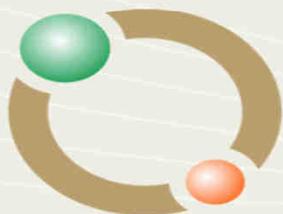


# Consideración en los planes de la radiación recibida por el uso de imágenes para simulación y control de posicionamiento de órganos (IGRT)

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[egarrigo@radioncologia-zunino.org](mailto:egarrigo@radioncologia-zunino.org)



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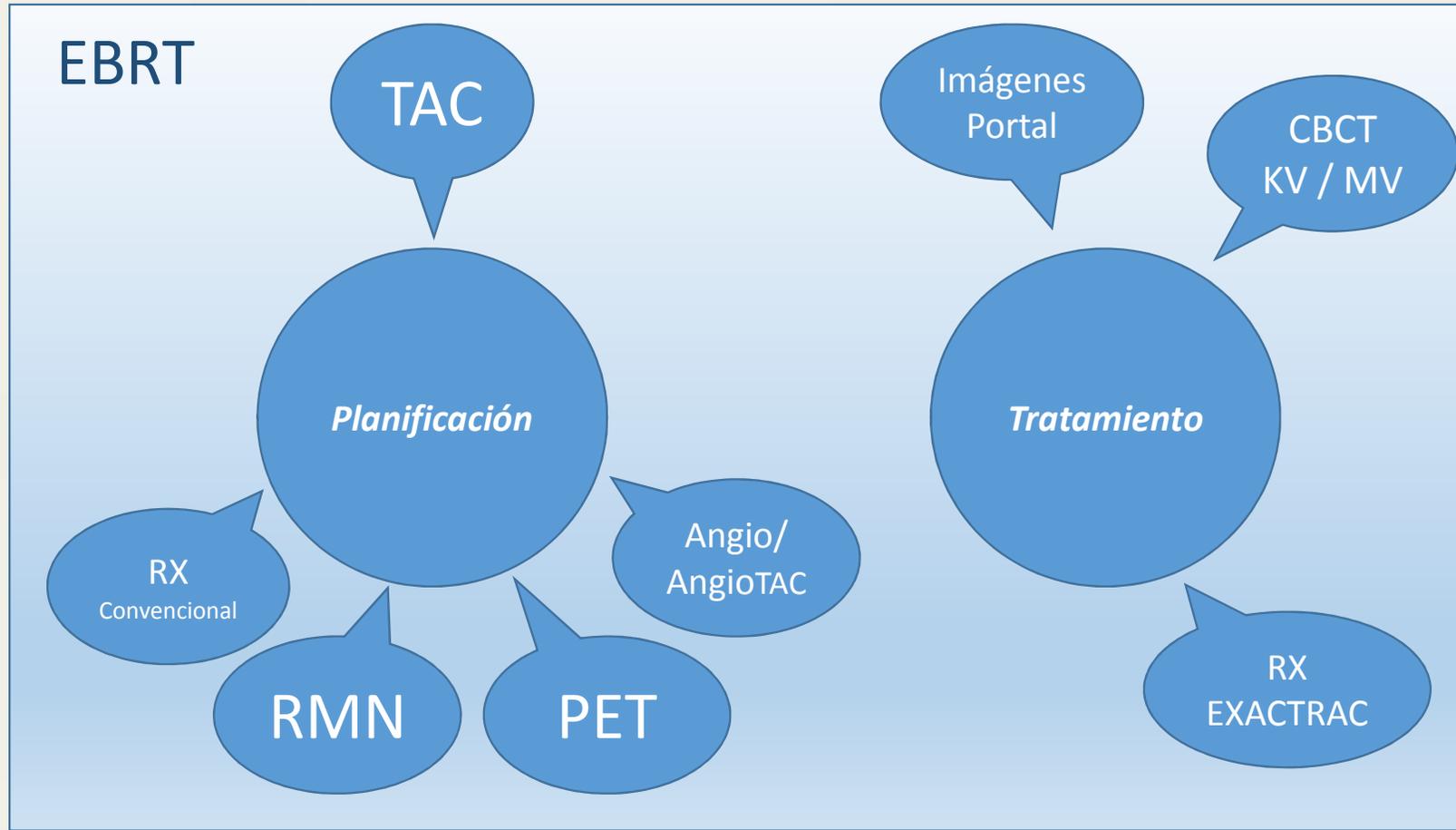
**PROGRAMA DE EDUCACION CONTINUA**  
FUNDACIÓN MARIE CURIE 2013 - 2014

**CURSO DE ACTUALIZACIÓN EN  
PROTECCIÓN RADIOLÓGICA**

## Braquiterapia



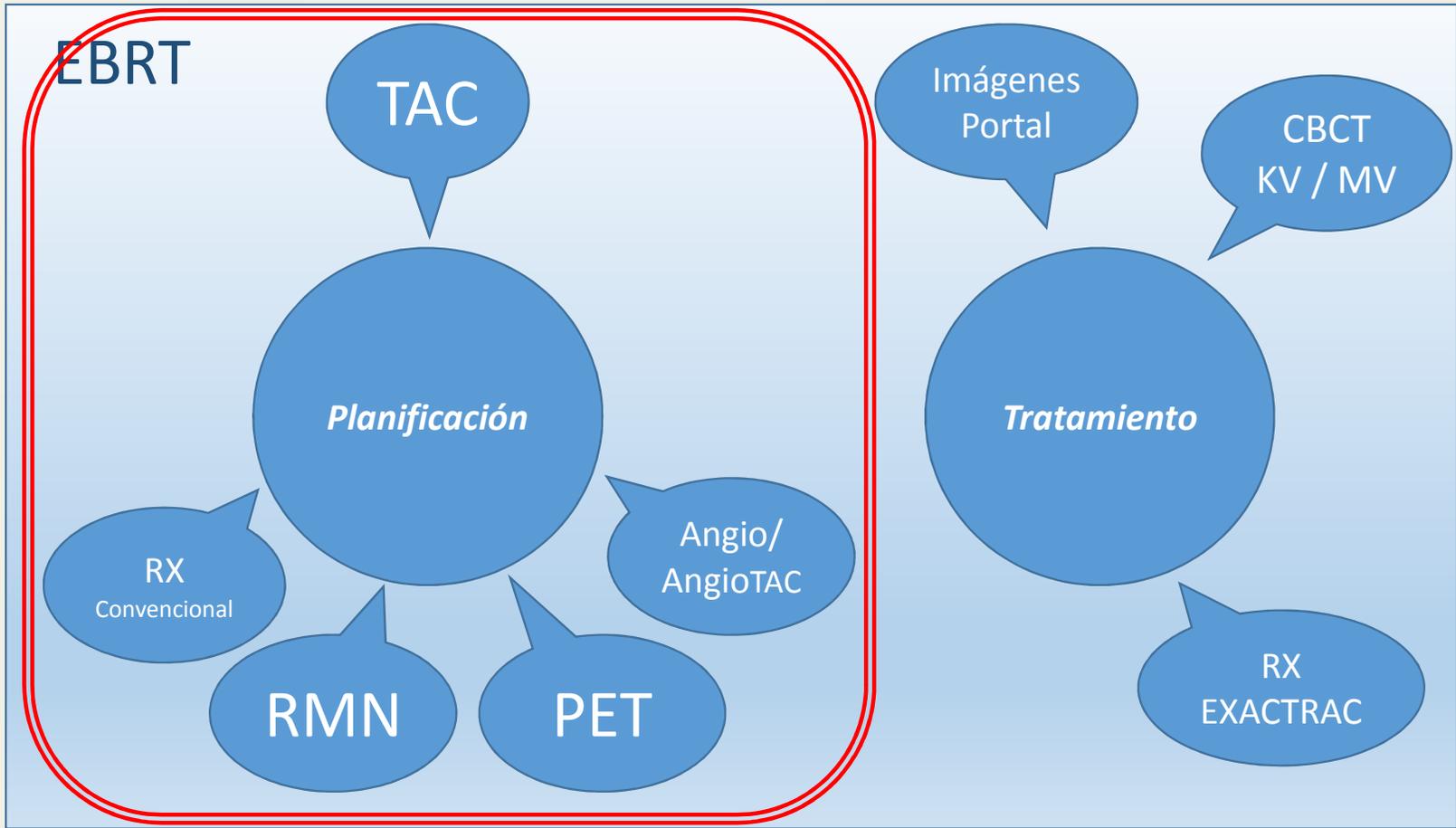
## EBRT



## Braquiterapia



## EBRT



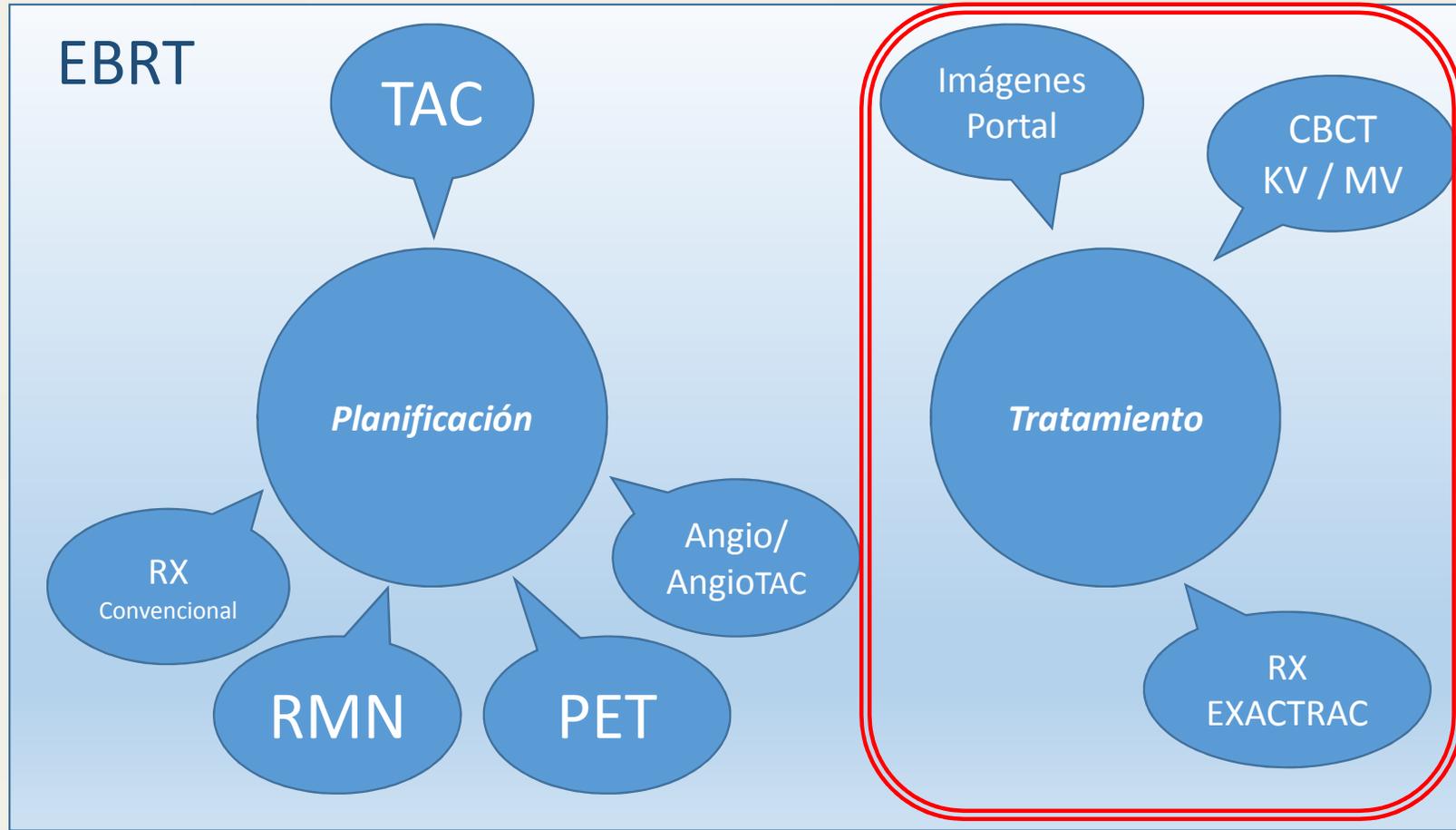
Diagnóstico

Seguimiento

## Braquiterapia



## EBRT

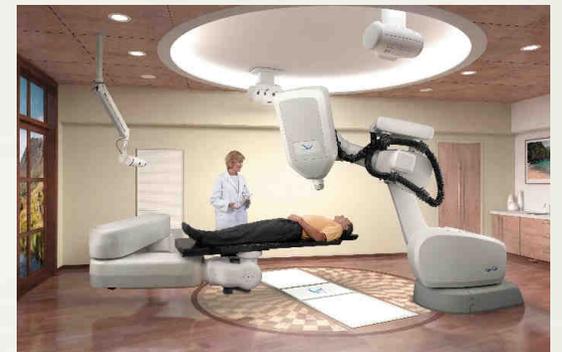
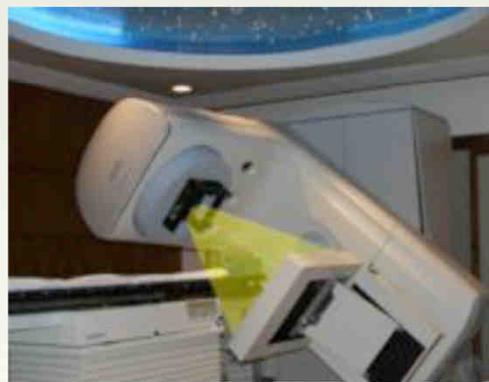


Diagnóstico

Seguimiento

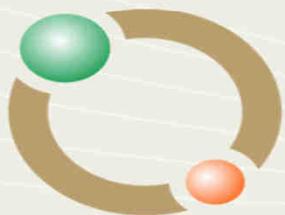


**IGRT**

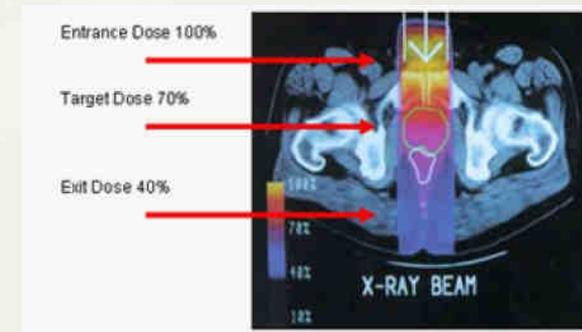
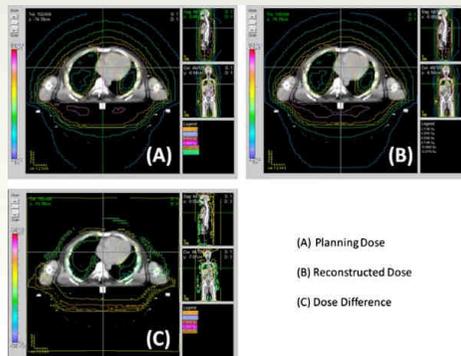


# Gran cantidad de trabajos que miden dosis en imágenes IGRT

## The management of imaging dose during image-guided radiotherapy: Report of the AAPM Task Group 75



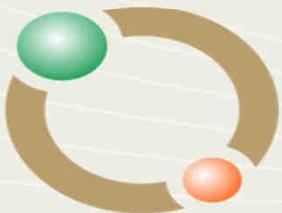
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# Gestión de la Dosis

## ALARA

- Valoración
- Reducción
- Optimización

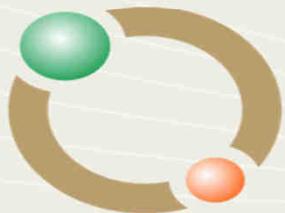
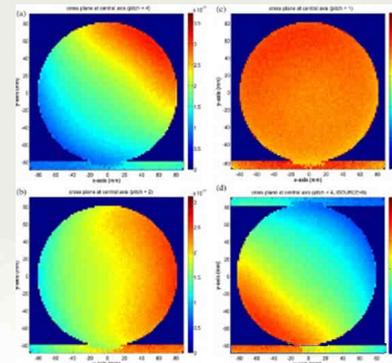
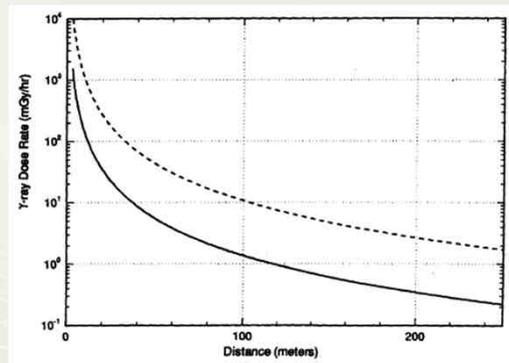


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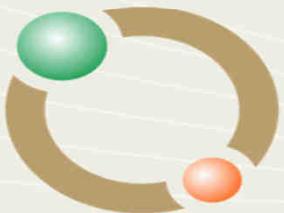
# Conceptos y Distinciones Básicas

- Dosis y Dosis Integral
  - Dosis: Energía por unidad de masa (puntual)
  - Dosis Integral: Dosis total integrada en el volumen irradiado
- Imágenes Planares - Imágenes Axiales

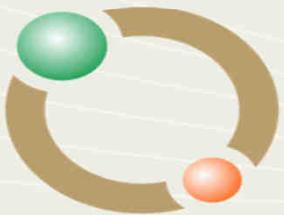
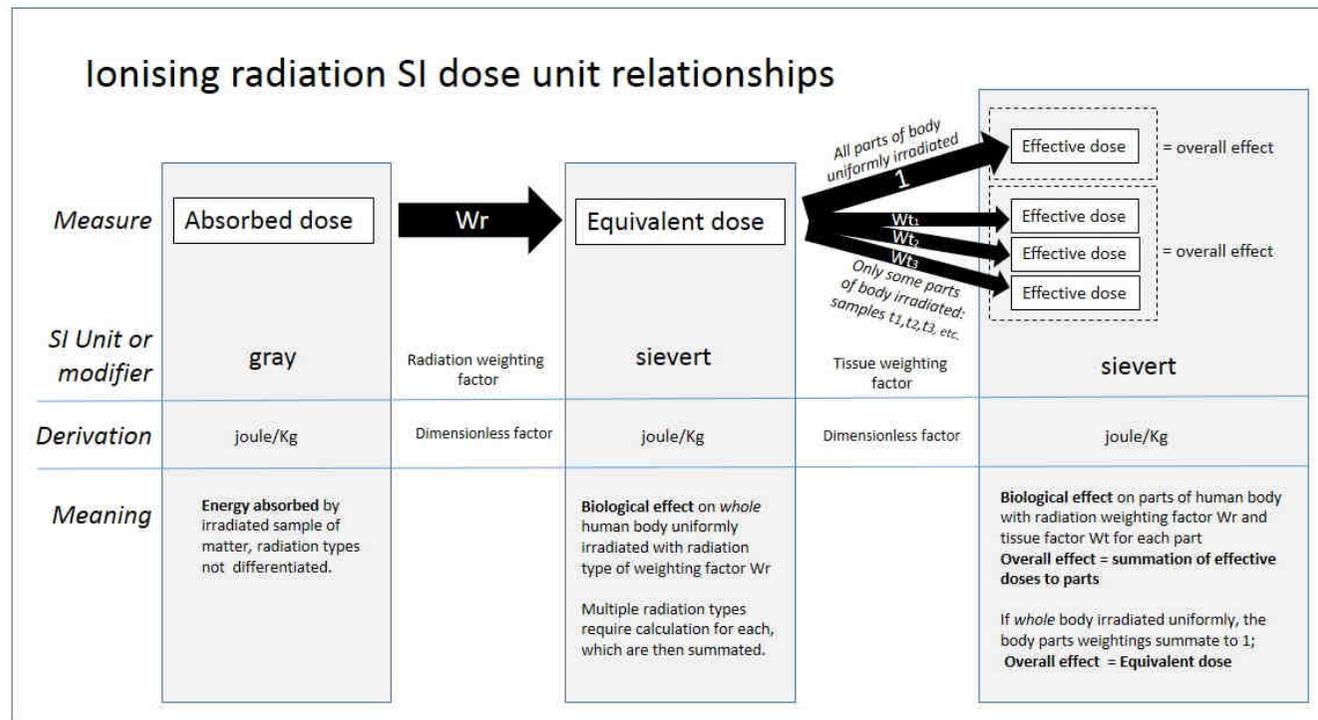


# Conceptos y Distinciones Básicas

- KV-MV  
Sin o con presencia de buildup
- Dosis en piel (entrada)  $CTDI_{air}$ ,  $CTDI_w$ , DLP



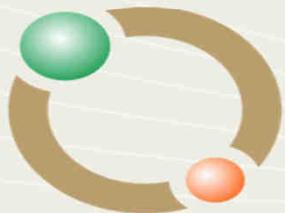
# Dosis Efectiva



# Dosis Efectiva

$$E = \sum_T W_T \cdot H_T = \sum_T W_T \sum_R W_R \cdot \bar{D}_{T,R}$$

*Nos permite estimar riesgo estocástico*

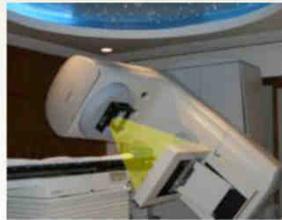


Organs	Tissue weighting factors		
	ICRP26 1977	ICRP60 1990 <sup>[4]</sup>	ICRP103 2007 <sup>[5]</sup>
<a href="#">Gonads</a>	0.25	0.20	0.08
Red <a href="#">Bone Marrow</a>	0.12	0.12	0.12
<a href="#">Colon</a>	-	0.12	0.12
<a href="#">Lung</a>	0.12	0.12	0.12
<a href="#">Stomach</a>	-	0.12	0.12
<a href="#">Breasts</a>	0.15	0.05	0.12
<a href="#">Bladder</a>	-	0.05	0.04
<a href="#">Liver</a>	-	0.05	0.04
<a href="#">Oesophagus</a>	-	0.05	0.04
<a href="#">Thyroid</a>	0.03	0.05	0.04
<a href="#">Skin</a>	-	0.01	0.01
<a href="#">Bone surface</a>	0.03	0.01	0.01
<a href="#">Salivary glands</a>	-	-	0.01
<a href="#">Brain</a>	-	-	0.01
Remainder of body	0.30	0.05	0.12
<b>Total</b>	<b>1.00</b>	<b>1.00</b>	<b>1.00</b>



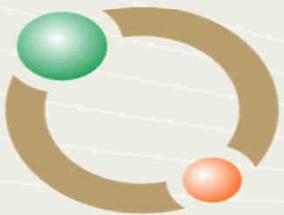
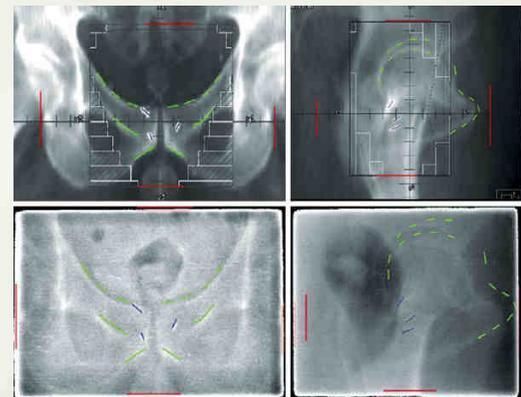
# MODALIDADES

- *Imagen Portal*
- *Radiografía*
- *CT On rail*
- *KVCBCT*
- *MVCBCT*
- *Fluoroscopia*

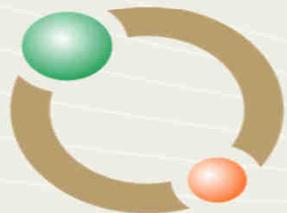


# Sistemas por Imagen Portal

- EPID mucho mas efectivo que film
- $<2-3 \text{ UM}$  ( $<1 \text{ UM}$ )



# Sistemas por Radiografía



# Sistemas por Radiografía

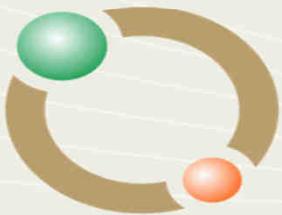


## ExacTrac:

- Dos tubos RX en piso, dos detectores en el techo
- Distancia fuente isocentro: 234 cm
- Distancia Isocentro Detector: 128 cm
- Area Activa del detector 20.5cm x 20.5cm  
Nominal: 13.5cm x 13.5cm

TABLE II. Measured planar radiographic entrance dose levels for the Brain-Lab Novalis image-guided radiosurgery system [from the Henry Ford Hospital (Ref. 27)].

Site	kV	mA	ms	mAs	mGy
Cranium and C-spine	120	125	100	12.5	0.335
Body	140	125	125	15	0.551



# Sistemas por Radiografía

## CyberKnife:

- Dos tubos RX en techo, dos detectores en el piso
- Distancia fuente isocentro: 265 cm
- Distancia Isocentro Detector: 65 cm
- Area Activa del detector 25cm x 25cm  
Nominal: 17cm x 17cm (se puede colimar)

TABLE I. Measured planar radiographic entrance dose levels per image for the CyberKnife image-guided radiosurgery system.

Site	kV	mA	ms	mAs	mGy
Cranium and C-spine	105–125	100	100	10	0.25
T-spine	120–125	100–150	100–125	10–20	0.25–0.50
L-spine	120–125	100–200	100–150	10–30	0.25–0.75
Sacrum	120–125	100–300	100–300	10–90	0.25–2.00
Synchrony	120–125	100–300	50–75	5–22.5	0.10–0.50



# Sistemas por Radiografía

## **Elekta:**

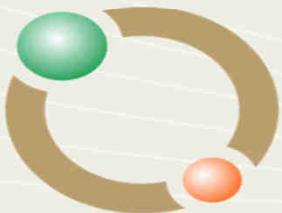
Synergy X-Volume Imaging (XVI)

## **Varian:**

On-Board Imager (OBI)



**1-3 mGy**



# Sistemas por CT



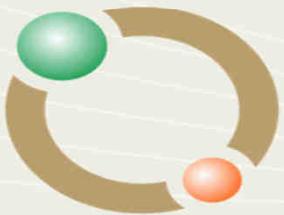
# Sistemas por CT

## CTDI

$$\text{CTDI} = (1/h) \int_{-\infty}^{\infty} D(z) dz,$$

$$\text{CTDI}_{100} = (1/h) \int_{-50}^{50} K_{\text{air}}(z) dz,$$

$$\text{CTDI}_w = [2/3\text{CTDI}_{100}(\text{Periphery}) + 1/3\text{CTDI}_{100}(\text{Center})].$$



# Sistemas por CT

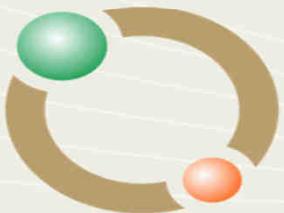
## CTDI

$$\text{CTDI} = (1/h) \int_{-\infty}^{\infty} D(z) dz,$$

$$\text{MSAD} = (1/p)\text{CTDI}.$$

$$\text{CTDI}_{w,\text{eff}} = \text{MSAD}_w = (1/p)\text{CTDI}_w.$$

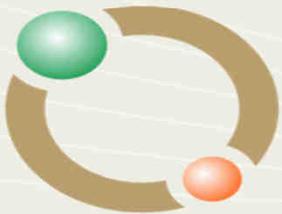
$$\text{DLP} = (\text{CTDI}_w) \times (\text{Scan Length}).$$



# Sistemas por CT



**CT on rail**



# Sistemas por CT

## KV CBCT

Tubo RX-detector ortogonal o en línea al haz de tratamiento

*Synergy XVI*

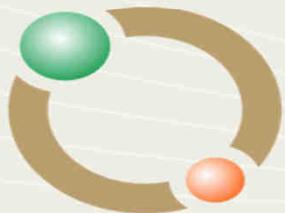
Body Phantom: 16 y 23 mGy (centro y periferia)

Head Phantom: 30 y 29 mGy (centro y periferia)

*OBI*

Head Phantom: 74 y 72 mGy (centro y periferia)

Head Phantom: 16 y 15 mGy (centro y periferia) (tec. baja dosis)



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# Sistemas por CT MV CBCT

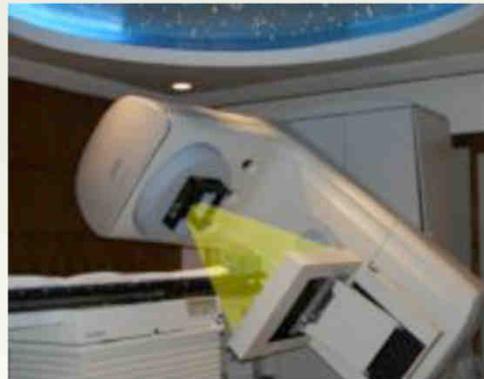
## Tomotherapy

- Opera con KV y MV
- MV 10 – 30 mGy



## Siemens y Varian

- 20 MU
- 5 MU



# Evaluación de Dosis

Para comparar las dosis de las imágenes, debemos convertir a Dosis Efectiva

$$E = D \cdot F [mSv/mGy].$$

TABLE IV. Conversion coefficients to give effective dose (mSv) from dose-area product of entrance skin dose ( $mGy \text{ cm}^2$ ) for AP projections. The total filtration is in millimeters of aluminum. All conversion coefficients are  $mSv/mGy \text{ cm}^2 \times 10^{-5}$ .

kVp	Filter (mm Al)	Head ( $10^{-5}$ )	Chest ( $10^{-5}$ )	Lumbar Spine ( $10^{-5}$ )	Abdomen ( $10^{-5}$ )	Pelvis ( $10^{-5}$ )
80	2	3.0	21.5	18.9	16.8	20.0
	4	4.1	26.9	24.9	22.2	25.2
100	2	4.1	25.5	24.0	21.5	24.3
	4	5.3	31.0	30.2	27.2	29.6
120	2	4.9	28.9	28.0	25.2	27.7
	4	6.1	33.9	33.8	30.5	32.6

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	4	5.3	31.0	30.2	27.2	29.6
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kVp	Filter (mm Al)	Head ( $10^{-5}$ )	Chest ( $10^{-5}$ )			
			Lumbar ne ( $10^{-5}$ )	Abdomen ( $10^{-5}$ )	Pelvis ( $10^{-5}$ )	
80	2	3.1	21.5	18.9	16.8	20.0
	4	4.1	26.9	24.9	22.2	25.2
100	2	4.1	25.5	24.0	21.5	24.3
	4	5.3	31.0	30.2	27.2	29.6
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# Evaluación de Dosis

Para comparar las dosis de las imágenes, debemos convertir a Dosis Efectiva

$$E = D \cdot F [mSv/mGy].$$

TABLE IV. Conversion coefficients to give effective dose (mSv) from dose-area product of entrance skin dose (mGy cm<sup>2</sup>) for AP projections. The total filtration is in millimeters of aluminum. All conversion coefficients are mSv/mGy cm<sup>2</sup> × 10<sup>-5</sup>.

kVp	Filter (mm Al)	Head (10 <sup>-5</sup> )	Chest	Lumbar ne (10 <sup>-5</sup> )	Abdomen (10 <sup>-5</sup> )	Pelvis (10 <sup>-5</sup> )
			(10 <sup>-5</sup> )			
80	2	3.1	<b>21.5</b>	18.9	16.8	20.0
	4	4.1	26.9	24.9	22.2	25.2
100	2	4.1	25.5	24.0	21.5	24.3
	4	5.3	31.0	30.2	27.2	29.6
120	2	4.9	28.9	28.0	25.2	27.7
	4	6.1	33.9	33.8	30.5	32.6

Ejemplo: Imagen Torax modalidad KV

KV:80,

Filtro: 2mm

Campo: 25cm de diam. (491 cm<sup>2</sup>)

Factor de conversion [mSv/mGy]=  
=2.15 10<sup>-5</sup> mSv/mGy cm<sup>2</sup> \* 491 cm<sup>2</sup>

**=0.11 mSv/mGy**

# Evaluación de Dosis

Para comparar las dosis de las imágenes, debemos convertir a Dosis Efectiva

TABLE VIII. Dose from kV cone-beam CT (Ref. 45).

Parameter	Head	Chest
Maximum skin dose (mGy)	100.5	85.4
Mean skin dose (mGy)	68.5	57.0
Effective dose (mSv)	10.9	24.6
Conversion factor (mSv/mGy cm <sup>2</sup> )	$6.0 \times 10^{-5}$	$16.0 \times 10^{-5}$

TABLE VI. Typical values of the conversion factor  $F$  from CTDI<sub>air</sub> (in mGy) to effective dose  $E$  (in mSv) for adult patients for recent routine CT exams in Germany (Ref. 74).

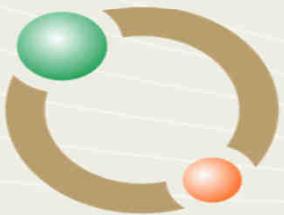
Examination	Scan Length (cm)	Pitch	Factor $F$	CTDI <sub>air</sub> (mGy)	$E$ (mSv)
Head	12.0	1.0	0.023	81	1.9
C-spine	18.0	1.2	0.044	55	2.4
Chest	27.0	1.3	0.136	47	6.4
Abdomen	42.0	1.3	0.239	54	12.9
L-spine	6.0	1.1	0.029	100	2.9
Pelvis (male)	24	1.2	0.137	60	8.2

TABLE X. Effective dose  $E$  from 6 MV portal images 18 cm × 15.6 cm taken at SSD=88 cm (Ref. 68).

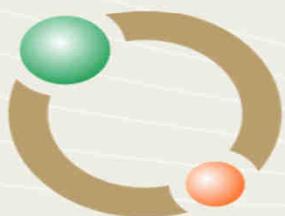
Port View	Gender	Effective Dose $E$ (mSv/MU)
AP pelvis	Male	0.34
	Female	0.52
Lat pelvis	Male	0.32
	Female	0.7
AP chest	Male	1.74
	Female	1.8
Lat chest	Male	2.56
	Female	2.23
Lat neck	N.A.	0.12

# Resumen

- Conocer que nivel de dosis aporta nuestro sistema
- Reducir la dosis como sea posible (colimación, energía, fluencia)
- La Dosis Efectiva es la magnitud que nos permite comparar dosis de distintos sistemas de imágenes, o dosis de tratamiento con sistema de imágenes



*MUCHAS GRACIAS*



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