IMAGE BASED BRACHYTHERAPY FOR CERVICAL CANCER

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Image Based Brachytherapy

- Image *guided* brachytherapy
  - Technique where imaging is used to guide brachytherapy applicator/source placement.

- Image *based* brachytherapy
  - Technique where advanced imaging modalities are used to gain information regarding the volumetric dose distribution.

Image Based Brachytherapy

- Historically

- Dose prescription & treatment planning have been mainly based on traditional schools using a certain system, including a given technique, loading pattern, & dose rate.

- "Manchester", "Stockholm", "Fletcher/MD Anderson"

- Current practice is to prescribe dose to **Point A**

- Empiric point, does not reflect dose to tumor, reference is with applicator, is located where **dose gradiant is high i.e.about 10%/mm.**

Image Based Brachytherapy

- Historically
- Uniform method for reporting **ICRU Report 38 (1985)**

- Dose be specified in terms of total reference air kerma TRAK
- Reference volume be determined – tissue **volume encomposed by a reference isodose surface, 60 Gy**
- **Points** for dose assessment **to bladder & rectum**
- Extended to dose-volume histograms DVH for OARs.
- Compare brachytherapy performed in different institutions.

- Applied only minimally, no correlation with primary cervical tumor control.

Image Based Brachytherapy

- Recently
- **3D & 4D image–based brachytherapy** treatment planning & dosimetry has been used for Cancer Cervix.
- Prescribed dose is always **related to the target** while the actual coverage can be evaluated with the use of DVH parameters
- Shape the spatial dose to conform to the target volume
  - Reduce dose to normal tissues & hence reduce the normal tissue toxicity.
  - **Escalate dose to the tumor to produce greater rates of local control**

Image Based Brachytherapy

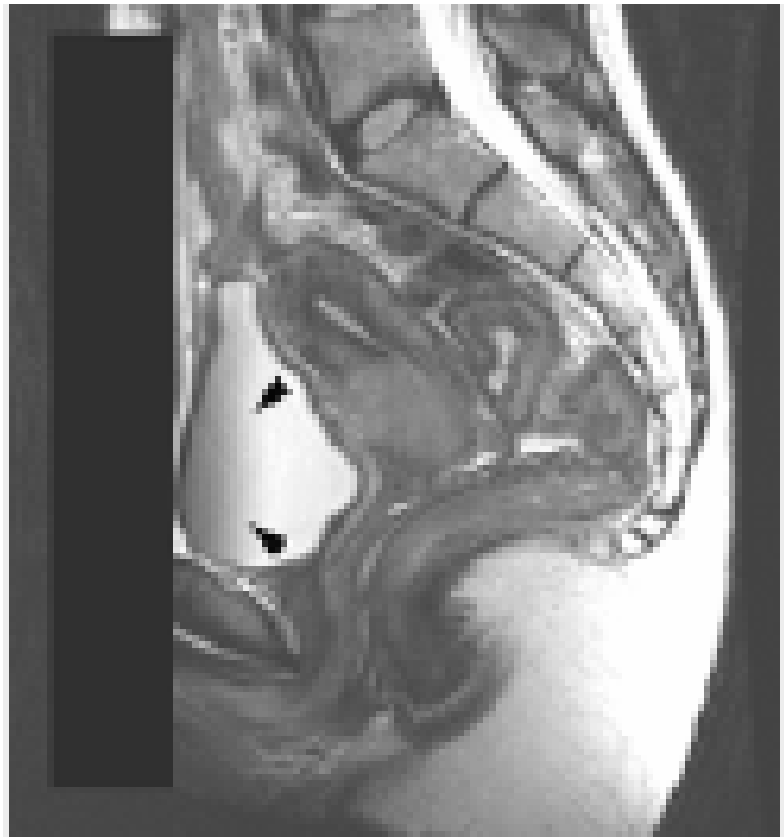
- Imaging modalities used
- **Ultrasonography**
- **Fluroscopy**
- **Computed tomography CT**
  - 3D anatomic relationship of applicator & neighbouring structures
  - **Difficult to separate cervical tumor from uterus, rectum & bladder & to ascertain where cervix ends & vagina begins**
- **MRI** T2-weighted images: High signal intensity,
  After ERT : intermediate signal intensity (grey zones)
- **PET**

Image Based Brachytherapy

- Imaging modalities used
- **MRI Scan**
  - Superior soft tissue resolution & is **the best imaging modality for visualisation of cervical tumor size, volume & extent**
  - Distinction of tumor from normal uterus & cervix
  - Definition of parametrial, & vaginal infiltration of disease
  - Visualise the anatomic relationship between applicator & tumor & adequacy of radiation coverage
  - Doses to rectum & bladder can be assessed
  - **Multiplanar scanning capabilities-**coronal, sagittal & axial

Image Based Brachytherapy

CT SCAN



MRI SCAN

Image Based Brachytherapy

- Imaging modalities used

- **MRI Scan –** disadvantages
  - **MRI – compatible applicator** made of nonferromagnetic materials. Titanium & zirconium alloy needles.
  - **Bony anatomy** not differentiated as well as on CT

  - **Treatment planning systems use Hounsfield numbers** hence they are not able to use MRI scans directly & it is necessary to fuse MRI with CT scans

Image Based Brachytherapy

- Imaging modalities used

- **MRI Scan accuracy**
  - Tumor volume - 93%
  - Deep stromal invasion - 94%
  - Parametrial infiltration - 87-94%
  - Lymph node involvement - 72-93% similar to CT
  - Overall Staging - 76-89% better than CT,USG, Clinical

Image Based Brachytherapy

- Requirements

- Imaging
- 'Image-able' & artifact free applicator
- Applicator fixation & immobilization
- Treatment planning system
- Compatible communication protocol-DICOM,so that the treatment planning system can interpret the images
- CT & MRI data sets need to be registered to superimpose one set on another
- Contouring tumor & OARs
- Dosimetry & dose-volume parameters for tumor & OARs

Image Based Brachytherapy

- Tumor volume assessment
  - First based on **Clinical Examination**
  - Appropriate **documentation** in three dimensions
  - **Sectional imaging** gives information on tumor extension & configuration & its topography

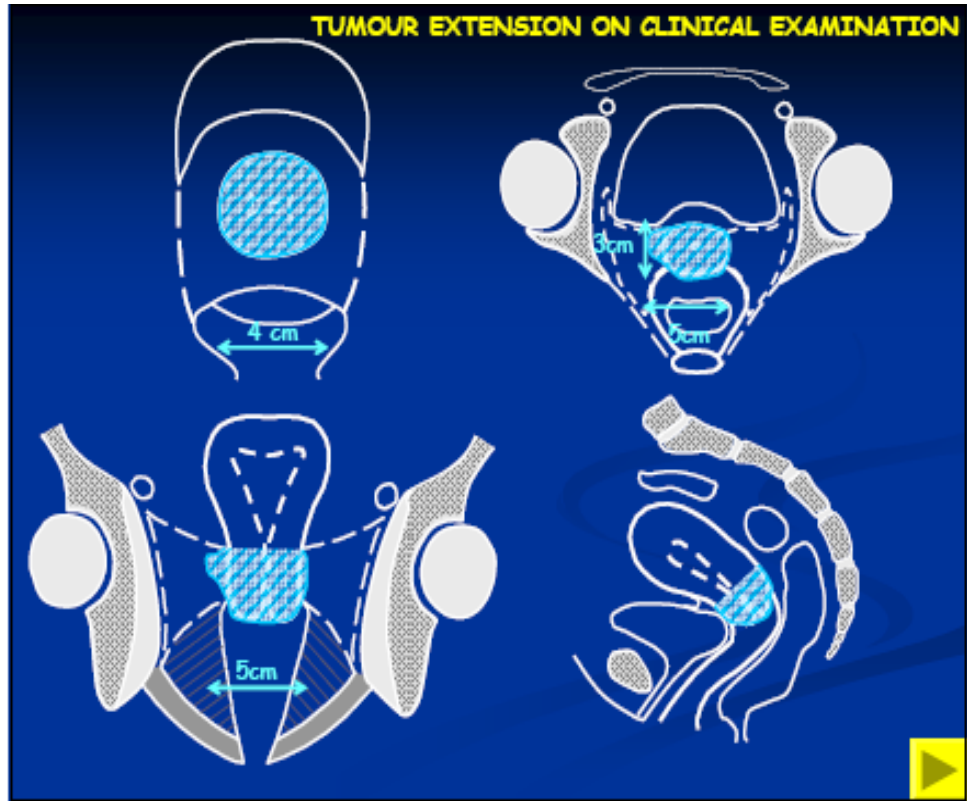


Image Based Brachytherapy

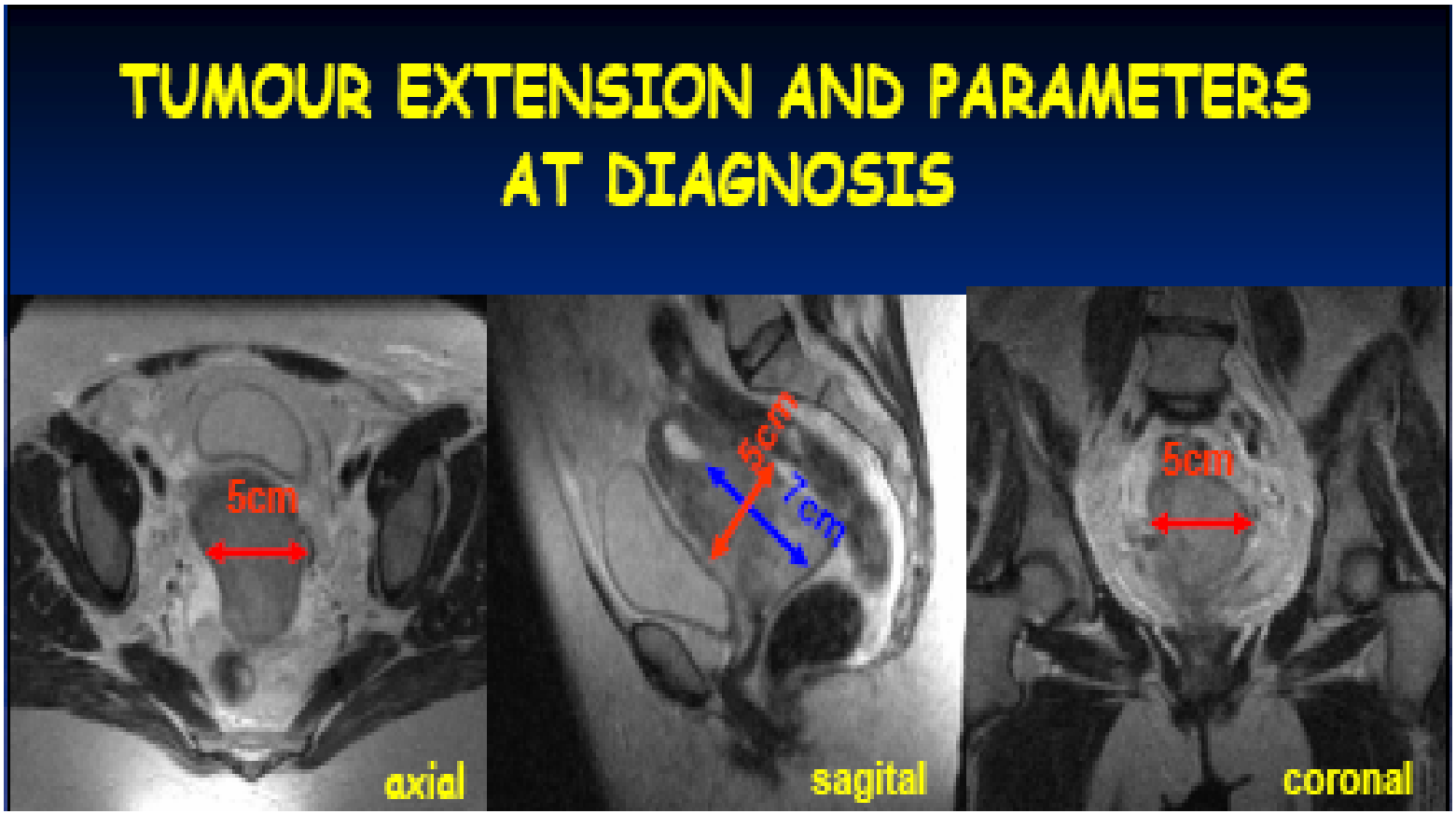


Image Based Brachytherapy

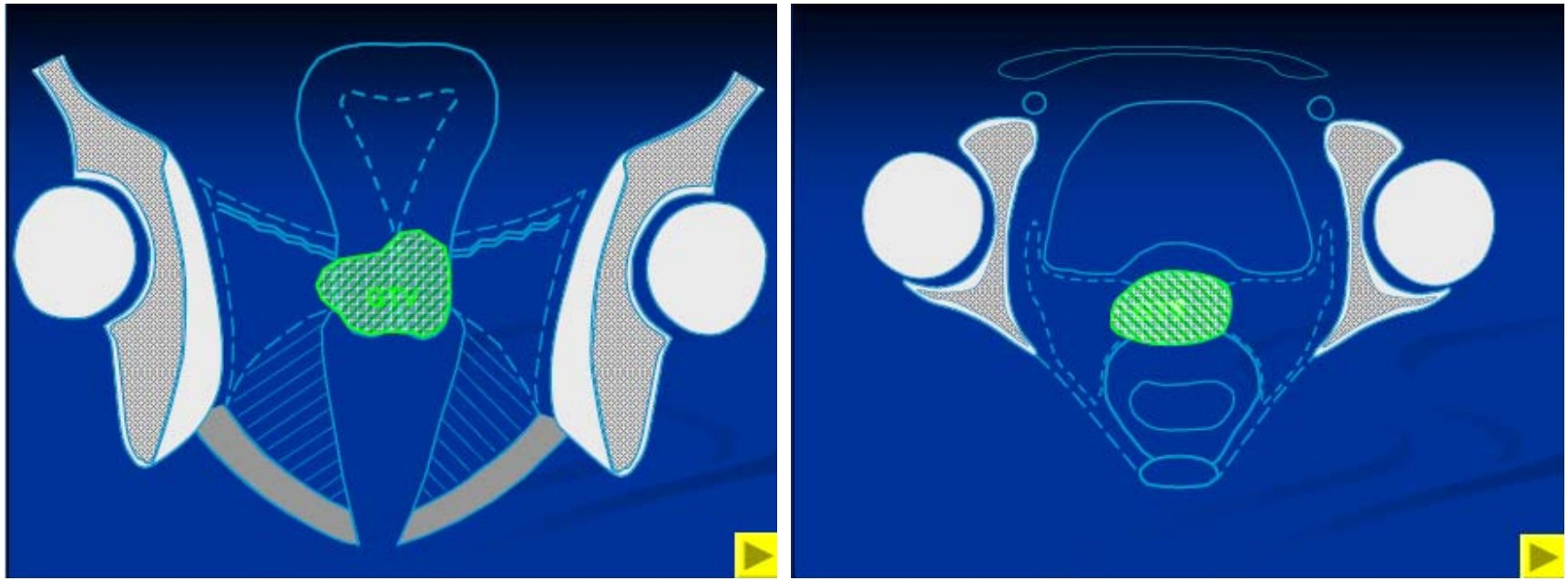
TUMOUR RESPONSE: GOOD

	Volume	Width	Thickness	Height	Distance PSW right	Distance PSW left
Diagnosis: involvement of the right proximal parametrium	88 cm^3	5 cm	5 cm	7 cm	4 cm	5 cm
Brachytherapy: minimal residual extension into the right parametrium	9 cm^3	3 cm	2 cm	3 cm	5 cm	6 cm

Image Based Brachytherapy

- Target Volume
  - **GTV**
    - Includes macroscopic tumor extension as detected by clinical examination (visualisation & palpation) & as visualised on MRI
    - Change of GTVs during treatment –
    - At diagnosis **GTV_D**
    - At brachytherapy **GTV_B**

Image Based Brachytherapy



The GTV encompasses the macroscopic tumour extension at time of brachytherapy: high signal intensity mass(es) (FSE, T2) in cervix/corpus, parametria, vagina, bladder and rectum

Image Based Brachytherapy

Target definition

2 CTVs

A first target related to the extent of GTV **at time of BT**: taking into account tumour extent at diagnosis.

- **High risk CTV**

- Major risk of recurrence because of residual **macroscopic** tumor
- Intent is to deliver a total dose as high as possible to eradicate all ***residual macroscopic tumor***
- ***High dose prescribed to this target (80-90+Gy)=dose to point A***

Image Based Brachytherapy

Target definition

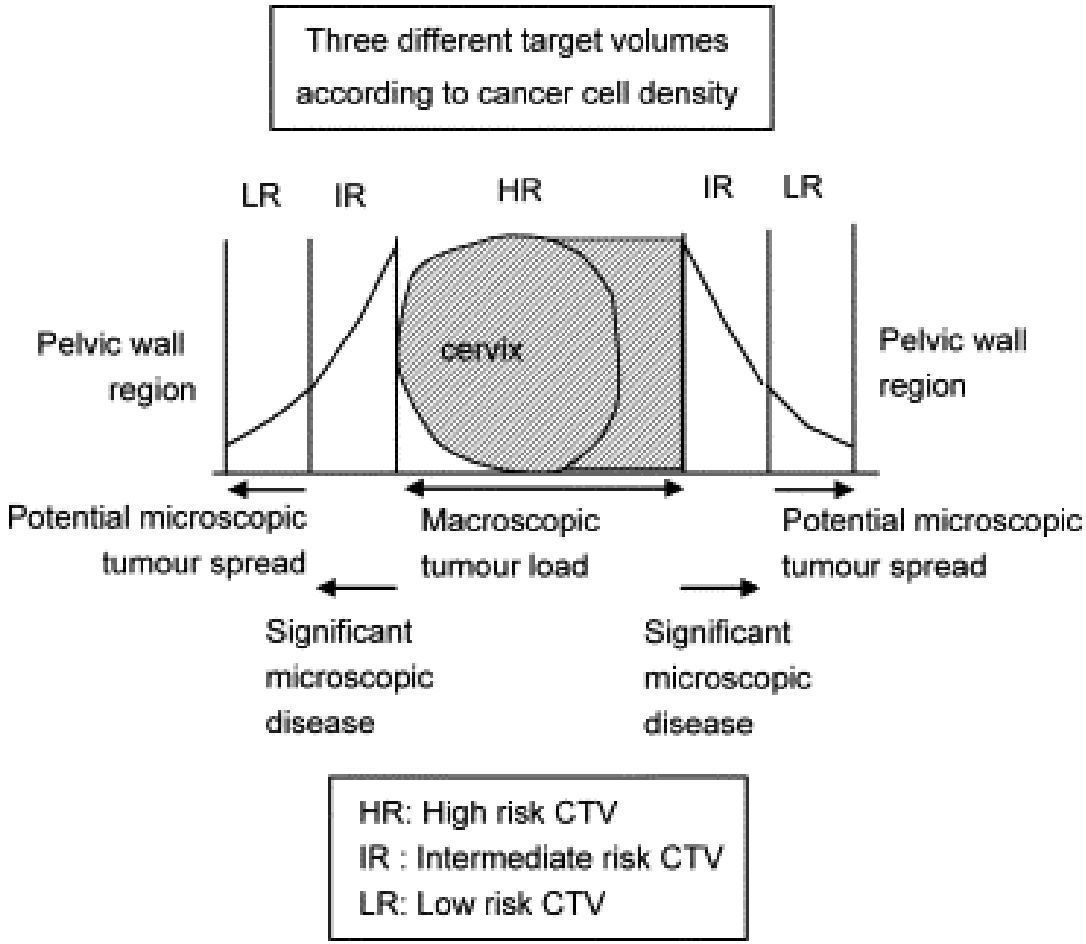
2 CTVs

A second target related to the extent of GTV **at diagnosis** :

- **Intermediate risk CTV**

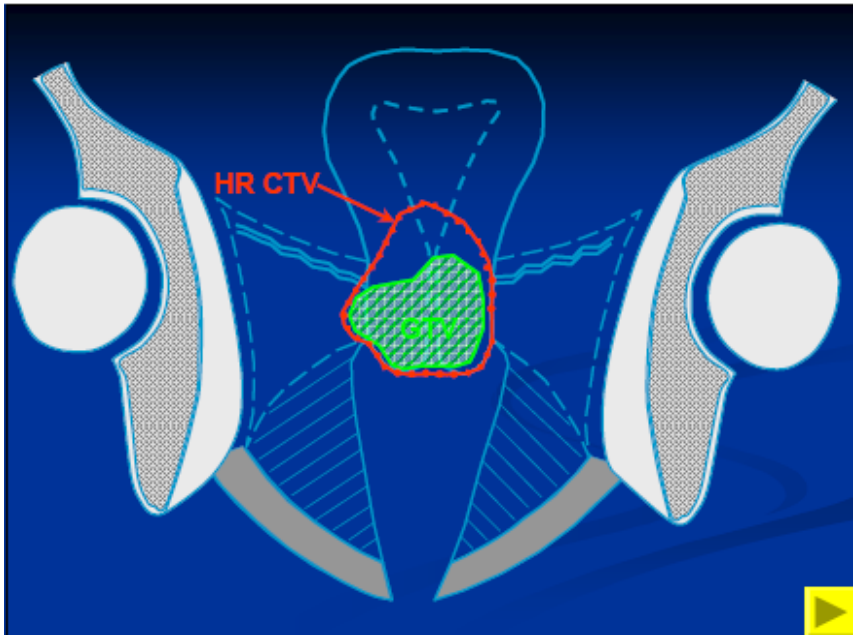
- Major risk of recurrence in areas that initially had macroscopic extent of disease with residual **microscopic** disease at time of BT
- Intent is to deliver dose appropriate to cure ***microscopic disease in cervix cancer***, **which corresponds to a dose of 60Gy**

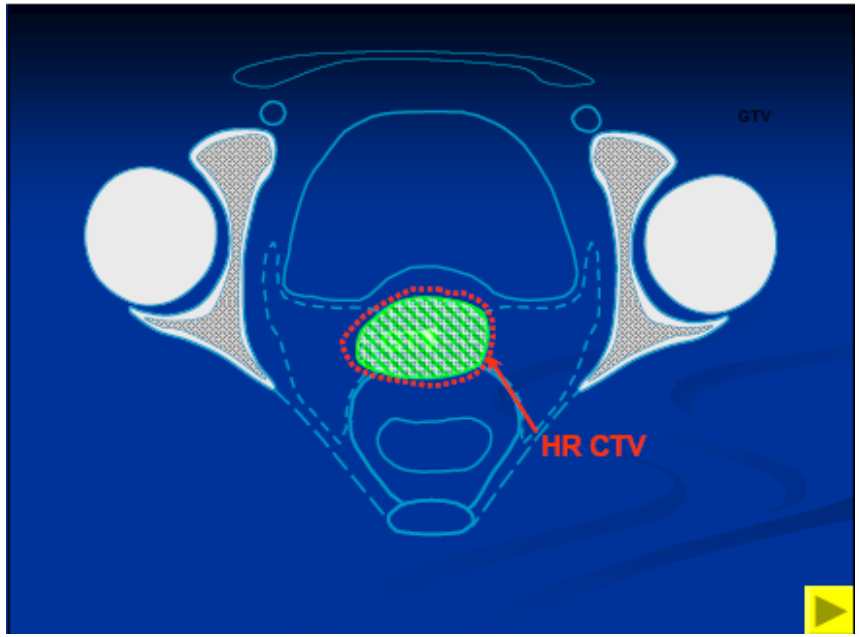
Image Based Brachytherapy



Haie-Meder, Radiot & Oncol, 74, 2005

Image Based Brachytherapy



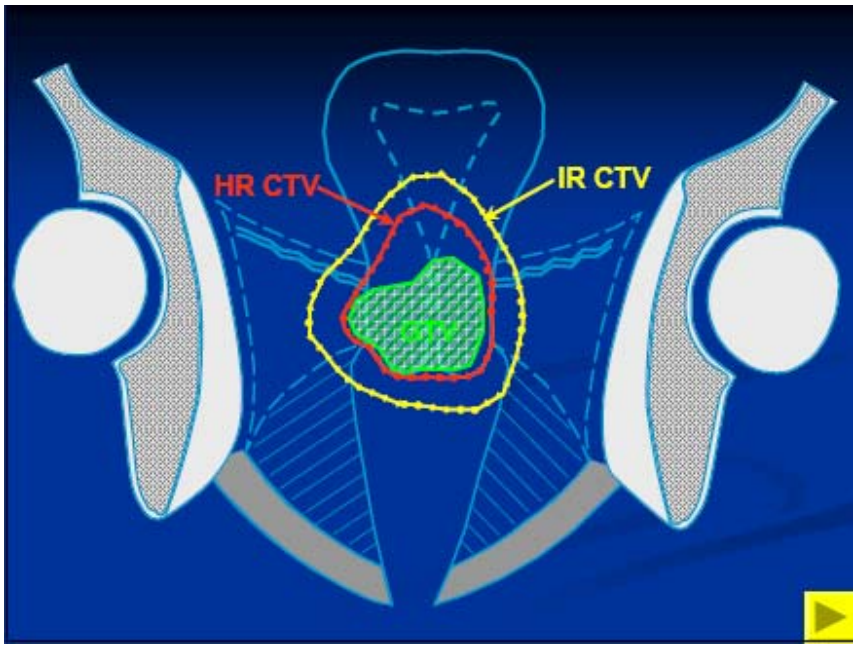


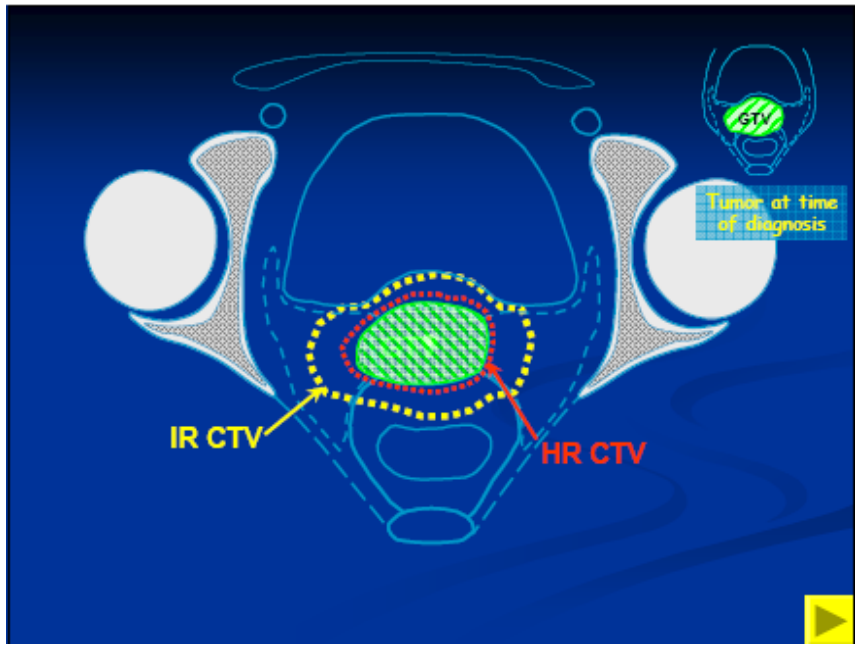
The HR-CTV includes GTV, whole cervix, and presumed extracervical tumor extension.

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

Image Based Brachytherapy





HR-CTV = the initial tumour extension at diagnosis

IR-CTV encompasses HR-CTV with a safety margin of 5-15 mm. Amount of safety margin is chosen according to tumour size an location, potential tumour spread, tumour regression and treatment strategy

Image Based Brachytherapy

- OARs
- Contouring organ wall volumes is difficult
- For organ wall volumes **upto 2-3 cm^3, organ & organ wall contouring lead to almost identical numerical results** this allows for organ contouring only
- If larger organ wall volumes are considered organ wall contouring has to be performed

- When assessing the late effects from **brachytherapy, small organ (wall) volumes irradiated to a high dose seems to be of major interest.**

Image Based Brachytherapy

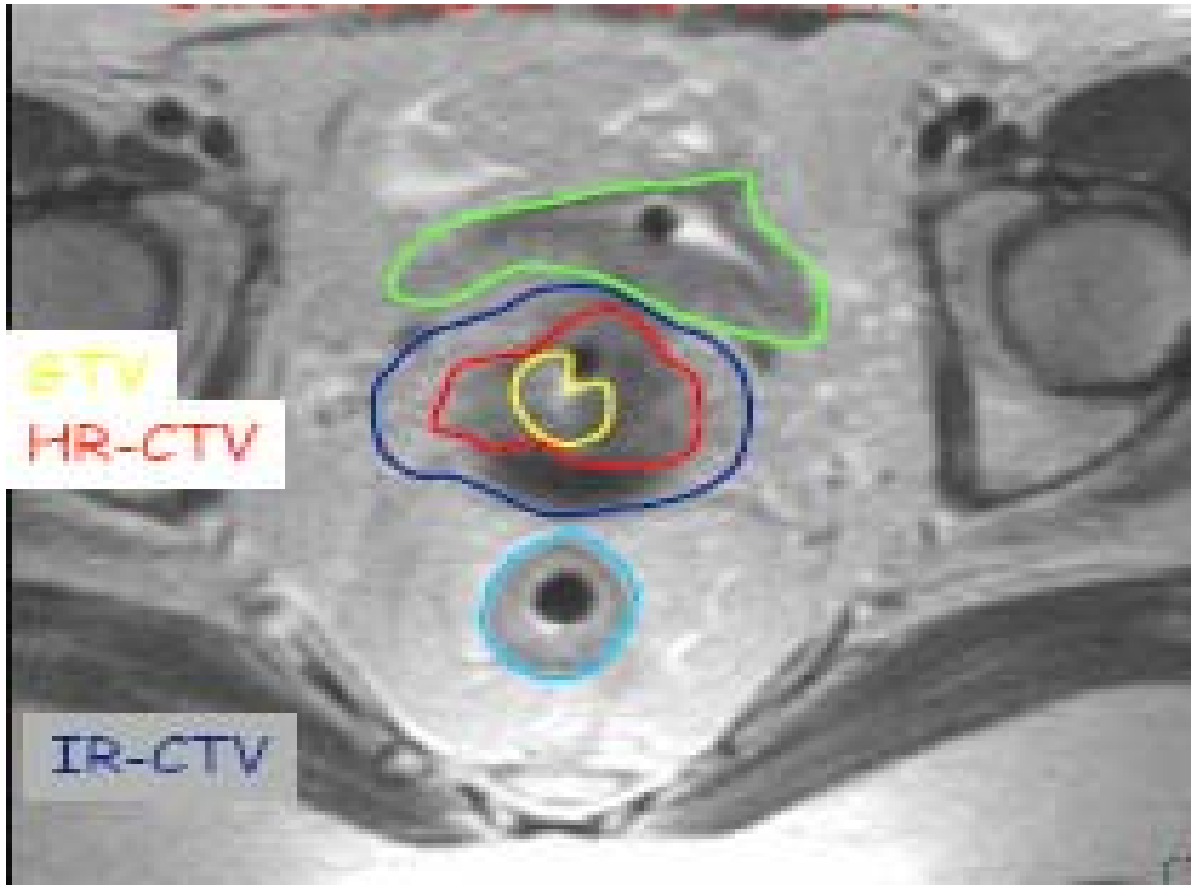


Image Based Brachytherapy

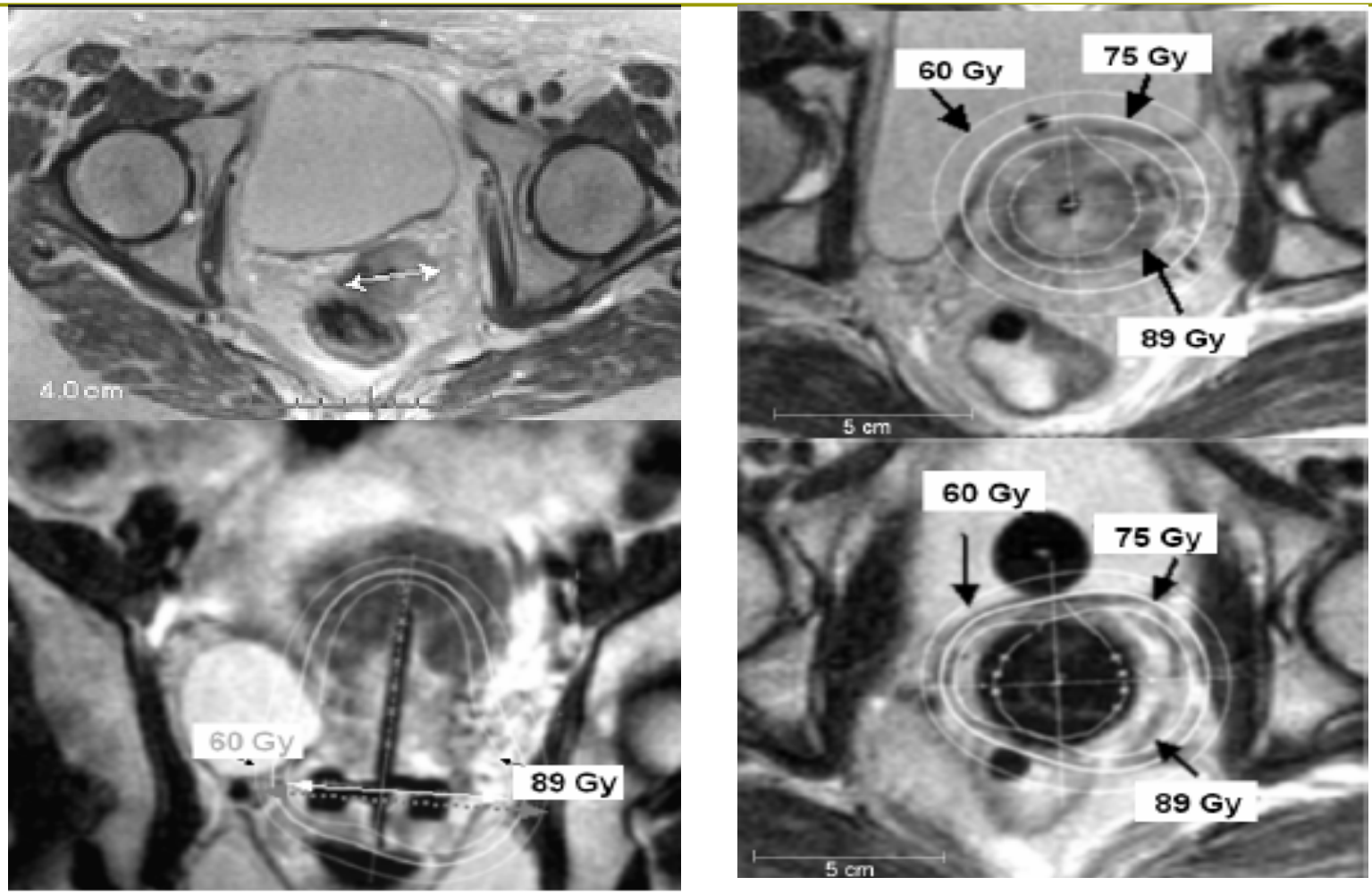
- Dose prescription

- **The prescribed dose is always related to the target.**

- The prescription dose is the planned dose **to cover this target as completely as possible.**

- Coverage of the target can be improved **starting from the standard dose prescription** & careful adaptation of the loading pattern & dwell times

Image Based Brachytherapy



Cervix Carcinoma

Alain Gerbaulet, Richard Pötter, Christine Haie-Meder

Image Based Brachytherapy

- **Dose prescription**
- **HR-CTV Dose**
  - Small tumor – **80-85 Gy**
  - Large tumor, good response – **85-90 Gy**
  - Large tumor, poor response - **90+ Gy**
- **IR-CTV ~ 60 Gy**

- **V(60 Gy_{EQD2})** plays a role for evaluating the **IR CTV**
- **V(85 Gy_{EQD2})** represents more closely the prescription dose to the **HR CTV**

- For comparison, dose reporting should refer to the prescribed dose to the image-based target **& to the traditional system - point A**

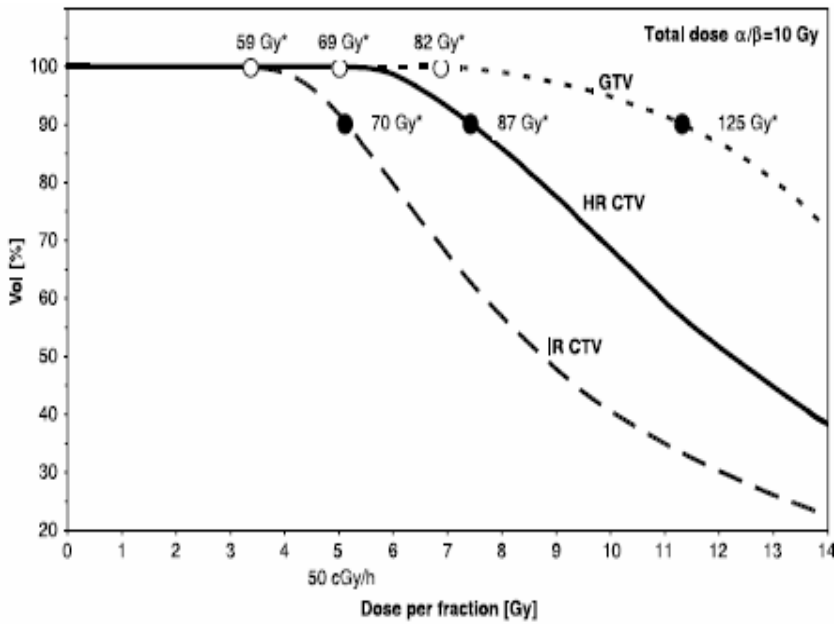
Image Based Brachytherapy

- **Parameters for dosimetric evaluation GTV/CTV**

- **Prescribed Dose - PD**
- **D100 & D90** – minimum dose delivered to 100 & 90% of the volume of interest respectively
- D100 is extremely dependent on target delineation.Due to steep dose gradiants, small spikes in the contour cause large deviations in D100
- **D90** is less sensitive to these influences & is therefore considered a more **'stable'** parameter
- **TRAK**
- **Point A** Dose
- **V 100** – Volume receiving ≥ 100%of PD
- **V150/200** – Volume receiving 150%/200%of PD

Image Based Brachytherapy

- **Dose volume parameters**
- Coverage of target volumes can be derived from **cumulative DVH** analysis
- DVHs for GTV & CTV in I/C brachytherapy have a plateau-100% dose coverage of the volume of interest
- Plateau goes down smoothly indicating decreasing % of dose coverage with increasing dose



Potter, Radiot & Oncol, 78,2006

Image Based Brachytherapy

- OARs
- As there is a rapid dose fall-off near the sources, in particular in adjacent small organ (wall) volumes, dose assessment has to refer to one (or more) defined dose points in these limited volumes

- **The minimum dose in the most irradiated tissue volume adjacent to the applicator (0.1,1,2,5cm^3)is recommended for recording & reporting**

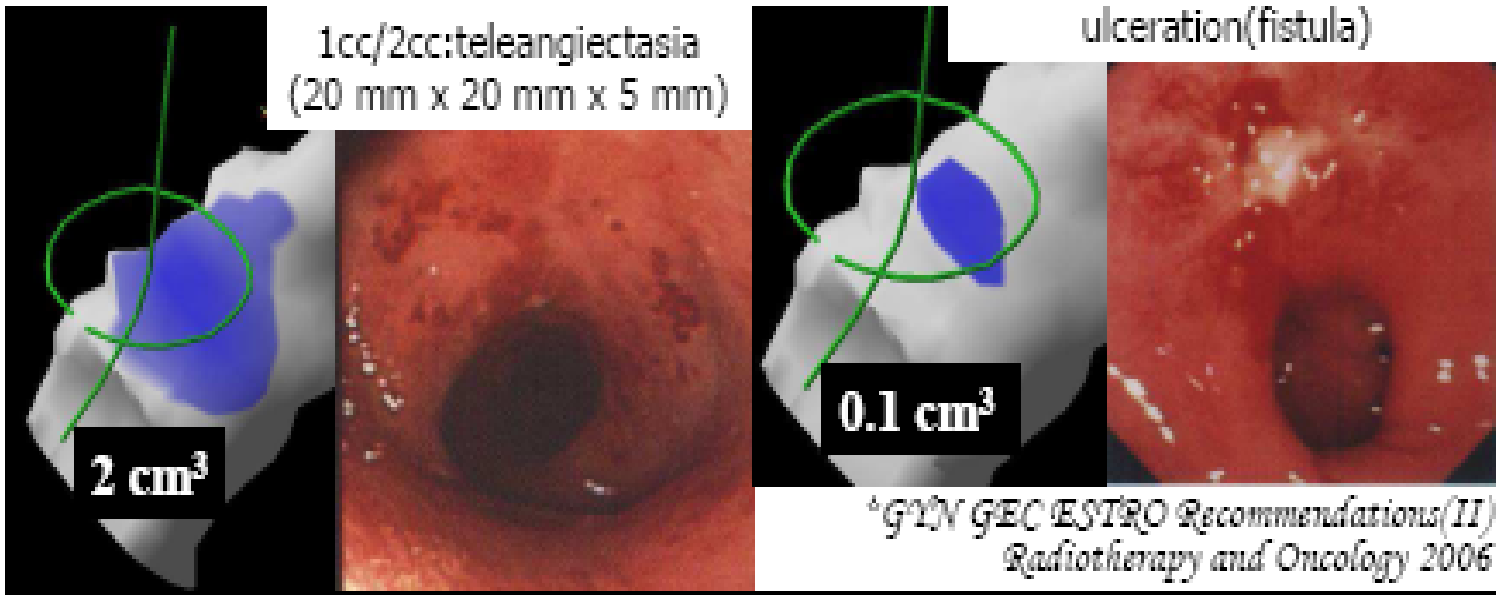
- It is assumed that these **volumes are contiguous**

- This is **wrongly** called as the '**maximum dose**' to a 2cm^3 tissue

Image Based Brachytherapy

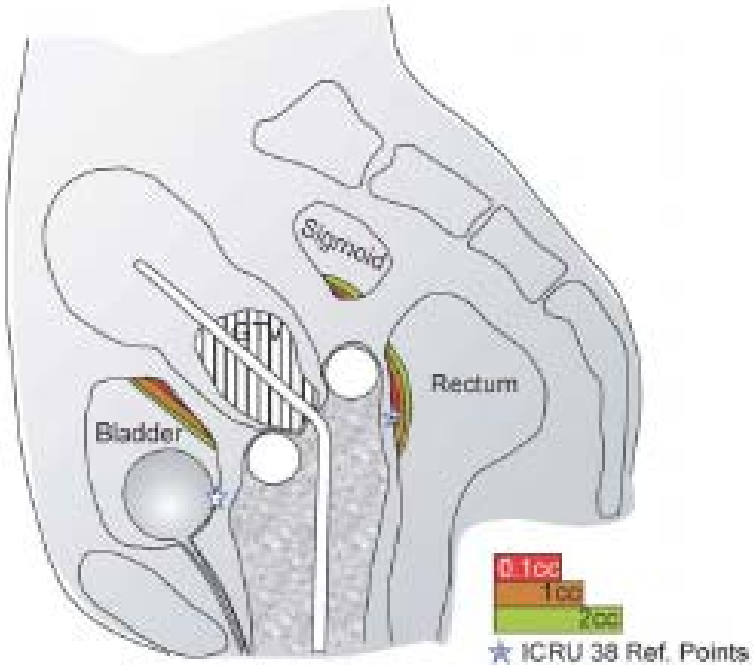
CLASSICAL MAX DOSE : in 3D no clinical relevant endpoint

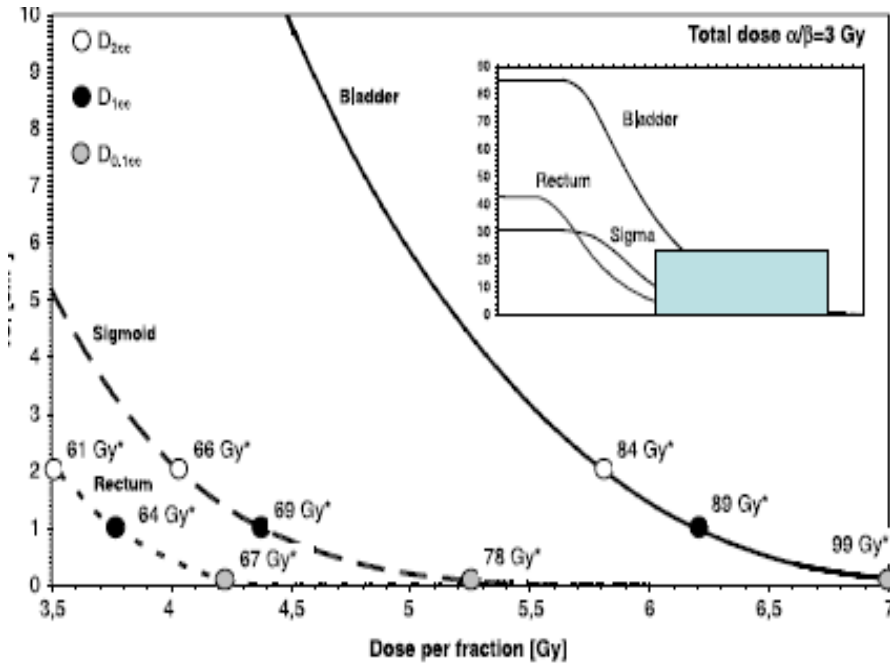
FIXED VOLUME: tolerance dose (total dose)-
"minimum dose to the most exposed tissue"*



*GYN GEC ESTRO Recommendations(II) Radiotherapy and Oncology 2006

Image Based Brachytherapy





Potter, Radiot & Oncol, 78,2006

Image Based Brachytherapy

- Dose volume constraints

2 cm^3 of rectum & sigmoid	**< 75 Gy_3**
2 cm^3 of bladder	**< 90 Gy_3**
High risk CTV & D_{90}	greater than the PD V_{100} > 90%

Image Based Brachytherapy

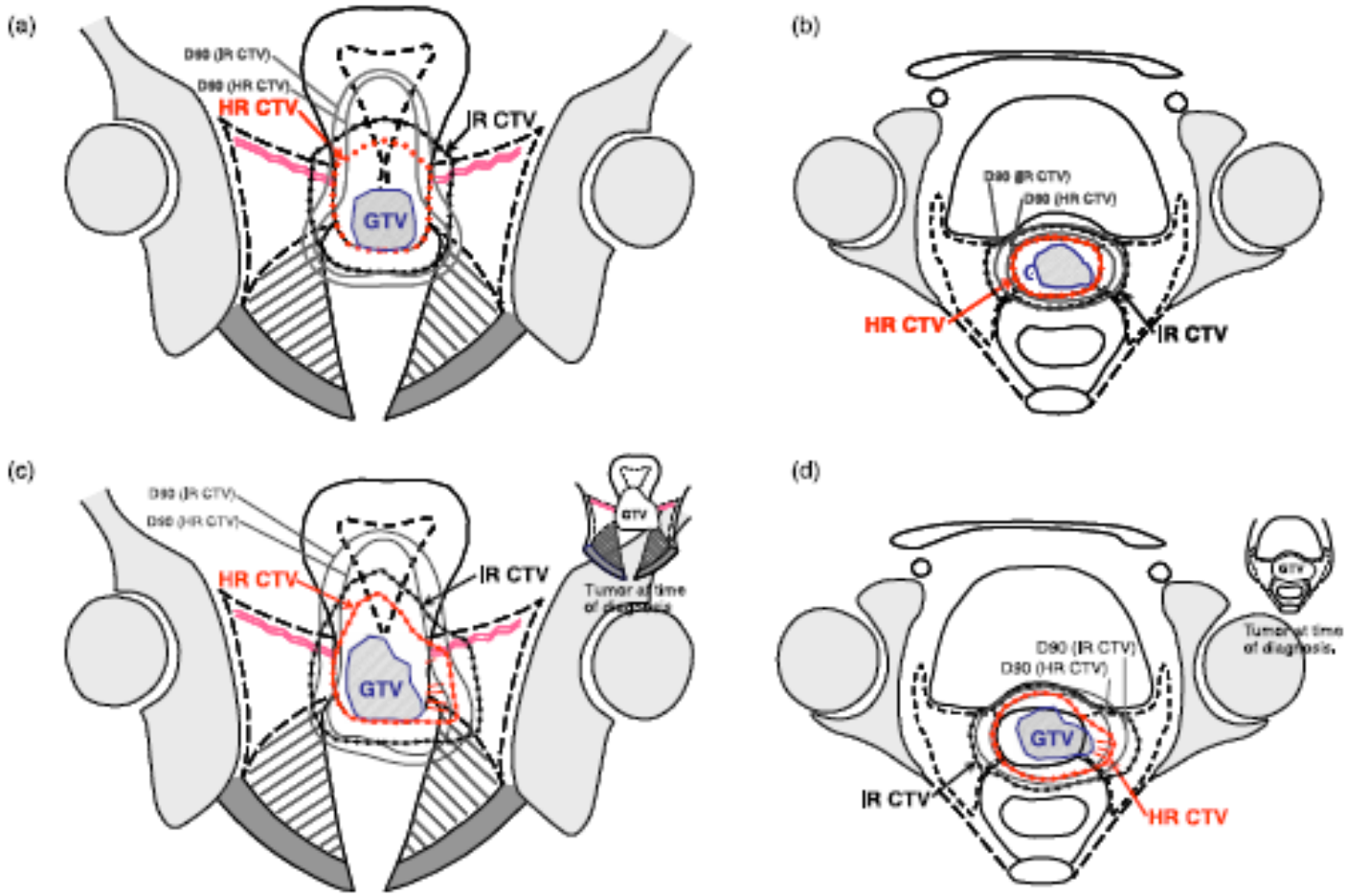
- Radiobiological modelling of doses:

- **Standard brachytherapy dose-rate – 50cGy/hr**
- Calculate the biologically weighted dose for brachytherapy

- **Standard external beam radiotherapy is 200cGy/Fr**
- Calculate the biologically weighted dose for external beam

- **Add both together to get the Total Biologically weighted Dose** for tumor & OAR

Image Based Brachytherapy



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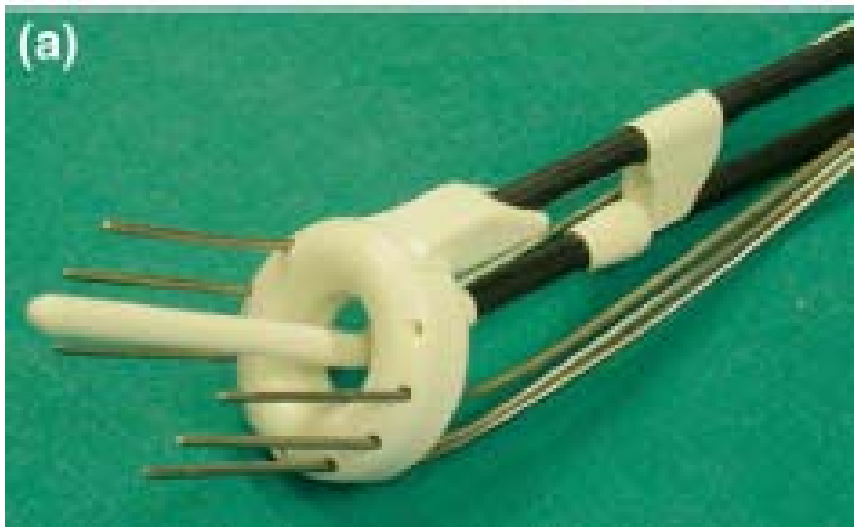

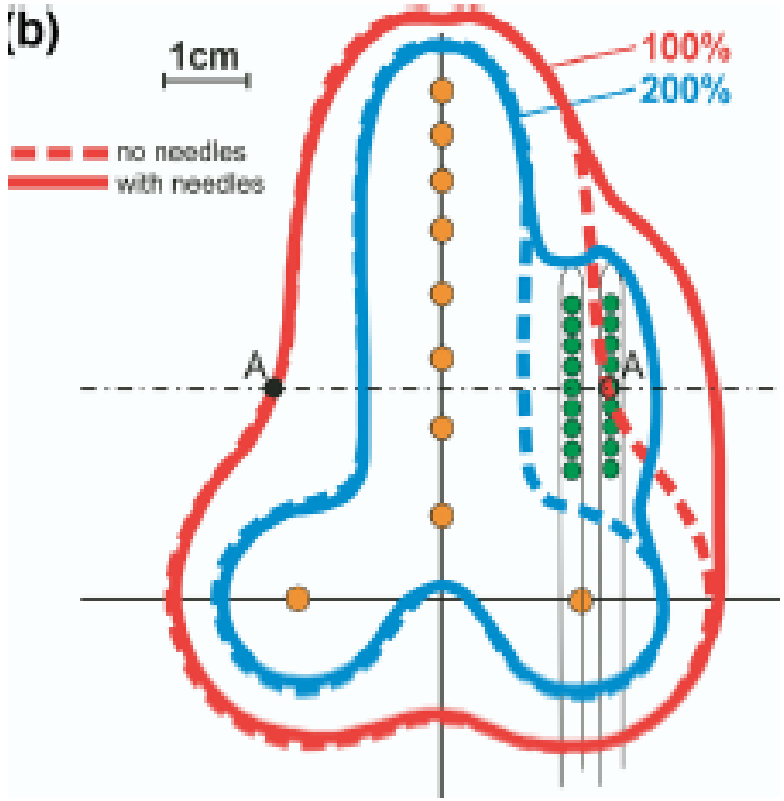

Kirisits, Int J. Rad Oncol Biol Phy 65,2 2006

Image Based Brachytherapy

- Situations requiring combined I/C & I/S
  - Unilateral tumor extension exceeding
    - 3.5 cm at level of ring
    - 2.5 cm at level of pt A
    - 2.2 cm at a distance 3-4cm cranial to ring surface
  - Tumor extension cannot be covered by symmetrical dose distribution of tandem alone without exceeding dose limits for OAR
  - Tumor extension to lower vagina, close to pelvic side wall, posteriorly along ant rectal wall

Image Based Brachytherapy

BALANCE

3-D Image Based

Dose volume relations

in OAR : tolerable effects

3-D Image Based

Dose volume relations

in HR/IR CTV : control of disease

Image Based Brachytherapy

- Conclusion

- It is expected that the therapeutic ratio including target coverage & sparing of OARs can be significantly improved,if radiation dose is prescribed to a 3D image-based CTV taking into account dose volume constraints for OARs

- However,prospective use of these recommendations in the clinical context is warranted, to further explore & develop the potential of 3D image-based cervix cancer brachytherapy