

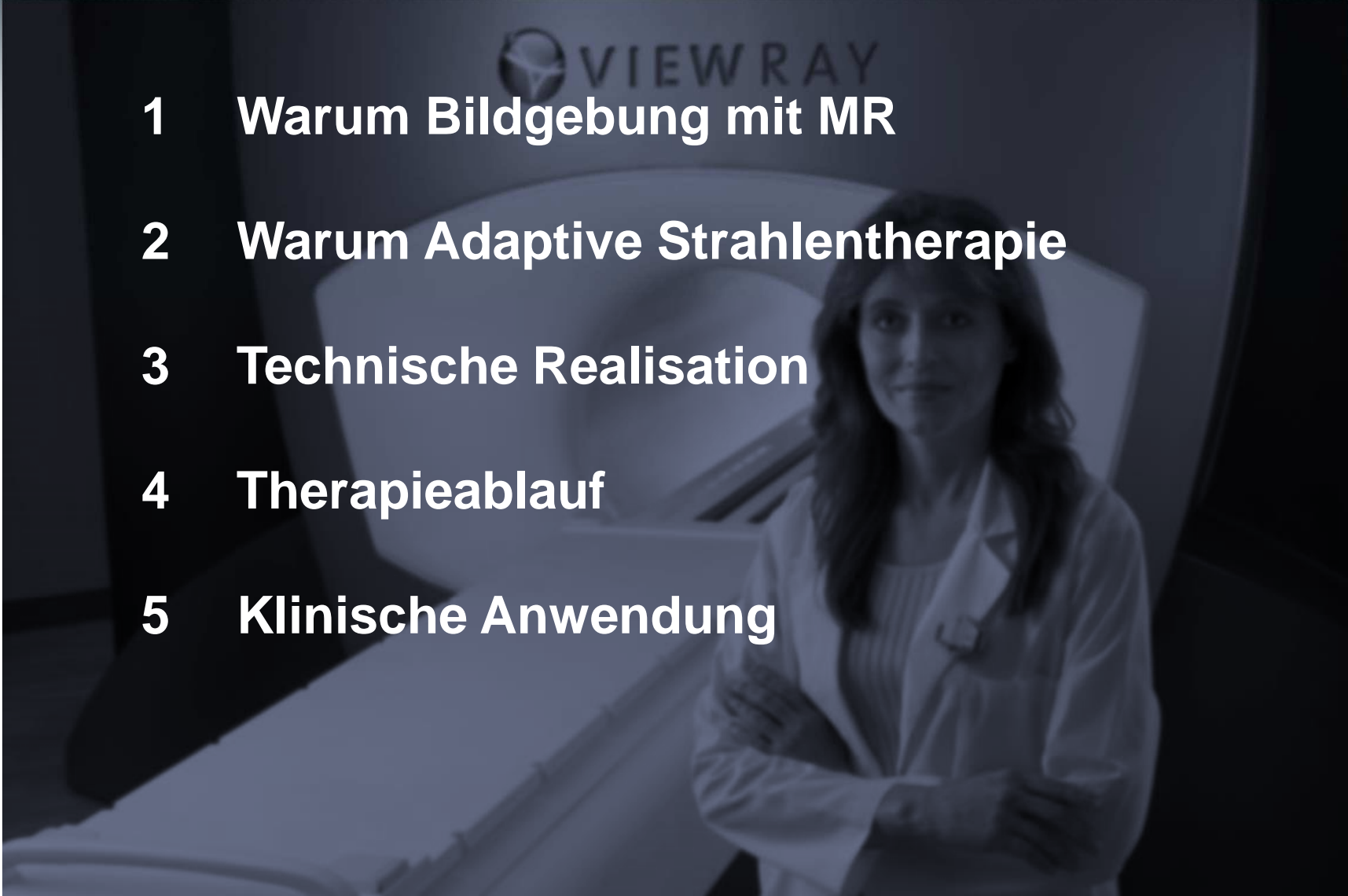


ViewRay



MRIdian

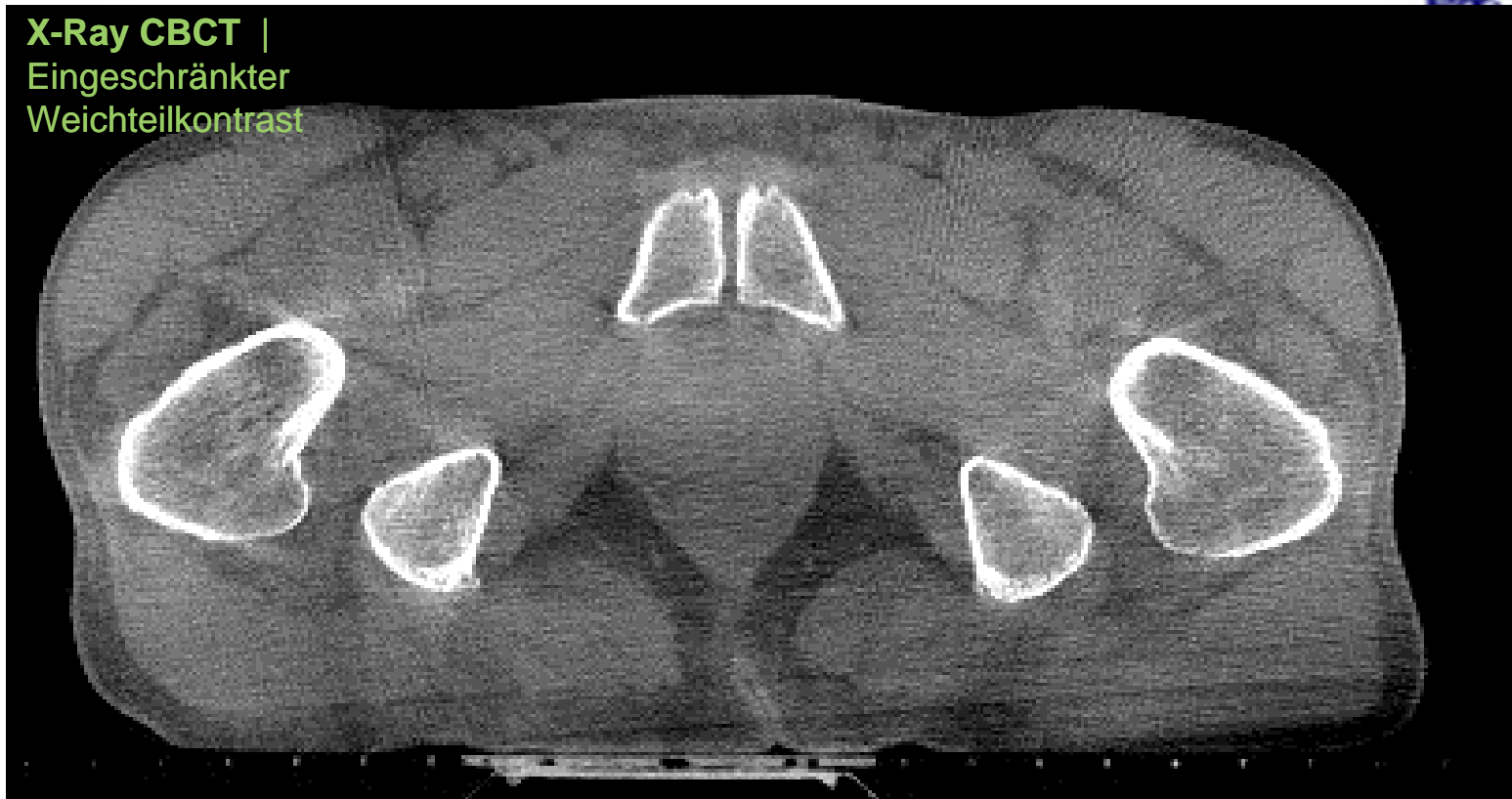


- 
- 1 Warum Bildgebung mit MR**
 - 2 Warum Adaptive Strahlentherapie**
 - 3 Technische Realisation**
 - 4 Therapieablauf**
 - 5 Klinische Anwendung**

Der Standard: Reference X-Ray CBCT



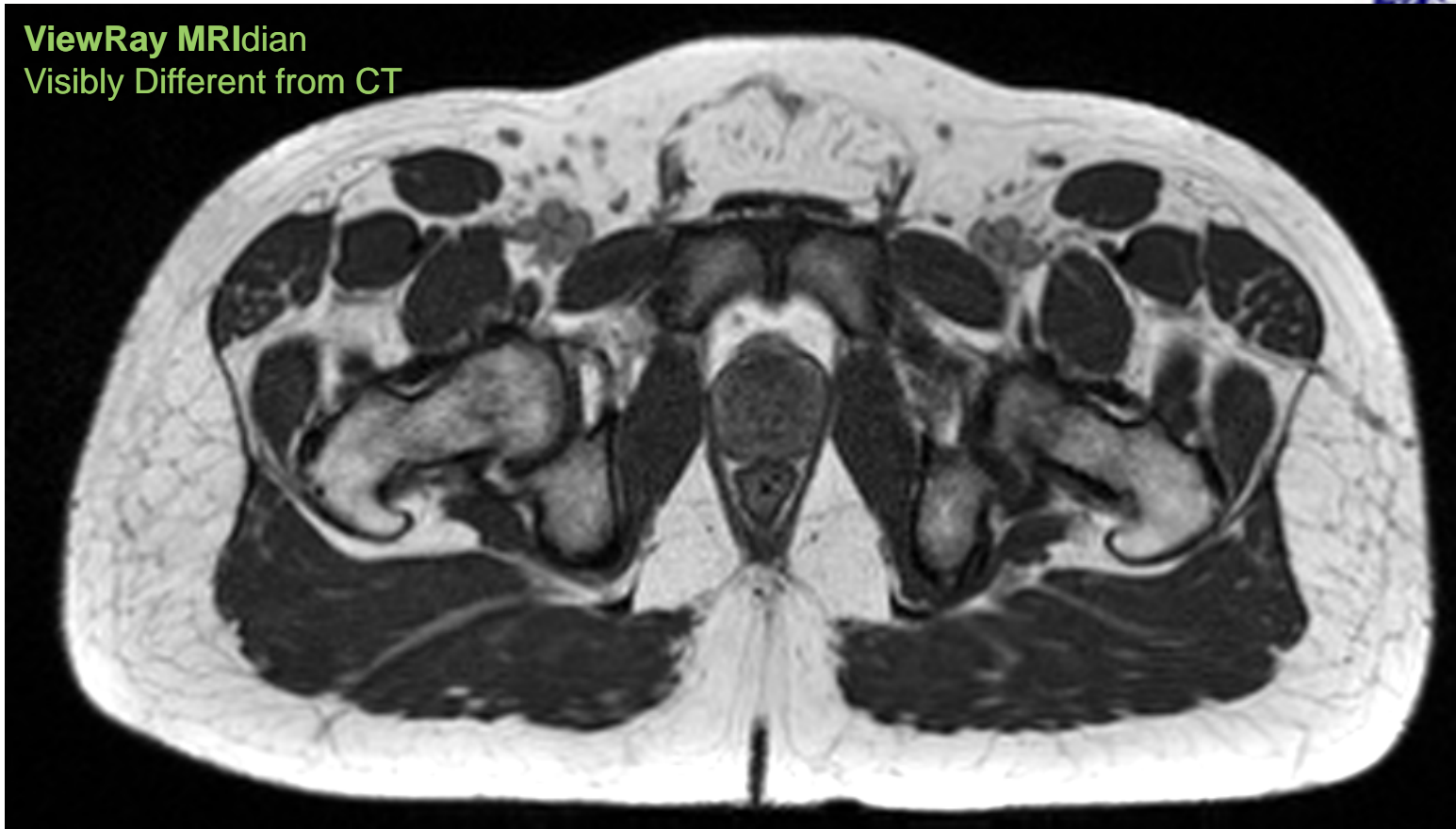
X-Ray CBCT |
Eingeschränkter
Weichteilkontrast



Der neue Ansatz: Weichteilkontrast



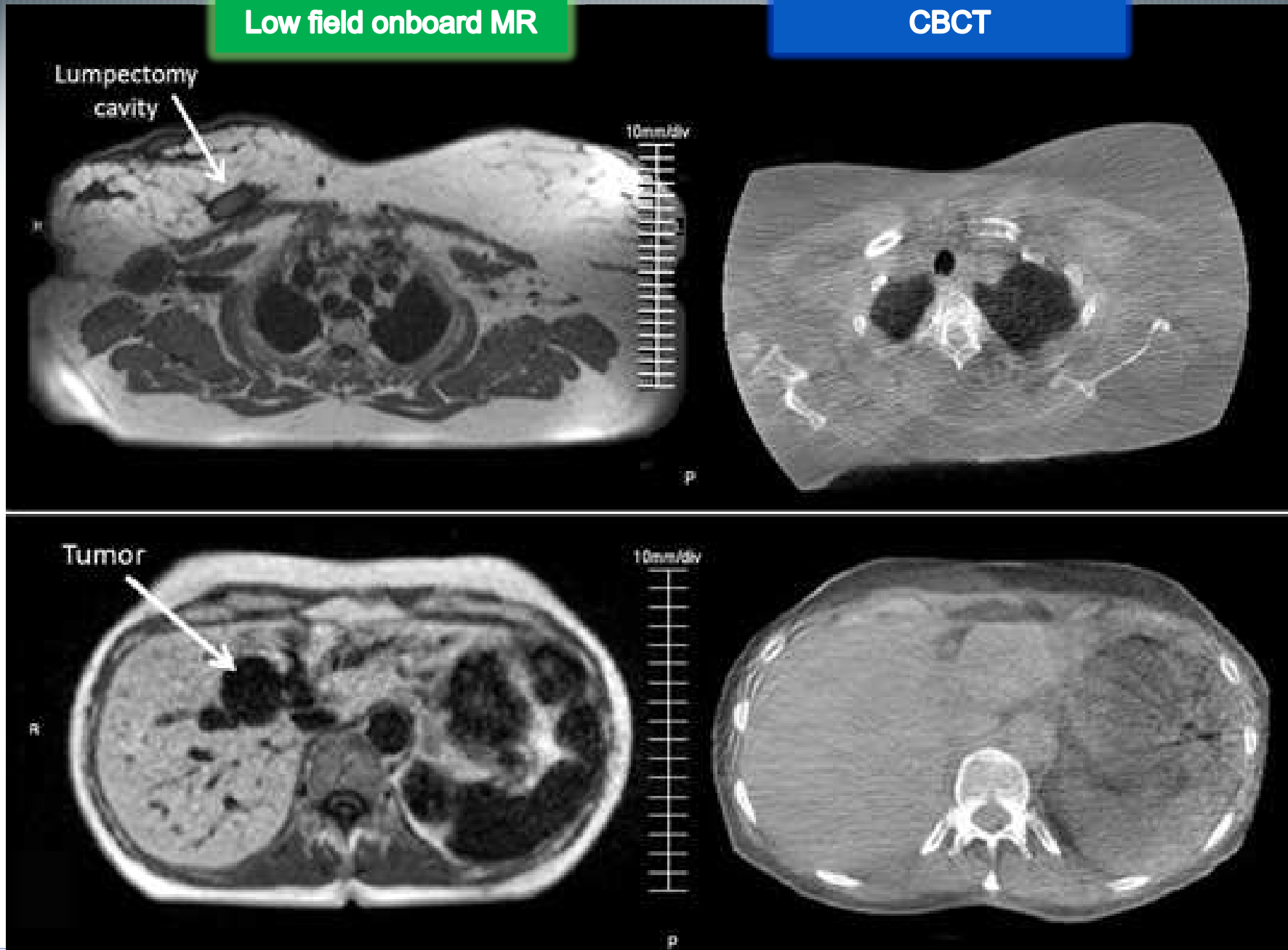
ViewRay MRIdian
Visibly Different from CT



Vergleiche

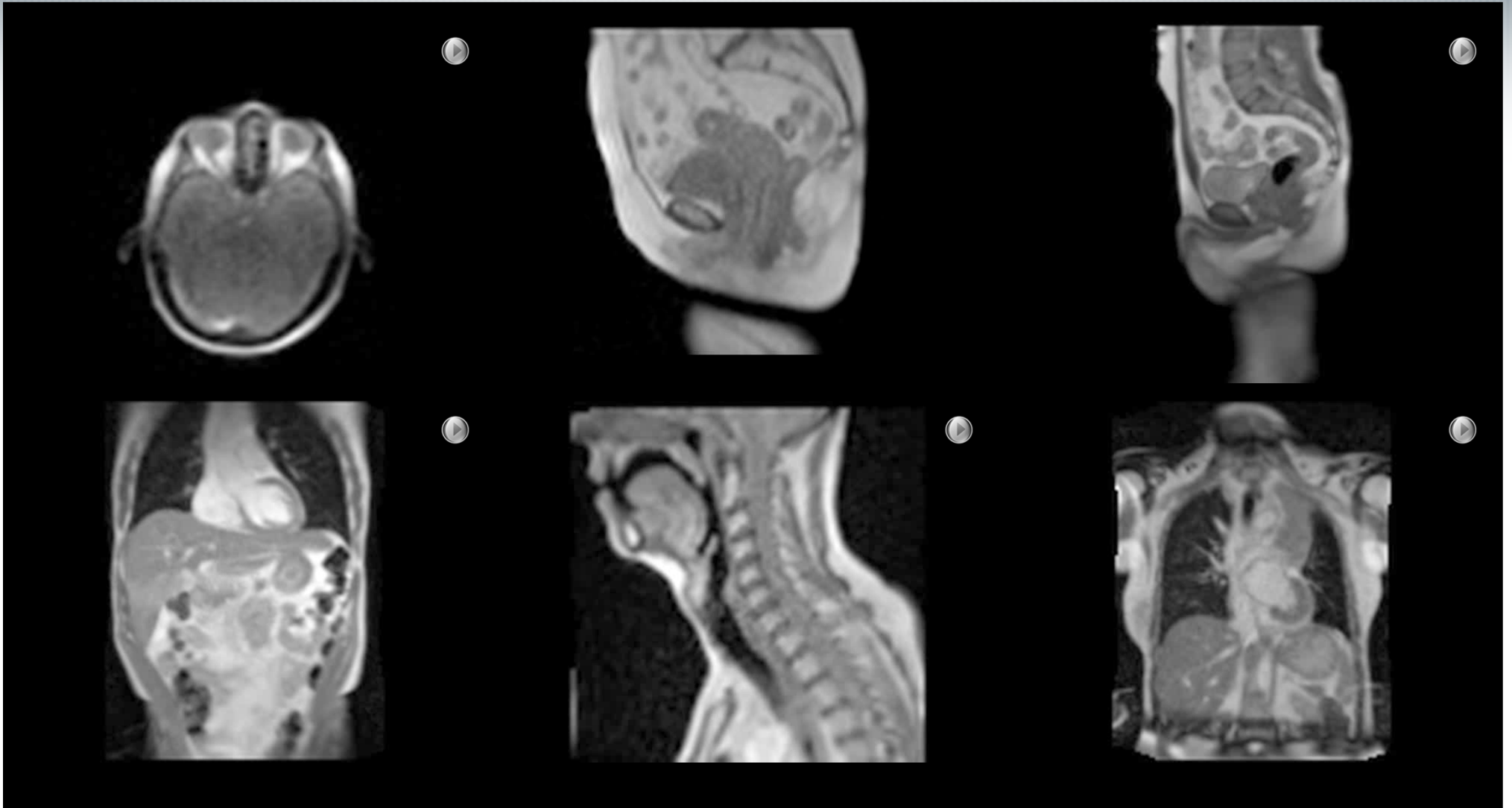
Low field onboard MR

CBCT



- 
- 1 Warum Bildgebung mit MR
 - 2 Warum Adaptive Strahlentherapie

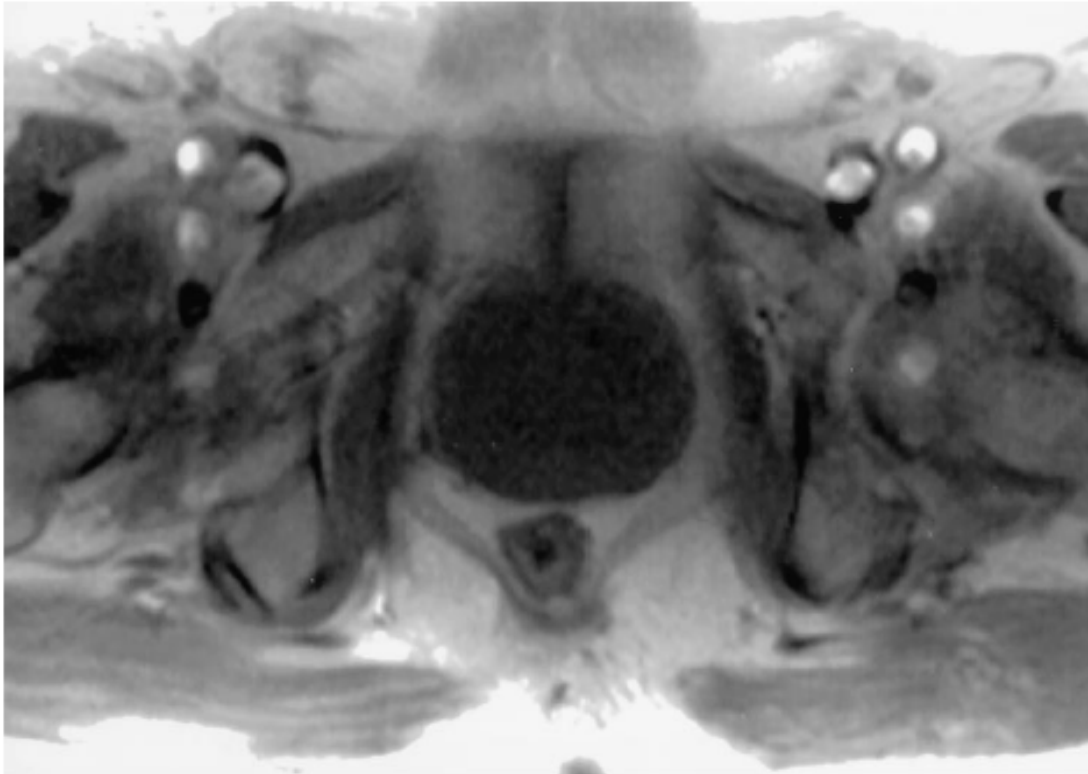
Kontinuierliche Organbewegung



Images provided courtesy of Washington University

Intrafraktionelle Organbewegung

Example: Rectal Gas Distention

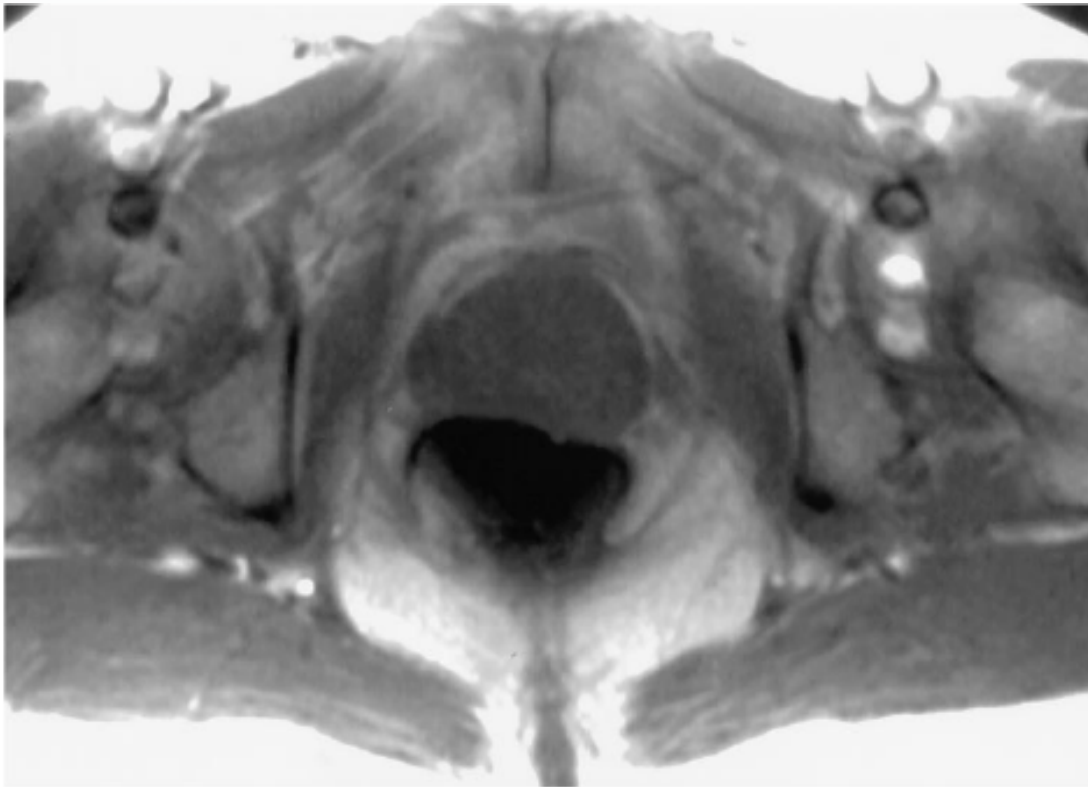


In 1999 Padhani et al. scanned 54 prostate cancer patients in axial plane every 10 second for 7 minutes

Padhani et al.
Int. J. Rad. Oncol. Biol. Phys., Vol. 44(3) pp. 525–533, 1999
Ghilezan et al.
Int J Radiat Oncol Biol Phys. 2005 Jun 1;62(2):406-17

Intrafraktionelle Organbewegung

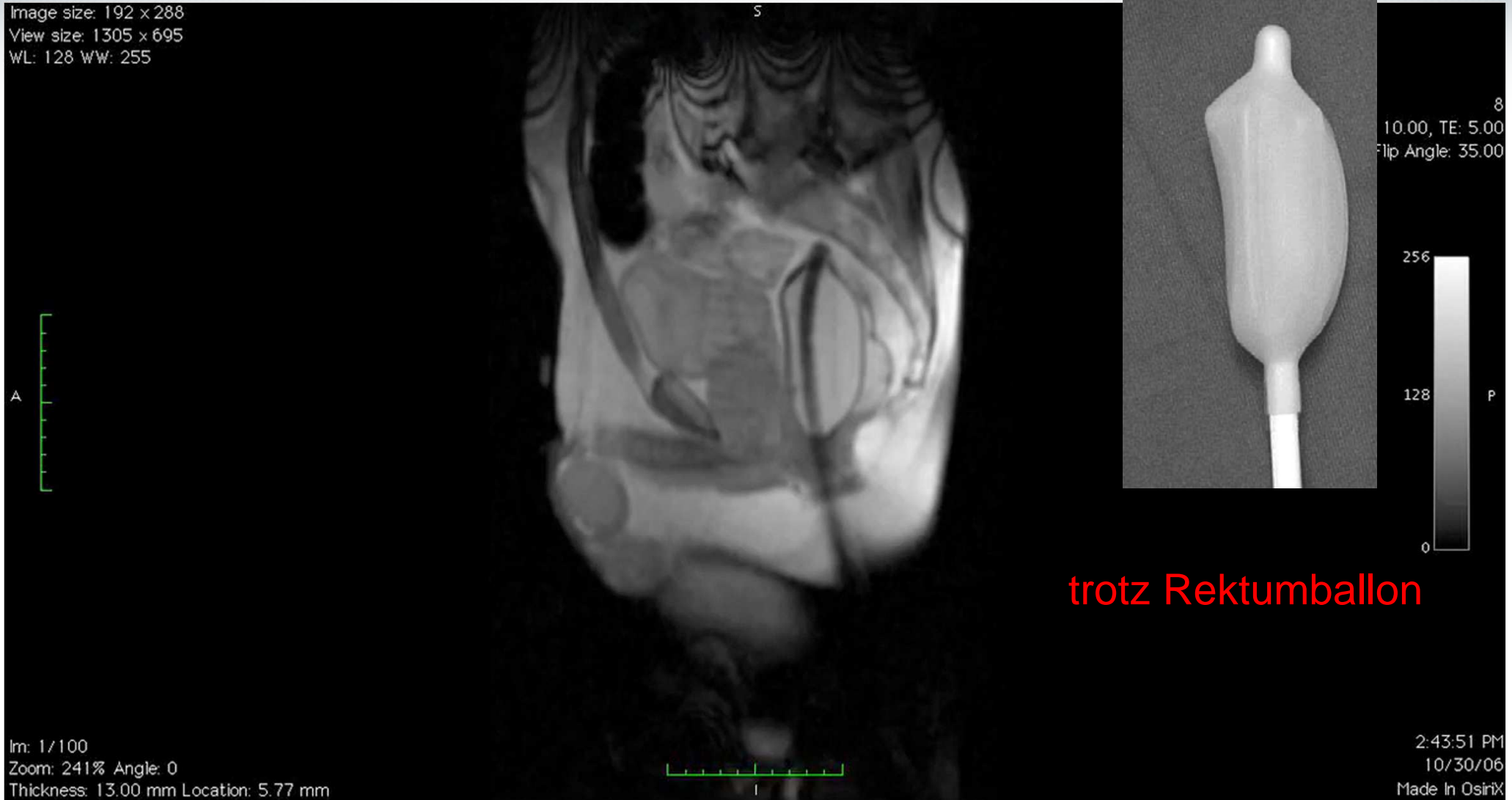
Example: Rectal Gas Distention



- Prostate Motion > 0.5 cm for 20-80 seconds observed in 16% of patients
- No considerable motion in 1/2
- 16.7% (9/54) had prostate move > 5mm
- median prostate AP displacement was anterior by 4.2
- Lasting 10-80s w/ mean of 20s

Padhani et al.
Int. J. Rad. Oncol. Biol. Phys., Vol. 44(3) pp. 525–533, 1999
Ghilezan et al.
Int J Radiat Oncol Biol Phys. 2005 Jun 1;62(2):406-17

Kontinuierliche Bewegung



The Geographic Miss Hypothesis: Missing the Target Lessens the Efficacy and Increases Side Effects of RT

$\alpha=0.14$ [Gy⁻¹]

$\beta=0.04$ [Gy⁻²]

$\lambda=0.12$ [d⁻¹] cell repopulation

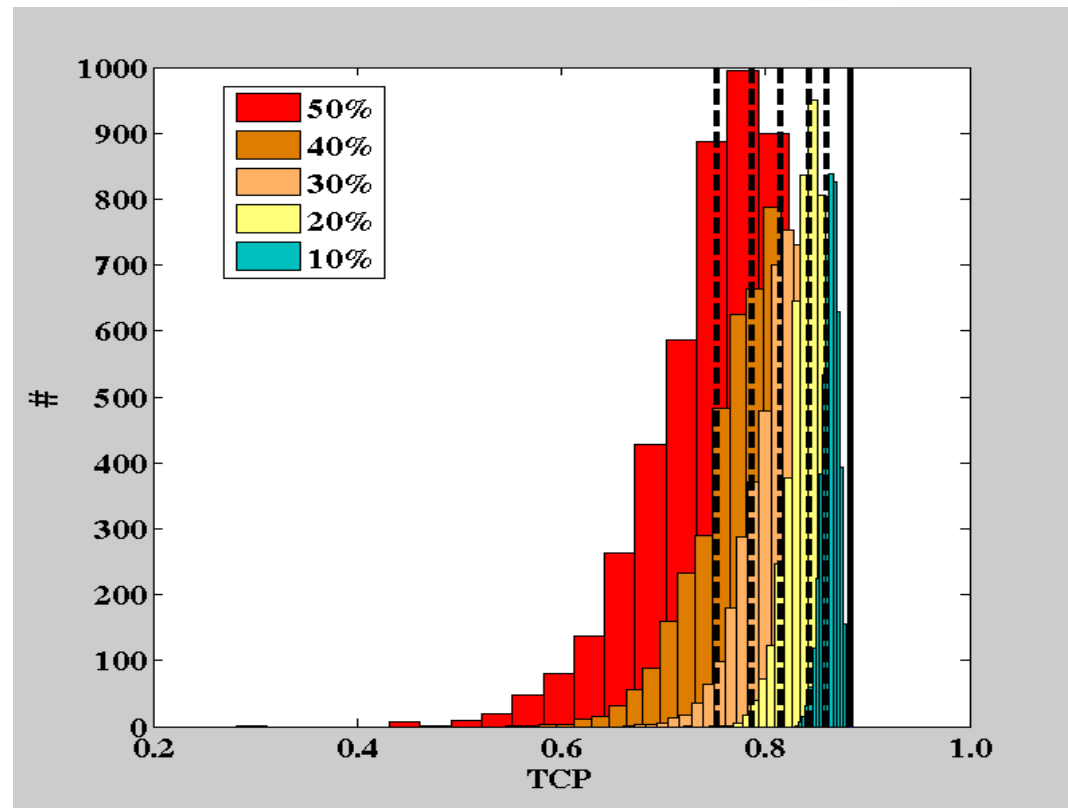
$\tau=0.576$ [d] sub-lethal damage repair time

Valid for different dose/time


Monte Carlo 5K cases 16.4% chance of
X% dose error in f_x

X = 10,20,30,40,50%

TCP @ 5yrs



Tumor Control Prob. Model of Stavrev et al.
Phys. Med. Biol. 50 (2005) pp 3053–3061

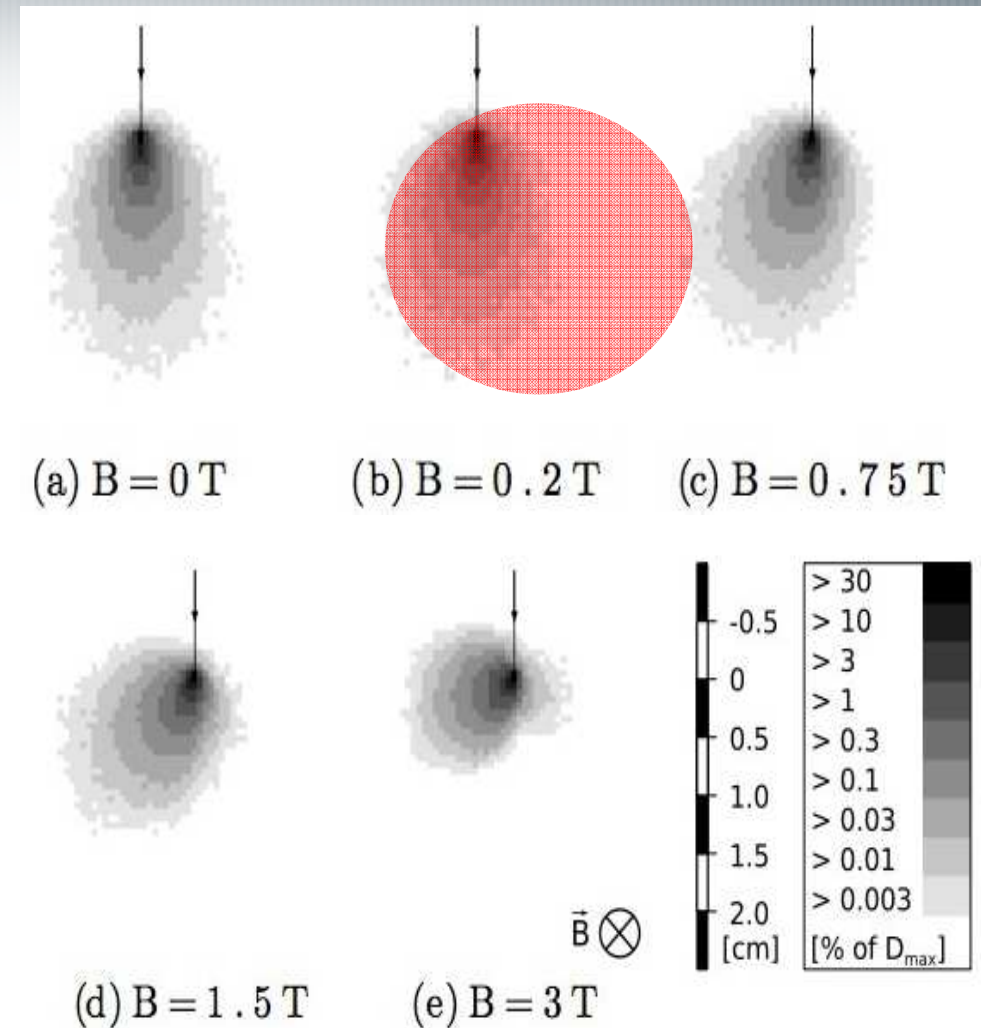
- 
- VIEWRAY**
- 1 Warum Bildgebung mit MR
 - 2 Warum Adaptive Strahlentherapie
 - 3 Technische Realisation**

Kombination Bestrahlungssystem und MR



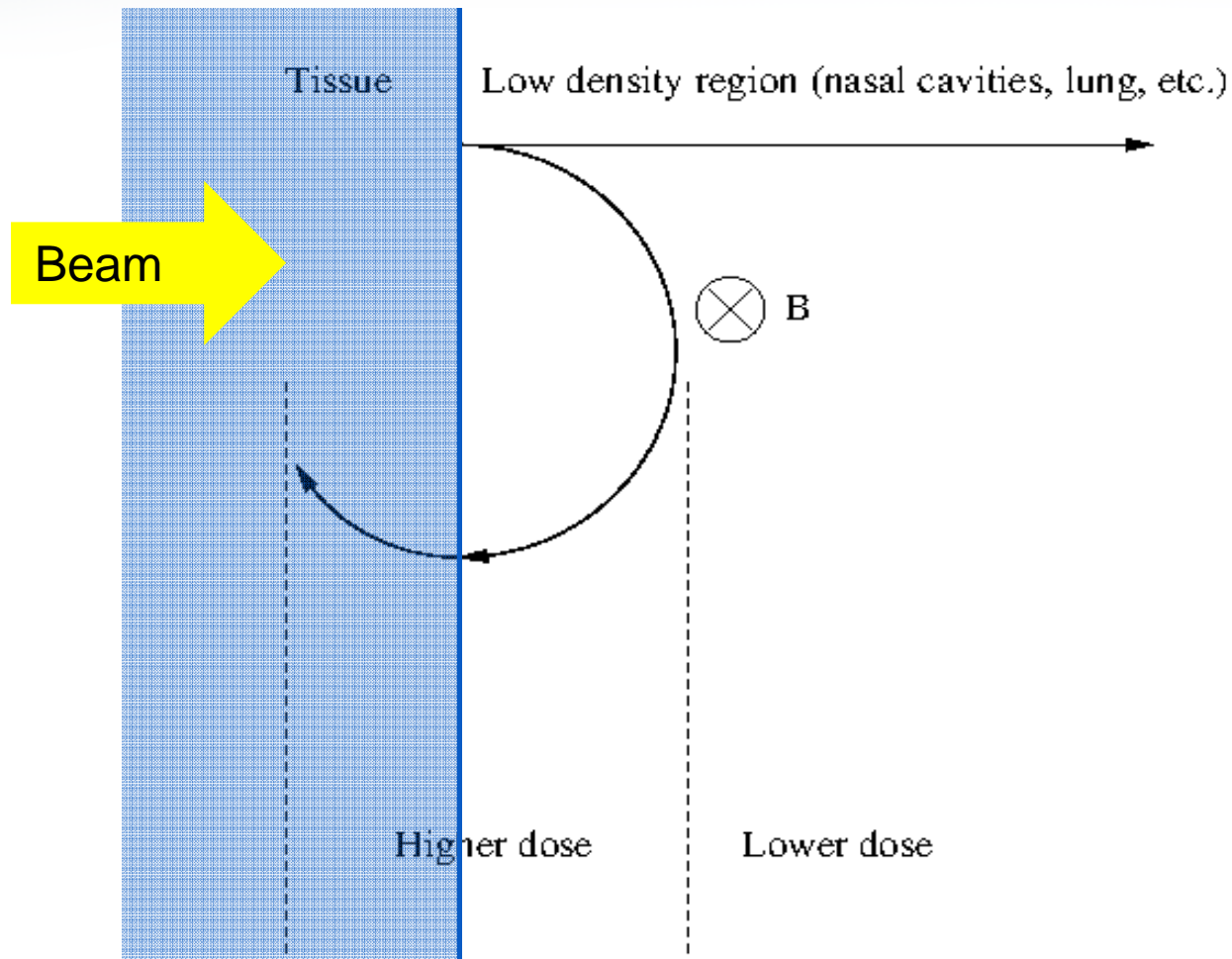
Physik

- Ablenkung der Sekundärelektronen im Magnetfeld



Raijmakers A, Raaymakers, B., Lagendijk, J, PMB 53, 909, 2008

Physik

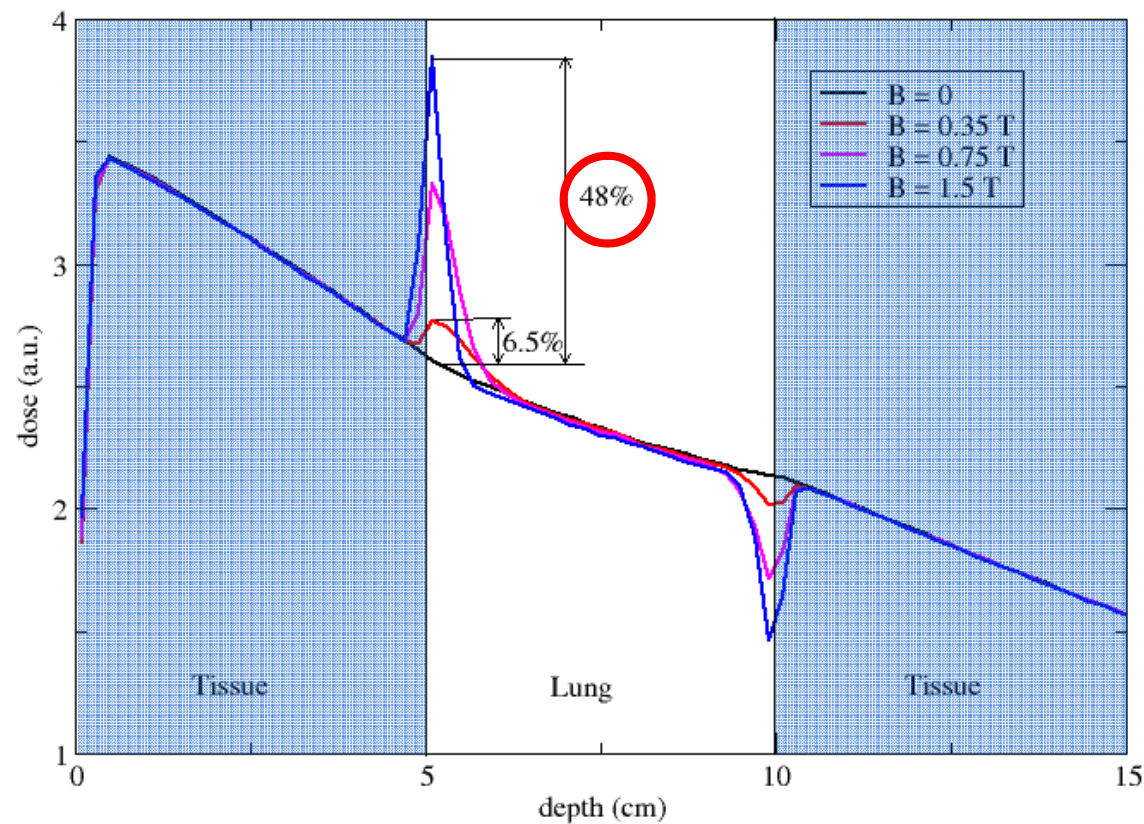


- Lorentz-Kraft
- **Electron-Return-Effect**

Einfaches Feld

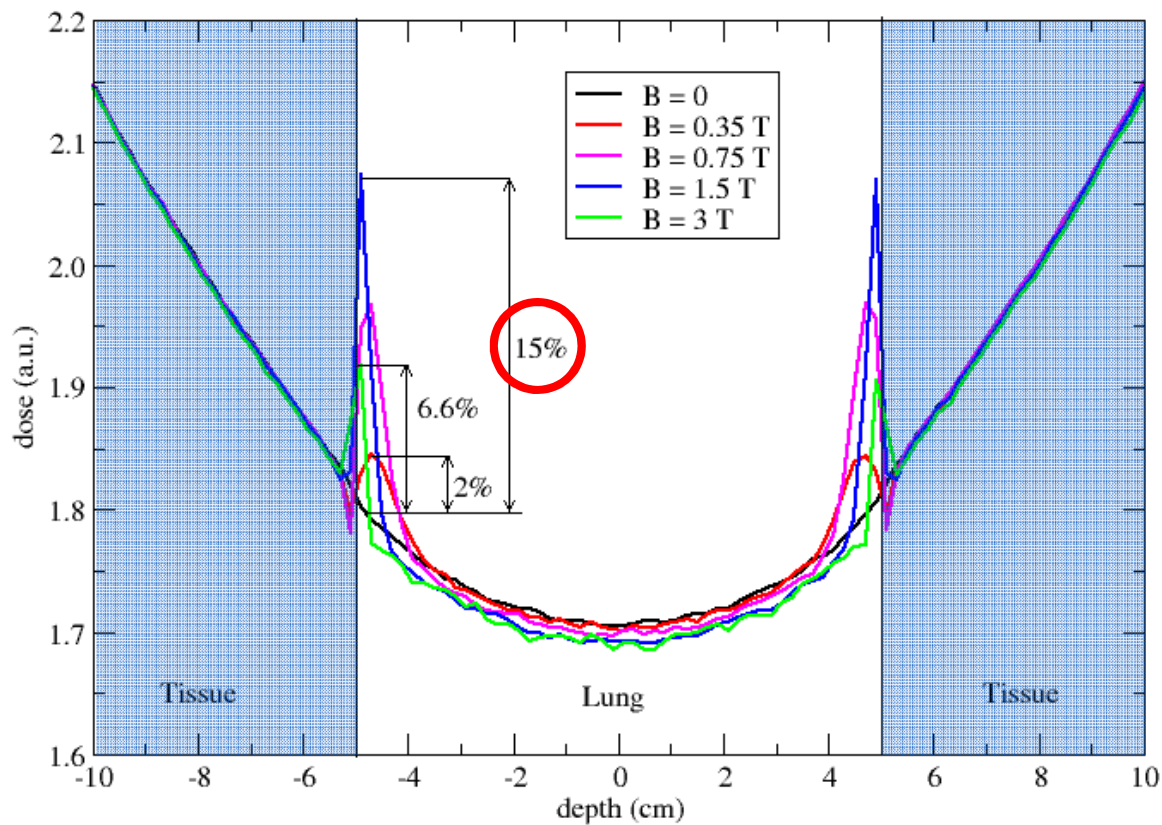
- Dosisüberhöhung an den Grenzflächen bei unterschiedlichen Gewebedichten in Abhängigkeit der Feldstärke des MR

Monte-Carlo-Berechnungen von Iwan Kawrakow, ViewRay Inc.



Opponierende Felder

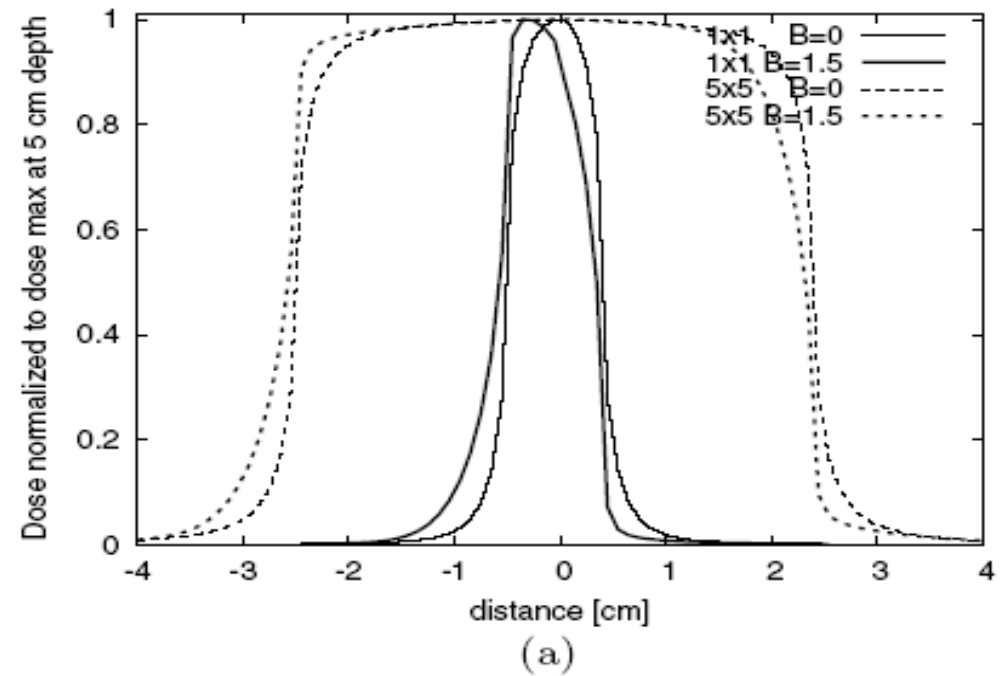
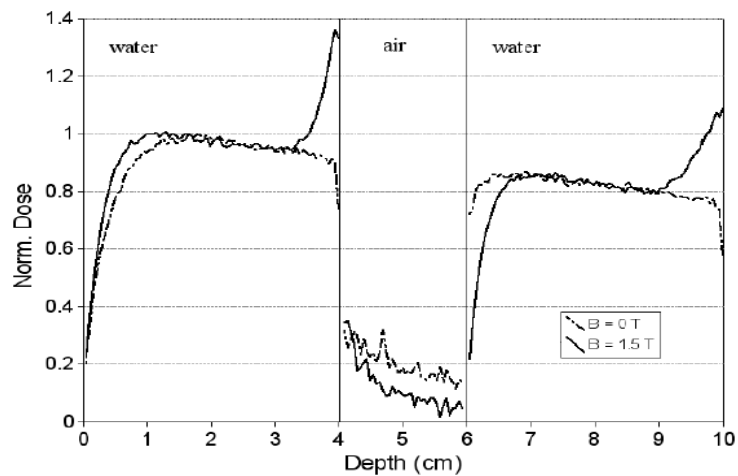
- Dosisüberhöhung an den Grenzflächen bei unterschiedlichen Gewebedichten in Abhängigkeit der Feldstärke des MR
- Kompensation bei Mehrfeld-techniken?



Monte-Carlo-Berechnungen von Iwan Kawrakow, ViewRay Inc.

Physik

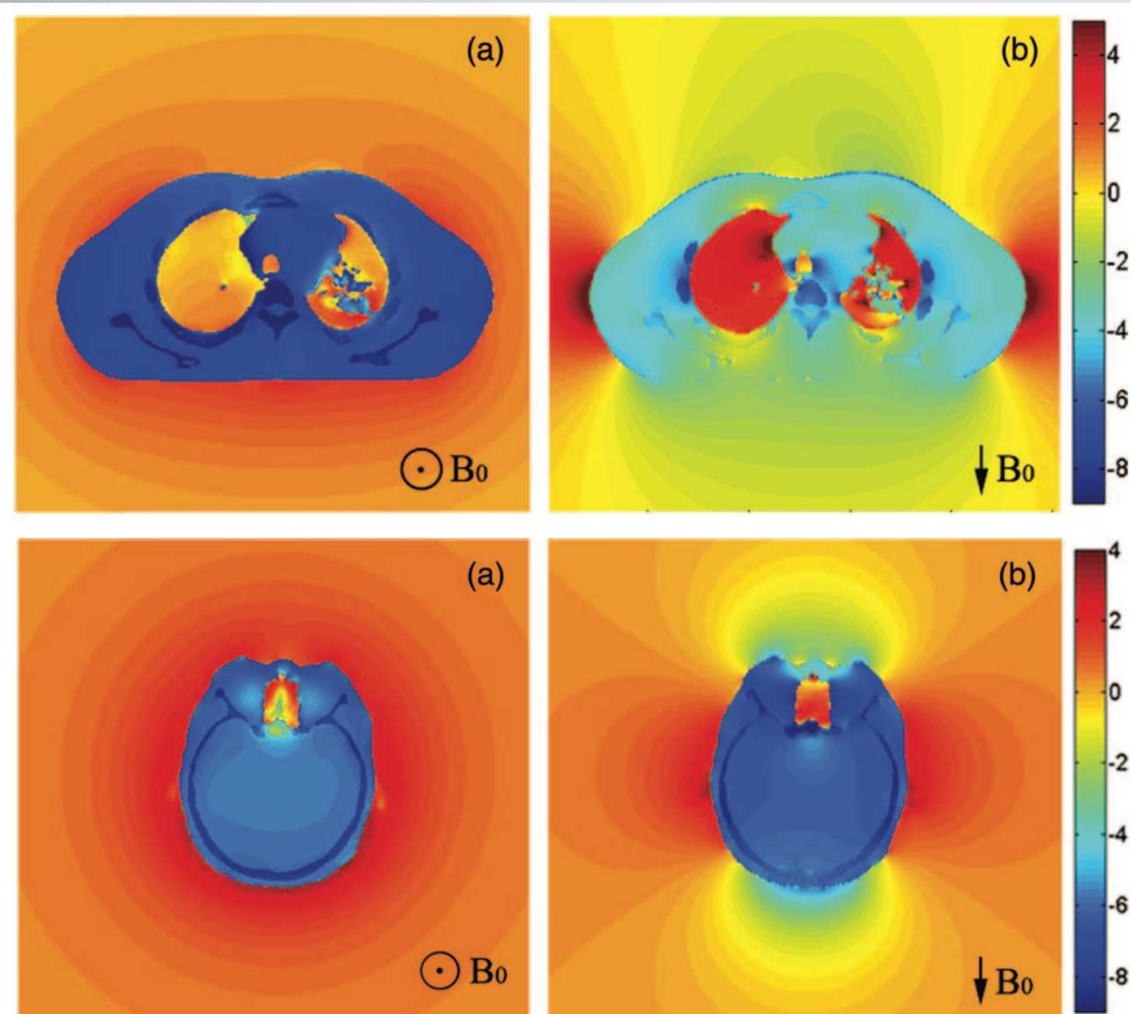
- Verzerrung der Penumbra bei 1,5 T



Raaysmaker et al. Phys. Med. Biol. **49**
(2004) 4109–4118

Raaijmakers et al. Phys. Med. Biol. **50**
(2005) 1363–1376

Physik



$B_0 = 3\text{T}$, $G_E = 5\text{ mT/m}$

Range of distortions: 5,7-12,0 mm

$B_0 = 0,5\text{T}$, $G_E = 5\text{ mT/m}$

Range of distortions: 0,3-1,0 mm

Stanescu, Wachowicz, & Jaffray
Med. Phys. 39 (12), December 2012 pp7185-7193

ViewRay MRIdian

$B_0 = 0,35\text{T}$, $G_E = 15\text{ mT/m}$

Range of distortions: 0,087-0,29 mm

Physik

Aufheizung des Patienten

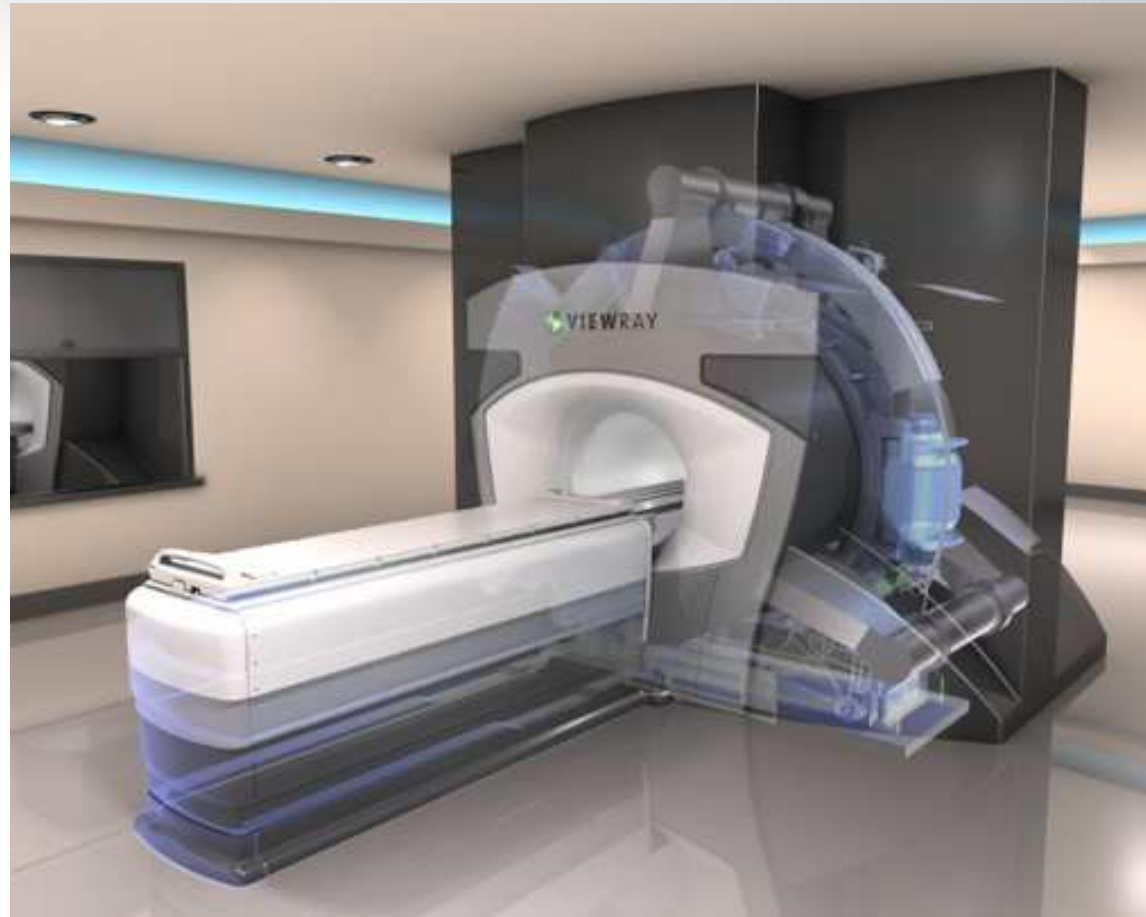
Larmorfrequenz: **63** MHz bei 1,5 T

Dauerbildunggebung fraglich?

Design

Konzeption

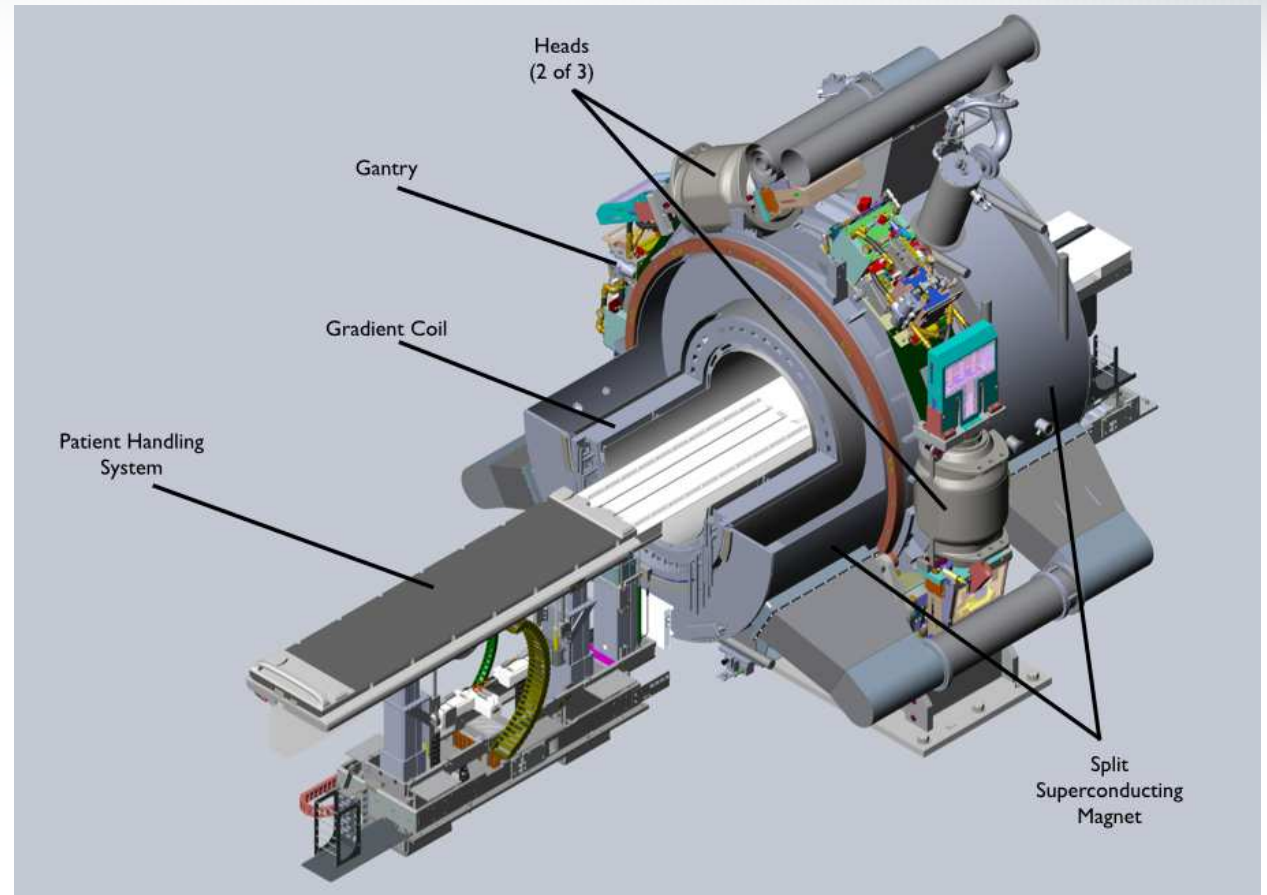
- Low Field MR und ^{60}Co
- MR-Magnet Neuentwicklung mit Siemens-Elektronik
- Monte-Carlo-Rechenalgorithmus
Iwan Kawrakow
- Adaptive Bestrahlung
“On table”



Design

Realisation

- Keine Elektronenkontamination
- Geringe Bildverzeichnung
AAPM TG 142:
SRS/SBRT < 1 mm 20 cm Radius
IMRT < 2 mm 35 cm Radius
- Schnelle und kontinuierliche
Bildgebung
Relaxationszeiten $f(B_0)$
- Geringe Dosisaberration im
Gewebe



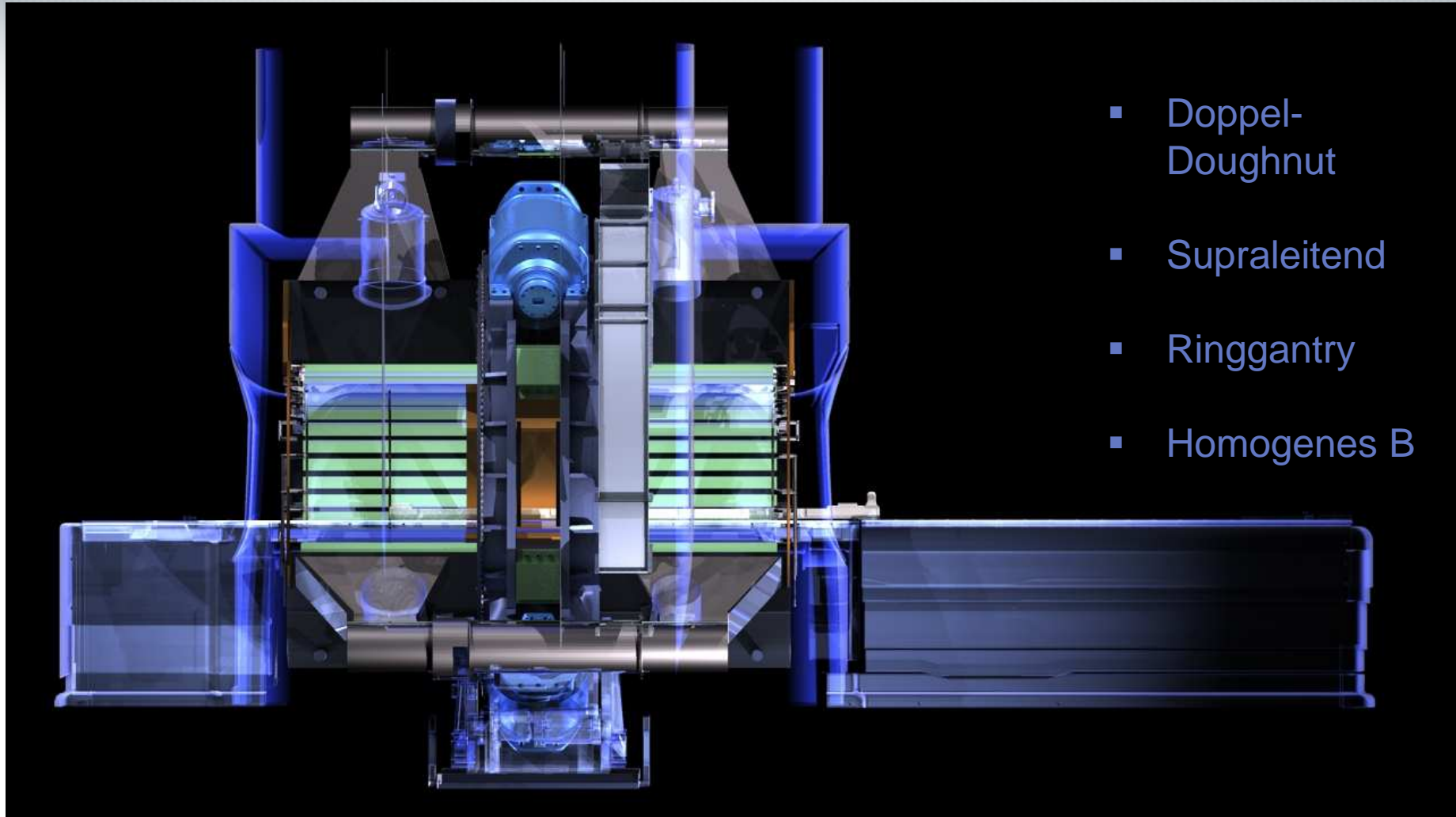
Design

MR verbessert Kobalt-Quelle

Electrons are
shown in
blue/white
Photons are
shown in pink

Elimination von kontaminierenden
Elektronen im Strahlerkopf

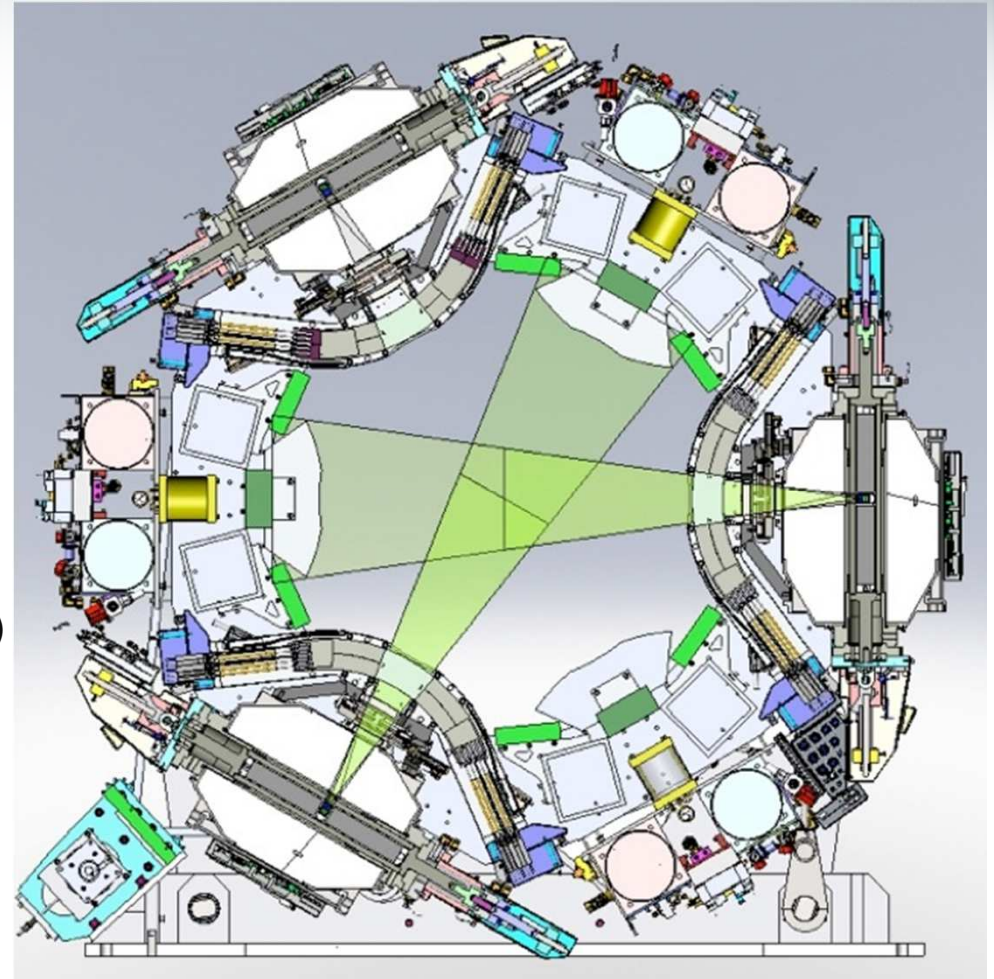
Design



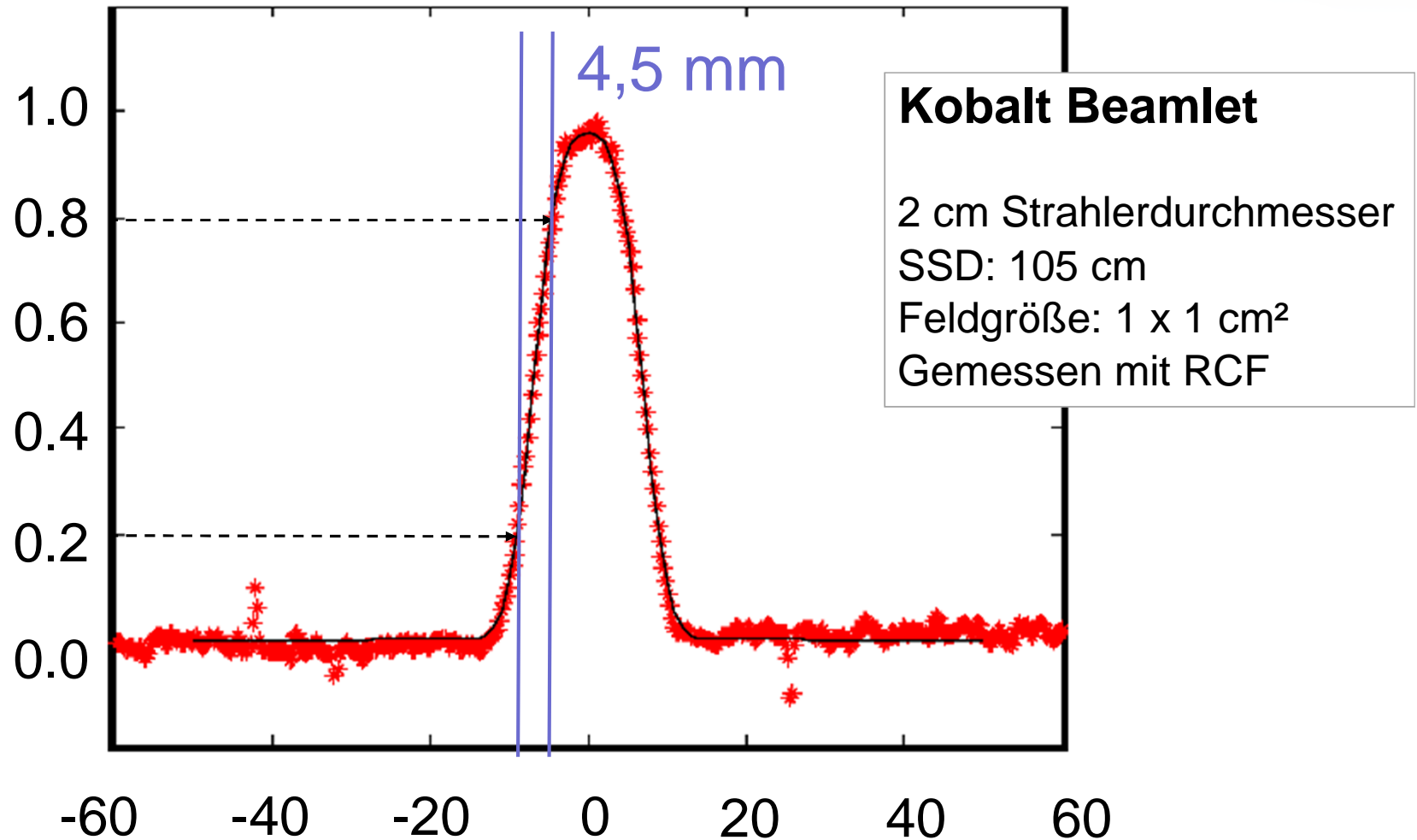
- Doppel-Doughnut
- Supraleitend
- Ringgantry
- Homogenes B

Technische Daten

- MR Feldstärke: 0,35 T
 - MR Bilddurchmesser: 50 cm
 - Bildfrequenz: 4 Schichten/s eine Ebene,
2 Schichten/s drei Ebenen
 - Integriertes System mit automatischer
Konturierung, Bestrahlungsplanung und
adaptiver Planung
 - Drei ^{60}Co -Quellen 15.000 Ci, jeweils um 120°
versetzt auf rotierender Ring-Gantry
 - Initiale Dosisleistung 550 cGy / min
 - Drei MLC (60 Lamellen, 1cm Breite im Isozentrum)
 - Maximale Feldgröße: 27 cm x 27 cm
 - Quellen-Isozentrum-Abstand: 105 cm
 - Gantry-Öffnung: 70 cm
 - Keine MR-Teile (Kryostat) im Strahlengang
-
- FDA 510k
 - CE November 2014



Design



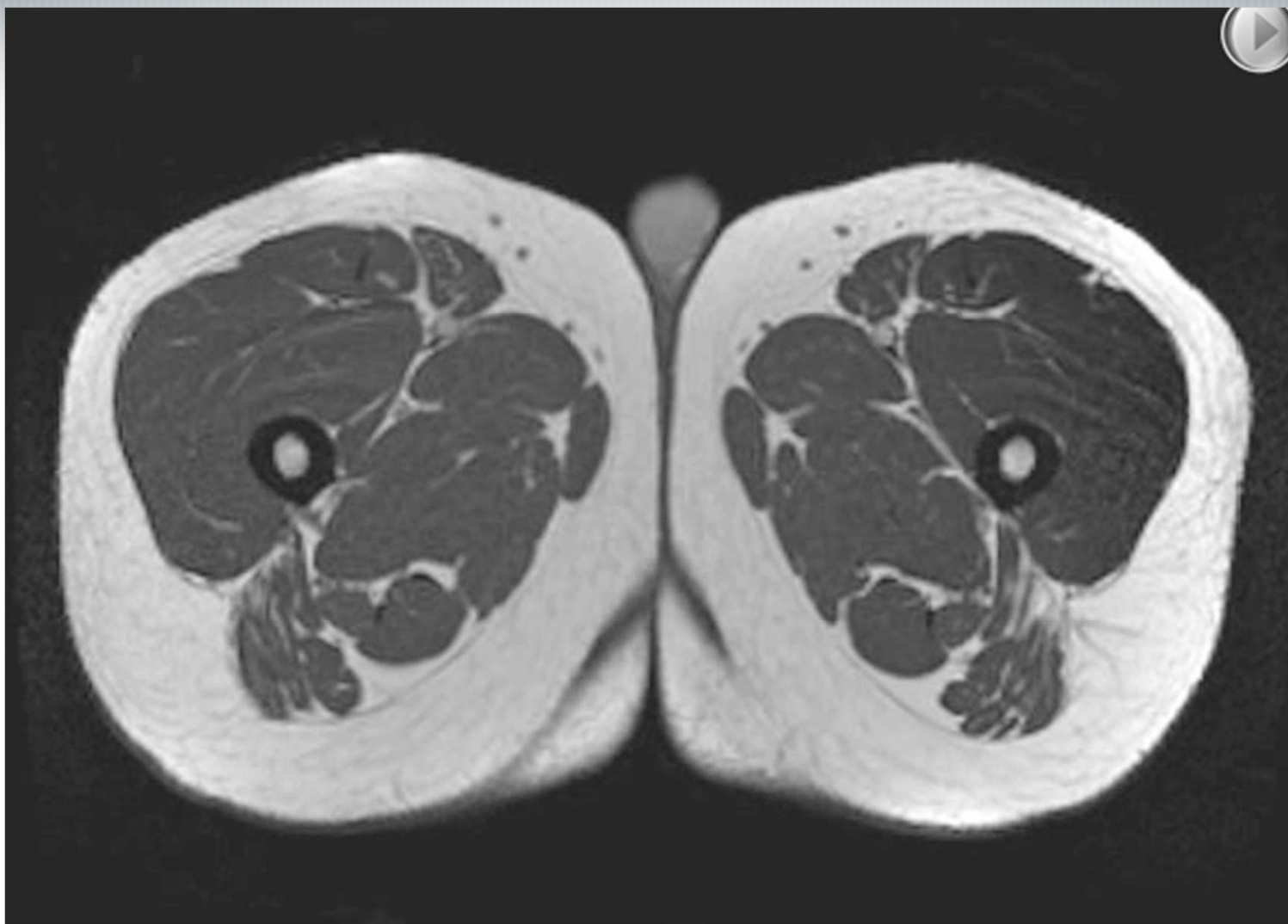
- 
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Täglicher Arbeitsablauf



RealView	Setup Image	15-90 sec MRI Scan zur Lokalisation und Positionierung
RealPlan	Auto-contour	Automatische Übertragung von Strukturen auf Anatomie
RealPlan	Dose Predict	Prädiktion von Dosis und DVH
RealPlan	Re-optimize	Adaption des Plans (Monte Carlo)
RealTarget	Gating Setup	Verifikation der Tracking-Grenzen
RealRX	Treatment	Track and Treat SBRT, IMRT or 2D/3D
RealReview	MD Review	Workstation und Werkzeuge

RealView Pilot-Scan



The screenshot displays the RealPlan software interface, which is used for medical image fusion and registration. The interface is divided into several main sections:

- Top Toolbar:** Contains icons for Patient & Plan, Images, Contour, Fusion (highlighted), Points, Beams, Dose, IMRT, Finish, Save, and Done.
- Display Panel (Left):**
 - Image View:** Includes a dropdown menu for 'Fusion Image View' and a 'Glow' slider.
 - Window/Level:** Sliders for 'Window' (set to 400) and 'Level' (set to 40), with an 'Auto' button.
 - Presets:** A dropdown menu for image presets.
 - Colormap Overlay:** A slider between 'Fused' and 'Primary'.
 - Moving Window Overlay:** A slider for the moving window overlay.
 - Structures:** A checkbox to toggle structure visibility.
 - Points of Interest:** A checkbox to toggle point of interest visibility.
- Main Viewport (Center):** Shows a 2D axial CT scan (Image 113) and a 3D volume rendering of the same scan. The 3D view shows a red contour on the skin and a green contour on the internal organs. The 2D view shows the same contours overlaid on the CT slice. The interface includes a 3D coordinate system with 'I' (Inferior), 'R' (Right), and 'A' (Anterior) markers.
- Perform Registration Panel (Right):**
 - Register Images:** A button to initiate the registration process.
 - Copy Deformation / Paste Deformation:** Buttons for copying and pasting deformation maps.
 - Lock / Unlock:** Buttons to lock or unlock the registration.
 - Reset / Apply:** Buttons to reset or apply the registration.
- Registration Parameters Panel (Bottom Right):**
 - Image Registration Types:**
 - Allow Rigid Registration
 - Allow Deformable Registration
 - Image Masks:**
 - Use Skin as Primary Mask
 - Use Secondary Mask
 - Rigid Registration Values:**
 - Translate Lateral: 13.628 cm
 - Translate Vertical: -4.651 cm
 - Translate Axial: -8.193 cm
 - Start Over:** A button to restart the registration process.
- Patient Information Panel (Far Right):**
 - Subject:** Subjects, WashU
 - Subject ID:** Subjects/WashU/1
 - MRN:** [Empty]
 - DOB:** 01/01/1970
 - Diagnosis:** Quick Diagnosis
 - Site:** Other
 - Quick Prescription:** [Empty]
 - Subject ID:** Subjects/WashU/1
 - Position:** RFS

RealPlan IMRT Dosisoptimierung

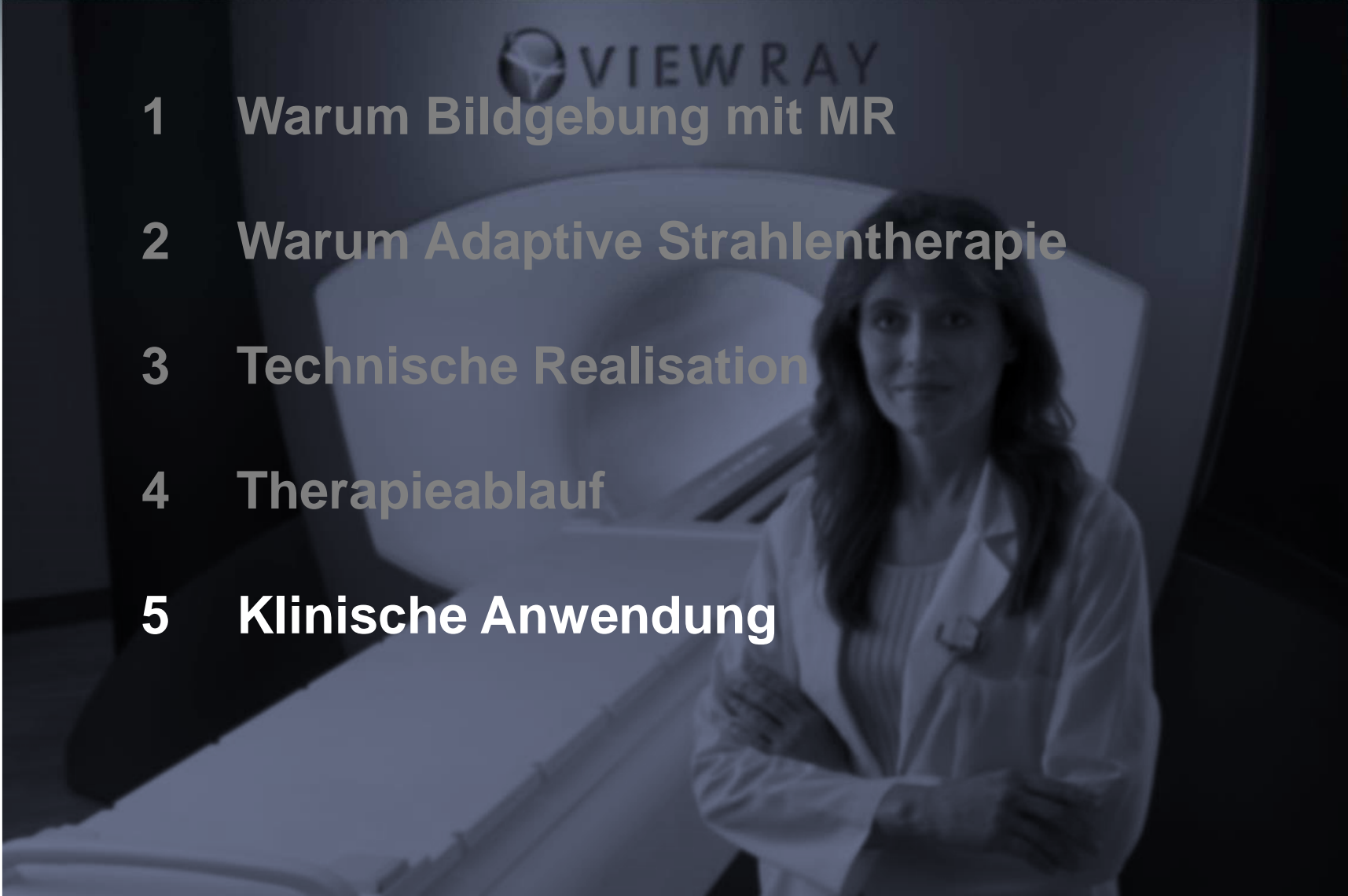
9 Beam IMRT Monte-Carlo in 28 s

Optimized Beams | Fixed Beams | Estimated Treatment Beam-On-Time: 0.00 minutes per fraction

Structure Name	Exclude	Volume	Target	Critical	Importance	Power	Save Template	Load Template	Reset
Skin	<input type="checkbox"/>	24373.6	<input type="radio"/>	<input type="radio"/>	Lower: <input type="text"/> Upper: 70	Lower: <input type="text"/> Upper: 2	Threshold: 35 Gy		
Bladder	<input type="checkbox"/>	106.2	<input type="radio"/>	<input type="radio"/>	Lower: <input type="text"/> Upper: 1.5	Lower: <input type="text"/> Upper: 2	Threshold: 30 Gy		
Prostate	<input type="checkbox"/>	19.3	<input type="radio"/>	<input type="radio"/>					
Rectum	<input type="checkbox"/>	54.7	<input type="radio"/>	<input type="radio"/>	Lower: <input type="text"/> Upper: 2	Lower: <input type="text"/> Upper: 2	Threshold: 30 Gy		
Femur, Right	<input type="checkbox"/>	149.2	<input type="radio"/>	<input type="radio"/>					
Femur, Left	<input type="checkbox"/>	150.3	<input type="radio"/>	<input type="radio"/>					
Bowel	<input type="checkbox"/>	30.7	<input type="radio"/>	<input type="radio"/>	Lower: <input type="text"/> Upper: 1.5	Lower: <input type="text"/> Upper: 2	Threshold: 30 Gy		

RealTarget Automatische Gewebelokalisation



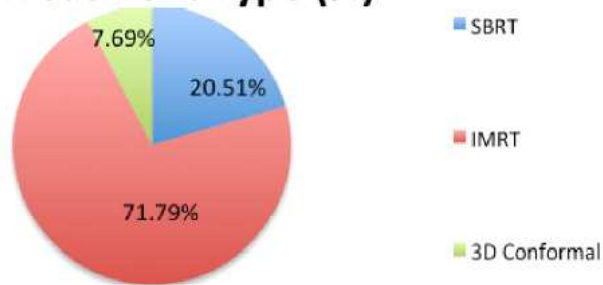
- 
- 1 Warum Bildgebung mit MR
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Klinische Anwendung

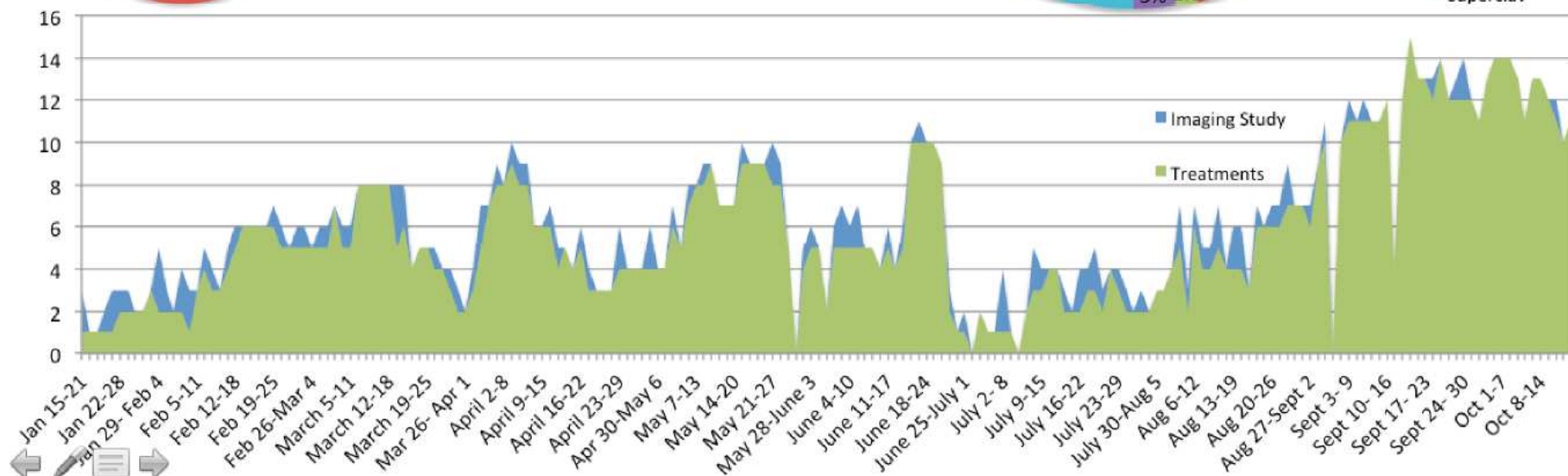
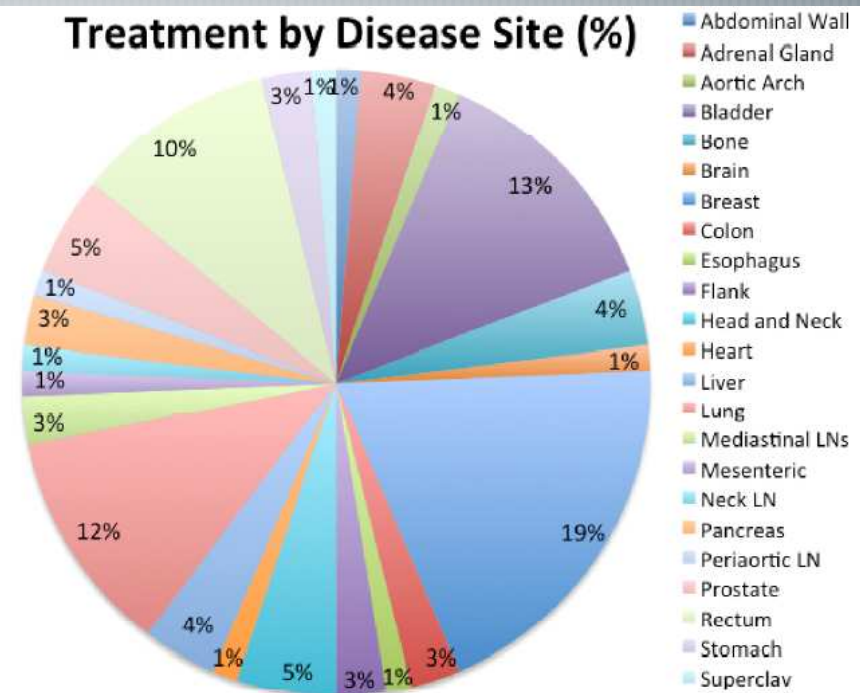
Washington University Clinical Dashboard

Courtesy of J. Olsen, Washington University

Treatment Type (%)



Treatment by Disease Site (%)



Klinische Beispiele

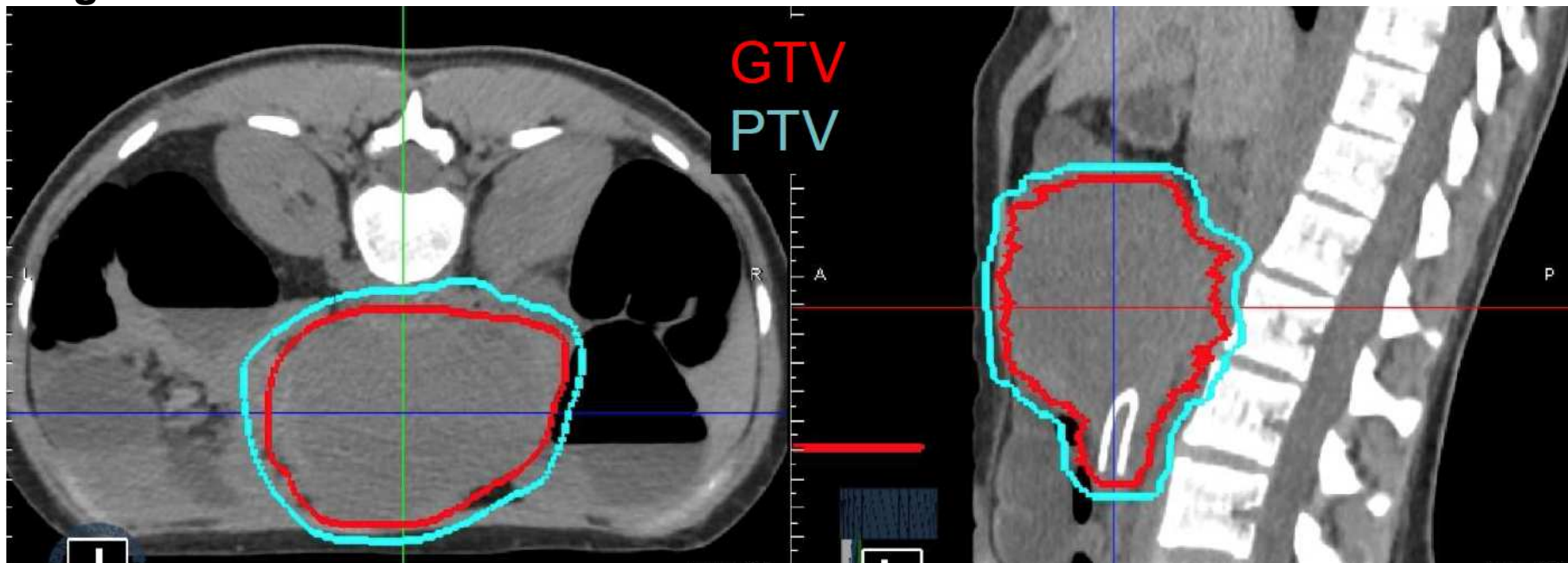
Unresectable Desmoid

29 y F with Gardner's sx and progression of unresectable abdominal desmoid tumor

Following tamoxifen, imatinib, sorafenib

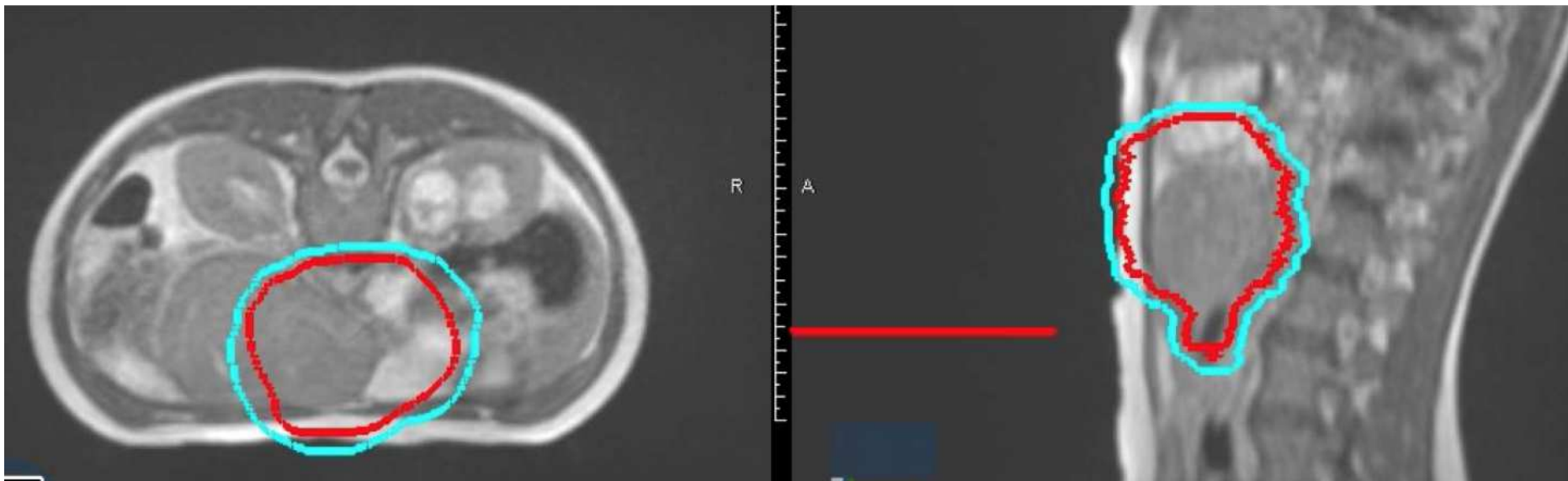
Definitive RT (54 Gy / 30 fx)

Target definition



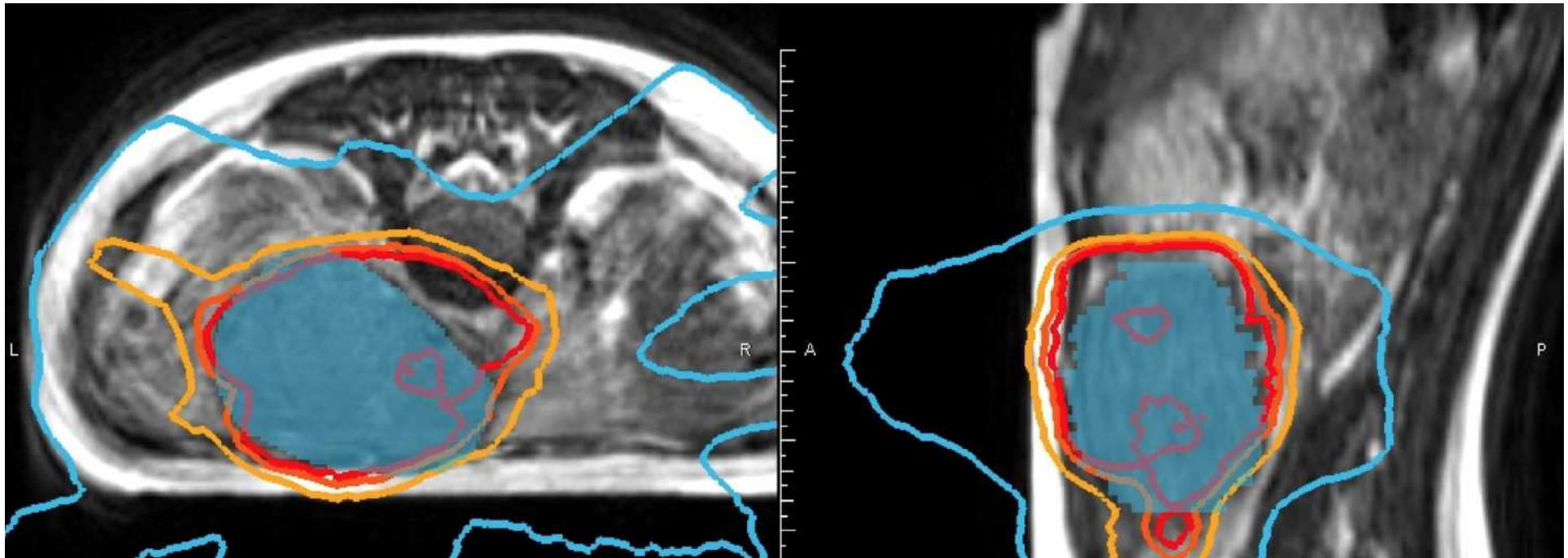
Klinische Beispiele

First application - target propagated



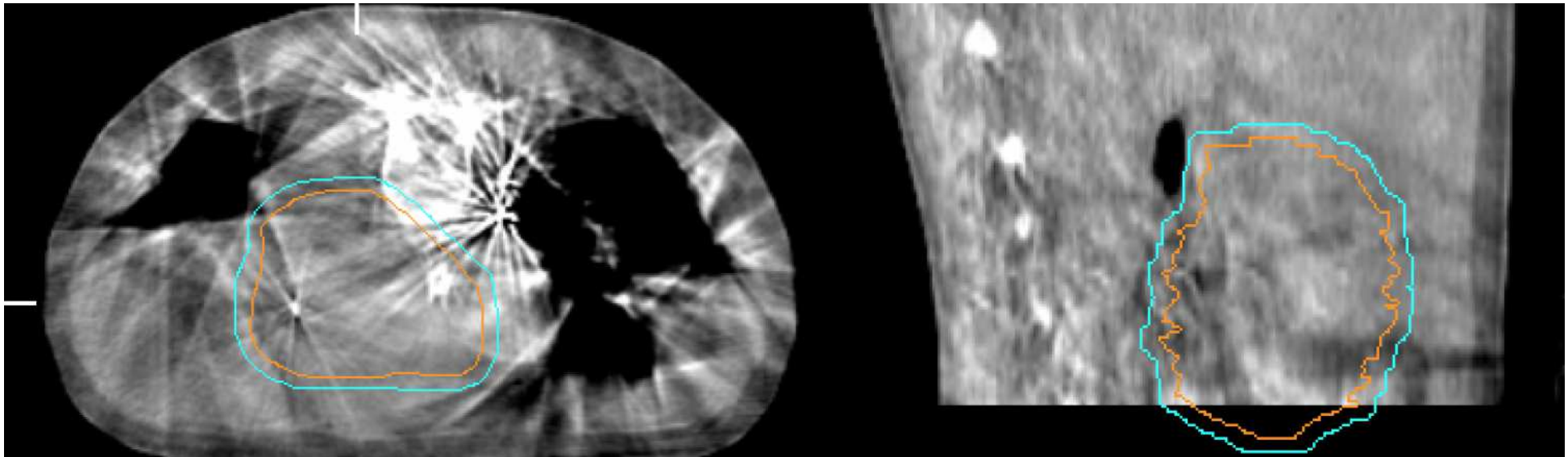
Klinische Beispiele

Reoptimization



Klinische Beispiele

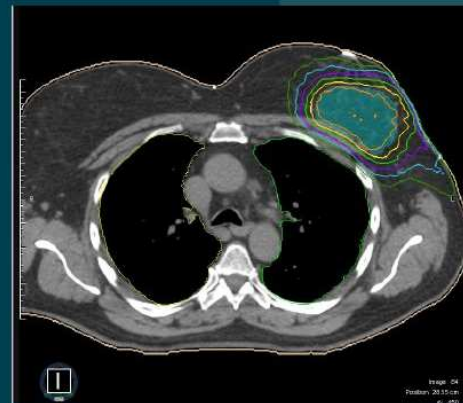
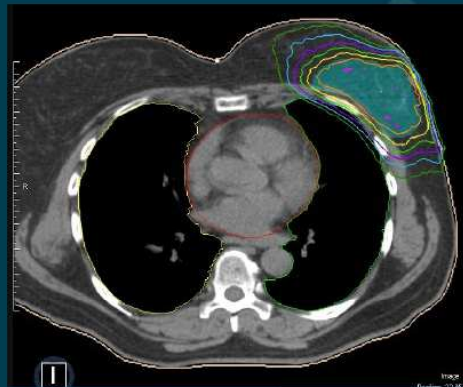
Comparison



APBI Left Breast

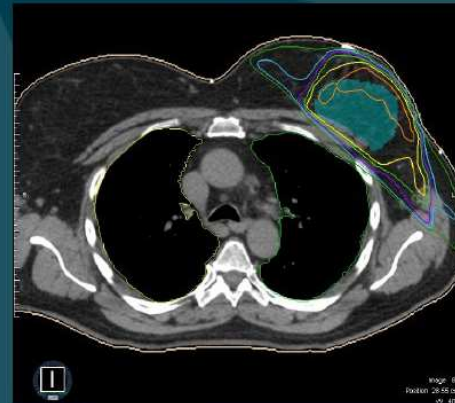
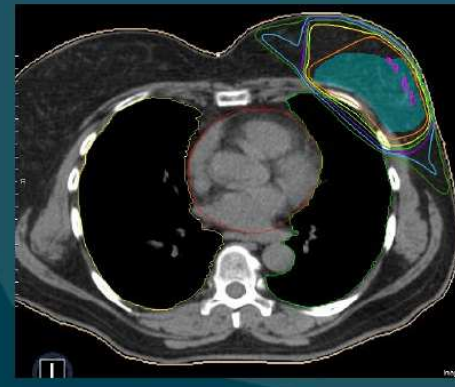
- T1bN0 Grade 1 adenocarcinoma
- History of stage IV adenosarcoma of the uterus
- 38.5Gy in 10 fractions, 3.85Gy/Fx, over 2 weeks
- Treated with Linac based 3DCRT created with Pinnacle

ViewRay



41.20 Gy	107.0 %
38.50 Gy	100.0 %
34.65 Gy	90.0 %
30.80 Gy	80.0 %
26.95 Gy	70.0 %
23.10 Gy	60.0 %
19.25 Gy	50.0 %

Linac



APBI Left Breast

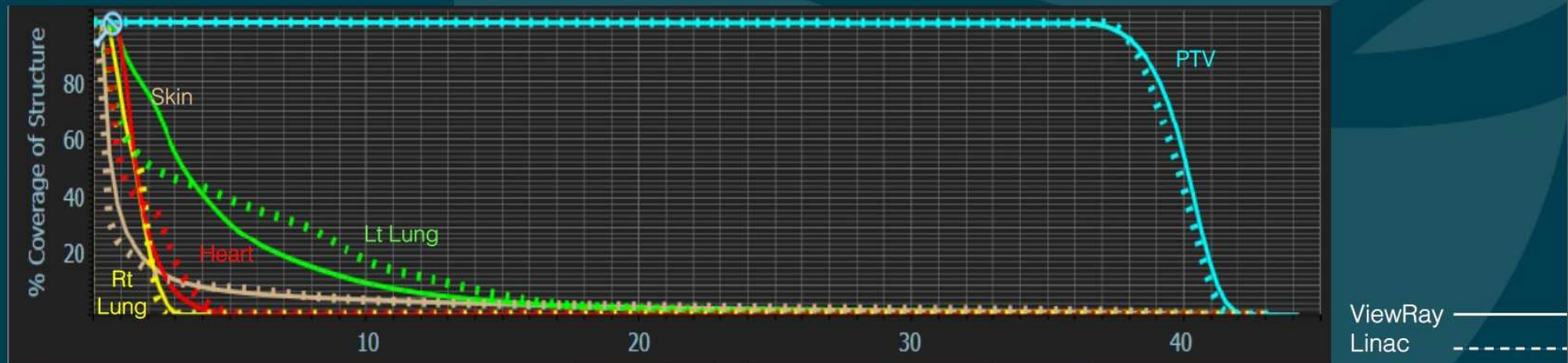
- T1bN0 Grade 1 adenocarcinoma
- History of stage IV adenosarcoma of the uterus
- 38.5Gy in 10 fractions, 3.85Gy/Fx, over 2 weeks
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Comparison

Summary:

- ViewRay delivers a highly conformal dose to the target with minimized dose to the healthy breast tissue and sensitive structures.
- Breast position and shape can differ daily and can be difficult to set up consistently, heart dose is a limiting factor in left breast treatments.
- Daily imaging during ViewRay treatment provides the clinician the confidence to know that the target is being treated as planned and the heart dose can be monitored and maintained

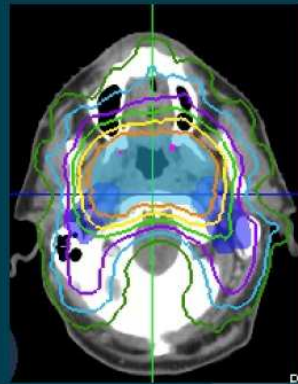
Structure	Prescription Goals	Linac Plan	ViewRay Plan <small>* Better than or equal to Linac plan or meets goals</small>
PTV 38.5Gy	>90% at 38.5Gy	85.0%	89.2% *
L Breast	<60% at 19.3Gy	56.0%	51.8% *
L Breast	<35% at 38.5Gy	22.4%	19.0% *
L lung	<15% at 11.6Gy	13.8%	8.0% *
R Lung	<15% at 1.93Gy	30.4%	27.5% *
Heart	<40% at 1.93Gy	37.2%	30.8% *



Head and Neck

- pT2N1aM0 squamous cell carcinoma of the left oral tongue
- Resection of primary tumor and left neck dissection
- 70Gy in 35 fractions to PTV70 & 56Gy in 35Gy to
- PTV56, 2Gy/Fx over 7 weeks

ViewRay



74.90Gy 107.0%

70.00Gy 100.0%

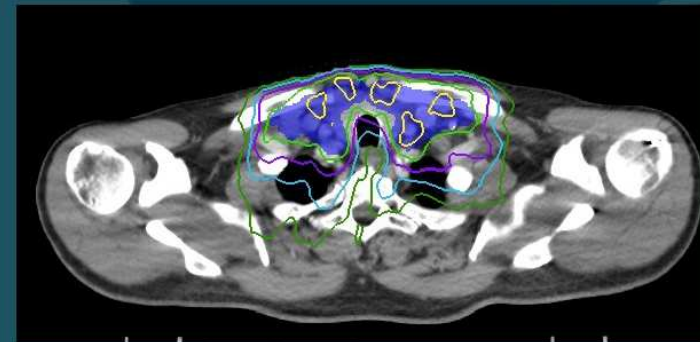
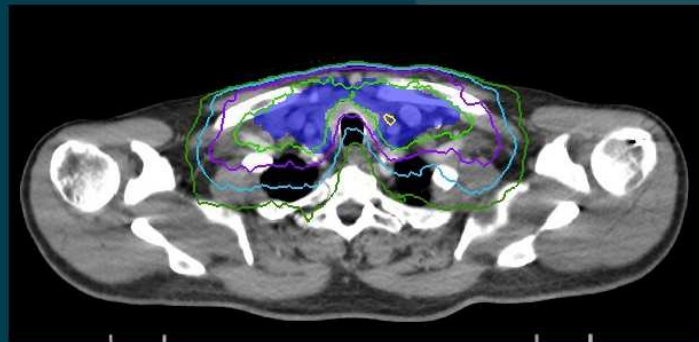
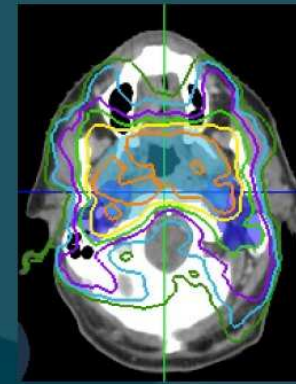
63.00Gy 90.0%

56.00Gy 80.0%

49.00Gy 70.0%

42.00Gy 60.0%

Linac



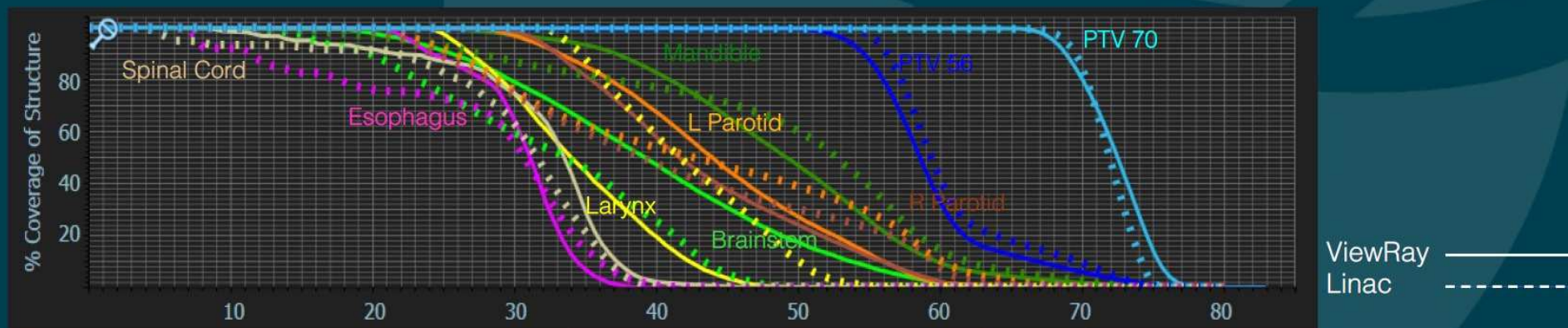
Head and Neck

- pT2N1aM0 squamous cell carcinoma of the left oral tongue
- Resection of primary tumor and left neck dissection
- 70Gy in 35 fractions to PTV70 & 56Gy in 35Gy to
- PTV56, 2Gy/Fx over 7 weeks

Comparison

Summary:

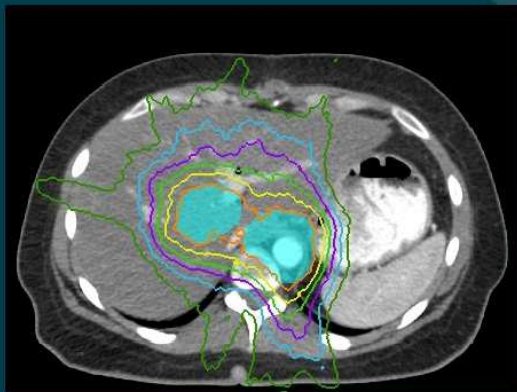
- Images of a moving tumor require high spatial fidelity
- Volumetric imaging shows exactly where the tumor is in space, relative to other structures
- Daily imaging during ViewRay treatment provides the clinician the confidence to know that the target is being treated as planned



Pancreas

- Poorly differentiated adenocarcinoma of the head of pancreas T3N1M0 with extra-pancreatic extension
- Adjuvant chemo/RT
- 50.4Gy in 28 fractions to PTV 50.4, 1.8Gy/Fx over 5 weeks

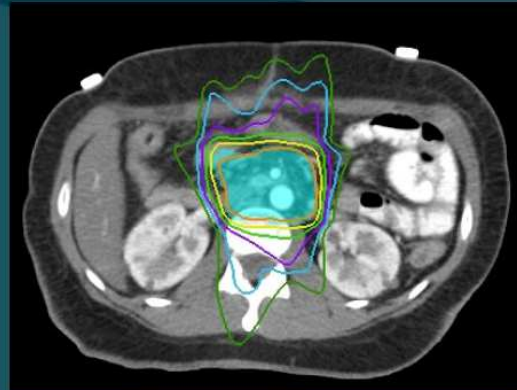
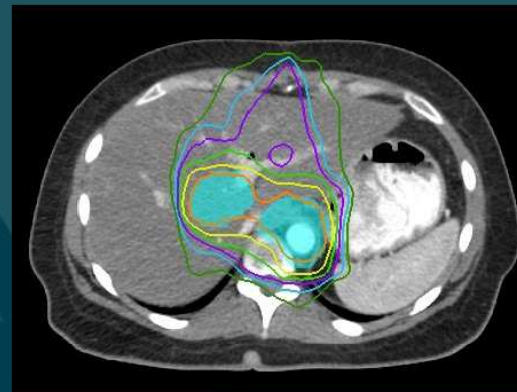
ViewRay



55.44 Gy	110.0%
50.40 Gy	100.0%
45.36 Gy	90.0%
40.32 Gy	80.0%
35.28 Gy	70.0%
30.24 Gy	60.0%
25.20 Gy	50.0%



Linac



Pancreas

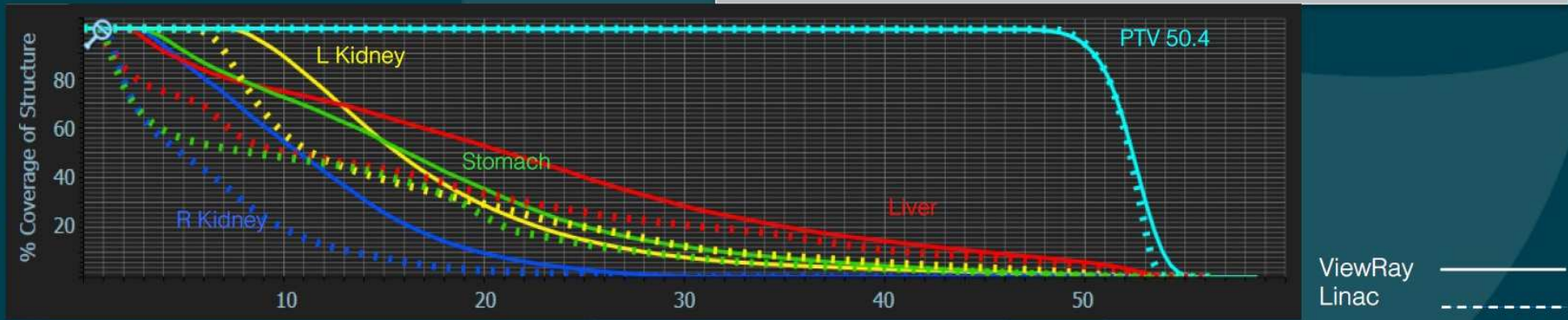
- Poorly differentiated adenocarcinoma of the head of pancreas T3N1M0 with extra-pancreatic extension
- Adjuvant chemo/RT
- 50.4Gy in 28 fractions to PTV 50.4, 1.8Gy/Fx over 5 weeks

Plan Results

Summary:

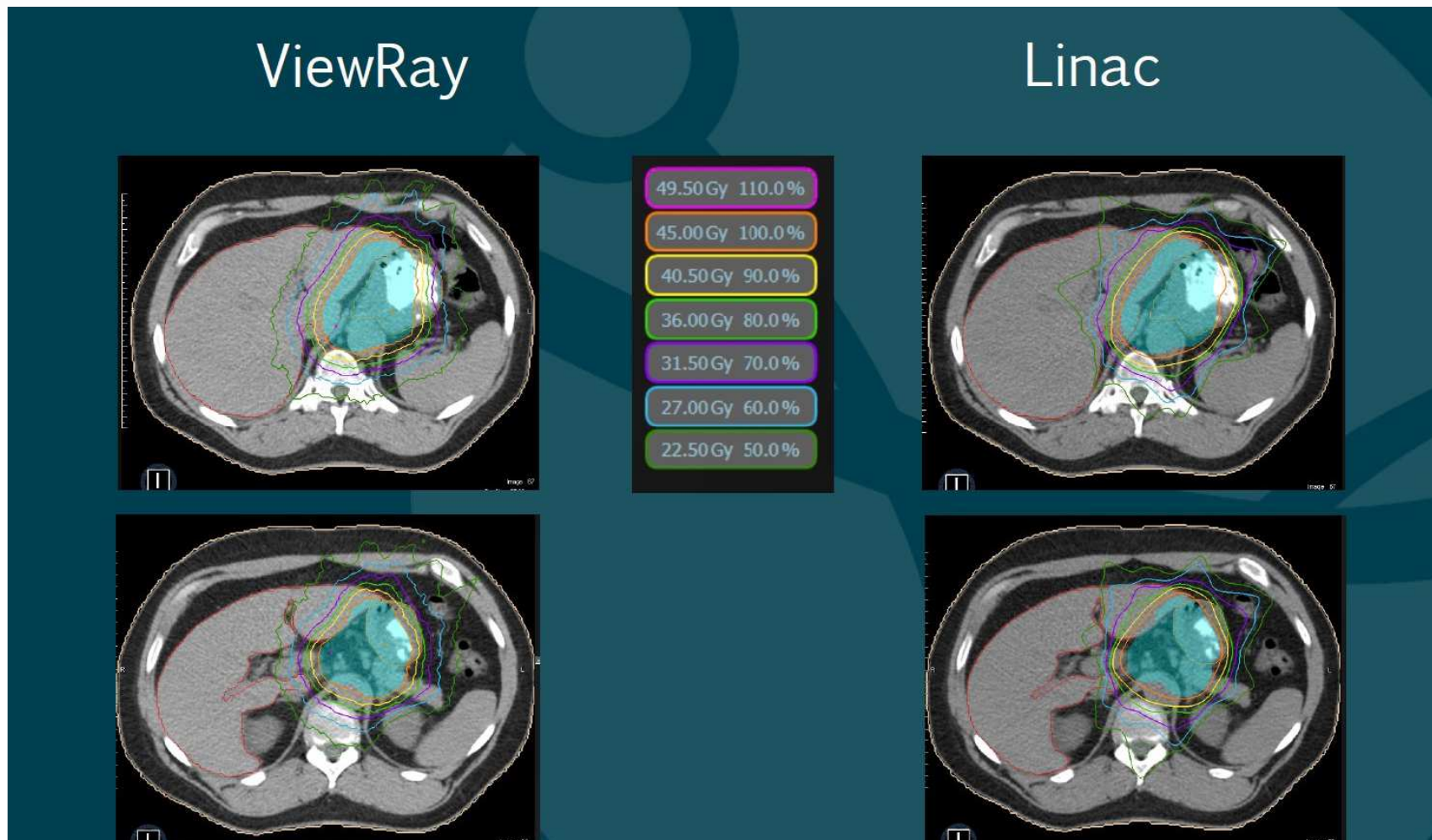
- The small bowel is clearly visible on MRI
- Re-optimize the plan daily to make sure the hotspot is not within the organs at risk due to their daily deformation
- Daily imaging during ViewRay treatment provides the clinician the confidence to know that the target is being treated as planned

Structure	Prescription Goals	Linac Plan	ViewRay Plan <small>* Better than or equal to Linac plan or meets goals</small>
PTV 50.4	>90% at 50.4Gy	90.5%	90.0%*
L Kidney	Mean <18Gy	16.1Gy	17.5Gy*
L Kidney	<50% at 18Gy	33.2%	37.4%*
R Kidney	Mean < 18Gy	6.0Gy	11.2Gy*
R Kidney	<50% at 18Gy	4.0%	14.5%*
Liver	Mean <25Gy	16.3Gy	22.1Gy*
Stomach	Max 54Gy	51.9Gy	54.0Gy*
Stomach	<15% at 45Gy	2.1%	2.5%*



Esophagus

- Adenocarcinoma of the distal esophagus T3N1M0
- Pre-operative Chemo/RT
- 45Gy in 25 fractions to PTV4500, 1.8Gy/Fx, over 5 weeks



Esophagus

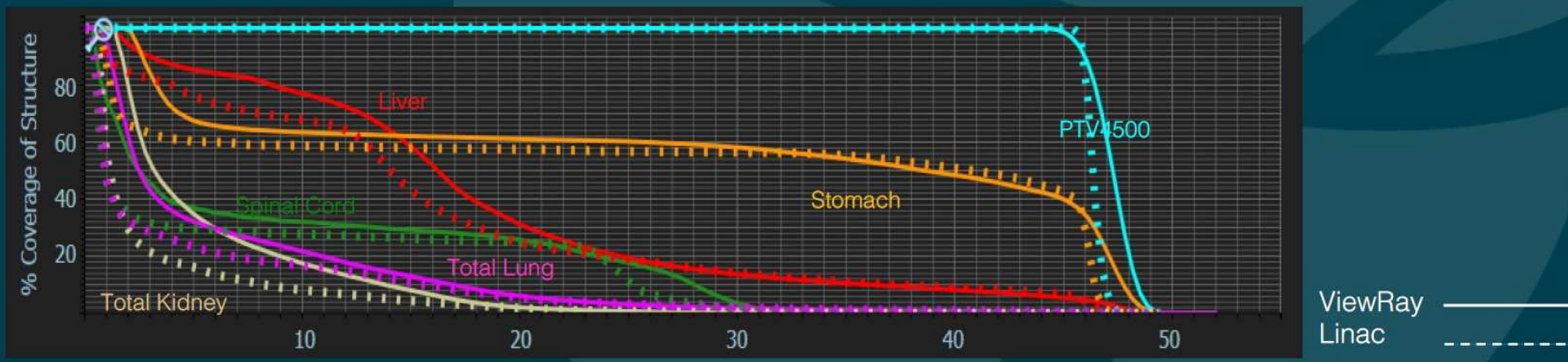
- Adenocarcinoma of the distal esophagus T3N1M0
- Pre-operative Chemo/RT
- 45Gy in 25 fractions to PTV4500, 1.8Gy/Fx, over 5 weeks

Comparison

Summary:

- ViewRay's MRI component features a custom designed split gradient coil with three-axis cooling and a split 0.35T magnet designed to enable continuous imaging
- With a radiation therapy gantry placed between a split magnet and gradient coil, MR imaging and treatment delivery can occur simultaneously, for true image guided radiation therapy
- Daily imaging during ViewRay treatment provides the clinician the confidence to know that the target is being treated as planned

Structure	Prescription Goals	Linac Plan	ViewRay Plan <small>* Better than or equal to Linac plan</small>
PTV 4500	>95% at 45Gy	100%	98.6%
Spinal Cord	Max 45Gy	33.3Gy	33.0Gy *
Liver	Mean < 30Gy	15.6Gy	17.6Gy
Total Lung	<65% at 5 Gy	23.4%	32.2%
Total Lung	<30% at 20Gy	5.5%	6.1%
Total Kidney	Mean < 20%	2.7%	5.3%
Stomach	Mean <30%	26.1%	28%



Zusammenfassung – Adaptive Radiotherapie

- **Tracking und Gating ohne Hilfsmittel**
- **Margins verkleinern**
- **Schonung von gesundem Gewebe**
- **Fehlbestrahlungen ausschließen**
- **Dosiseskalation**
- **Hypofraktionierung**
- **Stereotaxie**

Bestrahlungsbunker und RF-Abschirmung

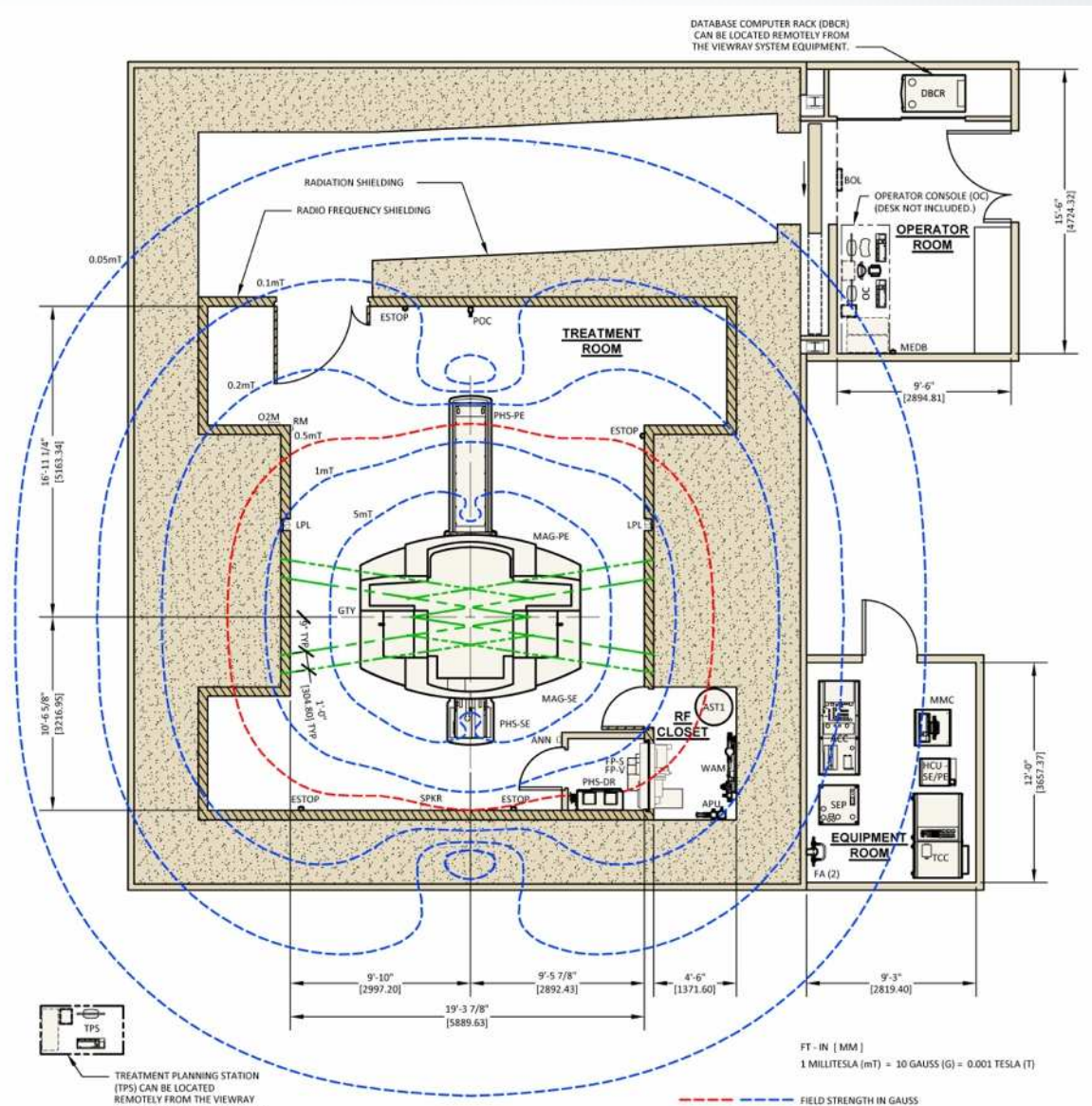
Raummaße (Angaben in Meter)

Empfohlene Bunkergröße
5,85 x 7,65

Minimale Raumhöhe:
2,90

Minimale Einbringöffnung
B 1,20 x H 2,11

RF-Technikbereich
1,10 x 1,25



Sehen Sie mehr.

