	vejiga	4600.0	95.0	100.0	212.3	281.6	4903.6	3024.3	4820
<input checked="" type="checkbox"/>	CRT3D (MLC)	vejiga	4600.0	96.0	100.0	212.3	277.5	4832.8	2988.0	4760



**Histogram Parameters**

Grid

Type:

- Cumulative
- Differential
- Natural

Dose range [cGy]:

0 to 5060

Apply range

Close



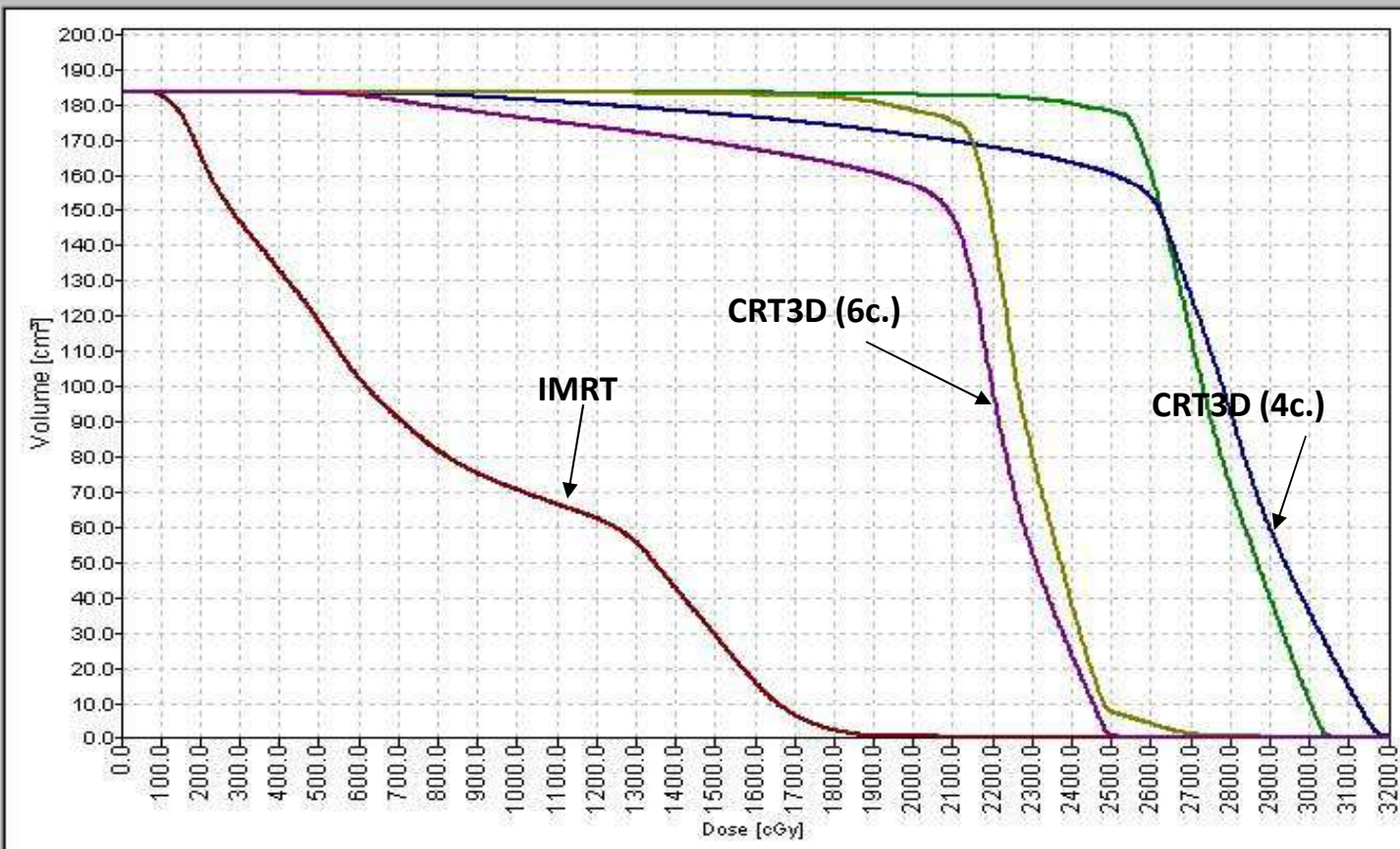
Plan Comparison with Dose Volume Histogram

Patient Volumes:

Calculate Export... Print...

Femur Der

	Plan	Structure	Prescr.[cGy]	Treat.[%]	Cov.[%]	Volume [cm <sup>3</sup> ]	Min [cGy]	Max [cGy]	Mean [cGy]	Mo
<input checked="" type="checkbox"/>	IMRT PTV1	Femur Der	4600.0	96.0	100.0	183.0	85.2	2062.6	838.7	194.
<input checked="" type="checkbox"/>	4 CAMPOS ABI	Femur Der	4600.0	99.0	100.0	183.0	2005.6	3052.7	2764.4	2700.
<input checked="" type="checkbox"/>	4 CAMPOS C/P	Femur Der	4600.0	95.0	100.0	183.0	380.5	3195.7	2731.2	2800.
<input checked="" type="checkbox"/>	6 CAMPOS ABI	Femur Der	4600.0	99.0	100.0	183.0	1555.2	2875.6	2294.5	2236.
<input type="checkbox"/>	CRT3D (Bloques)	Femur Der	4600.0	95.0						
<input checked="" type="checkbox"/>	CRT3D (MLC)	Femur Der	4600.0	96.0	100.0	183.0	314.0	2512.6	2132.2	2186.



**Histogram Parameters**

Grid

Type:

- Cumulative
- Differential
- Natural

Dose range [cGy]:

0 to 3200

Apply range

Close

Plan Comparison with Dose Volume Histogram

Patient Volumes:

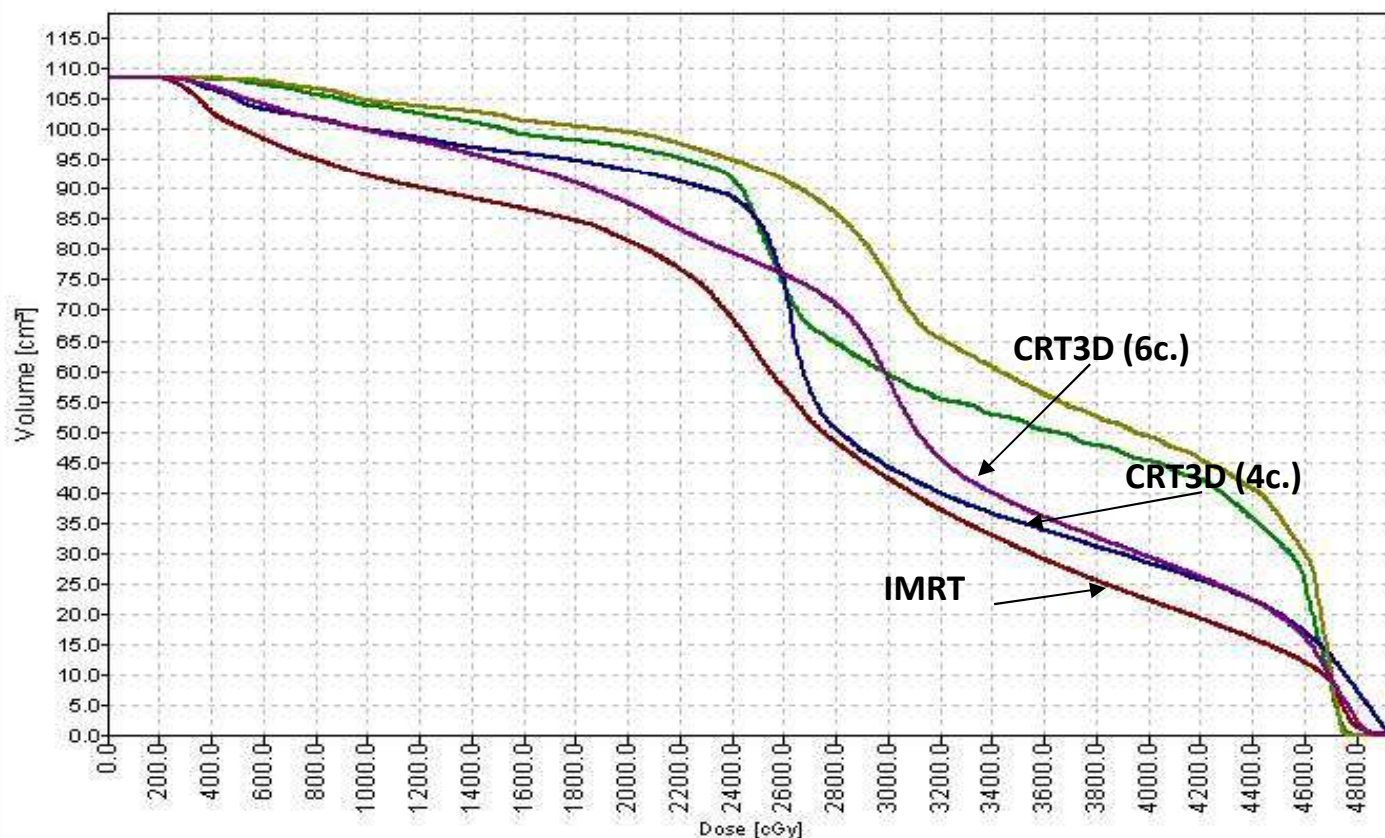
Calculate

Export...

recto cc

Print...

	Plan	Structure	Prescr.[cGy]	Treat.[%]	Cov.[%]	Volume [cm <sup>3</sup> ]	Min [cGy]	Max [cGy]	Mean [cGy]	Mo
<input checked="" type="checkbox"/>	IMRT PTV1	recto cc	4600.0	96.0	100.0	108.0	212.8	4950.2	2716.4	474
<input checked="" type="checkbox"/>	4 CAMPOS ABI	recto cc	4600.0	99.0	100.0	108.0	514.2	4775.0	3368.5	470
<input checked="" type="checkbox"/>	4 CAMPOS C/P	recto cc	4600.0	95.0	100.0	108.0	313.5	4956.7	3031.6	262
<input checked="" type="checkbox"/>	6 CAMPOS ABI	recto cc	4600.0	99.0	100.0	108.0	627.6	4756.9	3586.7	470
<input type="checkbox"/>	CRT3D (Bloques)	recto cc	4600.0	95.0						
<input checked="" type="checkbox"/>	CRT3D (MLC)	recto cc	4600.0	96.0	100.0	108.0	262.3	4861.2	3064.6	469



Histogram Parameters

Grid

Type:

- Cumulative
- Differential
- Natural

Dose range [cGy]:

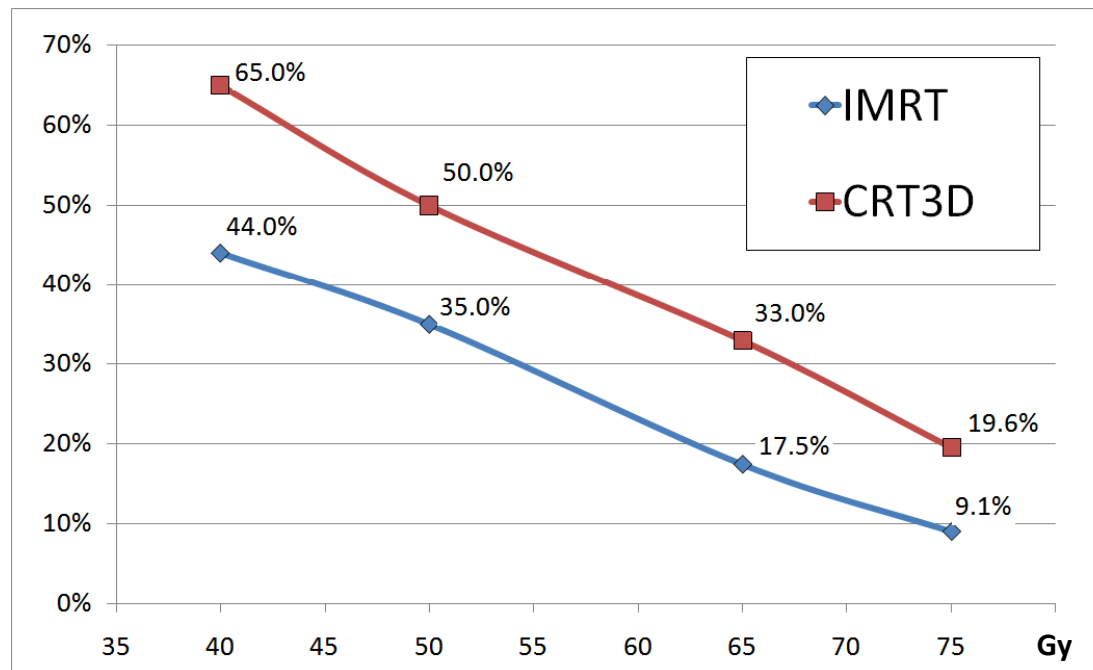
0 to 4960

Apply range

Close

# Comparación IMRT vs. CRT3D – Próstata

- HDV Recto -



N = 23 pacientes

## IMRT

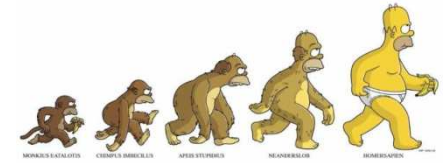
- 7cps. 6MV

## CRT3D

- 6cps. 10MV
- Conformación MLC

- Ídem Dosis media  
PTV ( $D_{PTV}$ )





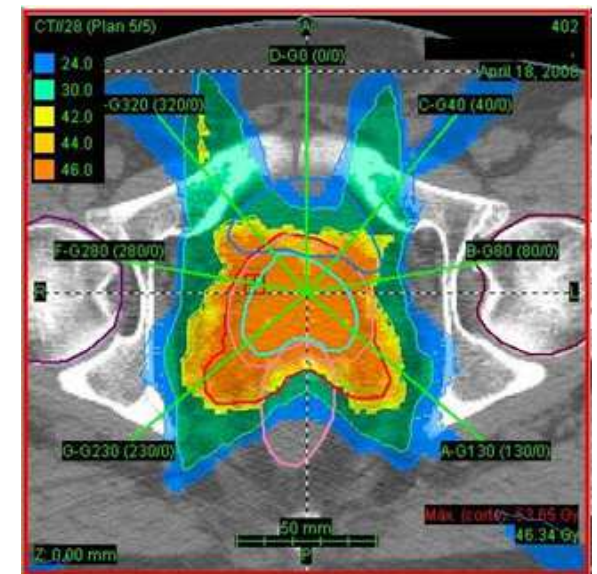
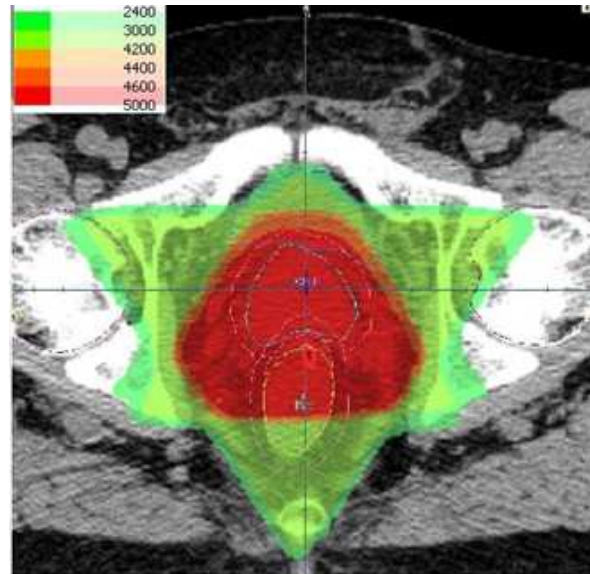
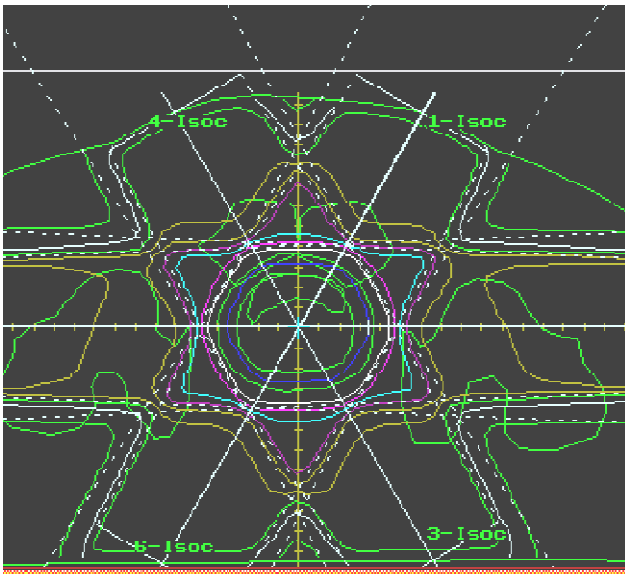
2D



3D

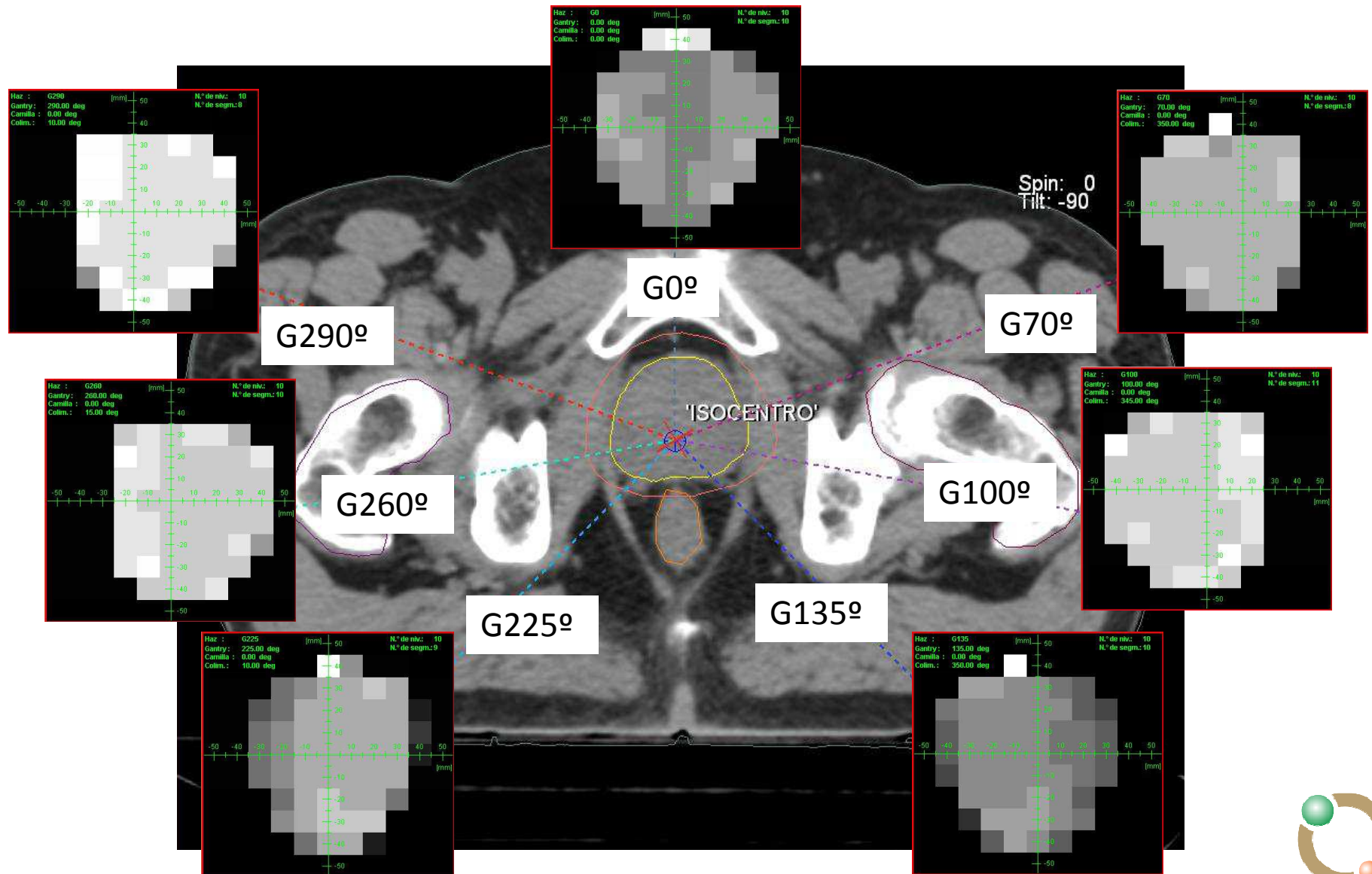


IMRT



- Disminución de la dosis en los OAR
- Generación de nuevos procedimientos
- Nuevas necesidades de formación – personal - QA

# Fluencias campos de IMRT

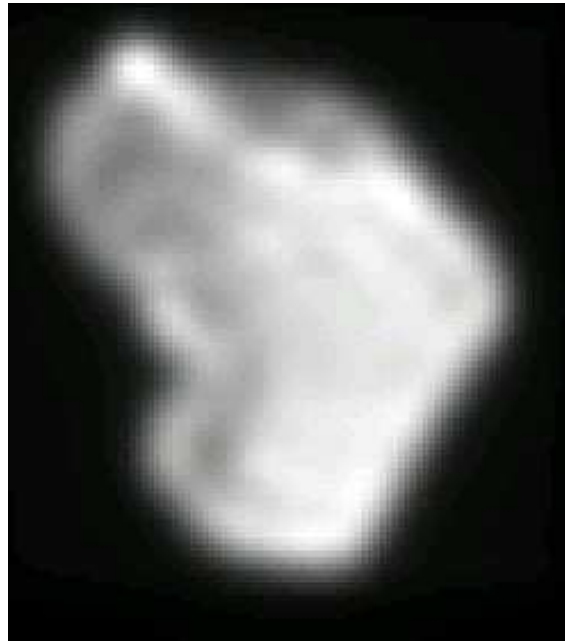


# QA IMRT – Especifico del paciente

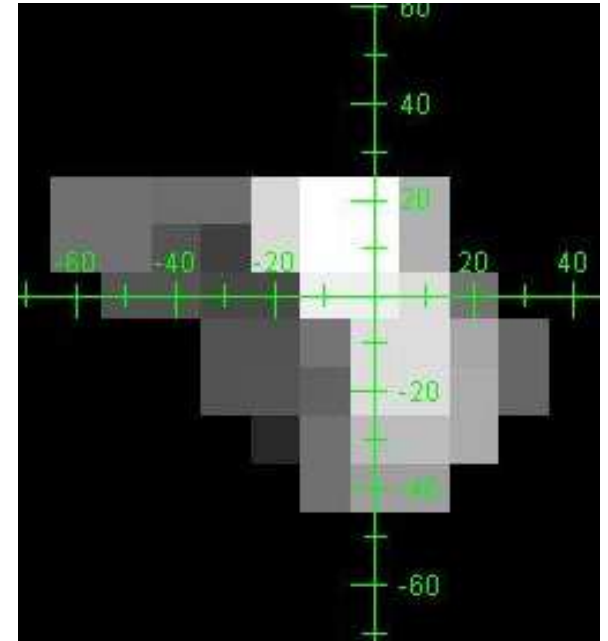
3D CRT



IMRT dinámico



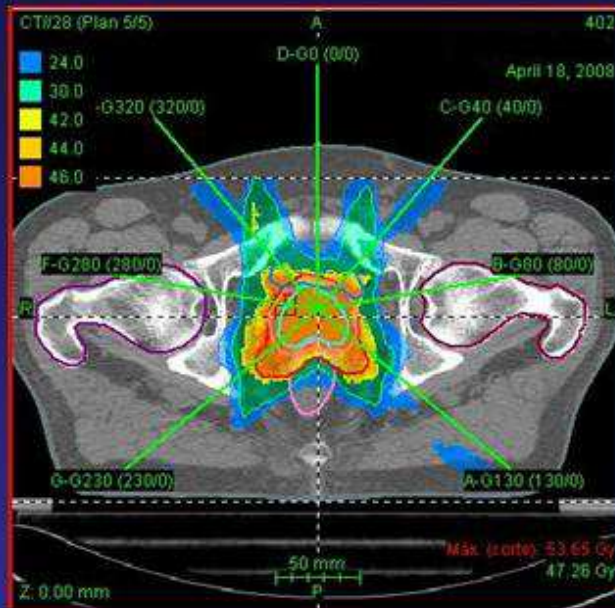
IMRT Step&Shoot



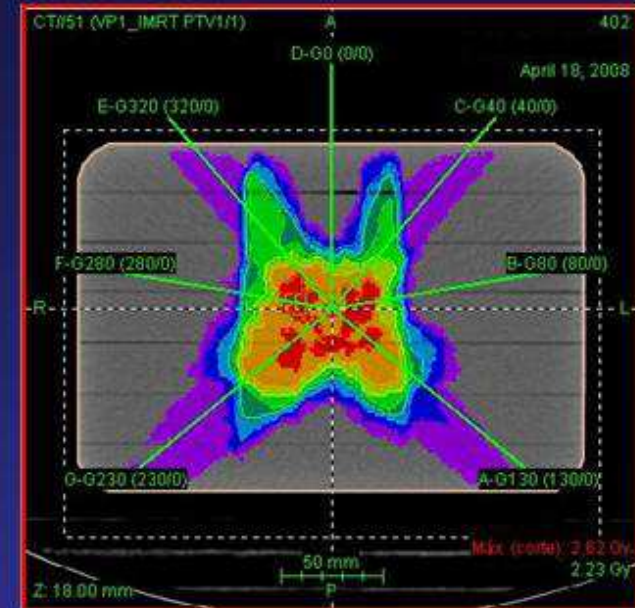
Como verificamos la dosis entregada por cada campo ?



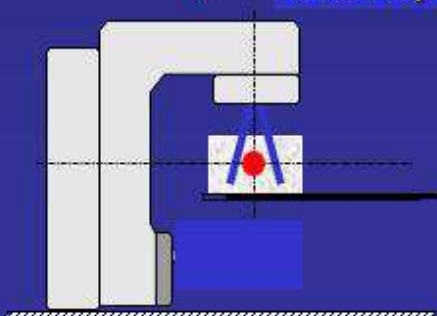
# Medición de la dosis total para el PLAN



- Geometrías
- Fluencia
- UM



Archivos de campo



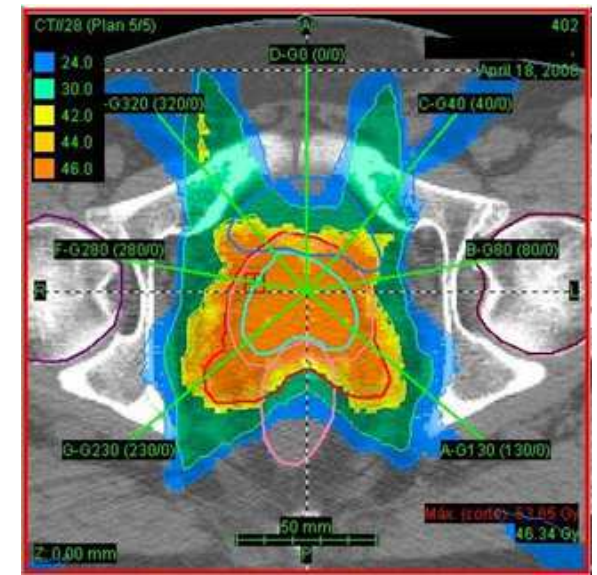
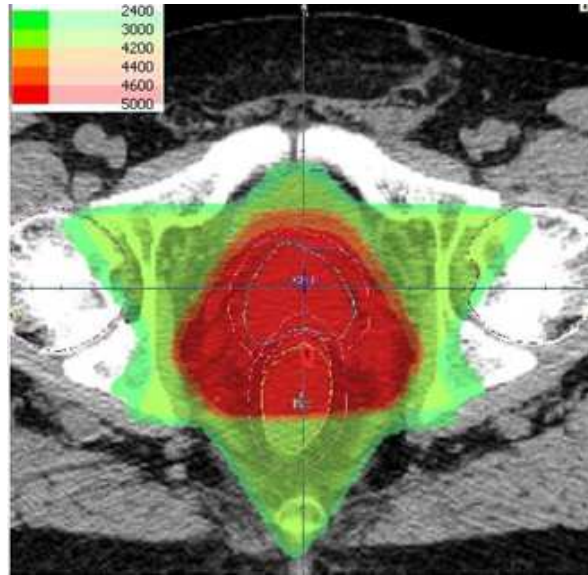
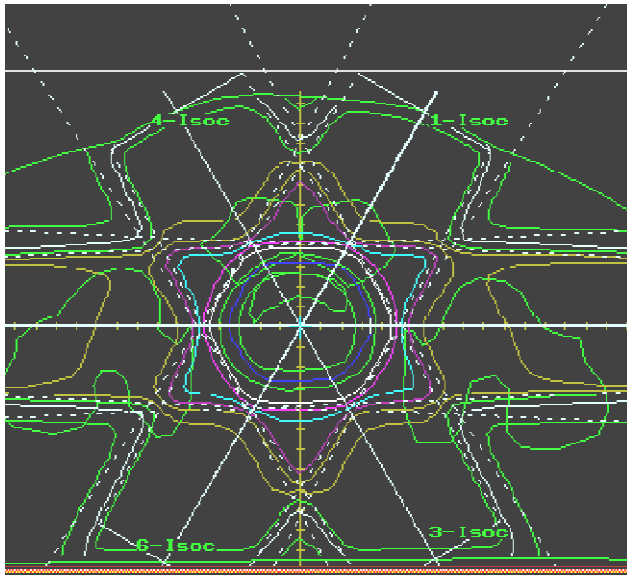
Dosis Medida

Dosis media  
(obtenida del HDV)





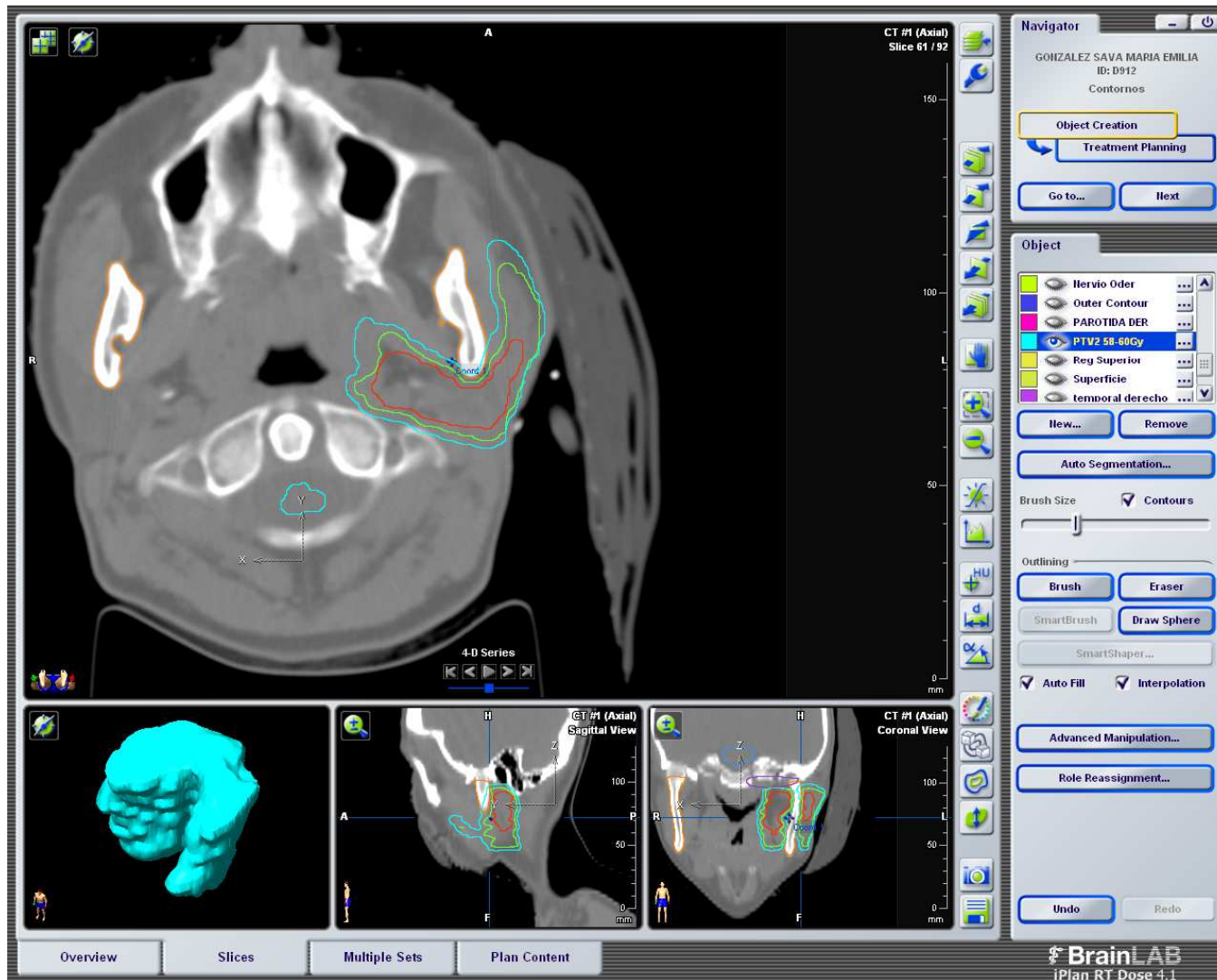
2D → 3D → IMRT →

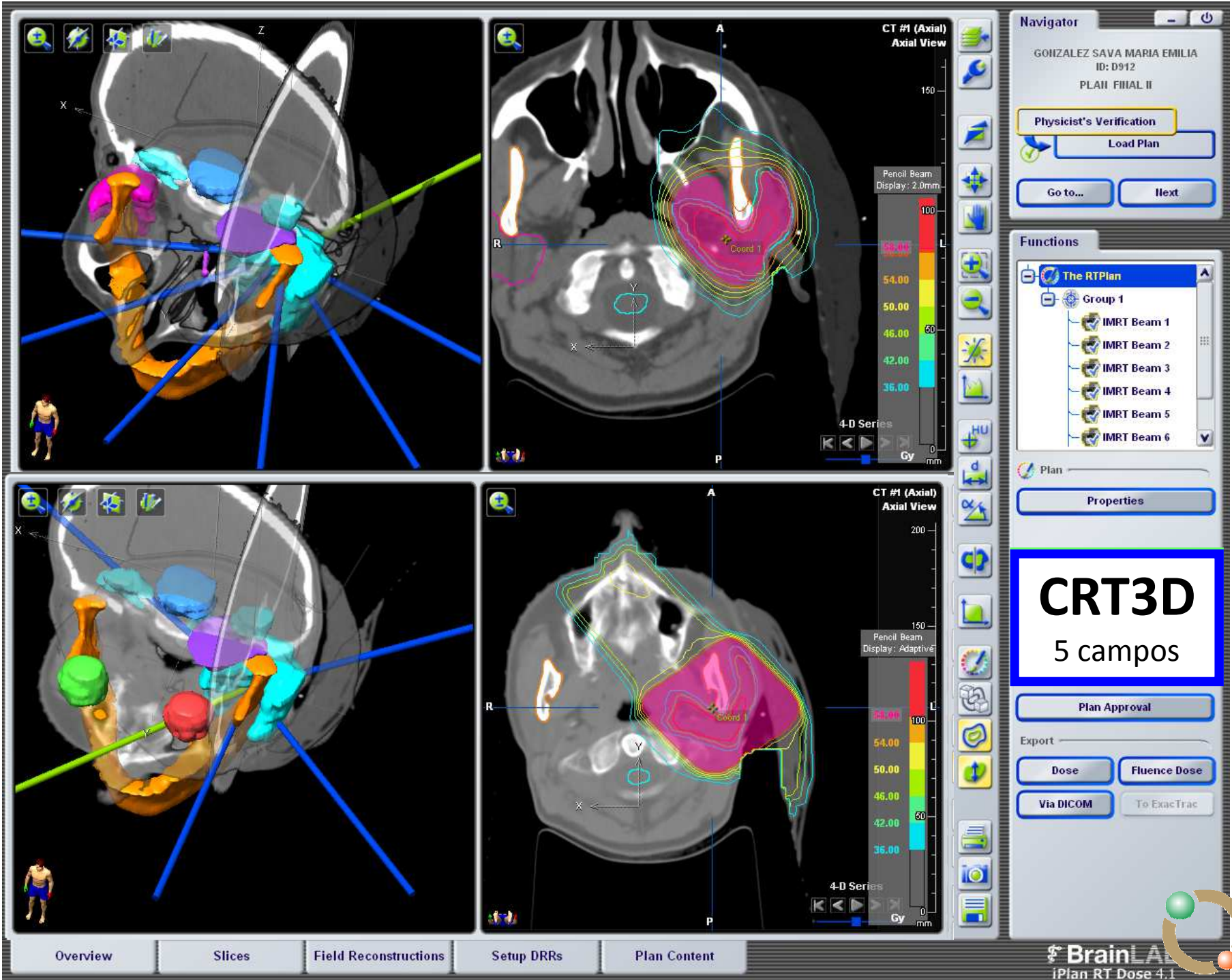


- Las nuevas tecnologías permiten tratamientos con **mayor conformación y gradiente de dosis**
- El aumento de las UM/incidencias podría generar un aumento del volumen de dosis bajas las cuales deben ser consideradas, estas dependen
  - Numero de haces
  - Energía del haz
  - Restricciones dosis volumen (modulación del haz, UM, tiempos de tratamiento)
  - Técnica de IMRT, etc., etc.

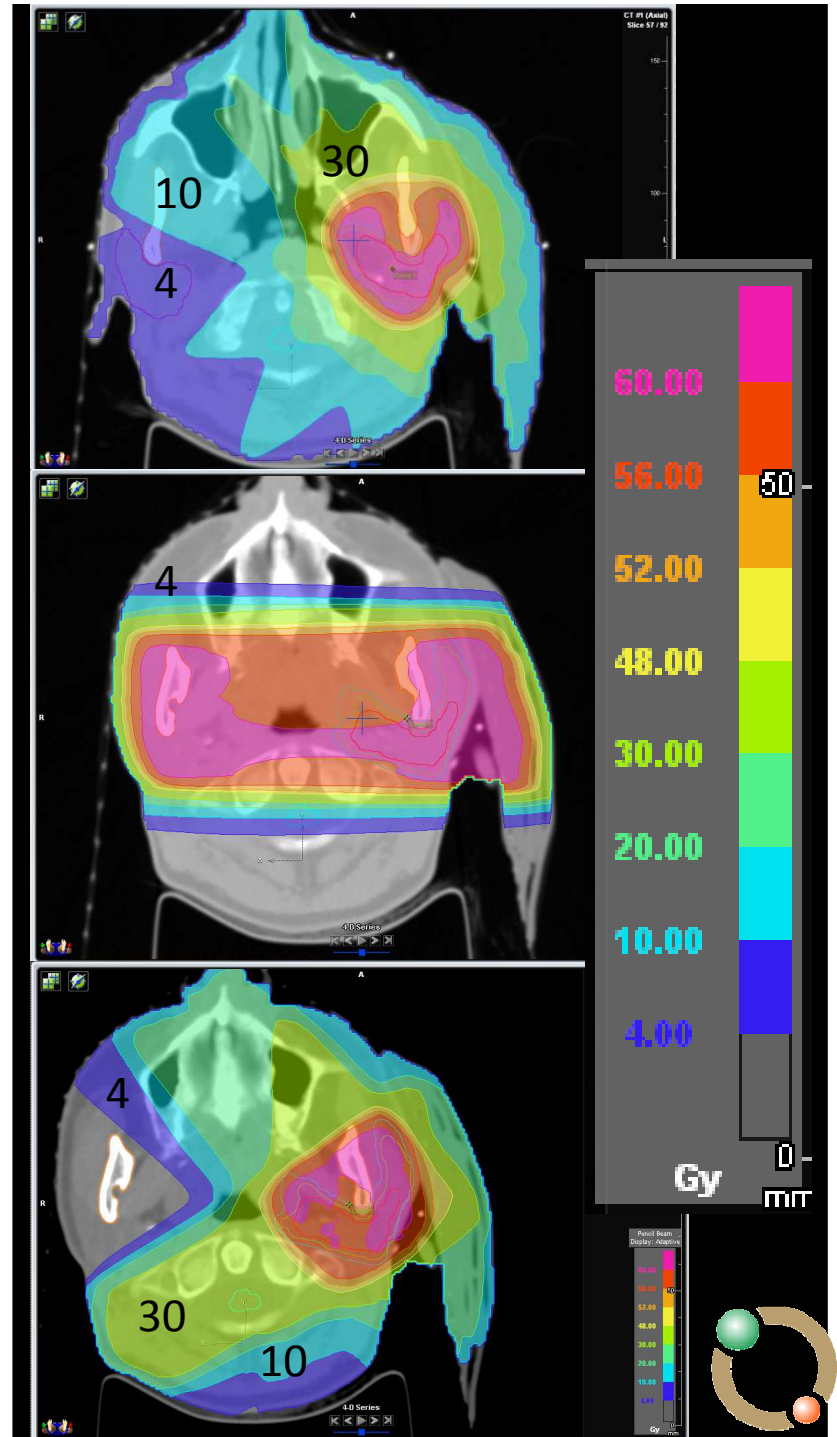
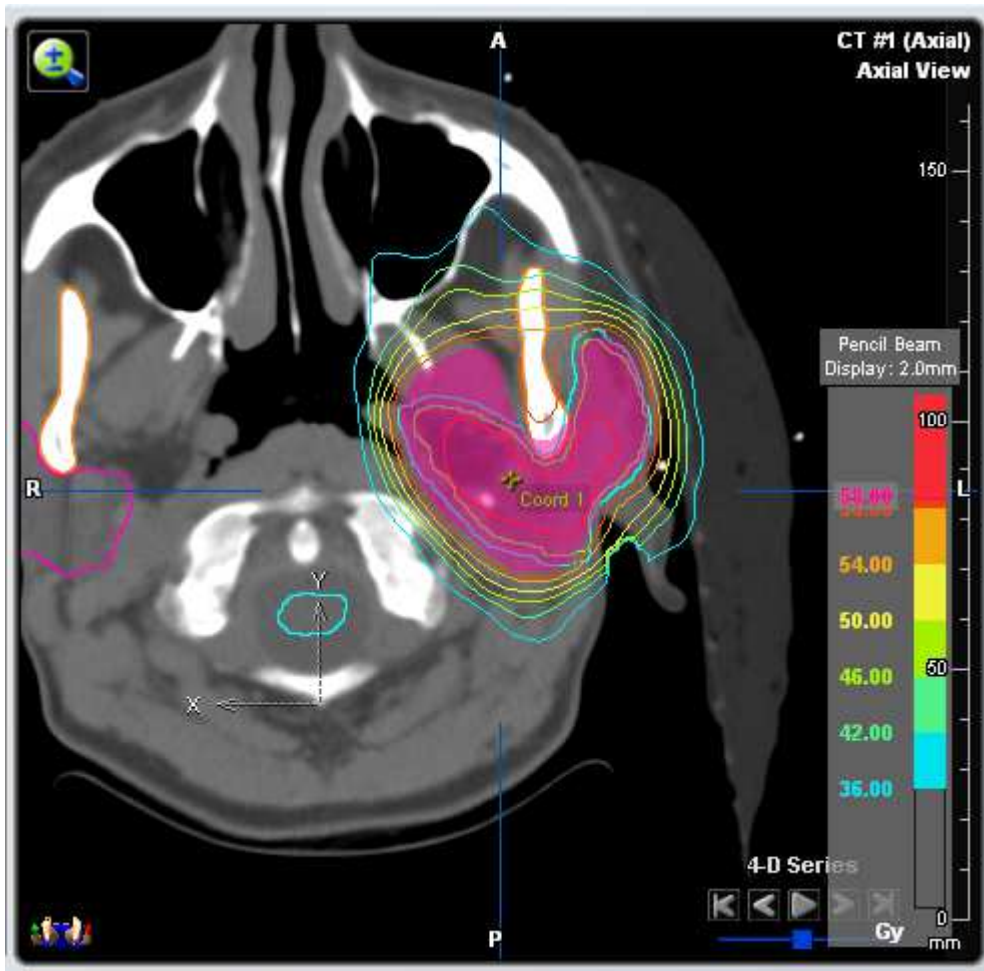


# Dosis bajas en Radioterapia - comparación









# Sistema de colimación

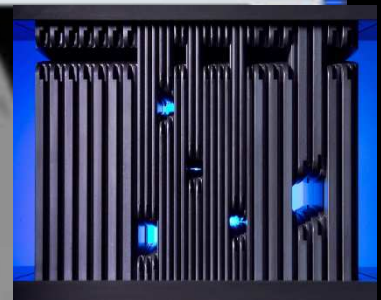
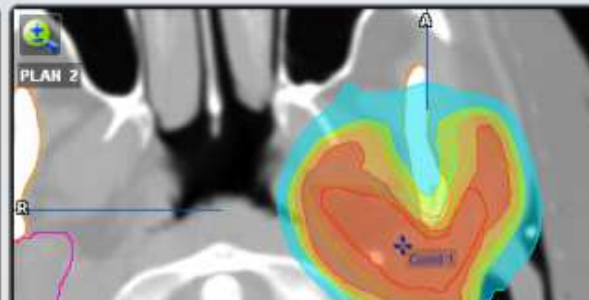
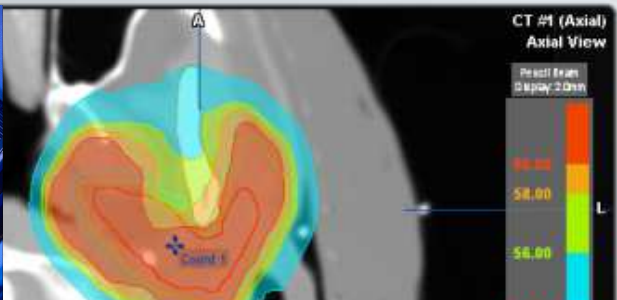
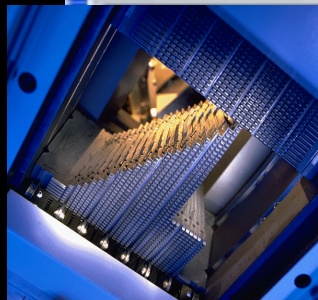


MLC Optifocus 10mm

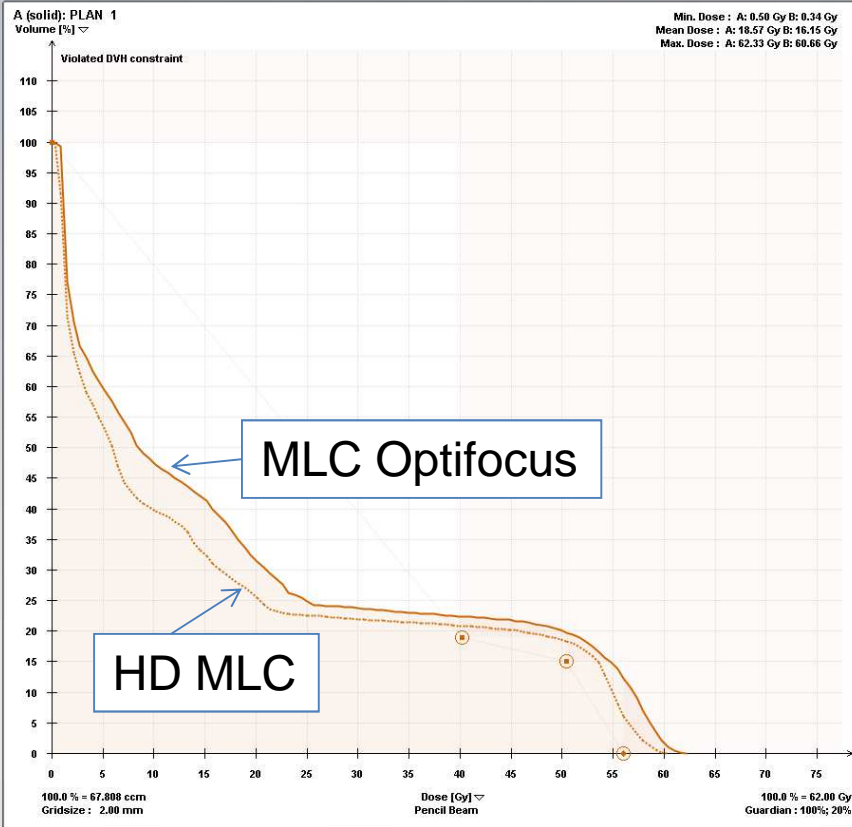
DVH

Plan Content

HD MLC (2.5mm / 5mm)



Dual Reconstr Spy Glass DVH Plan Content



Objects

Select single / multiple Item(s) or Group ▾

- CTV3 58Gy PTV
- PTV2 58-60Gy PTV
- PTV2 58-60Gy-Boost PTV
- CTV1 60-62Gy Boost
- bulbo OAR 1
- cas.oral OAR 1
- Cochlea, Left OAR 1
- Cochlea, Right OAR 1
- cuero cabelludo OAR 1
- MANDIBULA inferior OAR 1
- MANDIBULA inferior-PTV OAR 1
- ME OAR 1
- Superficie OAR 1
- CTV2 58-60Gy Other
- NERVIO OPT IZQ Other
- PAROTIDA DER Other
- Tissue
- Normal Tissue

Display Options

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

Calculation

Grid Size: 2.0 mm

Finer for Small Objects

Recalc

Export to Clipboard

Close

Close



# Márgenes





$$PTV = CTV + IM + SM$$

Volumen 22.2cc

The screenshot displays the Brainlab iPlan RT 4.5 Dose software interface. The main window shows an axial CT scan of a prostate with two segmented contours: a red contour representing the Clinical Target Volume (CTV) and an orange contour representing the Planning Target Volume (PTV). The PTV is defined as the CTV plus the Internal Margin (IM) and Setup Margin (SM). The volume of the PTV is indicated as 22.2cc.

The interface includes a Navigator panel on the right with the following information:

- Prostata SBRT
- ID: SIMPOSIO Prost
- PLAN IMRT
- Object Creation
- Treatment Planning
- Go to... Next

The Object panel on the right lists the following objects:

- Badder.
- Hip Joint, Left
- Hip Joint, Right
- Outer Contour
- Penile Bulb
- Prostate
- PTV - Defo FYT

The Object panel also includes buttons for New..., Remove, Auto Segmentation..., and a Brush Size slider with a Contours checkbox. The Outlining section includes buttons for Brush, Eraser, SmartBrush, Draw Sphere, and SmartShaper..., along with checkboxes for Auto Fill and Interpolation. The Advanced Manipulation..., Role Reassignment..., and Create Dose Object... buttons are also visible.

The bottom of the interface shows a navigation bar with the following tabs: Overview, Slices, Multiple Sets, and Plan Content. The bottom right corner features the Brainlab logo and the text "BRAINLAB iPlan RT 4.5 Dose".

$$PTV = CTV + IM + SM$$

PTV 1 volumen **90.5cc**

(referencias en piel)

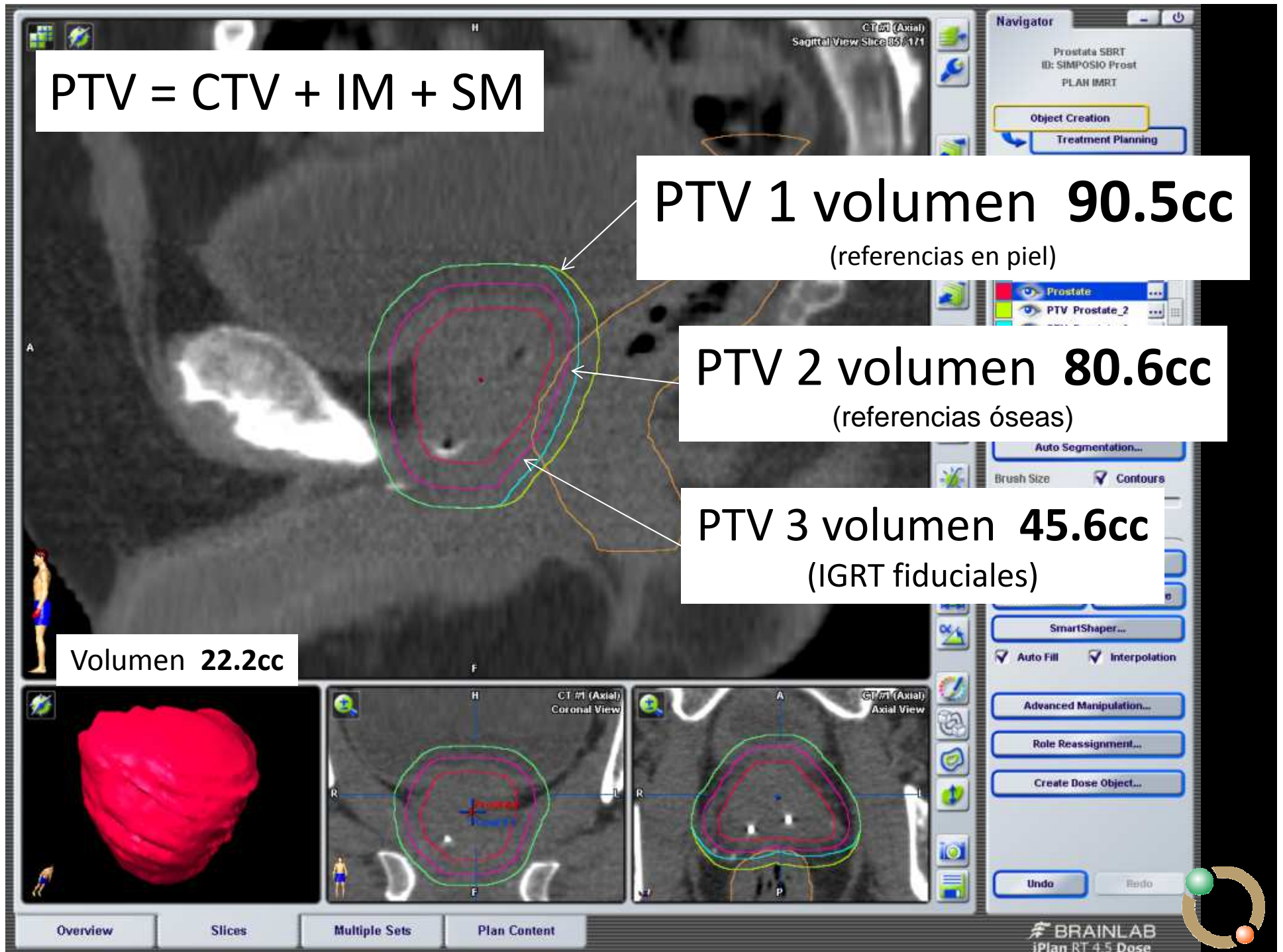
PTV 2 volumen **80.6cc**

(referencias óseas)

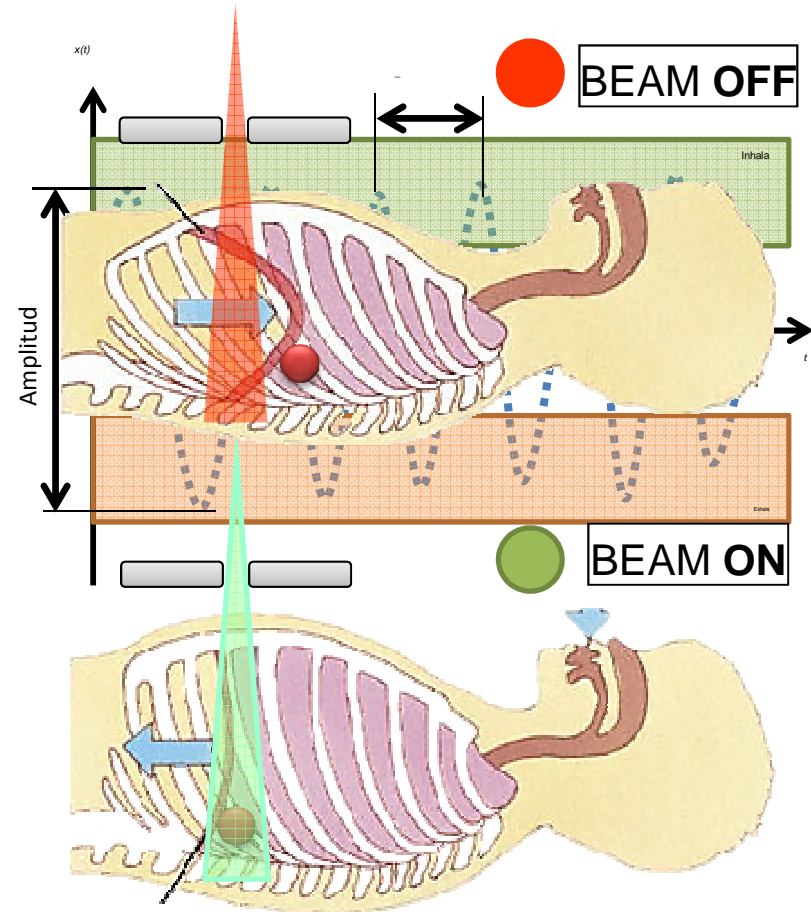
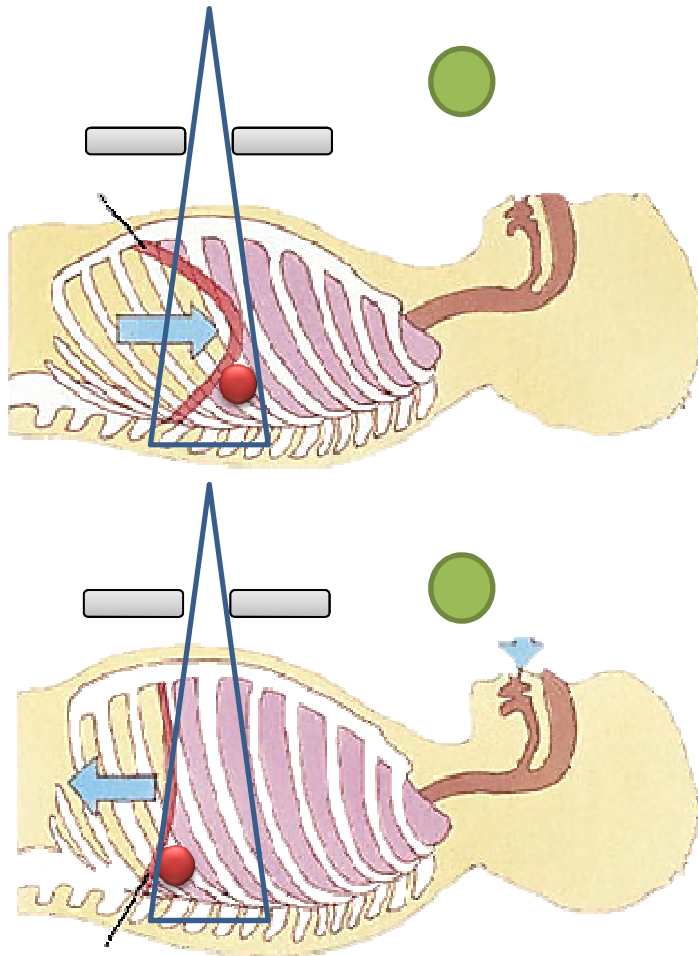
PTV 3 volumen **45.6cc**

(IGRT fiduciales)

Volumen **22.2cc**



# Reducción del **IM** por *respiratory gating*





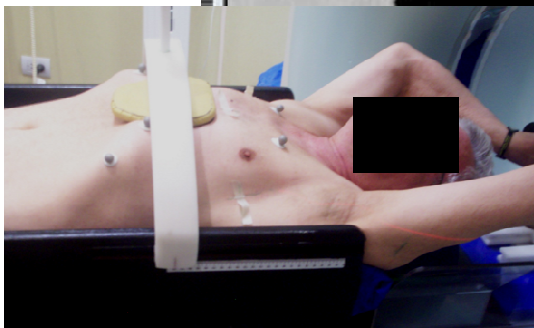
The screenshot displays the BrainLAB iPlan RT software interface. The main workspace is divided into four quadrants showing different views of the patient's anatomy: a 3D model (top-left), an axial CT scan (top-right), a sagittal CT scan (bottom-left), and a coronal CT scan (bottom-right). The right sidebar contains a 'Navigator' panel with 'Physicist's Verification' and 'Load Plan' buttons, and a 'Functions' panel showing a tree view of the RT plan with selected beam 'G40 - M330'. Below this is a 'Properties' table with the following data:

Properties	
Table:	330 °
Gantry:	40 °
Coll.:	345 °
Margin:	3 mm
Weighting:	9.38144 %
MU:	756 (4 x 189)

At the bottom of the interface are buttons for 'Field Reconstructions', 'Setup DRRs', and 'Plan Content'. A yellow callout box on the right side of the interface contains the following text:

- Posición supina
- Bolsa de vacío
- Bloqueador respiratorio

The bottom right corner of the software interface shows the logo for BrainLAB iPlan RT Dose 4.1 and the date/time: 23.September.2011 07.13.19 PM.



CT #1 (Axial) Axial View

CT #1 (Axial) Sagittal View

CT #1 (Axial) Coronal View

4-D Series

4-D Series

4-D Series

4-D Series

Navigator

PLAN FINAL

Physicist's Verification

Load Plan

Go to... Next

Functions

The RTPlan

Group 1

- G40 - M330
- G270 - M330
- G40 - M30
- G250 - M30
- G160
- G40

Beams / Arcs

Properties

Table:	330 °
Gantry:	40 °
Coll.:	345 °
Margin:	3 mm
Weighting:	9.38144 %
MU:	756 (4 x 189)

Plan Approval

Export

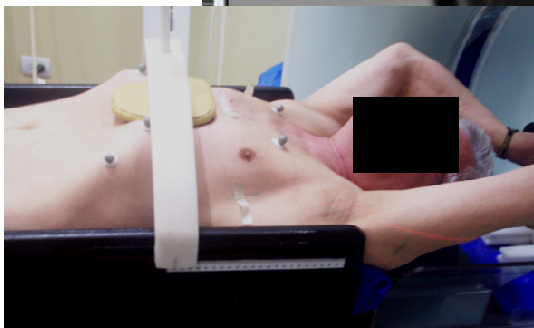
Dose Fluence Dose

Field Reconstructions Setup DRRs Plan Content

BrainLAB  
iPlan RT Dose 4.1

23-September-2011 07:15:17 PM

• TAC Inspiración





CT #2 (Axial) Axial View

CT #2 (Axial) Axial View

CT #2 (Axial) Sagittal View

CT #2 (Axial) Coronal View

4-D Series

4-D Series

4-D Series

4-D Series

Field Reconstructions

Setup DRRs

Plan Content

BrainLAB  
iPlan RT Dose 4.1

23-September-2011 07:15:27 PM

Navigator

PLAII FINAL

Physicist's Verification

Load Plan

Go to... Next

Functions

The RTPlan

Group 1

- G40 - M330
- G270 - M330
- G40 - M30
- G250 - M30
- G160
- G40

Beams / Arcs

Properties

Table:	330 °
Gantry:	40 °
Coll.:	345 °
Margin:	3 mm
Weighting:	9.38144 %
MU:	756 (4 x 189)

Plan Approval

Export

Dose Fluence Dose

• TAC Expiración

CT #3 (Axial) Axial View

CT #3 (Axial) Axial View

CT #3 (Axial) Sagittal View

CT #3 (Axial) Coronal View

4-D Series

4-D Series

4-D Series

4-D Series

Navigator

PLAII FINAL

Physicist's Verification

Load Plan

Go to... Next

Functions

The RTPlan

Group 1

- G40 - M330
- G270 - M330
- G40 - M30
- G250 - M30
- G160
- G40

Beams / Arcs

Properties

Table:	330 °
Gantry:	40 °
Coll.:	345 °
Margin:	3 mm
Weighting:	9.38144 %
MU:	756 (4 x 189)

Plan Approval

Export

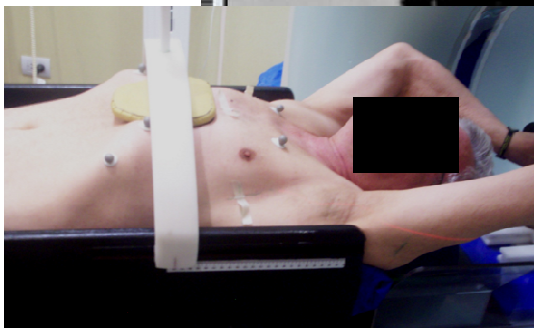
Dose Fluence Dose

Via DICOM To ExacTrac

Field Reconstructions Setup DRRs Plan Content

BrainLAB  
iPlan RT Dose 4.1

• TAC respiraci3n libre  
•  $ITV = CTV_I + CTV_E$





# Sistema de posicionamiento



# Posicionamiento



**Vertical**



**Longitudinal**



**Lateral**



**Angulo Mesa**



# Posicionamiento



**Vertical**



**Longitudinal**



**Lateral**



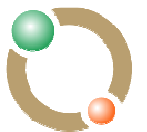
**Angulo Mesa**

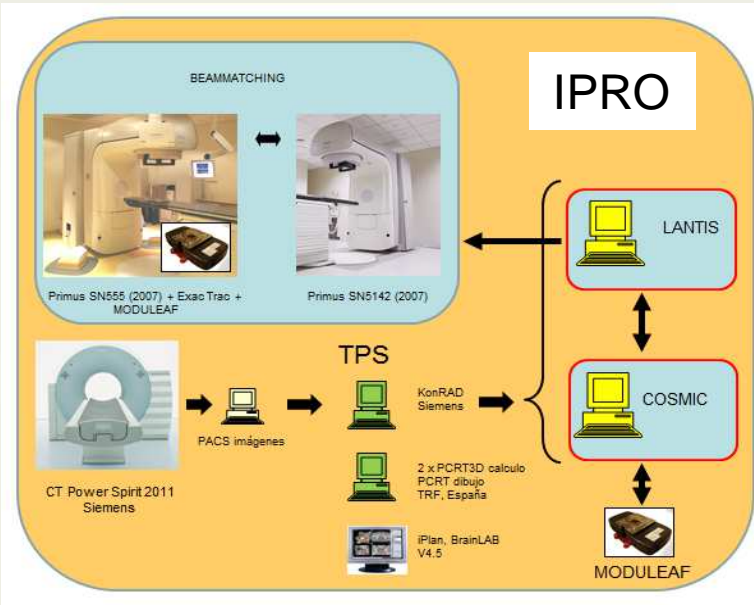


**Angulo longitudinal (SPIN)**



**Angulo lateral (TILT)**





**IPR**

- 5 licencias iPlan v4.5
- 2 licencia ECLIPSE
- ARIA**
  - Servidor ARIA
  - ARIA Patient Manager
  - ARIA Time Planner

**Equipment:**

- HDR v3 Nucleatron (2011)
- Seed Selectron Nucleatron (2011)
- Oncentra Brachy TPS Nucleatron (2011)
- Oncentra Prostate TPS Nucleatron (2011)



Departamento Física Medica



**INSTITUTO DE RADIOTERAPIA  
FUNDACIÓN MARIE CURIE**