CONNECTING LIFE AND SCIENCE

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

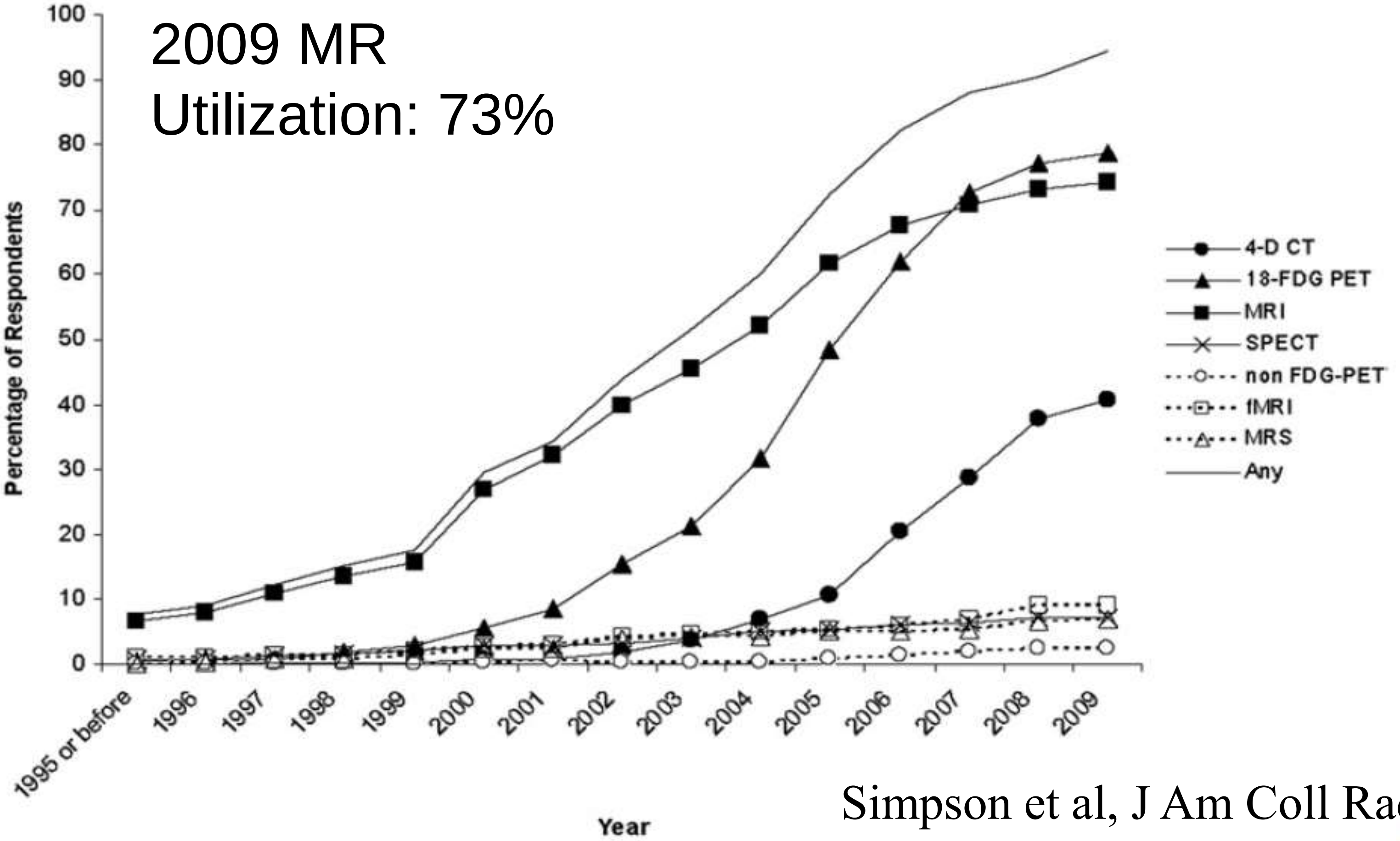
Treatment Planning

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

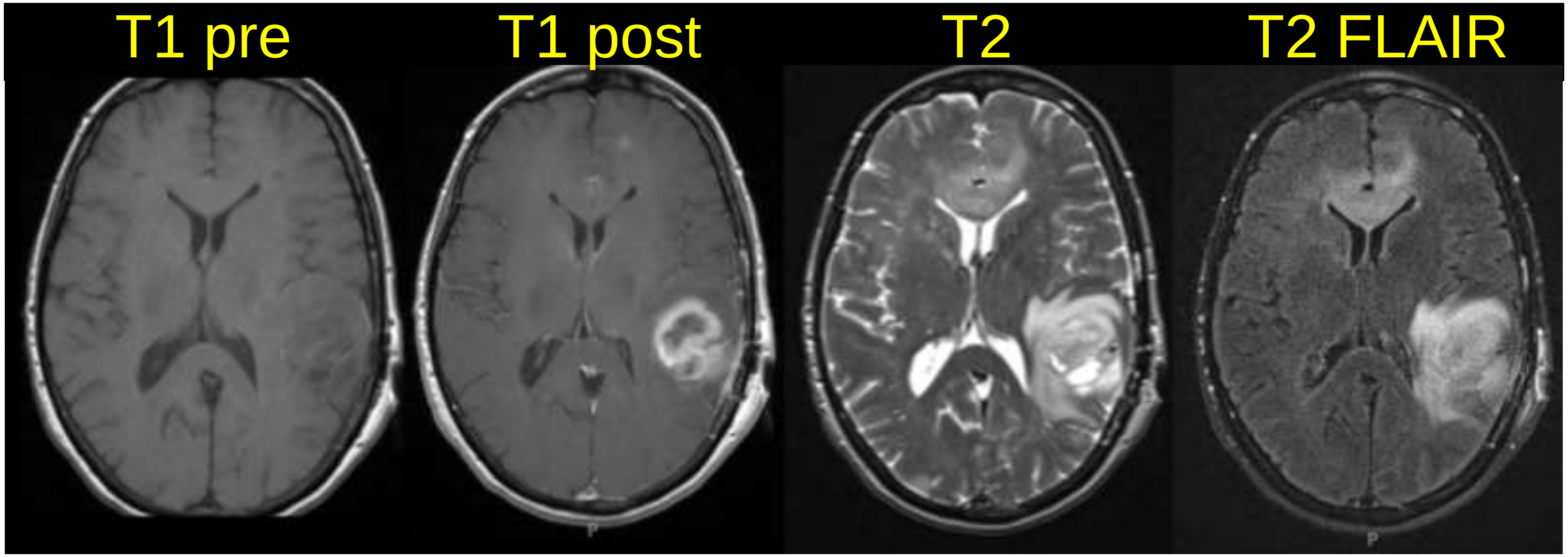
2009 MR
Utilization: 73%



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

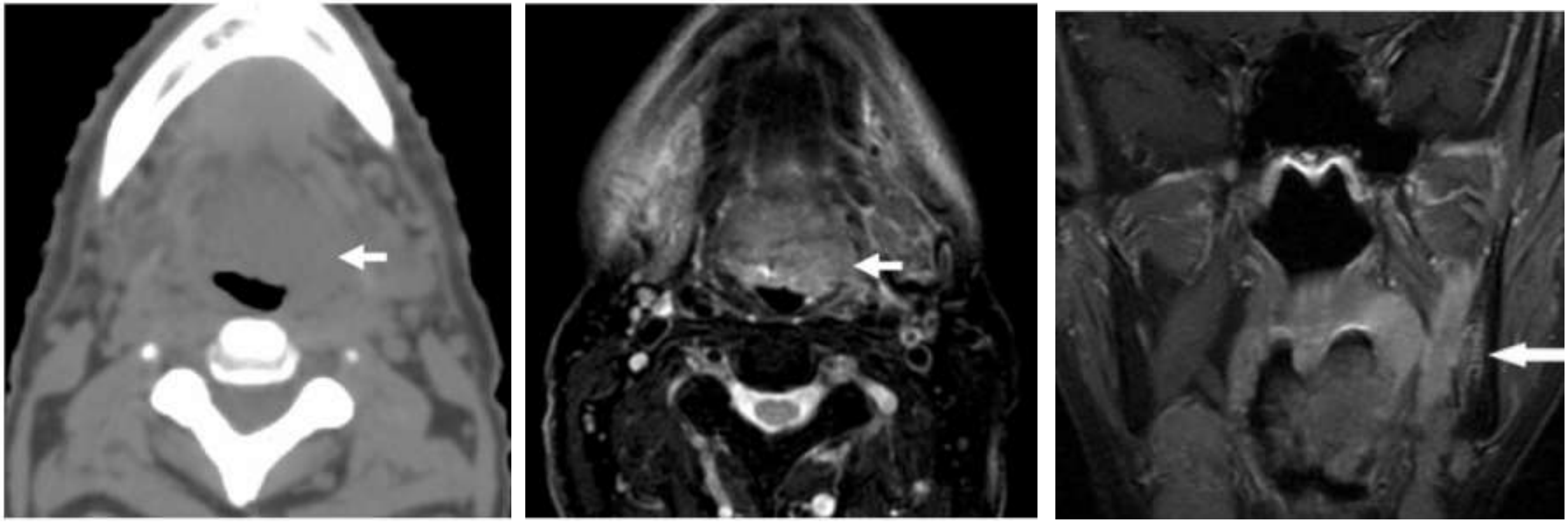
Simpson et al, J Am Coll Radiology 2009

Treatment Planning: CNS



- High grade tumors typically contrast enhance
- T2/FLAIR →edema and microscopic extension
- When resectable, include post-op imaging

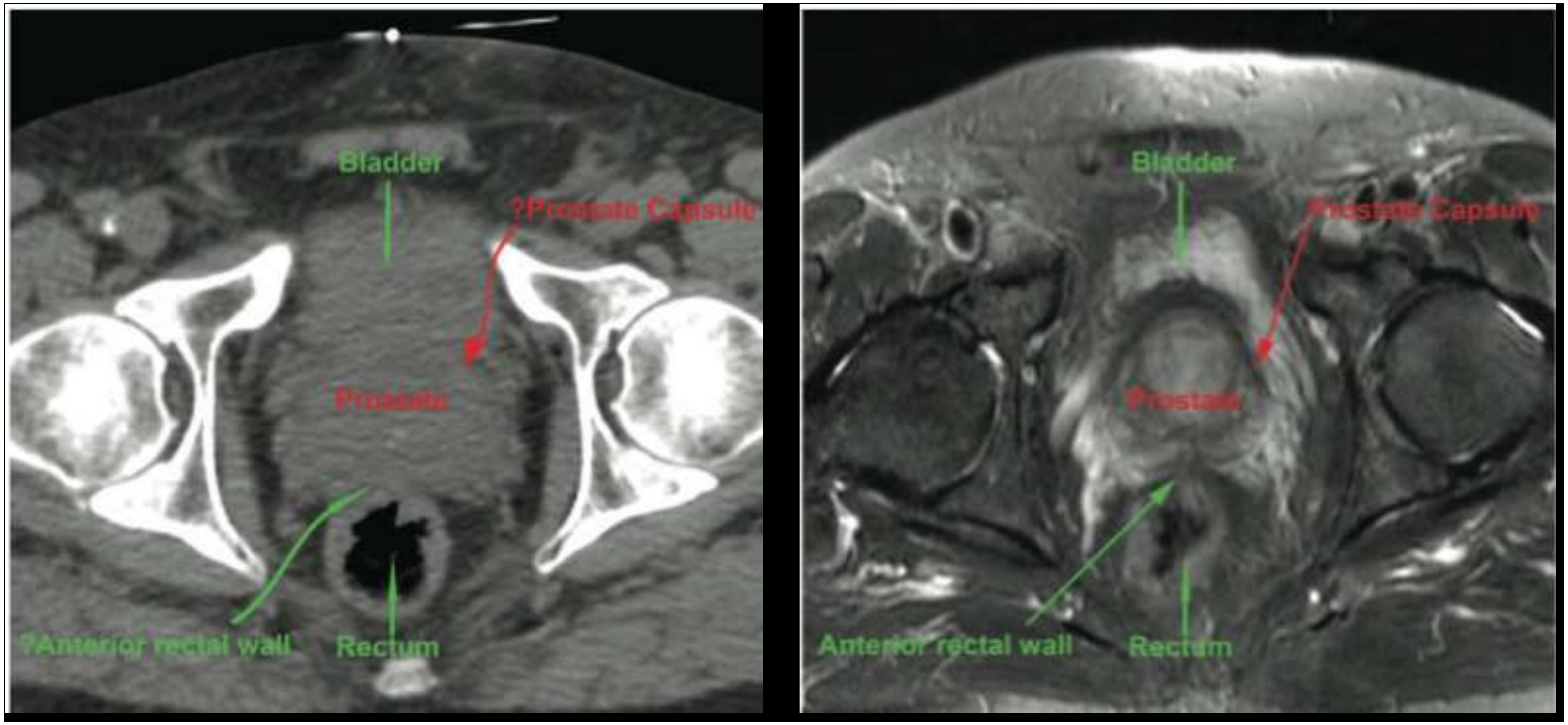
Treatment Planning: H&N



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

Khoo et al, Br J Radiol 2006, Shimamoto et al, DMFR 2012

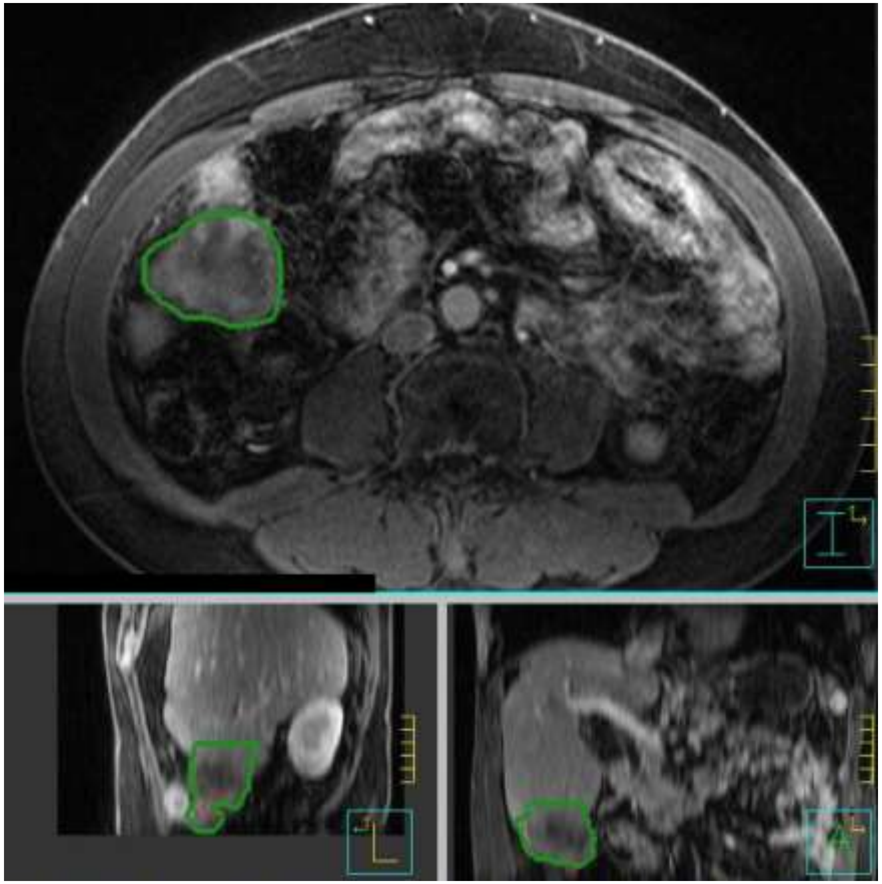
Treatment Planning: Prostate



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

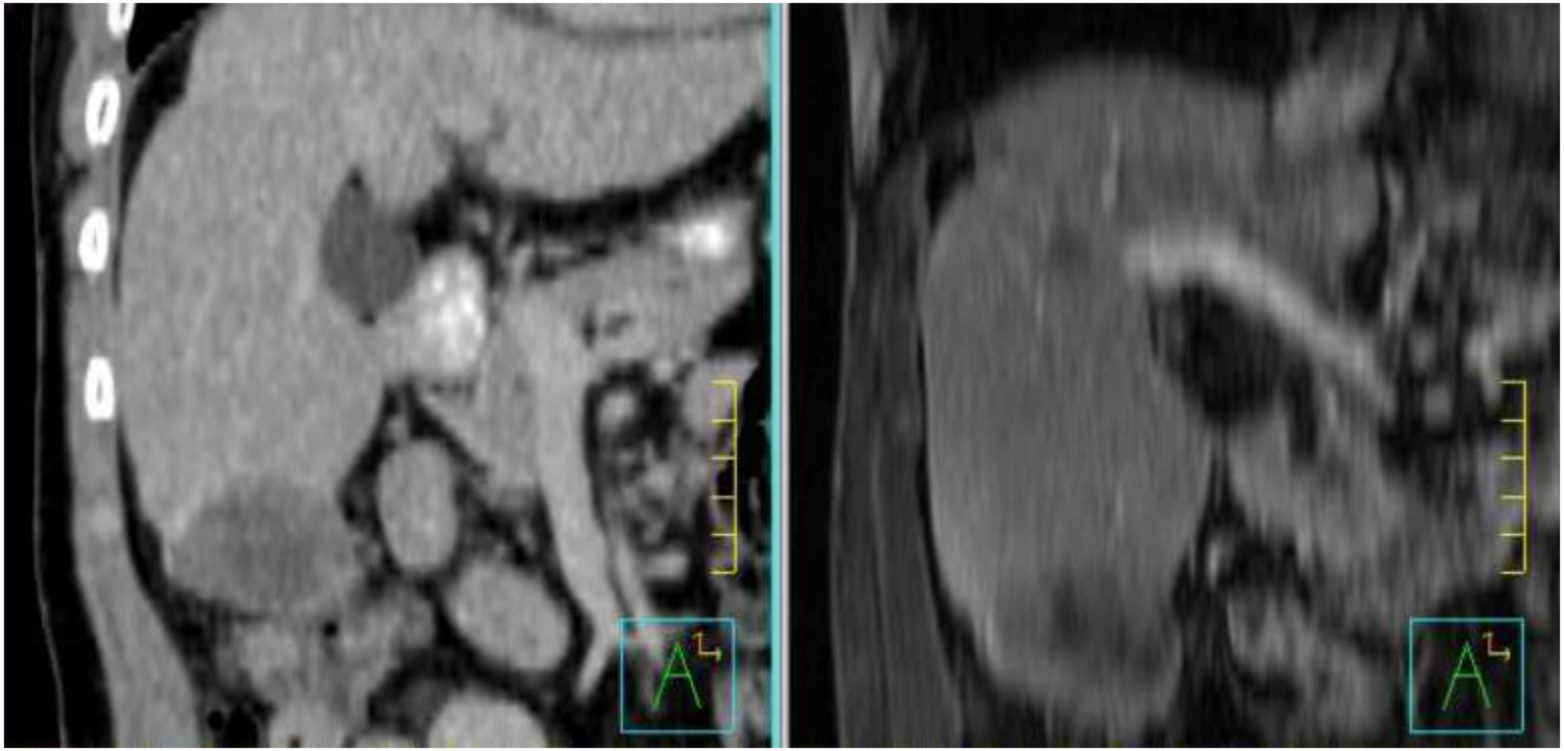
Khoo et al, Br J Radiol 2006

Treatment Planning: Liver SBRT

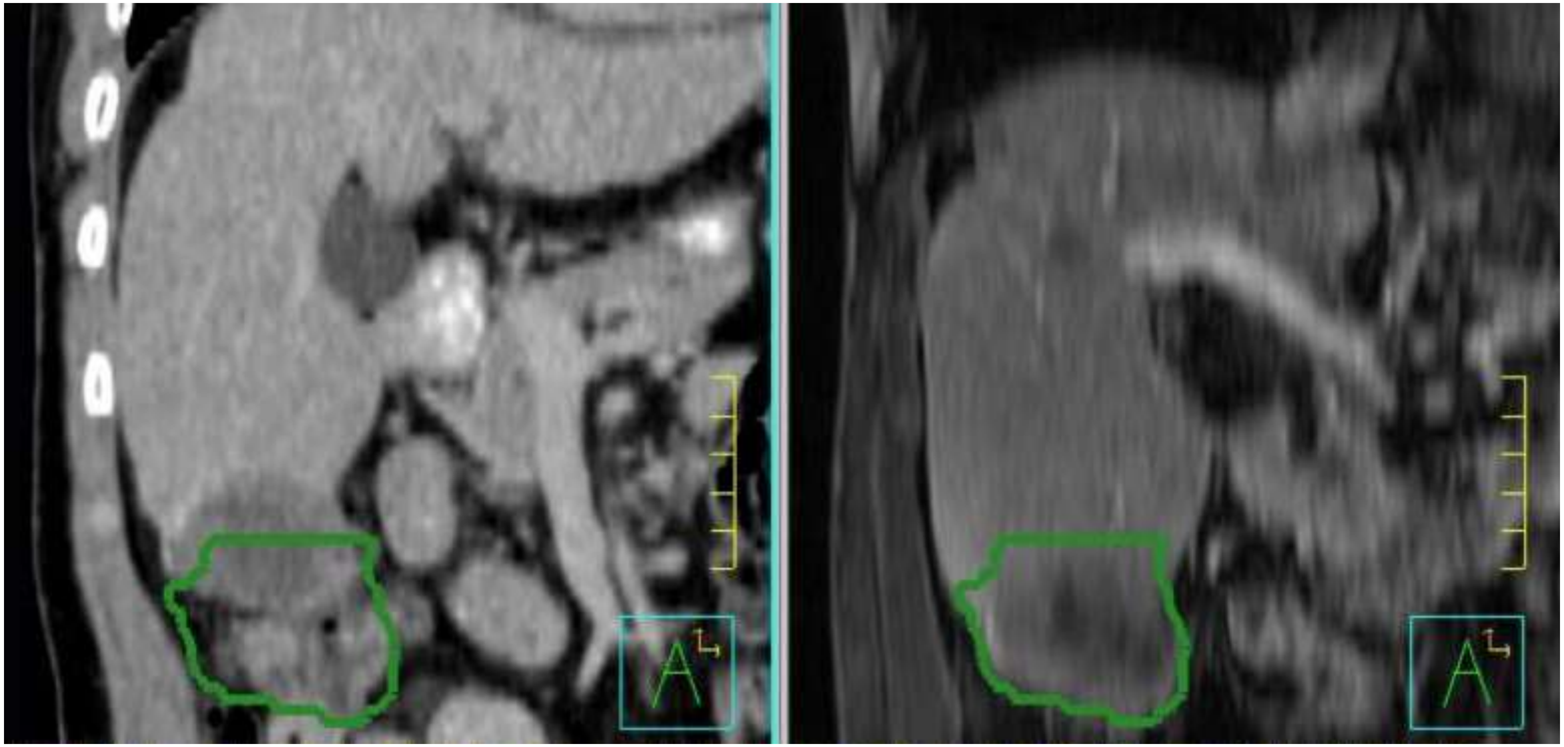


- 63 yo with HCC planned for liver SBRT
- T1 post contrast image used for contouring, fused as secondary image
- GTV = Green

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

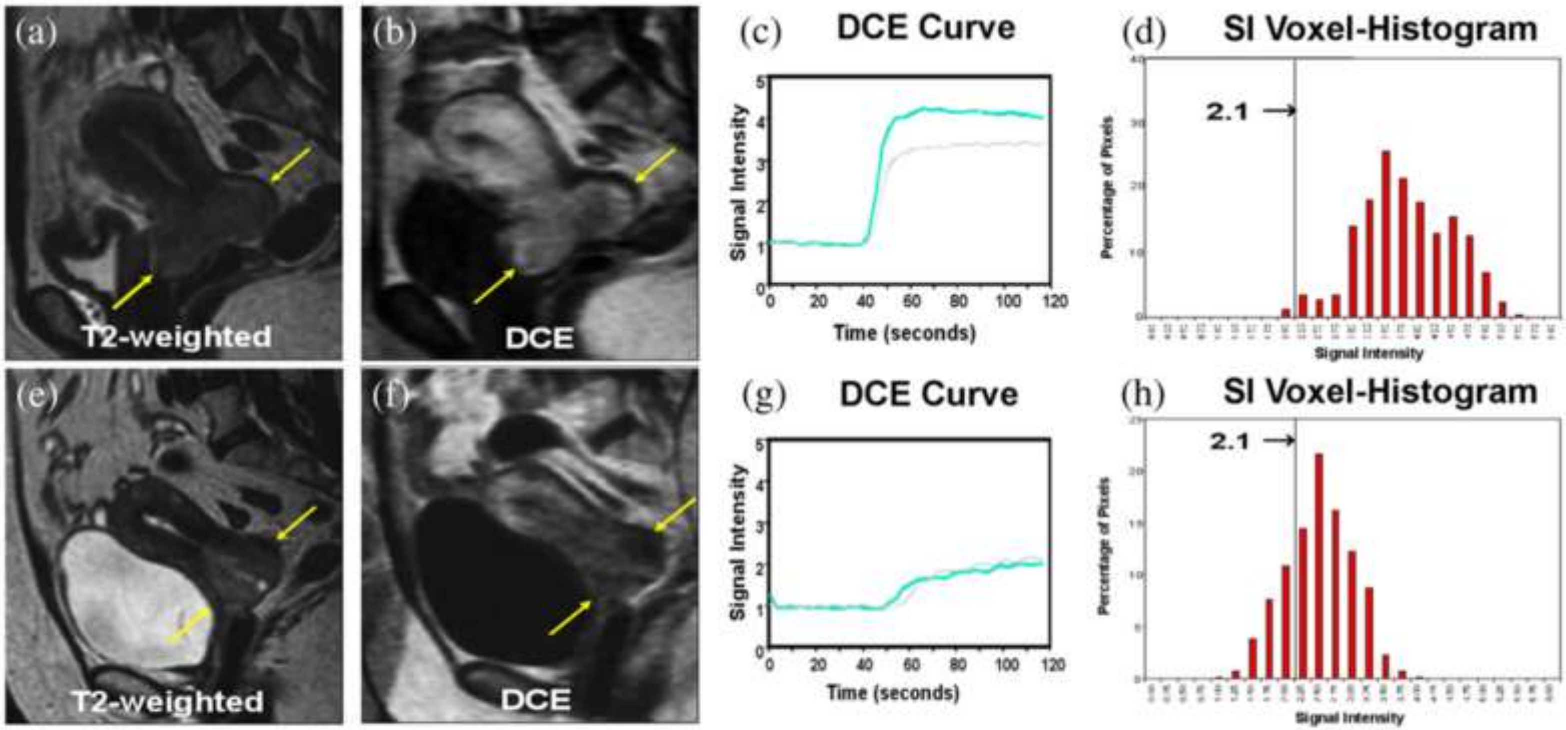
- MRI does not allow for reduced PTV (motion) margin
  - Greater precision in target delineation requires increased vigilance
  - Ex: Improved visualization of prostate does not reduce target motion
- Accurate fusion required to incorporate MRI for planning
  - Could be solved in part by MR primary simulation
- 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

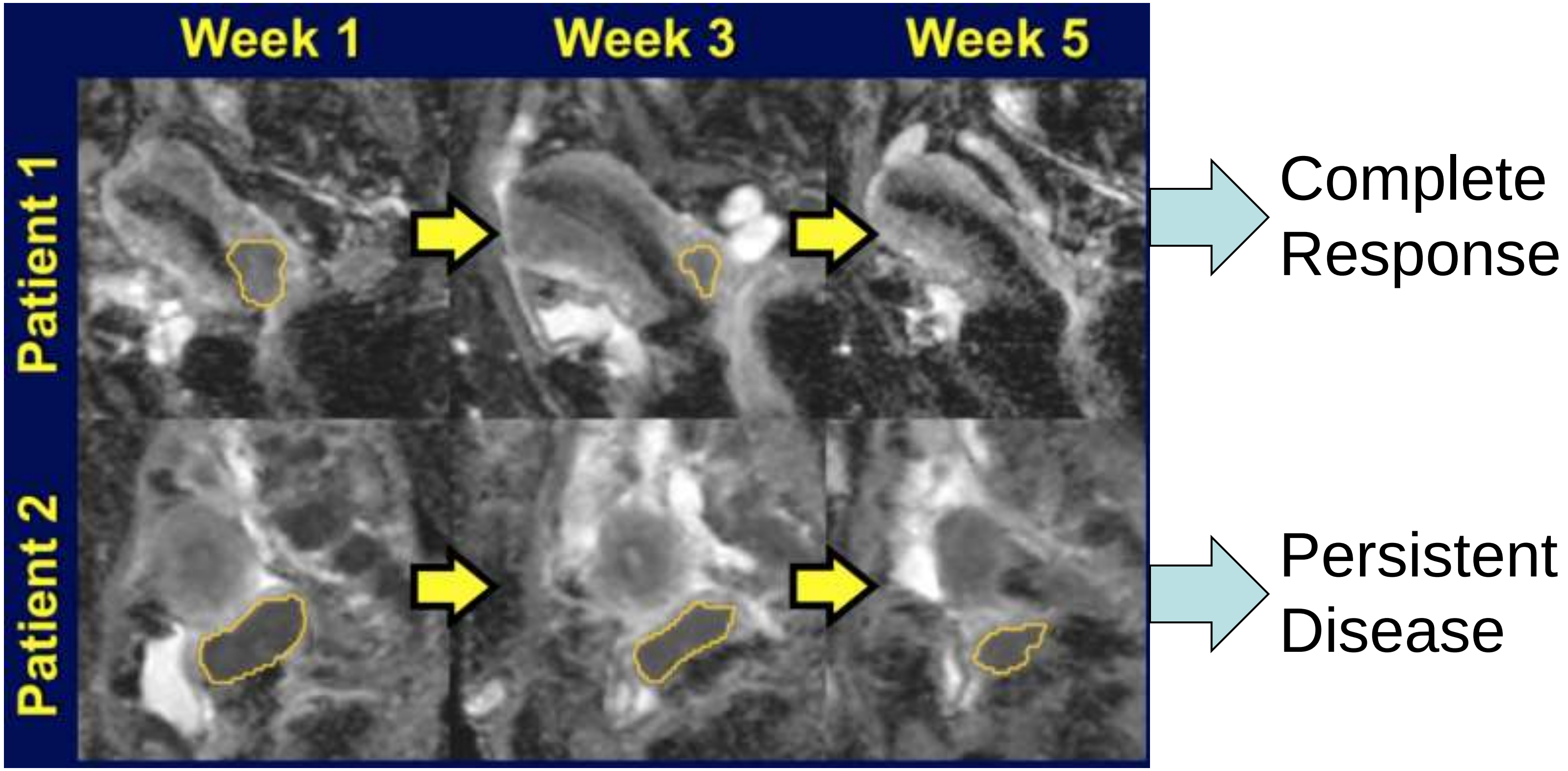
Treatment Response: GYN



- 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

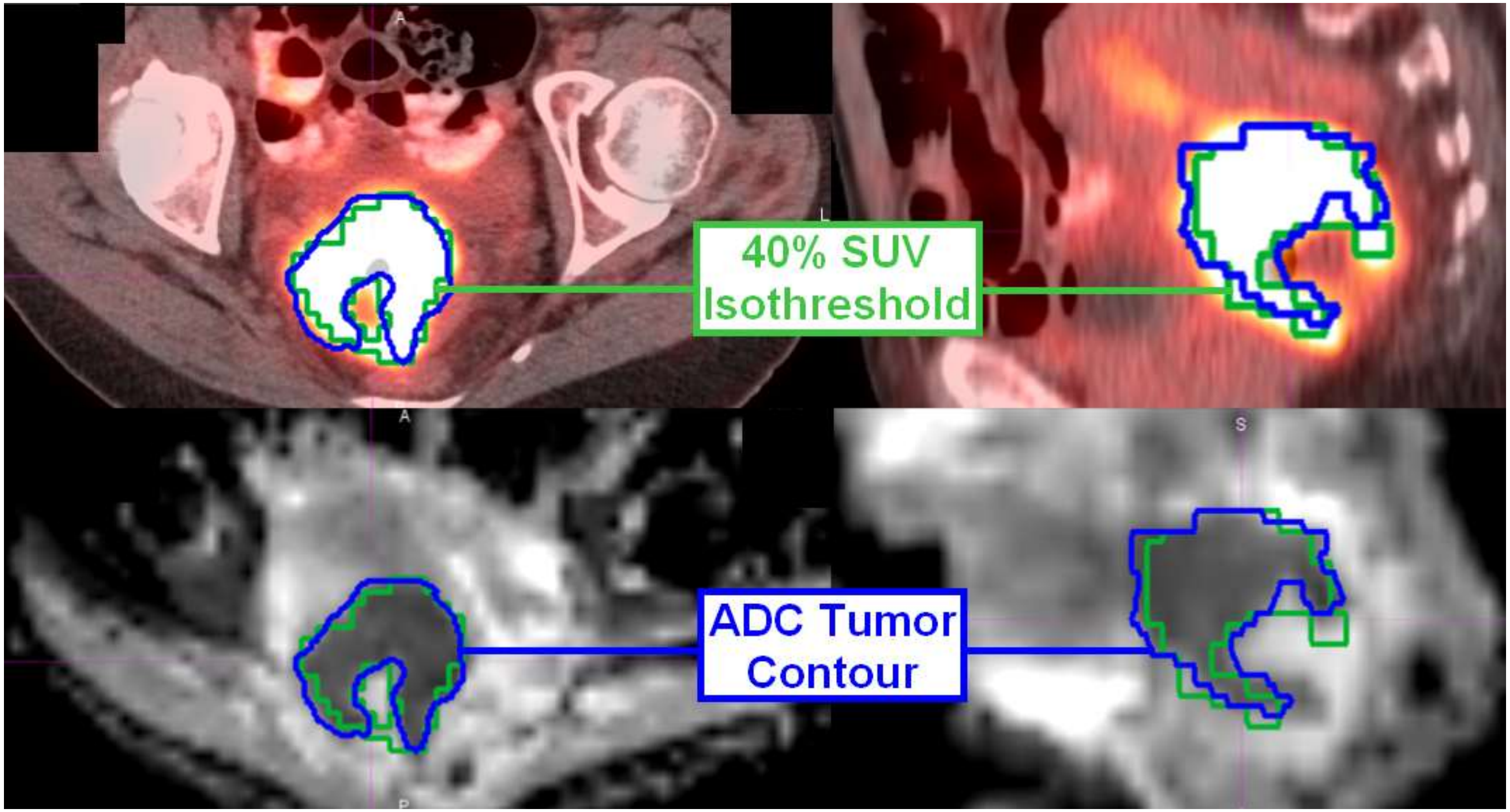
Treatment Response: GYN



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

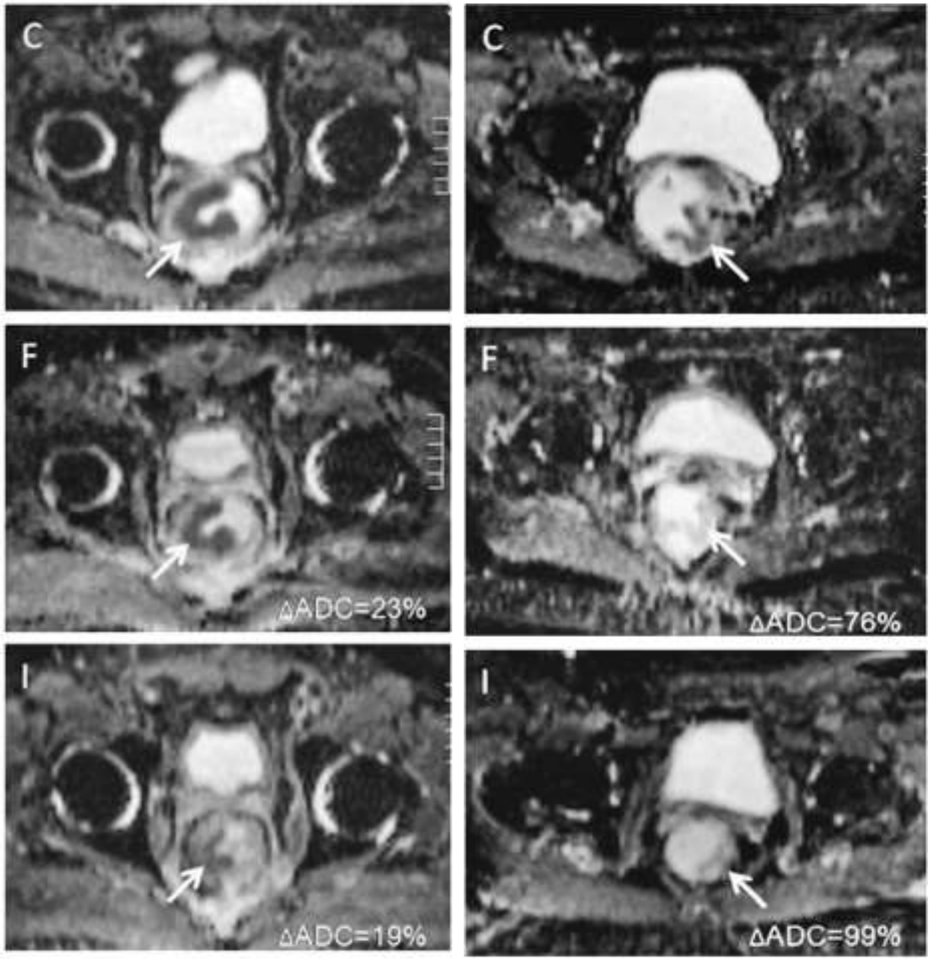
Olsen et al, ASTRO 2011

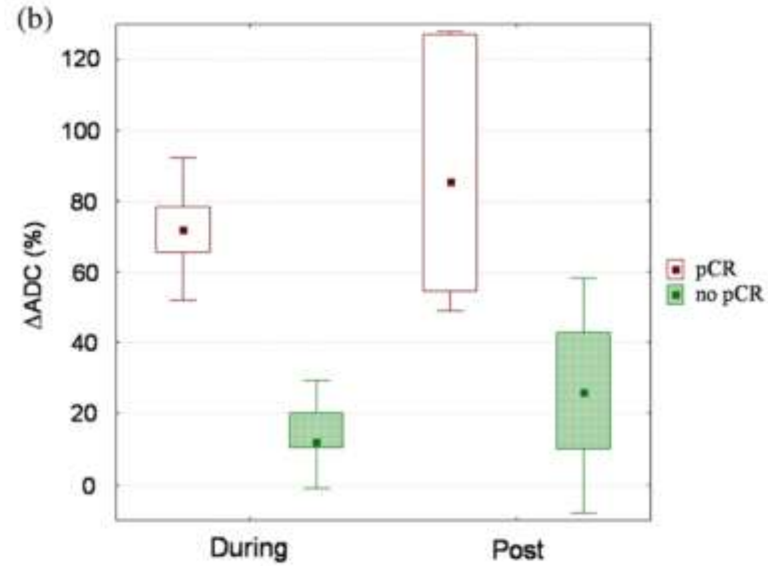
FDG-PET/ADC-MRI Concordance for GYN



Olsen et al, JMRI 2013

Treatment Response: GI

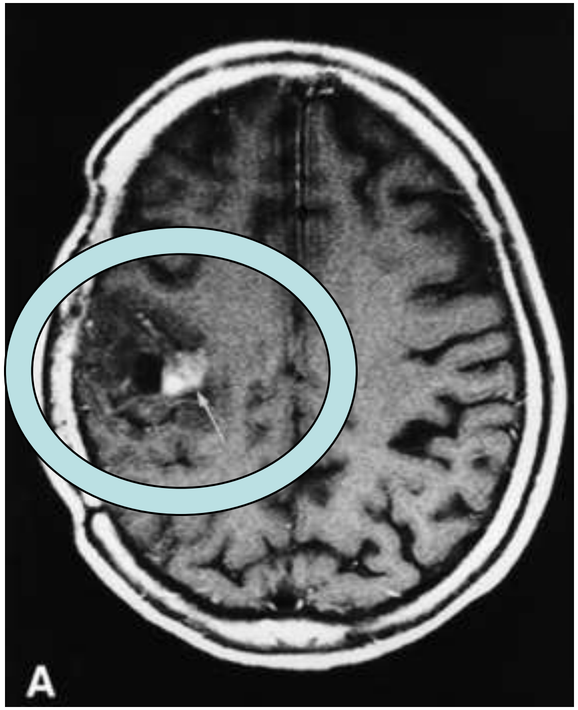




Resolution of restricted diffusion during preop RT predicts rectal cancer pathologic response

Lambrecht et al, IJROBP 2011

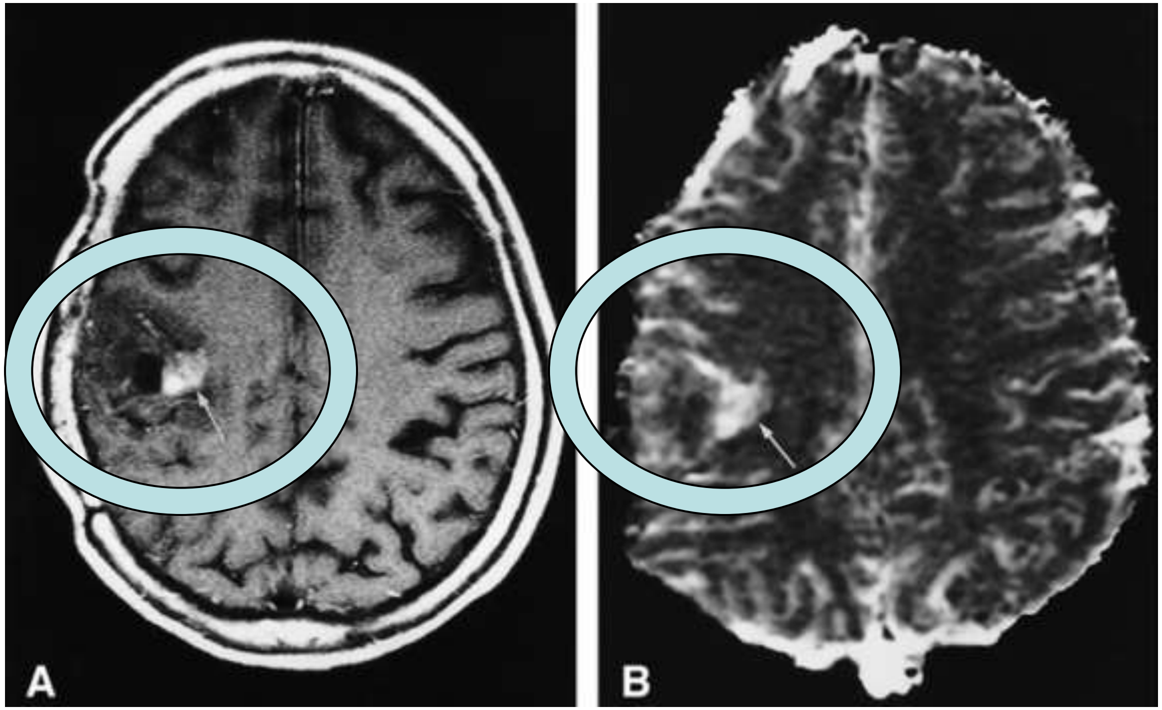
Progression or Pseudo-progression?



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

Sugahara et al, AJNR 2000

Progression or Pseudo-progression?



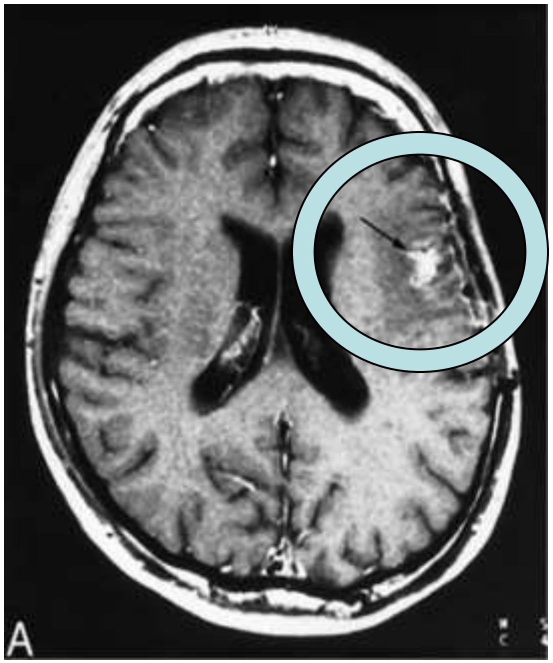
High rCBV

Recurrence confirmed by resection

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

Sugahara et al, AJNR 2000

Progression or Pseudo-progression?



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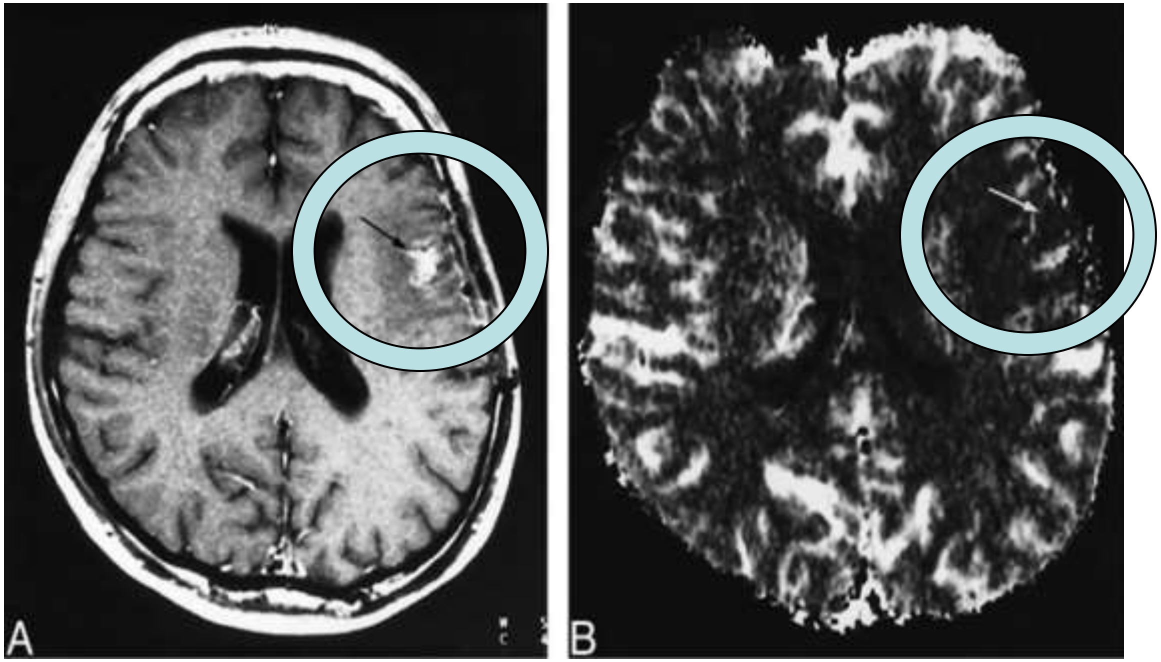


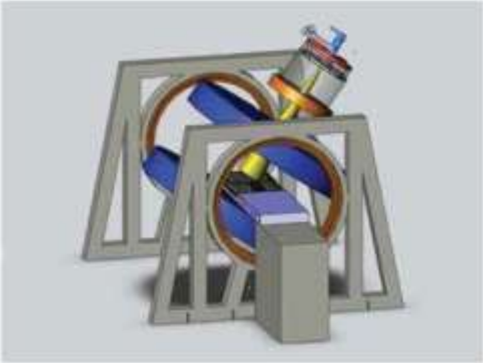
Low rCBV

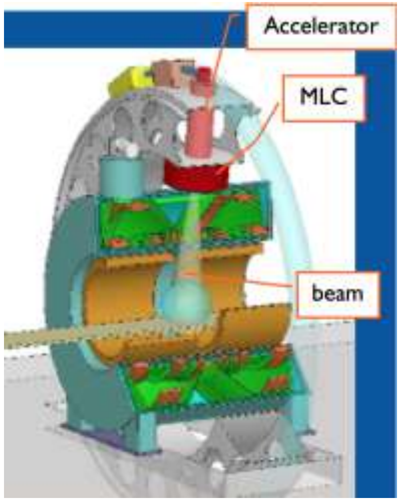
Necrosis confirmed by biopsy

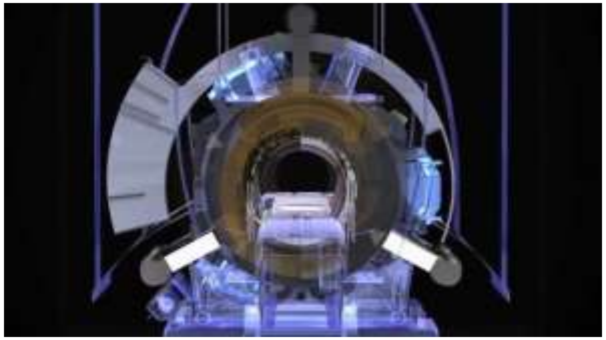
- 1/3 of glioma pts may develop pseudo-progression
- MR Perfusion/rCBV may be helpful to distinguish

Sugahara et al, AJNR 2000

MR Guided Localization & Delivery



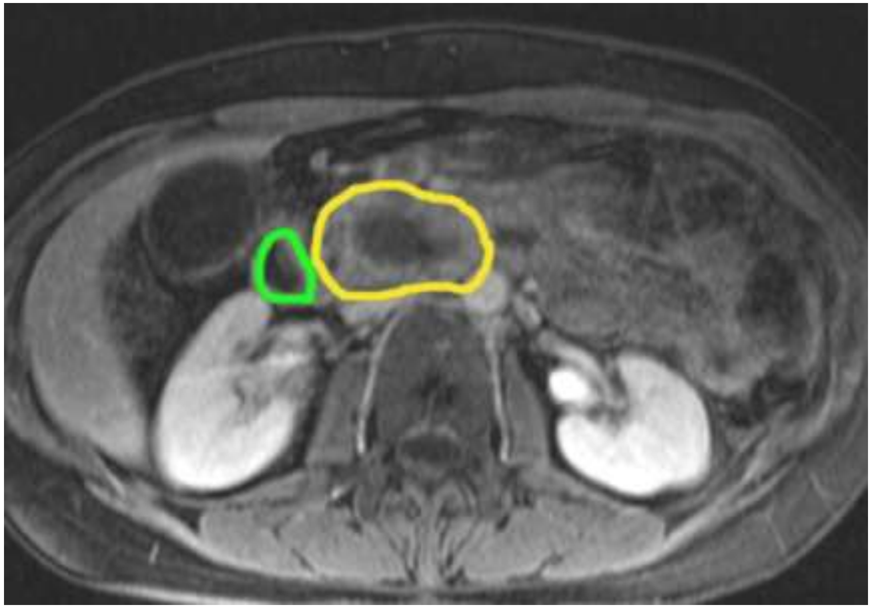




Treatment Localization & Delivery

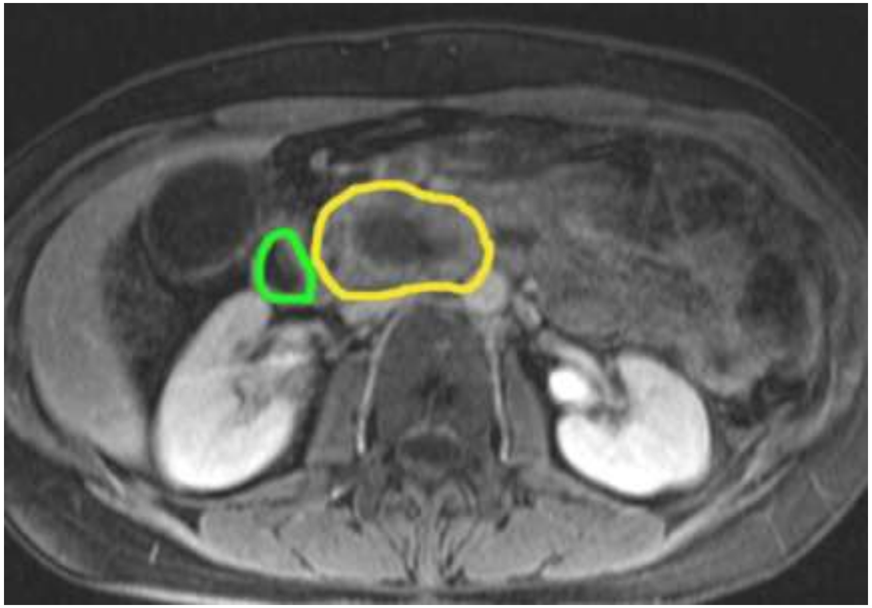
- Technical considerations and tradeoffs covered elsewhere
- Clinically, how might one use an ideal machine for MRI guided radiotherapy (localization & tracking)?

MR Guided RT: Localization



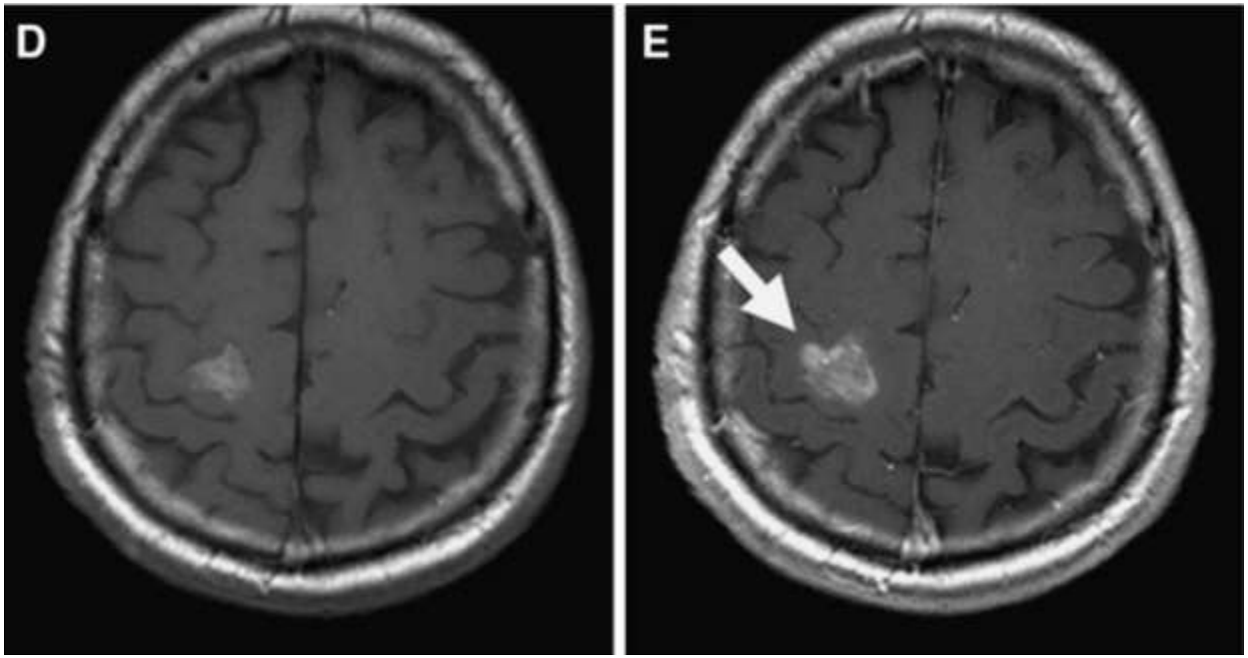
- Based on soft tissue rather than bony anatomy or fiducial marker
  - Allow localization directly to target (pancreas tumor, yellow) or critical structures (duodenum, green)

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

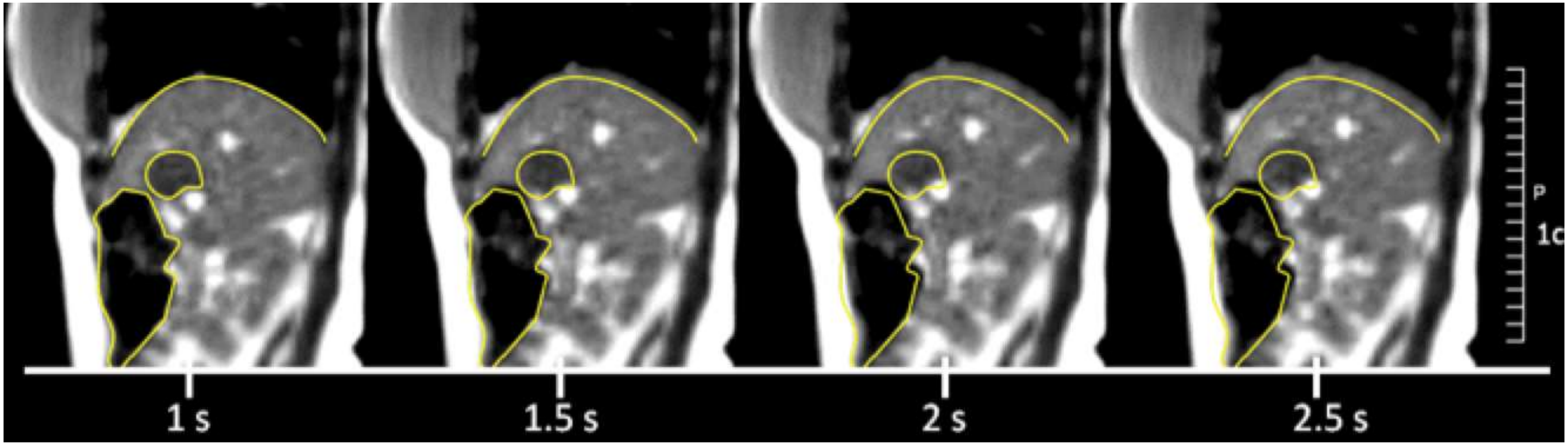


- May allow new ways to detect when re-plan required
- Emerging data suggests glioblastoma progression prior to RT initiation may occur up to 1/3 of cases
  - Not visualized using CBCT

Farace et al, J Neurooncol 2013

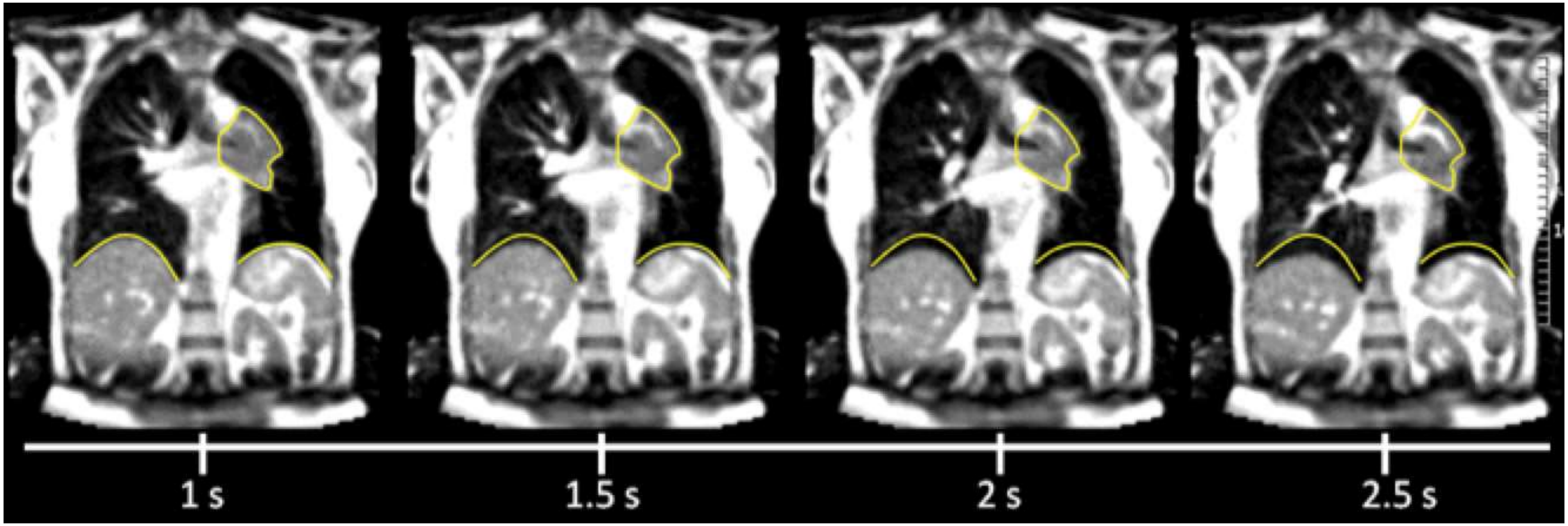
MR Guided RT: Tracking

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



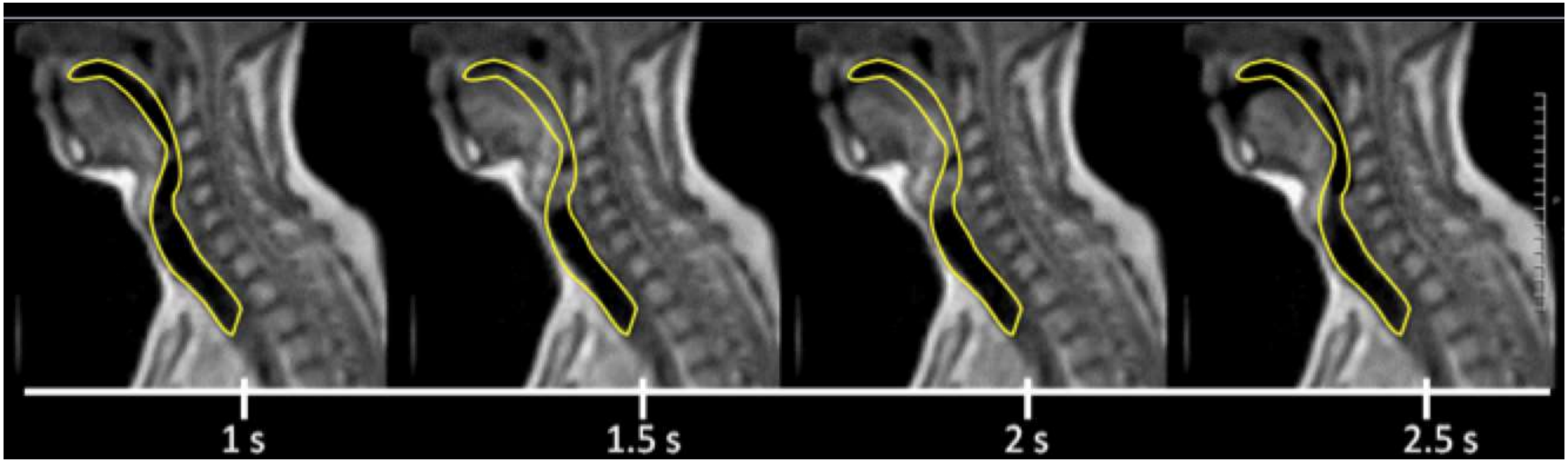
MR Guided RT: Tracking

- 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?
  - P

Take Home Points

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

Three distinct MR applications with unique clinical benefits and technical challenges

- T1/T2 → Spatial delineation of target structure
- DWI/DCE → Physiologic delineation of high/low risk target

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