MR Guided Radiation Therapy

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ViewRay, Inc.

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Disclosures

- I have no personal disclosures.
- Dr. Green has no personal disclosures.
- Dr. Mutic has stock and is a member of the ViewRay clinical advisory board.
- The Radiation Oncology department at Washington University has research and service agreements with ViewRay Inc.
- Dr. Dempsey is the inventor of ViewRay and founder of ViewRay Inc.
“MR-guided vascular intervention is appealing for its freedom from ionizing radiation, superior soft tissue contrast that allows it to display the vascular lumen [...] and tomographic capability that permits 3-dimensional display of the vascular path.

If these are combined with methods to visualize catheters and guidewires under MR, real-time navigation of those devices relative to the vascular true lumen, including the latent true lumen within the occluded segment, would be enabled.”
We are not *really* doing image guided RT
True image guidance

- Real time imaging
- “Guides” the operation
- Allows the clinician to see inside the patient through the entire operation
True image guidance

- Real time imaging
- “Guides” the operation
- Allows the clinician to see inside the patient through the entire operation
- TRUS guided prostate brachytherapy comes the closest to this realization
- Most RT patients are treated using external beam techniques
Image “guidance” in XRT ...
Image “guidance” in XRT ...
A vision of true image guided XRT

Courtesy of ViewRay, Inc.
We have a good idea how some things move
We have a good idea how some things move

Moving pockets of rectal gas:
– observed 1 out of 6
– caused CBCT streaking
– led to failed image registration

We have a good idea how some things move

- Cine MR detected
  - Prostate motion well correlated with rectal motion and distention
  - Prostate motion observed in 50% of cases, median AP = 4.2 mm, median 20 sec (range 10-80 sec)
  - Prostate motion > 5 mm in 16% of cases observed with Cine MR

We have a good idea how some things move

- Rectal balloons reduce motion, but don’t completely prevent it
Courtesy Dr. P Kupelian, MD Anderson Orlando
We have a good idea how some things move

- Over 1,325 Journal Articles Have Been Published on Organ Motion in the Last 3 Years

- Pubmed Search for:
  - (radiation therapy OR radiotherapy)
  - AND
  - (motion OR SBRT OR IGRT)
We have no idea how everything moves
We have no idea how everything moves
We have no idea how everything moves.
The imaging problem

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<th>Soft Tissue Contrast</th>
<th>Geometric Accuracy</th>
<th>Continous</th>
<th>Low noise</th>
<th>Instantaneous</th>
<th>Large FOV</th>
<th>Dose Calculation</th>
<th>See High Contrast Tumor</th>
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Low field MR images can play a role in XRT
Low magnetic field

- 0.35 T field
- 50 cm diameter spherical volume, < 25 ppm uniformity
- distortion worse farther out
Low magnetic field

- 0.35 T field
- 50 cm diameter spherical volume, < 25 ppm uniformity
- Distortion worse farther out
- Real time requires near zero lag for processing
- 8 ms reported (after field map acquisition)

Crijns, Raaymakers, Lagendijk, PMB 56, 289, 2011
Magnetic susceptibility effects

- **Example:**
  - $B_0 = 3\, \text{T}, \, G_E = 5\, \text{mT/m} \Rightarrow 5.7-12\, \text{mm}$
  - $B_0 = 0.5\, \text{T}, \, G_E = 5\, \text{mT/m} \Rightarrow 0.3-1.0\, \text{mm}$

- **ViewRay:**
  - $B_0 = 0.35\, \text{T}, \, G_E = 12\, \text{mT/m} \Rightarrow 0.087-0.29\, \text{mm}$

Wash U Imaging Comparison Study

Low-field Onboard MRI

Onboard CT

Noelle, C. et. al., manuscript submitted
Wash U Imaging Comparison Study

Noelle, C. et. al., manuscript submitted
Wash U Imaging Comparison Study

Noelle, C. et. al., manuscript submitted
Wash U Imaging Comparison Study

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Dosimetry in magnetic fields

- 0.35 T field
  - Kernel distortion increases with B strength in homogenous media

Dosimetry in magnetic fields

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  - Kernel distortion increases with B strength in homogenous media

Dosimetry in magnetic fields

- 0.35 T field
  - Electron return effects (ERE) in heterogeneous media

http://www.mp.med.ualberta.ca/linac%2Dmr/index.html
- 6 MV linac + 0.2 T MRI
- Rigidly fixed & rotate together
- 80 cm isocenter
- Biplanar magnet shielded from RF
- Linac waveguide shielded from magnet

Fallone et. al., Med Phys 36(6), 2084, 2009
- 6 MV linac + 1.5T MRI
- Magnet specially designed - toroidal shape of low magnetic field allows linac components to operate
- Dx quality images

**Figure 1.** Sketch of the MRI accelerator concept. The 1.5 T MRI is shown in blue (1), the 6 MV accelerator (2) is located in a ring around the MRI. The split gradient coil (3) is shown in yellow and in orange the superconducting coils (4) are shown. The light blue ring around the MRI indicates the low magnetic field toroid (5) in the fringe field.

Raaymakers et. al. PMB 54, N229, 2009
- 6 MV linac + 1.5T MRI
- Magnet specially designed - toroidal shape of low magnetic field allows linac components to operate
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Raaymakers et. al. PMB 54, N229, 2009
ECONOMY

NGHA in deal with Varian to build facility for MRgRT

JEDDAH: The Saudi Arabian National Guard Health Affairs (NGHA) announced Saturday it has signed an agreement with Varian Medical Systems and IMRIS, Inc., to develop and build a facility for magnetic resonance-guided radiation therapy (MRgRT).

Under the agreement, Varian and IMRIS will supply a cancer treatment solution that combines IMRIS’ unique movable magnetic resonance imaging (MRI) technology with Varian’s latest linear accelerator technology, the TrueBeam system. MRI provides high quality soft tissue imaging that can be used to eradicate tumors using radiotherapy or radiosurgery.

"While this technology is still in the early developmental phase, we see great potential to advance the ability of clinicians to target tumors within soft tissue more precisely," said Dow Wilson, president of Varian’s Oncology Systems business.

The solution will be designed to permit a high-field MRI scanner to move in and out of the radiation therapy room on demand, providing MR imaging to confirm a tumor’s location without having to move the patient from the treatment couch or transport the patient to and from another room, as would be required today. Due to the mobile nature of the MRI system, the radiation therapy systems are expected to be offered in multi-room configurations."
Treatment planning can be fast
We have a LOT to learn!
How do we best use these tools?
Thank you