Clinical implementation of 4D-MRI: needs, current status, and challenges

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Many slides courtesy of Sasa Mutic, PhD

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• I have consulting/ownership interest in Innovative Pulmonary Solutions, Oraya and medical litigation

Take Home Messages

• 4DMRI has the potential for on-table targeting
• 4DMRI has many more degrees of freedom than other tracking technologies
• 4DMRI may have unique opportunities in the abdomen
Delivery and Imaging in Radiotherapy

- Current radiotherapy equipment can deliver dose to millimeter scale precision and accuracy
- However, the accuracy of delivery is limited by our ability to visualize, define, and quantify anatomy and function

Where does MRI stack up?

- Patient receives MRI simulation with millimeter accuracy in both soft tissue tumor definition and functional assessment
- MRI decreases interobserver variability in performing tumor segmentation
- Patient has regular MRI-based evaluations during therapy for treatment targeting and adaptation
- MRI guided radiation penetrates market (like CT guided radiation) within 15 years.
### Requirements for tumor tracking systems

- Obtain localization information (radiographic imaging, surface imaging, electromagnetic, radioisotope detection)
- Process localization information into position of tumor (directly, internal surrogate, external surrogate, hybrid model)
- Implement a change in therapy (gating, changing treatment beam, changing patient position)

### Clinical tumor tracking is hard

- Very few commercial systems
- Why not more implementations?
  - Image processing more difficult than it would seem
  - Images don’t always show tumor
  - Not robust enough for clinical use
  - Too often requires high level supervision (physician/physicist)

Main purpose for tumor tracking work: AAPM abstracts and presentations?

### MRI/RT integrated prototypes

- **TH-E-BRA-10** The 1.5 T MRI Accelerator for MRI During Radiation Delivery: Status Report - B Raaymakers1*, J Lagendijk1, S Crijns1, J Kok1, M van Vulp1, J Overweg2, C Knox3, K Brown3, (1) University Medical Center Utrecht, (2) Philips, (3) Elekta
- **WE-A-BRA-1** The Hybrid Linac-MR System for Real-Time Tumour Tracking and Radiation Treatment - B G Fallone1*, (1) Cross Cancer Institute, Edmonton, AB
ViewRay Concept

- 0.3T split coil MR Scanner combined with three Co-60 heads
- Parallel imaging and delivery (Conventional and IMRT)
- Integrated system – Treatment planning, treatment management, delivery
- On-couch planning – auto-segmentation, optimization, calculation
- MR-guided gated delivery

Viewray magnet – Wash U
7/2011

Viewray picture today (installed!)
ViewRay – Current Status

• Treatment Planning
  – FDA 510K cleared
• Imaging & Delivering System
  – FDA 510K cleared
• First Patients imaged (mock sources)
  – Washington University 3/2012
• Current Work – further testing with active sources

MRI implementation

• Split coil design
• ‘Siemens Avantgo’ underpinning software
• 0.3 T
• Incorporating cine imaging
  • 4 fps – single plane
  • 2fps - 3 orthogonal planes

\textit{tao}

• Technology Assessment and Outcome
• Establish clinical trial support
  – Evaluating a new technology
  – Assessment of a novel implementation
  – Measuring CLINICAL outcomes (quality of life and/or tumor related outcomes)

Accelerates clinical testing of the device with early physician/physicist team
Trial evaluation parameters

- Does the trial use new radiation technology in a novel clinical fashion?
- Would the outcomes measured support a new billing code, or support an existing billing code for a new indication?
- Are clinical outcomes measurable from the novel use of radiation technology?

201105295 Feasibility Study of Low-Field Magnetic Resonance Imaging (MRI) for Radiotherapy Target Identification

- Uses Viewray magnet under IRB approved status
- Intermittent imaging based on organ site (CNS/H+N; thorax, abdomen, pelvis)
- Acquired images on 27 patients

Detailed information in upcoming sessions

- TU-G-217A-9 Feasibility of Bowel Tracking Using Onboard Cine MRI for Gated Radiotherapy - C Neel1*, J Olsen1, O Pechenaya Green1, Y Hu1, P Parikh1, (1) Washington University School of Medicine, Saint Louis, MO
- WE-A-BRA-2 First Commercial Hybrid MRI-IMRT System - S Mutic1*, (1) Washington University School of Medicine, Saint Louis, MO
- TH-E-BRA-7 Initial Experience with the ViewRay System – Quality Assurance Testing of the Imaging Component - Y Hu*, O Pechenaya Green, P Parikh, J Olsen, S Mutic, Washington University School of Medicine, Saint Louis, MO
- ASTRO 2012 - Physician evaluations of volumetric and cine MRI as compared to existing technologies
MRI – more questions than answers?

• What’s the best plane (or combination of planes?)
• What are we looking for (tumor, critical structure, both?)
• What’s the best sequence (fast versus tumor or critical structure contrast?)
• Is it spatially accurate?

HN structures

Thorax
Abdomen

Viewray software

- Tumor segmented in software
- Mutual information matching algorithm

Why worry about abdomen?

- Liver 1.20 cm
- Stomach 1.37 cm
- Spleen 1.47 cm
- Lt Kidney 1.20 cm
- Rt Kidney 1.32 cm
Lung versus Abdomen

- Lung
  - Can often be visualized on planar MV imaging
  - Respiratory motion dominates
  - Not all the tumors move (especially those above the carina)

- Abdomen
  - Never seen on MV or KV planar imaging
  - Respiratory motion and changes in bowel filling
  - All upper abdominal organs move with respiration

Abdominal Challenges

- Poor outcome of diseases
  - Inoperable pancreatic, liver and other hepatobiliary cancers notoriously have median survival around ~12 – 18 months

- Surrounding moving critical structures
  - Bowel, kidneys, stomach and liver all play a role in limiting doses of therapeutic radiation

- Tumors not visualized well on CT w/o intravenous contrast

Lung 4DCT
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