

# Szövetközi besugárzások - Emlőtűzdelések

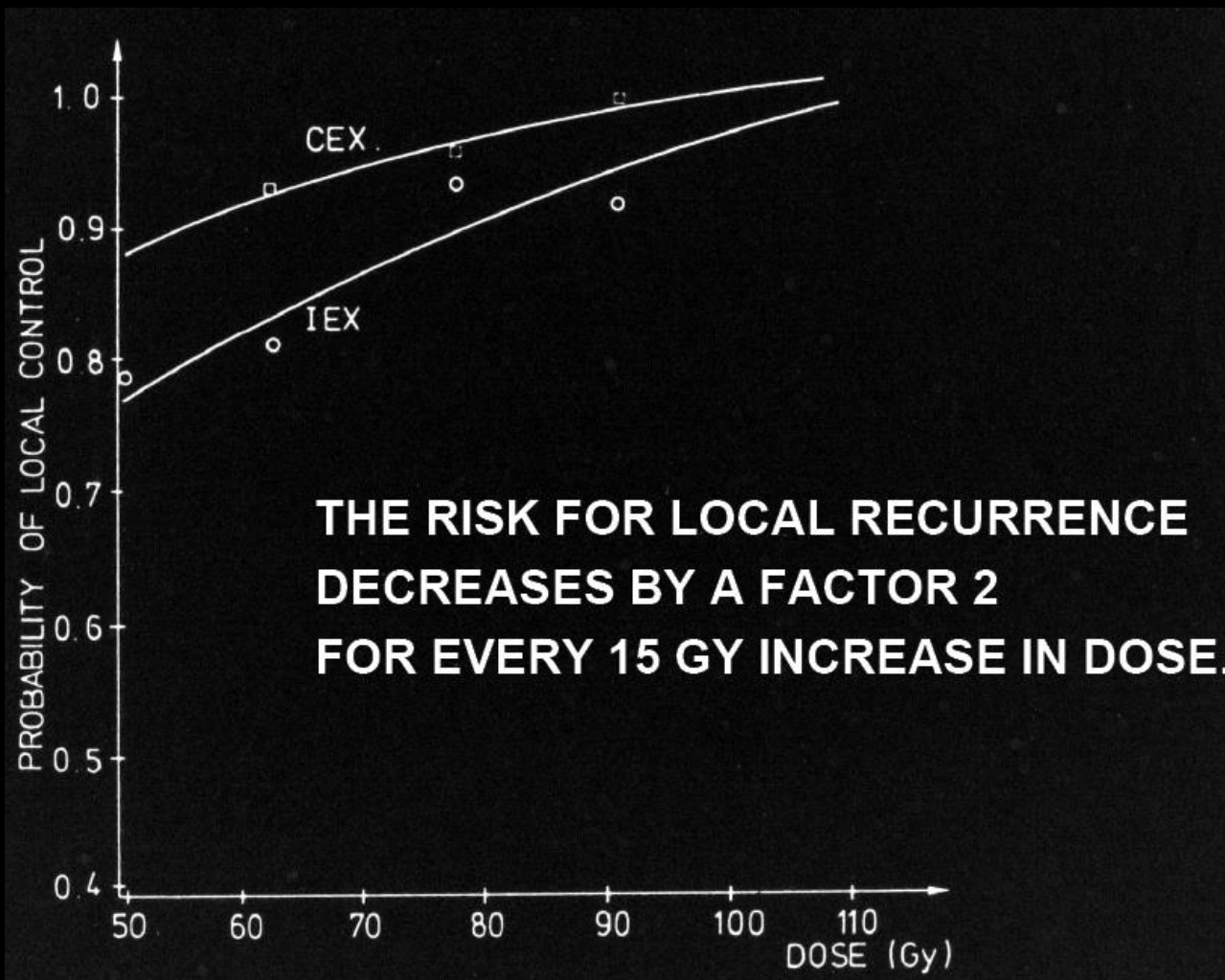
Dr. Fröhlich Georgina

Országos Onkológiai Intézet  
Sugárterápiás Központ  
Budapest



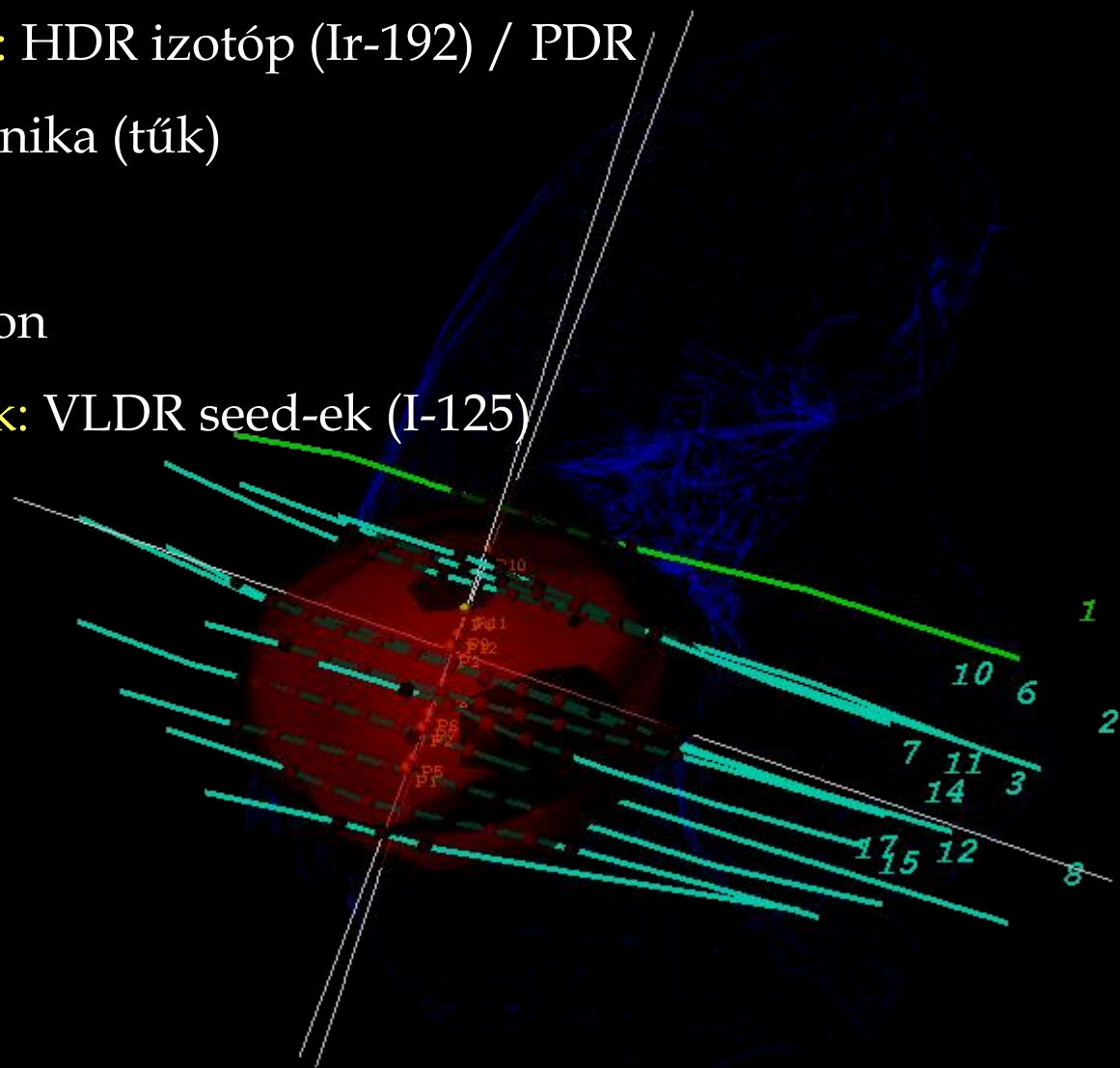
*Ionizáló sugárzások a gyógyításban  
ELTE TTK, Budapest*

# Emlőtűzdelés



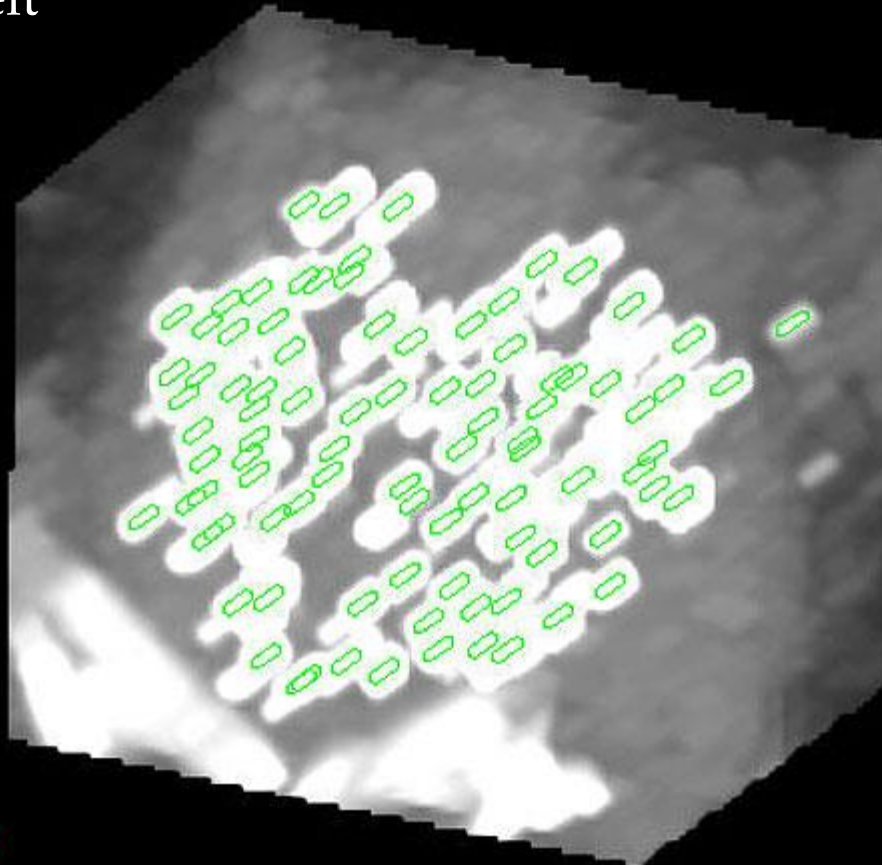
# Emlőtűzdelés típusai

- **ideiglenes beültetések:** HDR izotóp (Ir-192) / PDR
  - többkatéteres technika (tűk)
  - felfújható ballon
  - többkatéteres ballon
- **permanens beültetések:** VLDR seed-ek (I-125)
- monoterápia/boost
- postop./intraop.



# Seed-technika

- **permanens beültetések:** Very LDR seed-ek (I-125) – **PBSI**  
beültetés: ~ 1h → hazamehet a beteg – ambuláns beavatkozás!  
ált. UH-vezérelt



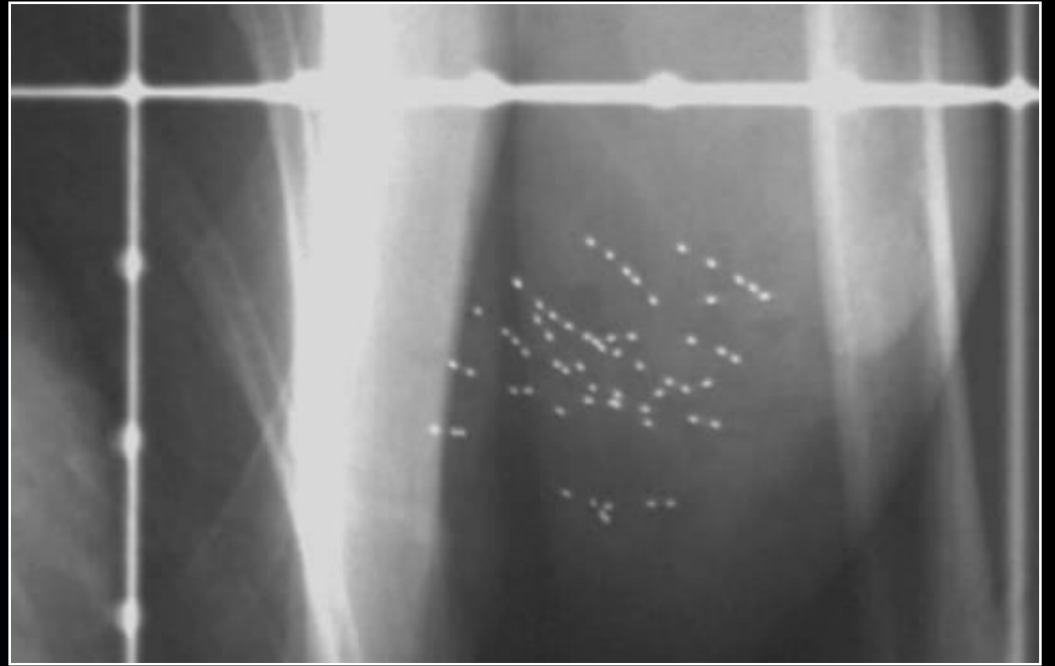
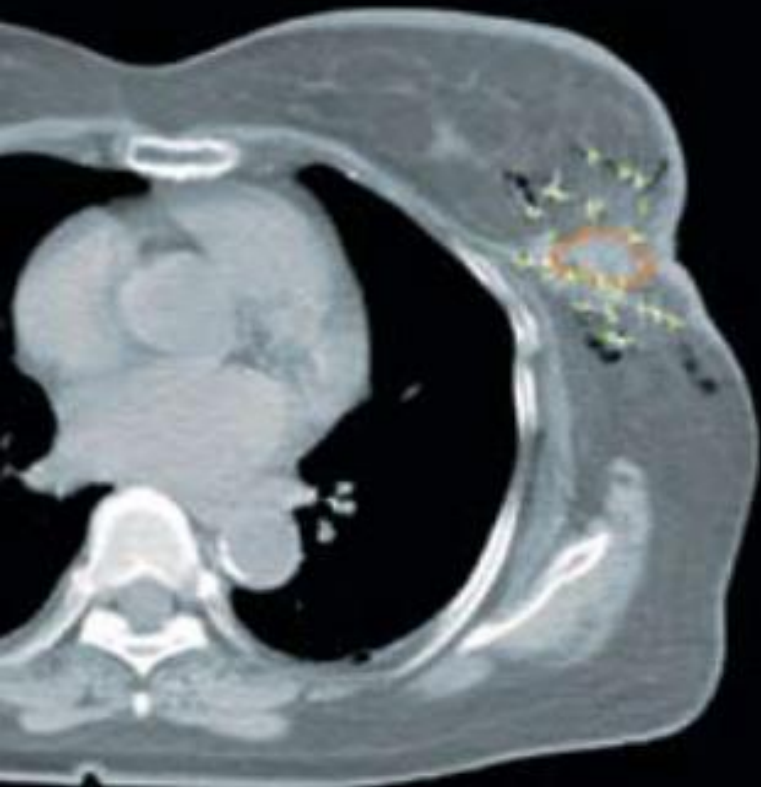
# Seed-technika



műtőasztalhoz rögzített templét (ált. vezetett seed-ek)

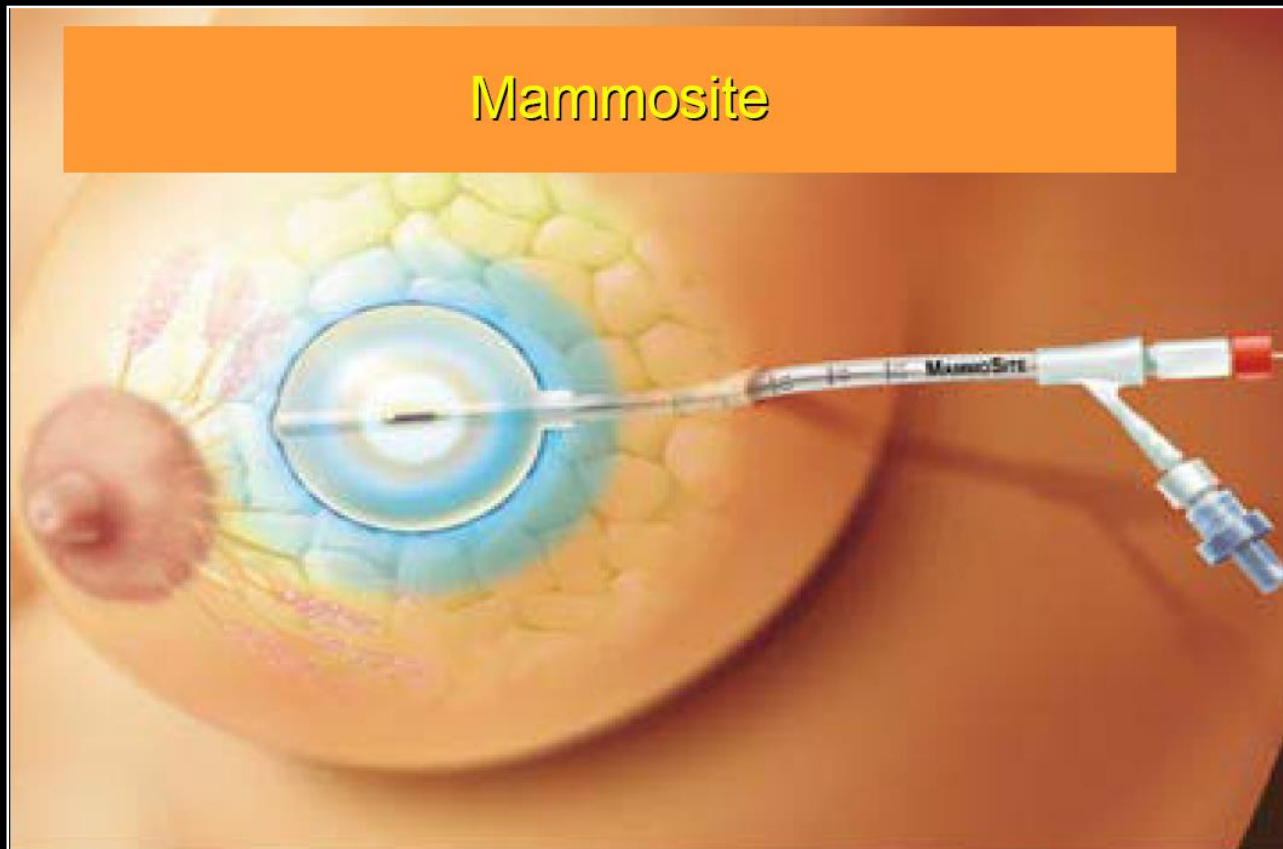
CI: PBSI < ballon < HDR

# Seed-technika

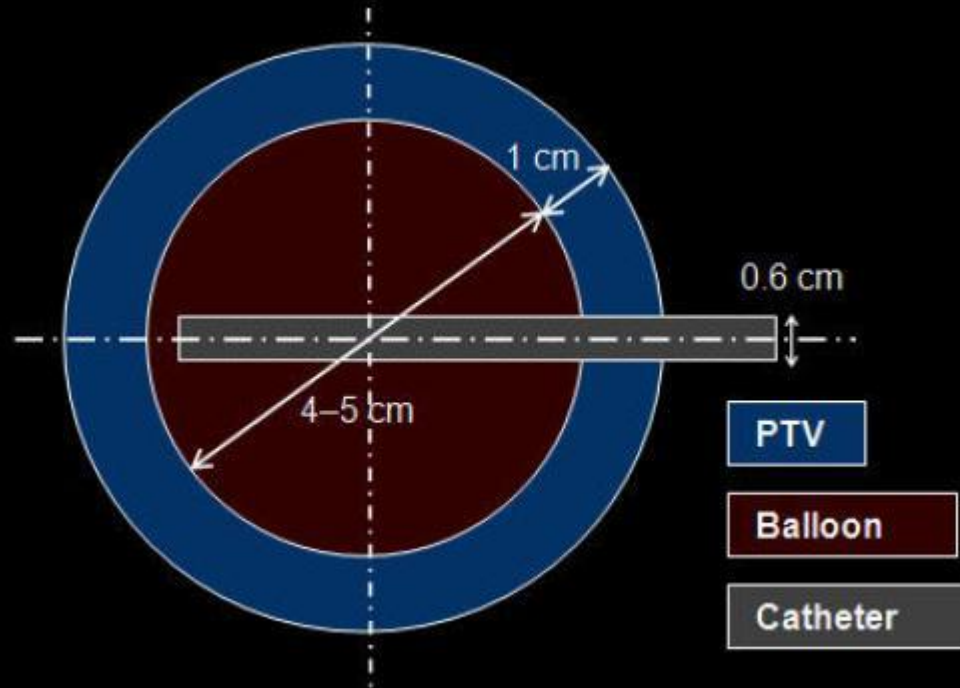


# Ballon

- ideiglenes beültetések: HDR izotóp (Ir-192)
  - **felfújható ballon**: ~gömbszimmetrikus, forrás 1 pozícióban áll meg → gömbszimmetrikus D-eloszlás (nincs optimalizálás)

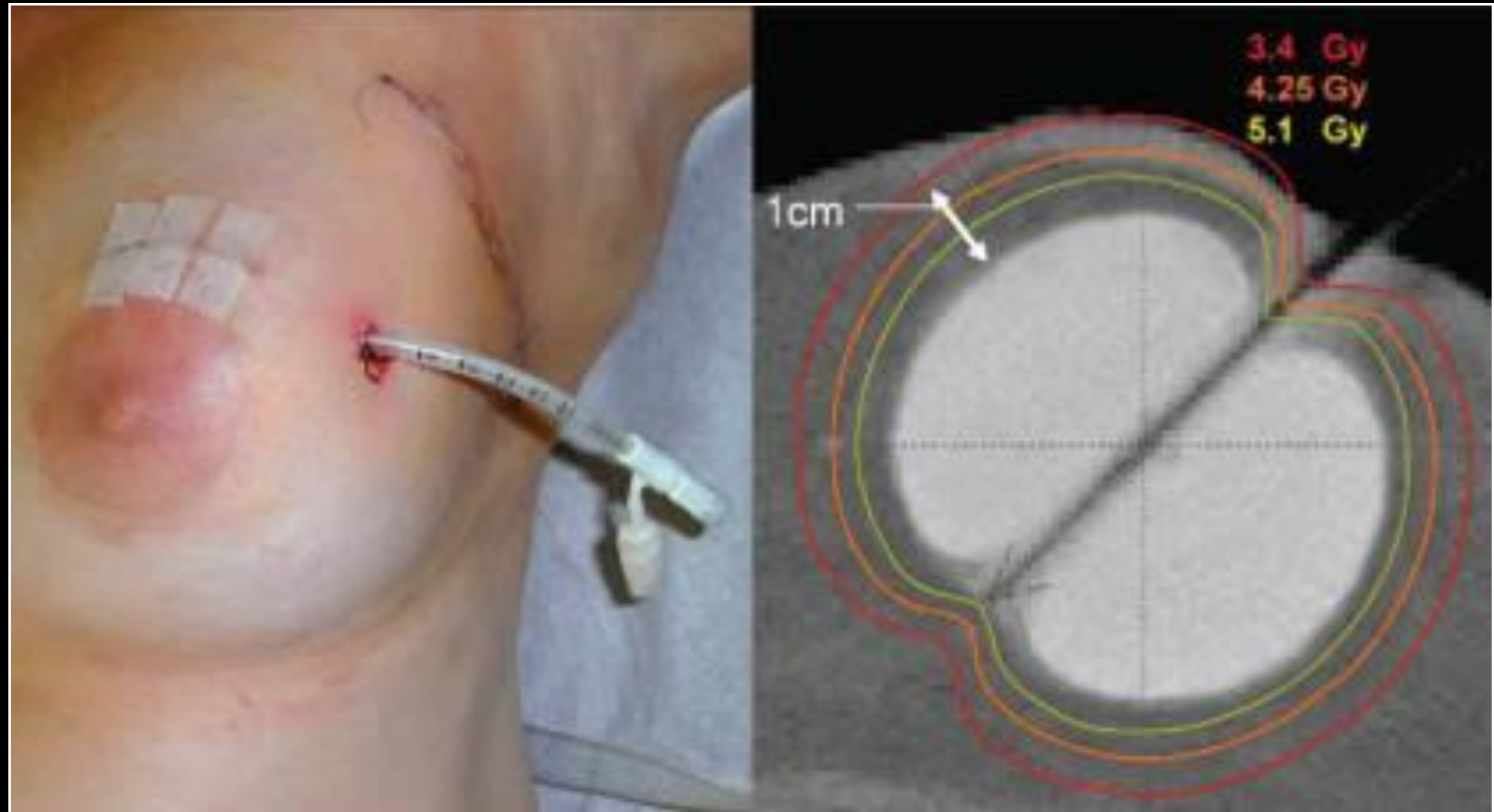


# Ballon





# Ballon



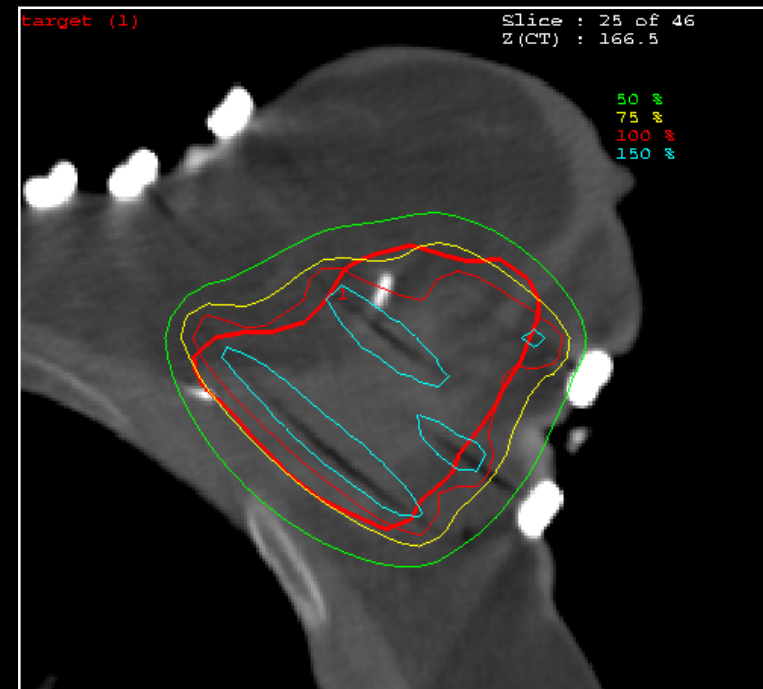
# Ballon

MammoSite



Max. bőrD > 100% !!!

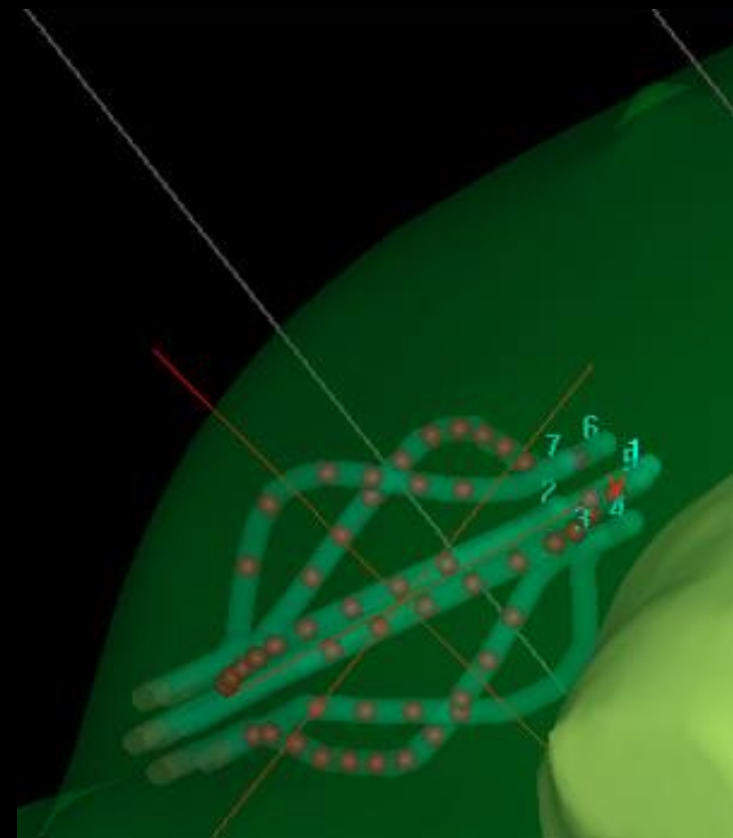
többkatéteres tűzdelés



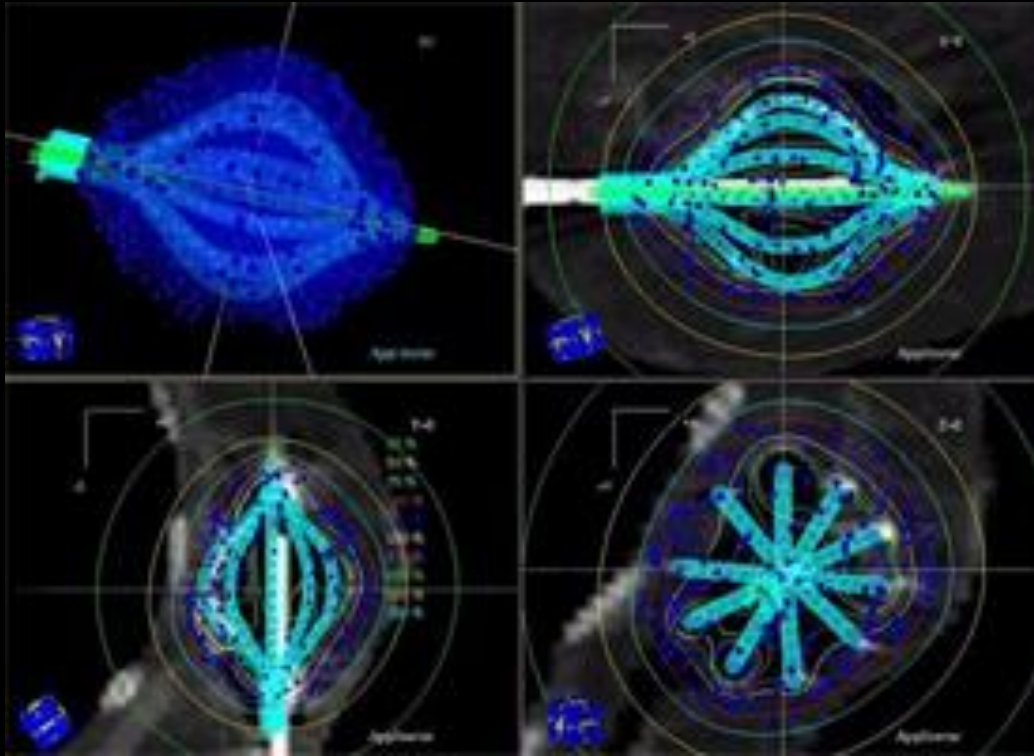
Max. bőrD = 50%

# Többkatéteres ballon

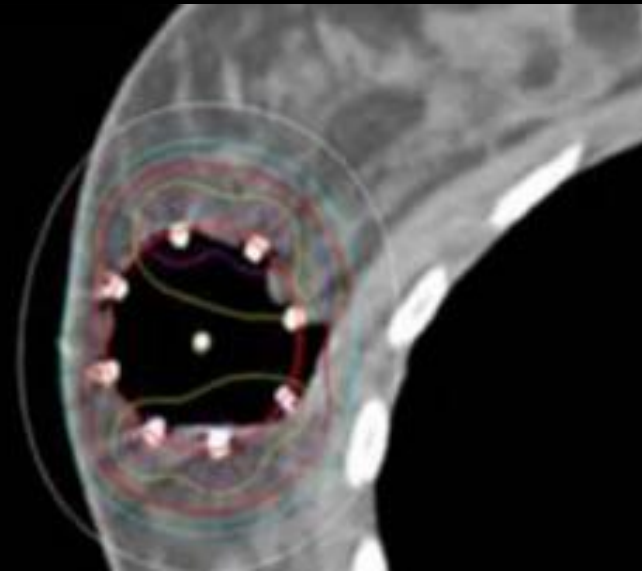
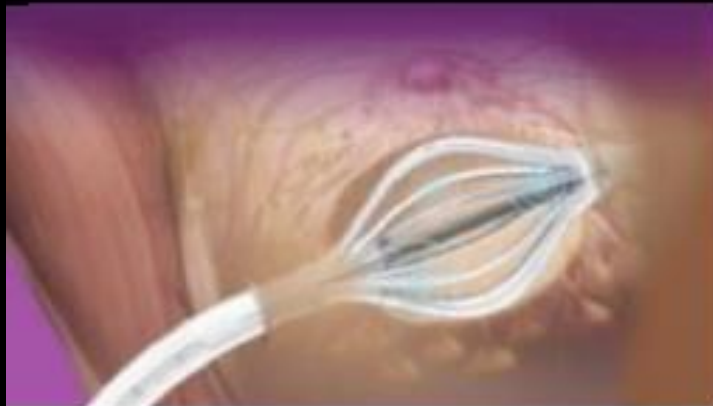
- ideiglenes beültetések: HDR izotóp (Ir-192) / PDR
- többkatéteres ballon (MLB)



# Többkatéteres ballon



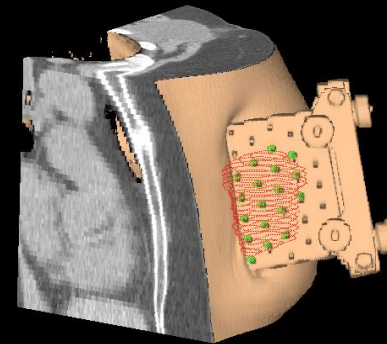
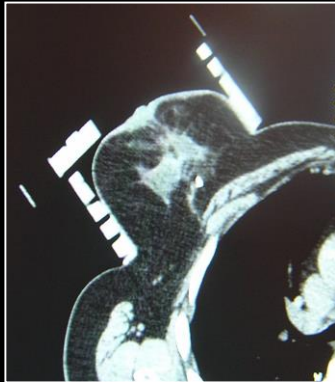
Strut Assisted Volume Implant (SAVI)



# HDR technika

- Céltérfogat meghatározás, katéter-elrendezés megtervezése:  
**előtervezés**

Elő-CT a  
műanyag  
templéttel



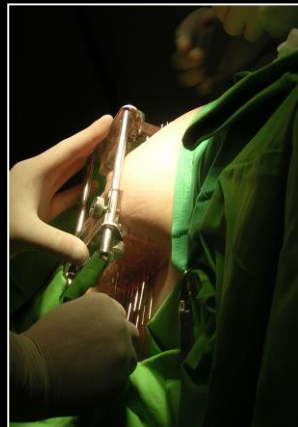
3D rekons.  
a PTV-vel  
és a  
tervezett  
tűkkel



- **implantáció**

1. fém tűk

2. műanyag szálak

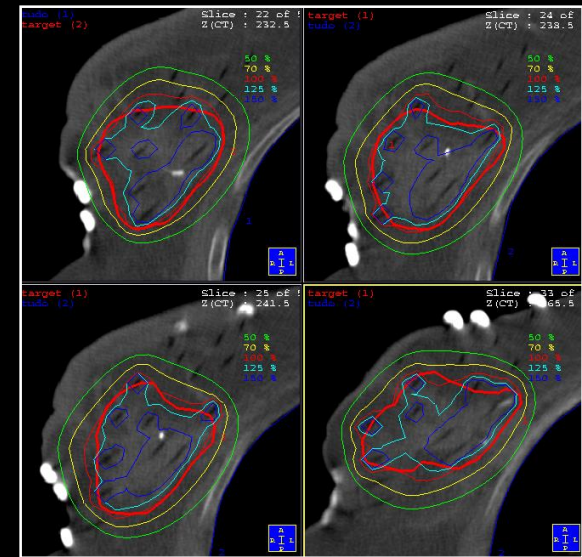


# HDR technika

- PTV-, tüdő- és szív-kontúrok

- tervezés

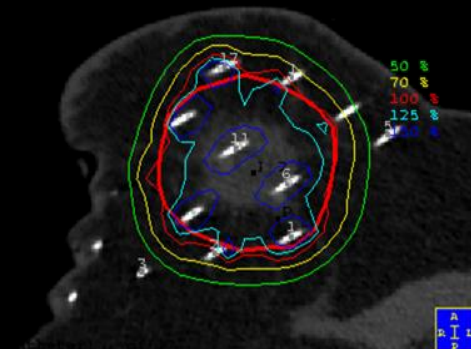
- katéterrekonstrukció



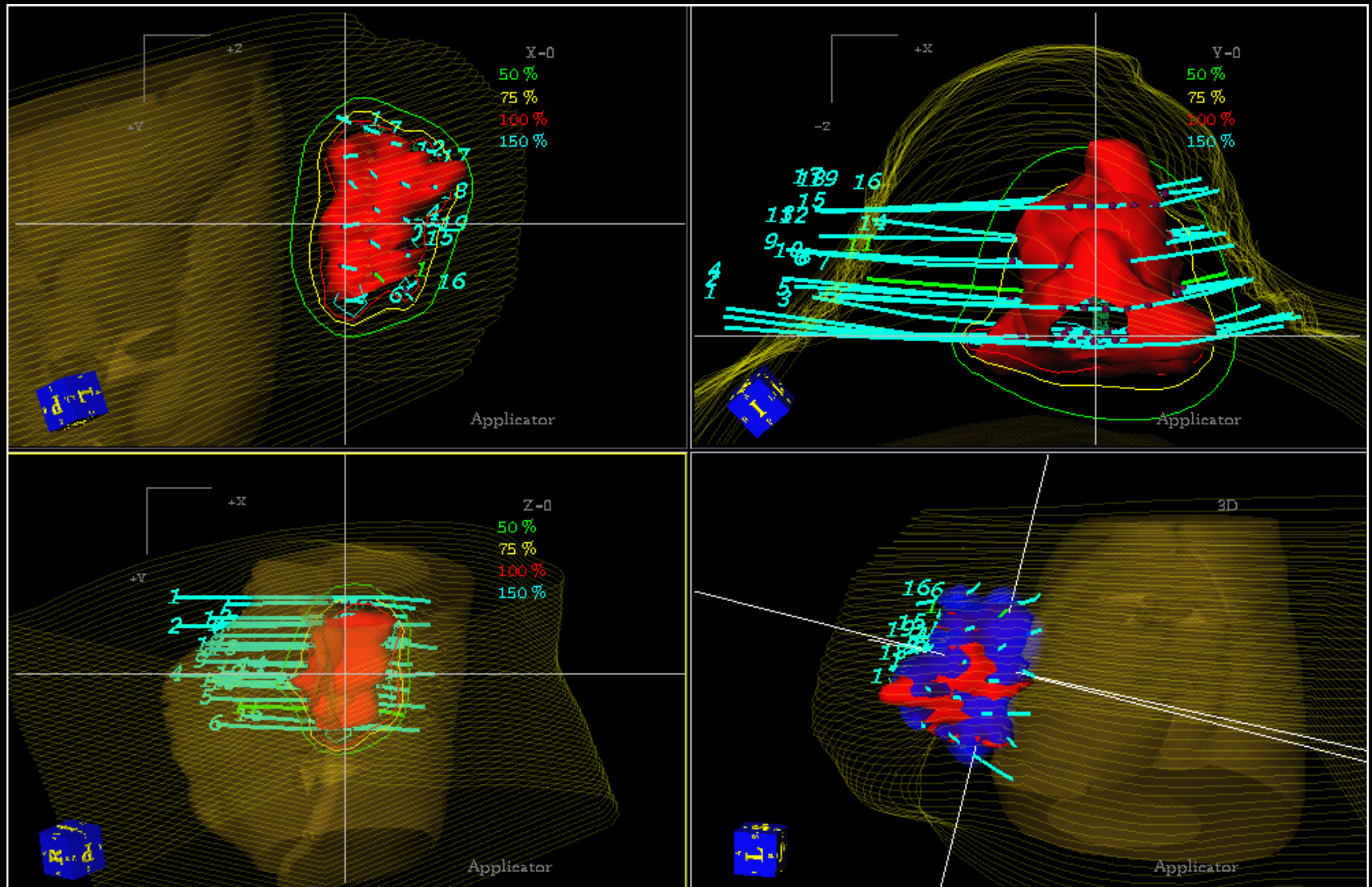
- **dózis referenciapontok**: a katéterek középső síkjában (Párizs DS) - dózist ezek átlagára normalizáljuk (MCD, Mean Central Dose)

- aktív **besugárzási pozíciók**: PTV-n belül (forrás lépésköze: 5 mm)

- geometriai és grafikus **optimalizálási** módszer

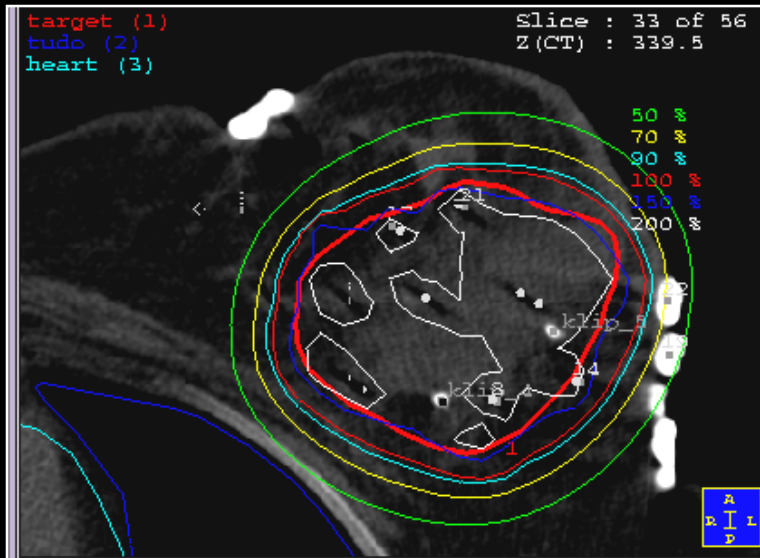


# HDR technika

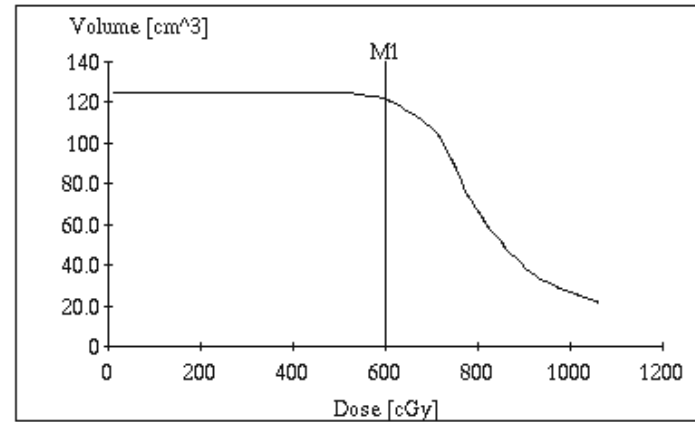


# F-faktor

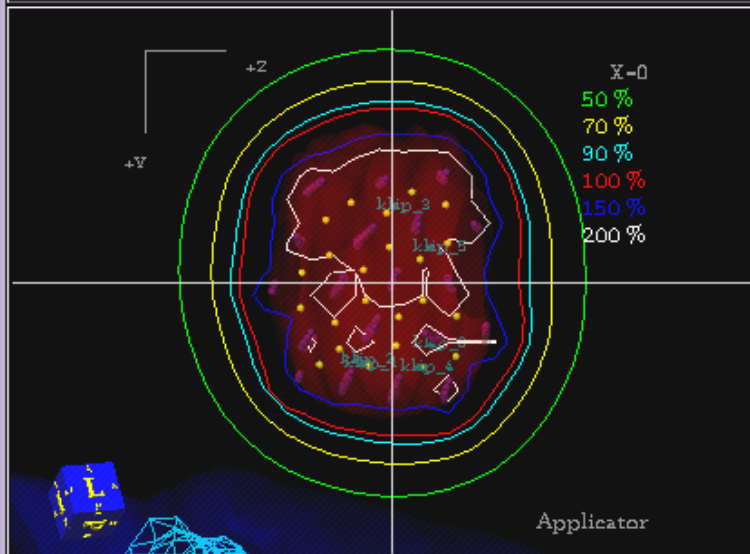
F=0,50, DNR=0,63, CI=1,00



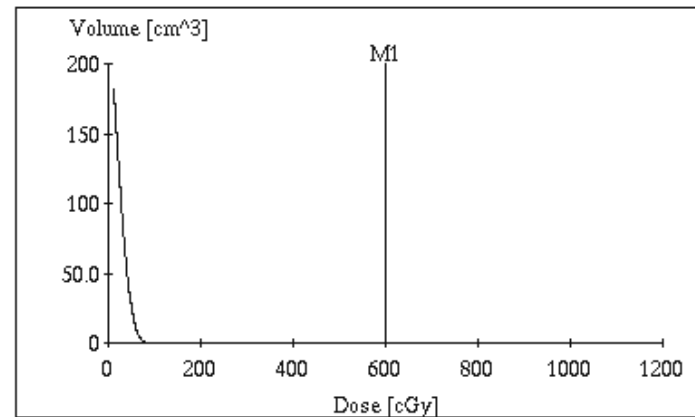
M1: 600 cGy 122 cm<sup>3</sup>



DVH\_5 : Cumulative DVH on target. State : Consistent.



M1: 600 cGy 0 cm<sup>3</sup>

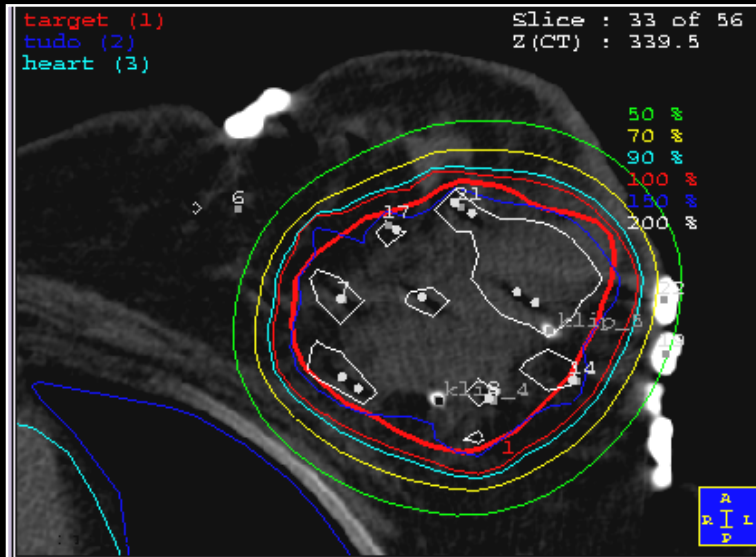


DVH\_6 : Cumulative DVH on heart. State : Consistent.

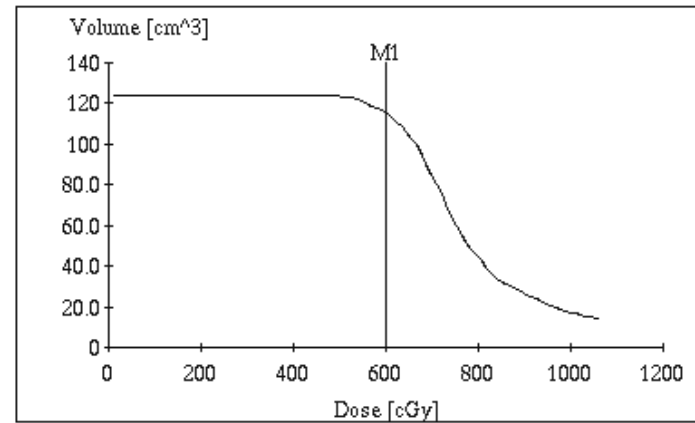


# F-faktor

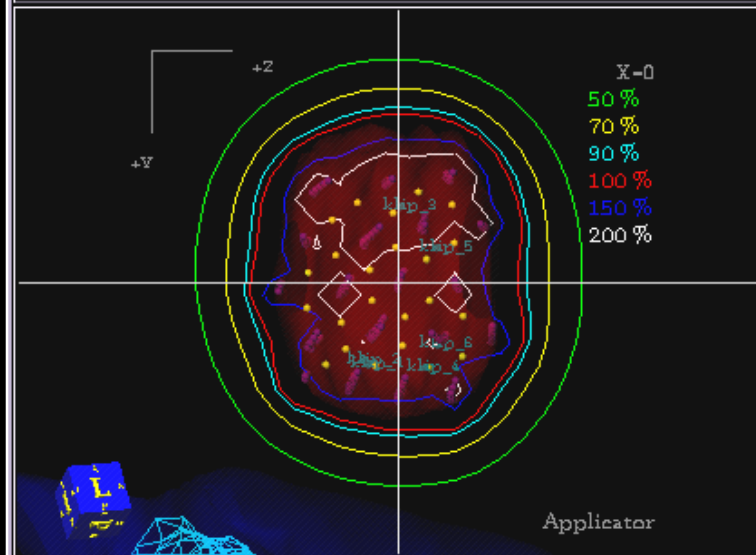
F=0,55, DNR=0,60, CI=1,00



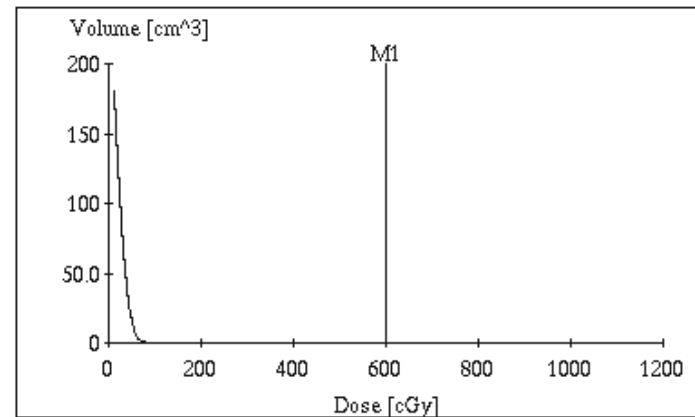
M1: 600 cGy 115 cm<sup>3</sup>



DVH\_7 : Cumulative DVH on target. State : Consistent.



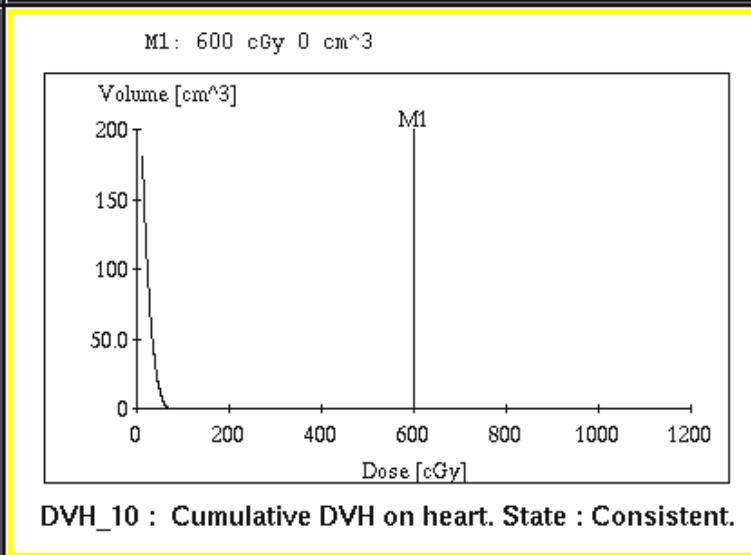
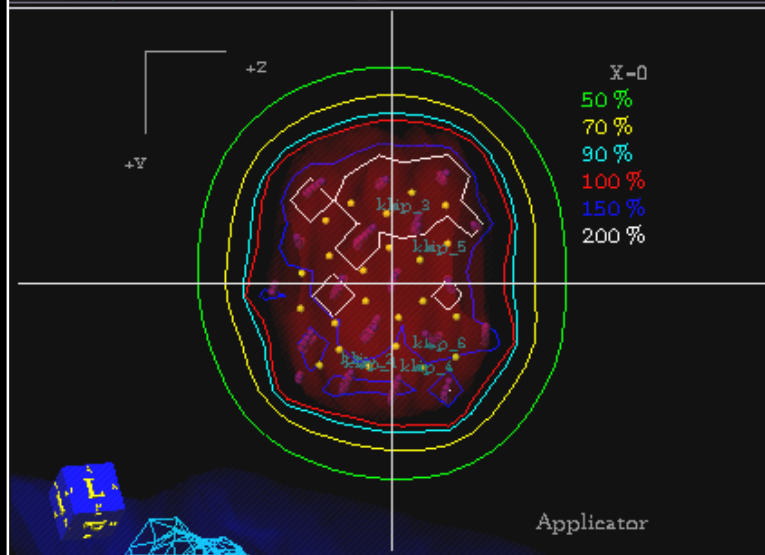
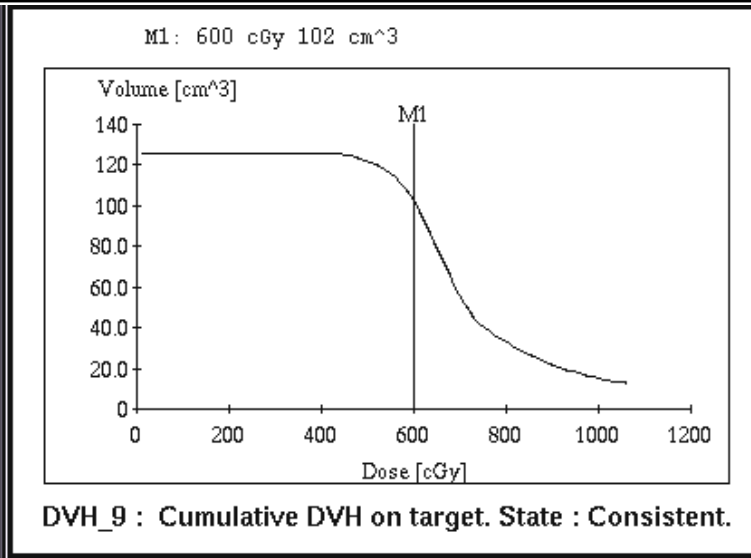
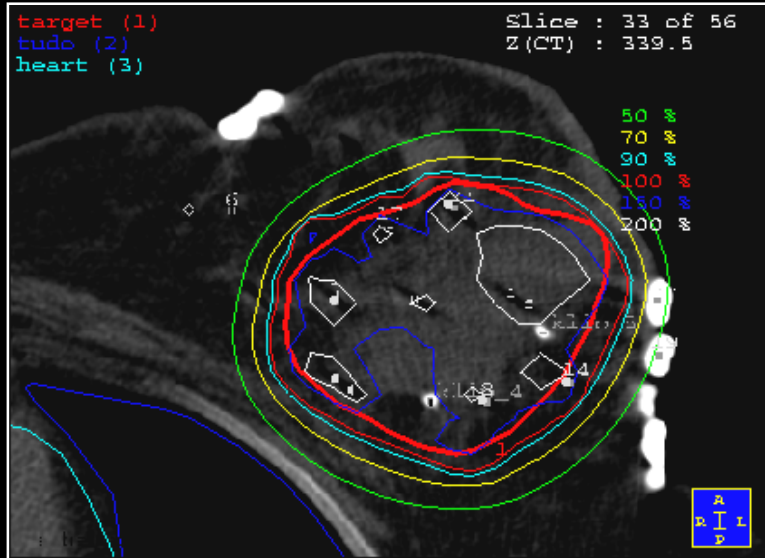
M1: 600 cGy 0 cm<sup>3</sup>



DVH\_8 : Cumulative DVH on heart. State : Consistent.

# F-faktor

$F=0,60$ ,  $DNR=0,50$ ,  $CI=1,00$

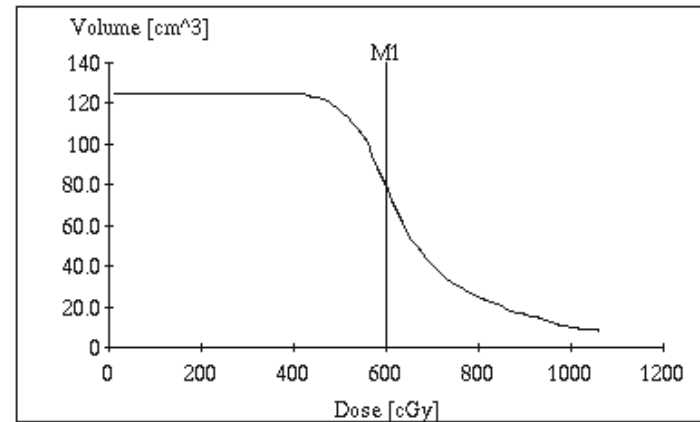


# F-faktor

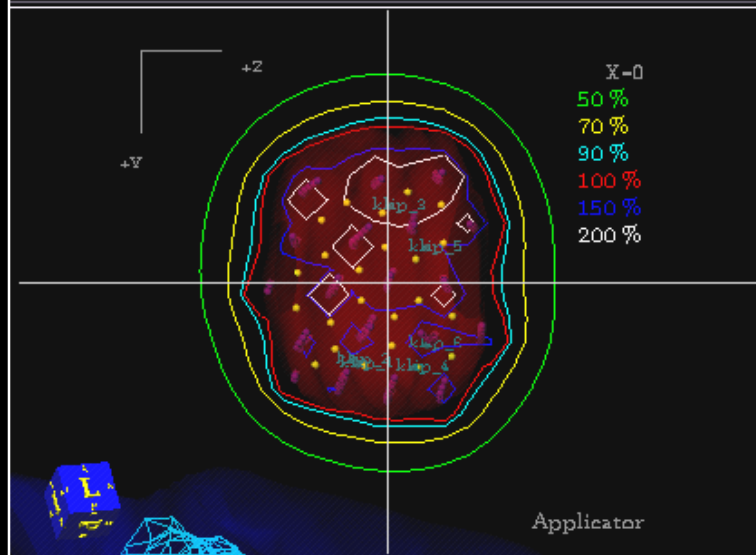
F=0,65, DNR=0,39, CI=1,00



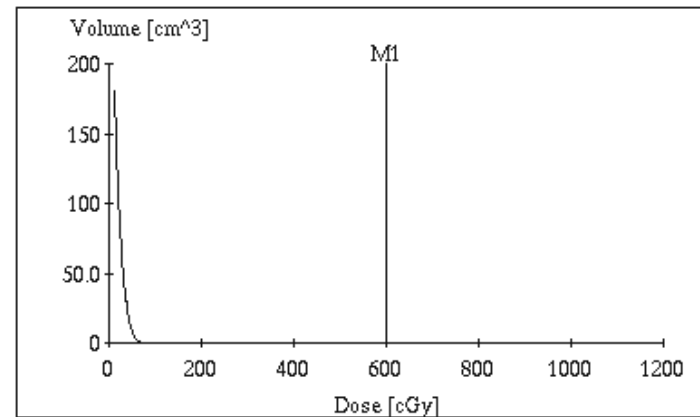
M1: 600 cGy 78.7 cm<sup>3</sup>



DVH\_11 : Cumulative DVH on target. State : Consistent.



M1: 600 cGy 0 cm<sup>3</sup>



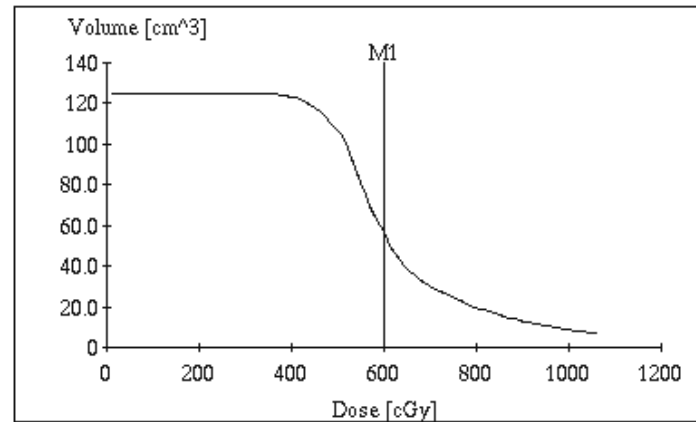
DVH\_12 : Cumulative DVH on heart. State : Consistent.

# F-faktor

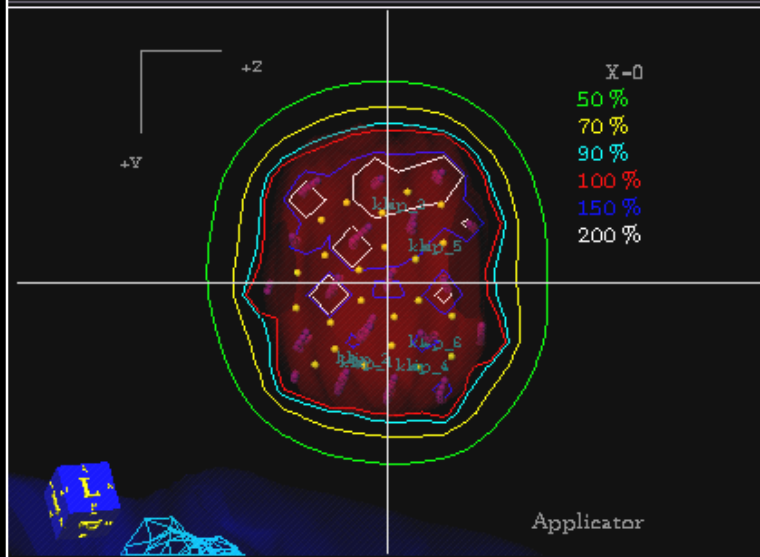
F=0,70, DNR=0,31, CI=0,98



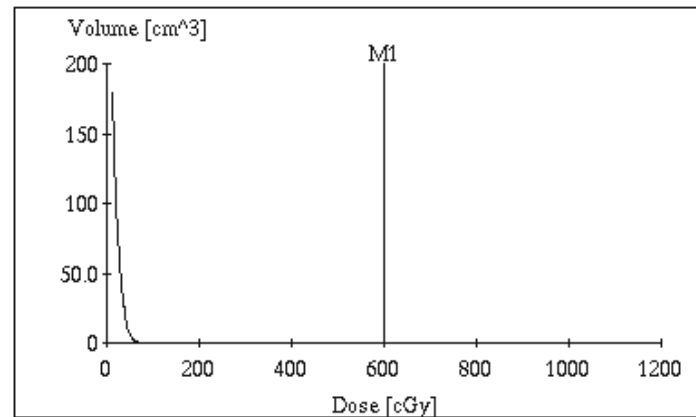
M1: 600 cGy 55.8 cm<sup>3</sup>



DVH\_13 : Cumulative DVH on target. State : Consistent.



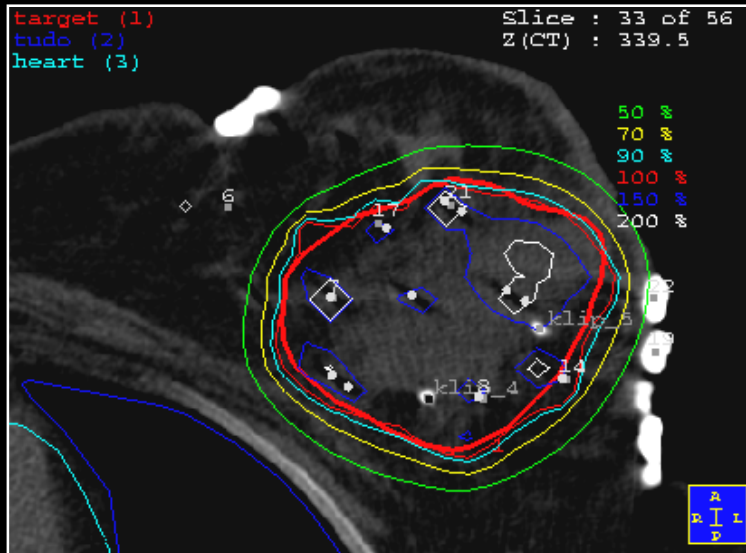
M1: 600 cGy 0 cm<sup>3</sup>



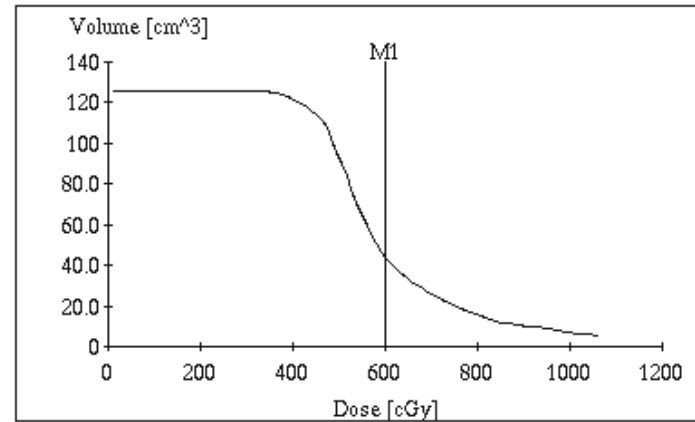
DVH\_14 : Cumulative DVH on heart. State : Consistent.

# F-faktor

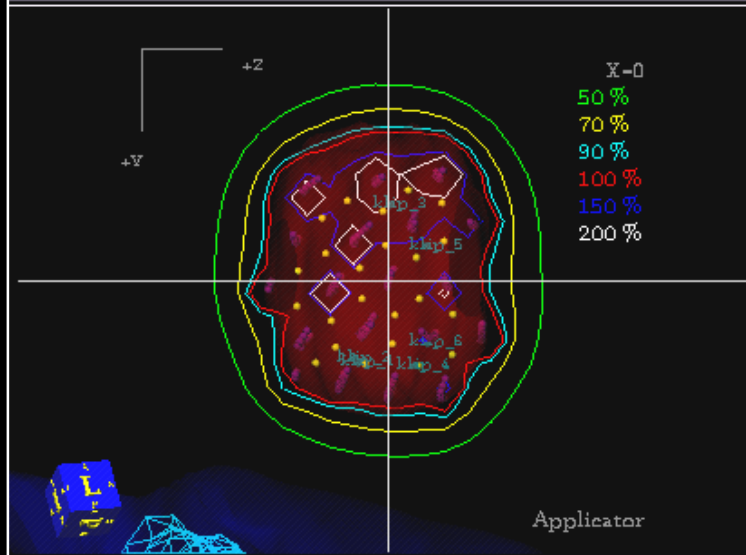
F=0,75, DNR=0,25, CI=0,96



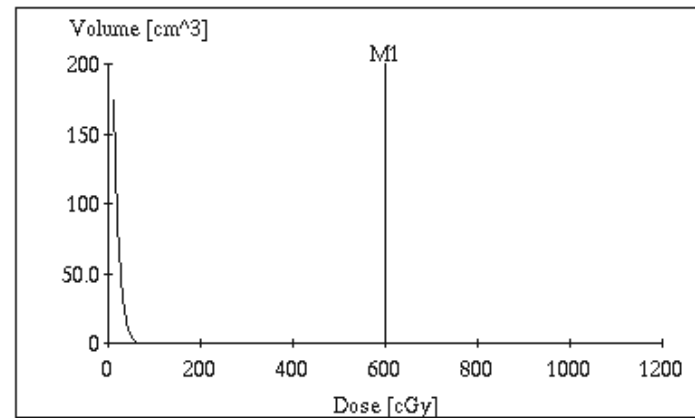
M1: 600 cGy 43.7 cm<sup>3</sup>



DVH\_15 : Cumulative DVH on target. State : Consistent.



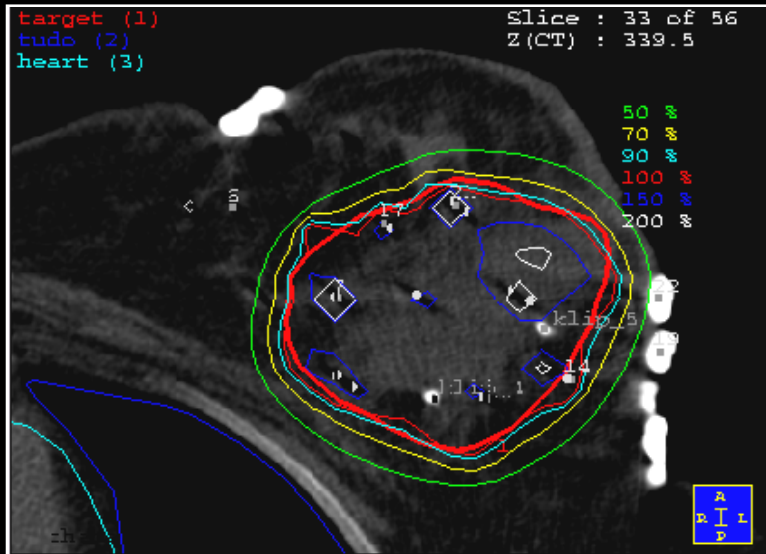
M1: 600 cGy 0 cm<sup>3</sup>



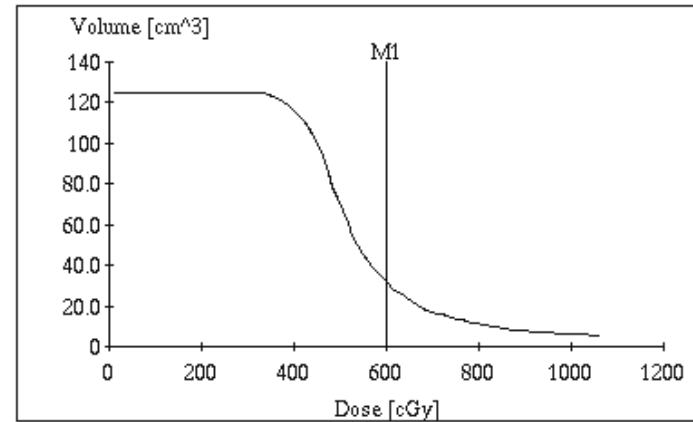
DVH\_16 : Cumulative DVH on heart. State : Consistent.

# F-faktor

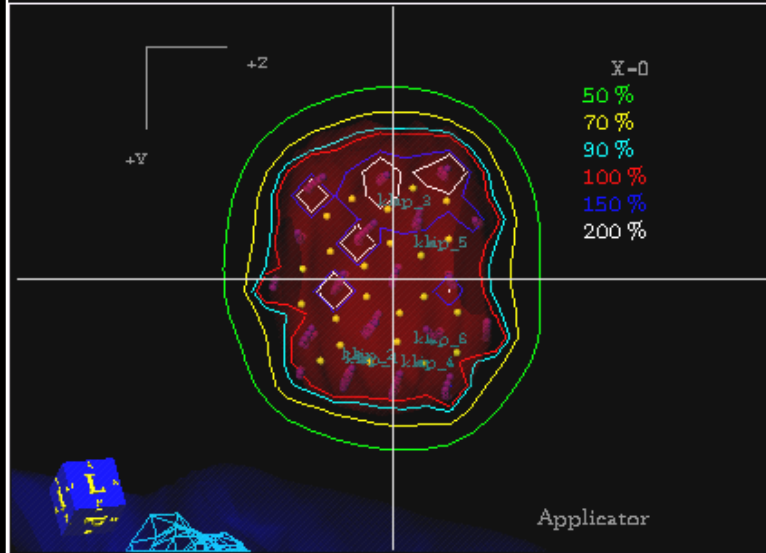
F=0,80, DNR=0,21, CI=0,89



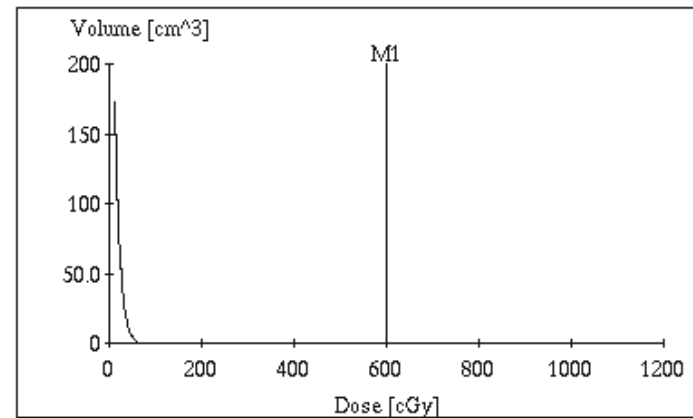
M1: 600 cGy 31.5 cm<sup>3</sup>



DVH\_17 : Cumulative DVH on target. State : Consistent.



M1: 600 cGy 0 cm<sup>3</sup>



DVH\_18 : Cumulative DVH on heart. State : Consistent.

# F-faktor

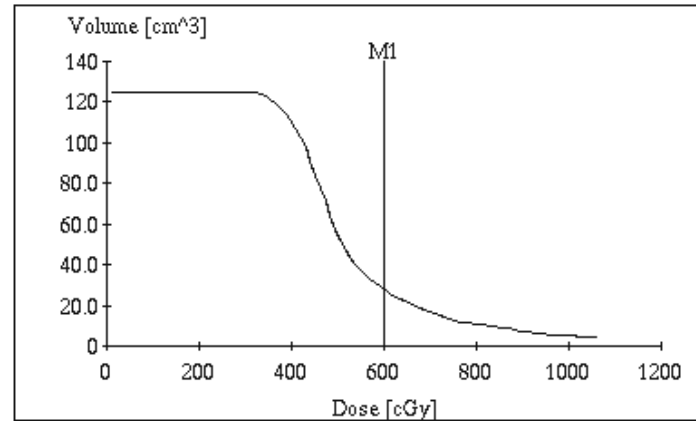
PDS

min.

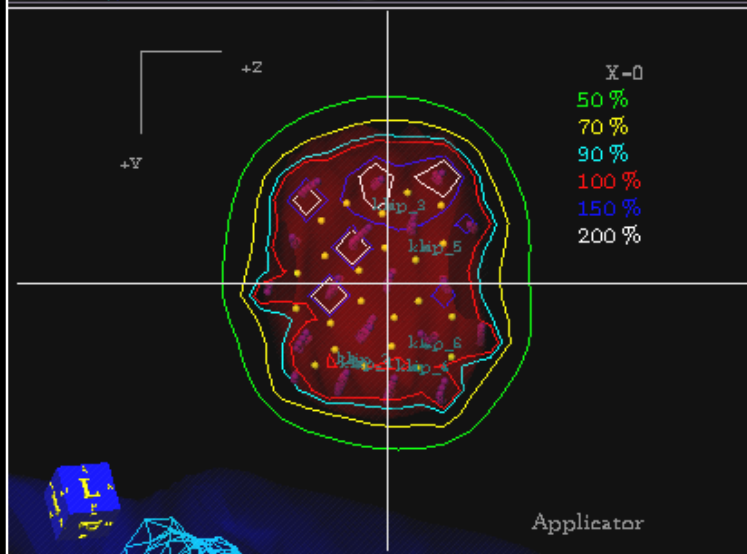
F=0,85, **DNR=0,19**, CI=0,79



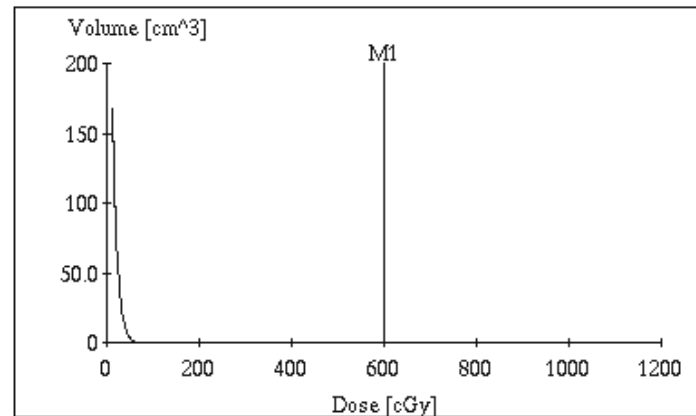
M1: 600 cGy 27.9 cm<sup>3</sup>



DVH\_19 : Cumulative DVH on target. State : Consistent.



M1: 600 cGy 0 cm<sup>3</sup>



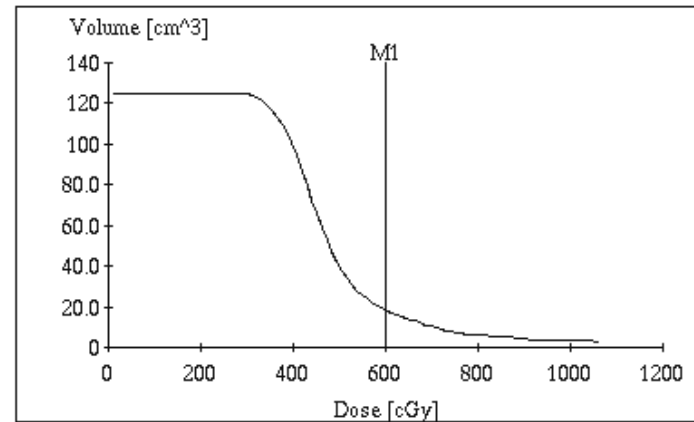
DVH\_20 : Cumulative DVH on heart. State : Consistent.

# F-faktor

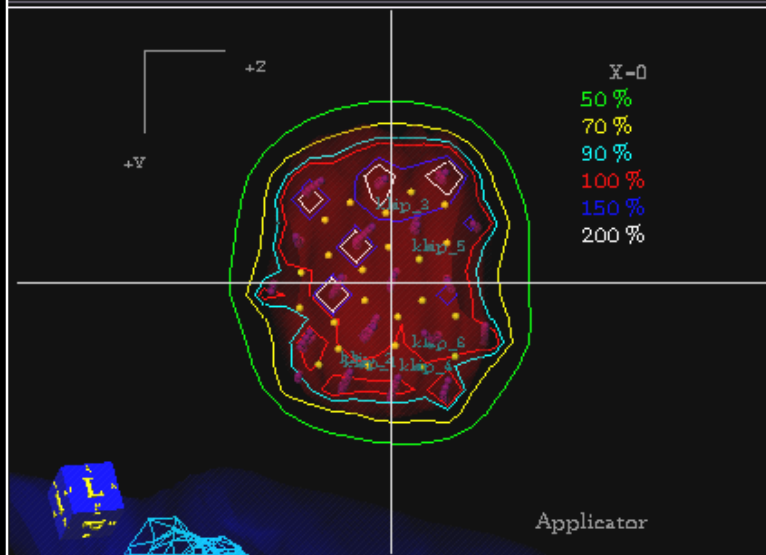
F=0,90, DNR=0,20, CI=0,65



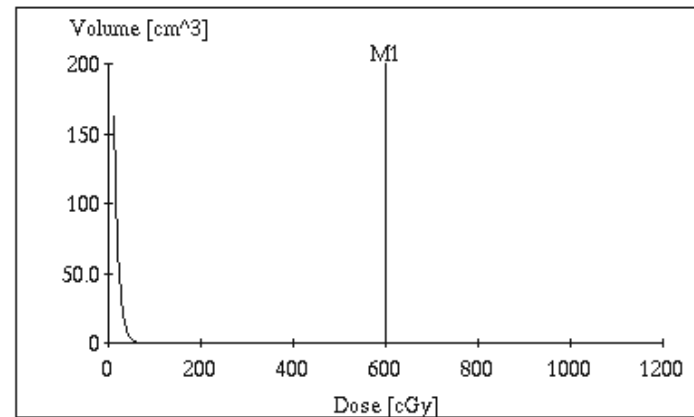
M1: 600 cGy 18.3 cm<sup>3</sup>



DVH\_21 : Cumulative DVH on target. State : Consistent.



M1: 600 cGy 0 cm<sup>3</sup>

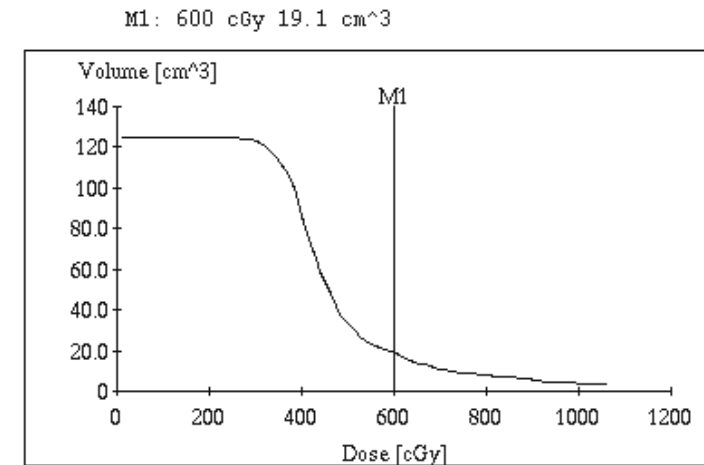
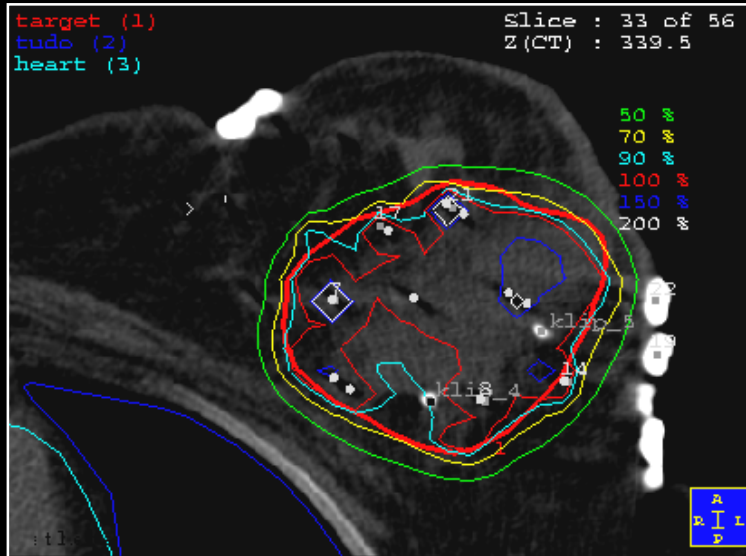


DVH\_22 : Cumulative DVH on heart. State : Consistent.

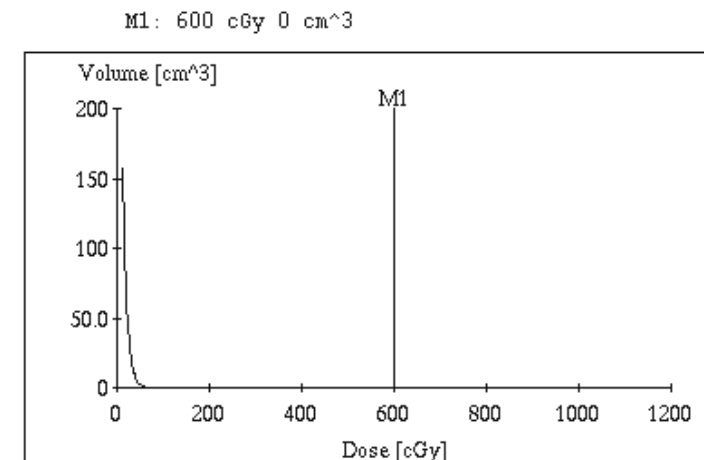
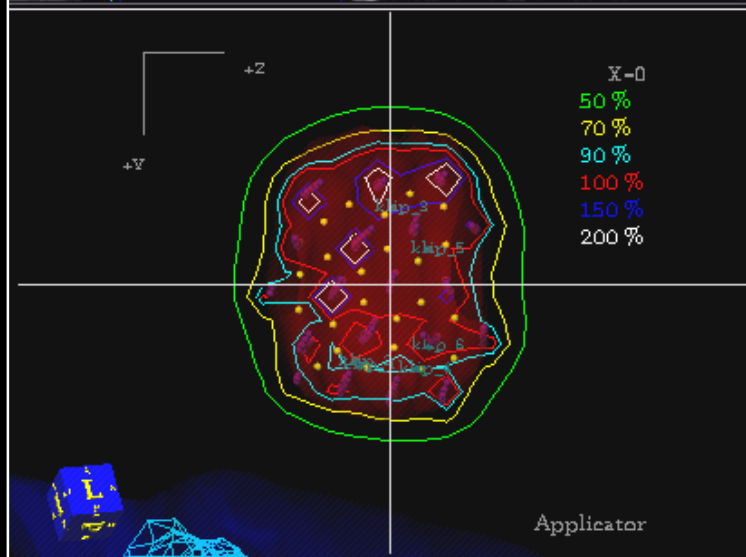


# F-faktor

F=0,95, DNR=0,21, CI=0,53



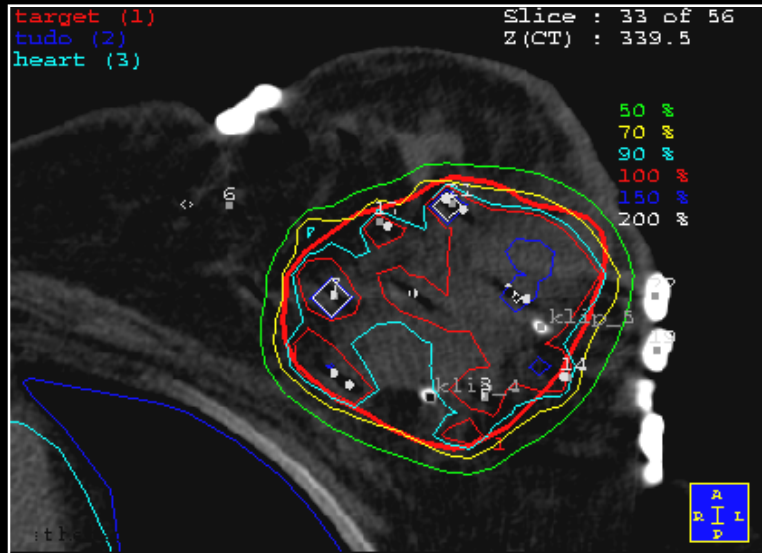
DVH\_23 : Cumulative DVH on target. State : Consistent.



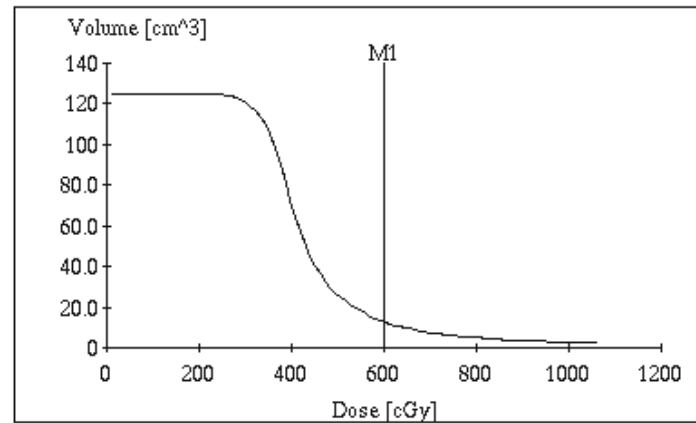
DVH\_24 : Cumulative DVH on heart. State : Consistent.

# F-faktor

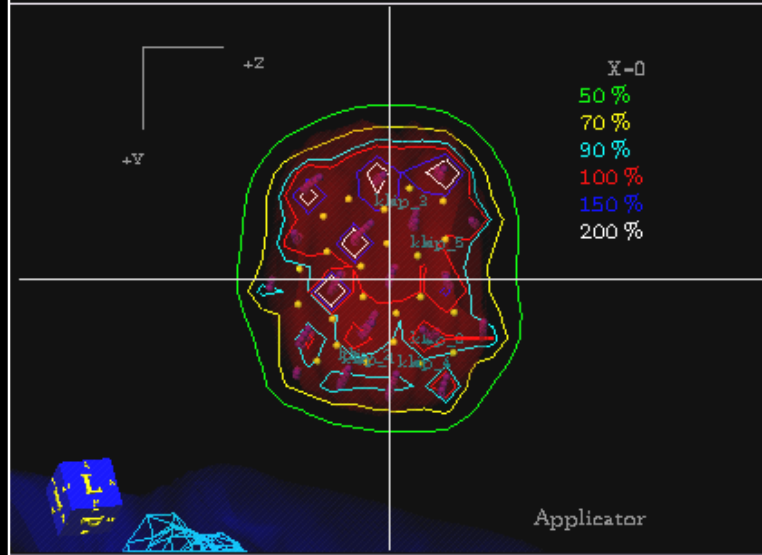
F=1,00, DNR=0,22, CI=0,39



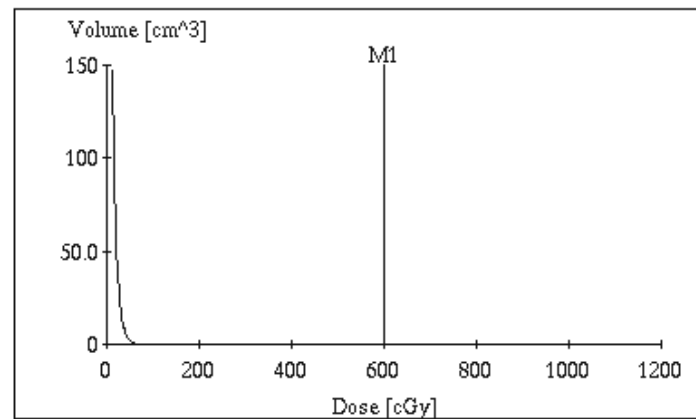
M1: 600 cGy 12.9 cm<sup>3</sup>



DVH\_25 : Cumulative DVH on target. State : Consistent.



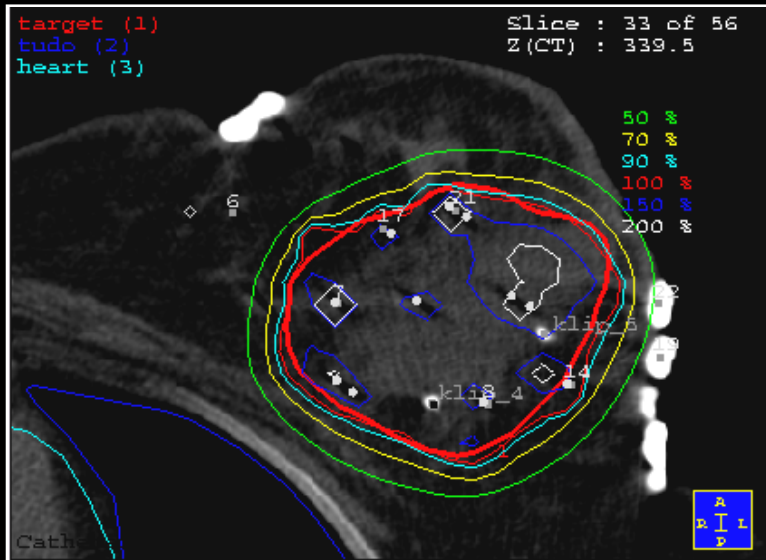
M1: 600 cGy 0 cm<sup>3</sup>



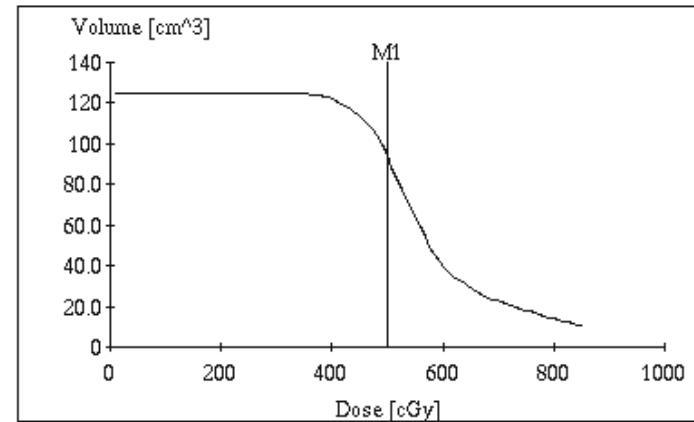
DVH\_26 : Cumulative DVH on heart. State : Consistent.

# F-faktor

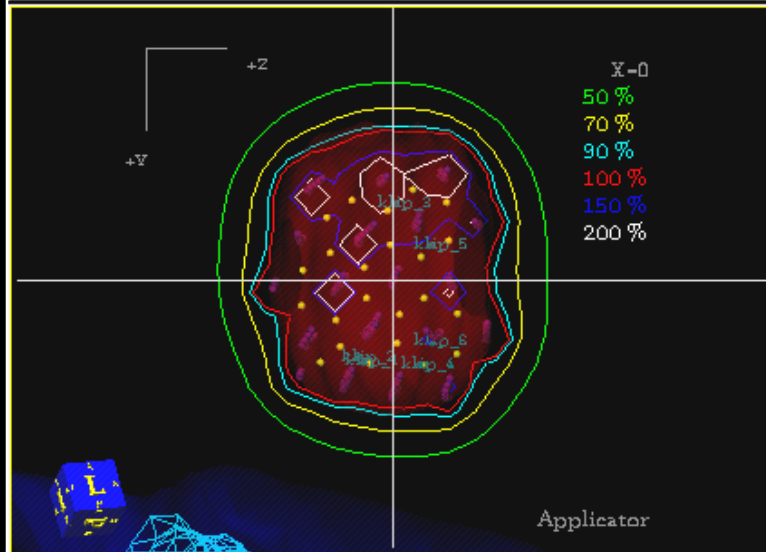
**F=0,74, DNR=0,25, CI=0,96**



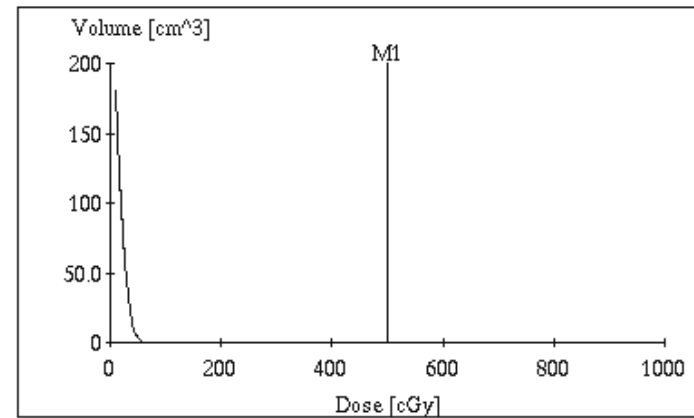
M1: 500 cGy 93.6 cm<sup>3</sup>



DVH\_2 : Cumulative DVH on target. State : Consistent.



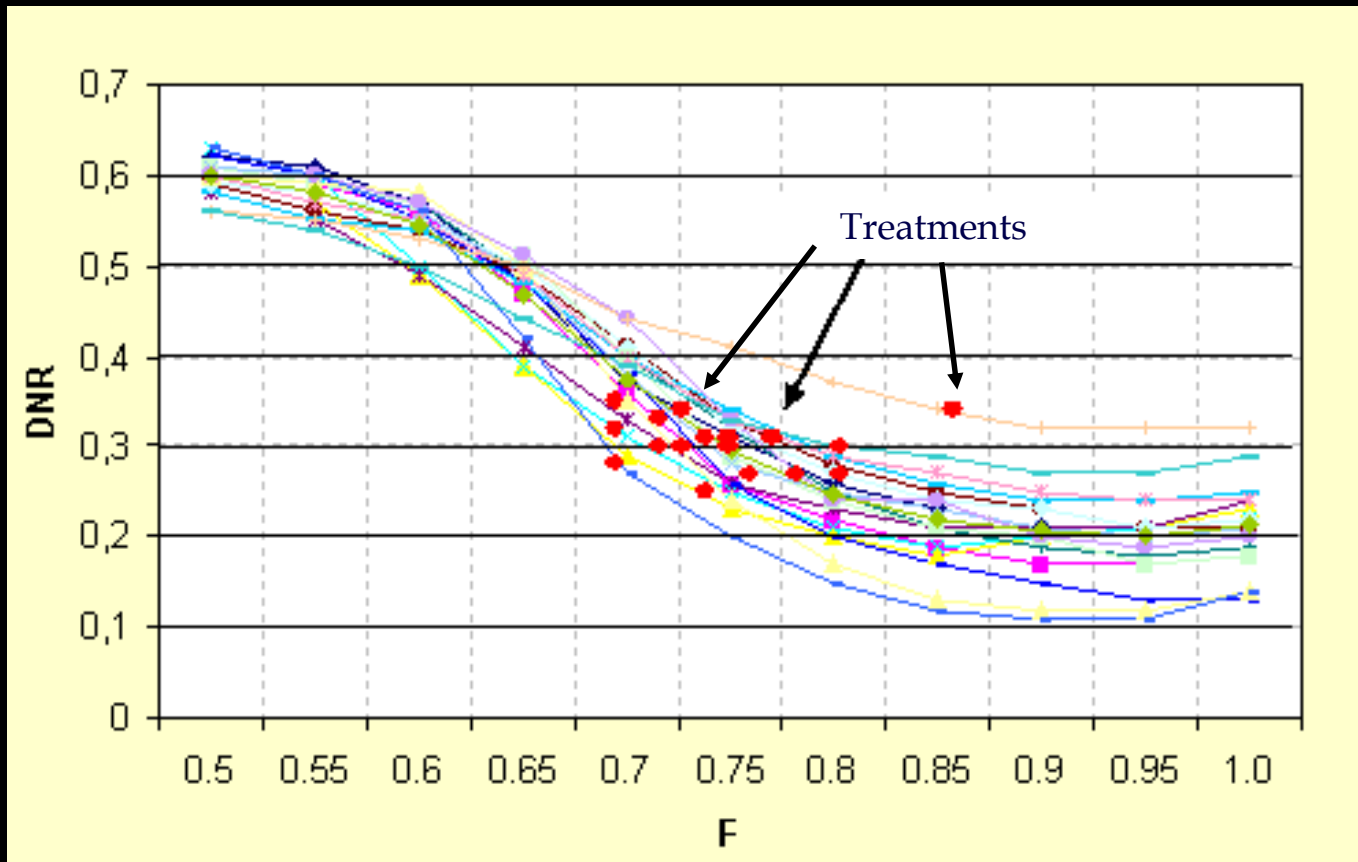
M1: 500 cGy 0 cm<sup>3</sup>



DVH\_4 : Cumulative DVH on heart. State : Consistent.

# F-faktor

F-DNR görbék az egyes betegek esetén



# F-faktor

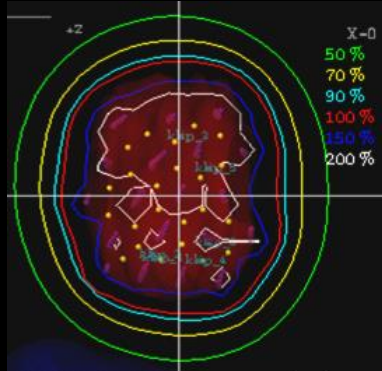
F-faktor = a ref. D ? %-a a MCD-nak

$F(PDS) = 0,85$

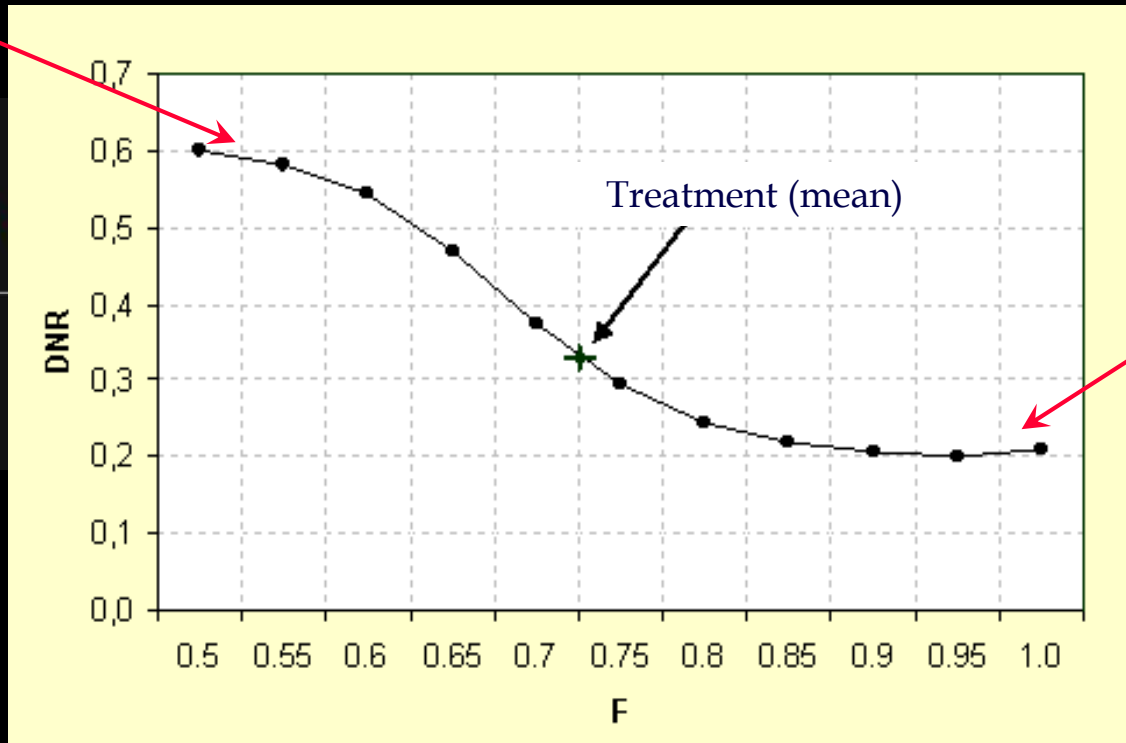
F: 0,5 → 1 ⇔ DNR

$$F = \frac{ref.D}{MCD} (\%)$$

távoli  
izodózis



~ pontforrás



közeli  
izodózis

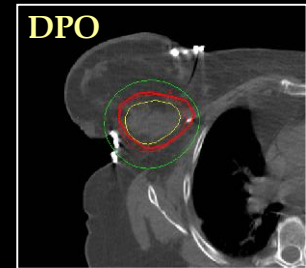
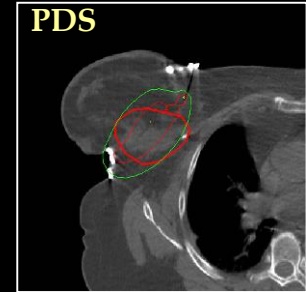
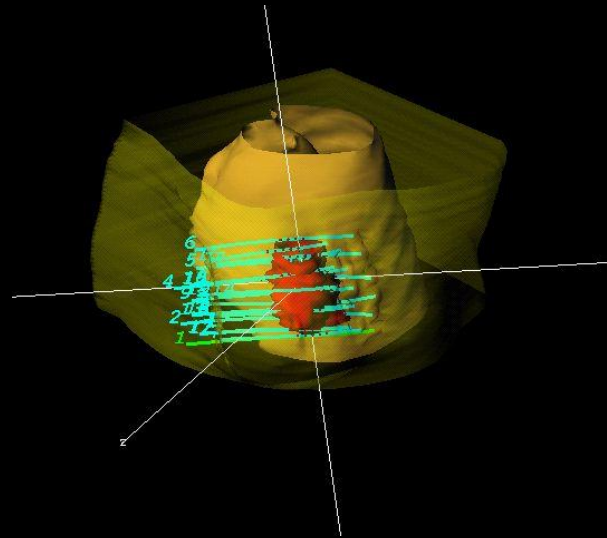
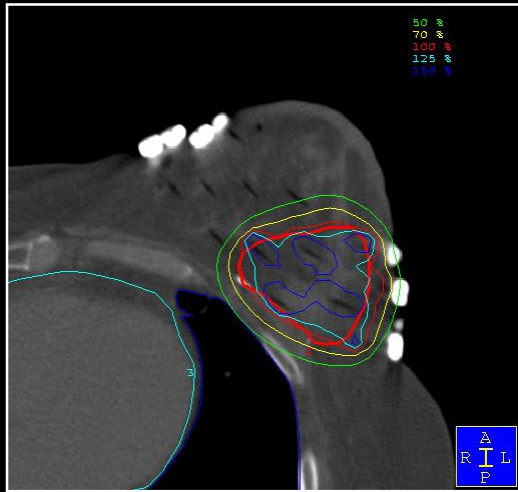


~ pontforrás

F-faktor = 0,75 (0,70-0,85)

DNR = 0,32 (0,25-0,41)

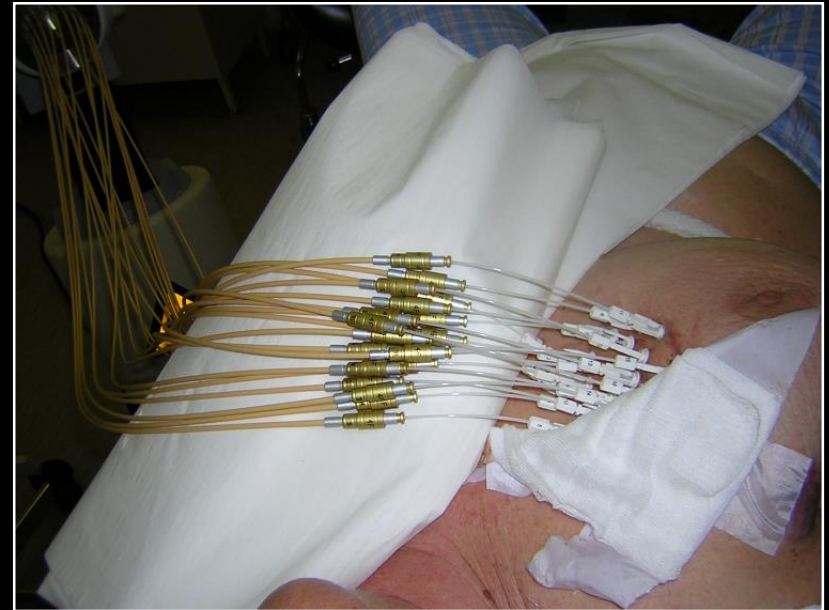
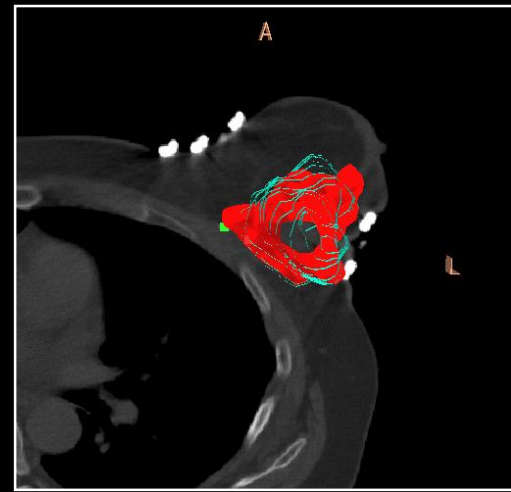
# Konformális dózistervezés



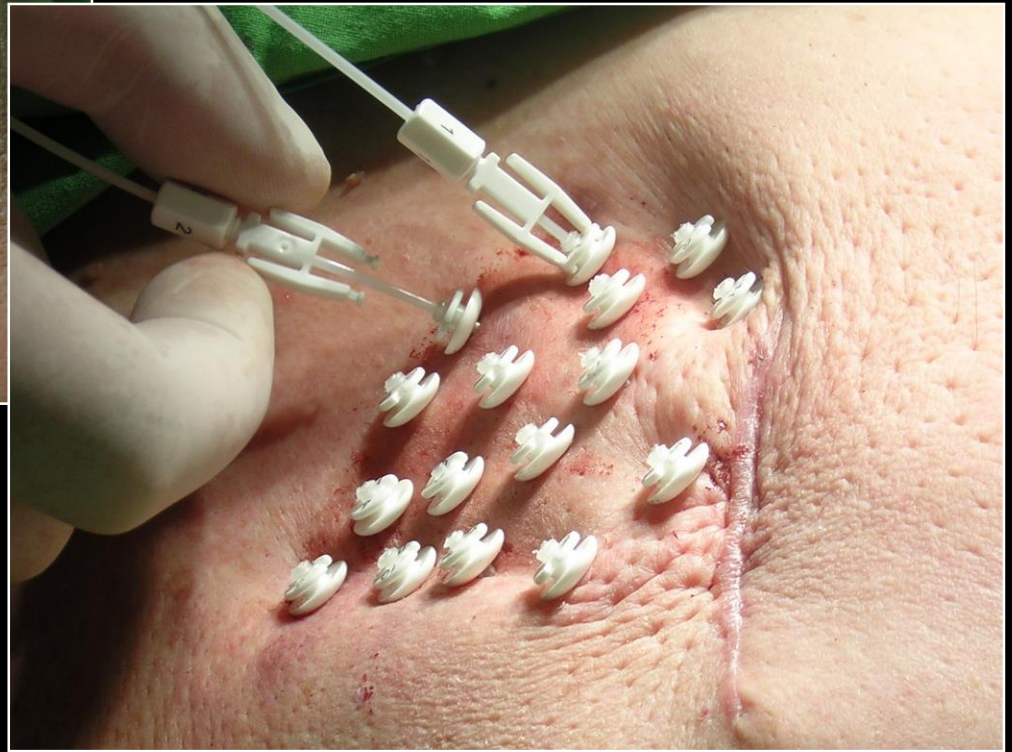
- **konformális** terv: dózis-pont optimalizálási módszer (ref. pontok a PTV felszínén, aktív pozíciók a PTV-n belül, a felszínétől max. 5 mm-re)

# HDR technika

- $\text{Ir}^{192}$  sugárforrás (10 Ci, 360 keV, 3,6 mm x 0,65mm)
- távvezérelt, utántöltéses (AL) módszer



# HDR technika



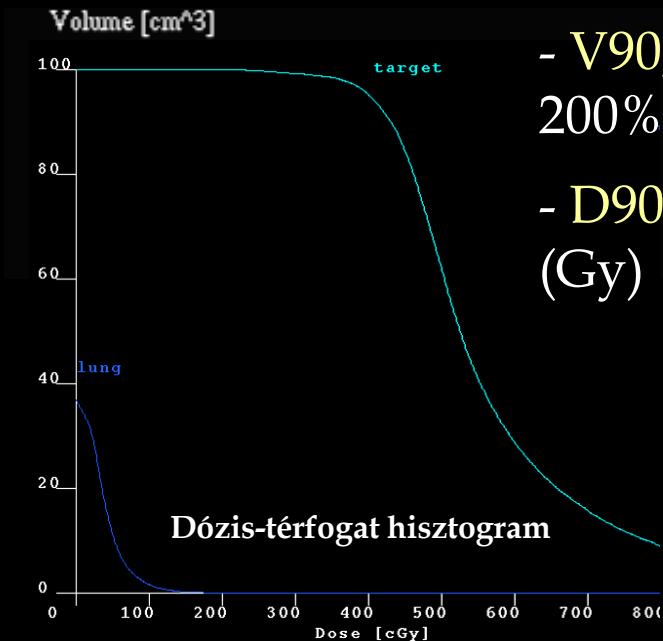
**OncoSmart katéterek** →  
biztosabb azonosítás +  
kényelmesebb betegnek



# HDR technika

## *i, Tértfogati paraméterek*

- **MCD** (Mean Central Dose) (Gy)
- $V_{ref}$ ,  $V_{1.5 \times ref}$ ,  $V_{1.5 \times MCD}$ ,  $V_{PTV}$ : a referenciadózis, a referenciadózis 1.5-szerese, a MCD 1.5-szerese által lefedett térfogat, illetve a PTV térfogata ( $\text{cm}^3$ )



-  $V_{90}$ ,  $V_{100}$ ,  $V_{150}$ ,  $V_{200}$ : : a PTV a ref.D 90, 100, 150, 200%-át kapott térfogata (%)

-  $D_{90}$ ,  $D_{100}$ : a PTV 90 illetve 100%-át besugárzott D (Gy)

-  $D_{max}$ : a védendő szervek (bőr, tüdő és szív) ref. pontjainak max. D-a (%)

-  $V_5$ ,  $V_{10}$ ,  $V_{15}$ : a tüdő és a szív legalább 5, 10 és 15 Gy-t kapott térfogata ( $\text{cm}^3$ )

# HDR technika

## *ii, Indexek*

- **CI** (Coverage Index): a PTV ref.D általi lefedettsége ( $\leq 1$ )

$$CI = \frac{V_{100}}{100}$$

- **DHI** (Dose Homogeneity Index): dózishomogenitás

$$DHI = \frac{V_{100} - V_{150}}{V_{100}}$$

- **DNR** (Dose Non-uniformity Ratio): dózis-egyenetlenség

$$DNR = \frac{V_{150}}{V_{100}}$$

- **COIN** (Conformal Index): konformalitás

- **EI** (External Index): a legalább ref.D-t kapott normál szövet/  $V_{PTV}$

$$COIN = \frac{PTV_{ref}}{PTV} \cdot \frac{PTV_{ref}}{V_{ref}} =$$

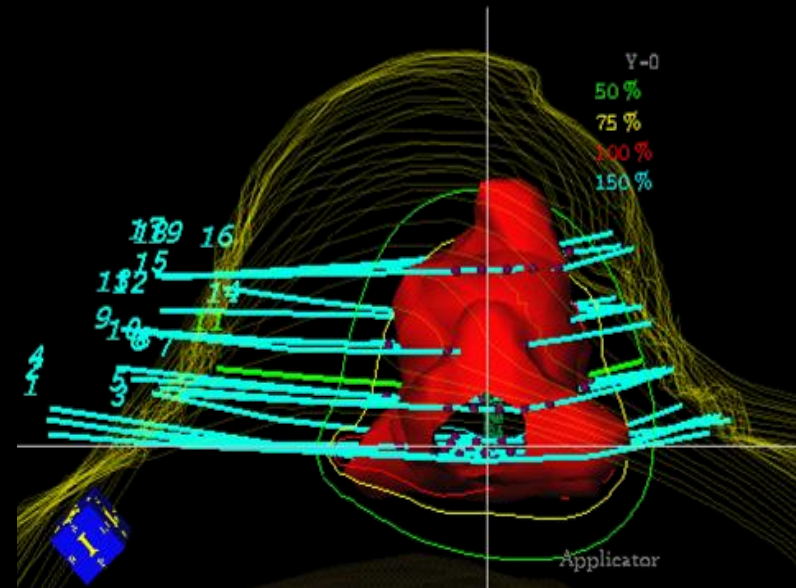
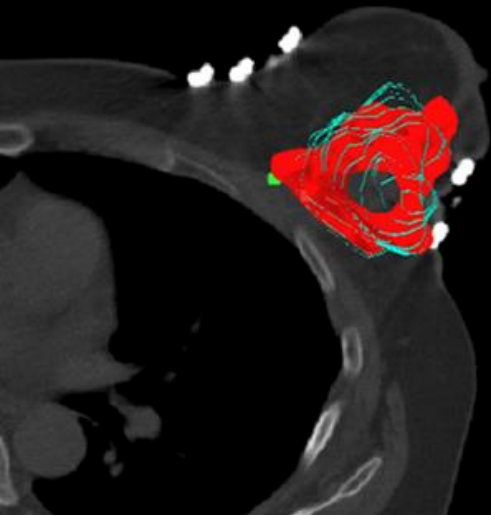
- **TRAK** (Total Reference Air Kerma): a ref. levegő Kerma és a besugárzási idők szorzatának összege minden besugárzási pozícióra (cGy/m)

$$= CI \cdot \frac{PTV_{ref}}{V_{ref}} = \frac{V_{100}^{Organ}}{V_{100}^{Implant}}$$

# HDR technika

## Dóziskövetelmények:

- ⇒ PTV-lefedettség ( $CI \geq 0,9$ )
- ⇒ dózishomogenitás ( $DNR \leq 0,35$ )
- ⇒ maximális bőrdózis ( $D_{bőr} \leq 70\%$ )



# HDR technika

## *i, Dozimetriai paraméterek*

Dozimetriai paraméterek	Átlag	Tartomány
Katéterek	15*	6-28
Katétersíkok	4*	3-6
V <sub>PTV</sub> (cm <sup>3</sup> )	66,4	15,5-176
V <sub>90</sub> (%)	96	93-100
V <sub>100</sub> (%)	92	90-96
V <sub>150</sub> (%)	32	23-45
V <sub>200</sub> (%)	11	5-22
V <sub>ref</sub> (cm <sup>3</sup> )	78,8	23,2-209,5
V <sub>1,5ref</sub> (cm <sup>3</sup> )	24,5	6,8-57,3
V <sub>1,5MCD</sub> (cm <sup>3</sup> )	8,1	3,4-21,4
D <sub>90</sub> (%)	102	99-108
D <sub>min</sub> (%)	69	53-92

Dozimetriai paraméterek	Átlag	Tartomány
CI	0,92	0,9-0,96
DHI	0,65	0,5-0,76
DNR	0,32	0,25-0,41
COIN	0,69	0,49-0,82
EI	0,31	0,12-0,75
MCD (%)	135	118-145
TRAK	0,21	0,1-0,39
D <sub>bőr</sub> (%)	54	12-75
D <sub>tüdő</sub> (%)	44	7-75
D <sub>szív</sub> (%)	22	4-41
V <sub>5Gy(t)</sub> (cm <sup>3</sup> )	49,5	0-160
V <sub>5Gy(sz)</sub> (cm <sup>3</sup> )	15	0-83

\*medián

# HDR technika

## *ii, Késői mellékhatások*

Kor: 65,2 év (53-85)

Követés: 43\* hó (3-72)

†Késői toxicitás: 26 (53%)			
	0	1	p
$V_{PTV}$ (cm <sup>3</sup> )	50,8	80,2	0,0043
$V_{PTV}/V_{emlő}$	0,07	0,12	0,0075
$V_{ref}$ (cm <sup>3</sup> )	61,8	93,8	0,0057
$V_{1,5ref}$ (cm <sup>3</sup> )	19,5	29	0,0039
$V_{1,5MCD}$ (cm <sup>3</sup> )	6,9	9,2	0,0057
Katéterek	12*	15,5*	0,0013
TRAK	0,18	0,23	0,0095

†EORTC/RTOG szerint:

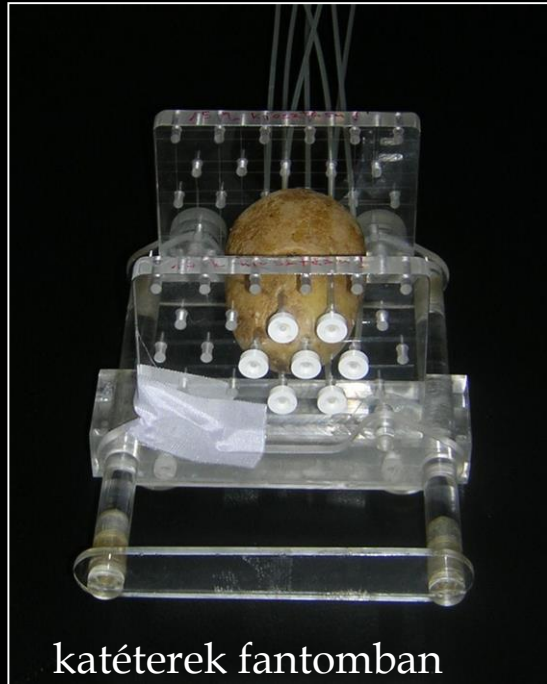
bőr-, subcutan mellékhatások, fájdalom,  
hiperpigmentáció, fibrózis,  
teleangiectázia, zsírnekrózis, limfödéma

\*medián

# HDR technika

Dozimetriai paraméterek	Geometriai és grafikus optimalizáció	Dózis-pont optimalizáció	p-érték
$V_{\text{ref}}$	$75.3 \pm 32.5 \text{ cm}^3$	$64.3 \pm 30.3 \text{ cm}^3$	$< 0.0001$
$V_{1.5\text{xref}}$	$24.4 \pm 9.7 \text{ cm}^3$	$35.5 \pm 17.2 \text{ cm}^3$	$< 0.0001$
DNR	$0.33 \pm 0.04$	$0.54 \pm 0.03$	$< 0.0001$
V100	$91\% \pm 1.6\%$	$88\% \pm 5.3\%$	0.0013
V150	$33\% \pm 5.4\%$	$54\% \pm 4.2\%$	$< 0.0001$
D90	$102\% \pm 2.1\%$	$96\% \pm 8.9\%$	0.0028
D100	$69\% \pm 9.7\%$	$60\% \pm 10.6\%$	0.0005
DHI	$0.64 \pm 0.06$	$0.38 \pm 0.03$	$< 0.0001$
COIN	$0.68 \pm 0.07$	$0.77 \pm 0.07$	$< 0.0001$
bőr: $D_{\text{max}}$	$53\% \pm 14.1\%$	$48\% \pm 13.5\%$	0.0011
tüdő: $D_{\text{max}}$	$42\% \pm 17\%$	$41\% \pm 15.1\%$	0.1952
$V_{5\text{Gy}}$	$42.6 \pm 40.7 \text{ cm}^3$	$35.4 \pm 35.8 \text{ cm}^3$	0.0868
szív: $D_{\text{max}}$	$21\% \pm 10.9\%$	$21\% \pm 11.6\%$	0.3522
$V_{5\text{Gy}}$	$8.0 \pm 12.7 \text{ cm}^3$	$6.1 \pm 13.1 \text{ cm}^3$	0.6679
TRAK	$0.20 \pm 0.05 \text{ cGy/1m}$	$0.20 \pm 0.06 \text{ cGy/1m}$	0.4901

# HDR technika

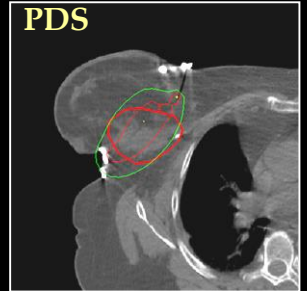


katéterek fantomban

→ katéterek-CT sík hajlásszöge

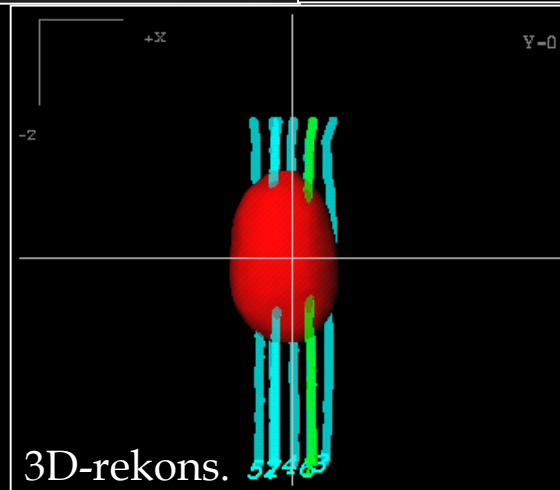
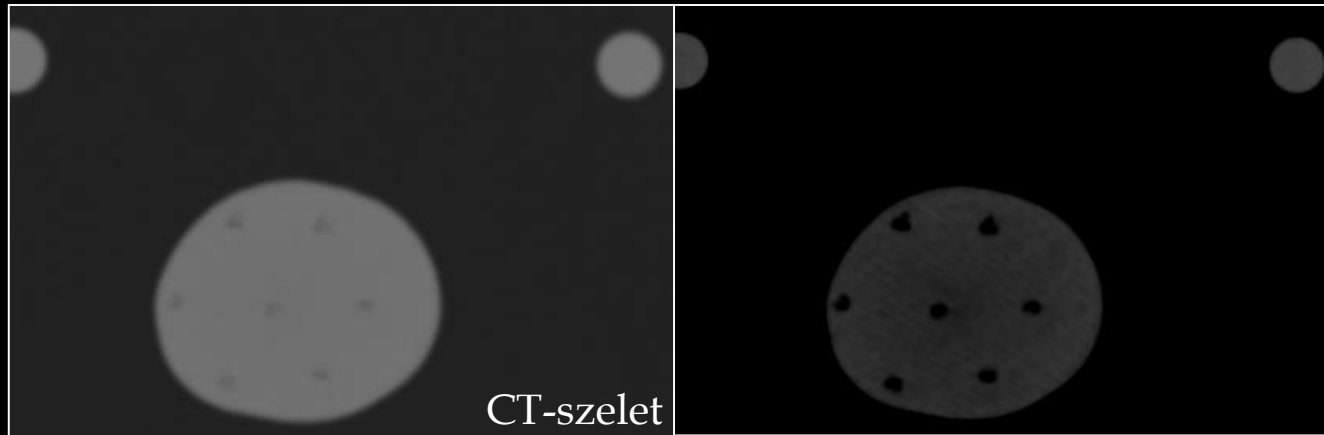
→ optimalizálási eljárások:

- Párizs dozimetriai rendszer (PDS)
- Dózispont optimalizáció (DPO)
- Geometriai optimalizáció (GOS)



# HDR technika

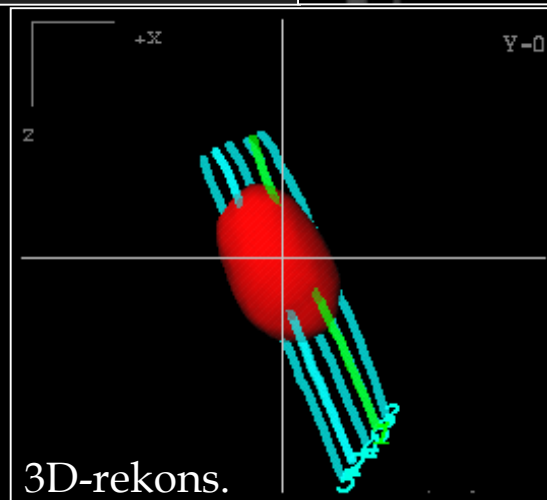
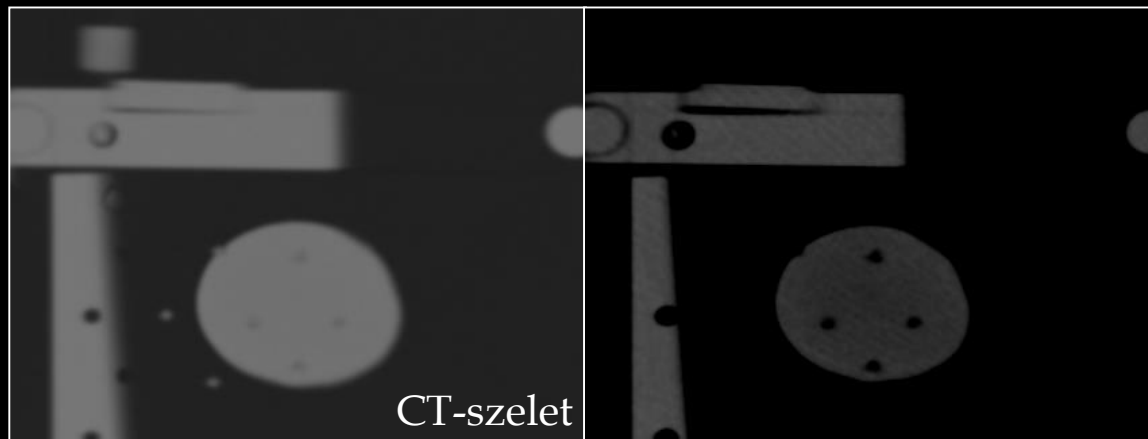
referencia pozíció – 90°





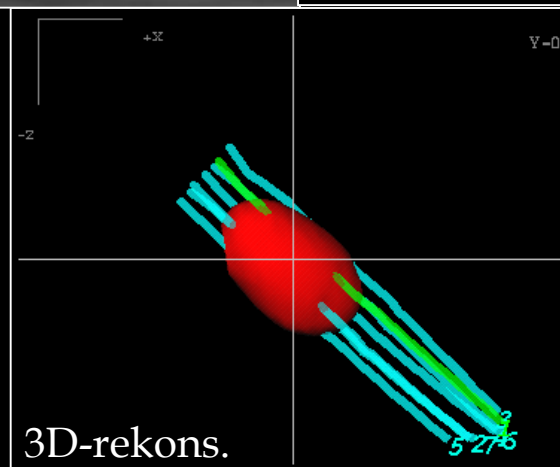
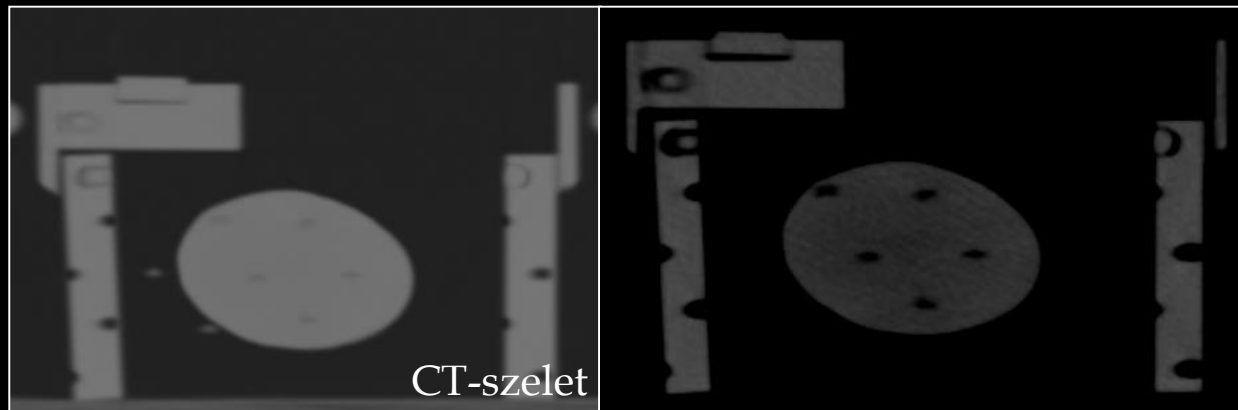
# HDR technika

60°



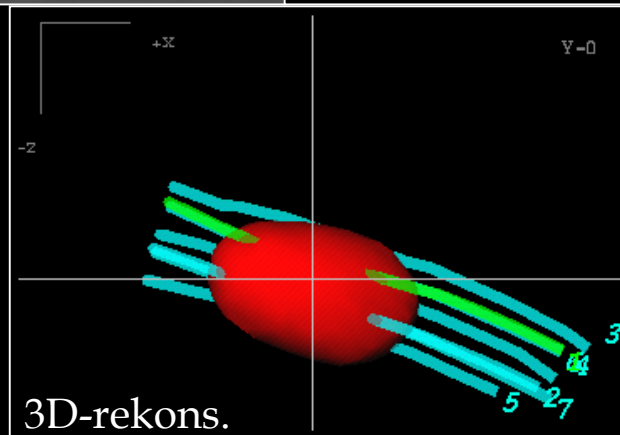
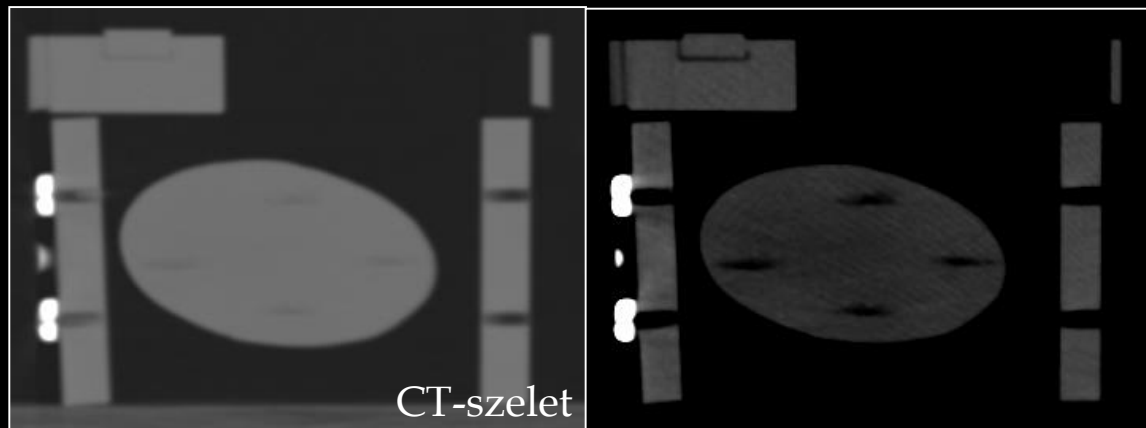
# HDR technika

40°



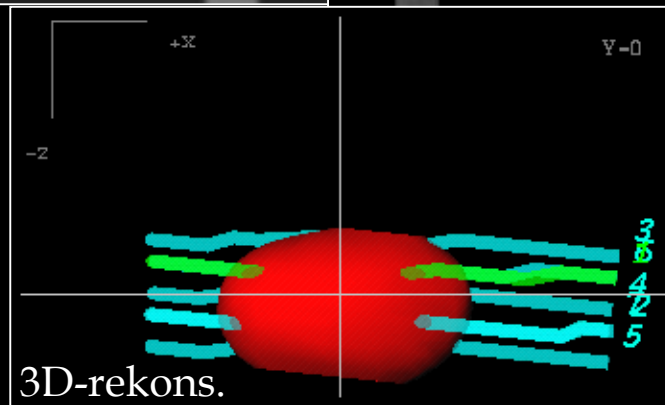
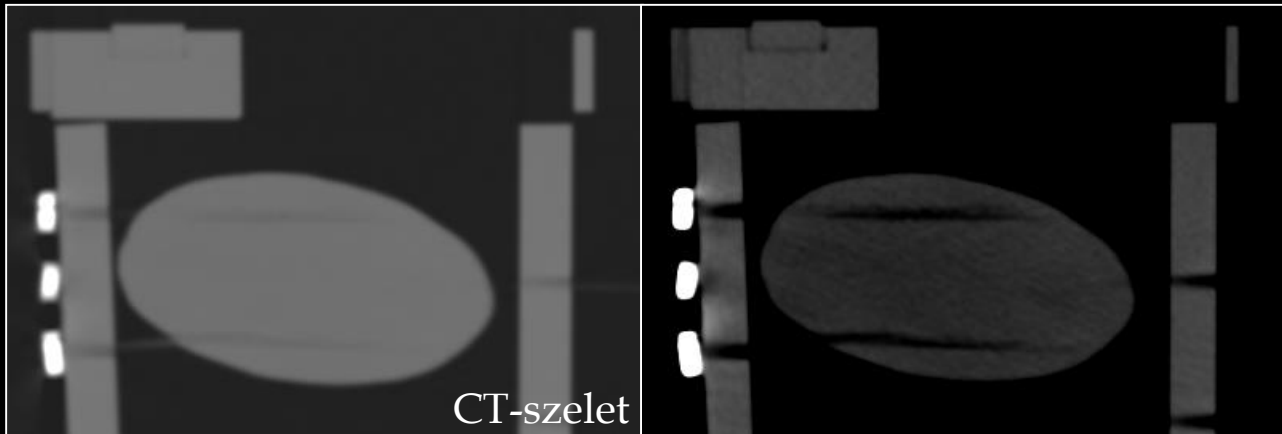
# HDR technika

20°



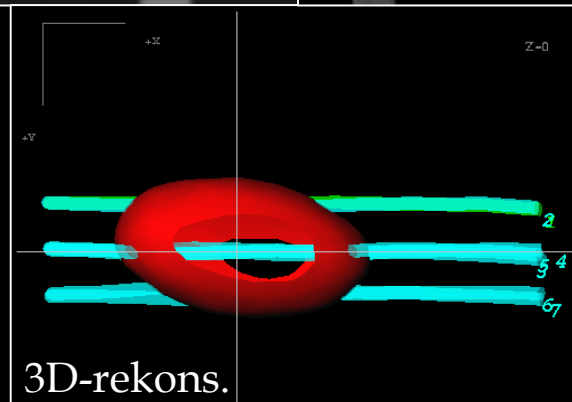
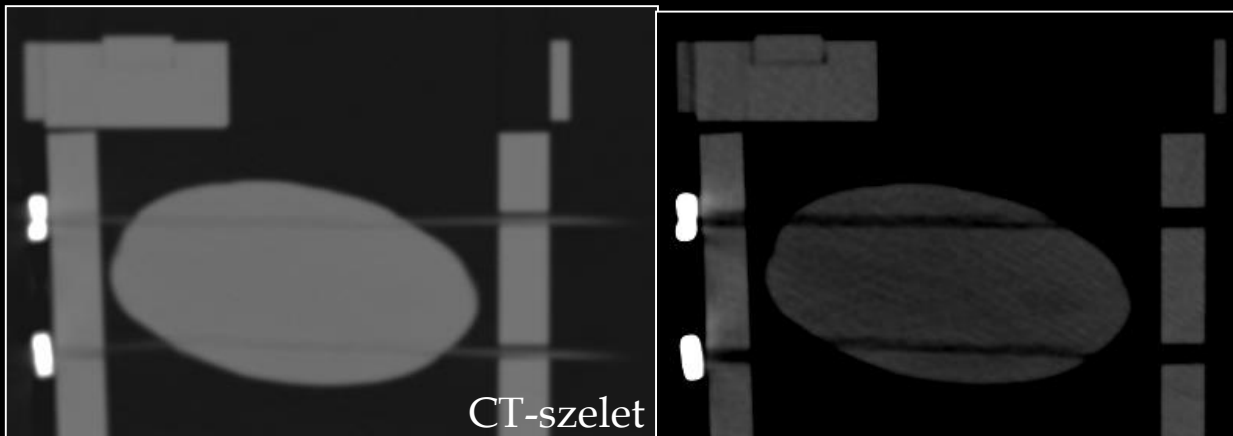
# HDR technika

1-2°

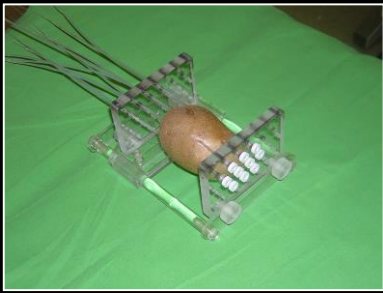


# HDR technika

párhuzamos pozíció – 0°



# HDR technika



- a CT szeletvastagsága:

		átlag (cm <sup>3</sup> )	SD (cm <sup>3</sup> )	max. eltérés az átlagtól (%)
V <sub>PTV</sub> (cm <sup>3</sup> )	3 mm	103,3	0,5	0,7
	5 mm	97,9	2,9	1,3

$$V_{PTV} = 104,1 \text{ cm}^3$$

$$p < 0,001$$

- Nincs szignifikáns különbség a dózis-térfogat paraméterek között 3 és 5 mm-es szeletvastagságnál.

# HDR technika

A szögtől való függés: a referenciaértékektől (90°) való maximális eltérések (%) GOS-nél

GOS	V <sub>ref</sub>	V <sub>1.5ref</sub>	V100 /CI/	V150	V200	D90	D <sub>min</sub>	DNR	DHI	COIN
60	+2,8	+5,0	+1,9	+3,9	+1,4	+3,5	+2,7	+2,7	-3,1	+1,2
40	-2,5	-2,9	-1,2	-3,3	+1,4	-2,5	-0,1	+0,1	+3,0	+0,6
20	-2,2	-3,1	-0,4	-1,7	-4,1	-1,0	-1,4	-0,3	+1,7	+1,6
1-2	+0,2	-2,4	+0,3	+0,4	+3,4	+0,7	+1,9	-2,1	-0,2	+0,7
0	+1,4	+1,4	-0,1	-0,4	-2,7	-0,2	-1,0	+0,6	+0,3	-1,4

# HDR technika

A szögtől való függés: a referenciaértékektől (90°) való maximális eltérések (%) a különböző opt. módszereknél

	$V_{\text{ref}}$	$V_{1.5\text{ref}}$	$V_{100}/\text{CI/}$	V150	V200
PDS	-6,6	+12,0	-5,7	-5,1	$\pm 5,2$
DPO	-2,0	+9,1	-1,5	+10,1	-21,5
GOS	-2,8	-5,0	-1,9	-3,9	+4,1

	D90	$D_{\text{min}}$	DNR	DHI	COIN
PDS	-6,7	-7,9	+9,4	+0,8	-5,3
DPO	-1,5	-4,9	-9,7	+9,4	+1,9
GOS	-3,5	-2,7	-2,7	+3,1	-1,6



# HDR technika

CT-szeletvastagság	3 mm	5 mm				
Optimalizálás	PDS	DPO	GOS			
Szög (fok)	90	60	40	20	1-2	0



*Köszönöm a figyelmet!*