HDR Brachytherapy: Interstitial Treatments for GYN Panel Discussion*

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*This session qualifies for SAM credits.

Disclosures

H. Al-Hallaq: None

J. Prisciandaro:
- Non-clinical evaluation agreement (Varian Brachytherapy)

J. Zoberi:
- Advisory Board (Varian Brachytherapy)
- Stock in publicly traded entities (Varian, Viewray)
Learning Objectives

- Describe the treatment and planning workflow for interstitial HDR brachytherapy for gynecologic (GYN) malignancies
- Discuss the role of 3D imaging including CT and MRI for interstitial HDR planning
- Describe the selection/optimization of applicator geometry
- Compare/contrast the use of standard loading to dosimetric optimization for plan development
- Understand the impact of increasing complexity on QA and safety

Outline

- Introduction
- Panel discussion
- Conclusions

Reminder: To obtain SAM credit, please answer questions online.
Clinical Motivation

- “Statement of consensus of the authors....[but] the suggested dose and fractionation schemes have not been thoroughly tested.”

- “Variations in approaches to interstitial brachytherapy, as with most medical procedures, are commonplace and may readily fall within accepted and appropriate management of these patients with vaginal cancers.”

- Panel discussion is intended to share the experience and practices of three institutions

S. Beriwal et al., Brachytherapy 2012, 11:68-75
Question 1 (HA)

Describe your institution’s workflow and timeline on day of HDR implant and subsequent treatment days.

HDR Brachy for GYN Workflow

Redesign of process map to increase efficiency: Reducing procedure time in cervical cancer brachytherapy
Department of Radiation Oncology, Dana-Farber Cancer Institute, Brigham and Women’s Hospital, Boston, MA

<table>
<thead>
<tr>
<th>Task no.</th>
<th>Task</th>
<th>Personnel</th>
<th>Resources</th>
<th>Perceivable task no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Preprocedure evaluation</td>
<td>AU, RN, anesthesia</td>
<td>Laboratory work, patient chart</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>Pre-implant preparations</td>
<td>AU, RN, RT, TA</td>
<td>Brachy suite</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Applicator insertion</td>
<td>AU, RN, RT, TA</td>
<td>Brachy suite, applicator, ultrasound</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Imaging</td>
<td>AU, RT, AMP</td>
<td>Brachy suite, CT scanner</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Consecution</td>
<td>AU</td>
<td>TPS</td>
<td>3, 4</td>
</tr>
<tr>
<td>6</td>
<td>Standard plan</td>
<td>AMP</td>
<td>TPS</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Prior radiation EQ02</td>
<td>AMP, AU</td>
<td>EQ02 spreadsheet, prior dose information</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>Plan optimization</td>
<td>AU, AMP</td>
<td>TPS, EQ02 spreadsheet</td>
<td>5, 6, 7</td>
</tr>
<tr>
<td>9</td>
<td>QA preparation</td>
<td>AMP</td>
<td>TPS, QA-V</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>Independent check</td>
<td>AMP (not same as for Tasks 6–9)</td>
<td>Secondary calculation software, TPS, R&amp;V</td>
<td>9</td>
</tr>
<tr>
<td>11</td>
<td>Treatment</td>
<td>AU, AMP, RT</td>
<td>Brachy suite, TCS, plan printout</td>
<td>10</td>
</tr>
<tr>
<td>12</td>
<td>Post-treatment</td>
<td>AU, RN, TA</td>
<td>Brachy suite</td>
<td>11</td>
</tr>
</tbody>
</table>

AU = authorized user; RN = registered nurse; RT = radiation therapist; TA = technical assistant; Brachy = brachytherapy; AMP = authorized medical physicist; TPS = treatment planning system;EQ02 = equivalent dose in 2 Gy fractions; R&V = record & verify; TCS = treatment console system.

For each task, the personnel, resources, and preceivable tasks needed to perform that task are listed. Anesthesiologist personnel remain with the patient throughout all the tasks.
HDR Brachy for GYN Workflow

- Contouring & planning in parallel
- Complete EQD2 worksheets prior to day of implant
- “Independent check... separated into subtasks to be performed/documentated at different phases of the process”
- Planning time = 88±19 min (pre-optimization)
- Planning time = 63±16 min (post-optimization)
- Reduction in planning time = 25 min (29%) (p<0.01)

A.L. Damato et al., Brachytherapy 2015, 14:471-480

HDR Brachy for GYN Workflow

- “Patient preoperative evaluation, the use of an anesthetic, applicator placement, image acquisition, dosimetric planning time, patient transfers, treatment delivery, applicator removal, and patient recovery... must be skillfully coordinated to ensure that the patient is treated in a safe and efficient manner.”
Workflow at U of C

<table>
<thead>
<tr>
<th>Workflow Overview</th>
<th>University of Chicago</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of implant</td>
<td>Operating room (OR)</td>
</tr>
<tr>
<td>3D imaging modality for simulation</td>
<td>CT scan (pre-implant MRI is registered)</td>
</tr>
<tr>
<td>Number of applicators implanted</td>
<td>&gt; 20 titanium needles + tandem</td>
</tr>
<tr>
<td>Number of applicators loaded</td>
<td>~ 16 titanium needles + tandem</td>
</tr>
<tr>
<td>Number of fractions/implants</td>
<td>5 fractions in 1 implant (75%)</td>
</tr>
<tr>
<td></td>
<td>6 fractions in 2 implants (25%)</td>
</tr>
<tr>
<td>Location of HDR afterloader</td>
<td>LINAC vault</td>
</tr>
<tr>
<td>Planning strategy</td>
<td>3D with volume optimization</td>
</tr>
<tr>
<td>Do you parallelize any tasks?</td>
<td>Yes (contouring, needle digitization &amp; check, EQD2 worksheet, MRI import)</td>
</tr>
<tr>
<td>Physics FTE allotment</td>
<td>2 FTE on initial day; 1 FTE on subsequent days</td>
</tr>
<tr>
<td>EQD2 worksheet use during planning?</td>
<td>Yes</td>
</tr>
<tr>
<td>Use of virtual plans or “pre-plans”?</td>
<td>Yes CT-based to plan needle loading &amp; retraction</td>
</tr>
<tr>
<td>Re-planning/re-imaging?</td>
<td>No, needles adjusted to match plan prior to treatment</td>
</tr>
</tbody>
</table>

Timeline at U of C

**Interstitial GYN HDR Timeline (Day 1)**

Currently: implant and treat fraction 1 on day 1
Treat BID day 2 and 3
Removed immediately following fraction 5 in hospital room
## Workflow at U of M

<table>
<thead>
<tr>
<th>Workflow Overview</th>
<th>University of Michigan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of implant</td>
<td>Operating room (OR)</td>
</tr>
<tr>
<td>3D imaging modality for simulation</td>
<td>CT and MR scans</td>
</tr>
<tr>
<td>Number of applicators implanted</td>
<td>~ 13 plastic needles (range 6 – 24)</td>
</tr>
<tr>
<td>Number of applicators loaded</td>
<td>~ 11 plastic needles</td>
</tr>
<tr>
<td>Number of fractions/implants</td>
<td>3 - 4 fractions in 1 implant</td>
</tr>
<tr>
<td>Location of HDR afterloader</td>
<td>HDR suite</td>
</tr>
<tr>
<td>Planning strategy</td>
<td>3D with volume optimization</td>
</tr>
<tr>
<td>Do you parallelize any tasks?</td>
<td>No, with exception of EQD2 worksheet</td>
</tr>
<tr>
<td>Physics FTE allotment</td>
<td>2 FTE on initial &amp; subsequent days (1 MP, 1 dosimetrist)</td>
</tr>
<tr>
<td>EQD2 worksheet use during planning?</td>
<td>Yes</td>
</tr>
<tr>
<td>Use of virtual plans or “pre-plans”?</td>
<td>No</td>
</tr>
<tr>
<td>Re-planning/re-imaging?</td>
<td>Yes if needles deviate by &gt; 3 mm</td>
</tr>
</tbody>
</table>

## Timeline at U of M

**Interstitial GYN HDR Timeline (Day 0)**

Currently: implant and plan day 0
Treat BID day 1 and 2
Removed immediately following fraction 3 or 4 in HDR suite
Workflow at WUSM

<table>
<thead>
<tr>
<th>Workflow Overview</th>
<th>Washington University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of implant</td>
<td>Dept. of RO (HDR suite or procedure room)</td>
</tr>
<tr>
<td>3D imaging modality for simulation</td>
<td>CT scan (may occasionally acquire MRI, too)</td>
</tr>
<tr>
<td>Number of applicators implanted</td>
<td>8-18 6-French plastic needles in VC/grid templates</td>
</tr>
<tr>
<td>Number of applicators loaded</td>
<td>All implanted needles</td>
</tr>
<tr>
<td>Number of fractions/implants</td>
<td>8 fractions in 1 implant (start T, finish F)</td>
</tr>
<tr>
<td>Location of HDR afterloader</td>
<td>HDR brachytherapy vault (2 RAUs with 1 per vault)</td>
</tr>
<tr>
<td>Planning strategy</td>
<td>Uniform dwell times to mimic LDR experience</td>
</tr>
<tr>
<td>Do you parallelize any tasks?</td>
<td>Occasionally (MRI sim while planning on CT)</td>
</tr>
<tr>
<td>Physics FTE allotment</td>
<td>1 AMP (+ 1 CMD) on initial day; 1 AMP on subsequent days for BID treatments</td>
</tr>
<tr>
<td>EQD2 worksheet use during planning?</td>
<td>No, not yet</td>
</tr>
<tr>
<td>Use of virtual plans or “pre-plans”?</td>
<td>No</td>
</tr>
<tr>
<td>Re-planning/re-imaging?</td>
<td>No, needles adjusted to match plan prior to treatment</td>
</tr>
</tbody>
</table>

Timeline at WUSM

**Interstitial GYN HDR Timeline (Day 1=Tuesday)**

Currently: Treat twice daily T-F (4-6 hours apart)
Implant removed after last treatment on Fridays
Implant 1-2 patients on Tuesdays
Question 2 (JZ)

What applicators and implant geometry do you use for HDR GYN interstitial brachytherapy?

Background: GYN Interstitial Applicators

- Needles
  - Metal
  - Plastic
- 2 main perineal template types
  - Martinez Universal Perineal Interstitial Template (MUPIT)
  - Syed-Neblett template

R. Zwicker et al., GEC-ESTRO Handbook of Brachytherapy, Ch 17 (2002)
A. Martinez et al., IJROBP 1984, 10:297-205
A.M.N. Syed et al., Endocurie Hyp Onc 1986; 2:1-13
### Background: Hybrid IC + ISI Applicators

**Vienna**

![Vienna Applicator Image]

**Venezia**

![Venezia Applicator Image]

C. Kirisits *et al.*, IJROBP 2006; 65(2):624-630

Wavelength.elekta.com

### Background: Custom ISI Applicators

**“2.5 cm ISI Cylinder”**: segments with holes drilled in periphery joined to a circular plexiglass template

![Custom ISI Applicator Image]

P.T. Dyk *et al.*, Brachytherapy 2015; 14:231-237

**4x3 vaginal recurrence at mid and distal vaginal wall. 2.5cm ISI Cyl, 13 caths insertion depth 10 cm**

![Vaginal Recurrence Image]
U of C: Syed-Neblett with Ti Needles & Central Tandem

Patient population: >67% with cervical cancers

U of M

Currently – Custom (template needles can be inserted straight or at an angle of 15°)

Near future (for limited lateral parametrial invasion)

Varian Medical Systems

Patient population: ~ 80% with endometrial cancer

Question 3 (JZ)

How do you optimize the applicator geometry for a particular implant?

Background: Placement Methods and Guidance

Aim: tailor the radiation dose to the patient’s anatomy with better target volume coverage

- Free-hand (Ra-226, Co-60)
- Use of templates: Perineal and/or vaginal
- Use of imaging-based techniques:
  - Fluoroscopy (Nag et al.)
  - CT (Erickson et al.)
  - U/S (Stock et al.)
  - MRI (Erickson et al.)
  - Laparoscopy (Fokdal et al.)
- Improved needle placement accuracy

GEC-ESTRO Handbook of Brachytherapy, Ch 17, 2002.
WUSM: Placement of Applicators

RO performs implant in Brachytherapy Center:
- Assisted by OR-trained nurses and RTTs dedicated to Brachy
- Pelvic EUA to evaluate disease extent
- Fiducial markers placed at the superior and inferior extents of the visible or palpable tumor (used later for reference on CT imaging)
- No real-time imaging guidance, but pre-implant images (e.g., MRI) are displayed in room to help reconstruct tumor geometry
- Determine applicator type, needle insertion depth, and no. of needles
- Needles placed, can use digital rectal exam guidance
- Post-implant CT reviewed by RO in TPS, determines activation length

U of M: Placement of Applicators

RO and Gyn Onc performs implant in OR:
- Pelvic exam to evaluate disease extent
- Pre-implant MRI reviewed/displayed in room
- Needles placed, guided manually by DRE and/or US imaging
- On occasion mini-lap is utilized
  - E.g., if lesion is in close proximity or adheres to bowel, patient unable to get MR and unsure of patient’s response to EBRT, for intact uterus – uterus extremely retro- or antevverted
- Determine number of needles and length
U of C: Placement of Applicators

- In OR:
  - Pelvic EUA
  - Fiducial markers into tumor (lateral, sup, inf borders)
  - Real-time transabdominal US guidance
  - Digital rectal exam to assess needle positions
  - Use of virtual pre-plan

- Needles adjusted during post-implant CT simulation

Question 4 (HA)

How do you digitize needles/catheters?
**Needle Digitization on CT**

- “The lumen of the [needle] is well visualised and a markerstring is not always necessary.” - Hellebust
- “Image-based catheter [and needle] digitization suffers from low efficiency and is prone to human errors.” – Wang

T.P. Hellebust et al., Radiotherapy and Oncology 2010, 96:153–160

**Needle Digitization on MRI**

- “In MRI-based reconstruction, using conventional clinical MR sequences, the catheter/stylet and metal applicator can only be visualized by susceptibility artifacts.
- The size and shape of the artifacts are not real representations of the catheter/stylet and applicator, and greatly depend on the MR sequence parameter”  

T.P. Hellebust et al., Radiotherapy and Oncology 2010, 96:153–160
Digitization accuracy in CT vs MRI

- "Imaging slice thickness limits digitization accuracy."
  - Typically, CT slices thickness < MRI slice thickness
  - CT: Accuracy to < 1mm if slice thickness < 2mm
  - MRI: Accuracy 1-2 mm*

\*W. Wang et al., Med. Phys. 2015, 42(12):7114-7121

Needle Digitization at U of C

- Thresholding-based applicator detection with manual tweaking:
  - Cannot account for the dead space in needle tip
  - Has reduced accuracy when needles cross
  - ~1.5-2 hours for 20-30 needles
Needle Digitization at U of M

- Two datasets acquired, one with coded x-ray markers and one without
  - Current technique – Needles reconstructed on the dataset with the x-ray marker (~1.5 min/needle)
  - Near future – Transitioning to thresholding-based applicator detection using dataset without markers (~1 min/needle)

Needle Digitization at WUSM

- CT, 2 mm slice thickness
- Al markers *(not coded—need implant diagrams)*
- Markers digitized by CMD ~ 30 min
- Checked by AMP ~ 15 min
- In rare cases, AMP will decide during the sim:
  - Take another CT w/ some markers out
  - Use metal artifact reduction
Question 5 (JZ)

With the added capability of customizing isodose distributions via source-stepping technology, what isodose planning strategies do you use for HDR GYN interstitial brachytherapy?

Background: Isodose Planning Strategy per ABS

- ABS 2012 recommends optimizing dose to CTV
  - Defined on CT using fiducials, pre-implant imaging, clinical findings (or on MRI)
- Optimization goals:
  - D90 >= 100% of Rx dose
  - Minimize dose to OARs, track 0.1 cc, 1cc, 2cc of B, R, S, & SB
  - Use GEC-ESTRO WG II recommendations for EQD2 dose limits
  - Review the dwell times – look for really high times
  - Evaluate location of hot spots, e.g., keep 150% isodose around needles
- Can use quality indices, e.g.,
  - Conformity index -- between 0.6 and 0.8 (Major et al)
  - HI or dose homogeneity index -- 0.6-0.7 of target receiving between 100% and 150% of Rx dose
Background: HDR Optimization Techniques

What optimization technique should we use? We have choices:

- **Point-based Optimization:**
  - Geometric Opt (GO): Source dwell positions used for optimization of dwell weights
  - Dose Point Opt (DPO): Dose points placed at some distance along catheters

- **Volume-based Optimization**, e.g. IPSA & VO
  - Contour structures, e.g. target, rectum, bladder
  - Input dose-volume constraints into an optimizer

- **Manual Optimization**, e.g., Graphic Optimization & Dose shaper
  - Real-time dose shaping tools to manually fine-tune isodose lines, e.g., after GO or VO
  - Can also be applied after use of conventional ISI systems, e.g., Paris system

- **ABS**: No specific strategy recommended other than **manual isodose shaping**


WUSM – Isodose Planning

- **No HDR optimization**
- **Plan** mimics LDR implant-based isodose
- **Activate dwells**: 1 cm spacing, AL based on MD (fiducials)
- Initially set time ~ 1 sec/dwell
- Based on Paterson-Parker system to derive “activity loading” needed to deliver a minimum dose to implant = Rx
- Distribute activity uniformly: Quimby-like, equal linear intensity
- Evaluate coverage of implant = surrogate for target (rarely contour a target)
- Evaluate dose in contact with OARs, size of 150-200% isodoses, track urethra dose.

U of M: Volume Optimization with Manual Tweaking

- Post-implant CT and MR simulations acquired and registered
- OAR contoured on CT
- HR-CTV contoured on MR, copied to CT and reviewed/edited on CT
- Initially run volume-based optimization
  - HR-CTV, bladder, rectum, sigmoid, and bowel contoured
  - Dose-volume constraints entered into optimizer
    - CTV 70-85 Gy (EQD2)
    - B D2cc < 80 Gy*
    - R/S/B D2cc < 65 Gy*
- Manually tweak to minimize hot/cold spots in dose distribution & re-evaluate EQD2

* Recently updated based on EMBRACE II: www.embracestudy.dk

U of C: Volume Optimization with Manual Tweaking

- Pare needles to ≤ 20:
  - Eliminate needles (< 1cm or converging)
  - Prioritize peripheral loading to cover target
  - Volume optimization can be used to indicate importance of needle
  - Manual tweaking to reduce hotspots & meet D2cc criteria for OAR
Question 6 (JIP)

How do you use MRI in the treatment of interstitial GYN cases?

Possible scenarios for integration of MR

- Pre-implant
  - Without the applicator
  - With the applicator
  - Can be used for pre-planning, rough estimation of location of disease during implant/planning, planning with registration to post implant CT

- Planning simulation
  - With CT
  - MR alone
U of M Technique

- Diagnostic MR is acquired in the absence of the applicator.
- Images provide a ballpark estimate of where to target the implant.
- Additionally, at time of planning simulation, an MR is acquired along with CT.
  - MR used to define the HR-CTV
  - CT used for applicator reconstruction and delineation of OARs
  - MR and CT are rigidly registered, HR-CTV copied to CT

U of M: Use of MRI
WUSM: Attempts with MRI

CT with Al markers

T2W 3D with no markers

U of C: Use of MRI

- Diagnostic MRI acquired without applicator (within 1 week of implant)
- Rigidly registered to CT scan
- Used to guide delineation of HR-CTV
Question 7 (HA)

At which points of the workflow do you implement safety checks?

“Checklists and forms can be useful tools in maintaining quality and prevention of errors.”

“A generic checklist for HDR brachytherapy is unlikely to prove useful.”

## Check Timepoints at U of C

<table>
<thead>
<tr>
<th>Timepoint</th>
<th>Univ. of Chicago Checks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicator insertion</td>
<td>N/A</td>
</tr>
<tr>
<td>Simulation</td>
<td>Use of oral/IV contrast, needle placement, scan parameters, CT image accuracy <em>(patient motion)</em></td>
</tr>
<tr>
<td>Planning*</td>
<td>Needle identification &amp; tip localization, dose/dwell accuracy</td>
</tr>
<tr>
<td>Physics Plan Check</td>
<td>EQD2 summary, accuracy of dwell positions, dose calculation, documentation</td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>Needle retractions, radiation survey</td>
</tr>
<tr>
<td>Applicator connection</td>
<td>Applicator + TGT length (n=2), accuracy of connection</td>
</tr>
<tr>
<td>Treatment</td>
<td>Delivery accuracy, equipment functionality</td>
</tr>
<tr>
<td>Post-Treatment</td>
<td>Rad survey, accuracy/documentation of dose delivery in charts</td>
</tr>
</tbody>
</table>

*Note: no formal checklists but AMP performs dry-run of physics plan check.

## Check for Patient Motion During CT sim

- **MOTION**
- **NO MOTION**

The images show the difference in motion during CT simulation.
## Check Timepoints at U of M

<table>
<thead>
<tr>
<th>Timepoint</th>
<th>Univ. of Michigan Checks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicator insertion</td>
<td>Review needle placement, length of needle extending from applicators, stylets in place, and connector end clear of fluid</td>
</tr>
<tr>
<td>Simulation</td>
<td>Review needle numbers, lengths, positions (subsequent scans), and integrity, presence of markers, and scan parameters</td>
</tr>
<tr>
<td>Planning*</td>
<td>Needle identification &amp; tip localization, review contours and OAR constraints, perform EQD2 calc</td>
</tr>
<tr>
<td>Physics Plan Check</td>
<td>EQD2 summary, accuracy of dwell positions, dose calculation, documentation</td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>Needle length, cleanliness, and numbering, patient comfort (AU); plan transfer, rad survey</td>
</tr>
<tr>
<td>Treatment</td>
<td>Delivery accuracy, equipment functionality</td>
</tr>
<tr>
<td>Post-Treatment</td>
<td>Rad survey, accuracy/documentation of dose delivery in charts</td>
</tr>
</tbody>
</table>

## Check Timepoints at WUSM

<table>
<thead>
<tr>
<th>Timepoint</th>
<th>Washington Univ. Checks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicator insertion</td>
<td>Post-insertion measurements of catheter lengths (2 sets: CMD/AMP)</td>
</tr>
<tr>
<td>CT sim</td>
<td>AMP/RTT: Markers fully inserted, catheters identifiable, scan parameters</td>
</tr>
<tr>
<td>Planning</td>
<td>CMD: CT scan ID, MD: implant geometry (needles near OARs, AL)</td>
</tr>
<tr>
<td><strong>Physics Plan Check</strong></td>
<td>Correct CT, Rx, contours, catheter digitization, catheter properties, activation length, dwell time entry, isodoses, independent check of total dwell time</td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>2 RTTs/AMP: Needle retractions, cleanliness, integrity, patient position; patient ID &amp; site; rad survey. AMP: console plan vs tx plan, accuracy of decay by console</td>
</tr>
<tr>
<td>Applicator connection</td>
<td>2 RTTs/AMP: Accuracy &amp; clearance of connection</td>
</tr>
<tr>
<td>Treatment</td>
<td>RTT/AMP/AU: T/O, delivery accuracy, equipment functionality</td>
</tr>
<tr>
<td>Post-Treatment</td>
<td>RTT/AMP: Rad survey, documentation of treatment record in chart</td>
</tr>
</tbody>
</table>
Use Checklists:

- Ensures all physicists do the “bare minimum” tasks & checks
- Common to other institutions
- Tailor/update these lists based on our individual practice & experience

Question 8 (JIP)

How do you assess reproducibility of implant over multiple fractions?
U of M Post Implant Workflow

Day 0
1. Planning simulations (CT and MR)
2. Treatment plan created and approved

Day 1
3. Verification CT
4. CT_n rigidly registered to CT_0 (based on applicator / needles)
   \[ \Delta \leq 3 \text{ mm} \]
5a. Decay & Treat
5b. Replan
6. Treat

Day 2
Repeat Day 1

x 2
If replanned, appropriate reference CT should be used in step 4

Additionally, replanning may be required if a needle becomes compromised

Note, n = fx #

WUSM: Reproducibility

- Goal: Use same plan with decay correction for all 8 fx
- Fixation at time of implant:
  - Templates sutured in place by RO
  - Plastic needles glued with friction collars against templates by RTTs.
  - Paint pen marks placed by RTTs
- Pre-tx:
  - Check “marks” (at expected distance)
  - Check integrity of implant
  - Have MD adjust, if needed
  - May re-plan, if needed
- Care instructions, U-shaped cushion if out-patient
U of C: Reproducibility

- AU measures needle retraction & verifies marks on needles
- Adjusts if necessary prior to each fraction (~ 1-3mm) to match planned retractions
- Initially, repeat CT was used to assess needle reproducibility over 3 days

Question 9 (JIP)

How can the safety of applicators for use in MRI be assessed?
Concerns Presented by Implanted Applicator

- Tissue damage due to:
  - Movement of the device due to displacement force due to the Bo
  - Torque of the device due to the Bo
  - Vibrations of the device due to gradient fields
  - Heating produced by gradient and RF fields
- Image artifacts


Classification of Passive Implants

- MR unsafe
  - An item that is known to pose hazards in all MRI environments (e.g., magnetic items)
- MR safe
  - An item that poses no known hazards in all MRI environments (e.g., nonconducting, nonmagnetic items) such as a plastic
- MR conditional
  - An item that has demonstrated no known hazards in an MR under specific conditions

Classification of Passive Implants

- Caution - A medical device that is deemed MR Conditional under one environment may not be safe to scan in another. This includes changes in:
  - Field strength
  - Spatial gradient
  - $dB/dt$ (time rate of change of the magnetic field)
  - RF fields
  - Specific absorption rate (SAR)


Example – 1.5T vs 3T

- Some clinics have transitioned from a 1.5T to 3T MRI
- Advantage of higher magnetic field strength
  - Higher signal-to-noise ratio (SNR)
  - Improved image contrast in the uterine cervix and uterus
  - Shorter acquisition time
- However, user needs to ensure MR testing has been performed using the field strength intended for clinical use

# Device Tests to Address Potential Hazards

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Related Tests</th>
<th>Test Method</th>
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<tbody>
<tr>
<td>Force</td>
<td>Magnetically induced</td>
<td>ASTM F2052</td>
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<tr>
<td></td>
<td>displacement force</td>
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<tr>
<td>Torque</td>
<td>Magnetically induced</td>
<td>ASTM F2213</td>
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<tr>
<td></td>
<td>torque</td>
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<tr>
<td>Heating</td>
<td>RF field-induced heating</td>
<td>ASTM F2182; ISO TS 10974</td>
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<td></td>
<td>Gradient field-induced</td>
<td>ISO TS 10974</td>
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<tr>
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<td>heating</td>
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<tr>
<td>Vibration</td>
<td>Gradient field-induced</td>
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<tr>
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<td>vibration</td>
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ASTM International – Founded as the American Society for Testing and Materials  
ISO TS - International Organization for Standardization/Technical Specification


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# Example IFU

Varian Medical Systems, IFU – Plastic Interstitial needles, GM11007560-7580, GM11010750
Alternatively...

- If you have a custom applicator or applicator not tested by the vendor:
  - Review and perform ASTM and ISO/TS test specifications
  - Contract with a MR testing lab (e.g., MR:comp, Magnetic Resonance Safety Testing Services)
  - Perform simple tests in-house

U of C In-House Testing

- Titanium needles not rated as MR conditional although vendor is performing tests
- MRI performed in Radiology so discussions with MR physicist and IFU provided to Radiology
Conclusions

Increasing Complexity for Interstitial GYN HDR Procedures

- 3D imaging (CT vs MRI)
  - Placement, planning, verification
  - Use of MRI may require commissioning
- Coordination among team → safety & efficiency
- Safety checks & communication essential during time-constrained procedures
- No one-size-fits-all
Thank you for your attention!