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

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

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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

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Goals

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

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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

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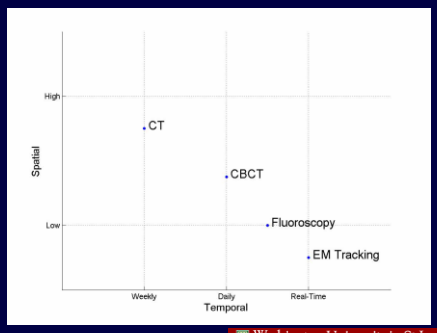
Where does MRI stack up?



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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.

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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)

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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?

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Radiographic localization information

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

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Radiographic versus MRI

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

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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

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Optical versus MRI

	Optical	MRI
FDA approved	Yes	No
Measurement geometry	Very limited	Arbitrary (in theory)
Measurement frequency	Very fast	fast
Unlimited measurements?	Yes	Yes
Soft tissue resolution	None	Great
Bony / fiducial resolution	None	Fair
Compatibility with all patients	Yes	No

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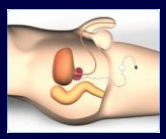
Nonradiographic fiducial systems

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






Nonradiographic comparisons

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

Nonradiographic versus MRI

	Nonradiographic	MRI
FDA approved	Yes	No
Imaging geometry	Sparse (points)	Arbitrary (in theory)
Measurement frequency	Very fast	fast
Unlimited measurements?	Yes	Yes
Soft tissue resolution	None	Great
Bony / fiducial resolution	Yes	Fair
Compatibility with all patients	No	No

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

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MRI @ WashU - Dual Leadership

- Sasa Mutic, PhD
  - Physics Lead
    - Planning
    - Commissioning
    - Imaging QA
    - Delivery QA
- Parag Parikh BSE, M.D.
  - Clinical Lead
    - Contractual
    - Regulatory (FDA/human studies)
    - Use Cases

WORKFLOW / PROCESS

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tao

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

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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)

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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?

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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

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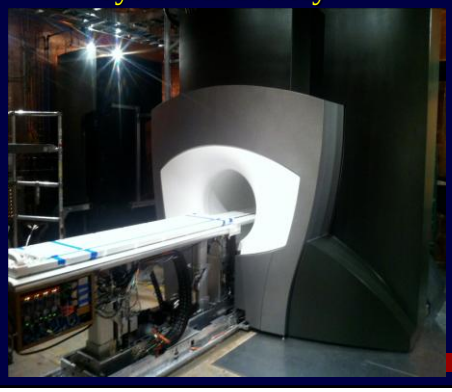
System in factory



Factory testing

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Viewray Baseplate – Wash U 7/2011

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Viewray magnet – Wash U 7/2011

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ViewRay – Current Status

• Treatment Planning System	FDA 510K cleared
• Imaging System	FDA 510K Submitted
• Delivery system	FDA 510K Submitted
• First Installation	Washington University ongoing

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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?

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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.

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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

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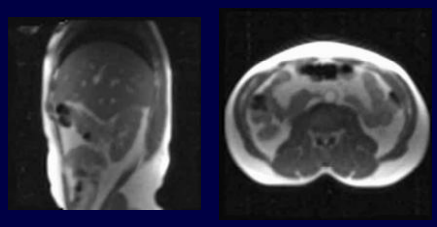
Abdomen



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

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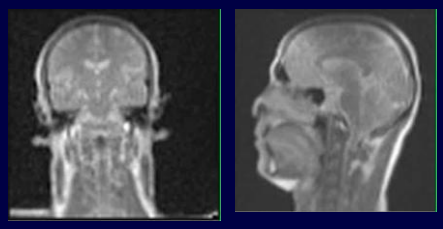
CNS



- Gating on optic nerves or swallowing structures?

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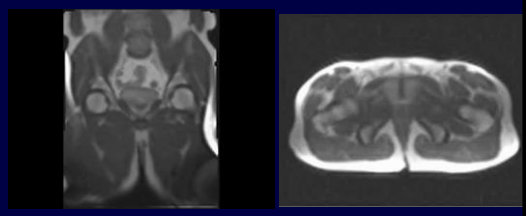
Pelvis



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

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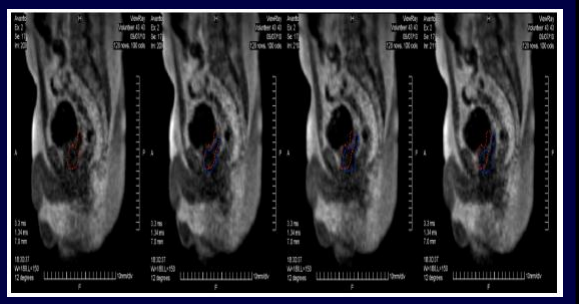
Prostate – real time MRI



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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

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Viewray tracking implementation

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Conclusions

- MRI tracking has great potential for radiation therapy; but should be developed with exisiting 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 .

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Prostate localization movie