Clinical Implementation of MRI for Gynecologic HDR Brachytherapy

Joann I. Prisciandaro, PhD
joannp@med.umich.edu
Disclosures

• None
Learning Objectives

1. Understand the rationale for implementing MR in high dose rate (HDR) brachytherapy (BT) for gynecologic cancer.

2. Understand the process of commissioning, QA, and clinical implementation of MR into HDR BT.

3. Discuss workflow options for implementing MR into HDR BT.
Imaging Modalities used for BT (GYN)

- kV radiograph
- CT
- 3D T2W MR (3T)
Rationale for Implementing MRI into HDR BT

- Compared to CT, MR provides:
  - Superior soft tissue resolution
  - Clear distinction of target(s) from organs at risk (OAR) - improved OAR sparing and dose escalation to targets

- Cervical BT
  - Ability to develop conformal volumetric based planning
  - Ability to generate adaptive plans

AAPM TG 303, under review Med Phys.
Rationale for Implementing MRI into HDR BT

- GEC ESTRO Report I (Haie-Meder et al.)
- GEC ESTRO Report II (Potter et al.)
- GEC ESTRO Report III (Hellebust et al.)
- GEC ESTRO Report IV (Dimopoulos et al.)

J.C.A. Dimopoulos et al., Radiother Oncol 2012, 103: 113 – 122
ICRU 89 Report – Prescribing, recording, and reporting BT for cancer of the cervix
  - Committee consisted of members from ABS and GEC-ESTRO
  - Provides description of the use of volumetric imaging for the cervix with the addition of 4D adaptive target concepts, radiobiology, and DVH parameter reporting for target and OARs.

• Based on the American Brachytherapy Society practice pattern survey of cervical brachytherapy, there has been an increased in utilization of MR with brachytherapy from 2% in 2007 to 34% in 2014.

However...

- Recommendations were based on experience of a few key European institutions using magnetic field strengths that did not exceed 1.5T.
AAPM Task Group 303

MRI Guidance in HDR Brachytherapy - Considerations from Simulation to Treatment

1. Firas Mourtada (Chair) – Christiana Care Hospital
2. Joann Prisciandaro (Vice-Chair) – University of Michigan
3. Gil’ad Cohen – Memorial Sloan Kettering Cancer Center
4. Ken-Pin Hwang – MD Anderson
5. Perry Johnson – University of Florida Health Proton Therapy Institute
6. Yusung Kim – University of Iowa
7. Eric Paulson – Medical College of Wisconsin
8. William Song – Virginia Commonwealth University
10. Sushil Beriwal – Allegheny Health
11. Beth Erickson – Medical College of Wisconsin
12. Christian Kirisits – Medical University of Vienna
AAPM Task Group 303 Charge

1. Describe workflow processes when implementing MRI in HDR brachytherapy from simulation to treatment for common sites such as gynecologic and prostate.

2. Develop recommendations for brachytherapy-specific MRI acquisition parameters.

3. Develop recommendations for the commissioning and on-going QA of applicators and/or needles when MRI is utilized with HDR brachytherapy.

4. Evaluate practical considerations arising when implementing MRI in HDR brachytherapy.
• Focus
  – Commissioning, QA, and clinical implementation of MR into HDR BT
  – Workflow options for implementing MR into HDR BT for gynecologic cancer
Requirements for Implementing MRI into HDR BT

• Access to MRI scanner
  – Diagnostic MRI
  – Dedicated Radiation Oncology MRI Simulator
• Provide appropriate staff training (e.g., procedural, MR safety training)
• Availability of MR safe or conditional applicators and ancillary equipment
Example Applicators

Varian Medical Systems

Elekta
Example Ancillary Equipment

- Siemens Tim Dockable Table
- HoverMatt®
- QFix Inc., Symphony System – Trolley and brachy transfer device
Commissioning Needs
Applicators Commissioning

- Become familiar with applicators
- Verify the device is safe in a high magnetic field environment
- Evaluate the accuracy of applicator reconstruction on MR
Commissioning Phantom (GYN)

Applicator Reconstruction

- Applicator reconstruction techniques
  - Markers (plastic applicators)
Plastic Applicators

CT

3D T1W
3T
w MRI marker

2D T2W
3T
w MRI marker

AAPM TG 303, under review Med Phys.
C4 Imaging LLC, Doylestown, PA, USA
Applicator Reconstruction

• Applicator reconstruction techniques
  – Markers (plastic applicators)
  – Direct digitization of tip and inner lumen of applicator in software
AAPM TG 303, under review Med Phys.
Applicator Reconstruction

- Applicator reconstruction techniques
  - Markers (plastic applicators)
  - Direct digitization w or w/o fusing multiple image sets
  - Applicator models
Example Applicator Models

CT/MR Titanium R&T
CT/MR Plastic R&T
CT/MR Titanium T&O (FSD)

Varian Medical Systems

CT/MR Fletcher T&O from Elekta Oncentra
Applicator Reconstruction - Models

CT

3D T1W MR (3T)
Commissioning – MR Sequences

• Optimization of MR scan sequences in phantom and *in vivo*
  – MR expertise critical (radiologists, MR physicists, vendor)
  – Need to assess sequences for:
    • Visualization of anatomy and applicator
    • Distortions and artifacts introduced by the applicator
### Example 2D/3D scan parameters

#### GYN BT (Institution 1, based on a 3.0 T Siemens Verio scanner)

<table>
<thead>
<tr>
<th>Prescription</th>
<th>Slice</th>
<th>TE (ms)</th>
<th>TR (ms)</th>
<th>Voxel Size (mm)</th>
<th>ETL</th>
<th>Readout BW (Hz/pix)</th>
<th>Scan Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA, PS, PC</td>
<td>2D FSE</td>
<td>85</td>
<td>2500</td>
<td>0.9x0.9x3.0</td>
<td>16</td>
<td>440/880</td>
<td>3</td>
</tr>
<tr>
<td>Ax</td>
<td>3D FSE</td>
<td>85³</td>
<td>2500</td>
<td>1.0x1.0x1.5</td>
<td>300⁴</td>
<td>440/880</td>
<td>12⁶</td>
</tr>
</tbody>
</table>

#### GYN BT (Institution 2, based on a 3.0 T Philips Ingenia scanner)

<table>
<thead>
<tr>
<th>Prescription</th>
<th>Slice</th>
<th>TE (ms)</th>
<th>TR (ms)</th>
<th>Voxel Size (mm)</th>
<th>ETL</th>
<th>Readout BW (Hz/pix)</th>
<th>Scan Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ax, Sag</td>
<td>2D FSE</td>
<td>100</td>
<td>4471</td>
<td>0.45x0.45x3.0</td>
<td>30</td>
<td>244.1</td>
<td>5:13</td>
</tr>
</tbody>
</table>

1. Ax = Axial, Sag = Sagittal, and PA = Para-Axial, PS = Para-Sagittal, PC = Para-Coronal to Applicator for GYN
2. Full 3D gradient non-linearity (GNL) correction may not be supported for 2D sequences.
3. Effective TE reported for 3D FSE VFL
4. Echo train duration reported for 3D FSE VFL
5. Readout bandwidth reported for 1.5T/3.0T; Additional optimization to recover SNR may be required.
6. Longer scan times may benefit from administration of antispasmodic agents to reduce motion.

AAPM TG 303, under review Med Phys.
Commissioning (Cont.)

• Develop and document policies and procedures
• Perform end-to-end testing to evaluate and optimize clinical workflow
MR BT Workflows

• MR-informed BT - placement of BT applicator(s)/needles based on pre-implant MRI data
  • Challenges: Anatomical variations and deformations given difference in time points and presence/absence of applicator(s)/needles

MR BT Workflows

- MR-informed BT - placement of BT applicator(s)/needles based on pre-implant MRI data
- MR-based BT (multi-modality) - utilizes an MRI dataset (e.g., fx 1) registered to a planning CT to aid in the delineation of the target and/or critical structures
  - Challenges: Potential variations in the position of the applicator and anatomy due to organ, patient, and/or applicator motion as patient is transferred between imaging systems

MR BT Workflows

- MR-informed BT - placement of BT applicator(s)/needles based on pre-implant MRI data
- MR-based BT (multi-modality sim) - utilizes an MRI dataset (e.g., fx 1) registered to a planning CT or US to aid in the delineation of the target and/or critical structures
- MR-based BT (single-modality sim) – utilizes an MRI dataset for contouring and planning for each fraction
  - Challenges: Resource and financial constraints

MR BT Workflows

• MR guided BT – guiding both implant and planning
  – Challenging:
    • Resource and financial constraints
    • Location of MR (i.e., outside of department)
    • Logistical issues
    • Required MR time

Quality Assurance & Checks - Daily

- MRI QA (e.g., MR SC TG 1, TG 284)
- Pre-implant / Pre-imaging checks
  - Verify MR safe or conditional applicators/needles selected
  - Confirm MRI screening questionnaire complete
  - Perform standard screening of patient and equipment before they enter zone III
  - Ensure padding used to avoid direct contact of non-ferromagnetic metal applicators patient skin
  - Ensure there is no skin-to-skin contact of limbs during MRI scans to prevent thermal injuries
  - Inspect marker integrity, if applicable

AAPM TG 303, under review Med Phys.
Summary

• MR based BT is viable, and allows for the visualization of targets, opportunity to conform dose to the target volume, and spare normal tissues.

• TG 303 provides recommendations to the medical physics community to safely and efficiently integrate MR into the HDR clinical workflow.
Special thanks to TG 303 members!

1. Firas Mourtada (Chair) – Christiana Care Hospital
2. Joann Prisciandaro (Vice-Chair) – University of Michigan
3. Gil’ad Cohen – Memorial Sloan Kettering Cancer Center
4. Ken-Pin Hwang – MD Anderson
5. Perry Johnson – University of Florida Health Proton Therapy Institute
6. Yusung Kim – University of Iowa
7. Eric Paulson – Medical College of Wisconsin
8. William Song – Virginia Commonwealth University
10. Sushil Beriwal – Allegheny Health
11. Beth Erickson – Medical College of Wisconsin
12. Christian Kirisits – Medical University of Vienna
Thank you!