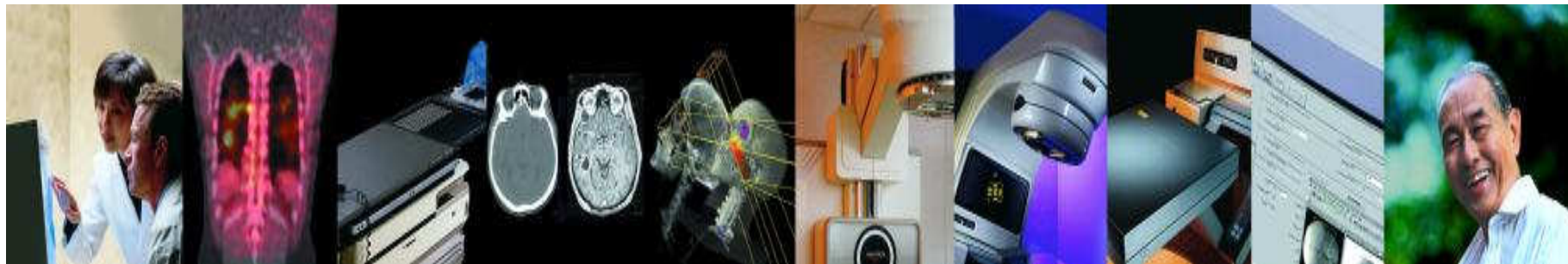
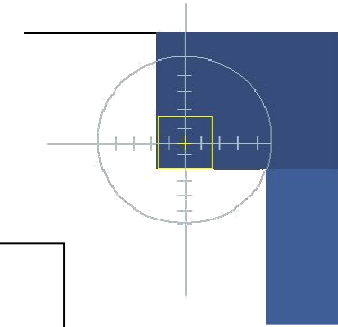


FFF: erste klinische Erfahrungen




S. Puccini
Strahlentherapie Bonn-Rhein-Sieg

Strahlentherapie Bonn-Rhein-Sieg



Bad Godesberg



3D-CRT
IMRT
Rapid-Arc

Troisdorf



1 x TrueBeam
3D-CRT
IMRT
Rapid-Arc
SBRT
Brachyther.

Euskirchen




3D-CRT
IMRT
Rapid-Arc

Wesel



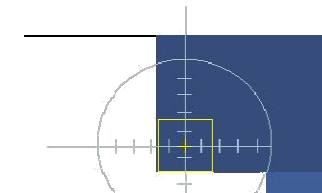
3D-CRT
IMRT
Rapid-Arc
IGRT

Bonn



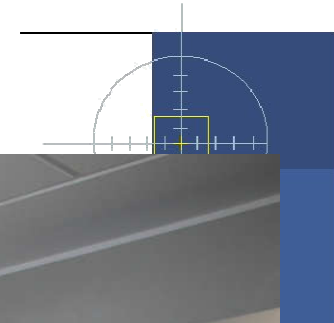
1 x TrueBeam
3D-CRT
IMRT
Rapid-Arc
SBRT
Brachyther.

Seit November 2010: TrueBeam



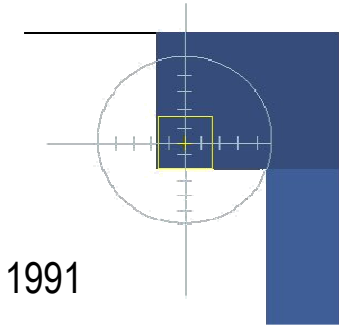
AK IMRT DGMP, Hamburg 11-12.04.2013

Go-Live: 28 Februar 2011



- 3D-CRT
- IMRT
- Rapid Arc
- IGRT
- Gating
- SBRT
- fff-mode

FFF ?



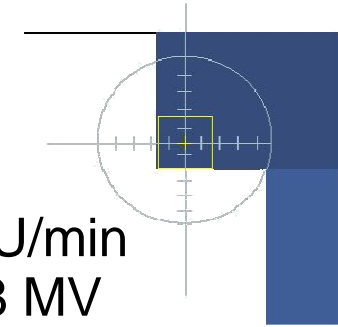
- O'Brien et al., *Radiosurgery with unflattened 6-MV photon beam*, Med.Phys. 18, 519-521, 1991
 - Hrbacek et al., *Commissioning of photon beams of a flattening filter-free linear accelerator and the accuracy of beam modeling using an anisotropical analytical algorithm*, Int. J. Rad. Oncol. Biol. Phys 80, 1228-1237, 2011
 - Scorsetti et al., *Feasibility and early clinical assessment of flattening free (FFF) based stereotactic body radiotherapy (SBRT) treatments*, Rad. Oncol. 6, 113-120 (2011)
 - Georg et al., *Current status and future perspective of flattening free photon beams*, Med. Phys 38, 1280-93 (2011)
-
- Höhere Dosirate ⇒ schnellere Behandlung
 - Kein Flattening-Filter ⇒ weniger Streuung im Beschleunigerkopf

6X FFF

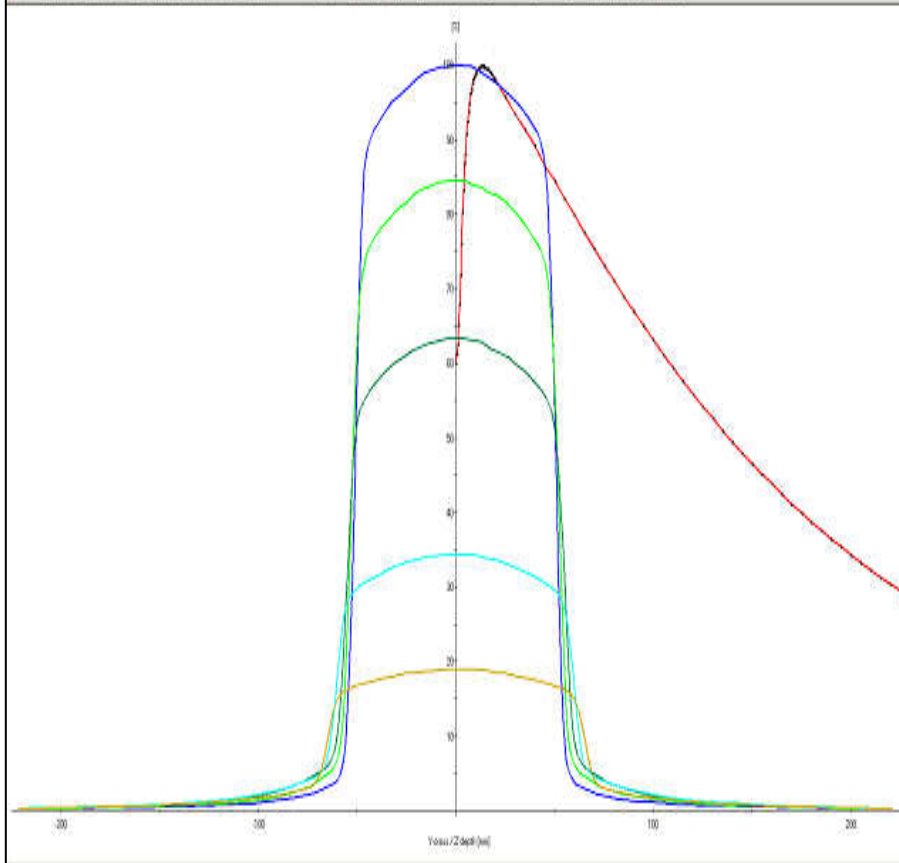
max. Dosisrate 1600 MU/min
Nominelle Energie ca. 4 MV

10X FFF

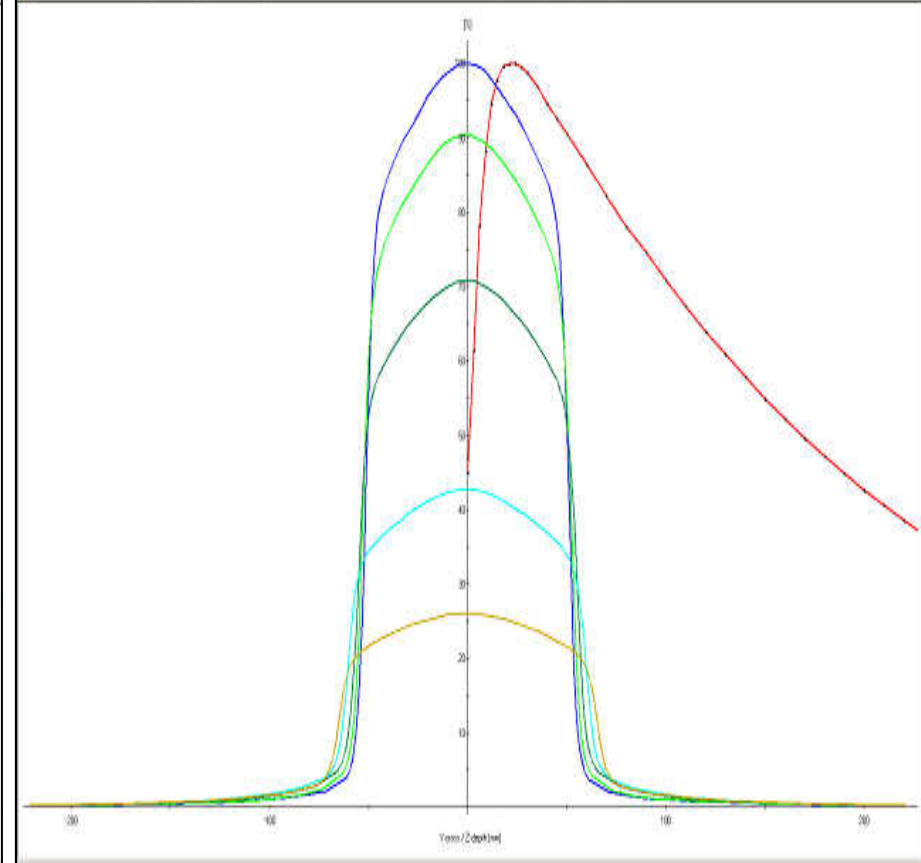
max. Dosisrate 2400 MU/min
Nominelle Energie ca. 8 MV



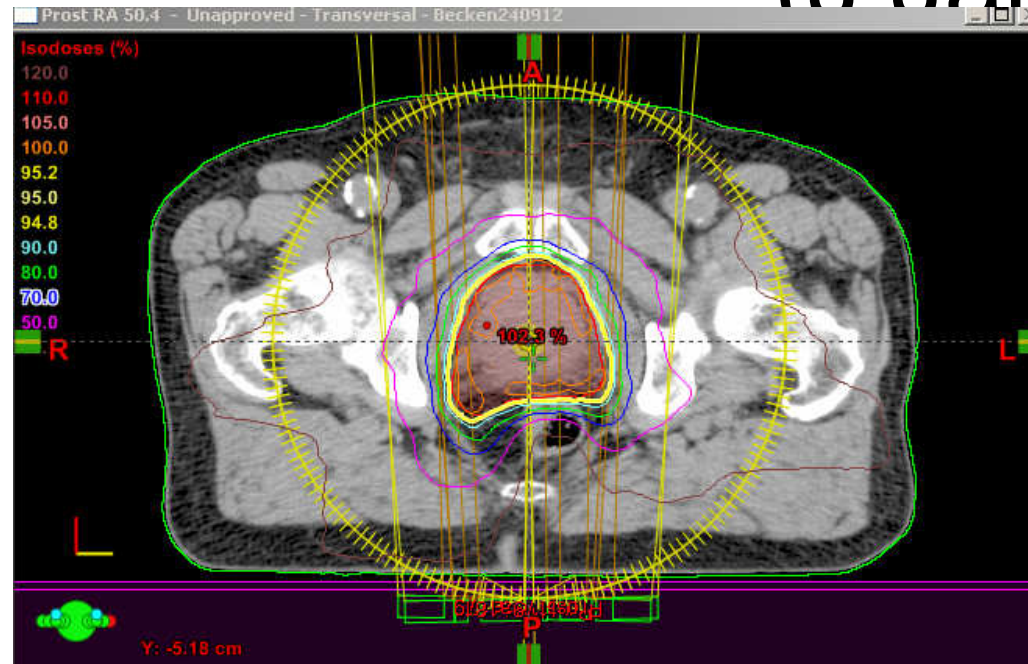
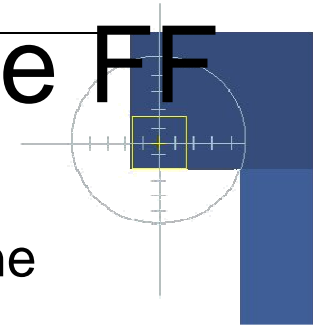
Field	Type	Modality	Energ. (kV/MeV)	Fld. (cm x cm)	Depth (cm)	Collim. (cm)	Wedge/Flap	Scatterer	Collimat.	Rotational	Block	Gain	Collimat. (cm)	X-ray Unit (cm)	Y-ray Unit (cm)	Rot. (deg)	SSD (cm)	Date/Time	Condition
1	PDD	Photon	6.00	10.0 x 10.0	1.00	0.00	Open	6.00	CIR 19.0	None	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2011-01-20 12:30	Raw Data
2	Y-axis Profile	Photon	6.00	10.0 x 10.0	1.00	0.00	Open	6.00	CIR 19.0	None	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2011-01-20 12:30	Raw Data
3	X-axis Profile	Photon	6.00	10.0 x 10.0	1.00	0.00	Open	6.00	CIR 19.0	None	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2011-01-20 12:30	Raw Data
4	Y-axis Profile	Photon	6.00	10.0 x 10.0	100.00	0.00	Open	6.00	CIR 19.0	None	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2011-01-20 12:30	Raw Data
5	X-axis Profile	Photon	6.00	10.0 x 10.0	100.00	0.00	Open	6.00	CIR 19.0	None	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2011-01-20 12:30	Raw Data
6	Y-axis Profile	Photon	6.00	10.0 x 10.0	200.00	0.00	Open	6.00	CIR 19.0	None	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2011-01-20 12:30	Raw Data
7	X-axis Profile	Photon	6.00	10.0 x 10.0	200.00	0.00	Open	6.00	CIR 19.0	None	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2011-01-20 12:30	Raw Data



Field	Type	Modality	Energ. (kV/MeV)	Fld. (cm x cm)	Depth (cm)	Collim. (cm)	Wedge/Flap	Scatterer	Collimat.	Rotational	Block	Gain	Collimat. (cm)	X-ray Unit (cm)	Y-ray Unit (cm)	Rot. (deg)	SSD (cm)	Date/Time	Condition
1	PDD	Photon	10.00	10.0 x 10.0	1.00	0.00	Open	10.00	CIR 19.0	None	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2011-01-20 12:40	Raw Data
2	Y-axis Profile	Photon	10.00	10.0 x 10.0	1.00	0.00	Open	10.00	CIR 19.0	None	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2011-01-20 12:40	Raw Data
3	X-axis Profile	Photon	10.00	10.0 x 10.0	1.00	0.00	Open	10.00	CIR 19.0	None	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2011-01-20 12:40	Raw Data
4	Y-axis Profile	Photon	10.00	10.0 x 10.0	100.00	0.00	Open	10.00	CIR 19.0	None	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2011-01-20 12:40	Raw Data
5	X-axis Profile	Photon	10.00	10.0 x 10.0	100.00	0.00	Open	10.00	CIR 19.0	None	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2011-01-20 12:40	Raw Data
6	Y-axis Profile	Photon	10.00	10.0 x 10.0	200.00	0.00	Open	10.00	CIR 19.0	None	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2011-01-20 12:40	Raw Data
7	X-axis Profile	Photon	10.00	10.0 x 10.0	200.00	0.00	Open	10.00	CIR 19.0	None	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2011-01-20 12:40	Raw Data

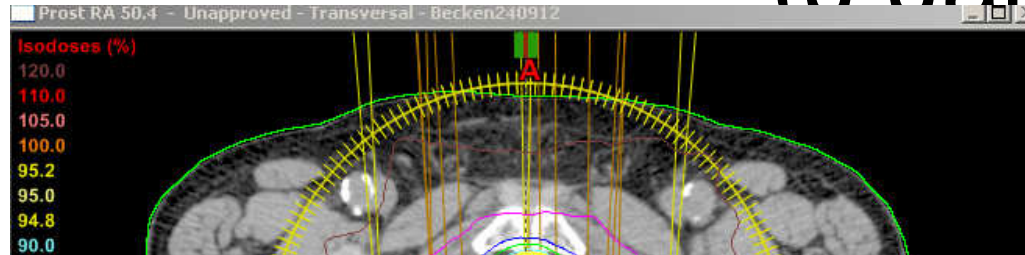
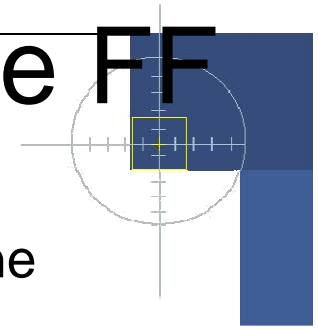


RapidArc Prostata mit / ohne FF (J. Jakobi)



Vergleich RA-Pläne
6X mit / ohne FF
Gleiche Constraints

RapidArc Prostata mit / ohne FF (J. Jakobi)



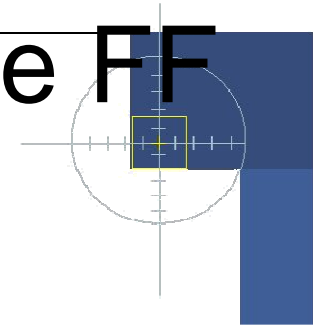
Vergleich RA-Pläne
6X mit / ohne FF
Gleiche Constraints

# Daten- satz	V (PTV) [cm ³]	D (mean) [%]	x6			x6 fff			x6 fff / x6 [%]		
			D (max)	D (min)	MU ges	D (max)	D (min)	MU ges	D (max)	D (min)	MU ges
1	255,41	100	106,5	91,2	501	105,9	89,9	518	-0,56	-1,43	3,39
2	169,79	100	107,1	85,9	498	107,9	84,1	509	0,75	-2,10	2,21
3	165,81	100	105,0	90,7	501	107,4	89,3	517	2,29	-1,54	3,19
4	274,65	100	106,3	90,0	445	107,4	89,5	433	1,03	-0,56	-2,70
5	177,56	100	106,6	94,3	500	107,1	93,0	514	0,47	-1,38	2,80
6	174,16	100	107,7	90,6	503	108,2	89,2	519	0,46	-1,55	3,18
7	237,80	100	108,2	81,1	499	108,2	80,8	517	0,00	-0,37	3,61
8	213,84	100	107,5	91,2	502	106,9	89,3	518	-0,56	-2,08	3,19
9	154,33	100	106,3	88,5	502	107,8	88,0	516	1,41	-0,56	2,79
10	237,77	100	106,1	91,4	498	106,6	85,3	518	0,47	-6,67	4,02

Werte aus Gesamtdatensatz (51 Patienten):

Mittelwert	106,4	90,4	498,3	107,2	89,3	513,7	0,7	-1,1	3,1
Standardabweichung	0,8	3,1	8,8	0,8	3,0	11,9	0,7	1,2	1,3

RapidArc Prostata mit / ohne FF (J.Jakobi)



Verisoft 4.0 bzw. 4.2

OktaviusDetektor (hohe Dosisrate)

Gamma 2D

Cut off: < 5% Dmax

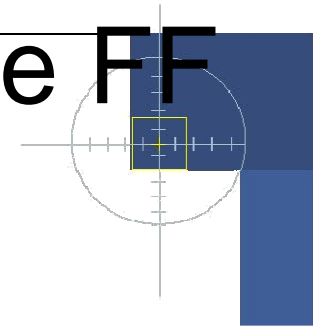
ΔD bezogen auf dem globalen Maximum

Gamma Index 3 mm, 3% bzw. 2 mm,

Streuung außerhalb
des Phantoms
Famerkammer im RW3



RapidArc Prostata mit / ohne FF (J.Jakobi)

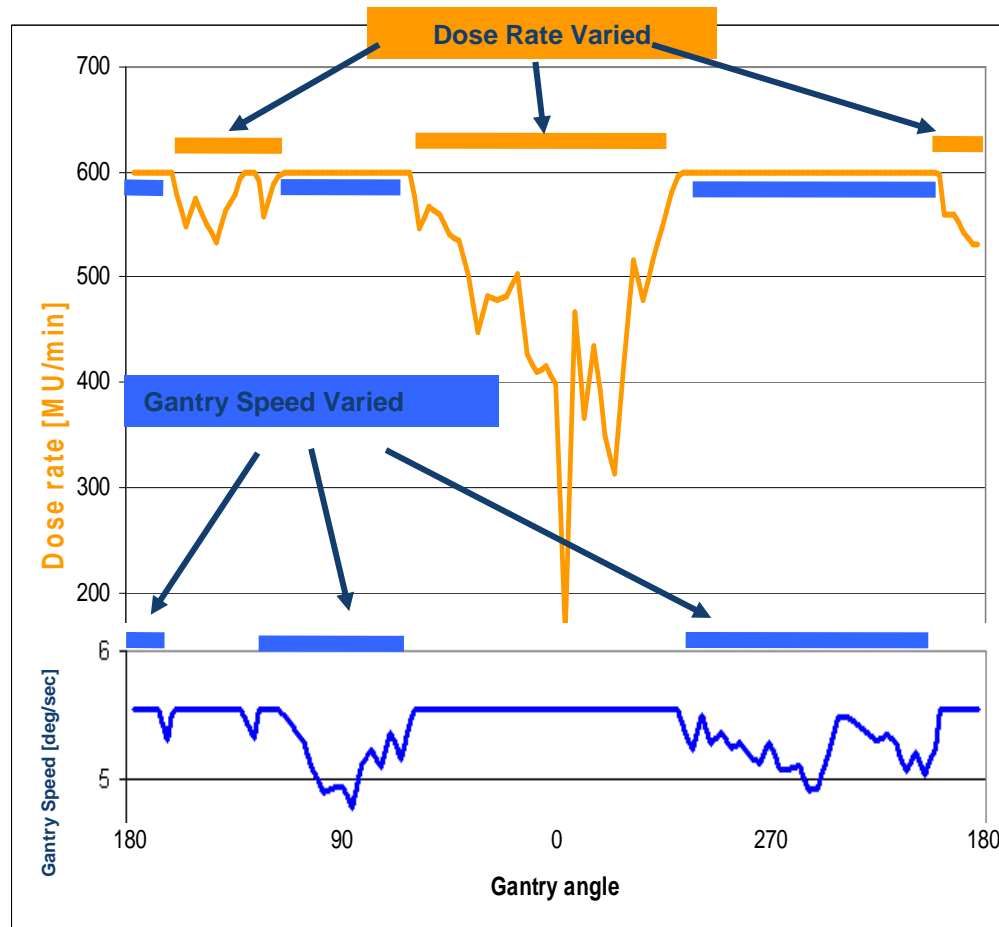
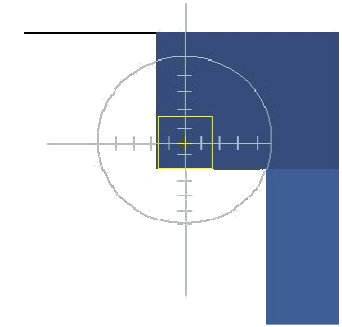


Daten- satz #	Planwerte		Verifikation		Streuung		
	MU ges	V (PTV)	Γ (2%/2mm) [%]		Streudosis [mGy]		Δ [%]
			x6	x6fff	x6	x6fff	
1	501	255,41	99,4	97,5	12,42	12,39	-0,24
2	498	169,79	99,6	95,5	8,16	7,62	-6,62
3	501	165,81	99,3	95,6	10,92	10,98	0,55
4	445	274,65	99,4	98,6	12,66	12,42	-1,90
5	500	177,56	96,2	98,9	10,50	10,26	-2,29
6	503	174,16	96,1	97,8	12,18	12,00	-1,48
7	499	237,80	98,2	92,6	9,99	9,78	-2,10
8	502	213,84	99,1	94,7	12,45	12,42	-0,24
9	502	154,33	99,6	95,7	9,66	9,45	-2,17
10	498	237,77	97,6	96,3	12,27	11,55	-5,87

Werte aus Gesamtdatensatz (51 Patienten):

Mittelwert	98,2	96,9	10,9	10,8	-1,7
Standardabweichung	1,2	2,4	2,2	2,3	2,5

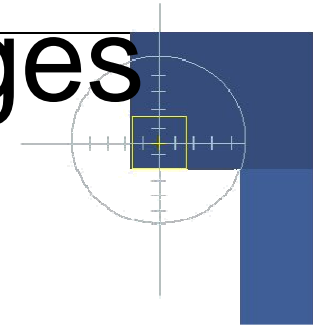
RapidArc



Fluenzmodulation:

- Gantrygeschwindigkeit:
0.5 – 4.8 Grad/Sek
- Dosisrate: 0-600 MU/min
- Dosis pro Grad: 0-20 MU/Grad
- MLC-Geschwindigkeit:
0-2.25 cm/Sek

ESRT – Nicht kleinzelliges Lungen-Ca



NSCLC

Die Standardbehandlung kleiner NSCLC im Stadium I (cT1/2 cN0 cM0) ist die Operation – entweder als Lobektomie, Bilobektomie, Pneumonektomie oder erweiterte Segmentresektion. Damit werden 5-Jahres-Überlebenszahlen von 60-90% erreicht⁹⁻¹². Ein Teil der Patienten mit lokal resektablem Tumorbefund wird allerdings aus Altersgründen oder wegen funktioneller Inoperabilität keiner operativen Therapie zugänglich sein. Für diese Patienten stellt dann die Bestrahlung die Therapie der Wahl dar. Allerdings sind die lokalen Tumor-Kontrollraten nach einer Strahlentherapie mit konventionellen Dosen deutlich schlechter als nach einer Operation. Aus Literaturanalysen von Sibley et al.^{13, 14} und Jeremic et al.¹⁵ geht hervor, dass nach konventionell fraktionierter Bestrahlung die lokale Tumorkontrolle lediglich bei 40-70% liegt und etwa 30% der bestrahlten Patienten allein an einem lokal unkontrollierten Tumor versterben. Aus diesen Ergebnissen leitet sich die Rationale zur Dosisescalation durch die stereotaktische Strahlentherapie von kleinen Bronchialkarzinomen ab. Die bisher publizierten lokalen Tumorkontrollraten nach stereotaktischer Bestrahlung lagen übereinstimmend bei mehr als 80%, zumeist bei mehr als 90%¹⁶⁻²⁸. Das bisher größte

Aus der Leitlinie der DEGRO

- **NSCLC Stadium I (cT1/2 cN0 cM0) – Überlebensrate nach 5 Jahren**
- **Operation** **60-90%**
- **Strahlentherapie konventionell** 40-70% (30% Sterberate lokal unkontrollierter Tumor)
- **Strahlentherapie hypofraktioniert** 80%

PRINCIPLES OF RADIATION THERAPY (7 of 10)

Table 2. Commonly Used Doses for SABR

Nominal Total Dose	# Fractions	Example Indications
25-34 Gy	1	Peripheral, small (< 2 cm) tumors, esp. > 1 cm from chest wall
45-60 Gy	3	Peripheral tumors, esp. > 1 cm from chest wall
48-50 Gy	4	Central or peripheral tumors < 4-5 cm, esp. < 1 cm from chest wall
50-55 Gy	5	Central or peripheral tumors, esp. < 1 cm from chest wall
60-70 Gy	8-10	Central tumors

3x 18,0 Gy 2x/ week

5 x 11 Gy 1.5 weeks

8x 7,5 Gy 3.5 weeks

Table 3. Normal Tissue Dose-Volume Constraints for SABR*

OAR	1 Fraction	3 Fractions	4 Fractions	5 Fractions
Spinal Cord	14 Gy	18 Gy (6 Gy/fx)	26 Gy (6.5 Gy/fx)	30 Gy (6 Gy/fx)
Esophagus	15.4 Gy	30 Gy (10 Gy/fx)	30 Gy (7.5 Gy/fx)	32.5 Gy (6.5 Gy/fx)
Brachial Plexus	17.5 Gy	21 Gy (7 Gy/fx)	27.2 Gy (6.8 Gy/fx)	30 Gy (6 Gy/fx)
Heart/ Pericardium	22 Gy	30 Gy (10 Gy/fx)	34 Gy (8.5 Gy/fx)	35 Gy (7 Gy/fx)
Great Vessels	37 Gy	39 Gy (13 Gy/fx)	49 Gy (12.25 Gy/fx)	55 Gy (11 Gy/fx)
Trachea & Proximal Bronchi	20.2 Gy	30 Gy (10 Gy/fx)	34.8 Gy (8.7 Gy/fx)	32.5 Gy (6.5 Gy/fx)
Rib	30 Gy	30 Gy (10 Gy/fx)	30 Gy (7.5 Gy/fx)	32.5 Gy (6.5 Gy/fx)
Skin	26 Gy	30 Gy (10 Gy/fx)	36 Gy (9 Gy/fx)	40 Gy (8 Gy/fx)
Stomach	12.4 Gy	27 Gy (9 Gy/fx)	30 Gy (7.5 Gy/fx)	35 Gy (7 Gy/fx)

*Based on constraints used in recent and ongoing RTOG SABR trials (RTOG 0618, 0813, & 0915).

Note: All recommendations are category 2A unless otherwise indicated.
Clinical Trials: NCCN believes that the best management of any cancer patient is in a clinical trial. Participation in clinical trials is especially encouraged.

Zielvolumendefinition

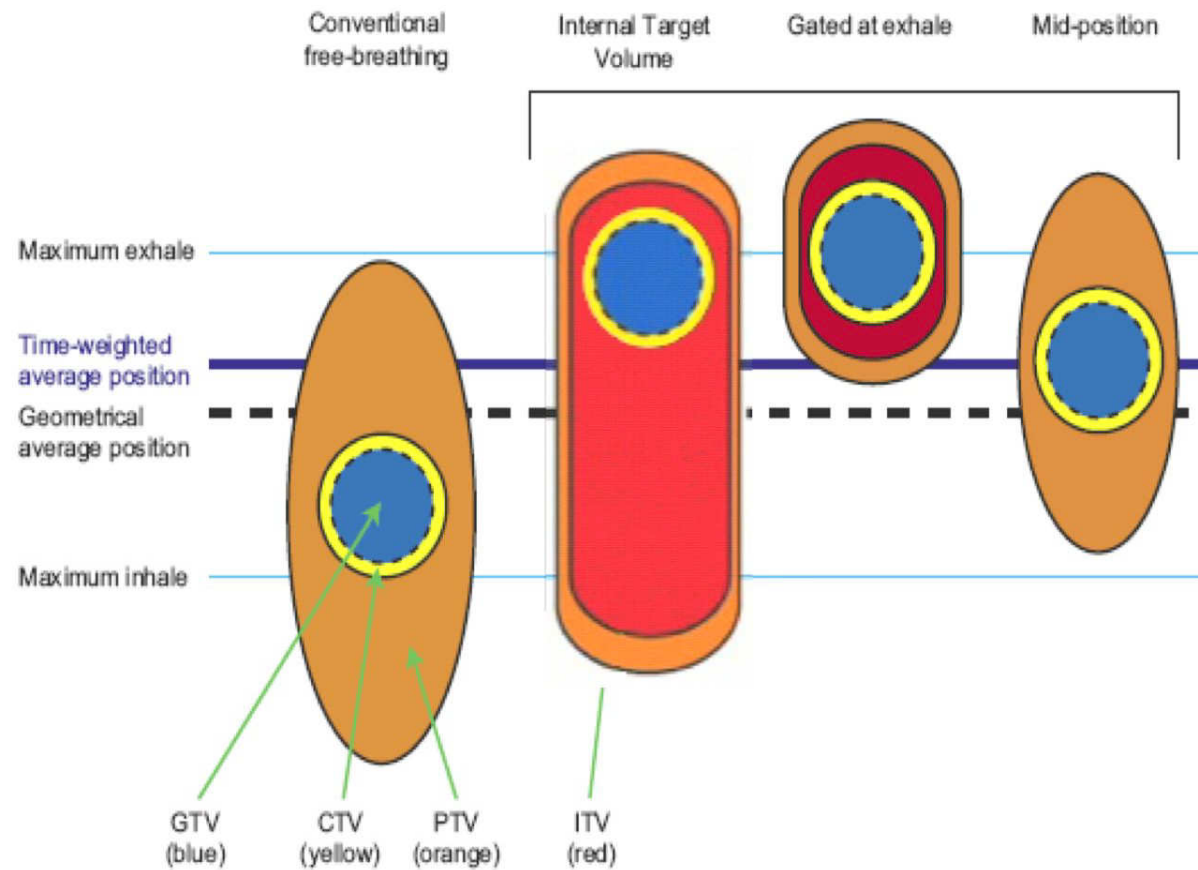
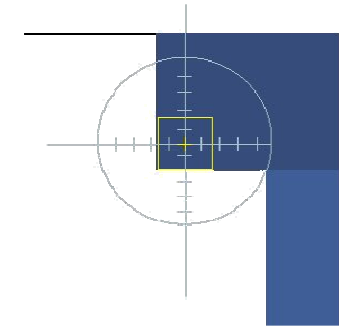
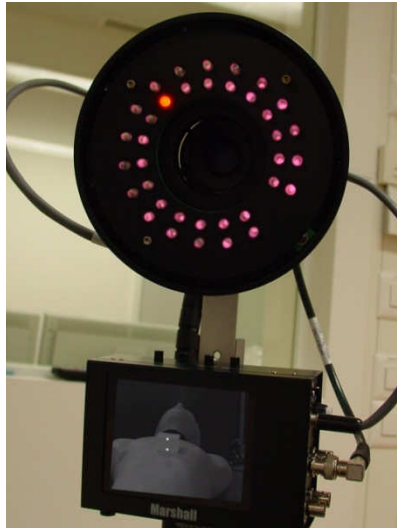
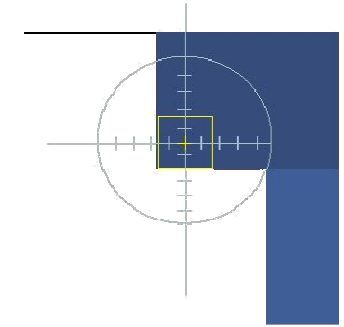


Fig. 1. Schematic overview of different treatment-planning concepts: conventional free-breathing, internal target volume (ITV), gating (at exhale), and mid-position. GTV = gross tumor volume; CTV = clinical target volume; PTV = planning target volume.

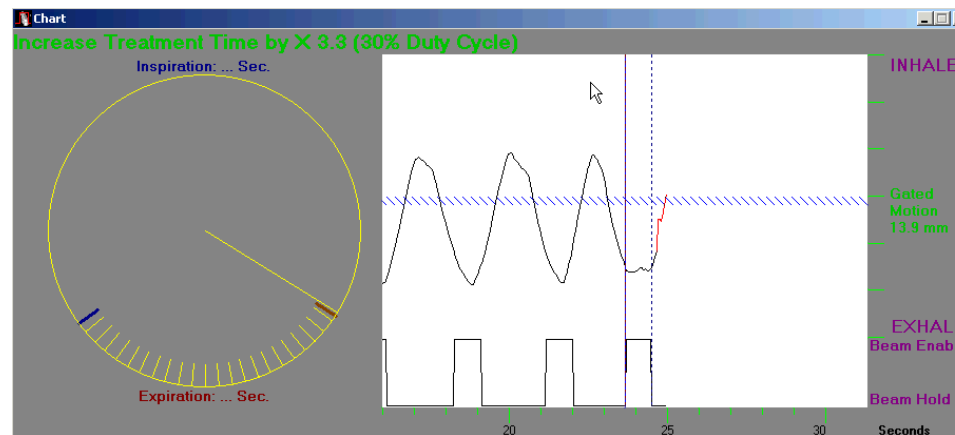
4D CT - The equipment



Lagerung im Vakuummatratze

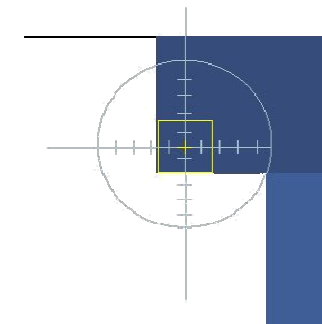


RPM Gating System

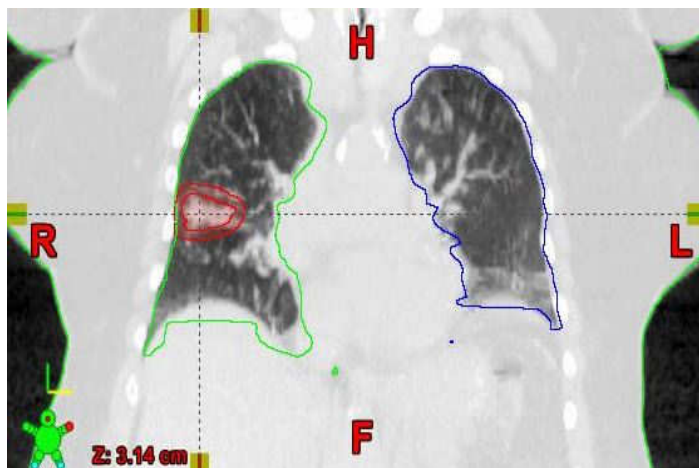


Atemtriggerung

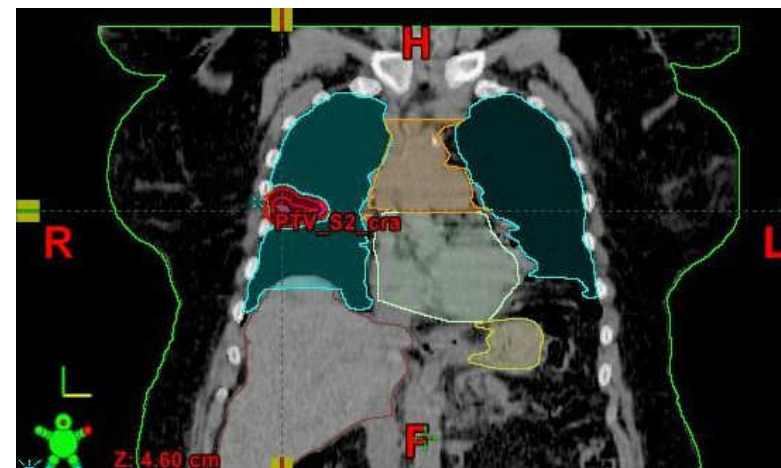
Target definition



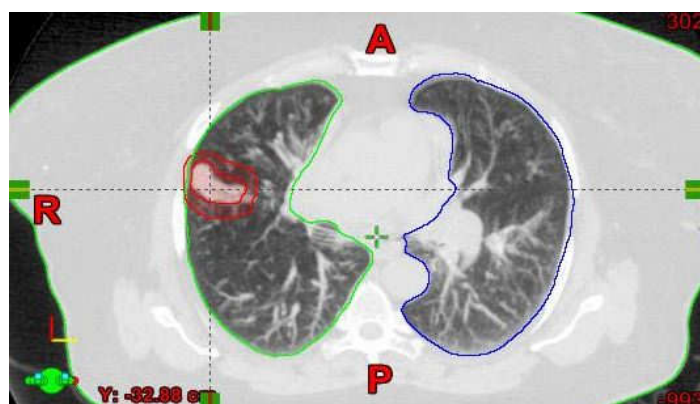
Contouring



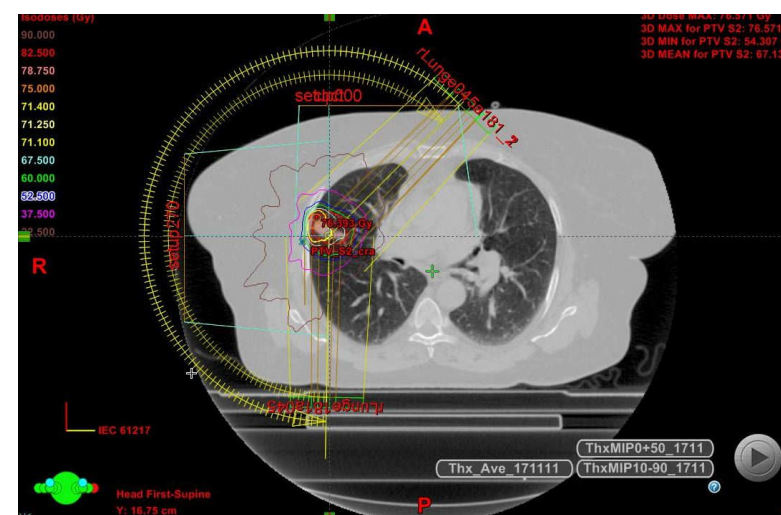
Planning



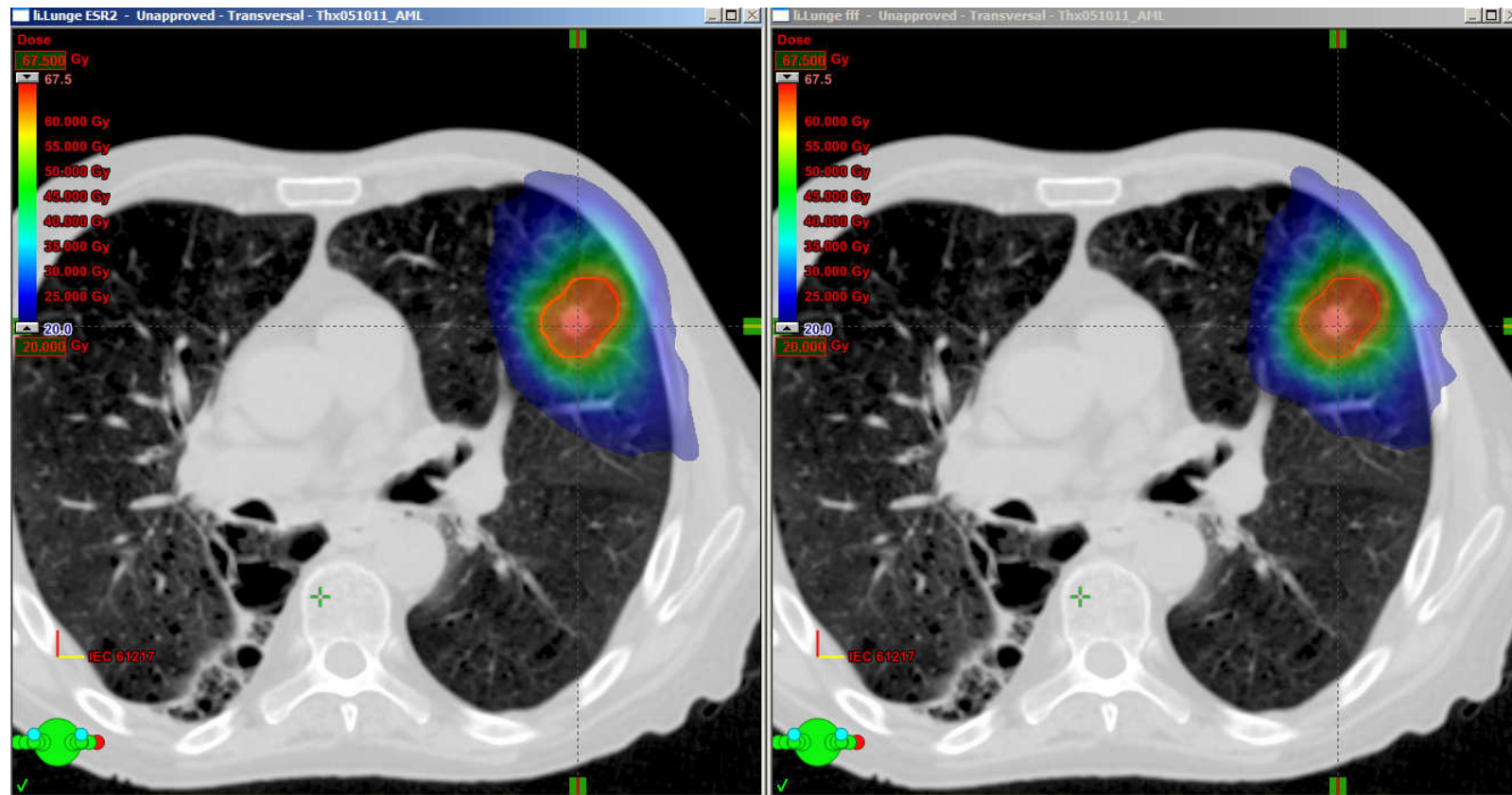
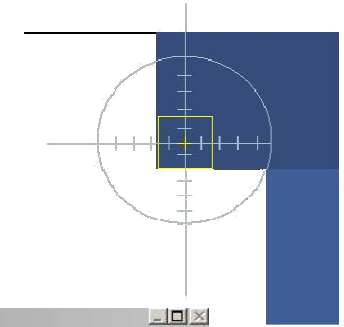
MIP



AIP



ESRT Lunge

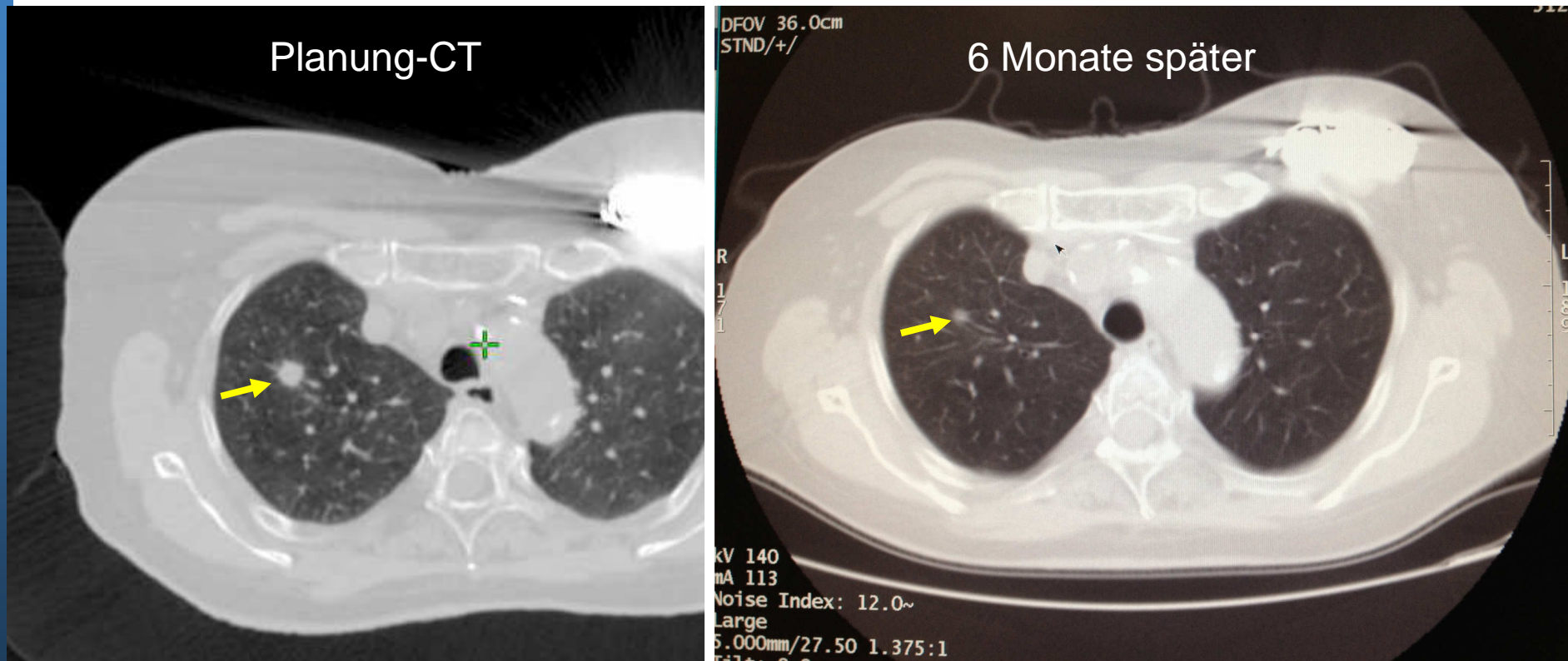


5 Arcs, 6X FF
4158 MU
ca. 7 min

3 Arcs, 10X FFF
4313 MU
ca. 2 min

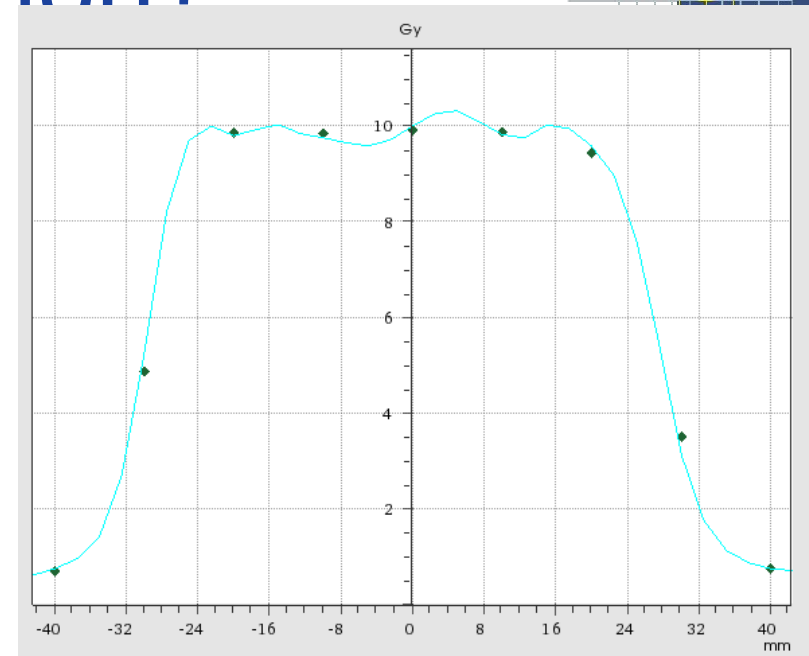
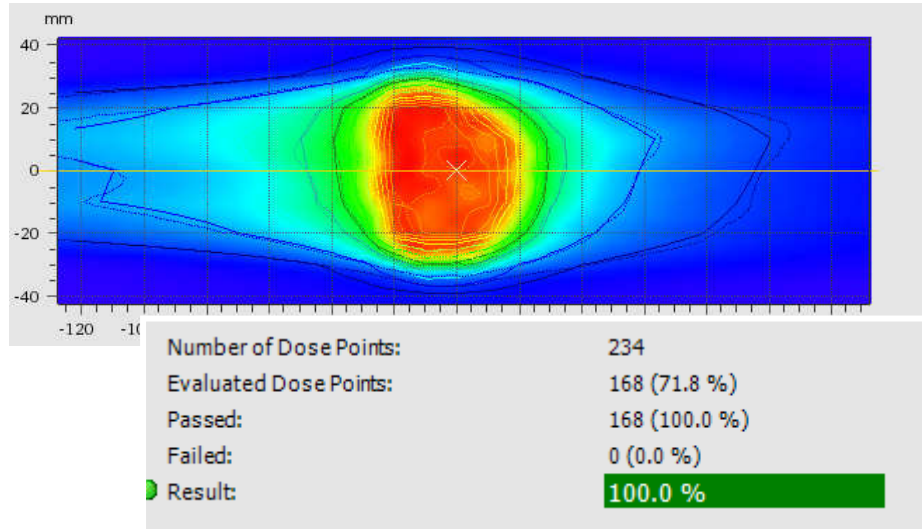
Bisherige Erfahrung (seit 2012)

- 12 Patienten
- Kaum Nebenwirkungen
- Deutliche Volumenverkleinerung

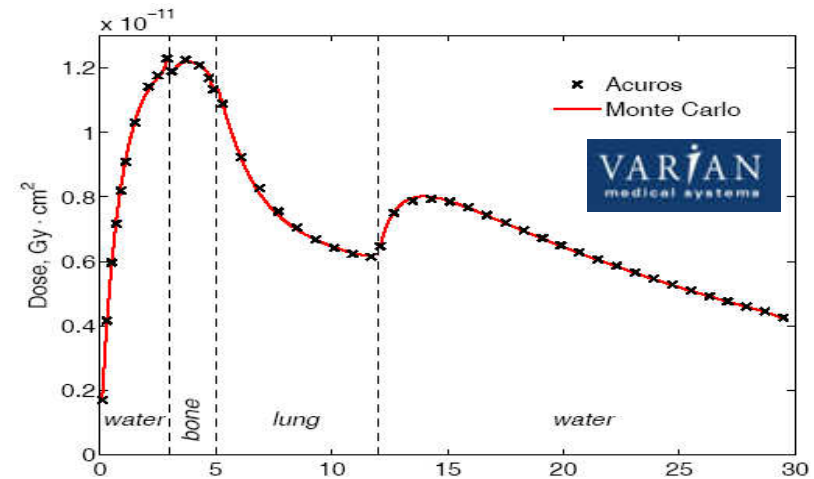


Alles schön?

- Patientenbezogene Verifikation?



- Algorithmen?
Auswirkung auf die Dosierung?
- Dosisrate?



18 MV Photon Beam, 2.5x2.5 cm field size

