MEDICAL UNIVERSITY OF VIENNA

COMPREHENSIVE CANCER CENTER VIENNA

Image guided Adaptive Brachytherapy for Cervical Cancer

Christian Kirisits

Acknowledgements

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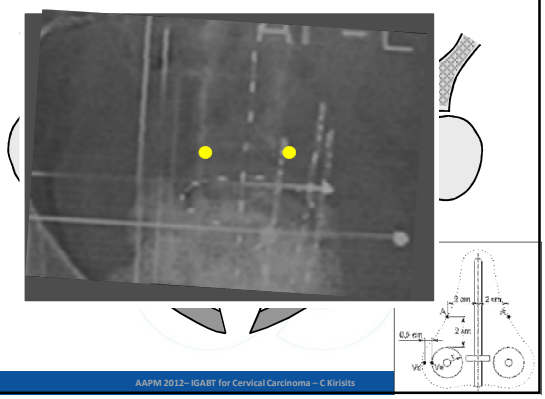
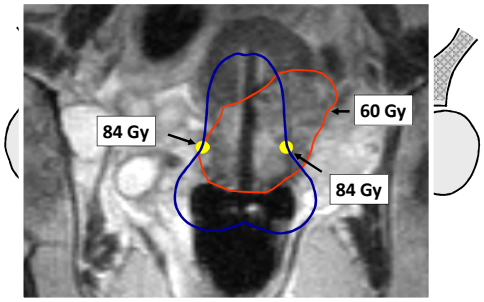
The financial support by the Federal Ministry of Economy, Family and Youth and the National Foundation for Research, Technology and Development is gratefully acknowledged.

Point A

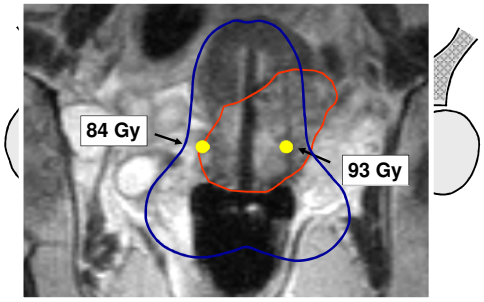


Point A / target dose



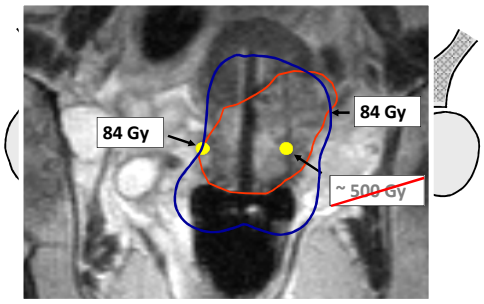
D90 = 65 Gy EQD2

Point A / target dose



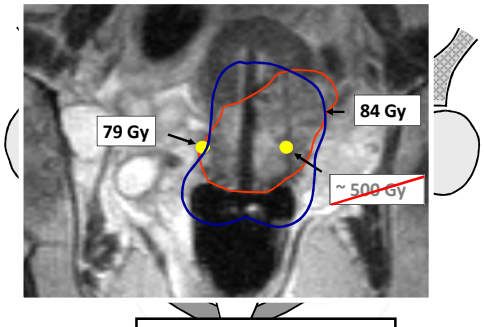
D90 = 75 Gy EQD2

Point A / target dose



D90 = 90 Gy EQD2

Point A / target dose



D90 = 85 Gy EQD2

Recommendations

- GYN GEC ESTRO recommendations I (Haie-Meder et al.) - contouring
- GYN GEC ESTRO recommendations II (Pötter et al.) - dose parameters
- GYN GEC ESTRO recommendations III (Hellebust et al.) - reconstruction
- GYN GEC ESTRO recommendations IV (Dimopoulos et al.) - imaging
- ABS recommendations on GYN general (Viswanathan and Thomadsen, ABS Cervical Cancer Recommendations Committee) -general
- ABS recommendations on GYN HDR (Viswanathan et al.)
- ABS recommendations on GYN PDR (Lee et al.)

- ICRU 38 revision (coordinators: R. Pötter and C. Kirisits, committee members: B. Erickson, C. Haie-Meder, J. Lindegaard, E. van Limbergen, J. Rownd, K. Tanderup, B. Thomadsen)

DOSE AND VOLUME PARAMETERS FOR PRESCRIBING, RECORDING, AND REPORTING TARGET VOLUMES AND ORGANS AT RISK

Target parameters

TRAK, point A

D_{98}, D_{90}, D_{50} for HR CTV, IR CTV* (*if used for prescription)

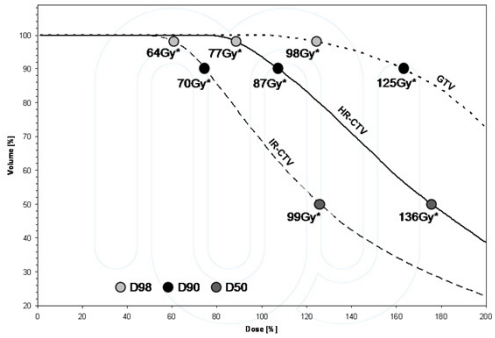
D_{98}, D_{90} for GTV

D_{98}, D_{90} for PTV (if applicable, only for research!!)

D_{98}?, D_{50}?, D_{90}? for pathological lymph nodes

(state of the art parameters in bold)

DVH for target volumes



DOSE AND VOLUME PARAMETERS FOR PRESCRIBING, RECORDING, AND REPORTING TARGET VOLUMES AND ORGANS AT RISK

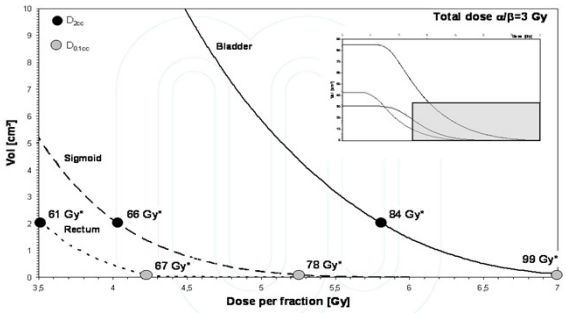
OAR parameters

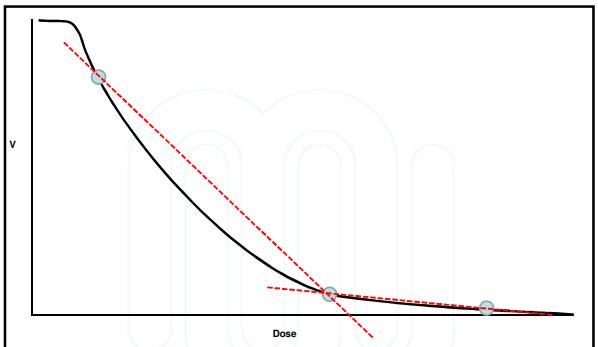
D_{2cm^3}, $D_{0.1cm^3}$ for high doses to bladder, rectum, sigmoid and bowel (if applicable)

Vaginal points at level of vaginal sources

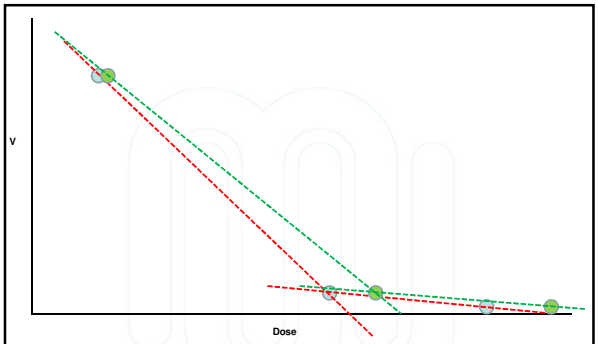
Intermediate dose by e.g. V_{50Gy}, D_{50}, and points and lengths

DVH for OAR

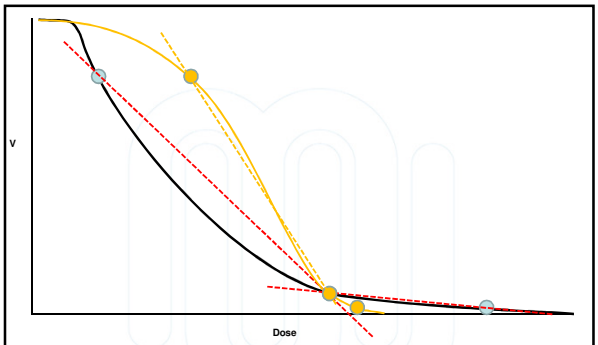




Typical DVH curve for OAR from intracavitary BT

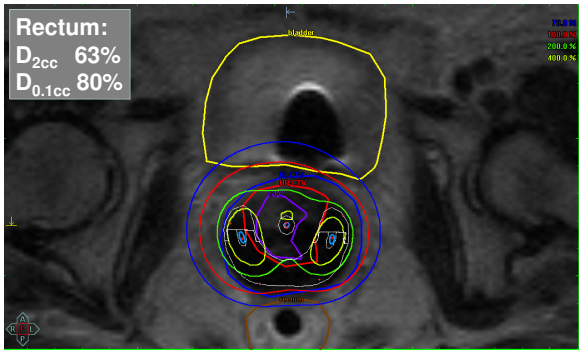


An increase of TRAK will result in an increase of the dose to the OAR. The shape of the new curve is strechted, the ratio of the two upper points on the DVH curve becomes larger. The impact on the low dose regions is smaller. The same ratio applies. The blue symbols are from the previous figure with lower dose to the OAR. The third point in the low dose region is not needed necessarily to describe the shape.

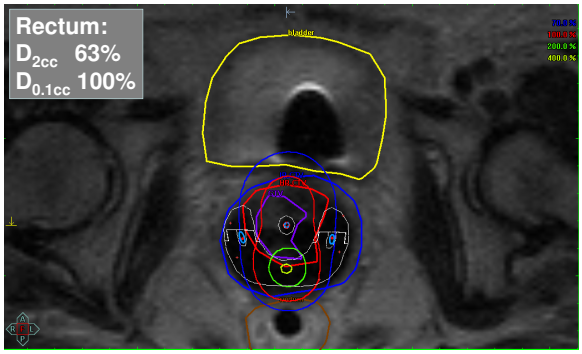


The orange curve could be the result of different external beam component or other treatment technique. The shape of the curve is completely changed. All three points on the DVH curve are needed to describe the difference to the two curves shown before.

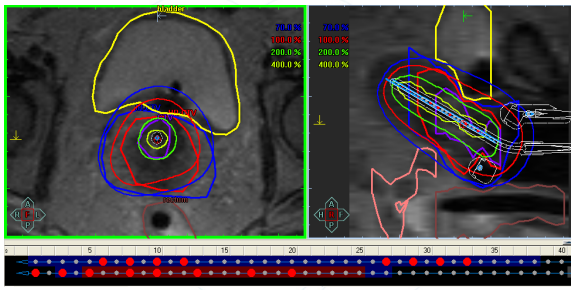
Typical dose distribution



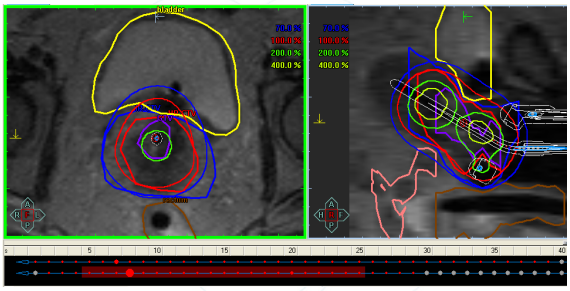
Optimized only based on limited parameter set

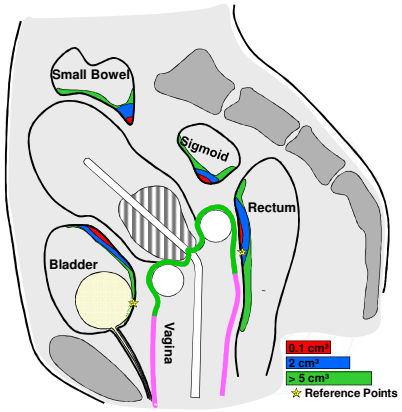


Standard loading

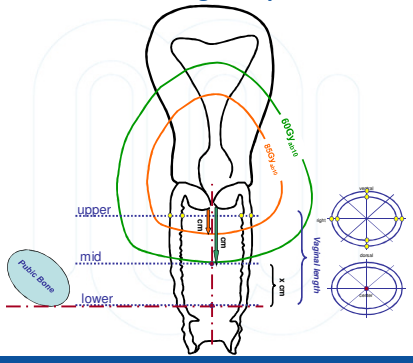


~~Inverse optimization~~
~~without thinking~~





Vaginal dose –
DVH, Dose surface histogram, points, dimensions



FROM PLANNING AIMS TO PRESCRIPTION

Traditional concepts:

"when prescribing to a target, the prescription dose is the planned dose to cover this target as completely as possible."

or

prescription to a 100% isodose which is "to cover" the target volume"

Need for common terminology according to ICRU reports on proton treatment and IMRT

- **Planning aim dose**
  - ➔ Set of dose and dose/volume constraints for a treatment
- **Prescribed dose**
  - ➔ Finally accepted treatment plan (which is assumed to be delivered to an individual patient)
- **Delivered dose**
  - ➔ Actually delivered dose to the individual patient

Need for common terminology according to ICRU reports on proton treatment and IMRT

Example:

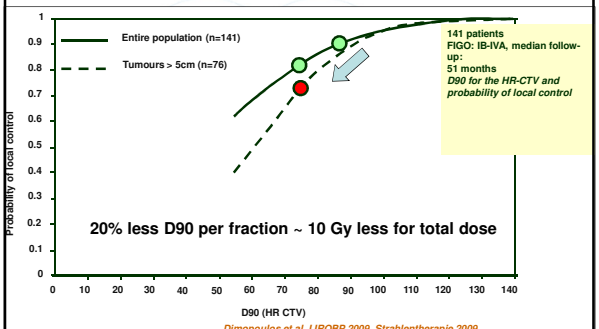
~~Previously: 4x7 Gy ~ 84 Gy EQD2 prescribed, D90 was mean 93 Gy~~

Planning aim was to deliver 4 x 7 Gy ~ 84 Gy, D_{2cm^3} for rectum, sigmoid < 70 Gy EQD2, bladder < 90 Gy EQD2

Prescribed dose was mean 93 Gy ± 13 Gy (1SD) EQD2 to D_{90} HR CTV

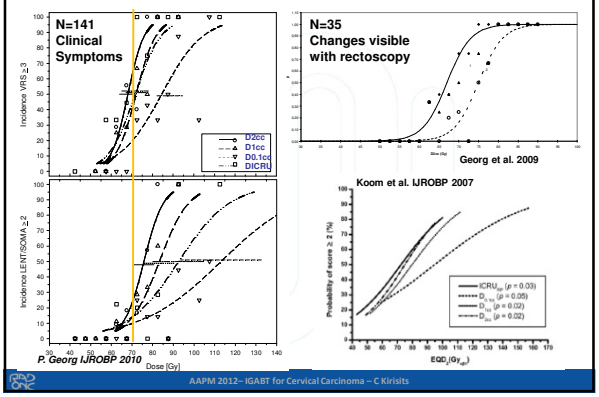
Delivered dose ? *Depending on variations and uncertainties – on average no systematic deviation from prescribed dose*

LINKING DVH PARAMETERS TO CLINICAL OUTCOME for TARGET/TUMOUR



Dimopoulos et al. IJROBP 2009, Strahlentherapie 2009

Rectum dose

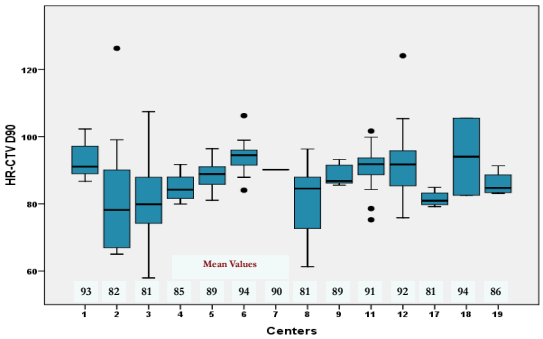


www.embracestudy.dk

> 650 patients enrolled!

HR CTV D90 by Center

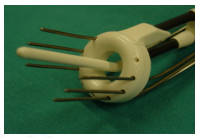
Preliminary - 3D QA pending!



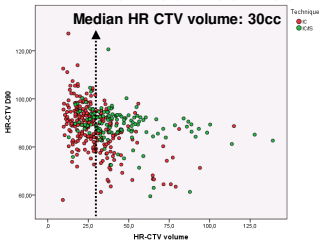
HR-CTV dose and technique

Large tumours (>30cc):
- IC/IS increases target dose by 6Gy
- OAR doses not increased

Small tumours (≤30cc)
- No difference for target or OARs

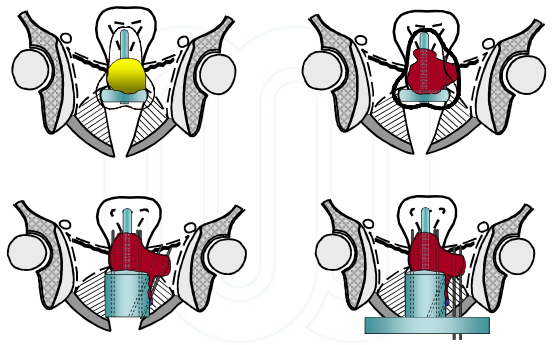


IC/IS Combination of intracavitary and interstitial application



HR CTV >30cc		Mean ± SD
HRCTV D90	IC	81.9 ± 9.5 Gy
	IC/IS	88.2 ± 7.7 Gy
Bladder D2cc	IC	79.1 ± 10.3 Gy
	IC/IS	78.7 ± 13.4 Gy
Rectum D2cc	IC	65.6 ± 8.2 Gy
	IC/IS	64.6 ± 6.1 Gy
Sigmoid D2cc	IC	64.4 ± 6.4 Gy
	IC/IS	63.7 ± 7.6 Gy

Application technique and patterns of tumor regression



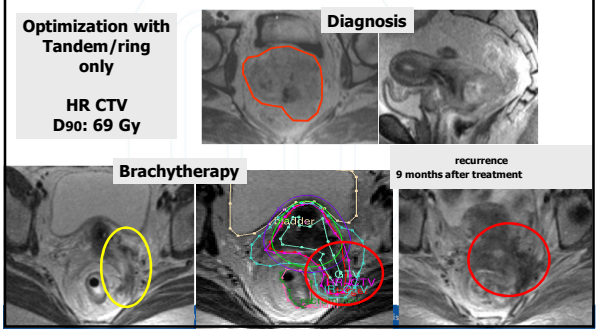
IIIB, 8 cm width, insufficient response (11/99)

no adaptation of application technique

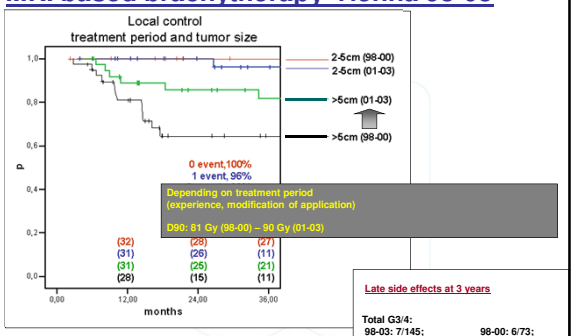
intracavitary approach only

Optimization with Tandem/ring only

HR CTV
D90: 69 Gy



Improvement of local control
MRI based brachytherapy Vienna 98-03

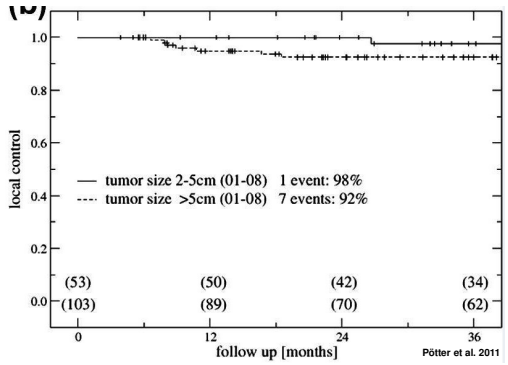


Late side effects at 3 years

Total G3/4:
98-03: 7/145; 98-00: 6/73;
[93-97: 14/189] 01-03: 1/72

Pötter et al. Radiother Oncol 2007

Current local control rates (Vienna experience)



Pötter et al. 2011

Uncertainties?
Where to improve?

Example for HDR intracavitary Cervix brachytherapy – per fraction

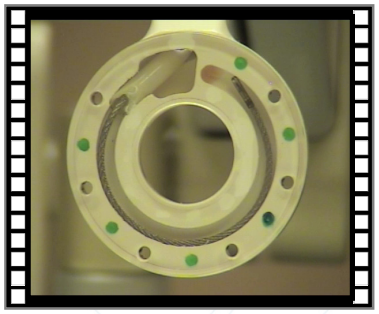
Category	Optimum level	Assumptions
Source strength	2%	PSDL traceable calibrations
Treatment planning	3%	Reference data with the appropriate bin width is used
Medium dosimetric corrections	1%	Applicator without shielding and CTV inside pelvis (concerning for scatter)
Dose delivery including registration of applicator geometry to anatomy	4%	Accurate QA concept for commissioning and constancy checks, especially for source positioning and applicator/source path geometry, appropriate imaging techniques, applicator libraries
Interfraction/Intrafraction changes	12%	For one treatment plan per applicator insertion but several subsequent fractions – check for major deviations in subsequent fractions
Total dosimetric uncertainty for one single fraction	**13%**	

Example for HDR intracavitary Cervix brachytherapy – total dose 4 fractions

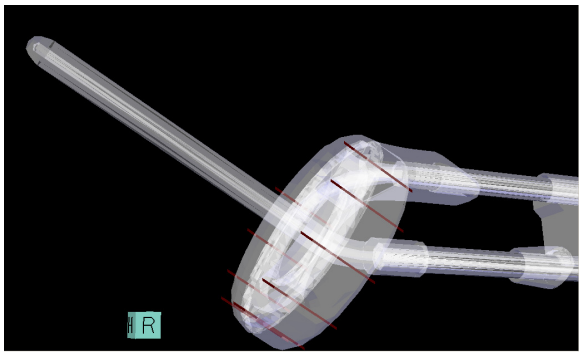
Category	Optimum level	Assumptions
Source strength	2%	PSDL traceable calibrations
Treatment planning	3%	Reference data with the appropriate bin width is used
Medium dosimetric corrections	1%	Applicator without shielding and CTV inside pelvis (concerning for scatter)
Dose delivery including registration of applicator geometry to anatomy	4% $\xrightarrow{1/\sqrt{N}}$ **2%**	Accurate QA concept for commissioning and constancy checks, especially for source positioning and applicator/source path geometry, appropriate imaging techniques, applicator libraries
Interfraction/Intrafraction changes	12% $\xrightarrow{1/\sqrt{N}}$ **6%**	For one treatment plan per applicator insertion but several subsequent fractions –
Total dosimetric uncertainty for entire BT	**7%**	

We would need interfraction value < 3% to have total uncertainy < 5 %

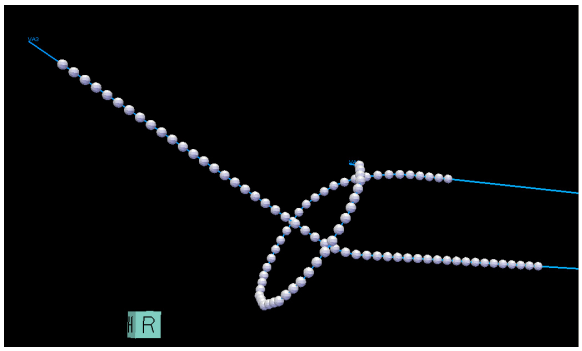
Visualization of the "real" source positions in relation to the outer dimensions and holes of the Vienna ring applicator



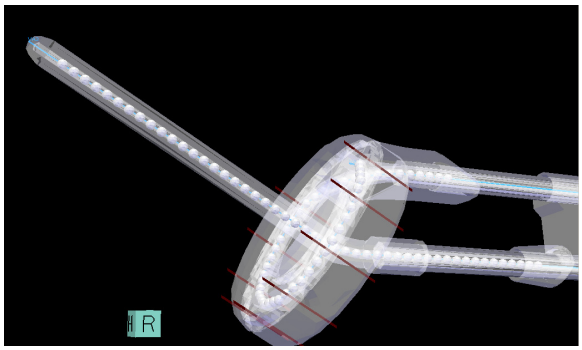
Applicator surface



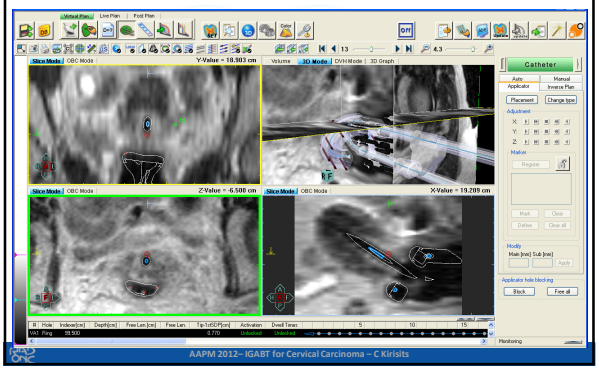
Source path



Applicator + Source path



Reconstruction



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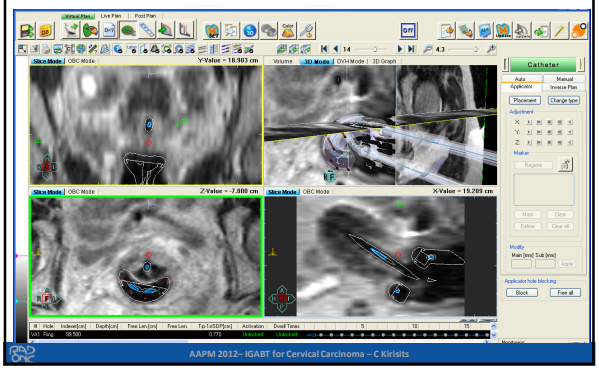

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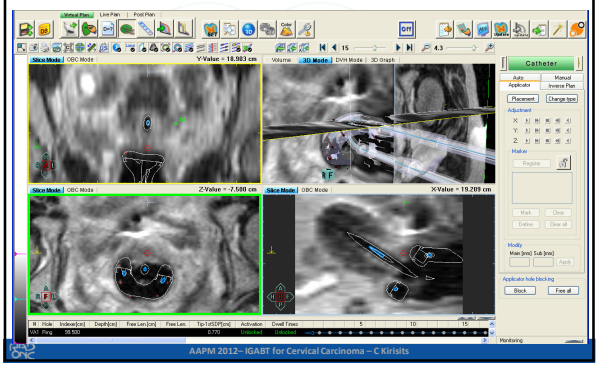

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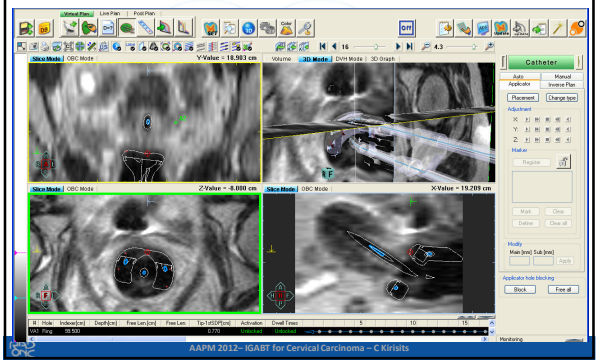

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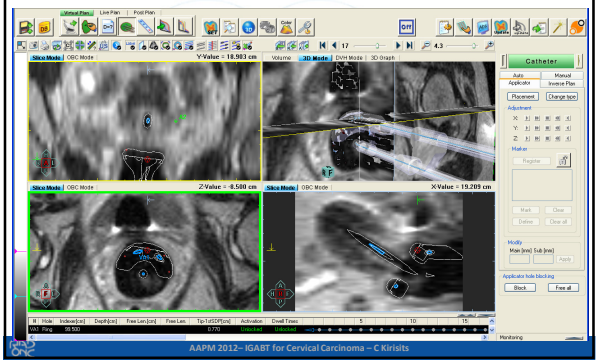

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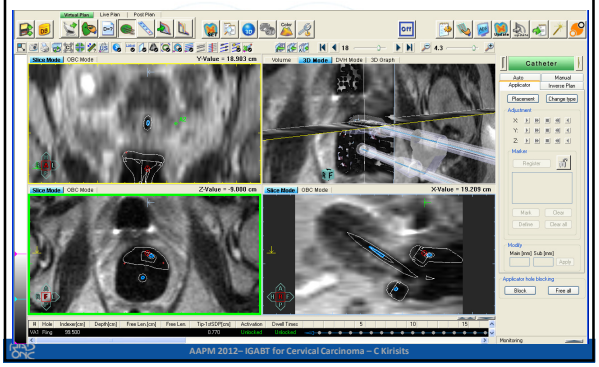
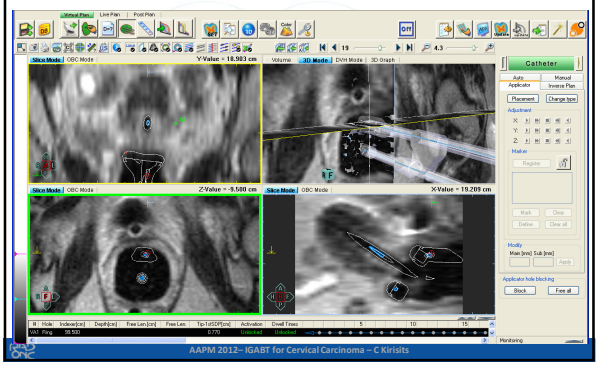


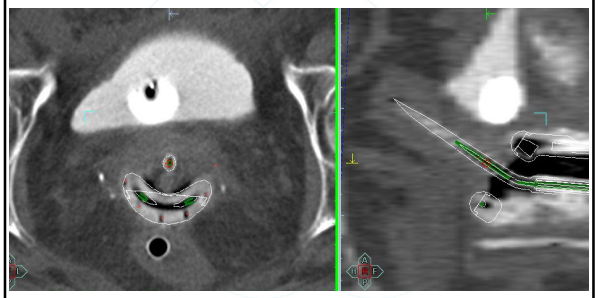
Reconstruction



MRI for each fraction?

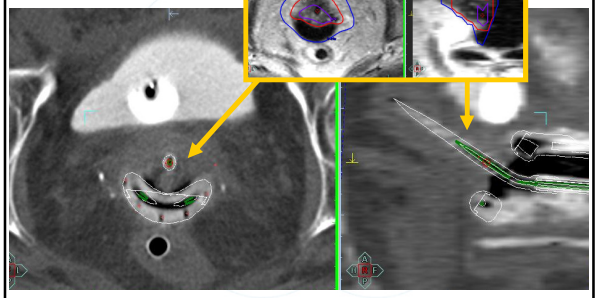
2nd application: CT

3D applicator reconstruction



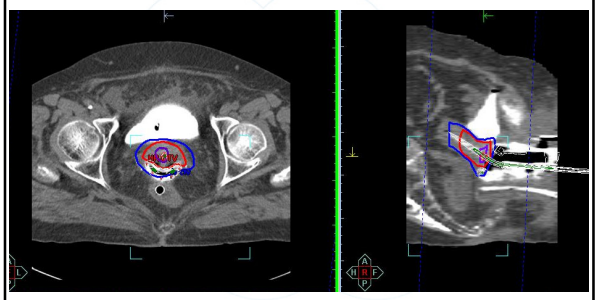
2nd application: CT

3D applicator reconstruction
Target transfer

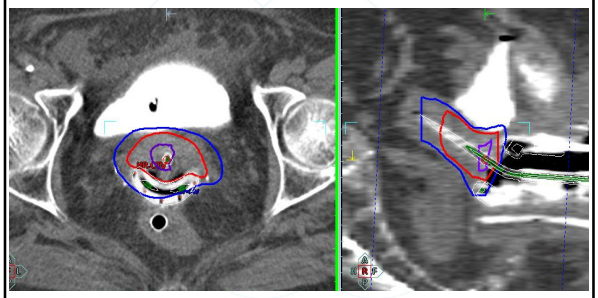


2nd application: CT

Target transfer from MRI to CT with applicator as reference system

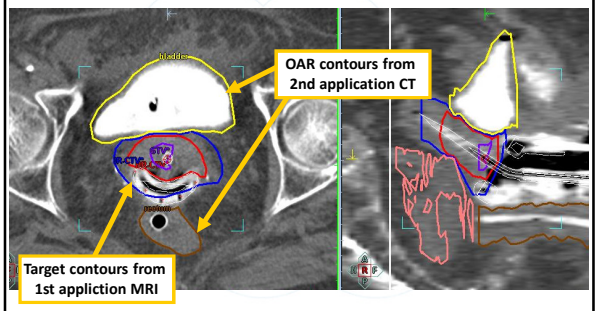


2nd application: CT



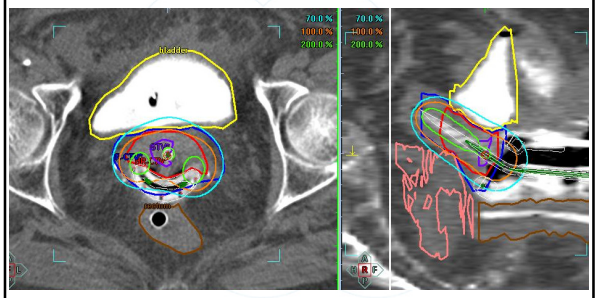
2nd application: CT

Contouring OAR on CT



2nd application: CT

Dose planning and optimization based on copied target and individual OAR contours. All dose constraints for targets and OAR have to be achieved.



Levels

- X-ray
- CT-based for one application
- CT-based for all applications
- MRI for first, CT for subsequent applications
- MRI for each application
- MRI for each fraction

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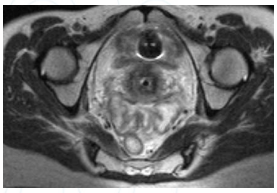
Ultrasoundtechnology



Outlook

- ICRU 38 revision
- EMBRACE studies to increase insight into dose-effect relationships
- New cost effective methods keeping accuracy reasonable