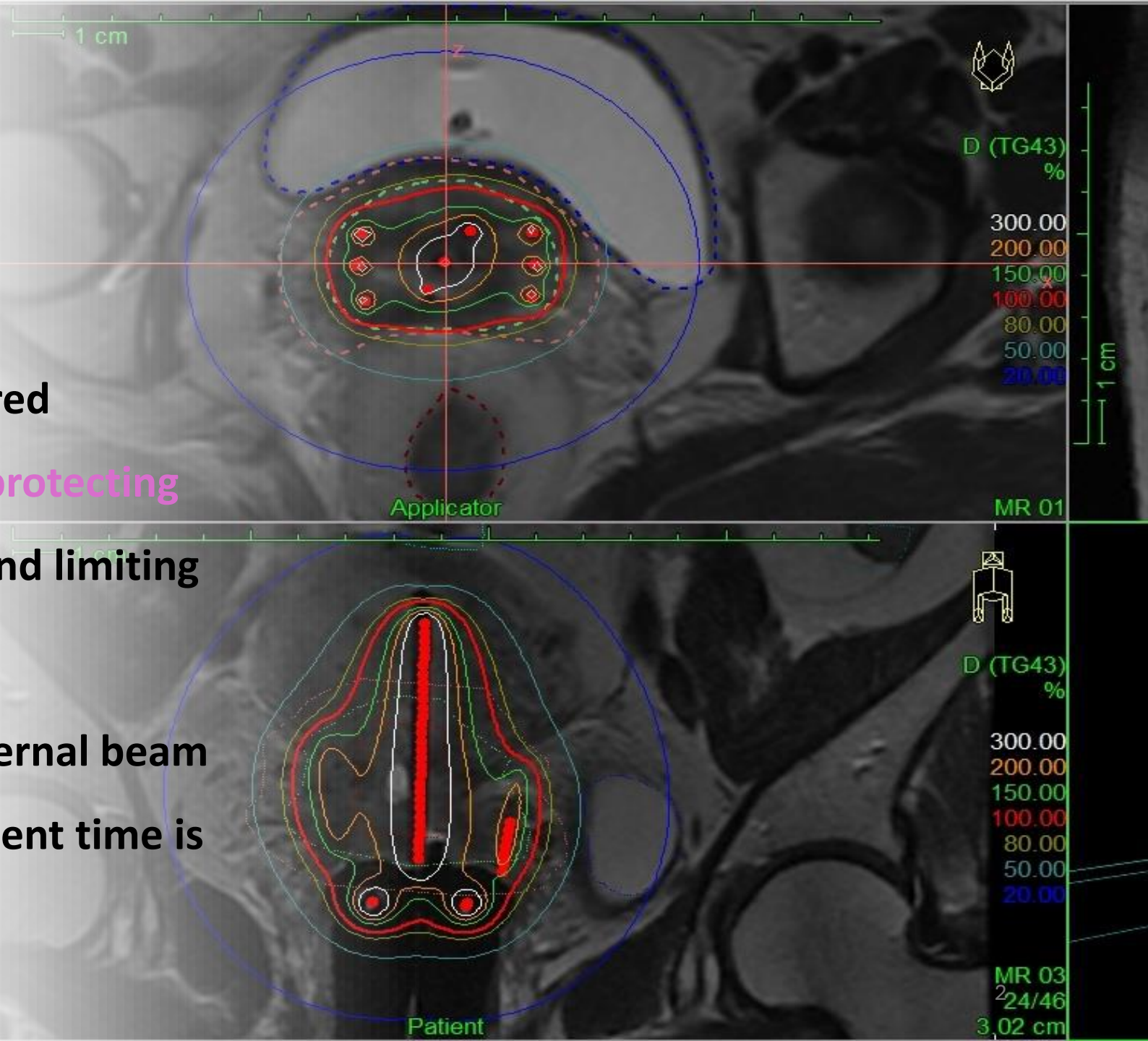
CHALLENGES IN BRACHYTHERAPY

Mintra Keawsamur

King Chulalongkorn Memorial Hospital

Benefits of Brachytherapy

- **Localized, the radiation is delivered specifically to the tumor mass, protecting the surrounding healthy tissue and limiting exposure.**
- **Fewer side effects than does external beam radiation, and the overall treatment time is usually shorter.**

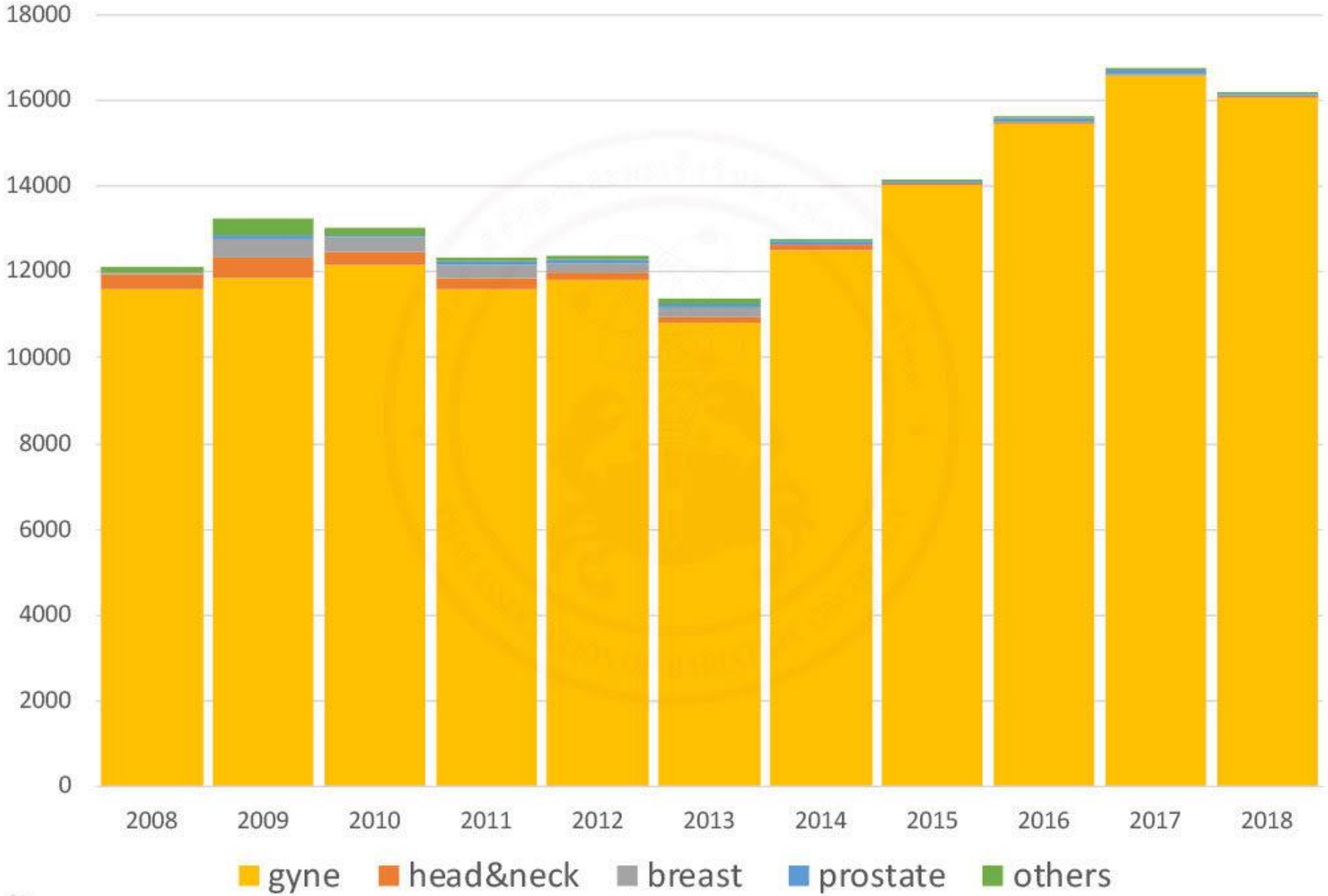


Thai Medical Physicist Society

THASTRO
สมาคมรังสีรักษาและมะเร็งวิทยาแห่งประเทศไทย

THASTRO: Brachytherapy Patients, 2008-2018 (insertions)

*some missing data



Ref* : https://www.thastro.org/

THASTRO
สมาคมรังสีรักษาและมะเร็งวิทยาแห่งประเทศไทย

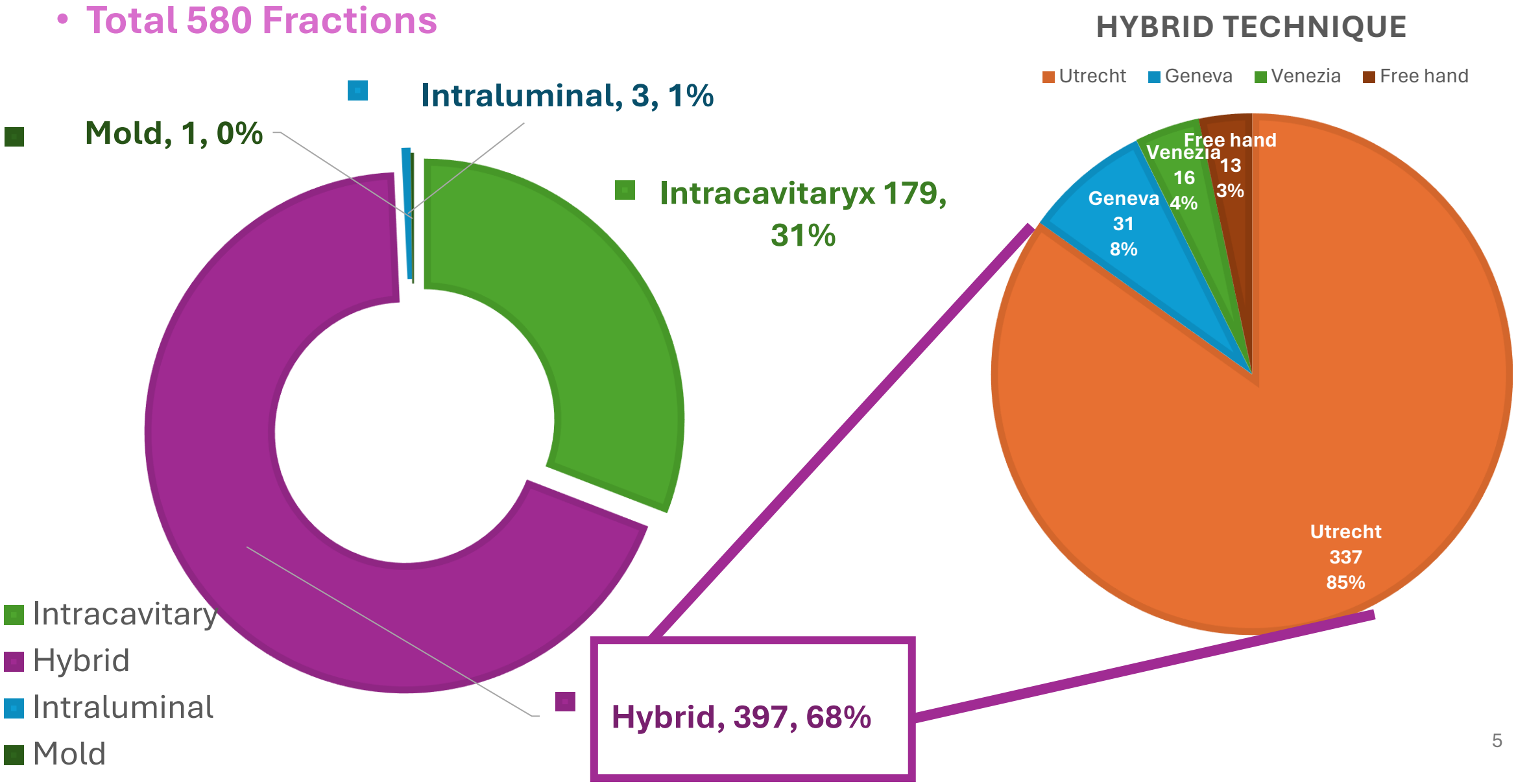
Thai Medical Physicist Society

Number of PT in Thailand 2020-2021

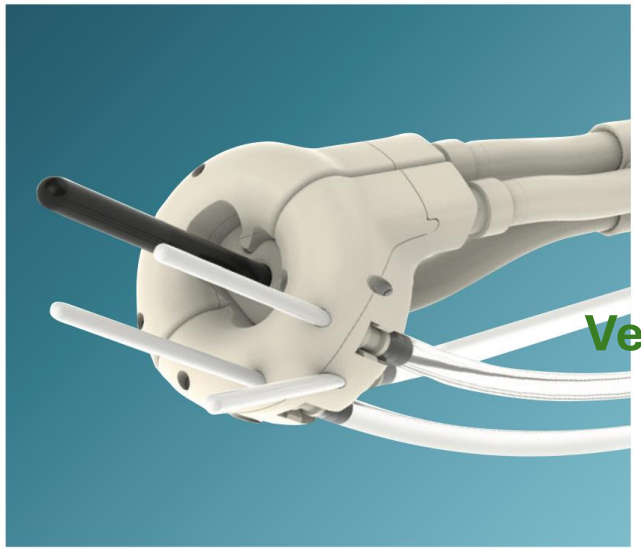
BRACHYTHERAPY number of patients (number of insertions)	
Head/neck	4(13)
Eye	12
Skin	2(8)
Brain	0
Lung	0
Colorectal	3(>2)
Other GI (e.g. liquid brachytherapy for liver metastases)	
Breast	1(1[illegible])
Gynaecological tumours	>5354(>10846)
Prostate	40(>57)
Intravascular brachytherapy	0
Other ……..	1(2)
TOTAL	>5417(>10938)

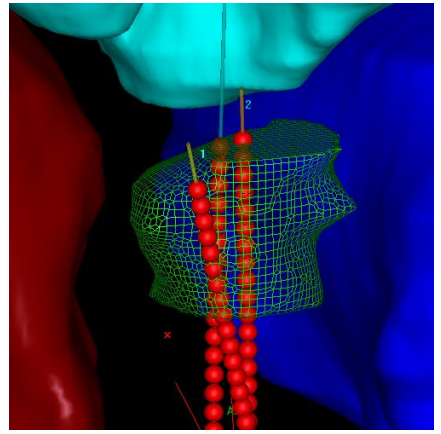
Ref* : https://www.thastro.org/

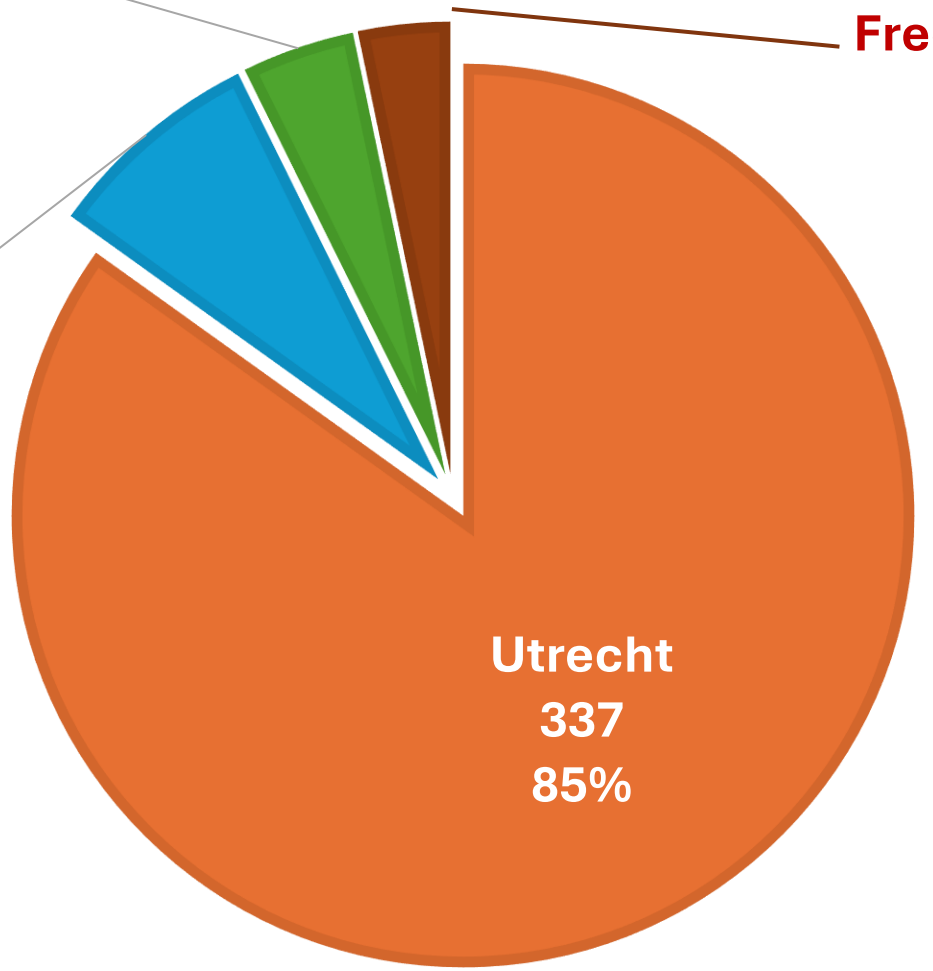
- King Chulalongkorn Memorial Hospital
- 2023
- Total 580 Fractions



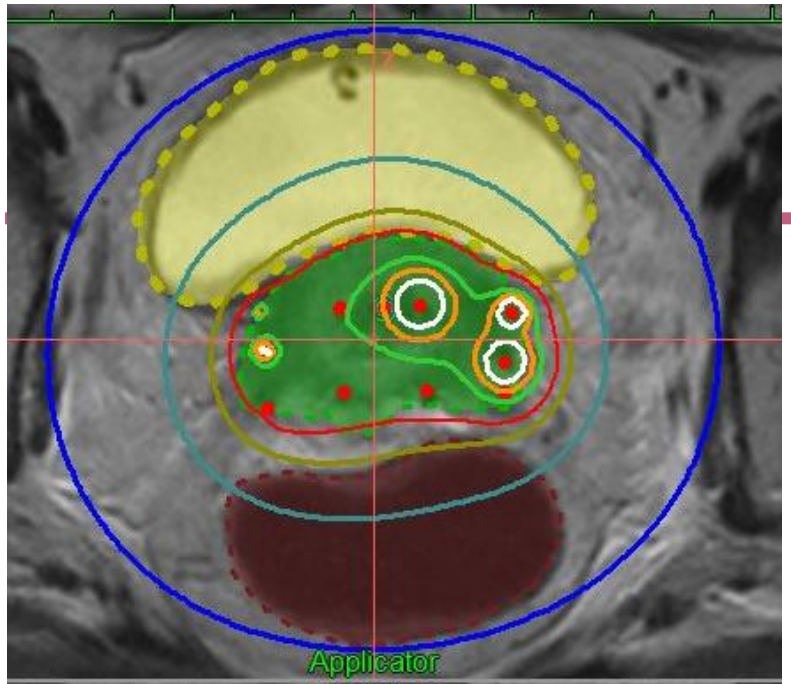
HYBRID TECHNIQUE

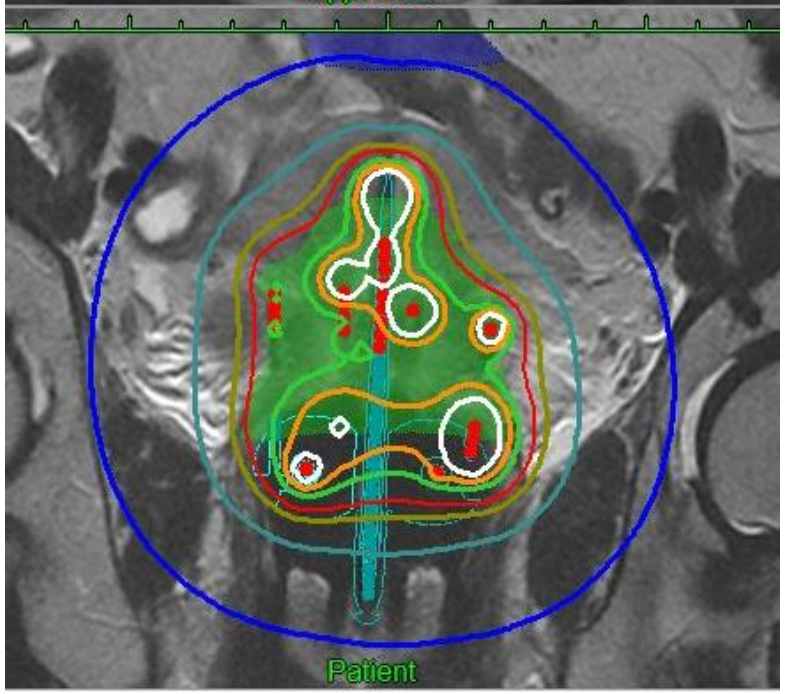






Brachytherapy

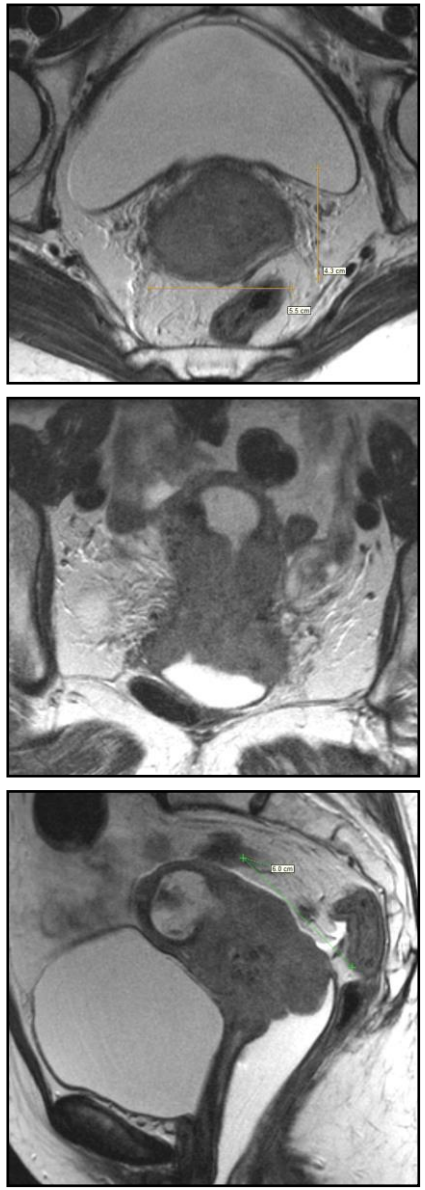


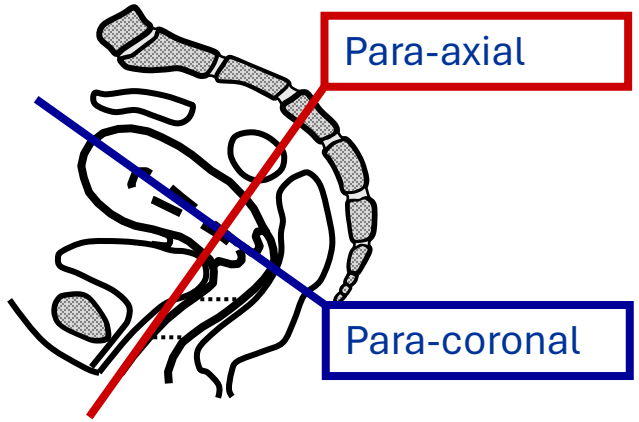


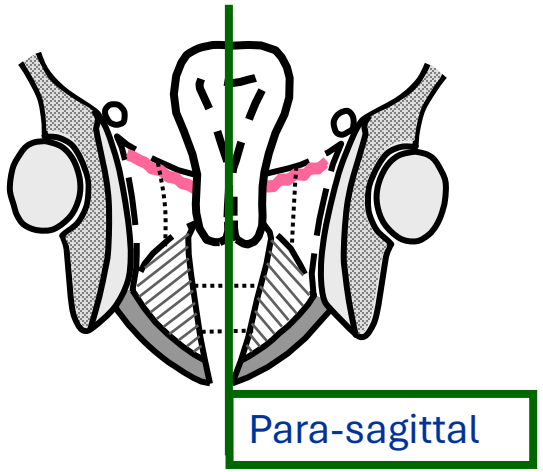
100% MR-based planning

Flexitron

Magnetic Resonance Imaging







Gold Standard

Advantages

- **Excellent soft tissue contrast**
- **Depict GTV, CTV, organs at risk**
- **Multiplanar imaging**
- **No radiation, no i.v. contrast**

Limitations

- **↑Cost, ↓availability**
- **Image acquisition time**
- **Equipment compatibility**
- **Infrastructure and personnel requirements**
- **Distortions, artifacts**

Dimopoulos J, et al. Radiother Oncol. GEC ESTRO recommendations

Magnetic Resonance Imaging

Contents lists available at SciVerse ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

GEC-ESTRO Recommendations

Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group (IV): Basic principles and parameters for MR imaging within the frame of image based adaptive cervix cancer brachytherapy

Johannes C.A. Dimopoulos[a], Peter Petrow[b], Kari Tanderup[c], Primoz Petric[d], Daniel Berger[e], Christian Kirisits[e], Erik M. Pedersen[c], Erik van Limbergen[f], Christine Haie-Meder[g], Richard Pötter[e,*]

[a] Metropolitan Hospital, Athens, Greece; [b] Institut Curie, Paris, France; [c] Aarhus University Hospital, Denmark; [d] Institute of Oncology Ljubljana, Slovenia; [e] Comprehensive Cancer Center, Medical University of Vienna, Austria; [f] Universitaire Ziekenhuis Gasthuisberg Leuven, Belgium; [g] Institut Gustave Roussy, Villejuif, France

Thai Medical Physicist Society

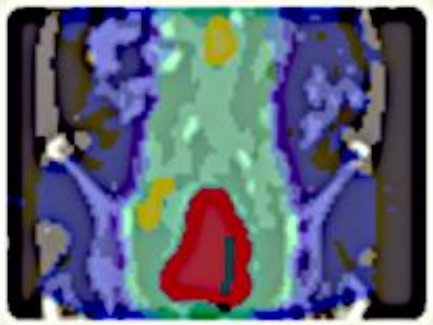
" It is useful to perform pelvic MRI scanning prior to radiotherapy (***"Pre-RT-MRI examination"***) and at the time of BT (***"BT MRI examination"***) with one MR imager. "

Pre-RT MRI examination

sufficient information about tumour extent, tumour growth pattern and topography of patho-anatomical structures in three dimensions (3D) **at the time of diagnosis**

BT MRI examination

sufficient information about tumour/target extent, tumour/target growth pattern and topography of patho-anatomical structures in three dimensions (3D) at **the time of BT with the applicators in place**



EMBRACE

{ Image guided intensity modulated External beam radiochemotherapy and MRI based adaptive BRAchytherapy in locally advanced CErvical cancer }

EMBRACE

Image-guided intensity modulated External beam radiochemotherapy and MRI-based adaptive BRAchytherapy in locally advanced CErvical Cancer, multicenter prospective cohort studies

EMBRACE

- The GEC ESTRO gyn network
- **EMBRACE I :** applies the Gyn GEC ESTRO Recommendations for target delineation and dose volume reporting. The retrospective data collection was analogue to that of what was implemented for EMBRACE I. (finalized in 2013 with overall 814 patient)
- **EMBRACE II :** prescribes MRI guided adaptive brachytherapy with combined intracavitary/interstitial techniques and specific dose volume constraints for adaptive targets and OARs and image guided external beam radiotherapy for specific targets and techniques and concomitant radiochemotherapy. (initiated in 4/2016)

Clinical and Translational Radiation Oncology 9 (2018) 48–60

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journal homepage: www.elsevier.com/locate/ctro

Review Article

The EMBRACE II study: The outcome and prospect of two decades of evolution within the GEC-ESTRO GYN working group and the EMBRACE studies

Richard Pötter [a,1], Kari Tanderup [b,1,*], Christian Kirisits [a], Astrid de Leeuw [c], Kathrin Kirchheiner [a], Remi Nout [d], Li Tee Tan [e], Christine Haie-Meder [f], Umesh Mahantshetty [g], Barbara Segedin [h], Peter Hoskin [i], Kjersti Bruheim [j], Bhavana Rai [k], Fleur Huang [l], Erik Van Limbergen [m], Max Schmid [a], Nicole Nesvacil [a], Alina Sturdza [a], Lars Fokdal [b], Nina Boje Kibsgaard Jensen [b], Dietmar Georg [a], Marianne Assenholt [b], Yvette Seppenwoolde [a], Christel Nomden [c], Israel Fortin [a,o], Supriya Chopra [g], Uulke van der Heide [n], Tamara Rumpold [a], Jacob Christian Lindegaard [b], Ina Jürgenliemk-Schulz [c], the EMBRACE Collaborative Group[2]

Image guided adaptive brachytherapy (IGABT) is changing clinical practice.

EMBRACE II

- Increased use of IC/IS technique in BT based on systematic adaptive volume contouring
- Reduction of vaginal source loading
- Systematic utilisation of IMRT
- Systematic utilisation of daily IGRT (set-up according to bony structures)
- EBRT target concept related to the primary tumour
- Concepts for OAR contouring
- EBRT dose prescription and reporting
- Adaptation of EBRT nodal elective CTV according to risk of nodal and systemic recurrence
- Systematic application of simultaneous chemotherapy
- Reduction of overall treatment time

Planning aims (soft constraints) and limits for prescribed dose (hard constraints) for BT treatment planning in EMBRACE II

Table 4
Planning aims (soft constraints) and limits for prescribed dose (hard constraints) for treatment planning in EMBRACE II. The EQD2 is calculated using $\alpha/\beta = 10$ for targets, $\alpha/\beta = 3$ for OAR and a repair halftime of 1.5 h. The total EQD2 include 45 Gy/25 fractions delivered by EBRT.

Target	D90 CTV_{HR} $EQD2_{10}$	D98 CTV_{HR} $EQD2_{10}$	D98 GTV_{res} $EQD2_{10}$	D98 CTV_{IR} $EQD2_{10}$	Point A $EQD2_{10}$
Planning Aims	>90 Gy <95 Gy	>75 Gy	>95 Gy	>60 Gy	>65 Gy
Limits for Prescribed Dose	>85 Gy	–	>90 Gy	–	–
OAR	Bladder D_{2cm3} $EQD2_3$	Rectum D_{2cm3} $EQD2_3$	Recto-vaginal point $EQD2_3$	Sigmoid D_{2cm3} $EQD2_3$	Bowel D_{2cm3} $EQD2_3$
Planning Aims	<80 Gy	<65 Gy	<65 Gy	<70 Gy*	<70 Gy*
Limits for Prescribed Dose	<90 Gy	<75 Gy	<75 Gy	<75 Gy*	<75 Gy*

* For the sigmoid/bowel structures these dose constraints are valid in case of non-mobile bowel loops resulting in the situation that the most exposed volume is located at a similar part of the organ.

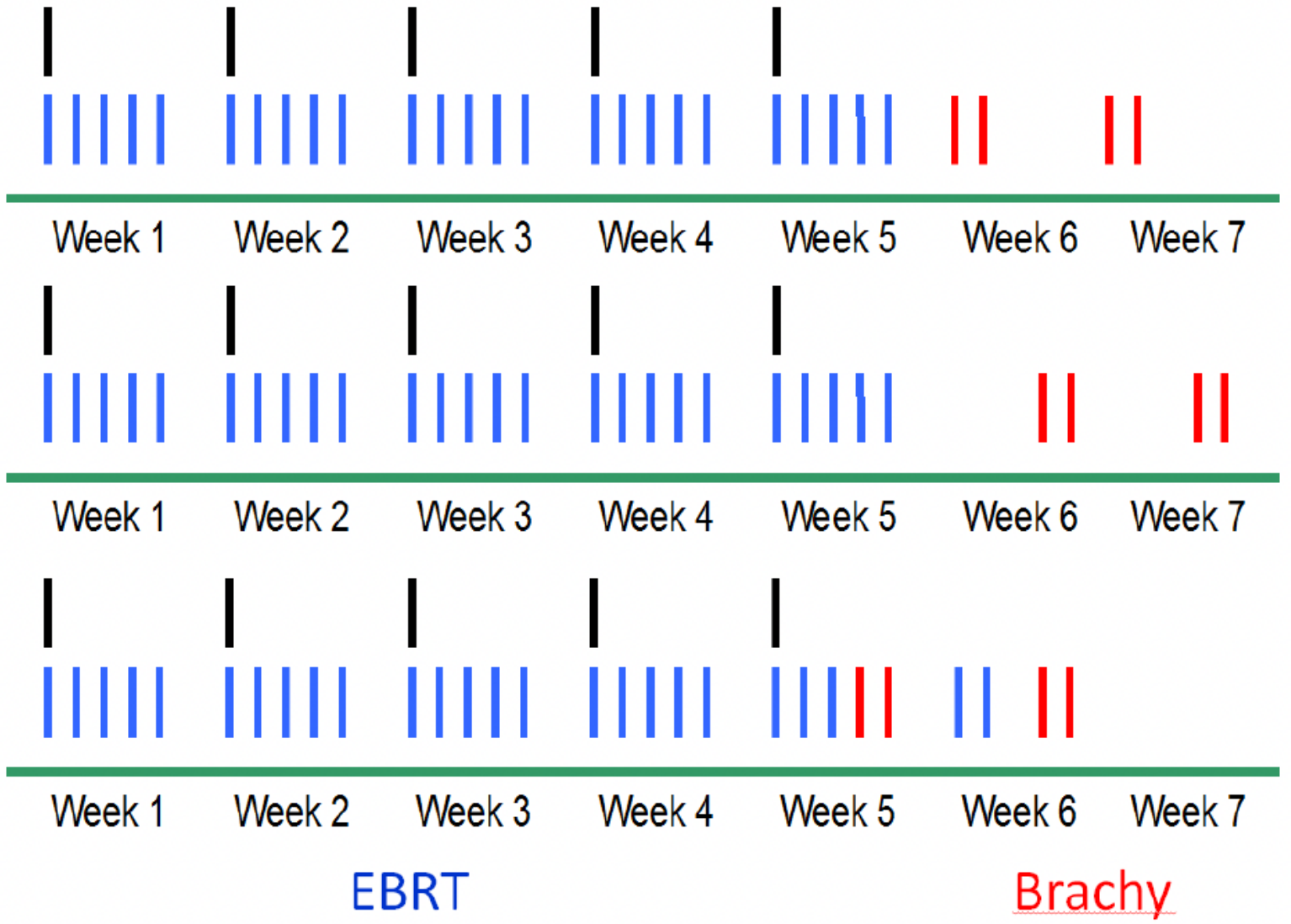
Dose constraints for **EBRT** of the EMBRACE II study protocol.

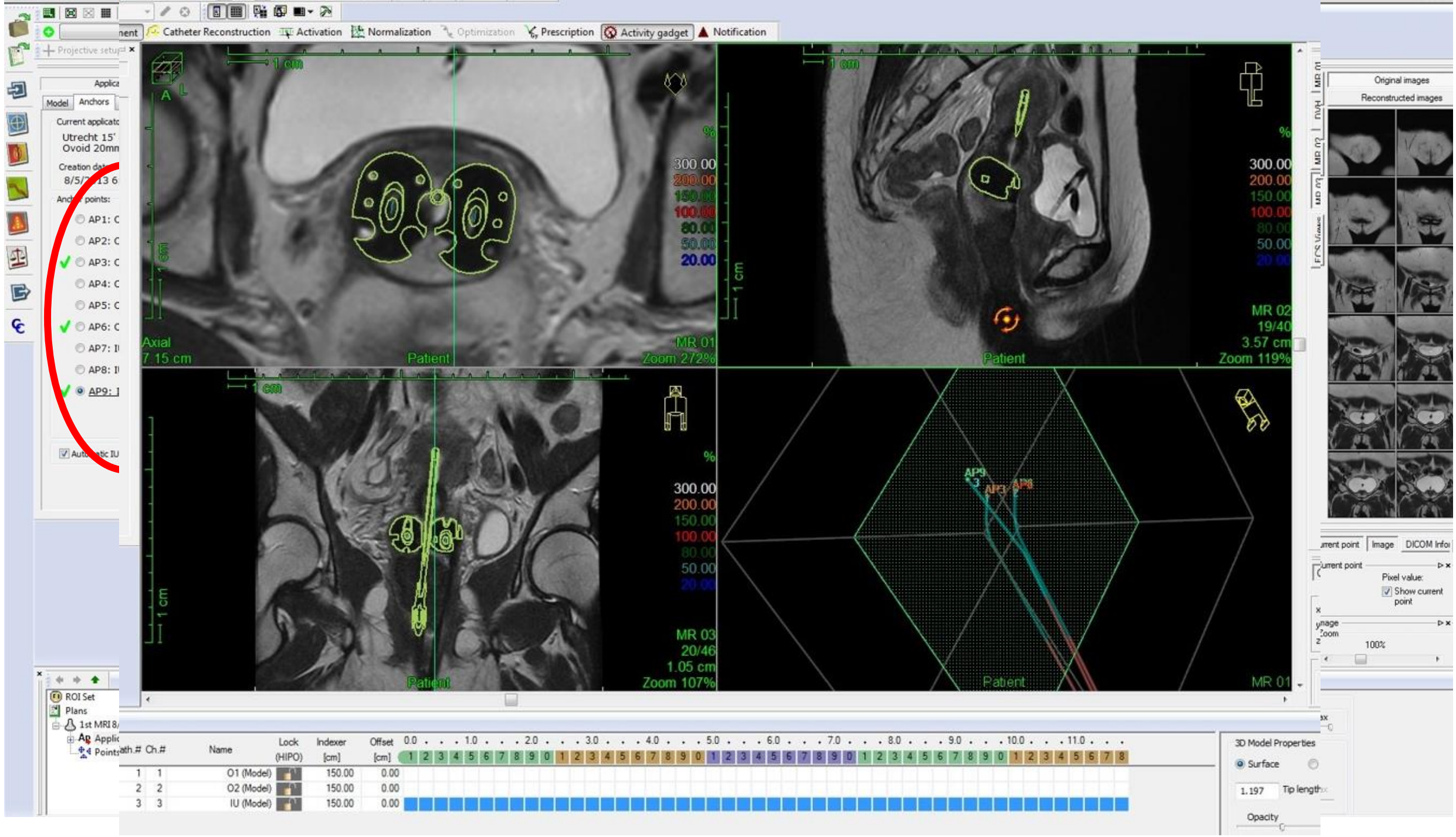
Table 3
Dose constraints for EBRT for N0 and N1 patients. This table is an update of table 9.4 of the EMBRACE II study protocol version 1.0.

	No lymph node involvement		Involved lymph nodes	
	Hard dose constraints	Soft dose constraints	Hard dose constraints	Soft dose constraints
PTV45	V42.75 Gy > 95% Dmax < 107%	V42.75 Gy = 95%	V42.75 Gy > 95%	V42.75 Gy = 95% Dmax < 107% for helper structure: PTV45 – (PTV-N(#) + 1 cm)
ITV45	Dmin > 95%		Dmin > 95%	
CTV-HR + 10 mm		Dmax < 103%		Dmax < 103% for helper structure: CTV-HR + 10 mm – (PTV-N(#) + 1 cm)
PTV-N(#)			D98% > 90% of prescribed LN dose Dmax < 107% of prescribed LN dose	D98% = 90% of prescribed LN dose
CTV-N(#)			D98% > 100% of prescribed LN dose	D50% > 102% of prescribed LN dose
Bowel	Dmax < 105%	V40Gy < 250 cm^3* V30Gy < 500 cm^3*	Dmax < 105% in regions outside 10–15 mm from PTV-N	When no para-aortic irradiation: V40Gy < 250 cm^3* V30Gy < 500 cm^3* For para-aortic irradiation: V40Gy < 300 cm^3* V30Gy < 650 cm^3*
Sigmoid	Dmax < 105%		Dmax < 105% in regions outside 10–15 mm from PTV-N	
Bladder	Dmax < 105%	V40Gy < 60%* V30Gy < 80%*	Dmax < 105% in regions outside 10–15 mm from PTV-N	V40Gy < 60%* V30Gy < 80%*
Rectum	Dmax < 105%	V40Gy < 75%* V30Gy < 95%*	Dmax < 105% in regions outside 10–15 mm from PTV-N	V40Gy < 75%* V30Gy < 95%*
Spinal cord	Dmax < 48 Gy		Dmax < 48 Gy	
Femoral heads	Dmax < 50 Gy		Dmax < 50 Gy	
Kidney	Dmean < 15 Gy	Dmean < 10 Gy	Dmean < 15 Gy	Dmean < 10 Gy
Body	Dmax < 107%		Dmax < 107% in regions outside 10–15 mm from PTV-N	
Vagina (if not involved)		$D_{PIBS-2cm}$ < 5 Gy		$D_{PIBS-2cm}$ < 5 Gy
Conformality		1.10 (V43/Volume of PTV) 1.55 (V36Gy/Volume of PTV)		1.10 (V43Gy/Volume of PTV) 1.55 (V36Gy/Volume of PTV)
Transposed ovaries	Dmean < 8 Gy	Dmean < 5 Gy	Dmean < 8 Gy	Dmean < 5 Gy
Duodenum	V55 < 15 cm^3		V55 < 15 cm^3	

Percentages of 45 Gy unless stated otherwise for nodes.
Dmax and Dmin for MC plans based on D99.9% and D0.1%.
* Soft constraints which can be used in the treatment plan optimisation. Values are based on DVH parameters of EMBRACE II patients entered in the study before June 2017. The constraints are not supposed to be fulfilled in all patients, but by ~70–80% of the patients.

The overall treatment time (OTT), defined from the first external beam fraction to the final external beam or brachytherapy fraction dose is delivered should be < 50 days




Catheter Reconstruction
Activation
Normalization
Optimization
Prescription
Activity gadget
Notification
Model
Anchors
Utrecht 15'
Ovoid 20mn
AP1:
AP2:
AP3:
AP4:
AP5:
AP6:
AP7:
AP8:
AP9:
1 cm
Axial
7.15 cm
Patient
MR 01
Zoom 272%
MR 02
19/40
3.57 cm
Zoom 119%
MR 03
20/46
1.05 cm
Zoom 107%
300.00
200.00
150.00
100.00
80.00
50.00
20.00
Original images
Reconstructed images
Current point
Image
DICOM Info
Pixel value:
Show current point
Zoom
100%
ROI Set
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O1 (Model)
O2 (Model)
IU (Model)
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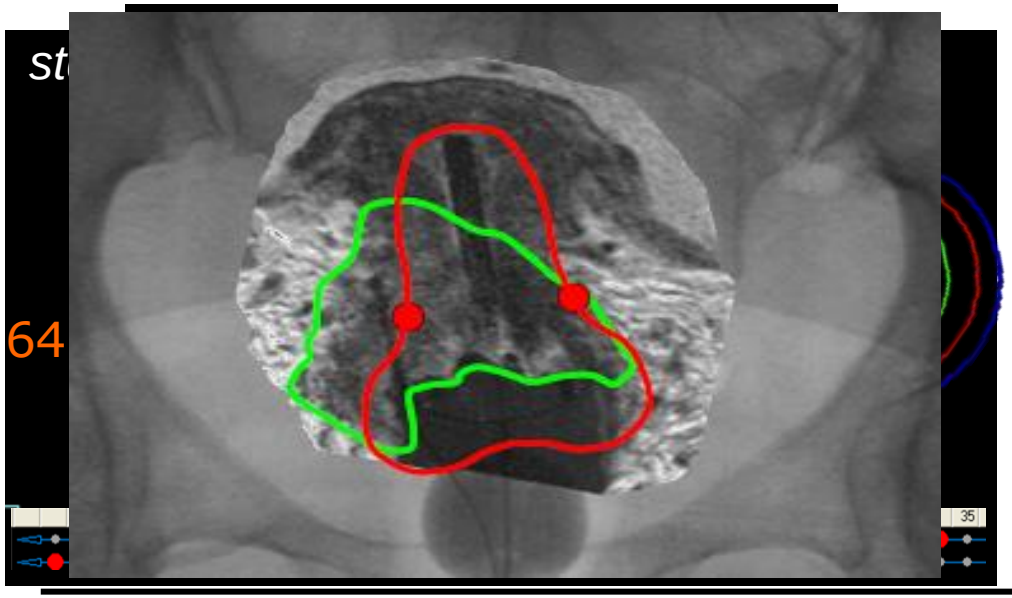
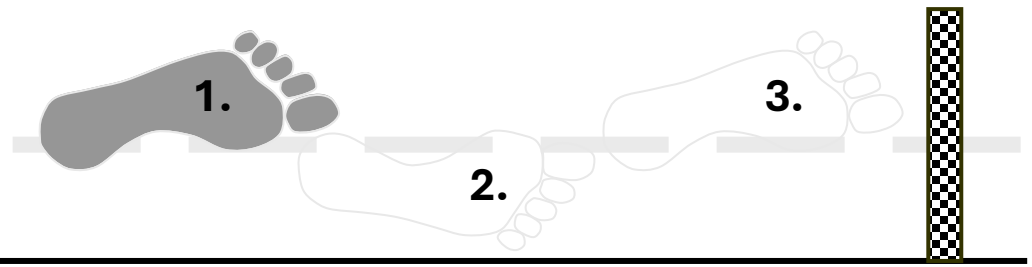
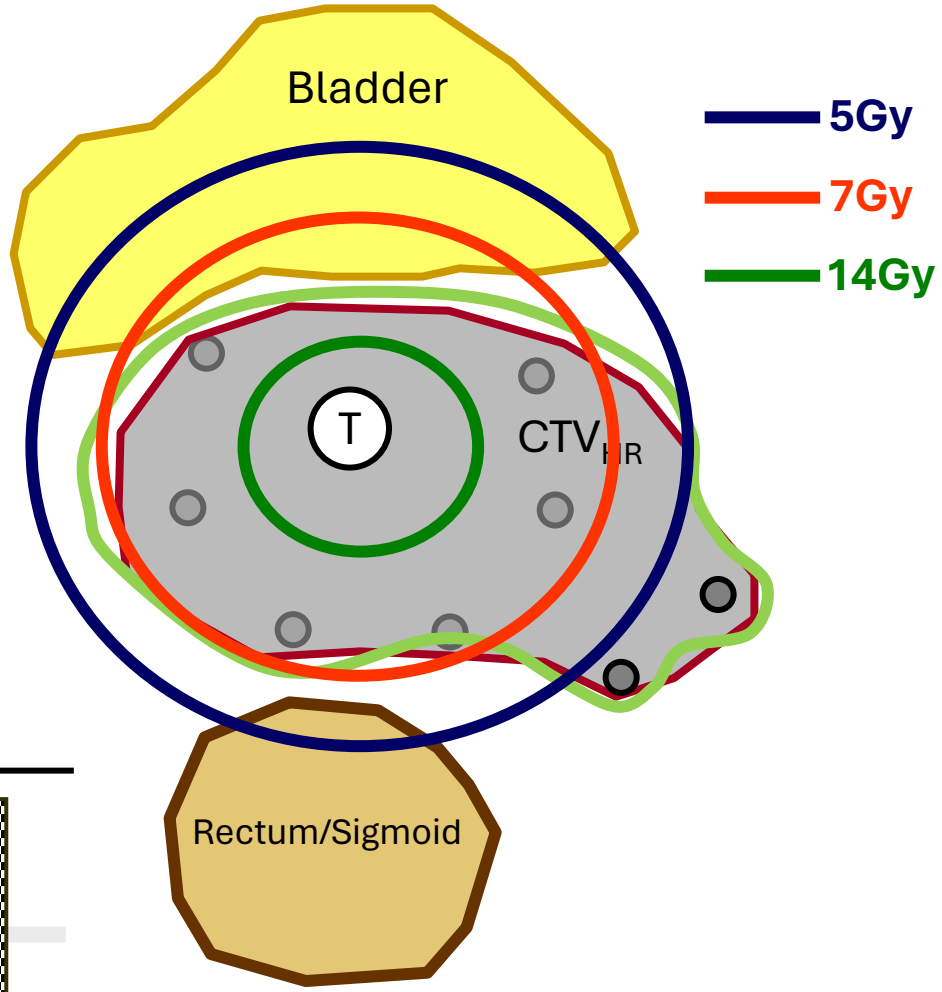
3D Model Properties
Surface
1.197
Tip length
Opacity

3 steps in treatment planning optimization

1: Apply (institutional) Standard Loading Pattern and normalize to Point A





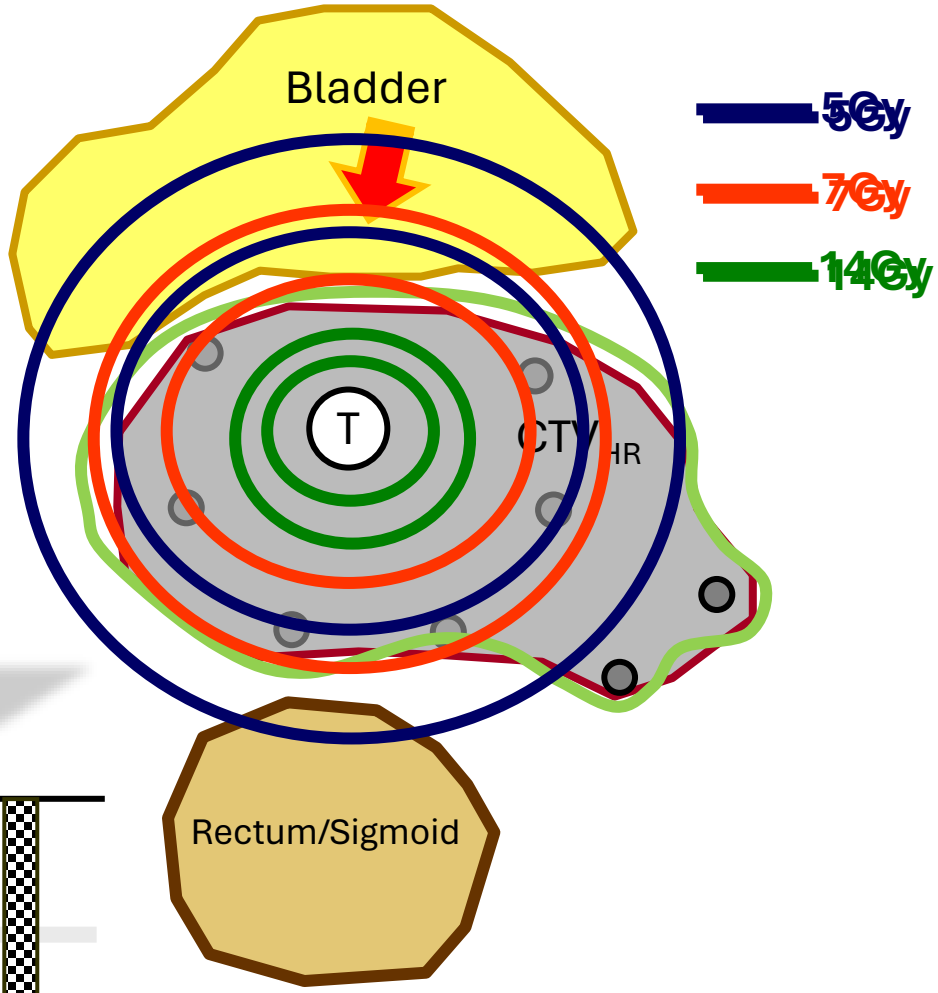


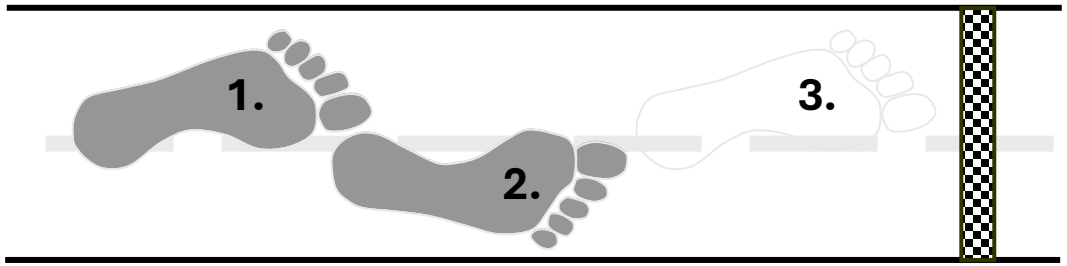
3 steps in treatment planning optimization

1: Apply (institutional) Standard Loading Pattern and normalize to Point A

2: Optimize the intracavitary applicator (T/R, T/O) based on OARs

Activate or deactivate intracavitary dwell position and de- or increase the dwell times to reach an OARs dose approx. 10% below the Dose constraint limit.



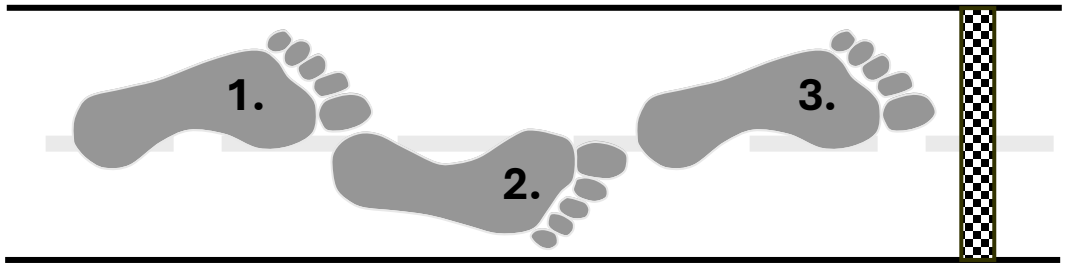


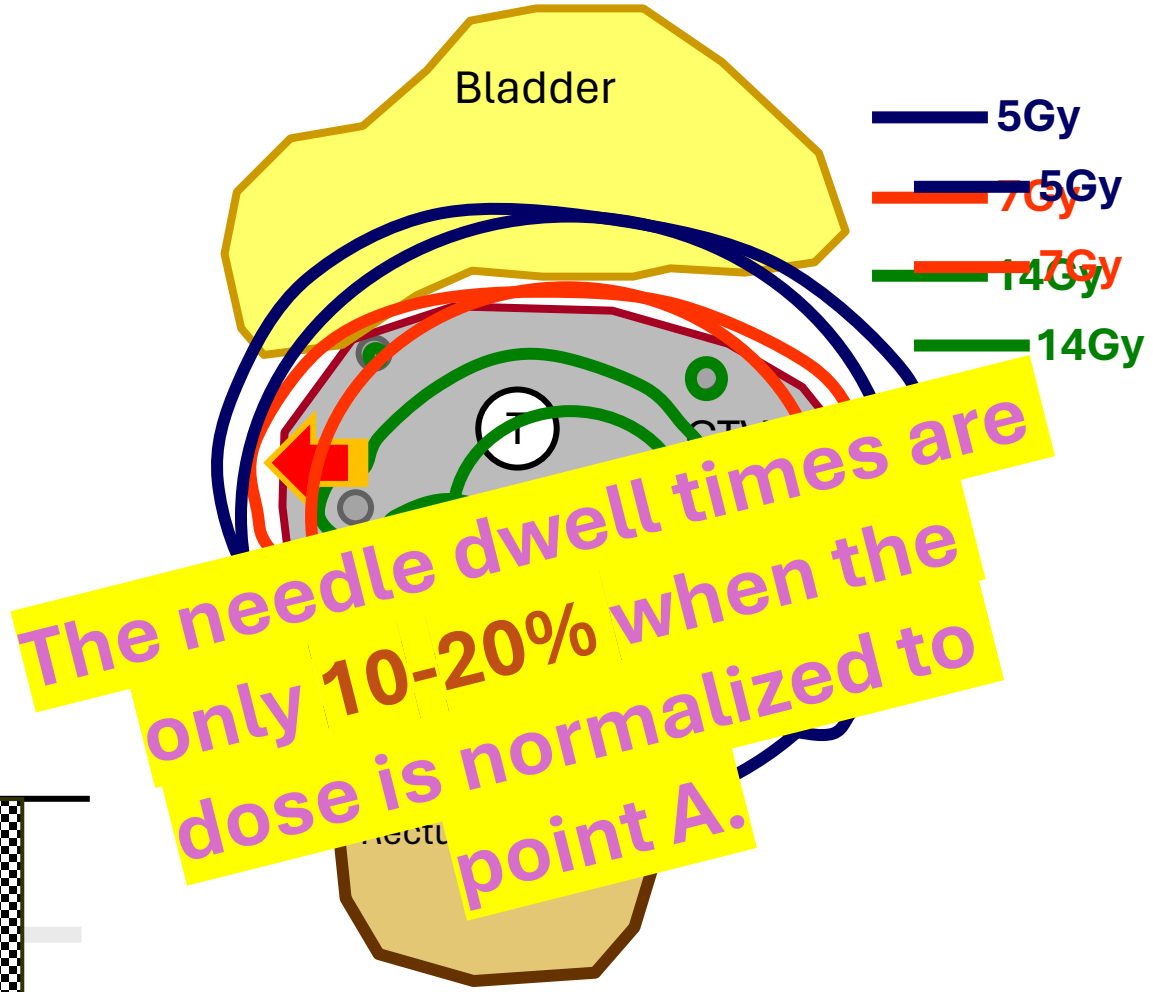
3 steps in treatment planning optimization

1: Apply (institutional) Standard Loading Pattern and normalize to Point A

2: Optimize the intracavitary applicator (T/R, T/O) based on OARs

3: Add the interstitial components (needles) to increase the target coverage



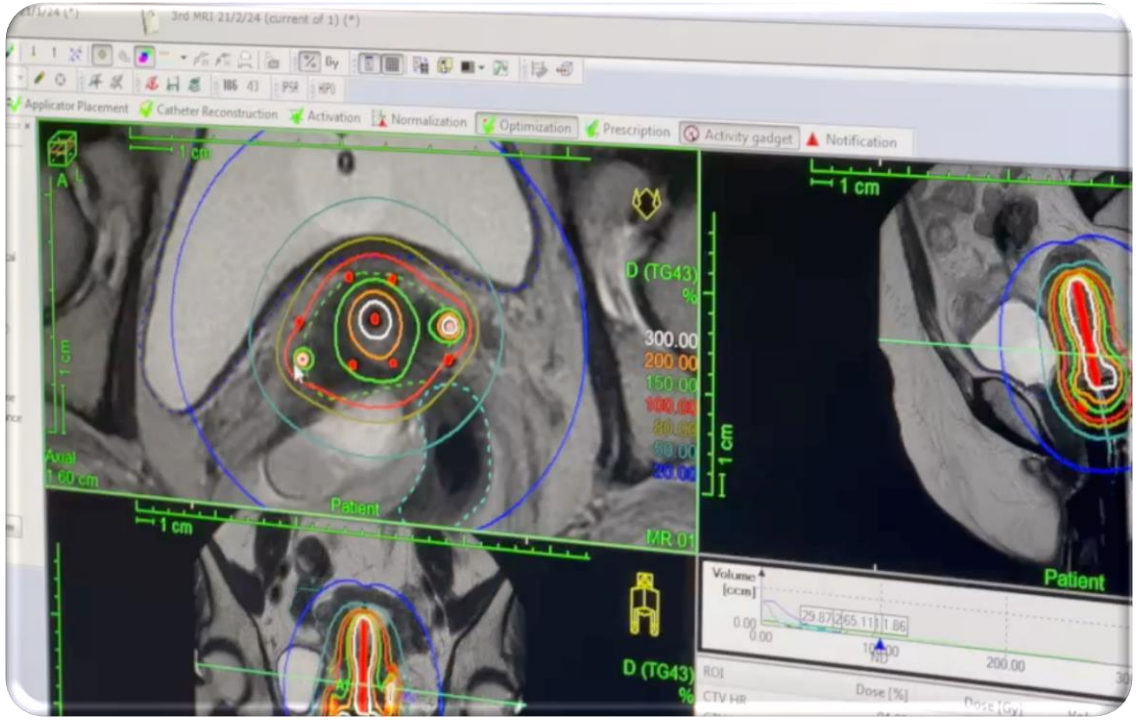


Optimization of the Dose Distribution

- **Forward planning**
  - The absorbed-dose distribution resulting from the initial loading pattern is evaluated using the constraints for absorbed-dose points, DVH parameters, and careful anatomical inspection of the isodose distribution.
  - If the resulting absorbed dose distribution does not meet the planning aims, changes are made.
  - These changes can be performed manually or with graphical tools.

Optimization of the Dose Distribution

- **Forward planning**
  - **manual optimization**

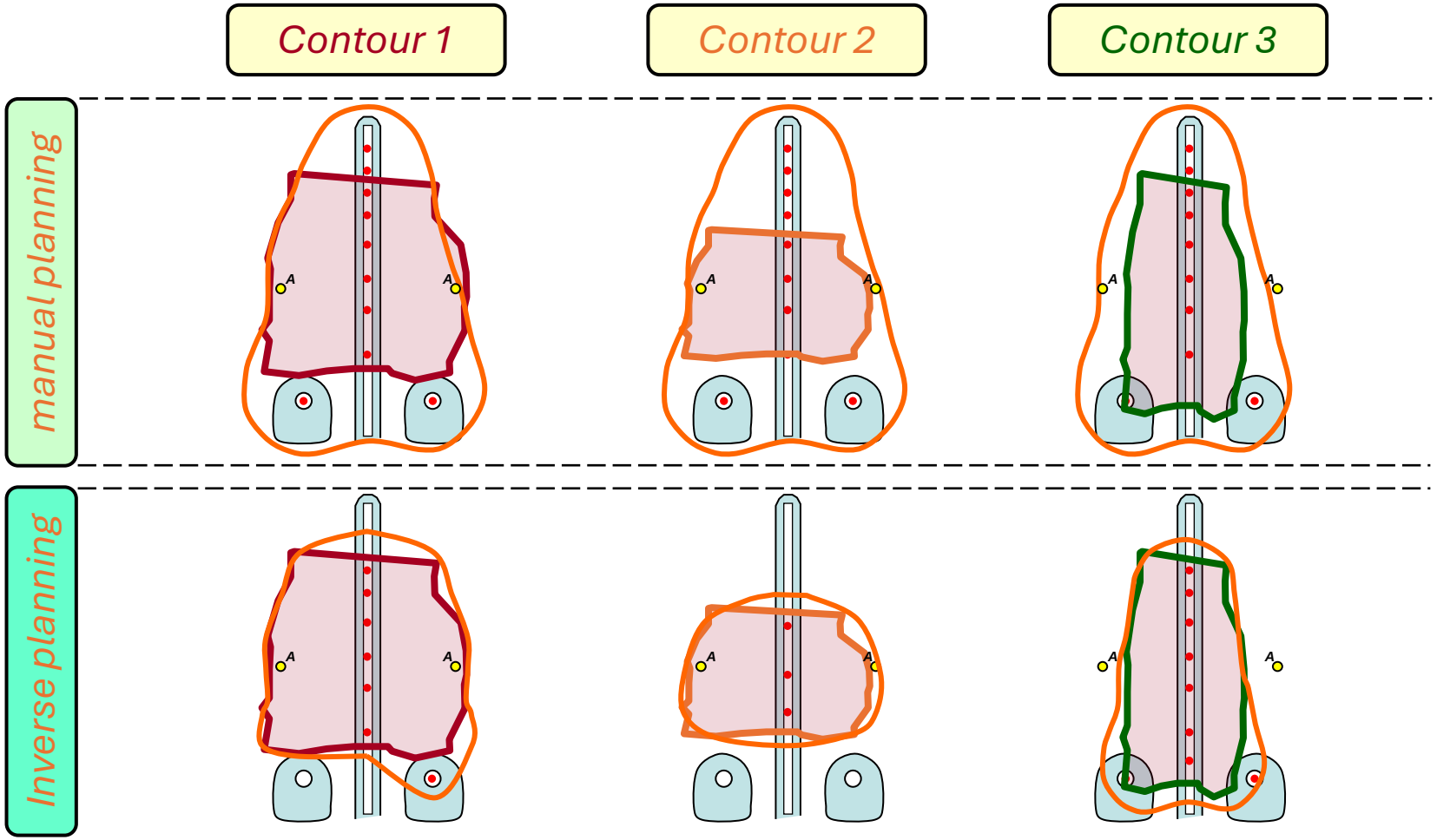


  - **graphical optimization**

Optimization of the Dose Distribution

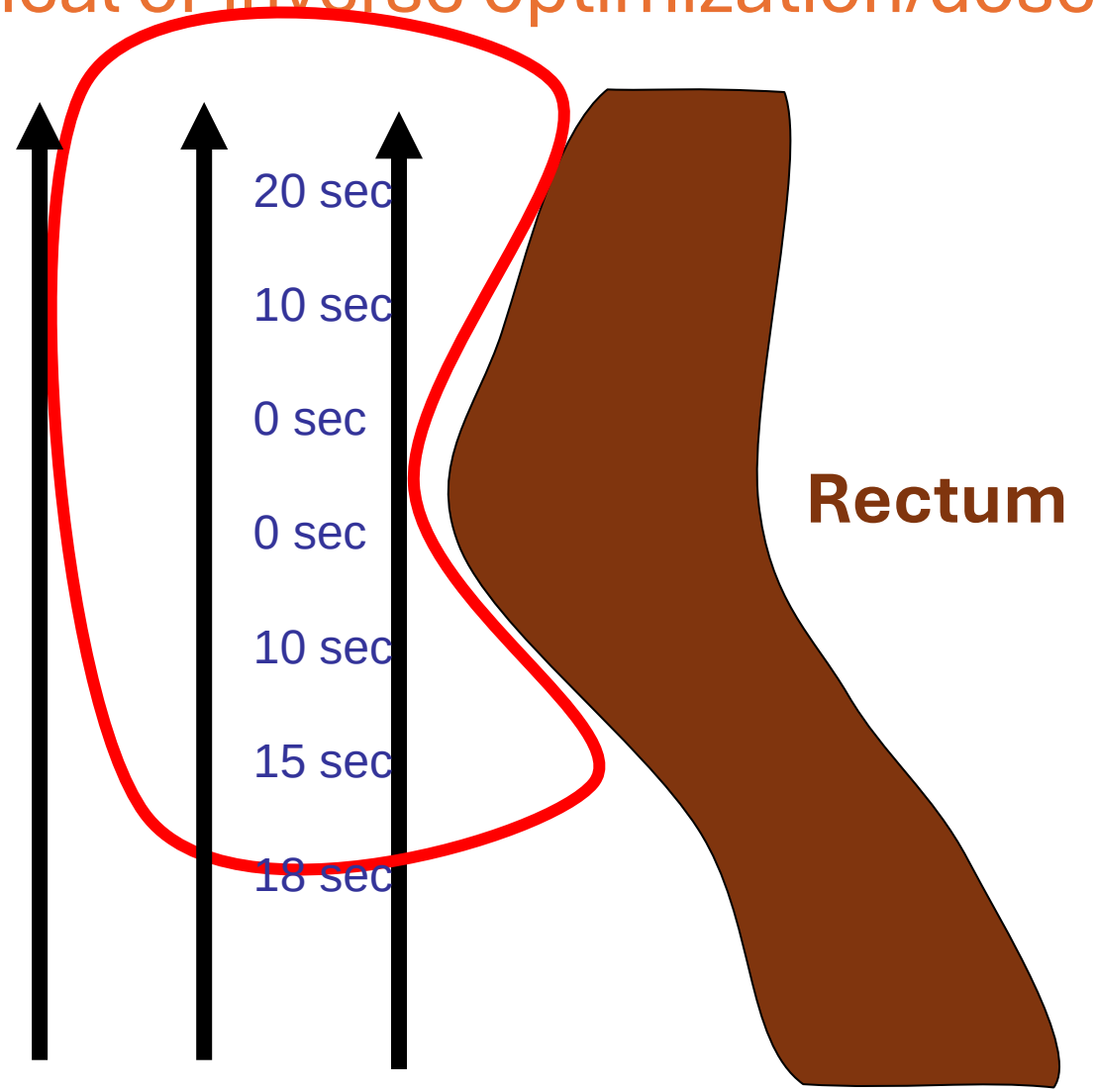
- **Inverse planning**
  - Inverse optimization can take into account only clearly described objectives and constraints
  - Major deviations from the standard pear-shaped loading pattern should be carefully studied before clinically implemented
  - Most clinical experience so far has been based on forward planning,
    - The spatial distributions of absorbed dose involved in this experience do not deviate dramatically from the conventional treatment plans from which the optimized loading patterns are derived

Pitfalls when using Inverse Planning: the plan will be adapted to the contour

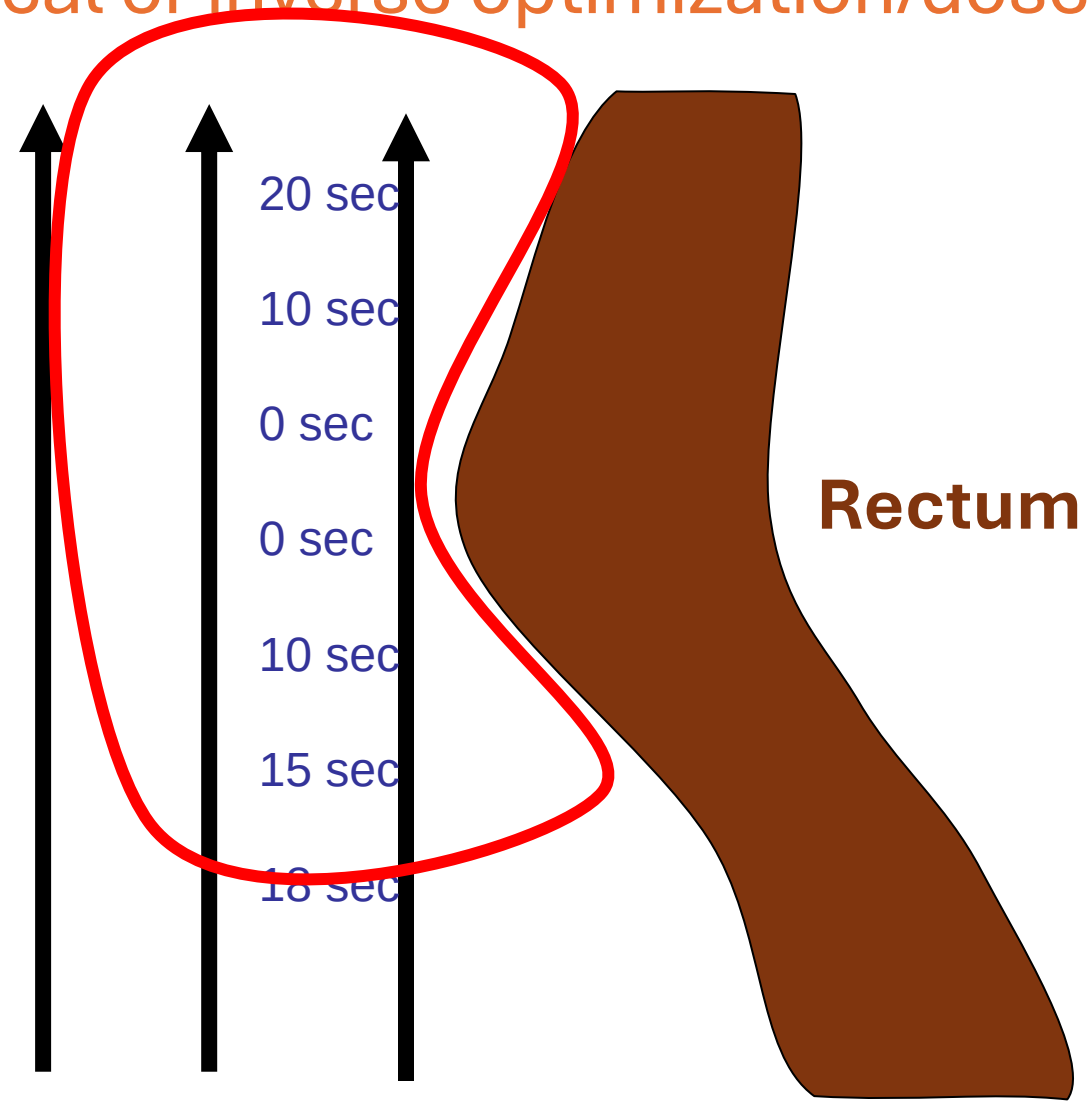


Problems when using graphical or inverse optimization/dose shaping

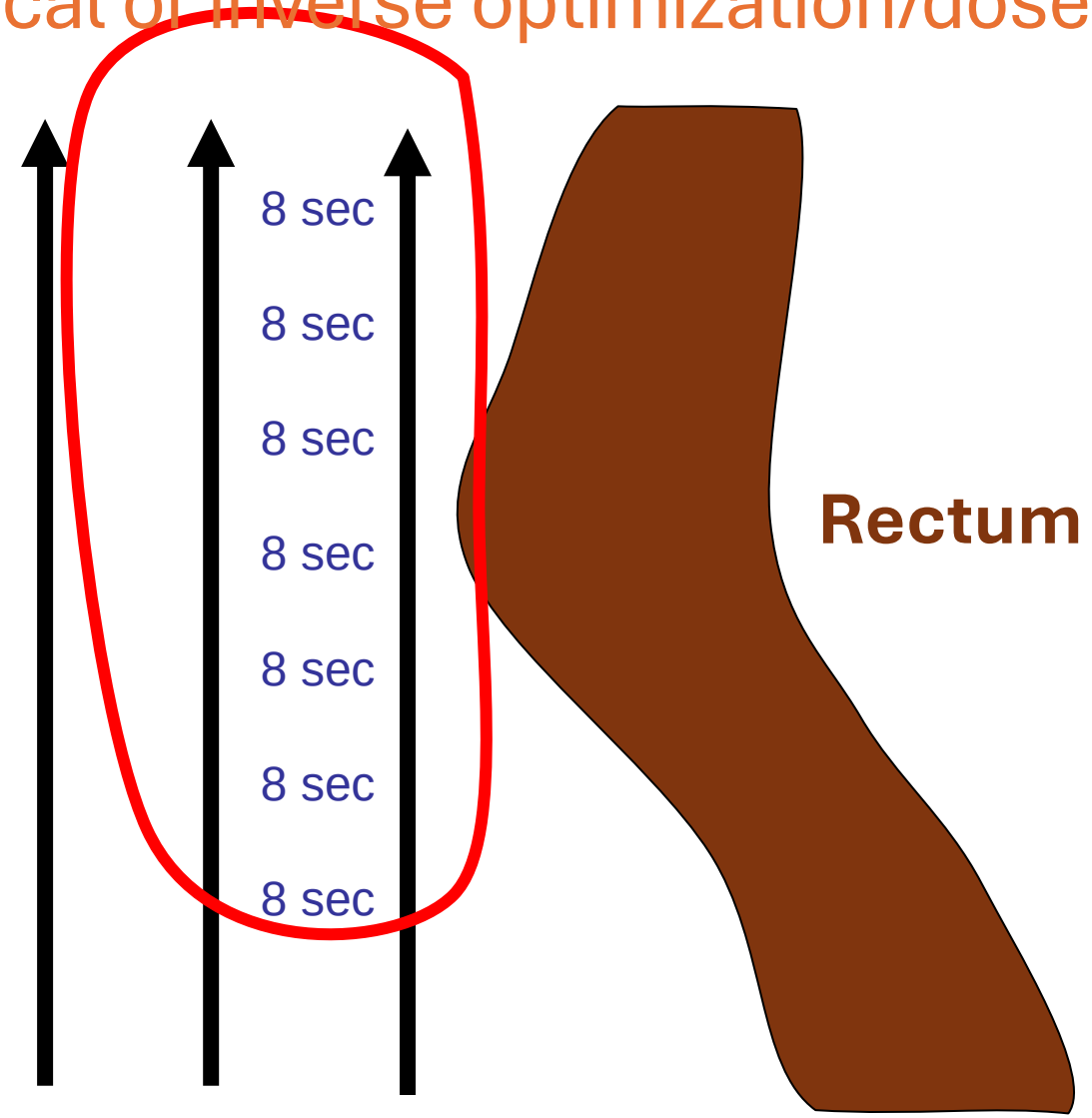
Perfectly shaped isodose line



Problems when using graphical or inverse optimization/dose shaping

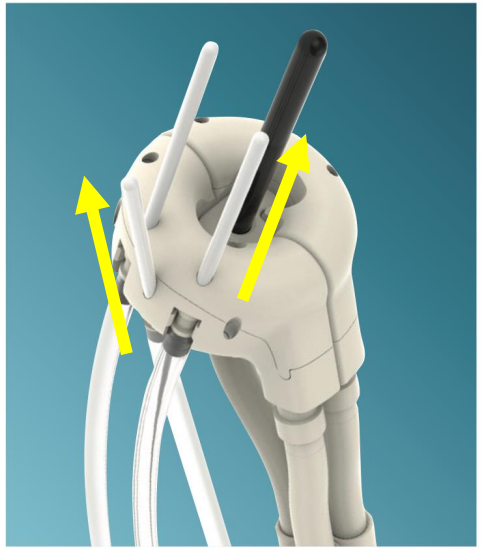


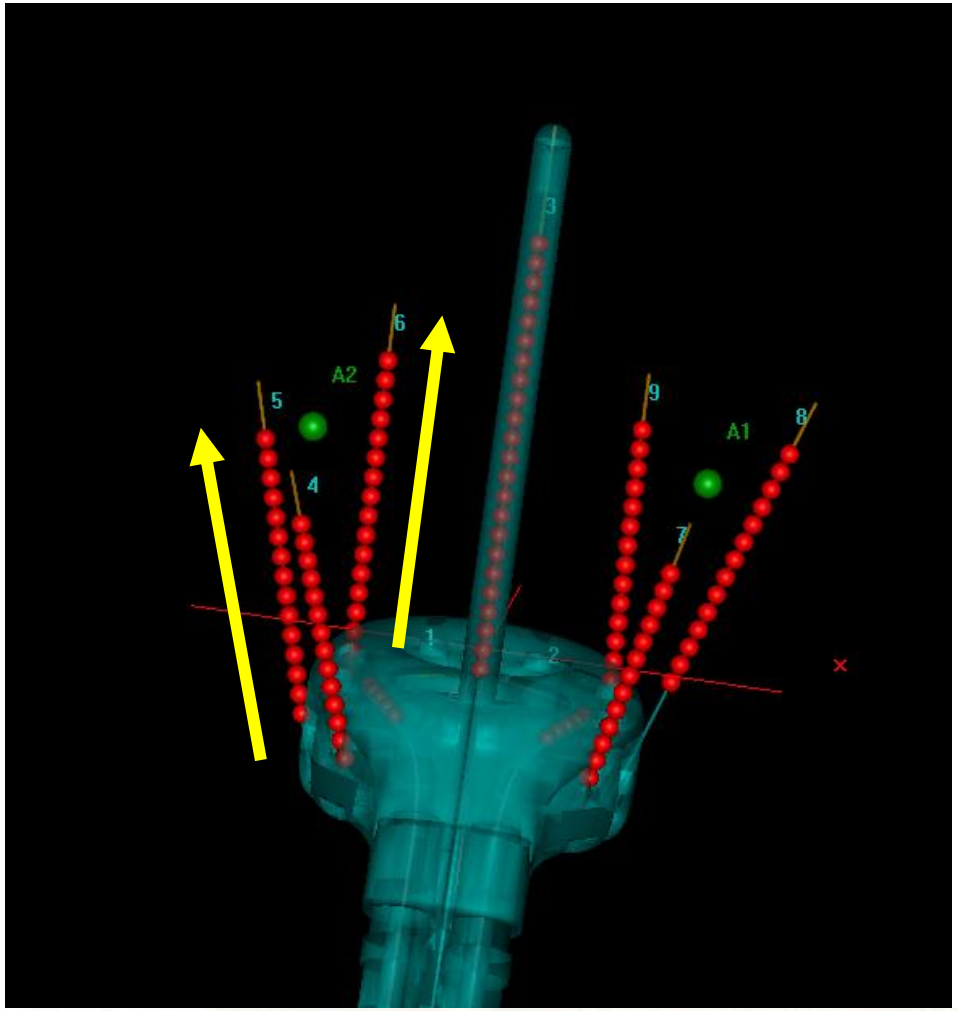
Problems when using graphical or inverse optimization/dose shaping



Experience cases @ KCMH

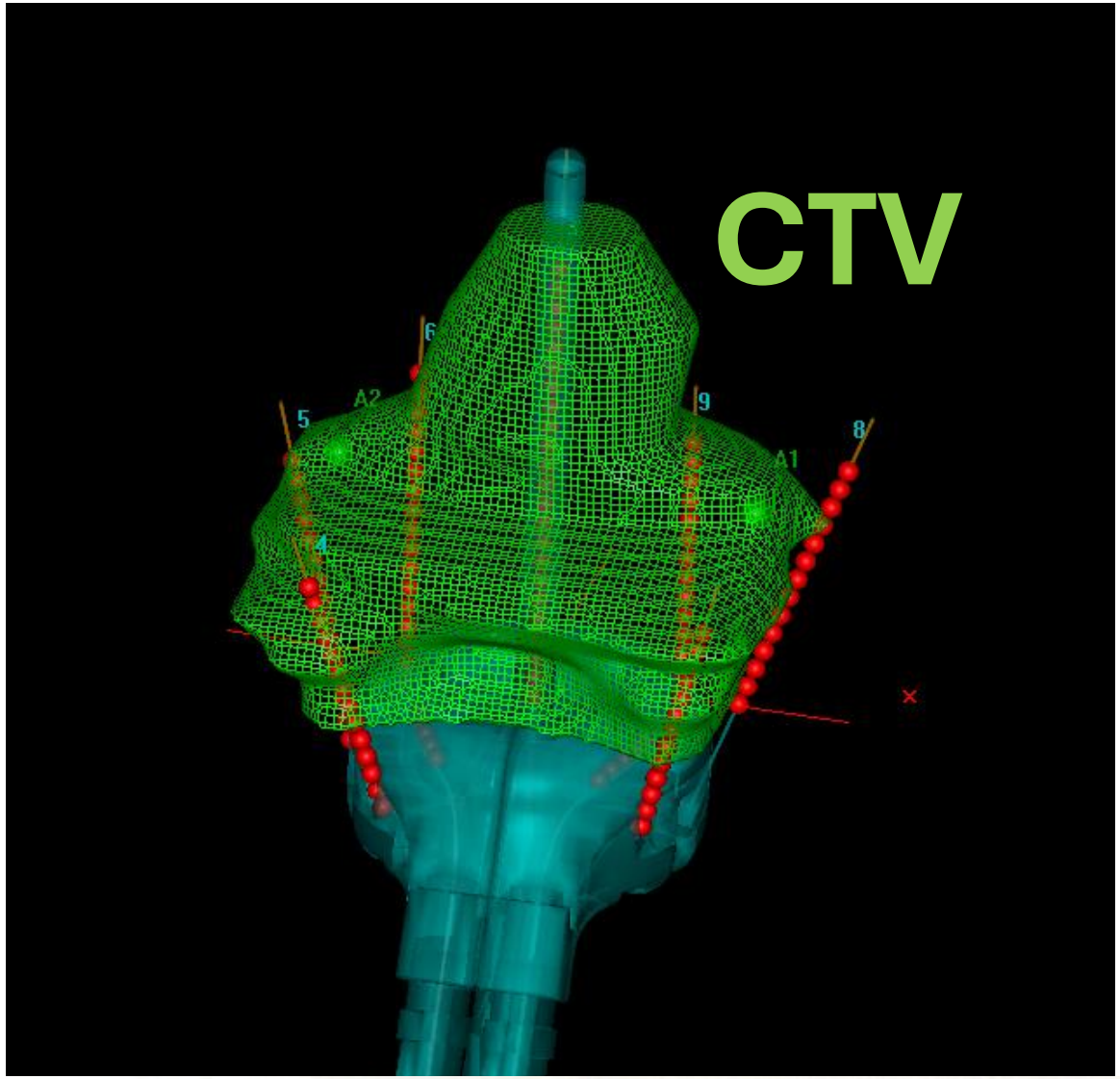
Venezia applicator with 6 needles





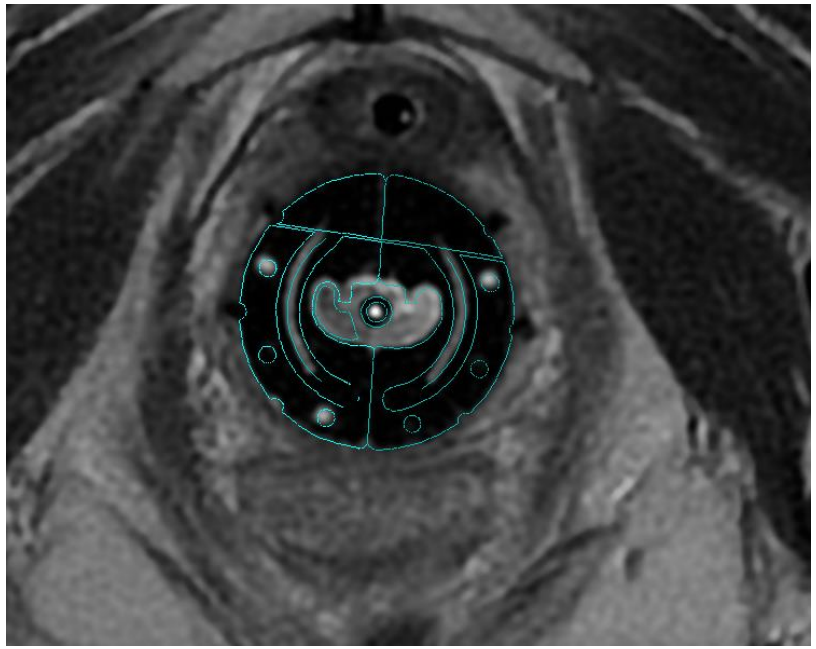
Experience cases @ KCMH

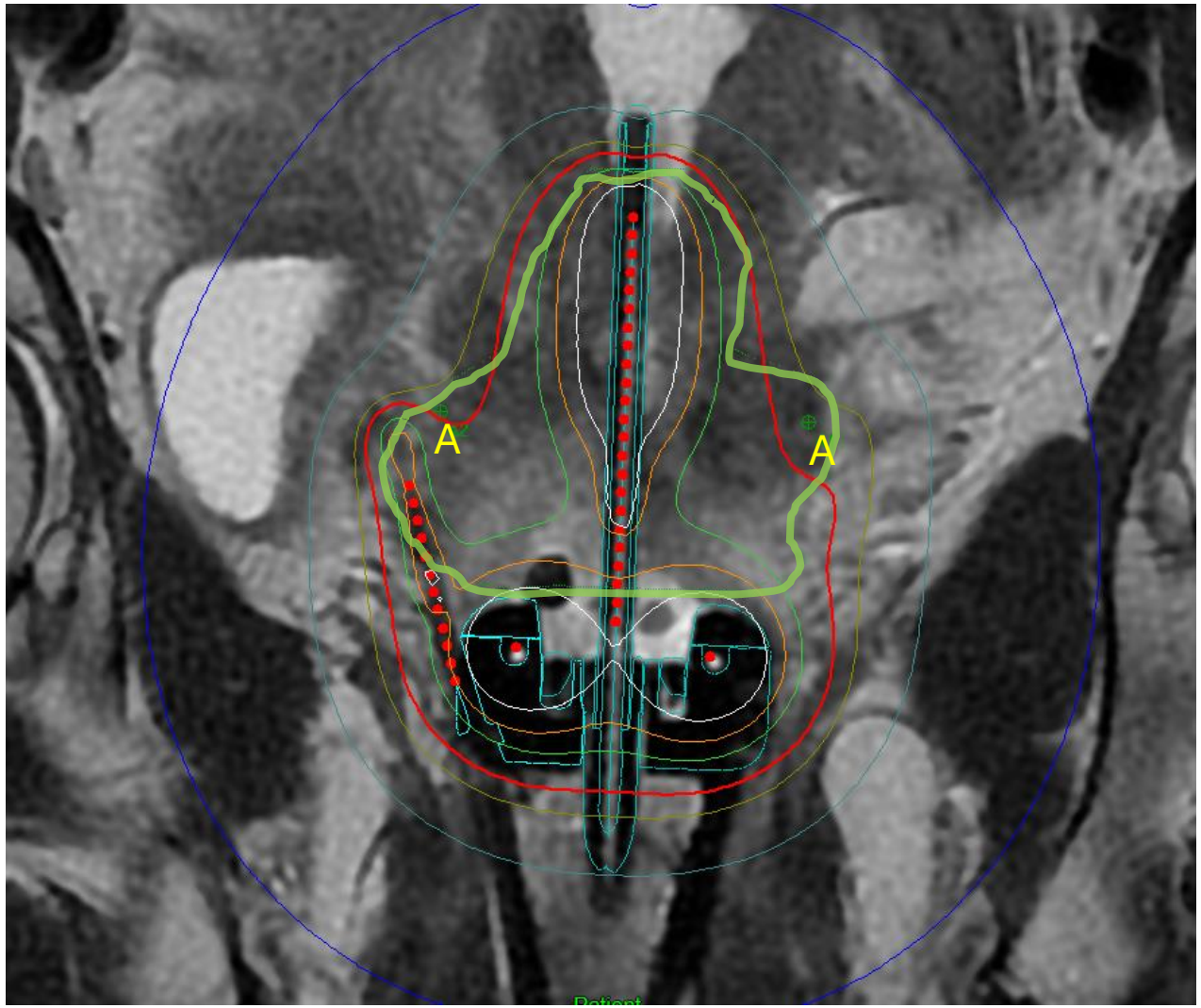
Venezia applicator with 6 needles



Experience cases @ KCMH

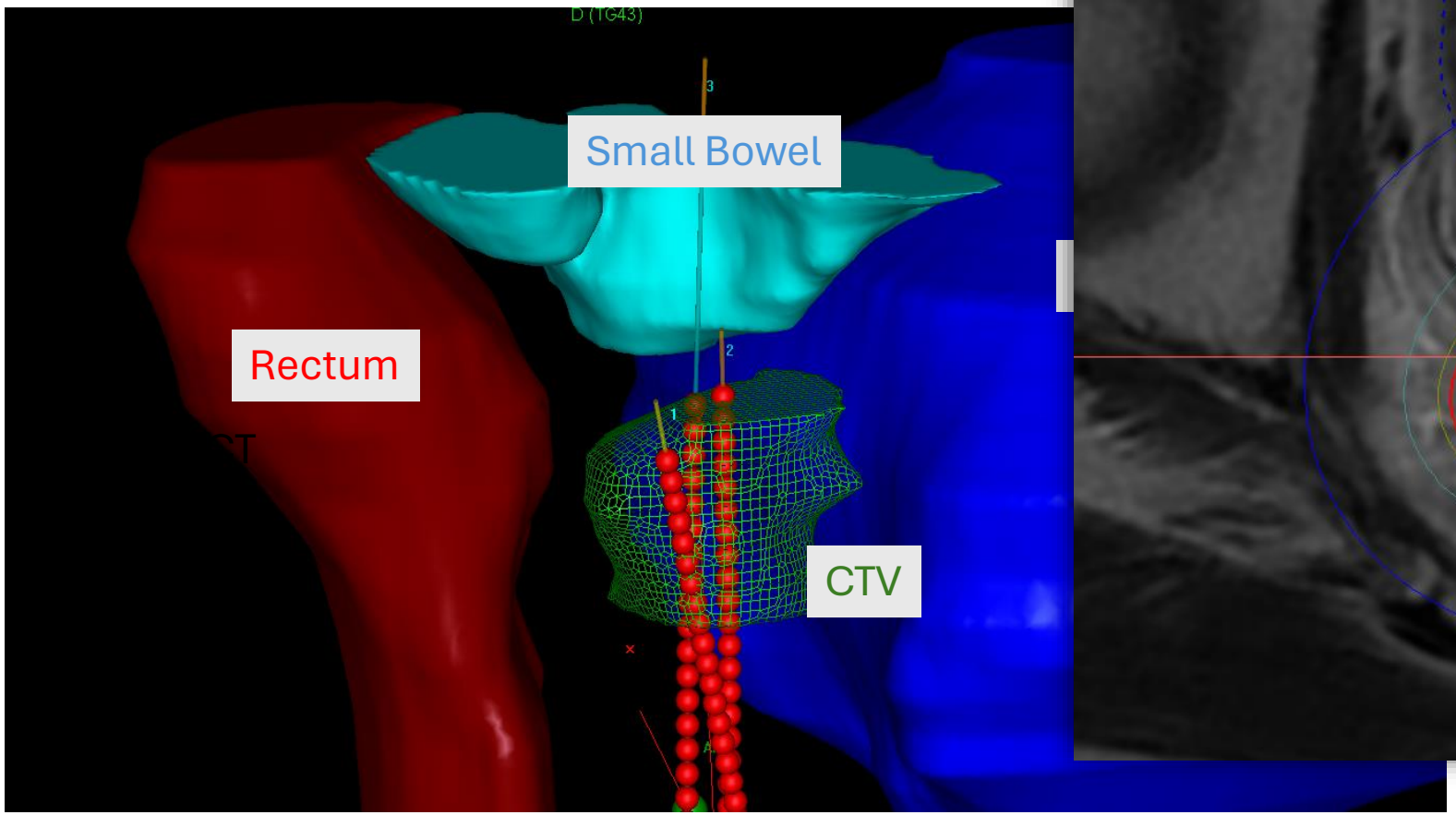
Venezia applicator with 6 needles

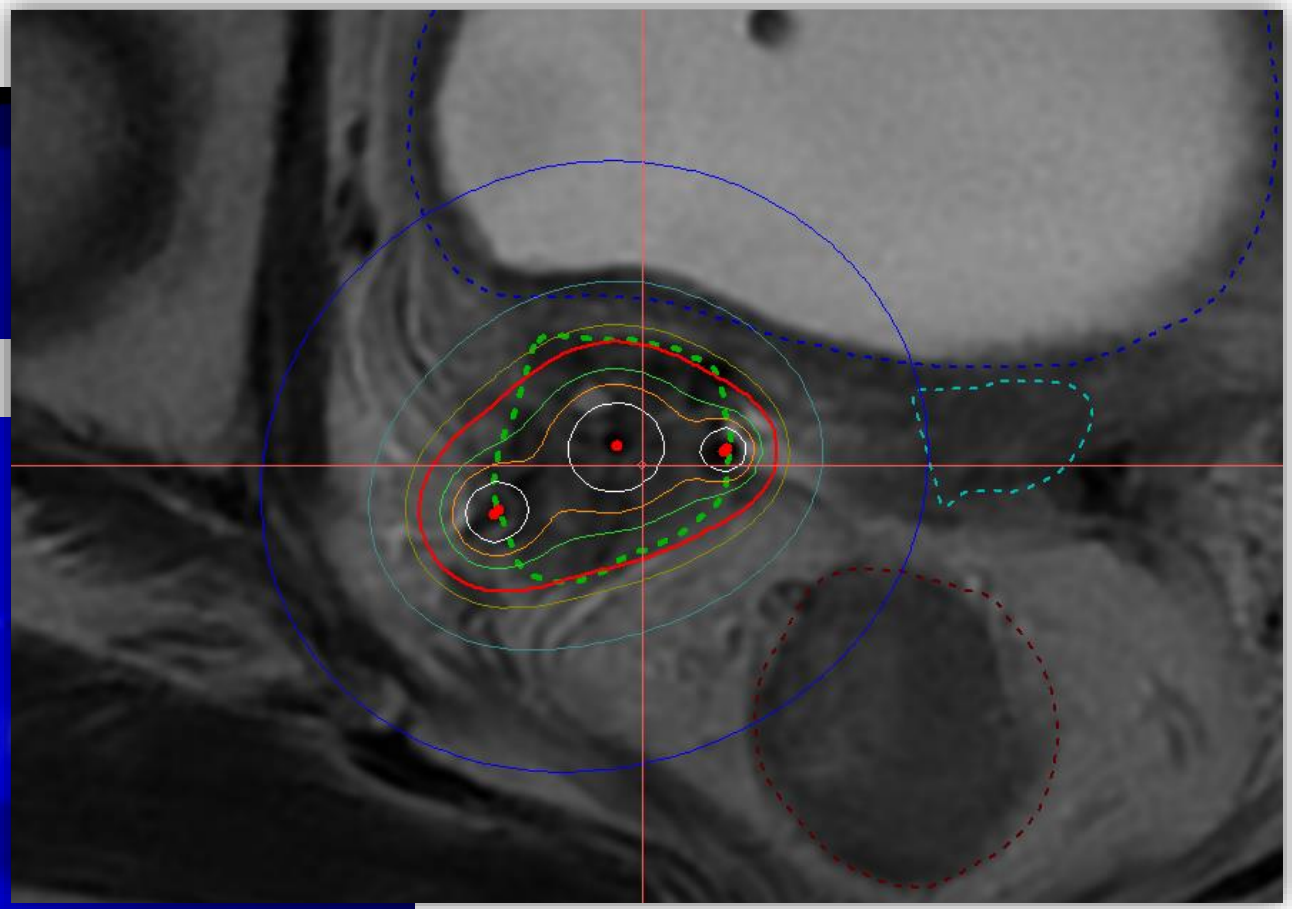




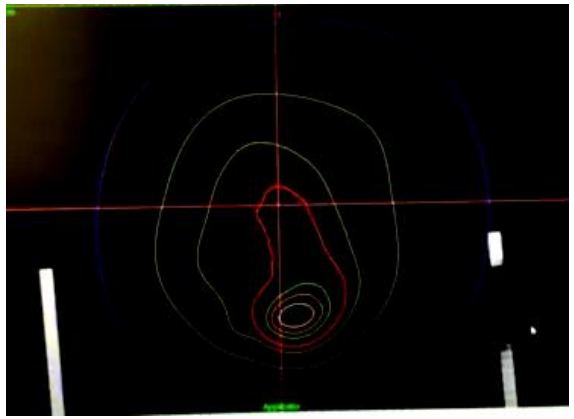
Experience cases @ KCMH

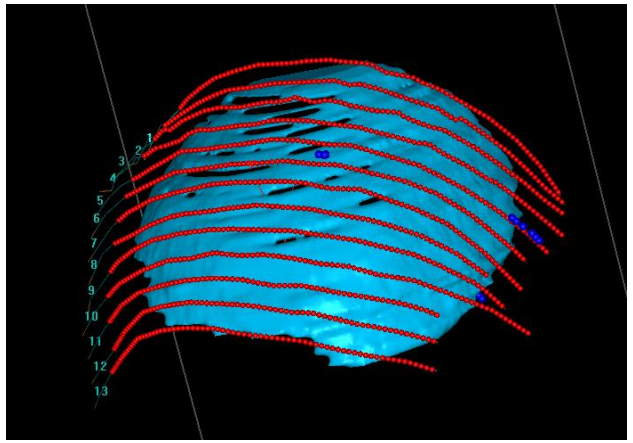
Free hand with three needles

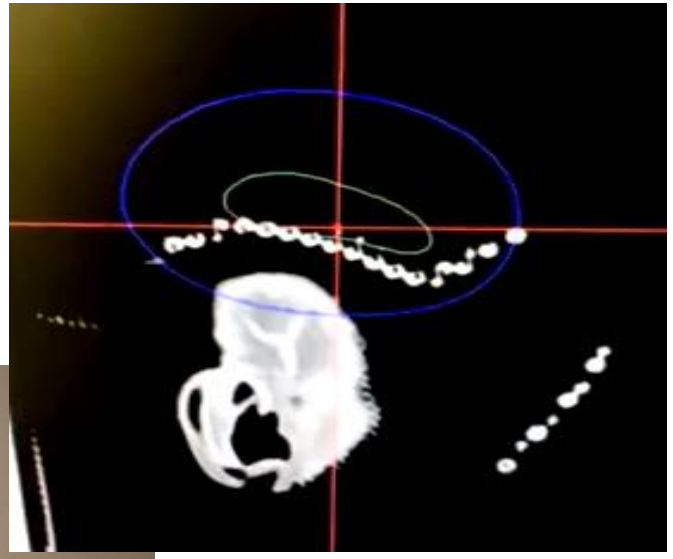




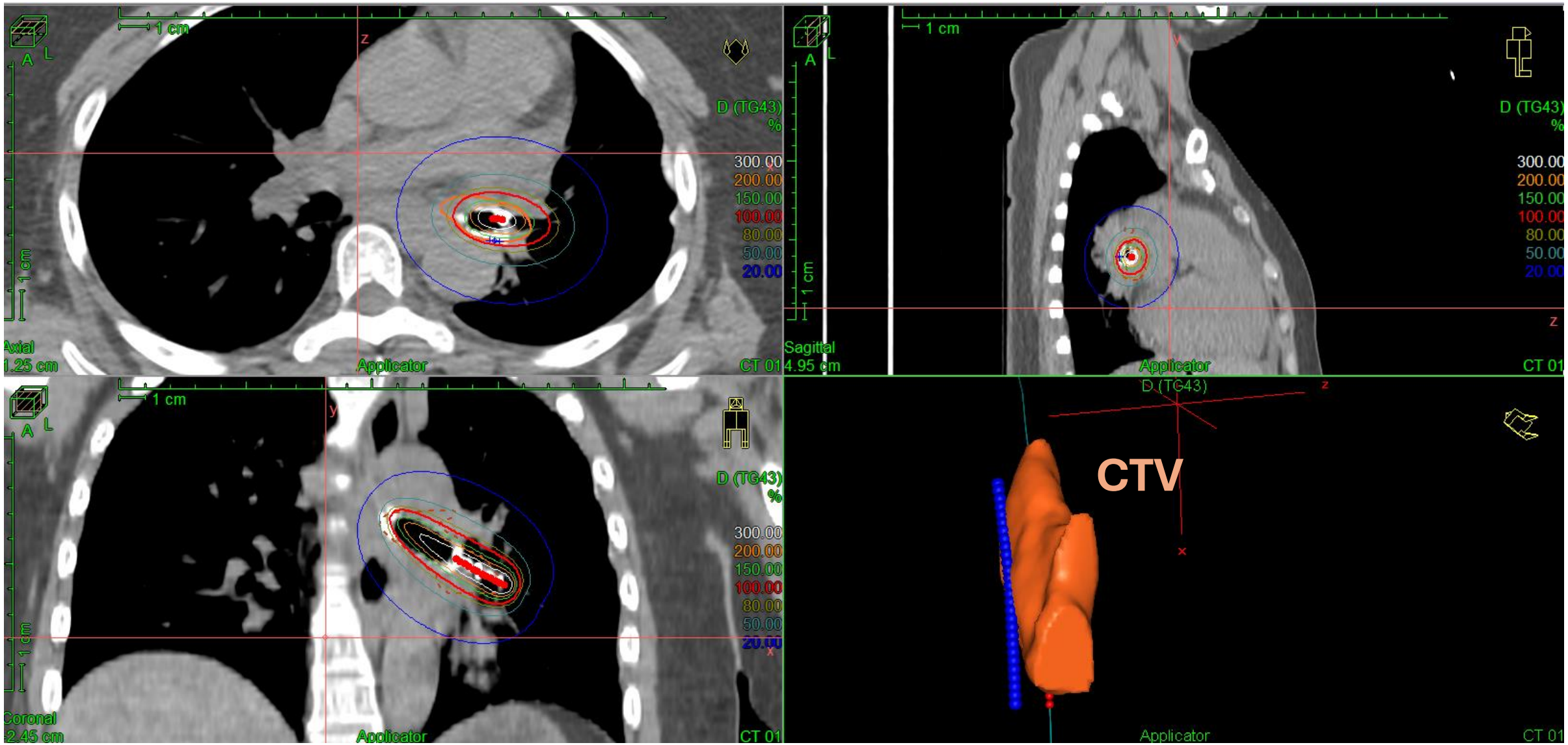
Surface Mold





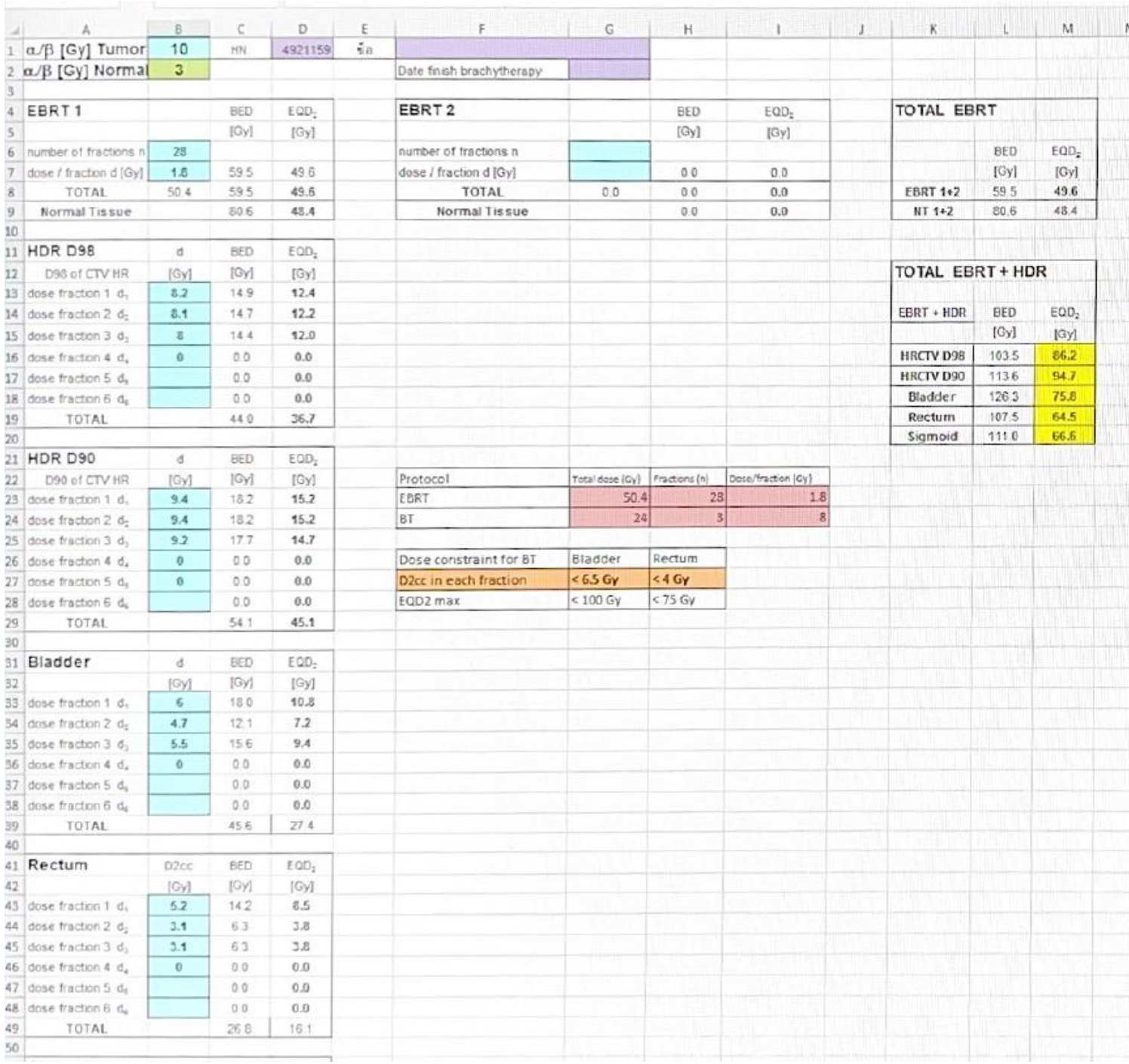


Intracavitary ??



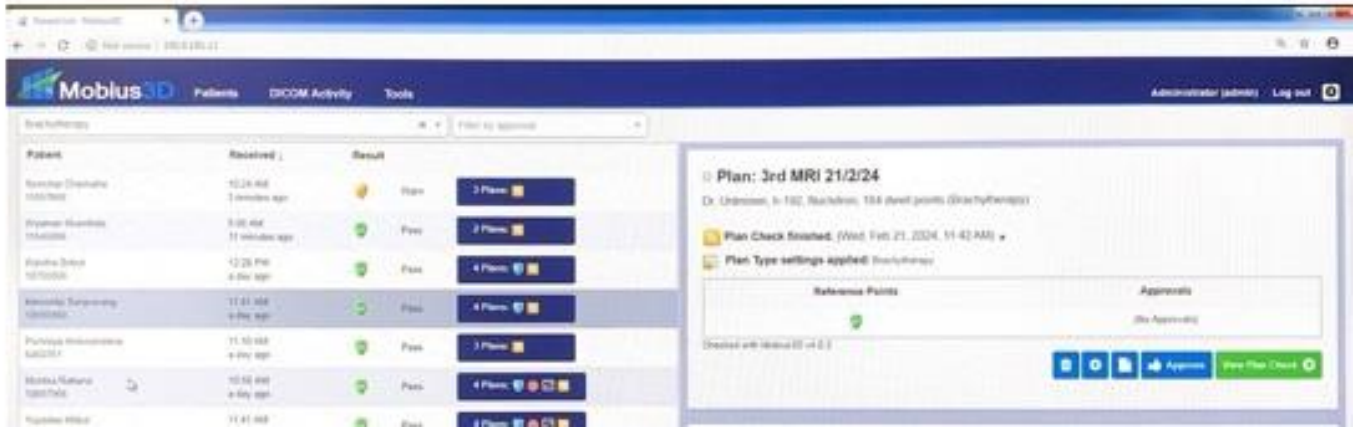
Dose reporting

- D90%, D98% of CTV HR
- D2cc and volume of normal organ
- TRAK (Total Reference Air Kerma)
- Total time



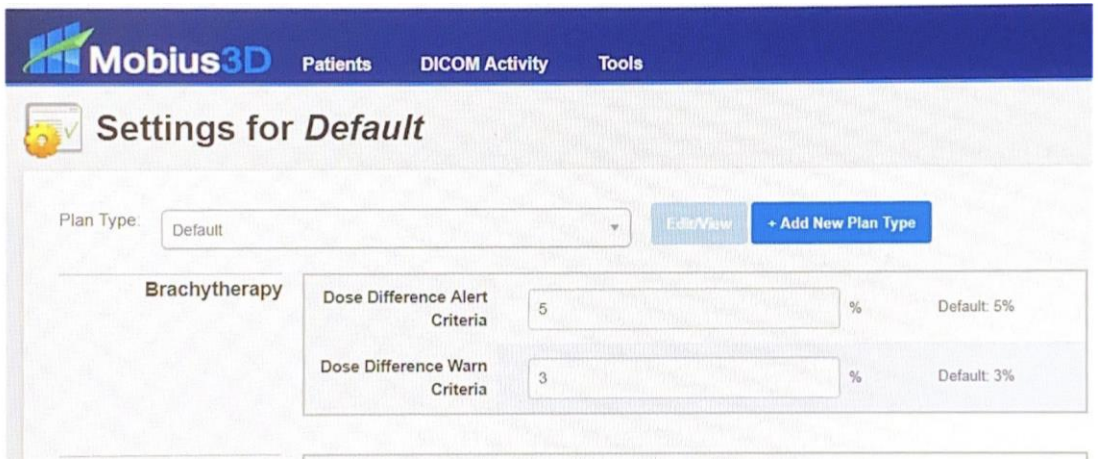
	A	B	C	D	E	F	G	H	I	J	K	L	M
1	α/β [Gy] Tumor	10	HN	4921159	5a								
2	α/β [Gy] Normal	3				Date finish brachytherapy							
3													
4	EBRT 1		BED	EQD_2		EBRT 2		BED	EQD_2		TOTAL EBRT		
5			[Gy]	[Gy]				[Gy]	[Gy]			BED [Gy]	EQD_2 [Gy]
6	number of fractions n	28				number of fractions n							
7	dose / fraction d [Gy]	1.8	59.5	49.6		dose / fraction d [Gy]		0.0	0.0		EBRT 1+2	59.5	49.6
8	TOTAL	50.4	59.5	49.6		TOTAL	0.0	0.0	0.0		NT 1+2	80.6	48.4
9	Normal Tissue		80.6	48.4		Normal Tissue		0.0	0.0				
10													
11	HDR D98	d	BED	EQD_2							TOTAL EBRT + HDR		
12	D98 of CTV HR	[Gy]	[Gy]	[Gy]							EBRT + HDR	BED [Gy]	EQD_2 [Gy]
13	dose fraction 1 d_1	8.2	14.9	12.4							HRCTV D98	103.5	86.2
14	dose fraction 2 d_2	8.1	14.7	12.2							HRCTV D90	113.6	94.7
15	dose fraction 3 d_3	8	14.4	12.0							Bladder	126.3	75.8
16	dose fraction 4 d_4	0	0.0	0.0							Rectum	107.5	64.5
17	dose fraction 5 d_5		0.0	0.0							Sigmoid	111.0	66.6
18	dose fraction 6 d_6		0.0	0.0									
19	TOTAL		44.0	36.7									
20													
21	HDR D90	d	BED	EQD_2									
22	D90 of CTV HR	[Gy]	[Gy]	[Gy]		Protocol	Total dose [Gy]	Fractions (n)	Dose/fraction [Gy]				
23	dose fraction 1 d_1	9.4	18.2	15.2		EBRT	50.4	28	1.8				
24	dose fraction 2 d_2	9.4	18.2	15.2		BT	24	3	8				
25	dose fraction 3 d_3	9.2	17.7	14.7									
26	dose fraction 4 d_4	0	0.0	0.0		Dose constraint for BT	Bladder	Rectum					
27	dose fraction 5 d_5	0	0.0	0.0		D2cc in each fraction	< 6.5 Gy	< 4 Gy					
28	dose fraction 6 d_6		0.0	0.0		EQD2 max	< 100 Gy	< 75 Gy					
29	TOTAL		54.1	45.1									
30													
31	Bladder	d	BED	EQD_2									
32		[Gy]	[Gy]	[Gy]									
33	dose fraction 1 d_1	6	18.0	10.8									
34	dose fraction 2 d_2	4.7	12.1	7.2									
35	dose fraction 3 d_3	5.5	15.6	9.4									
36	dose fraction 4 d_4	0	0.0	0.0									
37	dose fraction 5 d_5		0.0	0.0									
38	dose fraction 6 d_6		0.0	0.0									
39	TOTAL		45.6	27.4									
40													
41	Rectum	D2cc	BED	EQD_2									
42		[Gy]	[Gy]	[Gy]									
43	dose fraction 1 d_1	5.2	14.2	8.5									
44	dose fraction 2 d_2	3.1	6.3	3.8									
45	dose fraction 3 d_3	3.1	6.3	3.8									
46	dose fraction 4 d_4	0	0.0	0.0									
47	dose fraction 5 d_5		0.0	0.0									
48	dose fraction 6 d_6		0.0	0.0									
49	TOTAL		26.8	16.1									
50													

Independent PT QA



Reference Points ▲

Name	Coordinates X	Y	Z	Dose TPS	M3D	% Diff
	-25.2 mm	36.6 mm	113 mm	5.97 Gy	5.86 Gy	-1.93%
	14.8 mm	36.5 mm	113 mm	8.04 Gy	7.99 Gy	-0.7%



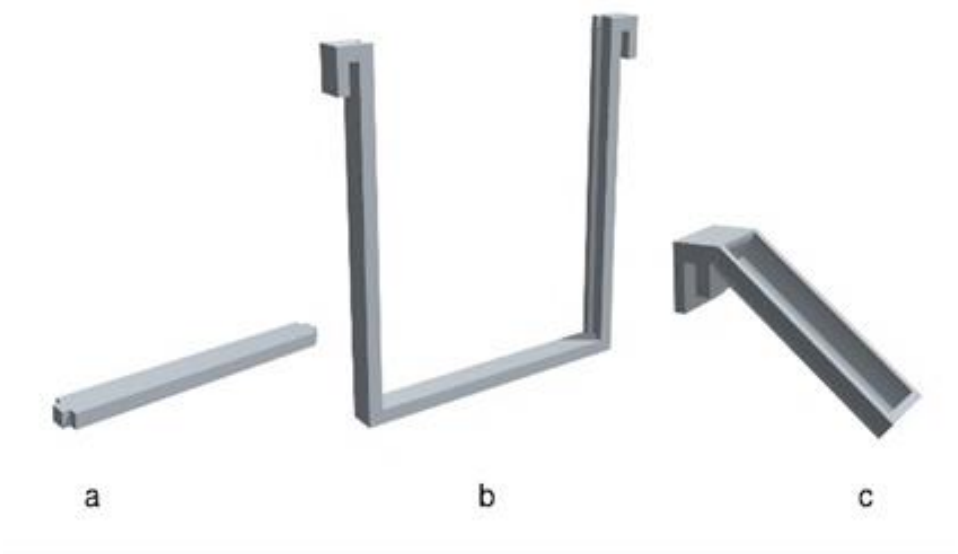
Source Overview ▲

Isotope	Ir-192
Model	Nucletron
Air Kerma Strength	12,519 U
Reference Date	Wed, Feb 21, 2024, 10:59 AM

- Mobius performs a ***point dose*** comparison for any point exported as part of the RTPLAN file using ***TG-43*** formalism for a point source (without anisotropy corrections).

In-house phantom

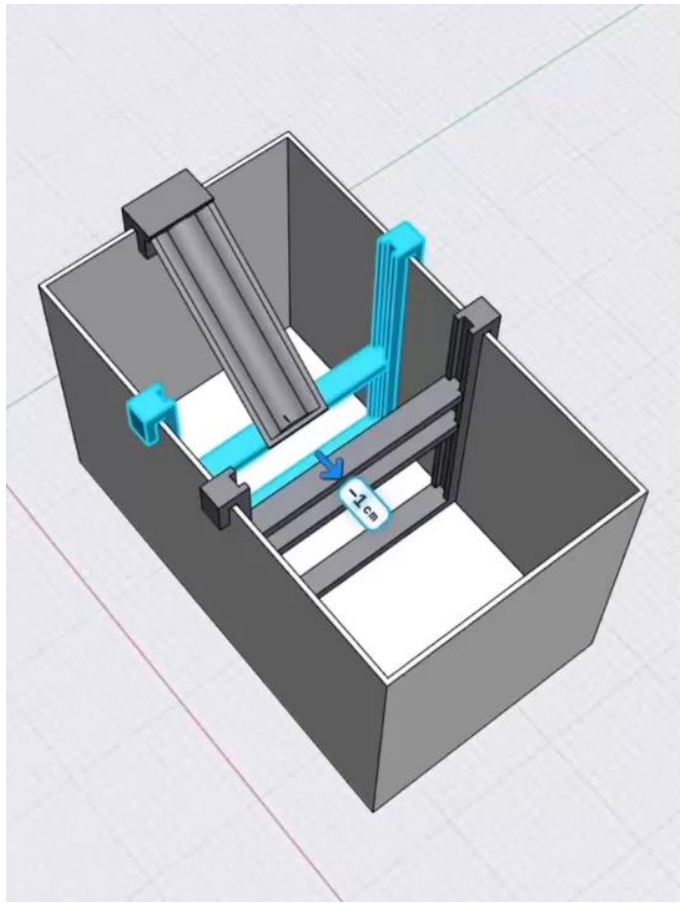
An illustration of the in-house phantom was designed in Shapr3D.



(a) The glass dosimeter holder.

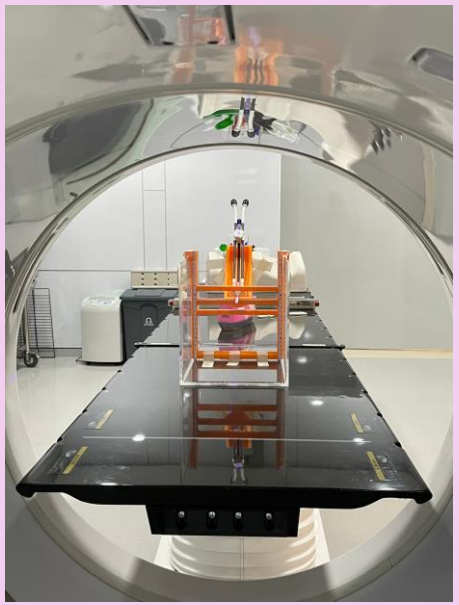
(b) The phantom holder.

(c) The holder of the applicator.

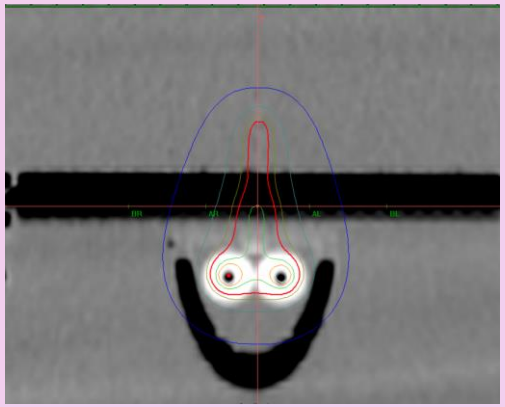


Ref * Itsaraporn Konlak *,In vivo dosimetry of 3D gynecological brachytherapy using the glass dosimeter (RPLGD): a phantom study*

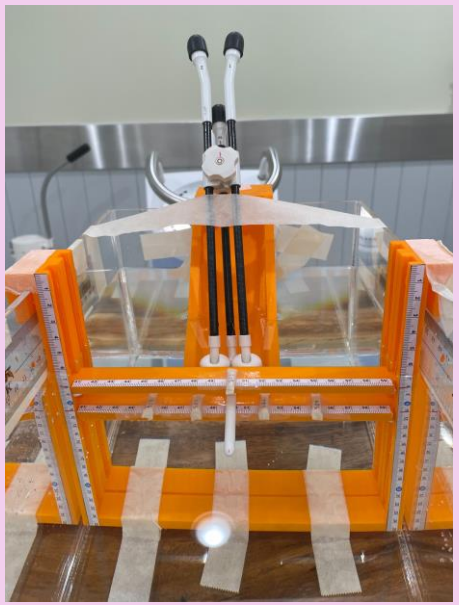
In-house phantom



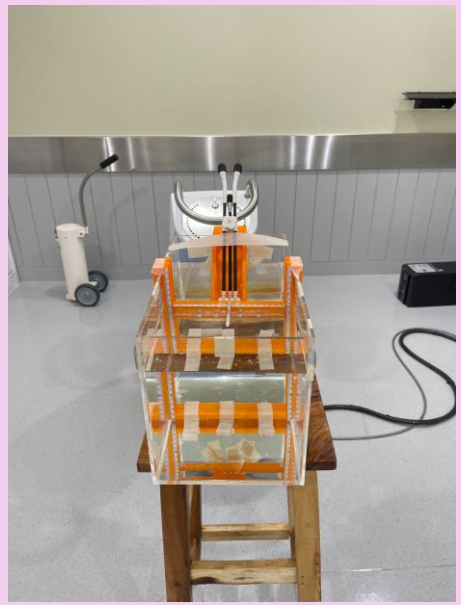
The phantom with the Fletcher applicator was scanned by CT scanner



Oncentra treatment planning system



The 3 Gynecological plans were exported and the phantom



The measurement was repeated three times

Ref * Itsaraporn Konlak *,In vivo dosimetry of 3D gynecological brachytherapy using the glass dosimeter (RPLGD): a phantom study*

Results

Number	1			2			3		
	Calculated dose (Gy)	Measured dose (Gy)	ΔD(%)	Calculated dose (Gy)	Measured dose (Gy)	ΔD(%)	Calculated dose (Gy)	Measured dose (Gy)	ΔD(%)
Point A (L)	2.56	2.64 ± 0.14	3.23	2.94	2.91 ± 0.10	-1.32	3.38	3.51 ± 0.05	3.88
Point A (R)	2.56	2.53 ± 0.32	-1.09	3.04	3.15 ± 0.08	3.48	3.42	3.52 ± 0.21	2.66

The mean dose difference was 2.61 %

Sun Young Moon et al.: The mean dose difference of 3.85%.

This value was within 5% of the recommended value in the report from ESTRO Booklet No. 8

Ref * Itsaraporn Konlak *,In vivo dosimetry of 3D gynecological brachytherapy using the glass dosimeter (RPLGD): a phantom study*

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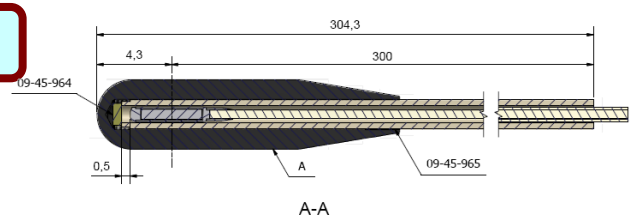
Thank you

Backup

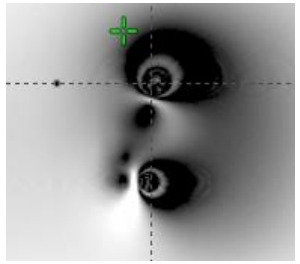
Commissioning of Applicators

„The process in which the (clinically relevant) location of the dwell positions in relation to each other or in relation to reference points in the applicator are determined/verified and the transfer into the treatment planning system is checked”

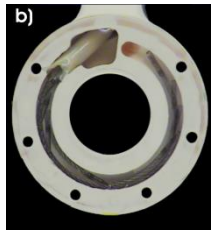
- **Characteristics of applicators**
  - Material (dosimetric influence, sterilisation)
  - Dimensions
  - Connectivity to afterloader (transfer tubes)
  - Indexer length and off-set (distance of 1st or most distal dwell position to tip-end)



- **Visibility of applicator in sectional imaging**
  - Distortion of dimensions
  - Artefacts (appearance of applicator tip-end: E.g. needle tip-end)



- **Verify source-path**
  - Predefined (from vendor provided) source-path stored in Applicator library
  - Direct reconstructed by the user following direct or in-direct reconstruction methods



Integrity of applicator materials	Visual inspection, depending on their use: before or after each treatment
Fixation mechanisms	Check each fixation screw and mechanism for proper functioning before and after treatment
Shielding in the applicators	Check for presence and position of shields included in the applicator at acceptance (radiography)
Source positioning	Autoradiography whenever applicable for verification of source pos. at acceptance or when there is suspicion of (length) changes
Identification of connecting mechanism	Check the identity of the applicator in relation to its connection to the afterloader at acceptance
Sterilisation procedures	Check for instructions and follow these meticulously to avoid unintended damaging
Validity of dose distribution in relation to specific applicators	Carefully check the applicability of any dosimetrical “atlas” for precalculated and tabulated treatment times, at acceptance
Radioactive contamination	Careful handling with, e.g., Sr-90 applicators to avoid radioactive contamination and checking of tubes in NaI crystal to detect leakage or contamin.

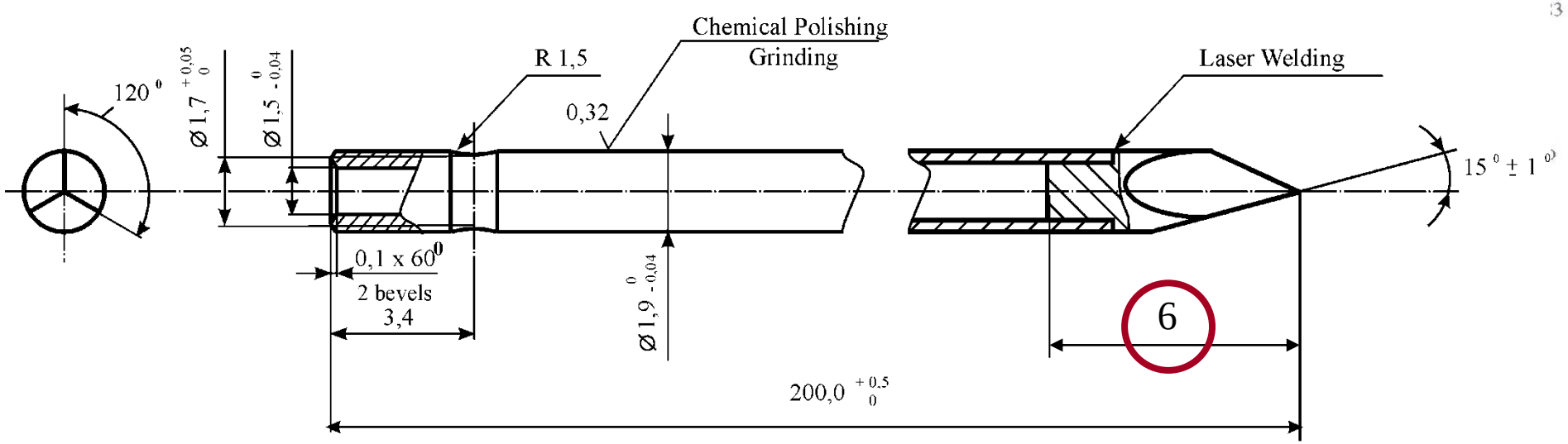
Titanium alloys used for manufacture of titanium needles (VT-6, RK-20,VT1-0)

Chemical composition , (%)

Allow / Element	VT1-0 (GOST 19807-91)	For comparing (ASTM Designation: F67-83) Grade 1 [1]	VT-6 [2]	RK-20 [3]	Perspec-tive alloy PT-7M
H	0,010	0,015	0,015	0,005	0,003
C	0,07	0,10	0,10	0,02	0,03
N	0,04	0,03	0,05	0,02	0,01
O	0,2	0,18	0,20	0,07	0,09
Al	0,03	-	6,10	-	2,10
Fe	0,25	0,20	0,60	-	0,06
Si	0,01	-	0,10	-	0,01
Cr	-	-	-		-
Mn	-	-	-		-
Zr	-	-	0,30	20,0	2,70
V		-	4,30	-	-
The sum remaining impurities	0,1	-	0,3	0,1	0,3

[3]

Quality Check for Titanium needles “indexer length and off-set”



Acceptance Test for Applicators on Flexitron Afterloader

Isodose Control Heyman Applicators

Length 300 -> Offset = 4mm