Planning aspects of Image based intracavitary and Interstitial Brachytherapy

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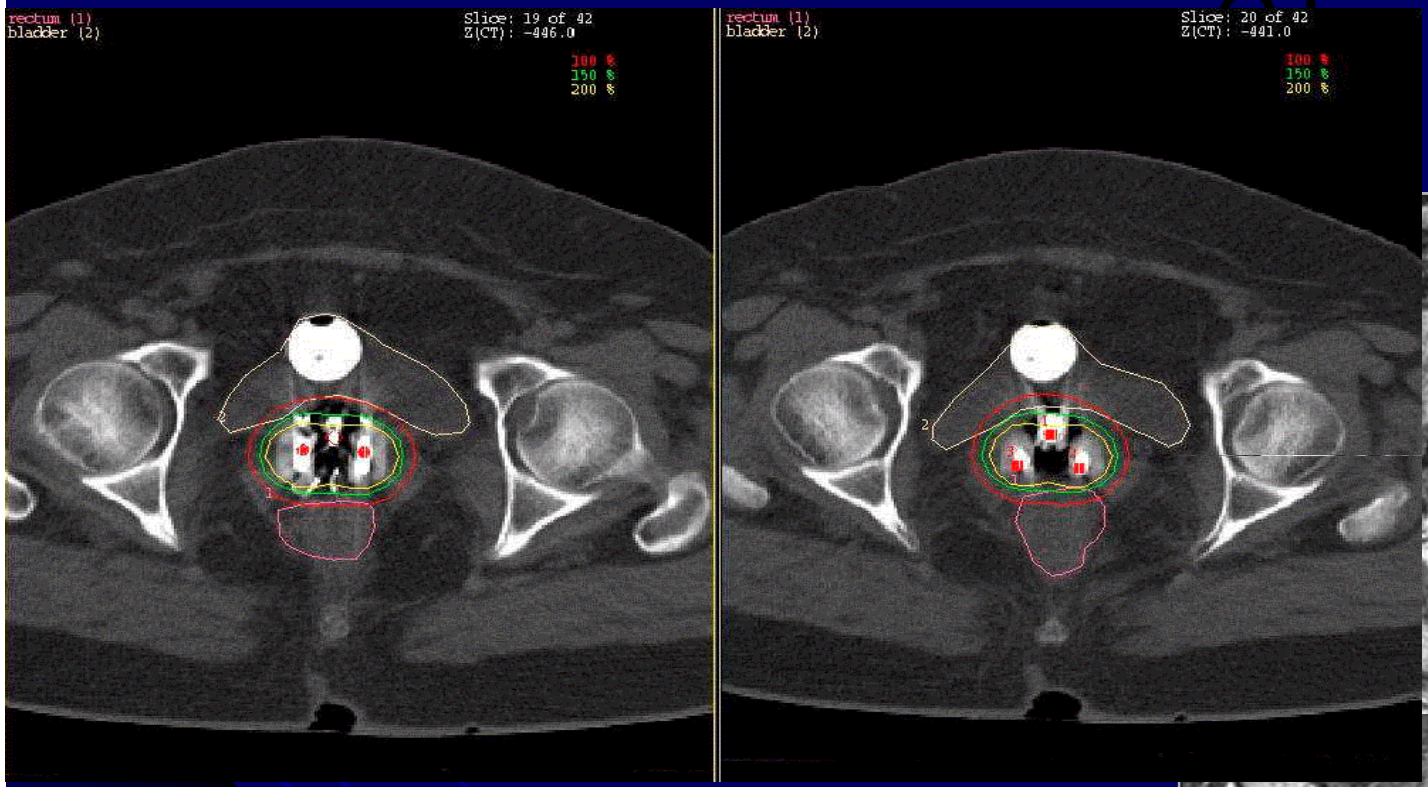
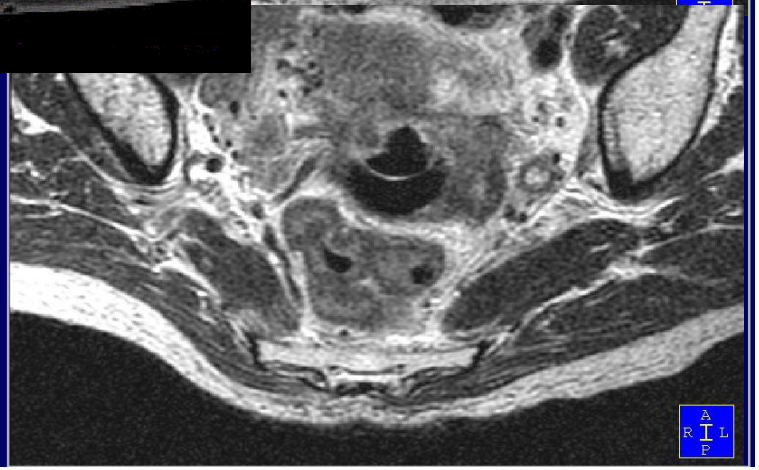
Image based planning



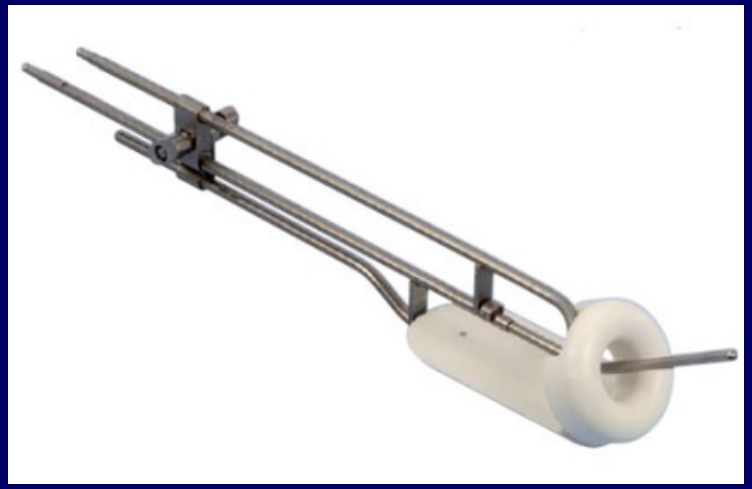


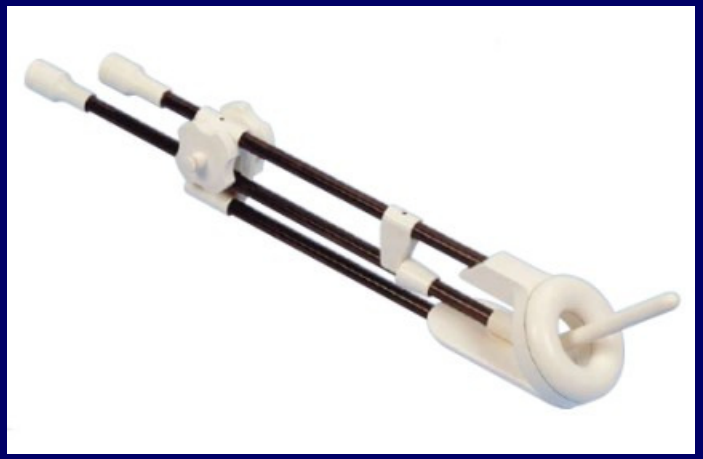
Three key points

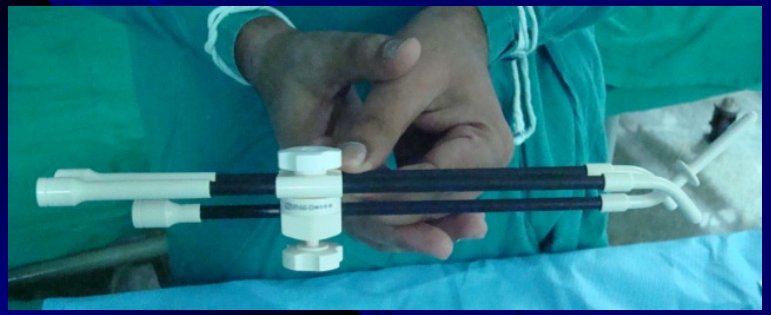
- *Applicators*
- Imaging
- Reconstruction
- Optimization

Applicators

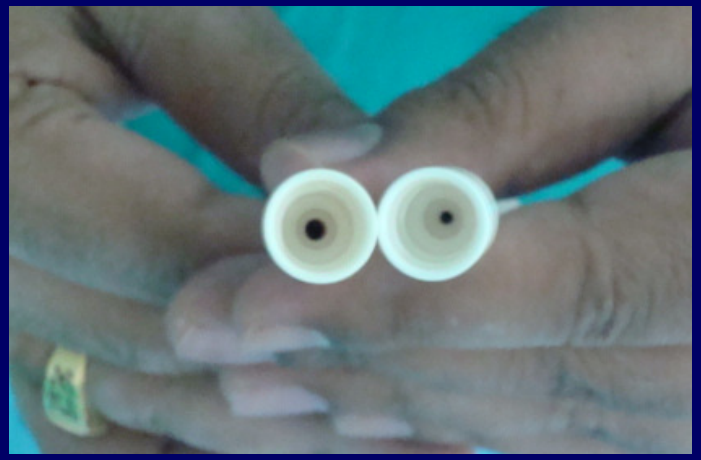
- Metal (SS applicators), produces streak artifacts
- CT/MR compatible applicators made of plastic/titanium-zirconium alloy (non ferromagnetic materials)

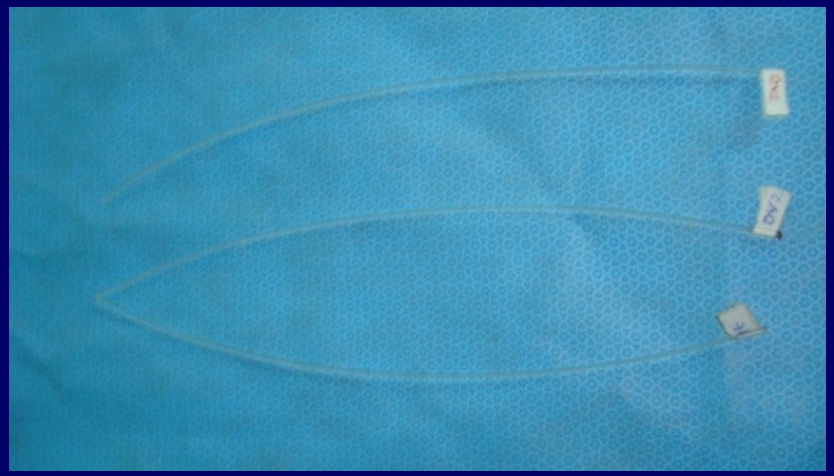




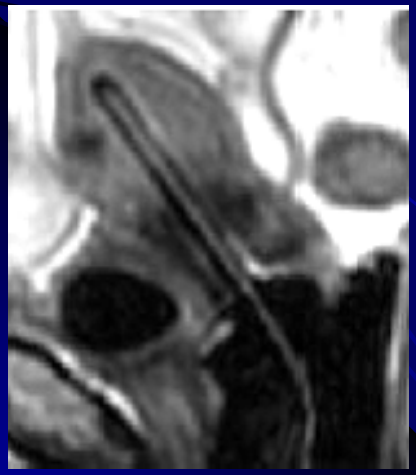


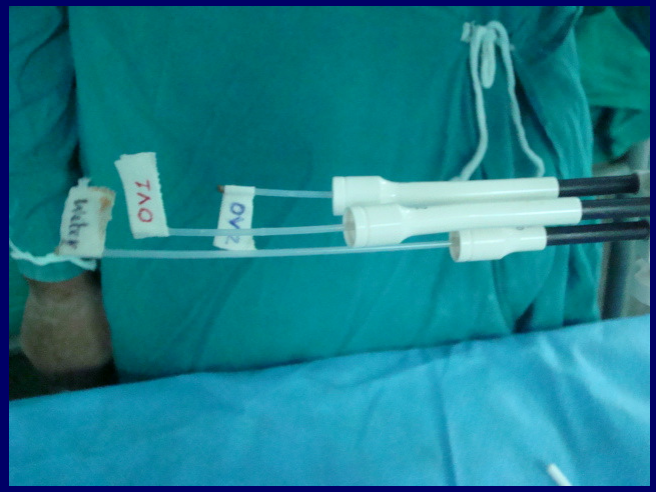
Applicators



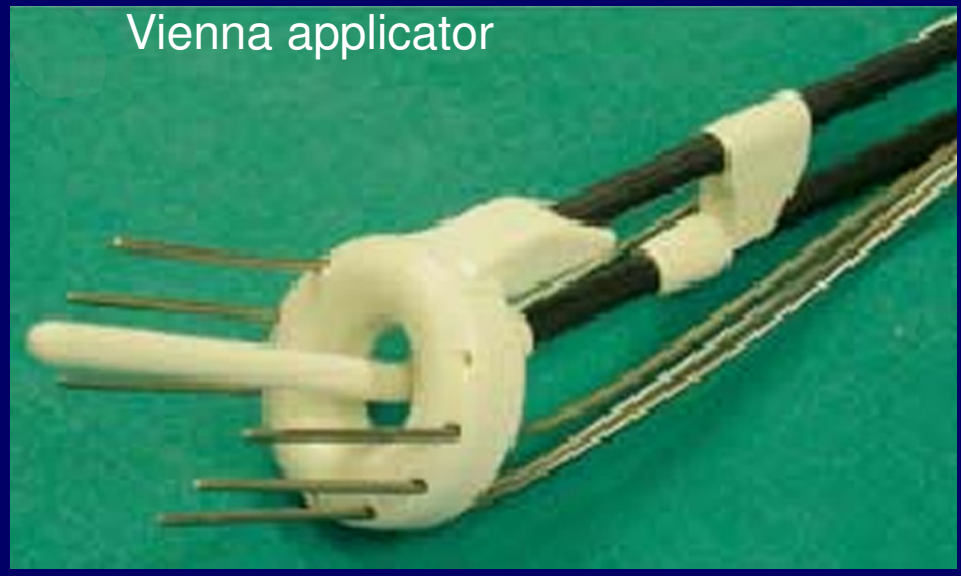


Markers: water filled 6F catheters





Applicators (IC+IS)



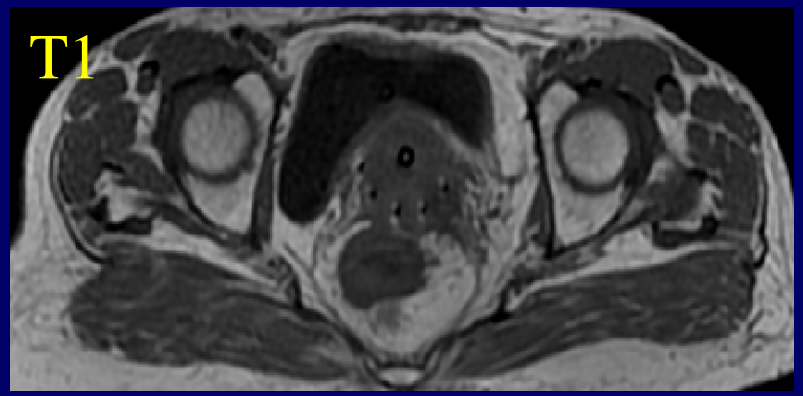
Imaging

Imaging protocol - CT

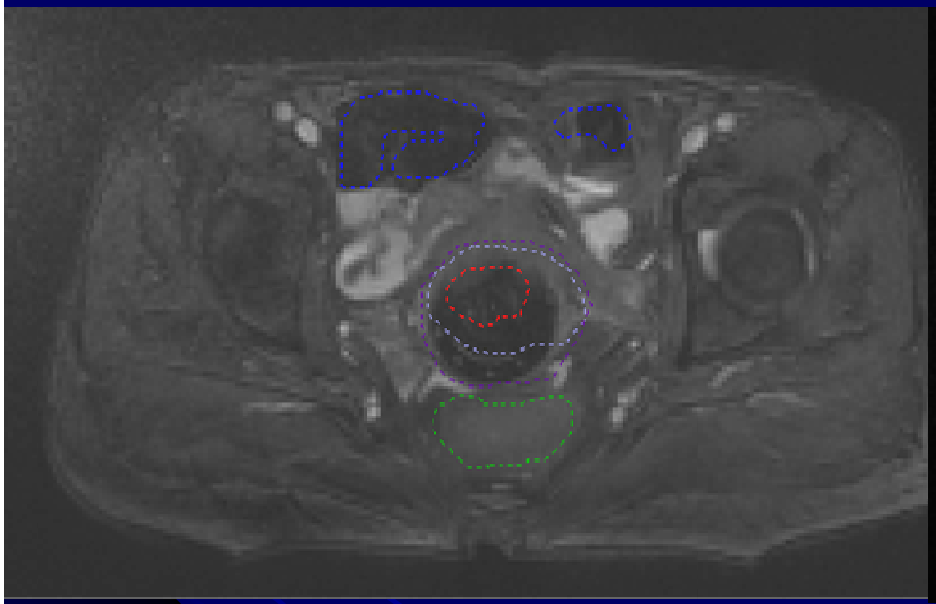
- 3-5 mm slice thickness
- HFS (if FFS, check for orientation)
- Optimize WL / WW (to minimize the artifacts in SS applicator to visualize OARs)
- Not necessarily full body contour as EXRT
- Bladder protocol - (empty/50cc – inst protocol)
- Markers required ? – institutional protocol

Imaging protocol - MR

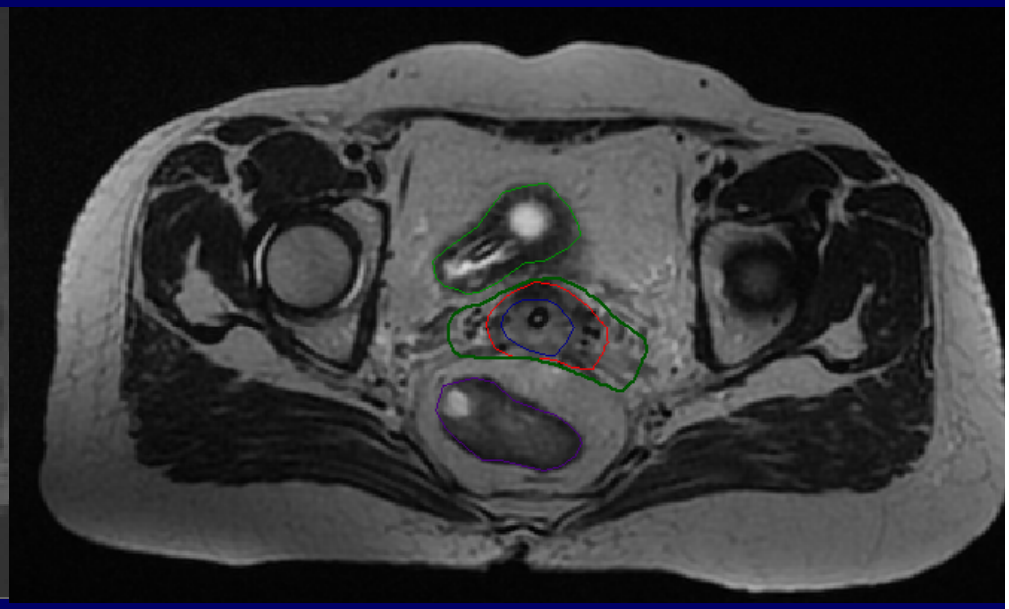
- 1.5 T / 3.0 T/ 0.5 T open MRI with body coil.
- Fast spin echo T1 and T2 para axial (true), sagittal, and coronal (in the plane of central tandem) sequences
- 3–4 mm thick slices and 0 – 1 mm slice gap.
- T1 images assist in catheter identification and reconstruction.
- T2 series helps to identify and delineate the residual disease



Imaging protocol



Suboptimal image quality



Optimized MR image sequences

Optimization of imaging sequences (institution specific) is essential to get an optimal image quality

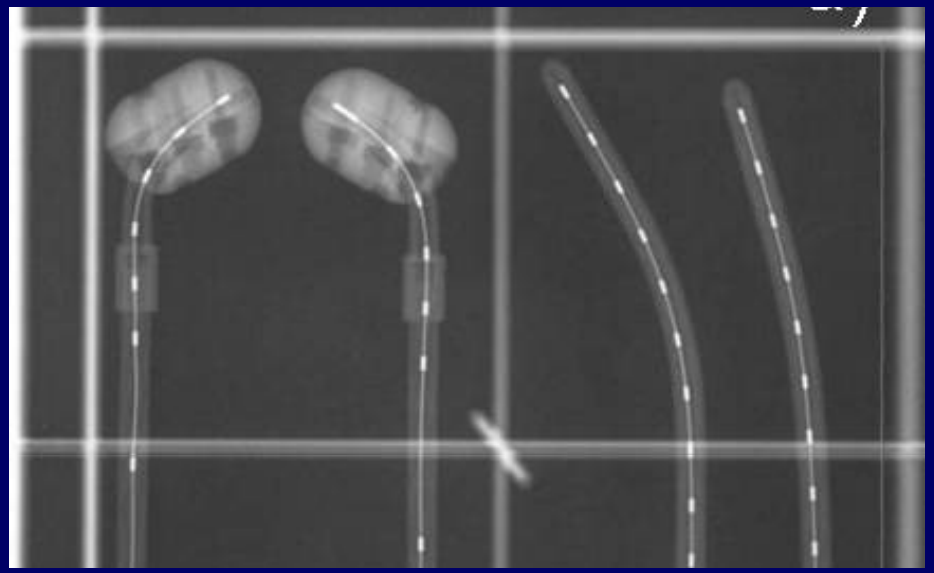
MR imaging – Physics point of view

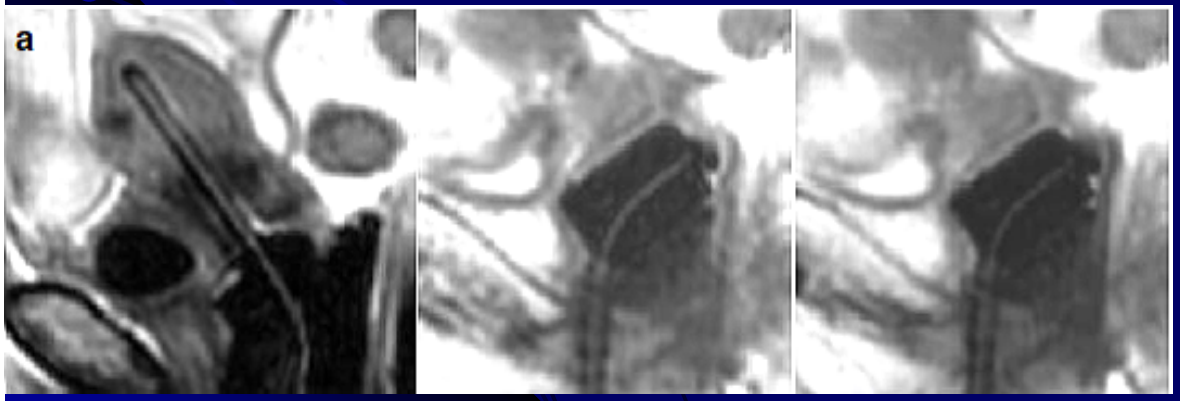
- No electron density information
  - Image registration with CT can be done
  - With iridium sources, tissue density is of less influence on the dose calculation due to the predominant Compton effect
- Image distortion
- Image artifacts
- Poor applicator visualization

Reconstruction

Applicator reconstruction

- Source channels are visualized clearly in both radiographs and CT and not in MR
- No markers/dummies available for MR





Applicator reconstruction

Inaccuracy in applicator reconstruction can lead to geometrical uncertainties and thus uncertainties in the definition of source positions which influence the accuracy of the delivered dose to both target volumes and organs at risk.

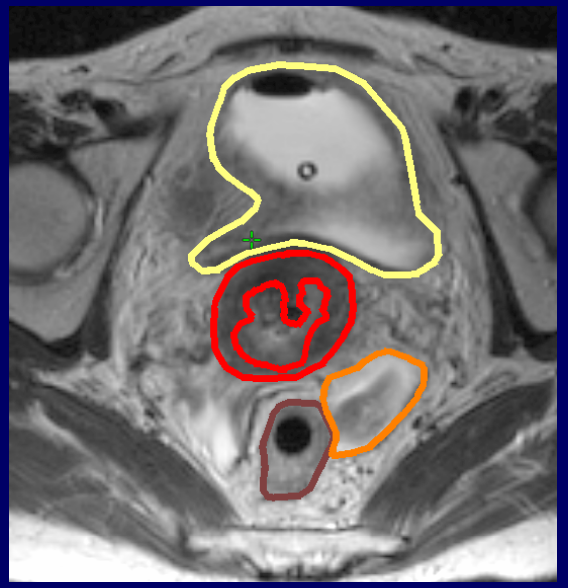
GEC-ESTRO Recommendations

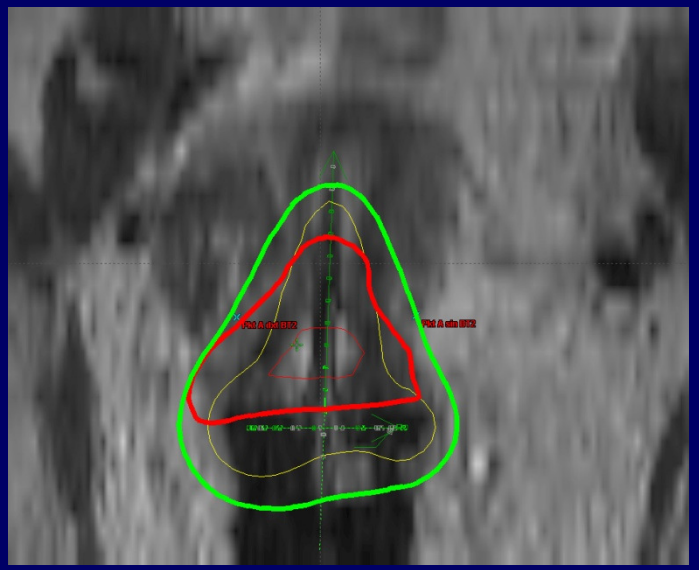
Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group: Considerations and pitfalls in commissioning and applicator reconstruction in 3D image-based treatment planning of cervix cancer brachytherapy

Taran Paulsen Hellebust[a,*], Christian Kirisits[b], Daniel Berger[b], José Pérez-Calatayud[c], Marisol De Brabandere[d], Astrid De Leeuw[e], Isabelle Dumas[f], Robert Hudej[g], Gerry Lowe[h], Rachel Wills[h], Kari Tanderup[i]

Applicator reconstruction accuracy clinical consequences

- 10 intracavitary cervical cancer patients
- MR scan with ring applicator in situ
- Contouring on transversal T2 images:
  - HR-CTV
  - Bladder
  - Rectum
  - Sigmoid
- Manual 3D dose optimisation
- DVH parameters:
  - D100, D90 for HR-CTV
  - D_{2cc} for bladder, rectum, sigmoid

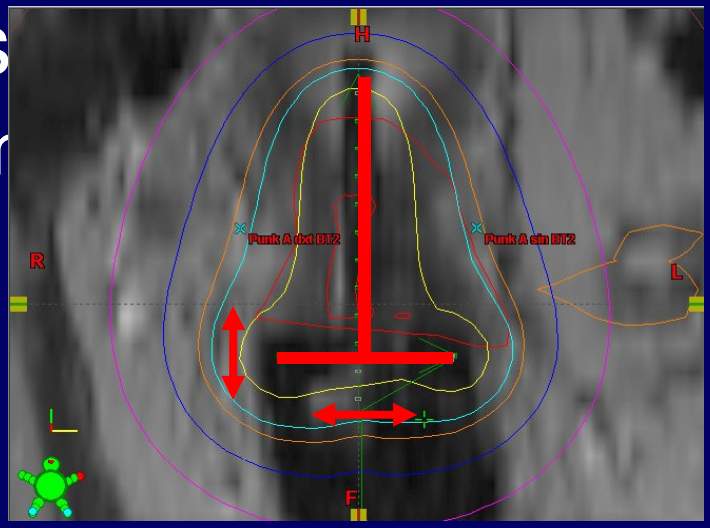


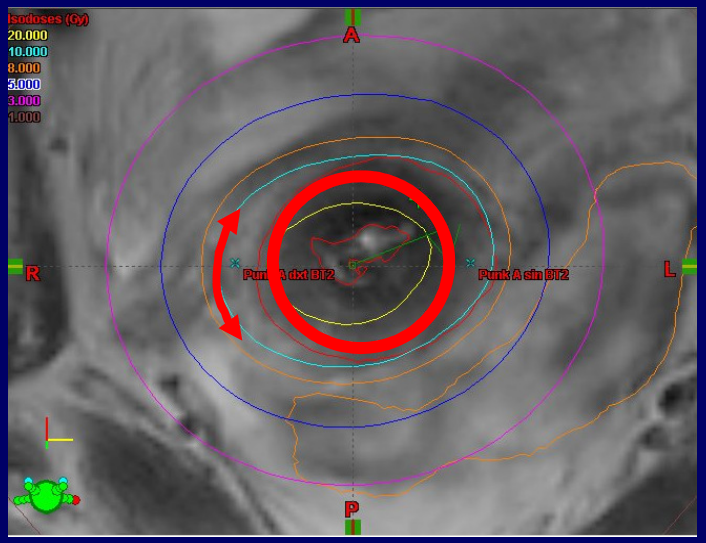


Tanderup et al, R&O 2008

Simulation of uncertainty

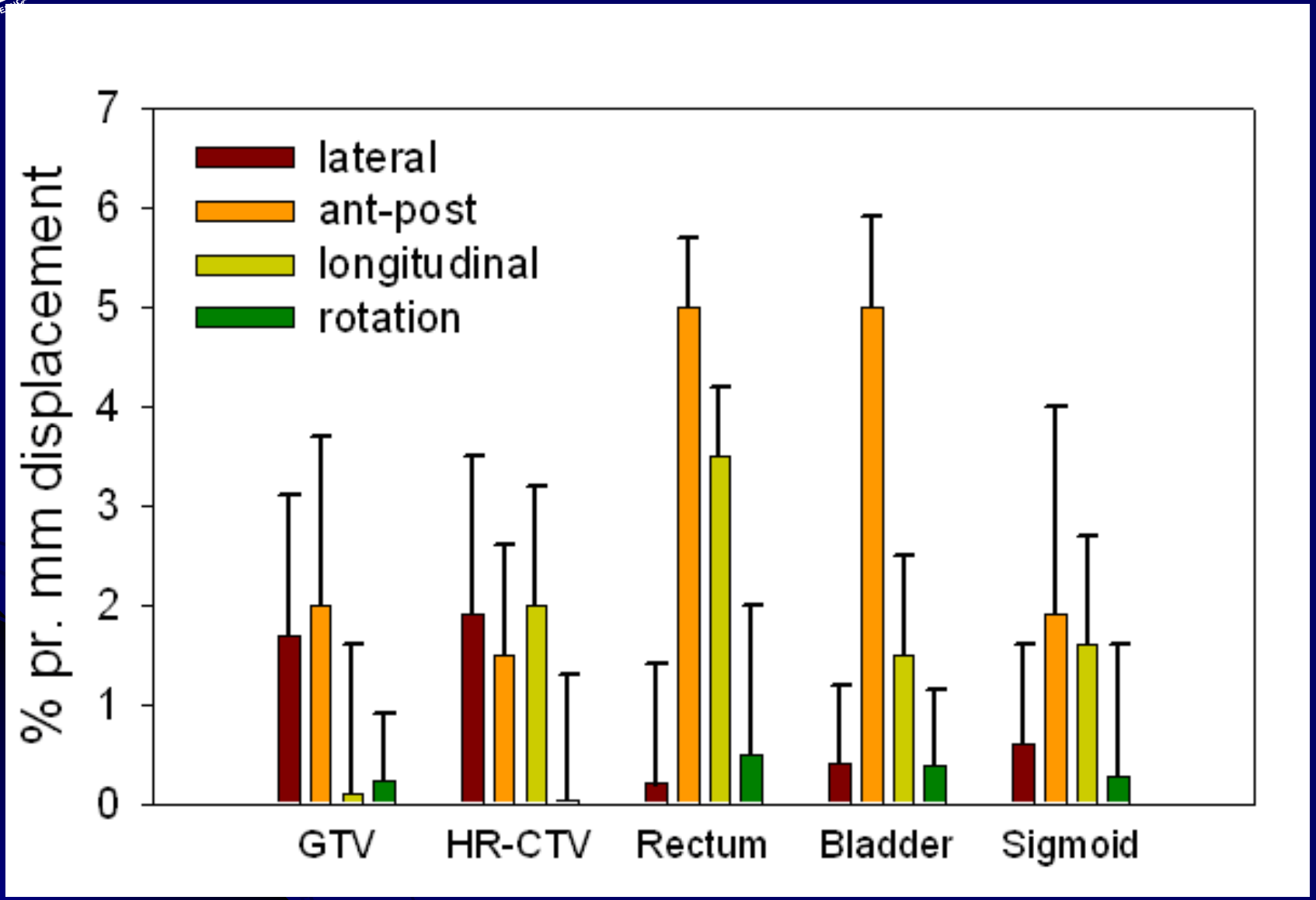
- Displacement in directions
  - Longitudinal (along tandem
    - ± 3 mm, ± 5 mm
  - Lateral:
    - ± 3 mm
  - Ant-post
    - ± 3 mm
- Rotation of ring:
  - ± 15 dgr (4 mm)





Tanderup et al, R&O 2008

Mean DVH shifts (%) pr mm



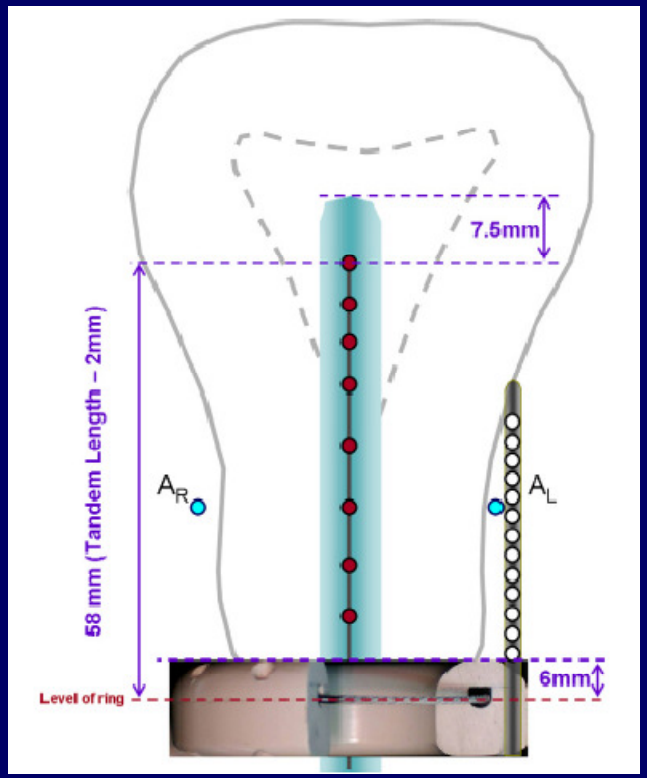
Tanderup et al, R&O 2008

Reconstruction

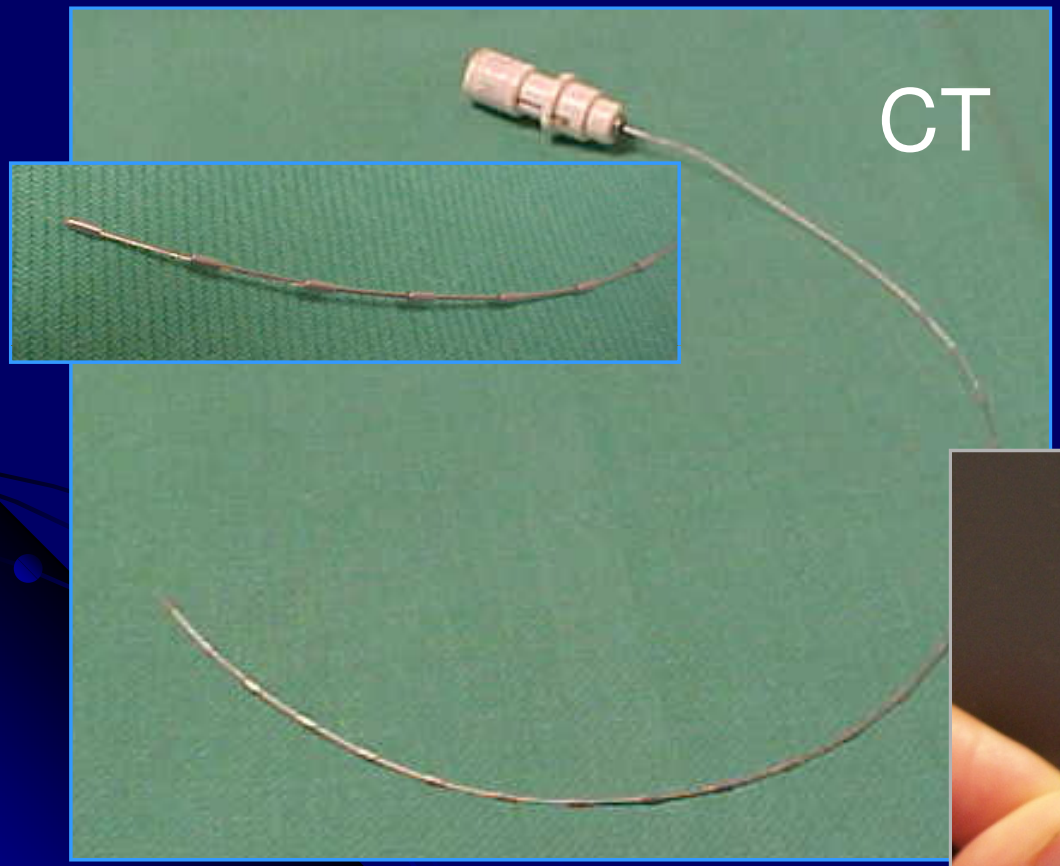
- Commissioning of the applicator
  - Knowledge of the applicator geometry essential
- Library plans
- MPR
- new reconstruction method

Commissioning of applicators

- Understand the geometry of the applicator (vendor)
- Use radiographs / CT

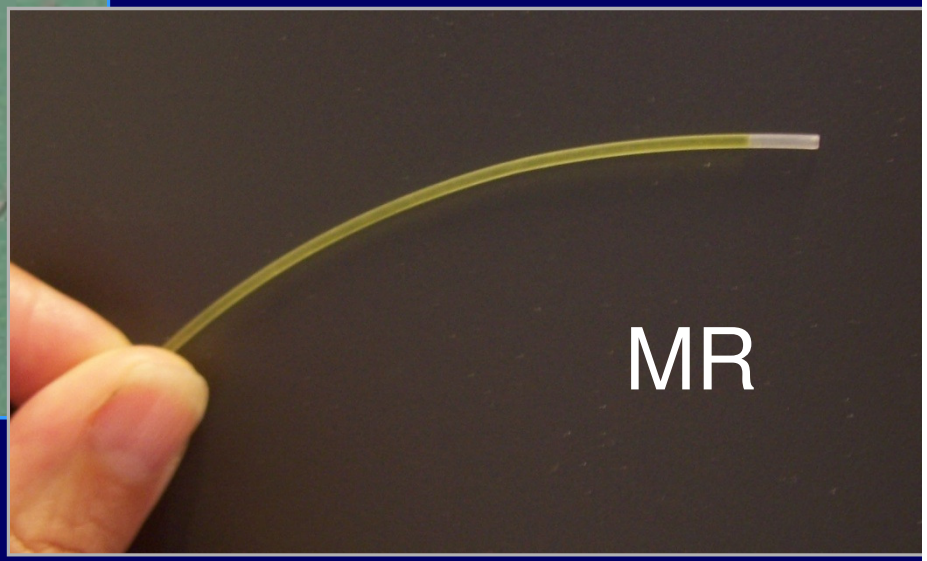


Markers – applicator specific



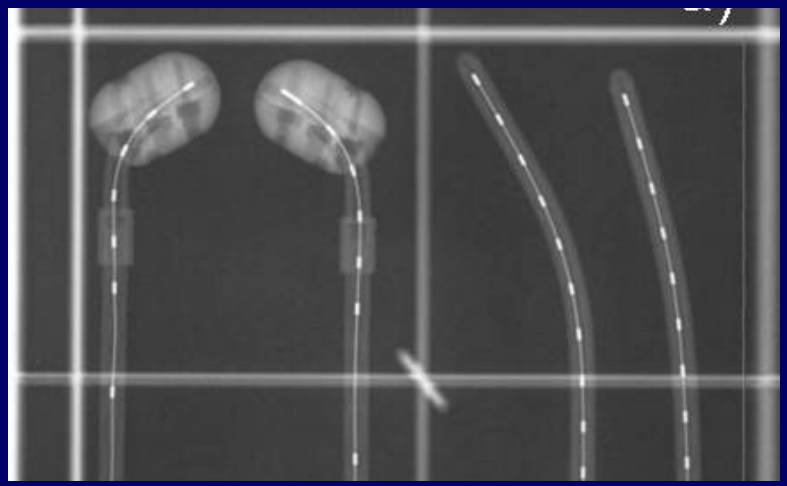
Markerstring

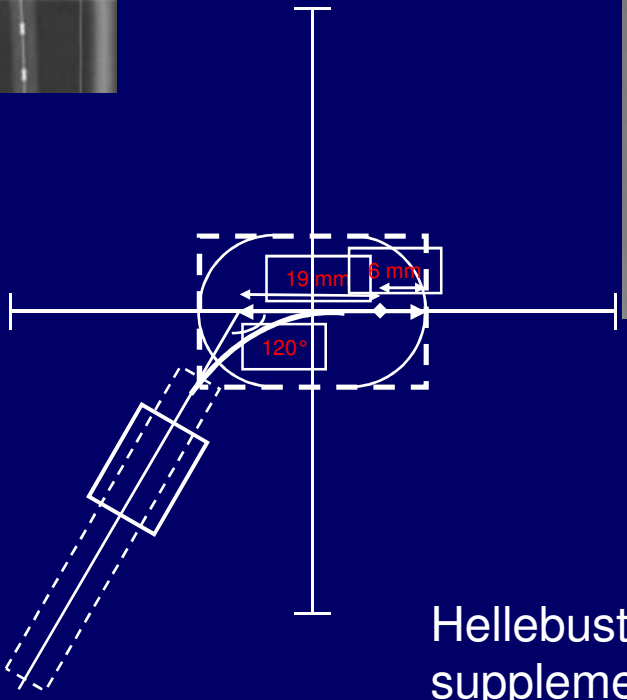
Dedicated for each type of applicator

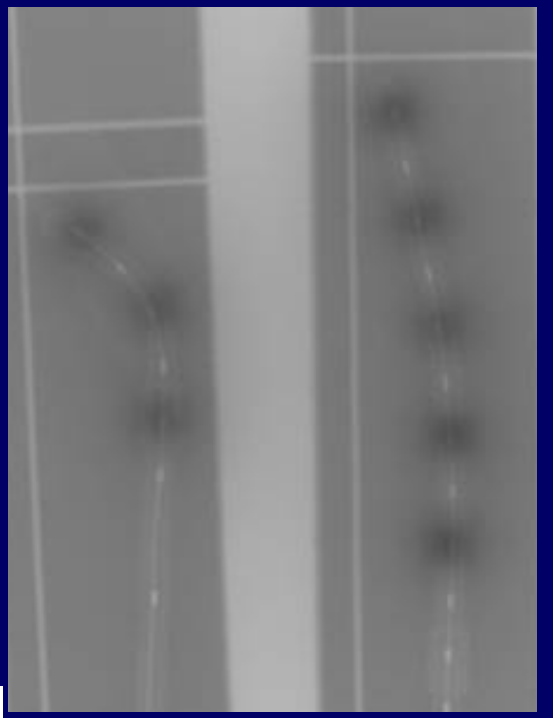


Ack: Hellebust TP

Commissioning, Fletcher applicator using radiographs

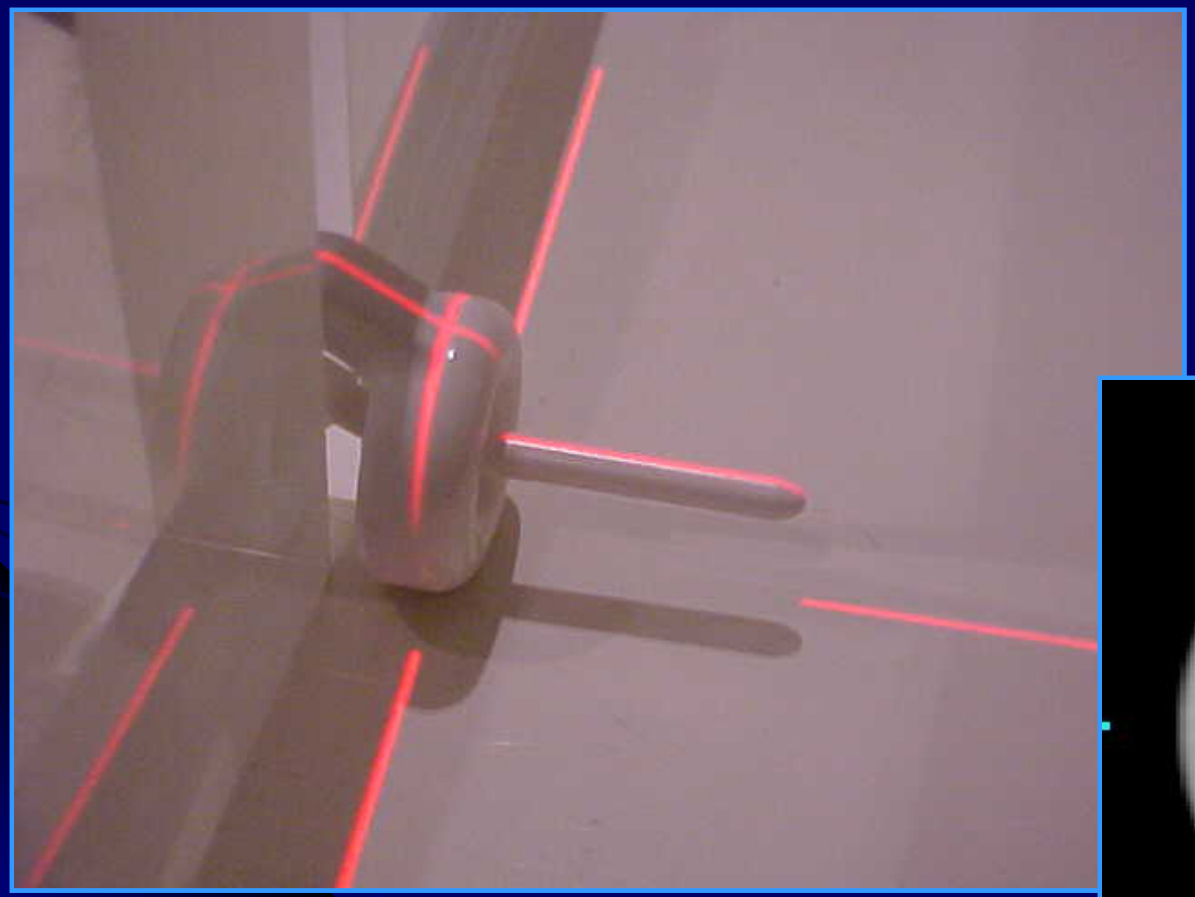


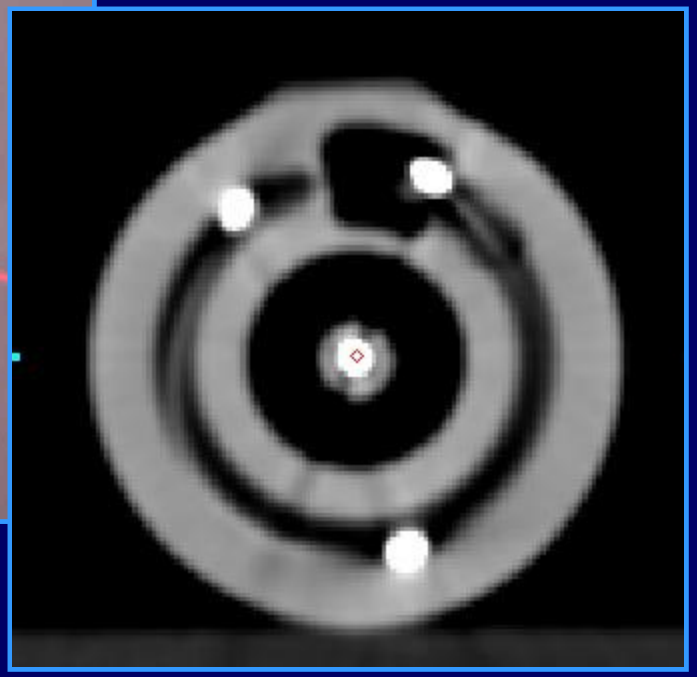




Hellebust et al, R&O 2010, supplementary data

Commissioning, Ring applicator using CT





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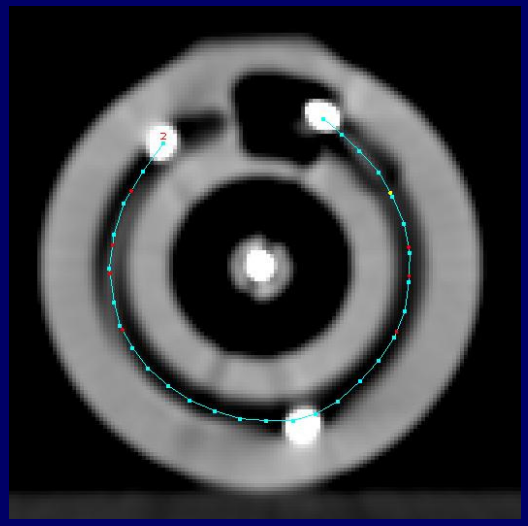
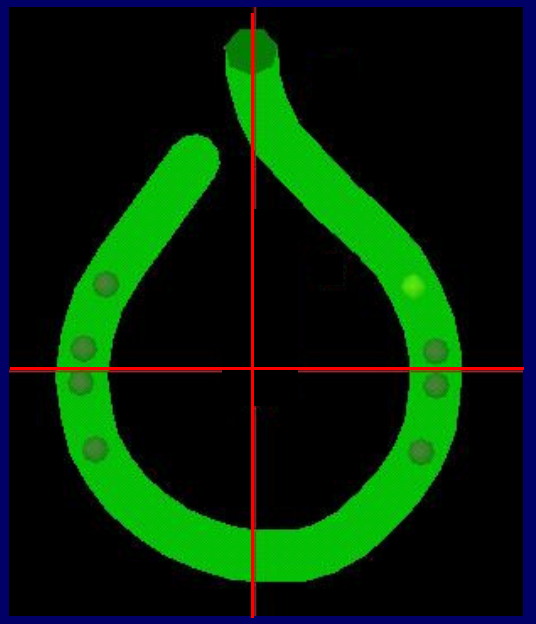
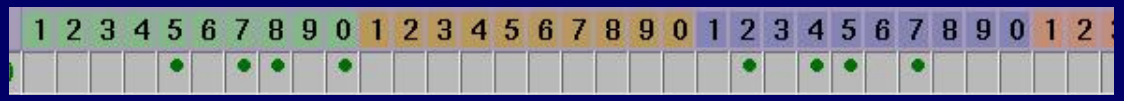
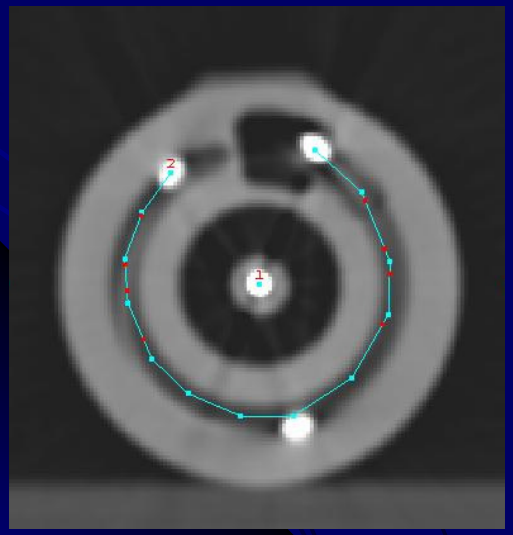
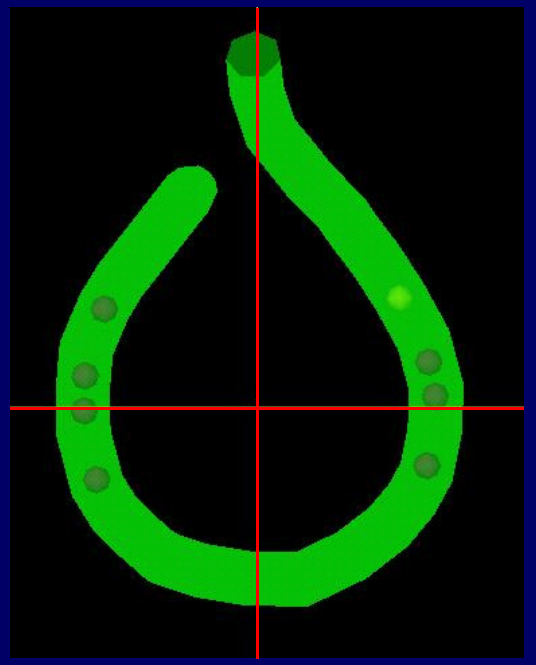






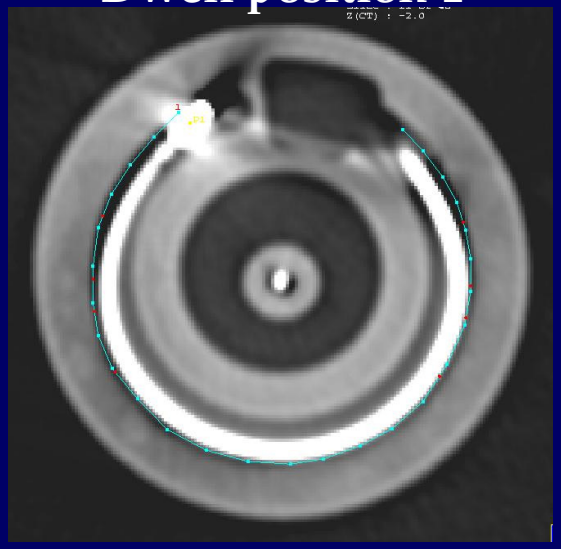




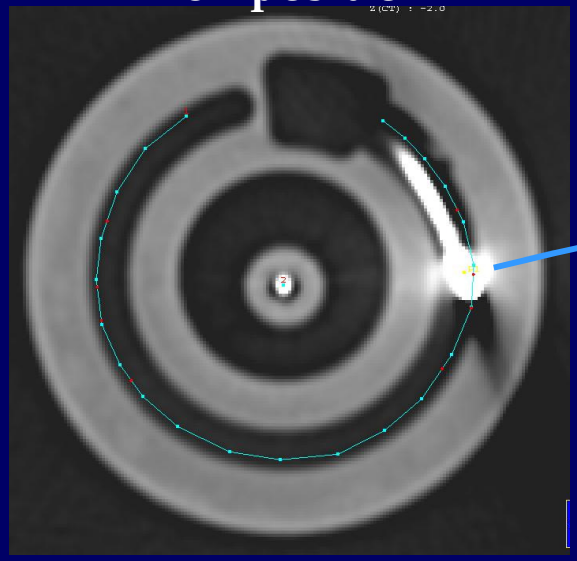
Ack: Hellebust TP

CT images of the ring with the source

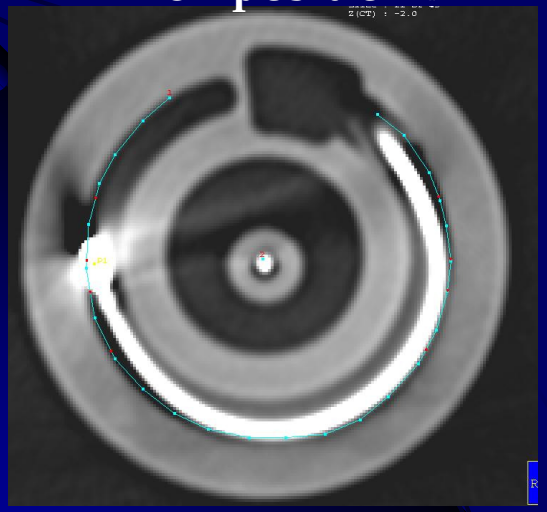
Dwell position 1

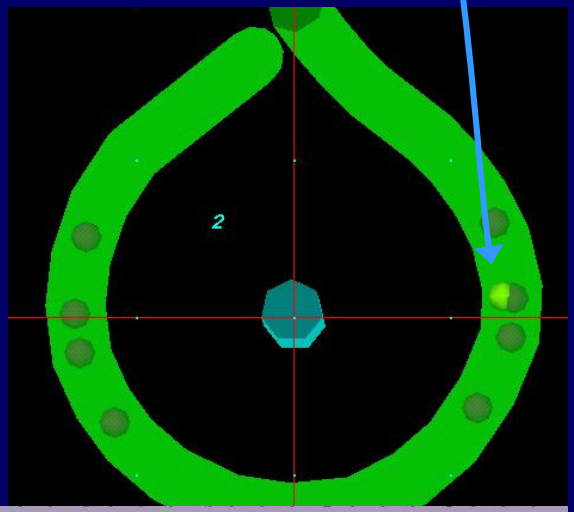


Dwell position 24

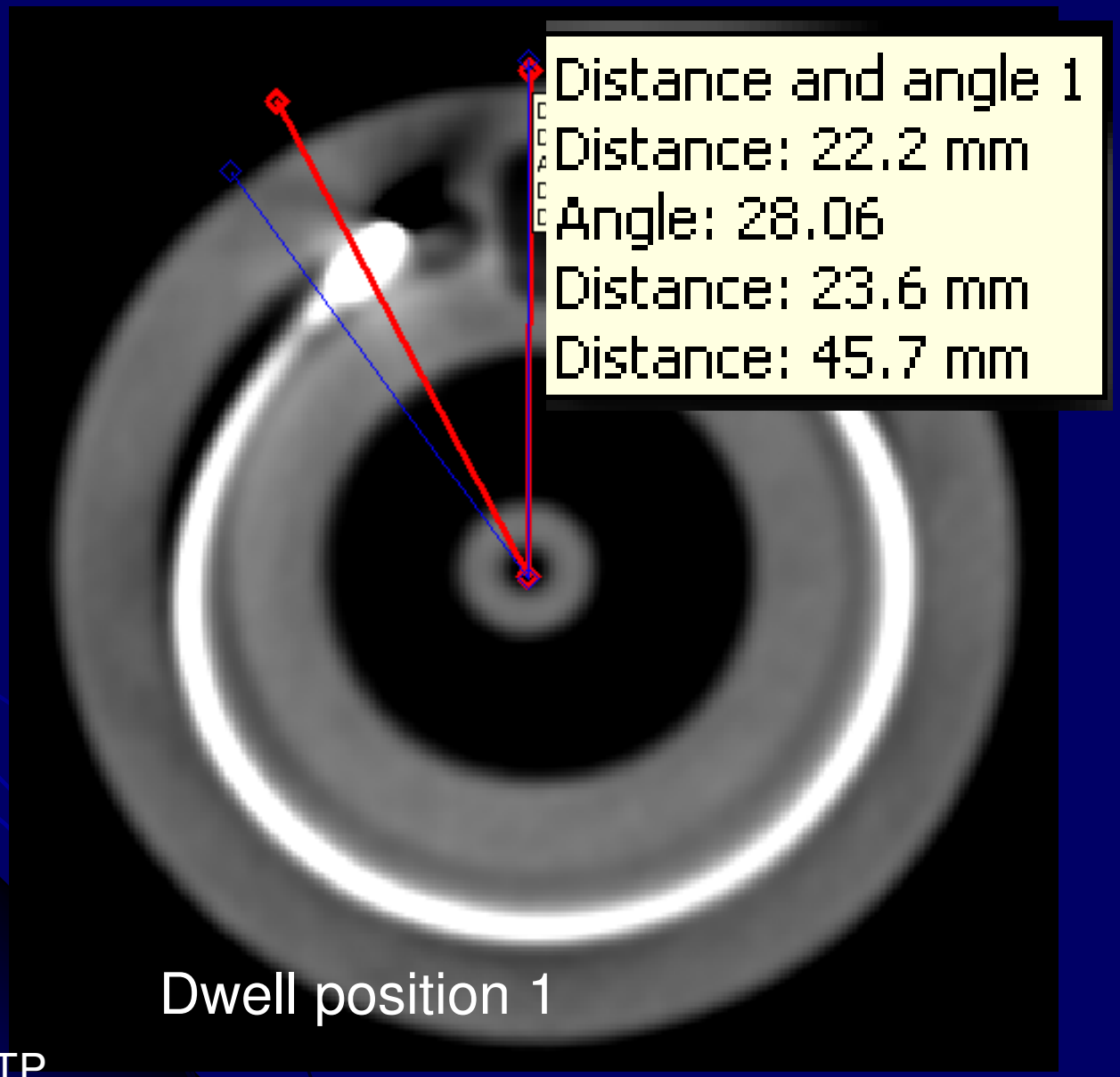


Dwell position 7





Hellebust et al, PMB 52 (2007)

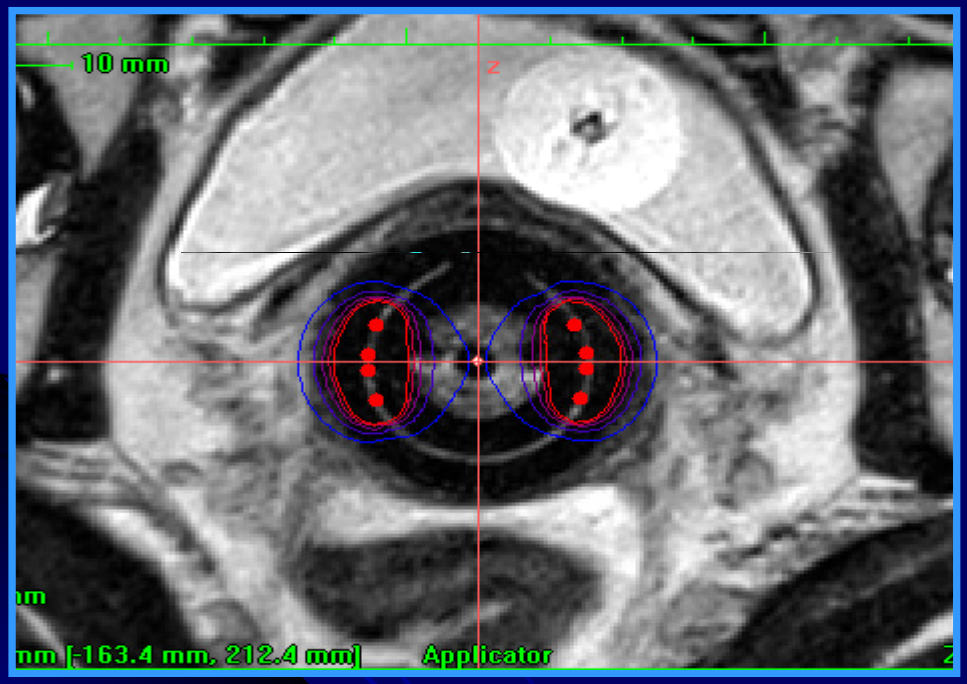


Dwell position 1

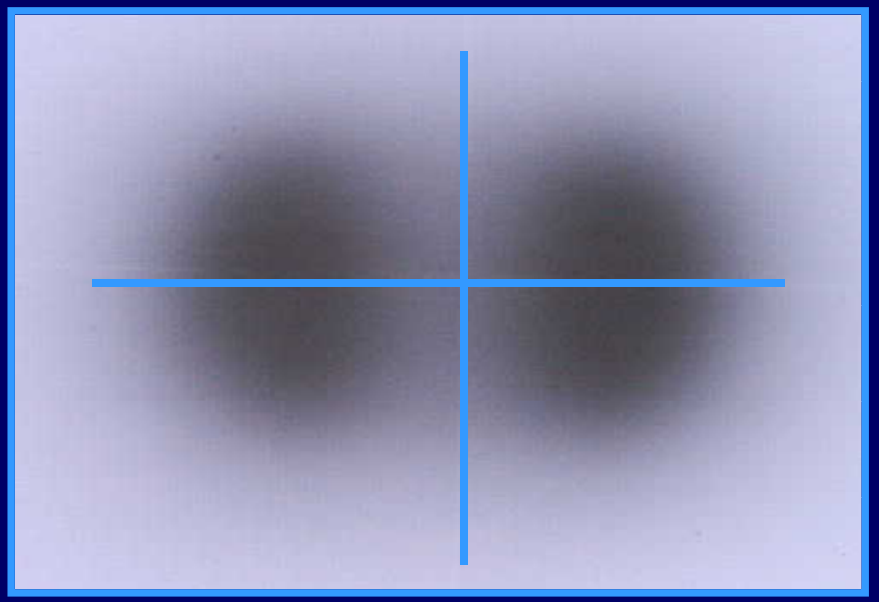
Ack: Hellebust TP

Auto radiograph

Standard loading



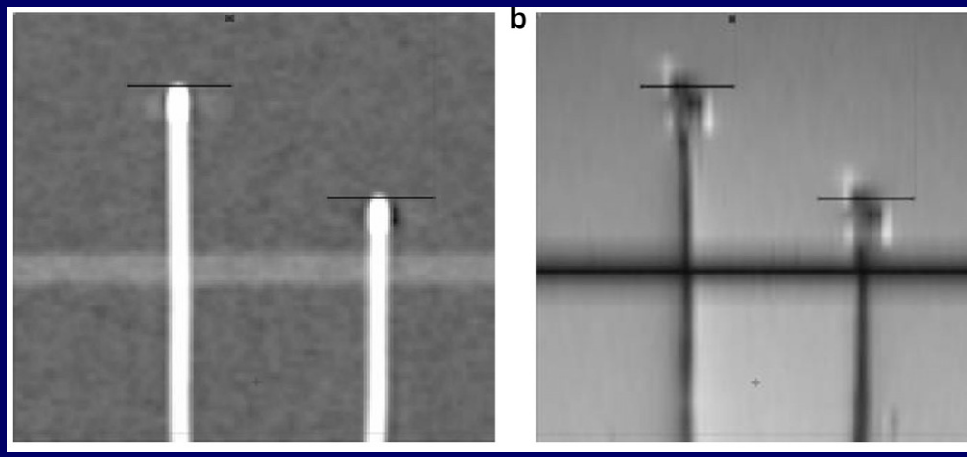
Auto-radiograph with standard loading

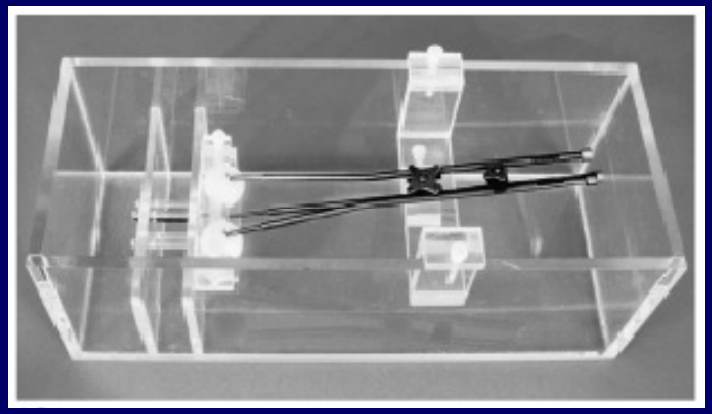


Ack: Hellebust TP

Titanium applicators

- Titanium produces susceptibility artifacts in MR images
- phantom MRI scans have to be performed for applicator commissioning.
- artifacts are dependent on image sequence,
- By fusing MRI and CT phantom scans, the position of the MR image artifacts can be assessed with regard to the applicator geometry as visualized on CT imaging





Kim et al, IJROBP,2010

Reconstruction

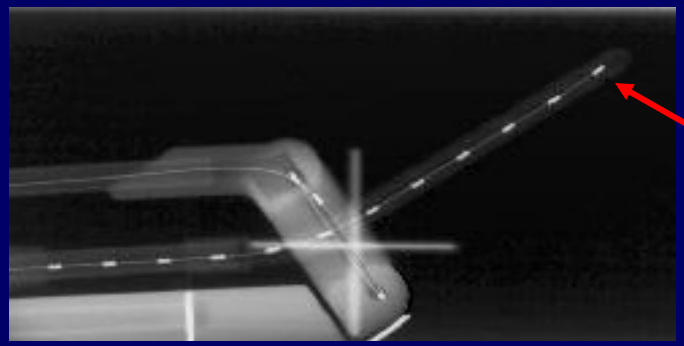
- Library plans
- Direct reconstruction
- New reconstruction method

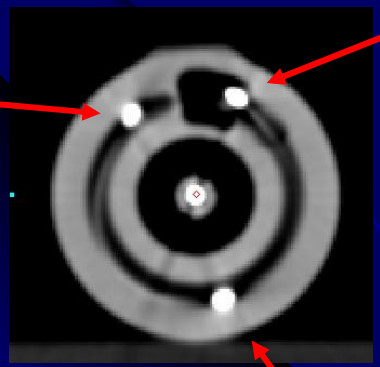
Library plans

- accurate compared to other methods
- used only for rigid applicators (ring)
- a pre-defined library file with the source path geometry is used and imported into the clinical image set.
- well defined points should be used to merge with the co ordinate system

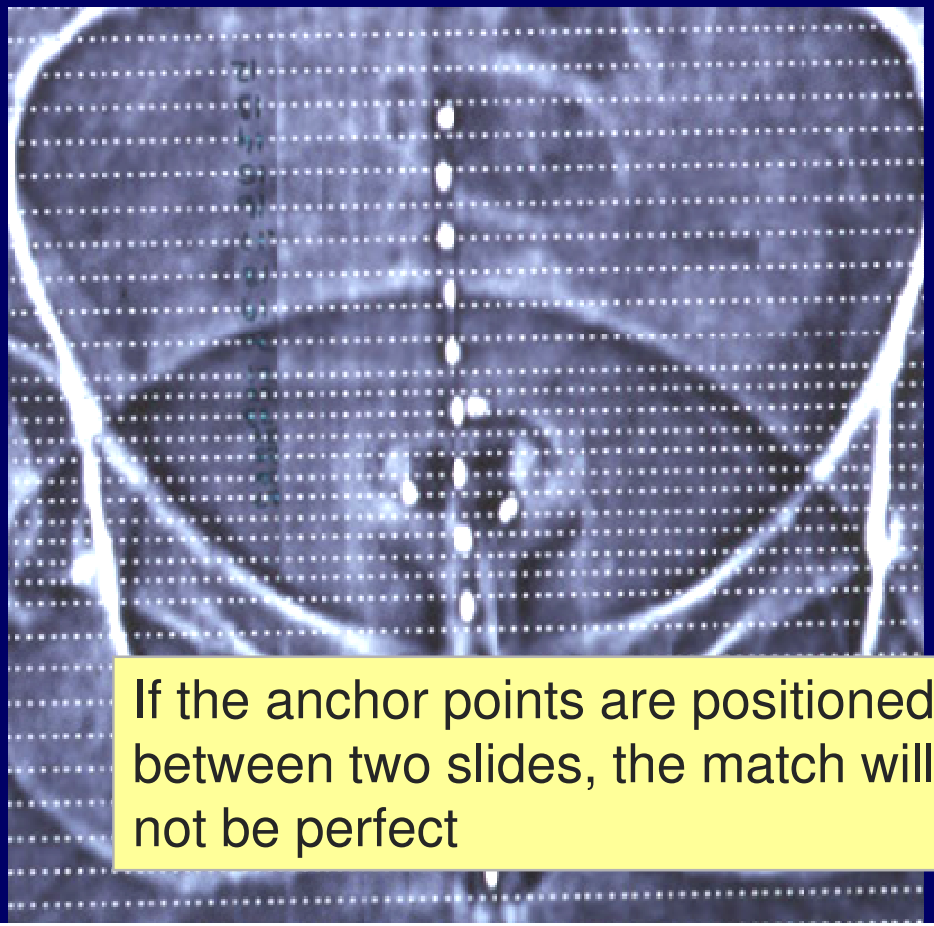
Library plans

Requires minimum three well defined points (anchor points) to position the applicator in the 3D study





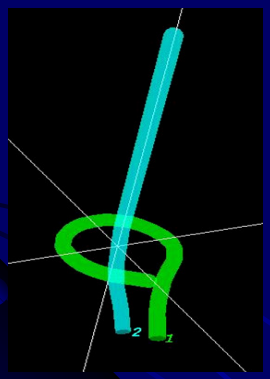
Ack: Hellebust TP

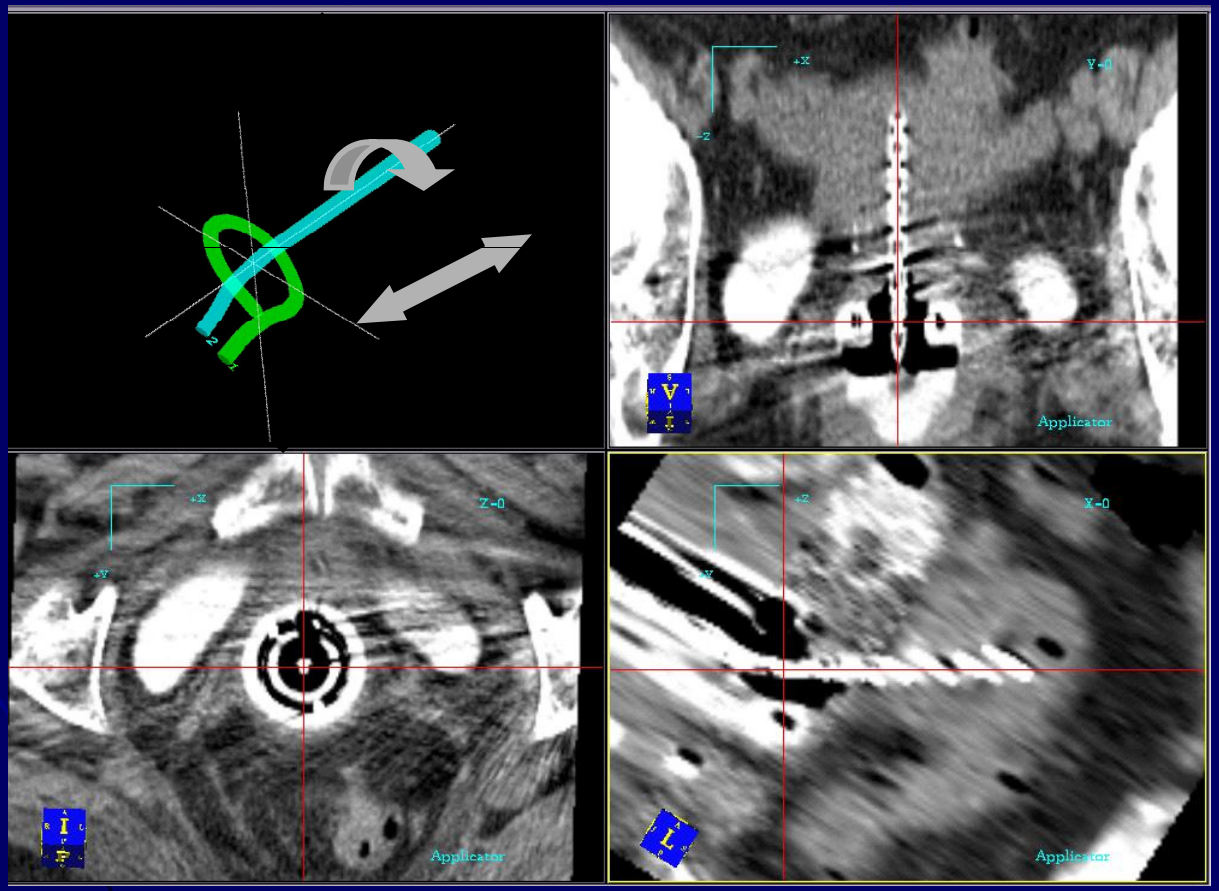


If the anchor points are positioned in between two slides, the match will not be perfect

Library plans – An advantage in image based planning

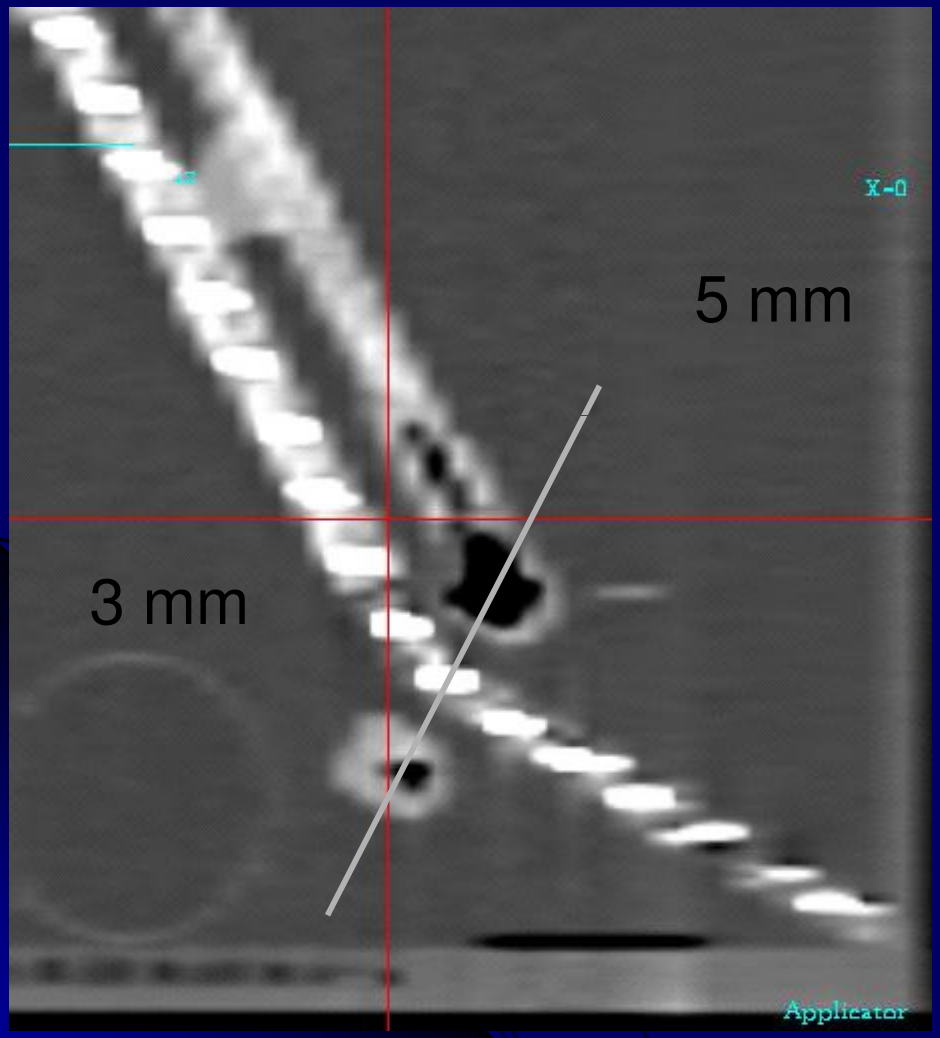
A facility to rotate and translate the applicator in the 3D study is more optimal

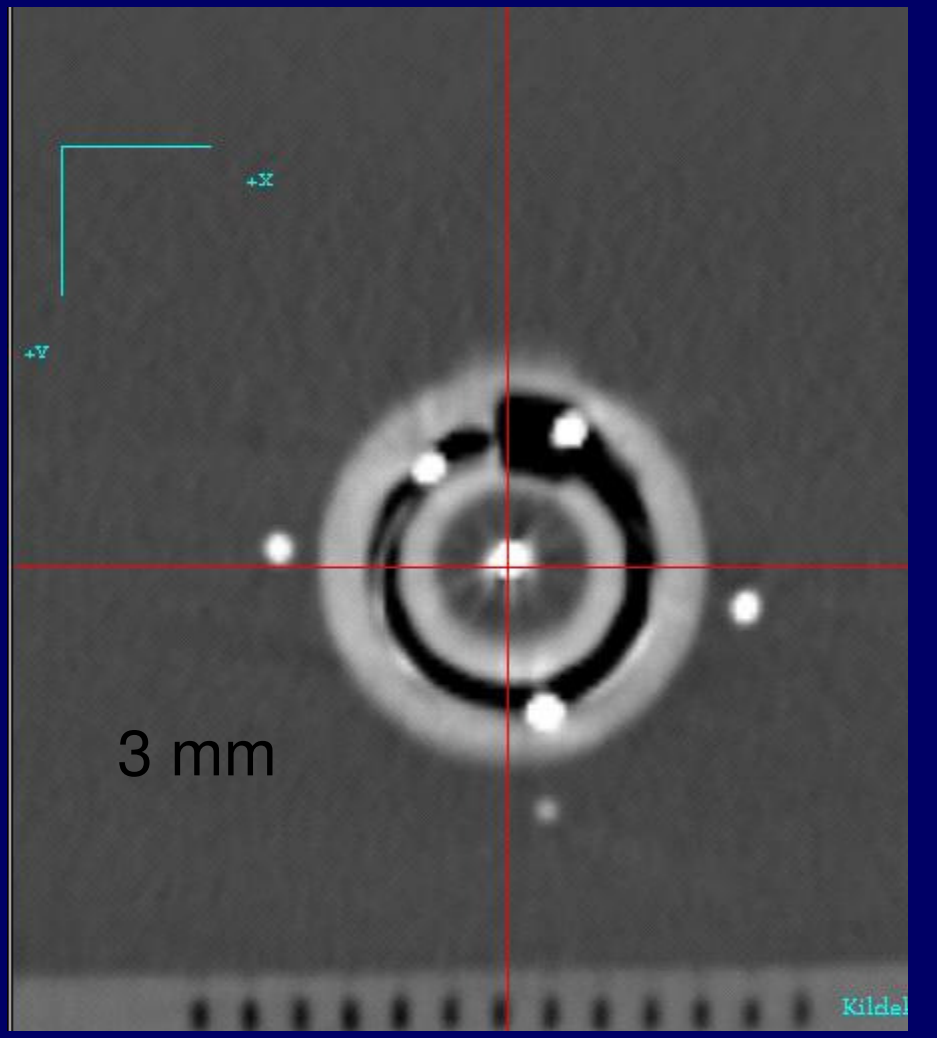




Ack: Hellebust TP

Multiplanar reconstruction, MPR

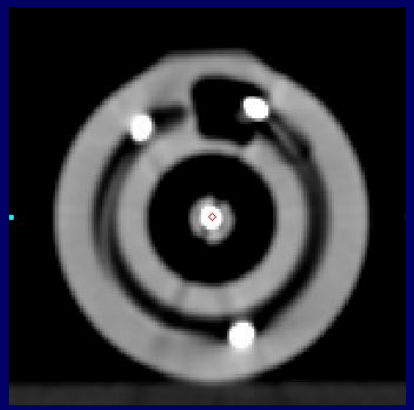


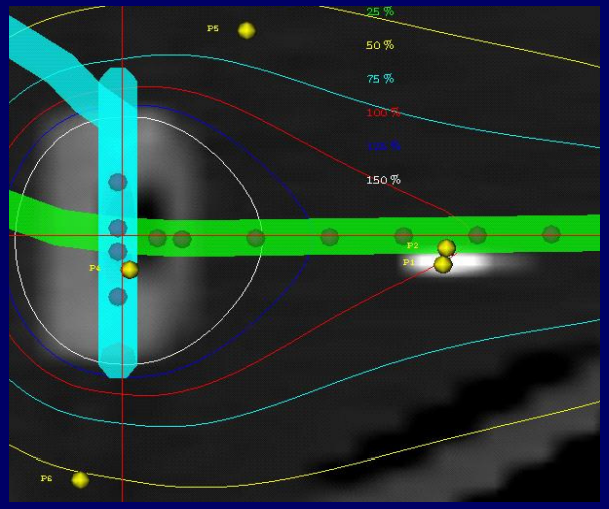


Ack: Hellebust TP

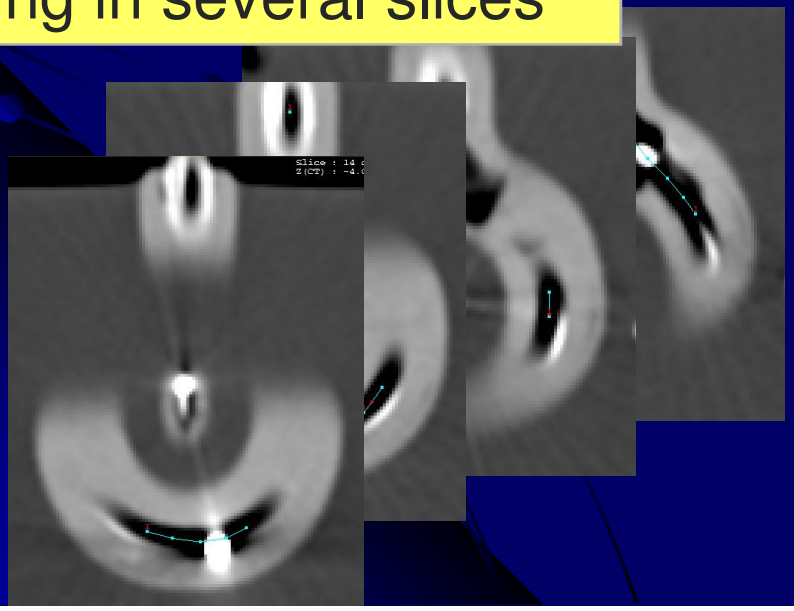
MPR- challenge

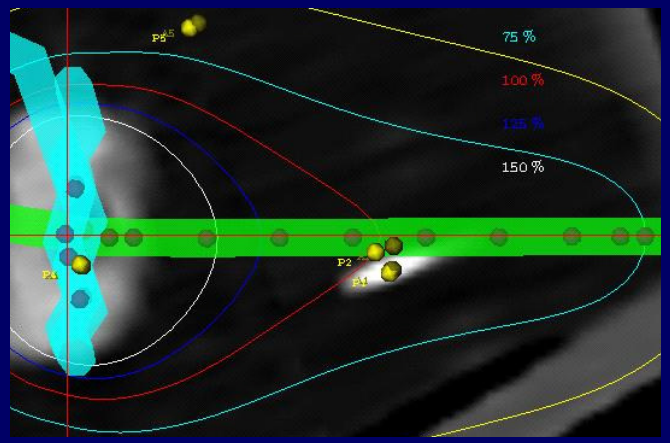
Ring in one slice





Ring in several slices

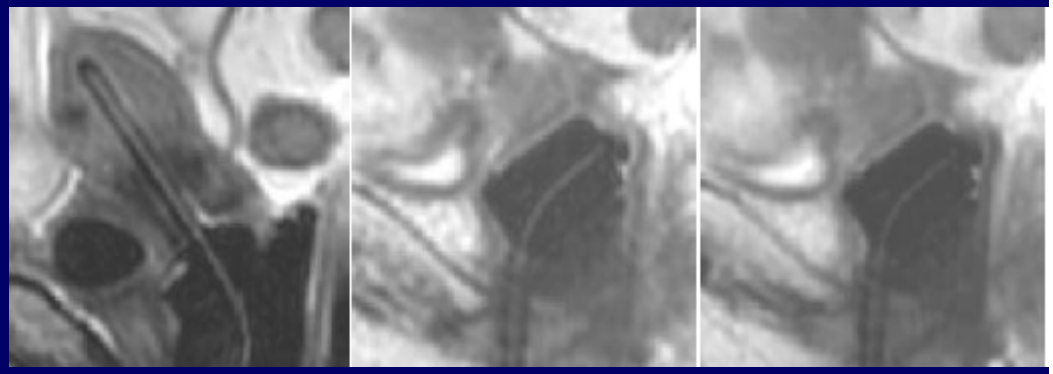


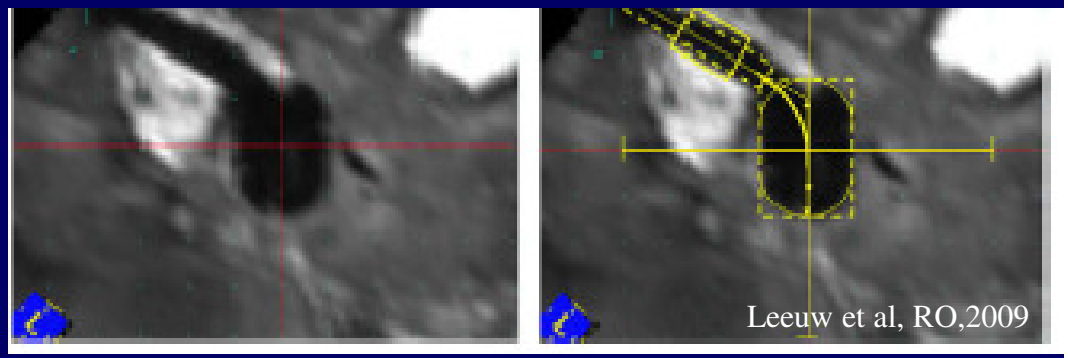


Ack: Hellebust TP

Applicator reconstruction – MPR

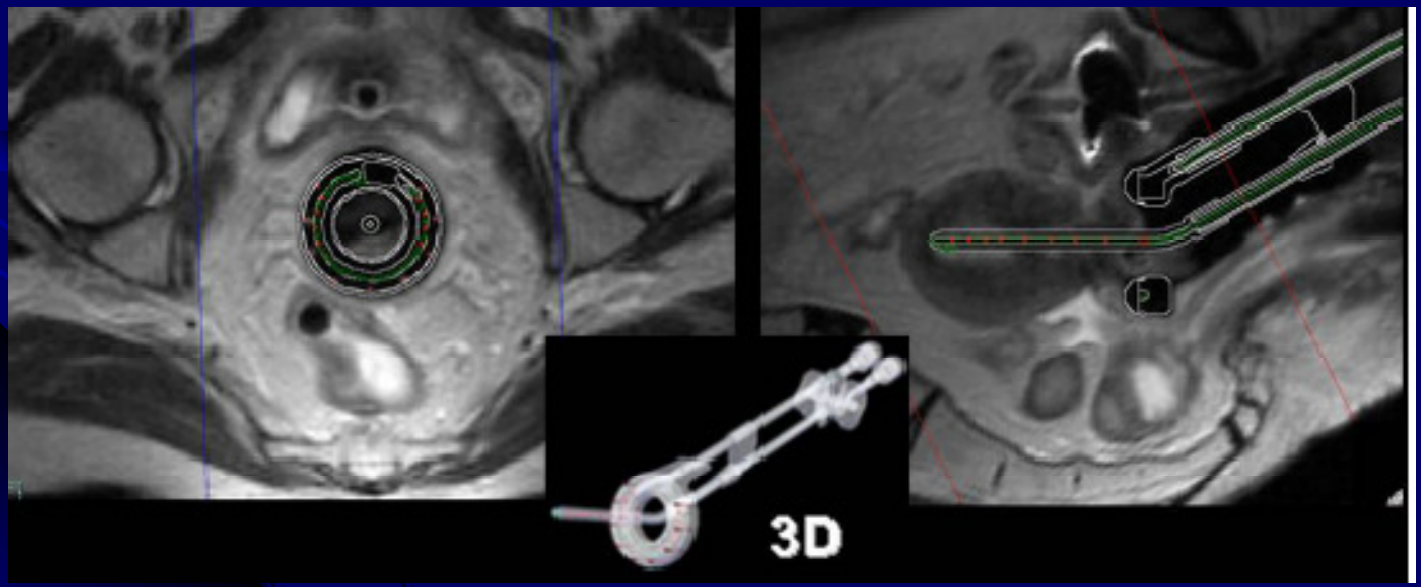
- Clear visualization of the source channels in a single plane.
- Check the geometry of the applicator verified during commissioning.
- Especially useful for curved applicators (ovoid/ring)





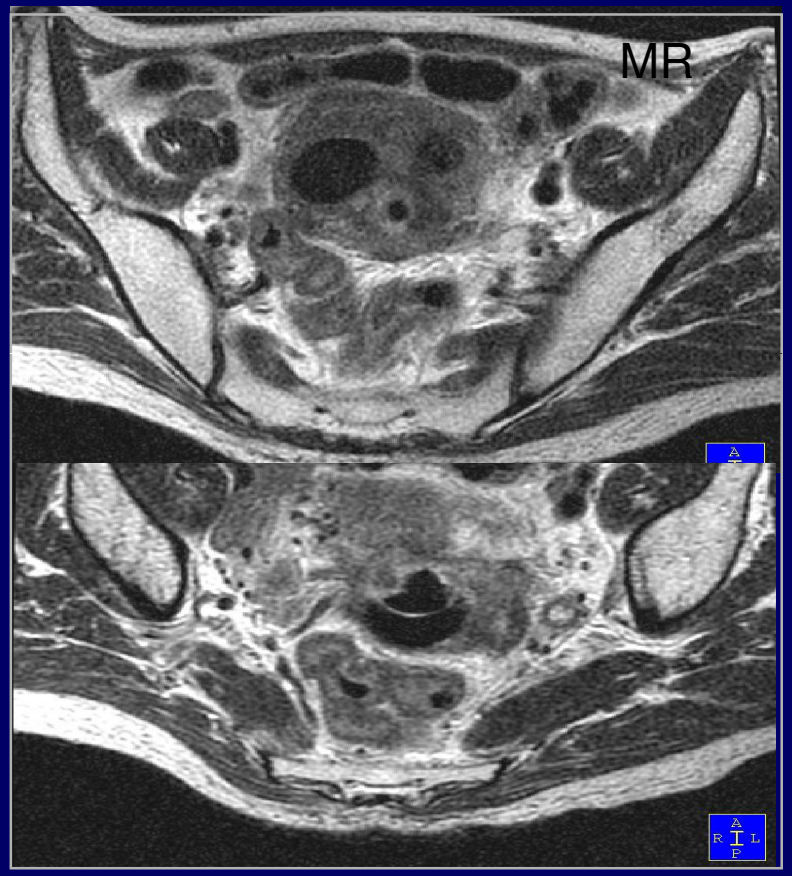
Applicator reconstruction – new method

- Some TPSs contain an applicator library which includes information about the physical outer applicator dimensions, an applicator file can be imported and rotated and translated until it matches the black area in the patient MR images
- fast, simple, and less prone to reconstruction errors.



Fusion

Reconstruction

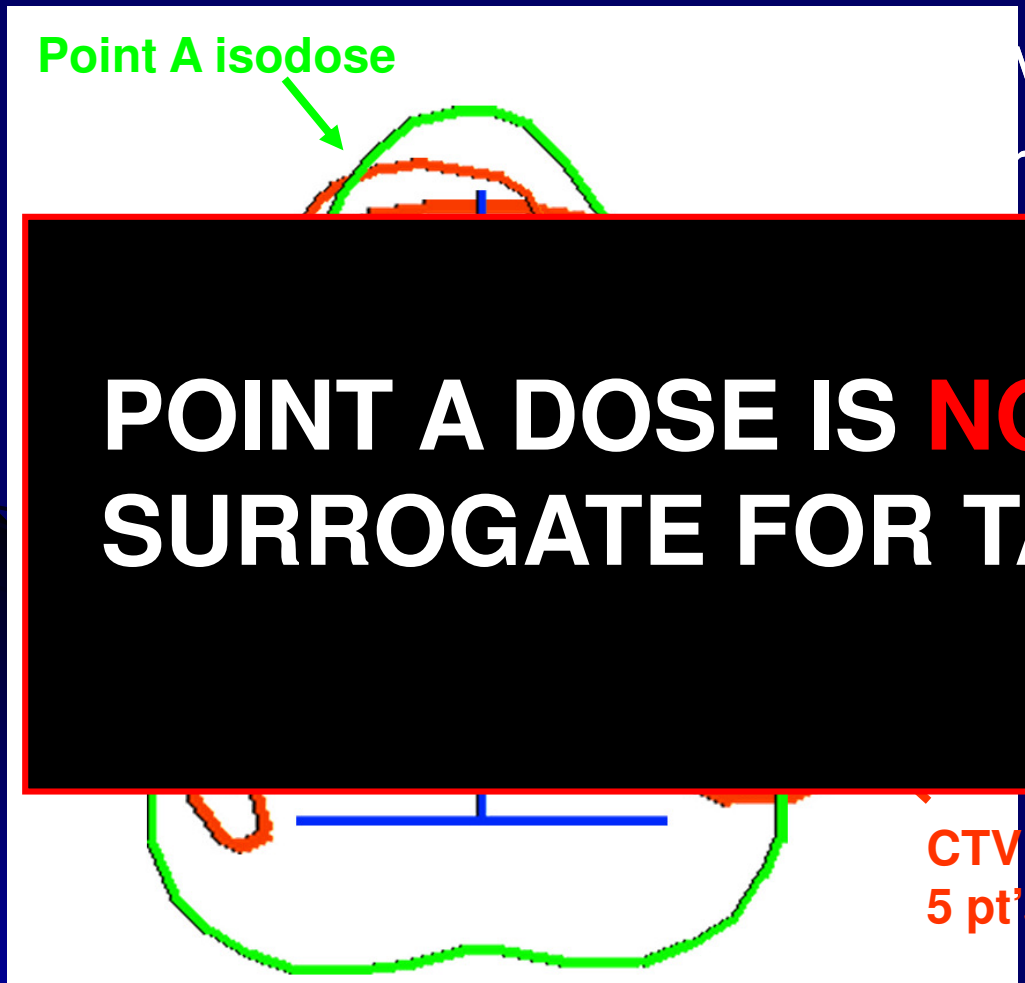


Delineation

Ack: Hellebust TP

Optimization

Limitation of point A and standard loading pattern



Minimum HR-CTV dose relative to point A:

POINT A DOSE IS NOT A GOOD SURROGATE FOR TARGET DOSE

CTV's assessed from MRI
5 pt's

Ack: Tanderup K

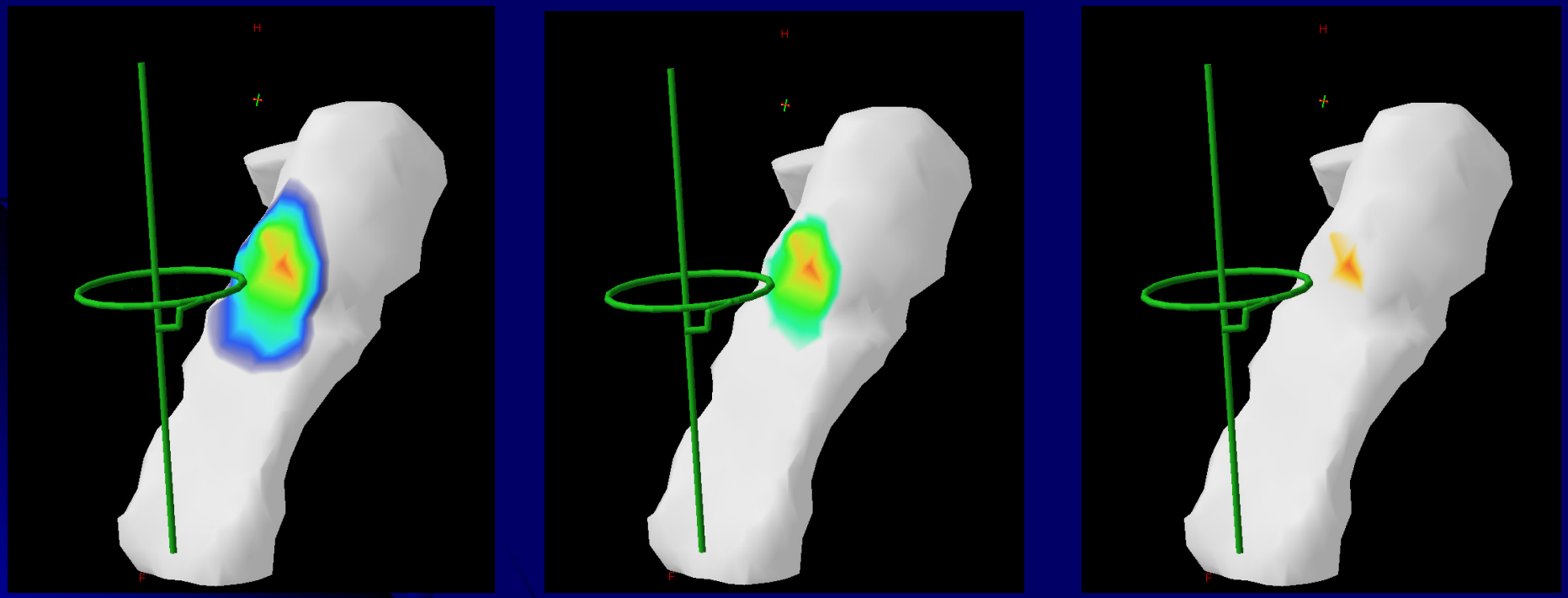
Objectives for optimization

- **Prescribed Dose (PD) (standard)**
- **Point A Dose**
- **D 90 (Minimum Dose in 90% of CTV)**
- D 100 (Minimum Target Dose)

- V 100 (Volume receiving ≥ 100% of PD)
- V 150/200 (150%/200% of PD)
- TRAK

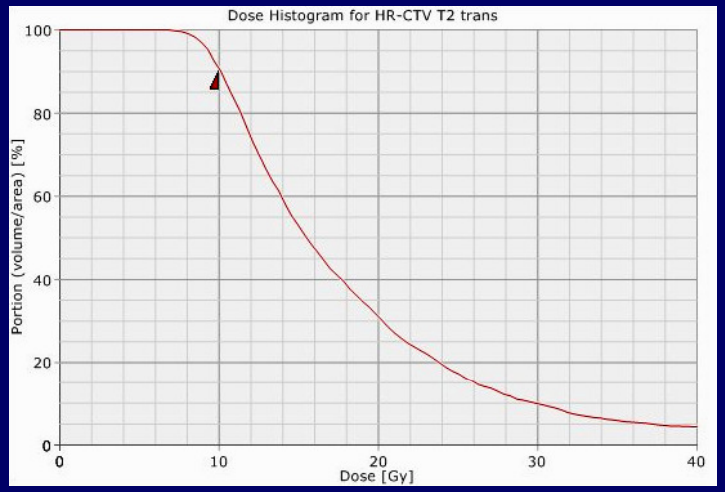
OARs – minimum dose to the most exposed volume

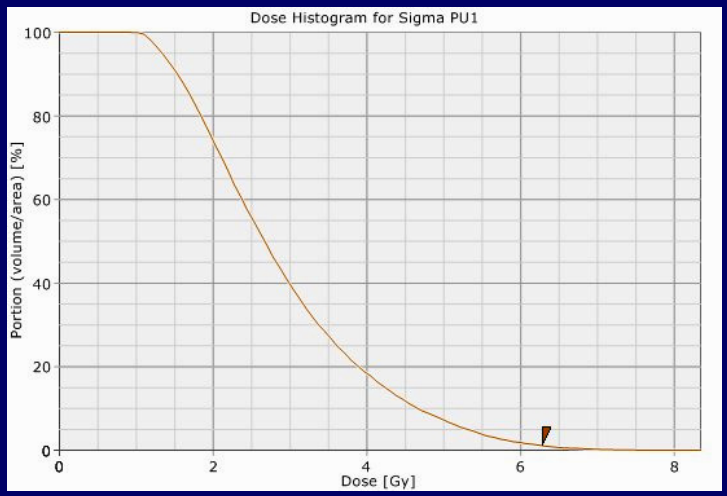
D_{2cc} D_{1cc} $D_{0.1cc}$



DVH constraints on total dose: EBRT + BT

- EQD_2 calculations
  - Tumor: α/β = 10 Gy
  - OAR: α/β = 3 Gy
  - T½ = 1.5 h
- Tumour, D90
  - HR-CTV ≥ 84 Gy
- OAR, D_{2cc}
  - Bladder ≤ 90 Gy
  - Rectum ≤ 70-75 Gy
  - Sigmoid ≤ 70-75 Gy





Loading pattern

- Standard loading pattern: 15,10,10 mg Ra in tandem and 17.5mg in ovoid
- Ratio of T/O = 1

Tools for dose optimisation

- Manual dose optimisation
- Graphical optimization / Dose shaper
- Inverse planning

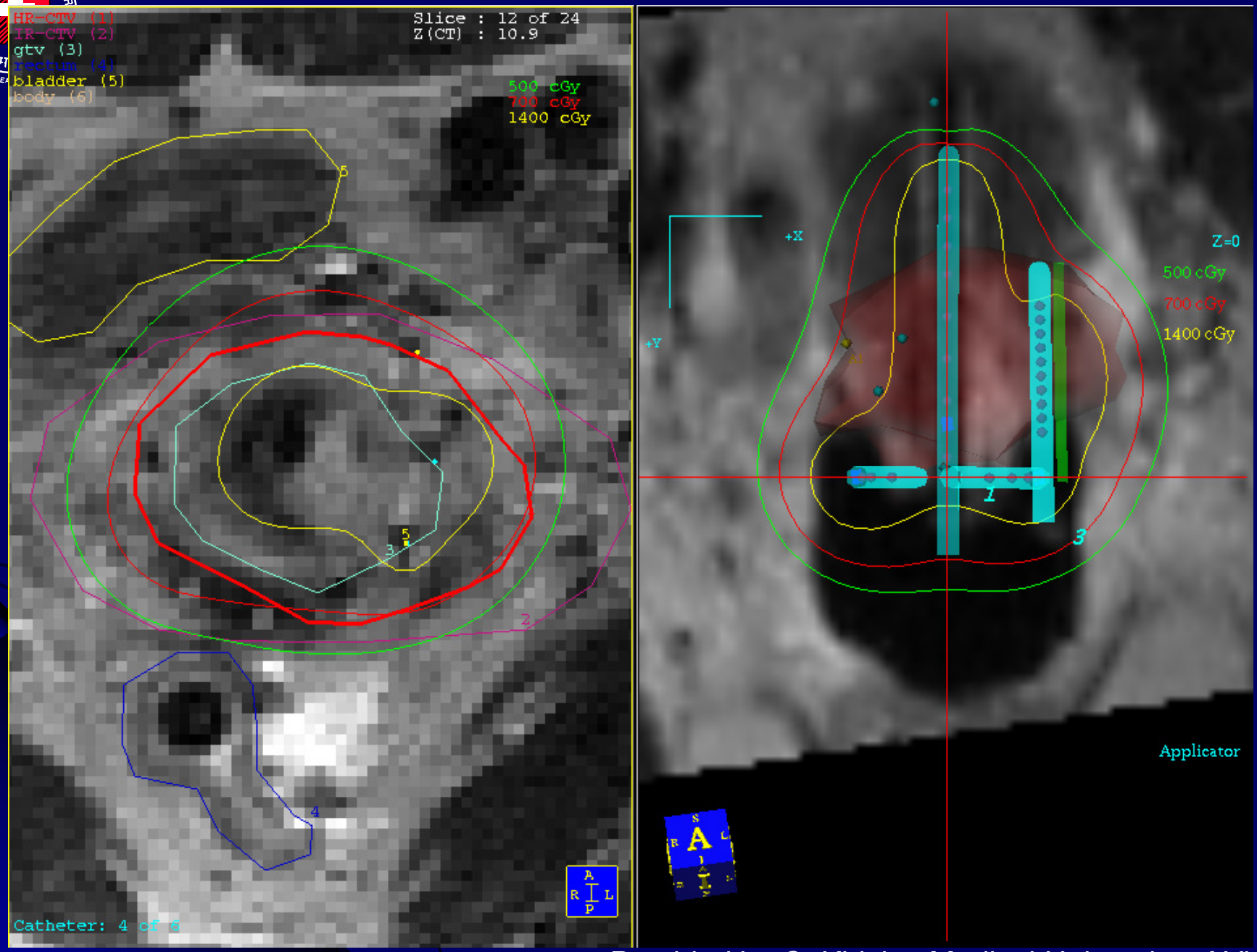
Manual optimization

- Manually changing the dwell weights
- Safe
- Requires experience and skill
- No large deviation from the standard loading pattern

Graphical optimization

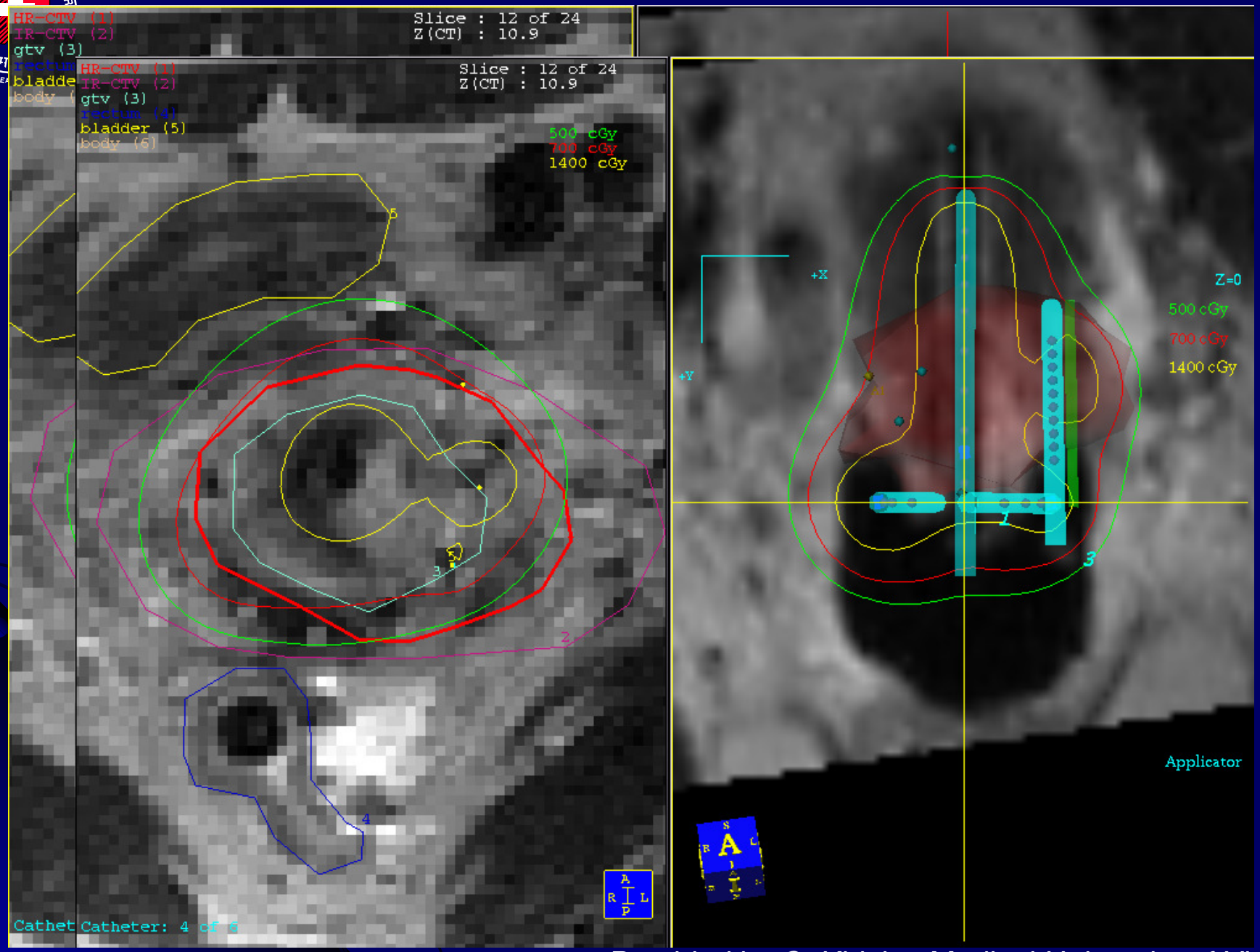
- Clicking or dragging the isodose to the desired location
- Quick and easy, but may be dangerous if not done carefully.
  - Standard loading pattern may change!
  - Localized hot spots

Graphical optimization



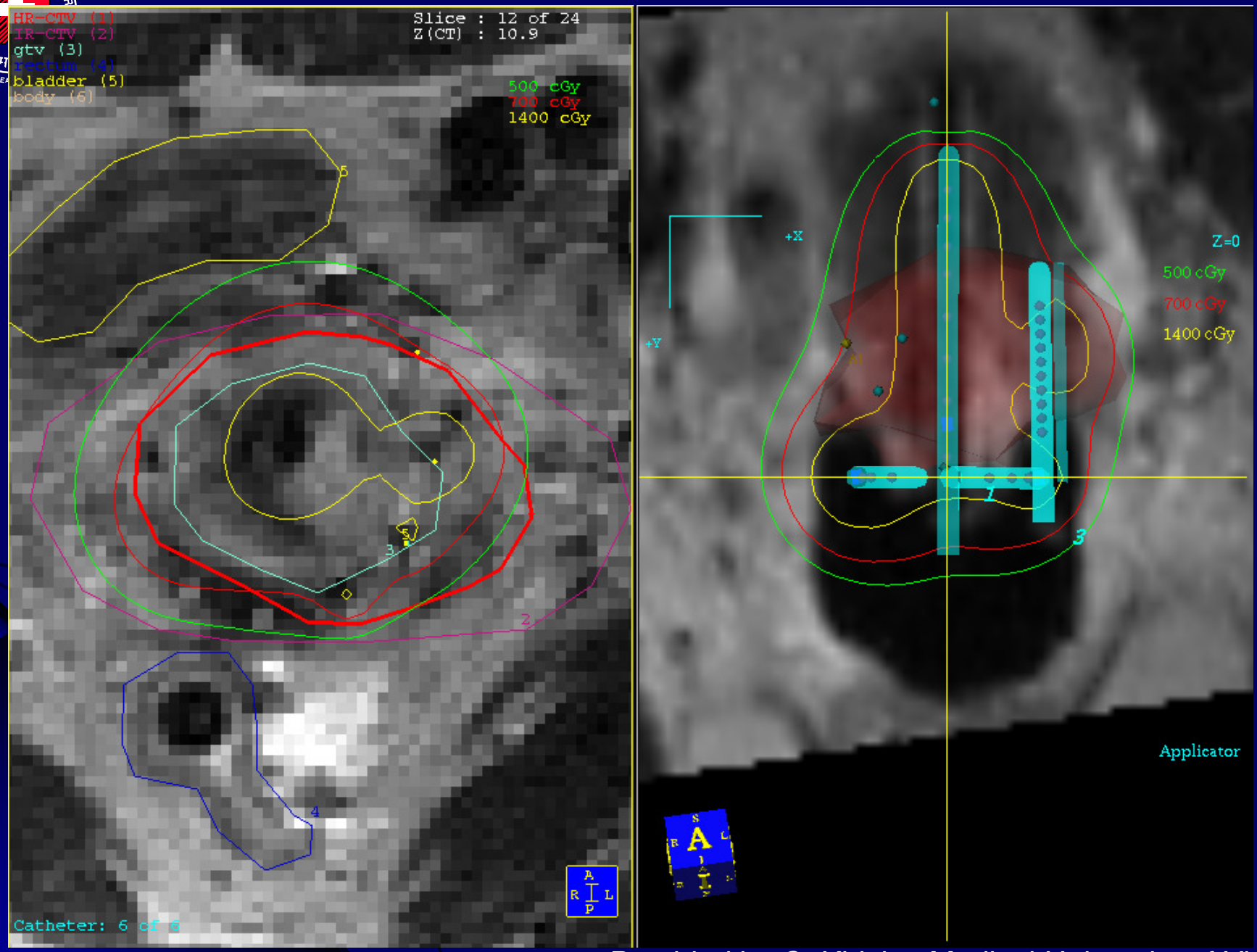
Provided by C. Kirisits, Medical University of Vienna

Graphical optimization



Provided by C. Kirisits, Medical University of Vienna

Graphical optimization



Provided by C. Kirisits, Medical University of Vienna

Inverse Optimization

- IPSA (Inverse Planning Simulated Annealing)
- HIPO (Hybrid Inverse Planning Optimization)

IPSA

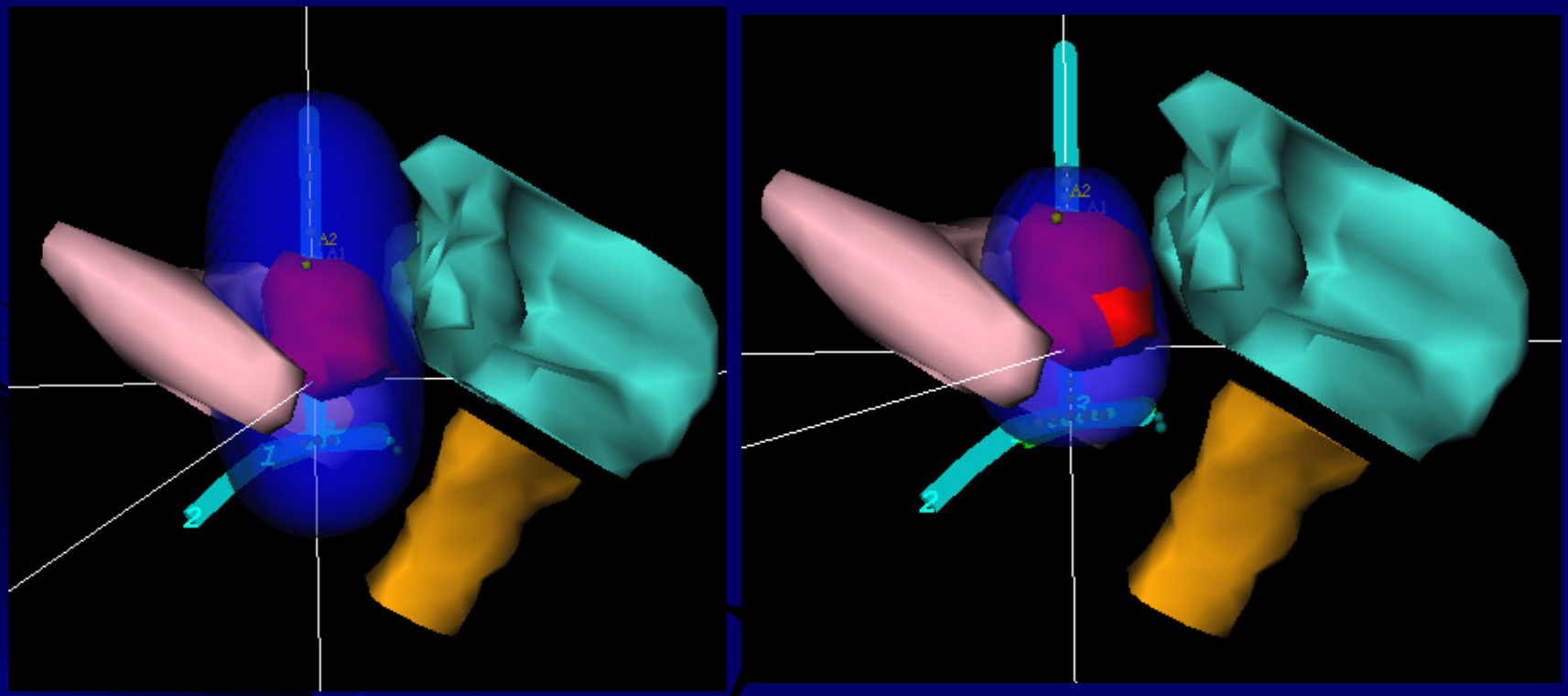
- Provides fast and automatic solutions
- Superior plans as compared to manually optimized plans
- large heterogeneity in dwell time values, clinical impact of which is unknown,
- Draw help structures around the catheter to minimize the variation of dwell times.

Chajon et al, IJROBP,2007

HIPO

- Dwell Time Gradient Restriction (DTGR) that reduces the variation of dwell time
- User can “lock” certain part of the dwell time so that the optimizer doesn’t change these dwell weights (very useful for IC+IS application)

Conventional Pear shaped
Vs
Conformal

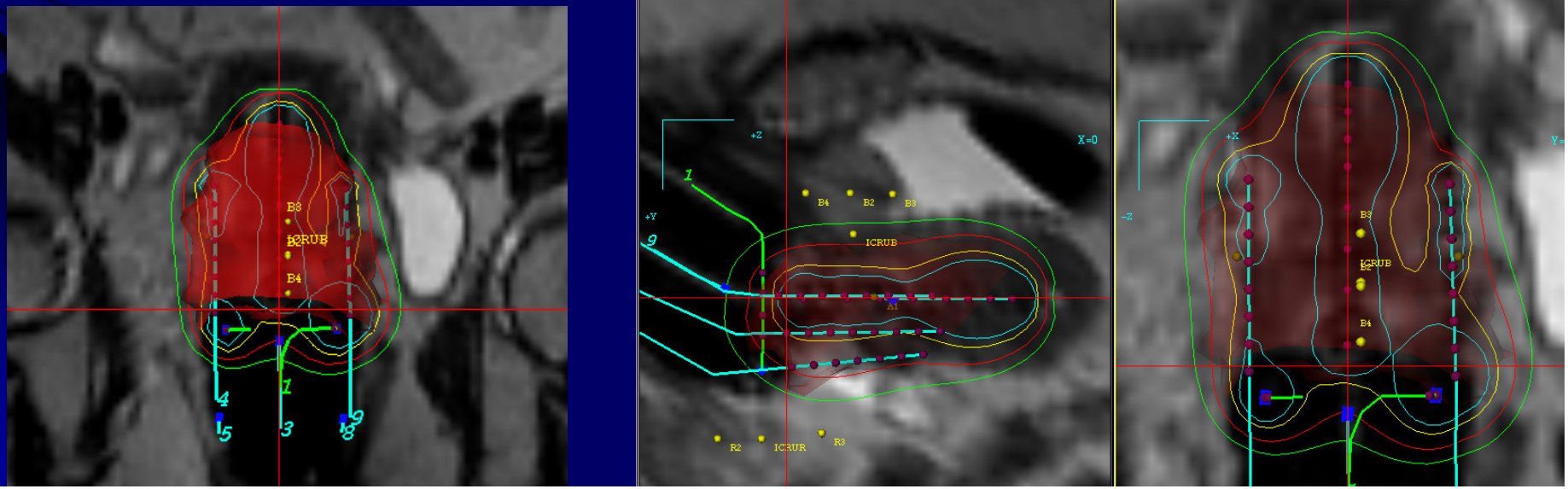


Conventional Pear shaped Vs Conformal

- GEC ESTRO recommendations only for reporting.
- Keep the pear shaped distribution unless it is really required to deviate
- Optimize the dwell weights in tandem and ovoid to reduce dose to sigmoid, Bladder & rectum respectively
- Large deviation from the standard loading pattern may be avoided
- If combined IC+IS is used IC loading pattern to be followed, with 25% loading to needles

optimization

- Check for
  - Hot spots
  - Loading pattern (graphical optimization may change the loading significantly which may not be acceptable)
  - If using needles, loading ratio of needles (10-20% to needles)
  - Pear shape, its distortion



Conclusion – optimisation techniques

Manual	Always start optimisation with standard loading pattern
Graphical	
Inverse	

Thank You