On-board MRI for Treatment Verification

O. L. Green, Ph.D.

MRI (0.35T) vs CBCT

Challenges of MRI – Linac Integration

- Dosimetry:
  - Magnetic field influences path of electrons, affecting dose distribution (especially at heterogeneous tissue boundaries)

- Image Quality:
  - Linac components may influence both field homogeneity (spatial integrity) and signal-to-noise ratios

- Additional patient concerns:
  - Presence of ferromagnetic materials in the body
  - Claustrophobia
  - Duration of treatment session
  - Patient heating (SAR)
Current Commercially-Available MRgRT Systems

1.5T (Elekta Unity) 0.35T (ViewRay MRIdian)

- On-board Volumetric MRI imaging
- Real-time cine imaging during treatment

0.35T MRgRT Utilization at Washington University


0.35T MRgRT Utilization at Washington University

Outline

• Localization
• Adaptation
• Response prediction via functional imaging
Accelerated Partial Breast Irradiation with 0.35T MRgRT:


- Treated breast volume has been shown to correlate with adverse cosmetic outcomes in APBI
  - Jagi et al, IJROBP, 2010

- MRgRT allows for accurate setup and gating – therefore, why not reduce the treated volume?

Accelerated Partial Breast Irradiation with 0.35T MRgRT:


- Prospective trial:
  - Single Fraction APBI for Low-risk Stage 0 and I Breast Carcinoma
  - PI: I. Zoberi, MD
  - Primary objective:
    - Incidence of acute and late Grade 3+ CTCAE toxicity
    - Inclusion:
      - 50 women with low-risk, stage 0-1 breast carcinoma with negative margins after lumpectomy
    - Prescription:
      - 20 Gy to cavity surface; 70 Gy to 1cm margin around cavity (replicate brachytherapy dose distribution)
Accelerated Partial Breast Irradiation with 0.35T MRgRT:


- Accrual completed in early 2018
- 1 patient with grade-2 chestwall pain
- No reduction in patient-reported QOL
- Excellent-to-good cosmesis:
  - 97% and 100% pretreatment
  - 97% and 100% at 8 weeks
  - 100% and 100% at 6 months
  - Radiation oncologist vs. patient

MRI-only APBI: Current Process

MRI-only APBI: New Process

Slide courtesy of Areti Marko, APRT
MRI-only APBI – Dosimetric Analysis

- 18 patients from Jan 2019 through June 2019
- Open FOV 1.5T MRI rather than previously used half scan, used as primary
- CT performed as a secondary scan
- Two plans generated
- Bulk-density overrides
- CT fused as secondary and calculated on
- D95 and Max doses

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CONVENTIONAL (CT) PLANNING

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<th>PTV Ipsilateral Breast</th>
<th>PTV Ipsilateral Lung</th>
<th>PTV Heart</th>
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<tr>
<td>D95 (%)</td>
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Oligometastatic lymph nodes with 1.5T MRgRT

- 10 patients: 7 pelvic, 3 para-aortic
- median short-axis diameter: 7.5 mm [5.3–21.3 mm]
- Rx 35 Gy

Slide courtesy of Areti Marko, APRT
Oligometastatic lymph nodes with 1.5T MRgRT

- Results:
  - All lesions were well-visualized on MRI
  - For 45 of the 50 fractions (90%) the GTV V35Gy on the post-delivery MRI remained 100%

Outline

- Localization
- Adaptation
- Response prediction via functional imaging

Adaptive Workflow – Elekta Unity
Adaptive Workflow - Elekta Unity

Done with couch movement and segment weight optimization on ViewRay based on daily 0.35T MRI


First Prospective Online Adaptive Radiotherapy Trial 0.35T:


- 20 patients, unresectable primary or oligometastatic disease
  - liver (n = 10) & non-liver (n=10) abdomen
- Prescription: 50Gy/5fx (BED=100) with SMART approach
  - using real-time cine MR gating with end-exhale breathhold for volumetric imaging
- Isotoxicity approach
  - dose escalation (or de-escalation) based on strict OAR constraints

First Prospective Online Adaptive Radiotherapy Trial 0.35T:


- 83% (79/95) fractions adapted
  - all patients had at least one adaptation during course of treatment
- Plans adapted for 64% of liver & 98% of non-liver abdomen fx
- Initial plans would have violated OAR constraints in 70/95 fx
- 100% of OAR violations resolved with adaptive planning

- No Grade 3+ toxicity at median 11.8 mo f/u
  - Expected up to 30% based on prior reports accounting for motion (Hoyer, et al. 2005)
- No change in patient-reported quality-of-life scores (P=0.29)
- 95% and 90% control of treated lesions at 3 and 6 months by RECIST criteria

Evaluated overall on-table time to establish feasibility
- Median time 79 min

2018: Introduced Advanced Practice Radiation Therapist Position
- Responsible for contouring of organs-at-risk
- Aids in workflow and process improvement
- Significantly reduced physician time at machine
- Maintain quality and consistency of contouring


- Unresectable primary or oligometastatic disease of the ultra-central thorax
  - 5 patients
- Prescription: 50Gy/5fx with SMART approach
- Isotoxicity approach
  - with dose escalation (or de-escalation) based on hard OAR constraints
Pilot/Phase I Trial for Ultra-Central Thorax:


- 10/25 fx adapted
  - 4/5 patients adapted at least once

- Reasons for adaptation:
  - 30% of adaptation performed to improve PTV coverage
  - 70% of adaptation performed to reverse unintended OAR violations

- 100% of OAR violations resolved with adaptive planning

- Local control by RECIST criteria was 100% at three and six months

- Zero Grade 3+ acute (within 6 months) treatment-related toxicities observed

Initial Clinical Experience 1.5T:

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Outline

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DWI using 0.35T

- Three patients with primary rectal adenocarcinoma
- One of the patients showed little evidence of response via pathological assessment, which corresponded to a high initial ADC value and decreasing ADC values measured over the 1st half of treatment
Future Directions

• MRgRT workflow optimization
• Response prediction
• Functional imaging for adaptation
• Real-time dose accumulation