

Strahlenschutz

- VMAT Planung mit Optimierung
- Brachytherapie

Dr. Silvan Müller



Strahlenschutzgesetz

1. Abschnitt: Grundsätze des Strahlenschutzes

Art. 8 Rechtfertigung der Strahlenexposition

Eine Tätigkeit, bei der Menschen oder die Umwelt ionisierenden Strahlen ausgesetzt sind (Strahlenexposition), darf nur ausgeübt werden, wenn sie sich mit den damit verbundenen Vorteilen und Gefahren rechtfertigen lässt.

Art. 9 Begrenzung der Strahlenexposition

Zur Begrenzung der Strahlenexposition jeder einzelnen Person sowie der Gesamtheit der Betroffenen müssen alle Massnahmen ergriffen werden, die nach der Erfahrung und dem Stand von Wissenschaft und Technik geboten sind.

Art. 10 Dosisgrenzwerte

Der Bundesrat legt, nach dem jeweiligen Stand der Wissenschaft, Grenzen der Strahlenexposition (Dosisgrenzwerte) für jene Personen fest, die aufgrund ihrer beruflichen Tätigkeit oder durch andere Umstände einer im Verhältnis zur übrigen Bevölkerung erhöhten und kontrollierbaren Strahlung ausgesetzt sein können (strahlenexponierte Personen).

Optimierung der Dosis zum Schutz von

- Patient
- Personal

(effektive Dosis < 20 mSv / Jahr)

Strahlenschutzverordnung

3. Abschnitt: Medizinische Optimierung

Art. 32 Optimierung medizinischer Expositionen

¹ Die Bewilligungsinhaberin oder der Bewilligungsinhaber muss bei diagnostischen Untersuchungen, bei Untersuchungen in der interventionellen Radiologie und bei

Untersuchungen in der Nuklearmedizin alle Strahlendosen so niedrig halten, wie dies für die Gewinnung der benötigten Bildinformation möglich ist.

² Sie oder er muss bei allen therapeutischen Expositionen eine individuelle dosimetrische Planung durchführen. Die Dosen für Risikoorgane müssen unter Berücksichtigung des beabsichtigten radiotherapeutischen Zwecks so niedrig wie möglich gehalten werden.

³ Der Optimierungsprozess beinhaltet zum Schutz der Patientinnen und Patienten insbesondere:

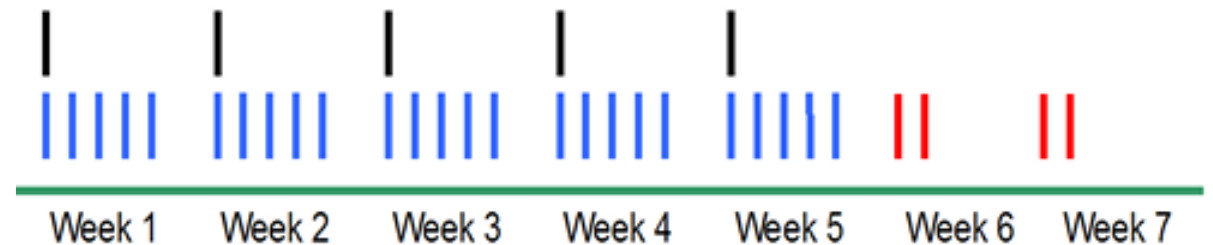
- a. die Auswahl der geeigneten Ausrüstung einschliesslich der Software;
- b. die Sicherstellung der Qualität der adäquaten diagnostischen Information oder des therapeutischen Erfolgs;
- c. die Einhaltung der praktischen Aspekte der Verfahren;
- d. die Qualitätssicherung;
- e. die Erfassung und Evaluation der Patientendosis oder der abgebenden Aktivität;
- f. die Verwendung von adäquaten Einstellparametern oder adäquaten Radionukliden;
- g. den Einsatz von empfindlichen Detektoren;
- h. den Einsatz der zum Schutz der Patientinnen und Patienten notwendigen Mittel zu jeder medizinischen Anlage.

⁴ Die Dosis des Personals muss im Optimierungsprozess berücksichtigt werden.

⁵ Das EDI kann Bestimmungen über die technische Optimierung zum Schutz von Patientinnen und Patienten erlassen.

Fallbeispiel Zervixkarzinom

- External beam radiochemotherapy (EBRT) mit 2 VMAT Plänen und CT/MR image
 - 28 x 1.8 Gy = **50.4 Gy** auf grosses Zielvolumen (weil Lymphknoten involviert)
 - 28 x 2.0 Gy = **56.0 Gy** Simultaneous integrated boost auf Lymphknoten
 - 3 x 2.0 Gy = **6.0 Gy** Sequential boost auf Lymphknoten
- Brachytherapy «Adaptiv» mit CT/MR image
 - 4 x 7.0 Gy = **28.0 Gy**

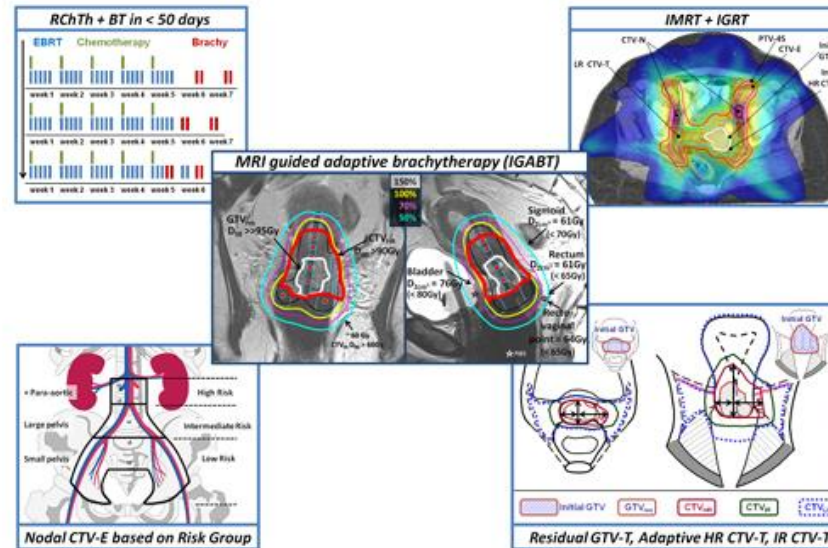


EMBRACE-II

EMBRACE II study protocol v.1.0

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

EMBRACE-II



Protocol writing committee: Kari Tanderup, Richard Pötter, Jacob Lindegaard, Christian Kirisits, Ina Juergenliemk-Schulz, Astrid de Leeuw, Israël Fortin, Kathrin Kirchheiner, Dietmar Georg, Remi Nout, Yvette Seppenwoolde, Wolfgang Dörr, Thomas Liederer, Li Tee Tan

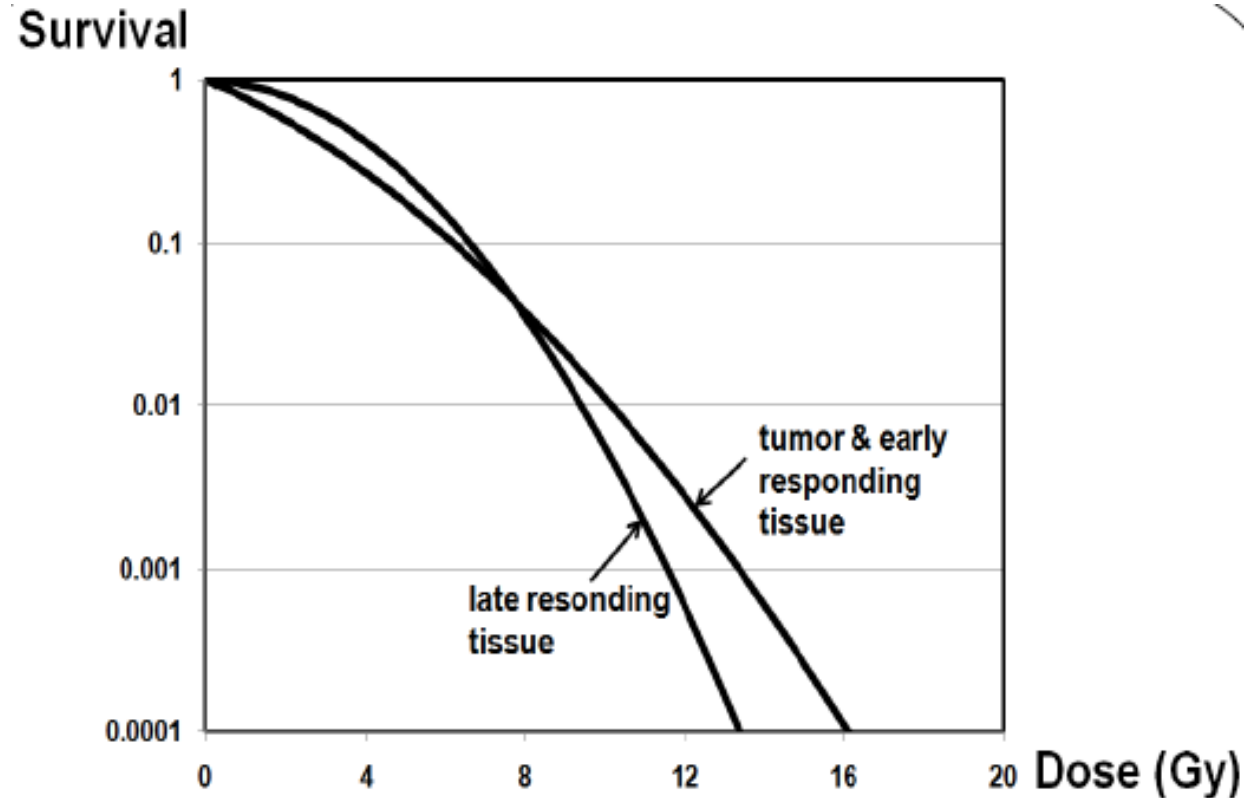
Was sind die dosimetrischen Gesamtziele? (EMBRACE-II)

PHYSICAL - BIOLOGICAL DOCUMENTATION OF GYNAECOLOGICAL HDR BT

PATIENT , ID-number					tumour entity	
EXTERNAL BEAM THERAPY					FIGO, TNM	
	1. Phase	2. Phase	TUMOUR	OAR		
dose per fraction	1.8	0	Diso [a/b=10Gy]	Diso [a/b=3Gy]		
fractions without central shield	28	0	49.6	48.4		
total dose	50.4	0.0	49.6	48.4	GTV at diag.	cm3
					chemoth.	
BRACHYTHERAPY						
	F 1	F 2	F 3	F 4	dose values in Gy	
date						
MR / CT	CT	CT	CT	CT	TOTAL BT	TOTAL BT + EBT
applicator(s): type	Venezia	Venezia + plastic	Geneva	Venezia + 3 Nad.		
applicator(s): dimensions	5 cm OLOR 22	IU5cm + Ov22mm	4 cm OLOR20	5cm 22mm	mean	stddev
TRAK [cGy at 1m]	0.24	0.21	0.20	0.18	0.83	
prescribed dose PD [Gy]	7	7	7	7		
PD iso [a/b=10Gy] [Gy]	9.9	9.9	9.9	9.9	39.7	89.2
volume of PD [cm3]	35.689	30.258	28.97	25.92	30.2	3.5
200% PD [Gy]	14.0	14.0	14.0	14.0		
200% PDx [a/b=10Gy] [Gy]	28.0	28.0	28.0	28.0	112.0	161.6
volume of 200% PD [cm3]	11.364	8.554	8.68	7.272	9.0	1.5
dose to + A left [Gy]	4.7	5.1	3.9			
Aleft - Diso [a/b=10Gy] [Gy]	5.8	6.4	4.5	0.0	16.6	66.1
dose to - A right [Gy]	3.8	3.3	3.4			
Aright - Diso [a/b=10Gy] [Gy]	4.4	3.7	3.7	0.0	11.8	61.4
dose to A mean [Gy]	4.3	4.2	3.6	0.0		
Amean - Diso [a/b=10Gy] [Gy]	5.1	5.0	4.1	0.0	14.1	63.7

Kann man Dosis von zwei Fraktionierungsschemas zusammenzählen?

- **Biologischer Effekt**
 - Fraktionsdosis d
 - Gewebetyp (α/β Wert)



EQD2 Summierung

- Equivalent dose in 2 Gy fractions (**EQD2**)
 - Umrechnung der Dosis mit biologischem Effekt gemäss 2 Gy Fraktionierung

$$EQD2 = D \times \frac{d + \alpha/\beta}{2 + \alpha/\beta}$$

Therapie	Phys. Dosis	EQD2
EBRT	28 x 1.8 Gy = 50.4 Gy	49.6 Gy
Brachytherapy	4 x 7 Gy = 28 Gy	39.6 Gy
Total	78.4 Gy	89.2 Gy

EBRT Workflow

**CT / MR
Imaging**

**Contouring
Prescription**

**Treatment
Planning**

**Plan
evaluation**

**Plan
Finalization**

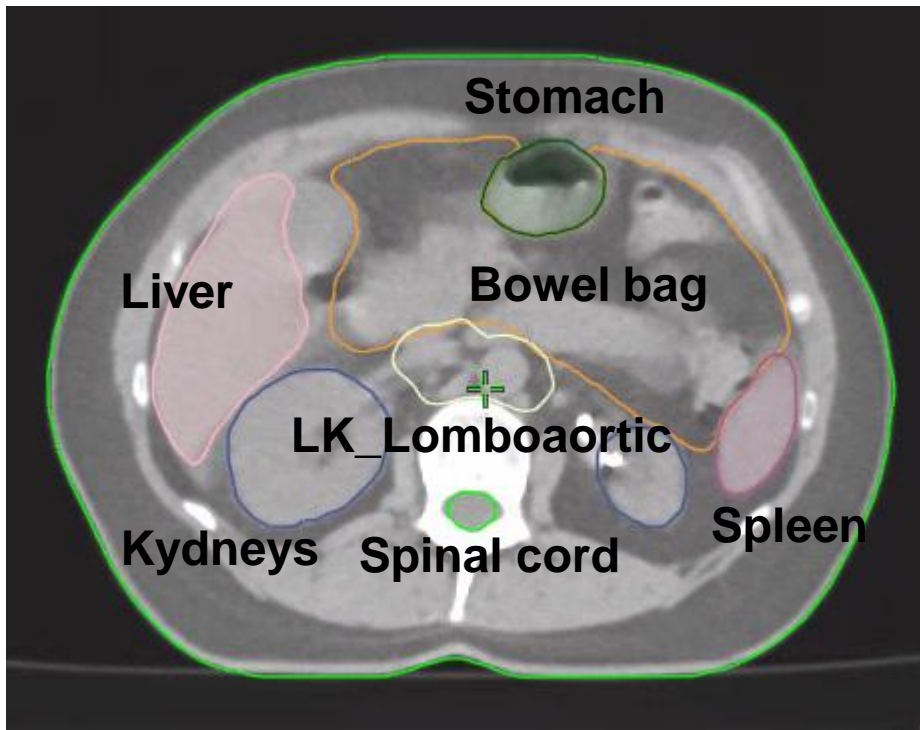
**Quality
Assurance**

Treatment

Contours

- Therapanacea: Auto-Segmentation von OARs

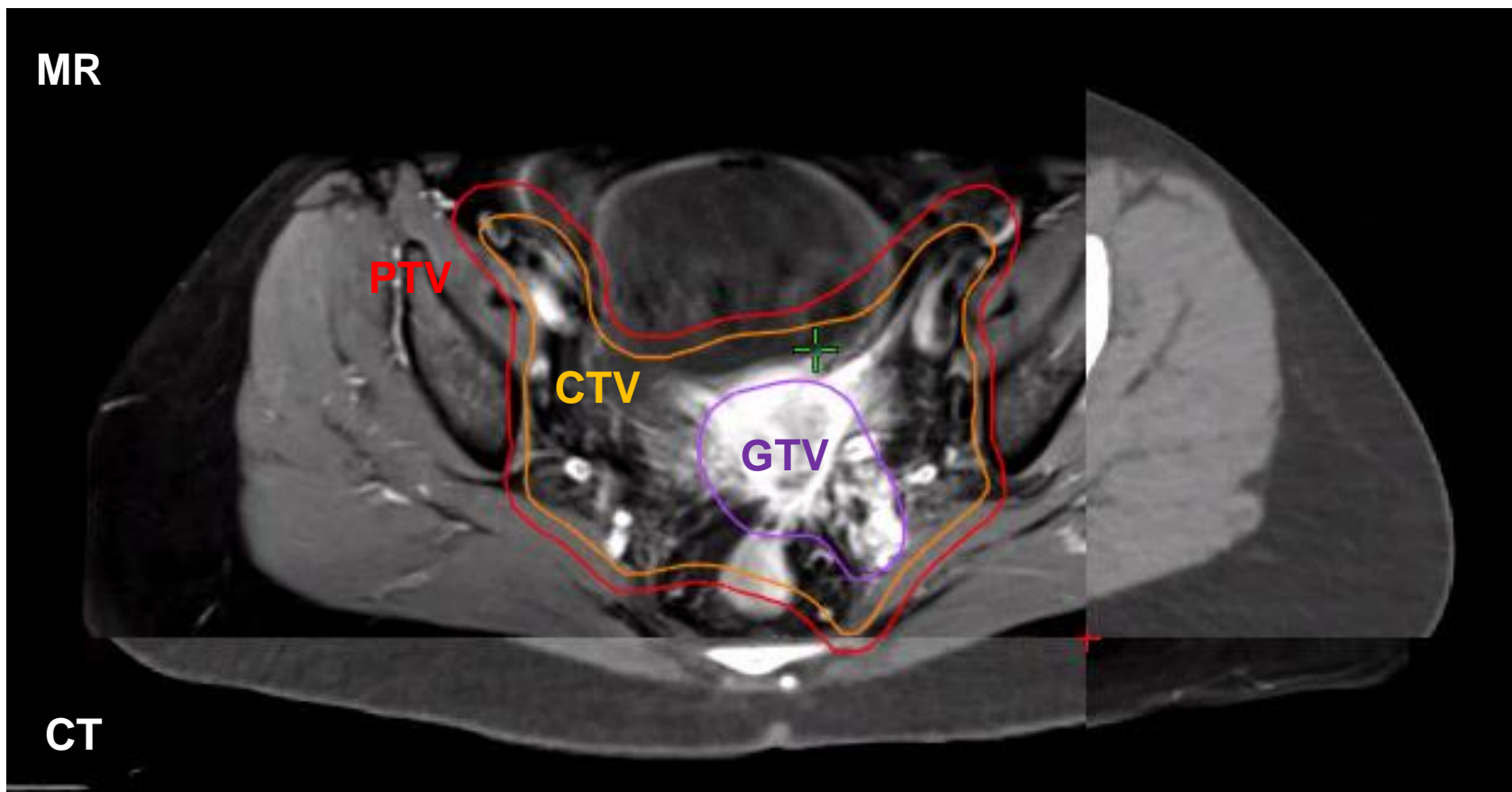
Resultat von Auto-Segmentierung



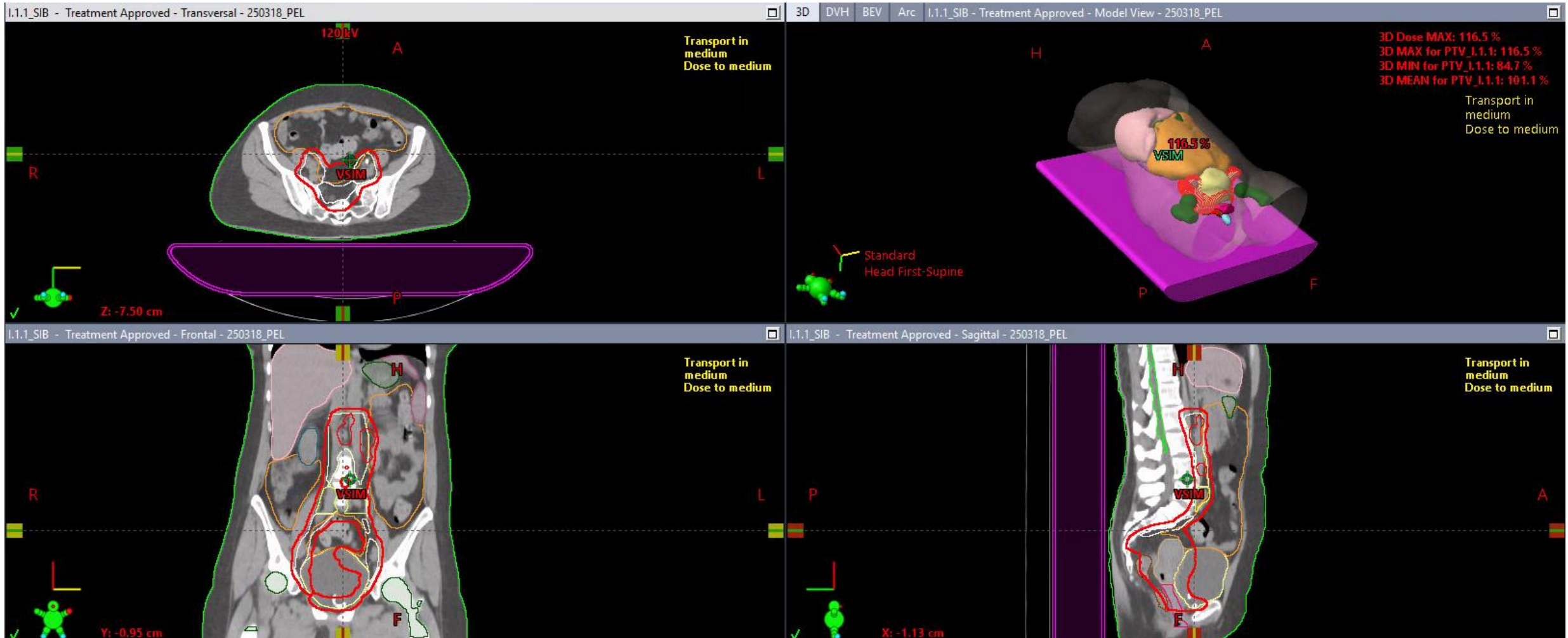
Korrekturen



Contours



Contours

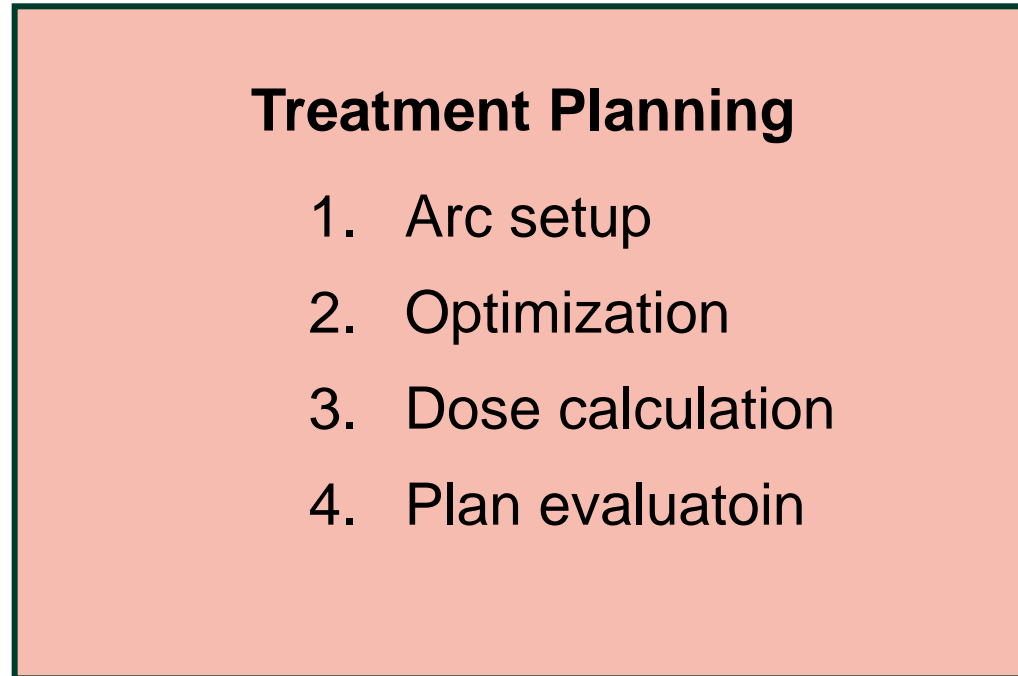


Treatment planning (VMAT)



Input

- CT
- StructureSet
- Prescription



Output

- Plan

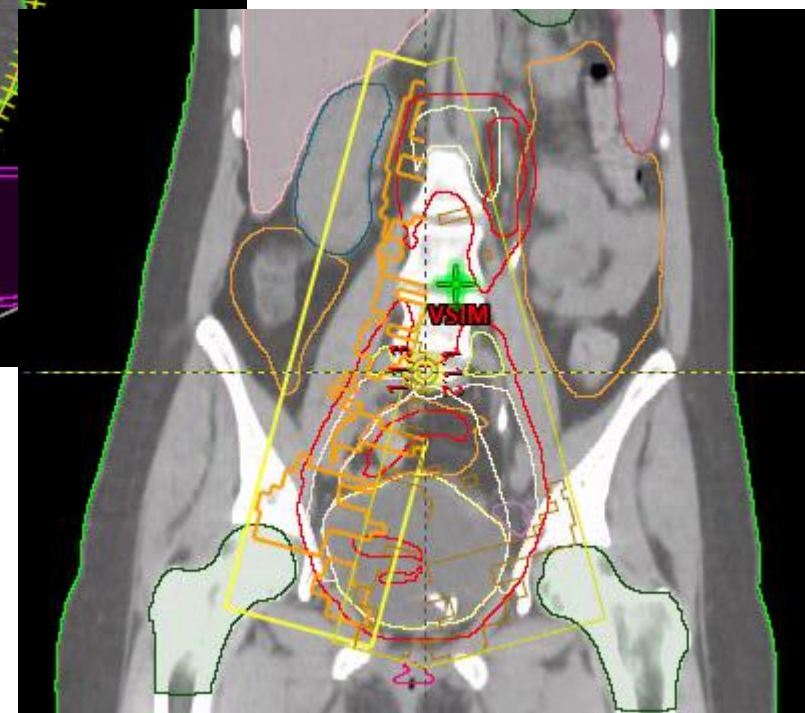
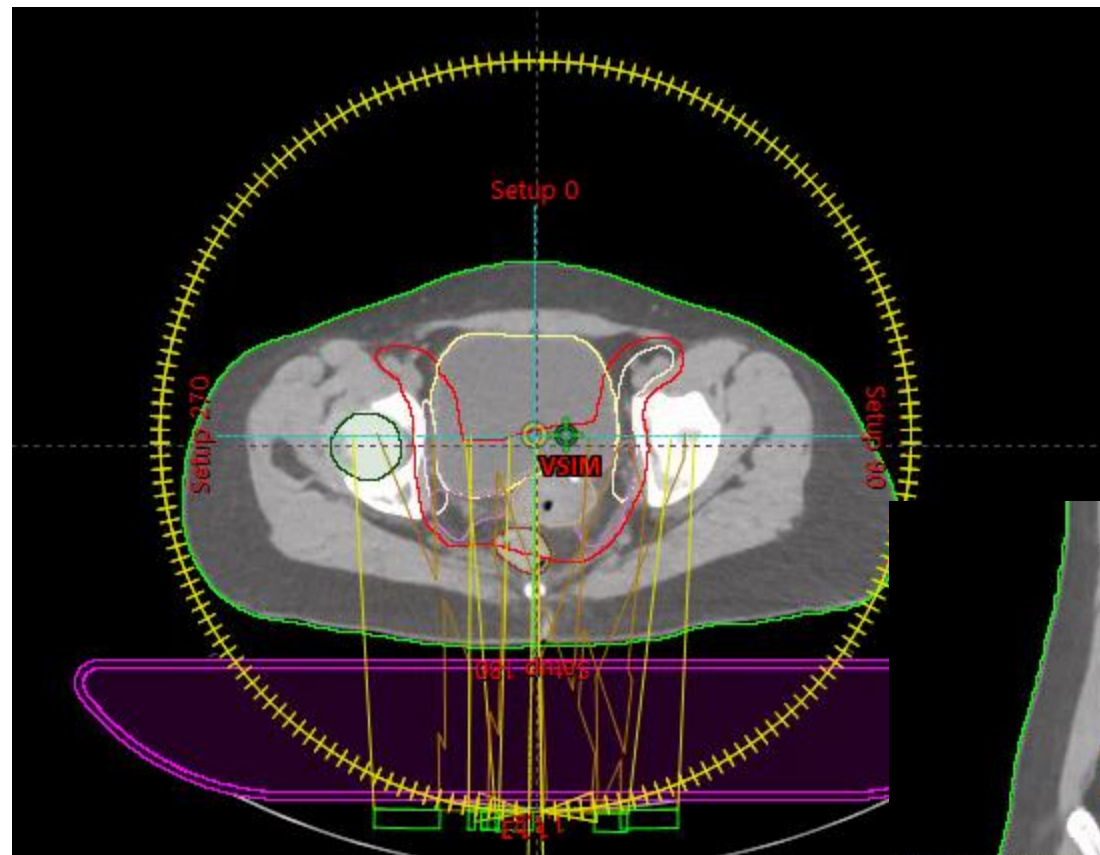
Klinische constraints

EMBRACE-II constraints

		Hard dose constraints	Soft dose constraints
Targets	PTV45	V95% > 95% Dmax < 107%*	
	ITV45	Dmin > 95%	
	PTV-N(#)	D98% > 90% of prescribed LN dose Dmax < 107% of prescribed LN dose	
	CTV-N(#)	D98% > 100% of prescribed LN dose	D50% > 102%
Help contour	CTV-HR +10mm		Dmax < 103%
OARs	Bowel	Dmax < 105% (47.3Gy)*	When no lymph node boost: <ul style="list-style-type: none"> V40Gy < 100cm³** V30Gy < 350cm³** When lymph node boost or para-aortic irradiation: <ul style="list-style-type: none"> V40Gy < 250cm³** V30Gy < 500cm³** Dmax < 57.5Gy
	Sigmoid	Dmax < 105% (47.3Gy)*	Dmax < 57.5Gy
	Bladder	Dmax < 105% (47.3Gy)*	V40Gy < 75%** V30Gy < 85%** Dmax < 57.5Gy
	Rectum	Dmax < 105% (47.3Gy)*	V40Gy < 85%** V30Gy < 95%** Dmax < 57.5Gy
	Spinal cord	Dmax < 48Gy	
	Femoral heads	Dmax < 50Gy	
	Kidney	Dmean < 15Gy	Dmean < 10Gy
	Body	Dmax < 107%*	
	Vagina PIBS-2cm		When vagina not involved: D _{PIBS-2cm} < 5Gy
Optional	Ovaries	< 5-8 Gy	
	Duodenum***	V55 < 15cm ³	

Arc setup (manuell)

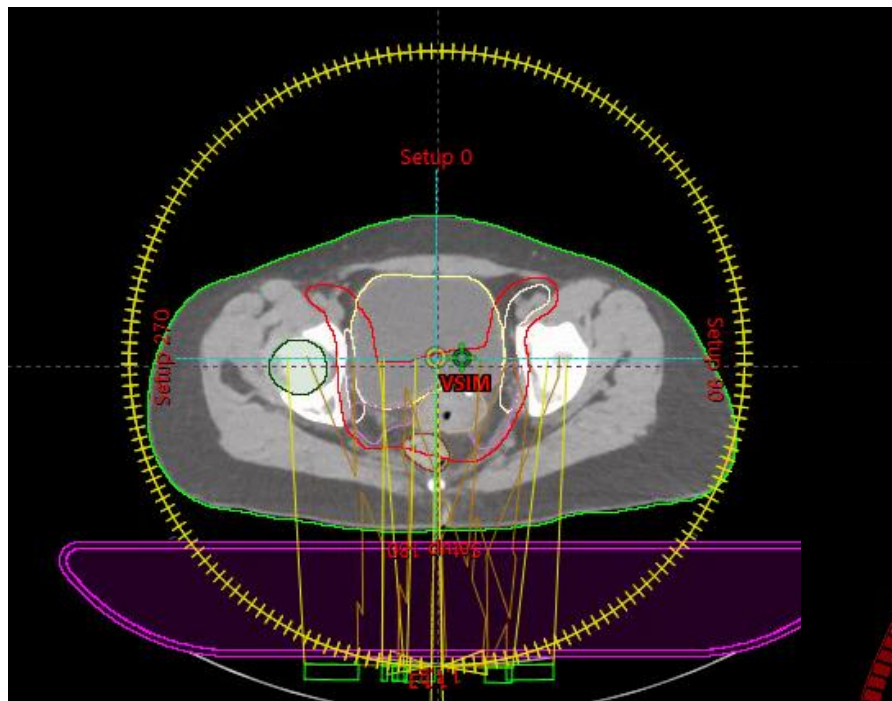
- Isocenter
- Beam modality
- Gantry start/stop angle
- Collimator angle
- Couch angle
- Field size (jaws)



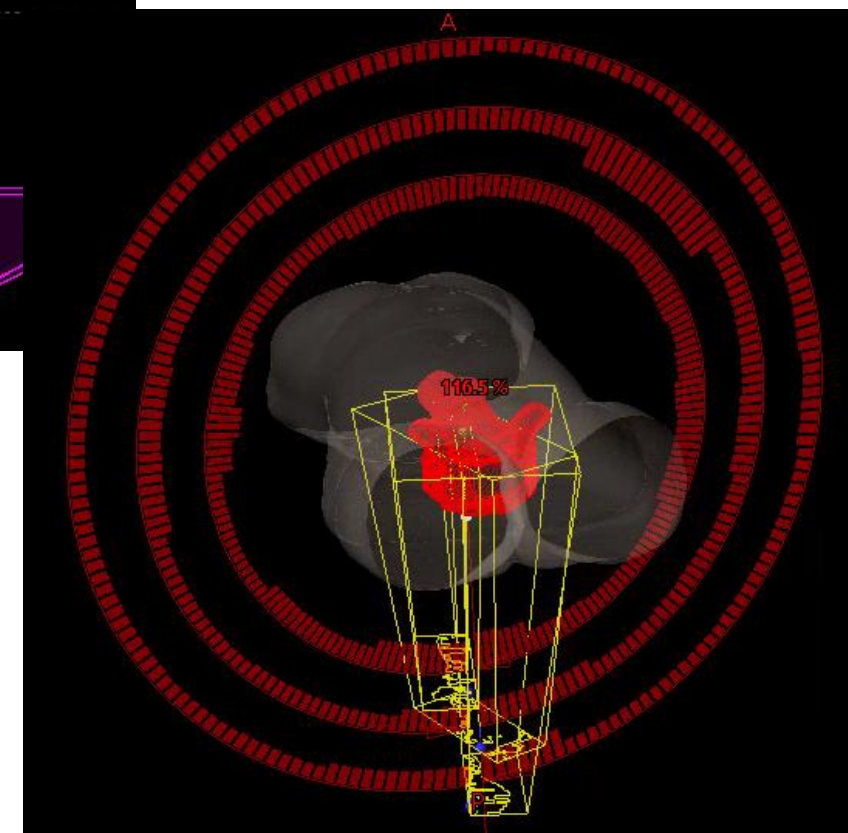
Group	Field ID	Technique	Machine/Energy	MLC	Field Weight	Scale	Gantry Rtn [deg]	Coll Rtn [deg]	Couch Rtn [deg]	Wedge	Field X [cm]	X1 [cm]	X2 [cm]	Field Y [cm]	Y1 [cm]	Y2 [cm]	X [cm]	Y [cm]	Z [cm]	Calculated SSD [cm]	MU	Ref. D [cGy]
I	Setup 90	Static-I	ROBO_TB2019 - 6X		0.000	Varian IEC	90.0	0.0	0.0	None	10.0	+5.0	+5.0	10.0	+5.0	+5.0	-1.70	0.00	-4.70	83.5		
I	1.1.1	Arc Therapy-I	ROBO_TB2019 - 6X-FFF	VMAT	2.458	Varian IEC	181.0 CW 179.0	15.0	0.0	None	9.9	+1.0	+8.9	31.3	+15.3	+16.0	-1.70	0.00	-4.70	89.1	440	
I	1.1.2	Arc Therapy-I	ROBO_TB2019 - 6X-FFF	VMAT	2.287	Varian IEC	179.0 CCW 181.0	345.0	0.0	None	12.0	+6.0	+6.0	31.3	+15.3	+16.0	-1.70	0.00	-4.70	89.1	409	
I	1.1.3	Arc Therapy-I	ROBO_TB2019 - 6X-FFF	VMAT	1.824	Varian IEC	181.0 CW 179.0	15.0	0.0	None	13.6	+12.6	+1.0	31.3	+15.3	+16.0	-1.70	0.00	-4.70	89.1	326	

Arc setup (manuell)

- Isocenter
- Beam modality
- **Gantry start/stop angle**
- **Couch angle**
- Collimator angle
- Field size (jaws)



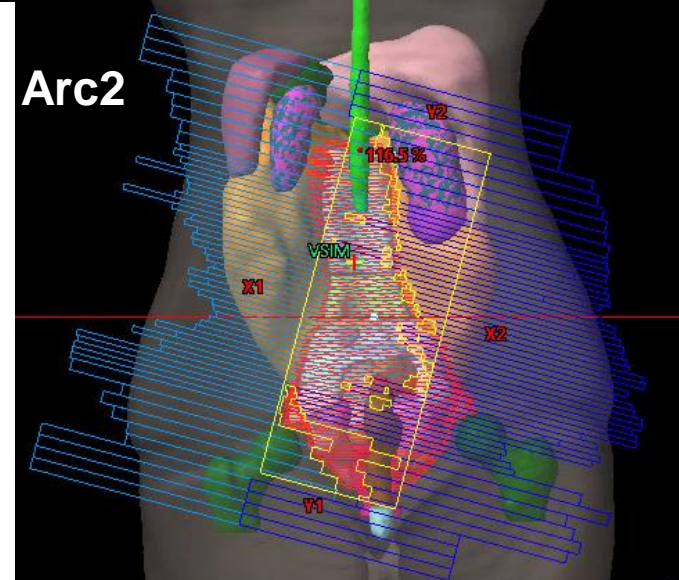
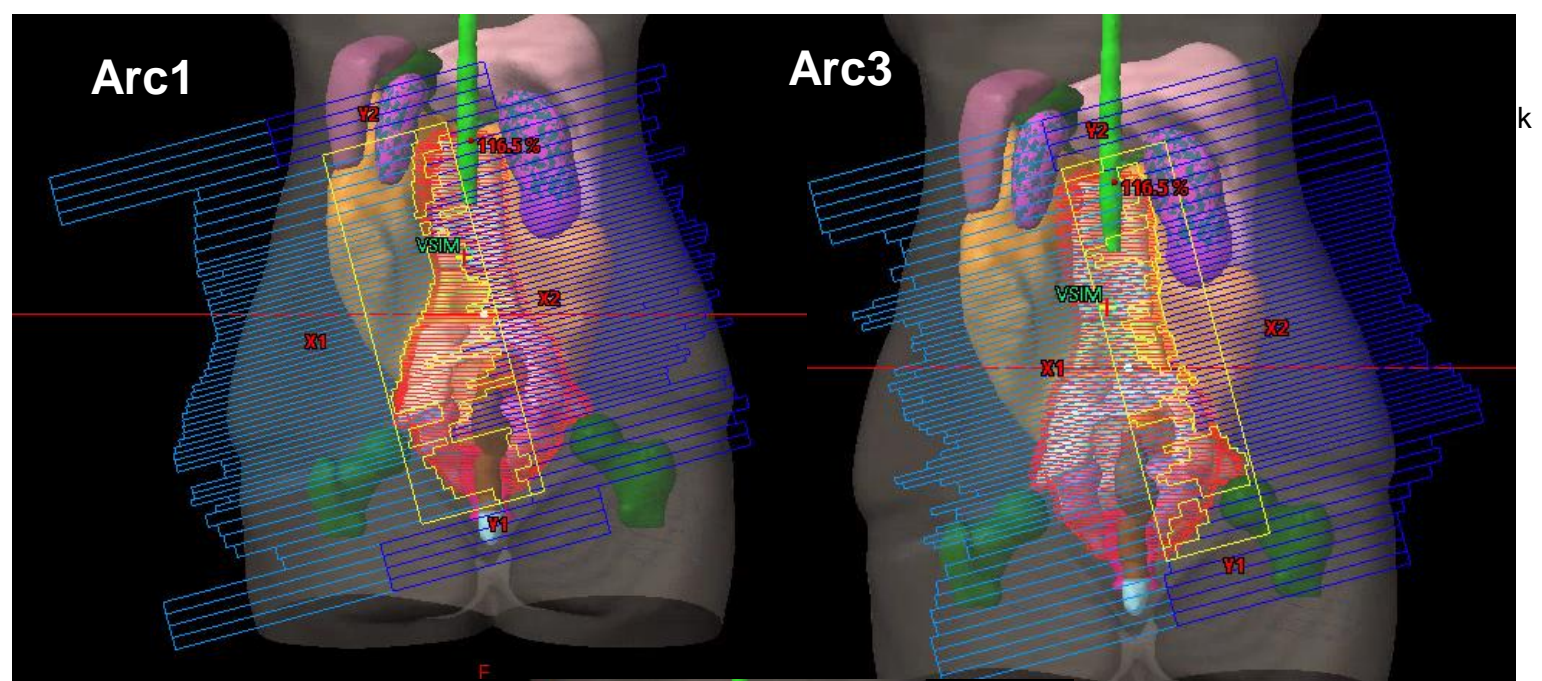
Abteilung für Medizinische Strahlenphysik



Group	Field ID	Technique	Machine/Energy	MLC	Field Weight	Scale	Gantry Rtn [deg]	Coll Rtn [deg]	Couch Rtn [deg]	Wedge	Field X [cm]	X1 [cm]	X2 [cm]	Field Y [cm]	Y1 [cm]	Y2 [cm]	X [cm]	Y [cm]	Z [cm]	Calculated SSD [cm]	MU	Ref. D [cGy]
I	Setup 90	Static-I	ROBO_TB2019 - 6X		0.000	Varian IEC	90.0	0.0	0.0	None	10.0	+5.0	+5.0	10.0	+5.0	+5.0	-1.70	0.00	-4.70	83.5		
I	1.1.1	Arc Therapy-I	ROBO_TB2019 - 6X-FFF	VMAT	2.458	Varian IEC	181.0 CW 179.0	15.0	0.0	None	9.9	+1.0	+8.9	31.3	+15.3	+16.0	-1.70	0.00	-4.70	89.1	440	
I	1.1.2	Arc Therapy-I	ROBO_TB2019 - 6X-FFF	VMAT	2.287	Varian IEC	179.0 CCW 181.0	345.0	0.0	None	12.0	+6.0	+6.0	31.3	+15.3	+16.0	-1.70	0.00	-4.70	89.1	409	
I	1.1.3	Arc Therapy-I	ROBO_TB2019 - 6X-FFF	VMAT	1.824	Varian IEC	181.0 CW 179.0	15.0	0.0	None	13.6	+12.6	+1.0	31.3	+15.3	+16.0	-1.70	0.00	-4.70	89.1	326	

Arc setup (manuell)

- Isocenter
- Beam modality
- Gantry start/stop angle
- Couch angle
- **Collimator angle**
- **Field size (jaws)**



Group	Field ID	Technique	Machine/Energy	MLC	Field Weight	Scale	Gantry Rtn [deg]	Coll Rtn [deg]	Couch Rtn [deg]	Wedge	Field X [cm]	X1 [cm]	X2 [cm]	Field Y [cm]	Y1 [cm]	Y2 [cm]	X [cm]	Y [cm]	Z [cm]	Calculated SSD [cm]	MU	Ref. D [cGy]
I	Setup 90	Static-I	ROBO_TB2019 - 6X		0.000	Varian IEC	90.0	0.0	0.0	None	10.0	+5.0	+5.0	10.0	+5.0	+5.0	-1.70	0.00	-4.70	83.5		
I	1.1.1	Arc Therapy-I	ROBO_TB2019 - 6X-FFF	VMAT	2.458	Varian IEC	181.0 CW 179.0	15.0	0.0	None	9.9	+1.0	+8.9	31.3	+15.3	+16.0	-1.70	0.00	-4.70	89.1	440	
I	1.1.2	Arc Therapy-I	ROBO_TB2019 - 6X-FFF	VMAT	2.287	Varian IEC	179.0 CCW 181.0	345.0	0.0	None	12.0	+6.0	+6.0	31.3	+15.3	+16.0	-1.70	0.00	-4.70	89.1	409	
I	1.1.3	Arc Therapy-I	ROBO_TB2019 - 6X-FFF	VMAT	1.824	Varian IEC	181.0 CW 179.0	15.0	0.0	None	13.6	+12.6	+1.0	31.3	+15.3	+16.0	-1.70	0.00	-4.70	89.1	326	

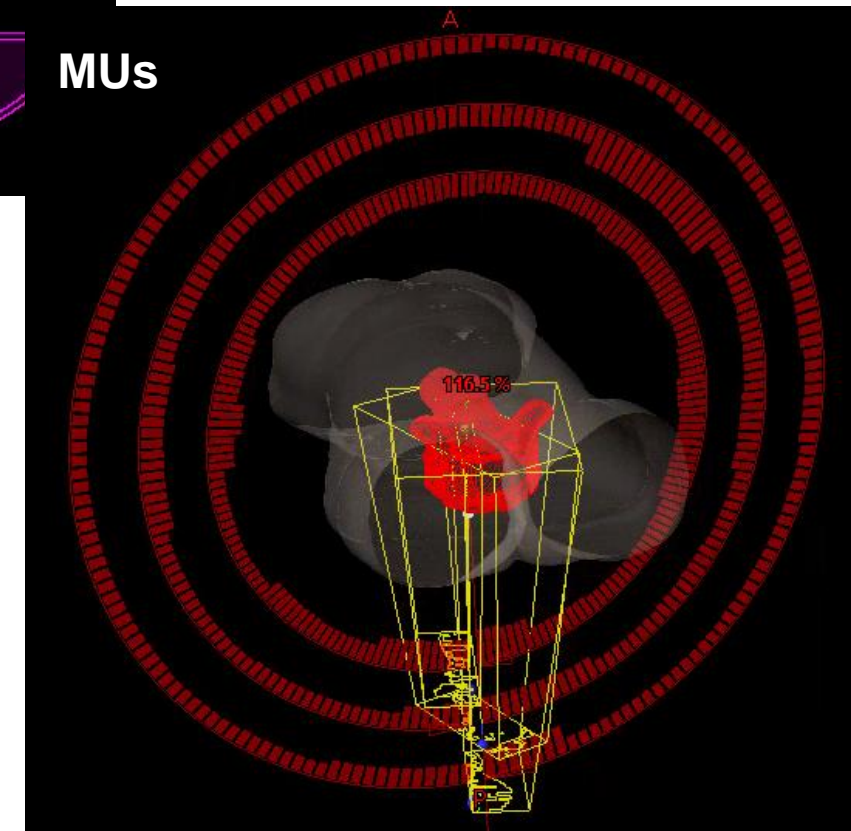
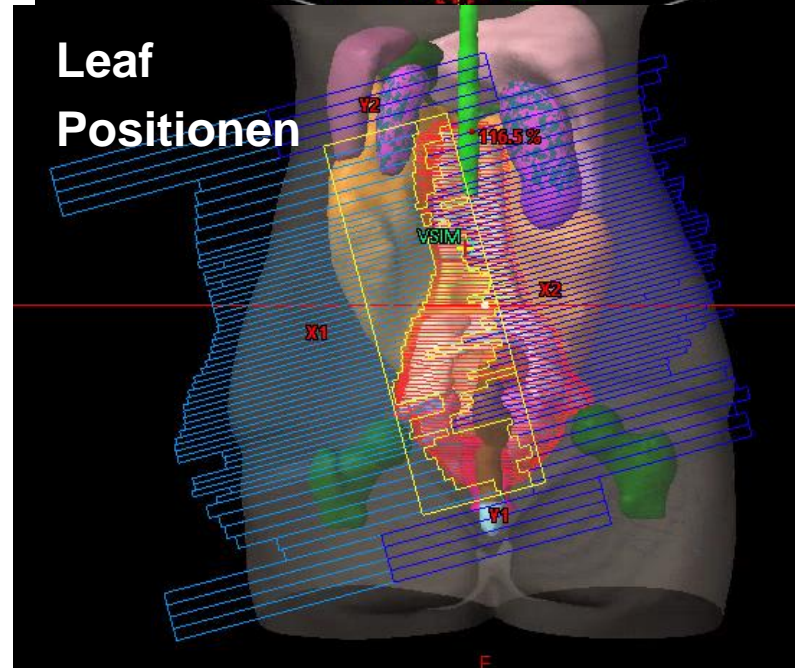
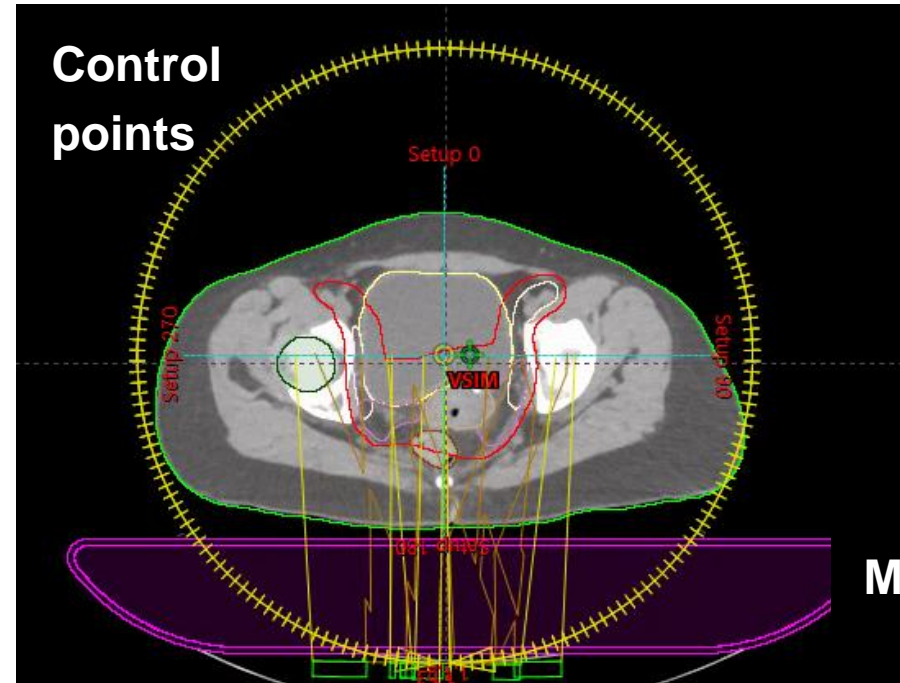
Optimization

Optimierungsvariablen

Für jeden Controllpoint

- Leaf Positionen
- MUs

Abteilung für Medizinische Strahlenphysik



Objectives

ID/Type	cm ³	Vol [%]	Dose[cGy]	Actual Dose [cGy]	Priority	gEUD _a	x
Lower	0.0	0.0	5880	5871	999		x
<input checked="" type="checkbox"/> PTV_I.1.1_SIB_	< 0.1						
Upper	0.0	0.0	5880	5801	999		x
Lower	< 0.1	99.9	5600	5693	999		x
<input checked="" type="checkbox"/> Anal_Canal	7.6						
Upper	3.8	49.9	425	406	900		x
Upper	1.7	21.8	576	557	900		x
Upper	0.0	0.0	1063	973	900		x
<input checked="" type="checkbox"/> Bladder	401.5						
Upper	10.0	2.5	5165	5143	999		x
Upper	316.0	78.7	2455	2448	900		x
Upper	231.0	57.5	4005	3999	900		x
Upper	167.6	41.8	5001	4971	999		x
Upper	361.6	90.1	1891	1882	900		x
Upper	279.9	69.7	3085	3062	900		x
Upper	190.9	47.5	4736	4737	900		x
Upper	0.0	0.0	5292	5311	999		x
Upper	79.6	19.8	5045	5019	999		x

3D Dose Max	5871 cGy
3D MAX for PTV_I.1.1	5871 cGy
3D MEAN for PTV_I.1.1	5097 cGy
3D MIN for PTV_I.1.1	4267 cGy
Elapsed Time	
Monitor Units	MU
Step in MR	
Leaf Sequence	
Intermediate Dose	

Isodoses...
 6048 cGy
 5544 cGy
 6292 cGy
 5040 cGy
 4788 cGy
 4536 cGy
 4032 cGy
 3528 cGy
 2520 cGy
 1512 cGy
 504 cGy

Z: -4.70 cm
 P
 10.00 cm

Progress Clinical Goals

Automatic Optimization Mode
 Automatic Intermediate Dose
 Use GPU

Start VMAT Optimization Intermediate Dose

Close and Apply Discard changes

Objective Function

- Eine Objective Function $F(l, mu)$ evaluiert mit einer Zahl wie stark die objectives nicht eingehalten wurden

$$F(\text{leafPos}, MU_s) = \text{prio}_{\text{Target}} \sum_{i=1}^{N_{\text{Target}}} (D_i - D_{\text{obj}}^{\text{Target}})^2$$

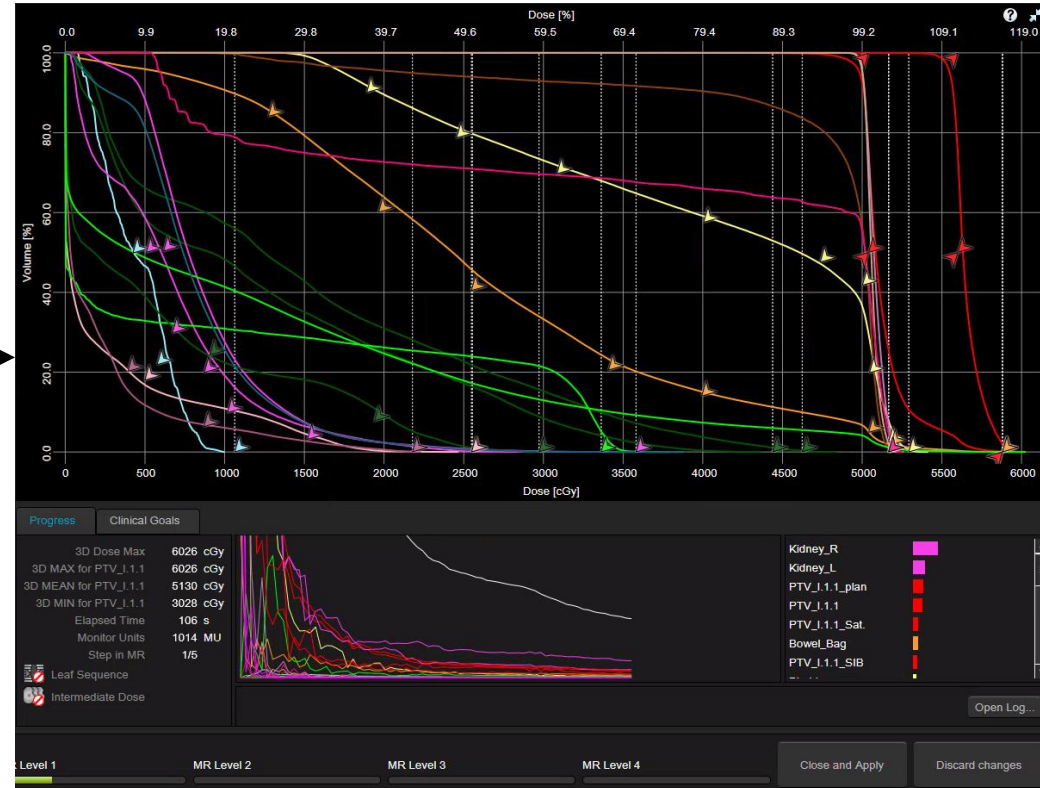
Target volume

$$+ \text{prio}_{\text{OAR}} \sum_{i=1}^{N_{\text{OAR}}} (D_i - D_{\text{obj}}^{\text{OAR}})^2$$

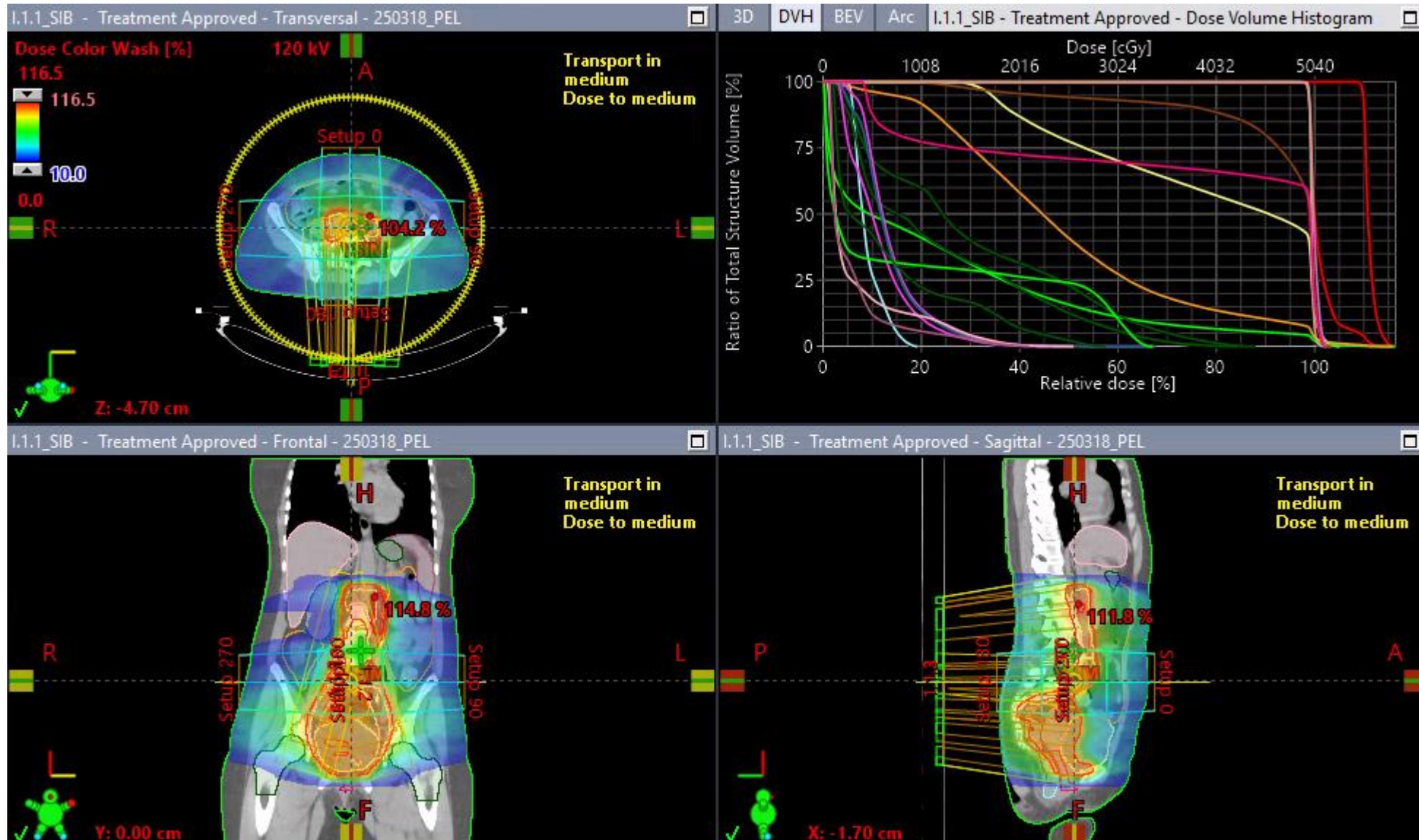
Organs at risk

D_i ist die Dosis an einer Stelle i beim aktuellen Plan

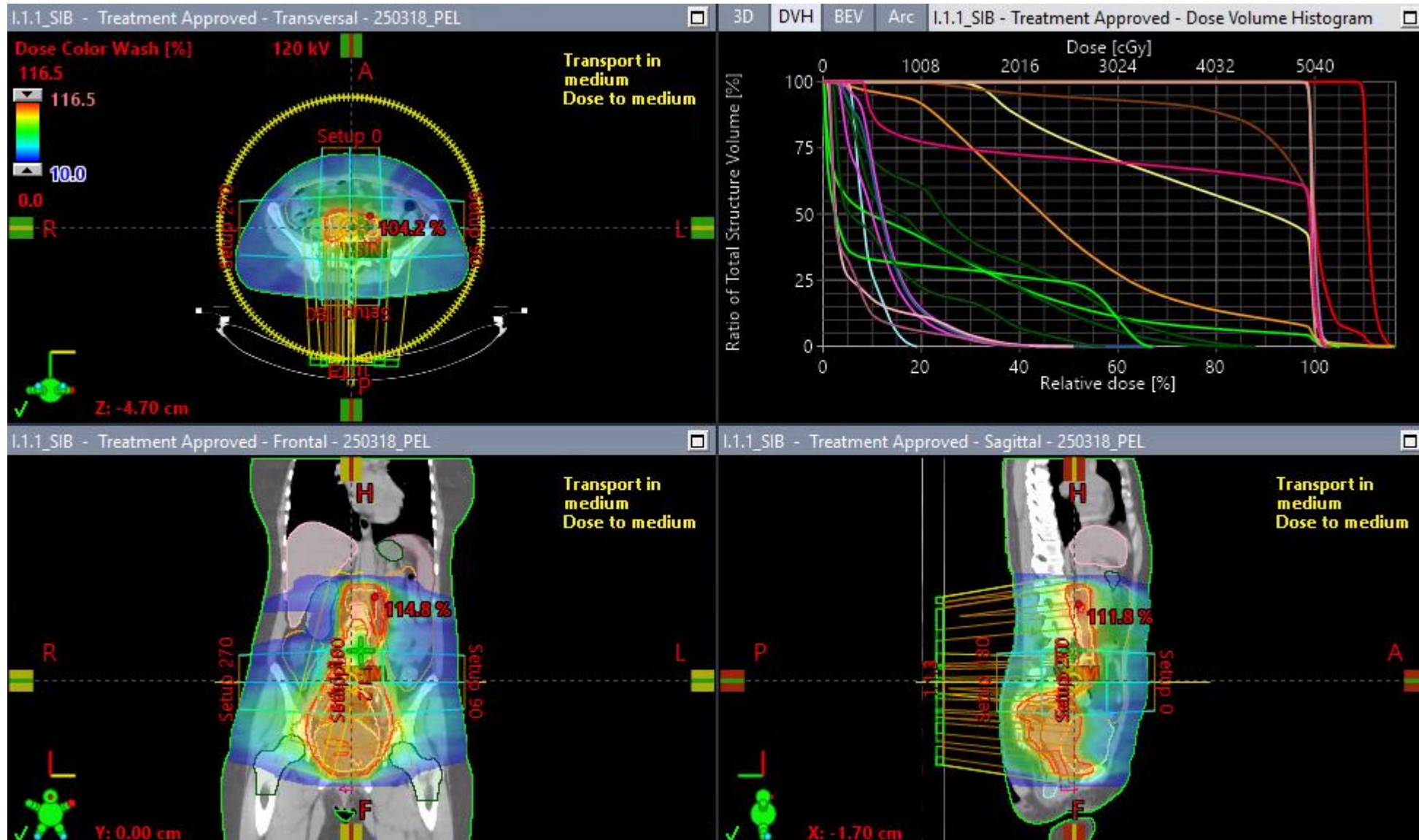
Iterationen (mit Zufallsänderungen)



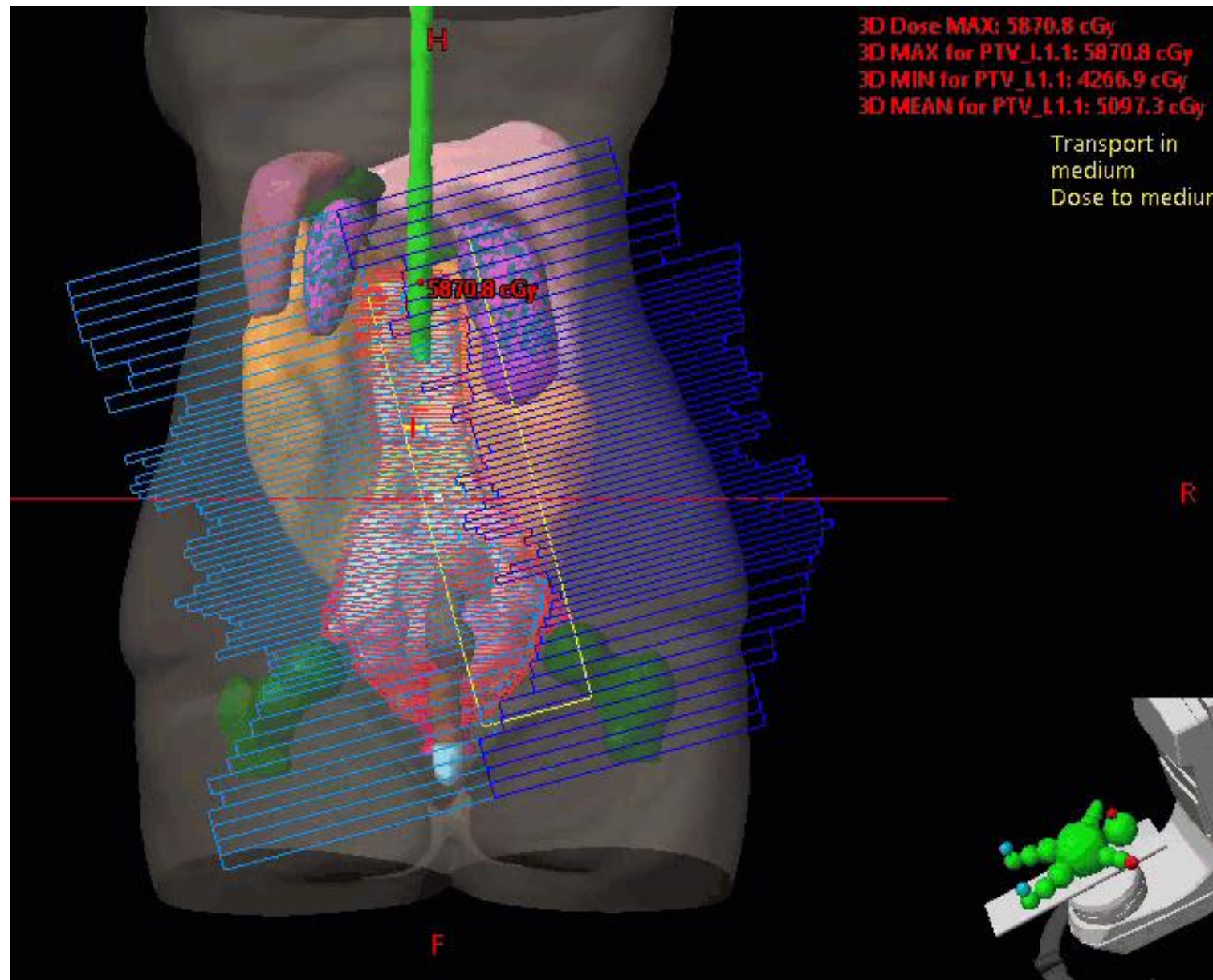
Dose calculation & Plan evaluation



Dose calculation & Plan evaluation



Simulation



Optimierung

- Der Optimierer muss gewisse Einschränkungen berücksichtigen
 - MU-Rate
 - Leafgeschwindigkeit
- Während der Optimierung wird die Auflösung der Control points erhöht
- Wie bei jeder Treatment-Technik , hochqualitative und effiziente Planung benötigt viel Erfahrung ...

Viele Beamrichtungen

Allgemein: VMAT > IMRT > 3DCRT

Aber es gibt Ausnahmen

	Viele Beamrichtungen (e.g. VMAT)	Wenige Beamrichtungen (e.g. 3DCRT)
High-dose conformality	High	low
Low dose bath	extended	minimal

MLC Typ

Millennium MLC

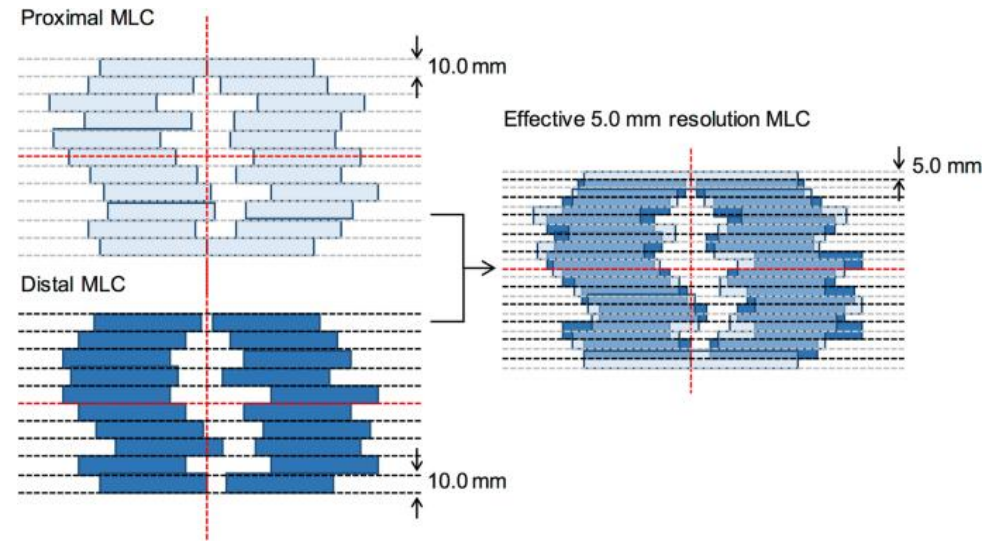
80 inner leaves 0.5 cm wide
40 outer leaves 1.0 cm wide
Max Field: 40 cm x 40 cm

HDMLC

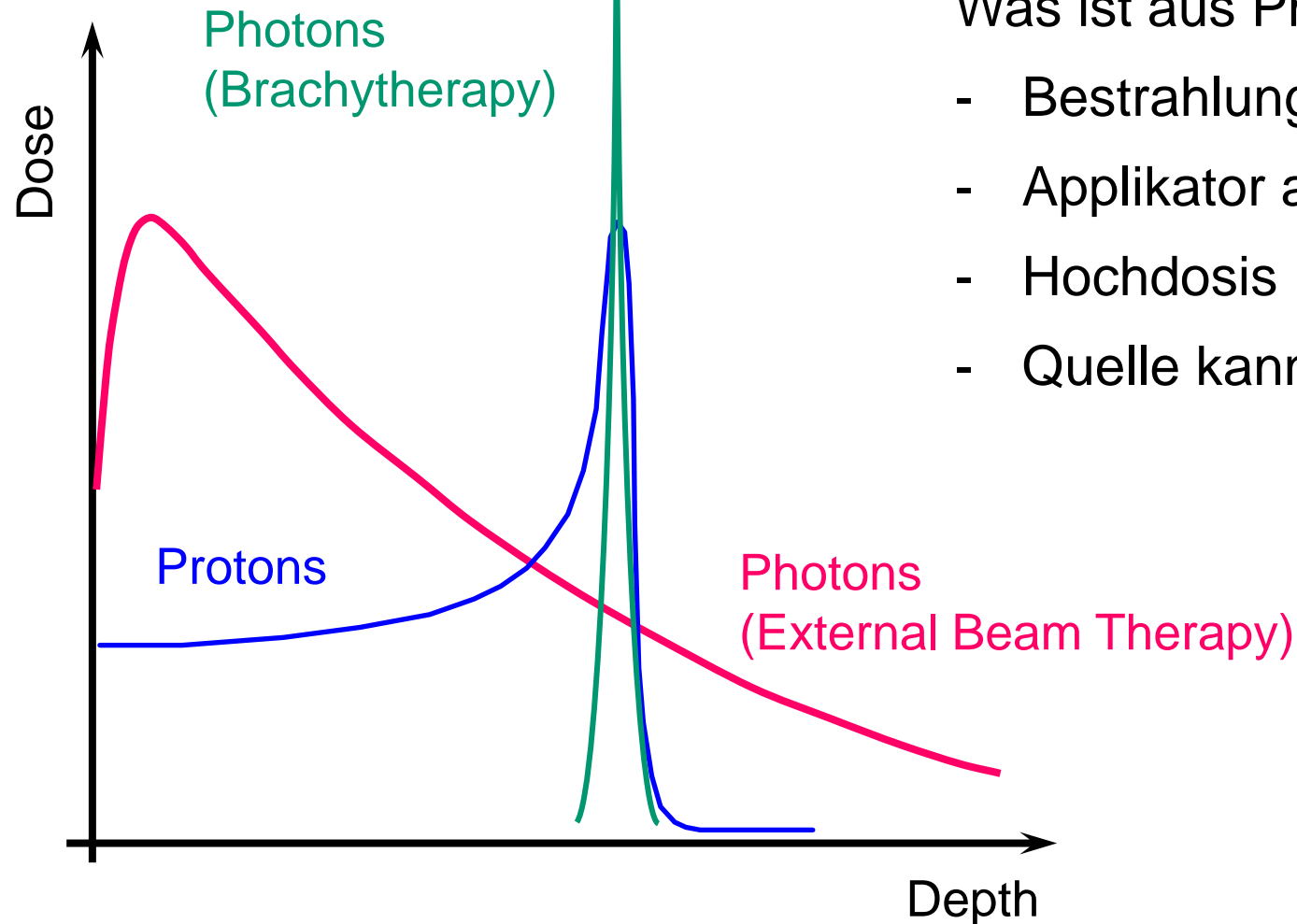
64 inner leaves 0.25 cm wide
56 outer leaves 0.5 cm wide
Max Field: 22 cm x 32 cm

ETHOS double stack MLC

29 proximal leaves 1 cm wide
28 distal leaves 1 cm wide
Max Field: 28 cm x 28 cm



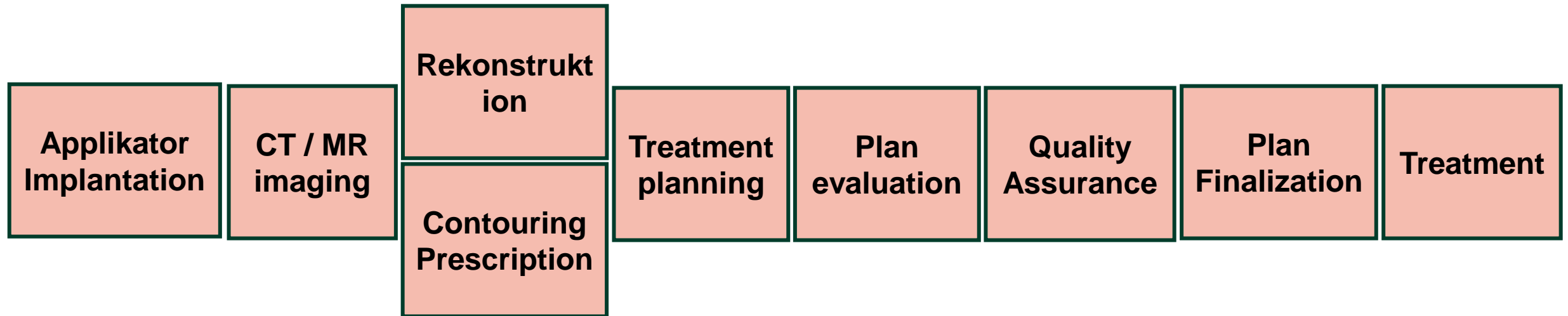
Brachytherapie – High dose Rate (HDR)



Was ist aus Physiker Sicht bei Brachy speziell?

- Bestrahlungsquelle im Tumor
- Applikator am Patient fixiert
- Hochdosis Peaks mit invers-quadratischem Abfall
- Quelle kann man nicht «abstellen»

Brachytherapie Workflow



- Der ganze Workflow innerhalb von ~5h
- Aria-Eclipse / Oncentra parallel
 - Wo wird welcher Task gemacht?

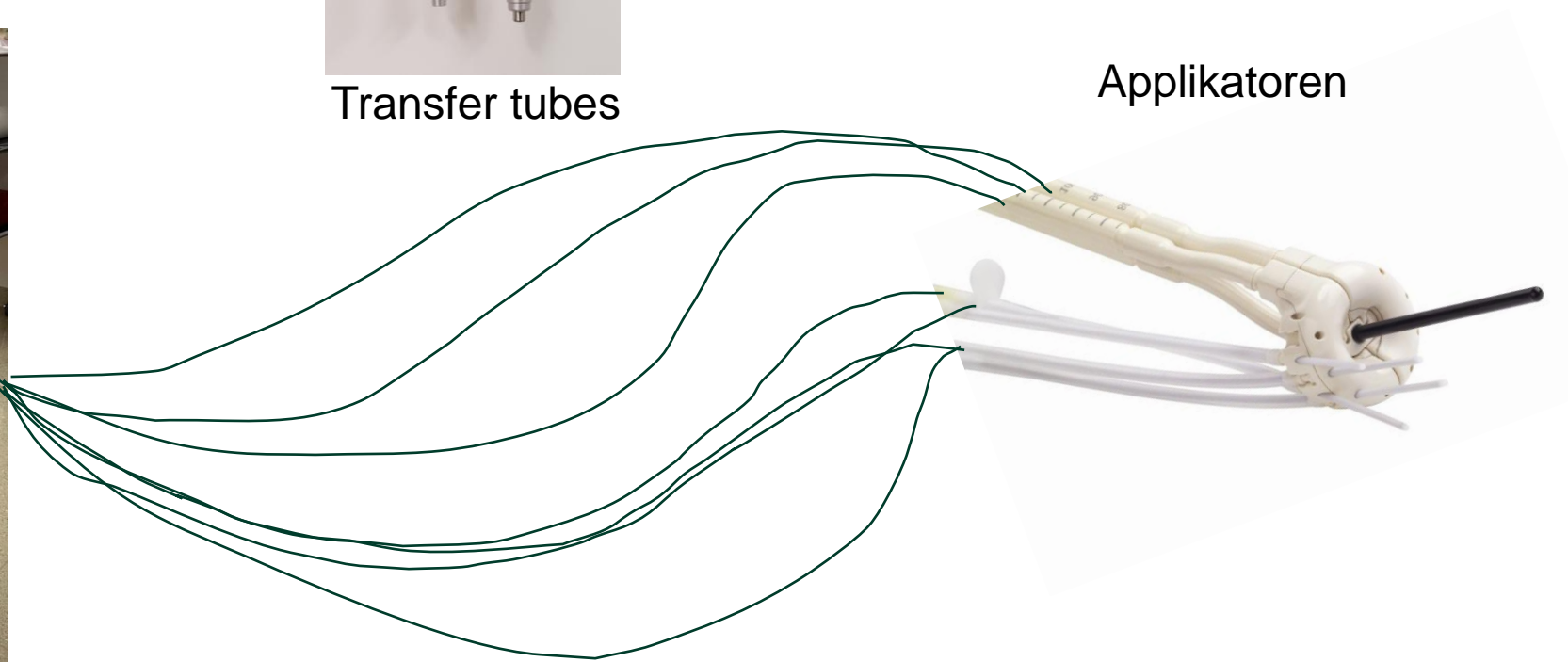
Fehlerquellen

Afterloader



Transfer tubes

Applikatoren



Nummerierung der Applikatoren

Markierungen



Afterloader Channel

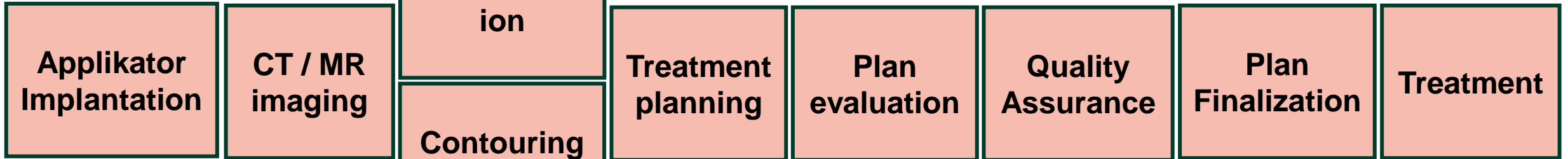


	Markierung	Masterplan Catheder	Afterloader Channel
Geneva / Venezia			
Ovoid/Ringteil Patient-Rechts	-	1	1
Ovoid/Ringteil Patient-Links	-	2	3
Stift	-	3	5
IS1 Gegenuhrzeigersinn	1	4	6
IS2 Gegenuhrzeigersinn	2	5	7
IS3 Gegenuhrzeigersinn	3	6	8
...
IS-frei1 Gegenuhrzeigersinn	4	7	9
IS-frei2 Gegenuhrzeigersinn	5	8	10
IS-frei3 Gegenuhrzeigersinn	6	9	11
...

Masterplan/Oncentra Catheder

Cath.#	Ch.#	Name	Lock (HIPO)	Indexer [cm]	Offset [cm]
1	1	O1 (Model)		130.00	0.00
2	3	O2 (Model)		130.00	0.00
3	5	IU (Model)		130.00	0.00
4	6	(Manual)		128.80	-0.40
5	7	(Manual)		128.80	-0.40
6	8	(Manual)		128.80	-0.40

Kommunikation <-> Strahlenschutz



Arzt/RFP nummerieren

Applikatoren

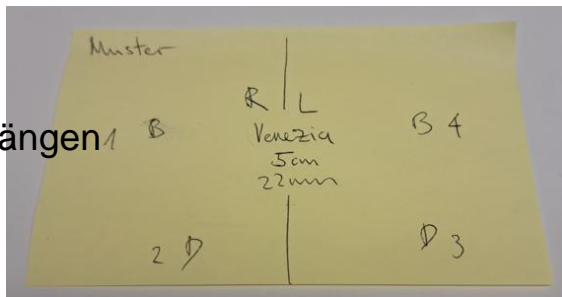
Arzt gibt Länge der

Applikatoren an bzw. RFP

messen die Länge

Physiker notiert

Nummerierung / Längen



Physiker gibt

Nummerierung /

Länge im TPS ein

- Venezia
- Library reconstruction
- Intrauterine Tube: 50mm 30'
- Ovoid Right: 22mm
- Ovoid Left: 22mm
- Channel Mapping: O1, Right → 1
O2, Left → 3
IU3 → 5

ProGuide sharp needles:

Channel Nr in the ovoids	Mapping	
	Channel	Connection
1A	-	-
1B	-	-
1C	-	-
1D	-	-
1E	-	-
1F	-	-
1H	-	-
2A	-	-
2B	-	8
2C	-	-
2D	-	7
2E	-	6
2F	-	-
2G	-	-
2H	-	-

Length: 1288 mm (if no library recon → Offset: -0.4cm)
(view from caudal to cranial)

Physiker / Arzt

kontrollieren

Nummerierung /

Länge

Applicator/catheter mapping checked
 Applicator/catheter orientation checked
 Applicator/catheter lengths checked
 Applicator/catheter smoothness checked

Plan:
 UKRO
 IORT
 Calibration date: 5.2025
 Stepize input for activation: 3 [mm]

Prescription:
 # Fractions: 1
 Dose per fraction: 700[Gy]
 Normalization:
 V100% x 100%
 TRAK depth: [cm]
 lower
 Same as in ARIA

PLAN FINALIZATION
 Checks by physician:
 Dosimetric values checked
 Prescription checked
 Applicator/catheter mapping checked
 Applicator/catheter lengths checked
 Dwell times checked
 Plan approved

QA:
 Plan QA
 TRAK checked
 [other]

Documentation:
 Treatment Plan - Brachy
 - TCC - Pre-assembly report
 - Masterplan - Treatment printout
 - Masterplan - Screenshot
 [other]

RFP kontrollieren

Nummerierung /

Länge

RFP schliessen

Applikator an

Afterloader an



Anhang

Channel	Length	Connection	
		Katheter	Kanal
Flexibile Implant according to tube lengths (CT markers)		1	1
ProGuide Needles Implant (Flassic)	□ 20 cm → 1194 mm □ 24 cm → 1234 mm □ 28.4 cm → 1288 mm	1	1
Esophageal Applicator	1480 mm	1	1
Esophageal Applicator	1480 mm	1	1
(Interstitial) Ring CTMR Applicator			
Channel	Length	Connection	
		Katheter	Kanal
Ring	1300 mm	1	1
Tube	1300 mm	2	5
Interstitial needle 1	1288 mm	3	6
Interstitial needle 2	1288 mm	4	7
Interstitial needle 9	1288 mm	11	14
Ulrecht Interstitial Fletcher CTMR Applicator			
Channel	Length	Connection	
		Katheter	Kanal
Ovoid 1 (Pat. right)	1300 mm	1	3
Ovoid 2 (Pat. left)	1300 mm	2	3
Tube	1300 mm	3	6
Interstitial needle 1	1288 mm	4	6
Interstitial needle 2	1288 mm	5	7
Interstitial needle 10	1288 mm	13	15
Vaginal Multi Channel Applicator			
Channel	Length	Connection	
		Katheter	Kanal
Intrauterine Tube	1300 mm	1	1
Interstitial needle 1	1288 mm	2	6
Interstitial needle 2	1288 mm	3	7
Interstitial needle 3	1288 mm	6	13

Venezia

- Library reconstruction
- Intrauterine Tube: 50mm 30°
- Ovoid Right: 22mm
- Ovoid Left: 22mm
- Channel Mapping: O1, Right → 1
O2, Left → 3
IU3 → 5

ProGuide sharp needles:

		Mapping	
		Channel Nr in the ovoids	Connection
22mm		1A	-
		1B	-
		1C	-
		1D	-
		1E	-
		1F	-
		1G	-
		1H	-
26mm		2A	-
		2B	8
		2C	-
		2D	7
		2E	6
		2F	-
		2G	-
		2H	-

Length: 1288 mm (if no library recon → Offset: -0.4cm)
(view from caudal to cranial)

- Applicator/catheter mapping checked
- Applicator/catheter orientation checked
- Applicator/catheter lengths checked
- Applicator/catheter smoothness checked

Plan:

Source:
 UKRO
 IORT
 Calibration date: 5.2025

Prescription:
 # Fractions: 1
 Dose per fraction: 700[cGy]
 Normalization:
 V100% ≥ 90%
 Tissue depth: -enter- (mm)
 other -
 Same as in ARIA

Stepsize input for activation: 3 [mm]

PLAN FINALIZATION

- Checks by physician:
- Dosimetric values checked
 - Prescription checked
 - Applicator/catheter mapping checked
 - Applicator/catheter lengths checked
 - Dwell times checked
 - Plan approved

QA:

- Plan QA
- TRAK checked
- enter-

Documentation:

- Treatment Plan – Brachy
 - TCC – Pre-treatment report
 - Masterplan – Treatment printout
 - Masterplan – Screenshot
- enter-

Comments:

Anhang

Implant

Implant & Needles

Channel	Length	Connection	
		Katheter	Kanal
Flexible Implant	according to tube lengths (CT markers)	1 n	1 ... n
ProGuide Needles Implant (Plastic)	<input type="checkbox"/> 20 cm → 1194 mm <input type="checkbox"/> 24 cm → 1234 mm <input type="checkbox"/> 29.4 cm → 1288 mm	1 n	1 ... n
LumenCare Azure (Bronchus)	1400 mm	1	1
Esophageal Applicator	1400 mm	1	1

(Interstitial) Ring CTMR Applicator

Channel	Length	Connection	
		Katheter	Kanal
Ring	1300 mm	1	1
Tube	1300 mm	2	5
Interstitial needle 1	1288 mm	3	6
Interstitial needle 2	1288 mm	4	7
.....
Interstitial needle 9	1288 mm	11	14

Utrecht Interstitial Fletcher CTMR Applicator

Channel	Length	Connection	
		Katheter	Kanal
Ovoid 1 (Pat. right)	1300 mm	1	1
Ovoid 2 (Pat. left)	1300 mm	2	3
Tube	1300 mm	3	5
Interstitial needle 1	1288 mm	4	6
Interstitial needle 2	1288 mm	5	7
.....
Interstitial needle 10	1288 mm	13	15

Vaginal Multi Channel Applicator

Channel	Length	Connection	
		Katheter	Kanal
Intrauterine Tube	1300 mm	1	5
Interstitial needle 1	1288 mm	2	6
Interstitial needle 2	1288 mm	3	7
.....
Interstitial needle 8	1288 mm	9	13

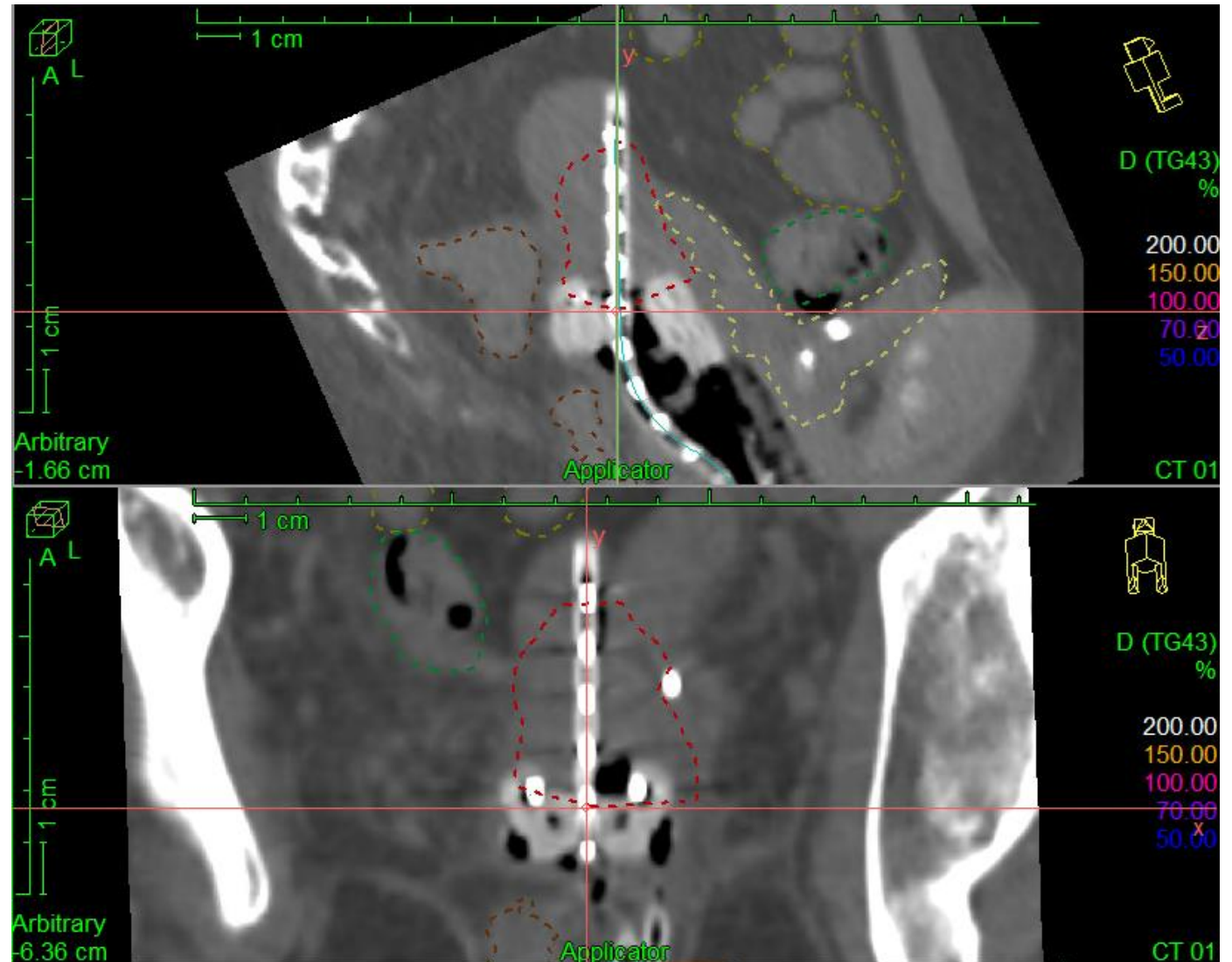
Rekonstruktion

Beispiel unten

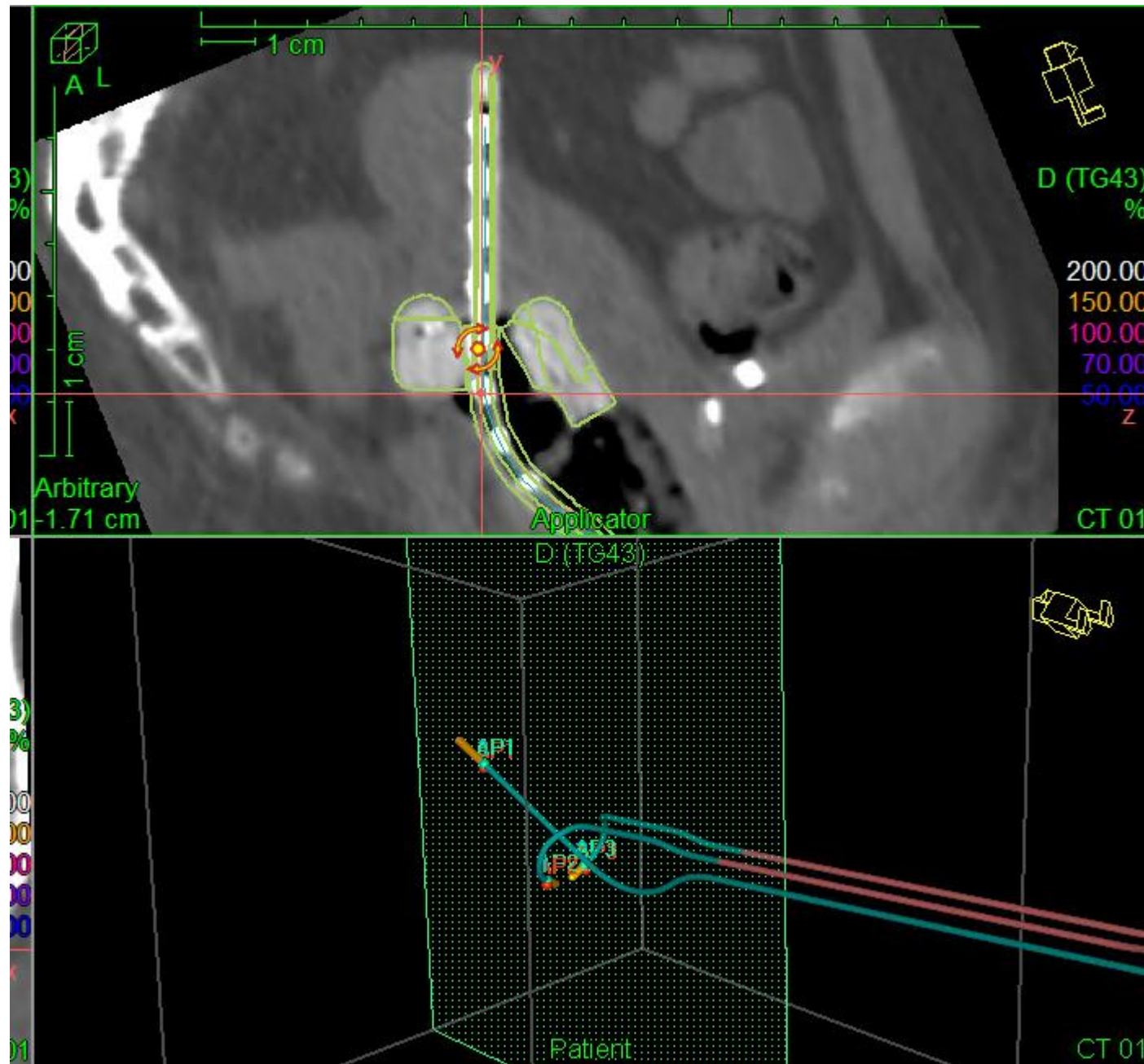
- 1 x Venezia Stift
- 2 x Venezia Ring
- 4 x Interstitiell



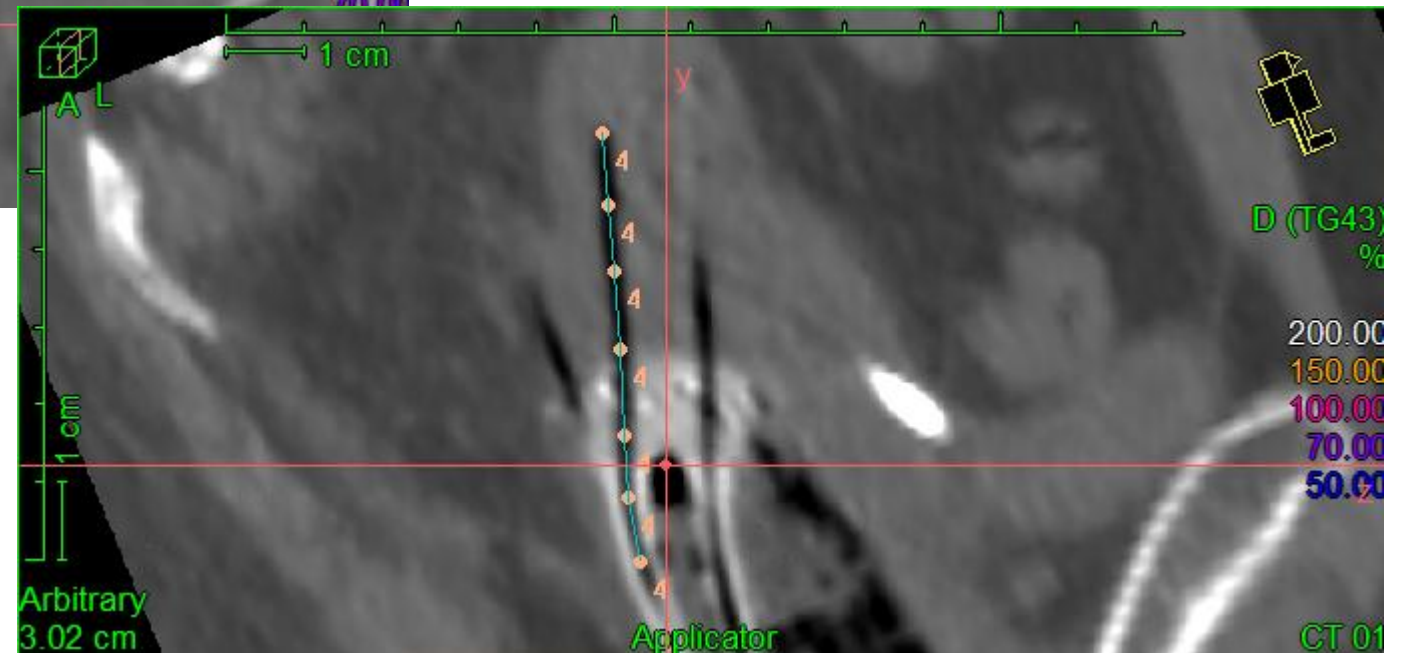
CT Image & Contours im Oncentra TPS



Rekonstruktion - Venezia Modell



Rekonstruktion – Interstitielle Nadeln



Treatment planning

Brachyplan besteht aus einer Liste von **Dwellpoints** und dazugehörigen **Dwelltimes** für jeden Applikator

Catheter	Dwell pos.	X [cm]	Y[cm]	Z[cm]	Weight	diff W	Time [s]	Dwell weight
● 1	300	0.09	58.99	18.17	0.13	0.00	1.32	
● 1	297	-0.14	58.93	18.35	0.13	0.00	1.32	
● 1	294	-0.32	58.84	18.57	0.13	0.00	1.32	
● 1	291	-0.42	58.74	18.84	0.14	0.00	1.42	
● 1	288	-0.45	58.63	19.11	0.19	0.00	1.93	
● 1	285	-0.39	58.51	19.38	0.22	0.00	2.23	
● 1	282	-0.26	58.36	19.60	0.32	0.00	3.24	
● 1	279	-0.08	58.19	19.78	0.57	0.00	5.78	
● 1	276	0.03	57.96	19.93	0.79	0.00	8.01	
● 2	300	1.34	58.91	18.24	0.11	0.00	1.12	
● 2	297	1.55	58.82	18.44	0.11	0.00	1.12	
● 2	294	1.69	58.72	18.68	0.11	0.00	1.12	
● 2	291	1.75	58.61	18.95	0.11	0.00	1.12	
● 2	288	1.73	58.49	19.23	0.13	0.00	1.32	
● 2	285	1.63	58.39	19.49	0.15	0.00	1.52	
● 2	282	1.46	58.26	19.70	0.21	0.00	2.13	
● 2	279	1.25	58.11	19.85	0.43	0.00	4.36	
● 2	276	1.09	57.90	19.99	0.68	0.00	6.89	
● 3	294	0.77	61.55	20.24	0.47	0.00	4.76	
● 3	291	0.76	61.27	20.12	0.69	0.00	7.00	
● 3	288	0.75	61.00	20.01	0.93	0.00	9.46	
● 3	285	0.74	60.72	19.90	1.00	0.00	10.14	
● 3	282	0.73	60.44	19.78	0.97	0.00	9.88	
● 3	279	0.71	60.16	19.67	0.86	0.00	8.70	
● 3	276	0.70	59.89	19.56	0.58	0.00	5.88	
● 3	273	0.69	59.61	19.44	0.53	0.00	5.37	
● 3	270	0.68	59.33	19.33	0.47	0.00	4.76	
● 4	276	2.10	59.98	17.96	0.13	0.00	1.32	
● 4	273	2.06	59.69	17.95	0.12	0.00	1.22	
● 4	270	2.01	59.39	17.95	0.11	0.00	1.12	
● 4	267	1.97	59.09	17.94	0.10	0.00	1.01	
● 4	264	1.91	58.80	17.91	0.10	0.00	1.01	
● 5	285	1.95	61.48	19.41	0.19	0.00	1.93	
● 5	282	1.96	61.19	19.31	0.19	0.00	1.93	
● 5	279	1.97	60.91	19.22	0.19	0.00	1.93	
● 5	276	1.98	60.62	19.12	0.16	0.00	1.62	
● 5	273	1.98	60.34	19.03	0.12	0.00	1.22	
● 5	270	1.99	60.05	18.95	0.12	0.00	1.24	
● 5	267	1.99	59.76	18.87	0.11	0.00	1.12	
● 5	264	2.00	59.47	18.80	0.12	0.00	1.22	
● 5	261	2.01	59.18	18.70	0.13	0.00	1.32	
● 5	258	2.02	58.90	18.61	0.18	0.00	1.82	
● 5	255	2.03	58.62	18.51	0.20	0.00	2.03	
● 6	288	1.60	61.19	20.56	0.08	0.00	0.81	
● 6	285	1.66	60.92	20.45	0.06	0.00	0.61	
● 6	282	1.73	60.65	20.34	0.05	0.00	0.51	
● 6	279	1.79	60.37	20.23	0.04	0.00	0.41	
● 6	276	1.84	60.09	20.14	0.04	0.00	0.41	
● 6	273	1.89	59.81	20.05	0.06	0.00	0.61	
● 6	270	1.93	59.53	19.95	0.08	0.00	0.81	
● 6	267	1.98	59.25	19.86	0.12	0.00	1.22	
● 6	264	2.00	58.97	19.76	0.15	0.00	1.52	
● 6	261	2.01	58.69	19.66	0.16	0.00	1.62	
● 6	258	2.03	58.40	19.56	0.18	0.00	1.82	

Schritt 1) Optimization

Dose objectives
Sampling points

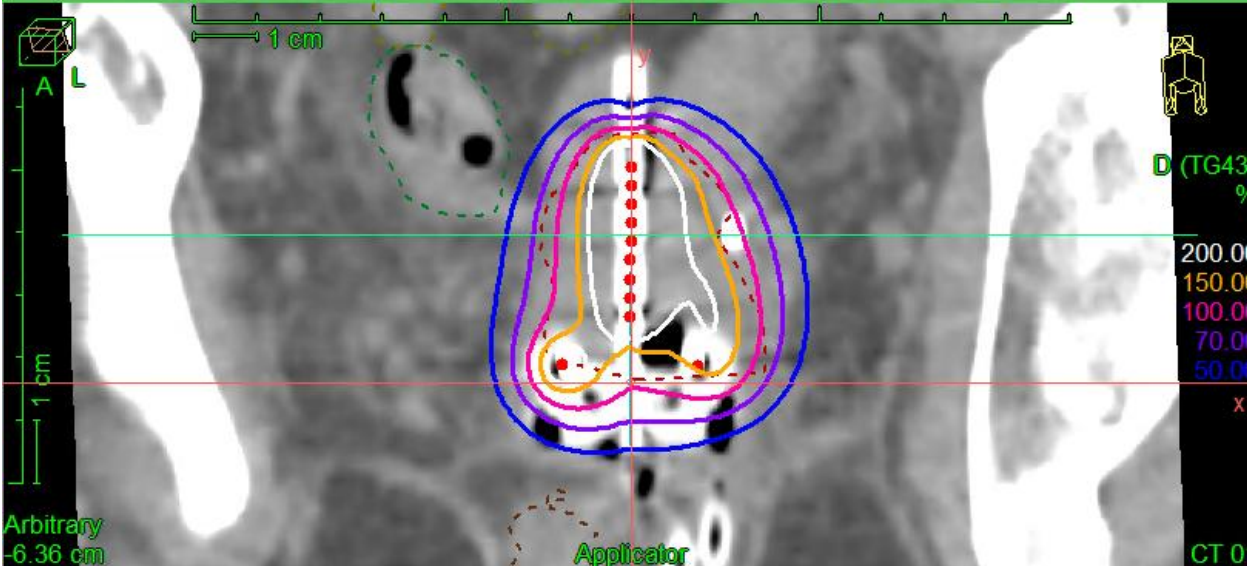
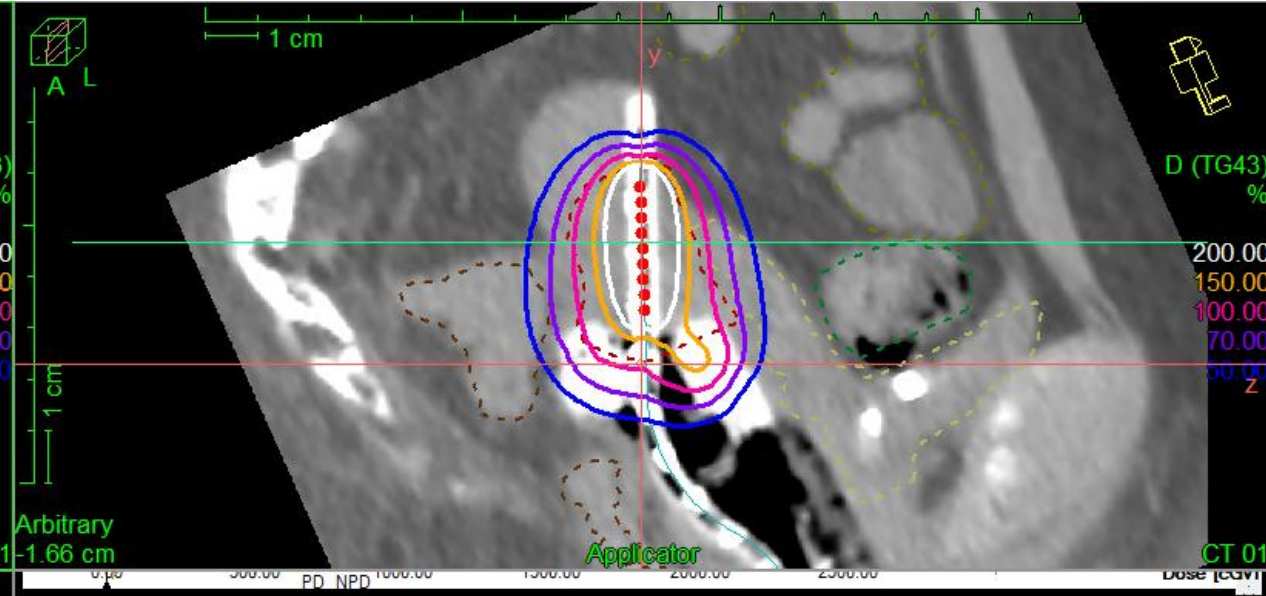
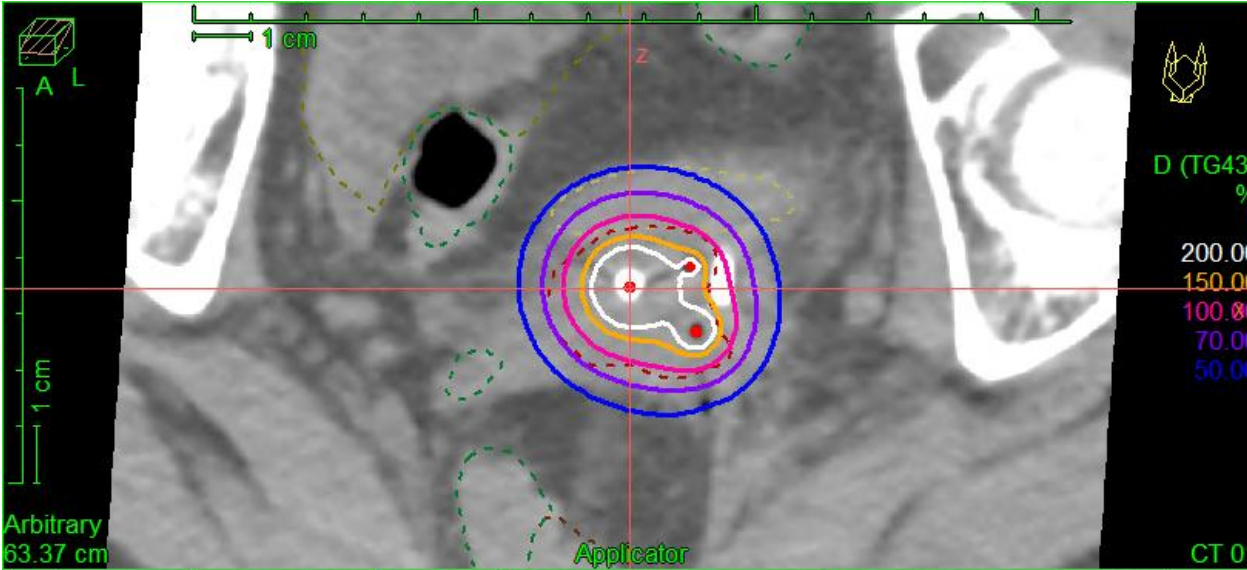
	ROI	Usage	MinWeight	Min Value [%]	Max Value [%]	MaxWeight	Priority
<input type="checkbox"/>	Rectum	Unused					
<input type="checkbox"/>	Intestines	Unused					
<input type="checkbox"/>	Sigmoid	Unused					
<input type="checkbox"/>	Bladder	Unused					
<input checked="" type="checkbox"/>	PTV_I_1.3/2	PTV	100	100	150	10	
<input type="checkbox"/>	Normal tissue	Normal Tissue			95	4	

(Hide Unused)

Optimize
DTGR:
Class solution:

Catheter	Dwell pos.	X [cm]	Y[cm]	Z[cm]	Weight	diff W	Time [s]	Dwell weight
1	300	0.09	58.99	18.17	0.26	0.00	2.24	
1	297	-0.14	58.93	18.35	0.21	0.00	1.84	
1	294	-0.32	58.84	18.57	0.18	0.00	1.52	
1	291	-0.42	58.74	18.84	0.18	0.00	1.58	
1	288	-0.45	58.63	19.11	0.26	0.00	2.25	
1	285	-0.39	58.51	19.38	0.38	0.00	3.30	
1	282	-0.26	58.36	19.60	0.50	0.00	4.31	
1	279	-0.08	58.19	19.78	0.62	0.00	5.31	
1	276	0.03	57.96	19.93	0.69	0.00	5.91	
2	300	1.34	58.91	18.24	0.06	0.00	0.55	
2	297	1.55	58.82	18.44	0.01	0.00	0.10	
2	294	1.69	58.72	18.68	0.00	0.00	0.00	
2	291	1.75	58.61	18.95	0.00	0.00	0.00	
2	288	1.73	58.49	19.23	0.00	0.00	0.00	
2	285	1.63	58.39	19.49	0.00	0.00	0.00	
2	282	1.46	58.26	19.70	0.08	0.00	0.71	
2	279	1.25	58.11	19.85	0.22	0.00	1.93	
2	276	1.09	57.90	19.99	0.33	0.00	2.85	
3	294	0.77	61.55	20.24	1.00	0.00	8.60	
3	291	0.76	61.27	20.12	0.96	0.00	8.22	
3	288	0.75	61.00	20.01	0.92	0.00	7.91	
3	285	0.74	60.72	19.90	0.88	0.00	7.53	
3	282	0.73	60.44	19.78	0.81	0.00	6.98	
3	279	0.71	60.16	19.67	0.73	0.00	6.27	
3	276	0.70	59.89	19.56	0.66	0.00	5.68	
3	273	0.69	59.61	19.44	0.61	0.00	5.20	
3	270	0.68	59.33	19.33	0.55	0.00	4.77	
4	276	2.10	59.98	17.96	0.25	0.00	2.13	
4	273	2.06	59.69	17.95	0.23	0.00	1.96	
4	270	2.01	59.39	17.95	0.20	0.00	1.69	
4	267	1.97	59.09	17.94	0.18	0.00	1.54	
4	264	1.91	58.80	17.91	0.20	0.00	1.69	
5	285	1.95	61.48	19.41	0.27	0.00	2.35	
5	282	1.96	61.19	19.31	0.25	0.00	2.16	
5	279	1.97	60.91	19.22	0.26	0.00	2.26	
5	276	1.98	60.62	19.12	0.25	0.00	2.14	
5	273	1.98	60.34	19.03	0.20	0.00	1.71	
5	270	1.99	60.05	18.95	0.17	0.00	1.49	
5	267	1.99	59.76	18.87	0.12	0.00	1.06	
5	264	2.00	59.47	18.80	0.10	0.00	0.85	
5	261	2.01	59.18	18.70	0.13	0.00	1.15	
5	258	2.02	58.90	18.61	0.21	0.00	1.84	
5	255	2.03	58.62	18.51	0.29	0.00	2.45	
6	288	1.60	61.19	20.56	0.15	0.00	1.26	
6	285	1.66	60.92	20.45	0.09	0.00	0.79	
6	282	1.73	60.65	20.34	0.05	0.00	0.41	
6	279	1.79	60.37	20.23	0.03	0.00	0.29	
6	276	1.84	60.09	20.14	0.09	0.00	0.73	
6	273	1.89	59.81	20.05	0.16	0.00	1.34	
6	270	1.93	59.53	19.95	0.24	0.00	2.10	
6	267	1.98	59.25	19.86	0.31	0.00	2.69	
6	264	2.00	58.97	19.76	0.36	0.00	3.11	
6	261	2.01	58.69	19.66	0.40	0.00	3.42	
6	258	2.03	58.40	19.56	0.42	0.00	3.65	

Schritt 2) Manuelles Fine-Tuning



ROI	Dose [%]	Dose [cGy]	Volume [%]	Volume [ccm]
PTV_I.1.3/2	100.00	700.00	92.79	21.57
PTV_I.1.3/2	70.81	495.69	100.00	23.24
PTV_I.1.3/2	104.63	732.44	90.00	20.92
PTV_I.1.3/2	87.46	612.24	98.00	22.78
Bladder	107.44	752.09	0.12	0.10
Bladder	2.03	14.18	100.00	86.69
Bladder	64.81	453.70	2.31	2.00
Implant	100.00	700.00	-	29.71
Implant	150.00	1050.00	-	15.61
Implant	200.00	1400.00	-	8.03
Intestines	29.92	209.41	0.07	0.10
Intestines	22.12	154.84	1.41	2.00
Rectum	60.86	426.04	0.32	0.10
Rectum	37.89	265.20	6.41	2.00
Sigmoid	37.56	262.94	0.17	0.10
Sigmoid	26.70	186.92	3.31	2.00

Schritt 2) Manuelles Fine-Tuning

Catheter	Dwell pos.	X [cm]	Y[cm]	Z[cm]	Weight	diff W	Time [s]	Dwell weight
1	300	0.09	58.99	18.17	0.26	0.00	2.24	
1	297	-0.14	58.93	18.35	0.21	0.00	1.84	
1	294	-0.32	58.84	18.57	0.18	0.00	1.52	
1	291	-0.42	58.74	18.84	0.18	0.00	1.58	
1	288	-0.45	58.63	19.11	0.26	0.00	2.25	
1	285	-0.39	58.51	19.38	0.38	0.00	3.30	
1	282	-0.26	58.36	19.60	0.50	0.00	4.31	
1	279	-0.08	58.19	19.78	0.62	0.00	5.31	
1	276	0.03	57.96	19.93	0.69	0.00	5.91	
2	300	1.34	58.91	18.24	0.06	0.00	0.55	
2	297	1.55	58.82	18.44	0.01	0.00	0.10	
2	294	1.69	58.72	18.68	0.00	0.00	0.00	
2	291	1.75	58.61	18.95	0.00	0.00	0.00	
2	288	1.73	58.49	19.23	0.00	0.00	0.00	
2	285	1.63	58.39	19.49	0.00	0.00	0.00	
2	282	1.46	58.26	19.70	0.08	0.00	0.71	
2	279	1.25	58.11	19.85	0.22	0.00	1.93	
2	276	1.09	57.90	19.99	0.33	0.00	2.85	
3	294	0.77	61.55	20.24	1.00	0.00	8.60	
3	291	0.76	61.27	20.12	0.96	0.00	8.22	
3	288	0.75	61.00	20.01	0.92	0.00	7.91	
3	285	0.74	60.72	19.90	0.88	0.00	7.53	
3	282	0.73	60.44	19.78	0.81	0.00	6.98	
3	279	0.71	60.16	19.67	0.73	0.00	6.27	
3	276	0.70	59.89	19.56	0.66	0.00	5.68	
3	273	0.69	59.61	19.44	0.61	0.00	5.20	
3	270	0.68	59.33	19.33	0.55	0.00	4.77	
4	276	2.10	59.98	17.96	0.25	0.00	2.13	
4	273	2.06	59.69	17.95	0.23	0.00	1.96	
4	270	2.01	59.39	17.95	0.20	0.00	1.69	
4	267	1.97	59.09	17.94	0.18	0.00	1.54	
4	264	1.91	58.80	17.91	0.20	0.00	1.69	
5	285	1.95	61.48	19.41	0.27	0.00	2.35	
5	282	1.96	61.19	19.31	0.25	0.00	2.16	
5	279	1.97	60.91	19.22	0.26	0.00	2.26	
5	276	1.98	60.62	19.12	0.25	0.00	2.14	
5	273	1.98	60.34	19.03	0.20	0.00	1.71	
5	270	1.99	60.05	18.95	0.17	0.00	1.49	
5	267	1.99	59.76	18.87	0.12	0.00	1.06	
5	264	2.00	59.47	18.80	0.10	0.00	0.85	
5	261	2.01	59.18	18.70	0.13	0.00	1.15	
5	258	2.02	58.90	18.61	0.21	0.00	1.84	
5	255	2.03	58.62	18.51	0.29	0.00	2.45	
6	288	1.60	61.19	20.56	0.15	0.00	1.26	
6	285	1.66	60.92	20.45	0.09	0.00	0.79	
6	282	1.73	60.65	20.34	0.05	0.00	0.41	
6	279	1.79	60.37	20.23	0.03	0.00	0.29	
6	276	1.84	60.09	20.14	0.09	0.00	0.73	
6	273	1.89	59.81	20.05	0.16	0.00	1.34	
6	270	1.93	59.53	19.95	0.24	0.00	2.10	
6	267	1.98	59.25	19.86	0.31	0.00	2.69	
6	264	2.00	58.97	19.76	0.36	0.00	3.11	
6	261	2.01	58.69	19.66	0.40	0.00	3.42	
6	258	2.03	58.40	19.56	0.42	0.00	3.65	



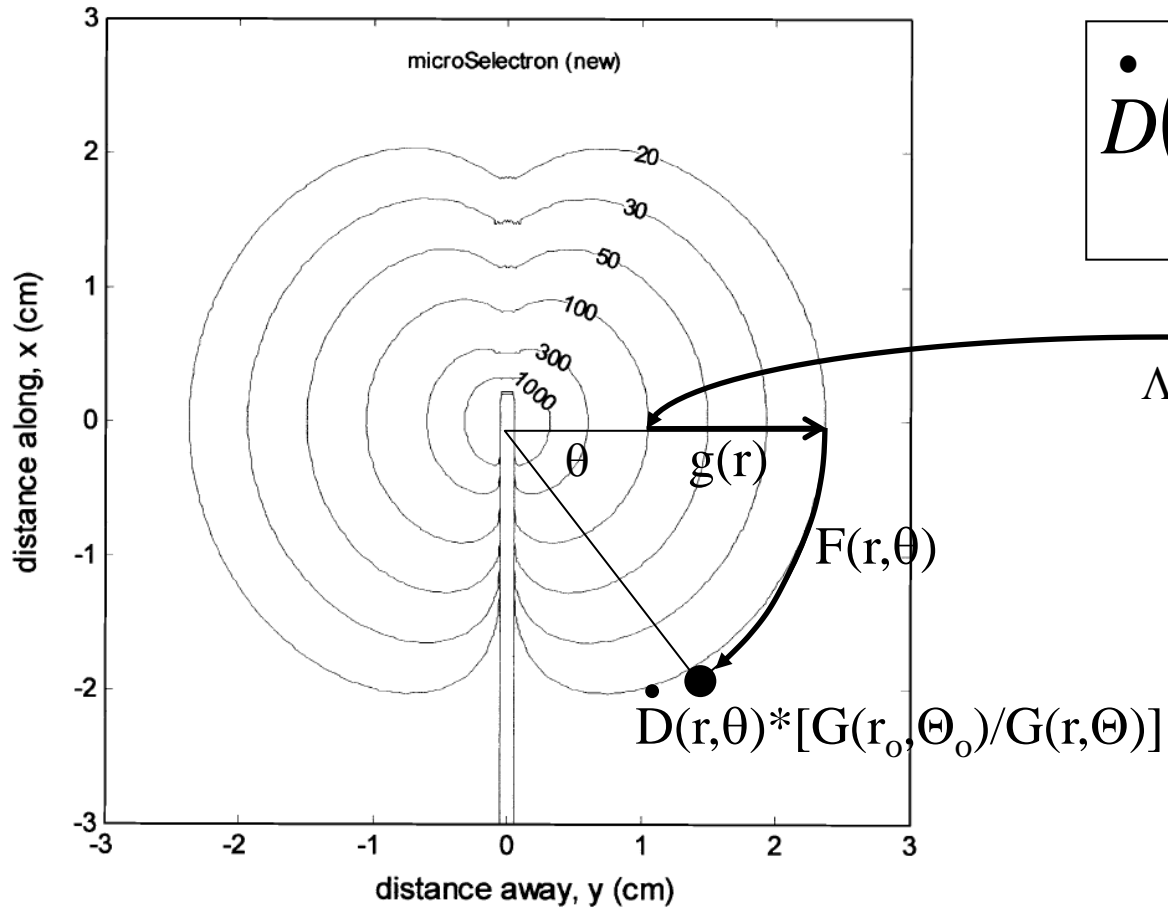
Catheter	Dwell pos.	X [cm]	Y[cm]	Z[cm]	Weight	diff W	Time [s]	Dwell weight
1	300	0.09	58.99	18.17	0.13	0.00	1.32	
1	297	-0.14	58.93	18.35	0.13	0.00	1.32	
1	294	-0.32	58.84	18.57	0.13	0.00	1.32	
1	291	-0.42	58.74	18.84	0.14	0.00	1.42	
1	288	-0.45	58.63	19.11	0.19	0.00	1.93	
1	285	-0.39	58.51	19.38	0.22	0.00	2.23	
1	282	-0.26	58.36	19.60	0.32	0.00	3.24	
1	279	-0.08	58.19	19.78	0.57	0.00	5.78	
1	276	0.03	57.96	19.93	0.79	0.00	8.01	
2	300	1.34	58.91	18.24	0.11	0.00	1.12	
2	297	1.55	58.82	18.44	0.11	0.00	1.12	
2	294	1.69	58.72	18.68	0.11	0.00	1.12	
2	291	1.75	58.61	18.95	0.11	0.00	1.12	
2	288	1.73	58.49	19.23	0.13	0.00	1.32	
2	285	1.63	58.39	19.49	0.15	0.00	1.52	
2	282	1.46	58.26	19.70	0.21	0.00	2.13	
2	279	1.25	58.11	19.85	0.43	0.00	4.36	
2	276	1.09	57.90	19.99	0.68	0.00	6.89	
3	294	0.77	61.55	20.24	0.47	0.00	4.76	
3	291	0.76	61.27	20.12	0.69	0.00	7.00	
3	288	0.75	61.00	20.01	0.93	0.00	9.46	
3	285	0.74	60.72	19.90	1.00	0.00	10.14	
3	282	0.73	60.44	19.78	0.97	0.00	9.88	
3	279	0.71	60.16	19.67	0.86	0.00	8.70	
3	276	0.70	59.89	19.56	0.58	0.00	5.88	
3	273	0.69	59.61	19.44	0.53	0.00	5.37	
3	270	0.68	59.33	19.33	0.47	0.00	4.76	
4	276	2.10	59.98	17.96	0.13	0.00	1.32	
4	273	2.06	59.69	17.95	0.12	0.00	1.22	
4	270	2.01	59.39	17.95	0.11	0.00	1.12	
4	267	1.97	59.09	17.94	0.10	0.00	1.01	
4	264	1.91	58.80	17.91	0.10	0.00	1.01	
5	285	1.95	61.48	19.41	0.19	0.00	1.93	
5	282	1.96	61.19	19.31	0.19	0.00	1.93	
5	279	1.97	60.91	19.22	0.19	0.00	1.93	
5	276	1.98	60.62	19.12	0.16	0.00	1.62	
5	273	1.98	60.34	19.03	0.12	0.00	1.22	
5	270	1.99	60.05	18.95	0.12	0.00	1.24	
5	267	1.99	59.76	18.87	0.11	0.00	1.12	
5	264	2.00	59.47	18.80	0.12	0.00	1.22	
5	261	2.01	59.18	18.70	0.13	0.00	1.32	
5	258	2.02	58.90	18.61	0.18	0.00	1.82	
5	255	2.03	58.62	18.51	0.20	0.00	2.03	
6	288	1.60	61.19	20.56	0.08	0.00	0.81	
6	285	1.66	60.92	20.45	0.06	0.00	0.61	
6	282	1.73	60.65	20.34	0.05	0.00	0.51	
6	279	1.79	60.37	20.23	0.04	0.00	0.41	
6	276	1.84	60.09	20.14	0.04	0.00	0.41	
6	273	1.89	59.81	20.05	0.06	0.00	0.61	
6	270	1.93	59.53	19.95	0.08	0.00	0.81	
6	267	1.98	59.25	19.86	0.12	0.00	1.22	
6	264	2.00	58.97	19.76	0.15	0.00	1.52	
6	261	2.01	58.69	19.66	0.16	0.00	1.62	
6	258	2.03	58.40	19.56	0.18	0.00	1.82	

Schritt 1) Optimierung

Schritt 2) Manuelles Fine-Tuning

Dosisberechnung – TG43

Dosisrate! (Gy/s)



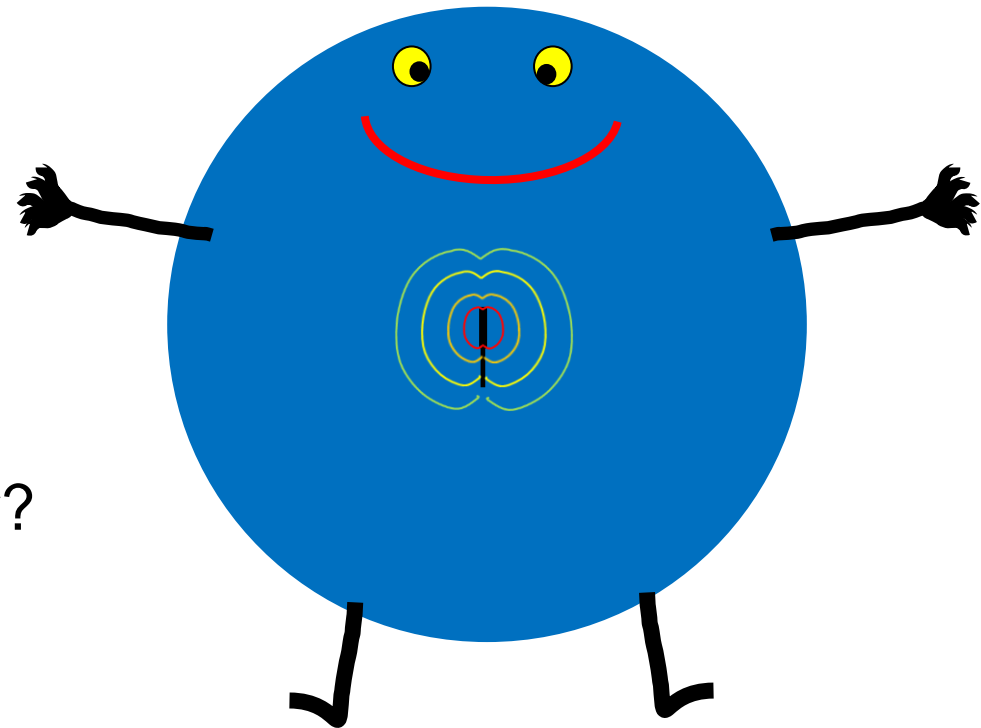
$$\dot{D}(r, \theta) = S_k \cdot \Lambda \cdot \frac{G(r, \theta)}{G(r_0, \theta_0)} \cdot g(r) \cdot F(r, \theta)$$

Dosisberechnung – TG43

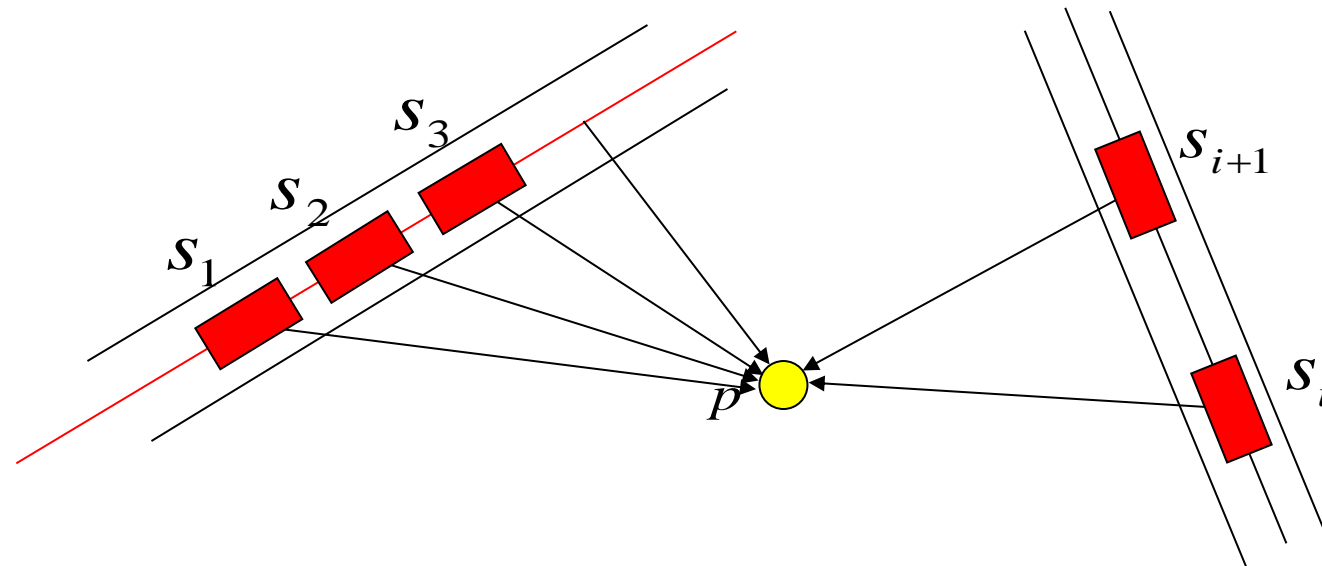
Dosisberechnung in Wasser

- Keine Inhomogenitäten
- Keine Applikatoren
- Kein Quellen-Interplay
- Patientengrösse unbeschränkt

Warum wäre dies bei EBRT undenkbar?



Dosissummierung

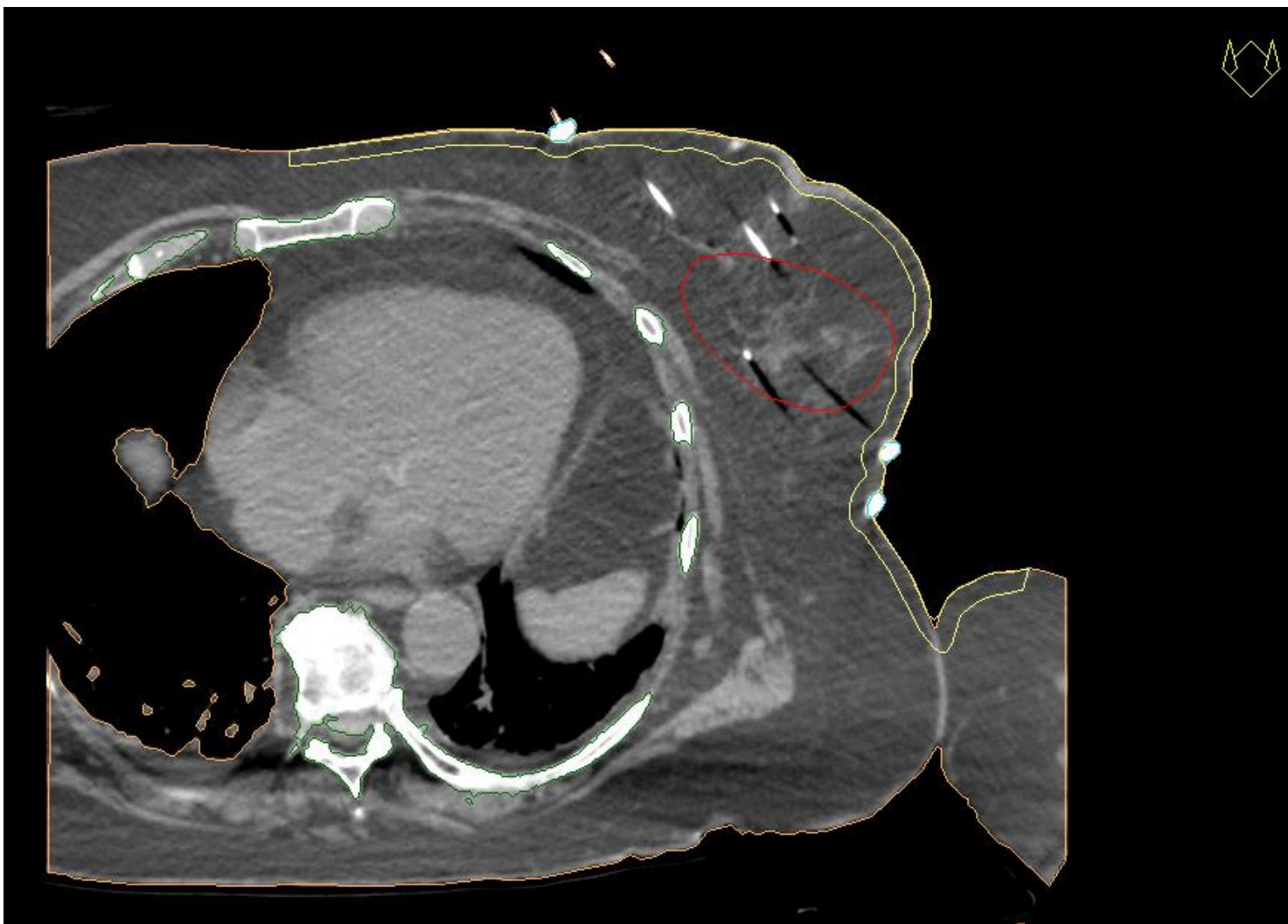


$$D_p = t_1 \cdot \dot{D}_p(S_1) + t_2 \cdot \dot{D}_p(S_2) + t_3 \cdot \dot{D}_p(S_3) + \dots$$

Fallbeispiel Mamma – CT Acquisition



Fallbeispiel Mamma - Contouring

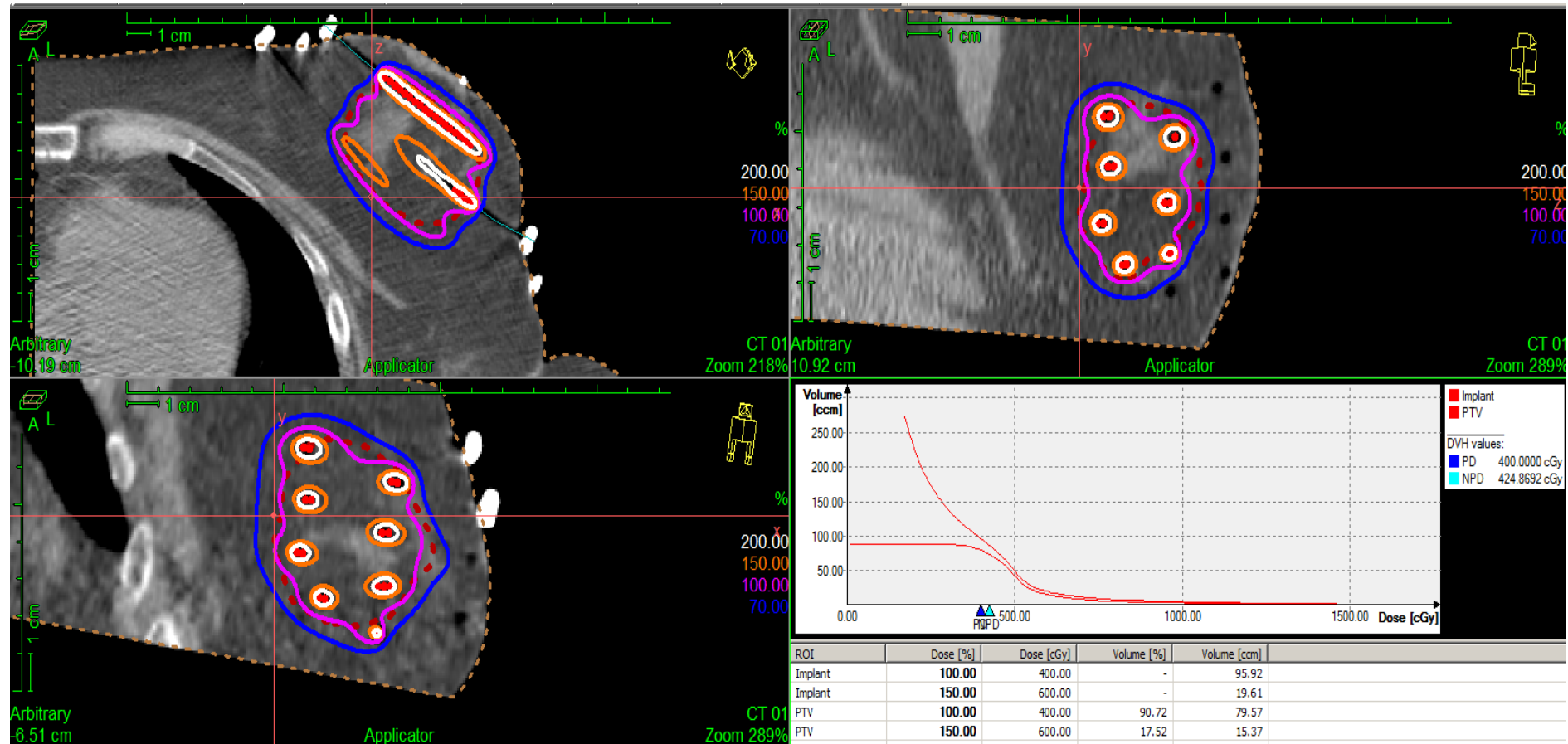


Fallbeispiel Mamma - Optimierung

Catheter	Dwell pos.	x [cm]	y [cm]	z [cm]	Weight	diff W	Time [s]	Dwell weight
1	20	14.57	-7.63	-6.83	1.00	0.00	0.74	
1	21	14.36	-7.63	-6.70	1.00	0.00	0.74	
1	22	14.14	-7.63	-6.57	1.00	0.00	0.74	
1	23	13.94	-7.64	-6.42	1.00	0.00	0.74	
1	24	13.74	-7.64	-6.27	1.00	0.00	0.74	
1	25	13.54	-7.64	-6.12	1.00	0.00	0.74	
1	26	13.34	-7.65	-5.97	1.00	0.00	0.74	
1	27	13.14	-7.65	-5.82	1.00	0.00	0.74	
1	28	12.94	-7.66	-5.67	1.00	0.00	0.74	
1	29	12.74	-7.66	-5.52	1.00	0.00	0.74	
1	30	12.55	-7.67	-5.37	1.00	0.00	0.74	
1	31	12.36	-7.68	-5.20	1.00	0.00	0.74	
1	32	12.18	-7.69	-5.03	1.00	0.00	0.74	
1	33	12.00	-7.71	-4.86	1.00	0.00	0.74	
1	34	11.81	-7.72	-4.69	1.00	0.00	0.74	
1	35	11.63	-7.73	-4.52	1.00	0.00	0.74	
1	36	11.45	-7.74	-4.35	1.00	0.00	0.74	
1	37	11.27	-7.76	-4.18	1.00	0.00	0.74	
2	17	15.66	-8.92	-7.35	1.00	0.00	0.74	
2	18	15.45	-8.92	-7.22	1.00	0.00	0.74	
2	19	15.23	-8.91	-7.10	1.00	0.00	0.74	
2	20	15.02	-8.90	-6.97	1.00	0.00	0.74	
2	21	14.80	-8.90	-6.84	1.00	0.00	0.74	
2	22	14.60	-8.92	-6.69	1.00	0.00	0.74	
2	23	14.40	-8.94	-6.55	1.00	0.00	0.74	
2	24	14.20	-8.96	-6.40	1.00	0.00	0.74	
2	25	14.00	-8.98	-6.25	1.00	0.00	0.74	
2	26	13.80	-9.00	-6.10	1.00	0.00	0.74	
2	27	13.60	-9.02	-5.95	1.00	0.00	0.74	
2	28	13.41	-9.03	-5.79	1.00	0.00	0.74	
2	29	13.23	-9.02	-5.62	1.00	0.00	0.74	
2	30	13.04	-9.01	-5.45	1.00	0.00	0.74	
2	31	12.85	-9.01	-5.29	1.00	0.00	0.74	
2	32	12.67	-9.00	-5.12	1.00	0.00	0.74	
2	33	12.48	-8.99	-4.95	1.00	0.00	0.74	
2	34	12.30	-9.00	-4.78	1.00	0.00	0.74	
2	35	12.12	-9.02	-4.61	1.00	0.00	0.74	
2	36	11.94	-9.04	-4.44	1.00	0.00	0.74	
2	37	11.76	-9.06	-4.27	1.00	0.00	0.74	
2	38	11.58	-9.08	-4.09	1.00	0.00	0.74	
2	39	11.40	-9.11	-3.92	1.00	0.00	0.74	
2	40	11.22	-9.13	-3.75	1.00	0.00	0.74	
2	41	11.04	-9.15	-3.58	1.00	0.00	0.74	
3	19	15.58	-10.39	-7.29	1.00	0.00	0.74	
3	20	15.38	-10.40	-7.14	1.00	0.00	0.74	
3	21	15.18	-10.41	-7.00	1.00	0.00	0.74	
3	22	14.97	-10.41	-6.85	1.00	0.00	0.74	
3	23	14.77	-10.42	-6.71	1.00	0.00	0.74	
3	24	14.56	-10.42	-6.56	1.00	0.00	0.74	
3	25	14.36	-10.43	-6.42	1.00	0.00	0.74	
3	26	14.16	-10.44	-6.28	1.00	0.00	0.74	
3	27	13.95	-10.44	-6.13	1.00	0.00	0.74	
3	28	13.75	-10.45	-5.99	1.00	0.00	0.60	
3	29	13.54	-10.46	-5.84	1.00	0.00	0.60	
3	30	13.36	-10.47	-5.68	1.00	0.00	0.60	
3	31	13.17	-10.47	-5.52	1.00	0.00	0.74	
3	32	12.98	-10.48	-5.35	1.00	0.00	0.74	
3	33	12.79	-10.49	-5.19	1.00	0.00	0.74	
3	34	12.60	-10.49	-5.02	1.00	0.00	0.74	
3	35	12.41	-10.50	-4.86	1.00	0.00	0.74	
3	36	12.22	-10.51	-4.70	1.00	0.00	0.74	
3	37	12.03	-10.52	-4.53	1.00	0.00	0.74	
3	38	11.84	-10.52	-4.37	1.00	0.00	0.74	
3	39	11.66	-10.53	-4.20	1.00	0.00	0.74	
3	40	11.49	-10.53	-4.01	1.00	0.00	0.74	
3	41	11.32	-10.53	-3.83	1.00	0.00	0.74	
4	19	15.79	-11.57	-6.83	1.00	0.00	0.74	
4	20	15.59	-11.57	-6.68	1.00	0.00	0.74	
4	21	15.39	-11.56	-6.53	1.00	0.00	0.74	
4	22	15.19	-11.56	-6.38	1.00	0.00	0.74	
4	23	14.99	-11.55	-6.23	1.00	0.00	0.74	
4	24	14.80	-11.55	-6.08	1.00	0.00	0.74	
4	25	14.61	-11.55	-5.91	1.00	0.00	0.74	
4	26	14.43	-11.55	-5.74	1.00	0.00	0.74	
4	27	14.24	-11.55	-5.57	1.00	0.00	0.74	
4	28	14.06	-11.54	-5.41	1.00	0.00	0.74	
4	29	13.87	-11.54	-5.24	1.00	0.00	0.74	
4	30	13.69	-11.54	-5.07	1.00	0.00	0.74	
4	31	13.50	-11.54	-4.90	1.00	0.00	0.74	
4	32	13.32	-11.54	-4.73	1.00	0.00	0.74	
4	33	13.13	-11.53	-4.57	1.00	0.00	0.74	
4	34	12.95	-11.53	-4.40	1.00	0.00	0.74	
4	35	12.76	-11.53	-4.23	1.00	0.00	0.74	
4	36	12.57	-11.53	-4.06	1.00	0.00	0.74	
4	37	12.39	-11.52	-3.90	1.00	0.00	0.74	
5	11	16.47	-8.13	-6.06	1.00	0.00	0.74	
5	12	16.26	-8.13	-5.92	1.00	0.00	0.74	
5	13	16.05	-8.13	-5.79	1.00	0.00	0.74	
5	14	15.84	-8.13	-5.66	1.00	0.00	0.74	
5	15	15.63	-8.13	-5.53	1.00	0.00	0.74	

Catheter	Dwell pos.	x [cm]	y [cm]	z [cm]	Weight	diff W	Time [s]	Dwell weight
1	20	14.57	-7.63	-6.83	0.77	0.00	0.91	
1	21	14.36	-7.63	-6.70	0.76	0.00	0.90	
1	22	14.14	-7.63	-6.57	0.75	0.00	0.89	
1	23	13.94	-7.64	-6.42	0.75	0.00	0.89	
1	24	13.74	-7.64	-6.27	0.75	0.00	0.89	
1	25	13.54	-7.64	-6.12	0.76	0.00	0.90	
1	26	13.34	-7.65	-5.97	0.76	0.00	0.91	
1	27	13.14	-7.65	-5.82	0.76	0.00	0.90	
1	28	12.94	-7.66	-5.67	0.76	0.00	0.90	
1	29	12.74	-7.66	-5.52	0.75	0.00	0.89	
1	30	12.55	-7.67	-5.37	0.75	0.00	0.89	
1	31	12.36	-7.68	-5.20	0.74	0.00	0.88	
1	32	12.18	-7.69	-5.03	0.75	0.00	0.88	
1	33	12.00	-7.71	-4.86	0.76	0.00	0.90	
1	34	11.81	-7.72	-4.69	0.77	0.00	0.92	
1	35	11.63	-7.73	-4.52	0.79	0.00	0.94	
1	36	11.45	-7.74	-4.35	0.83	0.00	0.98	
1	37	11.27	-7.76	-4.18	0.87	0.00	1.03	
2	17	15.66	-8.92	-7.35	0.76	0.00	0.93	
2	18	15.45	-8.92	-7.22	0.73	0.00	0.87	
2	19	15.23	-8.91	-7.10	0.69	0.00	0.82	
2	20	15.02	-8.90	-6.97	0.65	0.00	0.77	
2	21	14.80	-8.90	-6.84	0.62	0.00	0.74	
2	22	14.60	-8.92	-6.69	0.60	0.00	0.71	
2	23	14.40	-8.94	-6.55	0.58	0.00	0.69	
2	24	14.20	-8.96	-6.40	0.56	0.00	0.67	
2	25	14.00	-8.98	-6.25	0.55	0.00	0.65	
2	26	13.80	-9.00	-6.10	0.54	0.00	0.64	
2	27	13.60	-9.02	-5.95	0.53	0.00	0.63	
2	28	13.41	-9.03	-5.79	0.52	0.00	0.62	
2	29	13.23	-9.02	-5.62	0.52	0.00	0.62	
2	30	13.04	-9.01	-5.45	0.52	0.00	0.62	
2	31	12.85	-9.01	-5.29	0.52	0.00	0.62	
2	32	12.67	-9.00	-5.12	0.53	0.00	0.63	
2	33	12.48	-8.99	-4.95	0.54	0.00	0.64	
2	34	12.30	-9.00	-4.78	0.55	0.00	0.65	
2	35	12.12	-9.02	-4.61	0.56	0.00	0.67	
2	36	11.94	-9.04	-4.44	0.58	0.00	0.69	
2	37	11.76	-9.06	-4.27	0.61	0.00	0.72	
2	38	11.58	-9.08	-4.09	0.65	0.00	0.77	
2	39	11.40	-9.11	-3.92	0.69	0.00	0.82	
2	40	11.22	-9.13	-3.75	0.75	0.00	0.89	
2	41	11.04	-9.15	-3.58	0.82	0.00	0.97	
3	19	15.58	-10.39	-7.29	0.69	0.00	0.82	
3	20	15.38	-10.40	-7.14	0.64	0.00	0.76	
3	21	15.18	-10.41	-7.00	0.60	0.00	0.71	
3	22	14.97	-10.41	-6.85	0.57	0.00	0.68	
3	23	14.77	-10.42	-6.71	0.55	0.00	0.65	
3	24	14.56	-10.42	-6.56	0.53	0.00	0.63	
3	25	14.36	-10.43	-6.42	0.52	0.00	0.62	
3	26	14.16	-10.44	-6.28	0.51	0.00	0.61	
3	27	13.95	-10.44	-6.13	0.51	0.00	0.60	
3	28	13.75	-10.45	-5.99	0.51	0.00	0.60	
3	29	13.54	-10.46	-5.84	0.51	0.00	0.60	
3	30	13.36	-10.47	-5.68	0.51	0.00	0.60	
3	31	13.17	-10.47	-5.52	0.51	0.00	0.60	
3	32	12.98	-10.48	-5.35	0.51	0.00	0.61	
3	33	12.79	-10.49	-5.19	0.52	0.00	0.62	
3	34	12.60	-10.49	-5.02	0.53	0.00	0.63	
3	35	12.41	-10.50	-4.86	0.55	0.00	0.65	
3	36	12.22	-10.51	-4.70	0.57	0.00	0.67	
3	37	12.03	-10.52	-4.53	0.59	0.00	0.70	
3	38	11.84	-10.52	-4.37	0.63	0.00	0.74	

Fallbeispiel Mamma - Optimierung



Notfall

In der HDR Brachytherapie wird mit radioaktiven Quellen behandelt, die eine sehr hohe Dosisleistung aufweisen. Diese können nicht ausgeschaltet werden.

Bleibt eine Quelle wegen eines kritischen Ereignisses im Patienten stecken, wird der Patient schädlicher Strahlung ausgesetzt.

Weil während eines Notfalls die Zeit kritisch ist, muss jeder Mitarbeiter in der Lage sein richtig zu handeln.

Strahlenschutzmassnahmen

Aktivität

$$D \propto A$$

Abstand

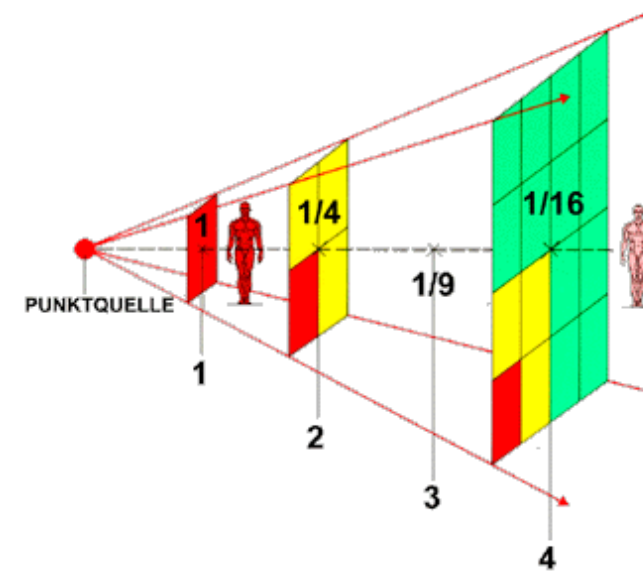
$$D \propto 1/d^2$$

Zeit

$$D \propto t$$

Abschirmung

$$D \propto e^{-\mu x}$$



Strahlenschutzmassnahmen

Situation Patient

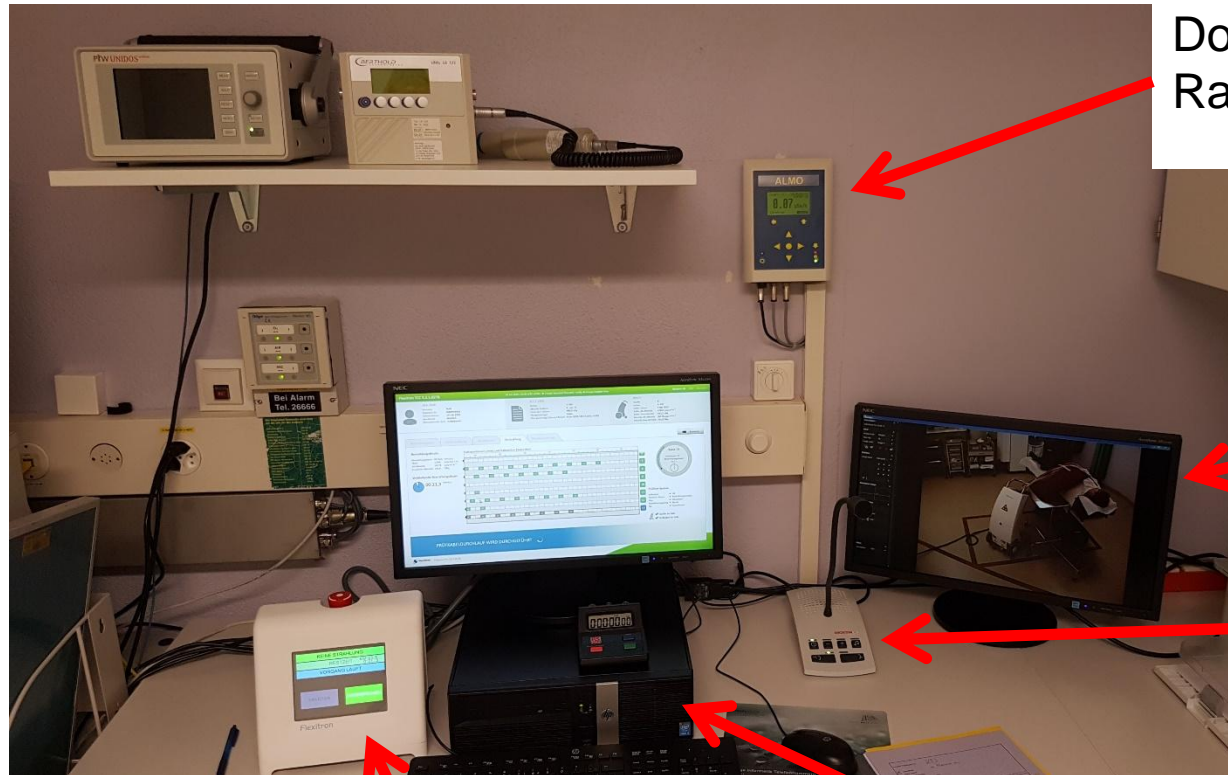
@ 1cm → ca. 6 Gy (lokal) in 1 Minute

Situation Personal

Maximale Dosis pro Jahr für beruflich strahlenexponiertes Personal: 20 mSv

@ 1m → ca. 20 mSv in 30 Minuten

Kontrollraum



Dosisleistungsgerät für die
Raumüberwachung

Kamera Monitor

Anlage

Treatment Control Console (TCC)

Treatment Control Panel (TCP)

Kontrollraum



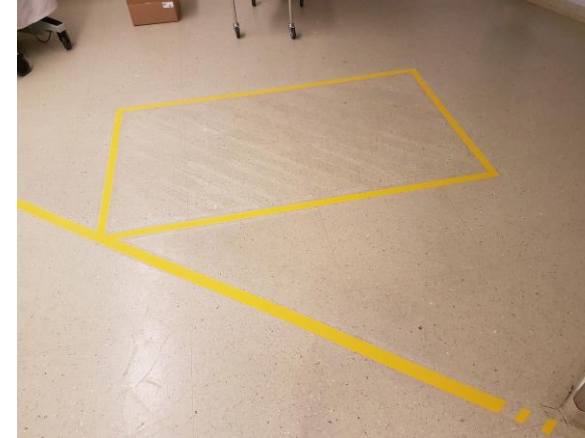
Kontrollraum



Afterloader



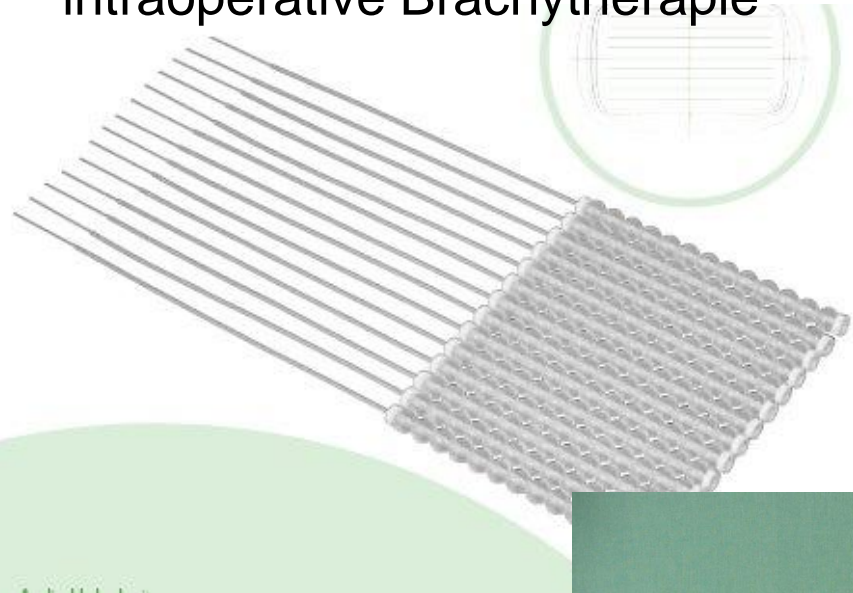
Notfall Behälter



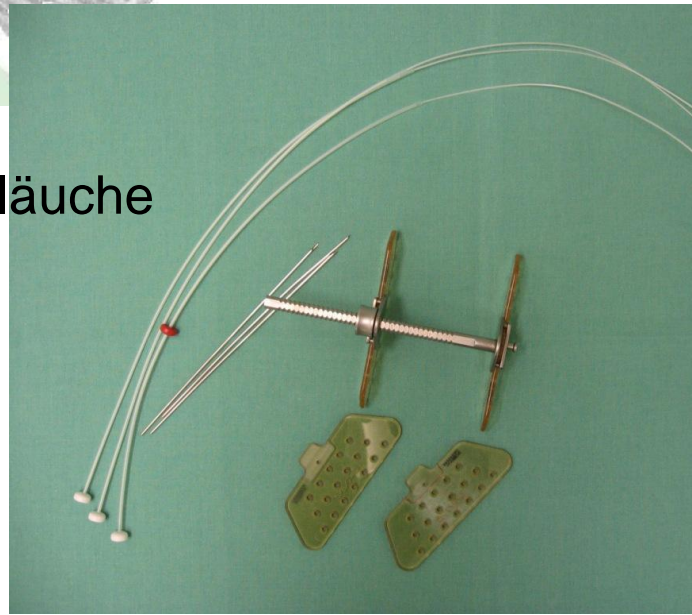
Notfall Zubehör

Applikatoren

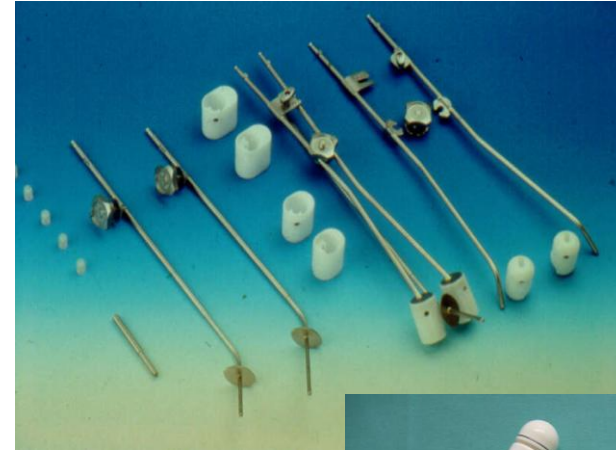
Oberflächenapplikatoren für
intraoperative Brachytherapie



Flexible Plastikschräuche



Gynäkologische Applikatoren

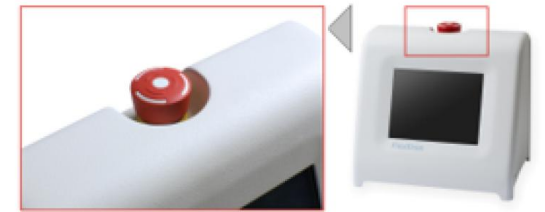


Plastiknadel

Notfallablauf

Während dem Vorfall:

- Überlegen
- Nicht alle reinlaufen (wer soll/muss rein?)
- Notfall Blatt folgen
- Hantierung am Patienten:
 - Primär Arzt
 - Falls nötig RFP/Physik
 - Zeit ist kritisch
- Zuständige Personen informieren
 - Arzt
 - Physik
 - Pflege
 - ...



Notschalter betätigen

Notruf ausrufen

Stoppuhr betätigen

Mechanische Kurbel

Applikator vom Patient entfernen

Raum sichern

