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 (MRIedian 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 (MRIedian by ViewRay)
Elekta + Philips
Upgrading the Prototype

- Cooling equipment
- Power supplies & electronics
- MLC & accelerator waveguide
- RF waveguides
- Slipring
- Modulator

Courtesy Raaymakers
MRI of Pancreas, Optical Flow for 4D Motion Quantification

Courtesy Bjorn Stemkens, Baudouin Denis de Senneville
MR-IGRT Workflow

Sagittal Cine Frame Acquisition (4 fps) → Deformable Registration to Key Frame (acquired just before treatment initiation)

Decision with respect to target boundary → Beam off if target is out

Continue therapy if target is in

Courtesy of Olga Green
Pancreas IMRT with breath hold gating

Superior

Heart
Liver
Stomach
Pancreatic Tumor
Radiation Target
Bowel Loops

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

Lung
Liver
Radiation
Tumor

Anterior
posterior

Inferior

Courtesy Michael Bassetti
Superior Pole Kidney SBRT
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
Exhalation Gating
Contrast for Visualization

Courtesy John Bayouth
Key Frame Needs To Match Gating Phase
Gating and Tracking with Prototype MRL

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

Dosimetric Consistency with RealTargeting –

<table>
<thead>
<tr>
<th>Measured values</th>
<th>Disposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured dose without motion.</td>
<td>Stationary Chamber (nC)</td>
</tr>
<tr>
<td>Measured dose with motion</td>
<td>Target Chamber (nC)</td>
</tr>
<tr>
<td>7.03 nC</td>
<td>7.12 nC</td>
</tr>
</tbody>
</table>

Dose difference between with and without target motion ≤ 3%

Stationary Chamber (% diff) ☐ Meets Criteria ☐ Nonconformity

1.3%

Describe:

Quality Assurance: ViewRay

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

Courtesy John Bayouth
CIRS MR-compatible Motion Phantom

Carbon Fiber rod

Moving Part of Phantom

Linear Motor Assembly

Sensor Assembly

Position Sensor Connection

ViewRay system couch (for illustration purposes only)

Internal envelope of ViewRay system magnets (for illustration purposes only)

Actuator - MRI Moving Rod shaft connector (two pieces connected with bridges)

CIRS model 008A Linear Actuator custom mounted on modified 008A Base Plate

MRI Body (shown with ViewRay Torso Coils and MRI Body/Coils support)

Courtesy Olga Green
Verification of Dose during MRTC

Courtesy John Bayouth
GATED DELIVERY

Direction of motion

STATIC DELIVERY

Dose Thresholded at 15 Gy

Courtesy Olga Green
What’s Next?

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

A. Is not yet feasible due to the challenges in programming pulse sequences

B. Is feasibly only for very high magnetic field strengths (<3T) due to signal to noise issues

C. Does not benefit patients because x-ray tracking is commonplace and easy

D. Unlike the claims made by MR manufacturers, delivers ionizing dose to the patient

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)
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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