Innovaciones en Braquiterapia

Jose Perez-Calatayud

Hospital Universitario y Politecnico La Fe. Valencia.

Clinica Benidorm. Benidorm. Alicante

perez_jos@gva.es

Reunión Sociedad Andaluza de Radiofísica Hospitalaria.
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Declaración intereses

Hospital La Fe & Universidad Valencia & Clínica Benidorm

Dosimetria MC fuentes Ir-192 y Co-60	*BEBIG*
Dosimetría HDR y eBT	*PTW*
Medidas QA semillas	*PTW*
Dosimetría MC fuentes Ir-192 y Co-60	*Nucletron-Elekta*
Desarrollo dummies MR	*Nucletron-Elekta*
Aplicadores Valencia	*Nucletron-Elekta*
Sistema de Planificación Oncentra	*Nucletron-Elekta*
QA SeedSelectron	*Nucletron-Elekta*
Desarrollo ESTEYA	*Nucletron-Elekta*
Estudio clínico Valencia	*Nucletron-Elekta*
Estudio clínico ESTEYA	*Nucletron-Elekta*
Desarrollo Aplicador Benidorm	*LORCA MARIN*
Calculo EQD2 en Sagiplan	*BEBIG*
Librerias Aplicadores Sagiplan	*BEBIG*

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Agradecimientos

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- V. Carmona
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- M. Santos

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- D. Granero

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- Z. Ouhib

Universidad Valencia
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- J. Vijande

Tufts University
- M. Rivard

CND
- C. Candela

H. Alzira
- T. García

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Contenido

- BT vs RTE.
- Fuentes en BT: LDR, PDR, HDR.
- BT en Próstata.
- BT en Cervix.
- BT en Piel.
- Planificación: Reconstrucción de Aplicadores.
- Planificación: Nuevos Algoritmos.
- QA Sistemas de Planificación
- Calibración en BT.
- Dosimetría "in vivo"
- Nuevas tendencias QM
- Incertidumbres
- Conclusiones

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BT vs RTE

EDITORIAL

Curative Radiation Therapy for Locally Advanced Cervical Cancer: Brachytherapy Is NOT Optional

Kari Tanderup, PhD,*,† Patricia J. Eifel, MD,‡ Catheryn M. Yashar, MD,§ Richard Pötter, MD,‖ and Perry W. Grigsby, MD*

IJROBP 2014

Is single fraction 15 Gy the preferred high dose-rate brachytherapy boost dose for prostate cancer?

Gerard Morton[a,*], Andrew Loblaw[a], Patrick Cheung[a], Ewa Szumacher[a], Manraj Chahal[a], Cyril Danjo[a], Hans T. Chung[a], Andrea Deabreu[a], Alexandre Mamedov[a], Liying Zhang[a], Raxa Sankreacha[a], Eric Vigneault[b], Colvin Springer[c]

RO 2011

Where Have You Gone, Brachytherapy?

Daniel G. Petereit, *Rapid City Regional Cancer Center, Rapid City, SD*
Steven J. Frank, *University of Texas MD Anderson Cancer Center, Houston, TX*
Akila N. Viswanathan, *Brigham and Women's Hospital and Dana-Farber Cancer Institute, Harvard Medical School, Boston, MA*
Beth Erickson, *Medical College of Wisconsin, Milwaukee, WI*
Patricia Eifel, *University of Texas MD Anderson Cancer Center, Houston, TX*
Paul L. Nguyen, *Brigham and Women's Hospital and Dana-Farber Cancer Institute, Harvard Medical School, Boston, MA*
David E. Wazer, *Tufts Medical Center, Tufts University School of Medicine, Boston, MA, and Rhode Island Hospital, The Alpert Medical School of Brown University, Providence, RI*

JCO 2015

National Cancer Data Base Analysis of Radiation Therapy Consolidation Modality for Cervical Cancer: The Impact of New Technological Advancements

Beant S. Gill, MD,* Jeff F. Lin, MD,† Thomas C. Krivak, MD,‡ Paniti Sukumvanich, MD,† Robin A. Laskey, MD,† Malcolm S. Ross, MD,† Jamie L. Lesnock, MD,† and Sushil Beriwal, MD*

IJROBP 2014

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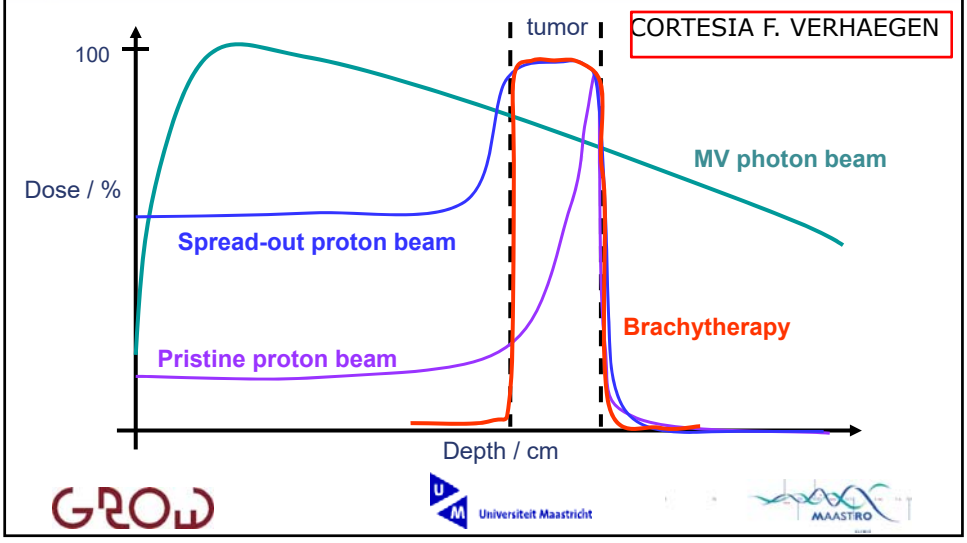
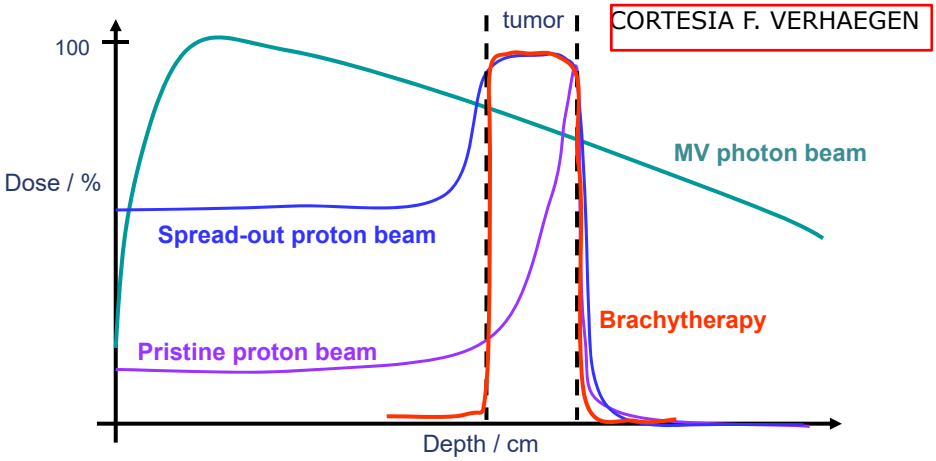
BT vs Protones

Comparison of dose distributions: advantage of brachytherapy



BT vs Protones

Comparison of dose distributions: motion



GROW

Universiteit Maastricht

MAASTRO

BT vs RTE

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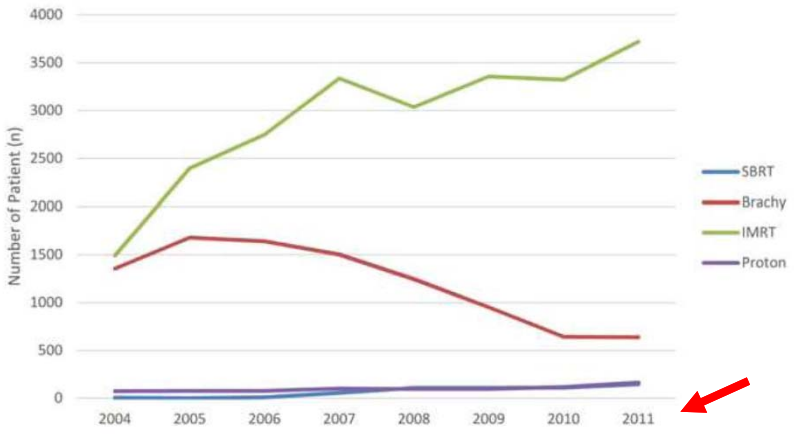
Utilization of Radiation Therapy



CORTESIA R. CHICAS

Halpern, et al. Cancer 2016

☞ BT vs RTE

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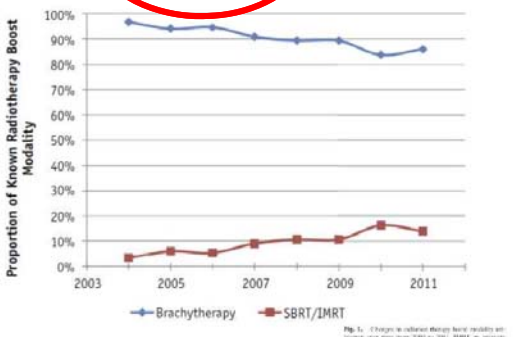
Brachytherapy v. SBRT in Cervical Cancer

- Cervical cancer treatment trends have mimicked trends of prostate cancer treatment
- Many centers with lower treatment volume may be more inclined to pursue alternative boost modalities



Gill et al. Int J Radiation Oncol Biol Phys. 2014.

☞ BT vs RTE

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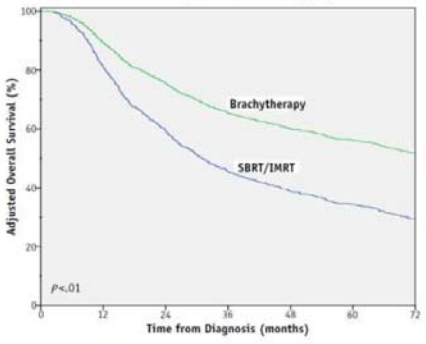
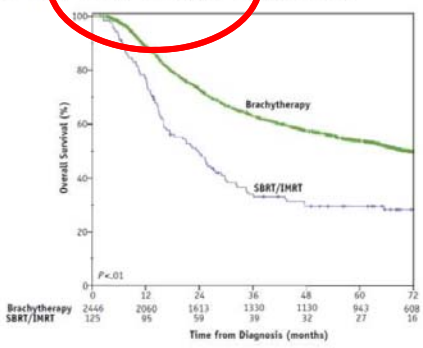
Brachytherapy v. SBRT in Cervical Cancer



Adjusted overall survival estimate, stratified by boost modality and corrected for significant variables on multivariable Cox proportional hazard model



Kaplan-Meier overall survival estimate stratified by boost modality.

Gill et al. Int J Radiation Oncol Biol Phys. 2014.

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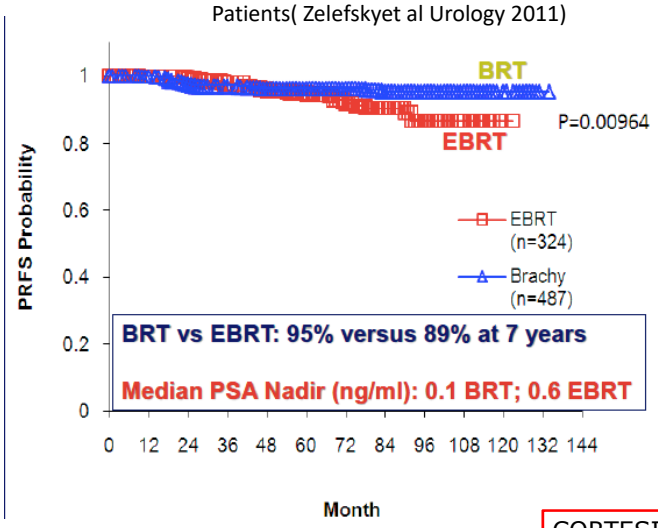
BAJO RIESGO Y BT CON SEMILLAS O HDR VARIAS FX

PSA-Relapse Free Survival Favorable Risk Patients(Zelefskyet al Urology 2011)



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Comparison of Combined Brachy and IMRT vs IMRT Alone

PSA-Relapse Free Survival

INTERMEDIO y ALTO

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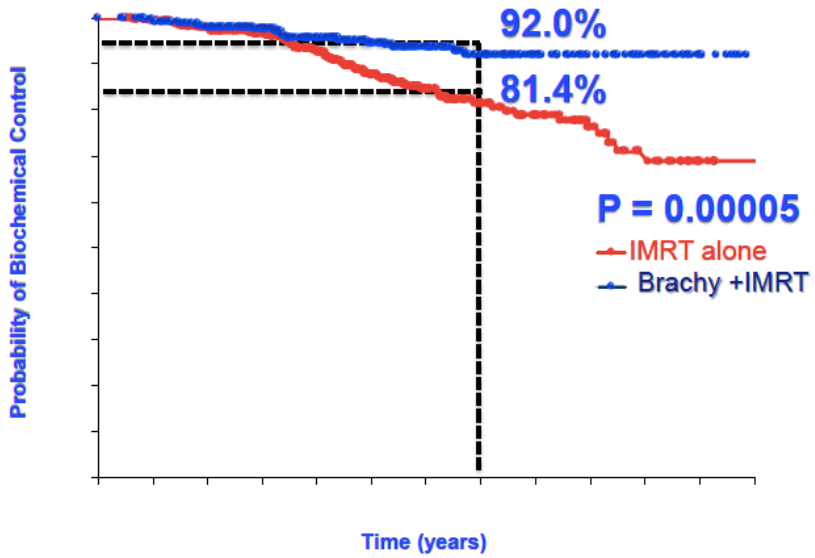

Spratt et al BJU 2014

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Comparison of Combined Brachy and IMRT vs IMRT Alone

Distant Metastasis-Free Survival

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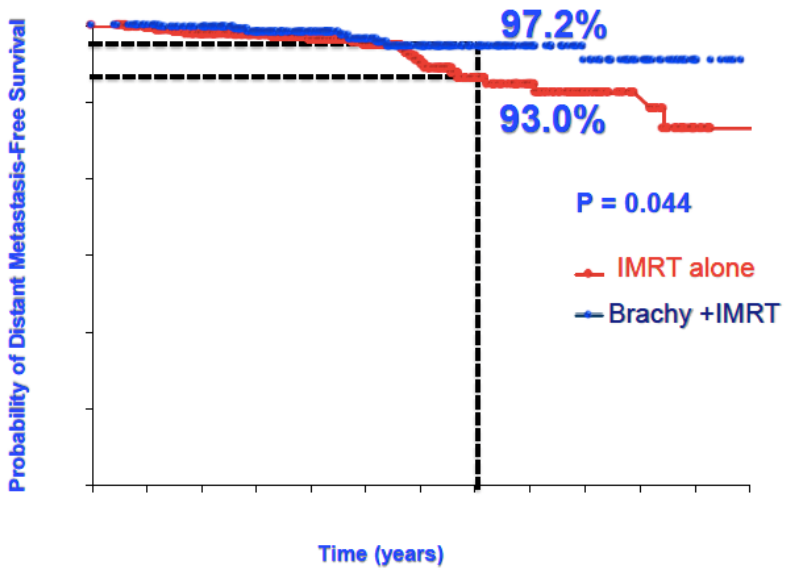

Spratt et al BJU 2014

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Can Modern External Beam Techniques Replace Brachytherapy in Prostate Cancer?

Michael J Zelefsky M.D

Conclusions

- Brachytherapy represents an established treatment with long track record providing superior conformality and dose intensification.
- Especially for unfavorable and high risk disease incorporating BRT with EBRT has been shown to provide superior disease outcomes.
- While it would be attractive to find a replacement for brachytherapy using targeted EBRT approaches, it may deny patients the opportunity of achieving optimal disease control.

BT vs RTE

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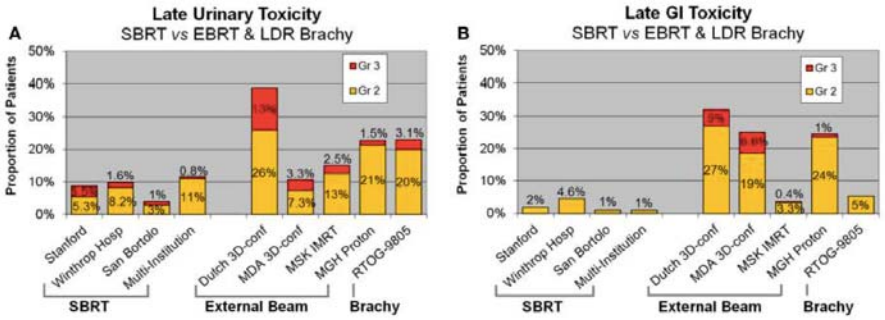
Stereotactic Body Radiation Therapy for Prostate Cancer: An Alternative to Brachytherapy?

Sean P. Collins, M.D., Ph.D.

Prevalence of CTC graded GU and GI Toxicities



Meier R. , Front. Oncol., 2015

SBRT: 7.25 Gy/fx 5 fx seguidas 36,25 Gy

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BT vs RTE

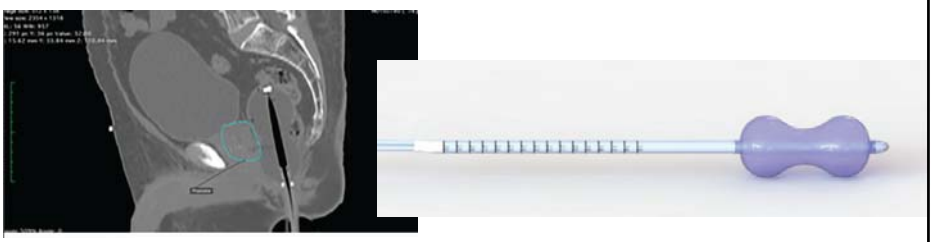
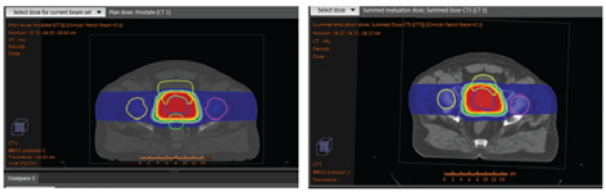


Figure 1 The Edge ERB (Ancer Medical, Hialeah, FL)



Pilot Study of the dose sparing capability and inter-fraction repeatability of a shape optimized endorectal balloon for proton beam prostate cancer treatment

Xuanfeng Ding, Ph.D.,[1] Colin Carpenter, PhD,[2] Hsinshun Wu, Ph.D.,[3] Lane Rosen, M.D.[3]
1. Beaumont Health System, Royal Oak, MI, 48304, 2. Siris Medical, Inc, 3. Willis-Knighton Cancer Center, Shreveport, LA 71103

BT vs RTE

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ASTRO'S 58TH ANNUAL MEETING
ENHANCING VALUE
IMPROVING OUTCOMES

Phase I/II study of urethral and rectal sparing following extreme hypofractionated (5x9Gy) SBRT in prostate cancer

Carlo Greco, Oriol Pares, Nuno Pimentel, Vasco Louro, Joep Stroom, Sandra Viera, Dalila Mateus, Zvi Fuks

Department of Radiation Oncology
Champalimaud Centre for the Unknown (CCU)
Lisbon, Portugal

Champalimaud Foundation

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BT vs RTE

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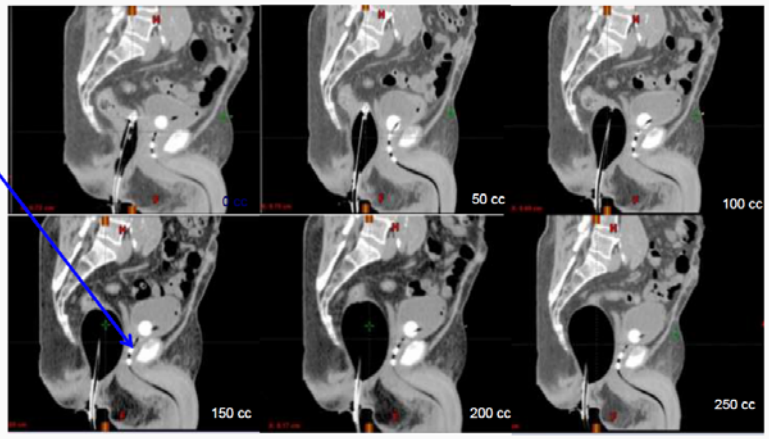
Locking the prostate:
optimal balloon filling to mitigate target motion

Foley catheter with endo-urethral transponders



Greco et al ASTRO 2016

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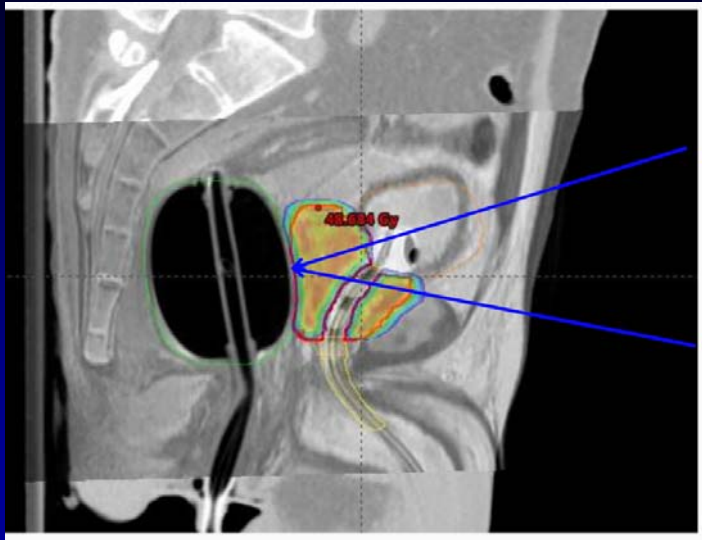

1. Accurate geometric reproducibility.
2. Smearing of rectal wall with rectal mucosa sparing due to air-tissue interface.
3. Rectal mucosa with no blood flow due to pressure: transient profound ischemia.

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Greco et al ASTRO 2016

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BT vs RTE

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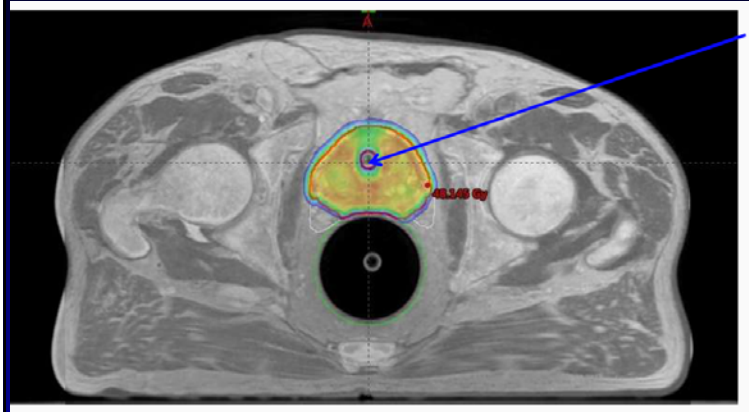

The trigone & intraprostatic urethra are identified by means of a Foley and properly constrained by negative dose-painting. Transponder tracking assures 1 mm geometrical consistency.

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Greco et al ASTRO 2016

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BT vs RTE

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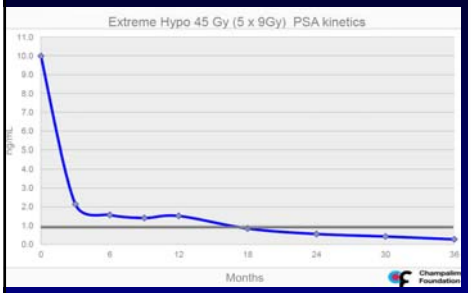

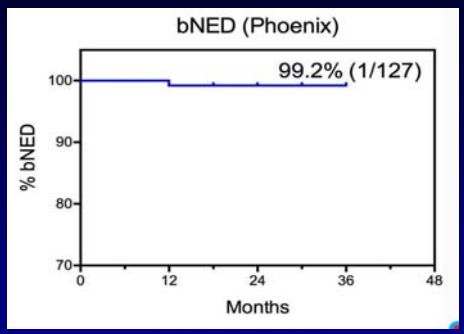

Greco et al ASTRO 2016

Similar a BT en caída PSA y toxicidad aguda temprana

Falta suficiente tiempo evolución para toxicidad tardia

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BT vs RTE

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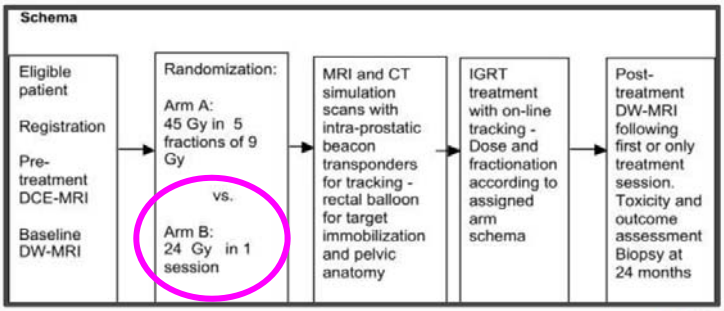
PROSINT

Phase II Randomized Study Comparing Ultra-High-Dose Hypofractionated vs. Single-Dose Image-Guided Radiotherapy (IGRT) with Urethral Sparing for Intermediate Risk Prostate Cancer

NCT02570919



Champalimaud Foundation

Contenido

- BT vs RTE.
- Fuentes en BT: LDR, PDR, HDR.
- BT en Próstata.
- BT en Cervix.
- BT en Piel.
- Planificación: Reconstrucción de Aplicadores.
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- QA Sistemas de Planificación.
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- Nuevas tendencias QM.
- Incertidumbres.
- Conclusiones.

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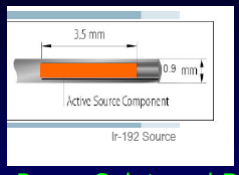
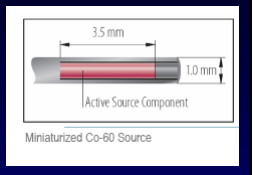
Fuentes

ALTA ENERGIA

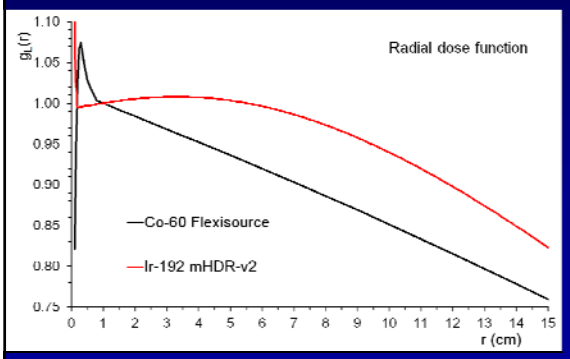
HDR Ir-192



HDR Co-60



Andrassy, Niatsetsky, Perez-Calatayud RFM 2012



Economia fuentes
Blindajes sala
Actividad inicial
Duración tratamientos
Dosis periferica
Blindajes aplicadores

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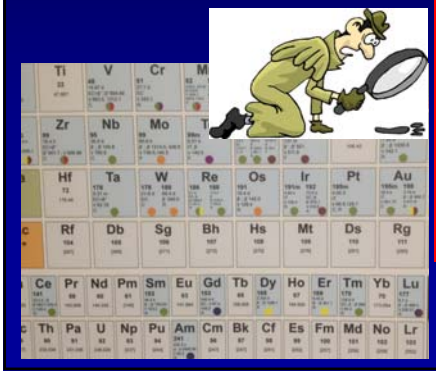
Fuentes

ALTA ENERGIA

Nuevas fuentes

Yb-169	Granero 2005, Currier 2013
Tm-170	Ballester 2010, Enger 2011
Co-57	Enger 2012
Gd-153	Enger 2013



- Menor energia → menor blindaje
- Mayor $T_{1/2}$
- Distribución dosis adecuada
- Actividad específica
- Tasa dosis
- Apantallamiento electrones

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Fuentes LDR

BAJA ENERGIA

	$T_{1/2}$	E
I-125	60 d	27 keV
Pd-103	17 d	23 keV
Cs-131	9,7 d	29 keV

Tasa inicial ↓

DISCUSION

- Energía
- Tasa inicial
- Precio
- Efectividad

	Dosis típica	Tiempo 90% dosis
I-125	145-160 Gy	197 d
Pd-103	125 Gy	56 d
Cs-131	100-125 Gy	32 d

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Fuentes

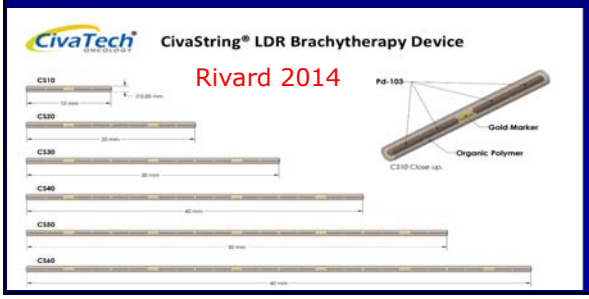
BAJA ENERGIA

	$T_{1/2}$	E
I-125	60 d	27 keV
Pd-103	17 d	23 keV
Cs-131	9,7 d	29 keV

Tasa inicial

DISCUSION
- Energía
- Tasa inicial
- Precio
- Efectividad

NOVEDAD Pd-103



Rivard 2014

DISCUSION
- Migración
- Reducción agujas
- Uso intraoperatorio ?

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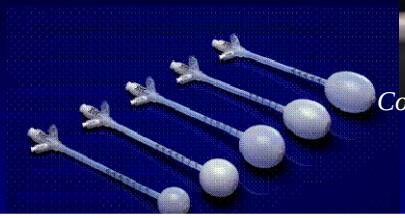
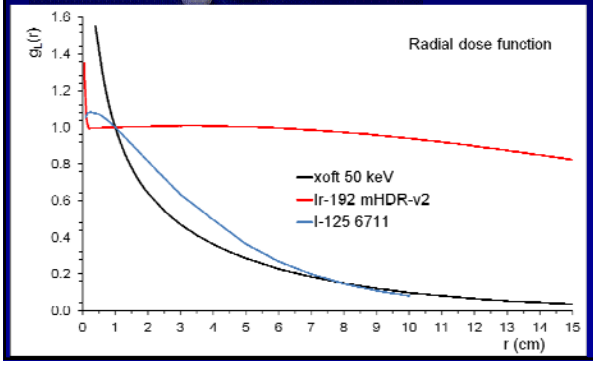
Fuentes

50 kVp

BT ELECTRONICA



Cortesía T W Rusch Xoft



- Mama balón
- Gyn vagina
- Piel
- CERVIX ????

- Tamaño
- Energía

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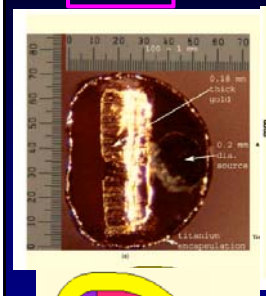
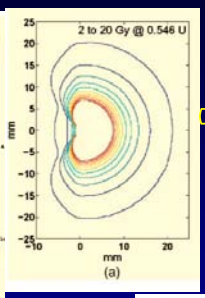
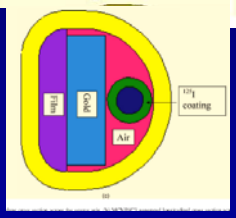
Fuentes

I-RSBT



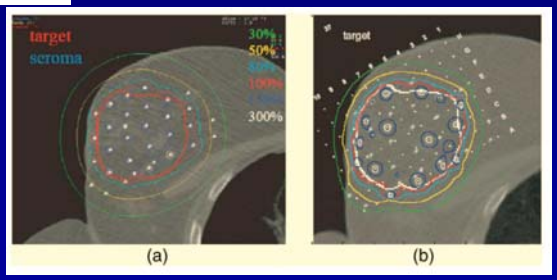




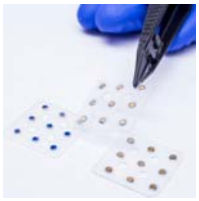
Lin 2008

Interstitial Rotating Shield Brachytherapy

Rotación fuente o blindaje

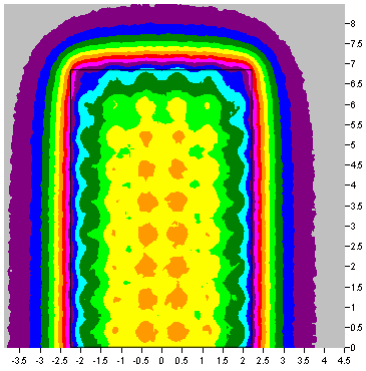


Extreme BT Shielding: LDR ^{103}Pd



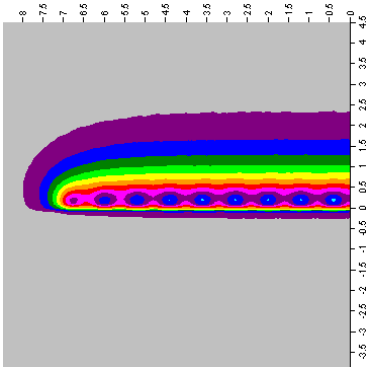
CivaSheet

2.5 mm diam.



Dose

160-170
150-160
140-150
130-140
120-130
110-120
100-110
90-100
80-90
70-80
60-70
50-60
40-50
30-40
20-30
10-20
0-10

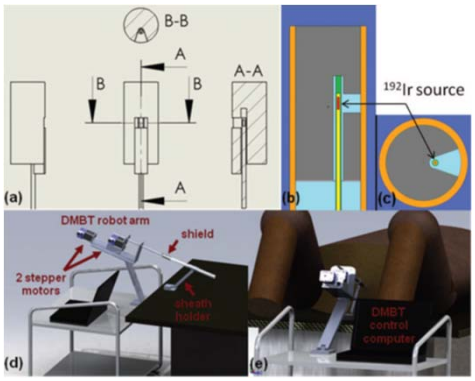


0.5 cm from front surface

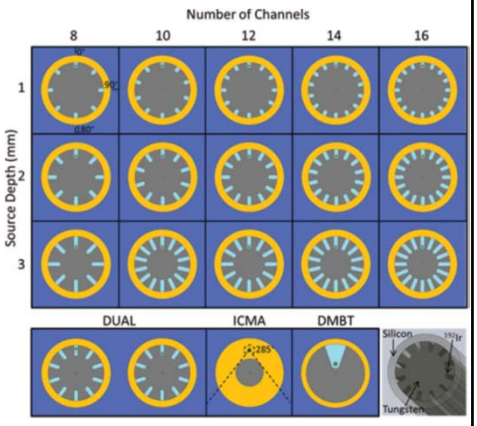
lateral view

Rivard et al, work-in-progress CORTESIA M. RIVARD

Extreme BT Shielding: HDR ^{192}Ir



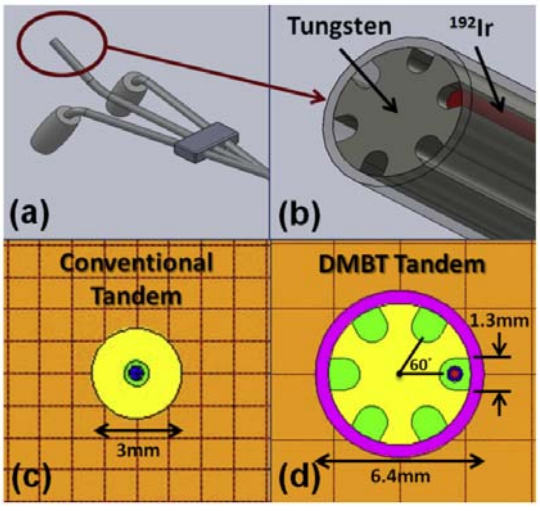
Webster et al, *Med Phys* 40, 011718 (2013)



Webster et al, *Med Phys* 40, 091704 (2013)

CORTESIA M. RIVARD

Extreme BT Shielding: HDR ^{192}Ir



Han et al, *IJROBP* 89, 666-673 (2014)

CORTESIA M. RIVARD

Fuentes

LDR	I-125, Pd-103 en próstata I-125 Placas Oculares (COMS) I-125 mama, pulmón
PDR	Ir-192 Uso minoritario y en descenso
HDR	Ir-192 y Co-60

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Contenido

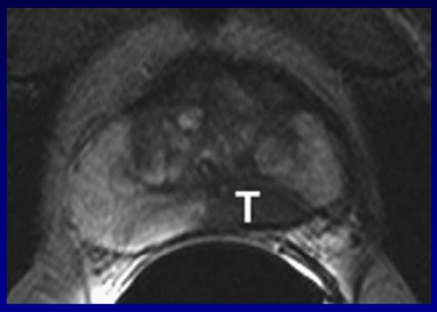
- BT vs RTE.
- Fuentes en BT: LDR, PDR, HDR.
- BT en Próstata.
- BT en Cervix.
- BT en Piel.
- Planificación: Reconstrucción de Aplicadores.
- Planificación: Nuevos Algoritmos.
- QA Sistemas de Planificación
- Calibración en BT.
- Dosimetría "in vivo"
- Nuevas tendencias QM
- Incertidumbres
- Conclusiones

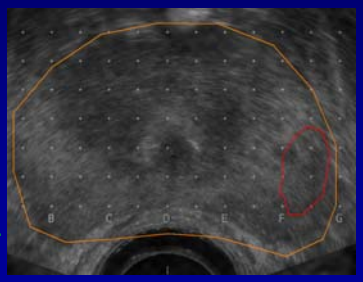
34

Registro deformado

HDR prostata

RMN → USBT



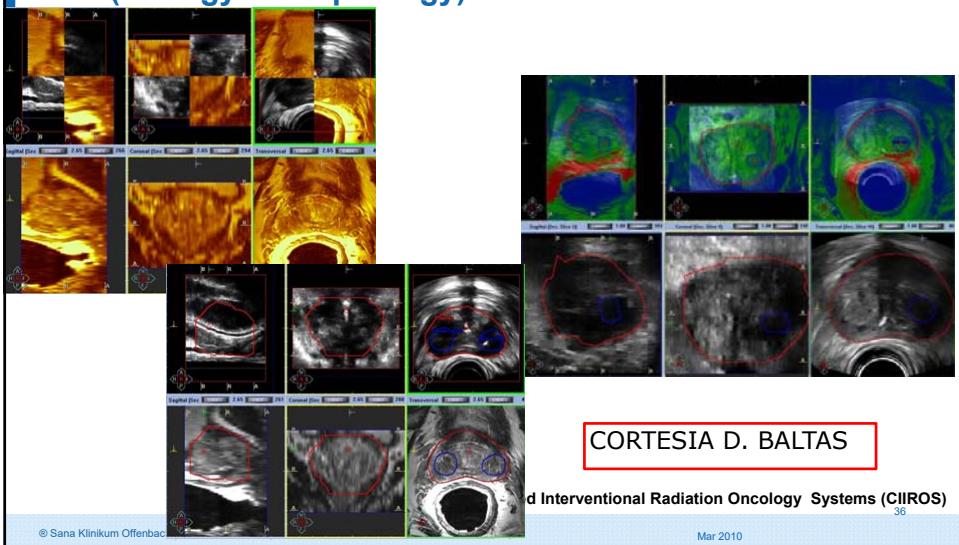


Lesiones Intraprostaticas
Dominantes (DIL) de MR a US BT

In progress Varian

Sana Klinikum Offenbach

Hybrid Imaging: Example of mP-MR und 3D-U/S (Biology + Morphology)



CORTESIA D. BALTAS

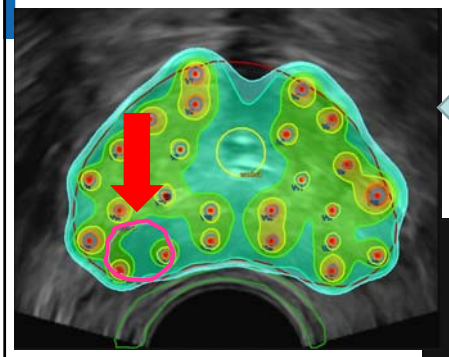
d Interventional Radiation Oncology Systems (CIIROS)

Mar 2010

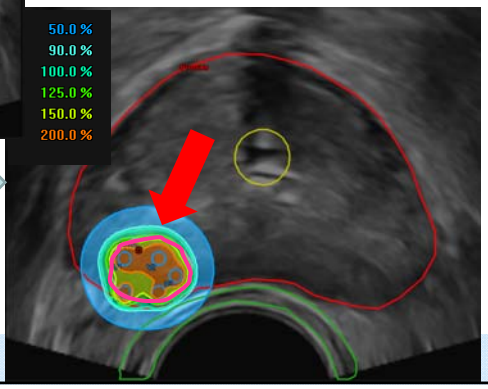
Change in Strategy ...

CORTESIA D. BALTAS

Sana Klinikum Offenbach



Treat the gland +/- Margin



Focal: Treat only the Significant (ID)/ Measurable Disease +/- Margin

Equipos: Investigación

ROBOT prostata

AAPM and ESTRO Guidelines for Image-Guided Robotic Brachytherapy: Report of Task Group 192

AAPM-ESTRO TG-192

In progress

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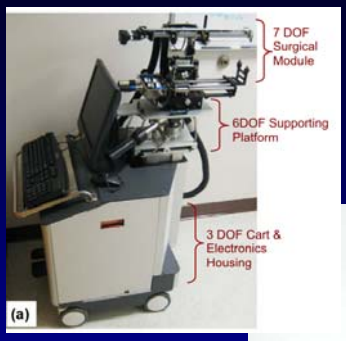
Equipos: Investigación

ROBOT prostata



EUCLIDEAN Robot

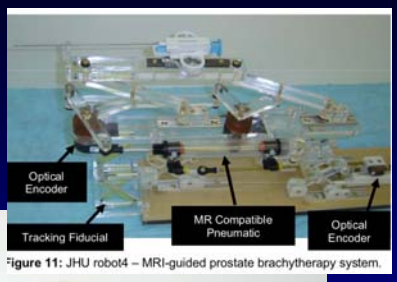
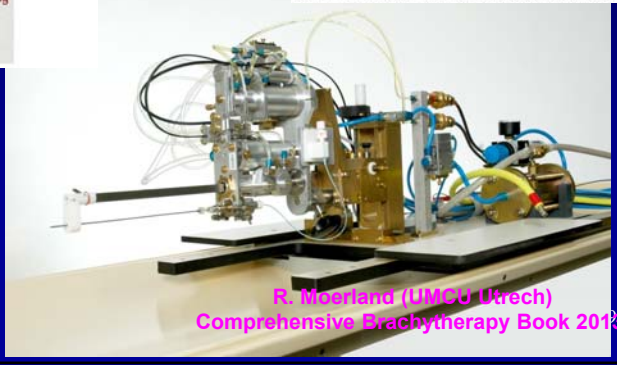


Figure 11: JHU robot4 – MRI-guided prostate brachytherapy system.

AAPM-ESTRO TG-192

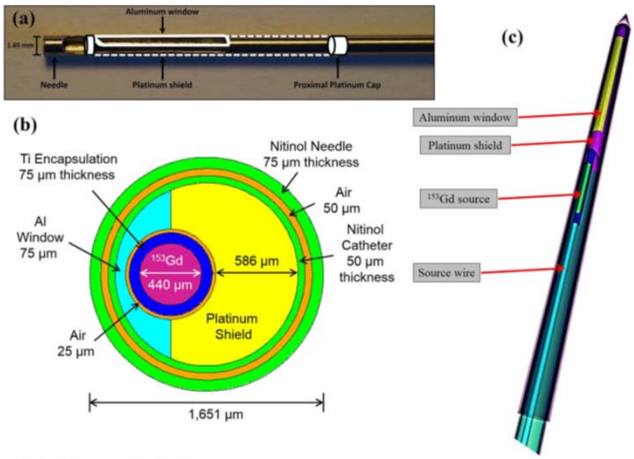
In progress



R. Moerland (UMCU Utrech)
Comprehensive Brachytherapy Book 2013

Extreme BT Shielding: ^{153}Gd

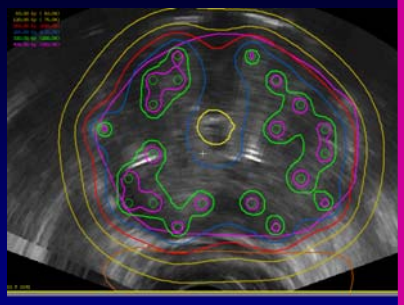
PROSTATA

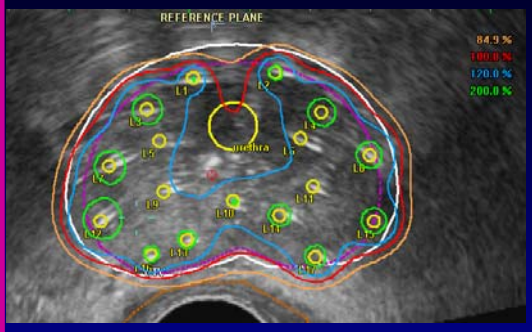


Adams et al, *Med Phys* 41, 051703 (2014)

CORTESIA M. RIVARD

BT Próstata





Permanente I-125

145 Gy

o

160 Gy

HDR Ir-192 o Co-60

13,5 Gy /app

2 app separadas 1 semana

41

Disminución semillas vs HDR

- Dosimetría (optimización)
- Migración, local y a distancia
- Variación dosis por edema
- Incertidumbres (siembra, …)
- Protección Radiológica tras implante
- Manejo fuentes pre-implante
- Carga Radiofísica
- $$$$$$$$$$$$

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BT vs RTE

Radiotherapy and Oncology 119 (2016) 411–416

Contents lists available at ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

Prostate cancer brachytherapy

High-dose-rate interstitial brachytherapy as monotherapy in one fraction for the treatment of favorable stage prostate cancer: Toxicity and long-term biochemical results

Pedro J. Prada [a,*], Juan Cardenal [a], Ana García Blanco [a], Javier Anchuelo [a], María Ferri [a], Gema Fernández [c], Elisabeth Arrojo [c], Andrés Vázquez [b], Maite Pacheco [b], José Fernández [d]

[a] Department of Radiation Oncology; [b] Department of Radiation Physics, Hospital Universitario Marqués de Valdecilla, Santander; [c] Department of Radiation Oncology; and [d] Department of Radiation Physics, Hospital Universitario Central de Asturias, Oviedo, Spain

HDR monotherapy in one fraction of 19 Gy resulted in a low genitourinary morbidity and no gastrointestinal toxicity but biochemical control rates is lower compared to LDR brachytherapy. We believe that higher doses might provide even more biochemical benefit without more toxicity.

43

AVANCES

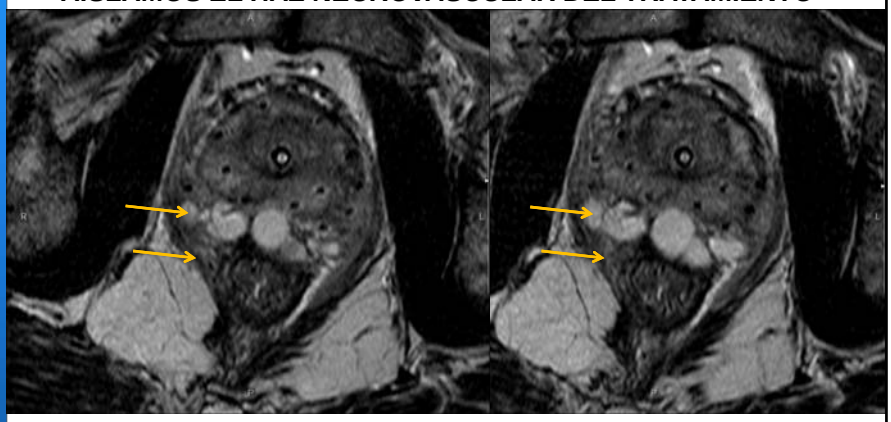
CORTESIA P. PRADA

AISLAMOS EL RECTO DE LA IRRADIACIÓN

AVANCES

CORTESIA P. PRADA

AISLAMOS EL HAZ NEUROVASCULAR DEL TRATAMIENTO



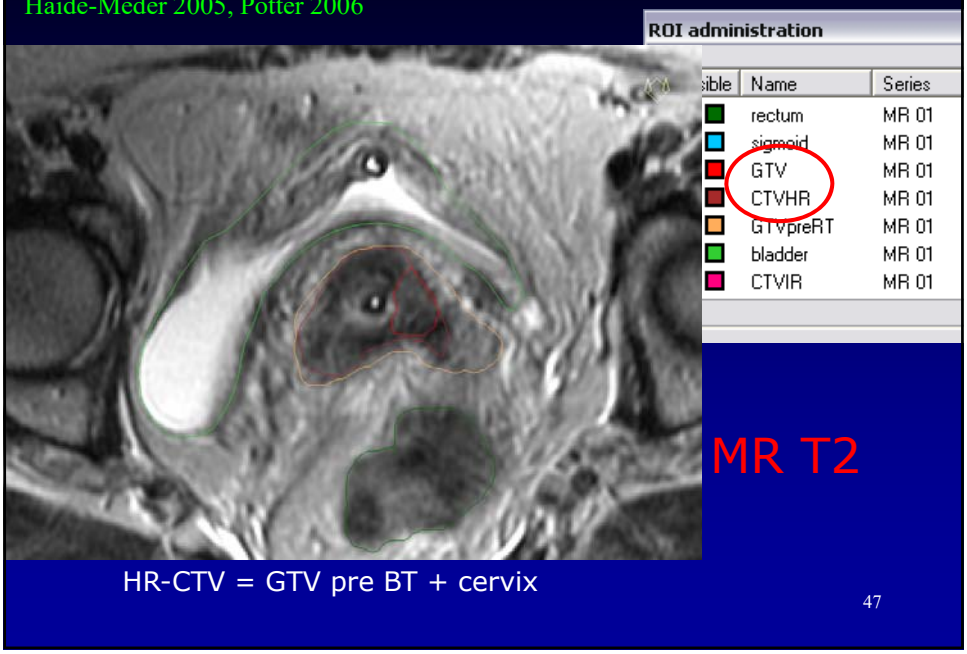
AVANCES

CORTESIA P. PRADA

PODEMOS PROTEGER LA URETRA DE LA IRRADIACIÓN CON HIPOTERMIA

☞ Recomendaciones GEC-ESTRO 2005-2006

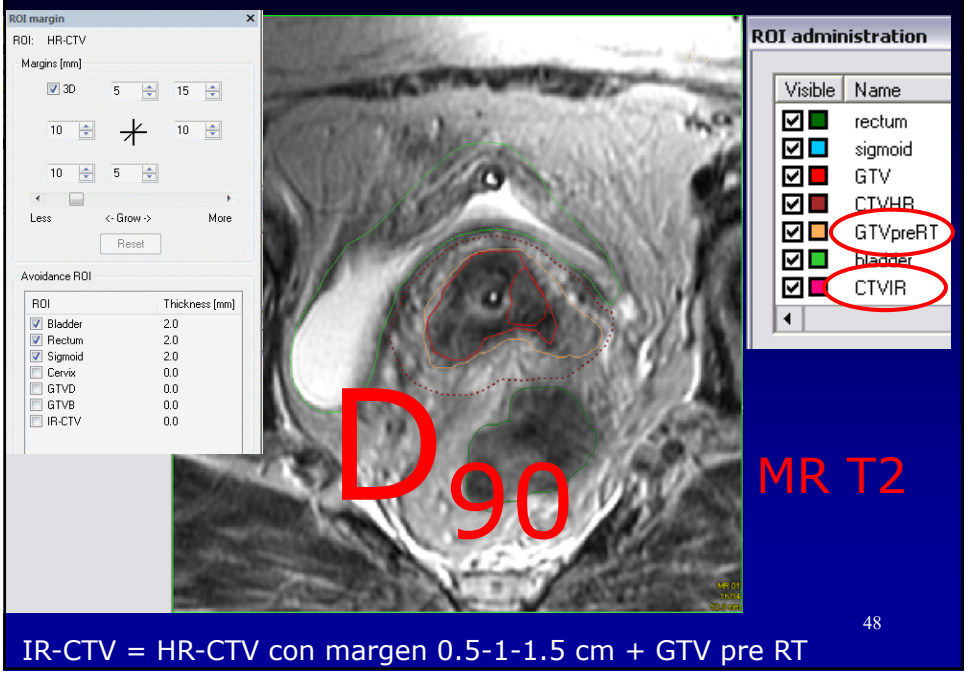
Haide-Meder 2005, Potter 2006



HR-CTV = GTV pre BT + cervix

47

☞ Recomendaciones GEC-ESTRO

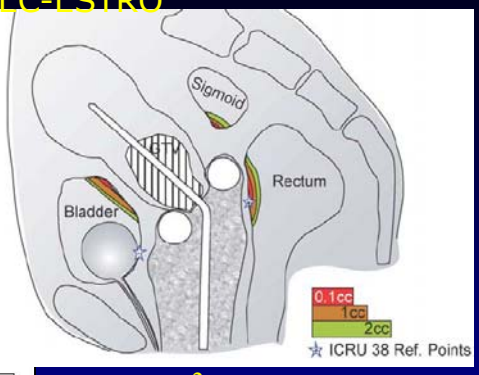


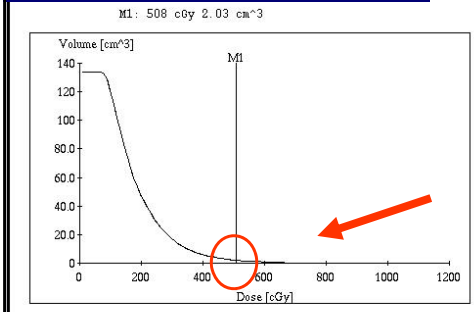
IR-CTV = HR-CTV con margen 0.5-1-1.5 cm + GTV pre RT

48

☞ Recomendaciones GEC-ESTRO

Recto, Vejiga, Sigma





DVH_1 : Cumulative DVH on VEJIGA. State : Consistent.

0.1 cm^3 *Potter RO 2006*

1 cm^3

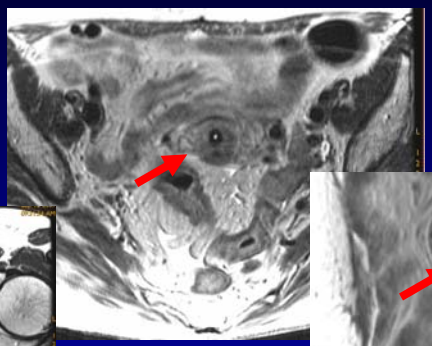
2 cm^3

5 cm^3

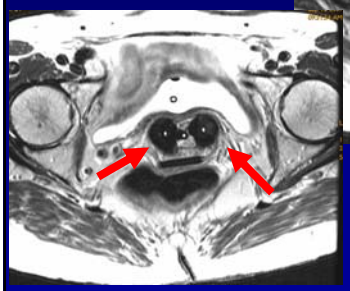
49

☞ SP: Reconstruccion cateteres

MR Dummies para algunos tipos de aplicadores



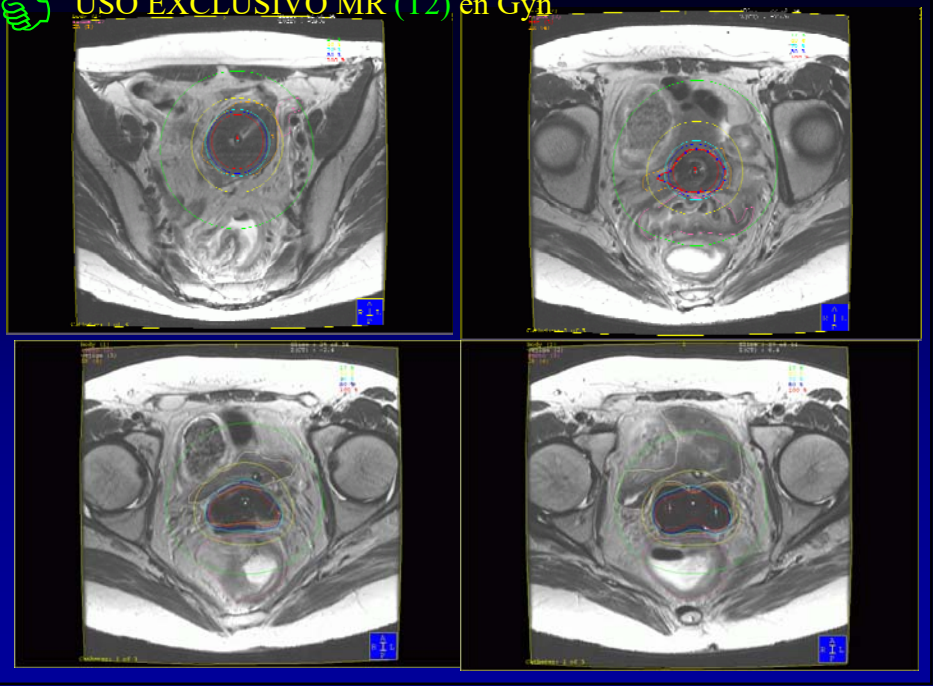
Suero fisiologico



T2

Perez-Calatayud 2009

USO EXCLUSIVO MR (T2) en Gyn



Valores referencia (2007)

GYN MR: Protocolo Viena

45 Gy RTE + BT 2fx 7Gy/fx + BT 2fx 7Gy/fx

Potter, Lindegaard, Kirisits, Haie-Meder

A European study on MRI-guided brachytherapy in locally advanced cervical cancer

EMBRACE

- Rectum D_{2cc} < 70-75 Gy
- Sigmoid colon D_{2cc} < 75 Gy
- Bladder D_{2cc} < 90 Gy

- For the HR-CTV D90 doses of 75-96 Gy are reported depending on tradition, technique, tumour volume and response (Leuven, Aarhus, Vienna, Paris IGR).
- For the IR CTV D90 doses of 60-75 Gy are reported dependent on tradition, technique, tumour volume and response (Paris, IGR, Nancy, Aarhus, Vienna).

Valores en EQD_2

CTV → α/β=10
OAR → α/β=3

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☞ EMBRACE II v1

Tanderup, Pötter, Lindegaard, Kirisits, et al

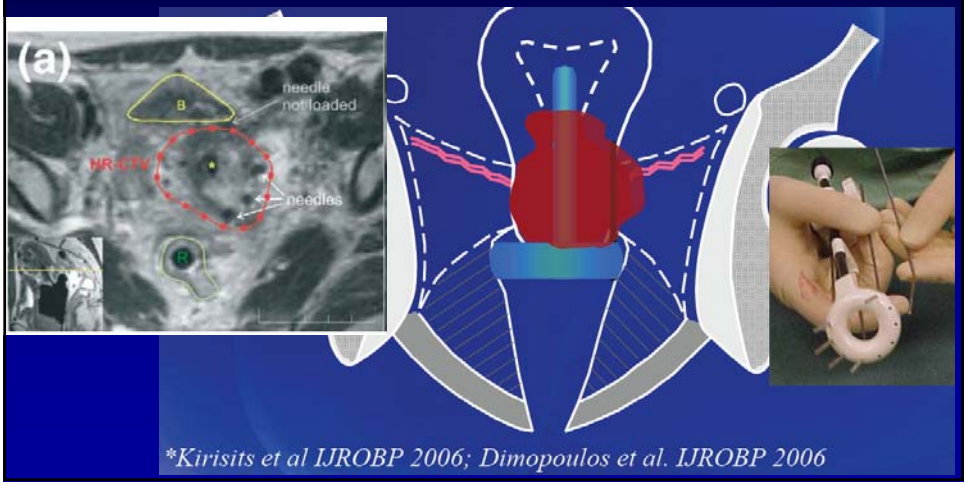
Target	D90 CTV_{HR} $EQD2_{10}$	D98 CTV_{HR} $EQD2_{10}$	D98 GTV_{res} $EQD2_{10}$	D98 CTV_{IR} $EQD2_{10}$	Point A $EQD2_{10}$
Planning Aims	> 90 Gy < 95 Gy	> 75 Gy	>95 Gy	> 60 Gy	> 65 Gy
Limits for Prescribed Dose	> 85 Gy	-	>90 Gy	-	-
OAR	Bladder D_{2cm^3} $EQD2_3$	Rectum D_{2cm^3} $EQD2_3$	Recto-vaginal point $EQD2_3$	Sigmoid D_{2cm^3} $EQD2_3$	Bowel D_{2cm^3} $EQD2_3$
Planning Aims	< 80 Gy	< 65 Gy	< 65 Gy	< 70 Gy*	< 70 Gy*
Limits for Prescribed Dose	< 90 Gy	< 75 Gy	< 75 Gy	< 75 Gy*	< 75 Gy*

☞ Evolución BT cervix

Planificación con MR

Necesidad complemento con intersticial

App Vienna



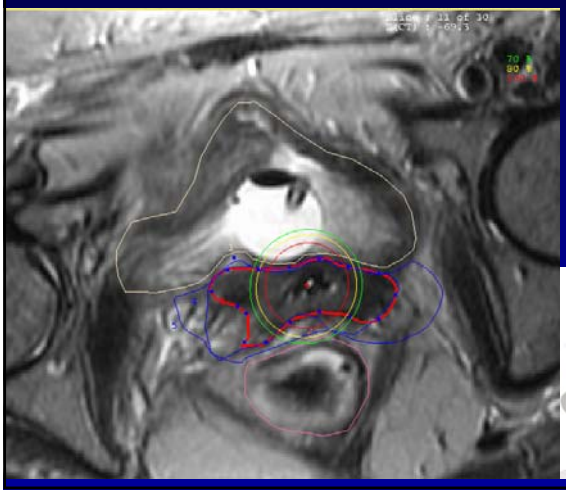
**Kirisits et al IJROBP 2006; Dimopoulos et al. IJROBP 2006*

☞ Evolución BT cervix

Planificación con MR

Necesidad complemento con intersticial

App Utrech



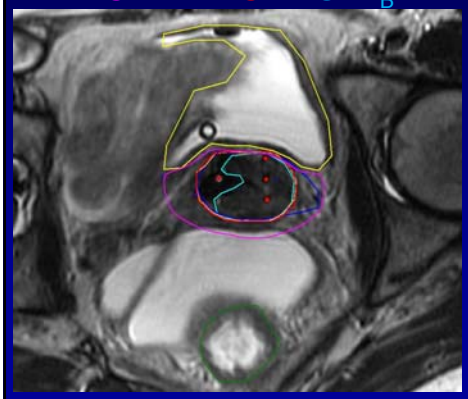
☞ Evolución BT cervix

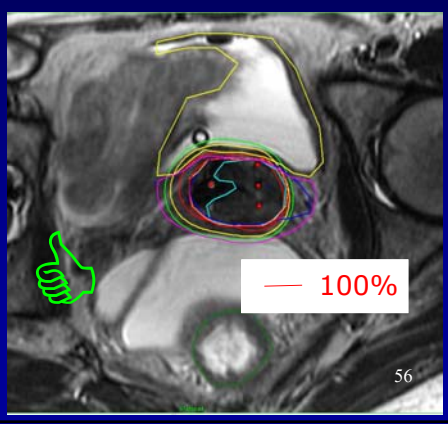
Planificación con MR

Necesidad complemento con intersticial

App Utrech

IR-CTV HR-CTV GTV_B



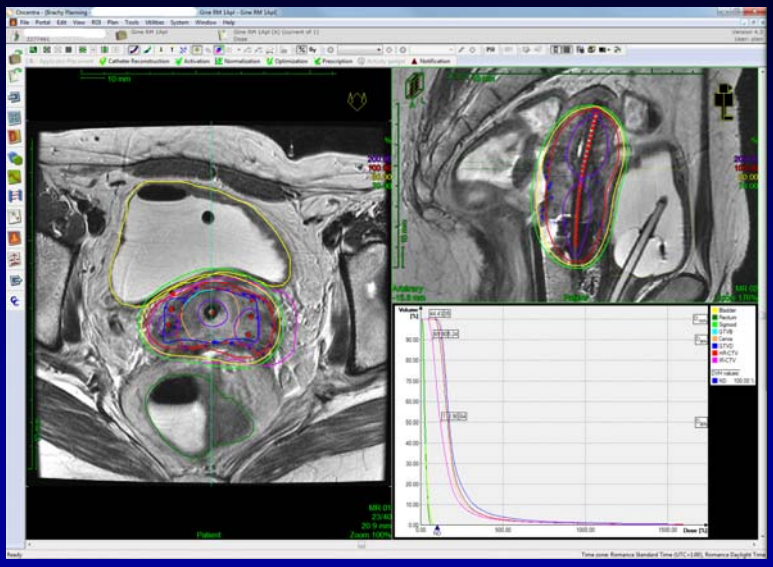


☞ Evolución BT cervix Planificación con MR

App Varian

☞ EQD_2 Radiobiología no incorporada en SPs

Proceso iterativo basado en la experiencia



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☞ EQD_2

- Hojas calculo externas

Cálculo de EQD_2 en braquiterapia ginecológica para HDR

Radiofísica - Radioterapia - Hospital La Fe

Identificación HDR10048 | Paciente: | Historia RT: 39640 | Médico:

Externa: Dosis / sesión 1.80 Gy; Sesiones: 25; Subtotal = 45.00 Gy

Número de aplicaciones: 2

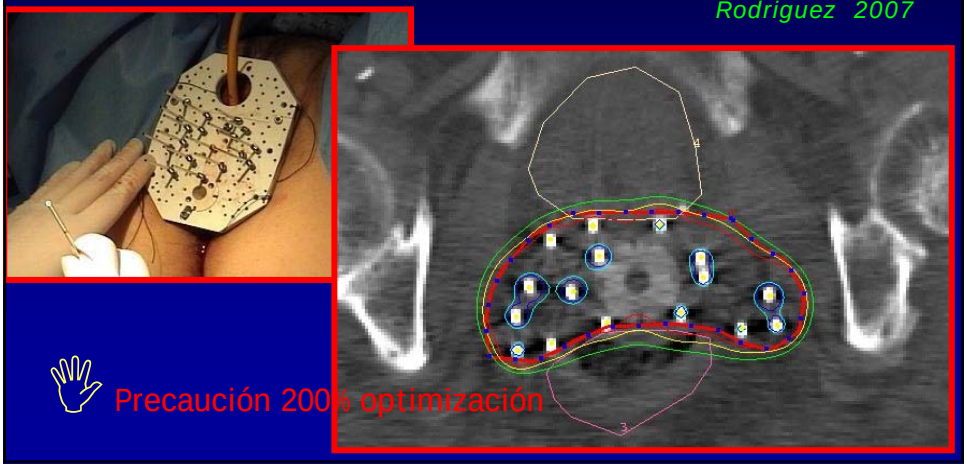
	HDR 1 Aplicación		HDR 2 Aplicación	
	Fracciones	Factor Dosis	Fracciones	Factor Dosis
	2	110%	2	115%
	Cálculo	**Tratamiento**	Cálculo	**Tratamiento**
Dosis / fracción	7.00 Gy	7.70 Gy	7.00 Gy	8.05 Gy
Dosis total / aplicación		15.40 Gy		16.10 Gy
Ext + D. total acumulada	Ext + HDR 1 =	60.40 Gy	Ant + HDR 2 =	76.00 Gy

			Dosis / fracción		Dosis / fracción		Dosis / fracción	
α/β = 10			Cálculo	**Tratamiento**	Cálculo	**Tratamiento**	Cálculo	EQD_2 Total
GTV$_B$		D_{100}	4.07 Gy	**4.48** Gy	3.78 Gy	**4.35** Gy		**65.50** Gy
		D_{90}	6.84 Gy	**7.52** Gy	5.14 Gy	**5.91** Gy		**81.90** Gy
HR-CTV		D_{100}	4.04 Gy	**4.44** Gy	3.83 Gy	**4.40** Gy		**65.50** Gy
		D_{90}	6.93 Gy	**7.62** Gy	5.65 Gy	**6.49** Gy		**84.50** Gy
		D_{50}	9.91 Gy	**10.90** Gy	8.36 Gy	**9.61** Gy		**113.60** Gy
		Volumen	19.81 cc		21.41 cc			
IR-CTV		D_{100}	2.31 Gy	**2.54** Gy	2.53 Gy	**2.91** Gy		**55.80** Gy
		D_{90}	4.00 Gy	**4.39** Gy	3.99 Gy	**4.59** Gy		**66.00** Gy
		D_{50}	6.66 Gy	**7.32** Gy	6.71 Gy	**7.72** Gy		**88.20** Gy
Punto H			4.55 Gy	**5.00** Gy	5.73 Gy	**6.59** Gy		**75.00** Gy
α/β = 3								
Vejiga		2 cm^3	4.67 Gy	**5.14** Gy	4.68 Gy	**5.39** Gy		**78.00** Gy
		1 cm^3	5.09 Gy	**5.60** Gy	5.03 Gy	**5.79** Gy		**82.80** Gy
		0.1 cm^3	5.90 Gy	**6.49** Gy	5.83 Gy	**6.71** Gy		**93.90** Gy
Recto		2 cm^3	3.42 Gy	**3.77** Gy	3.15 Gy	**3.62** Gy		**63.00** Gy
		1 cm^3	3.78 Gy	**4.16** Gy	3.36 Gy	**3.87** Gy		**65.70** Gy
		0.1 cm^3	4.51 Gy	**4.96** Gy	3.86 Gy	**4.44** Gy		**72.20** Gy
Sigmoide		2 cm^3	2.44 Gy	**2.68** Gy	1.71 Gy	**1.96** Gy		**53.20** Gy
		1 cm^3	2.71 Gy	**2.98** Gy	1.87 Gy	**2.15** Gy		**54.80** Gy
		0.1 cm^3	3.35 Gy	**3.68** Gy	2.25 Gy	**2.58** Gy		**58.80** Gy

☞ Tratamiento intersticial MUPIT

- Lesiones no abordables con Viena & Utrech
- MUPIT, uso en CT

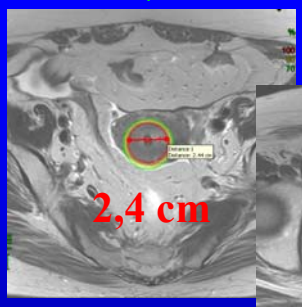
Rodriguez 2007



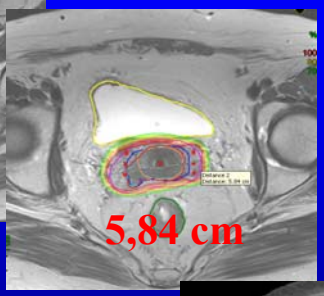
- Precaución 200% optimización

Diapositiva cortesía Silvia Rodriguez ITIC Benidorm

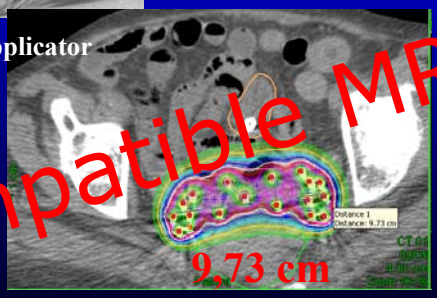
GAIN



Tandem + Ovoids



Utrecht applicator



MUPIT

Total lenght of vagina

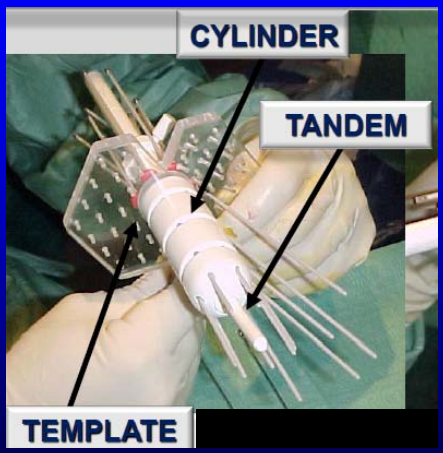
Distal parametrium

Rectum/Bladder

No compatible MR

Diapositiva cortesía Silvia Rodriguez ITIC Benidorm

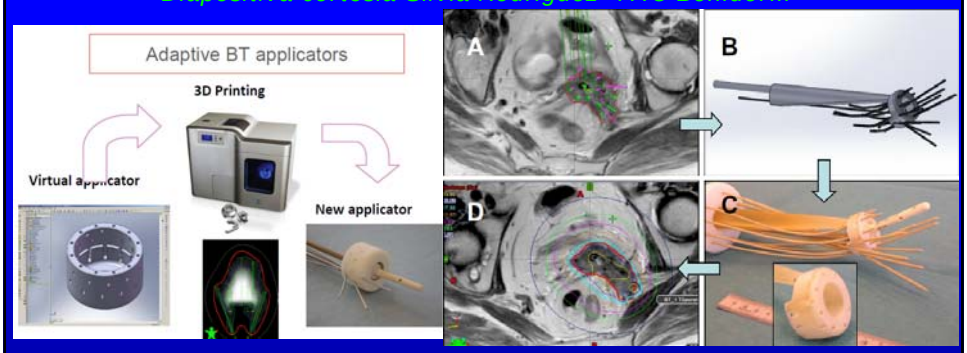
OTHER INTERSTICIAL APPROACHES



Courtesy JA. Dimopoulus. Interstitial techniques. Cervical Cancer. ESTRO teaching Course November 2015

Courtesy Dra. E. Villafranca. Hospital de Navarra.

Diapositiva cortesía Silvia Rodriguez ITIC Benidorm



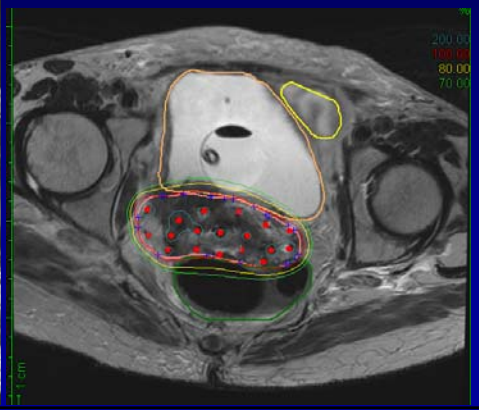
Petric P and Lindegaard (Ljubljana/Aarhus). Interstitial techniques. Cervical Cancer. ESTRO teaching Course November 2015

Lindegaard JC, Madsen ML, Traberg A, et al. Radiother Oncol 2016; 118: 173-175

☞Tratamiento intersticial/endocavitario T. Benidorm

Compatibles con MR
Componente uterina
Vectores Titanio

Rodriguez et al 2015

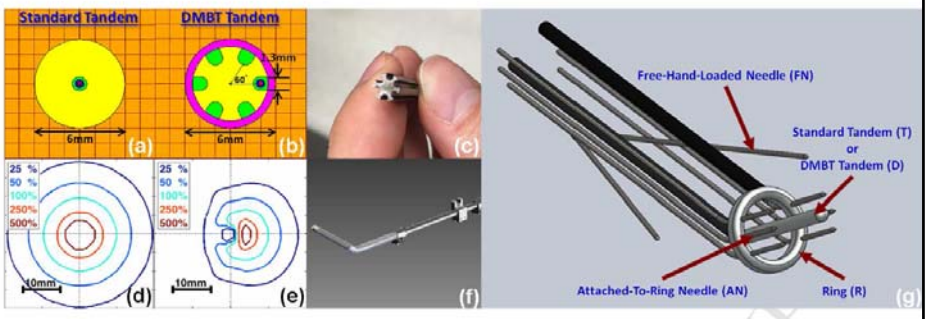


☞Tratamiento intersticial/endocavitario

Venezia (ELEKTA)

Vectores plásticos

ACCEPTED MANUSCRIPT



Direction Modulated Brachytherapy (DMBT) for Treatment of Cervical Cancer. II: Comparative Planning Study with Intracavitary and Intracavitary-Interstitial Techniques

Dae Yup Han, PhD,[1,2,3] Habib Safigholi, PhD,[1,4] Abraam Soliman, PhD,[1,4] Ananth Ravi, PhD,[1,5] Eric Leung, MD,[5,6] Daniel J. Scanderbeg, PhD,[7] Zhaowei Liu, PhD,[7] Amir Owrangi, PhD,[1,5] and William Y. Song, PhD[1,4,5]

Conclusions: Integrating the novel DMBT tandem onto both intracavitary and intracavitary-interstitial applicator assembly enabled consistent improvement in the sparing of the OARs, over a standard "single-channel" tandem, though individual variations in benefit were considerable. While at early stage of development, the DMBT concept design is demonstrated to be useful and pragmatic for potential clinical translation.

Piel

Moldes

Flaps

App blindados: Leipzig o Valencia

Intersticial

Applicadores HDR Ir-192 (Leipzig)

- Alta protección tejido sano alrededor
- Planificacion y tratamiento muy sencillo
- Prescripción típica 3 mm
- Limitado to superficies planas 3-4,5 cm ∅

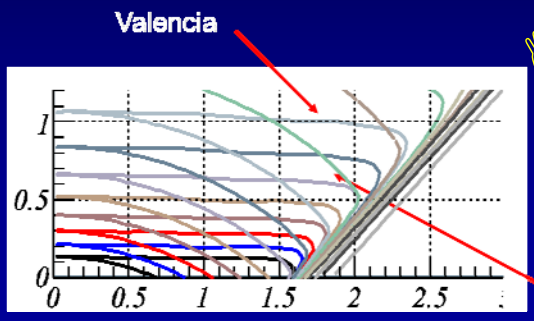
Varian

Elekta

68

Leipzig vs Valencia (Elekta)

Mejora flatness, penumbra y haz útil

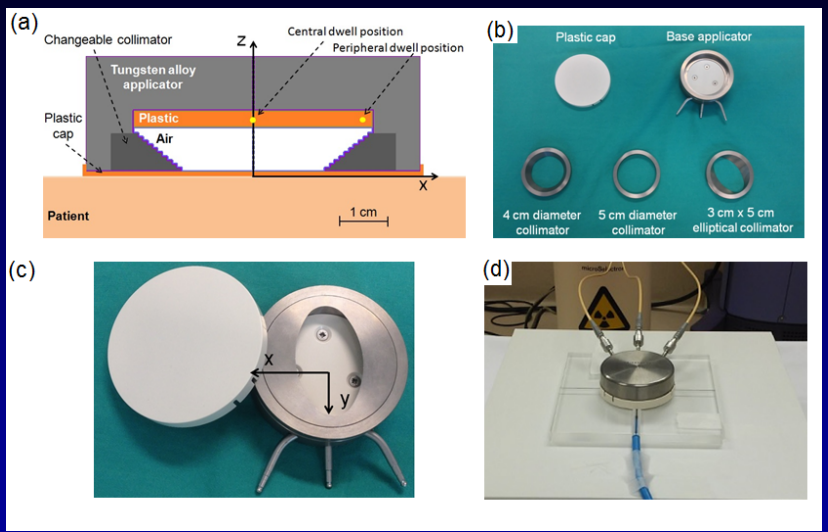


Aumento significativo tiempo tratamiento

Perez-Calatayud et al 2005, Granero et al 2008

69

En progreso: Nuevos Valencia (hasta 5 ∅ cm)



Candela, Niatsetski, van der Laarse, Granero, Ballester, Perez-Calatayud, Vijande Med Phys 2016

70

Heterogeneidad

"In lesions in close proximity to underlying bone such as shin or scalp the dose might be lower than expected because the bone backscatter reduction" Chow JACMP 2012, Butson PMB 2008

"In lesions in close proximity to underlying bone eBT gives excessive bone dose comparing HDR Ir-192 or electrons 4-6 MeV" Safigholi JACMP 2015

¡ Discusión abierta TG-253

Estudios paralelos

Relevancia clinica? ¡

71

Aplicadores BT electrónica

Axxent Electronic Brachyterapy System (Xoft)

50 kVp

App 1-5 cm ∅

SSD = 2.06 – 3.03 cm

Carl Zeiss INTRABEAM System

50 kVp

App 1-6 cm ∅

SSD = 0.96 – 2.56 cm

72

Aplicadores BT electrónica

Esteya (Elekta)

69.5 kVp

App 1-3 cm ∅

SSD = 6 cm

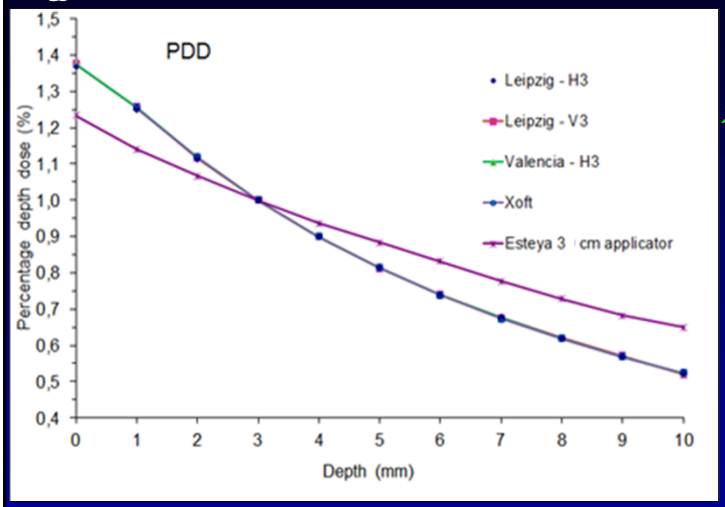
Mejoras vs Valencia:

- Penumbra 1.1 mm *vs.* 1.9 mm
- Treatment time
- Gradient on PTV
- Leakage

Tiempo tto 7 Gy	Esteya ∅ 3	Valencia H3
App 3 cm @ 3 mm	153 s	373-898 s

73

PDDs Aplicadores



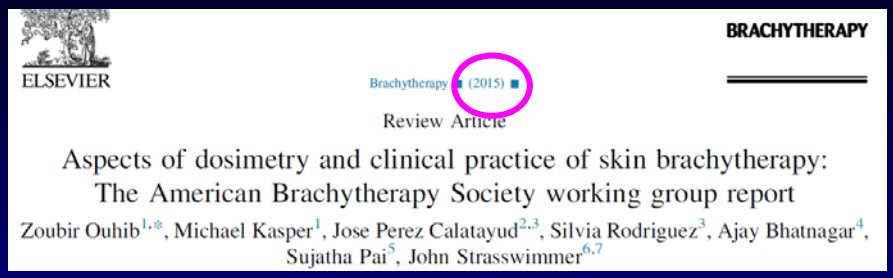
Garcia et al 2014

Xoft data provided by S. Pai

Leipzig & Valencia & Xoft	12% / mm
Esteya	8% / mm

74

ABS



ELSEVIER

BRACHYTHERAPY

Brachytherapy ■ (2015) ■

Review Article

Aspects of dosimetry and clinical practice of skin brachytherapy: The American Brachytherapy Society working group report

Zoubir Ouhib[1,*], Michael Kasper[1], Jose Perez Calatayud[2,3], Silvia Rodriguez[3], Ajay Bhatnagar[4], Sujatha Pai[5], John Strasswimmer[6,7]

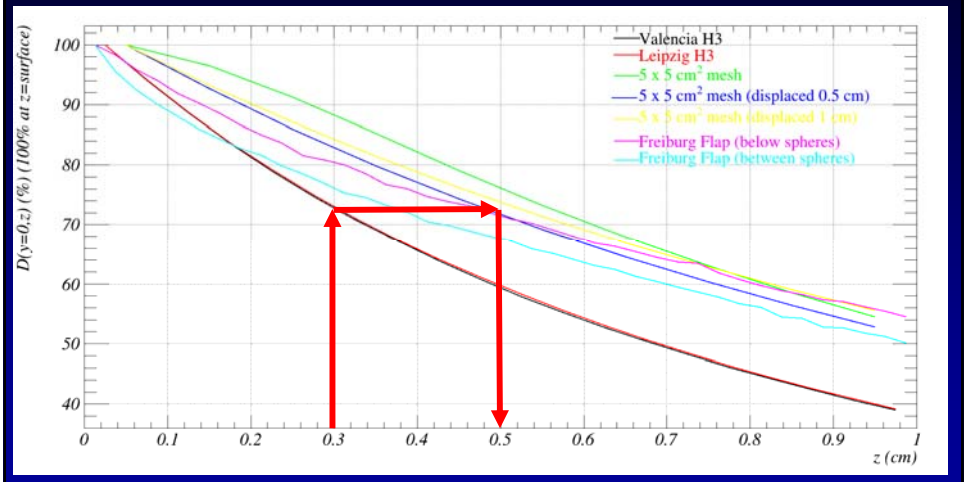
- Máxima sobredosis piel: 140% Moldes 125% Flaps
- Prescripción max Moldes & Flaps 5 mm
- Prescripción max App blindados 3 mm

Experiencia Clínica

75

Comparación PDD App y 5x5 cm² Moldes & Flaps

Granero 2016 Trabajo en progreso, resultados provisionales



76

Implementación clínica

Determinación PROF

HFUS

High resolution B-scan with 18 MHz hand-held transducer (Siemens Acuson S2000). Gel pad 2 cm x 9 cm (Aquaflex)

Superficial

Nodular

Pons, Ballester, Celada, Candela, García, Llavador, Botella, MD Barker, Ballesta, Tormo, Rodríguez, Perez-Calatayud JCB 2014

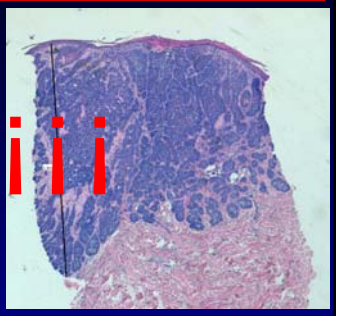
77

Implementación clínica

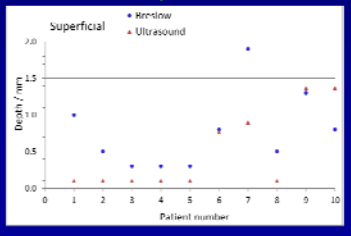
Determinación PROF

US *vs.* 3 mm punch biopsy

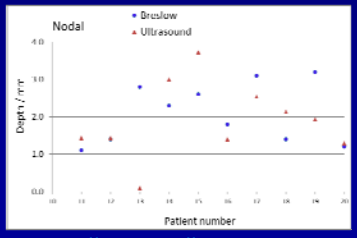
Prescribir a 3 mm cuando HFUS de valores menores que este umbral



Superficial



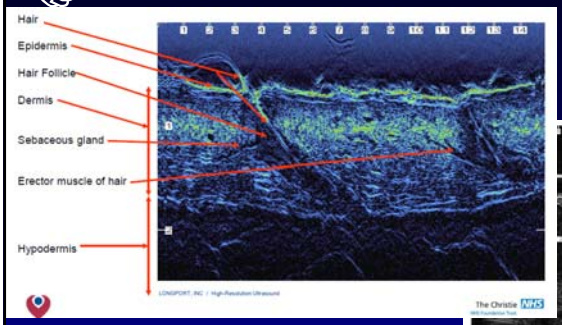
Nodular



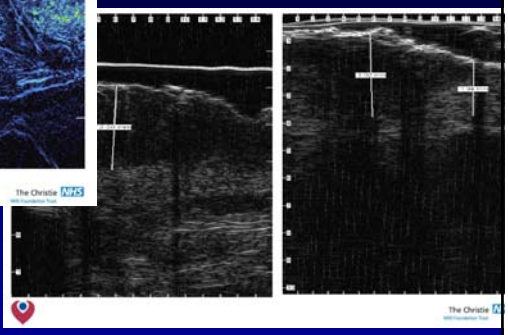
R. Ballester, O. Pons, M. Llavador, R. Botella, A. Ballesta, A. Tormo, F. Celada, S. Rodriguez, M. Santos, F. Ballester, J. Perez-Calatayud. JCB 2014

78

US para determinacion PROF y seguimiento ?



Longport Episcan 35MHz



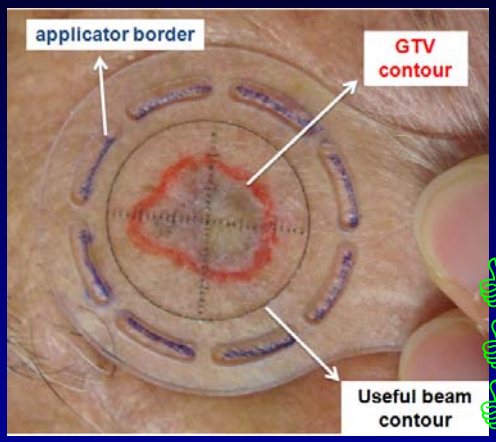
Cortesia Dr E. Allen
Christie Hospital

Projecto en evaluacion La Fe: US vs OCT vs MRI vs Biopsia

79

Implementación clínica

PTV & Marcado



Templates La Fe - ITIC

Set-up Aplicador

Campo útil

Margen GTV-CTV-PTV

Típico margen CTV-PTV: 2 mm

80

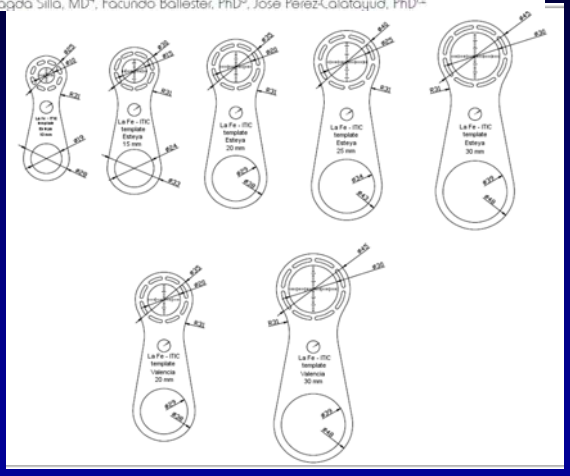
Novel simple templates for reproducible positioning of skin applicators in brachytherapy

JCB 2016

Silvia Rodríguez Villalba, MD[1], María José Pérez-Calatayud, MD[2], Juan Antonio Bautista, MSc[2], Vicente Carmona, MSc[2], Francisco Celada, MD[2], Alejandro Tormo, MD[2], Teresa García-Martínez, MSc[3], José Richart, MSc[1], Manuel Santos Ortega, MD[1], Magda Silla, MD[4], Facundo Ballester, PhD[5], José Pérez-Calatayud, PhD[1,2]

Esteya

Valencia



Disponibles gratuitos en perez_jos@gva.es patrocinados por Elekta

81

☞Implementación clínica

PTV & Marcado

Valencia app

Disponibles gratuitos en perez_jos@gva.es patrocinados por Elekta

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Applicators

Fractionation

Tormo, Celada, Rodriguez, Botella, Ballesta, Kasper, Ouhib, Santos, Perez-Calatayud. JCB 2014

Lynn Cancer Center (Florida) + La Fe Valencia + ITIC (Alicante)

7 Gy/fx 2 fx/week 6 fx 42 Gy *VALENCIA*

Baja energía 70 kV → Mayor efecto radiobiológico

~~6.1 Gy/fx 2 fx/week 6 fx 36.6 Gy~~ *ESTEYA*

Ballester, Pons, Candela, Celada, Barker, Tormo, Perez-Calatayud, Botella JCB 2016

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Recomendaciones Sociedades

2015


ELSEVIER

BRACHYTHERAPY

Brachytherapy ■ (2015) ■

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IN PROGRESS

TG-253 (AAPM-ESTRO) Surface Brachytherapy

R. Fulkerson, J. Perez-Calatayud, F. Ballester, I. Buzurovic, D. Harrington, Y. Kim, Y. Niatsetski, Z. Ouhib, S. Pai, M. Rivard, Y. Romg, T. Rusch, FA Siebert, B. Thomadsen, F. Weigand

Recommendations Commissioning and QM program for surface brachytherapy

Methods, detectors, traceability, periodic test: frequency & tolerance, and QM under the TG-100 (FMEA) perspective

☞ Controversia definición BRAQUITERAPIA

- AAPM, ABS, ASTRO, ACR, ….
- $$$$$$$$$$
- Dónde acaba BT y comienza RTE?

Propuesta TG-253, WGBCA, BTSC:

"Brachytherapy: radiotherapy using one or more radiation sources with the radiation source/sources inside or close to the target volume. Typically brachytherapy is within 10 cm and thus "close" is interpreted to include distances of < 10 cm."

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Contenido

- BT vs RTE.
- Fuentes en BT: LDR, PDR, HDR.
- BT en Próstata.
- BT en Cervix.
- BT en Piel.
- Planificación: Reconstrucción de Aplicadores.
- Planificación: Nuevos Algoritmos.
- QA Sistemas de Planificación
- Calibración en BT.
- Dosimetría "in vivo"
- Nuevas tendencias QM
- Incertidumbres.
- Conclusiones

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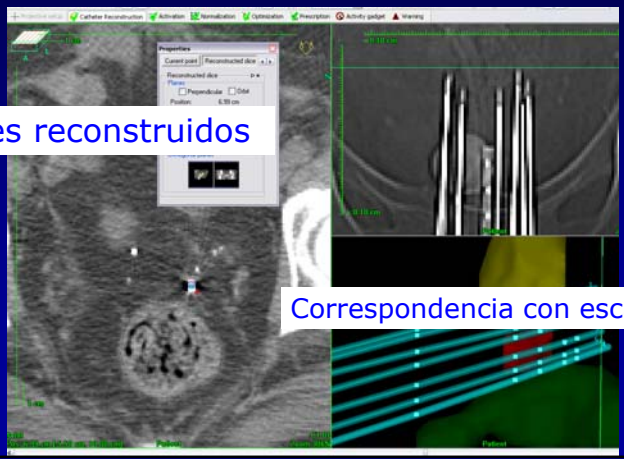
SP: Reconstruccion cateteres

CT *Kirisits GEC-ESTRO & AAPM Report 2014* ≈1 mm

Espesor y espaciado cortes

Tip



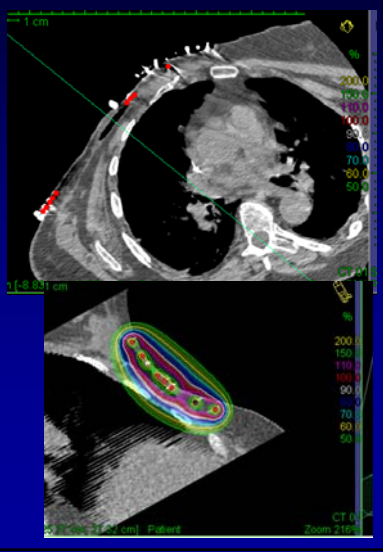
"Fine" cortes reconstruidos

Correspondencia con escanograma

87

SP: Reconstruccion cateteres

CT Implante casi transversales



Planos perpendiculares reconstruidos

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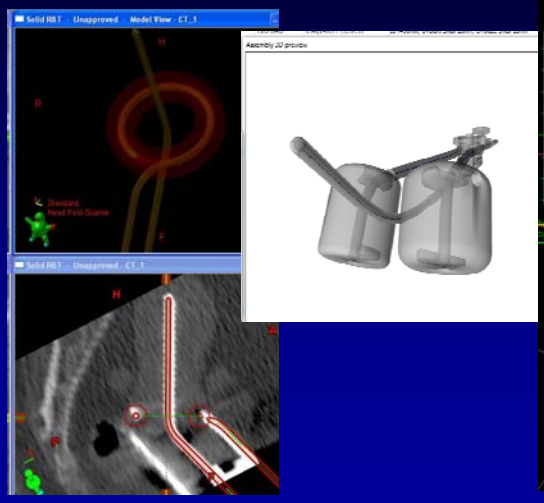
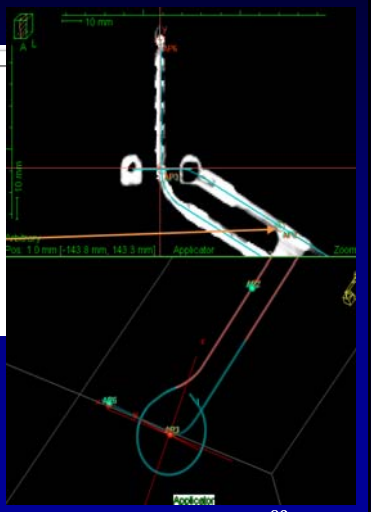
☞ SP: Reconstruccion cateteres

Libreria Aplicadores rigidos



Cortesia Varian



Cortesia Nucletron

89

☞ Librerias aplicadores

Radiotherapy and Oncology 96 (2010) 153–160

Contents lists available at ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

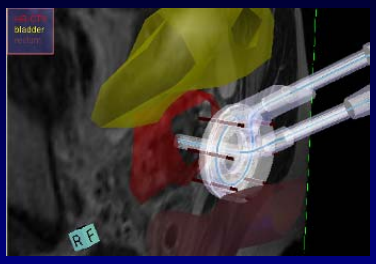
GEC-ESTRO Recommendations

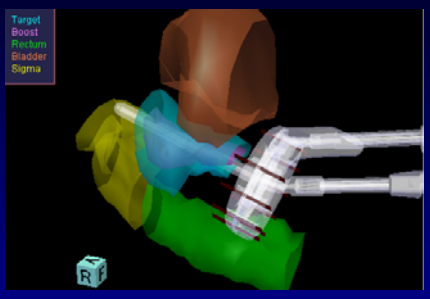
Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group: Considerations and pitfalls in commissioning and applicator reconstruction in 3D image-based treatment planning of cervix cancer brachytherapy

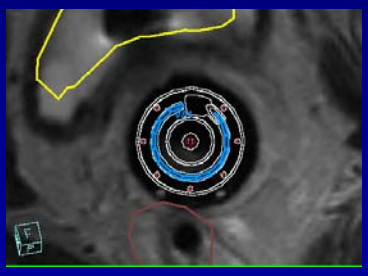
Taran Paulsen Hellebust [a,*], Christian Kirisits [b], Daniel Berger [b], José Pérez-Calatayud [c], Marisol De Brabandere [d], Astrid De Leeuw [e], Isabelle Dumas [f], Robert Hudej [g], Gerry Lowe [h], Rachel Wills [h], Kari Tanderup [i]

SP: Reconstruccion cateteres

Libreria Aplicadores rigidos





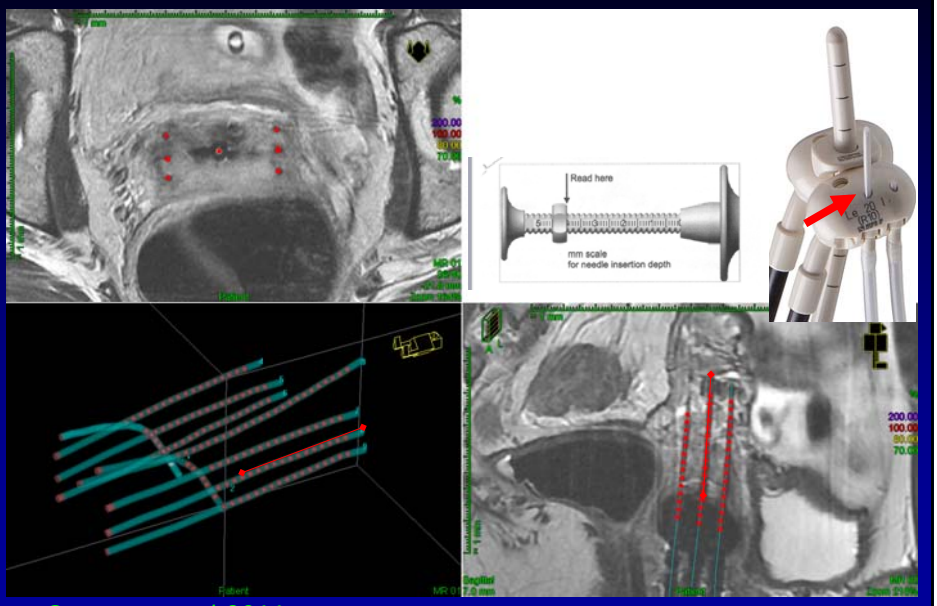


Cervix-Ca: Applicator + Needles
Data by courtesy of University of Vienna

Cortesia D. Baltas [91]

MR SP: Reconstruccion cateteres

No existencia de dummies para algunos tipos de App

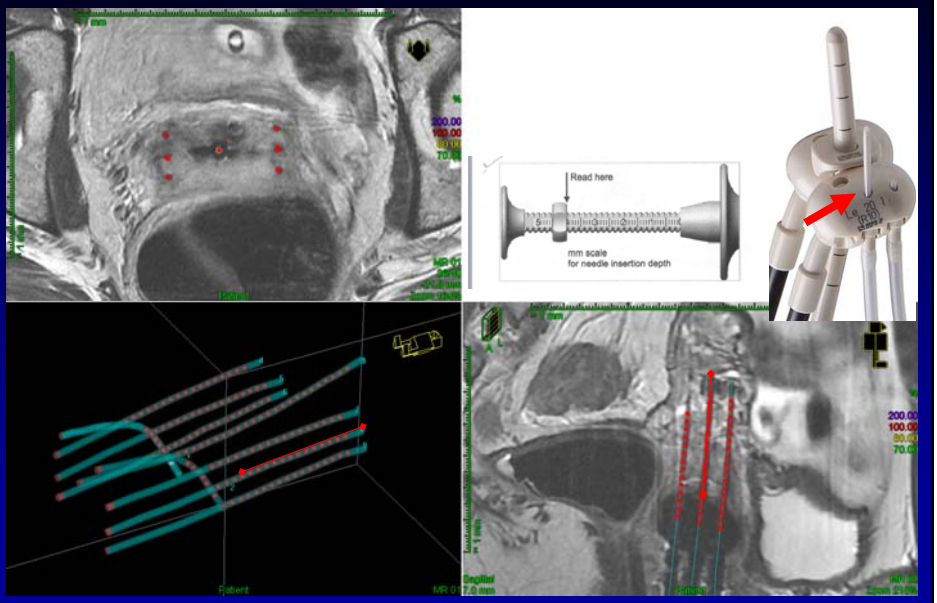


Carmona et al 2011

MR

SP: Reconstruccion cateteres

No existencia de dummies para algunos tipos de App

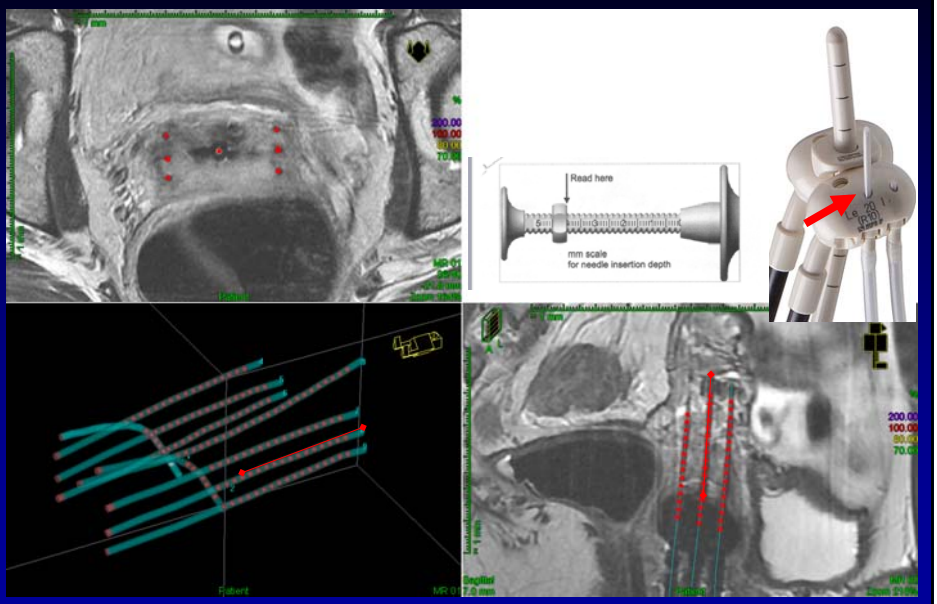


Carmona et al 2011

MR

SP: Reconstruccion cateteres

No existencia de dummies para algunos tipos de App



Carmona et al 2011

MR

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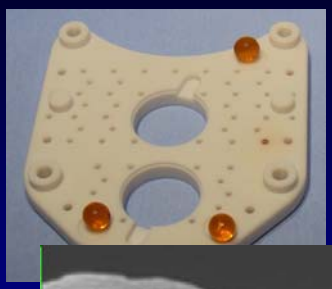
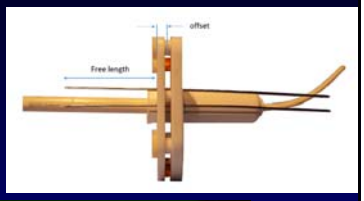
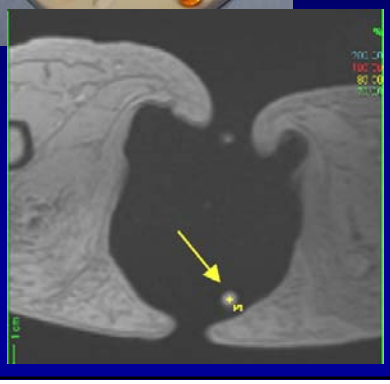
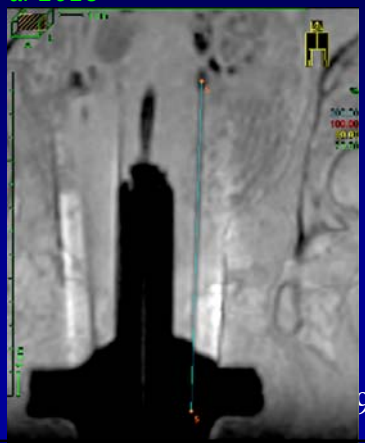




Richart et al 2015





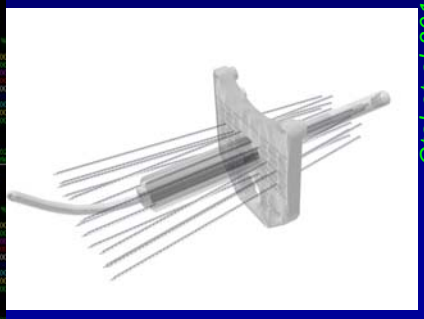
95

MR

SP: Reconstruccion cateteres

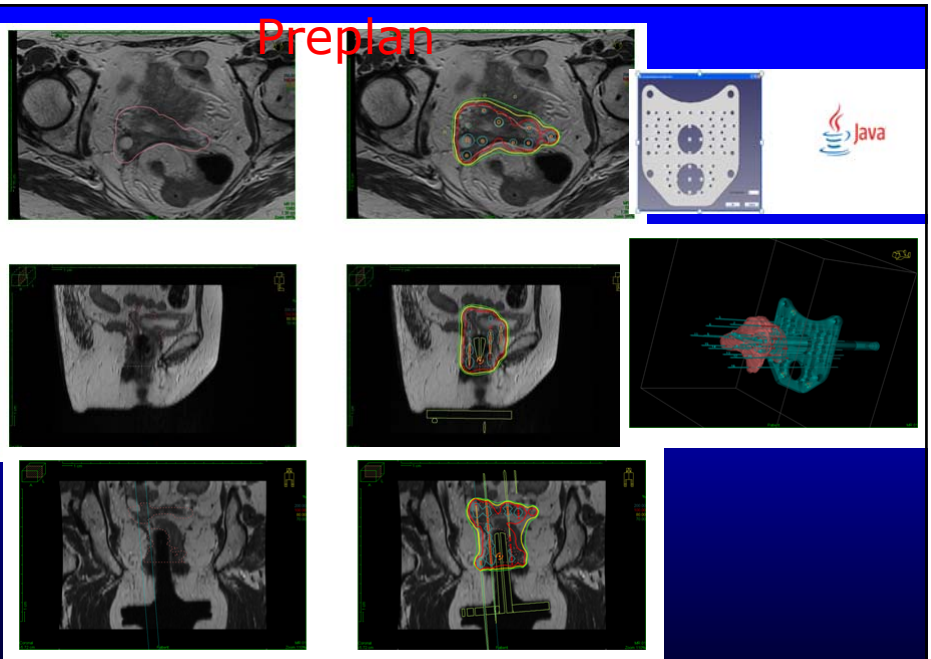
Librería rígida + intersticial específico

Uso con T2



Otal et al 2015, 2016

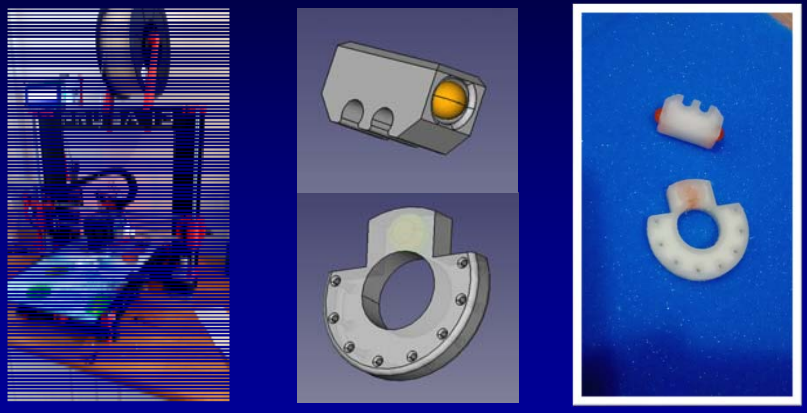
Preplan



Otal A., Richart J., Rodríguez S., Santos M and Pérez Calatayud J. Pre-plan technique feasibility in mulyi-interstitial gynecological brachytherapy. World Congress of Brachytherapy. San Francisco 2016.

☞ Uso de pellets. A Otal et al 2016

☞ 3D printer: Part prototipes with embebed MR markers.

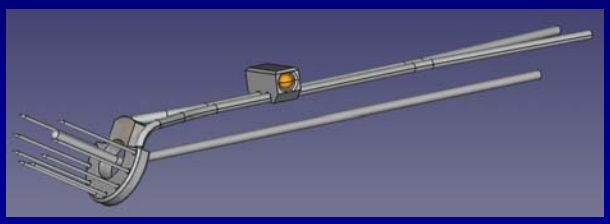


COLABORACION CON BEBIG

98

☞ Uso de pellets. A Otal et al 2016

☞ Proposal of App reconstruction using 3 embebed MR markers.

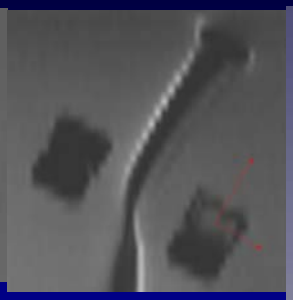


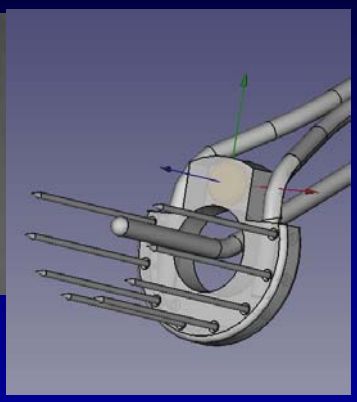
COLABORACION CON BEBIG

99

☞ Uso de pellets. A Otal et al 2016

☞ Proposal of App reconstruction using 3 embebed MR markers.





After positioning the pellet, It's only necessary get the correct orientation.

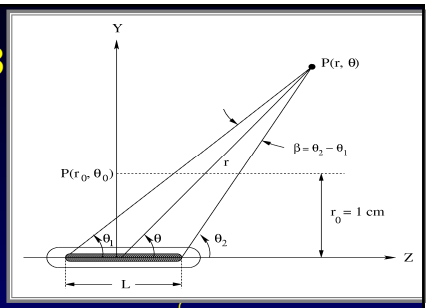
Poor quality here because MR in waterphantom

COLABORACION CON BEBIG

100

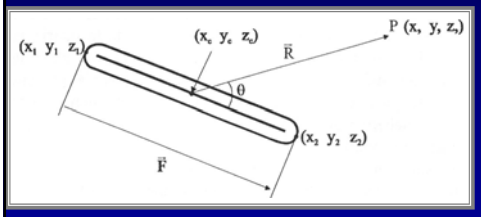
TPS basados en TG-43

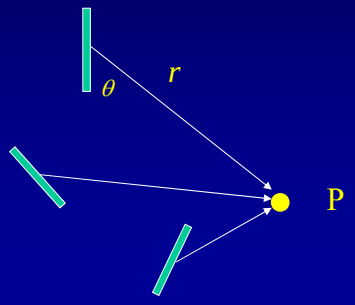
$$\dot{D}(r,\theta) = S_K \Lambda \frac{G_L(r,\theta)}{G_L(r_0,\theta_0)} g_L(r) F(r,\theta),$$



$$\mathbf{FR} = FR\cos\theta$$

$$\mathbf{FR} = (x_2 - x_1)(x - x_C) + (y_2 - y_1)(y - y_C) + (z_2 - z_1)(z - z_C)$$





- Simetría cilíndrica
- Medio agua infinito
- No interfuentes

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Limitaciones TG-43

- Interfuentes — Cs-137, semillas I-125, …
- Defecto scatter — Mama, piel, …
- Blindajes — Ovoides gyn, recto,
- Heterogeneidad tejido — Pulmón
- Dm,m ≠ Dw,w — Baja energía (I-125, Pd-103, kV,)

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Model Based Dosimetric Calculation Algorithms

Interfuentes + Dispersión+ Blindajes + Heterogeneidad (Dm,m)

AAPM-ESTRO WG-MBDCA

- Acuros (Brachyvision Varian)

HDR Ir-192 Varian. Solución determinista ecuación transporte Boltzmann

- ACE (Oncentra Brachy Elekta)

HDR Ir-192 Elekta . "Collapse Cone"

- MC "subminute" (no comerciales)

MC simplificados. Semillas I-125, Pd-103 en próstata

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TG-186: Dm,m vs Dw,w

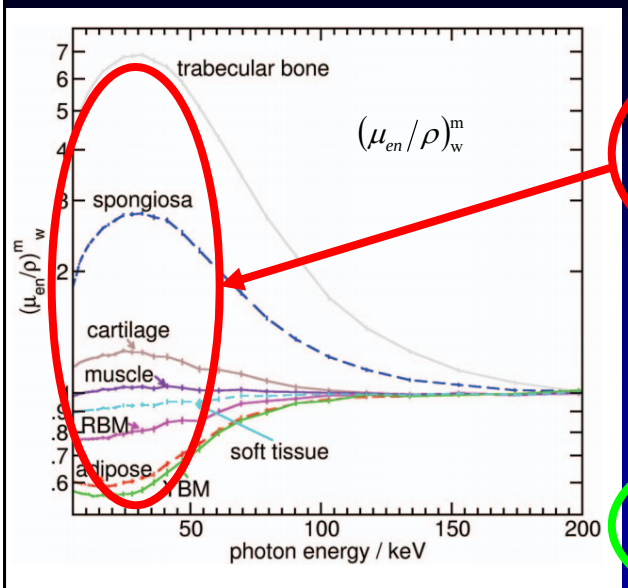

FIG. 1. Mass energy absorption coefficients for the materials indicated relative to those for water for energies from 5 to 200 keV, calculated with the

Pd-103 20.8 keV
I-125 28.5 keV
Cs-131 30.4 keV
eBT 50-70 kV

Ir-192 350 keV
Cs-137 613 keV
Co-60 1253 keV

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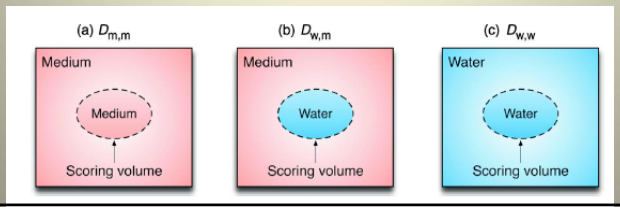
$D_{m,m}$ - $D_{w,TG-43}$

Cortesía de R. Sloboda

Site	Tissue	Radiation Source	$D_{m,m}$ - $D_{w,TG-43}$
prostate	prostate (ICRP 23 & 89)	^{125}I, ^{103}Pd	-10% [1]
eye	homogenized eye (ICRP 23)	^{125}I, ^{103}Pd	-13% [2]
breast	glandular (ICRU 44)	eBT	-15% [1]
lung	lung – blood filled (Woodard & White 1986)	^{125}I	+36% [3]

[1] Taylor REP., MSc thesis, Carleton University, Ottawa, 2006
[2] Thomson RM et al, Med Phys 35:5530-43, 2008
[3] Sutherland JGH et al, Med Phys 39:4365-77, 2012



105

$D_{m,m}$ - $D_{w,TG-43}$

Cortesía de R. Sloboda

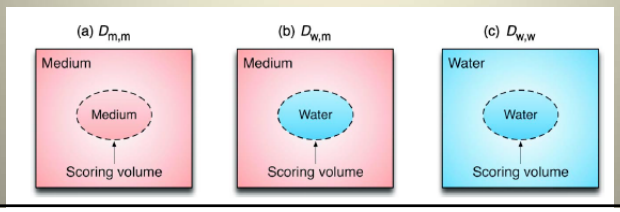
Site	Tissue	Radiation Source	$D_{m,m}$ - $D_{w,TG-43}$

Experiencia clínica actual: $D_{w,w}$

✓ Futuro: implementación $D_{m,m}$

✓ Mejor correlación D vs Outcome

[2] Thomson RM et al, Med Phys 35:5530-43, 2008
[3] Sutherland JGH et al, Med Phys 39:4365-77, 2012



106

TG-186 AAPM-ESTRO

Report of the Task Group 186 on model-based dose calculation methods in brachytherapy beyond the TG-43 formalism: Current status and recommendations for clinical implementation

Luc Beaulieu[a)]
Département de Radio-Oncologie et Centre de Recherche en Cancérologie de l'Université Laval, Centre hospitalier universitaire de Québec, Québec, Québec G1R 2J6, Canada and Département de Physique, de Génie Physique et d'Optique, Université Laval, Québec, Québec G1R 2J6, Canada

Med Phys 2012

- "Maintains TG43 dose prescriptions. Unless societal recommendation otherwise"
- "Model-based dose calculations should be performed in parallel with TG43. Radiation transport using the most accurate tissue medium compositions available"

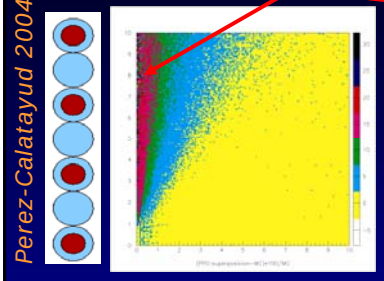
107

Interfuentes

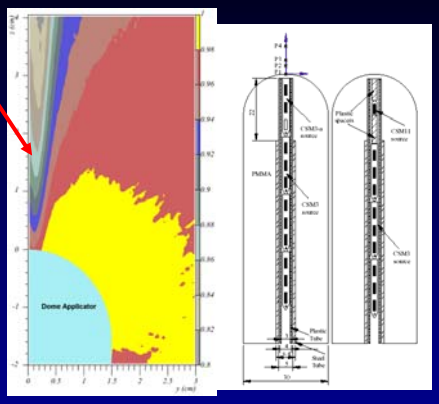
Cs-137 Selectron

15-20 %

Cs-137 tubos

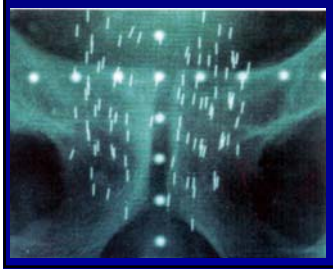


Perez-Calatayud 2004



Perez-Calatayud 2005

I-125 Pd-103 próstata



Reducción D_{90} 2-5%

Chibani 2005

108

☞ Interfuentes

Cs-137 Selectron

15-20 %

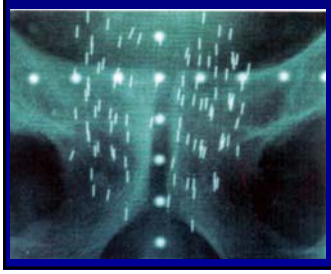
Cs-137 tubos

Perez-Calatayud 2004

LDR Cs-137 → DESUSO

Perez-Calatayud 2005

I-125 Pd-103 próstata



Reducción D_{90} 2-5%

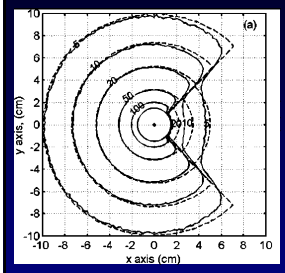
Chibani 2005

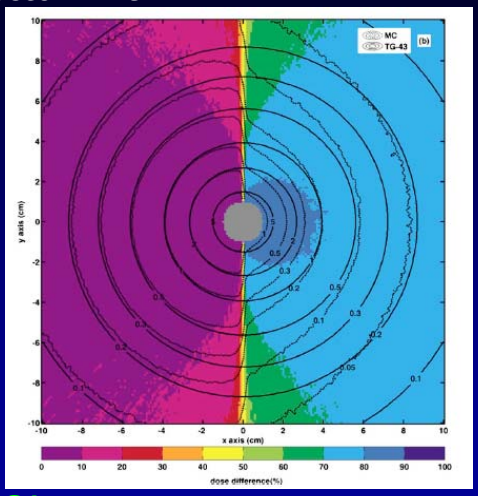
109

☞ Blindajes

Cilíndros vaginales & recto Ir-192

Zourari 2010





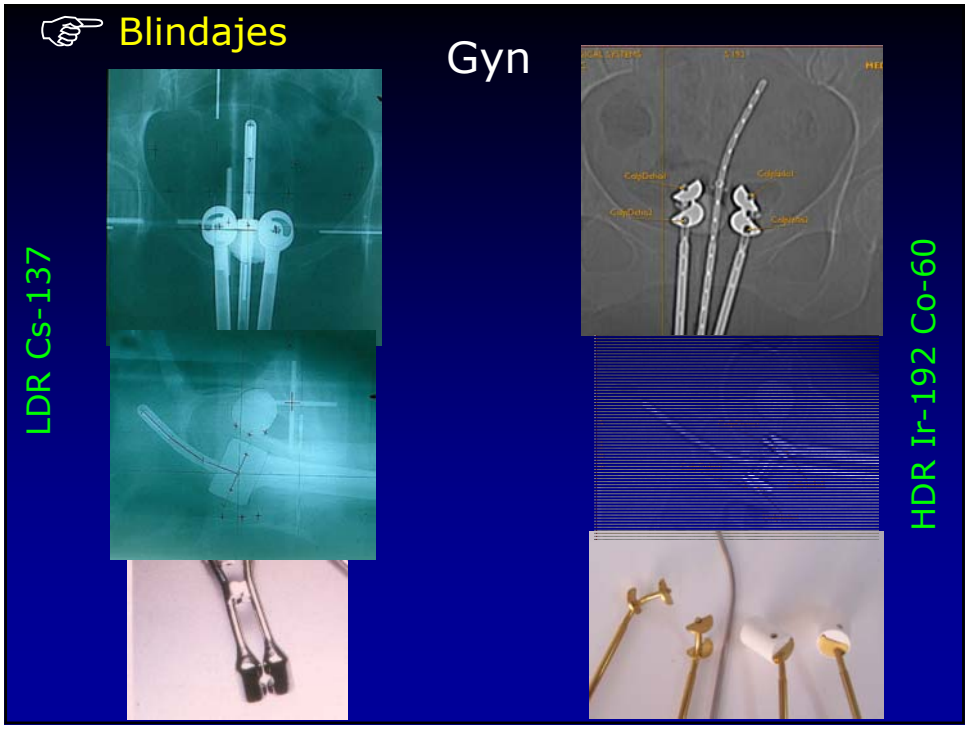
Lymperopoulou 2004
Shureka 2006
Poon 2008

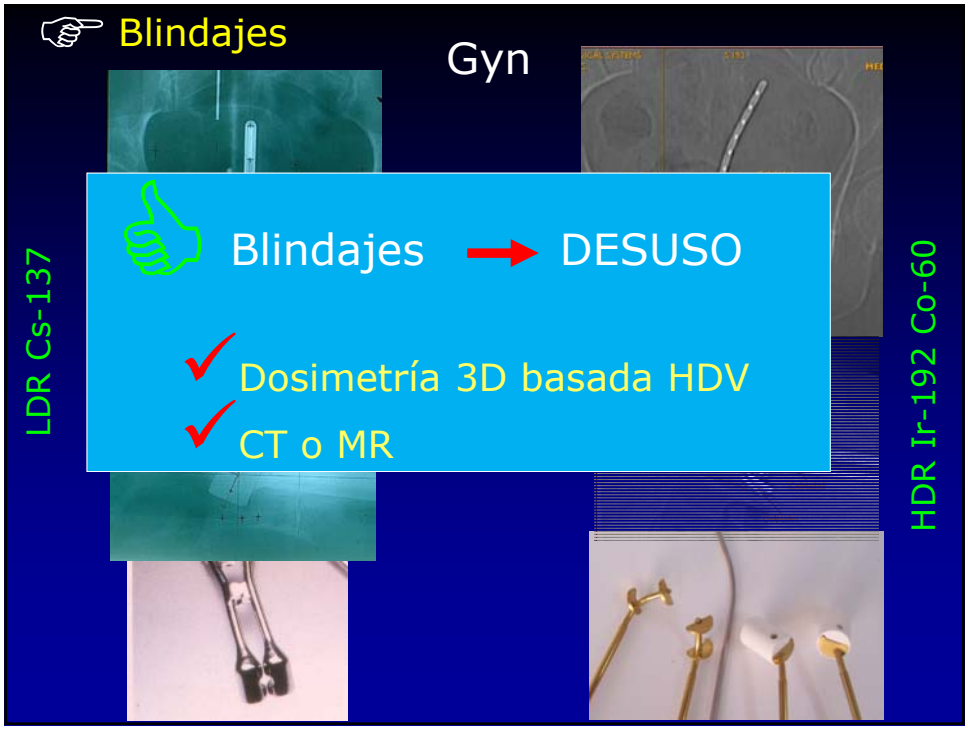
TG-43 vs MC-MBDCA

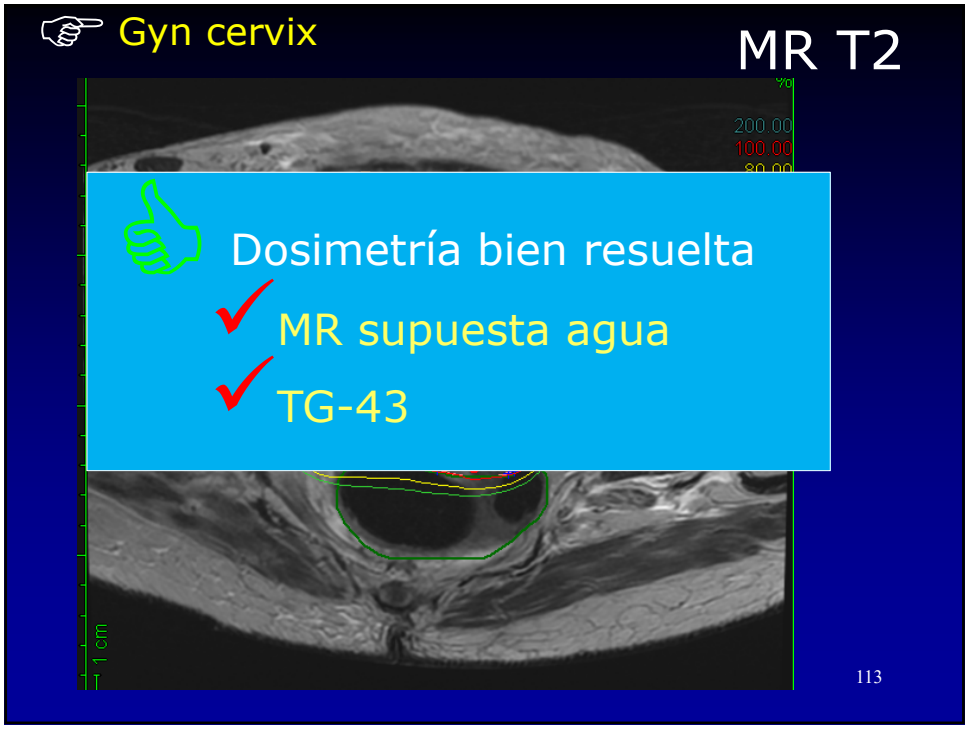
↓

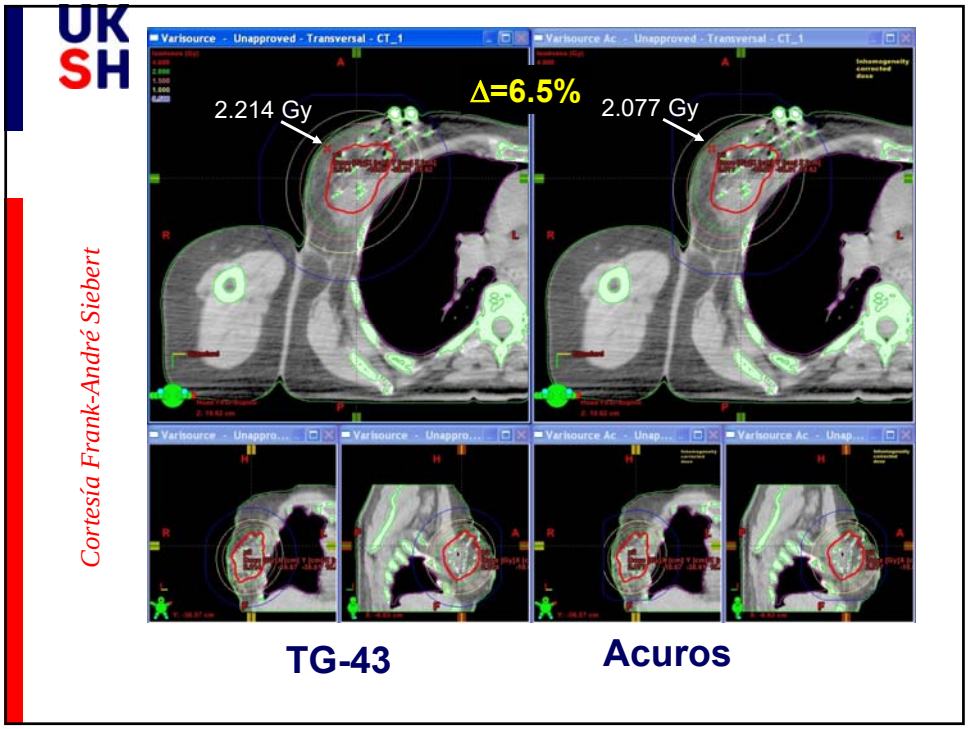
Reducción en bordes por defecto scatter

110


Blindajes
Gyn
LDR Cs-137
HDR Ir-192 Co-60


Blindajes
Gyn
LDR Cs-137
HDR Ir-192 Co-60
Blindajes → DESUSO
Dosimetría 3D basada HDV
CT o MR

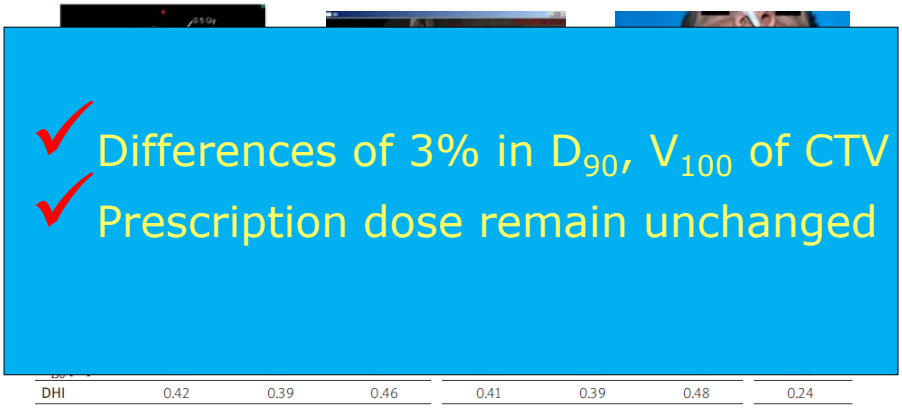

Gyn cervix
MR T2
Dosimetría bien resuelta
MR supuesta agua
TG-43
1 cm
113


UK SH
Cortesía Frank-André Siebert
2.214 Gy
Δ=6.5%
2.077 Gy
TG-43
Acuros

UKSH, Campus Kiel
Clinic of Radiotherapy

Head and neck ^{192}Ir HDR-brachytherapy dosimetry using a grid-based Boltzmann solver

Frank-André Siebert, PhD[1], Sabine Wolf, MD[1], George Kovacs, MD, PhD[2]
[1]Clinic of Radiotherapy, University Hospital of Schleswig-Holstein, Kiel, [2]Interdisciplinary Brachytherapy Unit, University of Luebeck, Luebeck, Germany



- ✓ Differences of 3% in D_{90}, V_{100} of CTV
- ✓ Prescription dose remain unchanged

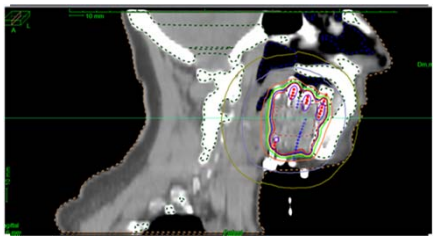
DHI	0.42	0.39	0.46	0.41	0.39	0.48	0.24

Siebert et al. JCBT (2013)

Cortesía Frank-André Siebert

ACE vs TG-43 @ H. La Fe

New joint research project
La Fe – UV – Elekta!!!

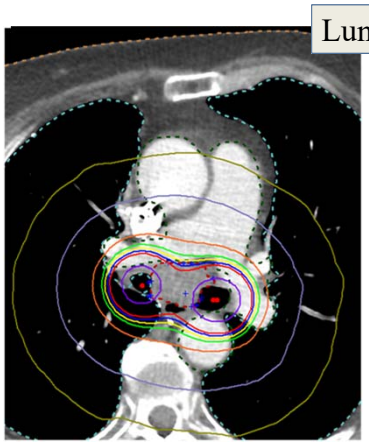


TG43+ACE

Small differences outside the CTV

Tongue

Lung



TG43+ACE

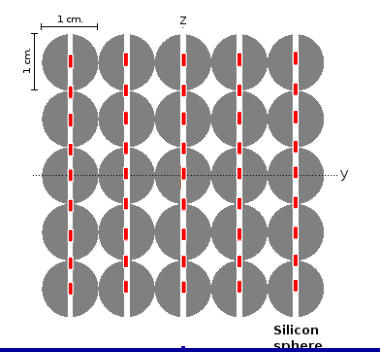
Some differences inside and outside the CTV

☞ Defecto scatter Piel

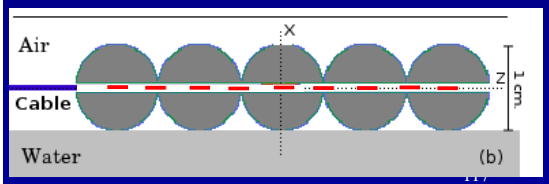
Brachytherapy 2012

Dosimetry comparison between TG-43 and Monte Carlo calculations using the Freiburg flap for skin high-dose-rate brachytherapy

Javier Vijande[1,2,*], Facundo Ballester[1], Zoubir Ouhib[3], Domingo Granero[4], M. Carmen Pujades-Claumarchirant[5], Jose Perez-Calatayud[5]



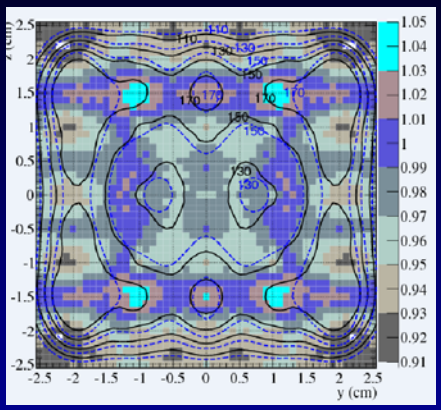
- Evaluar el defecto de scatter y air gaps
- Tipico mesh 5x5 cm²

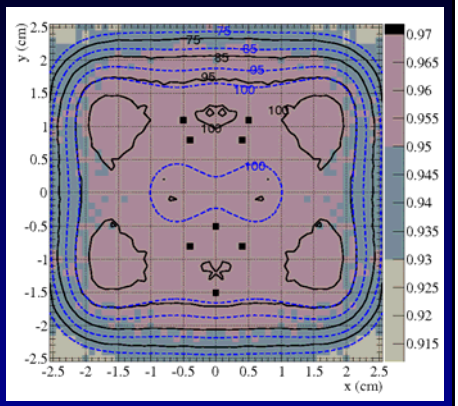


☞ Defecto scatter Piel

Vijande et al 2012

Monte Carlo (MCFF) / TG-43





superficie +5 to -7%

5 mm prof -4 to -7%

Compensación entre esferas

118

Superficial & Intersticial: Se requiere Bolus ??

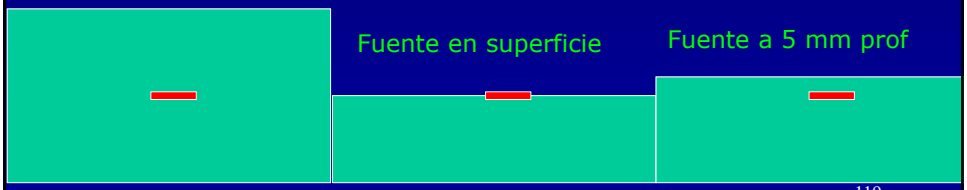
Granero, Perez-Calatayud, Vijande, Ballester, Rivard Med Phys 2014

Uso MC para evaluar:

? Subdosificación debido al defecto de scatter

? Compensation con bolus

Full scatter



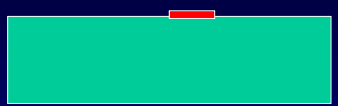
119

Superficial & Intersticial: Se requiere Bolus ??

Granero et al 2014

Ir-192 Co-60

Prof prescripción 5 mm



NO se requiere bolus

Impacto mínimo en el gradiente

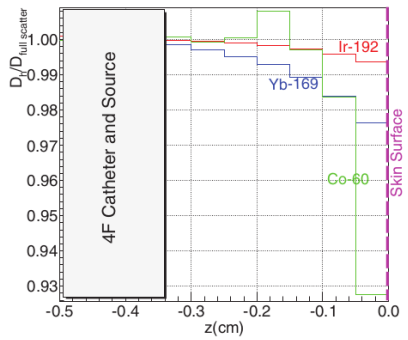
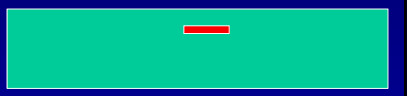


FIG. 8. Ratio between the dose rate distributions for an HDR source inside the 4F catheter below the phantom surface.

Cateter a 5 mm prof

CTV 10 mm prof



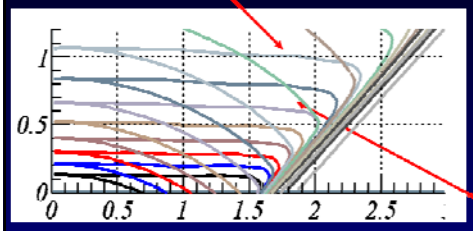
Co-60 bolus > 1-2 mm

120

☞ App blindados

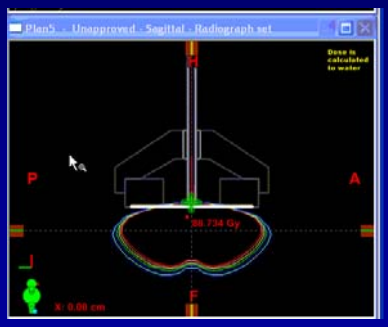
Piel

Valencia

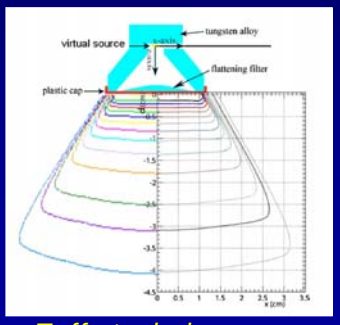


Leipzig

Perez-Calatayud 2005, Granero 2008



Acuros algorithm



Tuffs technique

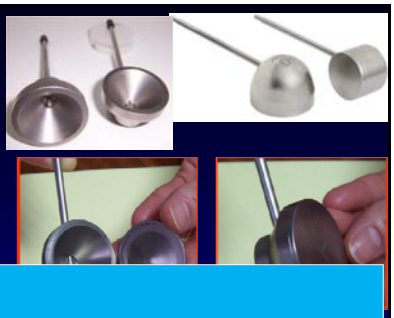
121

Rivard, Melhus, Granero, Perez-Calatayud, Ballester, Rivard Med Phys 2009

☞ App blindados

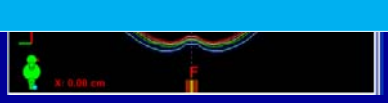
Piel

Valencia

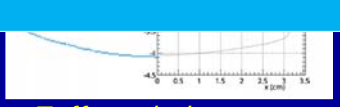


Clínica práctica:

- ✓ Planificación por atlas (flatness & PDD)
- ✓ No CT



Acuros algorithm



Tuffs technique

122

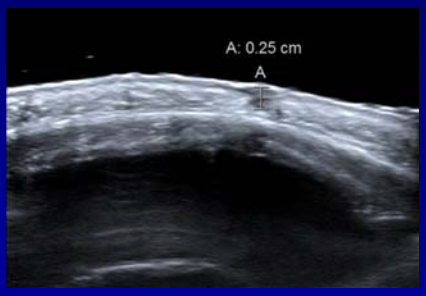
Rivard, M... Perez-Ca... Rivard M...

☞ eBT 50-70 kV
Axxent (Xoft)

Piel

$D_{m,m} \neq D_{w,w}$

US



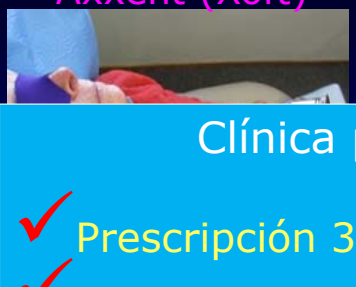
Esteya (Elekta)

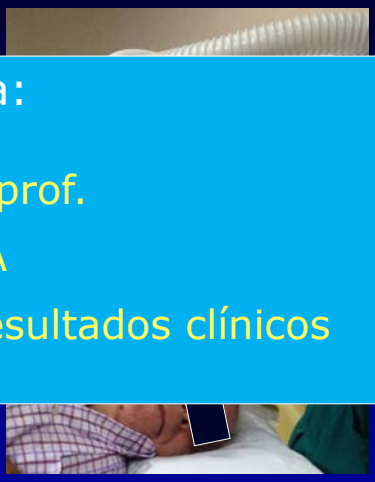
123

☞ eBT 50-70 kV
Axxent (Xoft)

Piel

$D_{m,m} \neq D_{w,w}$





Clínica práctica:

- ✓ Prescripción 3-4 mm prof.
- ✓ Tejido supuesto AGUA
- ✓ Correlacionado con resultados clínicos

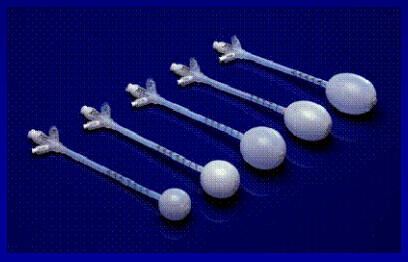
Esteya (Elekta)

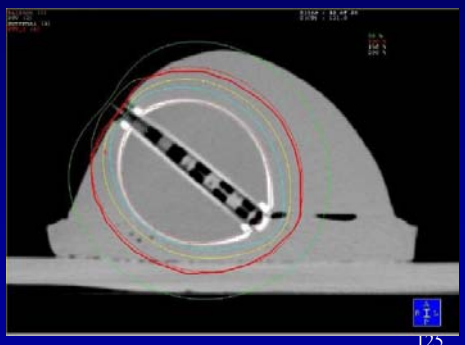
124

☞ eBT 50 kV Mama & vagina

$D_{m,m} \neq D_{w,w}$

Cortesía T W Rusch Xoft





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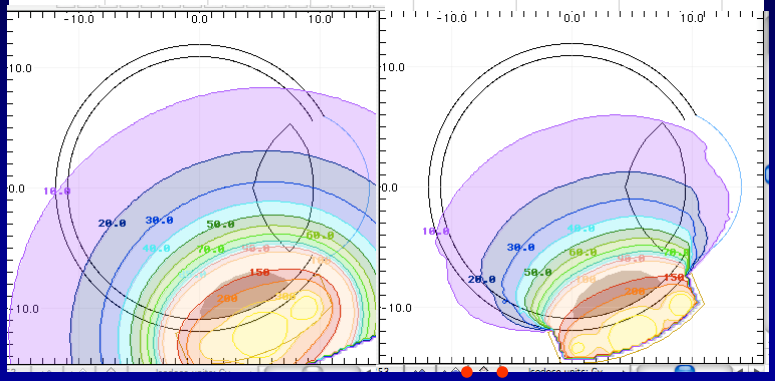
☞ BT ocular (melanoma) placas COMS

Comparación dosis total en punto de prescripción COMS vs USC (University of Suot

Plaque Simulator 5.3.6

Melanomas

Distancia desde la placa (mm)		10,0	6,8	6,5	6,0
Dosis total (Gy)	COMS	85,00	85,00	84,98	84,98
	USC	67,50	65,05	68,87	71,49



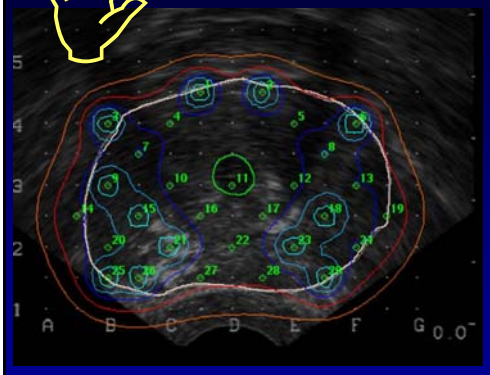
COMS prescribe TG-43

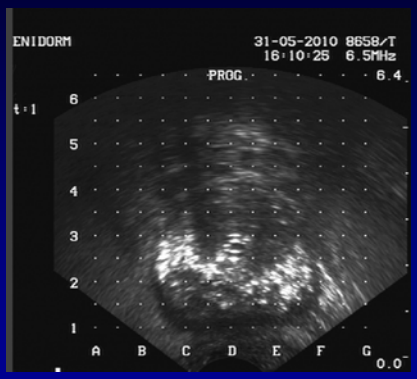
126

Próstata I-125 Pd-103 Cs-131

Medio ⇨ agua

No interfuentes





Calcificaciones 1%-5% del volume prostata (Pd-103)

D_{90} ⬇ 37%

Chibani et al MP 2005

127

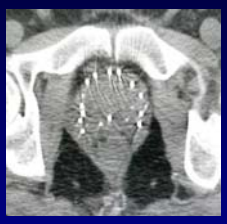
Próstata I-125 Pd-103 Cs-131

Medio ⇨ agua

No interfuentes

MBDCA basados MC

LDR I-125 seeds



Williamson-Chibani 2005

Baltas 2006

Yegin-Taylor-Roger 2006

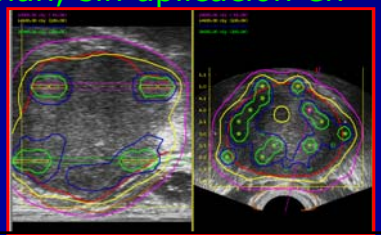
Le-Todor-Williamson 2006

Carrier-Amours-Verhaegen 2007

Poon 2009

.....

Todos basados en CT-postplan, sin aplicacion en intraoperatoria US



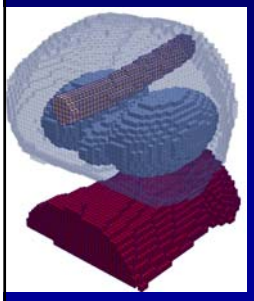
Próstata Raystretch

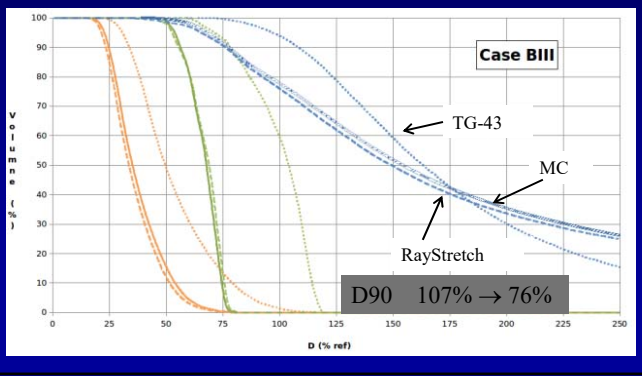
Hueso PMB 2015 y trabajo en progreso

$$\dot{D}(r) = S_k \Lambda \, g_{eq}(r) \left(\frac{r_0}{r}\right)^2$$

$$\Downarrow$$

$$g_{eq}(r) = \begin{cases} g_{water}(r_{eq}) & \text{if outside calcification} \\ \frac{\rho_{water}}{\rho_{Calc}} \frac{1}{L_{Calc}} \int_{Calc} g_{water}(r')\,dr' & \text{if inside calcification} \end{cases}$$





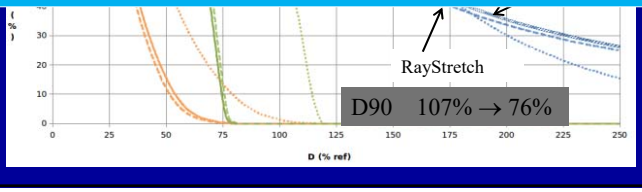
Próstata Raystretch

Hueso PMB 2015 y trabajo en progreso

$$\dot{D}(r) = S_k \Lambda \, g_{eq}(r) \left(\frac{r_0}{r}\right)^2$$

Clínica práctica:

- ✓ % calcificaciones pequeña...
- ✓ Buena correlación dosimetria agua con resultados clínicos
- ✓ Paso gradual a HDR Ir-192 Co-60 en bajo riesgo...



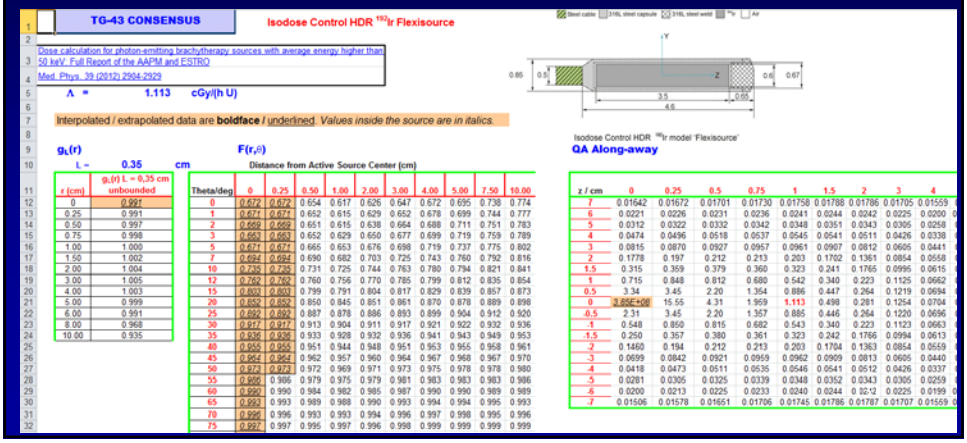
AAPM-ESTRO Consensus Datasets:

AAPM-IROC rpc.mdanderson.org/rpc

ESTRO www.estro.org/about/governance-organisation/committees activities/gec-estro-braphyqs

Valencia www.uv.es/braphyqs

Excel



MBDCA Commissioning

- BV-ACUROS & ACE HDR Ir-192
- TG-186 y WGMBDCA

A generic high-dose rate ^{192}Ir brachytherapy source for evaluation of model-based dose calculations beyond the TG-43 formalism

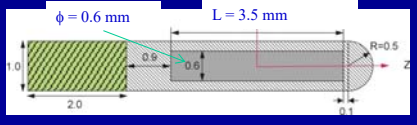
Med Phys 2015

Facundo Ballester[a)]
Department of Atomic, Molecular and Nuclear Physics, University of Valencia, Burjassot 46100, Spain

Åsa Carlsson Tedgren
Department of Medical and Health Sciences (IMH), Radiation Physics, Faculty of Health Sciences, Linköping University, Linköping SE-581 85, Sweden and Department of Medical Physics, Stockholm SE-171 76, Sweden

Domingo Granero
Department of Radiation Physics, ERESA, Hospital General Universitario, Val

Generic HDR ^{192}Ir source MBDCA model



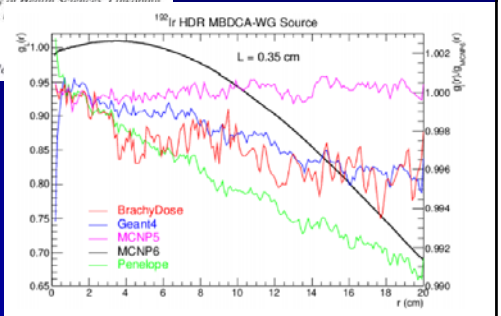
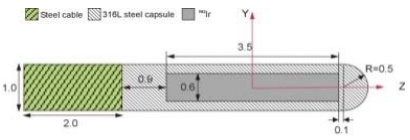


FIG. 2. Radial dose function (left axis) calculated with MCNP6 and the ratios (right axis) from the other MC codes to MCNP6.

WG-MBDCA Test cases

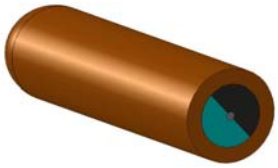
DICOM (512 mm)^3
(1 mm)^3 voxel

Generic HDR
^{192}Ir source



HDR ^{192}Ir model MBDCA-WG source

Shielded GYN applicator

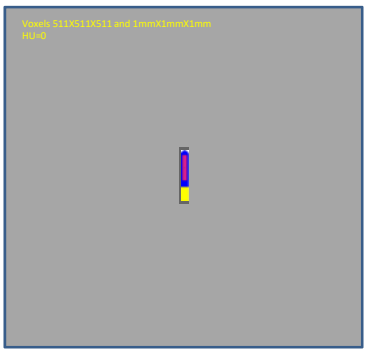


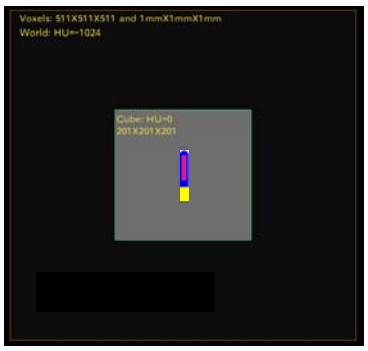
	Material	Elemental composition	Mass Density (g/cm^3)
Body	PMMA	$C_5O_2H_8$	1.19
Shield	Densimet D176	Fe (2.5%), Ni (5%), W (92.5%)	17.6

Cortesía J. Vijande

WG-MBDCA Test cases

- Test case 1
- Test case 2





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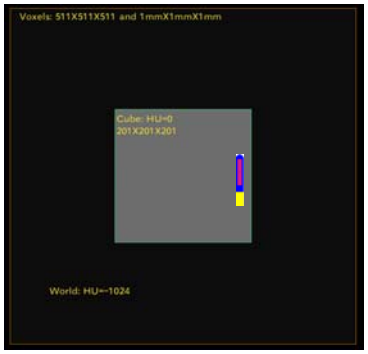
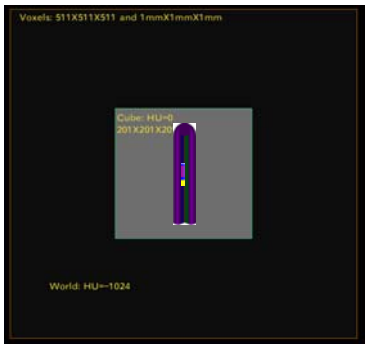
Cortesía J. Vijande

WG-MBDCA Test cases

- Test case 3



- Test case 4



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Cortesía J. Vijande

VNIVERSITAT DE VALÈNCIA

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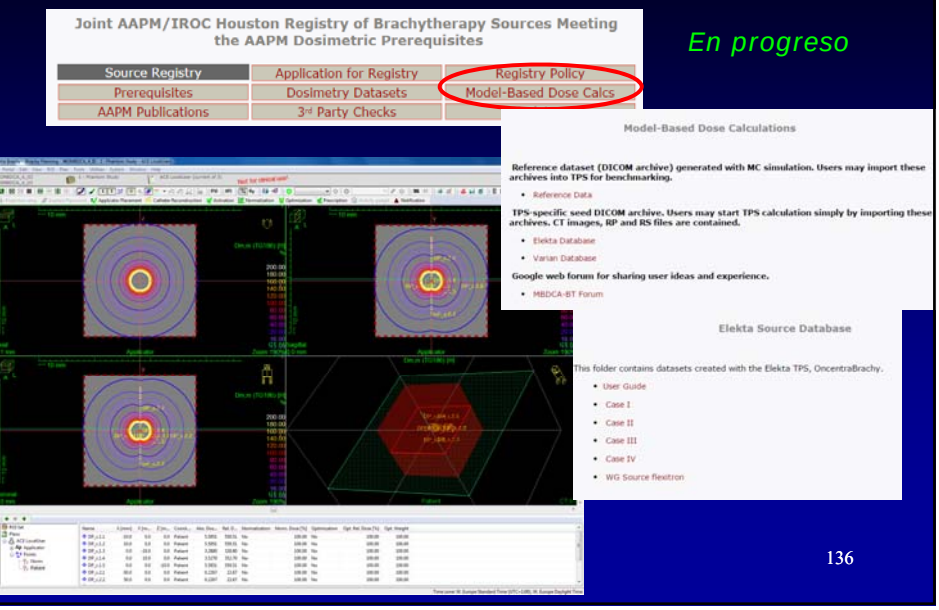

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Contenido

- BT vs RTE.
- Fuentes en BT: LDR, PDR, HDR.
- BT en Próstata.
- BT en Cervix.
- BT en Piel.
- Planificación: Reconstrucción de Aplicadores.
- Planificación: Nuevos Algoritmos.
- QA Sistemas de Planificación
- Calibración en BT.
- Dosimetría "in vivo"
- Nuevas tendencias QM
- Incertidumbres
- Conclusiones

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Calibracion

NIST, PTB, NPL, LNHB, NMi

Trazabilidad desde Labs a Hospitales todas fuentes en uso

Incertidumbre a 1cm 3-4% (k=1)

OBJETIVO 2% (k=1)

Calibración en agua *Siebert 2012*

Cortesy H.-J. Selbach PTB

Grovex II

I-125 Pd-103

Water Calorimeter

HDR Ir-192

Dependence with air density of the response of the PTW SourceCheck ionization chamber for low energy brachytherapy sources

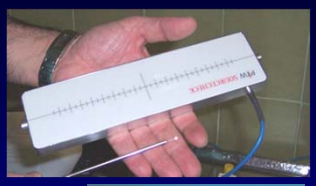
Ana M. Tornero-López, Damián Guirado, Jose Perez-Calatayud, Samuel Ruiz-Arrebola, Fernando Simancas, Maja Gazdic-Santic, and Antonio M. Lallena

Med Phys 2013

SelectSeed

$K_{P,T} = (T/T_0)\times(P_0/P) = (\rho/\rho_0)^{-1}$

$$g_1(\rho) \equiv \frac{1}{y(\rho)} = \left[A\left(\frac{\rho}{\rho_0} - 1\right) + 1\right]^{-1}$$



A dependiente de cada ejemplar

Torres del Rio *et al* ESTRO 2015

A = -0.49±0,02

Nueva SourceCheck independiente de cada ejemplar

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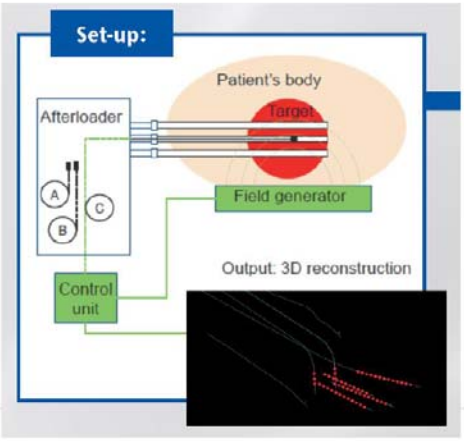
Verificación posición

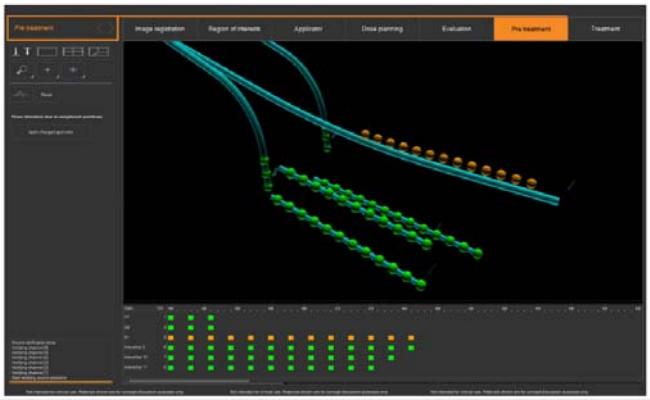
Implant Verification by Electro-Magnetic Tracking



140

Verificación posición

Pre-treatment verification



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Verificación posición

Conclusions

- Brachytherapy is very beneficial for many patients
- Highly conformal therapy
- Changes may occur during treatment delivery
- Further steps in improving treatment certainty needed
- Image guidance and implant verification can provide certainty
- Benefits of Implant Tracking
  - √ Integrated solution
  - √ Straightforward workflow
  - √ No need for in-room imaging
  - √ Reduces many uncertainties

ELEKTA

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AVANCES

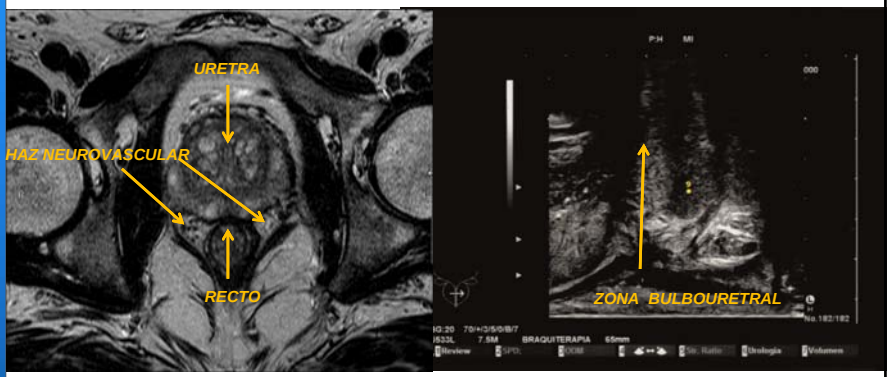
CORTESIA P. PRADA

MICRO MOSFET

AVANCES

CORTESIA P. PRADA

MICRO MOSFET



In Vivo

Lambert 2007

In vivo dosimetry in brachytherapy

Kari Tanderup[a)]
Department of Oncology, Aarhus University Hospital, Aarhus 8000, Denmark and Depar
Medicine, Aarhus University, Aarhus 8000, Denmark

Sam Beddar
Department of Radiation Oncology, The University of Texas MD Anderson Cancer Cente
Texas 77030

Claus E. Andersen and Gustavo Kertzscher
Center of Nuclear Technologies, Technical University of Denmark, Roskilde 4000, Denma

Joanna E. Cygler
Department of Physics, The Ottawa Hospital Cancer Centre, Ottawa, Ontario K1H 8L6,

(Received 15 January 2013; revised 12 April 2013; accepted for publication 16 A
published 25 June 2013)

In vivo dosimetry (IVD) has been used in brachytherapy (BT) for decades with a detectors and measurement technologies. However, IVD in BT has been subject to certain difficulties and complexities, in particular due to challenges of the high-gradient BT dose distribution and the large range of dose and dose rate. Due to these challenges, the sensitivity and specificity toward error detection has been limited, and IVD has mainly been restricted to detection of gross errors. Given these factors, routine use of IVD is currently limited in many departments. Although the impact of potential errors may be detrimental since treatments are typically administered in large fractions and with high-gradient-dose-distributions, BT is usually delivered without independent verification of the treatment delivery. This Vision 20/20 paper encourages improvements within BT safety by developments of IVD into an effective method of independent treatment verification. © *2013 American Association of Physicists in Medicine*. [http://dx.doi.org/10.1118/1.4810943]

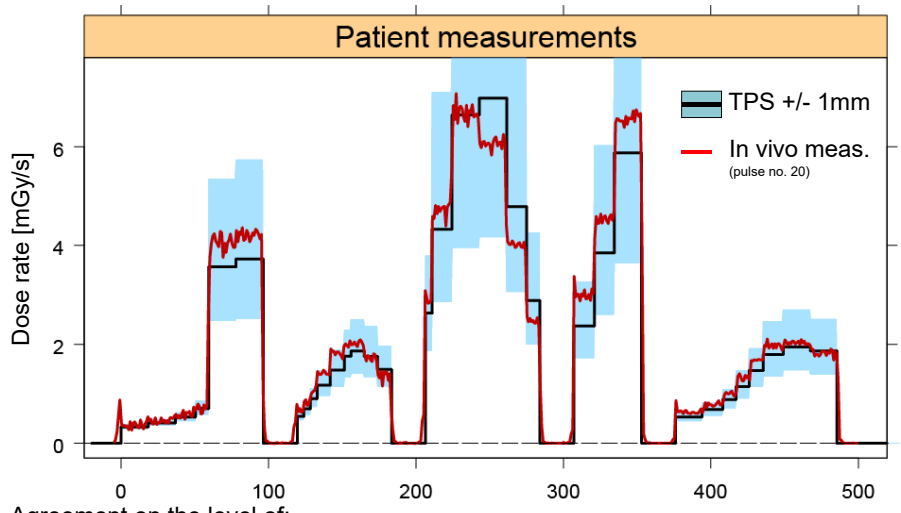
In Vivo

TABLE III. Characteristics of detectors and dosimetry systems of importance for precise routine IVD in brachytherapy. The items are rated according to: advantageous (++), good (+), and inconvenient (−).

	TLD	Diode	MOSFET	Alanine	RL	PSD
Size	+	+/−	+/++	−	++	++
Sensitivity	+	++	+	−	++	+/++
Energy dependence	+	−	−	+	−	++
Angular dependence	++	−	+	+	++	++
Dynamic range	++	++	+	−	++	++
Calibration procedures, QA, stability, robustness, size of system, ease of operation	+	++	++	−	−/+	+/++
Commercial availability	++	++	++	++	−	+
Online dosimetry	−	++	+	−	++	++
Main advantages	No cables, well studied system	Commercial systems at reasonable price, well studied system	Small size, commercial system at reasonable price	Limited energy dependence, no cables	Small size, high sensitivity	Small size, no angular and energy dependence, sensitivity
Main disadvantages	Tedious procedures for calibration and readout, not online dosimetry	Angular and energy dependence	Limited life of detectors, energy dependence	Not sensitive to low doses, tedious procedures for calibration and readout, not online dosimetry, expensive readout equipment not available in clinics	Needs frequent recalibration, stem effect, not commercially available	Stem effect

Time-resolved dose verification

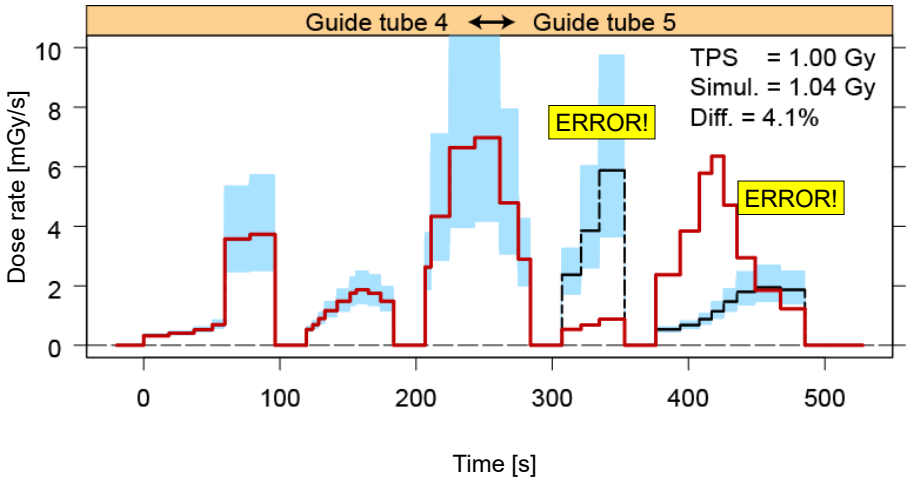
Cortesia Kari Tanderup



Agreement on the level of:
pulse / applicator / dwell position

Simulated errors (part of the protocol evaluation)

Cortesia Kari Tanderup

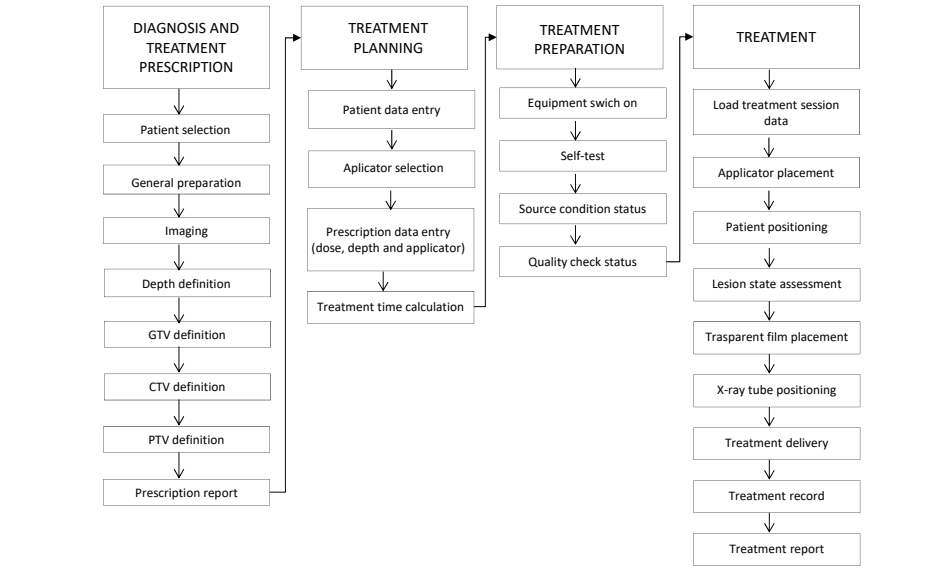


No significant implication on the integrated dose, but
the error clearly shows up in the time-resolved dose verification.

FMEA Valencia H La Fe (TG-253 TG-100)

#	Process mode	Failure mode	Cause	Effect	O	S	D
1.1	**Patient selection**	Inadequate selection	Not sufficient training	Wrong indication	1	4	9
1.2			Inattention	Wrong indication	1	4	9
2.1	**General preparation**	No patient agreement document	Not sufficient training	Legal issues	1	2	9
2.2			Inattention	Legal issues	3	2	9
2.3		Treatment explanation to the patient	Not sufficient training	Legal issues and patient discomfort	1	2	4
2.4			Inattention	Legal issues and patient discomfort	1	2	4
3.1	**Imaging**	Wrong depth	Not sufficient training	Over or under dose	1	7	9
3.2			Inattention	Over or under dose	2	7	9
3.3			US uncertainty	Over or under dose	3	7	9
4.1	**Volumes definition**	Wrong GTV with dermoscopy	Not sufficient training	Over or under dose	1	7	9
4.2			Inattention	Over or under dose	2	7	9
4.3		Wrong CTV (margin)	Not sufficient training	Over or under dose	1	7	9
4.4			Inattention	Over or under dose	2	7	9
4.5		Wrong PTV (margin)	Not sufficient training	Over or under dose.	1	7	9
4.6			Inattention	Over or under dose.	2	7	9
4.7			Wrong Template used	Over or under dose.	1	7	9
5.1	**Applicator selection**	Wrong applicator selection	Not sufficient training	Over or under dose	1	7	5

RESULTS PM



RESULTS FMEA

AAPM2016 JUL 31–AUG 4 COMMUNICATING OUR VALUE. IMPROVING OUR FUTURE. 58TH ANNUAL MEETING & EXHIBITION | WASHINGTON, DC

#	Step	Failure Mode	Cause	Effect	O	S	D	RPN
137	X-ray tube positioning	Insufficient pressure	Heavy patient workload	Wrong dose distribution	(4) 4	6	(5)5	(126) 126
121	Patient positioning	Patient movement	Uncomfortable patient position	Wrong dose distribution	(4) 4	6	(5)4	(141) 101
122	Patient positioning	Patient movement	No sufficient attachment elements	Wrong dose distribution	(4) 4	6	(5)4	(144) 101
136	X-ray tube positioning	Insufficient pressure	Inattention	Wrong dose distribution	(4) 3	6	(5)5	(106) 94
56	Prescription report	Wrong lesion in a pat with multiple lesions	Heavy patient workload	Wrong treatment delivery	(4) 4	7	(6)3	(178) 79
125	Lesion state assessment	Wrong lesion in a pat with multiple lesions	Heavy patient workload	Wrong treatment delivery	(4) 4	6	(6)3	(147) 75
138	X-ray tube positioning	Insufficient pressure	Equipment or software malfunction	Wrong dose distribution	(3) 3	6	(4)4	(84) 75
13	Imaging	Inadequate image	Heavy patient workload	Wrong dose distribution	(4) 4	6	(6)3	(145) 72
17	Depth definition	Wrong depth definition	Heavy patient workload	Wrong dose distribution	(4) 4	6	(7)3	(160) 72
74	Prescription data entry	Wrong depth	Heavy patient workload	Wrong dose distribution	(3) 3	7	(6)3	(145) 62
5	Patient selection	Inadequate selection	Heavy patient workload	Suboptimal treatment	(4) 4	5	(7)3	(147) 60
6	Patient selection	Inadequate selection	Heavy patient workload	Suboptimal treatment	(4) 4	5	(7)3	(142) 60
20	Depth definition	Assignment of lesion depth to another lesion	Heavy patient workload	Wrong dose distribution	(3) 3	6	(6)3	(137) 58
53	Prescription report	Wrong pat data	Heavy patient workload	Wrong treatment delivery	(4) 4	7	(4)2	(98) 54
71	Prescription data entry	Wrong doses per fraction	Heavy patient workload	Wrong treatment delivery	(4) 4	7	(4)2	(91) 54
77	Prescription data entry	Wrong applicator	Heavy patient workload	Wrong dose distribution	(4) 4	7	(4)2	(92) 54
38	Prescription report	Wrong total dose	Heavy patient workload	Wrong absolute dose	(4) 4	7	(4)2	(89) 53
41	Prescription report	Wrong dose per fraction	Heavy patient workload	Wrong absolute dose	(4) 4	6	(4)2	(97) 51
134	X-ray tube positioning	Offset X-ray tube	Heavy patient workload	Wrong dose distribution	(4) 4	6	(4)2	(114) 51
44	Prescription report	Wrong fraction	Heavy patient workload	Wrong absolute dose	(4) 4	6	(4)2	(96) 50
68	Prescription data entry	Wrong fraction number	Heavy patient workload	Wrong treatment delivery	(4) 4	6	(4)2	(85) 50

RESULTS FMEA

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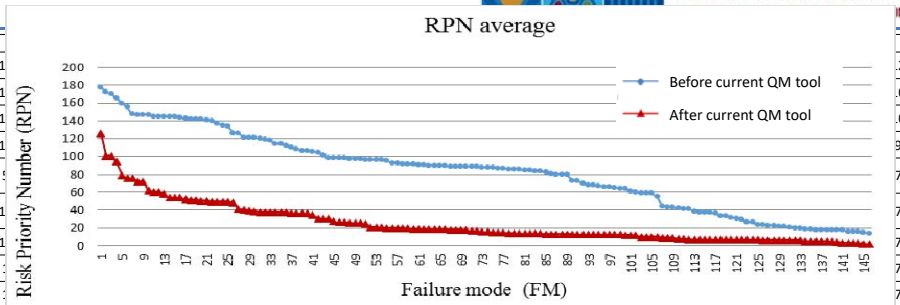

146 FM were identified:

- Initially, 43 of which had RPN ≥ 100 and 30 had S ≥ 7.
- After introduction of the tools of quality management, only 3 FM had RPN ≥ 100 and 21 FM had RPN ≥ 50.

These 21 FM were thoroughly analyzed and new tools for quality management were proposed.

RESULTS

CURRENT QUALITY MANAGEMENT TOOLS

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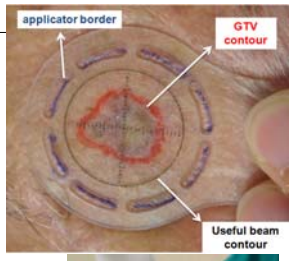
Quality Management tools

1 Adequate training
2 Recheck treatment indication
3 Previous first treatment fraction to check patient's agreement
4 Adequate protocols and supervision to claim for the required attention
5 Checklist of each procedure
6 Standard communication paper between doctor and medical physicist
7 Check the plan with an independent evaluation.
8 Periodic quality audits
9 Periodic training refresh
10 Templates clearly labeled and with rulers in main axis
11 Independent treatment time calculation with spreadsheet
12 Second revision of the calculated treatment time by another medical physicist
13 Threshold prescription depth (3 mm selected for depth smaller than 3 mm)
14 Zoom TV of treatment area
15 Second TV controlling the patient position
16 Patient face picture
17 Lesion identification picture
18 Set-up picture
19 Identification by voice of patient: First and Family Name
20 QA graphic: The number of fractions, planning of treatment and accumulated dose are reviewed for each patient
21 Flatness and symmetry of the applicator of 30 cm
22 Periodic output and Percentage depth dose curves
23 Automatic detection of the applicator placed on the head software



Incertidumbres

Guidelines

Review of clinical brachytherapy uncertainties: Analysis guidelines of GEC-ESTRO and the AAPM ☆

Christian Kirisits [a,*], Mark J. Rivard [b], Dimos Baltas [c], Facundo Ballester [d], Marisol De Brabandere [e], Rob van der Laarse [f], Yury Niatsetski [g], Panagiotis Papagiannis [h], Taran Paulsen Hellebust [i,j], Jose Perez-Calatayud [k], Kari Tanderup [l], Jack L.M. Venselaar [m], Frank-André Siebert [n]

2014

Table 5
Example 5 – HDR ^{192}Ir source for temporary prostate BT.

Category	Typical level (%)	Assumptions
Source strength	2	PSDL traceable calibrations
Treatment planning	3	Reference data with the appropriate bin width
Medium dosimetric corrections	1	Full scatter conditions in the pelvic region and for the prostate location are assumed
US-based Treatment planning and delivery: Catheter reconstruction and source positioning accuracy	2	Assuming usage of dedicated catheter reconstruction tools (catheter free-length measurement based methods) for an accurate (0.7 mm) reconstruction of catheter tip and 1.0 mm source positioning accuracy by the afterloader for straight catheters and transfer tubes
US-based 2D and 3D-imaging overall effect	2	US QA performed according to AAPM TG-128 report
Changes of catheter geometry relative to anatomy between intraoperative treatment planning and intraoperative treatment delivery	2	Assuming that new image acquisition and treatment plan calculation is done always before each fraction. It is also required that no manipulation of the implant and anatomy occurs, as it is the case when removing/manipulating the US-probe or moving the patient from the operation table before treatment delivery
Target contouring uncertainty	2	Using CT or CT + T2 imaging
Total dosimetric uncertainty ($k = 1$)	**5**	For treatment delivery without patient movement and changes in the lithotomic set-up and with the US probe at the position of the acquisition (transversal plane at the prostate base)

Guidelines

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2014

HDR- Ir-192 for intracavitary, image-guided cervical cancer

D_{90} HR-CTV

2	Source strength	(PSDL traceable calibration)
3	Treatment Planning	(Consensus data)
1	Medium dosimetric corrections	(Scatter)
4	Dose delivery	(Comm & QA app, positioning, app reconstruction) …
11	Interfraction/intrafraction changes	(Countouring uncertainties, one plan per application but several fractions,…)
12	k=1	

Guidelines

Review of clinical brachytherapy uncertainties: Analysis guidelines of GEC-ESTRO and the AAPM ☆

Christian Kirisits [a,*], Mark J. Rivard [b], Dimos Baltas [c], Facundo Ballester [d], Marisol De Brabandere [e], Rob van der Laarse [f], Yury Niatsetski [g], Panagiotis Papagiannis [h], Taran Paulsen Hellebust [i,j], Jose Perez-Calatayud [k], Kari Tanderup [l], Jack L.M. Venselaar [m], Frank-André Siebert [n]

2014

HDR- Ir-192 for intracavitary, image-guided cervical cancer

D_{90} HR-CTV

2	Source strength	(PSDL traceable calibration)
3	Treatment Planning	(Consensus data)
1	Medium dosimetric corrections	(Scatter)
~~4~~	Dose delivery	(Comm & QA app, positioning, app reconstruction) …
~~11~~	Interfraction/intrafraction changes	(Countouring uncertainties, one plan per application but several fractions,…)
12	k=1	
↓		
7	←	Assuming 4 fx with non-systematic organ changes in-between

Guidelines

Review of clinical brachytherapy uncertainties: Analysis guidelines of GEC-ESTRO and the AAPM ☆

Christian Kirisits [a,*], Mark J. Rivard [b], Dimos Baltas [c], Facundo Ballester [d], Marisol De Brabandere [e], Rob van der Laarse [f], Yury Niatsetski [g], Panagiotis Papagiannis [h], Taran Paulsen Hellebust [i,j], Jose Perez-Calatayud [k], Kari Tanderup [l], Jack L.M. Venselaar [m], Frank-André Siebert [n]

2014

HDR- Ir-192 for intracavitary, image-guided cervical cancer

D_{90} HR-CTV

2 Source strength (PSDL traceable calibration)

3 Treatment Planning (Consensus data)

1 Medium dosimetric corrections (Scatter)

~~4~~ Dose delivery (Comm & QA app, positioning, app reconstruction) …

~~11~~ Interfraction/intrafraction changes (Countouring uncertainties, one plan per application but several fractions,…)

12 → 5 k=1

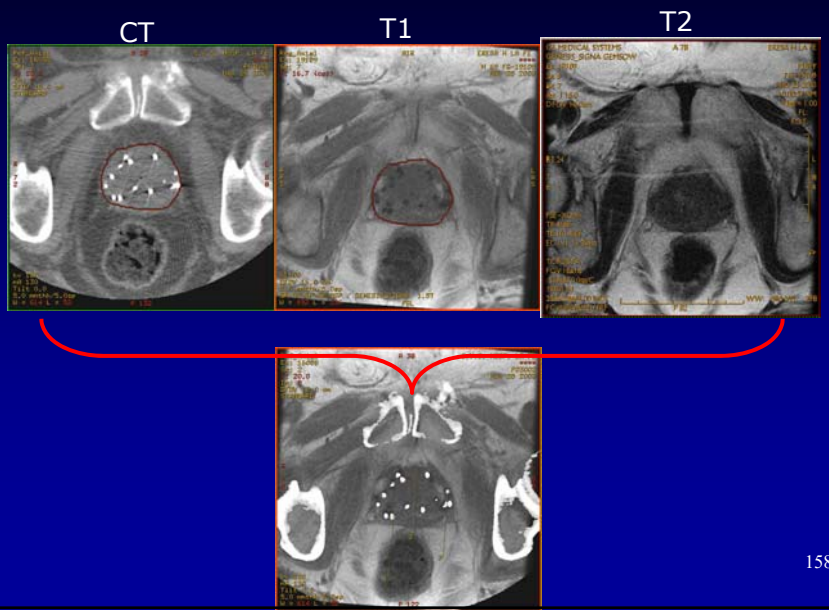
Additional 3D imaging prior each fx

Próstata LDR

Postplan 1 mes

Recomendado CT-MR

CT T1 T2



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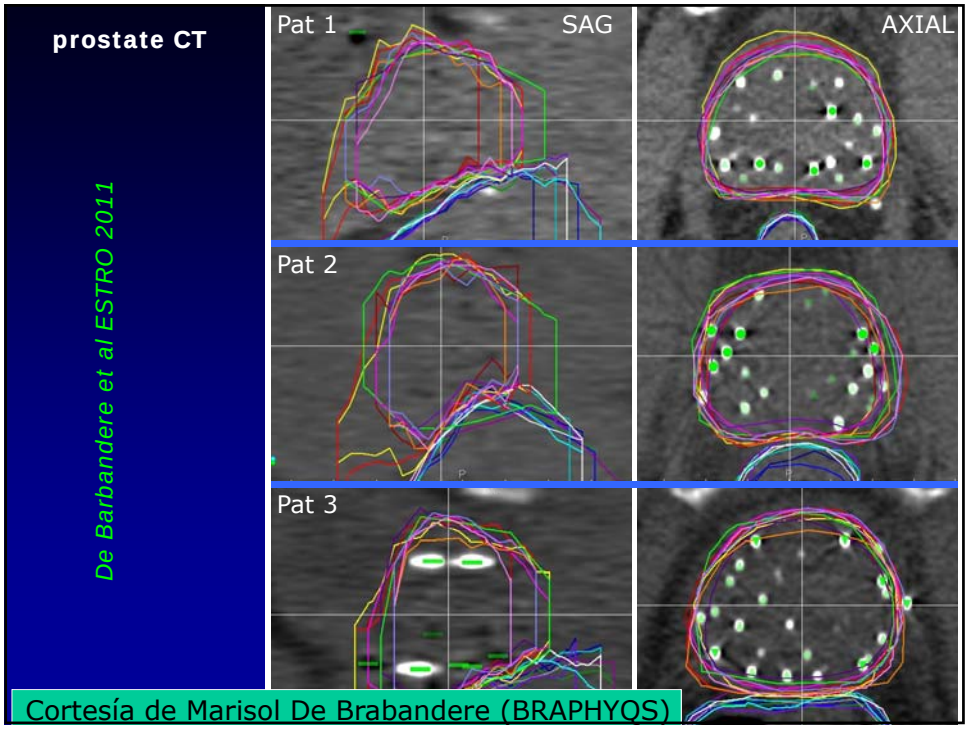
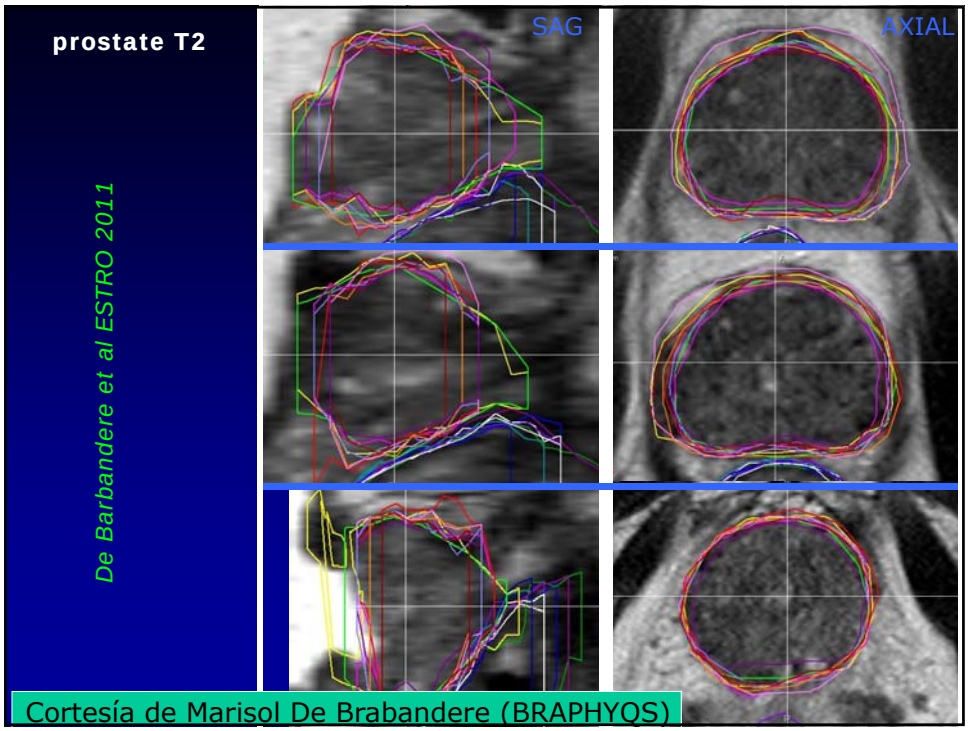
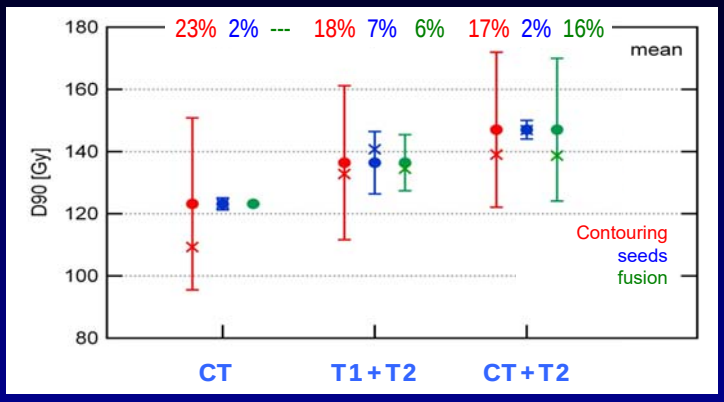

prostate CT
De Barbandere et al ESTRO 2011
Pat 1
SAG
AXIAL
Pat 2
Pat 3
Cortesía de Marisol De Brabandere (BRAPHYQS)


prostate T2
De Barbandere et al ESTRO 2011
SAG
AXIAL
Cortesía de Marisol De Brabandere (BRAPHYQS)

Interobservador

Mean 3 patients



Cortesía de Marisol De Brabandere (BRAPHYQS)

➡ Protocolos y consenso

Revisitar el CT ?

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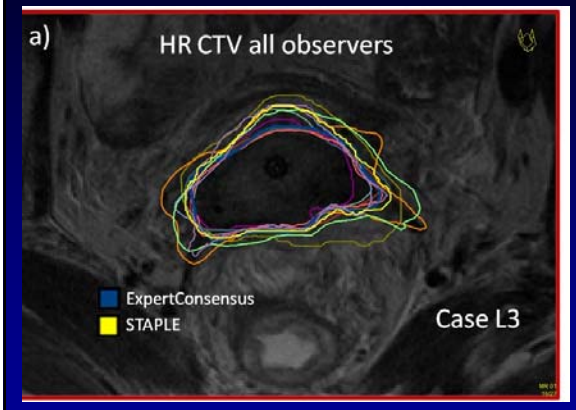
Interobservador

RM Gyn

Petric 2012
Hellebust 2012



SD 10% HR-CTV

±5,5 Gy tto tipico ¡

➡ Protocolos y consenso NECESARIOS

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Cortesía de Taran Paulsen Hellenbust 2012

Conclusiones

- Ultimas decadas **importante impulso tecnológico y clínico** en BT, siendo una herramienta terapéutica **clave en los SORT**. Existen importantes estudios en marcha de evaluación de **alternativas RTE** en algunas de sus modalidades.
- Tras un gran avance en los últimos años, los aspectos de **dosimetria fisica y clinica** estan **bien establecidos.**
- Existen aspectos que necesitan **mayor atención**: incorporación MR, registro multimodalidad, biologia, cálculo en bajas energías, **in vivo**….
- La fuente de incertidumbre principal en BT, al igual que RTE es el **establecimiento de volúmenes**.

Gracias

perez_jos@gva.es