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COMPREHENSIVE  
CANCER  
CENTER VIENNA



## **Transition from 2D to 3D Brachytherapy in Cervical Cancers: The Vienna Experience**

*Richard Pötter MD*



**BrachyNext, Miami, 2014**



## **Disclosures**

Richard Pötter, MD, does not have any financial relationships or products or devices with any commercial interest related to the content of this activity of any amount during the past 12 months.

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## Driving forces for the evolution

### from point (A) to 3D/4D image guided adaptive approach

Improvement of local control in advanced disease

Improvement of cure

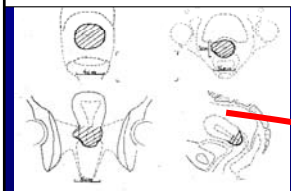
Decrease of adverse side effects/improvement in QoL  
(rectosigmoid, bladder, vagina, bowel, fatigue...)

Not accepting the „mystery“ of point A-based  
intracavitary brachytherapy

Implementation of 3D/4D Radiotherapy into Gynaecol.

## 2D Image based brachytherapy (100 years)

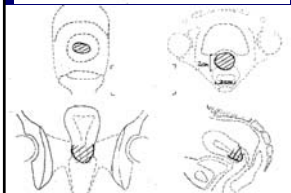
Clinical examination  
3D/4D drawing



Applicator insertion



Standard dose plan



Dose delivery





**Vienna 1918**

**Painting**

**Clinical Evaluation**

**Drawing Diagram**

**Radiography**

**MRI Since 1998**

**CT since 1983**

Adler: Strahlentherapie 1918

## Image-guided adaptive Brachytherapy

~~Repetitive Imaging~~ diagnosis, EBR/CIT

Applicator insertion

3D/4D imaging

Contouring

Repetitive clin exam +3D/4D drawing

Applicator Reconstruction

3D dose planning

Dose delivery



**Fig. 3.** Transversal CT-scan with calculated isodose distribution (90-60% in steps of ten) for the standard field technique on the top and for the BEV-technique on the bottom, CTV, PTV, bladder and rectum can be identified; the 70% isodose of the standard field technique encloses the cervix uteri tightly, whereas the cervix uteri is covered by the 90% isodose for the BEV based treatment plan. The rectum is shifted by the enlarged cervix uteri from the posterior to a lateral position.

**EBRT  
from 2D  
to 3D**

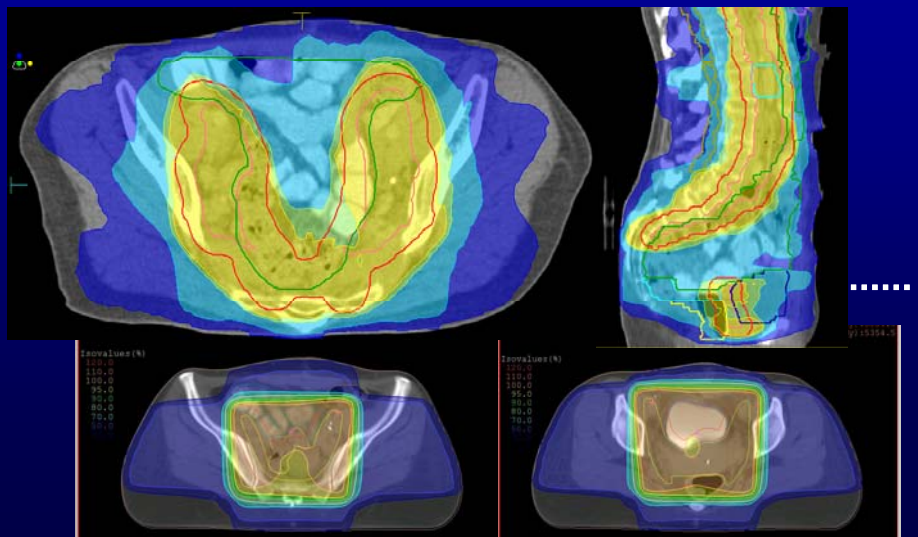
**Avoidance  
of  
„geographical  
miss“**

- \* posterior field border
- \* anterior field border

**Gerstner et al. R&O 1999**

**Zunino et al. IJROBP 1999**

**Technology Development: Higher conformity through IMRT**  
**Better sparing of OAR (bowel/bladder)**  
**Higher chance for geographical miss**

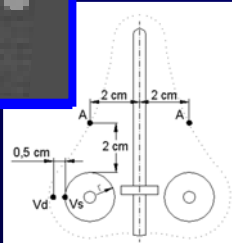
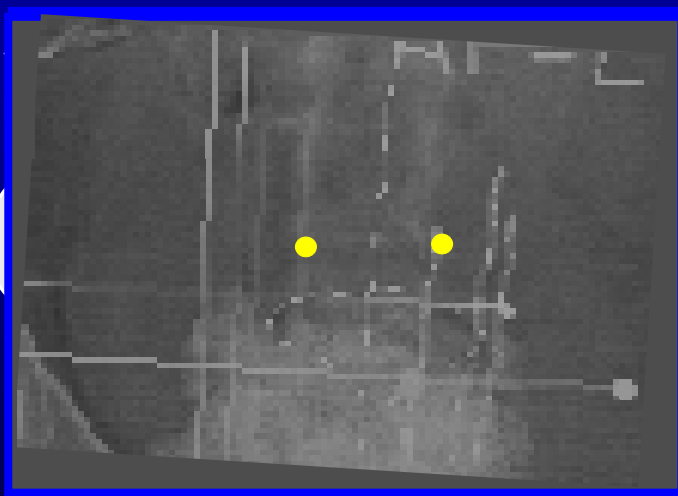




## Treatment Planning 2D vs 3D In Brachytherapy

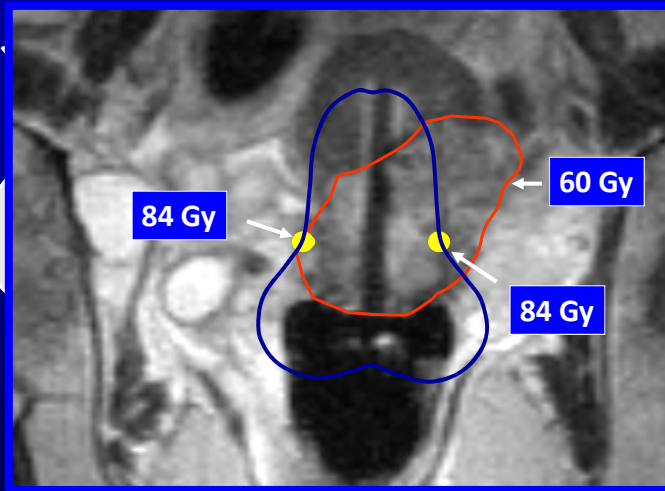
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### Point A (since 1938)



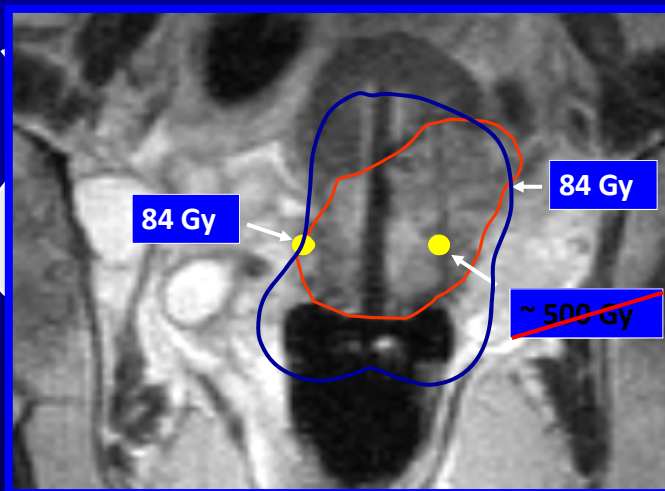


## Point A / target dose



D90 = 65 Gy

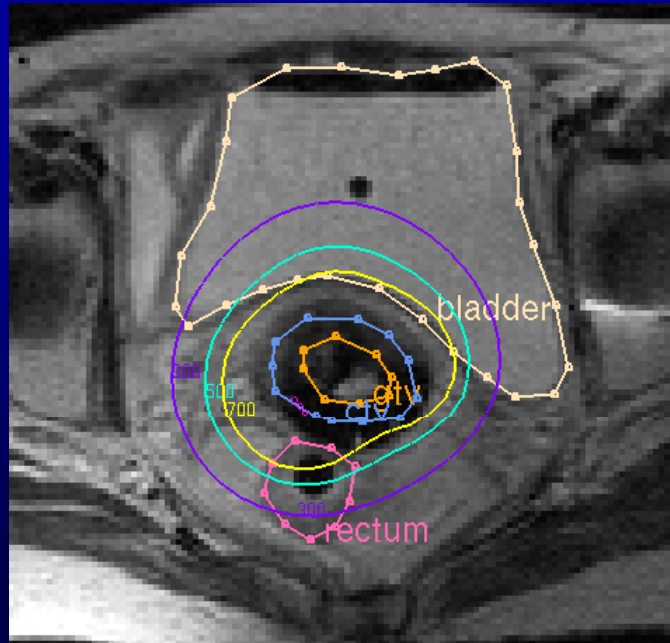
## Point A / target dose



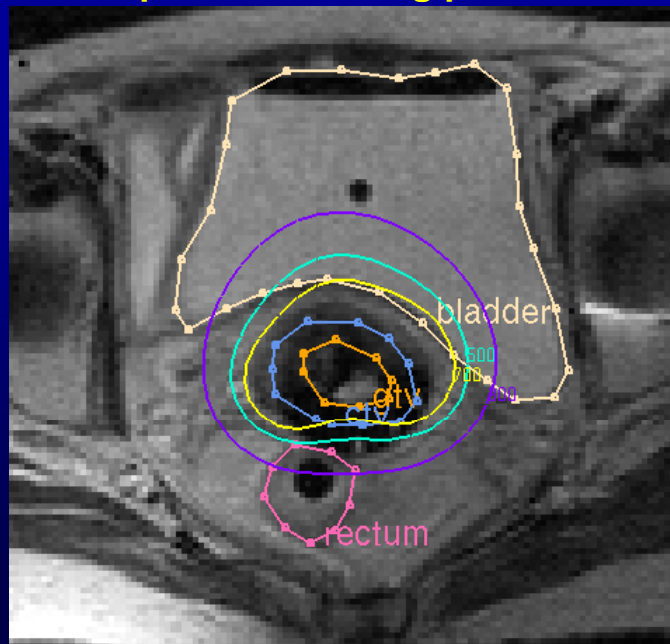
D90 = 90 Gy



## Standard loading pattern

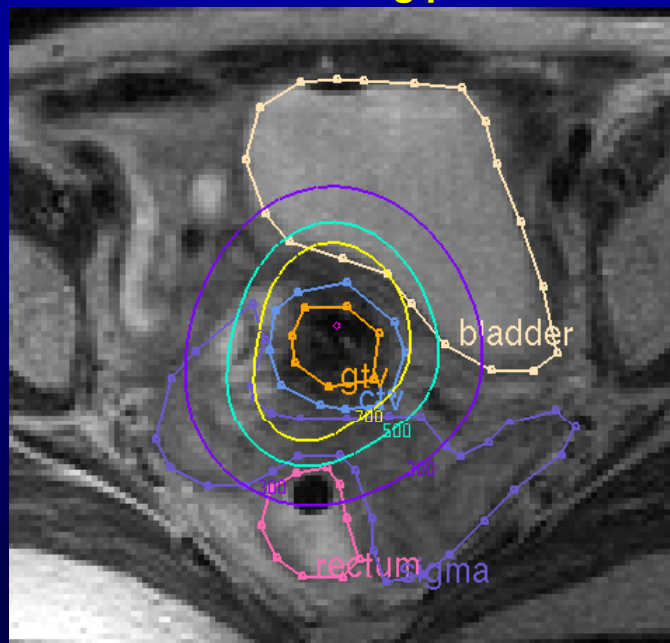


## Optimized loading pattern

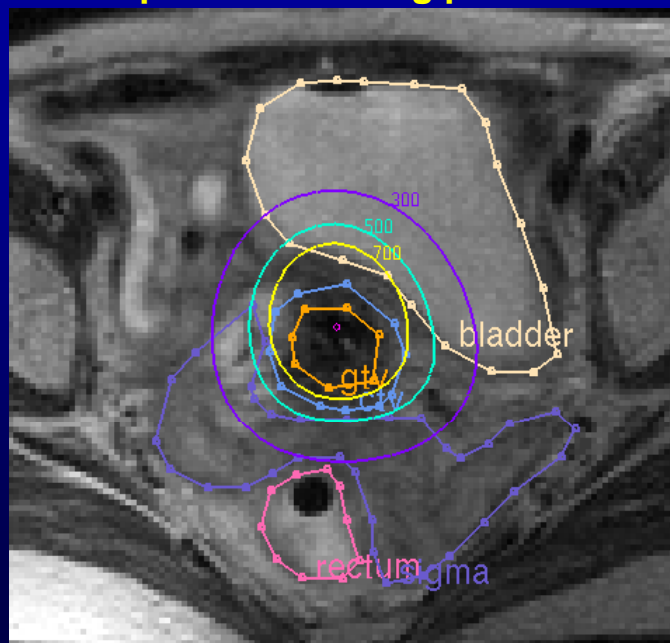




## Standard loading pattern



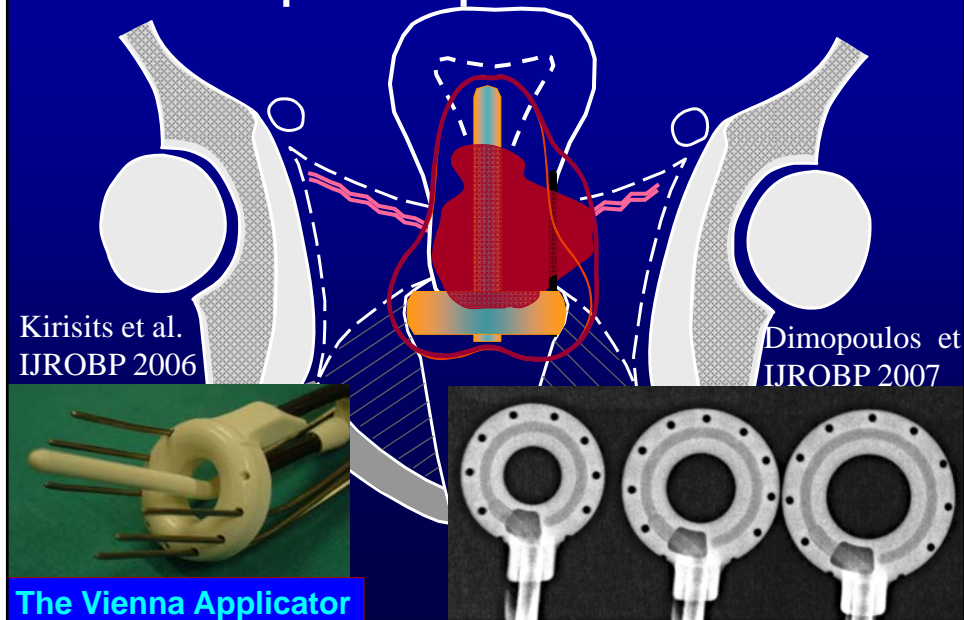
## Optimized loading pattern







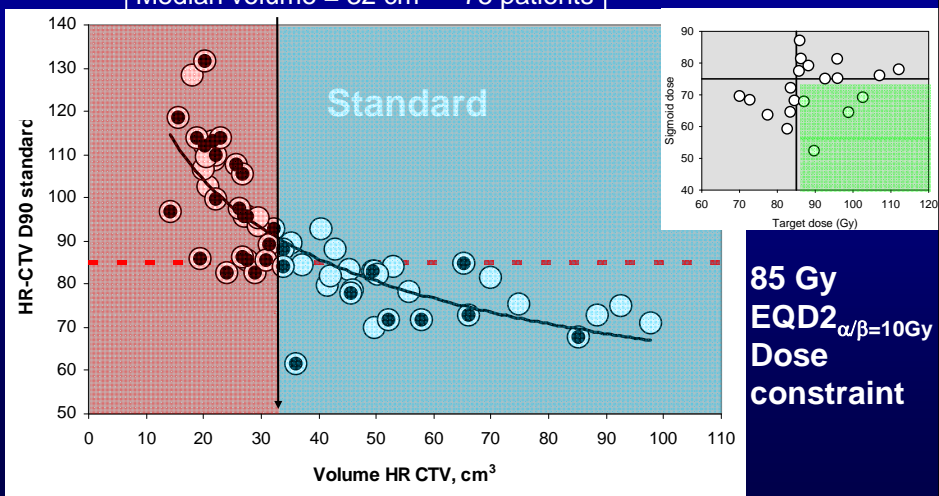
## Pattern of tumor regression: up to mid parametrium



From point A to the sculpted pear: MR image guidance significantly improves tumour dose and sparing of organs at risk in brachytherapy of cervical cancer

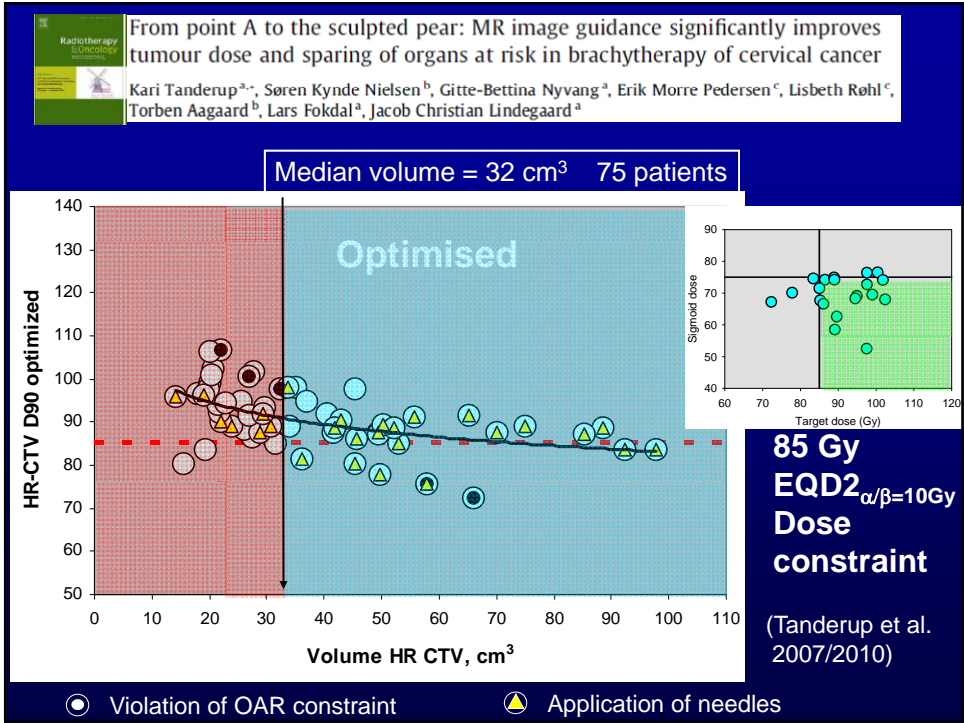
Kari Tanderup<sup>a</sup>\*, Søren Kynde Nielsen<sup>b</sup>, Gitte-Bettina Nyvang<sup>a</sup>, Erik Morre Pedersen<sup>c</sup>, Lisbeth Røhl<sup>c</sup>, Torben Aagaard<sup>b</sup>, Lars Fokdal<sup>a</sup>, Jacob Christian Lindegaard<sup>a</sup>

Median volume = 32 cm<sup>3</sup> 75 patients



Violation of OAR constraint

Tanderup 2007/2010





## Imaging And Target Definition

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**Stage IIB**

**Target Definition**

**At diagnosis**


Pathology and Topography  
Stage IIB

Tumour  
Cervix  
Uterus  
Parametria  
Organs at Risk

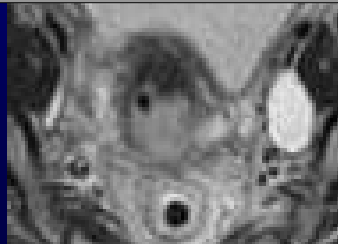
**At brachytherapy**

Pathology and Topography

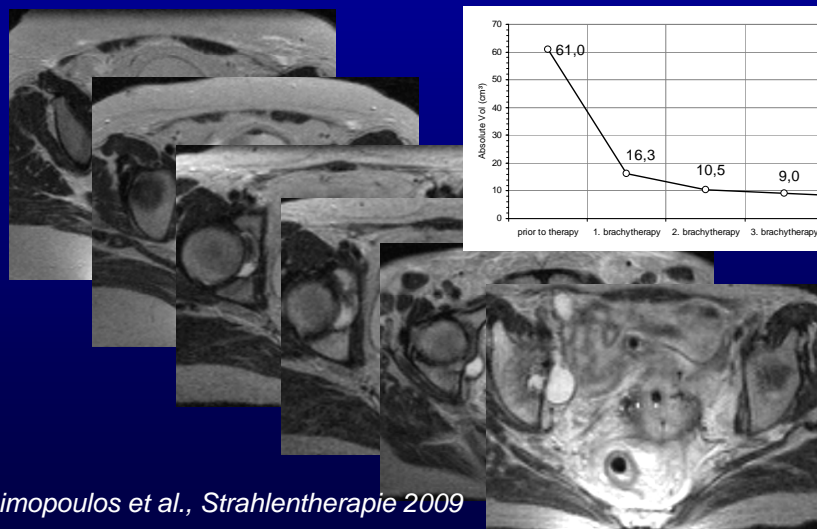
Contouring and Dose Volume Assessment

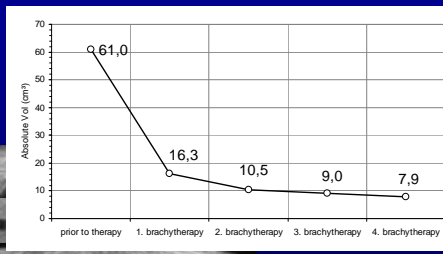


**Change of GTV and CTV with time (4D RT)**



## MRI: Initial tumour extension (3D RT) pattern of response (4D RT) for adaptive MRI based planning





Time Point	Volume (cm³)
prior to therapy	61,0
1. brachytherapy	16,3
2. brachytherapy	10,5
3. brachytherapy	9,0
4. brachytherapy	7,9

*Dimopoulos et al., Strahlentherapie 2009*



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## BT-Preplanning in cervical cancer: Different imaging modalities

Max Schmid, Vienna University

## Target delineation on CT with help of MRI and 3D clinical examination

(Federico et al. ABS 2012)

Analysis with respect to the overall study cohort:

	Volume [ccm]	CT/MR volume ratio
	Median	Median
HR-CTV1	57.62	1.58
HR-CTV2	46.19	1.26
HR-CTV3	37.55	1.09
HR-CTV MRI	30.09	

Relative volume

HR-CTV FIGO      HR-CTV Clinical Drawings      HR-CTV Pre-BT MRI

normalized median volume reduction      ~32%  $p < 0.05$       ~17%  $p < 0.05$

Relative volume

Stage

IB1 - IB2      IIA - IB      IIIA-IVA

HR-CTV1   HR-CTV2   HR-CTV3      HR-CTV1   HR-CTV2   HR-CTV3      HR-CTV1   HR-CTV2   HR-CTV3

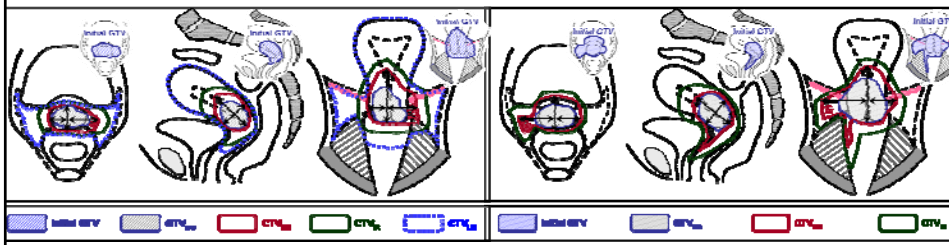
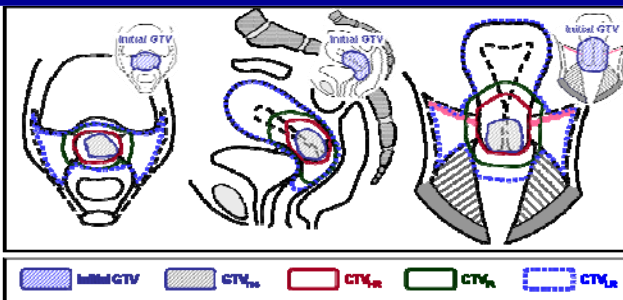


## 3D Dose Reporting And Clinical Outcome

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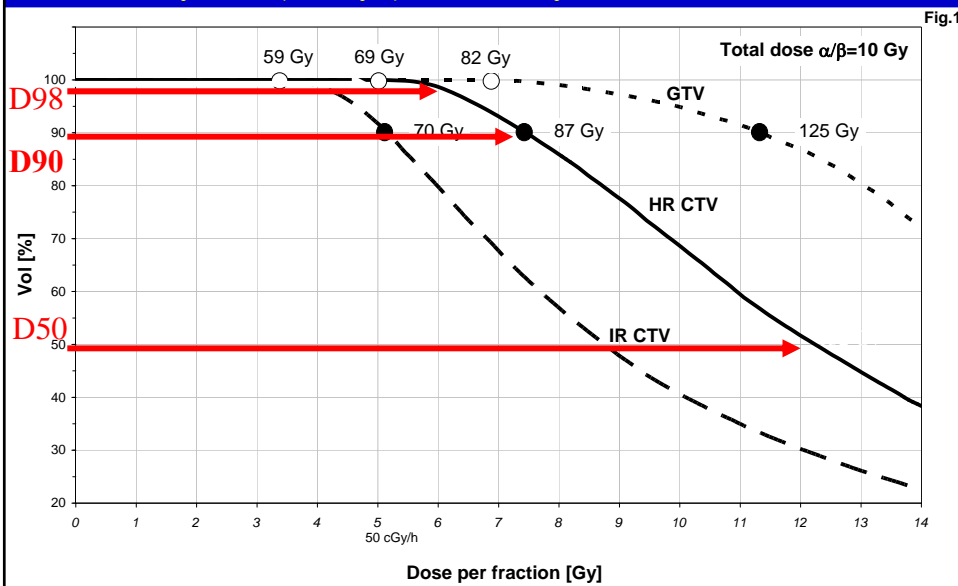
## Overview of adaptive target concepts in cervix cancer

ICRU/GEC ESTRO  
report 88  
under publication  
Fig. 5.9-11





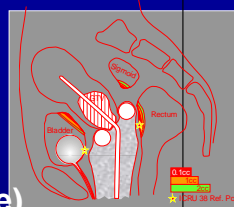
## Cumulative Dose Volume Histograms for GTV, HR CTV, IR CTV for 45 Gy EBT (1.8 Gy/f) and 4x7 Gy HDR BT in HR CTV\*



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

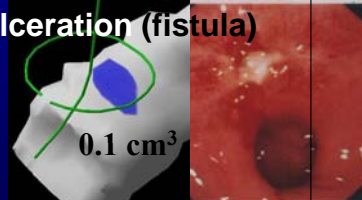
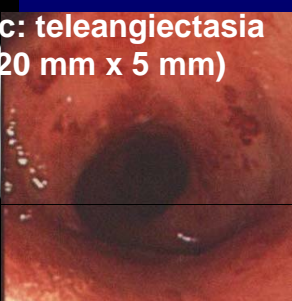
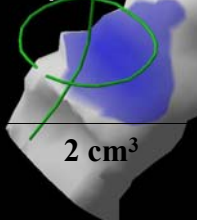
## 3D based dose volume constraints OAR

- Classical Maximum Dose
- In 3D no clinical relevant endpoint
- fixed volume ~ tolerance dose (total dose)  
„minimum dose to the most exposed tissue“\*



0.1 cc: 3D „maximum dose“: ulceration (fistula)

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

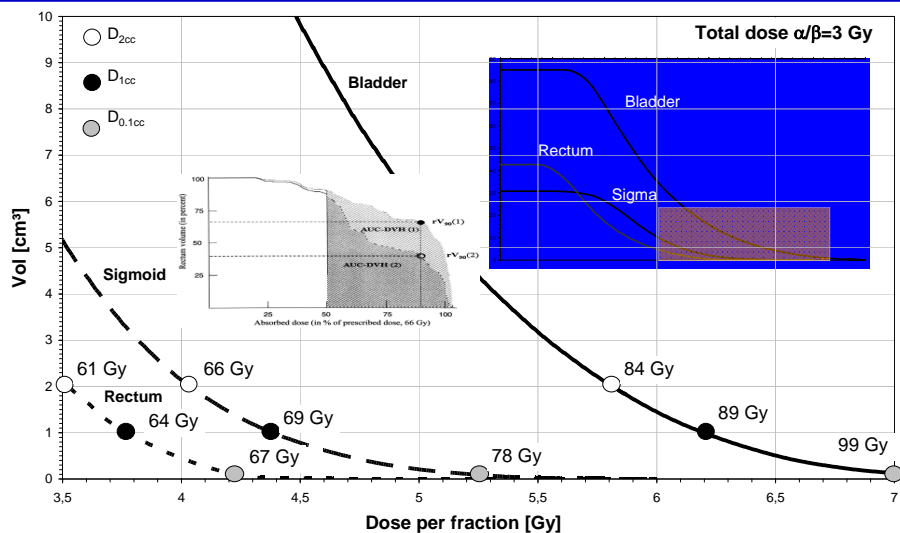


(>5 cc: fibrosis endpoint)

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



## Cumulative Dose Volume Histograms for Bladder, Sigmoid, Rectum for 45 Gy EBT (1.8 Gy/f) and 4x7 Gy HDR BT in HR CTV\*



represents the *minimal dose for the most irradiated Volume of x cm<sup>3</sup>*

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

### LOCAL CONTROL - CLINICAL DATA

#### DOSE AT POINT A vs. D90 IN IMAGE BASED HR-CTV

	DOSE Pt A / D90 HR	BEST STANDARDS	AIM
<b>EARLY DISEASE</b>	75 Gy / 95+ Gy	90-95%	100%
<b>ADVANCED DISEASE</b>			
IIB<5cm	80 Gy / 90+ Gy	70-85%	95-100%
IIB/IIIB>5cm	85 Gy / 85+ Gy	50-65%	85-90%

Expected Improvement through Image Guided Adaptation:

5-40%: IB: 5-10%; IIB lim: 10-20%; IIB ext, IIIB: 20-40%



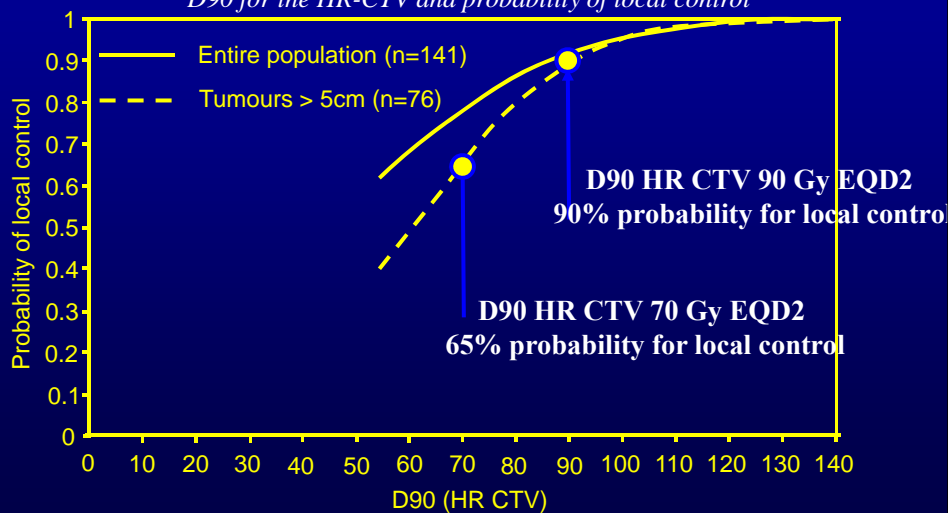
## MRI based Treatment Planning

- **Major Learning Period: 98-2000** (73 consecutive patients)  
no systematic prospective protocol (point A/ICRU points OAR)
- **Systematic prospective protocol since 2001** (72 consecutive pts.)  
HR CTV concept  
GTV, HR CTV + OAR contouring  
Biological modelling (linear-quadratic model)  
Dose Volume constraints: OAR ( $2 \text{ cm}^3$ ): 75/90 Gy(EQD2,  $\alpha/\beta=3\text{Gy}$ )  
Prescription: HR CTV (D90): 85+ Gy(EQD2,  $\alpha/\beta=10\text{Gy}$ )  
  
Intracavitary + interstitial Brachytherapy, if D90 < 85 Gy  
  
Prospective 3D image based optimisation

## Linking DVH-parameters to clinical outcome D90 for the HR CTV

Analysis (n=141, FIGO: IB-IVA, median follow-up=51 months)

*D90 for the HR-CTV and probability of local control*

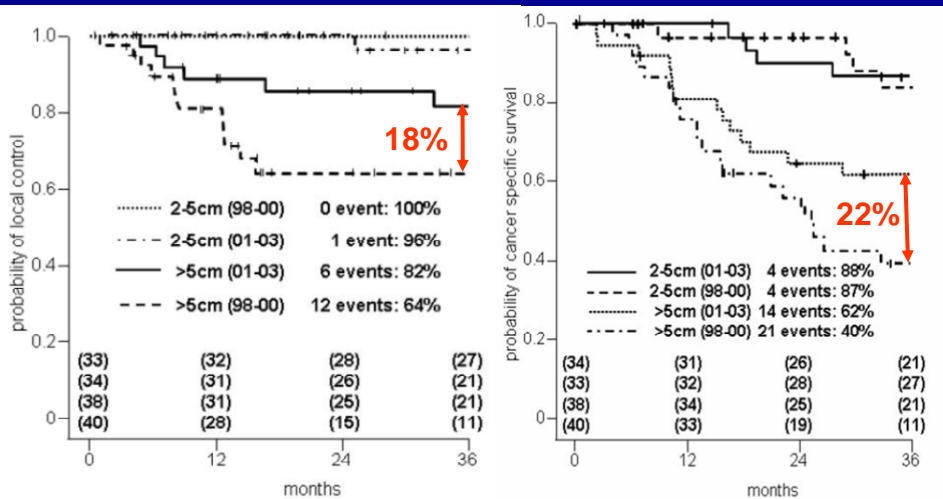


*Dimopoulos et Radioth & Oncol 2010*



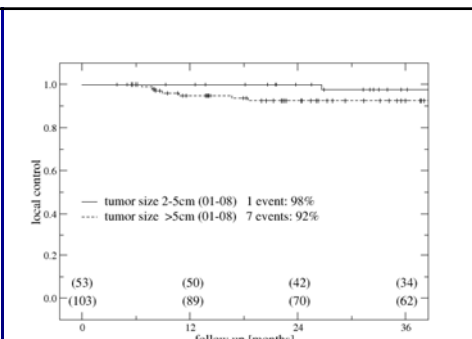
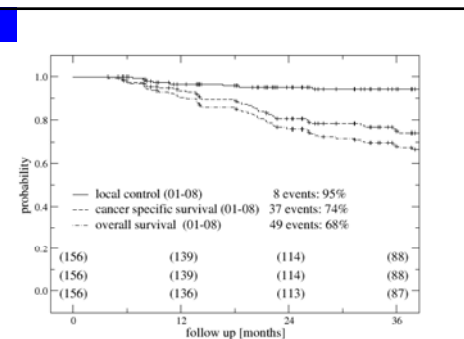


### Image guided adaptive brachytherapy (IGABT) cervix cancer local control and cancer specific survival (1998-2003) TREATMENT PERIOD (-/+ IGABT) AND TUMOUR SIZE

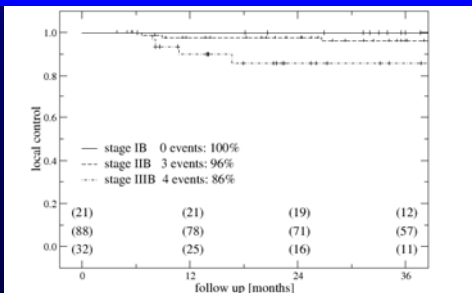
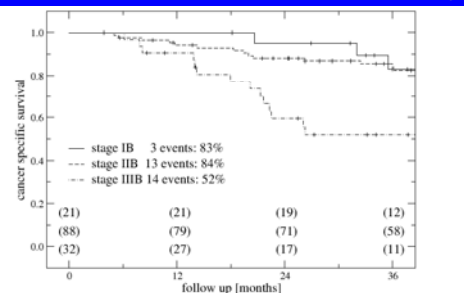


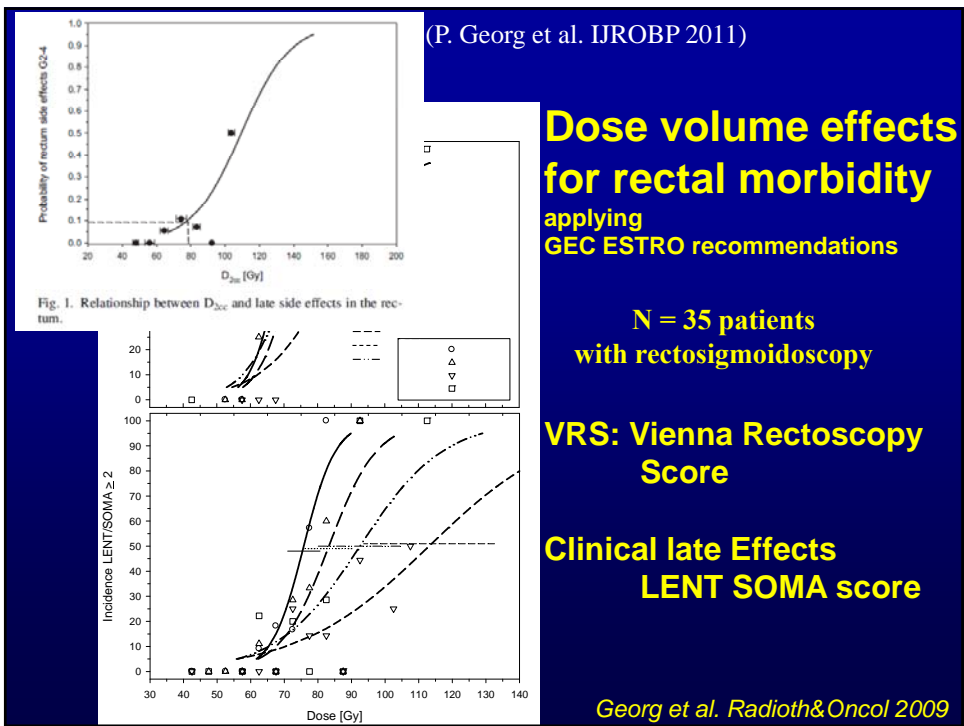
mean 81 Gy vs. 90 Gy in CTV<sub>HR</sub>

Pötter R. et al. *Radiother Oncol* 2007



156 patients MRI guided BT, Vienna 2001-2008, mean D90 to HR CTV 92 Gy  
7/156 with G3 and 4/156 G4 toxicity (LENT SOMA) *Radioth & Oncol* 2011





**„New“ Paradigm  
 Image guided adaptive brachytherapy:  
 Adaptation of target in space (3D) and time (4D)**

- *macroscopic tumour response plus change of overall topography*
- *adaptation of high risk Clinical Target Volume in 3D (space) and 4D (time) [each fraction]*
- *enables high radiation doses (up to >90 Gy) in limited volumes (HR CTV 15-80 ccm)*
- *prospective application of dose volume constraints 3D/4D for high risk CTV and organs at risk [each fraction]*