Clinical Implementation of MRI for Gynecologic HDR Brachytherapy

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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

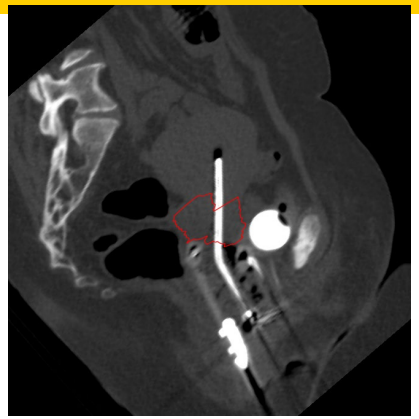
CT

3D T2W MR (3T)

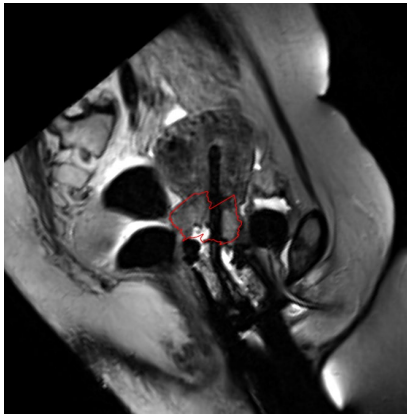
Rationale for Implementing MRI into HDR BT

- 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

CT



2D T2W FSE



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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.)*

C. Haie-Meder *et al.*, Radiotherapy Oncology 2005, 74: 235 – 245.
R. Pötter *et al.*, Radiother Oncol 2006, 78: 67 – 77.
T. Hellebust *et al.*, Radiother Oncol 2010, 96: 153 – 160.
J.C.A. Dimopoulos *et al.*, Radiother Oncol 2012, 103: 113 – 122

Additional Published Recommendations

- 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.

Journal of ICRU 2013, 13, No 1-2.

- 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.

S. Grover *et al.*, Int J Radiation Oncol Biol Phys 2016, 94(3): 598 – 604

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
9. Jacqueline Zoberi – Washington 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

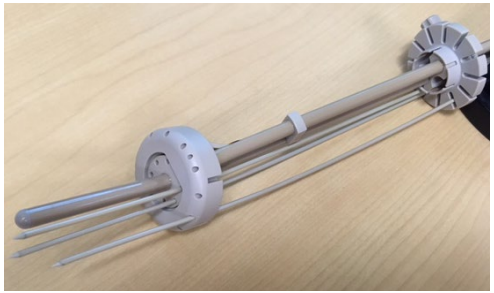
1. Describe workflow processes when implementing MRI in HDR brachytherapy from simulation to treatment for common sites such as gynecologic and prostate.
2. Develop recommendations for brachytherapy-specific MRI acquisition parameters.
3. Develop recommendations for the commissioning and on-going QA 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

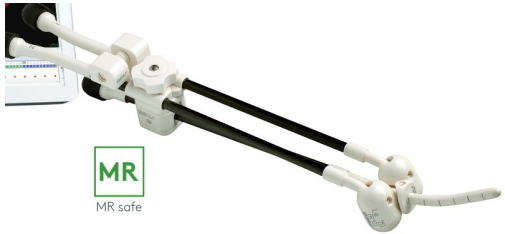
Requirements for Implementing MRI into HDR BT

- 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



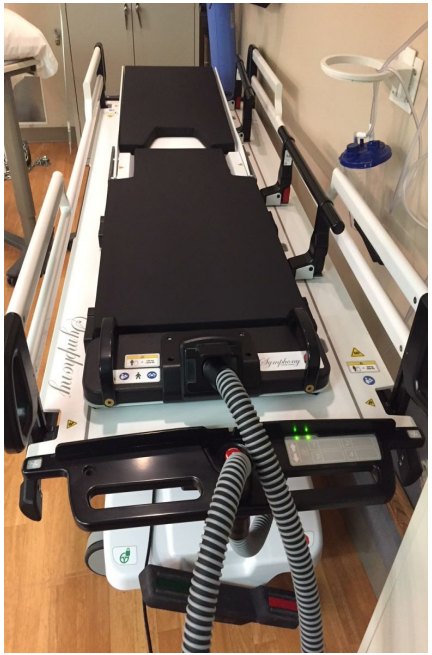
Varian Medical Systems



Elekta

Example Ancillary Equipment

Siemens Tim Dockable Table



QFix Inc., Symphony System – Trolley and brachy transfer device

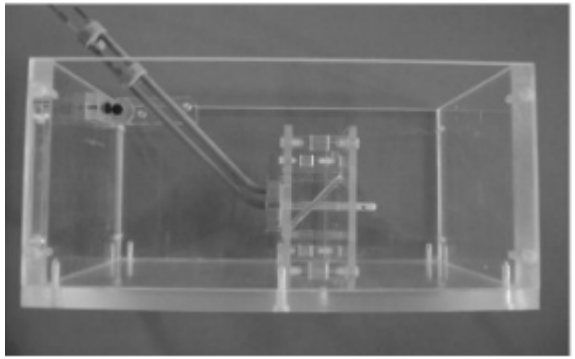
HoverMatt®

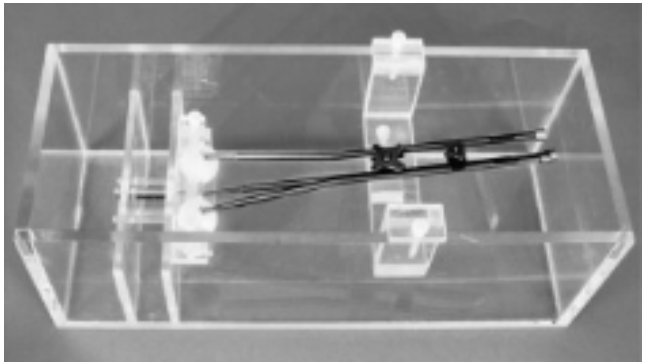
Commissioning Needs

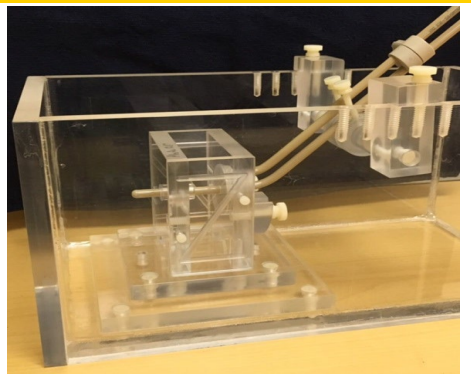
Applicators Commissioning

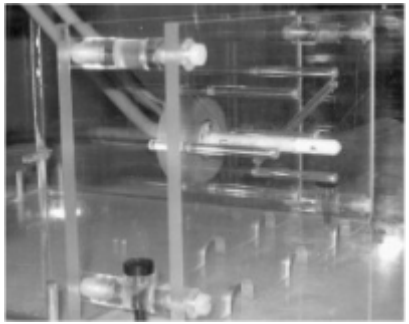
- Become familiar with applicators
- Verify the device is safe in a high magnetic field environment
- Evaluate the accuracy of applicator reconstruction on MR

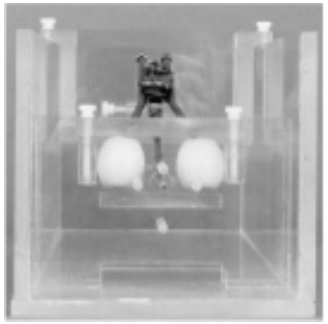
Commissioning Phantom (GYN)

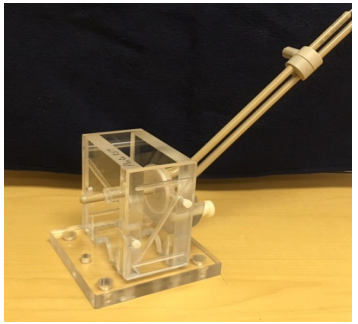










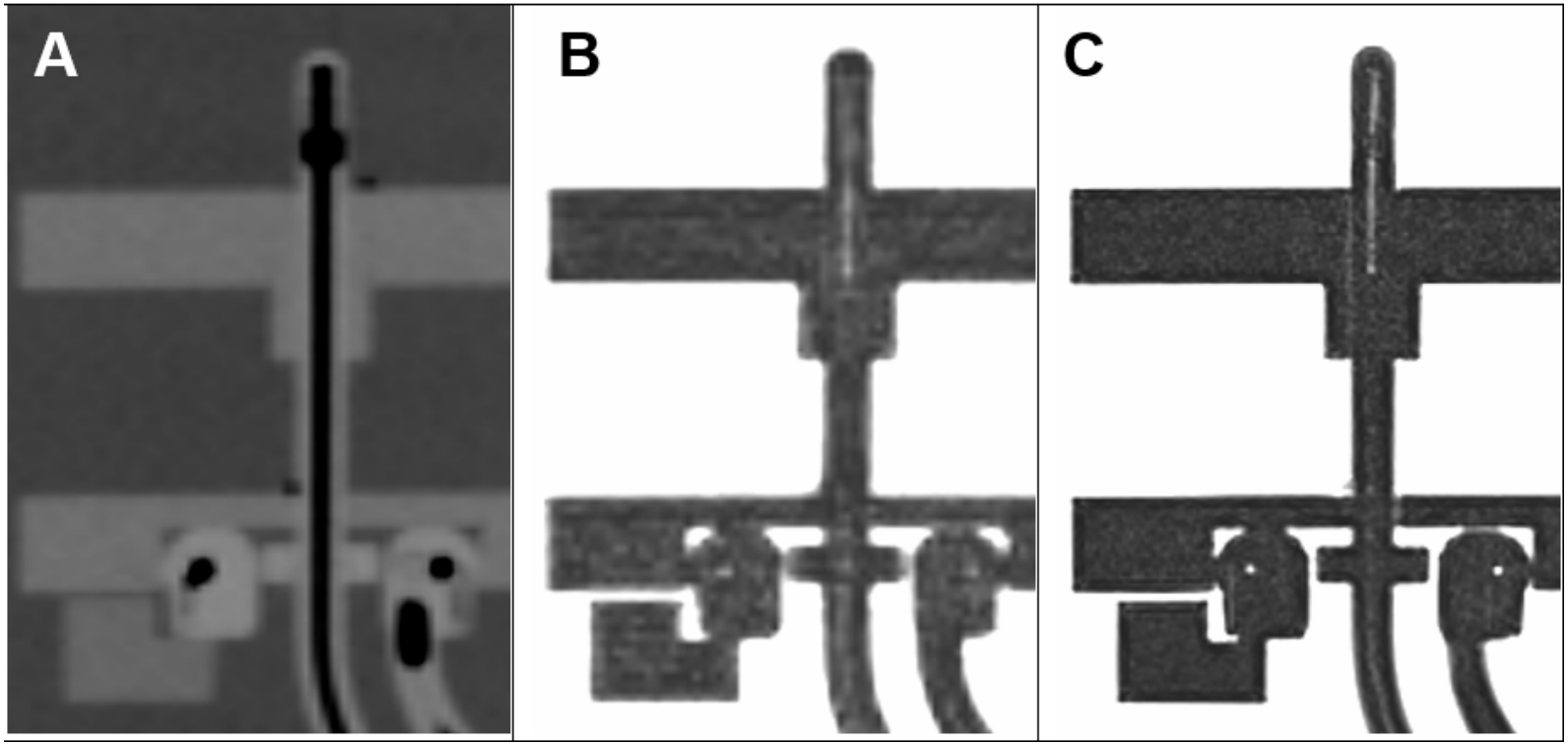


S. Haack *et al.*, Radiother Oncol 2009, 91(2): 187 – 193.
Y. Kim *et al.,* Int J Radiation Oncology 2011, 80(3): 947 – 955.

Applicator Reconstruction

- Applicator reconstruction techniques
  - Markers (plastic applicators)

Plastic Applicators



CT

3D T1W
3T
w MRI marker

2D T2W
3T
w MRI marker

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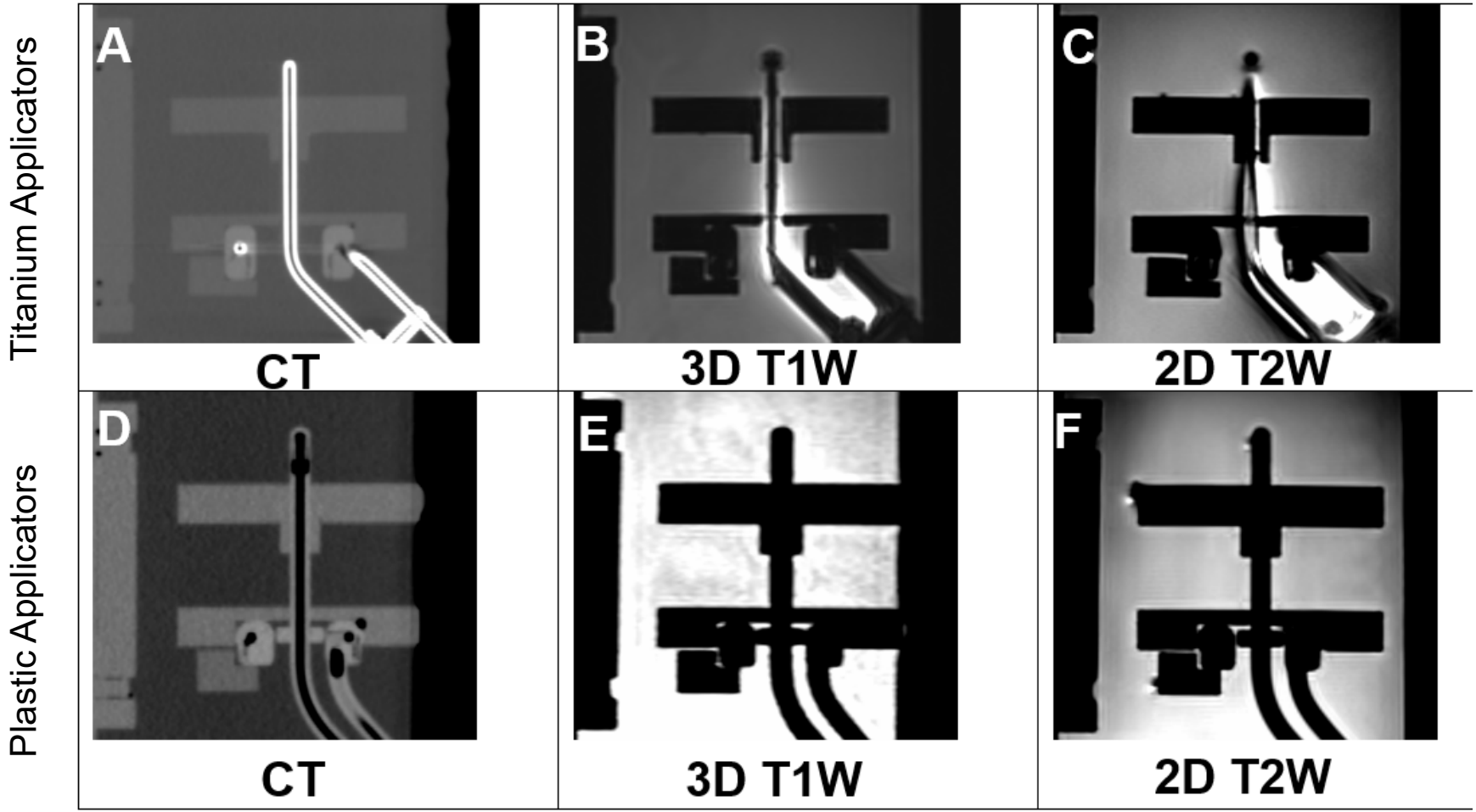
C4 Imaging LLC, Doylestown, PA, USA

Applicator Reconstruction

- Applicator reconstruction techniques
  - Markers (plastic applicators)
  - Direct digitization of tip and inner lumen of applicator in software



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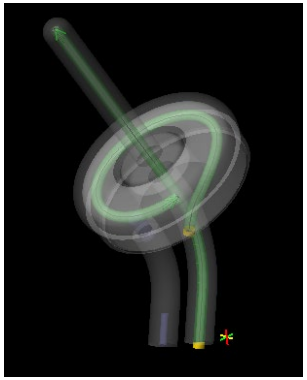
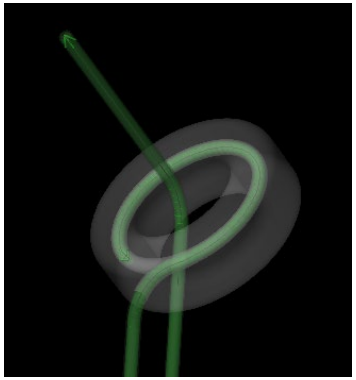
Applicator Reconstruction

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

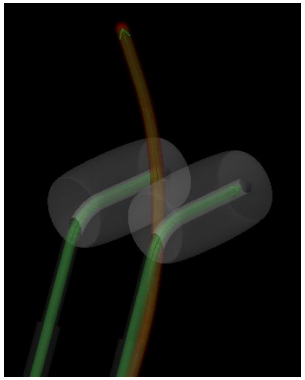
Example Applicator Models



CT/MR
Titanium R&T



CT/MR Plastic
R&T

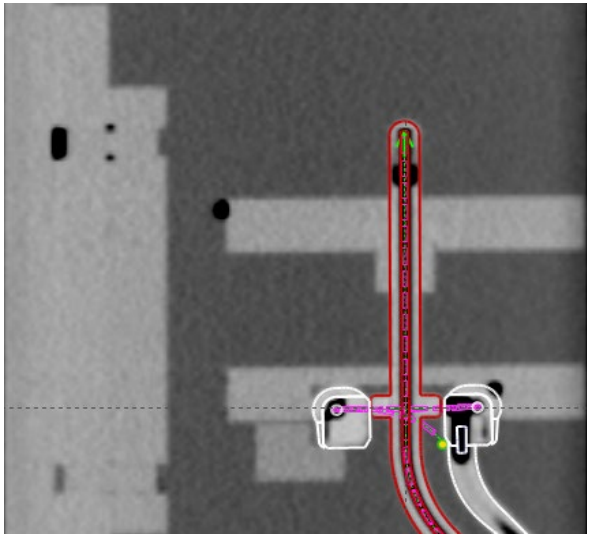


CT/MR
Titanium T&O
(FSD)

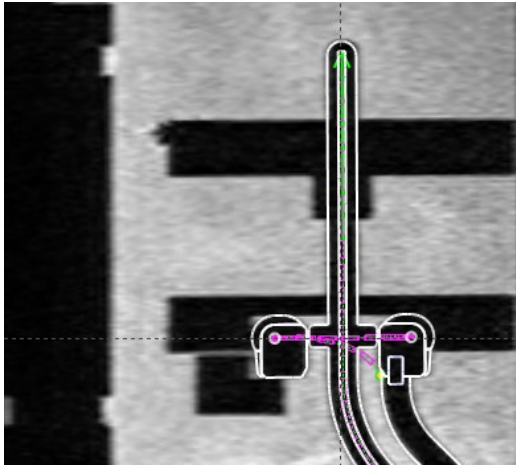
Varian Medical Systems

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)

	Slice Prescription[1]	TE (ms)	TR (ms)	Voxel Size (mm)	ETL	Readout BW (Hz/pix)[5]	Scan Time (min)
2D FSE[2]	PA, PS, PC	85	2500	0.9x0.9x3.0	16	440/880	3
3D FSE VFL	Ax	85[3]	2500	1.0x1.0x1.5	300[4]	440/880	12[6]

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

	Slice Prescription[1]	TE (ms)	TR (ms)	Voxel Size (mm)	ETL	Readout BW (Hz/pix)	Scan Time (min)
2D FSE[2]	Ax, Sag	100	4471	0.45x0.45x3.0	30	244.1	5:13

[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.

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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

J. Wang *et al.*, Brachytherapy 2017, 16(4): 715 - 727.

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

J. Wang *et al.*, Brachytherapy 2017, 16(4): 715 - 727.

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

J. Wang *et al.*, Brachytherapy 2017, 16(4): 715 - 727.

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

J. Wang *et al.*, Brachytherapy 2017, 16(4): 715 - 727.

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.
EF Jackson *et al.,* Report of MR Subcommittee Task Group I, 2010.
CK Glide-Hurst *et al.*, Med Phys 2021, 48: e636 – e670.

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
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Thank you!