

# **Basic Concepts in Image Based Brachytherapy**

## **(GEC-ESTRO Target Concept & Contouring)**



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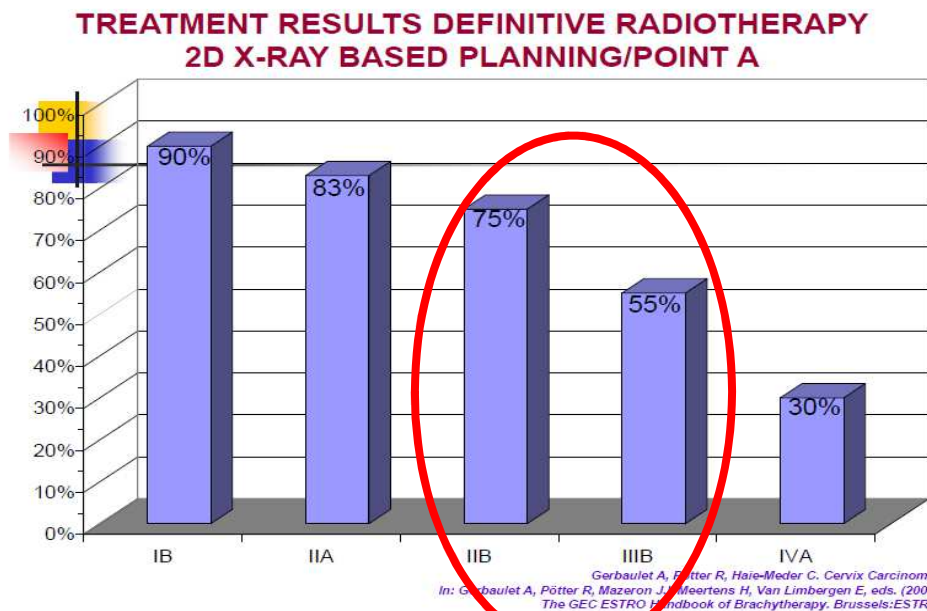
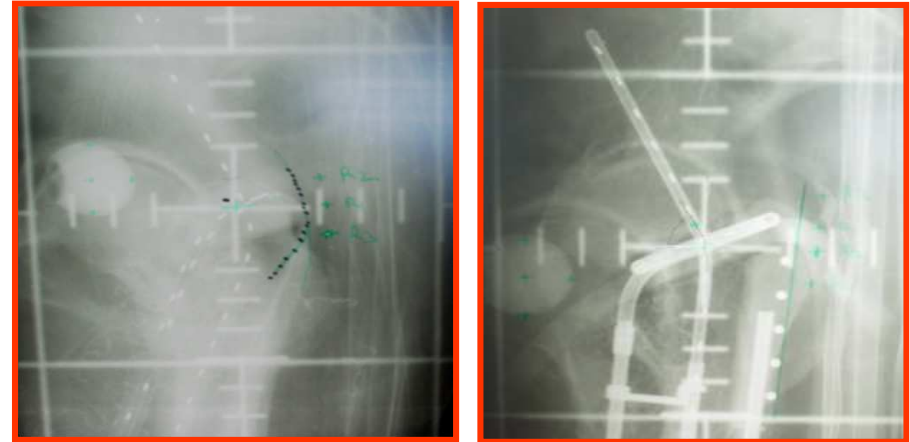
***Mumbai, India***

***GYN GEC – ESTRO NETWORK MEMBER AND FACULTY***

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

# Two Dimensional (2D) Brachytherapy Planning in Cancer Cervix

- Orthogonal X-ray Based
- Target: Point A Prescription
- OAR's: ICRU Rectal & Bladder point based (ICRU 38)



**Local control rates**

**2D + CRT : additional 5 - 10%**

**MORBIDITY RATES AFTER RADIOTHERAPY (EBRT+BT)**

	STAGE				
	IB	IIA	IIB	IIIB	IVA
Total no. of patients	415	137	391	326	23
G2 complications	51 (12%)	14 (10%)	65 (17%)	38 (12%)	3 (13%)
G3 complications	26 (6%)	23 (17%)	57 (15%)	45 (14%)	2 (9%)

**G3 morbidity > 10% ~ all stages**

*„Refinements in brachytherapy techniques are necessary to improve the present results“*

**Perez CA in Perez/Brady 1998**

## Limitations in Conventional 2D Brachytherapy Planning

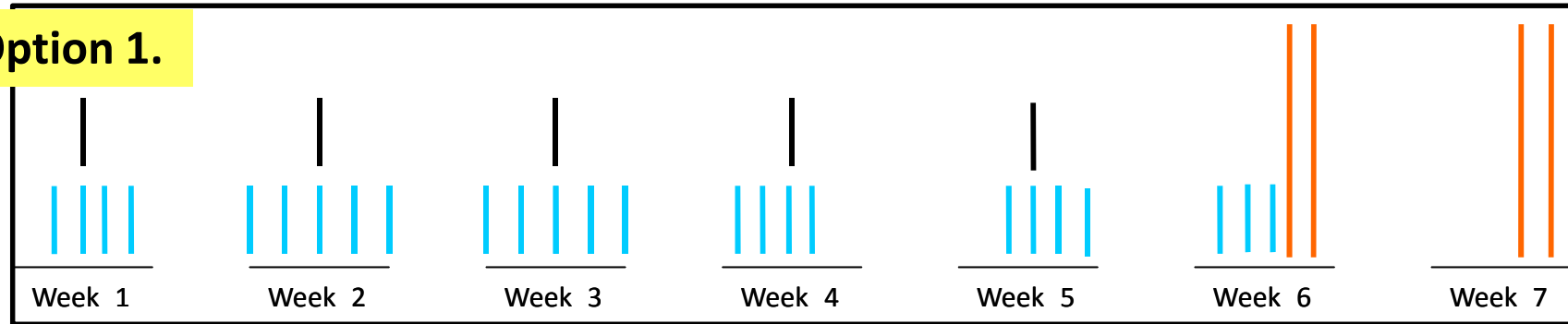
- Limitations of Point A Based Dosimetry: Small & large tumors
- OAR Dose Assessment: Relative and Indirect
- Several Studies: No correlation with toxicities
- Tumor related Target Volume Assessment : Not possible
- Delineation of Target and Organs at Risk
  - Residual tumor at brachytherapy
  - Rectum, bladder, sigmoid,
  - Small intestine, vagina etc....
- Advances in Brachytherapy : Although slow

## ***ADVANCES IN GYNAECOLOGICAL BRACHYTHERAPY***

- Applicator development: *Intracavitary (IC), Interstitial (IS) & IC+IS*
- In corporation of Newer Imaging Modalities: *CT, MR, PET, etc.*
- Advances in Treatment Planning Systems
- **Image / Volume Based Brachytherapy**

# RADIOTHERAPY TREATMENT SCHEDULE for MR - IGABT

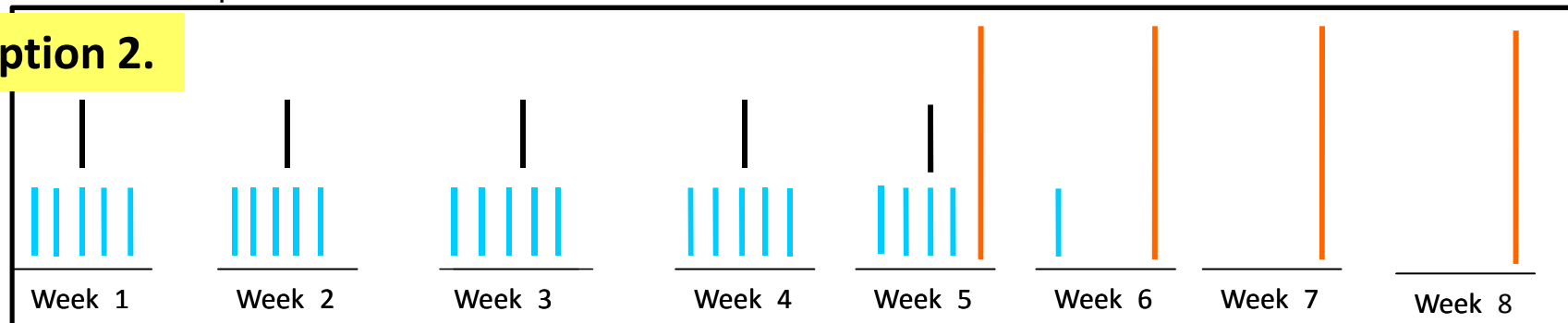
## Option 1.



- blue bar represents a fraction of EBRT 1.8 Gy
- black bar represents a course of cisplatin 40 mg/m<sup>2</sup>,
- orange bar represents a fraction of HDR brachytherapy 7 Gy (2 fractions within one application) X 2 applications one week apart

**overall treatment time 46 days**

## Option 2.



**overall treatment time 56 days**

# *Imaging protocols MRI and CT*

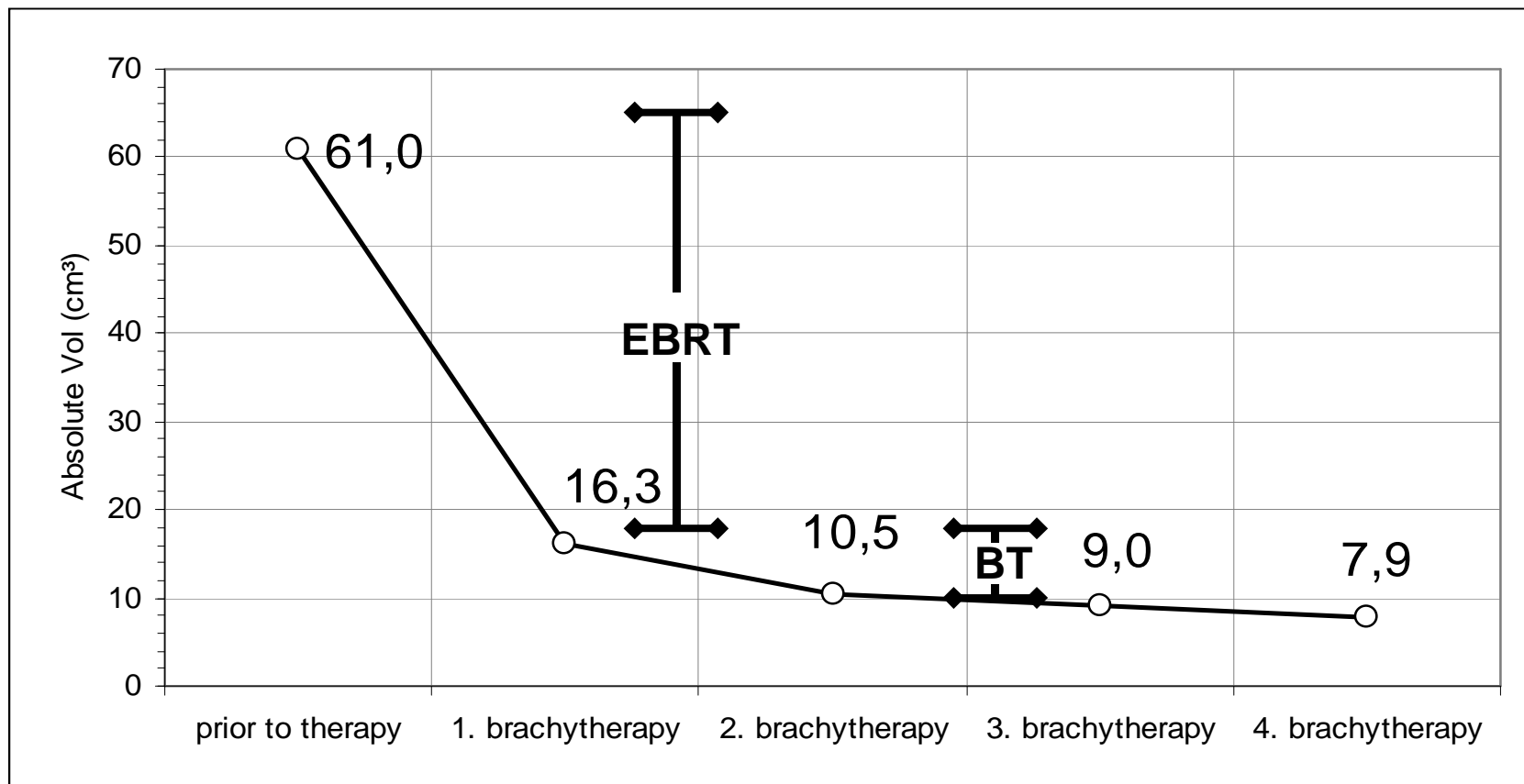
## *Key issues for image-guided radiotherapy*

### **Quantitative tumor regression**

Courtesy : Johannes Dimopoulos

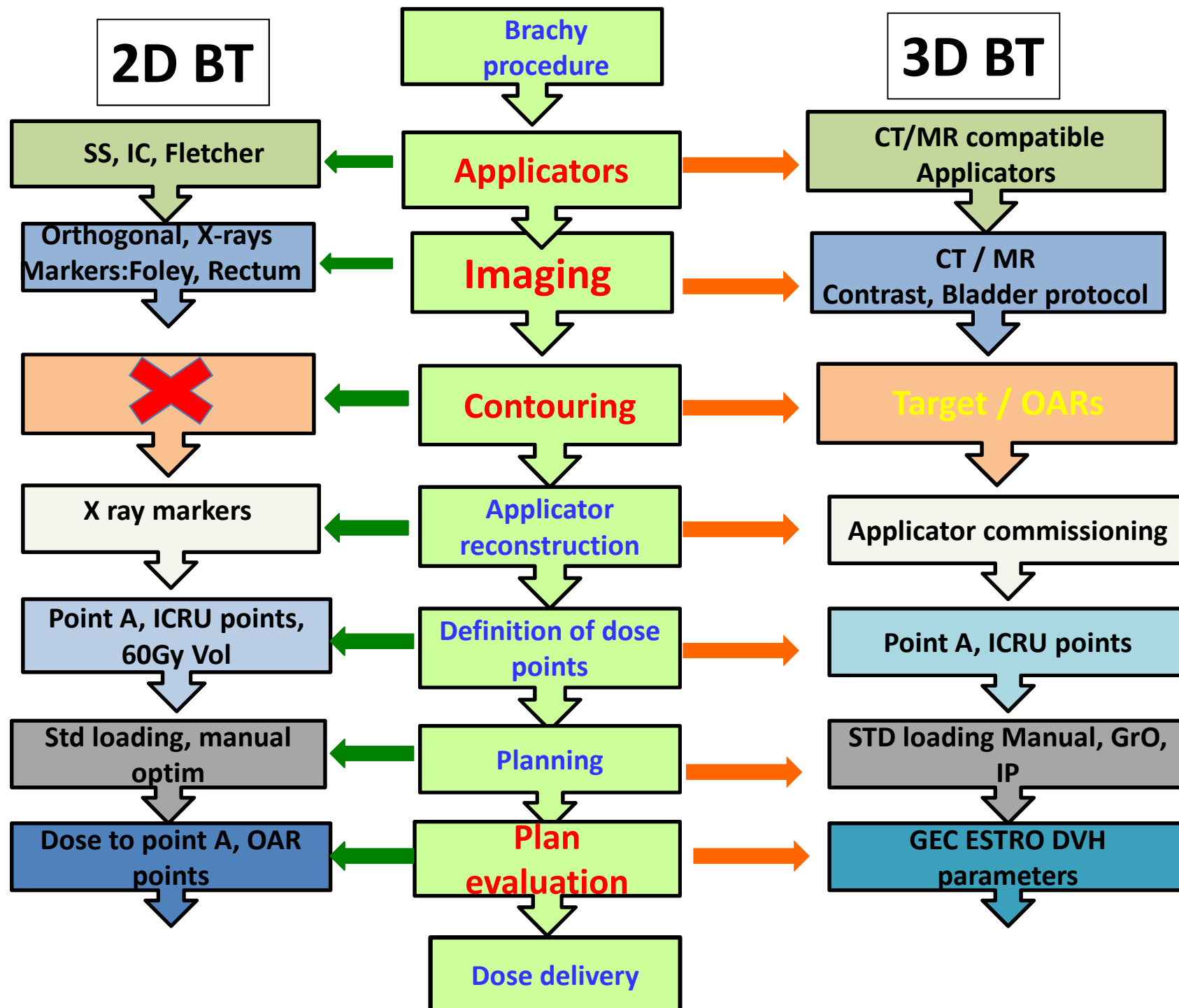
EBRT: tumor regression 75%  
Brachytherapy: tumor regression 10%

easy to predict



*Dimopoulos et al. Strahlenther Onkol 2009*

# Work flow



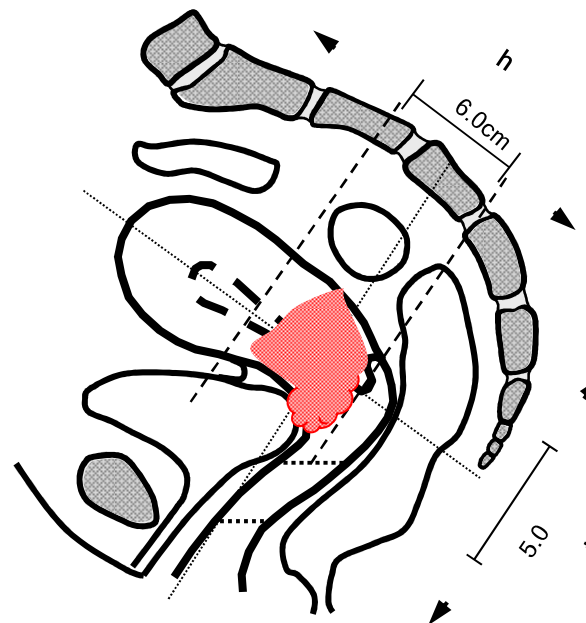
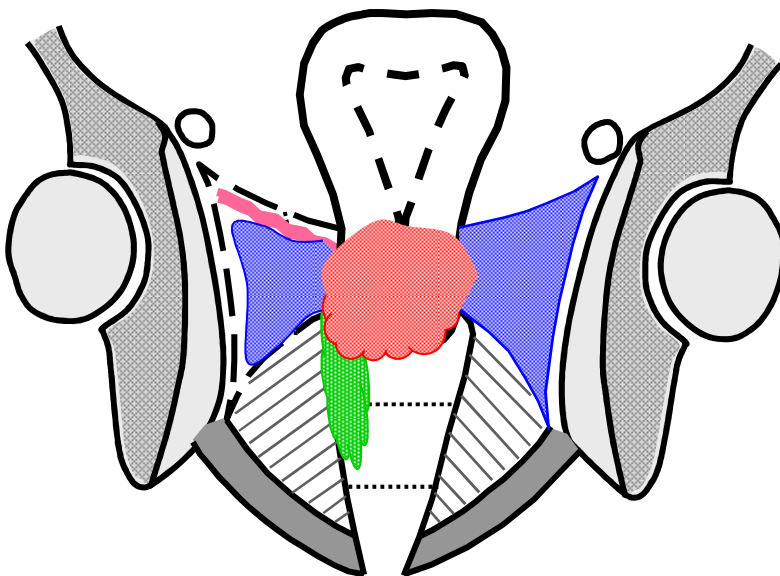
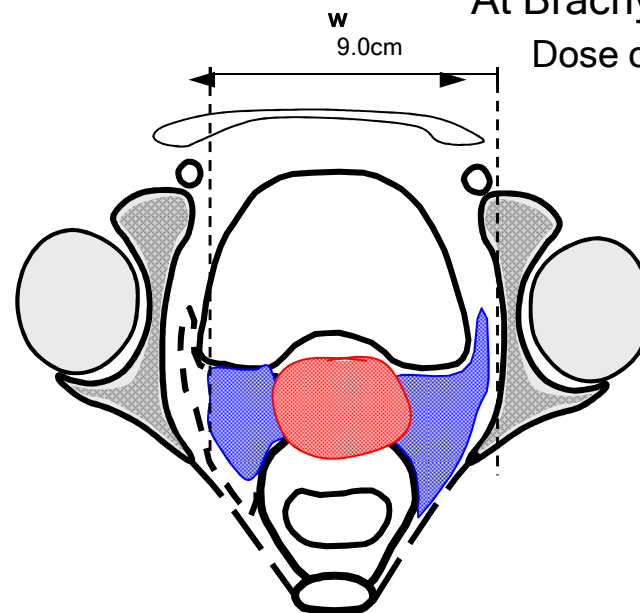
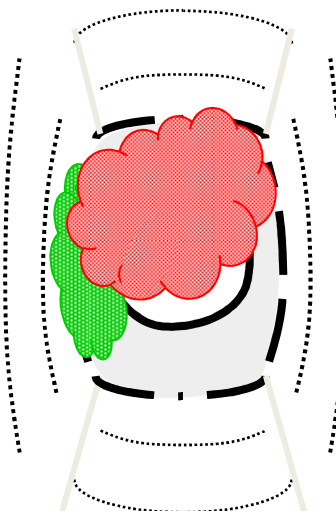
At Diagnosis ☒

At Brachytherapy ☐  
Dose of EBRT \_\_\_\_\_ Gy

IIIB

w = 9.0 cm  
h = 6.0 cm  
t = 5.0 cm

Vagina: 5 cm



dd/mm/yy  
/ /

Signature

Note: vagina and parametria not included in h



At Diagnosis ☒

At Brachytherapy ☐  
Dose of EBRT \_\_\_\_\_ Gy

IIIB

w = 9.0 cm  
h = 6.0 cm  
t = 5.0 cm

Vagina: 5 cm

dd/mm/yy

Signature

Note: vagina and parametria not included in h

At Brachytherapy ☒

Dose of EBRT 50.4 Gy

IIIB

w = 6.8 cm  
h = 4.2 cm  
t = 4.5 cm

Vagina: 0 cm

dd/mm/yy

Signature

Note: parametria **not** included in h.

# GEC-ESTRO Volume Concept (Rad. Oncol. 2005)

- 2000: GYN GEC-ESTRO Working Group formulated
  - Dimensions and volumes of GTV, CTV as defined by clinical examination and by MRI:
    - at time of diagnosis
    - at time of BT (after external irradiation);
  - Dimensions and volumes of reference volume (60, 75, 90, and 120 Gy);
  - Volume of isodose going through point A;
  - Treated volume (prescribed dose);
  - Coverage in percent related to CTV and GTV;
  - DVH analysis for fixed doses and certain coverage percentage of GTV and CTV;
  - Doses to points A and B, right and left, mean;
  - Dose volume parameters for organs at risk (no details here);
  - Radiobiological modelling (linear-quadratic model).
- 2001 /2: Initial Protocol Development
- Within GEC-ESTRO, 3 teams coming from different traditions:
  - Paris : mould / LDR / PDR / Reference volume (60 Gy)
  - Leuven : ovoid / mould PDR / point A
  - Vienna : ring / HDR / point A
- 2003/4: Protocol Development: 2 workshops / training
- 2004: GTV / CTV Recommendations: final in Sept. 2004

# Principles for MRI based Cervix BT

Delineation of GTV, CTV and OAR in relation to the applicator

- MRI compatible applicators
- Specific investigation protocols
  - Quality of images
- Image acquisition: orientation
- Accuracy of Images (QA)
- Planning details : DVH parameters (CTV / OAR's)

## Pre-Workshop : 2002/3

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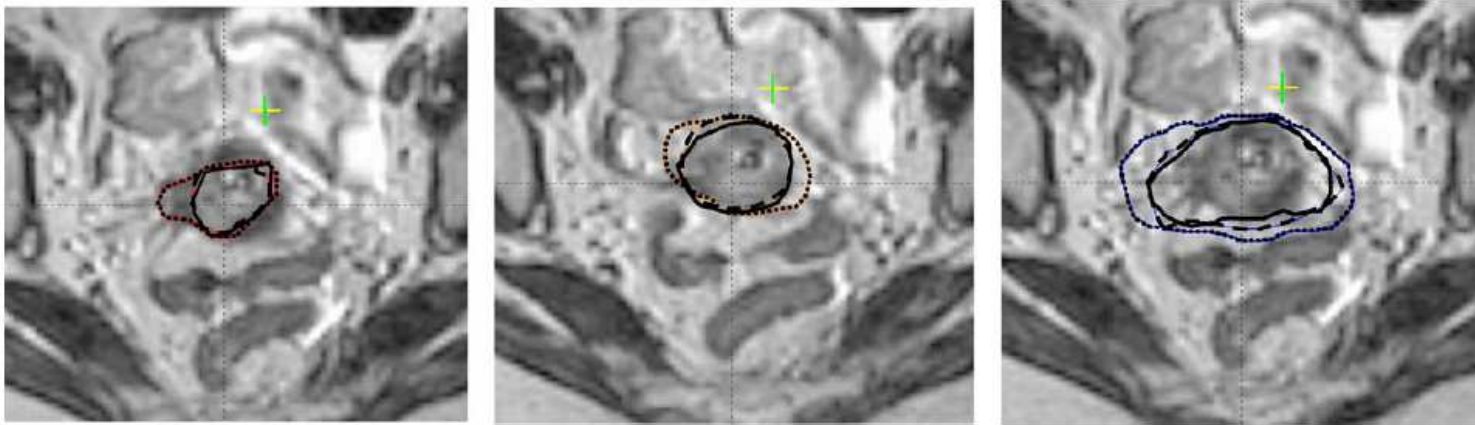


Fig. 1. Examples of delineation variations for GTV (left), HD CTV (middle) and ID CTV (right) from three different experts from GYN GEC-ESTRO GTV and CTV delineation workshop I (7/2003): FIGO stage IIIB patient with involvement of right pelvic wall and left distal parametrium; partial remission after radio-chemotherapy with high signal intensity mass in cervix and pathologic residual mass in right proximal parametrium at brachytherapy.

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## Post - Workshop + Consensus : 2003/4

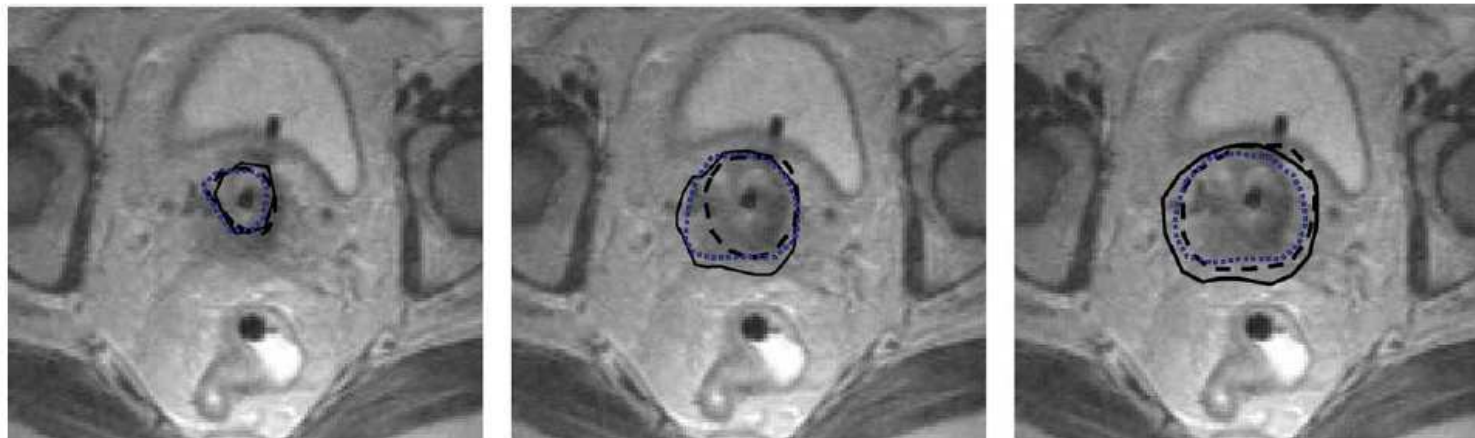
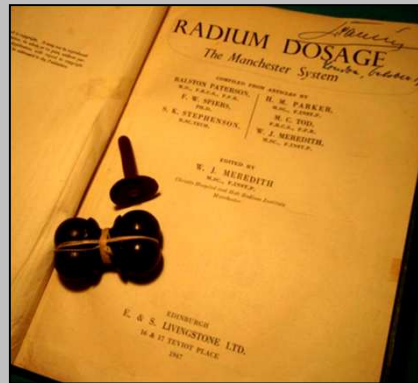


Fig. 2. Example of delineation for GTV (left), HR CTV (middle) and IR CTV (right) based on final version of GYN GEC-ESTRO protocol 12/2003 presented at GYN GEC-ESTRO GTV and CTV delineation workshop II (12/2003) with full description of all different terms.

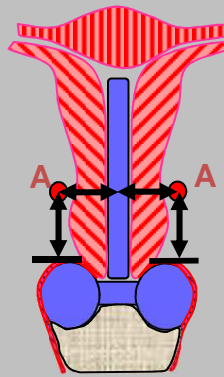
# Gyn GEC ESTRO Recommendations Target Concept

Bringing different traditions together

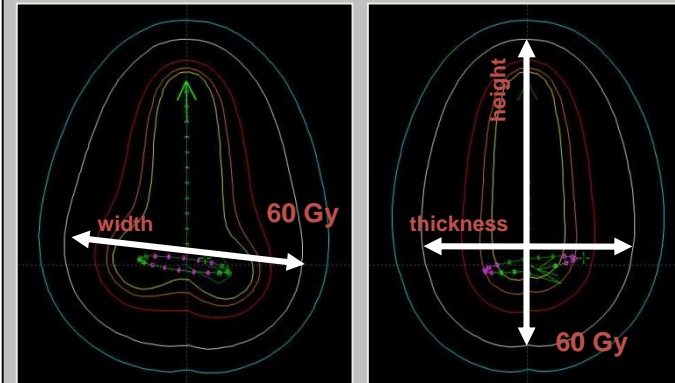
“Point A” tradition



*The Manchester system. Edinburgh;1947.*

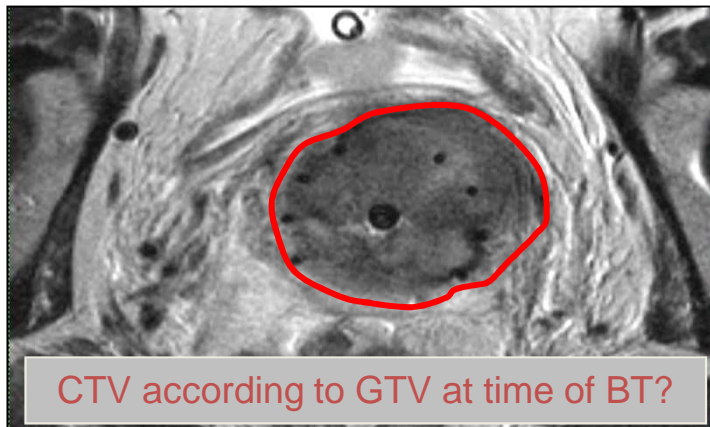


“60 Gy reference volume” tradition

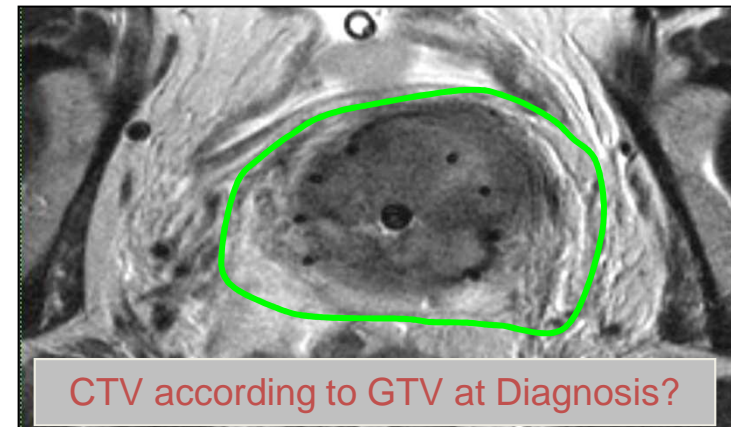


*ICRU report 38, Bethesda, 1985.*

Moving from 2D to 3D



CTV according to GTV at time of BT?



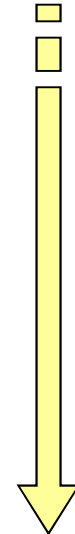
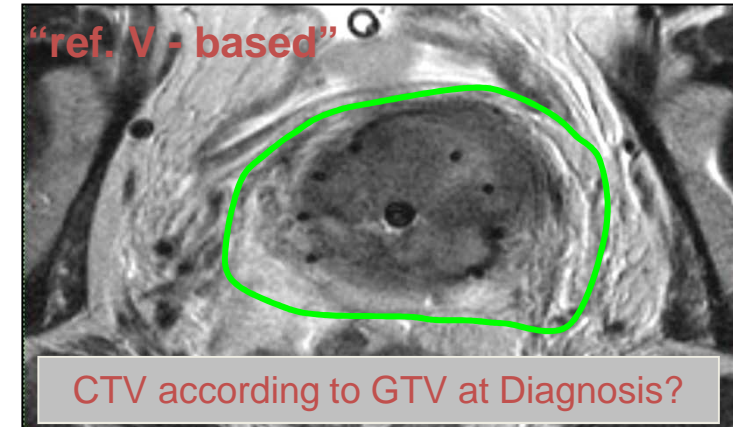
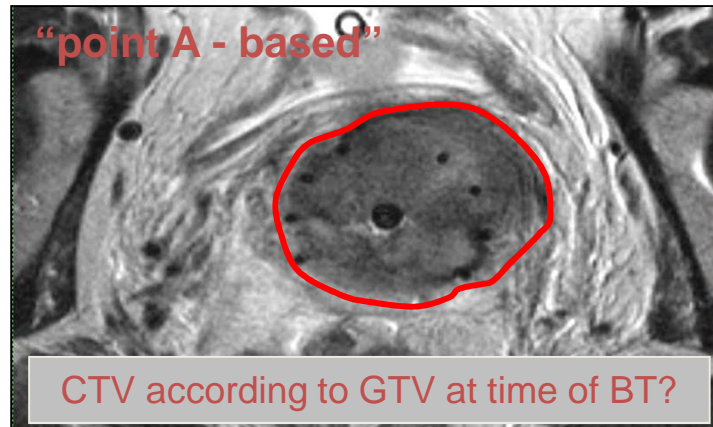
CTV according to GTV at Diagnosis?



# Gyn GEC ESTRO Recommendations

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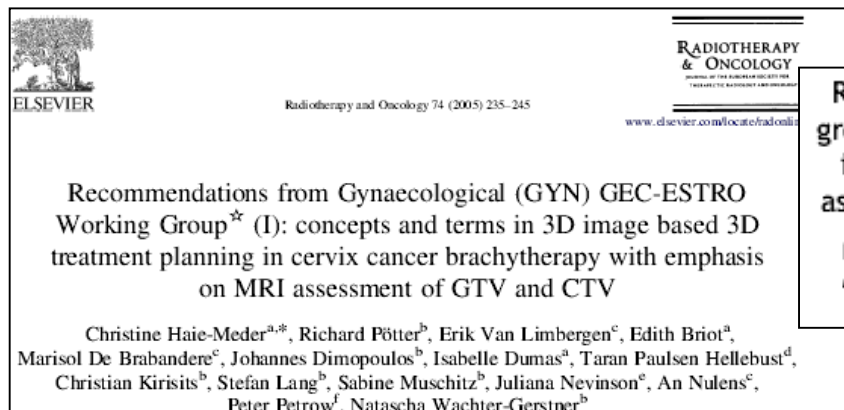
## Bringing different traditions together



Historical difficulties in communicating results

We need a common language!

# GYN GEC ESTRO Recommendations: 4 papers



**Recommendations from gynaecological (GYN) GEC ESTRO working group (II): Concepts and terms in 3D image-based treatment planning in cervix cancer brachytherapy—3D dose volume parameters and aspects of 3D image-based anatomy, radiation physics, radiobiology**

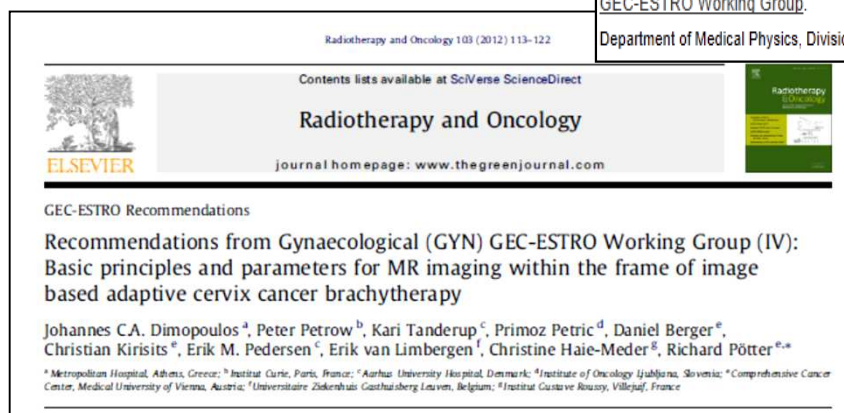
Richard Pötter<sup>a,\*</sup>, Christine Haie-Meder<sup>b</sup>, Erik Van Limbergen<sup>c</sup>, Isabelle Barillot<sup>d</sup>, Marisol De Brabandere<sup>c</sup>, Johannes Dimopoulos<sup>a</sup>, Isabelle Dumas<sup>b</sup>, Beth Erickson<sup>e</sup>, Stefan Lang<sup>a</sup>, An Nulens<sup>c</sup>, Peter Petrow<sup>f</sup>, Jason Rownd<sup>e</sup>, Christian Kirisits<sup>a</sup>

Radiother Oncol. 2010 Aug;96(2):153-60. doi: 10.1016/j.radonc.2010.06.004.

**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.**

Hellebust TP, Kirisits C, Berger D, Pérez-Calatayud J, De Brabandere M, De Leeuw A, Dumas I, Hudej R, Lowe G, Wills R, Tanderup K; Gynaecological (GYN) GEC-ESTRO Working Group.

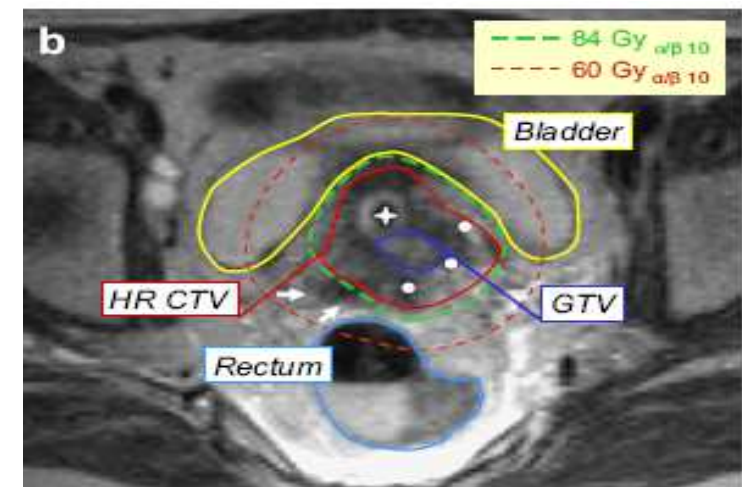
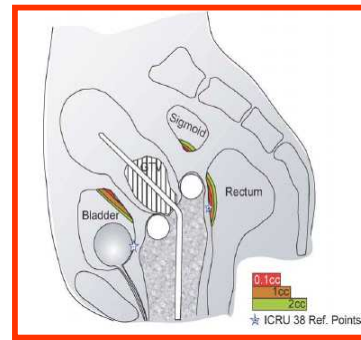
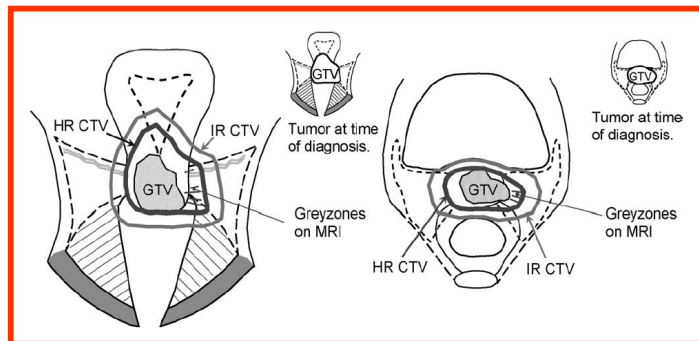
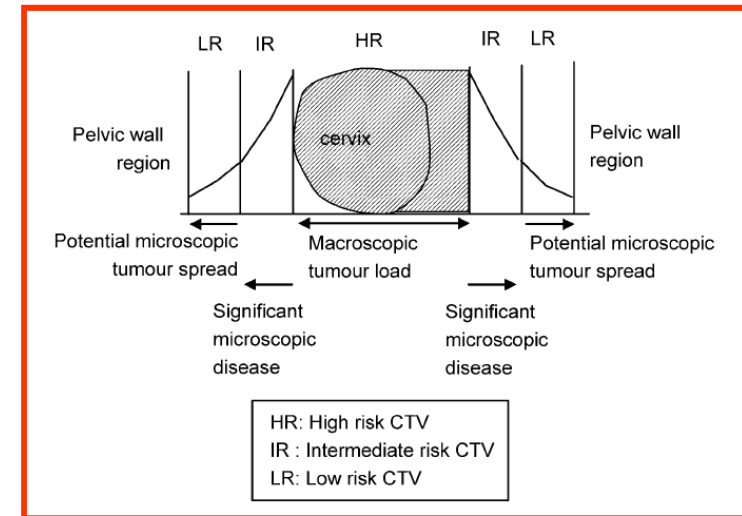
Department of Medical Physics, Division of Cancer and Surgery, Oslo University Hospital, Norway. Taran.Paulsen.Hellebust@nrpa.no



# MR Imaging Based: Volumes and DVH Parameters

## GEC ESTRO RECOMMENDATIONS – I & II

- **GTV:**  
macroscopic tumour extension at time of brachytherapy...  
**High signal intensity mass(es)** (FSE, T2) in cervix/corpus, parametria, vagina, bladder and rectum
- **HR-CTV:**  
includes **gtv, whole cervix**, and **presumed extracervical tumour extension**. Pathologic residual tissue(s) as defined by palpable indurations and/or **grey zones** in parametria, uterine corpus, vagina or rectum and bladder are included in HR-CTV. **No safety margin are added.**
- **IR-CTV:**  
encompasses the **HR-CTV** different **safety margins** are added according to the treatment strategy, tumour size and tumour regression. **In any case a minimal safety margin of 5 to 15 mm have to be added.**



**D90, D98, V100 for GTV, HR-CTV, IR-CTV**

**D0.1cc, D1cc, D2cc for OAR's : RECTUM, SIGMOID, BLADDER, SBR,.....**

**Radiother & Oncol. 2005; 2006;**



# Target Volume Concepts

## Target definition

### 2 CTVs

A first target related to the extent of GTV at time of BT:  
taking into account tumour extent at diagnosis  
with a high dose prescribed to this target (80-90 Gy)

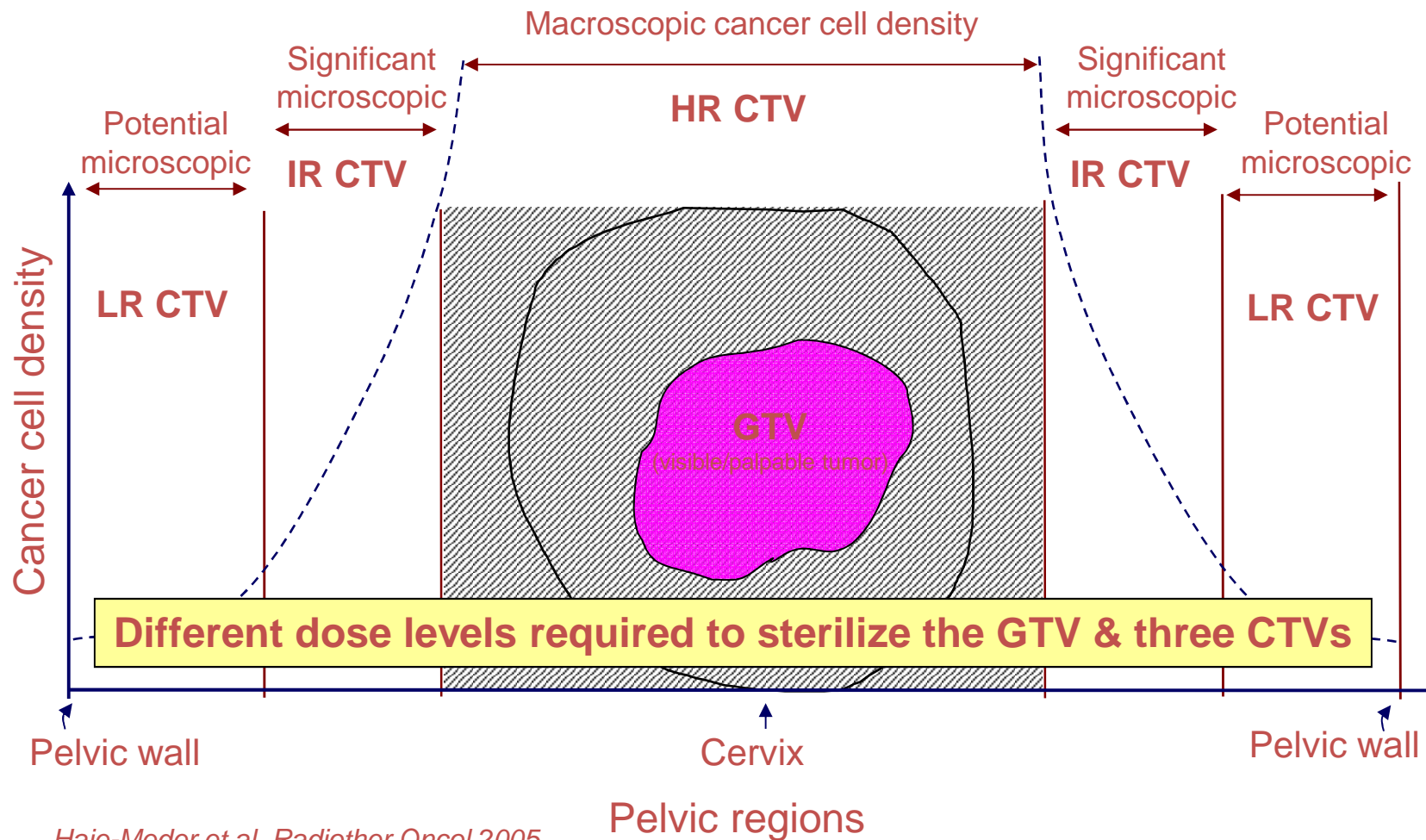
*High risk CTV*

A second target related to the extent of GTV at diagnosis :  
with an intermediate dose prescribed to this target (60 Gy)

*Intermediate risk CTV*

# GEC ESTRO Definition of BT target volumes

## GTV and Three CTVs according to cancer cell density & risk of recurrence



# Target volume concepts

## HR CTV :

- GTV at the time of BT
- CTV defined for brachytherapy if major response :  
limited to cervix and adjacent structures with presumed residual disease (~30-60 cc)
- Intent : 80 to 90 + Gy total dose to CTV in definitive radiotherapy in advanced disease
- Dose comparable with dose to point A

# Target volume concepts

## High Risk CTV:

GTV at time of brachytherapy

In all cases includes:

- Whole cervix
- Presumed tumour extension
  - Clinical assessment
  - Residual grey zones on MRI

NO SAFETY MARGINS

AIM : DOSE HIGH ENOUGH TO STERILIZE  
MACROSCOPIC TUMOUR

# Target volume concepts

## IR CTV :

- Integrates GTV at the time of diagnosis
- Always includes HR-CTV
- In case of major response :
  - includes safety margins with regard to GTV initial size
- Intent : 60 + Gy total dose to CTV in definitive radiotherapy in advanced disease
- Dose comparable with dose to the 60Gy isodose (ICRU 38 recommendations)

# Target volume concepts

## Intermediate Risk CTV :

GTV at time of diagnosis

In all cases includes:

- HR-CTV
- integrates initial CTV

SAFETY MARGINS :

1-1.5 cm cranially

0.5cm antero-posteriorly

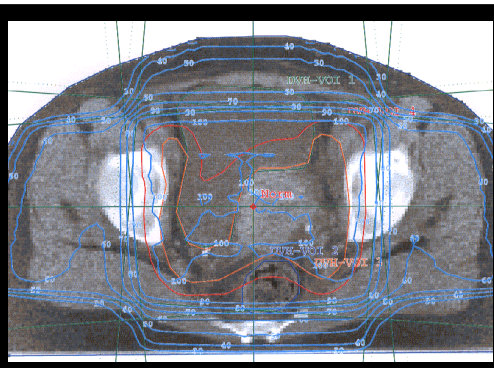
1cm laterally

AIM : TO STERILIZE MICROSCOPIC TUMOUR

# Delineation of BT target volumes

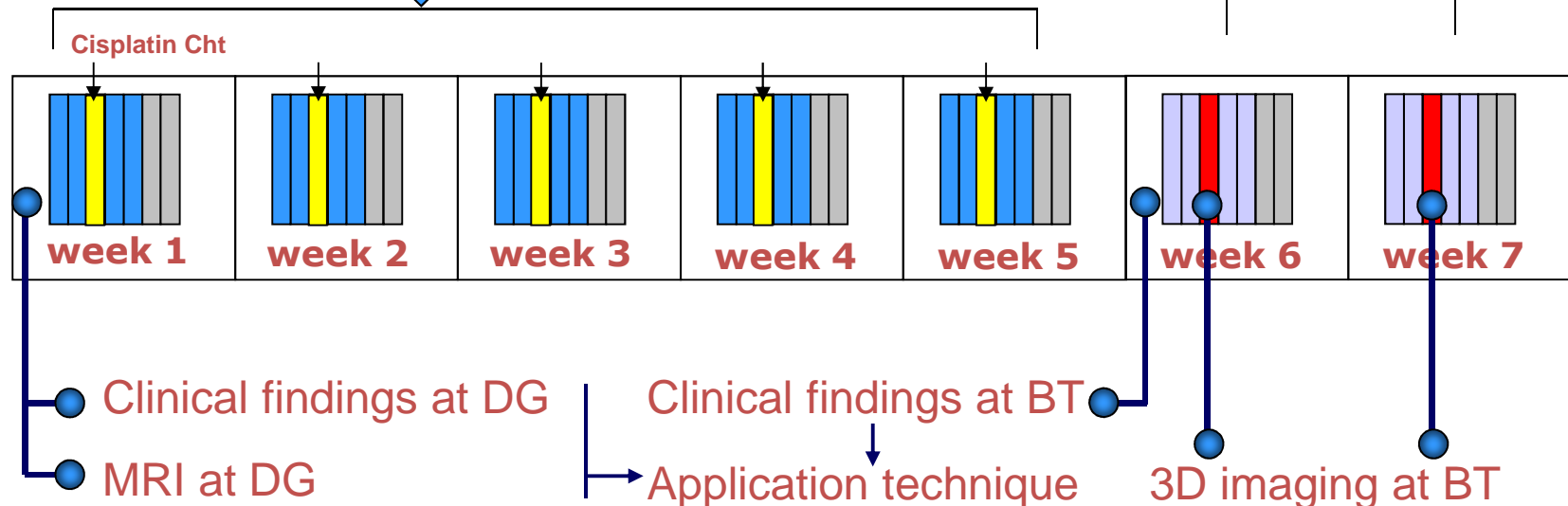
## Practical requirements for contouring

Treatment schedule example (Institute of Oncology Ljubljana example; Treatment schedules vary across institutions!!!)



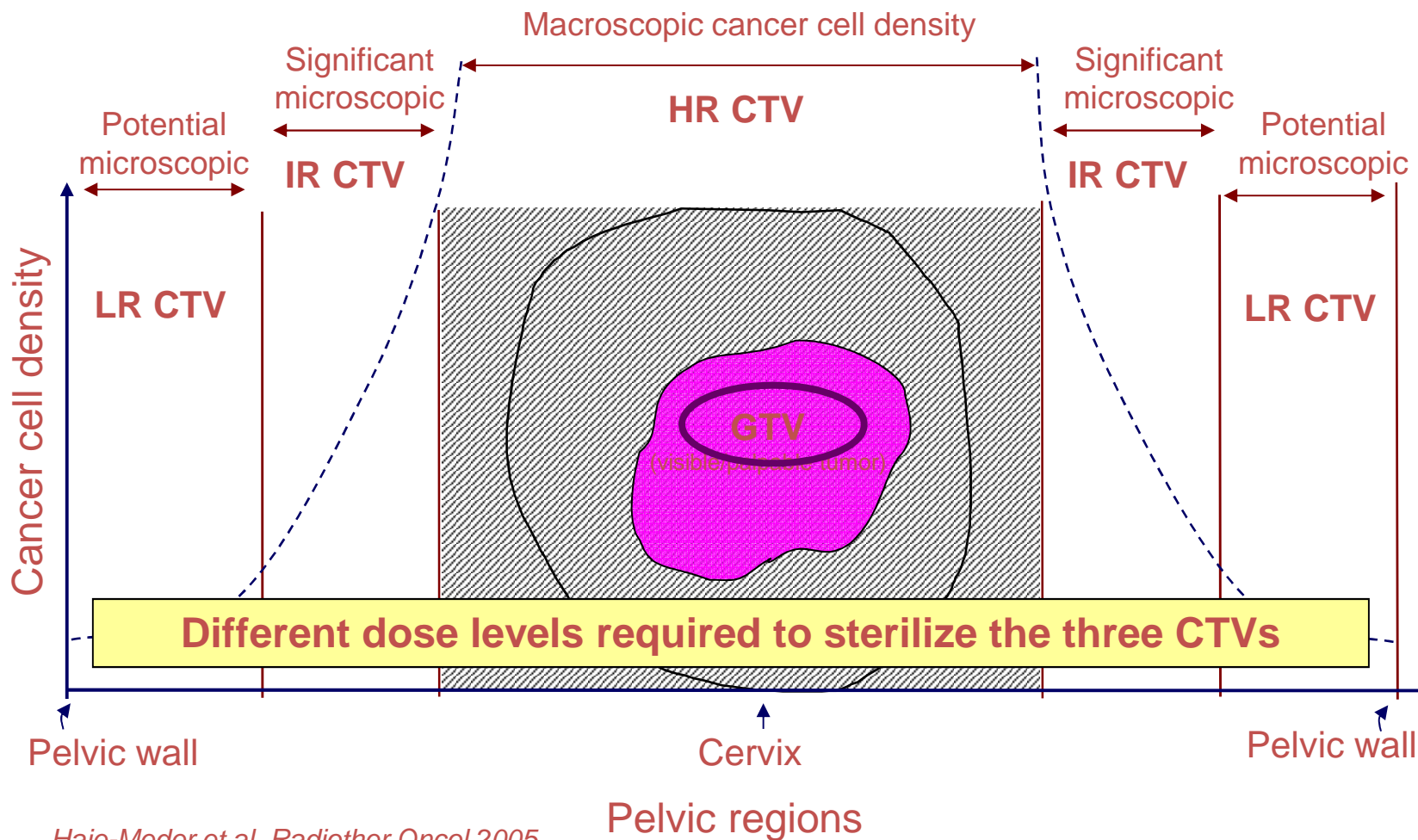
↓ EBRT

↓ BT



# Definition of BT target volumes

## GTV





# Definition of BT target volumes

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## Limited Disease

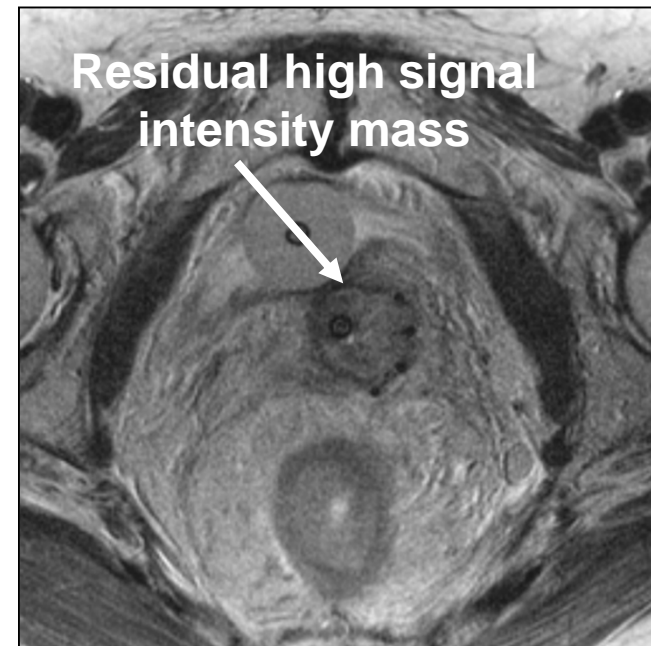
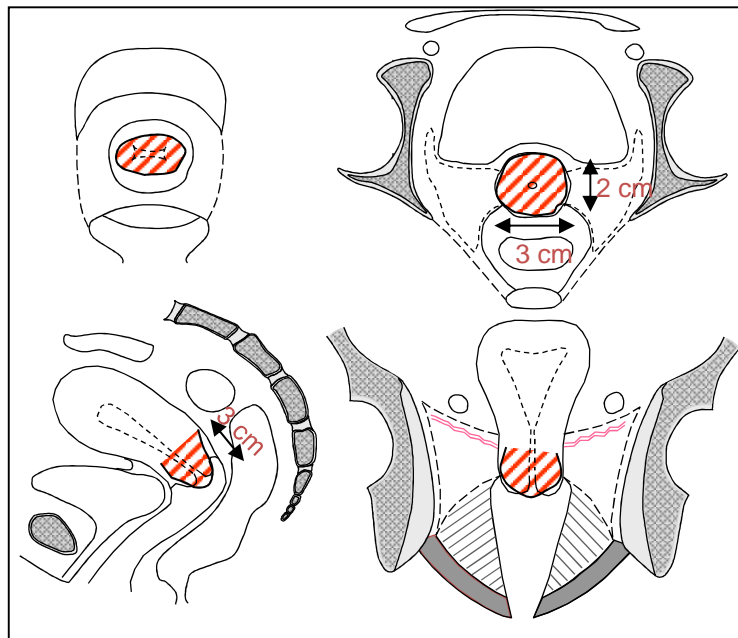
**Gross Tumor Volume =  $GTV_{BT1}$ ,  $GTV_{BT2}$ ...**

**Clinical Findings at BT:**

Macroscopic - palpable and visible residual tumor

**MRI Findings at BT:**

Residual high signal intensity mass

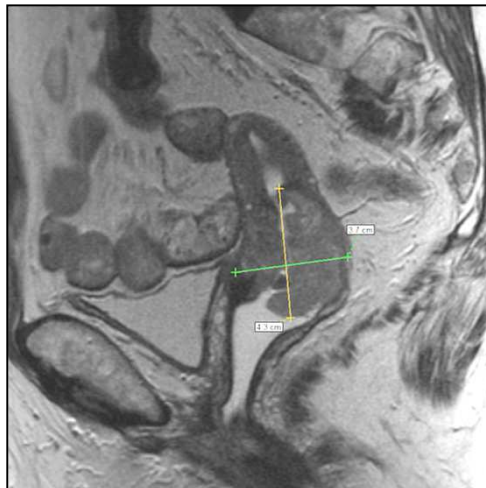


**Initial tumour extension (clinical, MRI) taken into account!**

# Definition of BT target volumes

## Limited Disease : $GTV_{BT1,2...}$

Initial MRI findings



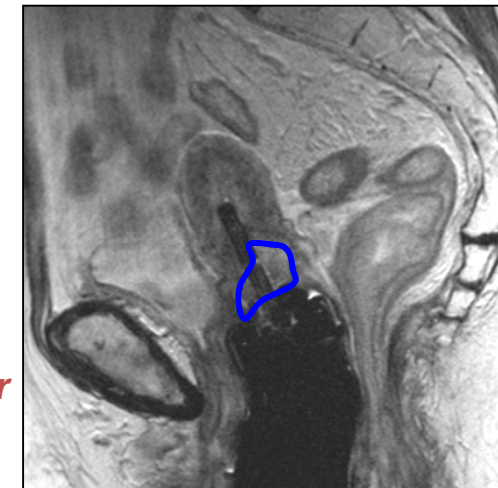
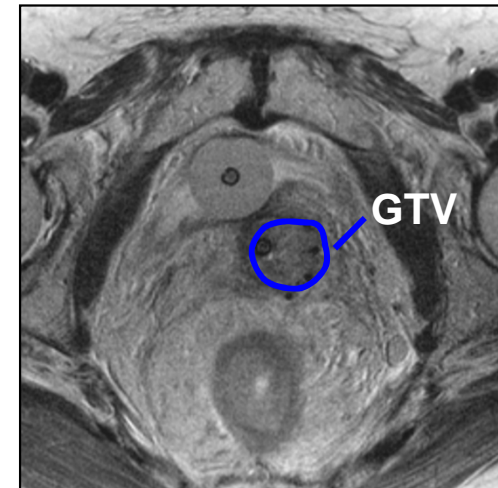
EBRT + ChT

*No grey zones and palpable indurations at BT*

EBRT + ChT

$GTV_{BT}$  = Gross residual disease after EBRT

MRI findings at BT



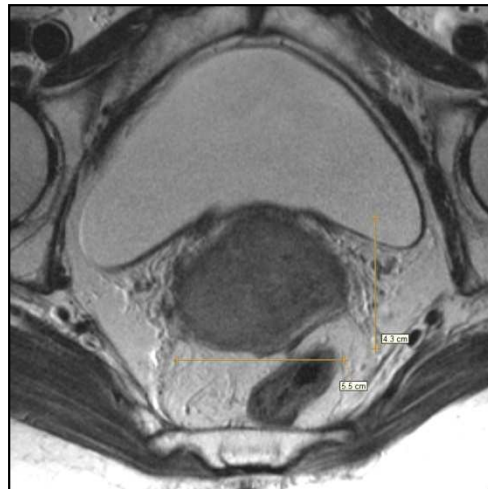
# Definition of BT target volumes

## Advanced Disease

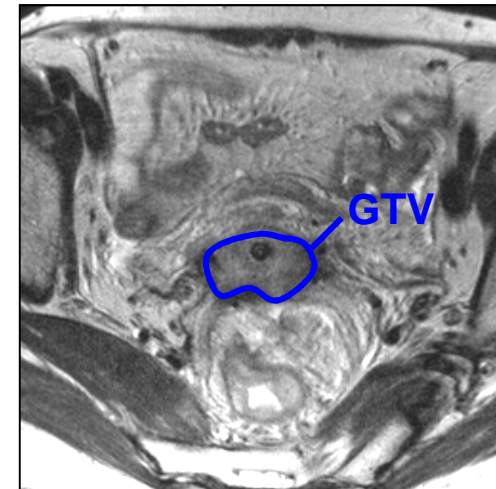
Gross Tumor Volume =  $GTV_{BT1,2,...}$

Initial MRI findings

MRI findings at BT



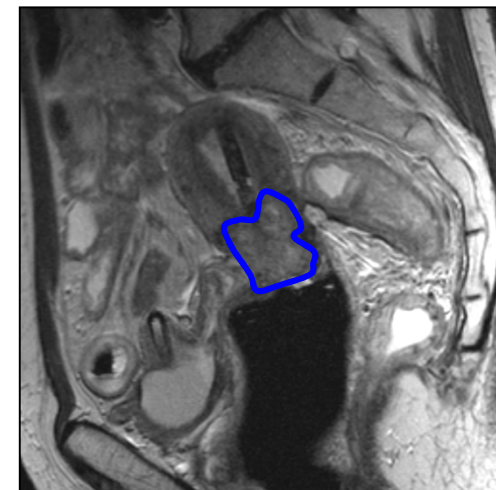
EBRT + ChT



*Grey zones and palpable indurations in parametria and uterus at BT*



EBRT + ChT



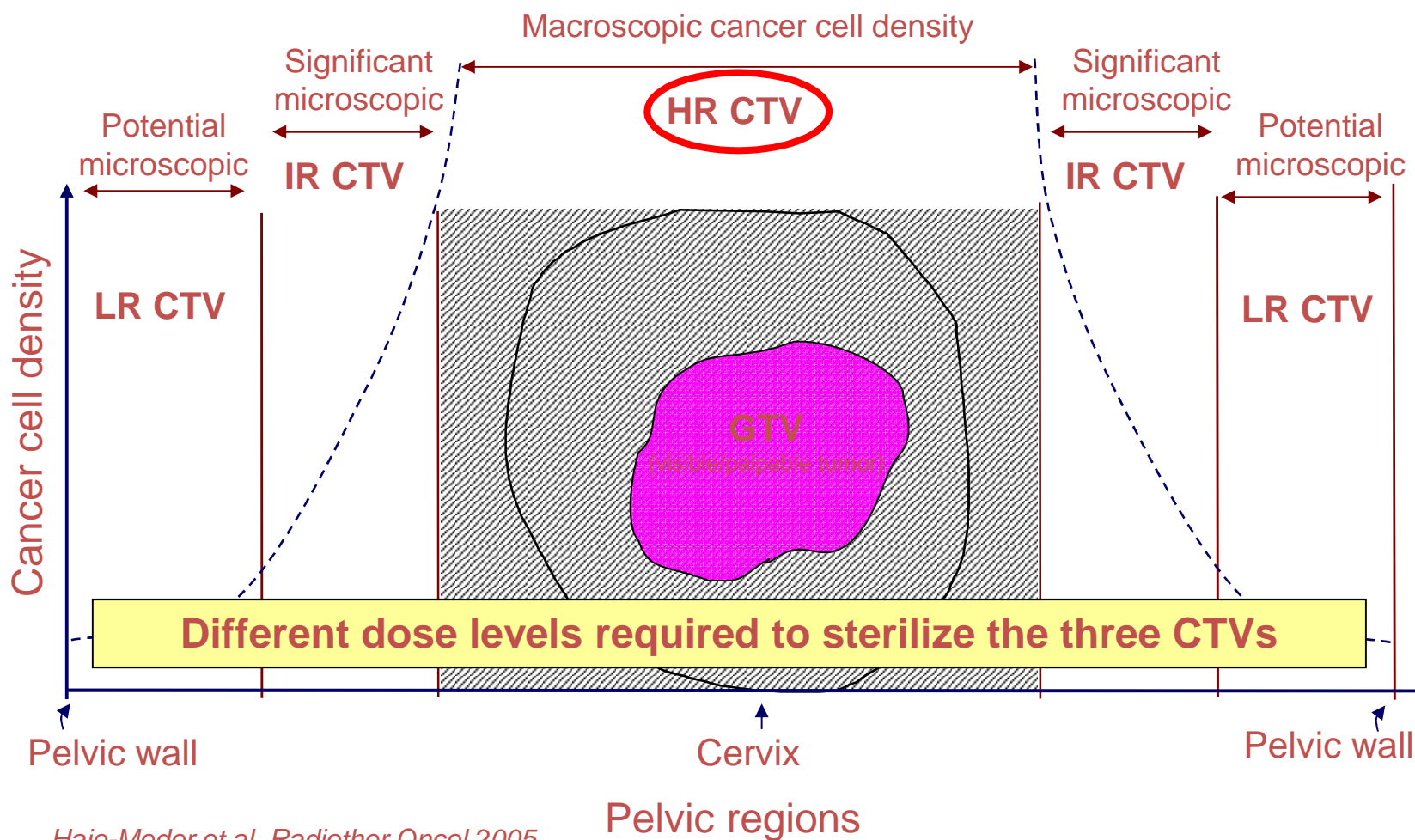
**HR CTV**

=

$GTV_{Bt} + \text{cervix} + \text{grey zones}$

# Definition of BT target volumes

## HR CTV



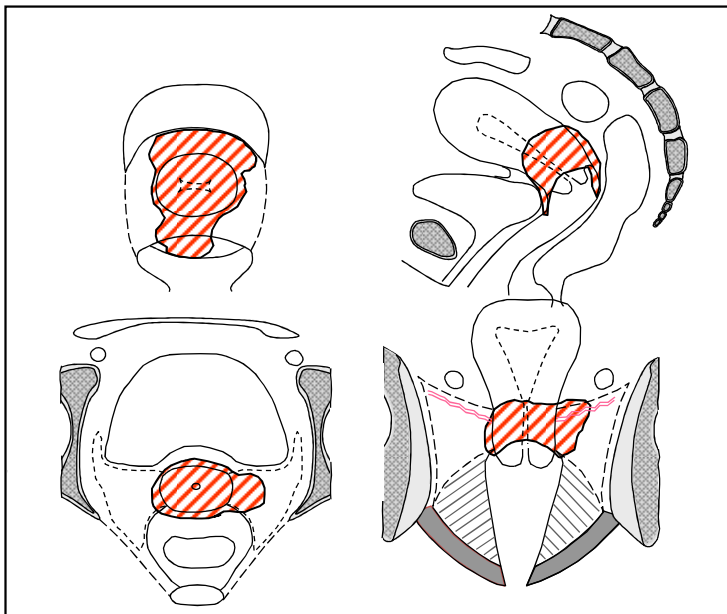
## Definition of BT target volumes

**High Risk Clinical Target Volume = HR CTV<sub>BT1,2...</sub>**

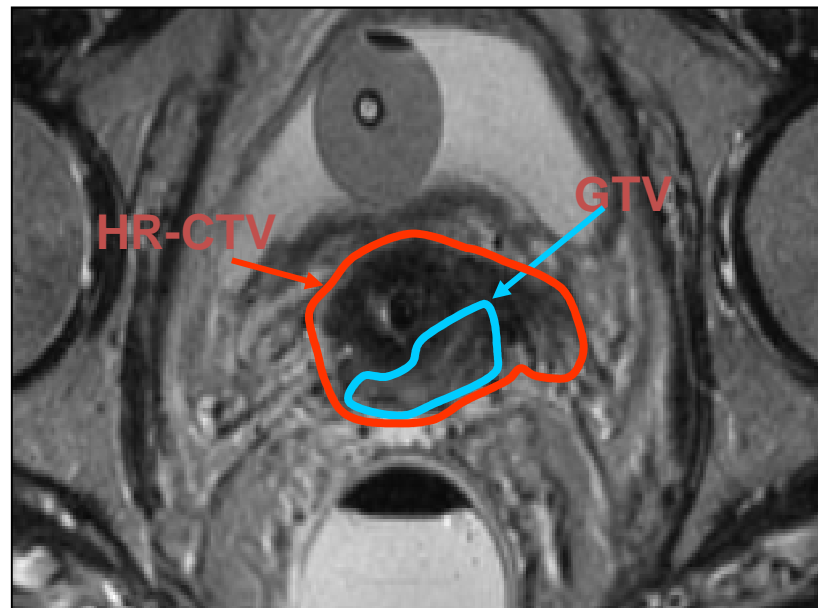
**HR-CTV Includes:**

- GTV<sub>BT</sub>
- Whole cervix
- Presumed extracervical tumour extension at BT:
  - Clinically palpable indurations
  - MRI: residual “grey zones”

**Clinical Findings at BT:**



**MRI Findings at BT:**



**Initial tumour extension (clinical, MRI) taken into account!**

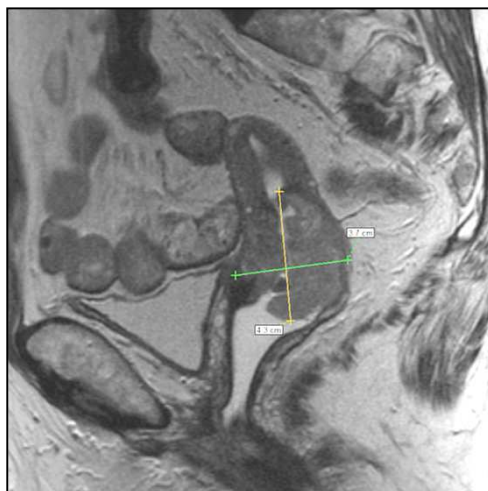
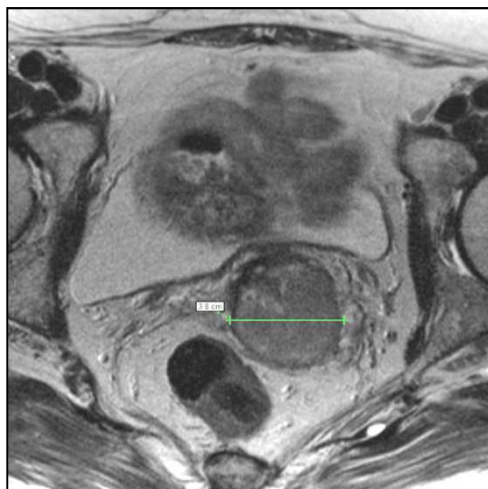


# Definition of BT target volumes

## Limited Disease

High Risk Clinical Target Volume = HR CTV<sub>BT1,2...</sub>

Initial MRI findings



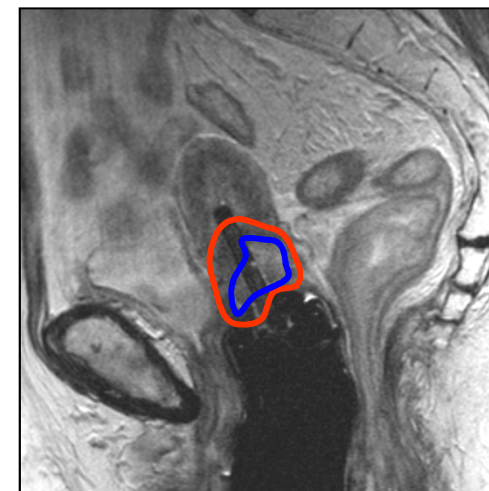
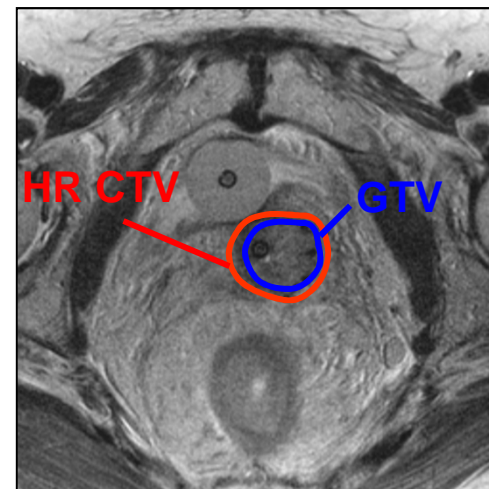
EBRT + ChT

No grey zones and palpable indurations at BT

EBRT + ChT

HR CTV  
=  
GTV<sub>Bt</sub> + cervix

MRI findings at BT



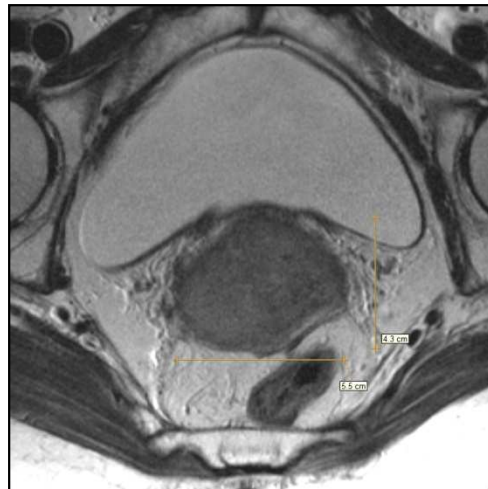
# Definition of BT target volumes

## Advanced Disease

High Risk Clinical Target Volume = HR CTV<sub>BT1,2...</sub>

Initial MRI findings

MRI findings at BT



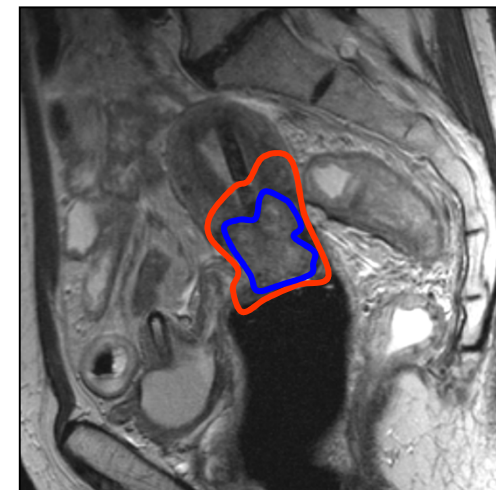
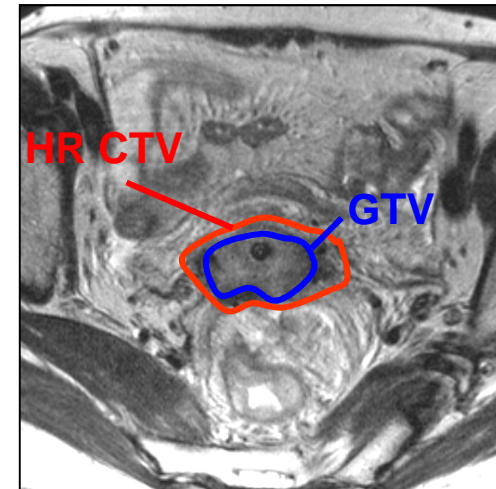
EBRT + ChT

*Grey zones and palpable indurations in parametria and uterus at BT*



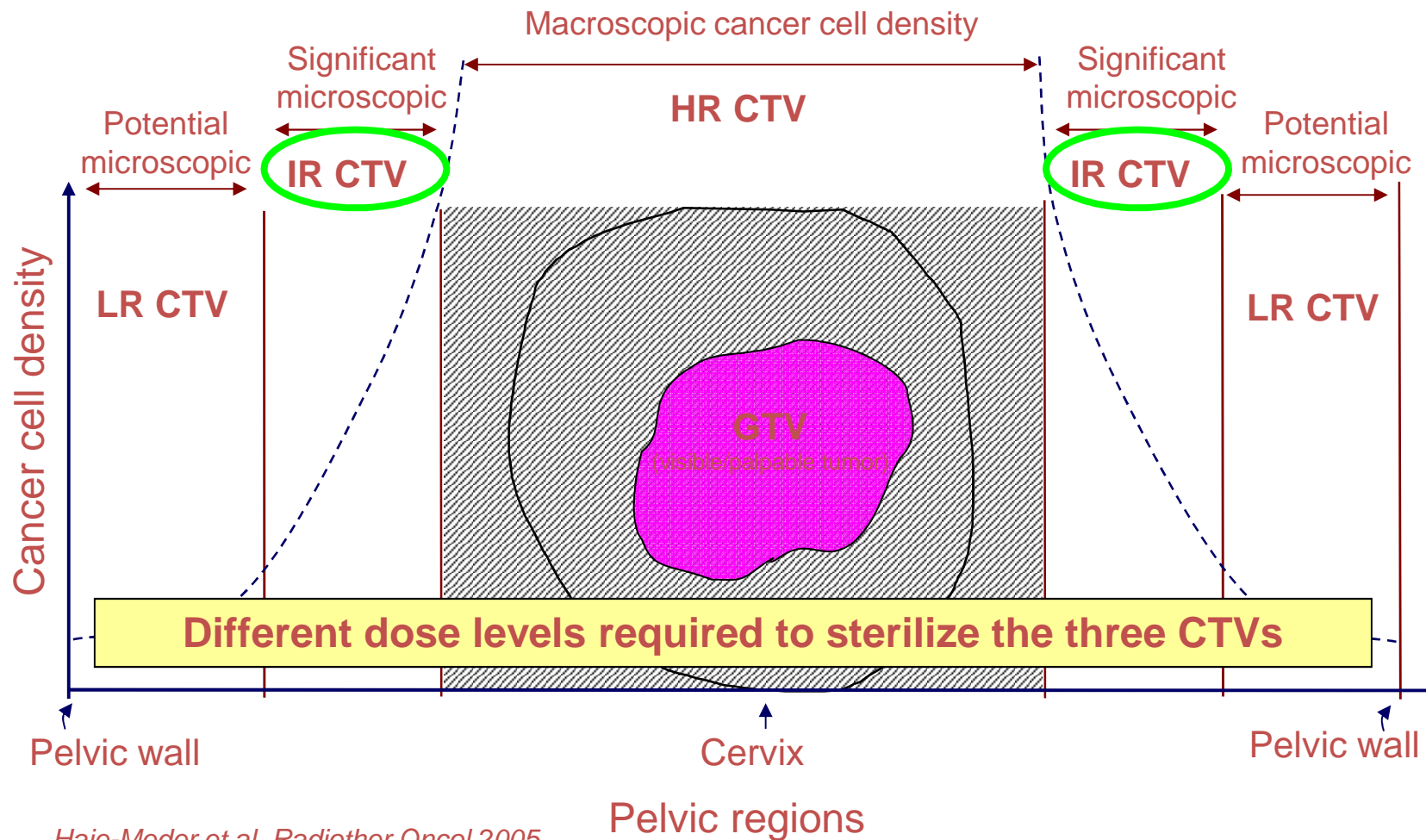
EBRT + ChT

**HR CTV**  
=  
 $GTV_{Bt} + \text{cervix} + \text{grey zones}$



# Definition of BT target volumes

## IR CTV





# Definition of BT target volumes

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**Intermediate Risk Clinical Target Volume = IR CTV<sub>BT1,2...</sub>**

**IR-CTV Includes:** HR-CTV + presumed adjacent significant microscopic disease  
→ Safety margin

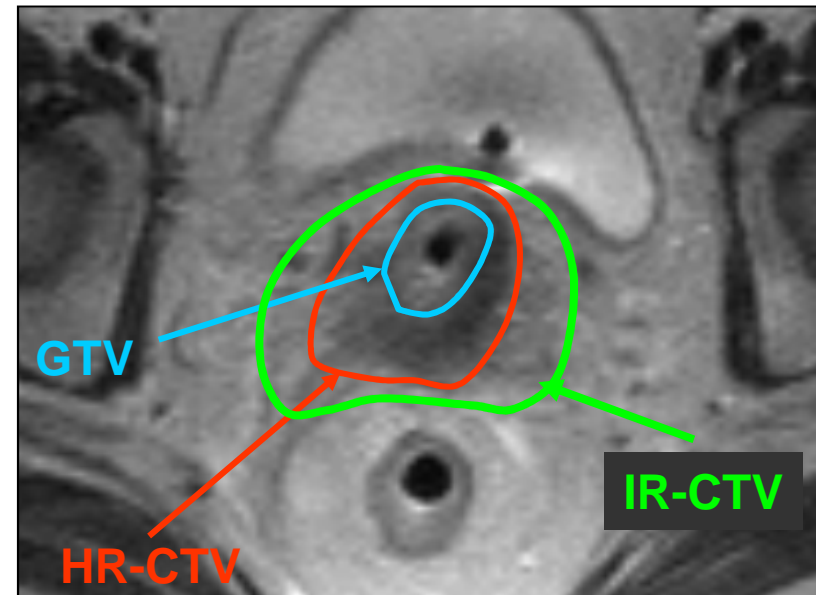
Confined by anatomical borders: bladder, rectum, pelvic wall  
In case of invasion of bladder/rectum at DG, wall included, no lumen

**Limited disease** (BT alone or preop.):

- HR-CTV + margin 5-15 mm

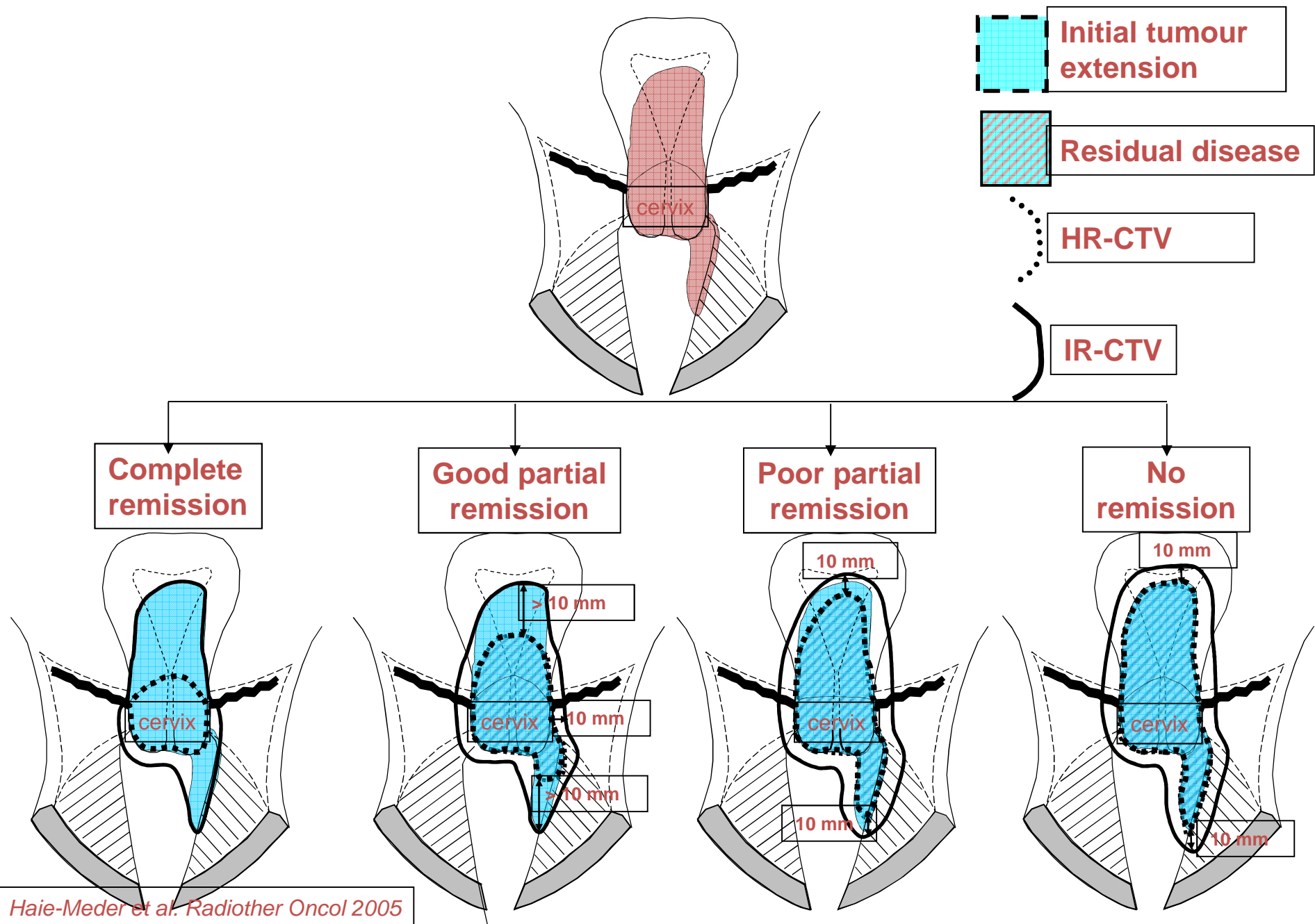
**Extensive disease** (EBRT + BT):

- Initial macroscopic tumor (GTV<sub>Dg</sub>)
- margins depend on:
  - extent at diagnosis
  - regression after EBRT



**Initial tumour extension (clinical, MRI) taken into account!**

## IR-CTV depends on initial tumor extent and degree of remission



# Definition of BT target volumes

## Limited Disease

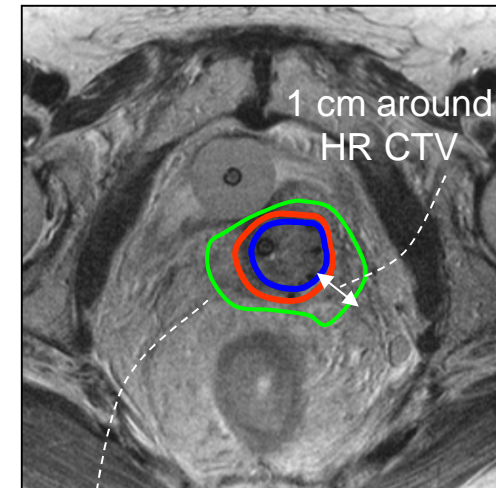
Intermediate Risk Clinical Target Volume = IR CTV<sub>BT1,2...</sub>

Initial MRI findings

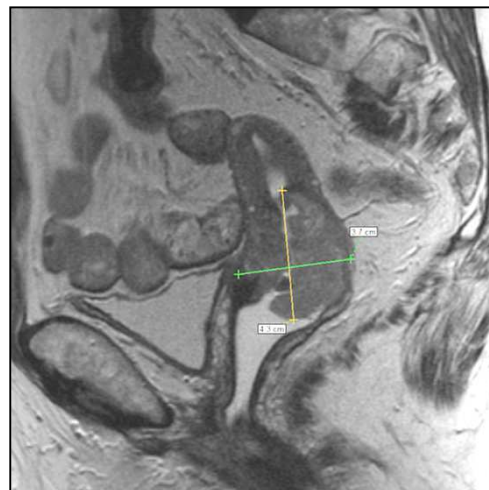


EBRT + ChT

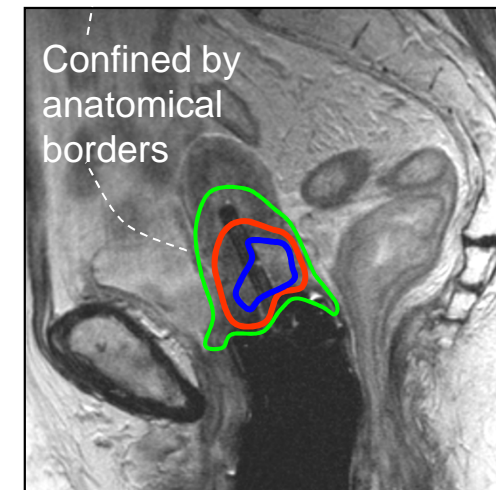
MRI findings at BT



*Good remission*



EBRT + ChT



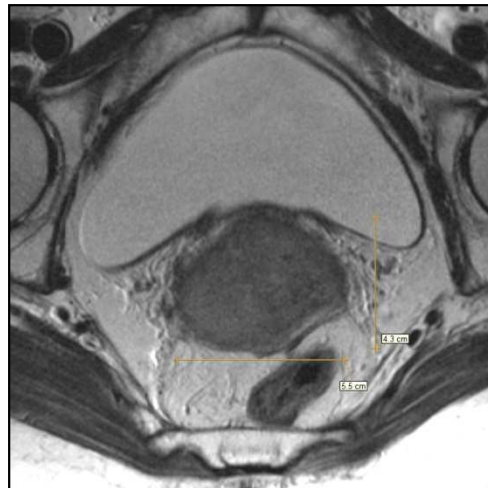
*IR CTV*  
 $\approx$   
*initial tumor extent*

# Definition of BT target volumes

## Advanced Disease

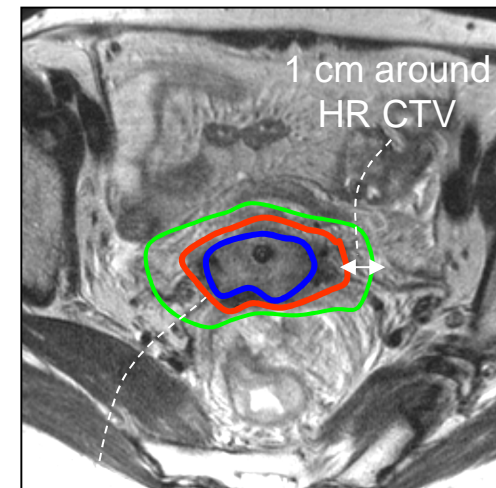
Intermediate Risk Clinical Target Volume = IR CTV<sub>BT1,2...</sub>

Initial MRI findings



EBRT + ChT

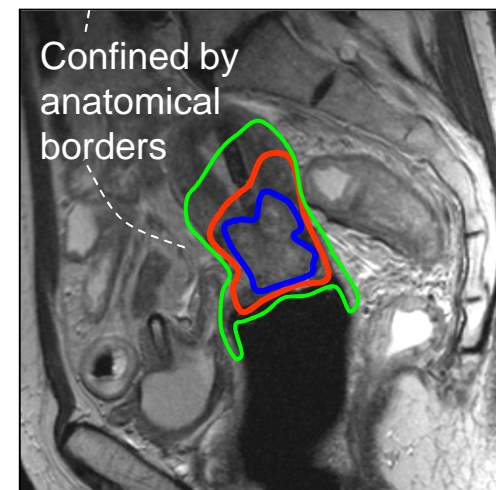
MRI findings at BT



*Poor  
remission*

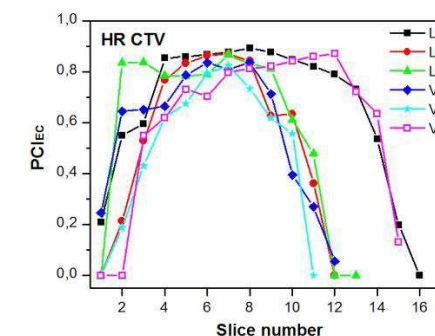
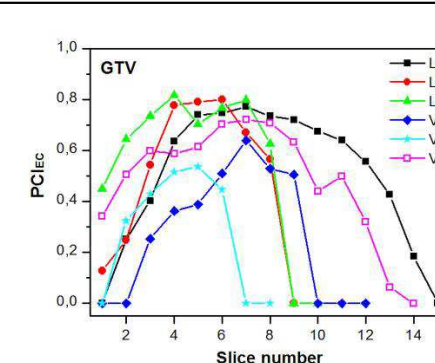
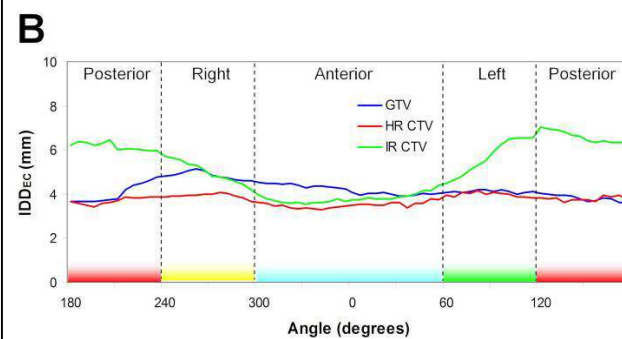
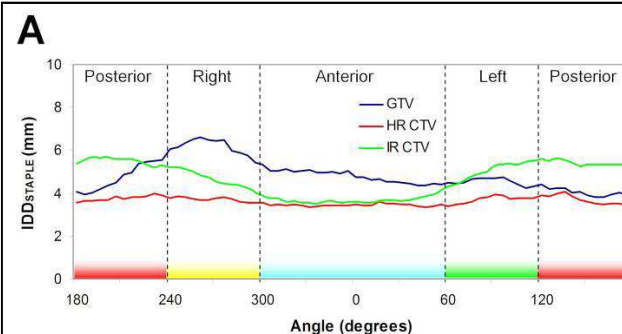
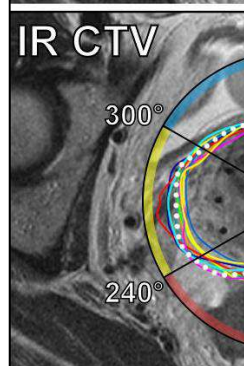
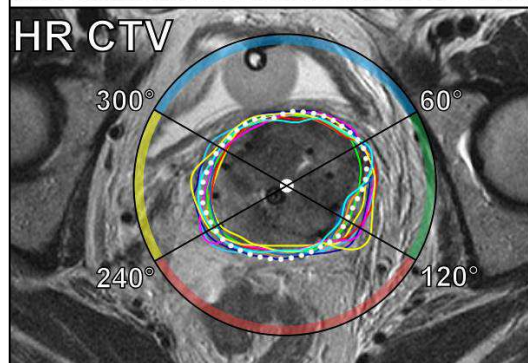
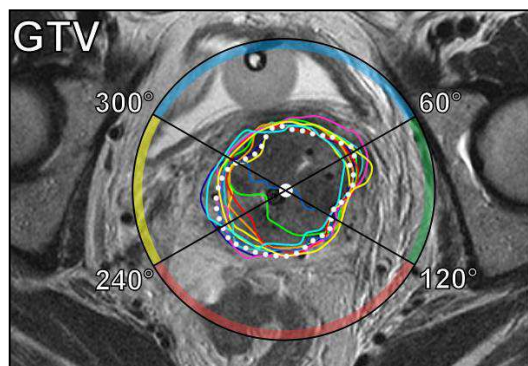


EBRT + ChT



*IR CTV  
>  
initial tumor extent*





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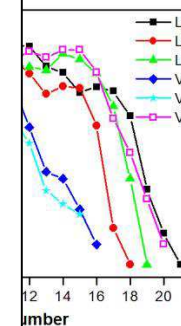


Original article

## Uncertainties of target volume delineation in MRI guided adaptive brachytherapy of cervix cancer: A multi-institutional study

Primož Petrič<sup>a,b,\*</sup>, Robert Hudej<sup>b</sup>, Peter Rogelj<sup>c</sup>, Mateja Blas<sup>d</sup>, Kari Tanderup<sup>e,f</sup>, Elena Fidarova<sup>g,h</sup>, Christian Kirisits<sup>h,i</sup>, Daniel Berger<sup>h</sup>, Johannes Carl Athanasios Dimopoulos<sup>j</sup>, Richard Pötter<sup>h,i</sup>, Taran Paulsen Hellebust<sup>k,l,m</sup>

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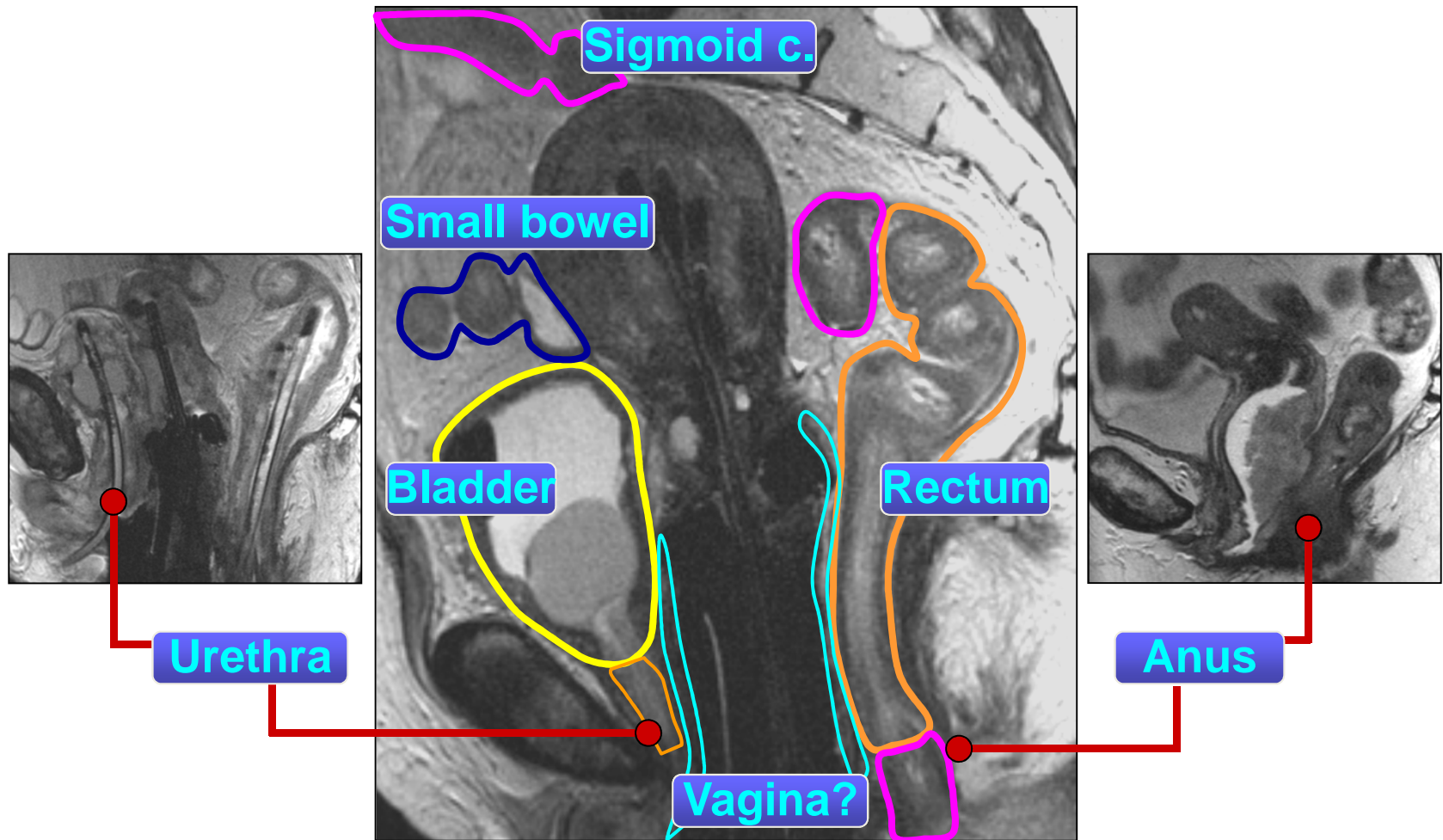


Radiotherapy & Oncology 2013, April issue: **UNCERTAINTIES** in gynae IGABT

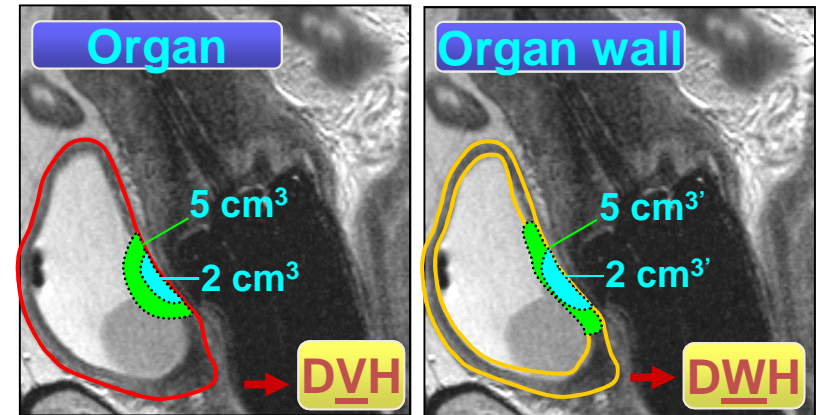
# Which organs at risk?

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OTHER?

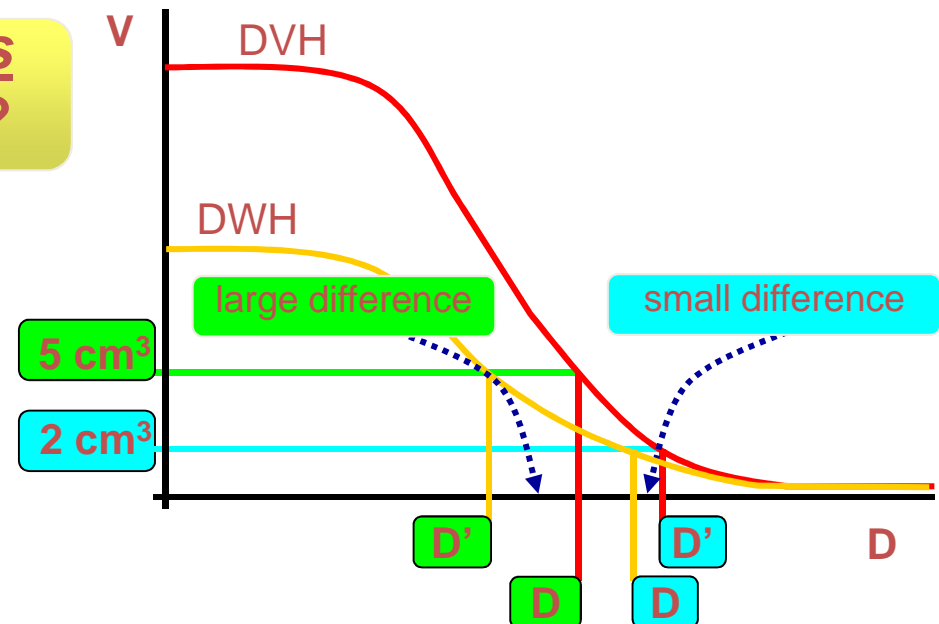


# Organs at risk



Can we contour organs  
instead of organ walls?

↓  
Yes, if doses to  
**2 cm<sup>3</sup>** are evaluated.



DVH – dose volume histogram  
DWH – dose wall histogram

Wachter-Gerstner N. *Radiother Oncol* 2003;68:269-276    Olszewska AM. *Radiother Oncol* 2001

# Work flow

