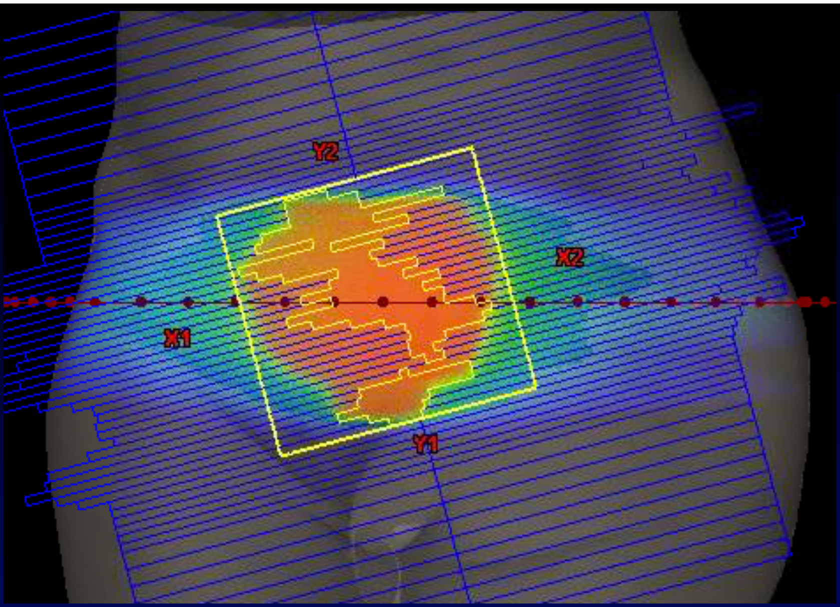
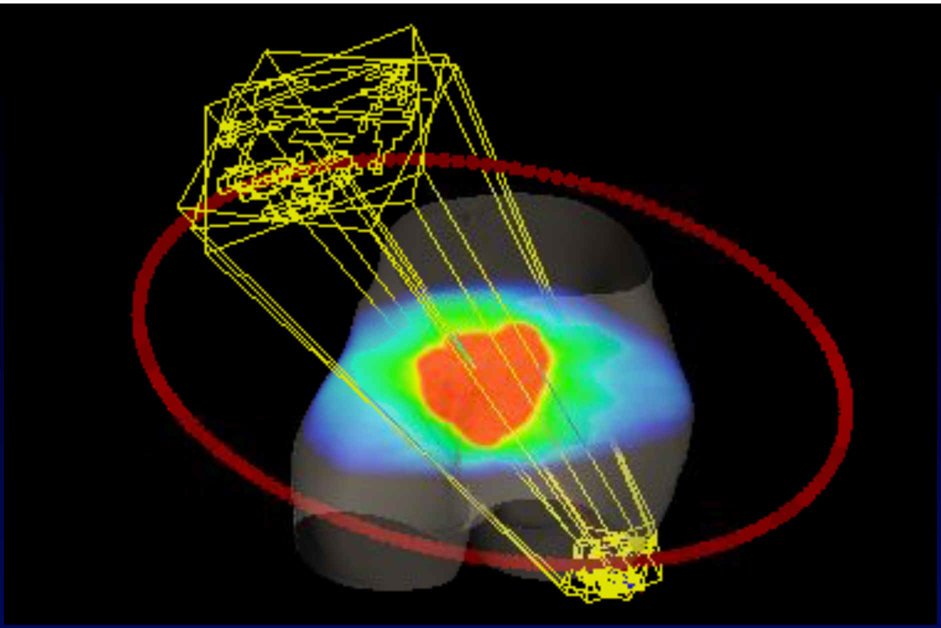
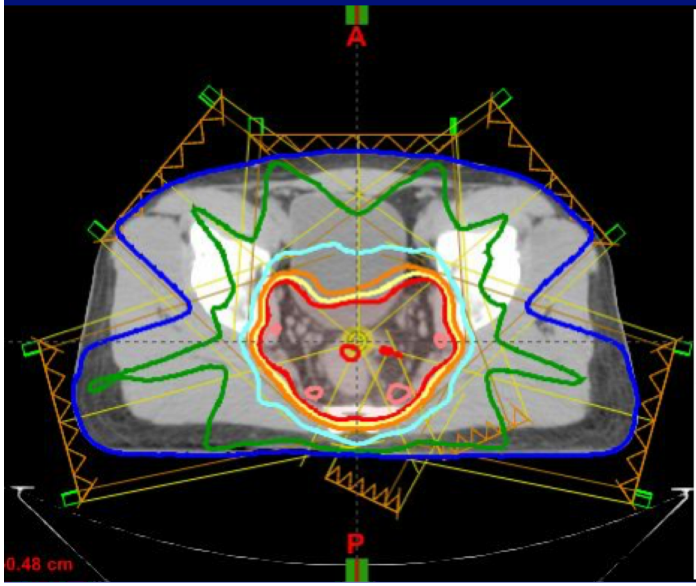
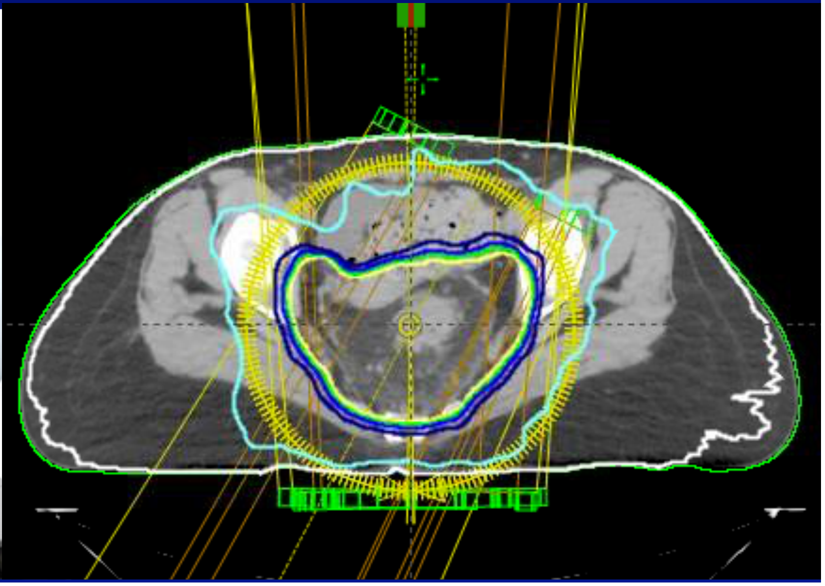




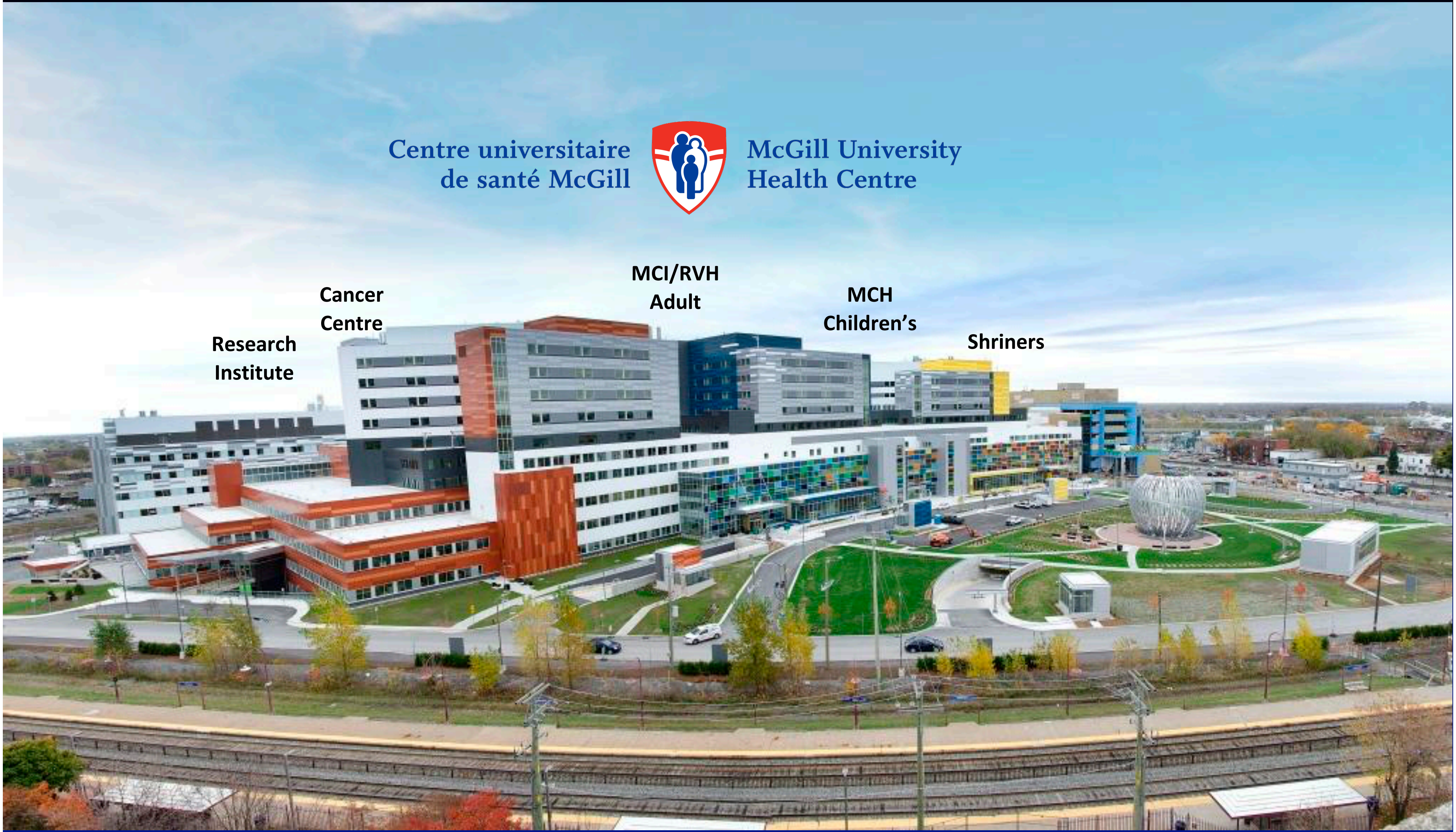
Conceptos generales de la IMRT rotatoria. Diferentes alternativas (Tomotherapy - VMAT - RapidArc). Consideraciones desde el punto de vista físico

William Parker





Centre universitaire de santé McGill
McGill University Health Centre

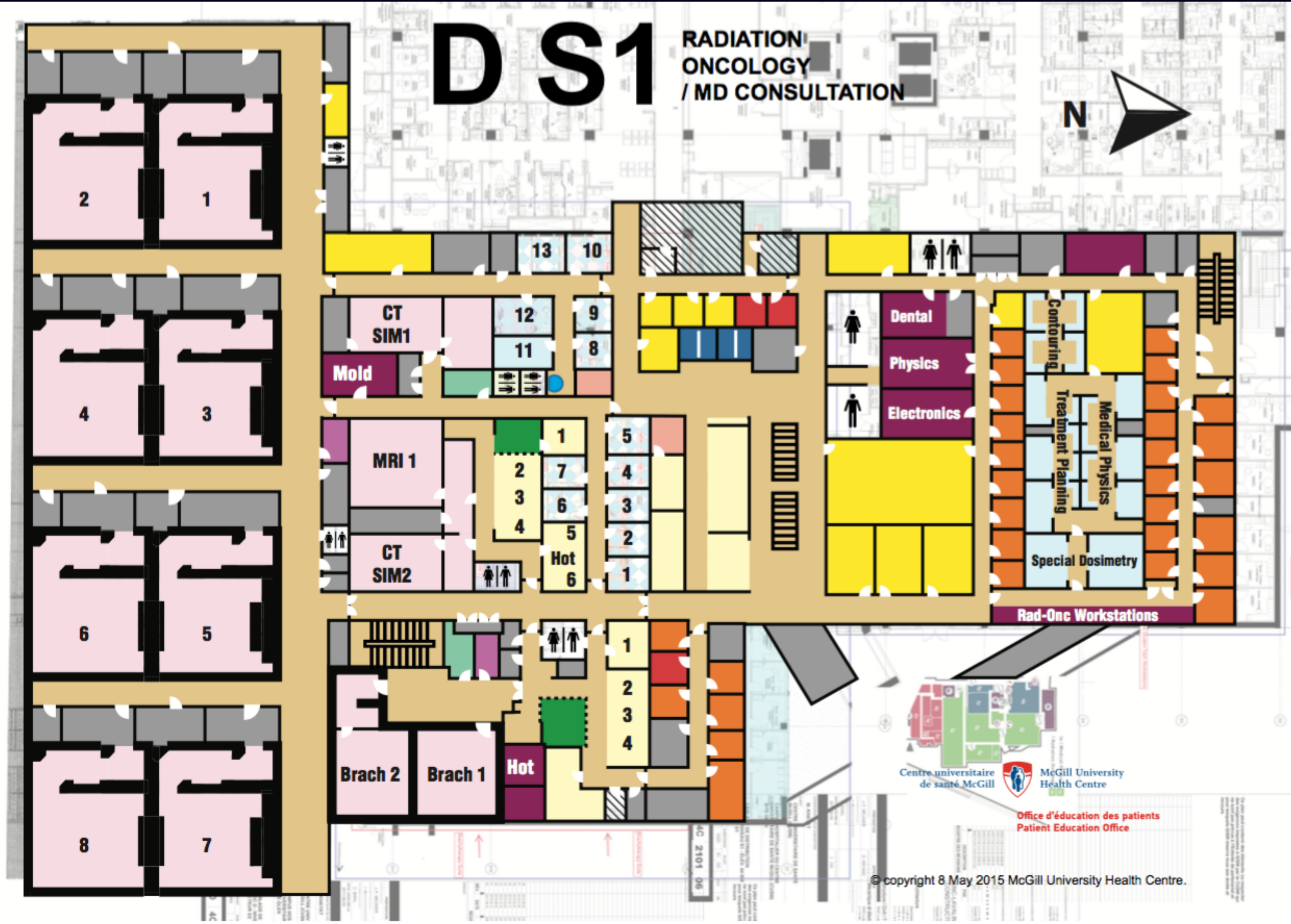

Research Institute
Cancer Centre
MCI/RVH Adult
MCH Children’s
Shriners

Radiation Oncology - McGill

- Instalaciones de 70,000 pies cuadrados - 2015
- 150 personal incluyen:
  - 14 MDs + 14 residentes
  - 14 físicos + 9 dosimetristas + 4 res
  - 45 tecnologos
- 3000 nuevos pacientes por ano
- 160 tratamientos diarios
- 60 MD diarios
- 7 aceleradores – 6 TB + 1 CK
- 3 CTs
- 1 braquiterapia
- 1 MRI
- ARIA - Eclipse

Centre universitaire de santé McGill
McGill University Health Centre
Centre du cancer des Cèdres
Cedars Cancer Centre

D S1 RADIATION ONCOLOGY / MD CONSULTATION


N
2
1
4
3
6
5
8
7
13
10
CT SIM1
12
9
11
8
Mold
MRI 1
1
2
7
3
6
4
5
Hot
6
5
4
3
2
1
CT SIM2
Dental
Physics
Electronics
Contouring
Treatment Planning
Medical Physics
Special Dosimetry
Rad-Onc Workstations
1
2
3
4
Brach 2
Brach 1
Hot

Centre universitaire de santé McGill
McGill University Health Centre

Office d'éducation des patients
Patient Education Office

© copyright 8 May 2015 McGill University Health Centre.

- 🟧 Registration
- 🟨 Waiting room
- ⬜ Patient room
- ⬜ Treatment room
- ⬜ Examining room
- ⬜ Procedure room
- ▨ Staff lockers
- 🟪 Lab
- 🟩 Nursing station
- 🟨 Team room / Conference
- 🟥 Can Support
- 🟪 Supply room
- 🟩 Soiled utilities
- 🟧 Office
- ▮ Elevator
- ● Pneumatic Tube
- 🚻 Washroom
- ▤ Staircase

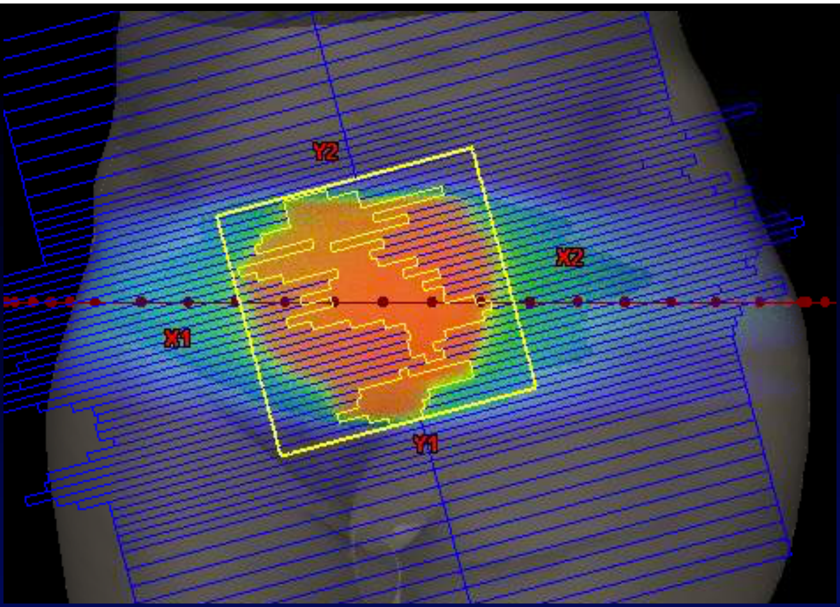
Centre du cancer des Cèdres
Cedars Cancer Centre

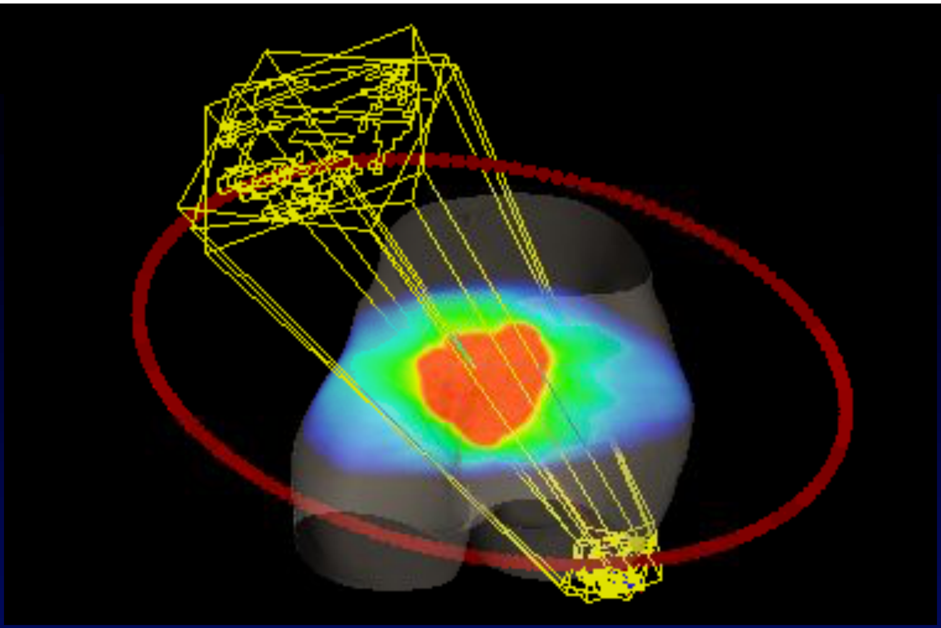
CyberKnife
ACCURAY

PHILIPS

C D E
Radio-oncologie
Radiation Oncology
D S1.1620

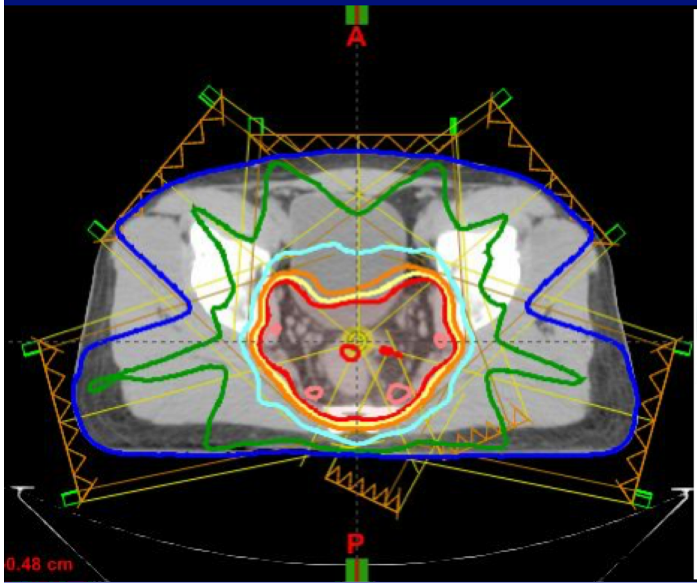
McGill

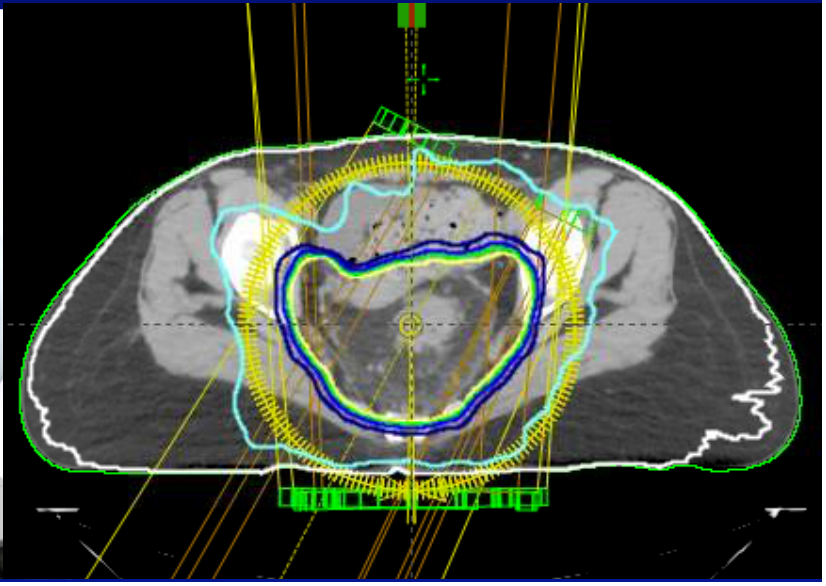




Conceptos generales de la IMRT rotatoria. Diferentes alternativas (Tomotherapy - VMAT - RapidArc). Consideraciones desde el punto de vista físico

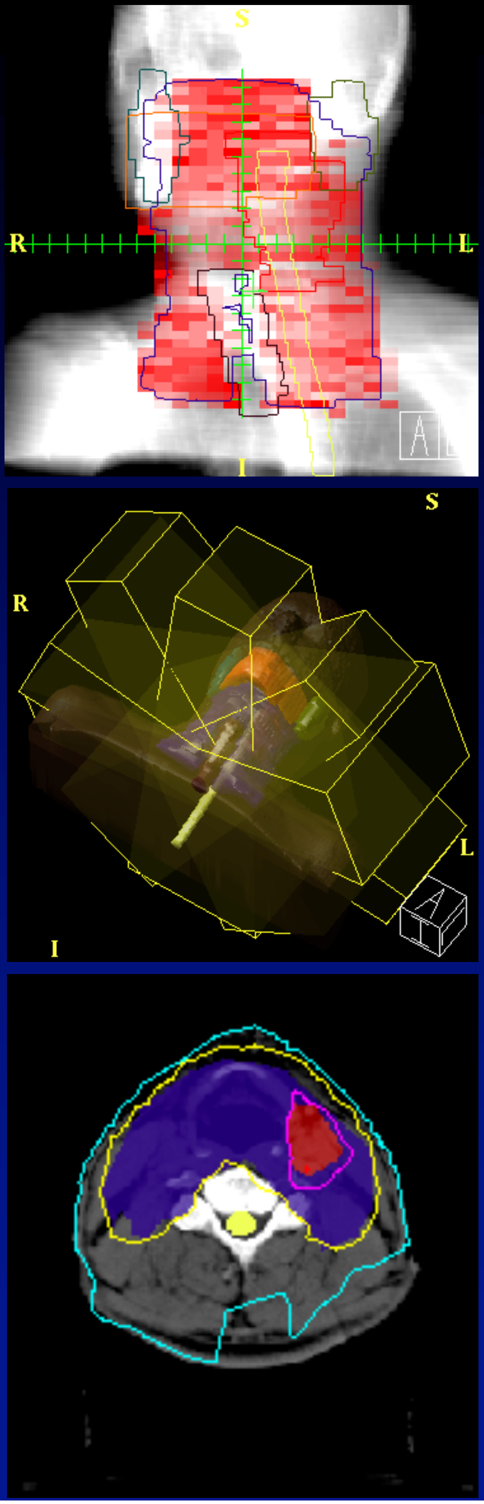
William Parker





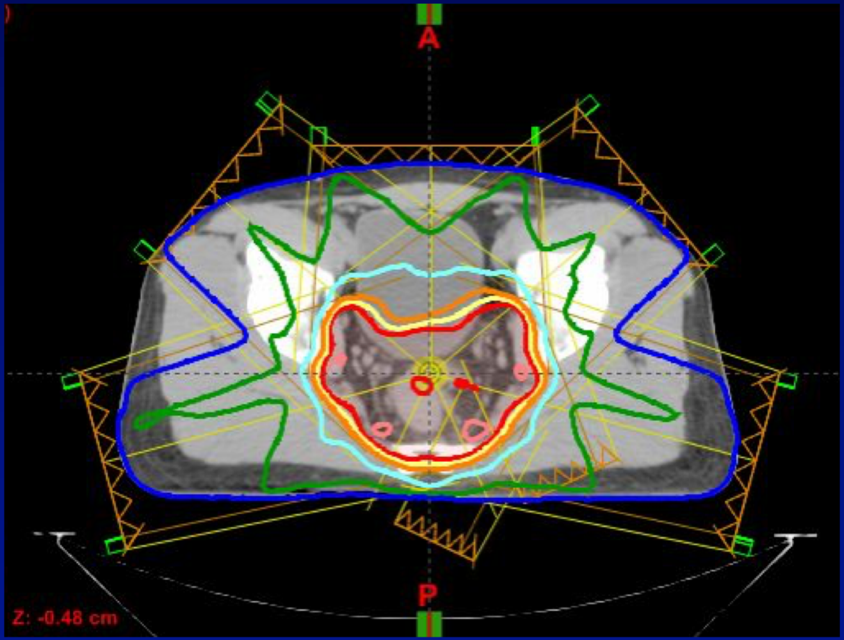
IMRT definicion

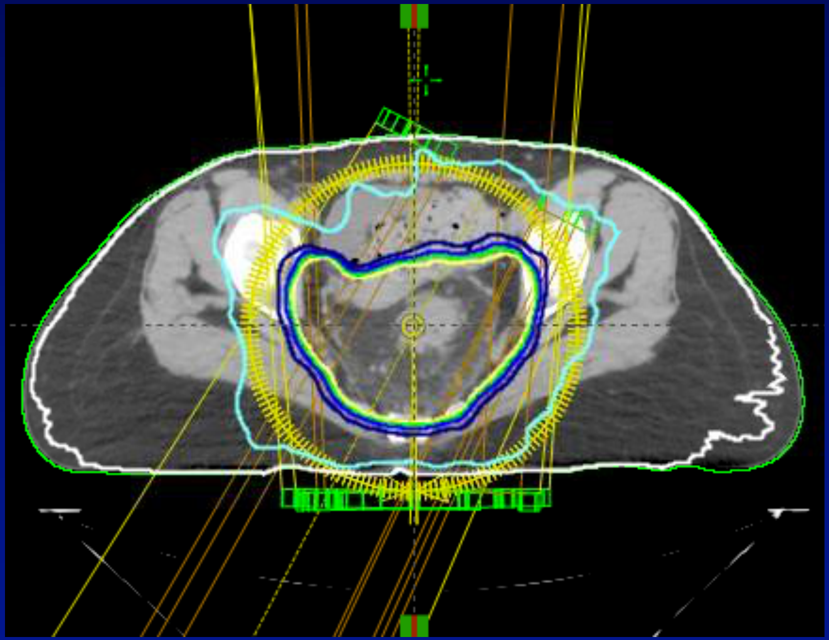
- Intensity Modulated Radiation Therapy
- "La IMRT se basa en el uso de intensidades de haz de radiación no uniformes optimizadas que inciden en el paciente" (NIH CWG, IJROBP, 2001).
- Gran número de campos
- Alto número de MUs (5 - 10 veces más que la CRT 3D)
- Largo tiempo de tratamiento



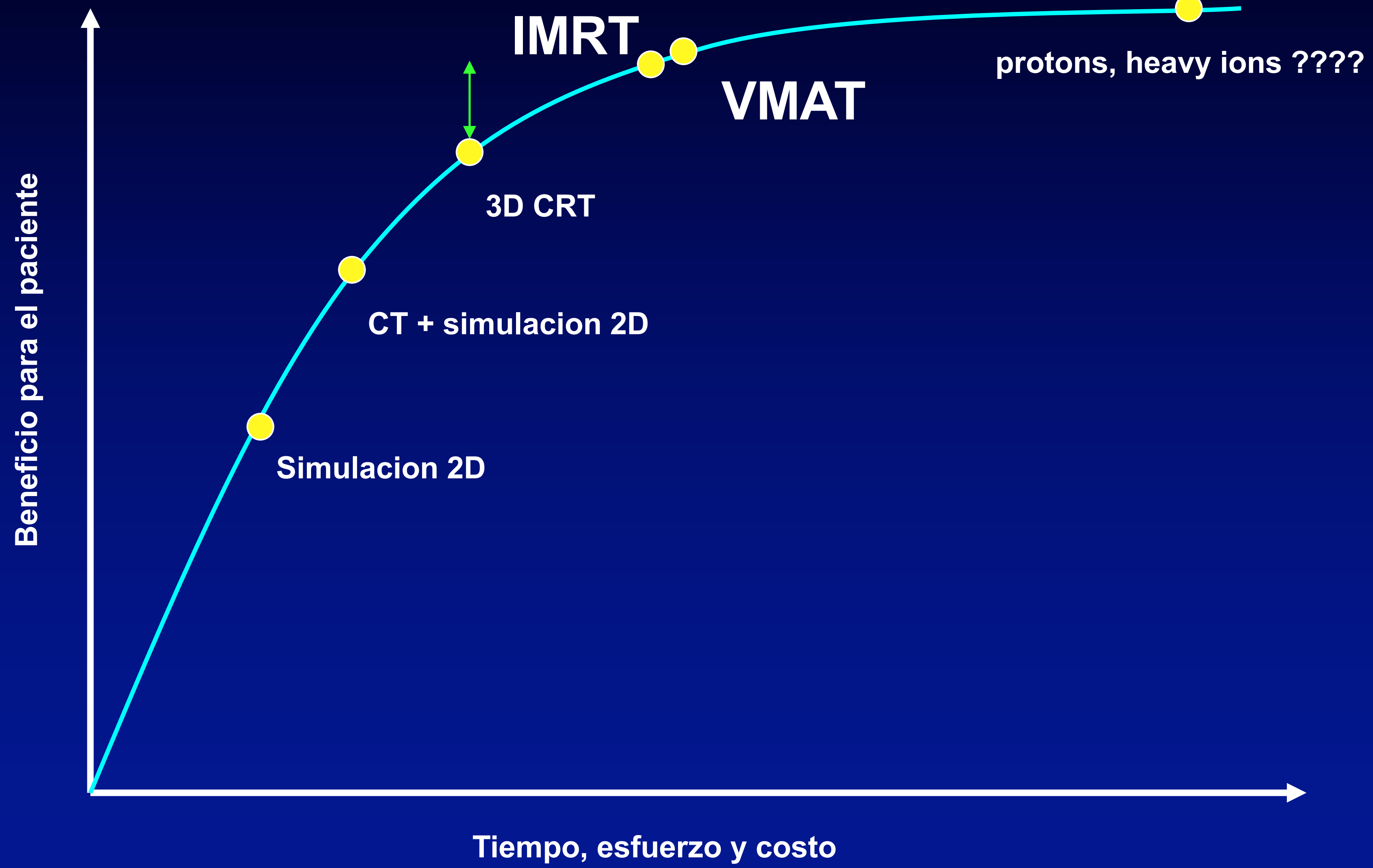
VMAT definición

- Volumetric modulated arc therapy
- IMRT realizado en un solo arco (Otto 2008)





Tiempo, esfuerzo, costo vs. beneficio



McGill

Year	Investigators	Milestone
1982	Brahme et al. [2]	Solving of an 'inverse' problem of rotational beam fluence to deliver a uniform dose to a donut-shaped target
1984	Brahme [15]	First commercial MLCs patented by Brahme and commercialized by Scanditronix
1988	Brahme [8]	First paper on algebraic inverse planning
1989	Webb [9]	Cast the inverse planning problem as an optimization problem that minimizes an objective or 'cost' function
1990	Bortfeld et al. [10]	Developed algebraic/iterative optimization for inverse plannin
1991	Boyer et al. [48]	Developed principle of multiple segmented-field IMRT
1992	Convey and Rosenbloom [18]	Developed principle of sliding-window technique IMRT
1992	Carol [16]	First full IMRT system, based on serial tomotherapy, was introduced. NOMOS MIMiC binary MLC and simulated annealing optimization inverse planning (Peacock Plan)
1993	Mackie et al. [17]	Concept of helical tomotherapy
1994	Svensson et al. [19]	Independent finding of optimal and analytic solutions for sliding-window leaf trajectory problem by three research groups (Karolinska group in Stockholm, MSKCC group in New York, and DKFZ group in Heidelberg)
	Spirou and Chui [20]	
	Stein et al. [21]	
1994	Bortfeld et al. [49]	First multiple-static-field (MSF) experiments
1994	Carol et al. [50]	First IMRT treatment using serial tomotherapy (NOMOS MIMi
1995	Ling et al. [11]	First MLC-based IMRT at the Memorial Sloan Kettering Cancer Center
1995	Yu [28]	Intensity-modulated arc therapy; proposed as a tomotherapy-mimicking IMRT using a linac
2002	-	Tomotherapy released commercially
2007	Otto [26]	Volumetric-modulated arc therapy: IMRT in a single gantry arc
2010	Bogdanich [38]	New York Times IMRT accident reports

Peacock™: A System for Planning and Rotational Delivery of Intensity-Modulated Fields

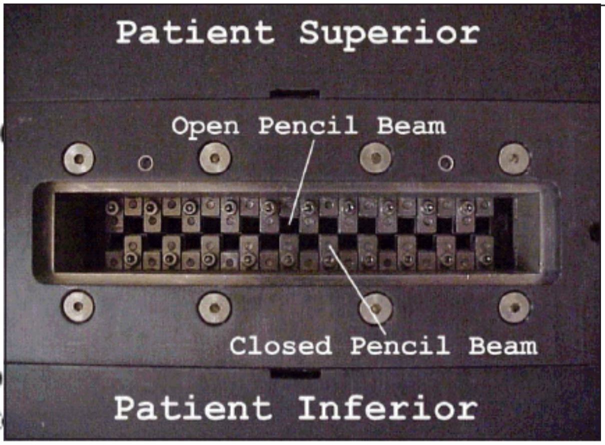
Mark P. Carol

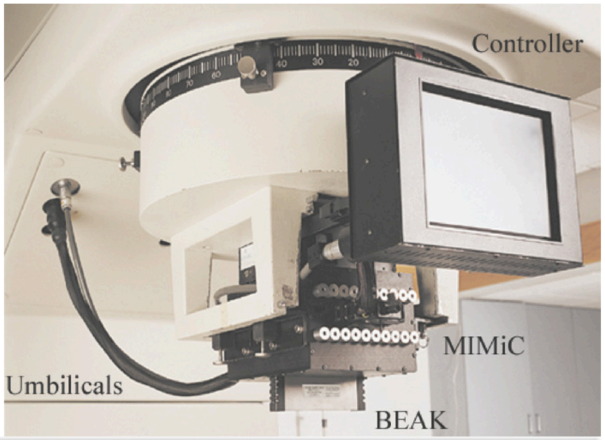
Nomos® Corporation, 2591 Wexford-Bayn

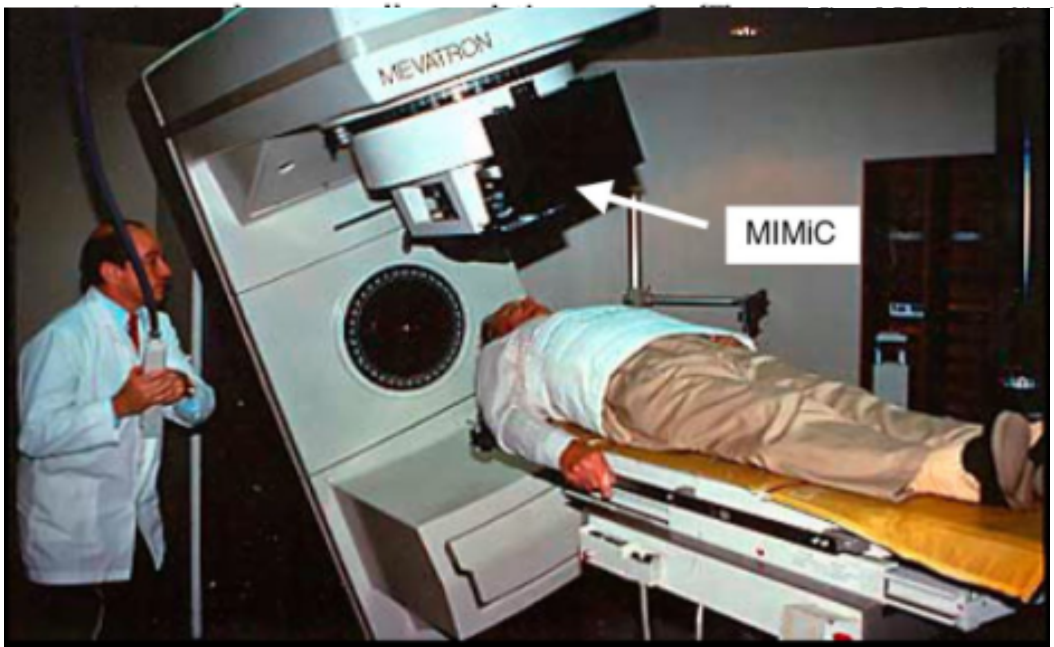
1992

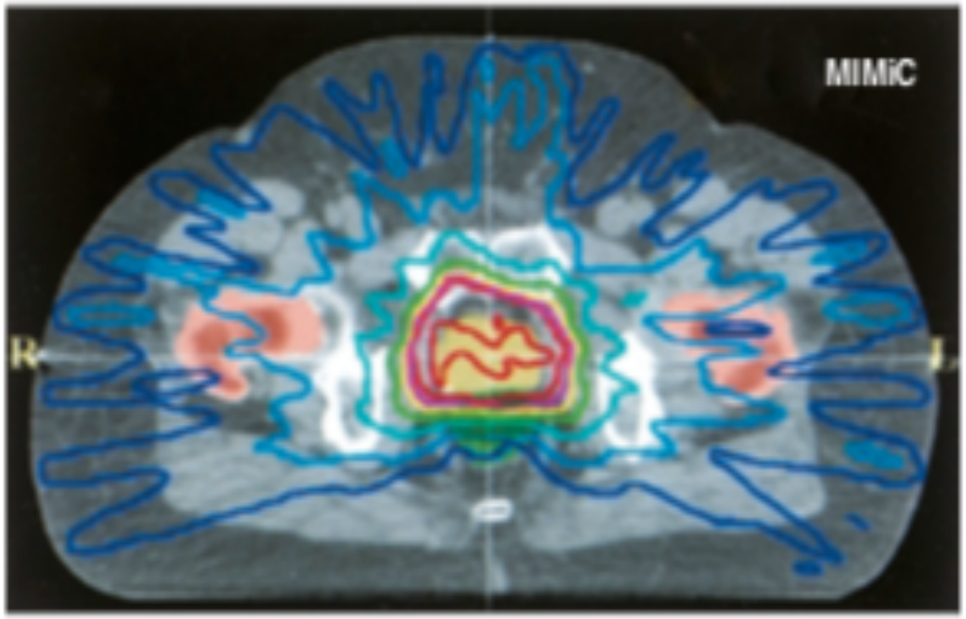
I. INTRODUCTION

The effectiveness of radiation therapy in to
practice is limited by the oncologist's ability t


Patient Superior
Open Pencil Beam
Closed Pencil Beam
Patient Inferior


Controller
MIMiC
Umbilicals
BEAK

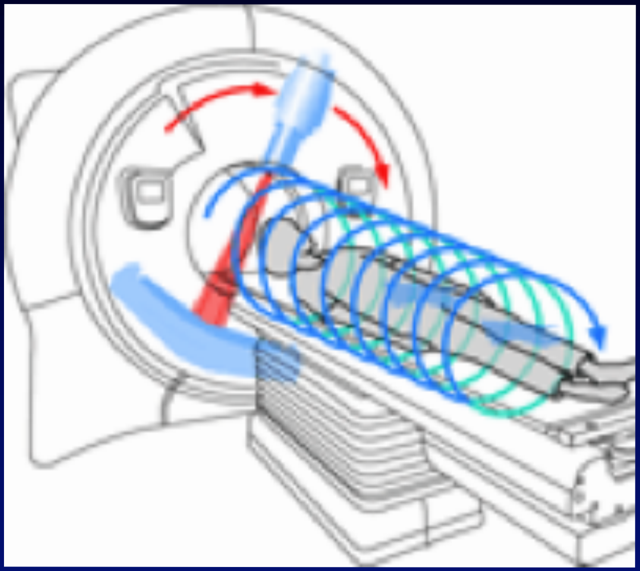

MEVATRON
MIMiC

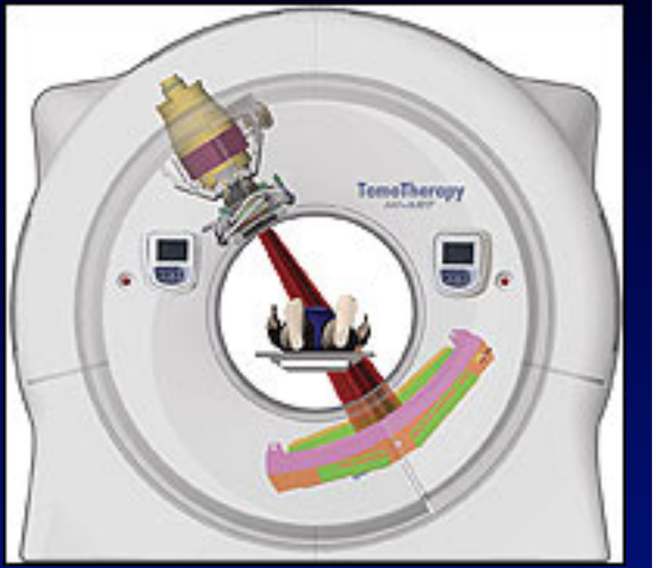


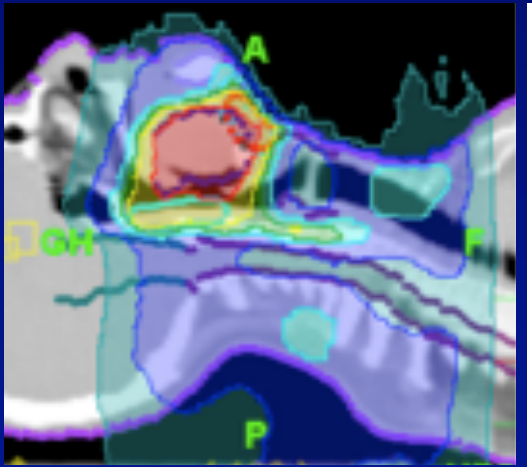
Helical Tomotherapy

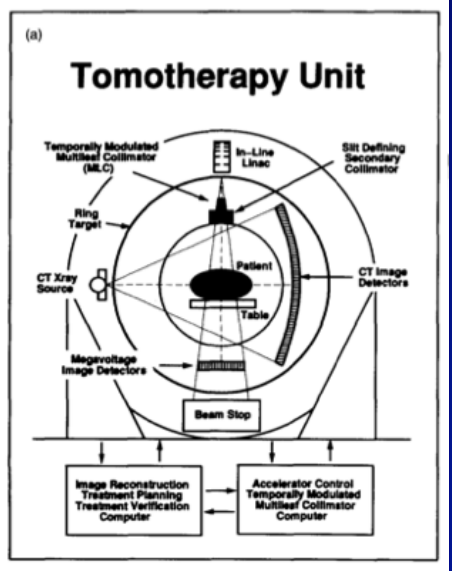
1993

TomoTherapy
HI-ART




TomoTherapy




(a)
Tomotherapy Unit
Temporally Modulated Multileaf Collimator (MLC)
In–Line Linac
Slit Defining Secondary Collimator
Ring Target
CT Xray Source
Patient
CT Image Detectors
Table
Megavoltage Image Detectors
Beam Stop
Image Reconstruction Treatment Planning Treatment Verification Computer
Accelerator Control Temporally Modulated Multileaf Collimator Computer

Mackie et al. Med Phys. 20(6) 1993

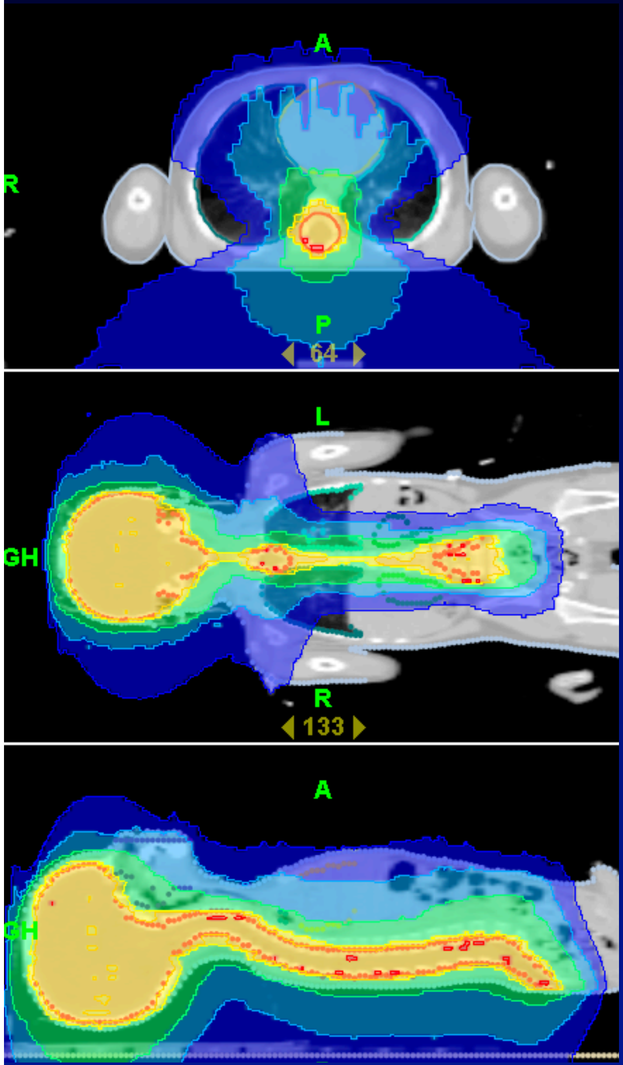
Experiencia McGill con Tomotherapy

- 2007-2014
- Mas de 1,500 pacientes
- Todos sitios anatómicos
- Primera maquina de IGRT y rotatoria
- TPS lento, pero distribuciones exquisitas
- Campos largos
- Tecnólogos gustaban mucho
- “single point setup”

HÔPITAL GÉNÉRAL DE MONTRÉAL
THE MONTREAL GENERAL HOSPITAL
TomoTherapy
HI-ART

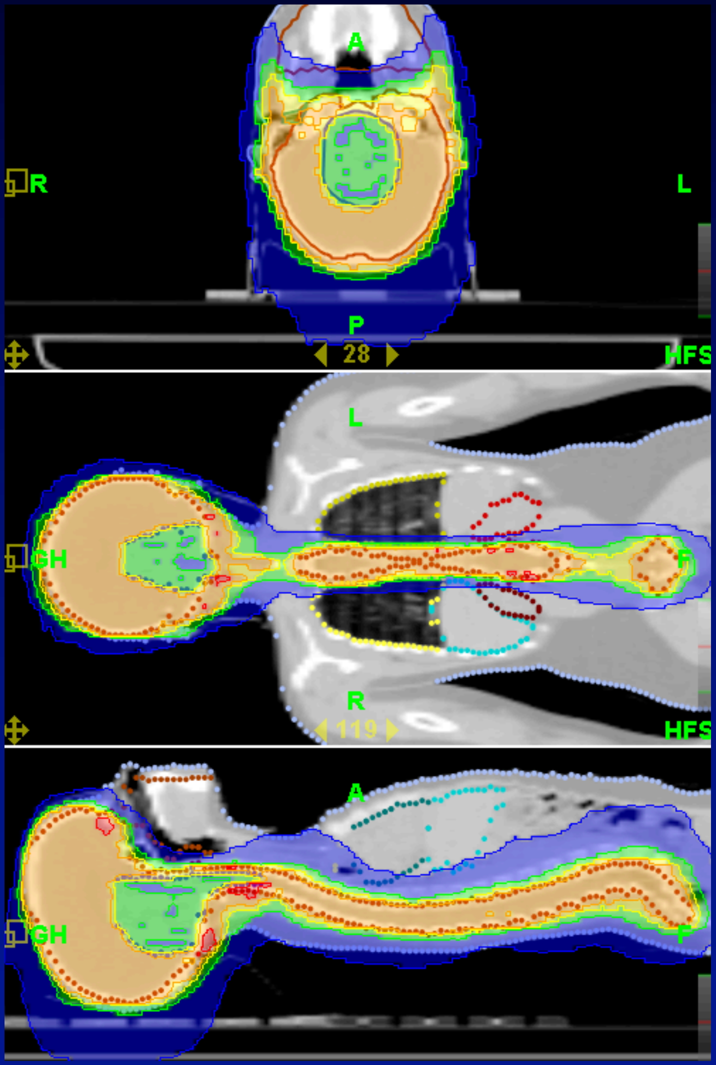
Craniospinal radiotherapy

Pediatric CSI



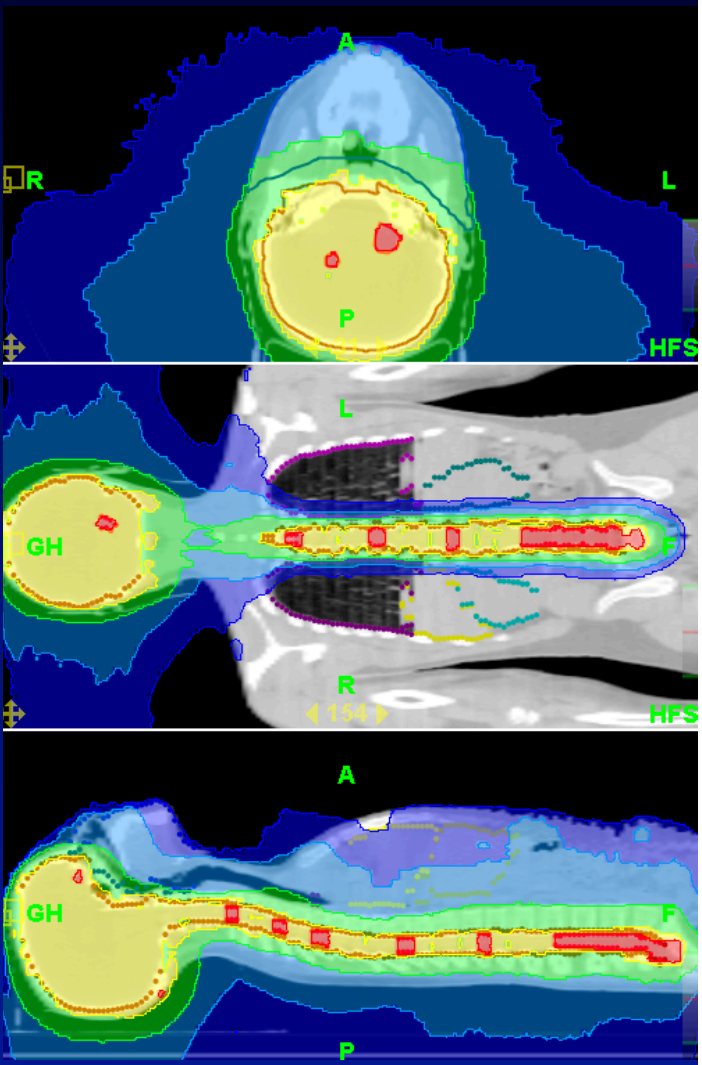
A
R
P
64
L
GH
R
133
A
GH

PF dose reduction



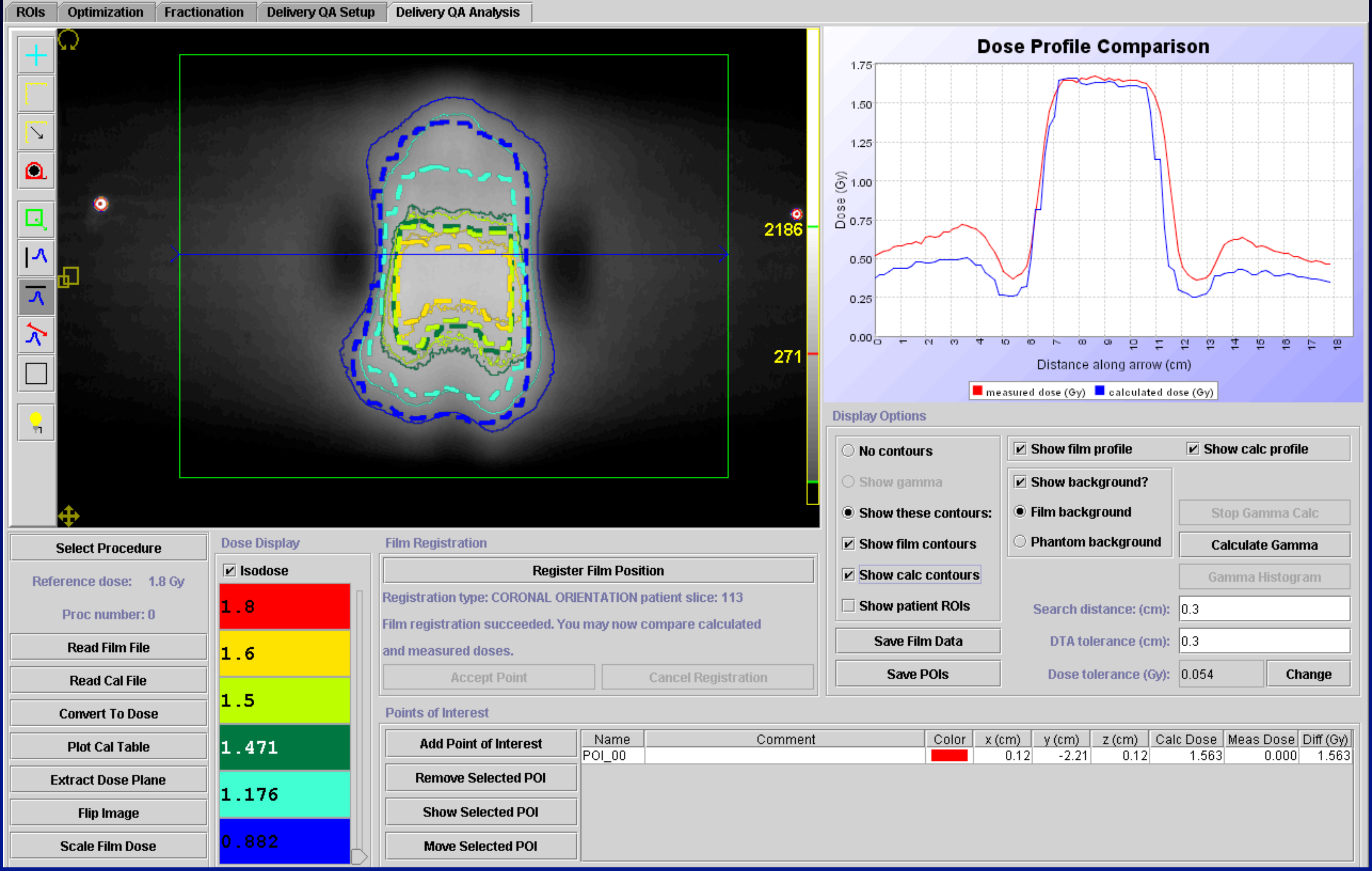
A
R
L
P
28
HFS
L
GH
F
R
119
HFS
A
GH
F

Boost to mets



A
R
L
P
HFS
L
GH
F
R
154
HFS
A
GH
F
P

Aseguramiento de calidad integrado


ROIs
Optimization
Fractionation
Delivery QA Setup
Delivery QA Analysis
2186
271
Dose Profile Comparison
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Dose (Gy)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Distance along arrow (cm)
measured dose (Gy)
calculated dose (Gy)
Select Procedure
Read Film File
Read Cal File
Convert To Dose
Plot Cal Table
Extract Dose Plane
Flip Image
Scale Film Dose
Dose Display
Film Registration
Register Film Position
Accept Point
Cancel Registration
Display Options
Save Film Data
Save POIs
Stop Gamma Calc
Calculate Gamma
Gamma Histogram
Change
Points of Interest
Add Point of Interest
Remove Selected POI
Show Selected POI
Move Selected POI

Reference dose: 1.8 Gy

Proc number: 0

☑ Isodose

- 1.8
- 1.6
- 1.5
- 1.471
- 1.176
- 0.882

Registration type: CORONAL ORIENTATION patient slice: 113

Film registration succeeded. You may now compare calculated and measured doses.

○ No contours
○ Show gamma
● Show these contours:
☑ Show film contours
☑ Show calc contours
☐ Show patient ROIs

☑ Show film profile
☑ Show calc profile
☑ Show background?
● Film background
○ Phantom background

Search distance: (cm): 0.3

DTA tolerance (cm): 0.3

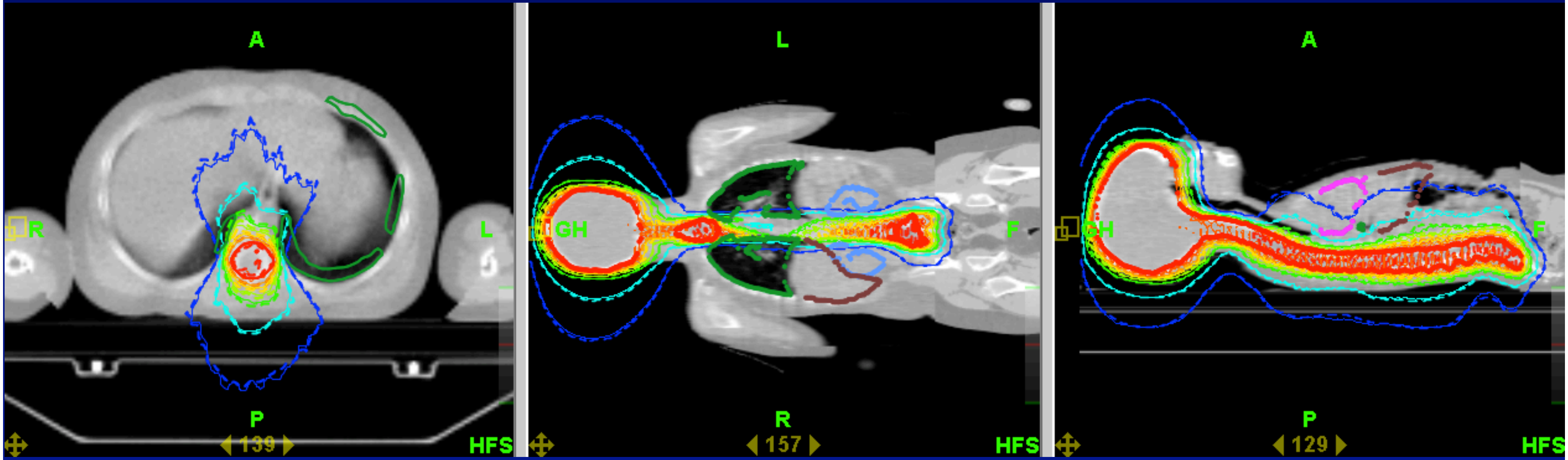
Dose tolerance (Gy): 0.054

Name	Comment	Color	x (cm)	y (cm)	z (cm)	Calc Dose	Meas Dose	Diff (Gy)
POI_00		🟥	0.12	-2.21	0.12	1.563	0.000	1.563

McGill

Planificación adaptable de la IMRT

- Calcular la dosis en cada fracción
- "dosis deformada" para volver a la tomografía computarizada de planificación o al último conjunto de imágenes
- Calcular la DVH y las estadísticas de la dosis acumulada

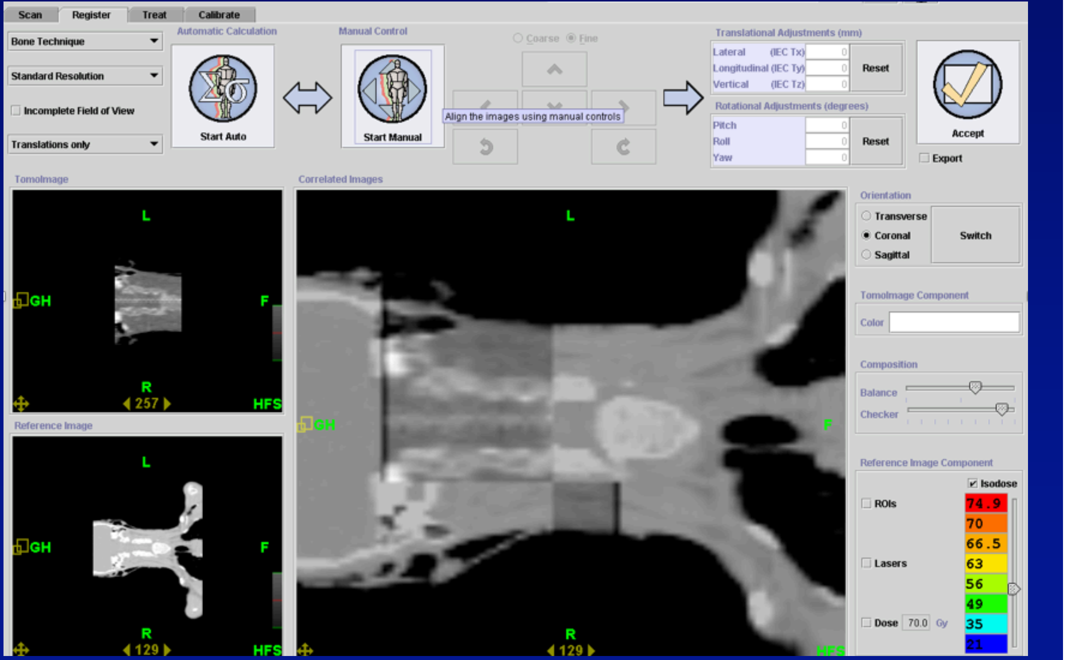

A
R
L
P
139
HFS
L
GH
F
R
157
HFS
A
GH
F
P
129
HFS

Tomotherapy

- Tiempos de planificación largos
- Tiempo de toma de imágenes ~ 5 minutos por MVCT
- Tiempo de tratamiento ~ 10 - 15 minutos de haz
- 15 pacientes por día máximum

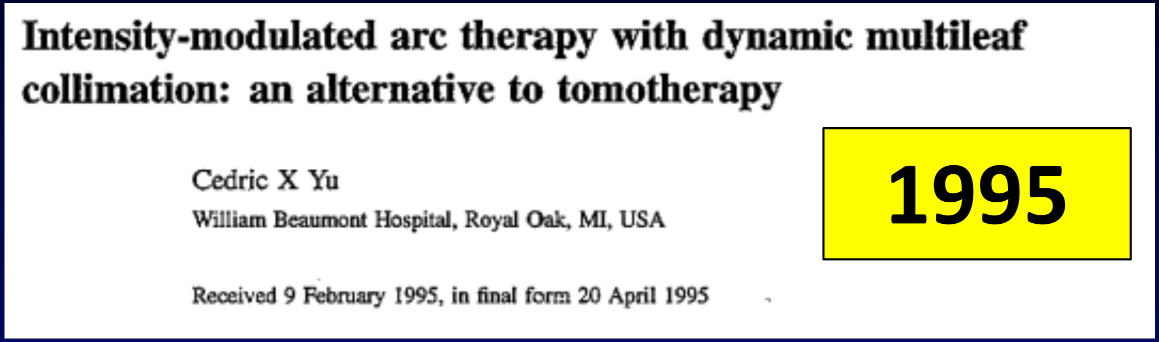
TomoTherapy
HI·ART

Jessica Giuszco, Mélanie Gravelme, Radiation Technologists


Scan
Register
Treat
Calibrate
Bone Technique
Standard Resolution
☐ Incomplete Field of View
Translations only
Automatic Calculation
Start Auto
Manual Control
Start Manual
○ Coarse ● Fine
Align the images using manual controls
Translational Adjustments (mm)
Lateral (IEC Tx) 0
Longitudinal (IEC Ty) 0
Vertical (IEC Tz) 0
Reset
Rotational Adjustments (degrees)
Pitch 0
Roll 0
Yaw 0
Reset
Accept
☐ Export
TomoImage
Correlated Images
Reference Image
L
GH
F
R
257
129
HFS
Orientation
○ Transverse
● Coronal
○ Sagittal
Switch
TomoImage Component
Color
Composition
Balance
Checker
Reference Image Component
☑ Isodose
☐ ROIs
☐ Lasers
☐ Dose 70.0 Gy
74.9
70
66.5
63
56
49
35
21

McGill

VMAT concepto



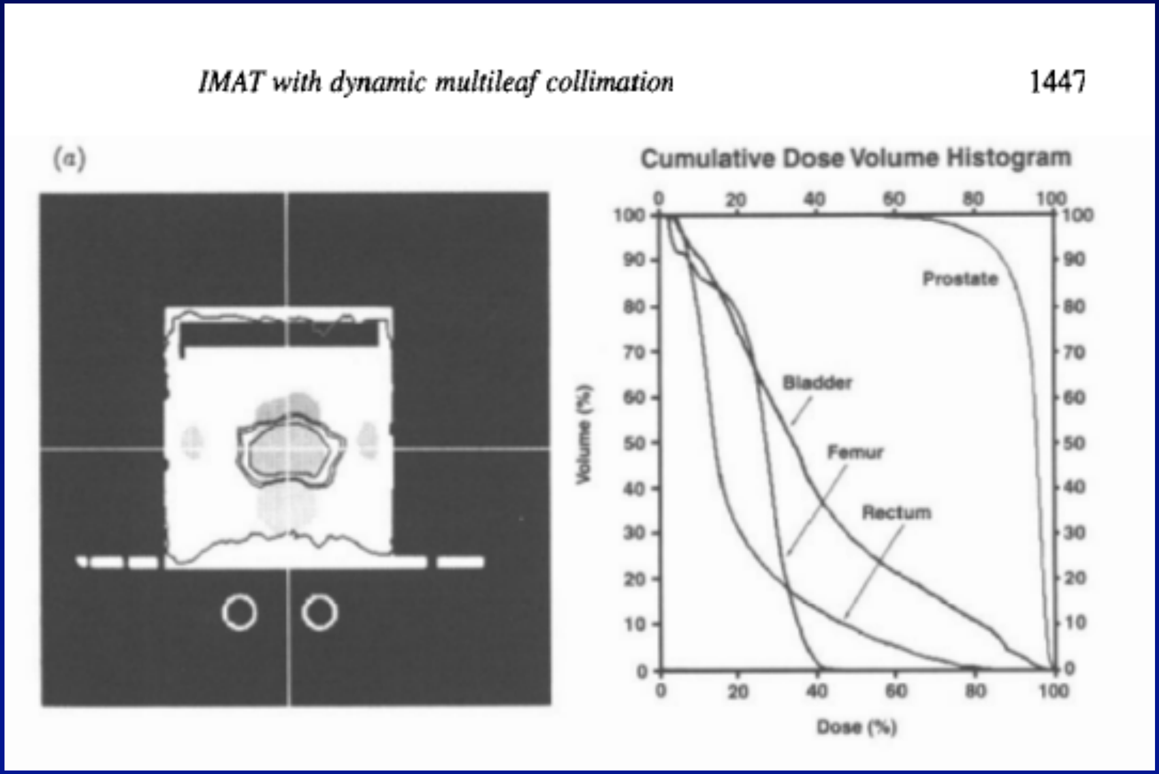
Intensity-modulated arc therapy with dynamic multileaf collimation: an alternative to tomotherapy

Cedric X Yu

William Beaumont Hospital, Royal Oak, MI, USA

Received 9 February 1995, in final form 20 April 1995

1995

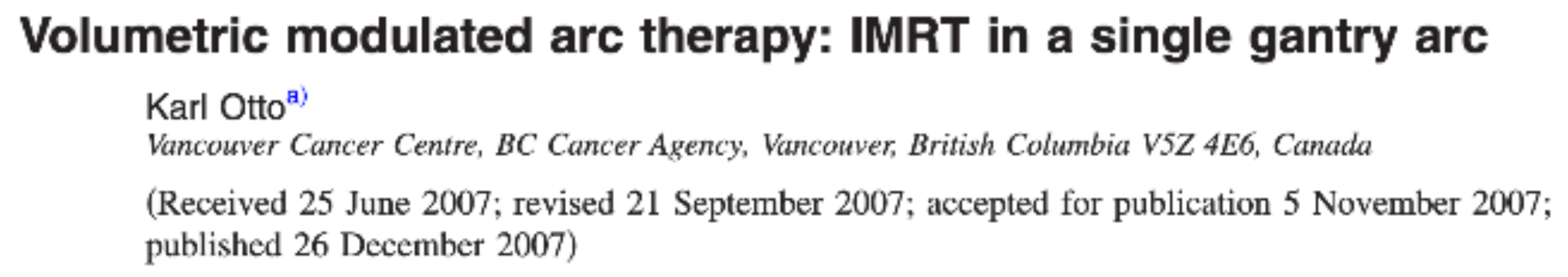


IMAT with dynamic multileaf collimation 1447

McGill

VMAT solución práctica

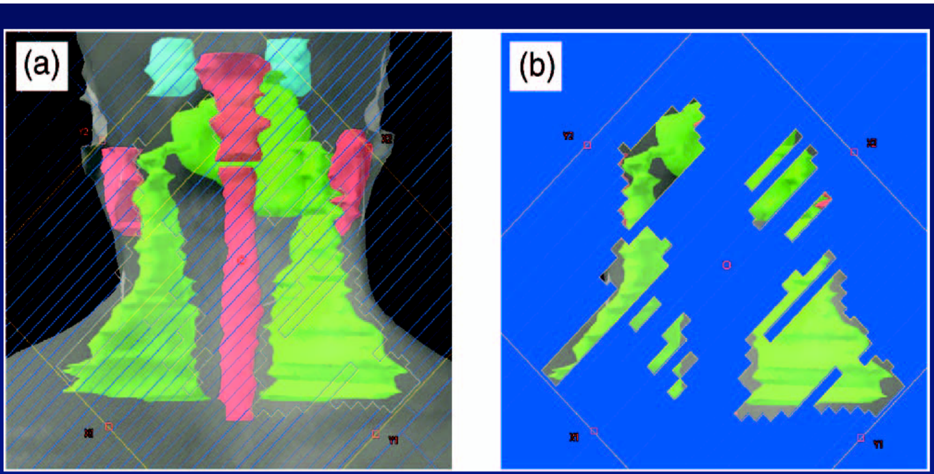
2007

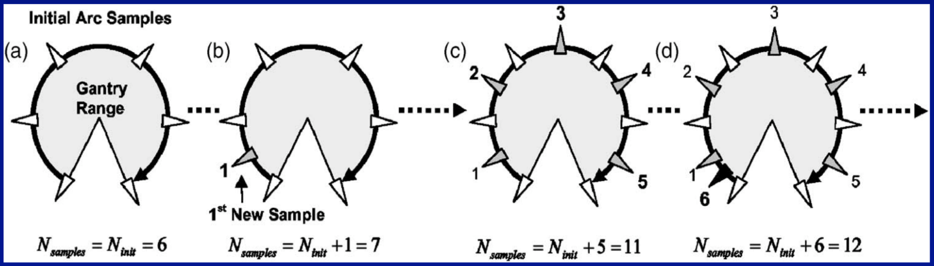


Volumetric modulated arc therapy: IMRT in a single gantry arc

Karl Otto[a)]
Vancouver Cancer Centre, BC Cancer Agency, Vancouver, British Columbia V5Z 4E6, Canada

(Received 25 June 2007; revised 21 September 2007; accepted for publication 5 November 2007; published 26 December 2007)




Initial Arc Samples
(a)
Gantry Range
$N_{samples} = N_{init} = 6$
(b)
1
1st New Sample
$N_{samples} = N_{init} + 1 = 7$
(c)
3
2
4
1
5
$N_{samples} = N_{init} + 5 = 11$
(d)
3
2
4
1
6
5
$N_{samples} = N_{init} + 6 = 12$

En particular, la técnica VMAT está diseñada para que se puedan entregar planos optimizados:

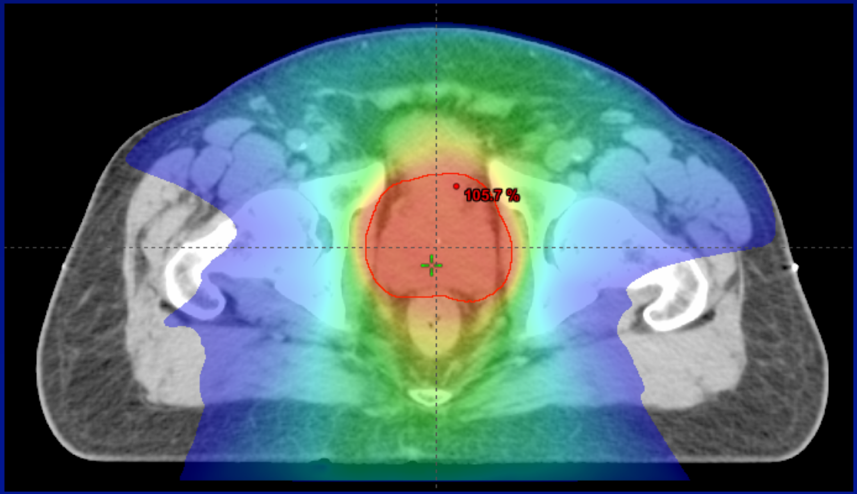
- Eficientemente en un solo arco
- Con alta conformidad de dosis usando un rango de 360 grados de direcciones de pórtico
- Con precisión con muestreo de alta resolución de las direcciones de los haces durante la planificación

Otto. Med Phys. 2008.

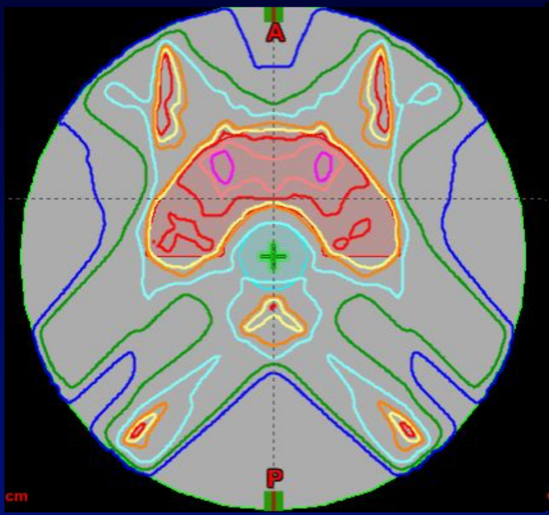
¿Por qué rotar?

- Mejores planes de tratamiento
  - El aumento de los grados de libertad resulta en mejores planes de tratamiento
- Entrega eficiente
  - Sin arranques ni paradas
  - Menos unidades de monitor
  - Tratamiento más corto

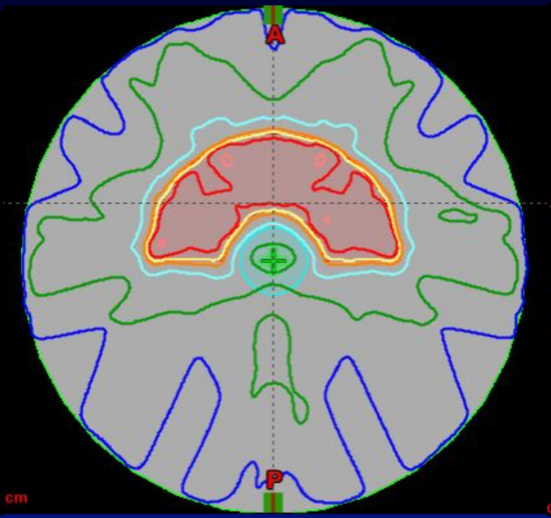
Linac con OBI - compite bien con la Tomoterapia



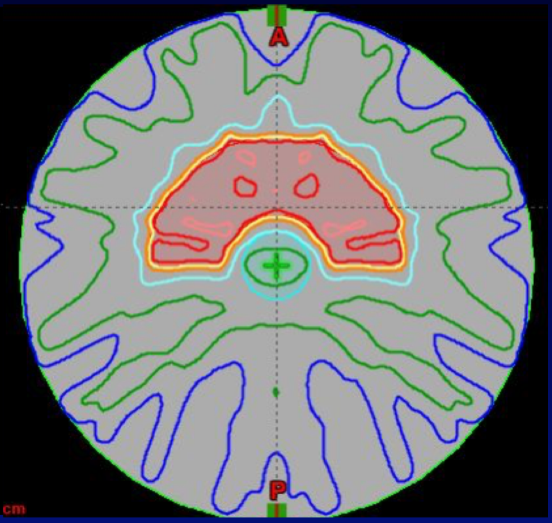
Planificación de la IMRT - # de campos



5 Fields



7 Fields

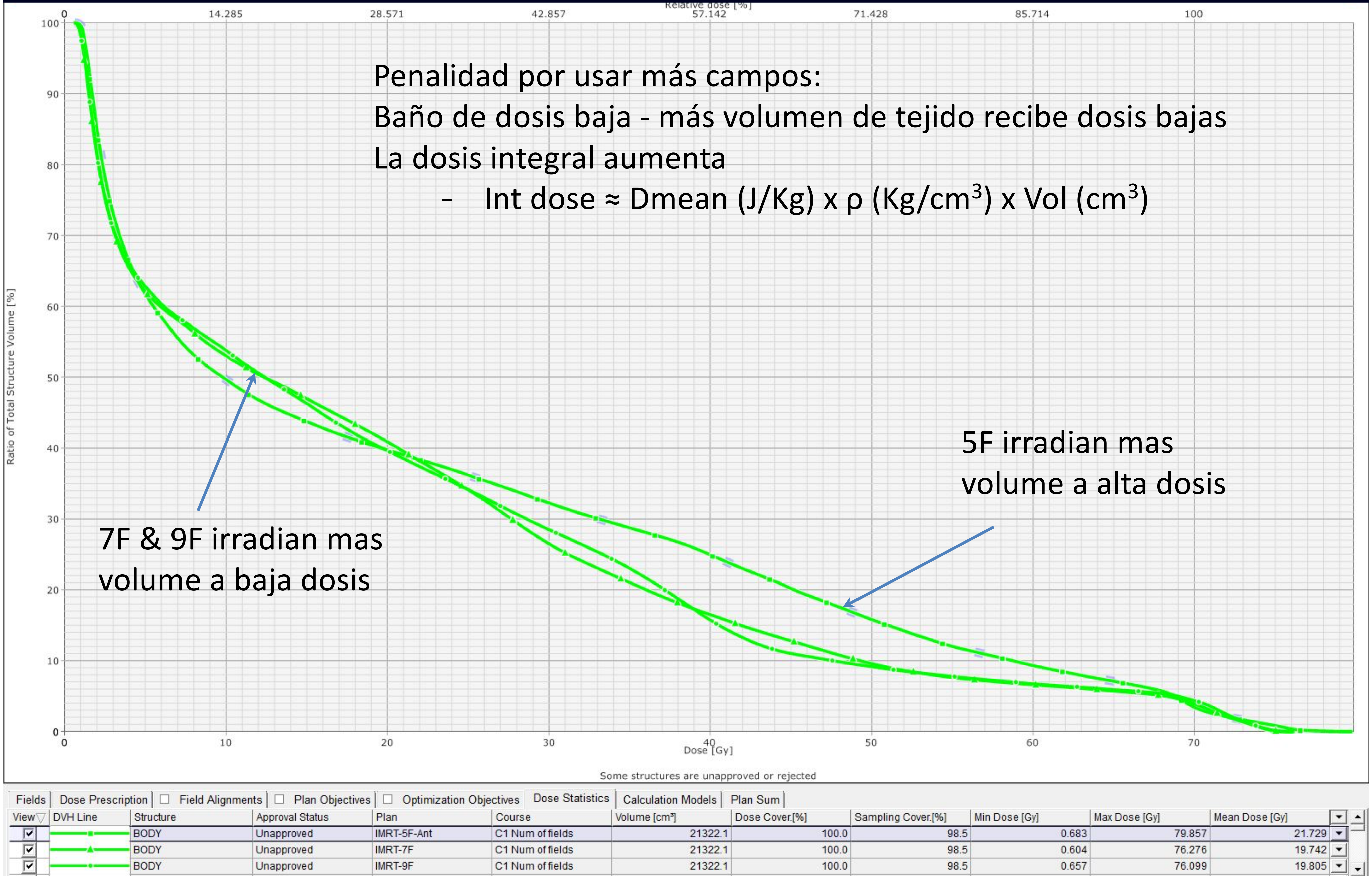


9 Fields

La adición de más campos proporciona más grados de libertad para la optimización

Lo que ofrece una mayor posibilidad de adaptar la dosis al PTV y a los OAR.

Planificación de la IMRT - # de campos


Relative dose [%]
0
14.285
28.571
42.857
57.142
71.428
85.714
100
Ratio of Total Structure Volume [%]
100
90
80
70
60
50
40
30
20
10
0
Dose [Gy]
0
10
20
30
40
50
60
70
Some structures are unapproved or rejected
Fields
Dose Prescription
☐ Field Alignments
☐ Plan Objectives
☐ Optimization Objectives
Dose Statistics
Calculation Models
Plan Sum

Penalidad por usar más campos:

Baño de dosis baja - más volumen de tejido recibe dosis bajas

La dosis integral aumenta

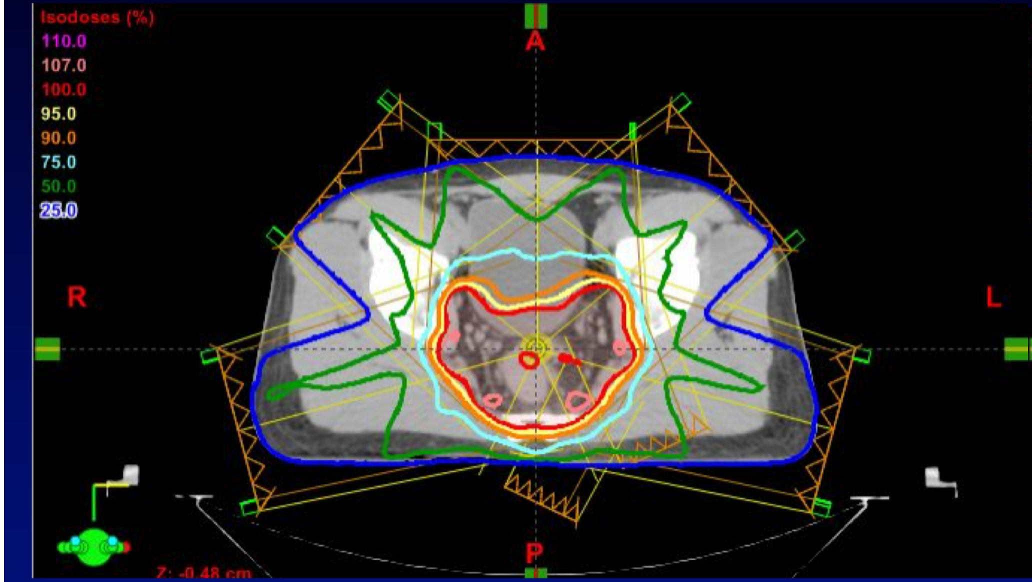
- Int dose ≈ Dmean (J/Kg) x ρ (Kg/cm^3) x Vol (cm^3)

5F irradian mas volume a alta dosis

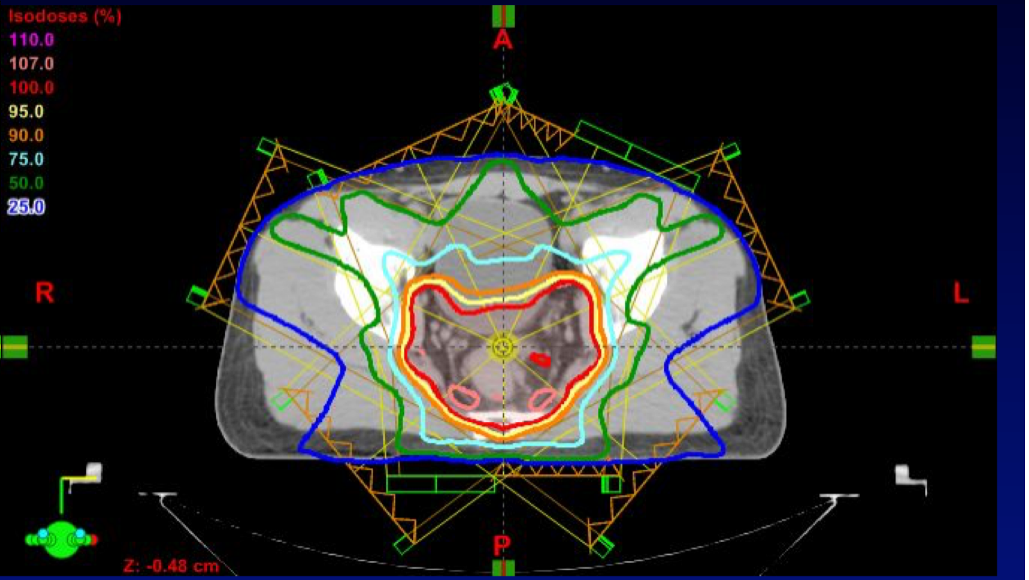
7F & 9F irradian mas volume a baja dosis

View	DVH Line	Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover.[%]	Sampling Cover.[%]	Min Dose [Gy]	Max Dose [Gy]	Mean Dose [Gy]
☑	■	BODY	Unapproved	IMRT-5F-Ant	C1 Num of fields	21322.1	100.0	98.5	0.683	79.857	21.729
☑	▲	BODY	Unapproved	IMRT-7F	C1 Num of fields	21322.1	100.0	98.5	0.604	76.276	19.742
☑	●	BODY	Unapproved	IMRT-9F	C1 Num of fields	21322.1	100.0	98.5	0.657	76.099	19.805

IMRT - Ángulos de campo


Isodoses (%)
110.0
107.0
100.0
95.0
90.0
75.0
50.0
25.0
A
R
L
P
Z: -0.48 cm

7F Anterior


Isodoses (%)
110.0
107.0
100.0
95.0
90.0
75.0
50.0
25.0
A
R
L
P
Z: -0.48 cm

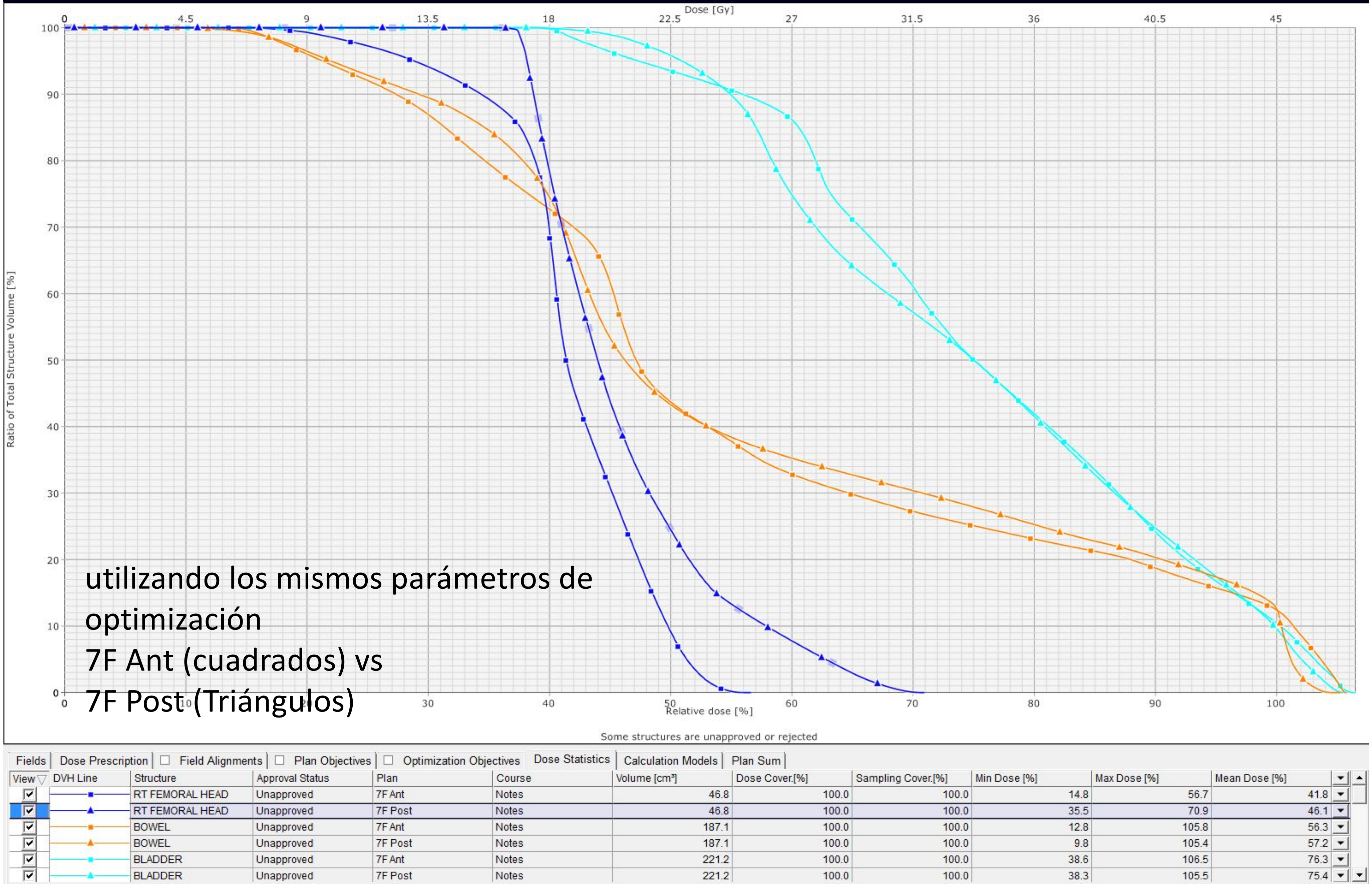
7F Posterior

El uso de ángulos de haz que atraviesan un OAR puede ser contrario a la intuición, pero es una opción.

Permite que el optimizador restrinja la dosis a los OAR con más bloqueo del MLC

NO use campos opuestos. Los campos no deben entrar y salir de la misma dirección para evitar campos POP.

IMRT - Ángulos de campo


Dose [Gy]
0
4.5
9
13.5
18
22.5
27
31.5
36
40.5
45
Ratio of Total Structure Volume [%]
100
90
80
70
60
50
40
30
20
10
0
Relative dose [%]
10
20
30
40
50
60
70
80
90
100
Some structures are unapproved or rejected
Fields
Dose Prescription
☐ Field Alignments
☐ Plan Objectives
☐ Optimization Objectives
Dose Statistics
Calculation Models
Plan Sum

utilizando los mismos parámetros de optimización

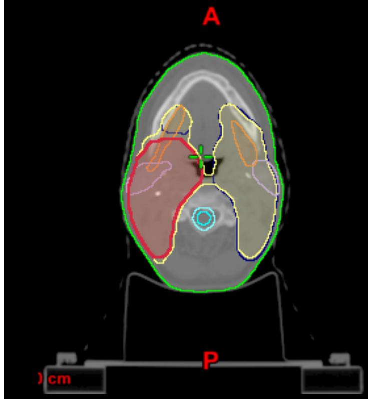
7F Ant (cuadrados) vs

7F Post (Triángulos)

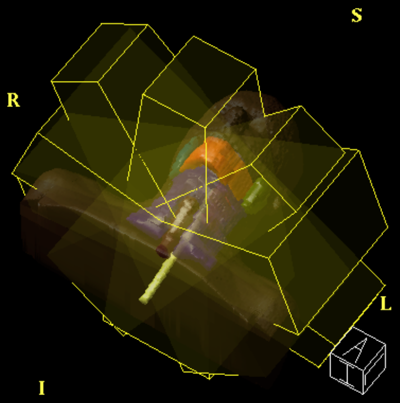
View	DVH Line	Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover.[%]	Sampling Cover.[%]	Min Dose [%]	Max Dose [%]	Mean Dose [%]
☑	■	RT FEMORAL HEAD	Unapproved	7F Ant	Notes	46.8	100.0	100.0	14.8	56.7	41.8
☑	▲	RT FEMORAL HEAD	Unapproved	7F Post	Notes	46.8	100.0	100.0	35.5	70.9	46.1
☑	■	BOWEL	Unapproved	7F Ant	Notes	187.1	100.0	100.0	12.8	105.8	56.3
☑	▲	BOWEL	Unapproved	7F Post	Notes	187.1	100.0	100.0	9.8	105.4	57.2
☑	■	BLADDER	Unapproved	7F Ant	Notes	221.2	100.0	100.0	38.6	106.5	76.3
☑	▲	BLADDER	Unapproved	7F Post	Notes	221.2	100.0	100.0	38.3	105.5	75.4

ProcesoIMRT

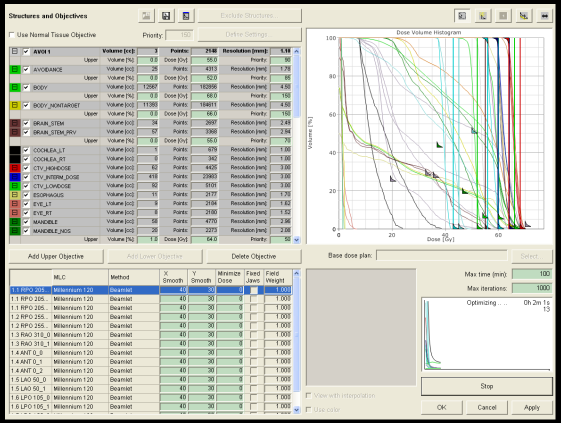
DATOS DEL PACIENTE



GEOMETRÍA DE CAMPO



OPTIMIZACIÓN


Exclude Structures...
Define Settings...
Add Upper Objective
Add Lower Objective
Delete Objective
Select...
View with interpolation
Use color
Stop
OK
Cancel
Apply
Dose Volume Histogram
Volume [%]
Dose [Gy]
100
80
60
40
20
0
0
20
40
60

Structures and Objectives

☐ Use Normal Tissue Objective   Priority: 150

☑ **AVOI 1**	**Volume [cc]:**	**3**	**Points:**	**2148**	**Resolution [mm]:**	**1.10**
Upper	Volume [%]:	0.0	Dose [Gy]:	55.0	Priority:	90
☑ AVOIDANCE	Volume [cc]:	25	Points:	4313	Resolution [mm]:	1.78
Upper	Volume [%]:	0.0	Dose [Gy]:	52.0	Priority:	85
☑ BODY	Volume [cc]:	12567	Points:	182856	Resolution [mm]:	4.50
Upper	Volume [%]:	0.0	Dose [Gy]:	68.0	Priority:	150
☑ BODY_NONTARGET	Volume [cc]:	11393	Points:	184611	Resolution [mm]:	4.50
Upper	Volume [%]:	0.0	Dose [Gy]:	66.0	Priority:	150
☑ BRAIN_STEM	Volume [cc]:	34	Points:	2697	Resolution [mm]:	2.49
☑ BRAIN_STEM_PRV	Volume [cc]:	57	Points:	3368	Resolution [mm]:	2.94
Upper	Volume [%]:	0.0	Dose [Gy]:	55.0	Priority:	70
☑ COCHLEA_LT	Volume [cc]:	1	Points:	679	Resolution [mm]:	1.00
☑ COCHLEA_RT	Volume [cc]:	0	Points:	342	Resolution [mm]:	1.00
☑ CTV_HIGHDOSE	Volume [cc]:	62	Points:	4425	Resolution [mm]:	3.00
☑ CTV_INTERM_DOSE	Volume [cc]:	418	Points:	23983	Resolution [mm]:	3.00
☑ CTV_LOWDOSE	Volume [cc]:	92	Points:	5101	Resolution [mm]:	3.00
☑ ESOPHAGUS	Volume [cc]:	11	Points:	2177	Resolution [mm]:	1.70
☑ EYE_LT	Volume [cc]:	9	Points:	2184	Resolution [mm]:	1.62
☑ EYE_RT	Volume [cc]:	8	Points:	2180	Resolution [mm]:	1.52
☑ MANDIBLE	Volume [cc]:	58	Points:	4770	Resolution [mm]:	2.96
☑ MANDIBLE_NOS	Volume [cc]:	20	Points:	2273	Resolution [mm]:	2.08
Upper	Volume [%]:	1.0	Dose [Gy]:	64.0	Priority:	50

	MLC	Method	X Smooth	Y Smooth	Minimize Dose	Fixed Jaws	Field Weight
1.1 RPO 205...	Millennium 120	Beamlet	40	30	0	☐	1.000
1.1 RPO 205...	Millennium 120	Beamlet	40	30	0	☐	1.000
1.1 RPO 205...	Millennium 120	Beamlet	40	30	0	☐	1.000
1.2 RPO 255...	Millennium 120	Beamlet	40	30	0	☐	1.000
1.2 RPO 255...	Millennium 120	Beamlet	40	30	0	☐	1.000
1.3 RAO 310_0	Millennium 120	Beamlet	40	30	0	☐	1.000
1.3 RAO 310_1	Millennium 120	Beamlet	40	30	0	☐	1.000
1.4 ANT 0_0	Millennium 120	Beamlet	40	30	0	☐	1.000
1.4 ANT 0_1	Millennium 120	Beamlet	40	30	0	☐	1.000
1.4 ANT 0_2	Millennium 120	Beamlet	40	30	0	☐	1.000
1.5 LAO 50_0	Millennium 120	Beamlet	40	30	0	☐	1.000
1.5 LAO 50_1	Millennium 120	Beamlet	40	30	0	☐	1.000
1.6 LPO 105_0	Millennium 120	Beamlet	40	30	0	☐	1.000
1.6 LPO 105_1	Millennium 120	Beamlet	40	30	0	☐	1.000

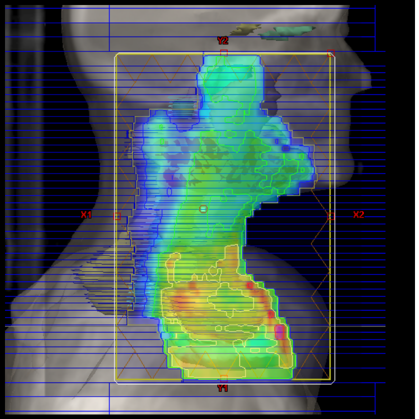
Base dose plan:

Max time (min): 100

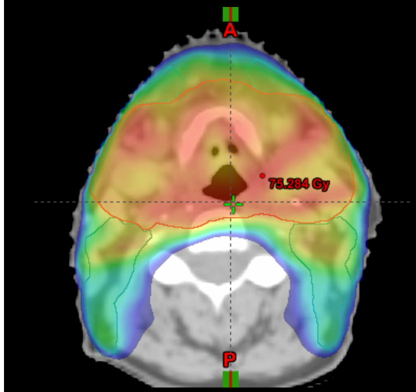
Max iterations: 1000

Optimizing 0h 2m 1s
13

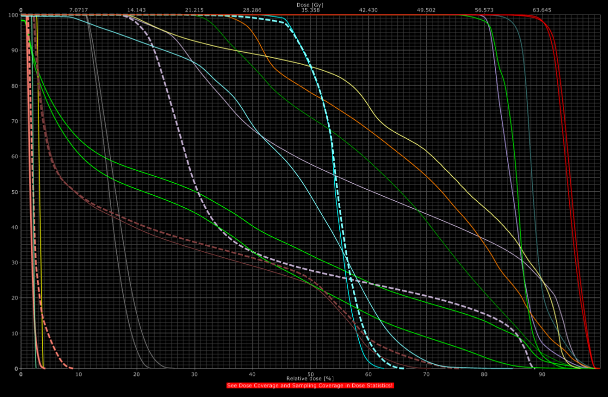
FLUENCIA



CÁLCULO DE DOSIS



EVALUACIÓN DE PLAN



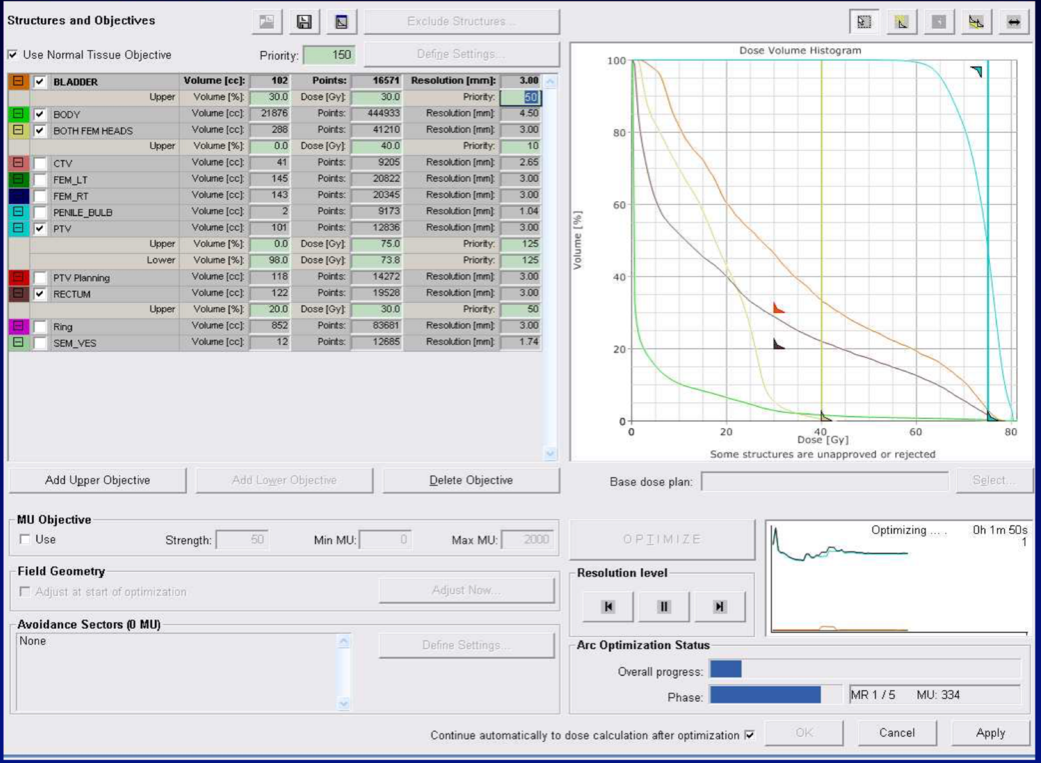
PREPARACION TRATAMIENTO

TARTAMEINTO

McGill

Overview of Planning Steps

- Seleccione Arcos
- Arranque y parada de gantry
- Tamaños de campo
- Colimador
- Objetivos del plan
- Optimizar
- Revisar los resultados de optimización
- Continúe optimizando hasta que se cumplan las restricciones del plan y no haya puntos calientes fuera del PTV



Structures and Objectives

☑ Use Normal Tissue Objective   Priority: 150

☑ **BLADDER**	**Volume [cc]:**	**102**	**Points:**	**16571**	**Resolution [mm]:**	**3.00**
Upper	Volume [%]:	30.0	Dose [Gy]:	30.0	Priority:	50
☑ BODY	Volume [cc]:	21876	Points:	444933	Resolution [mm]:	4.50
☑ BOTH FEM HEADS	Volume [cc]:	288	Points:	41210	Resolution [mm]:	3.00
Upper	Volume [%]:	0.0	Dose [Gy]:	40.0	Priority:	10
☐ CTV	Volume [cc]:	41	Points:	9205	Resolution [mm]:	2.65
☐ FEM_LT	Volume [cc]:	145	Points:	20822	Resolution [mm]:	3.00
☐ FEM_RT	Volume [cc]:	143	Points:	20345	Resolution [mm]:	3.00
☐ PENILE_BULB	Volume [cc]:	2	Points:	9173	Resolution [mm]:	1.04
☑ PTV	Volume [cc]:	101	Points:	12836	Resolution [mm]:	3.00
Upper	Volume [%]:	0.0	Dose [Gy]:	75.0	Priority:	125
Lower	Volume [%]:	98.0	Dose [Gy]:	73.8	Priority:	125
☐ PTV Planning	Volume [cc]:	118	Points:	14272	Resolution [mm]:	3.00
☑ RECTUM	Volume [cc]:	122	Points:	19528	Resolution [mm]:	3.00
Upper	Volume [%]:	20.0	Dose [Gy]:	30.0	Priority:	50
☐ Ring	Volume [cc]:	852	Points:	83681	Resolution [mm]:	3.00
☐ SEM_VES	Volume [cc]:	12	Points:	12685	Resolution [mm]:	1.74

Some structures are unapproved or rejected

Base dose plan:

MU Objective
☐ Use   Strength: 50   Min MU: 0   Max MU: 2000

Field Geometry
☐ Adjust at start of optimization

Avoidance Sectors (0 MU)
None

Optimizing 0h 1m 50s
1

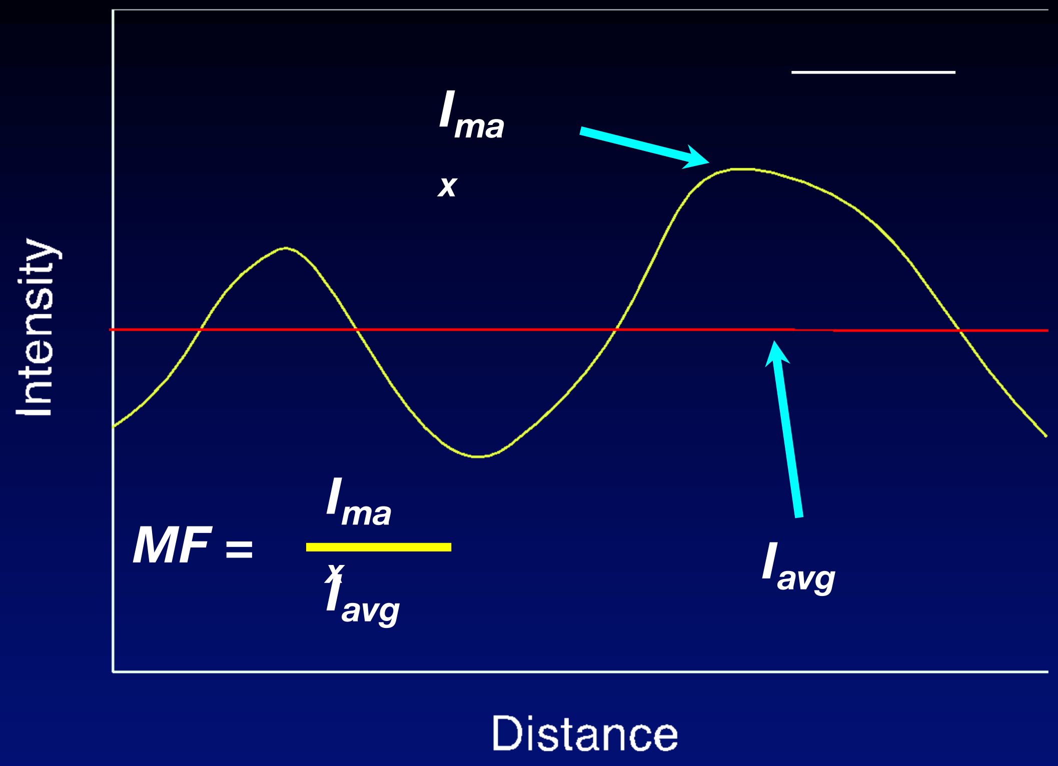
Arc Optimization Status
Overall progress:
Phase: MR 1 / 5   MU: 334

Continue automatically to dose calculation after optimization ☑

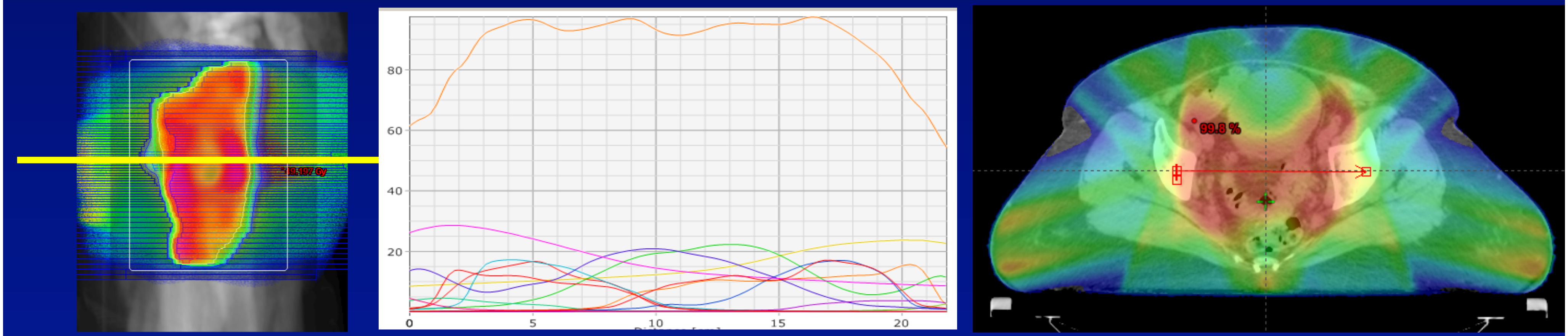
Exclude Structures ...
Define Settings ...
Dose Volume Histogram
Volume [%]
100
80
60
40
20
0
0
20
40
60
80
Dose [Gy]
Add Upper Objective
Add Lower Objective
Delete Objective
Select...
OPTIMIZE
Resolution level
Adjust Now...
Define Settings...
OK
Cancel
Apply

Factor de modulación

***IMPORTANTE:** Una mayor modulación significa más flexibilidad en la planificación a expensas de más MUs y mayor tiempo de tratamiento.*



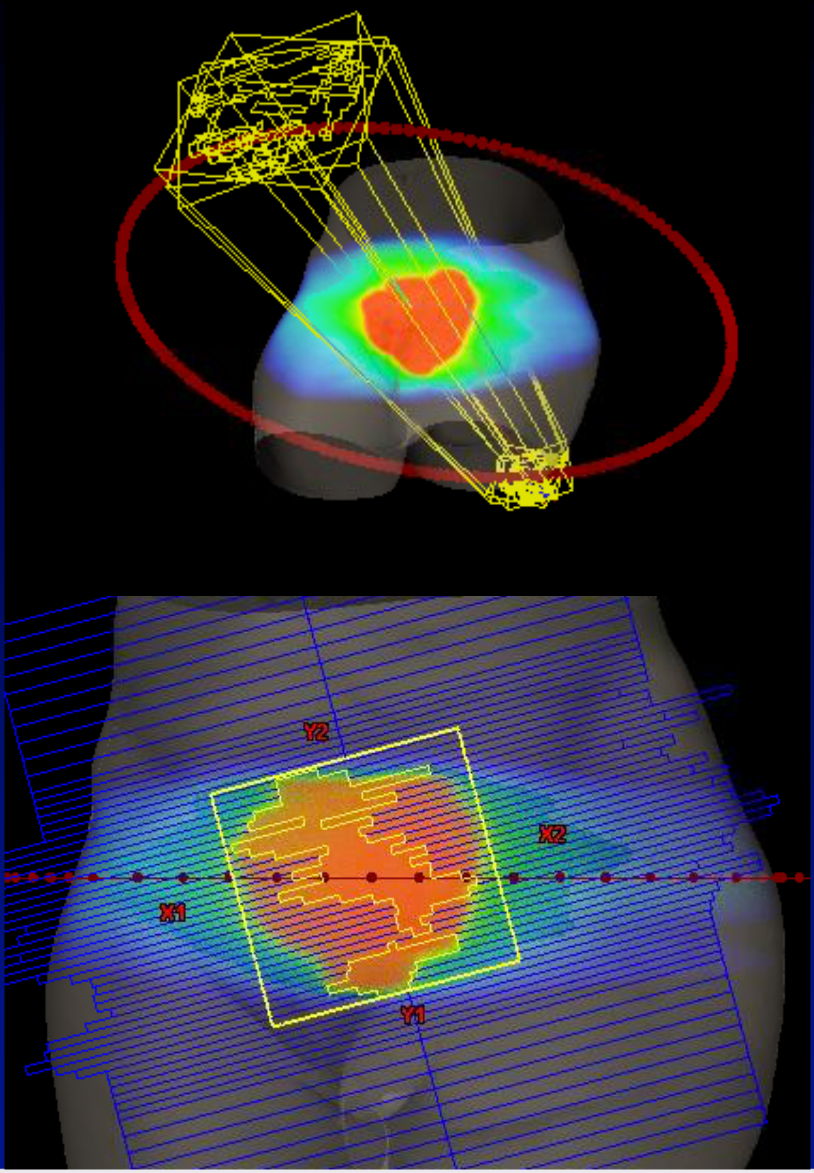
$$MF = \frac{I_{max}}{I_{avg}}$$

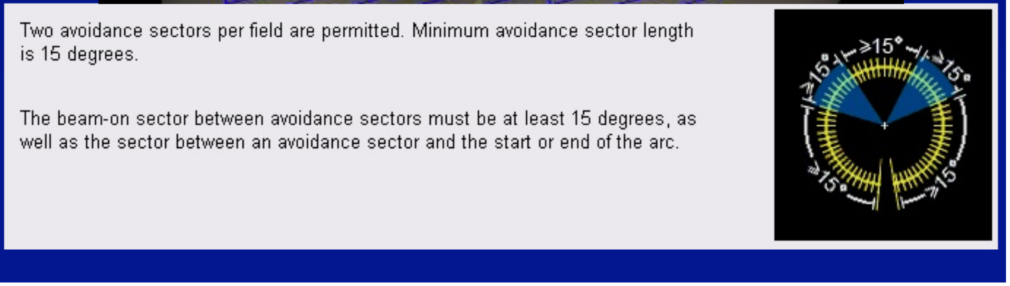


80
60
40
20
0
5
10
15
20
99.8 %

Elección de los campos

- Máximo 10 arcos (típicamente 1-3)
- Número máximo de grados-1000° (aprox. 3 arcos completos)
- Longitud del arco más corto-30° grados
- Sectores de evasión (áreas en las que la tasa de dosis es de 0 mu/min), 2 por arco, longitud mínima 15°.
- El colimador no puede ser de 0° debido a fugas entre las hojas.
- Varian recomienda 45°, usamos 30°.



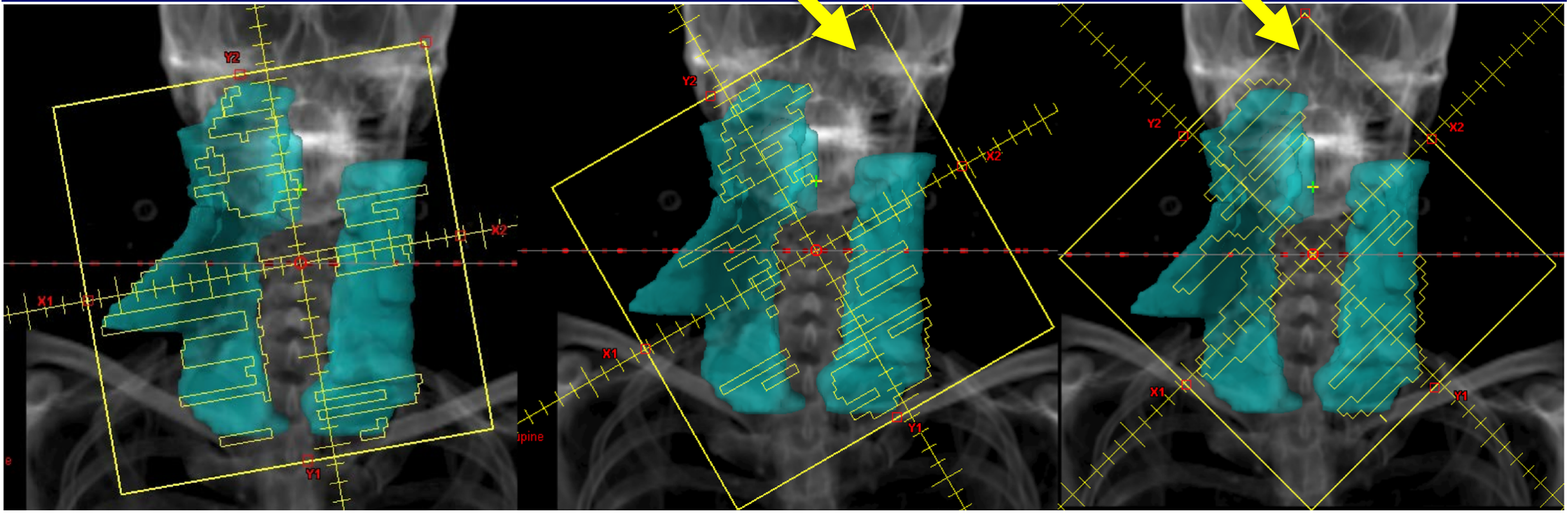


Two avoidance sectors per field are permitted. Minimum avoidance sector length is 15 degrees.

The beam-on sector between avoidance sectors must be at least 15 degrees, as well as the sector between an avoidance sector and the start or end of the arc.

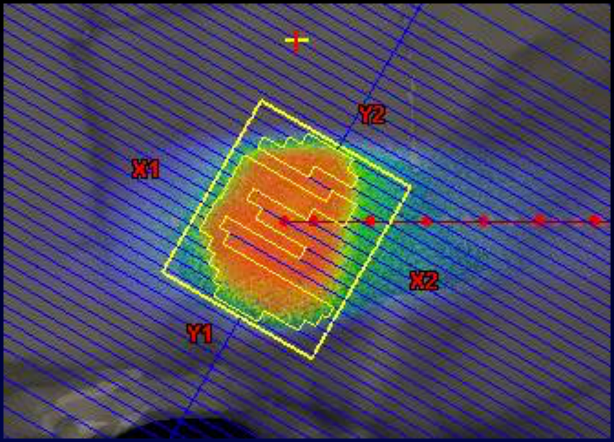
Parámetros del haz VMAT

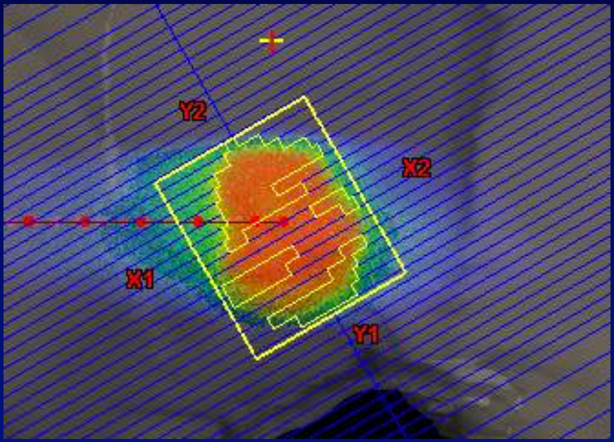
- El ángulo del colimador no se pone de 0° para evitar la superposición de la transmisión MLC durante el arco.
- Gire el colimador al ángulo que mejor permita que el MLC se adapte a la forma del objetivo, evite grandes rotaciones

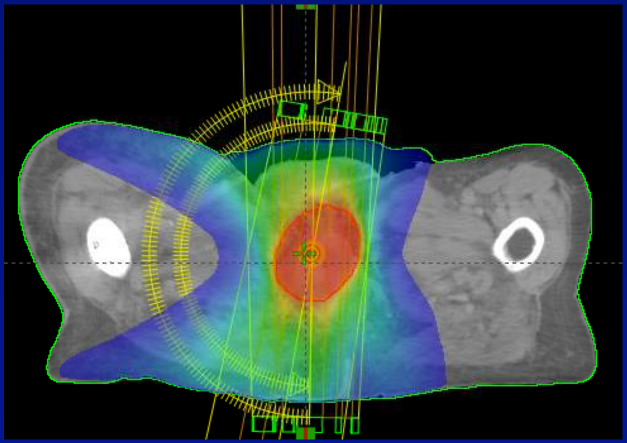

Y2
X1
X2
Y1
Y2
X1
X2
Y1
pine
Y2
X2
X1
Y1

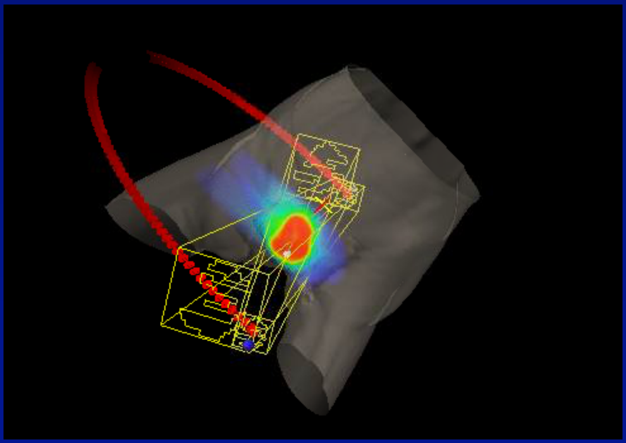
¿Por qué arcos múltiples?

- Dispersa la modulación a varios haces
- Tal vez se necesite si el volumen entero no encaja
- Ayuda si el objetivo es tratado a niveles de dosis múltiples
- Segundo campo con colimador inverso para aumentar la modulación



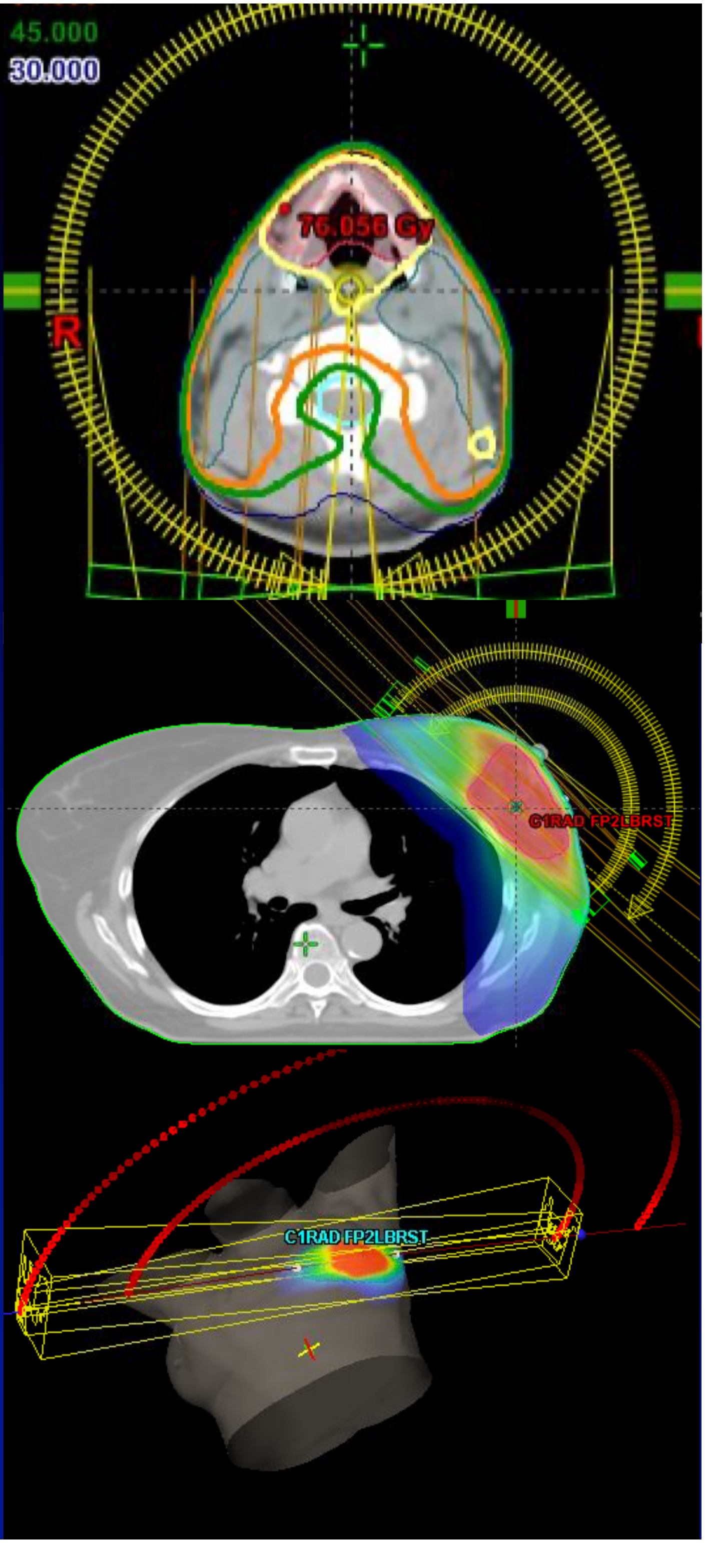






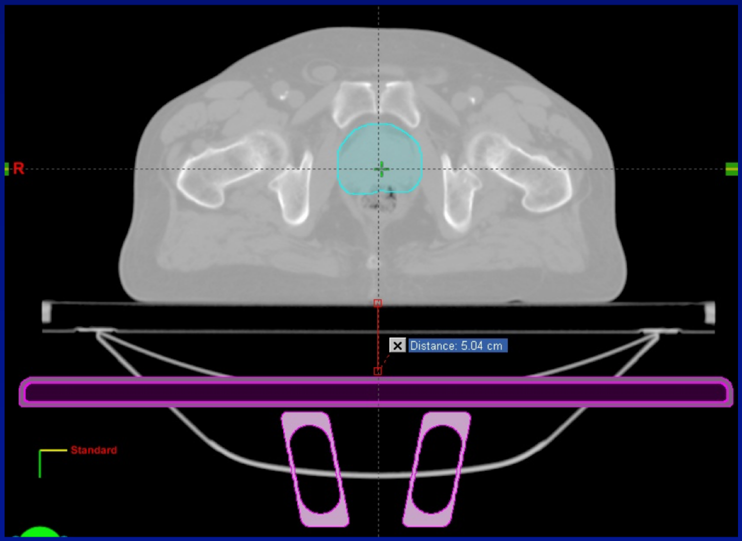
Arreglos típicos

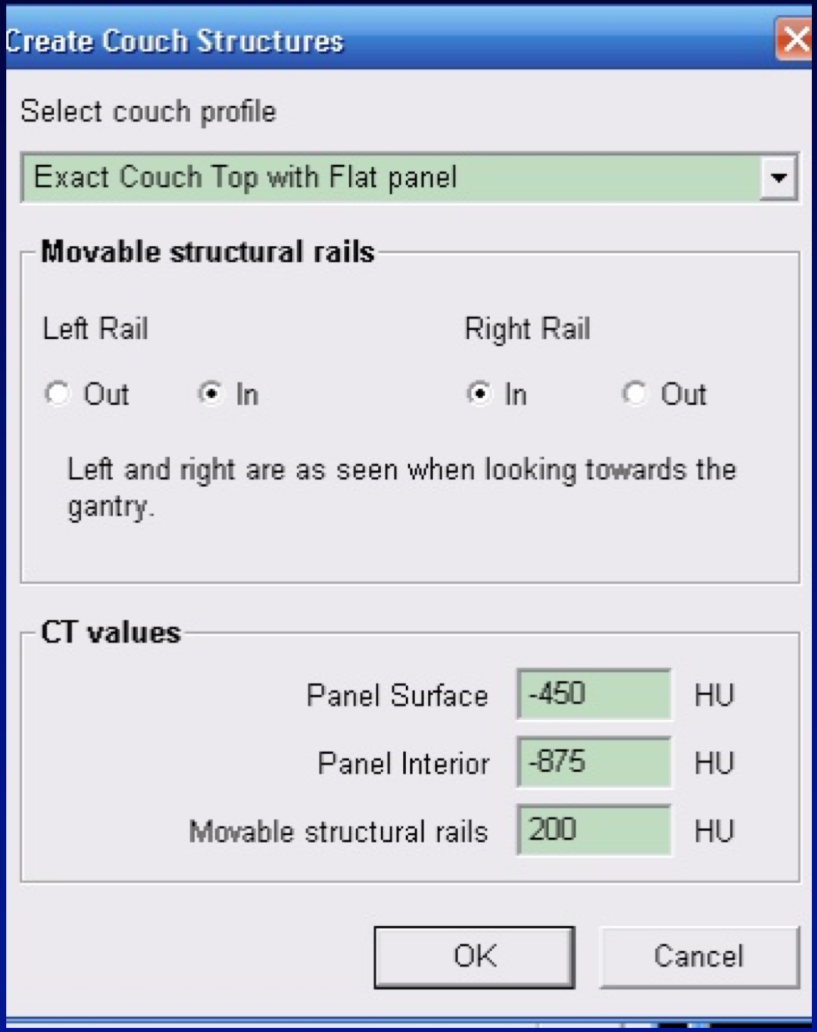
- Senos: Dos arcos de poco más de 180 grados
- Pelvis: Dos arcos completos que evitan la posible entrada a través de las barras (~300°)
- Cabeza y Cuello: Dos arcos de casi 360
- Los planes que requieren niveles de dosis múltiples o que tienen restricciones de planificación estrictas pueden requerir 3 arcos
- Cuidado con colisiones


45.000
30.000
76.056 Gy
R
C1RAD FP2LBRST
C1RAD FP2LBRST

Why is the couch important?

- CT couch different than linac
- Beam passes through the couch
- Linac couches not transparent to radiation
- Depends on the couch





Create Couch Structures

Select couch profile

Exact Couch Top with Flat panel

Movable structural rails

Left Rail

○ Out ● In

Right Rail

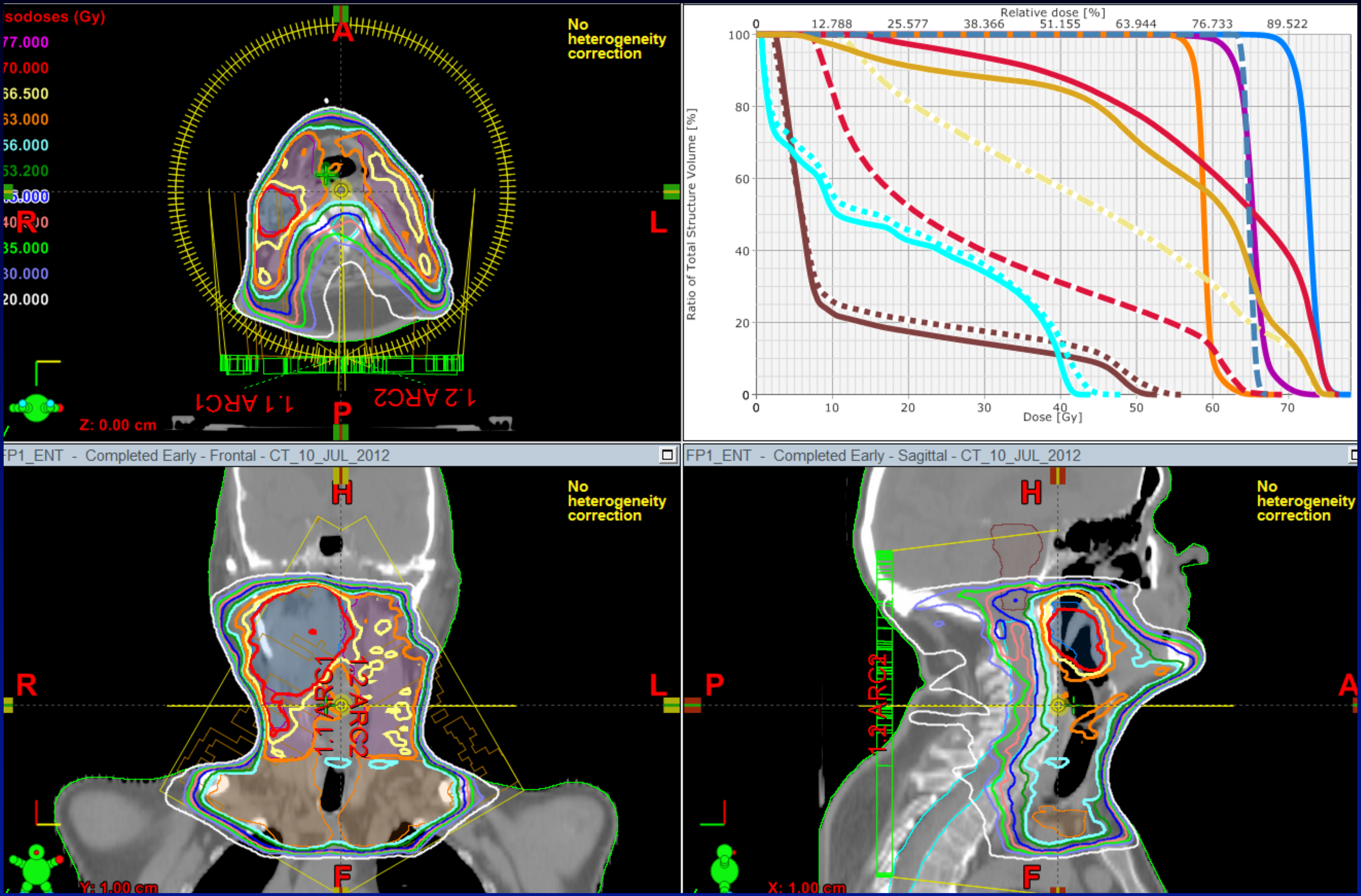
● In ○ Out

Left and right are as seen when looking towards the gantry.

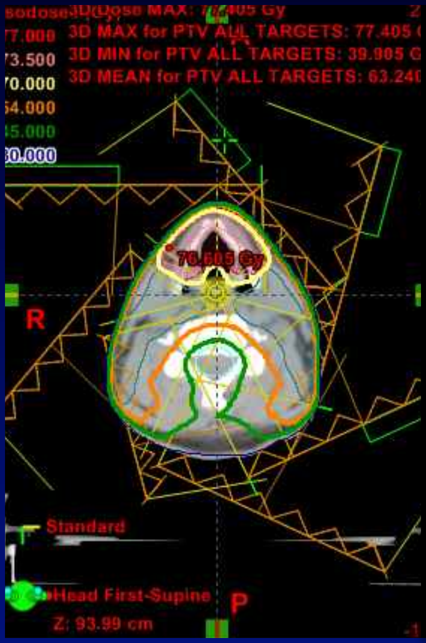
CT values

Panel Surface	-450	HU
Panel Interior	-875	HU
Movable structural rails	200	HU

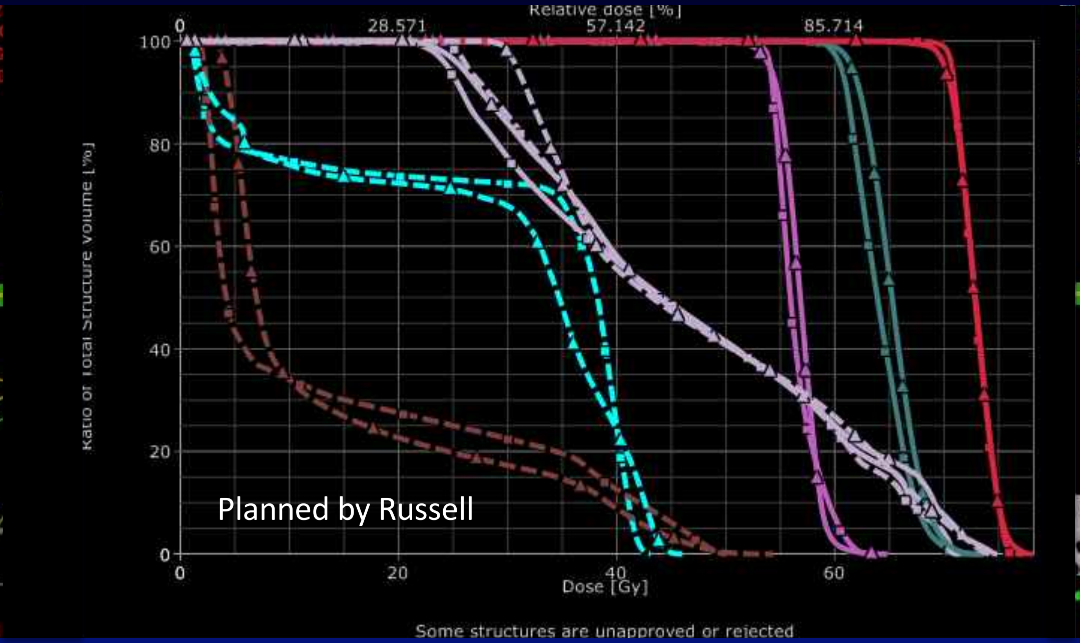
VMAT vs. IMRT for Head and Neck


sodoses (Gy)
77.000
70.000
56.500
53.000
56.000
53.200
5.000
40.000
35.000
30.000
20.000
A
P
R
L
No heterogeneity correction
1.1 ARC1
1.2 ARC2
Z: 0.00 cm
Relative dose [%]
0
12.788
25.577
38.366
51.155
63.944
76.733
89.522
Ratio of Total Structure Volume [%]
100
80
60
40
20
0
Dose [Gy]
10
20
30
40
50
60
70
FP1_ENT - Completed Early - Frontal - CT_10_JUL_2012
H
F
Y: 1.00 cm
FP1_ENT - Completed Early - Sagittal - CT_10_JUL_2012
X: 1.00 cm

VMAT vs. IMRT para Cabeza y Cuello

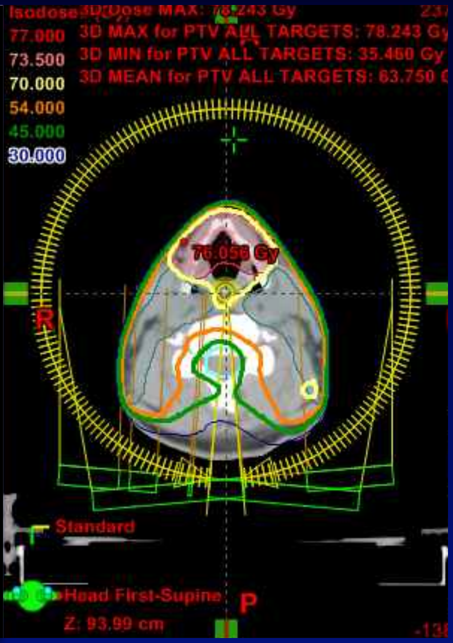

Isodose 3D Dose MAX: 77.405 Gy
77.000 3D MAX for PTV ALL TARGETS: 77.405
73.500 3D MIN for PTV ALL TARGETS: 39.905
70.000 3D MEAN for PTV ALL TARGETS: 63.240
54.000
45.000
30.000
76.605 Gy
R
Standard
Head First-Supine
Z: 93.99 cm
P

Static Field IMRT: **1260 MU**



Planned by Russell

Squares: Static Field
Triangles: VMAT


Isodose 3D Dose MAX: 78.243 Gy
77.000 3D MAX for PTV ALL TARGETS: 78.243 Gy
73.500 3D MIN for PTV ALL TARGETS: 35.460 Gy
70.000 3D MEAN for PTV ALL TARGETS: 63.750
54.000
45.000
30.000
76.058 Gy
R
Standard
Head First-Supine
Z: 93.99 cm
P

VMAT: **588 MU**

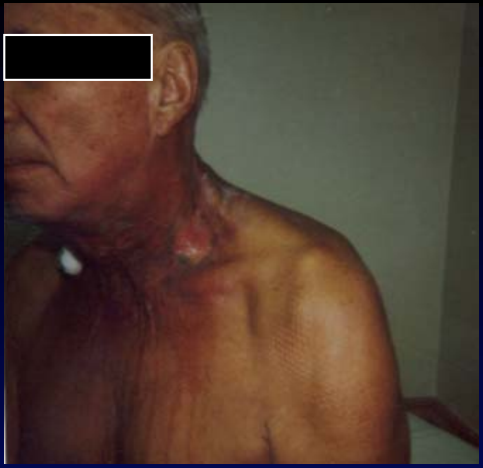
la calidad de los planes generalmente similares
Tiempo de tratamiento reducido sobre IMRT con campos estáticos
MU reducido por VMAT en comparación con otras formas de IMRT
El modo FFF reducirá los tiempos aún más

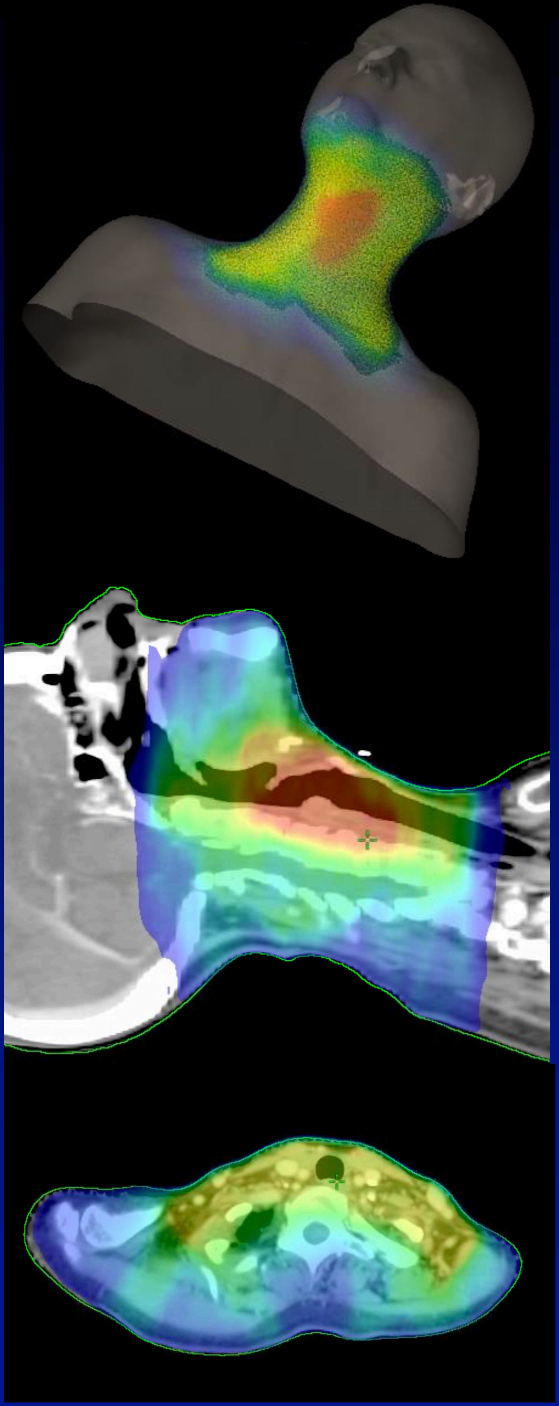
Los estudios NO concluyen que el VMAT resulta en una mejor distribución de las dosis sobre otras formas de IMRT, pero el VMAT ha mejorado enormemente la eficiencia de la administración.

VMAT a McGill

- Desde 2009
- Actualmente en 6 TrueBeams
- 65% de nuestros planes y tratamientos son con VMAT, 1% IMRT estática (técnicas heredadas)
- Todos los pacientes de VMAT en intervalos de 15 minutos
- Todos los pacientes son planificados y tratados de la misma manera

cuidados

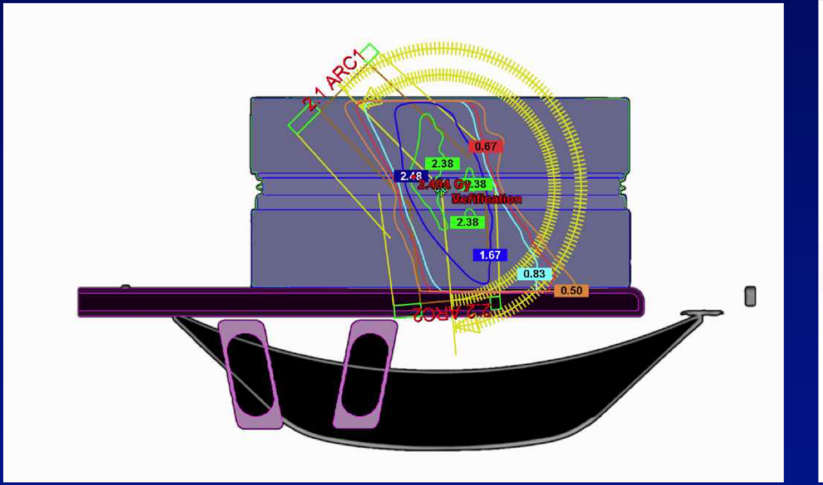

[redacted]



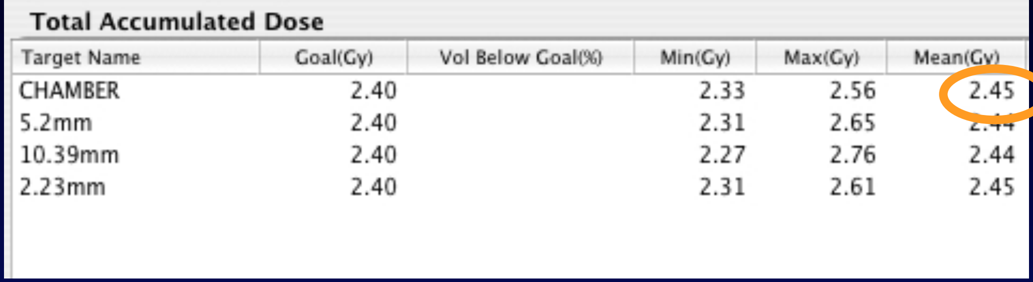
- Piel
- Colisiones
- Sectores de evasión
- Transmisión
- La técnica no cambia la práctica
- Por ejemplo, IGRT vs VMAT vs PTV definición

¿Cómo sabemos que la dosis se administra con precisión?

- Medidas
- Cálculos

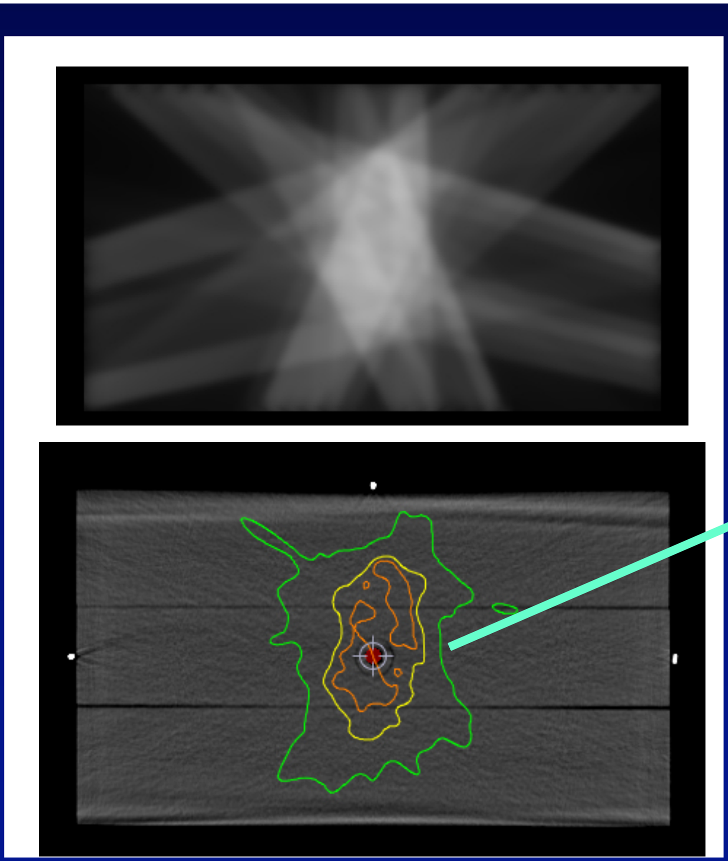

2.1 ARC1
0.67
2.38
2.48
2.494 Gy
38
Verification
2.38
1.67
0.83
0.50
2.2 ARC2

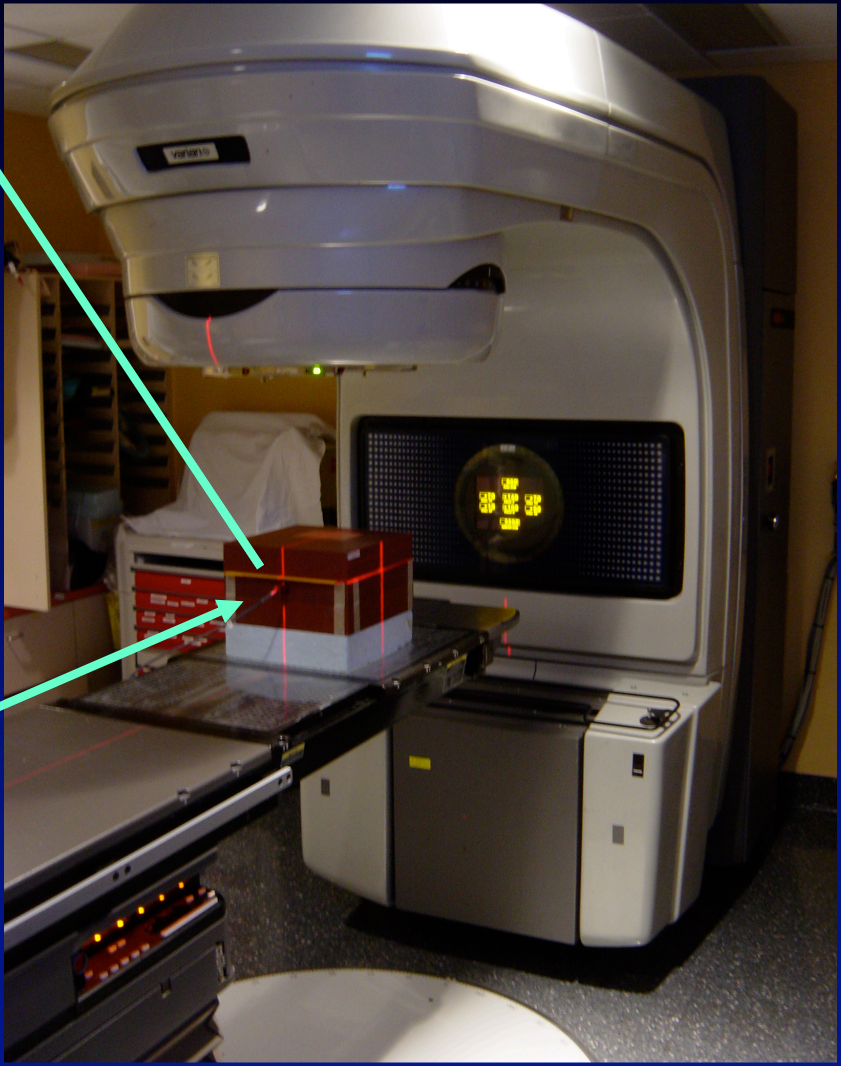
Medición de control de calidad



Total Accumulated Dose

Target Name	Goal(Gy)	Vol Below Goal(%)	Min(Gy)	Max(Gy)	Mean(Gy)
CHAMBER	2.40		2.33	2.56	2.45
5.2mm	2.40		2.31	2.65	2.44
10.39mm	2.40		2.27	2.76	2.44
2.23mm	2.40		2.31	2.61	2.45





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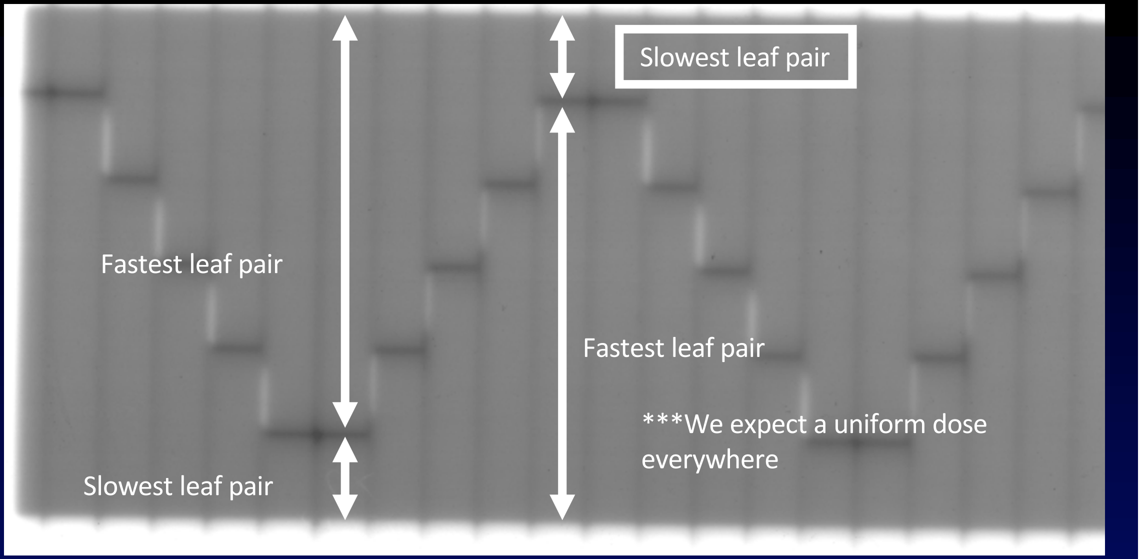
MLC QA

HARDWARE TESTS

120 leaf MLC

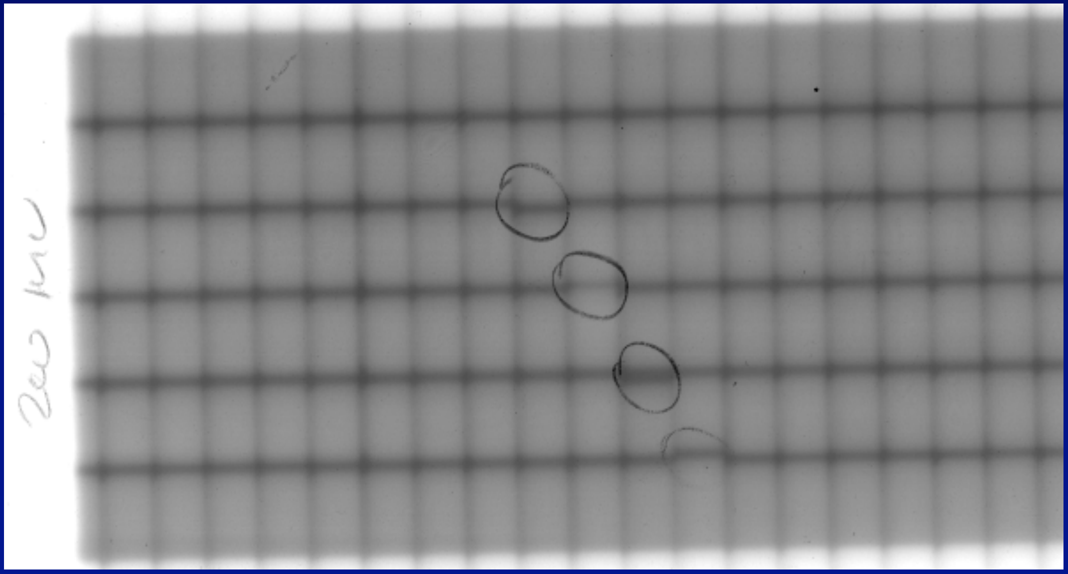
20 pairs of 0.5 cm wide leaves

40 pairs of 1 cm wide leaves


Slowest leaf pair
Fastest leaf pair
Fastest leaf pair
Slowest leaf pair

***We expect a uniform dose everywhere

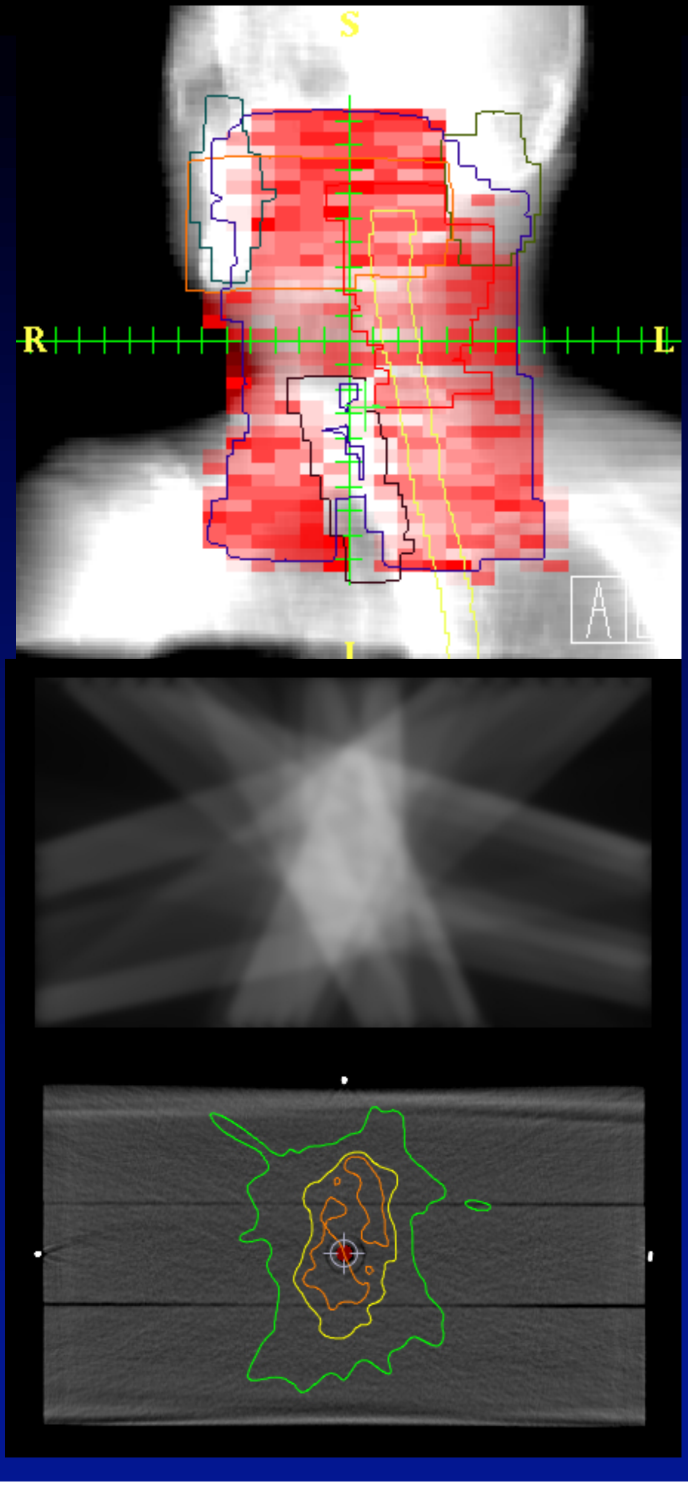
Test for leaf speed and acceleration



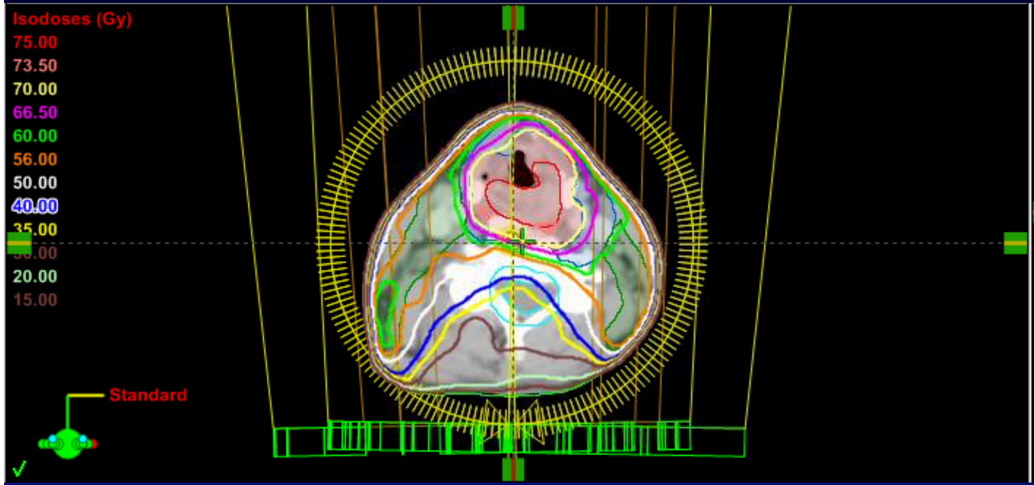
Test for position

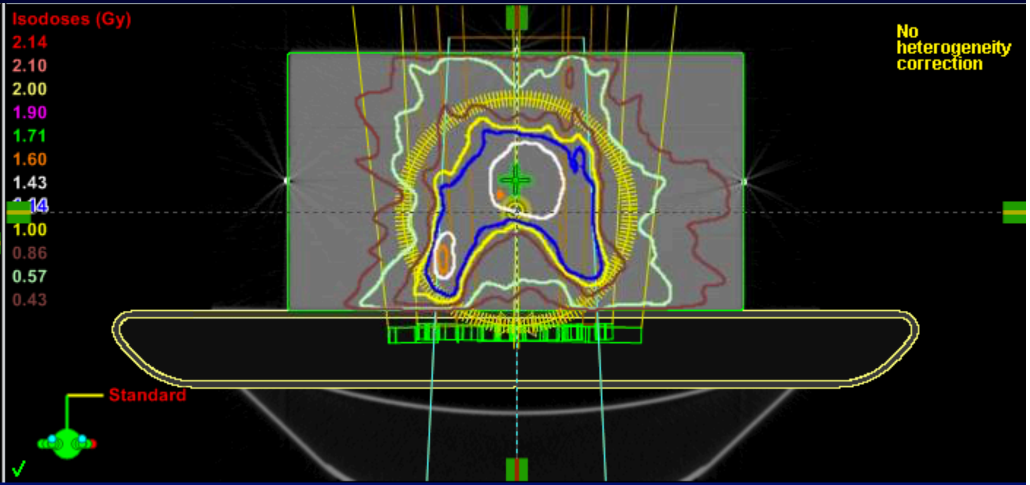
Control de calidad específico del paciente: ¿por que?

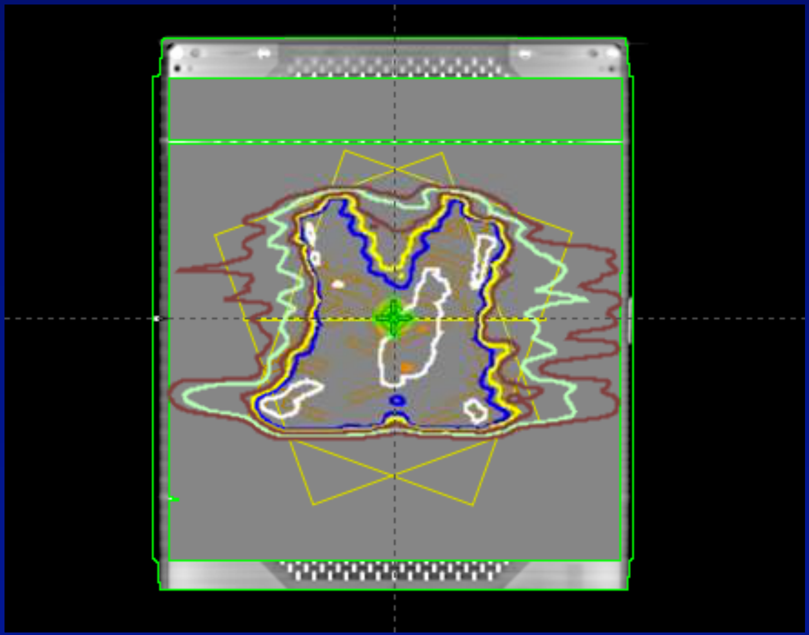
- Verificar el cálculo de UM
- Verificar la entrega compleja
- Puede ser legalmente requerido
- Puede ser laborioso y consumir mucho tiempo
- ¡Compruebe lo bueno que es usted a la hora de medir las dosis!



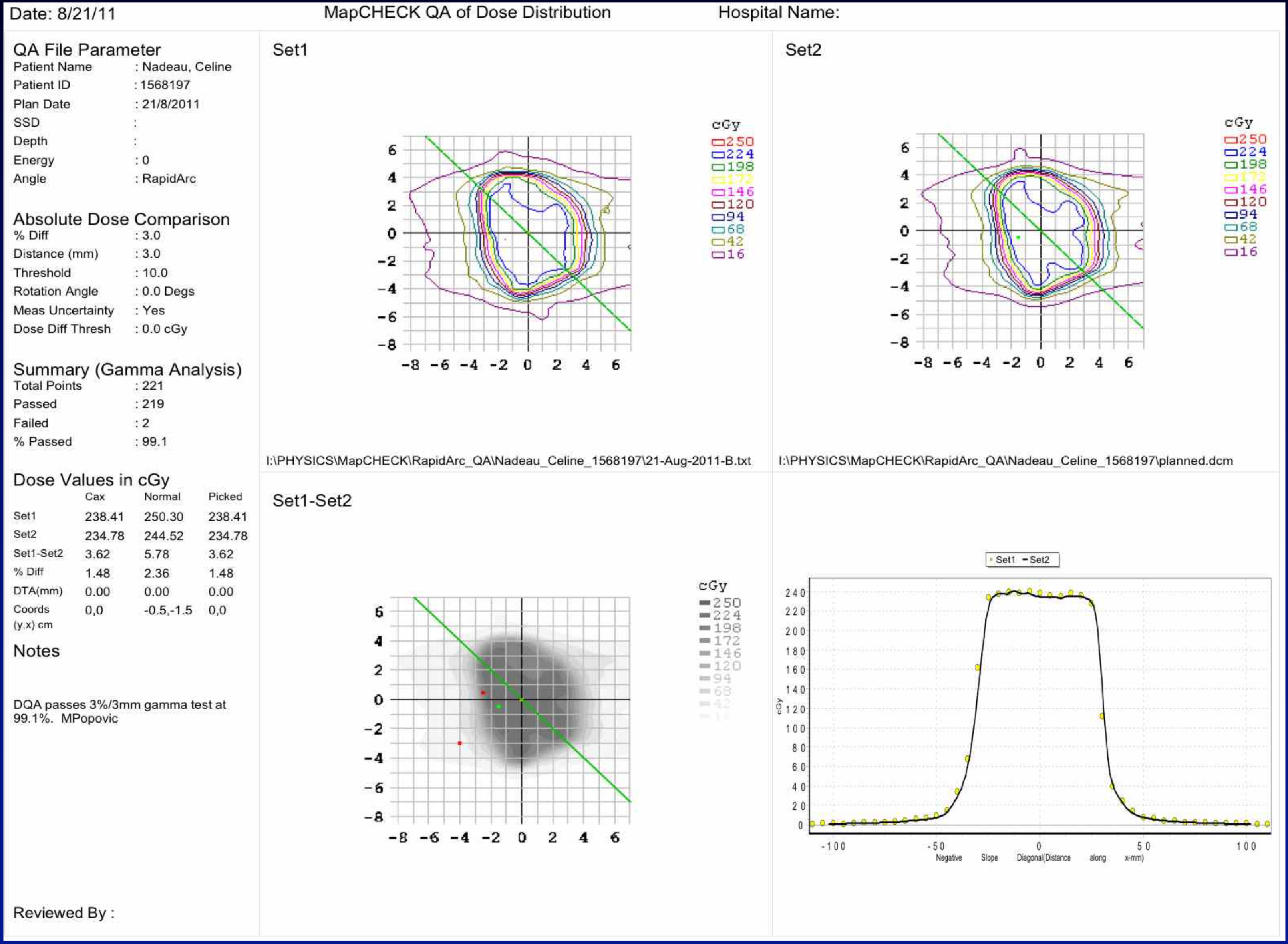
Control de calidad específico del paciente


Isodoses (Gy)
75.00
73.50
70.00
66.50
60.00
56.00
50.00
40.00
35.00
20.00
15.00
Standard


Isodoses (Gy)
2.14
2.10
2.00
1.90
1.71
1.60
1.43
1.00
0.86
0.57
0.43
No heterogeneity correction
Standard



Control de calidad específico del paciente



Date: 8/21/11 MapCHECK QA of Dose Distribution Hospital Name:

QA File Parameter

Patient Name	: Nadeau, Celine
Patient ID	: 1568197
Plan Date	: 21/8/2011
SSD	:
Depth	:
Energy	: 0
Angle	: RapidArc

Absolute Dose Comparison

% Diff	: 3.0
Distance (mm)	: 3.0
Threshold	: 10.0
Rotation Angle	: 0.0 Degs
Meas Uncertainty	: Yes
Dose Diff Thresh	: 0.0 cGy

Summary (Gamma Analysis)

Total Points	: 221
Passed	: 219
Failed	: 2
% Passed	: 99.1

Dose Values in cGy

	Cax	Normal	Picked
Set1	238.41	250.30	238.41
Set2	234.78	244.52	234.78
Set1-Set2	3.62	5.78	3.62
% Diff	1.48	2.36	1.48
DTA(mm)	0.00	0.00	0.00
Coords (y,x) cm	0,0	-0.5,-1.5	0,0

Notes

DQA passes 3%/3mm gamma test at 99.1%. MPopovic

Reviewed By :

Set1

I:\PHYSICS\MapCHECK\RapidArc_QA\Nadeau_Celine_1568197\21-Aug-2011-B.txt

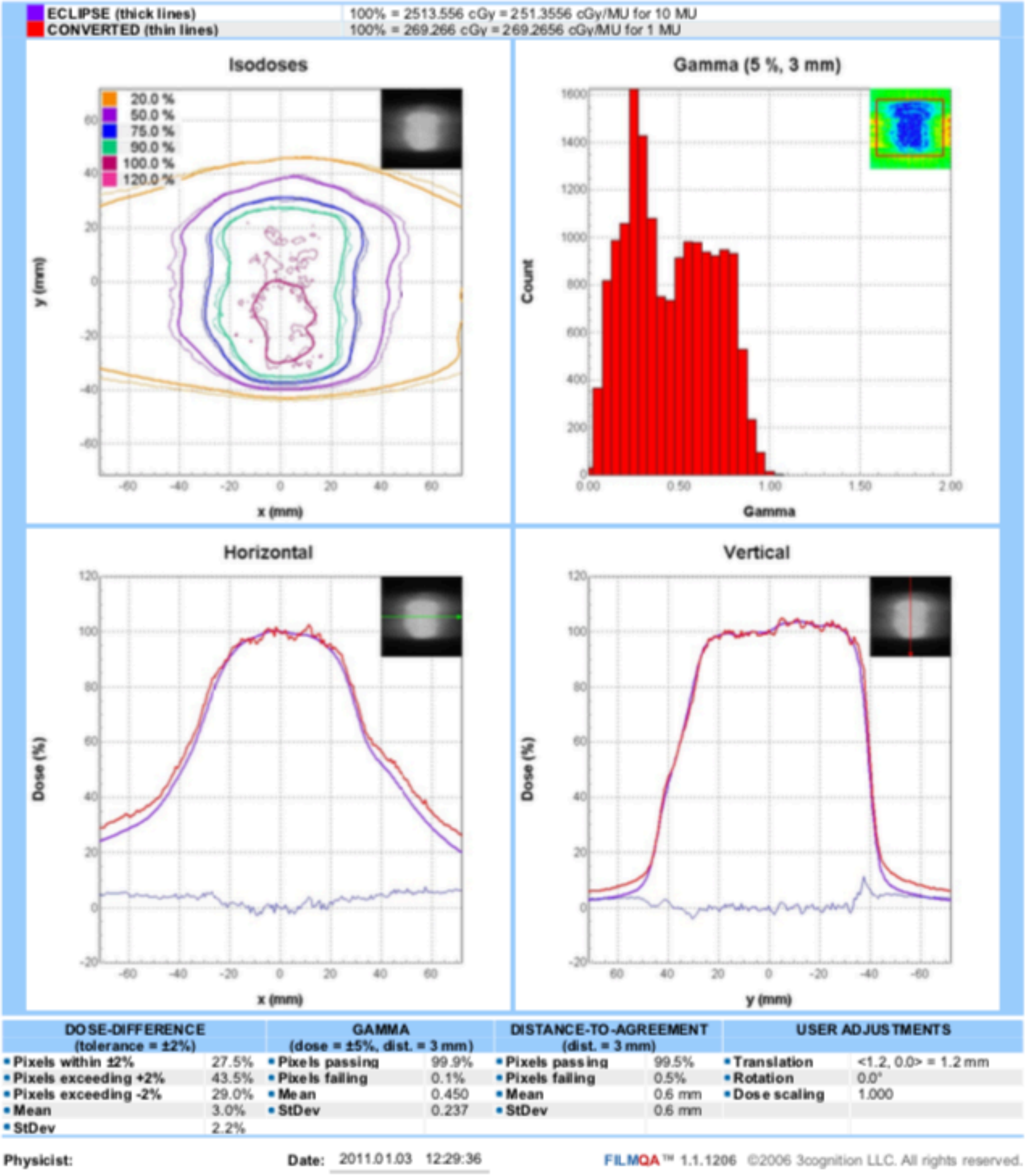
Set2

I:\PHYSICS\MapCHECK\RapidArc_QA\Nadeau_Celine_1568197\planned.dcm

Set1-Set2

cGy
250
224
198
172
146
120
94
68
42
16
6
4
2
0
-2
-4
-6
-8
-8 -6 -4 -2 0 2 4 6
Set1 Set2
240
220
200
180
160
140
120
100
80
60
40
20
0
cGy
-100
-50
0
50
100
Negative Slope Diagonal(Distance along x-mm)

Control de calidad específico del paciente - pelicula



🟪 **ECLIPSE (thick lines)** 100% = 2513.556 cGy = 251.3556 cGy/MU for 10 MU

🟥 **CONVERTED (thin lines)** 100% = 269.266 cGy = 269.2656 cGy/MU for 1 MU

Isodoses
20.0 %
50.0 %
75.0 %
90.0 %
100.0 %
120.0 %
y (mm)
x (mm)
60
40
20
0
-20
-40
-60
Gamma (5 %, 3 mm)
Count
Gamma
1600
1400
1200
1000
800
600
400
200
0
0.00
0.50
1.00
1.50
2.00
Horizontal
Dose (%)
x (mm)
120
100
80
60
40
20
0
-20
Vertical
Dose (%)
y (mm)

DOSE-DIFFERENCE (tolerance = ±2%)		GAMMA (dose = ±5%, dist. = 3 mm)		DISTANCE-TO-AGREEMENT (dist. = 3 mm)		USER ADJUSTMENTS	
• **Pixels within ±2%**	27.5%	• **Pixels passing**	99.9%	• **Pixels passing**	99.5%	• **Translation**	<1.2, 0.0> = 1.2 mm
• **Pixels exceeding +2%**	43.5%	• **Pixels failing**	0.1%	• **Pixels failing**	0.5%	• **Rotation**	0.0°
• **Pixels exceeding -2%**	29.0%	• **Mean**	0.450	• **Mean**	0.6 mm	• **Dose scaling**	1.000
• **Mean**	3.0%	• **StDev**	0.237	• **StDev**	0.6 mm		
• **StDev**	2.2%						

Physicist: **Date:** 2011.01.03 12:29:36

FILMQA ™ 1.1.1206 ©2006 3cognition LLC. All rights reserved.

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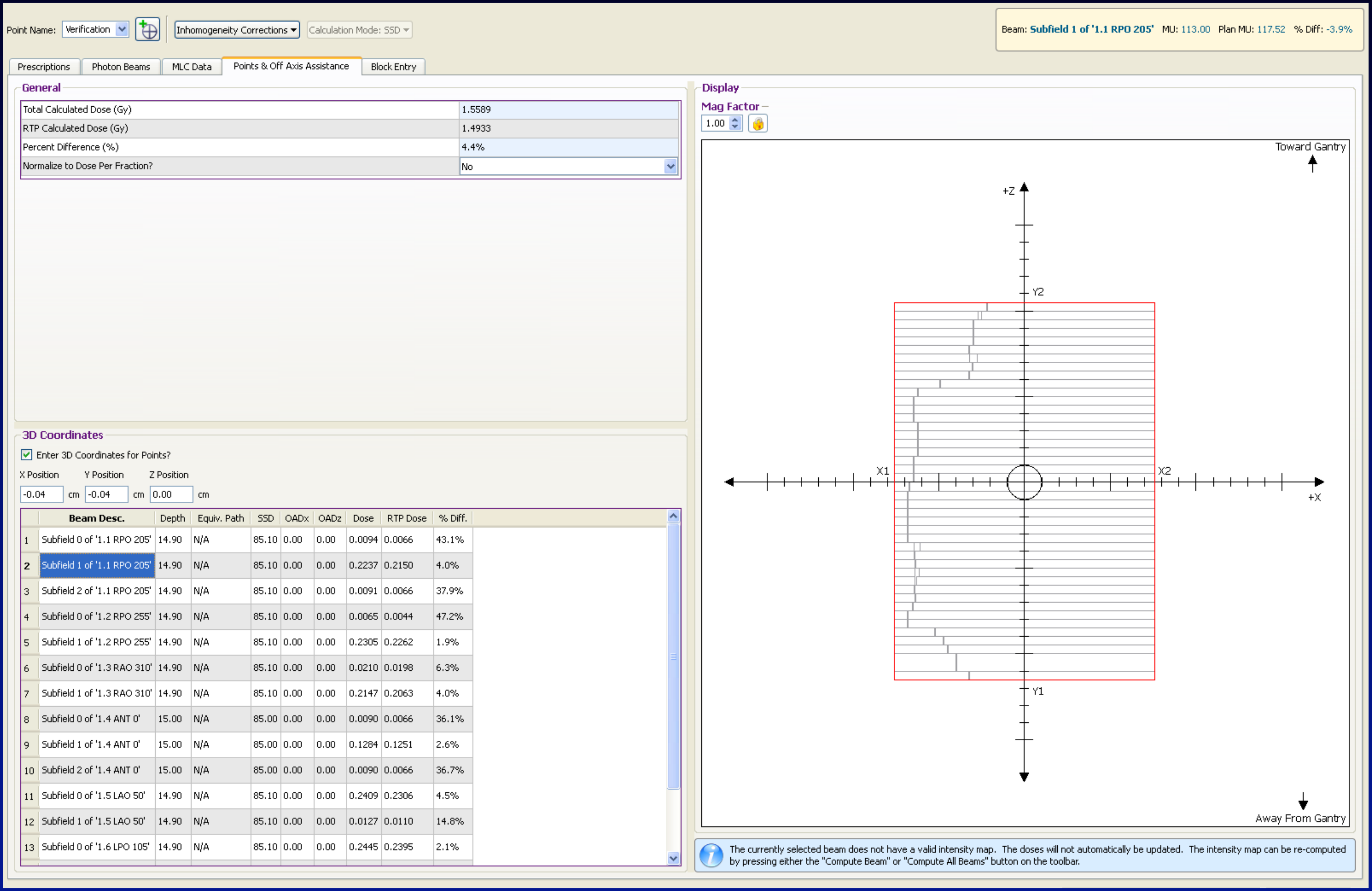
MU checker


Inhomogeneity Corrections
Calculation Mode: SSD
Prescriptions
Photon Beams
MLC Data
Points & Off Axis Assistance
Block Entry
Display
Mag Factor
Toward Gantry
+Z
Y2
X1
X2
+X
Y1
Away From Gantry

Point Name: Verification

Beam: **Subfield 1 of '1.1 RPO 205'** MU: 113.00 Plan MU: 117.52 % Diff: -3.9%

General

Total Calculated Dose (Gy)	1.5589
RTP Calculated Dose (Gy)	1.4933
Percent Difference (%)	4.4%
Normalize to Dose Per Fraction?	No

Mag Factor: 1.00

3D Coordinates

☑ Enter 3D Coordinates for Points?

X Position -0.04 cm Y Position -0.04 cm Z Position 0.00 cm

	Beam Desc.	Depth	Equiv. Path	SSD	OADx	OADz	Dose	RTP Dose	% Diff.
1	Subfield 0 of '1.1 RPO 205'	14.90	N/A	85.10	0.00	0.00	0.0094	0.0066	43.1%
2	Subfield 1 of '1.1 RPO 205'	14.90	N/A	85.10	0.00	0.00	0.2237	0.2150	4.0%
3	Subfield 2 of '1.1 RPO 205'	14.90	N/A	85.10	0.00	0.00	0.0091	0.0066	37.9%
4	Subfield 0 of '1.2 RPO 255'	14.90	N/A	85.10	0.00	0.00	0.0065	0.0044	47.2%
5	Subfield 1 of '1.2 RPO 255'	14.90	N/A	85.10	0.00	0.00	0.2305	0.2262	1.9%
6	Subfield 0 of '1.3 RAO 310'	14.90	N/A	85.10	0.00	0.00	0.0210	0.0198	6.3%
7	Subfield 1 of '1.3 RAO 310'	14.90	N/A	85.10	0.00	0.00	0.2147	0.2063	4.0%
8	Subfield 0 of '1.4 ANT 0'	15.00	N/A	85.00	0.00	0.00	0.0090	0.0066	36.1%
9	Subfield 1 of '1.4 ANT 0'	15.00	N/A	85.00	0.00	0.00	0.1284	0.1251	2.6%
10	Subfield 2 of '1.4 ANT 0'	15.00	N/A	85.00	0.00	0.00	0.0090	0.0066	36.7%
11	Subfield 0 of '1.5 LAO 50'	14.90	N/A	85.10	0.00	0.00	0.2409	0.2306	4.5%
12	Subfield 1 of '1.5 LAO 50'	14.90	N/A	85.10	0.00	0.00	0.0127	0.0110	14.8%
13	Subfield 0 of '1.6 LPO 105'	14.90	N/A	85.10	0.00	0.00	0.2445	0.2395	2.1%

The currently selected beam does not have a valid intensity map. The doses will not automatically be updated. The intensity map can be re-computed by pressing either the "Compute Beam" or "Compute All Beams" button on the toolbar.

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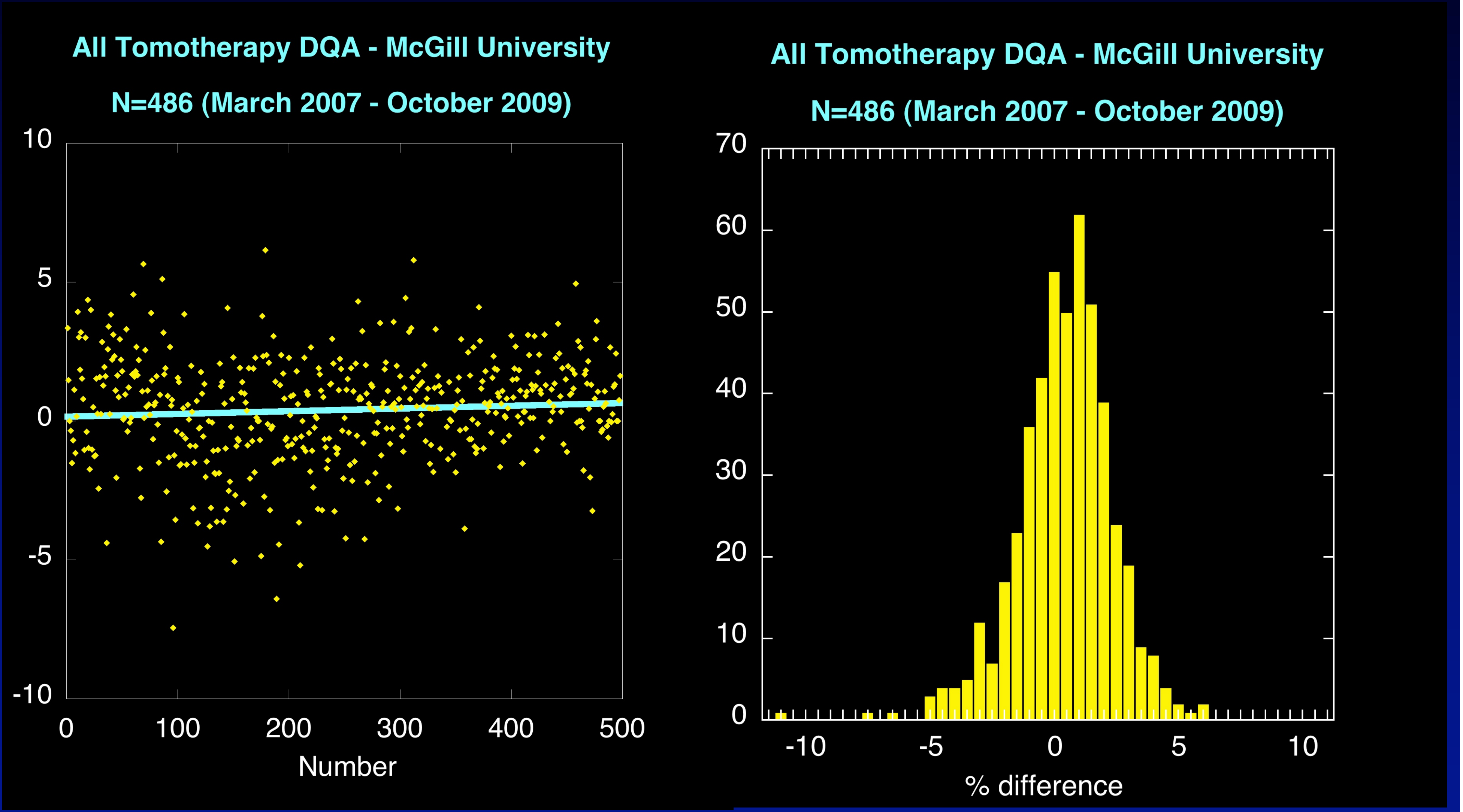
QA results table

YEAR	TPS	#QA	Measured/ calc	% from calc	ST DEV	CI (95%)
2002	CORVUS	41	0.985	-1.488	0.041	9.6
2003	CORVUS	87	0.972	-2.839	0.036	10
2004	CORVUS	125	0.998	-0.174	0.024	4.9
2005	CORVUS	134	1.005	0.457	0.025	5.4
2006	CORVUS	182	0.998	-0.238	0.021	4.4
2007	CORVUS	164	0.984	-1.578	0.019	5.3
2008	CORVUS	223	0.988	-1.239	0.024	6.0
2009	ECLIPSE	25	1.010	1.032	0.014	3.8
2009 (RA)	ECLIPSE	98	1.013	1.341	0.015	4.2
RADCALC	ECLIPSE	205	1.022	2.184	0.012	4.6

Tomotherapy DQA



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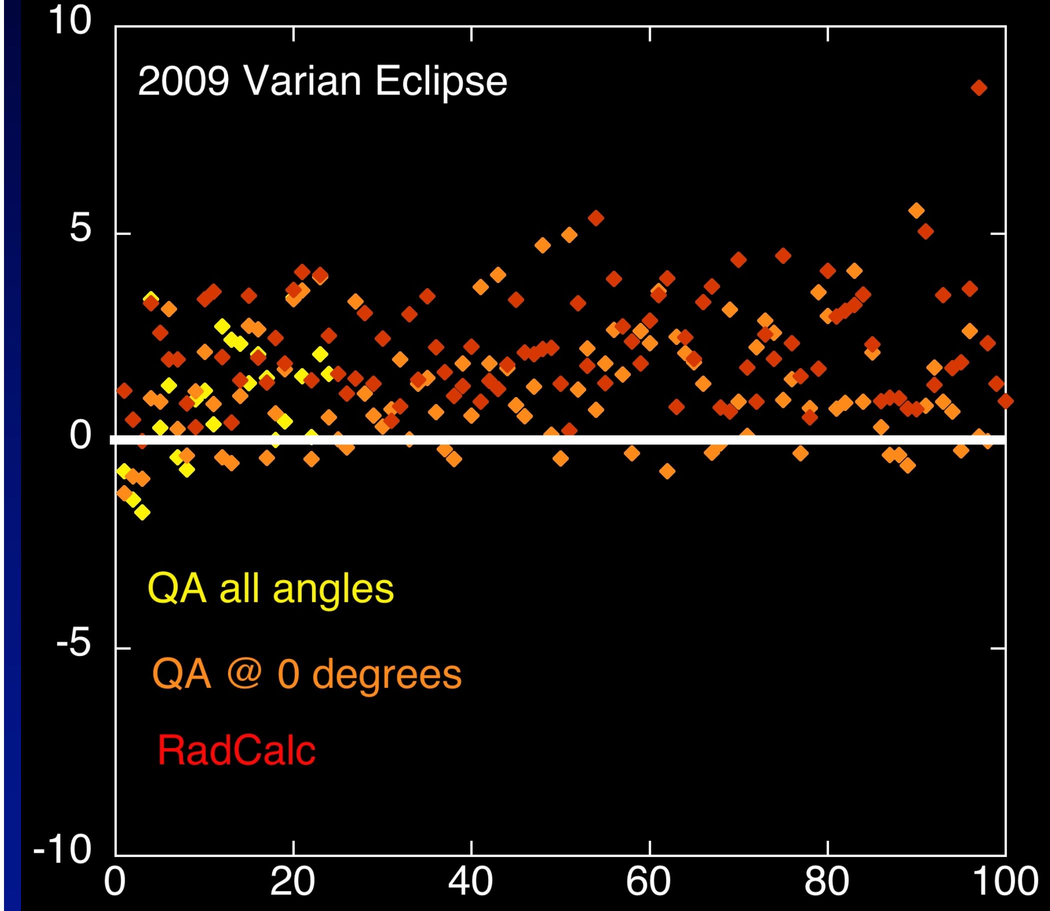
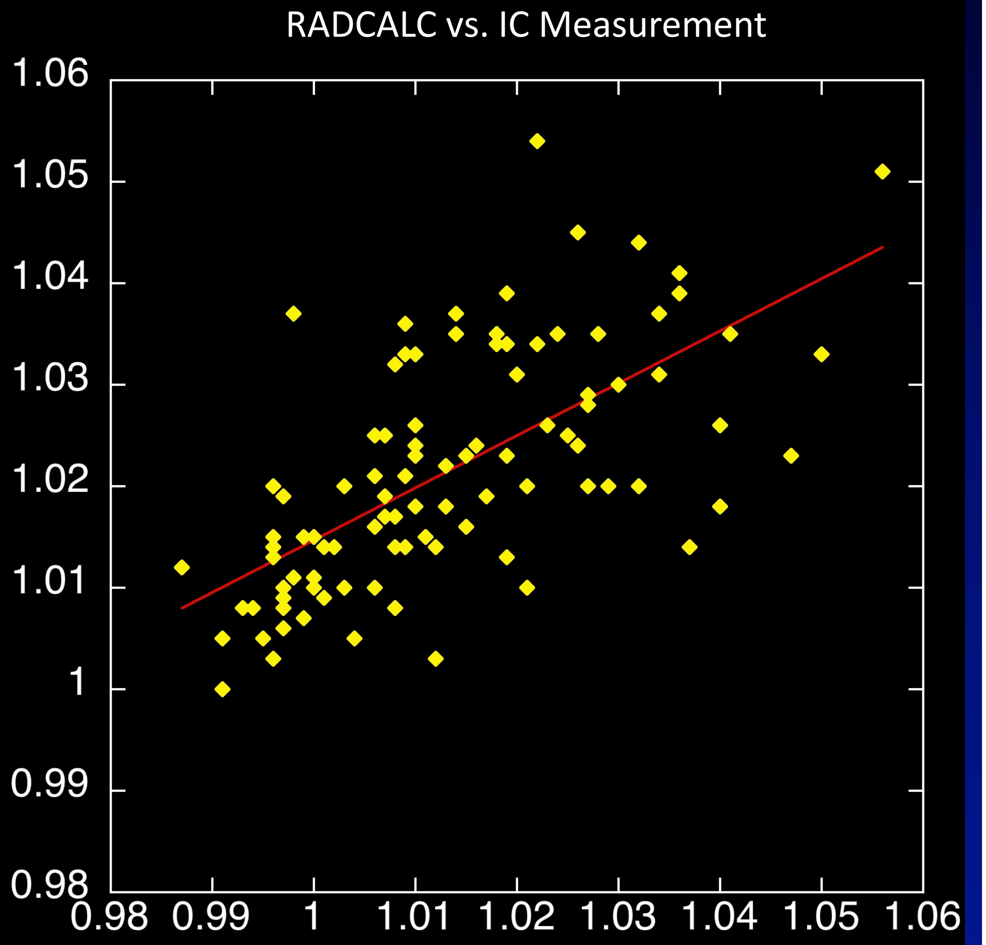
PSQAs – VMAT 2009

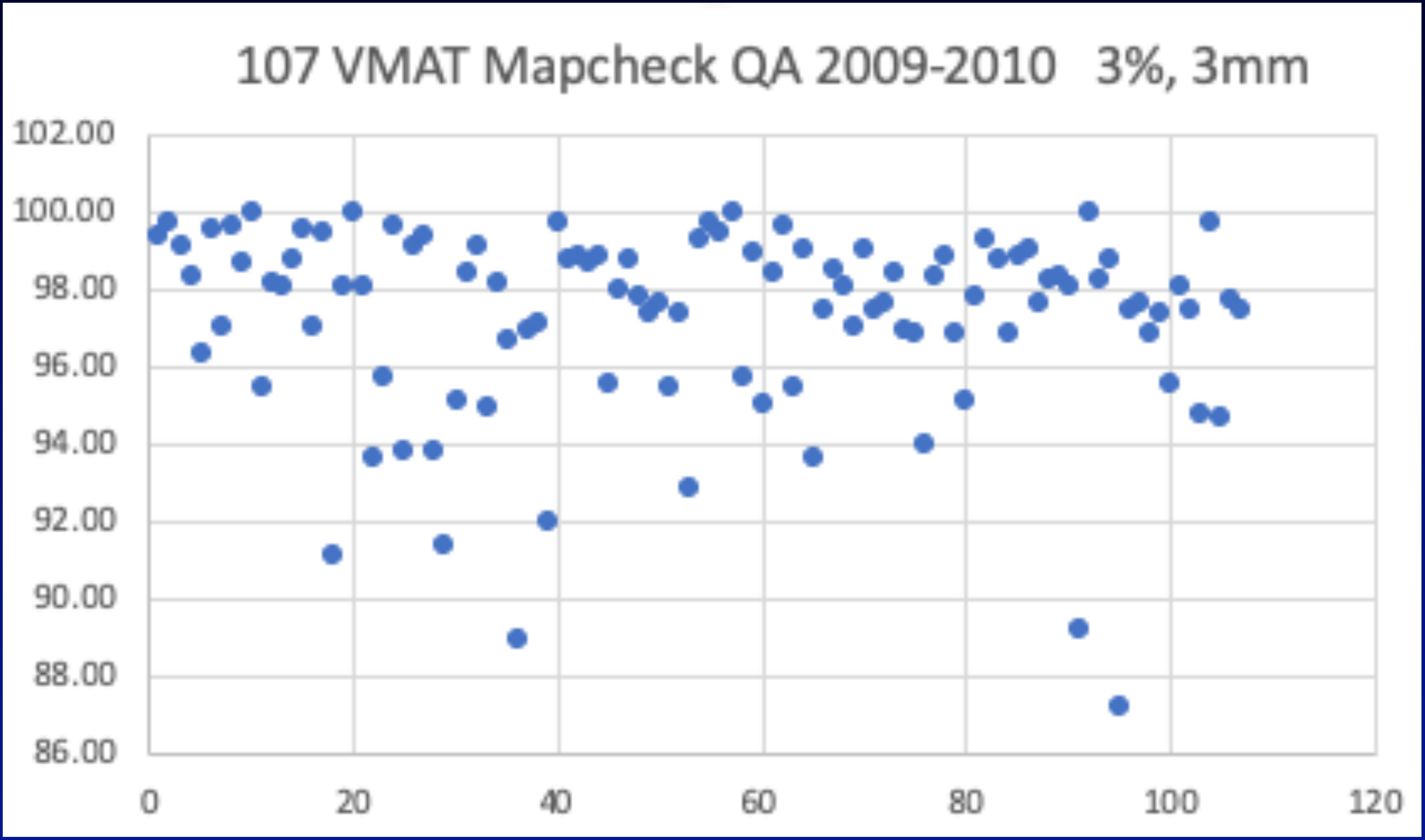



RADCALC vs. IC Measurement

McGill action levels for IMRT QA

QA method	Measurement point	Action level	Action if level exceeded
Software (RadCalc)	High dose point	±5%	Perform IC/film mapcheck
Ion chamber	High dose point	±5%	Redo QA
Film/mapcheck	High isodose lines	3 mm DTA	Redo QA
filmFilm/mapcheck	Isodose distribution	90% pixels pass 5%,3mm	Investigate/rationalize
Audit of point measurements	High dose point	90% of points ±3% per year	Investigate/rationalize

PSQAs – VMAT 2009



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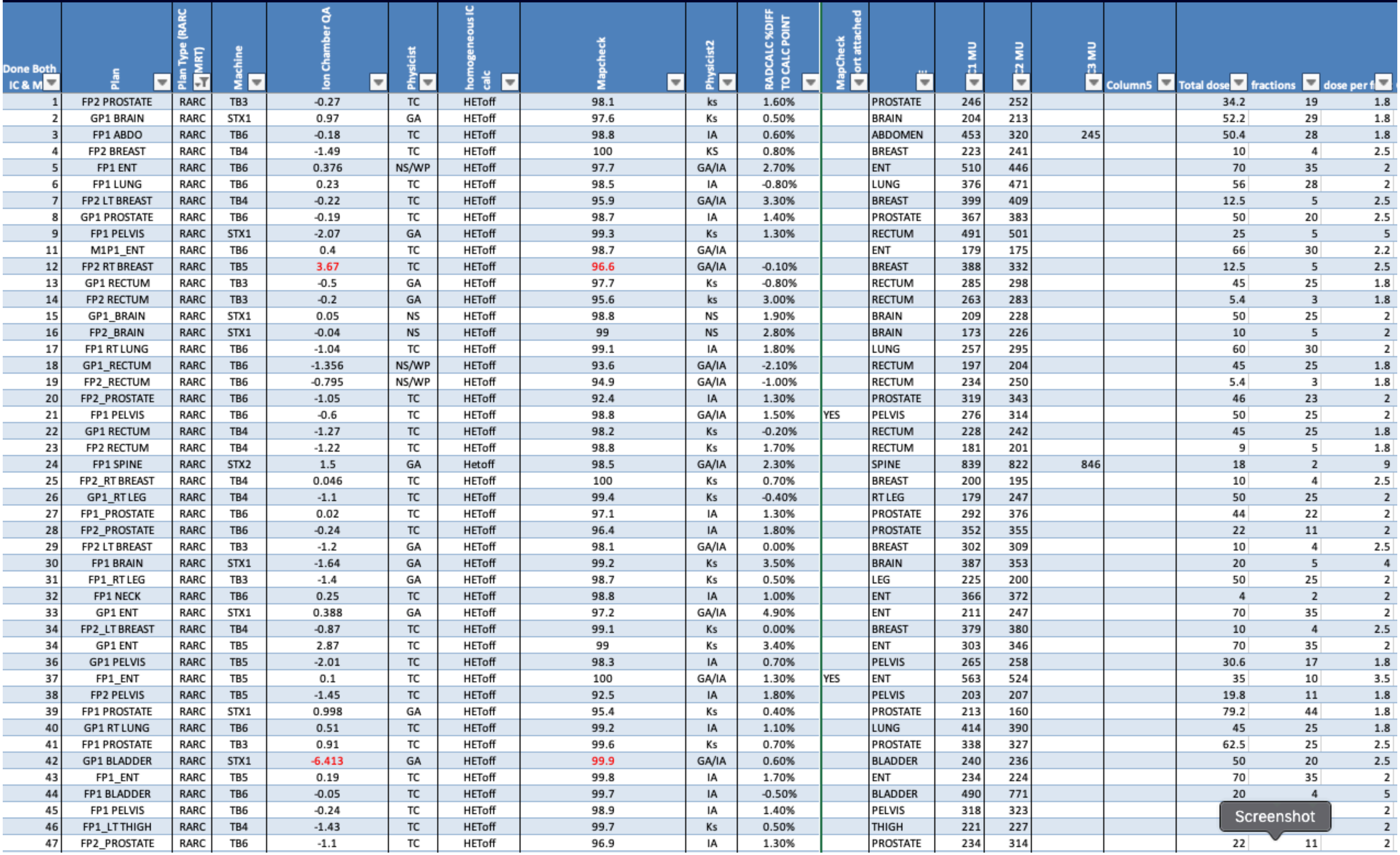
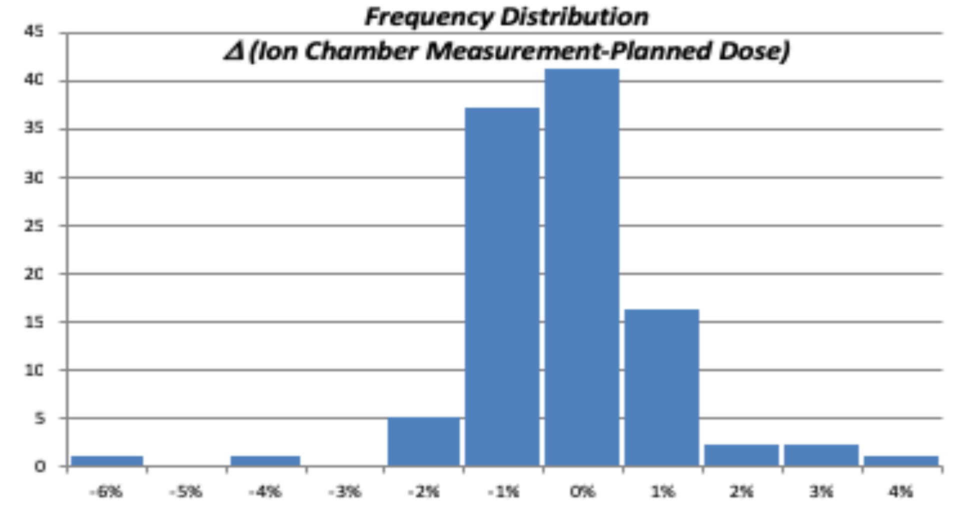
VMAT Puesta en marcha 2015

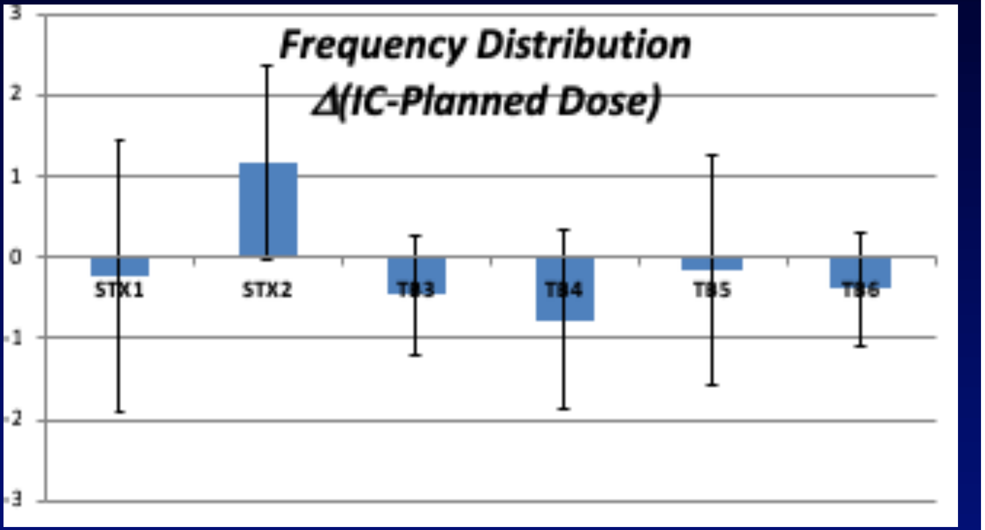


Done Both IC & M	Plan	Plan Type (RARC MRT)	Machine	Ion Chamber QA	Physicist	homogeneous IC calc	Mapcheck	Physicist2	RADCALC %DIFF TO CALC POINT	MapCheck ort attached	:	1 MU	2 MU	3 MU	Column5	Total dose	fractions	dose per f
1	FP2 PROSTATE	RARC	TB3	-0.27	TC	HEToff	98.1	ks	1.60%		PROSTATE	246	252			34.2	19	1.8
2	GP1 BRAIN	RARC	STX1	0.97	GA	HEToff	97.6	Ks	0.50%		BRAIN	204	213			52.2	29	1.8
3	FP1 ABDO	RARC	TB6	-0.18	TC	HEToff	98.8	IA	0.60%		ABDOMEN	453	320	245		50.4	28	1.8
4	FP2 BREAST	RARC	TB4	-1.49	TC	HEToff	100	KS	0.80%		BREAST	223	241			10	4	2.5
5	FP1 ENT	RARC	TB6	0.376	NS/WP	HEToff	97.7	GA/IA	2.70%		ENT	510	446			70	35	2
6	FP1 LUNG	RARC	TB6	0.23	TC	HEToff	98.5	IA	-0.80%		LUNG	376	471			56	28	2
7	FP2 LT BREAST	RARC	TB4	-0.22	TC	HEToff	95.9	GA/IA	3.30%		BREAST	399	409			12.5	5	2.5
8	GP1 PROSTATE	RARC	TB6	-0.19	TC	HEToff	98.7	IA	1.40%		PROSTATE	367	383			50	20	2.5
9	FP1 PELVIS	RARC	STX1	-2.07	GA	HEToff	99.3	Ks	1.30%		RECTUM	491	501			25	5	5
11	M1P1_ENT	RARC	TB6	0.4	TC	HEToff	98.7	GA/IA			ENT	179	175			66	30	2.2
12	FP2 RT BREAST	RARC	TB5	3.67	TC	HEToff	96.6	GA/IA	-0.10%		BREAST	388	332			12.5	5	2.5
13	GP1 RECTUM	RARC	TB3	-0.5	GA	HEToff	97.7	Ks	-0.80%		RECTUM	285	298			45	25	1.8
14	FP2 RECTUM	RARC	TB3	-0.2	GA	HEToff	95.6	ks	3.00%		RECTUM	263	283			5.4	3	1.8
15	GP1_BRAIN	RARC	STX1	0.05	NS	HEToff	98.8	NS	1.90%		BRAIN	209	228			50	25	2
16	FP2_BRAIN	RARC	STX1	-0.04	NS	HEToff	99	NS	2.80%		BRAIN	173	226			10	5	2
17	FP1 RT LUNG	RARC	TB6	-1.04	TC	HEToff	99.1	IA	1.80%		LUNG	257	295			60	30	2
18	GP1_RECTUM	RARC	TB6	-1.356	NS/WP	HEToff	93.6	GA/IA	-2.10%		RECTUM	197	204			45	25	1.8
19	FP2_RECTUM	RARC	TB6	-0.795	NS/WP	HEToff	94.9	GA/IA	-1.00%		RECTUM	234	250			5.4	3	1.8
20	FP2_PROSTATE	RARC	TB6	-1.05	TC	HEToff	92.4	IA	1.30%		PROSTATE	319	343			46	23	2
21	FP1 PELVIS	RARC	TB6	-0.6	TC	HEToff	98.8	GA/IA	1.50%	YES	PELVIS	276	314			50	25	2
22	GP1 RECTUM	RARC	TB4	-1.27	TC	HEToff	98.2	Ks	-0.20%		RECTUM	228	242			45	25	1.8
23	FP2 RECTUM	RARC	TB4	-1.22	TC	HEToff	98.8	Ks	1.70%		RECTUM	181	201			9	5	1.8
24	FP1 SPINE	RARC	STX2	1.5	GA	Hetoff	98.5	GA/IA	2.30%		SPINE	839	822	846		18	2	9
25	FP2_RT BREAST	RARC	TB4	0.046	TC	HEToff	100	Ks	0.70%		BREAST	200	195			10	4	2.5
26	GP1_RT LEG	RARC	TB4	-1.1	TC	HEToff	99.4	Ks	-0.40%		RT LEG	179	247			50	25	2
27	FP1_PROSTATE	RARC	TB6	0.02	TC	HEToff	97.1	IA	1.30%		PROSTATE	292	376			44	22	2
28	FP2_PROSTATE	RARC	TB6	-0.24	TC	HEToff	96.4	IA	1.80%		PROSTATE	352	355			22	11	2
29	FP2 LT BREAST	RARC	TB3	-1.2	GA	HEToff	98.1	GA/IA	0.00%		BREAST	302	309			10	4	2.5
30	FP1 BRAIN	RARC	STX1	-1.64	GA	HEToff	99.2	Ks	3.50%		BRAIN	387	353			20	5	4
31	FP1_RT LEG	RARC	TB3	-1.4	GA	HEToff	98.7	Ks	0.50%		LEG	225	200			50	25	2
32	FP1 NECK	RARC	TB6	0.25	TC	HEToff	98.8	IA	1.00%		ENT	366	372			4	2	2
33	GP1 ENT	RARC	STX1	0.388	GA	HEToff	97.2	GA/IA	4.90%		ENT	211	247			70	35	2
34	FP2_LT BREAST	RARC	TB4	-0.87	TC	HEToff	99.1	Ks	0.00%		BREAST	379	380			10	4	2.5
34	GP1 ENT	RARC	TB5	2.87	TC	HEToff	99	Ks	3.40%		ENT	303	346			70	35	2
36	GP1 PELVIS	RARC	TB5	-2.01	TC	HEToff	98.3	IA	0.70%		PELVIS	265	258			30.6	17	1.8
37	FP1_ENT	RARC	TB5	0.1	TC	HEToff	100	GA/IA	1.30%	YES	ENT	563	524			35	10	3.5
38	FP2 PELVIS	RARC	TB5	-1.45	TC	HEToff	92.5	IA	1.80%		PELVIS	203	207			19.8	11	1.8
39	FP1 PROSTATE	RARC	STX1	0.998	GA	HEToff	95.4	Ks	0.40%		PROSTATE	213	160			79.2	44	1.8
40	GP1 RT LUNG	RARC	TB6	0.51	TC	HEToff	99.2	IA	1.10%		LUNG	414	390			45	25	1.8
41	FP1 PROSTATE	RARC	TB3	0.91	TC	HEToff	99.6	Ks	0.70%		PROSTATE	338	327			62.5	25	2.5
42	GP1 BLADDER	RARC	STX1	-6.413	GA	HEToff	99.9	GA/IA	0.60%		BLADDER	240	236			50	20	2.5
43	FP1_ENT	RARC	TB5	0.19	TC	HEToff	99.8	IA	1.70%		ENT	234	224			70	35	2
44	FP1 BLADDER	RARC	TB6	-0.05	TC	HEToff	99.7	IA	-0.50%		BLADDER	490	771			20	4	5
45	FP1 PELVIS	RARC	TB6	-0.24	TC	HEToff	98.9	IA	1.40%		PELVIS	318	323			[illegible]	[illegible]	2
46	FP1_LT THIGH	RARC	TB4	-1.43	TC	HEToff	99.7	Ks	0.50%		THIGH	221	227			[illegible]	[illegible]	2
47	FP2_PROSTATE	RARC	TB6	-1.1	TC	HEToff	96.9	IA	1.30%		PROSTATE	234	314			22	11	2

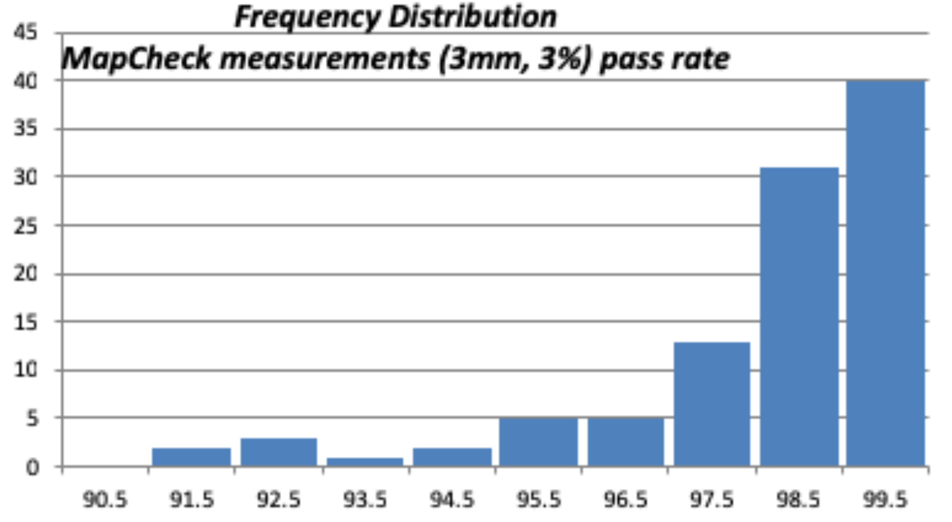
VMAT Puesta en marcha 100 PSQA



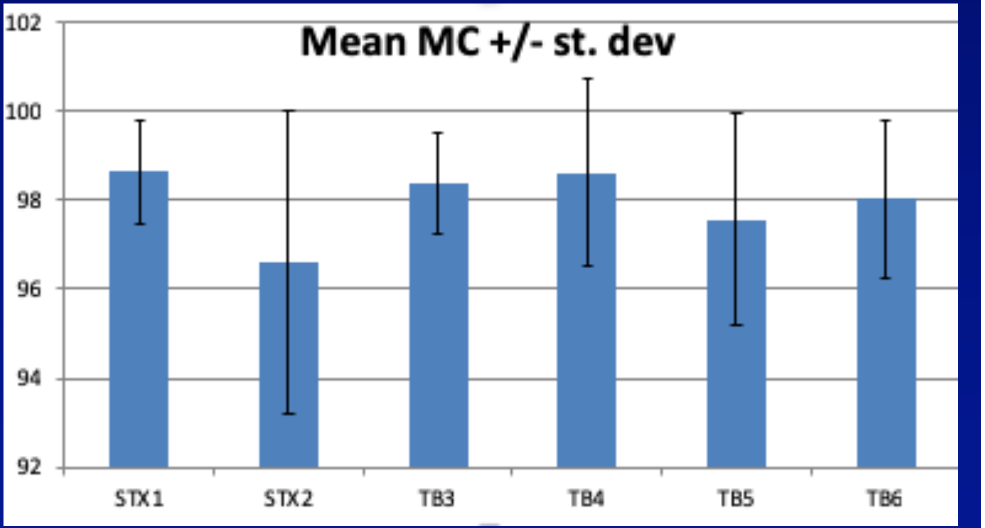
Frequency Distribution
Δ (Ion Chamber Measurement-Planned Dose)



Frequency Distribution
Δ(IC-Planned Dose)

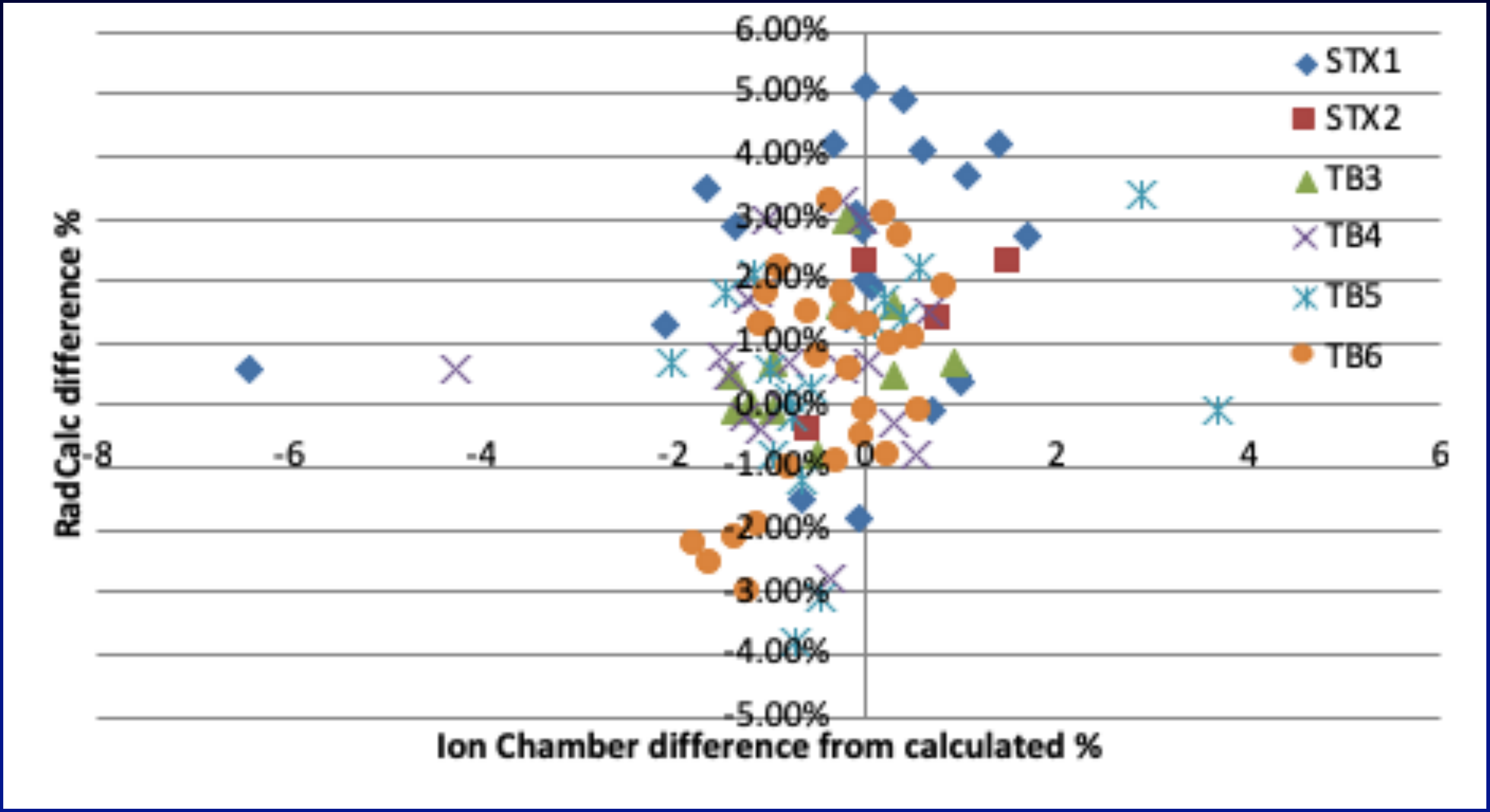


Frequency Distribution
MapCheck measurements (3mm, 3%) pass rate



Mean MC +/- st. dev

Verificando el verificador MU!



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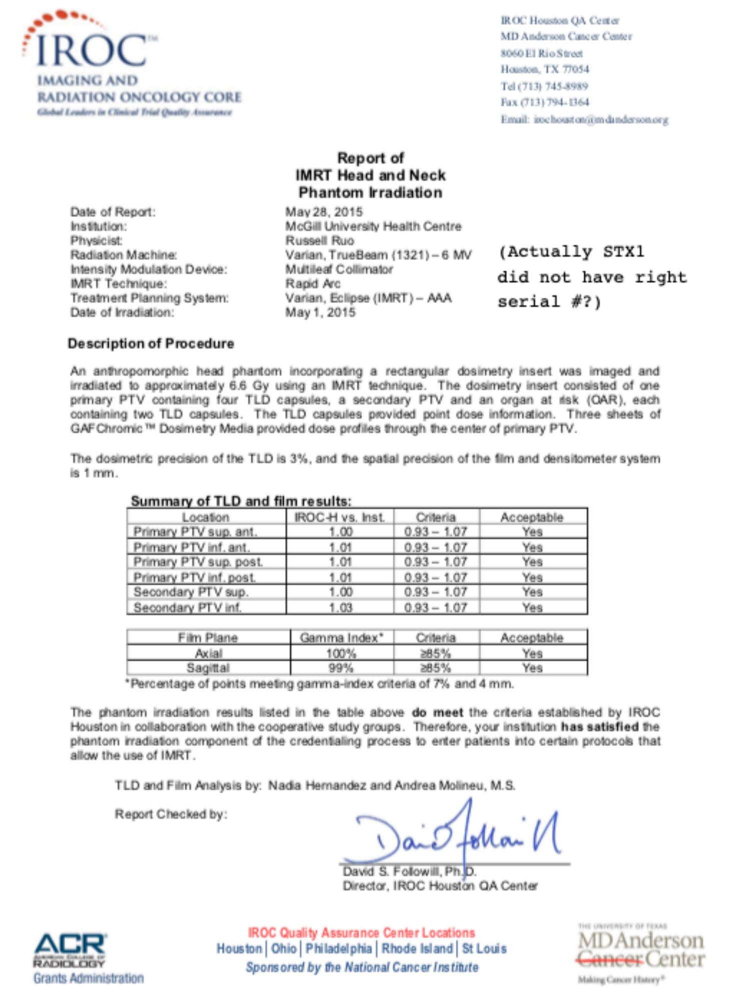

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Report of
IMRT Head and Neck
Phantom Irradiation

Date of Report:	May 28, 2015
Institution:	McGill University Health Centre
Physicist:	Russell Ruo
Radiation Machine:	Varian, TrueBeam (1321) – 6 MV
Intensity Modulation Device:	Multileaf Collimator
IMRT Technique:	Rapid Arc
Treatment Planning System:	Varian, Eclipse (IMRT) – AAA
Date of Irradiation:	May 1, 2015

(Actually STX1
did not have right
serial #?)

Description of Procedure

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

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

Summary of TLD and film results:

Location	IROC-H vs. Inst.	Criteria	Acceptable
Primary PTV sup. ant.	1.00	0.93 – 1.07	Yes
Primary PTV inf. ant.	1.01	0.93 – 1.07	Yes
Primary PTV sup. post.	1.01	0.93 – 1.07	Yes
Primary PTV inf. post.	1.01	0.93 – 1.07	Yes
Secondary PTV sup.	1.00	0.93 – 1.07	Yes
Secondary PTV inf.	1.03	0.93 – 1.07	Yes

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

*Percentage of points meeting gamma-index criteria of 7% and 4 mm.

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

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

Report Checked by:

David S. Followill, Ph.D.
Director, IROC Houston QA Center

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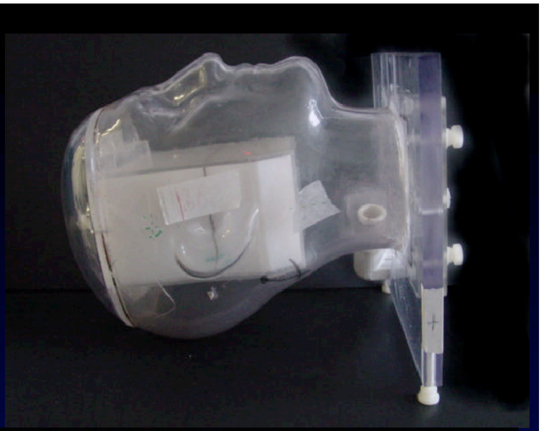
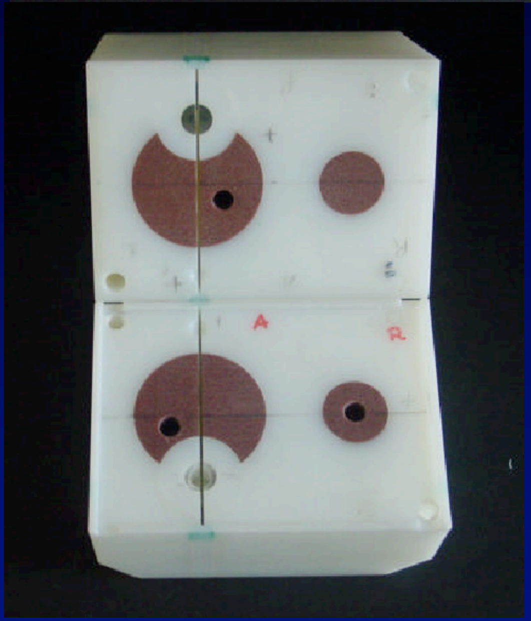
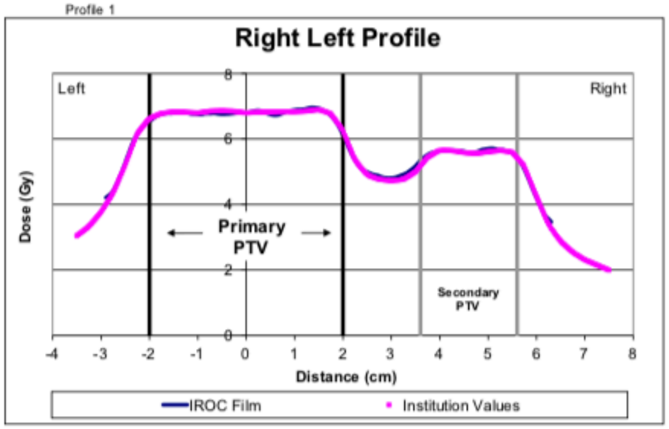
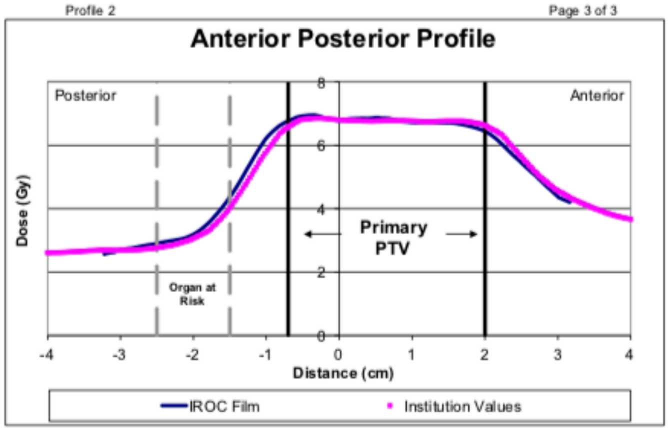
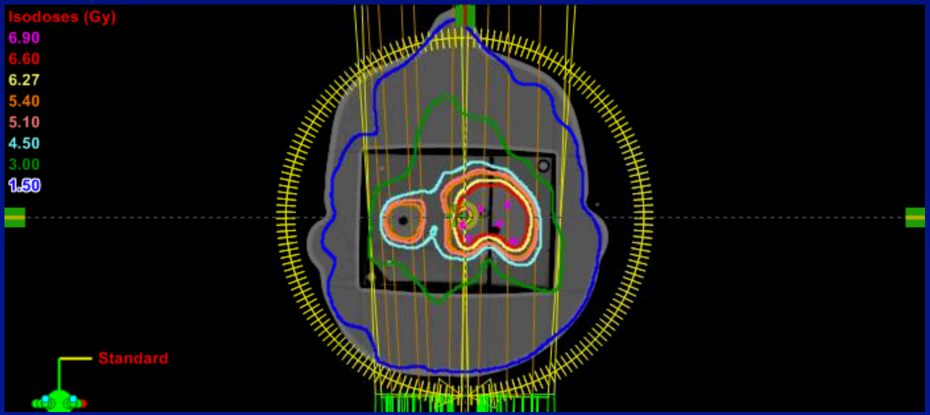
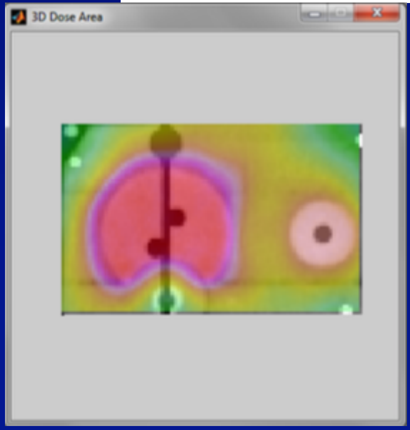


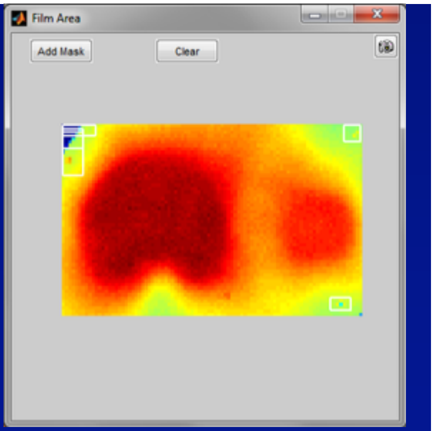








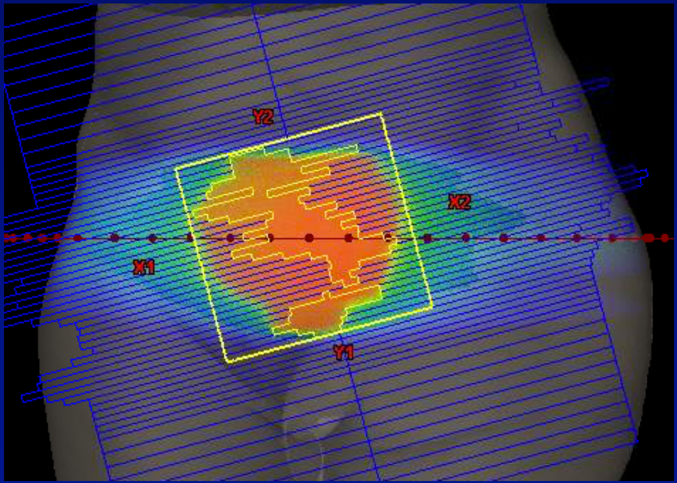


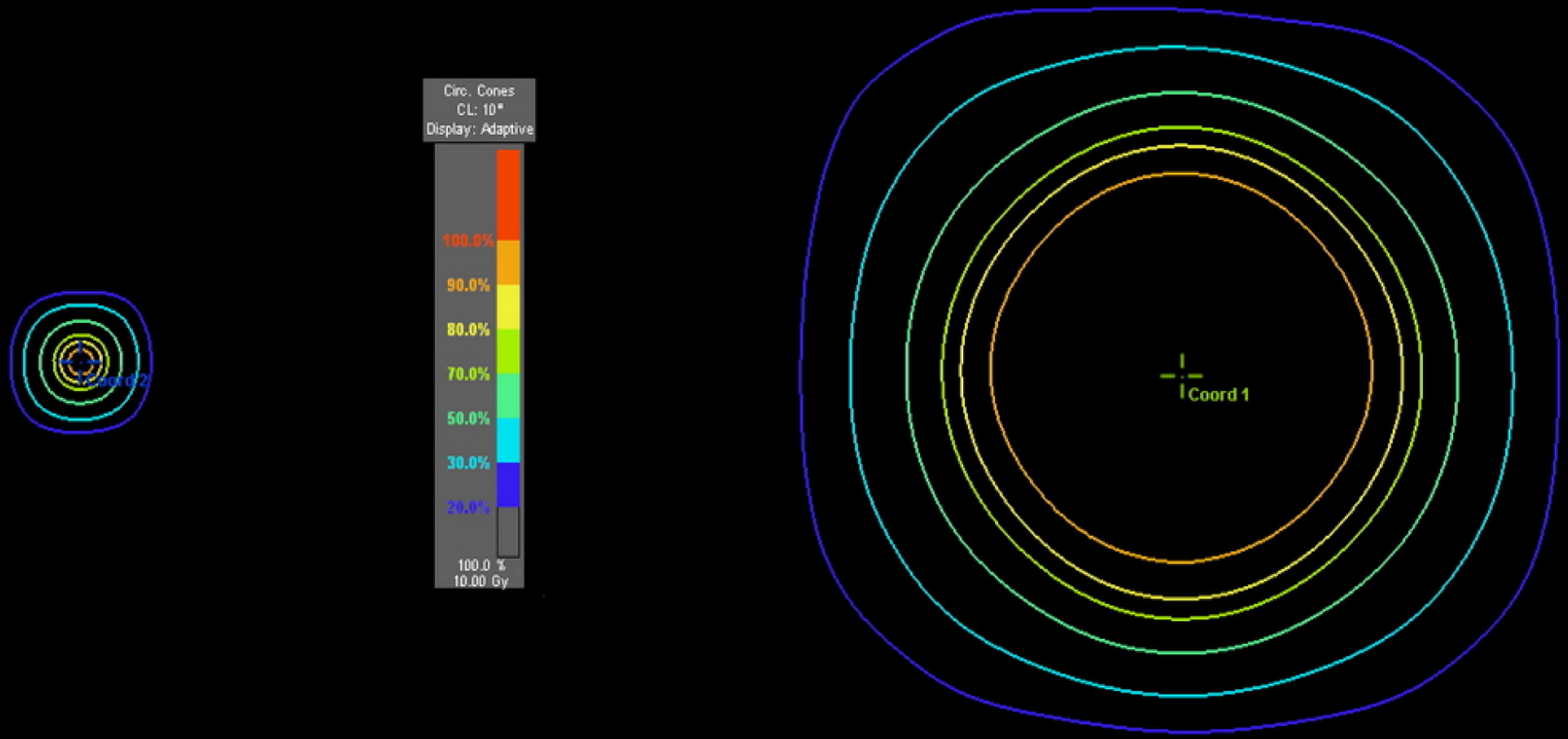


McGill

Conclusiones
VMAT

- tratamiento rápido
- distribución conforme
- puede beneficiar al 90% de los pacientes
- “workflow” único para tecnólogos





Cone 4 mm

Cone 40 mm

80 – 50% : 2 mm
80 – 20% : 5 mm

80 – 50% : 6 mm
80 – 20% : 16 mm