Using MRI to track tumors: Comparison with existing tumor tracking systems

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Many slides courtesy of Sasa Mutic, PhD

Goals

- Describe commercially available tumor tracking technologies and compare with MRI
- Describe proposed clinical implementation of MRI tracking/gating on a commercial device

Disclosures

- I receive research funding from Calypso Medical Technologies, Philips Medical, Varian Medical Systems, selling 4D Phantoms & NCI R01
- I will highlight devices mentioned that do not have regulatory clearance in the United States

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.

Vision for MRI Guided XRT

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?
Radiographic localization information

- Radiographic
  - Intermittent kV imaging or fluoroscopy
  - Mostly fixed panel systems (for tumor tracking)
  - Fixed geometry

Radiographic versus MRI

<table>
<thead>
<tr>
<th></th>
<th>Radiographic</th>
<th>MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDA approved</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Imaging geometry</td>
<td>limited</td>
<td>Arbitrary (in theory)</td>
</tr>
<tr>
<td>Imaging frequency</td>
<td>Very fast</td>
<td>fast</td>
</tr>
<tr>
<td>Unlimited images?</td>
<td>No (due to dose)</td>
<td>Yes</td>
</tr>
<tr>
<td>Soft tissue resolution</td>
<td>Poor</td>
<td>Great</td>
</tr>
<tr>
<td>Bony / fiducial resolution</td>
<td>Great</td>
<td>Fair</td>
</tr>
<tr>
<td>Compatibility with all patients</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Optical systems

- Active and passive IR marker systems as well as surface monitoring
- Used mostly as respiratory surrogates with respect to tumor tracking
- Most have direct implementations with therapy gating and/or repositioning

Optical versus MRI

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<thead>
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<th>MRI</th>
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</thead>
<tbody>
<tr>
<td>FDA approved</td>
<td>Yes</td>
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</tr>
<tr>
<td>Measurement geometry</td>
<td>Very limited</td>
<td>Arbitrary (in theory)</td>
</tr>
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Nonradiographic fiducial systems

• Use specialized internal markers for non-radiographic localization
• Examples include Calypso, Micropos and Navotek

Nonradiographic comparisons

<table>
<thead>
<tr>
<th></th>
<th>Calypso</th>
<th>Navotek</th>
<th>Micropos</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDA approved</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Size</td>
<td>Large 14 gauge</td>
<td>Smallest 22 gauge</td>
<td>Largest (wired!)</td>
</tr>
<tr>
<td>Rotation</td>
<td>Yes</td>
<td>No</td>
<td>Unknown</td>
</tr>
<tr>
<td>Compatibility with imaging (CBCT)</td>
<td>Less</td>
<td>More</td>
<td>Most</td>
</tr>
<tr>
<td>Compatibility with follow up MRI imaging</td>
<td>Less (safe but w/ artifact)</td>
<td>No problem</td>
<td>OK post-tx Removable</td>
</tr>
</tbody>
</table>

Nonradiographic versus MRI

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<tr>
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<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Imaging geometry</td>
<td>Sparse (points)</td>
<td>Arbitrary (in theory)</td>
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MRI vs available targeting: conclusions

• MRI has much potential for tumor tracking due to the lack of ionizing radiation dose and soft tissue resolution.
• Researchers should keep in mind the good features from commercial tumor targeting systems
  – Radiographic: how to overcome the lack of robustness for non fiducial/bony tracking?
  – Optical: how to match the high frequency respiratory monitoring?
  – Nonradiographic: how to take complex MRI information and distill it to tumor position for implementation?
MRI guided XRT: Washington University progress with Viewray

Device as shown not approved for human use by the FDA

MRI @ WashU - Dual Leadership

- Sasa Mutic, PhD
  - Planning
  - Commissioning
  - Imaging QA
  - Delivery QA

- Parag Parikh BSE, M.D.
  - Clinical Lead
  - Contractual
  - Regulatory (FDA/human studies)
  - Use Cases

WORKFLOW / PROCESS

-tao-

(central) (noun) ταία: the art or skill of doing something in harmony with the essential nature of the thing

-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)
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?

ViewRay Concept

- MR Scanner combined with three Co-60 heads
- Parallel imaging (4 frames/second) and delivery (Conventional and IMRT)
- Integrated system – Treatment planning, treatment management, delivery
- On couch planning – auto-segmentation, optimization, calculation
- MR-guided gated delivery
- Fits in standard size treatment room

System in factory

Factory testing
**Viewray Baseplate – Wash U 7/2011**

**Viewray magnet – Wash U 7/2011**

**ViewRay – Current Status**
- Treatment Planning System: FDA 510K cleared
- Imaging System: FDA 510K Submitted
- Delivery system: FDA 510K Submitted
- First Installation: Washington University ongoing

**ViewRay timeline**
- July – Installation imaging system / Treatment Planning Training
- August – Installation continues
- September – Start patient imaging trial
- October - Installation of delivery system
- November – Commissioning begins
- 2012 - First patient?
201105295 Feasibility Study of Low-Field Magnetic Resonance Imaging (MRI) for Radiotherapy Target Identification

- Uses Viewray magnet under IRB / low risk status
- Intermittent imaging based on organ site (CNS/H+N; thorax, abdomen, pelvis)
- Will be used for treatment planning and adaptive planning modeling
- Already open at Washington University; awaiting completion of installation of imaging subsystem.

Viewray MRI tracking information

- 0.3 T ‘Siemens Avantgo’
- Three parallel planes or three orthogonal planes (cine slab imaging)
- 0.25 seconds from frame to frame
- Gating performed by closing aperture on Co-60

Abdomen

- Most potential is in abdomen for liver/pancreas tumors
- Respiratory and gastrointestinal motion

CNS

- Gating on optic nerves or swallowing structures?
Pelvis

- Need to find best slices for rectoprostatic interface
- Potential with seminal vesicles

Prostate – real time MRI

Viewray Tracking Workflow

- User can segment tumor, normal structure or some interface on localization MR or from planning CT
- User can set beam to ‘gating’ and also specify how long image should not match prior to aperture closing
- User can set ‘tracking points’ that show the results of the MMI algorithm to help QA / understand results

Viewray tracking implementation
Conclusions

- MRI tracking has great potential for radiation therapy; but should be developed with existing tracking systems in mind.
- There is progress on a commercial system; and the gating/tracking lessons learned can benefit MRI guided radiation therapy on large scale.

Prostate localization movie