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

Parag Parikh, BSE., M.D.
Assistant Professor of Biomedical Engineering & Radiation Oncology
Chief, GI Radiation Oncology Service
Washington University Medical School
St. Louis, MO, USA

Many slides courtesy of Sasa Mutic, PhD

Disclosures

- I receive research funding from Calypso Medical Technologies, Philips Medical, Varian Medical Systems, Viewray, and selling 4D Phantoms & NCI R01
- I have consulting/ownership interest in Innovative Pulmonary Solutions, Oraya and medical litigation

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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

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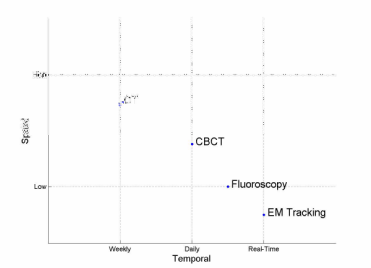
Delivery and Imaging in Radiotherapy

- 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?



Vision for MRI Guided XRT

- 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 Vulpen1, 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

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

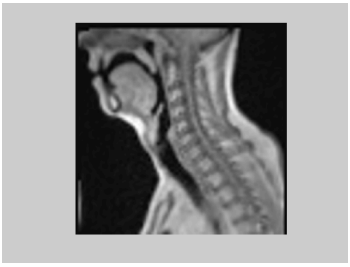
Detailed information in upcoming sessions

- **TU-G-217A-9 Feasibility of Bowel Tracking Using Onboard Cine MRI for Gated Radiotherapy** - C Noel1*, 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

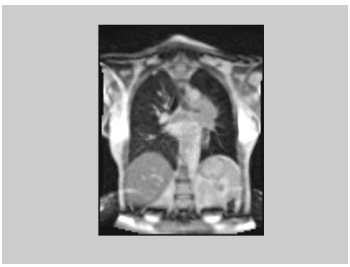
MRI – more questions than answers?

- 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?

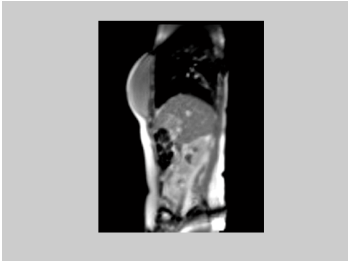
HN structures



Thorax



Abdomen



Viewray software

- Tumor segmented in software
- Mutual information matching algorithm

Why worry about abdomen?

Liver
1.20 cm

Rt Kidney
1.32 cm

Stomach
1.37 cm

Spleen
1.47 cm

Lt Kidney
1.20 cm

Ma (AAPM 2005), Parikh (ARS, 2004)

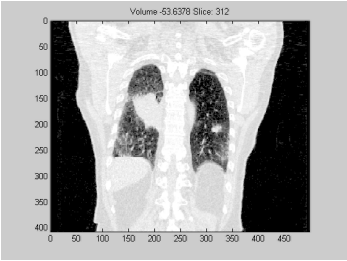
Lung versus Abdomen

- 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

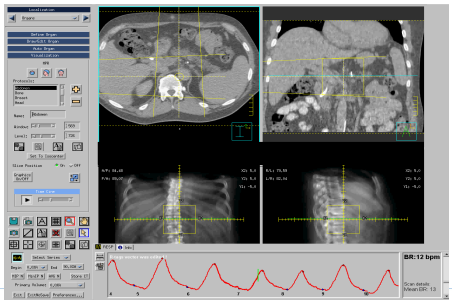
Abdominal Challenges

- 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



Abdomen 4DCT



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