PLAN EVALUATION & REPORTING

Dr Umesh Mahantshetty,

Professor, Radiation Oncology

GYN & Urology Disease Management Group (DMG) Member

Tata Memorial Hospital,

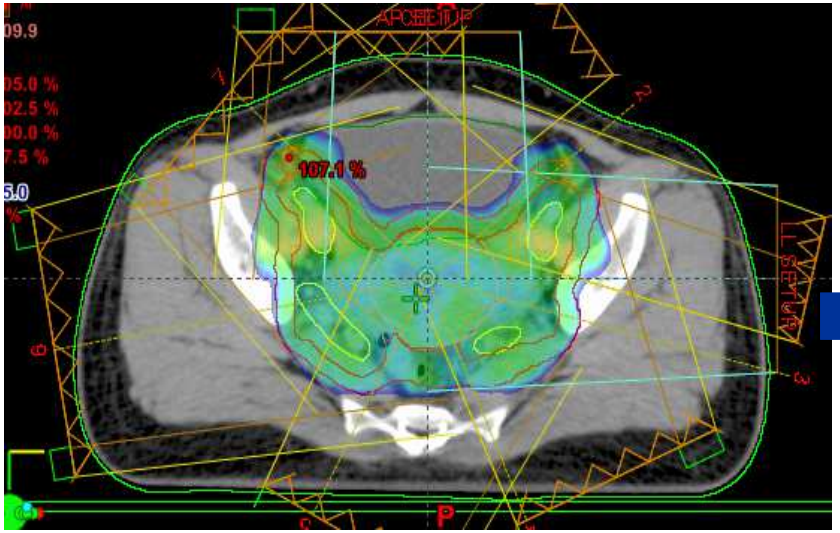
Mumbai, India

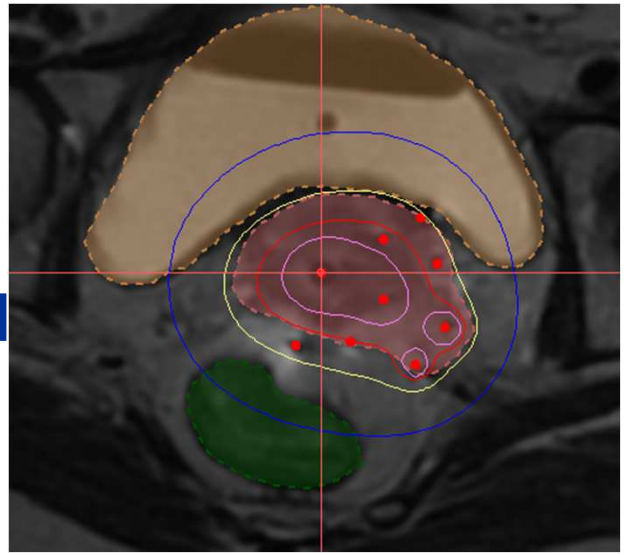
GYN GEC – ESTRO NETWORK MEMBER AND FACULTY

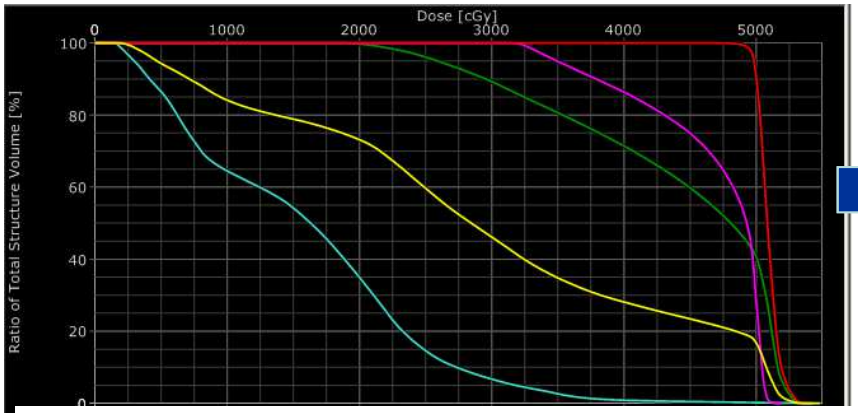
ACKNOWLEDGEMENTS: GYN GEC – ESTRO Teaching Faculty, ESTRO & IAEA Teaching Material

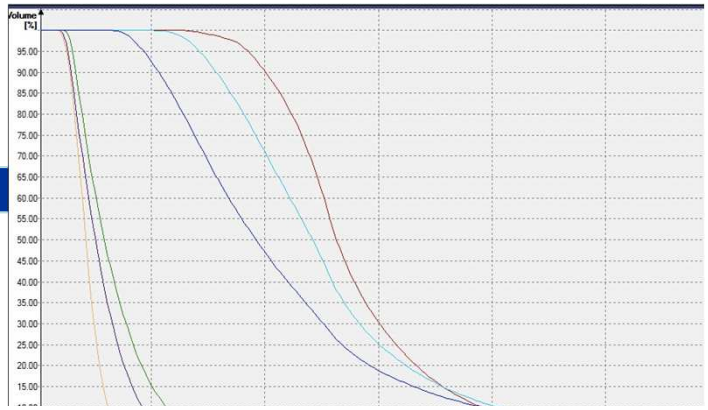
Challenges (combining EXRT +BT)

EXRT **BT**





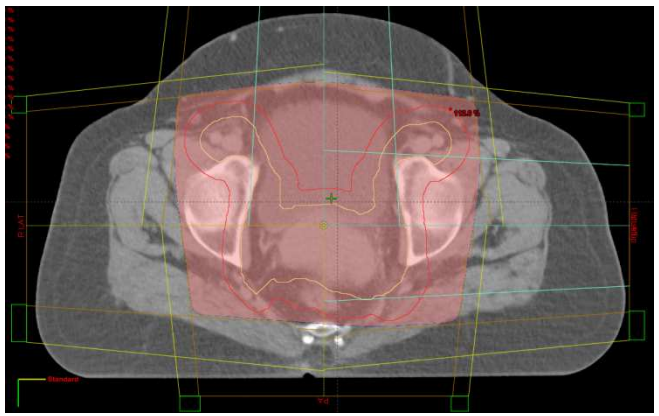


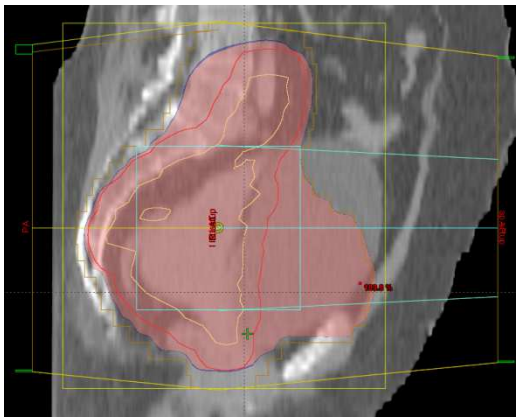


USE EQD2 formula to combine and report (treatment) dose parameters

1. EBRT + Chemotherapy + BRT

EBRT Technique: 3D, CT based CRT; box technique
TD: 45 - 50 Gy / 25#
Dose per fraction: 1,8 Gy
Boost: no
Concomitant CT: Cisplatin 40 mg/m2 weekly, 5 cycles
Brachytherapy : 7 Gy x 4# HDR : Point A / HR-CTV





CTVs for Brachytherapy receives the prescribed dose of EBRT

80-90% of the Rectum receives 90% of the prescribed dose

<80% of the Bladder receives 90% of the prescribed dose

The high and medium dose regions of brachytherapy in OAR
rectum, sigmoid, bladder, vagina receive the prescribed dose of EBRT

Major issues for dose volume assessment Integrating EBRT and Brachytherapy (II)

- **Physical doses of EBT and Brachytherapy may be added** at the CTV for BT and/or specific points (A) : 45+4x7

- **Physical doses of EBT and Brachytherapy may be added** at high dose regions in OAR and/or specific points (ICRU) : 45+4x4

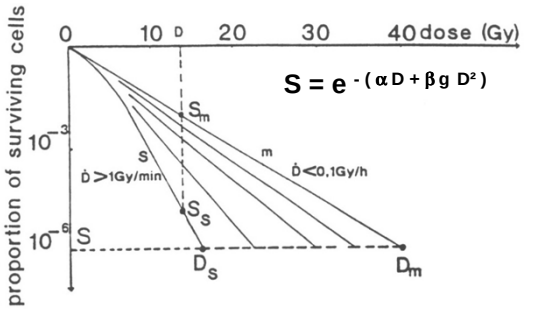
- **Biologically weighted doses must be generated and added** in case of dose per fraction different from 2 Gy/fractíon or dose rate different from 50 cGy/hour

Radiobiological Considerations

Linear - Quadratic model for incomplete monoexponential sublethal (DNA) damage repair

- **Biologically Effective Dose:**

(1) $$BED = nd\,[\,1 + g\,d\,/\,(\alpha/\beta)\,]$$



The Role of Dose Rate in Brachytherapy (J. Dutreix) In: A Practical Manual of Brachytherapy (Pierquin / Marinello, Medical Physics Publishing)

tissue dependent

- **BED ... virtual dose value that produces the same biological effect as the physical dose with an infinite low dose rate**

n ... number of equal fractions
d … dose per fraction

arameters :

α/β ...parameter describing lethal / sublethal lesions
g ... repair function depending on - half time for cell repair $T_{1/2}$
- fractionation

Mathematical Description /Normalization - EQD2

- **LQ model gives biological equivalence for**

1. **classical LDR brachytherapy (50 cGy/h) and**
2. **conventional external beam therapy (2 Gy / fraction) with $T_{1/2}$ = 1.5 hours (clinical experience, ICRU 38)**

1

- **Calculated BED values are normalized to conventional EBRT with 2 Gy / fraction (reference schedule) :**

2

$$BED = D_{IsoE} [1 + 2 / (\alpha/\beta)]$$

$$D_{IsoE} = BED / [1 + 2 / (\alpha/\beta)] \quad = EQD_2$$

"isoeffective dose" = "equivalent dose in 2 Gy fractions"

- **To calculate the total isoeffective dose D_{IsoE} of a combined treatment, all isoeffective doses D_{IsoE} are added up :**

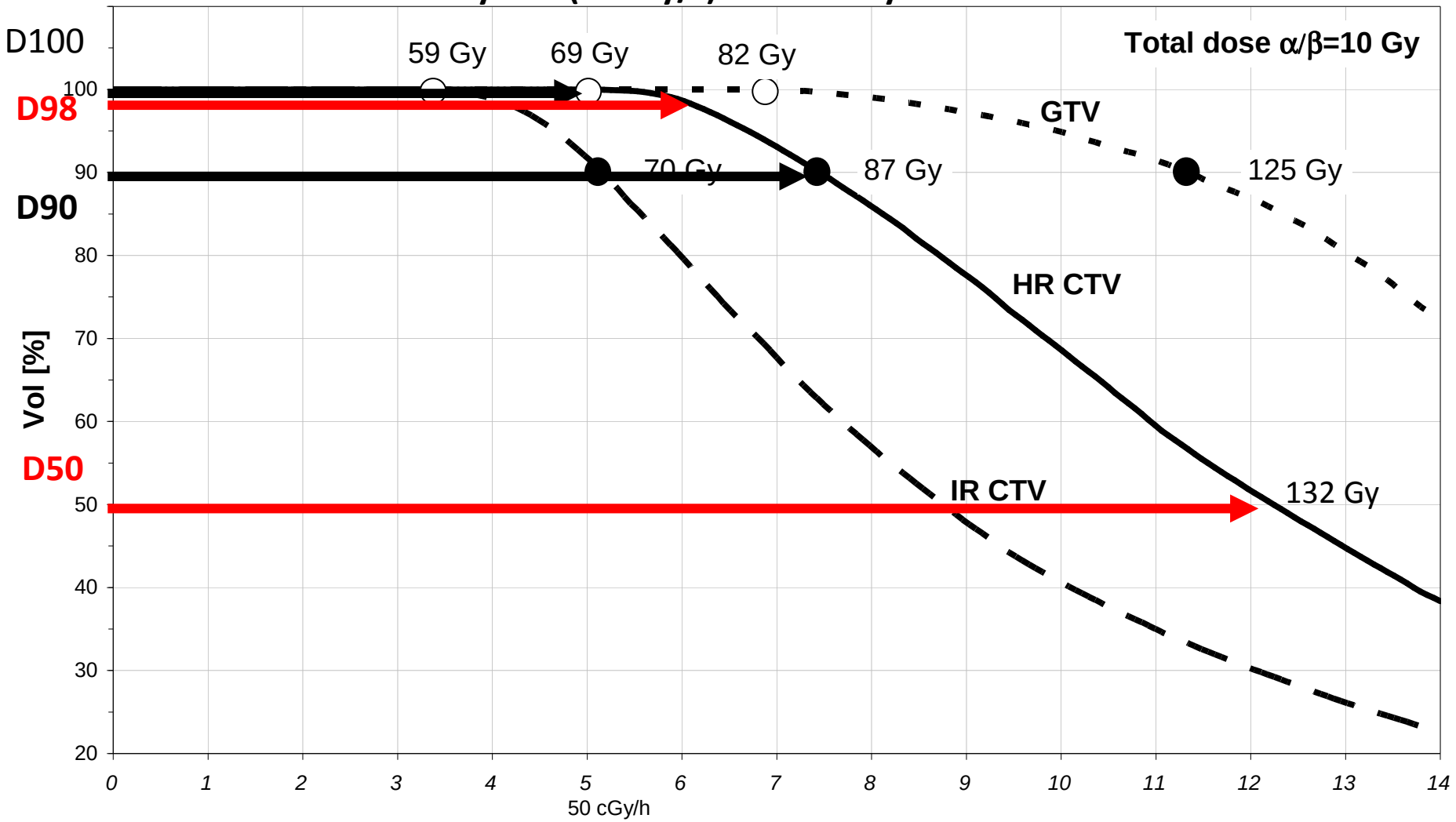
$$D_{IsoE,TOTAL} = D_{IsoE,EXTERNAL} + D_{IsoE,BRACHY}$$

$$D_{isoE} = \frac{nd \cdot (1 + \frac{d}{(\alpha/\beta)})}{1 + \frac{2}{(\alpha/\beta)}}$$

Cumulative Dose Volume Histograms for GTV, HR CTV, IR CTV

for 45 Gy EBT (1.8 Gy/f) and 4x7 Gy HDR BT in HR CTV*

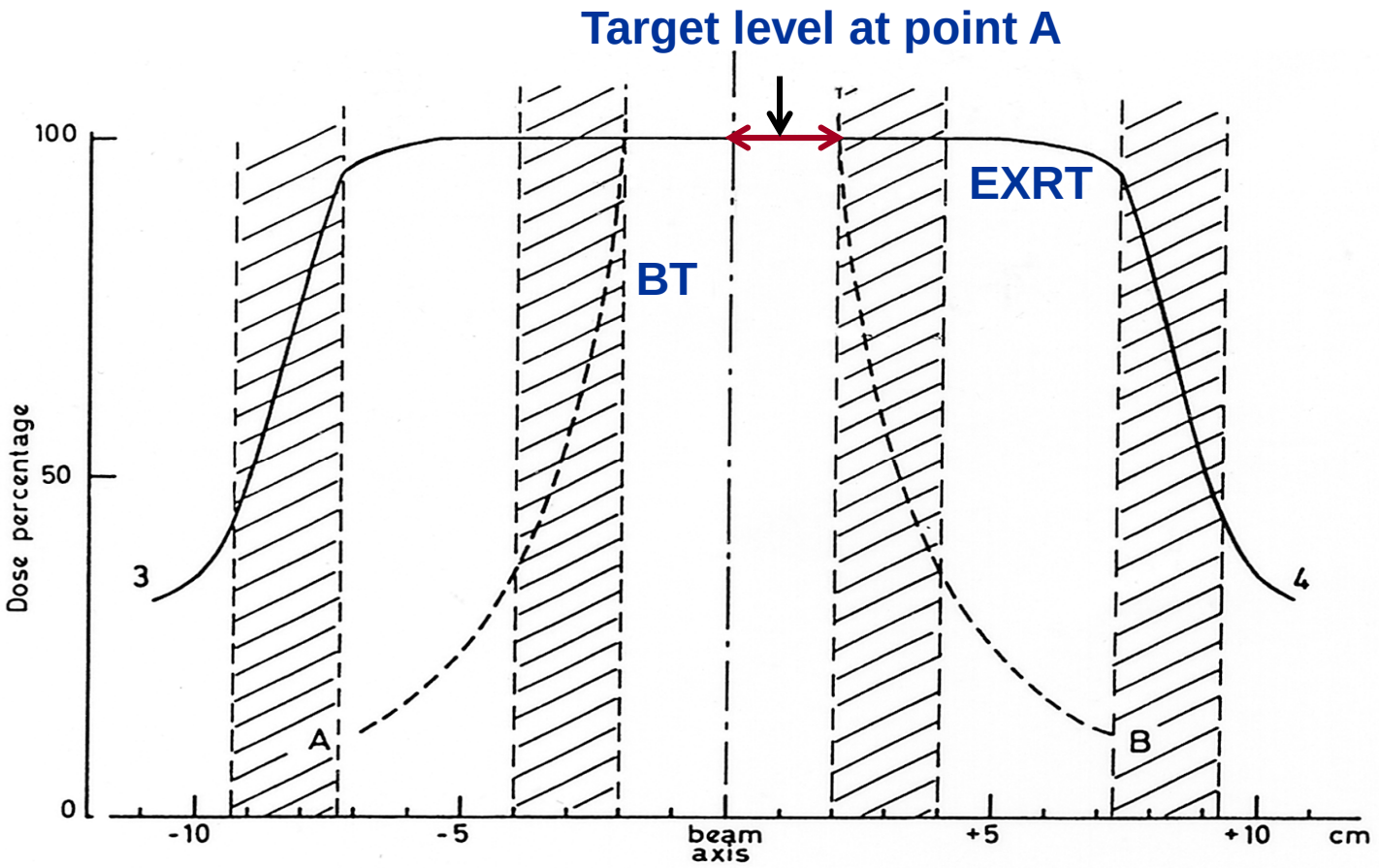
Fig.10

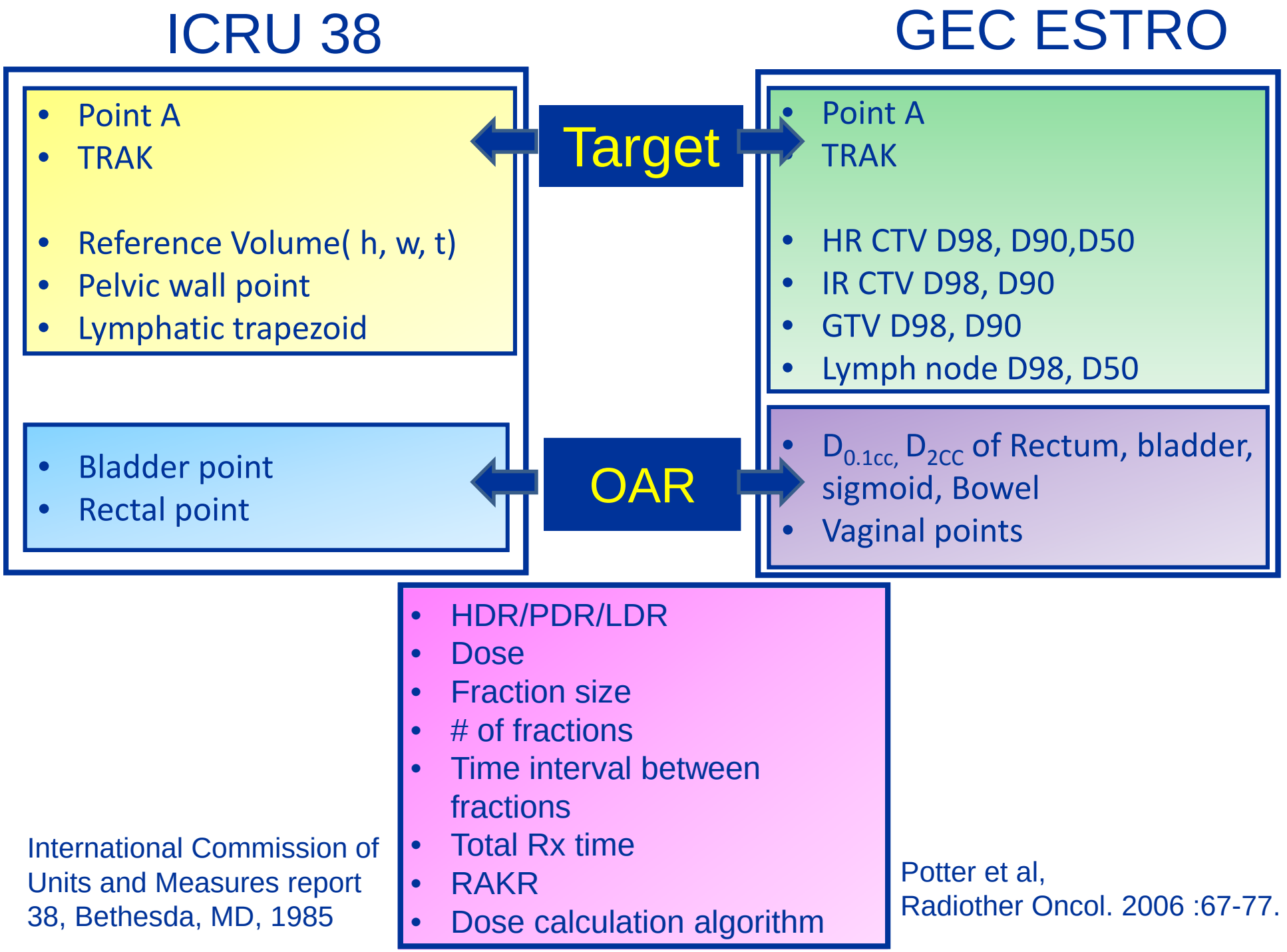


*GYN GEC ESTRO Recommendations (II) Radioth. Oncol. 2006 (modified)

Challenges (combining EXRT +BT)

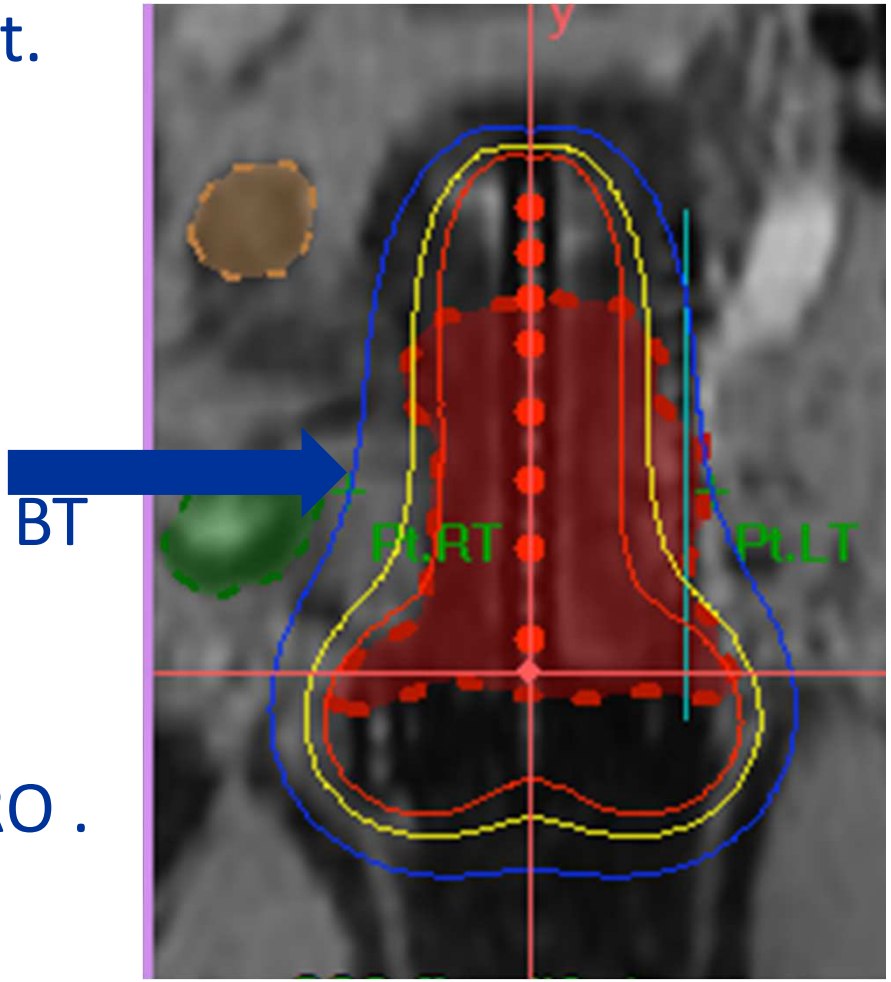
- Dose gradient




ICRU 38
GEC ESTRO
Target
Point A
TRAK
Reference Volume(h, w, t)
Pelvic wall point
Lymphatic trapezoid
Point A
TRAK
HR CTV D98, D90,D50
IR CTV D98, D90
GTV D98, D90
Lymph node D98, D50
OAR
Bladder point
Rectal point
D0.1cc, D2CC of Rectum, bladder, sigmoid, Bowel
Vaginal points
HDR/PDR/LDR
Dose
Fraction size
# of fractions
Time interval between fractions
Total Rx time
RAKR
Dose calculation algorithm
International Commission of Units and Measures report 38, Bethesda, MD, 1985
Potter et al, Radiother Oncol. 2006 :67-77.

Point A

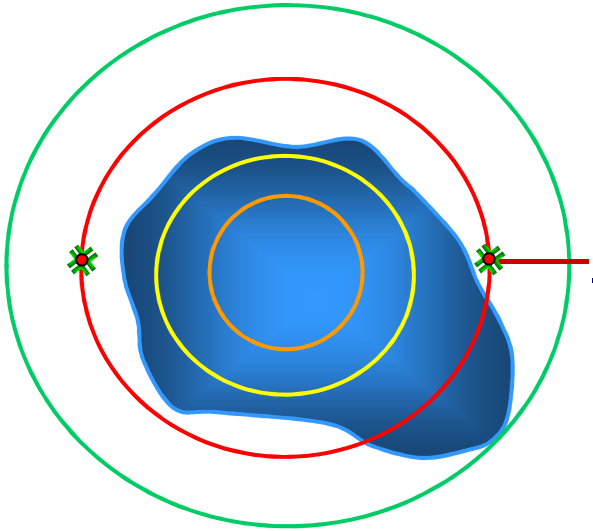
- Related to dose to the target.
- Robust – not dependent on contouring, fractionation schedules, dose rate etc
- The total dose at point A delivered through EXRT and BT can be calculated using the EQD2 concept
- Recommended by GEC ESTRO .



Target Dose: 2D and 3D

Correlating tumour effect(s) with doses:

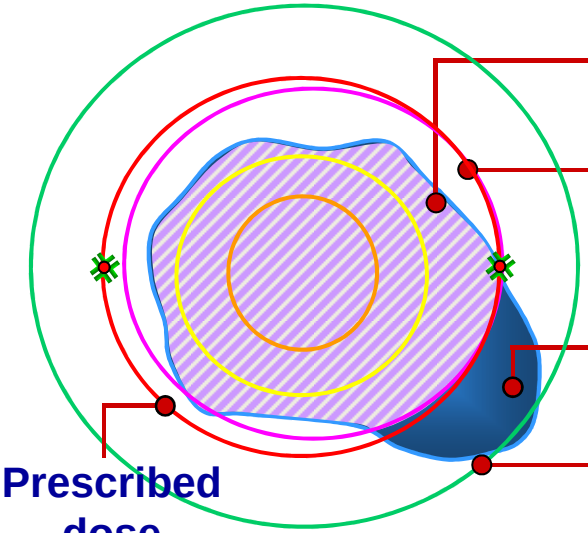
correlate effects with doses to volumes, instead of points



D to point A

= plannning aim Dose

TUMOR EFFECT: Tumour regression



90% of CTV

D90: Dose to 90% of CTV

100% of CTV

D98: Dose to 98% of CTV

Prescribed dose

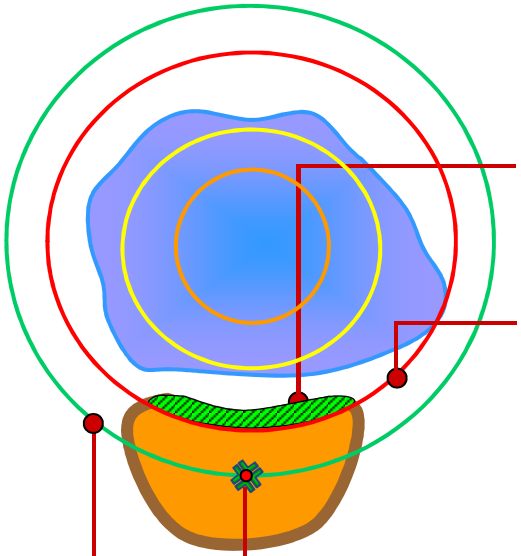
These corelations enabled by 3D imaging

Pötter et al. Radioth Oncol 2006. *Haie-Meder et al. Radiother Oncol 2005.*

Dose to organs at risk 2D→3D→4D

Correlating tissue effect(s) with doses

More appropriate to correlate tissue effects with doses to tissue volumes (at different times-4D), rather than points...



Most exposed V of OAR

Minimum dose to this V

D, V of clinical relevance?

0.1 cm3	D0.1cc
1 cm3	D1cc
2 cm3	D2cc
5 cm3	D5cc

OAR Point (i.e. ICRU-R)

Dose to OAR Point

TISSUE EFFECT: damage to OAR

Pötter et al. Radioth Oncol 2006. *Haie-Meder et al. Radiother Oncol 2005.*

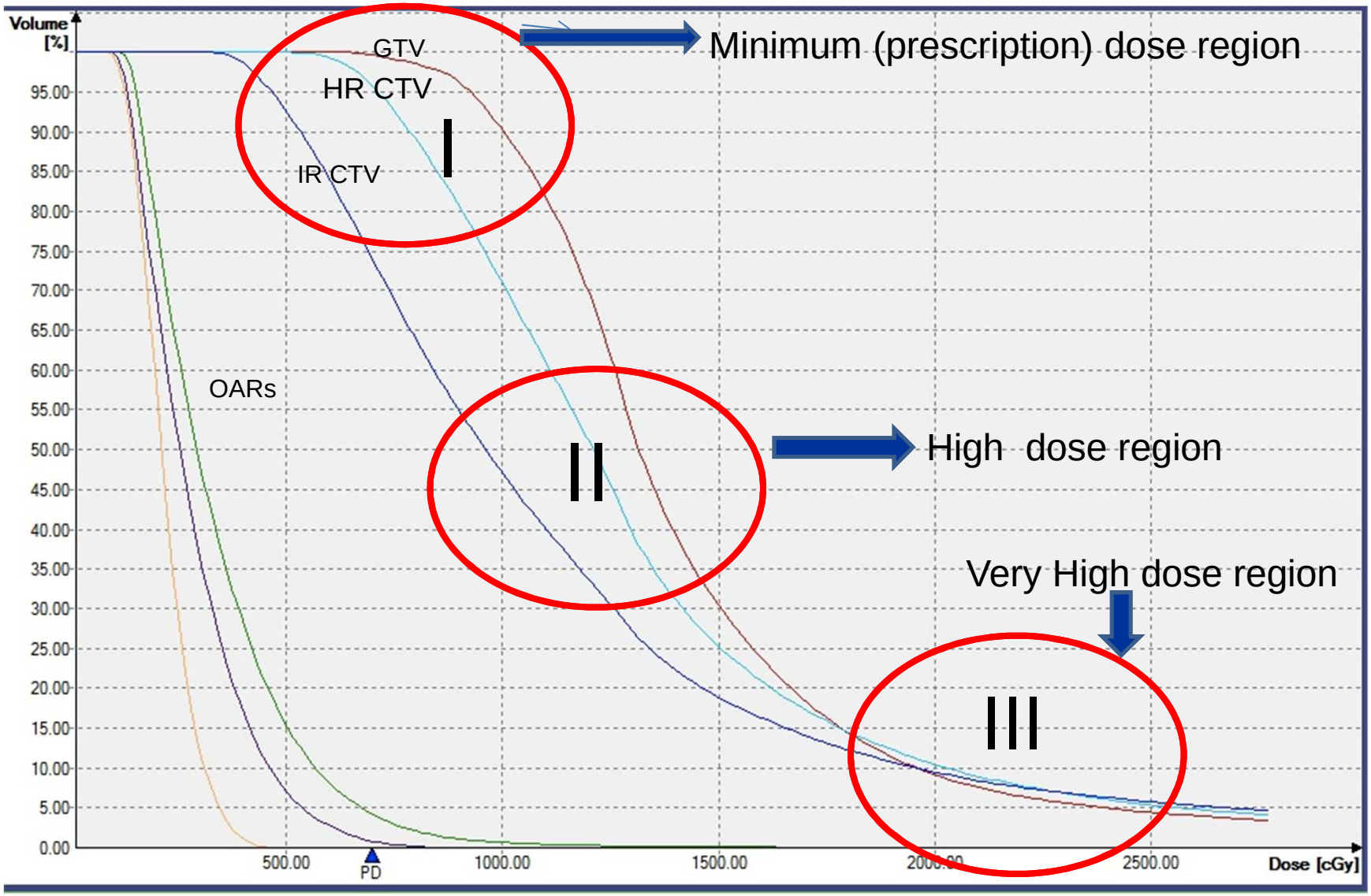
Dose reporting in 3D BT
HR CTV D_{90}, D_{98}

- Minimum dose delivered to 98% and 90% of the most exposed part of the target volume

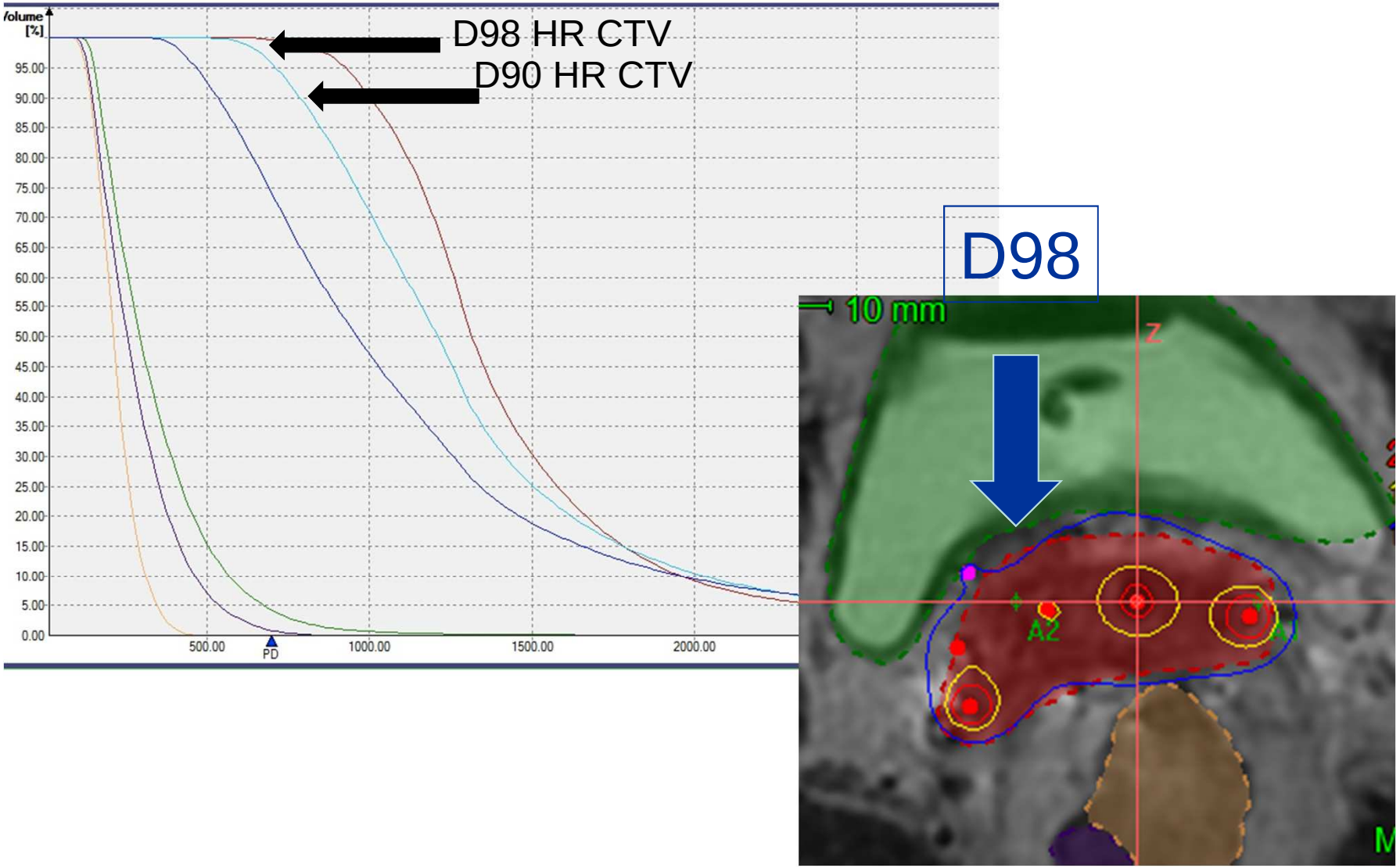
D_{90}	D_{98}
• Stable with respect to contouring uncertainties • May look favorable even though a small portion of the target receives less dose.	• Sensitive to contouring uncertainties • More robust indication for near minimum dose, where 2% target volume is outside the isodose line

Potter et al, Radiother Oncol. 2006 :67-77

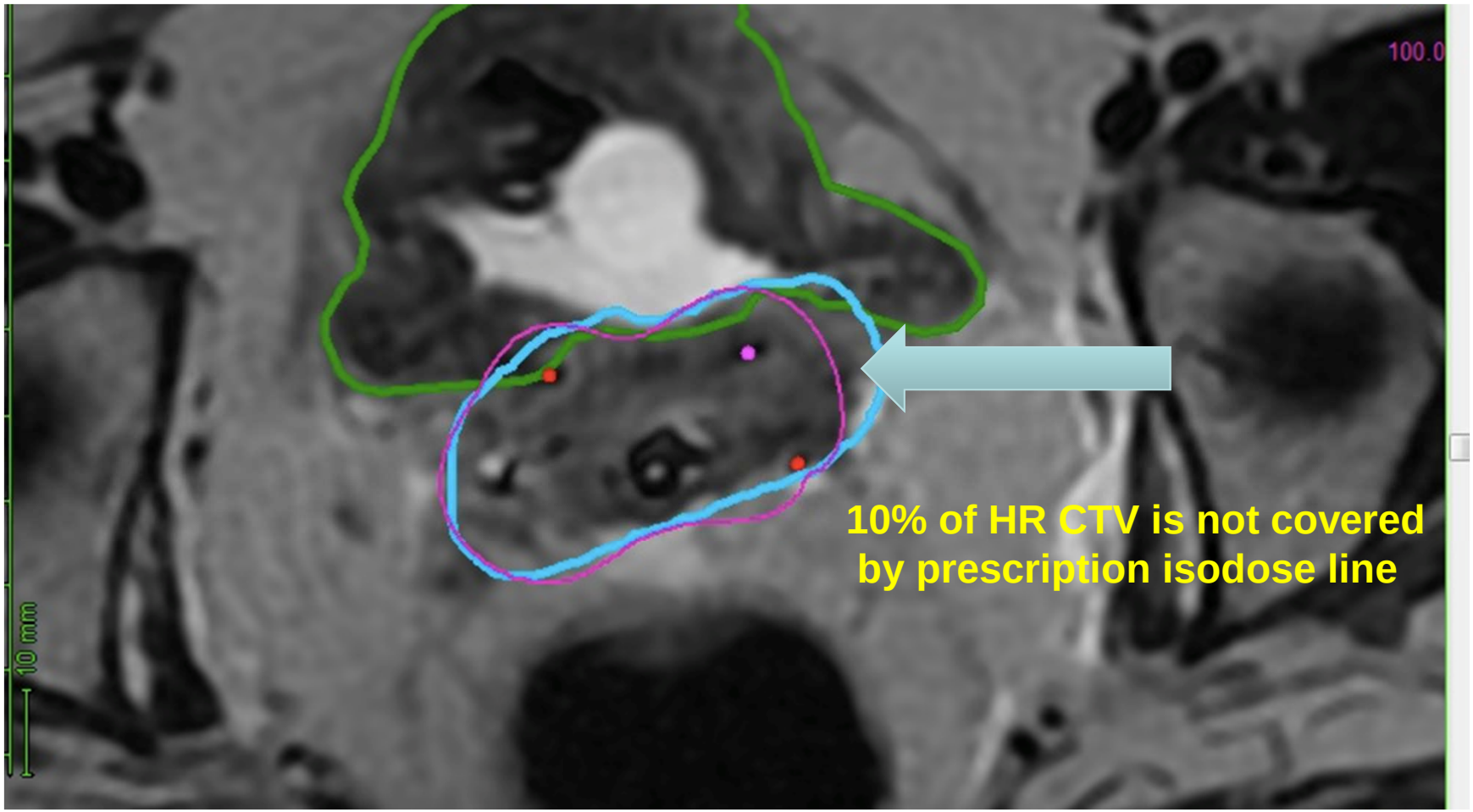
Dose volume histogram - Target



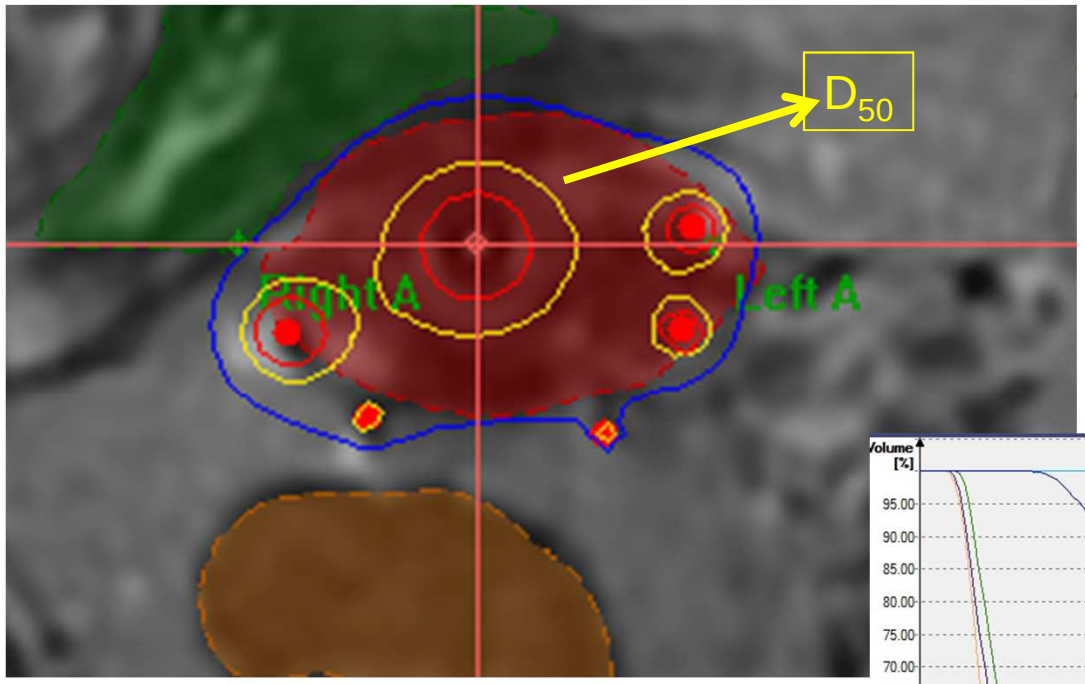
HR CTV D90 & D98



HR CTV D90 – 7.1 Gy

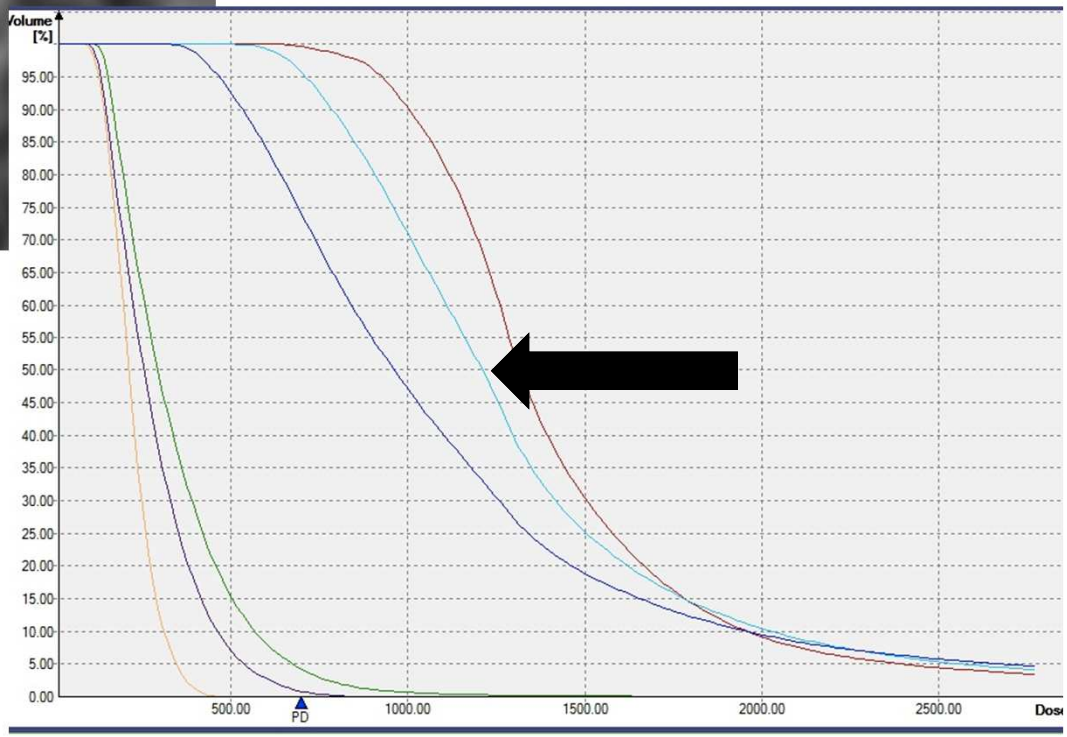


HR CTV D50 – High dose region

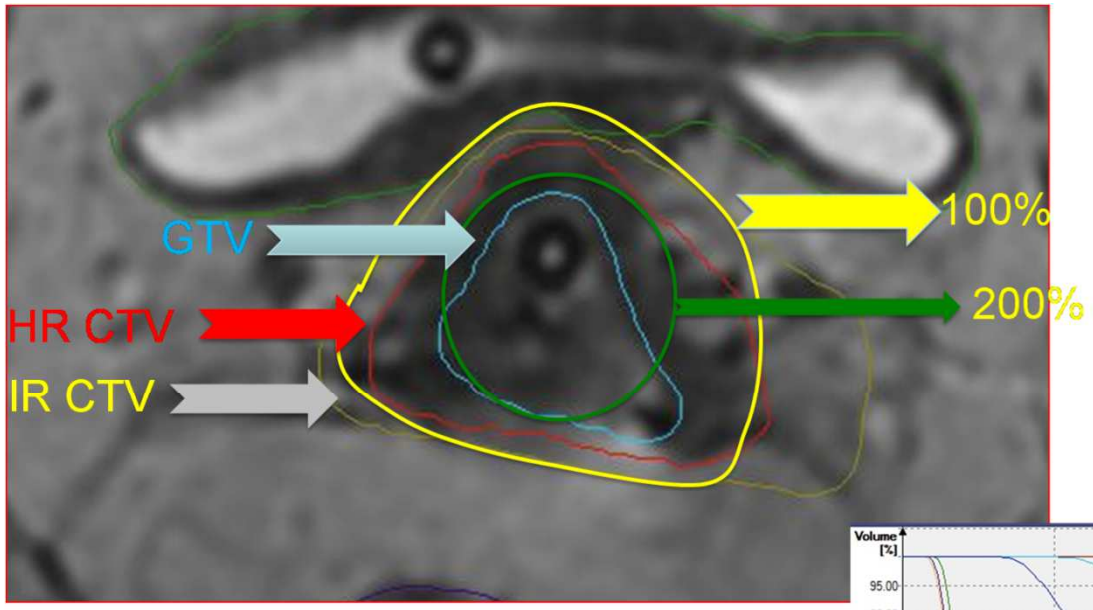


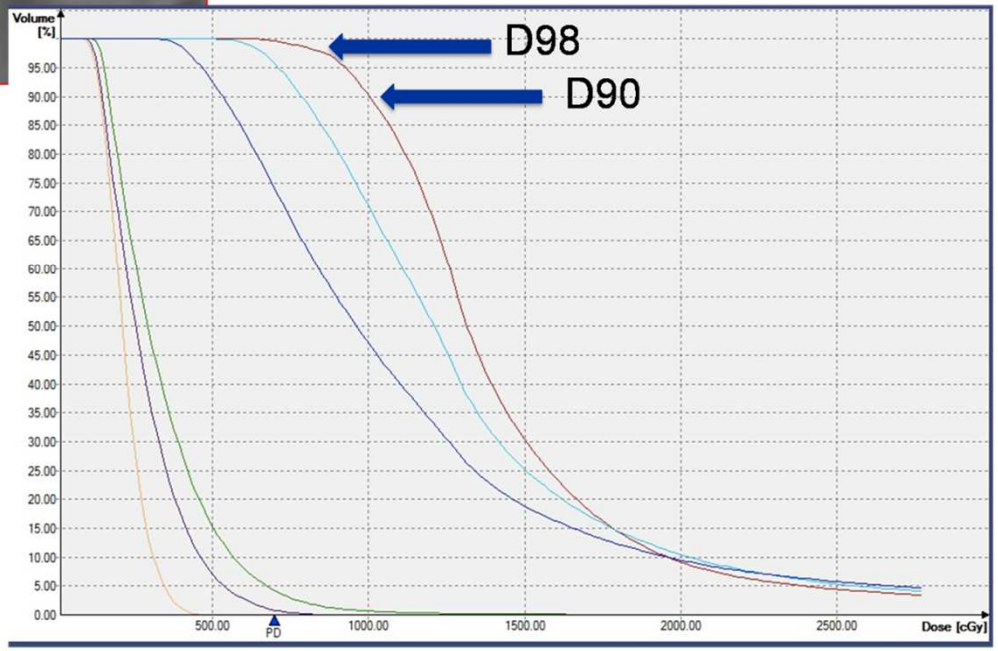
Dose gradient : 5 to 25% per mm

- Very high dose rate
- Large fraction size
- Biological dose??

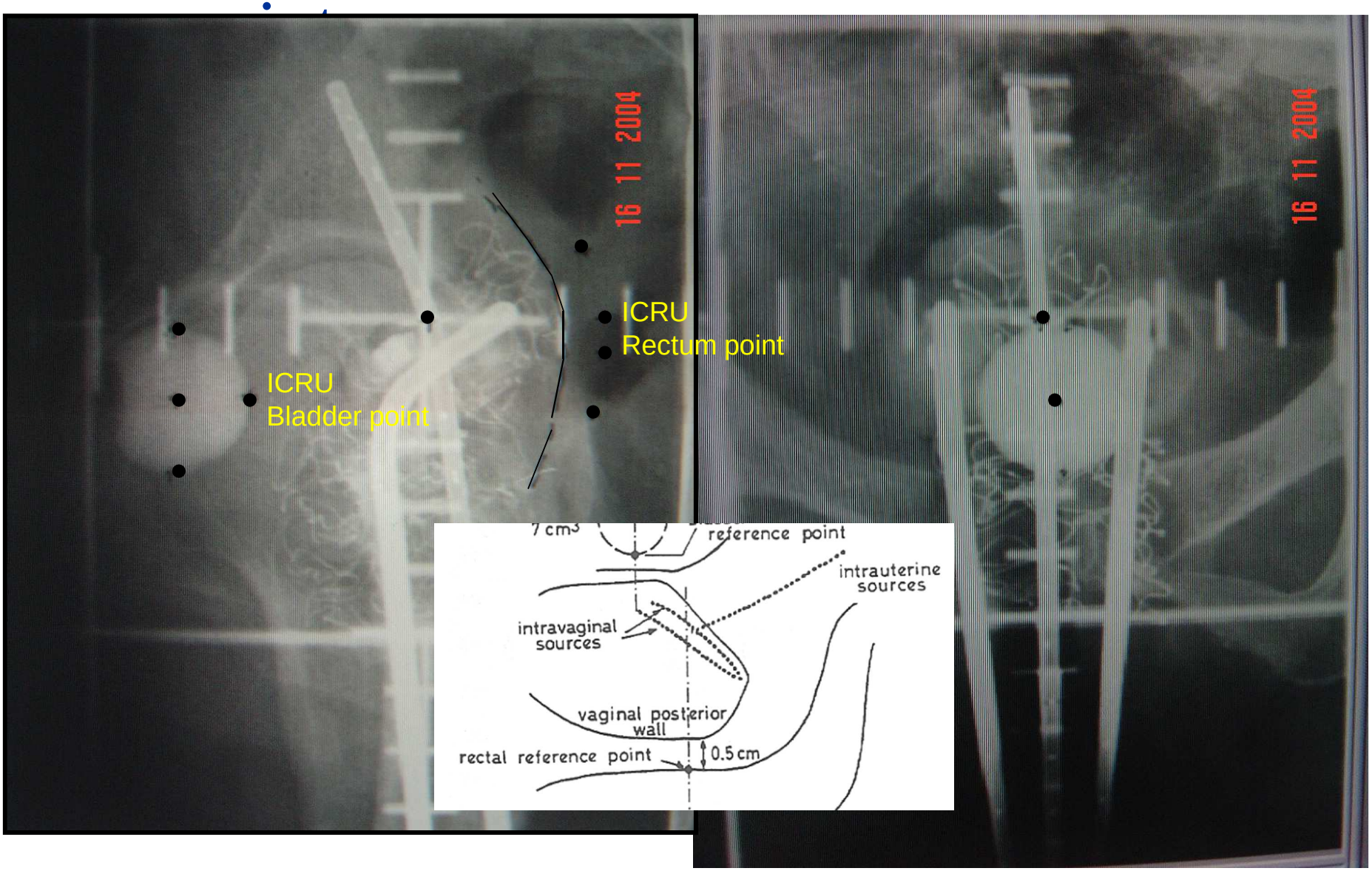


GTV & IR CTV – D98, D90





ICRU 38 rectum and bladder



Correlation of ICRU reference point and D_{2cc}

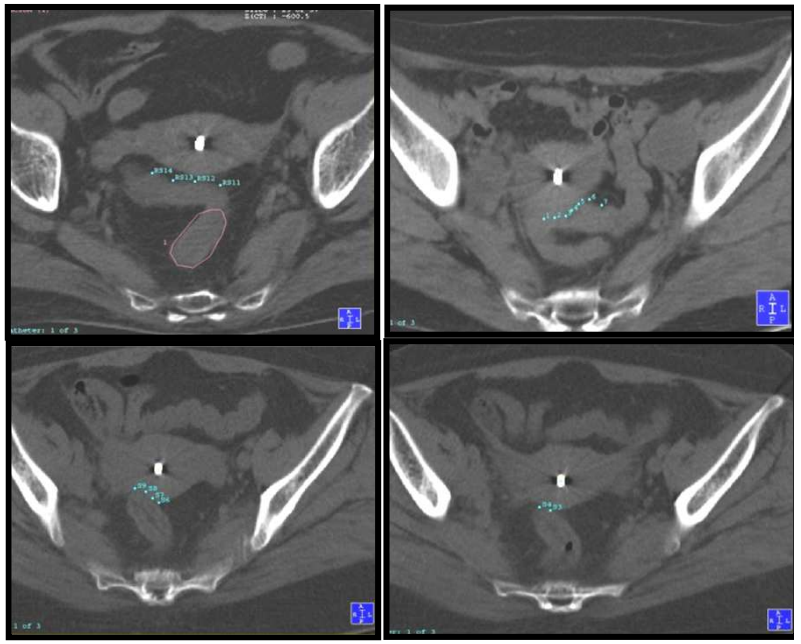
- **Rectum:** ICRU rectal reference point correlates with the D_{2cc} dose of the organ rectum

- **Bladder:** ICRU bladder reference point, does not correlate well with bladder complications (ICRU 38 bladder point underestimates the bladder dose)

Barillot et al, Perez et al, George P et al, Koom Wset et al.

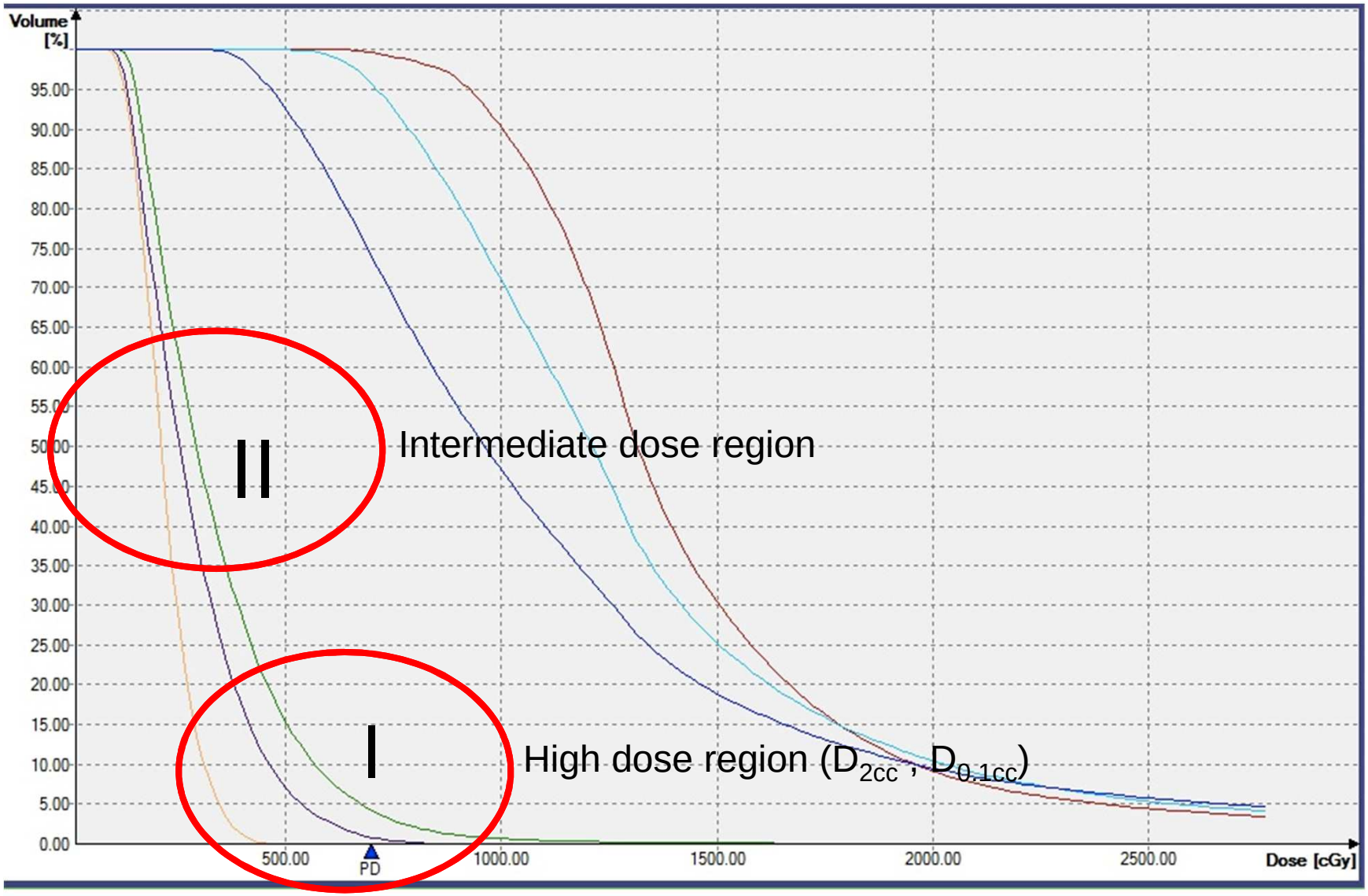
Upper rectal and sigmoid points on 2D radiographs

- 27 Patients treated with CT image based dosimetry
- Upper rectal and sigmoid points were marked on CT images
- Searched for a reproducible point with respect to applicator and other points
- No point was found that was reproducible that can act as a surrogate for upper rectal and sigmoid

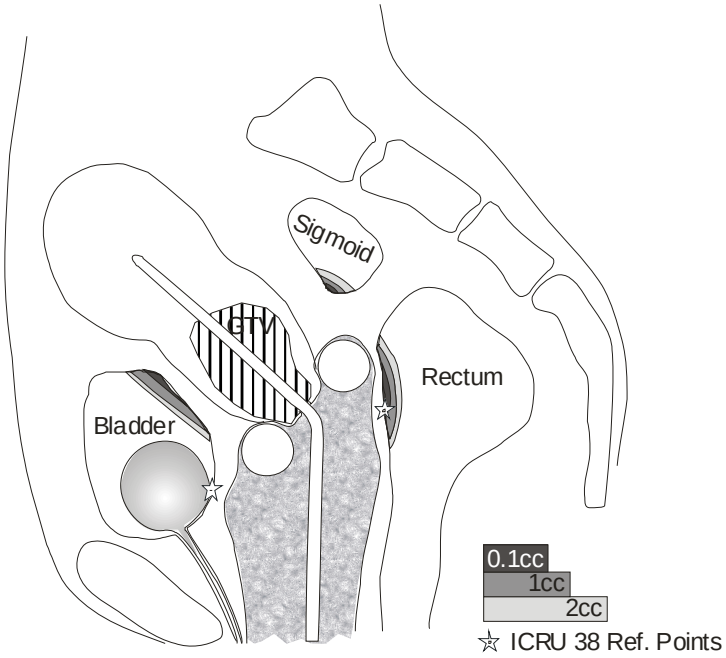


Mahantshetty et al, J Cancer Res Ther. 2011 :298-303

Dose volume histogram - OAR

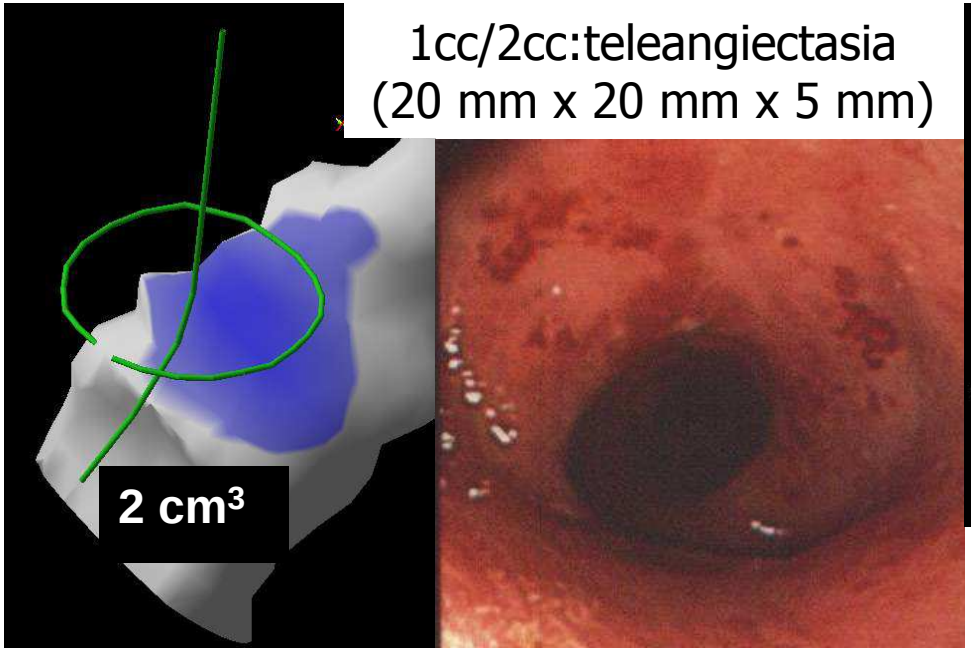


3D-based Dose Volume Parameters for OAR

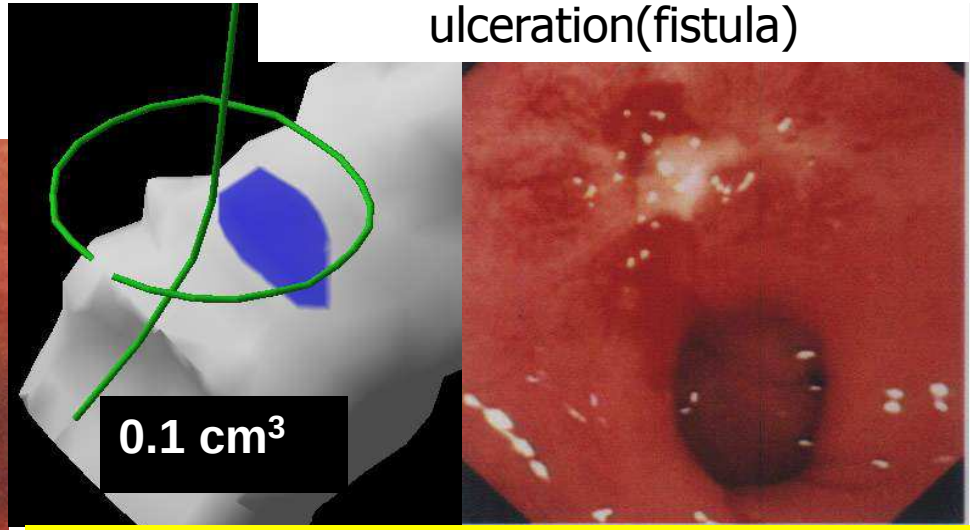


FIXED VOLUME: tolerance dose (total dose)-
"minimum dose to the most exposed tissue"*

1cc/2cc:teleangiectasia
(20 mm x 20 mm x 5 mm)



0.1 cc: 3D"maximum dose":
ulceration(fistula)



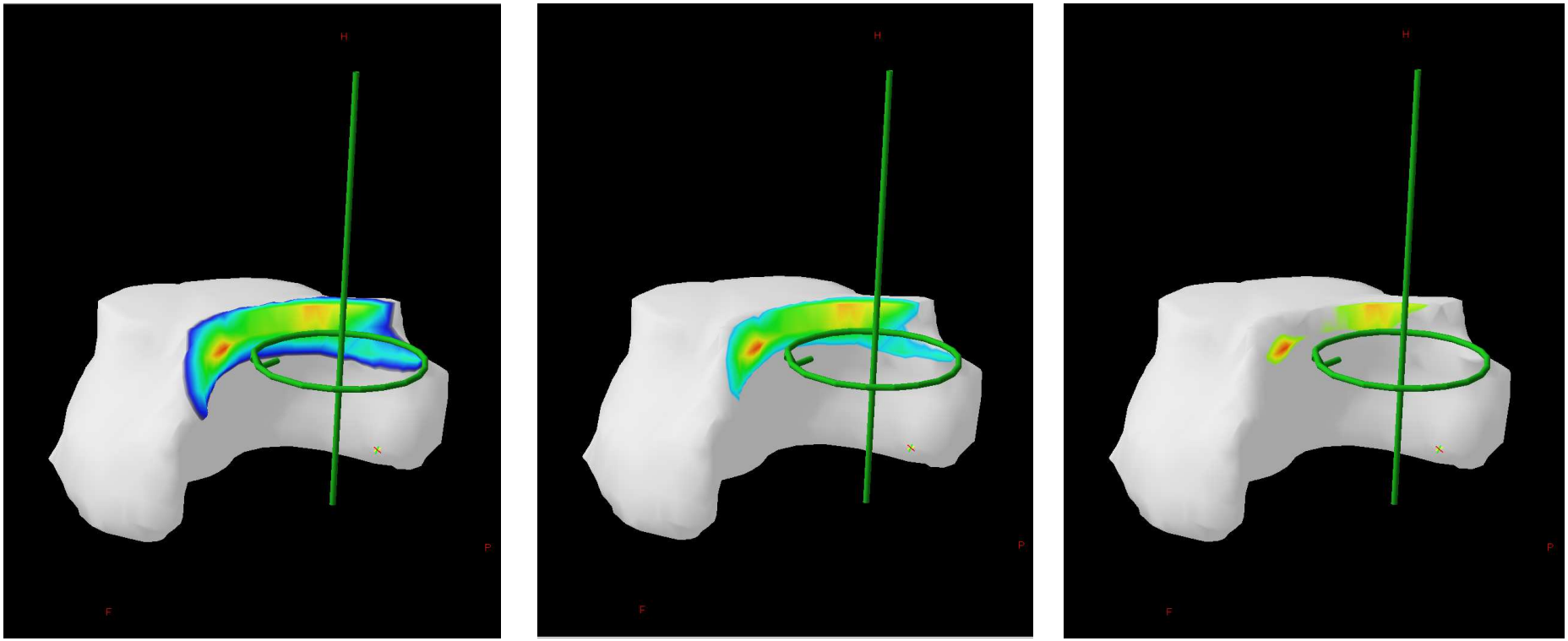
Radiotherapy and Oncology 78 (2006) 67–77
Slide Courtesy: Prof: R Potter, MUW, Vienna

Bladder

D_{2cc} D_{1cc} $D_{0.1cc}$

w x h:

40mm x 20mm 20mm x 10mm



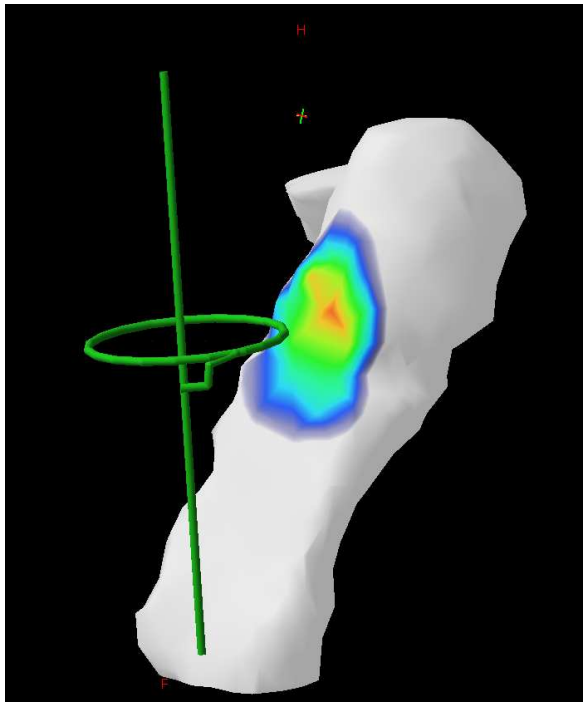
Slide Courtesy: Prof: R Pötter, MUW, Vienna

Rectum

D_{2cc}

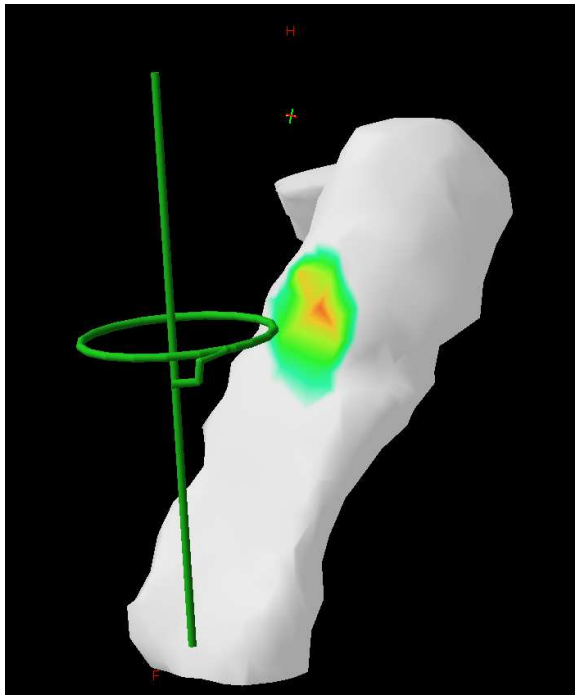
w x h:

30mm x 30mm

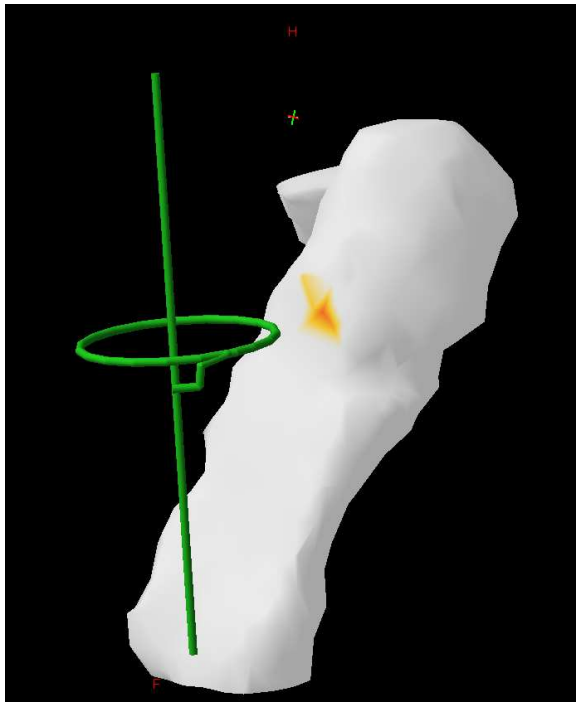


D_{1cc}

10mm x 10mm



$D_{0.1cc}$



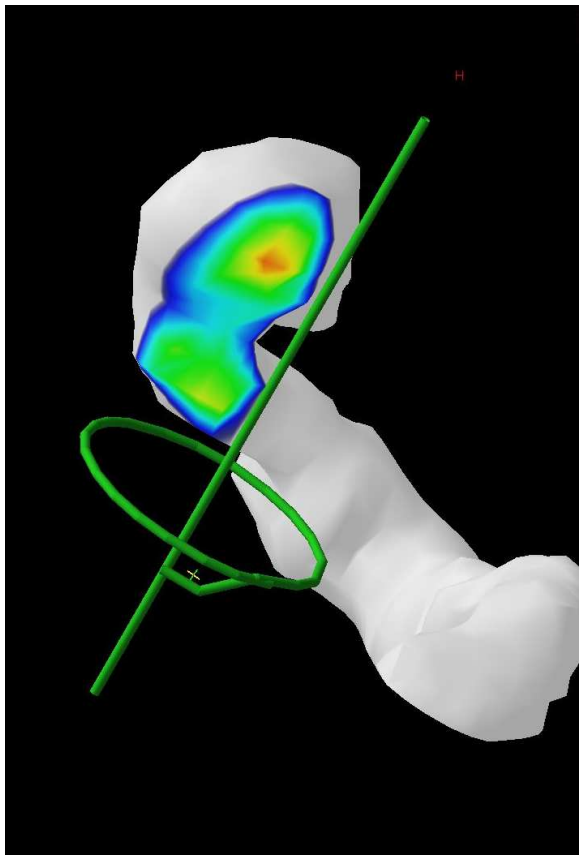
Slide Courtesy: Prof: R Pötter, , MUW, Vienna

Sigmoid

D_{2cc}

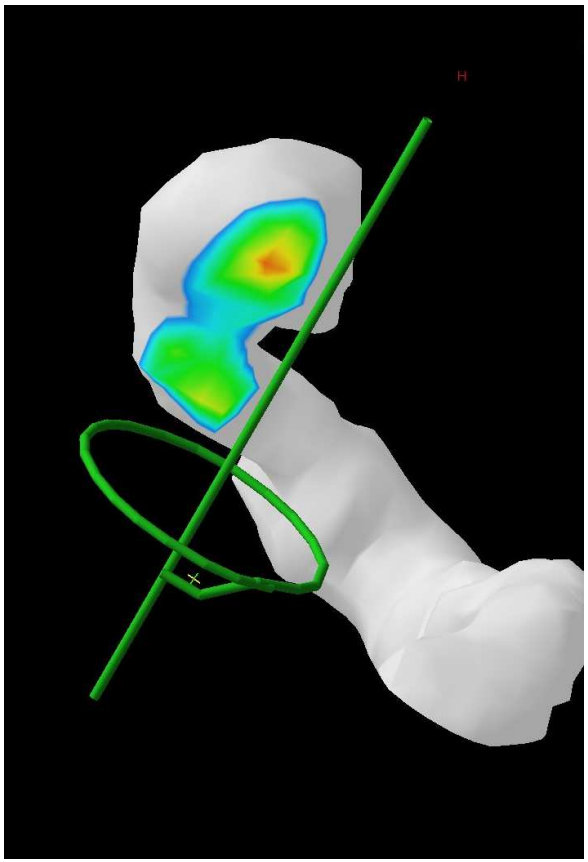
w x h:

25mm x 20mm

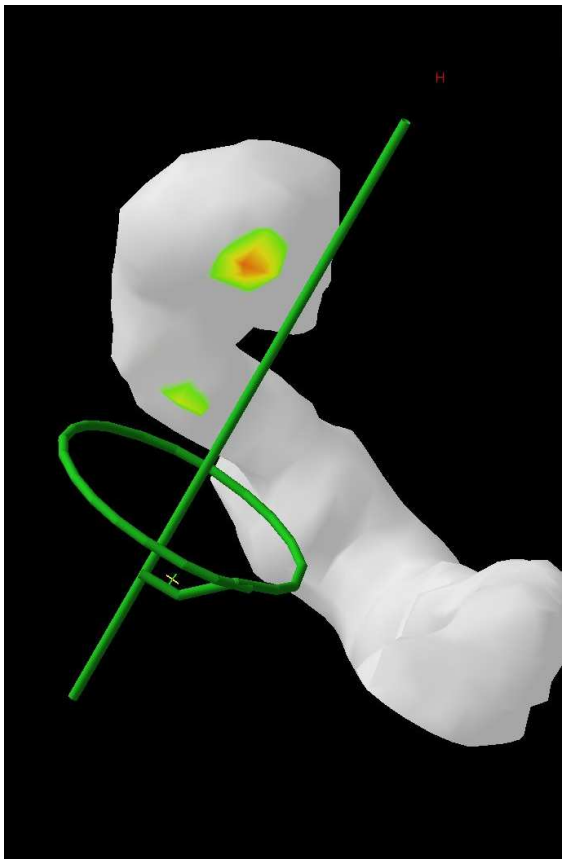


D_{1cc}

10mm x 10mm

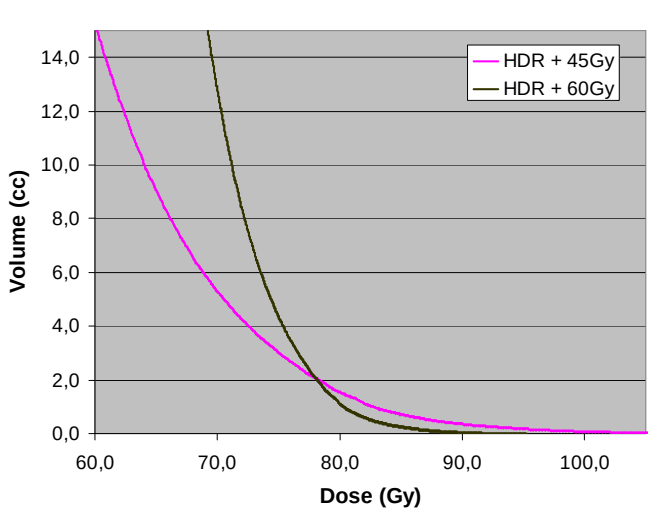


$D_{0.1cc}$



Slide Courtesy: Prof: R Pötter, MUW, Vienna

Limitations of fixed parameters of DVH
Rectum DVH (EQD2)



e.g.
10 ccm
2 ccm

EBRT: 3D CRT 45 Gy 45 + 15 Gy Boost to Tumour region
BT: 2 x 17.5 Gy BT 2 x 12 Gy

Limitations of adding doses according to „ICRU point-3D model“ both for CTV and OAR

- Non-homogenous dose distribution EBRT
  e.g. IMRT, VMAT…
- Parametrial boost
- Lymph node boost
- Limitations of the linear-quadratic model

- Future solution for complex adding doses….

Intermediate and larger volumes

- Global organ side effects,
  - stricture,
  - stenosis,
  - functional impairments
    - continence,
    - urgency

Dose tolerance: 45 – 65 Gy more

ACKNOWLEDGMENTS

- *Tata Memorial Centre*
- *GYN GEC-ESTRO Faculty & Teaching Material*
- *IAEA Teaching Material*
- *Patients*

Case Capsule