Real-Time Imaging and Tracking Techniques for Intrafractional Motion Management: MR Tracking

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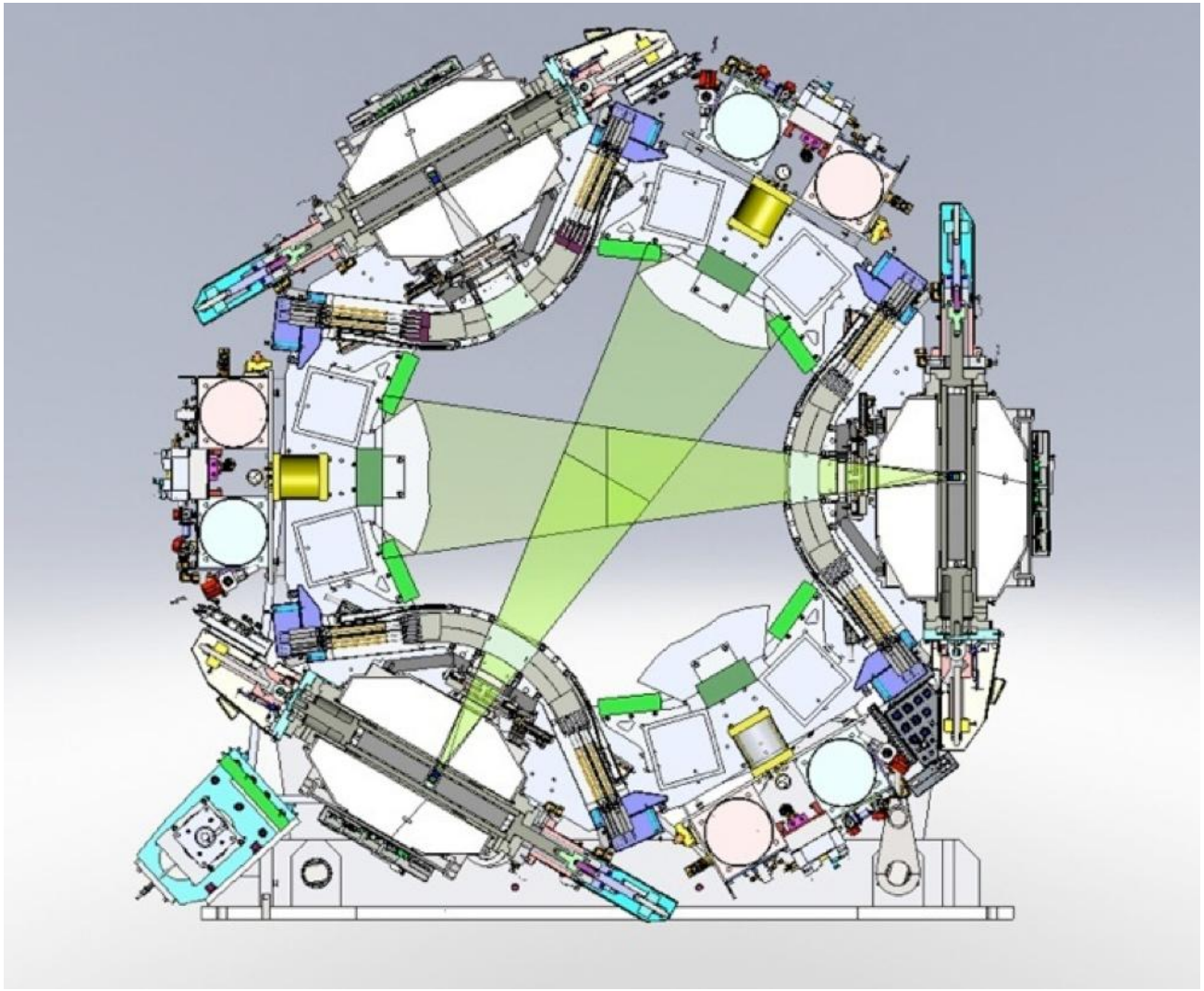
Outline

- Current MR+RT projects
- Methods for real-time imaging
- Process for object tracking
- Clinical examples
- Next steps

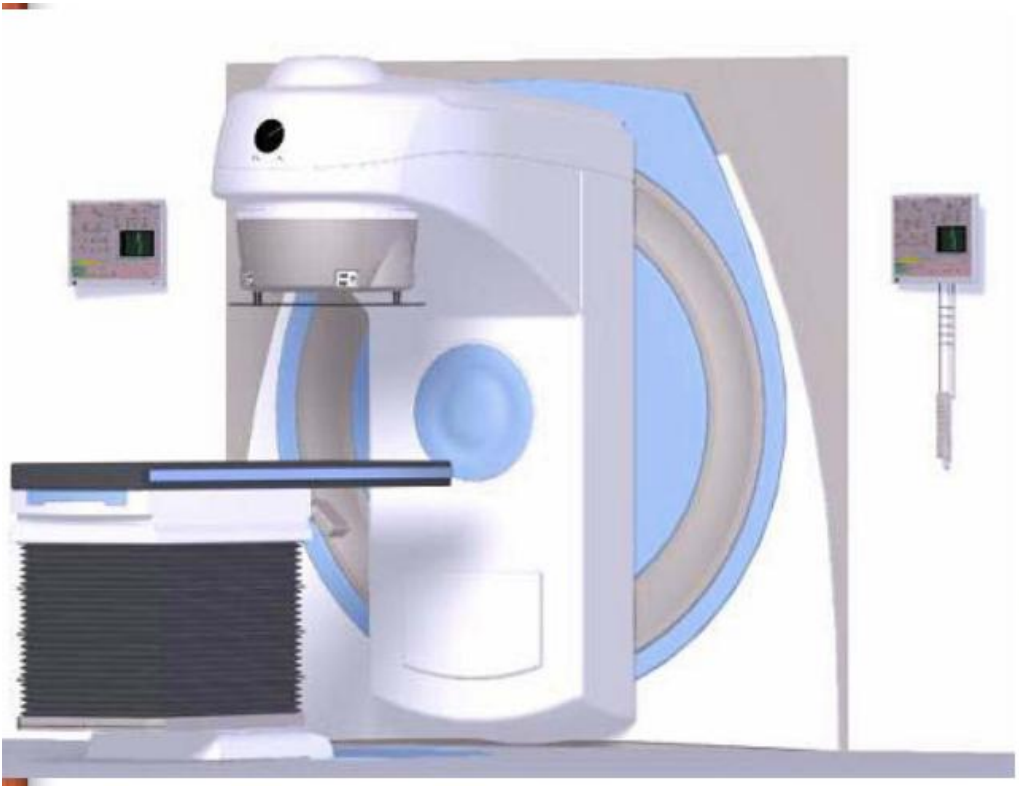
MR-IGRT (MRIdian by ViewRay)

- 0.35T MRI
- 3 Co-60 heads
  - ~550 cGy/min @ iso
- Each head is equipped with divergent MLCs
- Large imaging FOV (50 cm)
- Integrated planning system
  - Monte Carlo dose calculation

MR-IGRT (MRIdian by ViewRay)

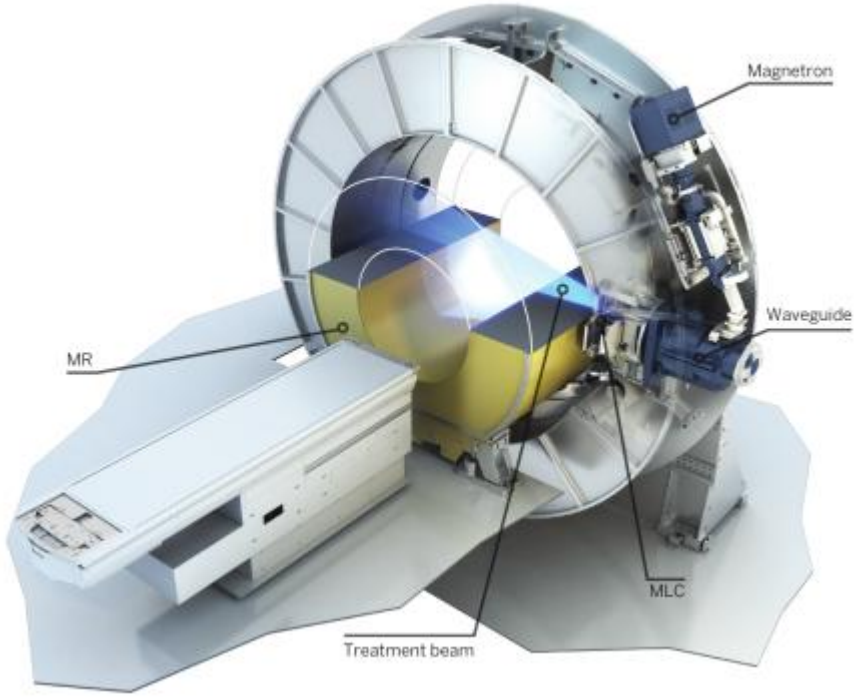


Elekta + Philips



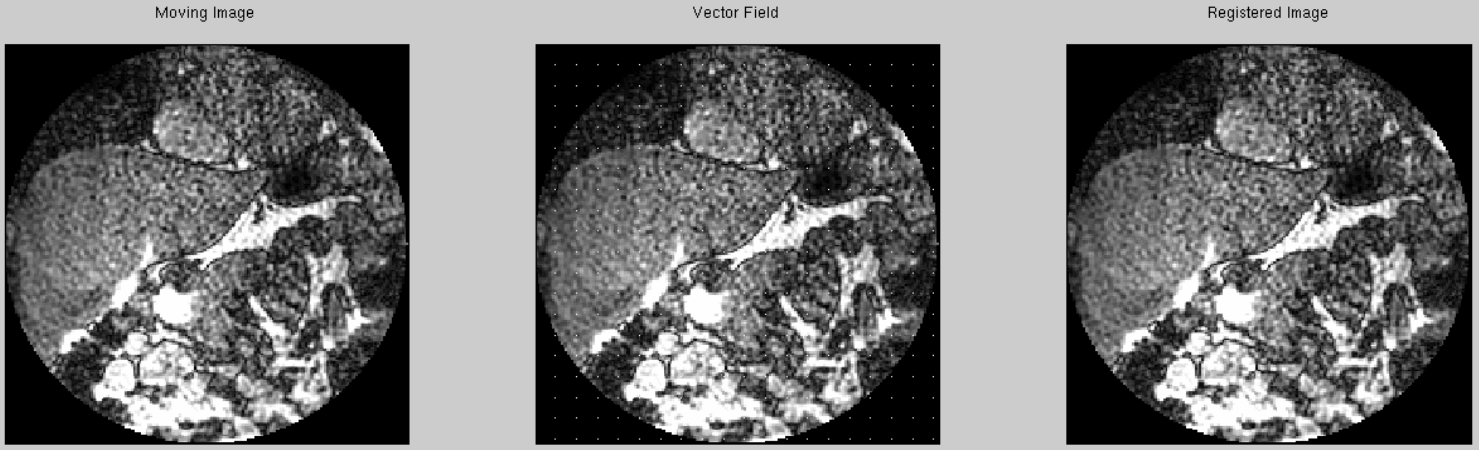
Upgrading the Prototype

Courtesy Raaymakers



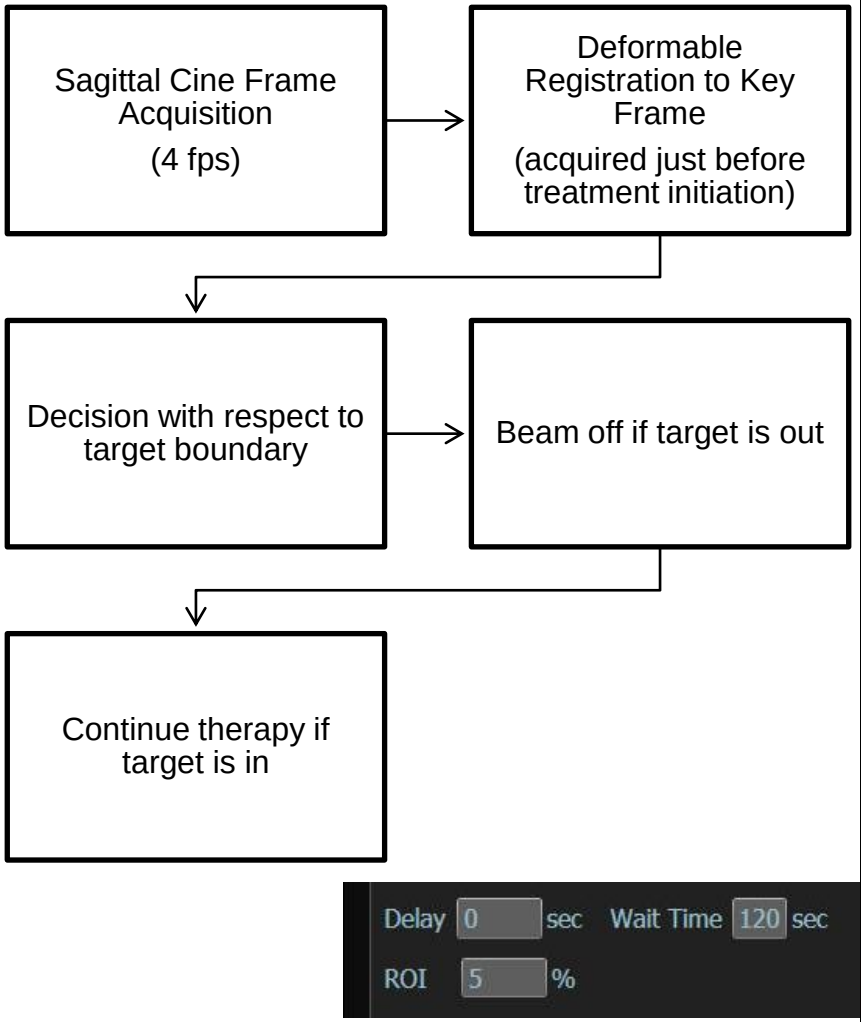
Courtesy Raaymakers

MRI of Pancreas, Optical Flow for 4D Motion Quantification



Courtesy Bjorn Stemkens, Baudouin Denis de Senneville

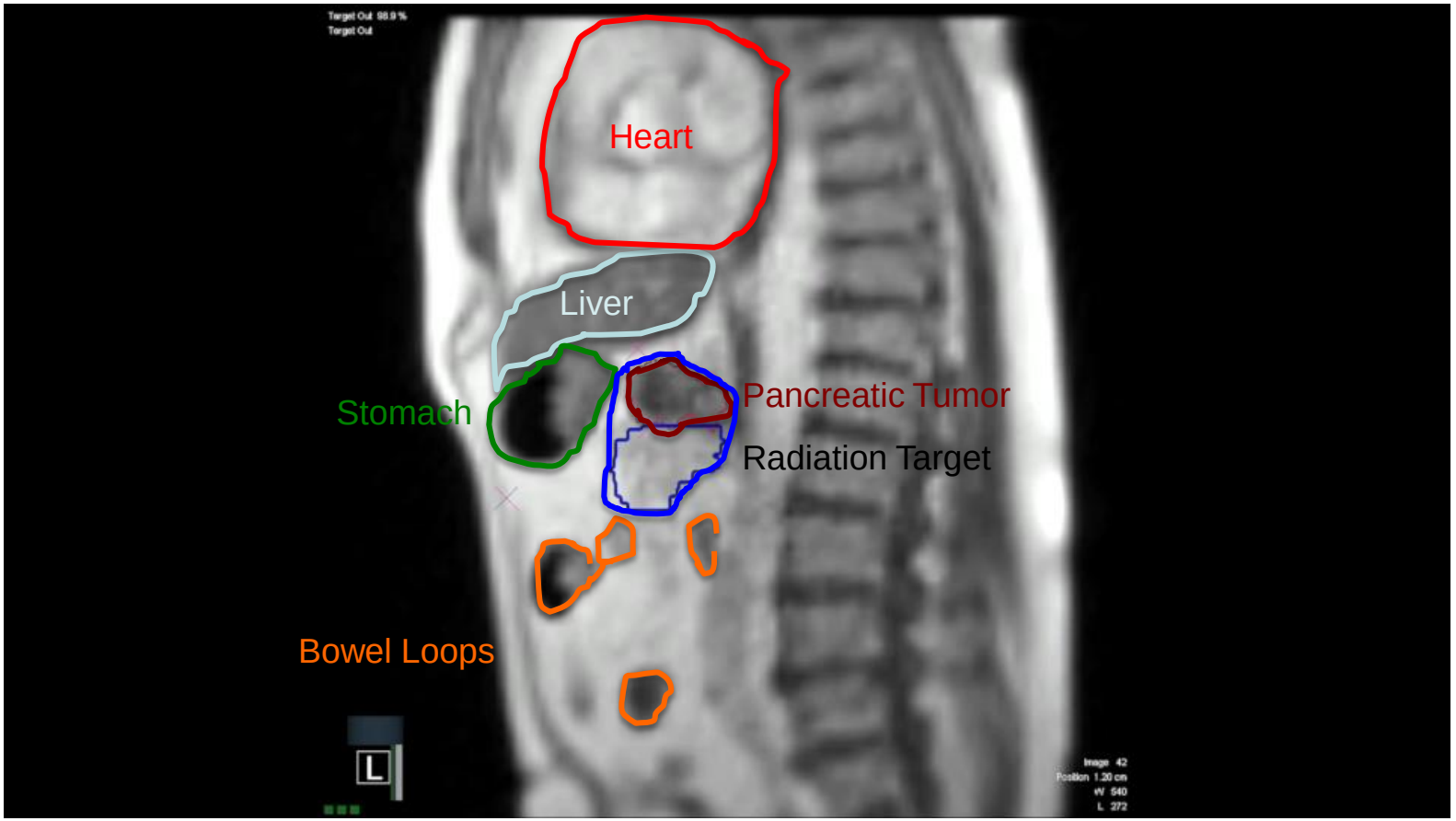
MR-IGRT Workflow



Courtesy of Olga Green

Pancreas IMRT with breath hold gating

Superior



Anterior

posterior

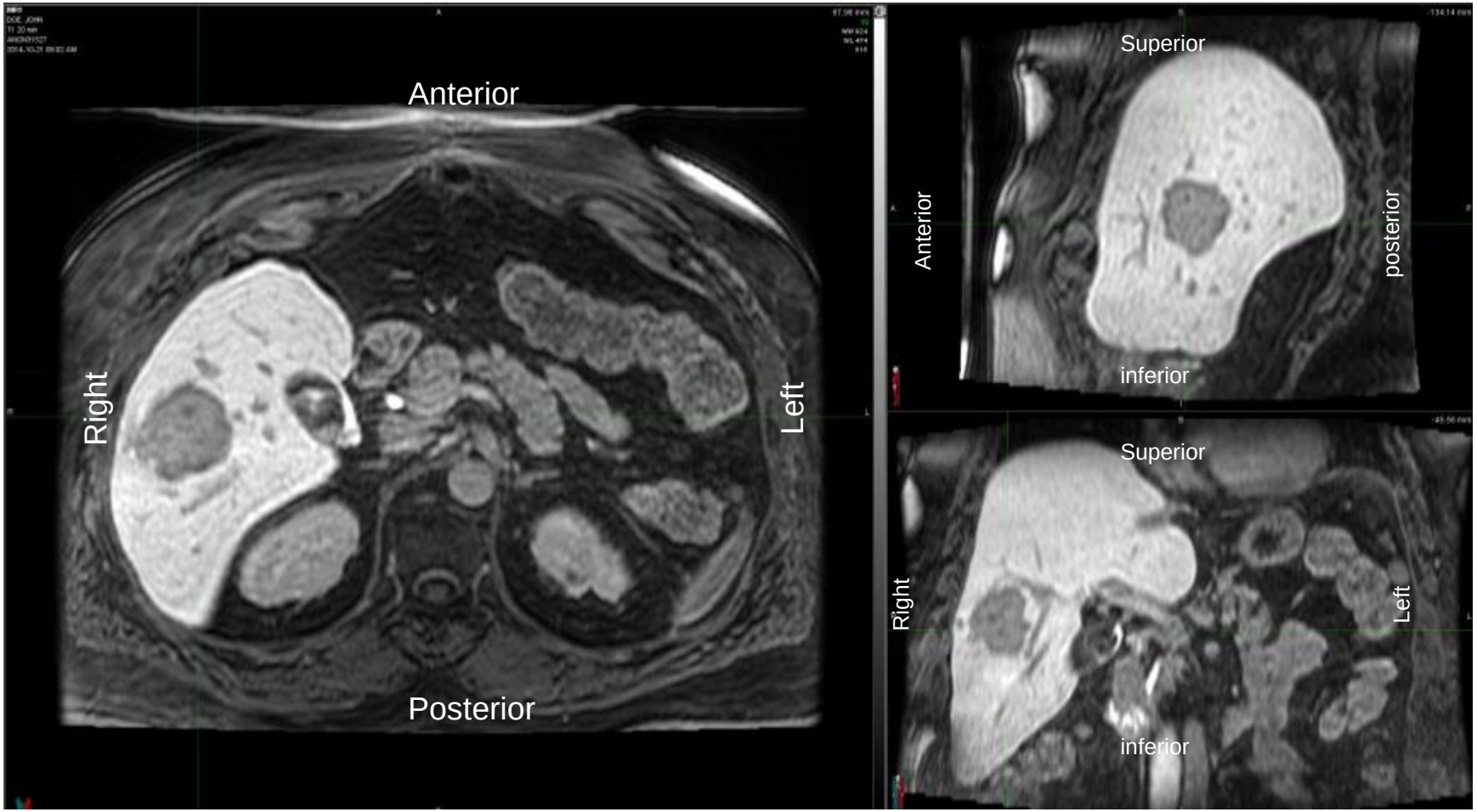
Inferior

Sagittal View

Courtesy Michael Bassetti

Stereotactic Liver Radiation

Diagnostic T1 weighted Gadoxetic acid contrast enhanced MRI of Metastatic Colorectal Cancer



Courtesy Michael Bassetti

Stereotactic Ablative Liver Metastasis Radiation

50Gy in 5 Fx

Patient driven repeated breath-hold technique with a high duty cycle

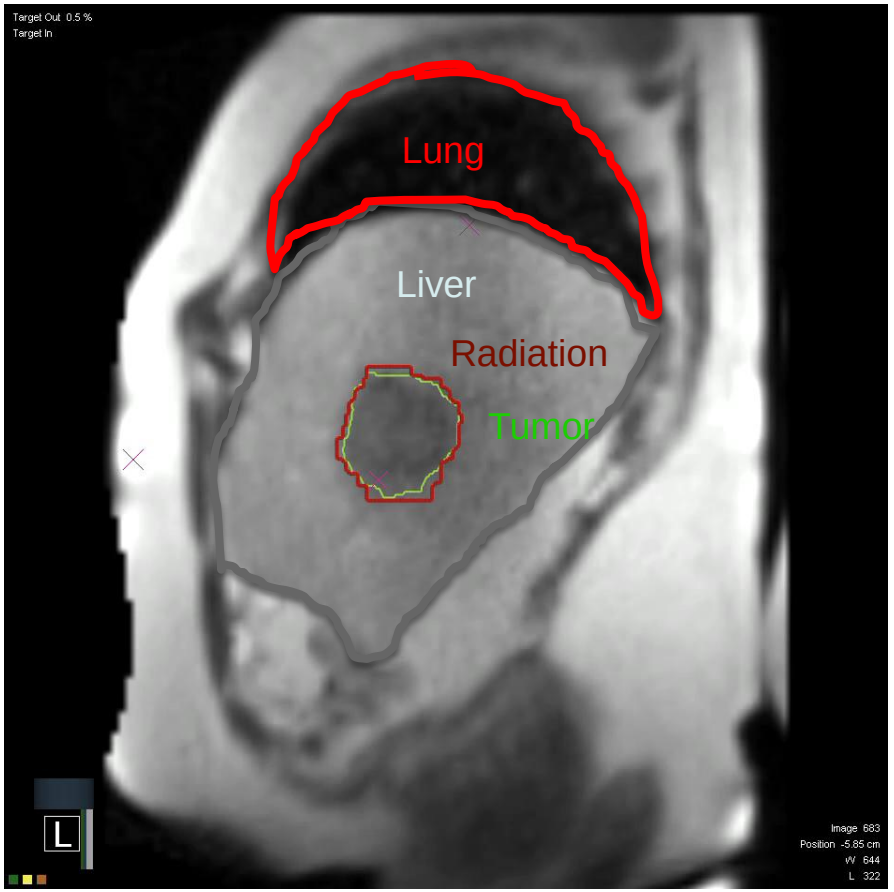
Radiation beam is only on when tumor is in proper position

Contrast used to highlight the tumor and allow daily tracking

Unique to be able to see and track actual tumor (not a surrogate) in realtime

MRI Tracking During Treatment

Superior



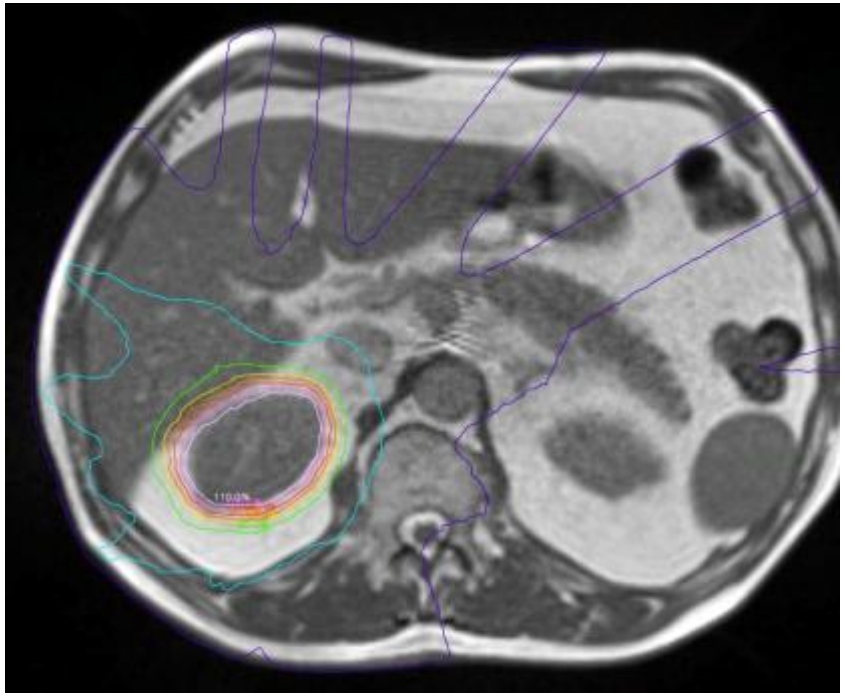
Anterior

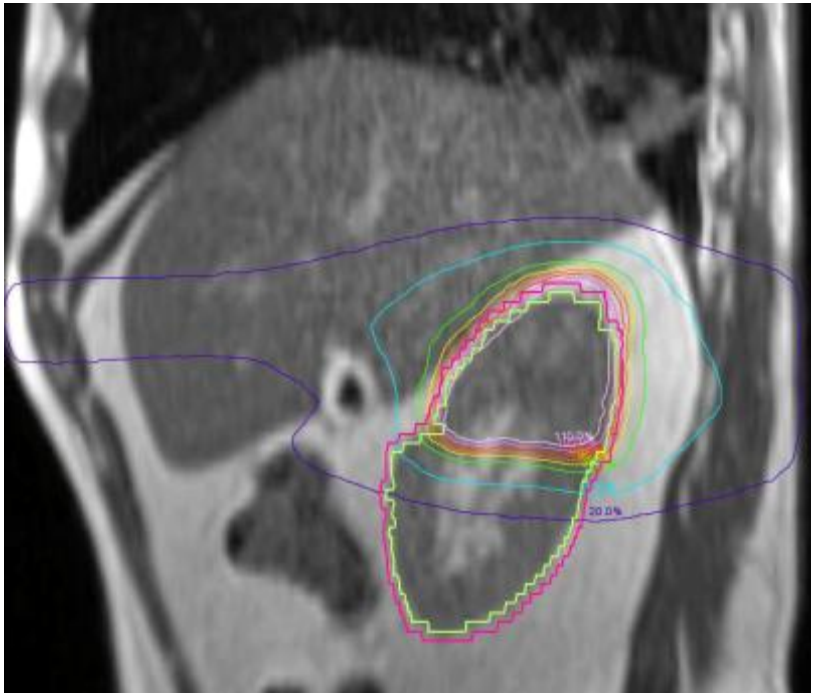
posterior

Inferior

Courtesy Michael Bassetti

Superior Pole Kidney SBRT





Courtesy Michael Bassetti

Superior Pole Kidney SBRT

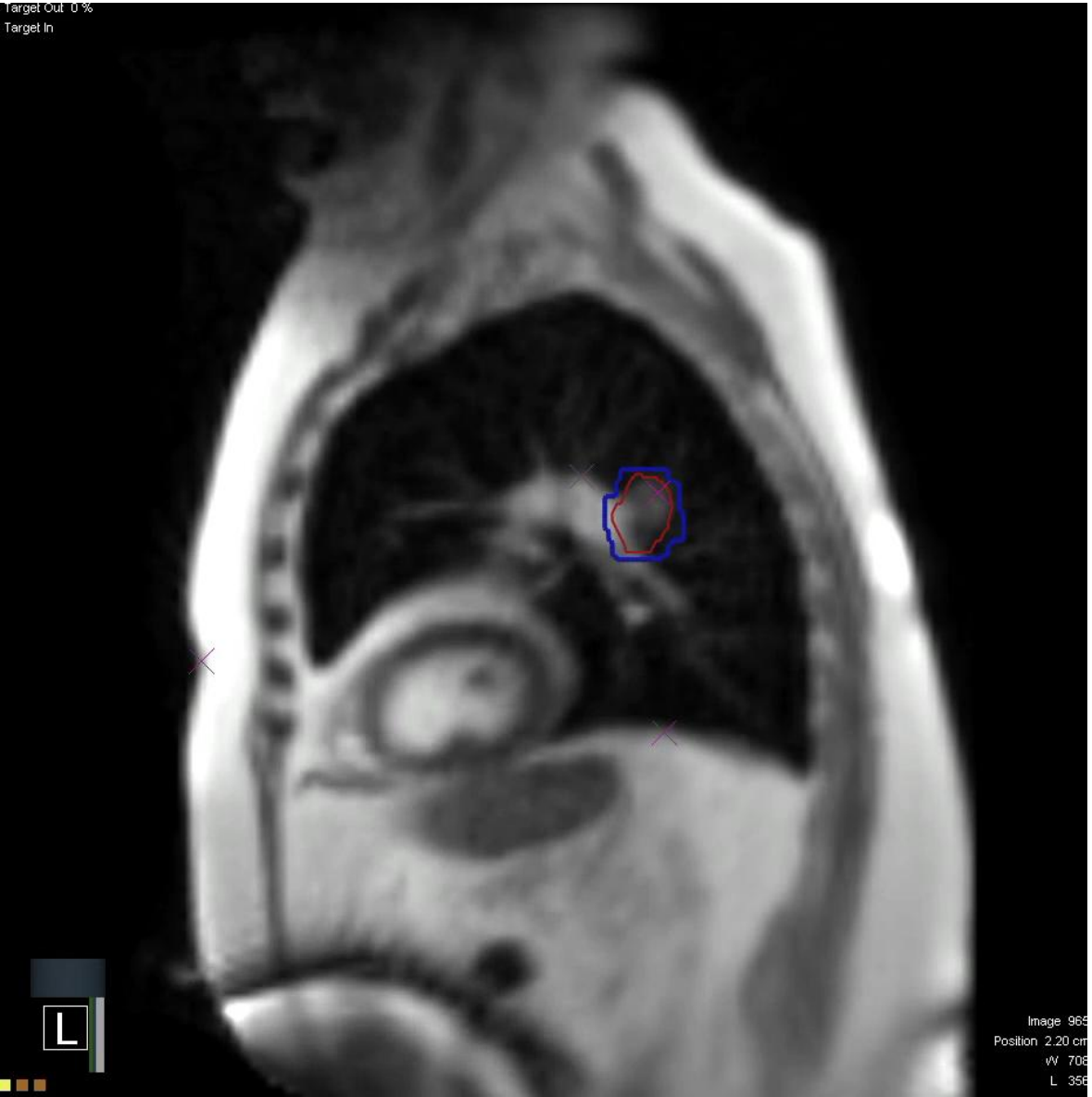
- Tumor tracking required to spare uninvolved kidney
- Tracking algorithm works very well with nice contrast difference
- Track the entire kidney with 98% within PTV for beam on

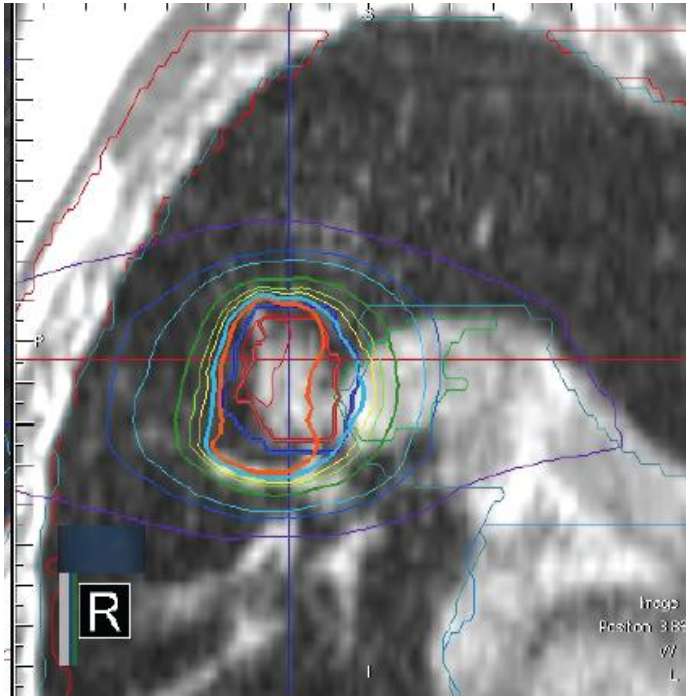
Courtesy Michael Bassetti

Patient Coached To Correct Amplitude

Courtesy John Bayouth

Exhalation Gating





Isodose Lines

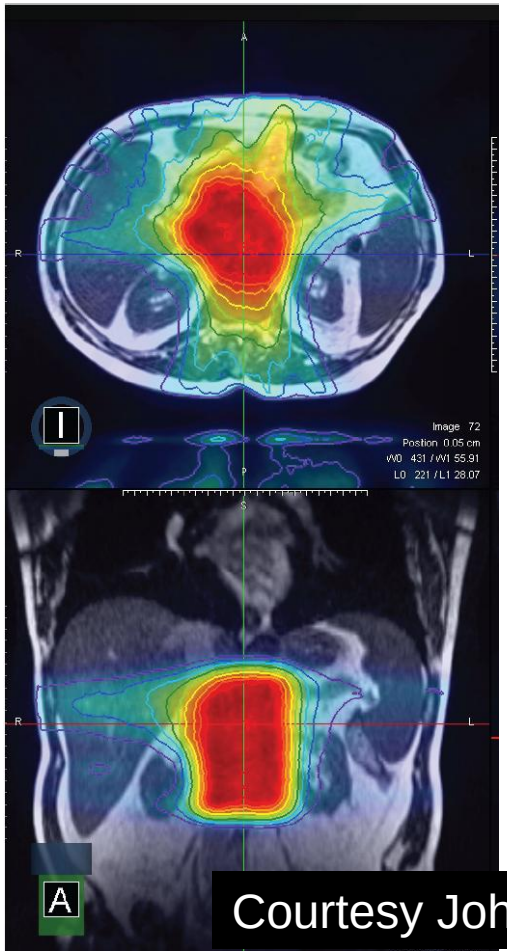
Max Dose = 65.00 Gy

Rx Dose = 50.00 Gy

Dose (Gy)	Rx %	Visible
12.50	25.0	Yes
25.00	50.0	Yes
30.00	60.0	Yes
40.00	80.0	Yes
45.00	90.0	Yes
47.50	95.0	Yes
52.50	105.0	Yes
50.00	100.0	Yes

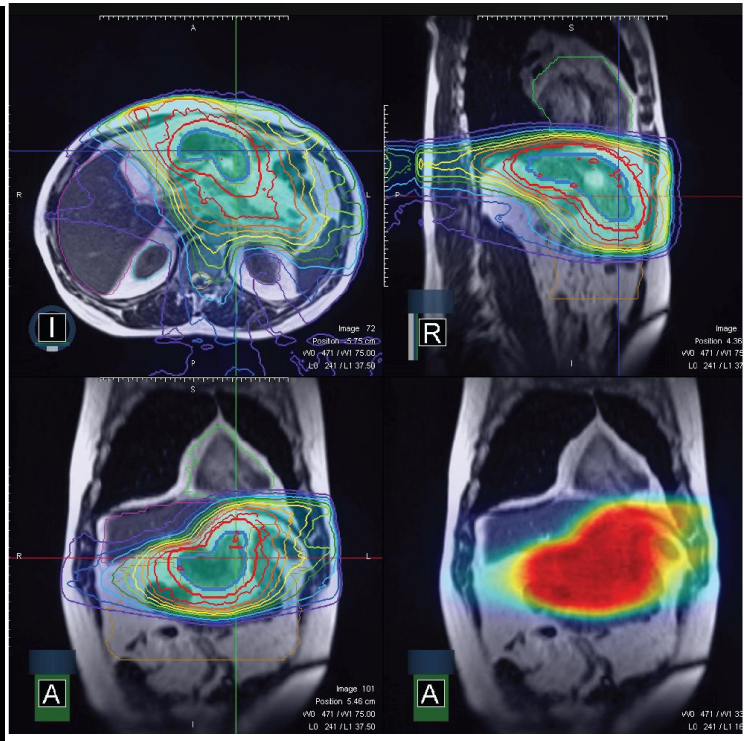
Courtesy John Bayouth

Contrast for Visualization



Courtesy John Bayouth

Key Frame Needs To Match Gating Phase



Isodose Lines

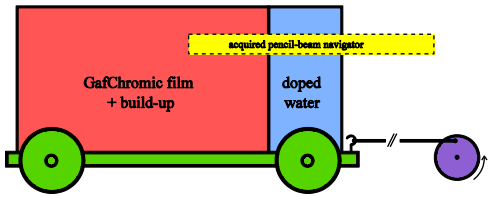
Max Dose = 35.00 Gy

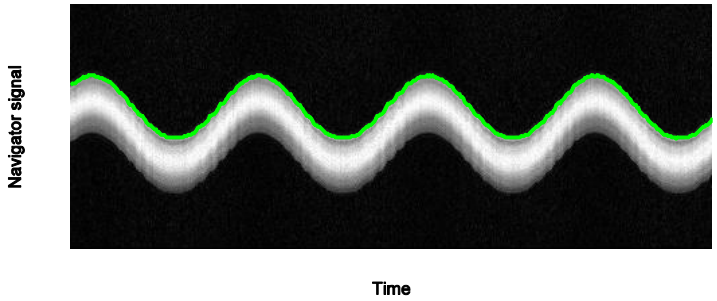
Rx Dose = 30.00 Gy

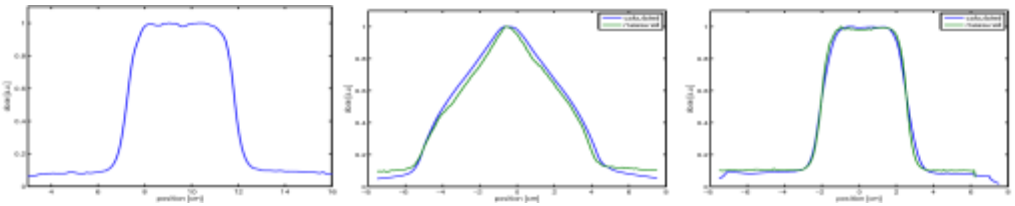
Dose (Gy)	Rx %	Visible
6.00	20.0	Yes
9.00	30.0	Yes
12.00	40.0	Yes
15.00	50.0	Yes
18.00	60.0	Yes
21.00	70.0	Yes
24.00	80.0	Yes
27.00	90.0	Yes

Courtesy John Bayouth

Gating and Tracking with Prototype MRL



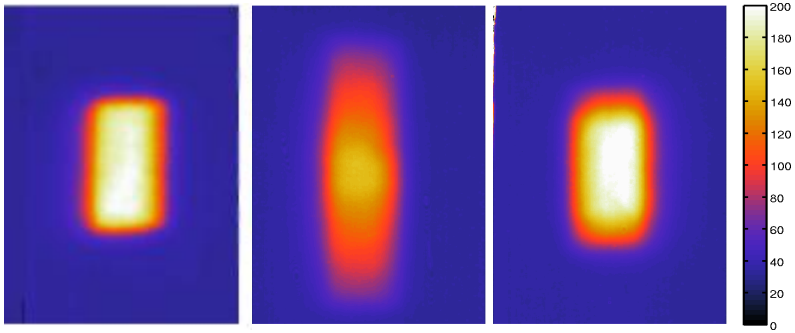




Static

Non gated delivery

Gated delivery



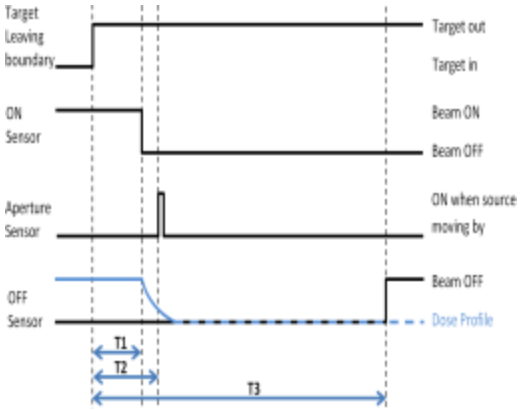
Impact of tracked delivery

From Crijns et al., 2011, 2012

Courtesy Raaymakers

Quality Assurance: ViewRay

- System Latency
- Trigger beam hold within 500 msec of target moving outside pre-defined boundary



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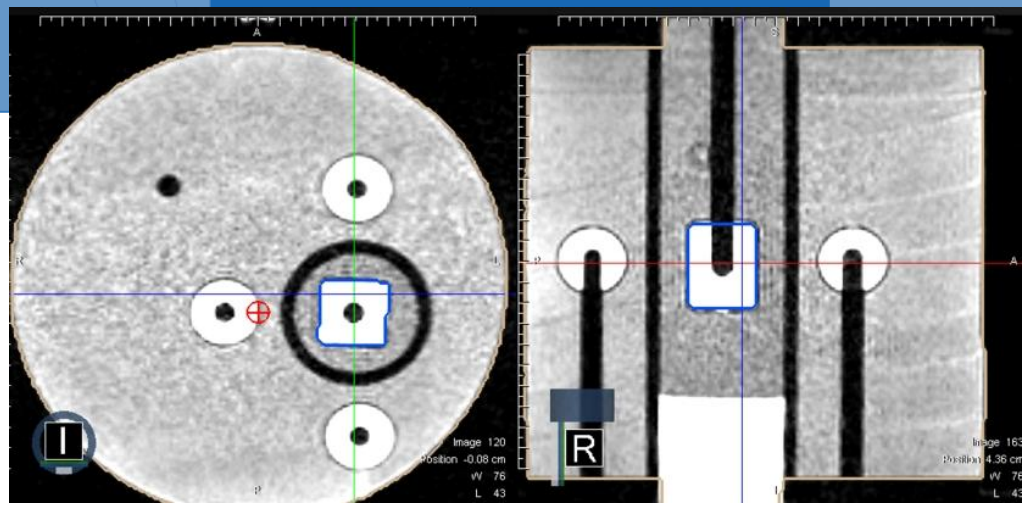
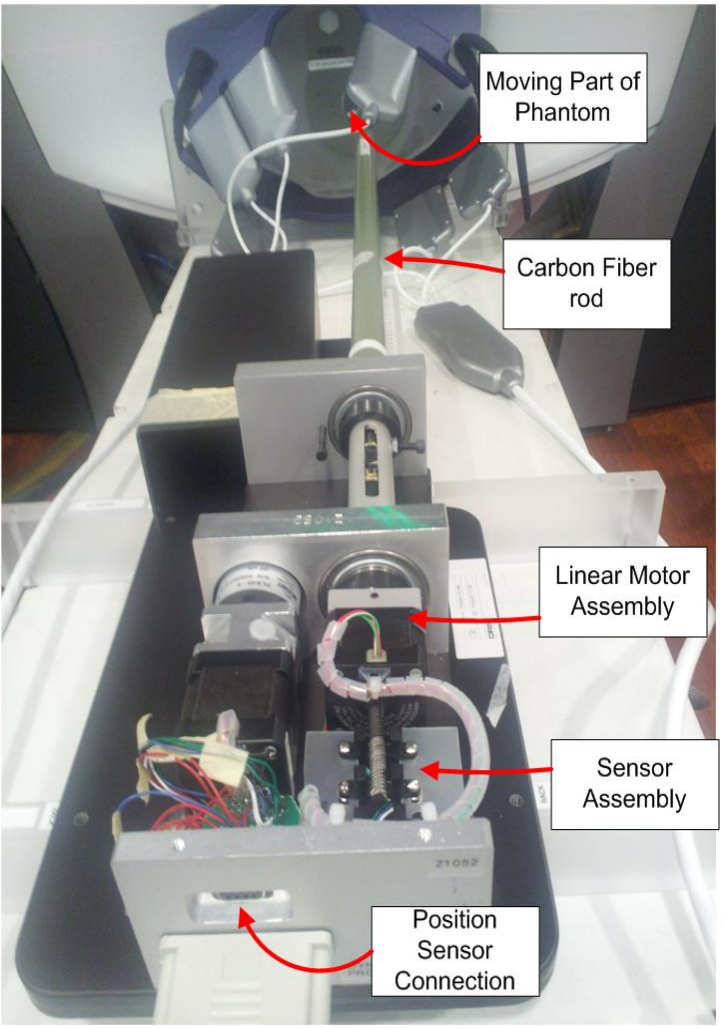
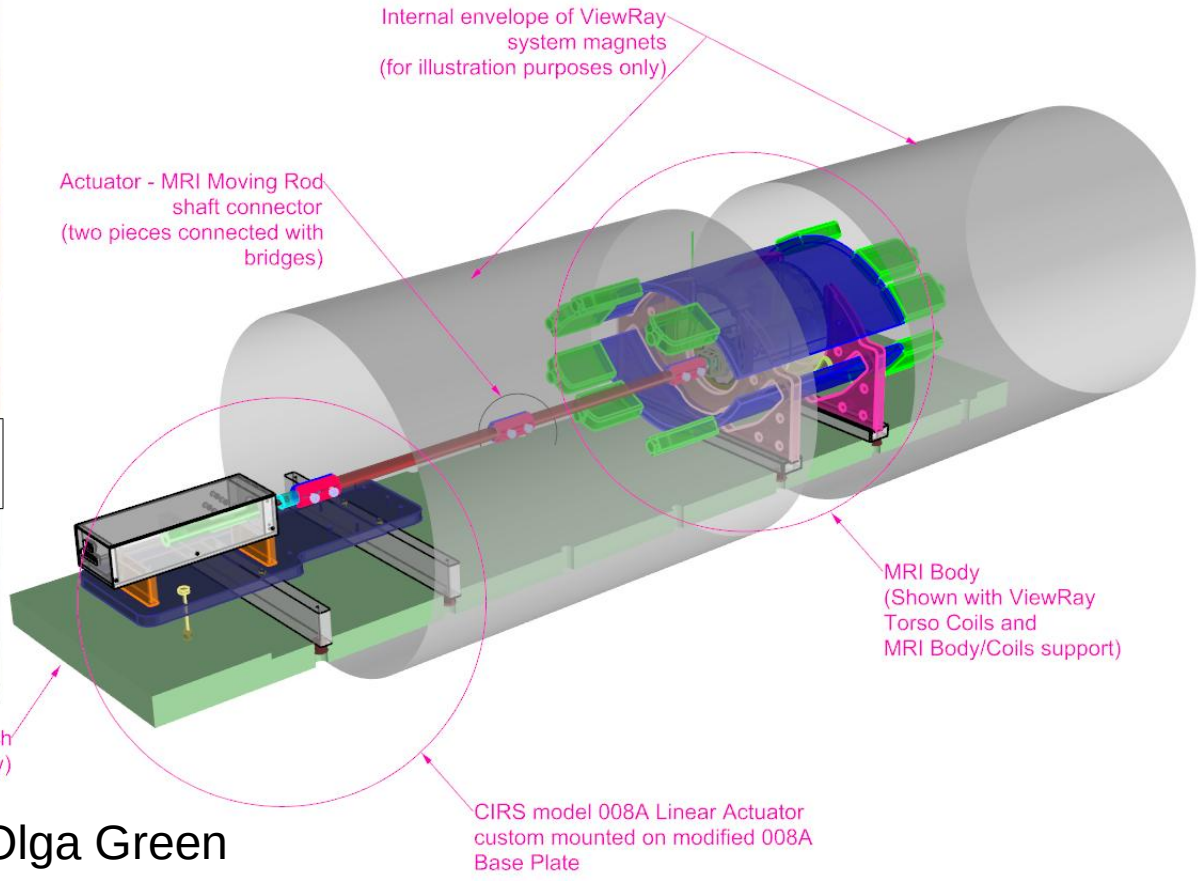
CIRS MR-compatible Motion Phantom







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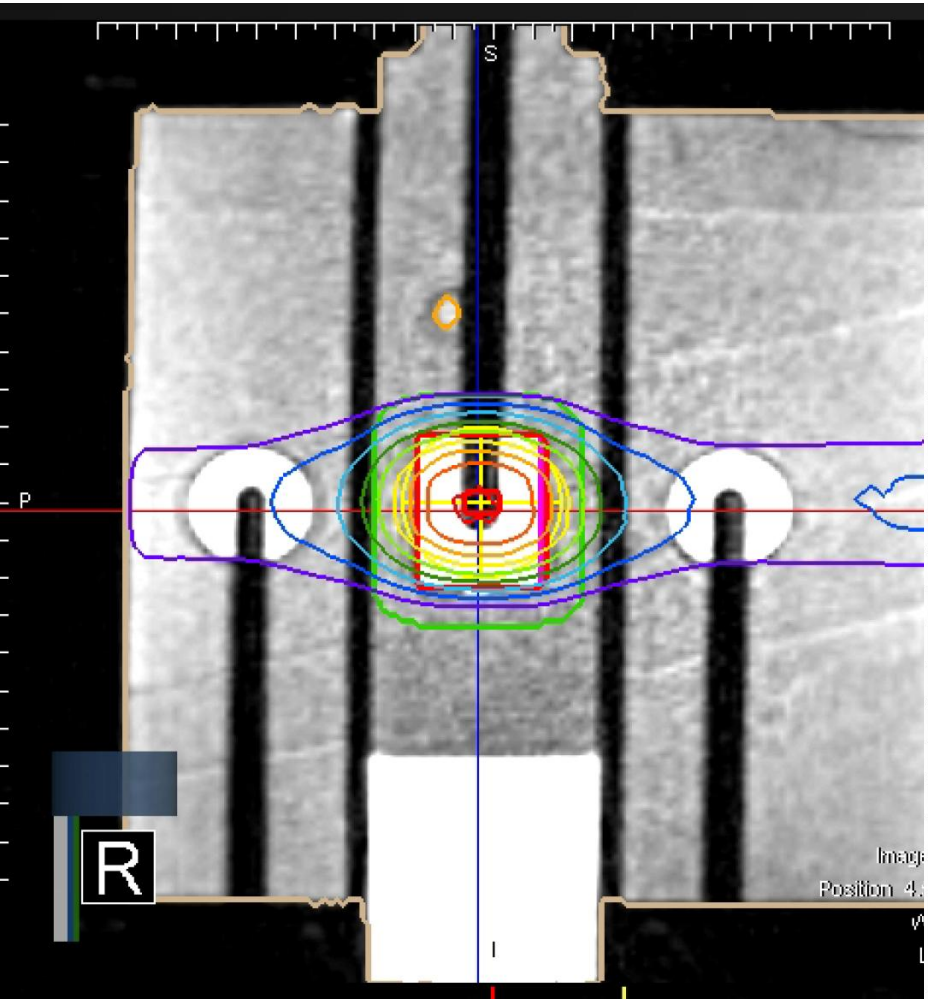
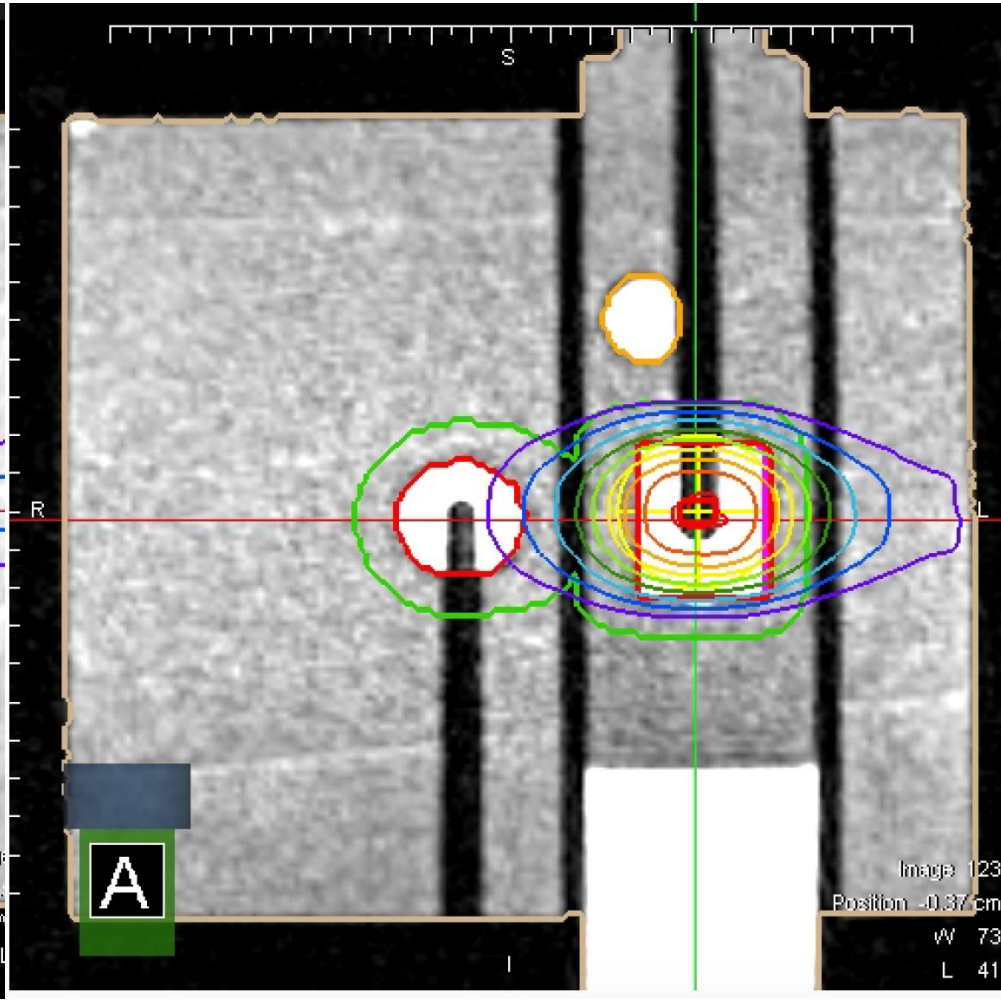
Verification of Dose during MRTC





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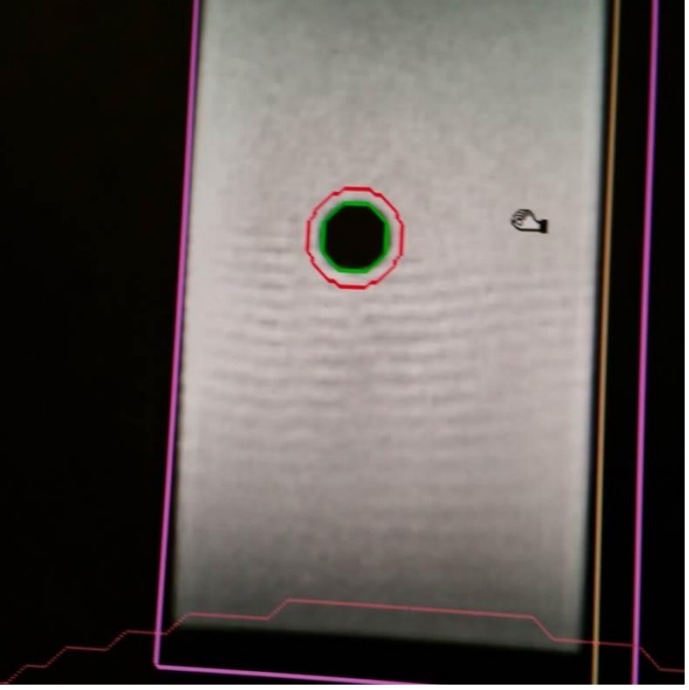

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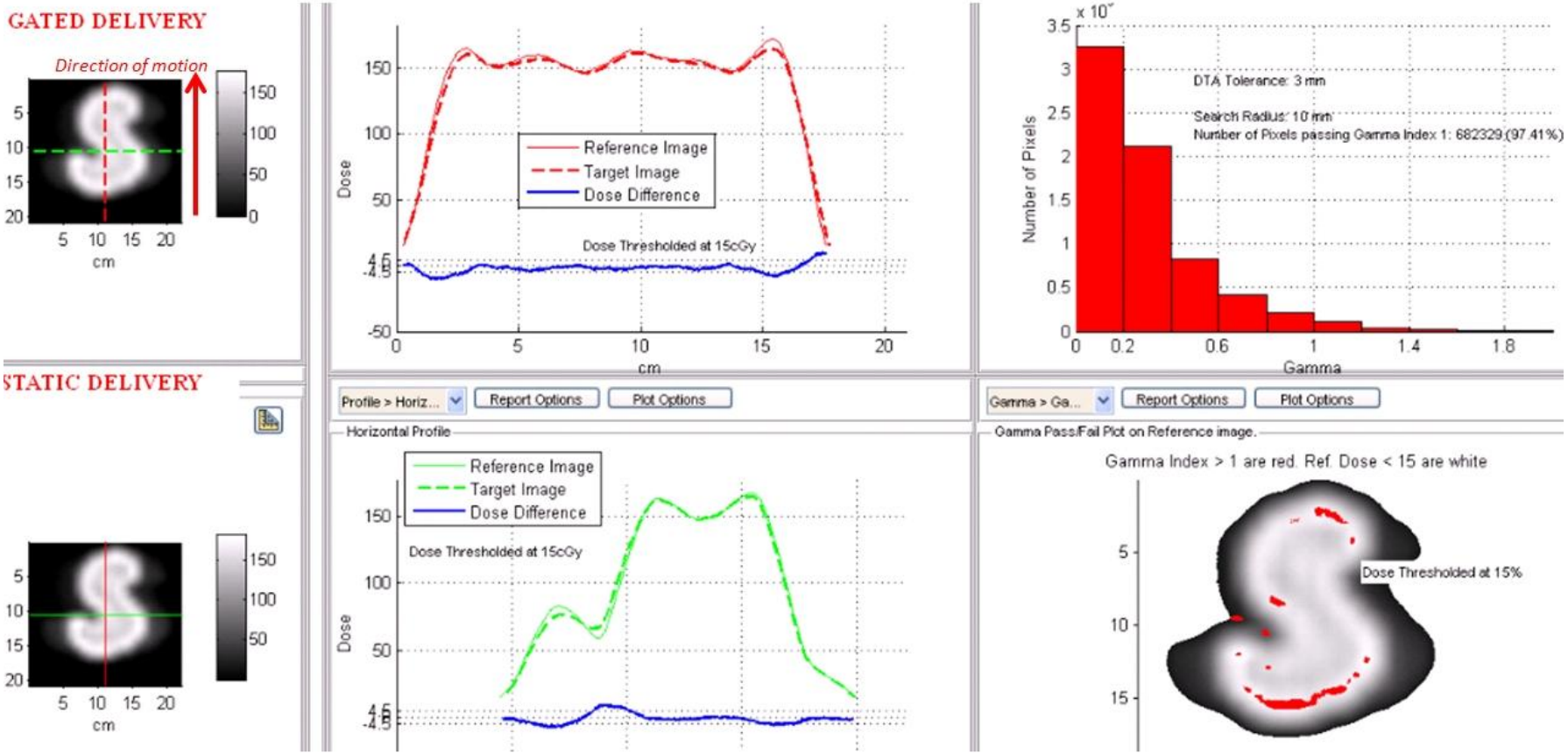

Courtesy Olga Green

What’s Next?

- 3D real time imaging
- Volume of data
- Real time review and monitoring by therapists?

SAMS Question

MR-Based Tracking

4%	A. Is not yet feasible due to the challenges in programming pulse sequences
5%	B. Is feasibly only for very high magnetic field strengths (<3T) due to signal to noise issues
0%	C. Does not benefit patients because x-ray tracking is commonplace and easy
1%	D. Unlike the claims made by MR manufacturers, delivers ionizing dose to the patient
90%	E. Is one of the more important features of MR-guided RT

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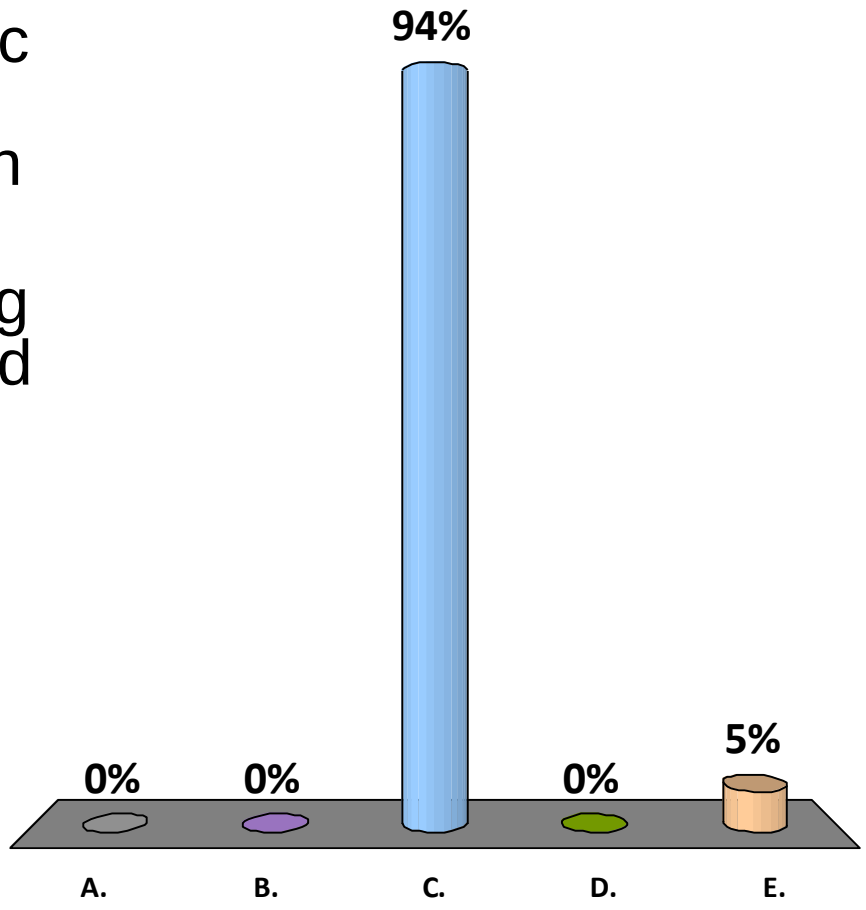
Mutic and Dempsey, Seminars in Rad. Onc. 196-199 (2014)

SAMS Question

MR Based Tracking

A. Has no role in radiation therapy
B. Is available only on diagnostic MR units and therefore will provide no benefit to radiation therapy
C. Has the potential for providing more accurate treatments and ultimately reduced margins
D. Will result in increased margins due to challenges with sequence synchronization
E. Is so theoretical that we will not see it made practical in our lifetimes



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