MRI Applications in Radiation Oncology: 
Physician’s Perspective

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Disclosures

- Washington University has research and service agreements with Viewray Inc.

- I have no personal financial conflict of interest as a result of above
Goals

• Describe utility and limitations of MRI for radiotherapy treatment planning from clinical perspective

• Illustrate how MRI may guide evaluation of treatment response in the clinic during or post-treatment

• Understand potential clinical utilization of MR based treatment localization & delivery
Clinic Wishlist for MR Guided RT

• MR incorporation for simulation & treatment planning allows reproducible millimeter accuracy in soft tissue definition

• Functional imaging (DCE/DWI) allows dose painting to high risk tumor volume for greater tumor control

• MR OBI allows target and critical structure localization & tracking based on gold-standard anatomy rather than fiducial, bony anatomy or other surrogate

• Intra-fraction anatomic and functional imaging allows early evaluation of tumor response and adaptive treatment escalation or de-escalation to improve tumor control or treatment toxicity
MRI: 3 Distinct RT Applications

• Treatment Planning
  – Accurate target delineation (typically GTV or tumor bed)
  – Functional imaging to define high risk volume

• Treatment Response
  – During or post-treatment

• Treatment localization & delivery
Treatment Planning
Treatment Planning: CT vs MRI

• CT Advantages
  – Electron density information → dose calculation
  – Improved target definition for selected cases (e.g. lung)
  – Established motion management technique (4DCT)
  – Lower cost

• MRI Advantages
  – Excellent soft tissue contrast, sequences optimized to highlight target
  – Target definition: Increased accuracy of target structure
  – DWI/DCE: Physiologic accuracy of high/low risk target function
Adoption of IGRT by US Radiation Oncologists

2009 MR Utilization: 73%

Disease Sites:
1) CNS
2) H&N
3) GU

Simpson et al, J Am Coll Radiology 2009
Treatment Planning: CNS

- High grade tumors typically contrast enhance
- T2/FLAIR → edema and microscopic extension
- When resectable, include post-op imaging
Treatment Planning: H&N

- Delineate GTV
- Determine extent of tumor invasion, perineural invasion

Treatment Planning: Prostate

- Decrease inter-observer variability
- Decrease volume of CTV
- Visualization of capsule, anterior rectal wall

Khoo et al, Br J Radiol 2006
Treatment Planning: Liver SBRT

- 63 yo with HCC planned for liver SBRT
- T1 post contrast image used for contouring, fused as secondary image
- GTV = Green
Liver SBRT: CT Fusion
Liver SBRT: CT Fusion

High quality image does not compensate for poor quality fusion or absence of motion management
Treatment Planning: Limitations

- MRI does not allow for reduced PTV (motion) margin
  - Greater precision in target delineation requires increased vigilance
  - Ex: Improved visualization of prostate does not reduce target motion

- Accurate fusion required to incorporate MRI for planning
  - Could be solved in part by MR primary simulation

- Must account for deformation of both target & critical structures (e.g. bladder, rectum) on MRI compared to primary dataset
Treatment Response
MRI For Treatment Response

- **GYN (Cervix):**
  DWI/DCE predicts response to definitive chemoRT

- **GI (Rectum):**
  DWI predict response to neoadjuvant chemoRT

- **CNS:**
  MR Perfusion/MRS Distinguish progression vs pseudoprogression
Treatment Response: GYN

- Functional (DCE) MRI used to predict response to definitive chemoRT for cervical cancer
- Better prediction for functional DCE than anatomic T2 risk volume

Mayr et al, IJROBP 2012
Treatment Response: GYN

- Favorable tumor control also predicted by resolution of diffusion restriction during RT

Olsen et al, ASTRO 2011
FDG-PET/ADC-MRI Concordance for GYN

Olsen et al, JMRI 2013
Resolution of restricted diffusion during preop RT predicts rectal cancer pathologic response

Lambrecht et al, IJROBP 2011
Progression or Pseudo-progression?

- 1/3 of glioma pts may develop pseudo-progression
- MR Perfusion/rCBV may be helpful to distinguish

Sugahara et al, AJNR 2000
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Low rCBV
Necrosis confirmed by biopsy

Sugahara et al, AJNR 2000
MR Guided Localization & Delivery
Treatment Localization & Delivery

• Technical considerations and tradeoffs covered elsewhere

• Clinically, how might one use an ideal machine for MRI guided radiotherapy (localization & tracking)?
MR Guided RT: Localization

- Based on soft tissue rather than bony anatomy or fiducial marker
  - Allow localization directly to target (pancreas tumor, yellow) or critical structures (duodenum, green)
MR Guided RT: Localization

- Gain information on accumulated dose for critical structures with significant interfraction variability (e.g. bowel), or at risk for complication (spinal cord)
  - Escalate or de-escalate dose based on complication risk
MR Guided RT: Localization

- May allow new ways to detect when re-plan required
- Emerging data suggests glioblastoma progression prior to RT initiation may occur up to 1/3 of cases
  - Not visualized using CBCT

Farace et al, J Neurooncol 2013
MR Guided RT: Tracking

- Real-time cine visualization of target or normal structures for MR based gating
- Example: Liver
MR Guided RT: Tracking

- Real-time cine visualization of target or normal structures for MR based gating
- Example: Lung
MR Guided RT: Tracking

- Real-time cine visualization of target or normal structures for MR based gating
- Example: H&N
MR Guided RT: Tracking

- Clinical & physics collaboration required to determine tracking feasibility and clinical benefit
  - Optic nerve?
  - Penile bulb?
  - Bowel?
Take Home Points

- Treatment planning
- Treatment response evaluation
- Treatment localization/delivery

Three distinct MR applications with unique clinical benefits and technical challenges

- T1/T2 $\rightarrow$ Spatial delineation of target structure
- DWI/DCE $\rightarrow$ Physiologic delineation of high/low risk target
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