AAPM 2022
JULY 10–14 | WASHINGTON, DC
64TH ANNUAL MEETING & EXHIBITION

USC University of Southern California

Quality Control Checklists for MRI-based Interstitial Gyn HDR Brachytherapy

Zhilei (Julie) Liu Shen, Ph.D.
Hualin Zhang, Ph.D.

Department of Radiation Oncology
University of Southern California
Norris Cancer Hospital

Learning Objectives

- To learn the workflow for implementing the MRI-based HDR interstitial brachytherapy (MRI-HDR-IBT).
- To review the quality control checklists for MRI-HDR-IBT.
- To understand the potential errors and solutions associated with MRI-HDR-IBT.

Introduction

- Interstitial brachytherapy (IBT) is often used to treat women with bulky endometrial or cervical cancers not suitable for intracavitary treatments.
- A modern trend in IBT is the utilization of MRI and a HDR afterloader for conformal 3D image-based treatments.
- The main challenge is to properly complete many sequenced and corelated physics preparations. Therefore, checklists with proper workflow are important for a successful treatment.

Introduction (cont.)

- We will present the physics preparations and clinical workflow required for implementing MRI-based HDR IBT for patients with gynecologic cancers.
- We will discuss the following clinical steps:
  1. Preparation of MRI compatible catheters and templates
  2. Preparation of MRI line markers
  3. Acquisition and utilization of MRI images
  4. Delineation of target and organs at risk

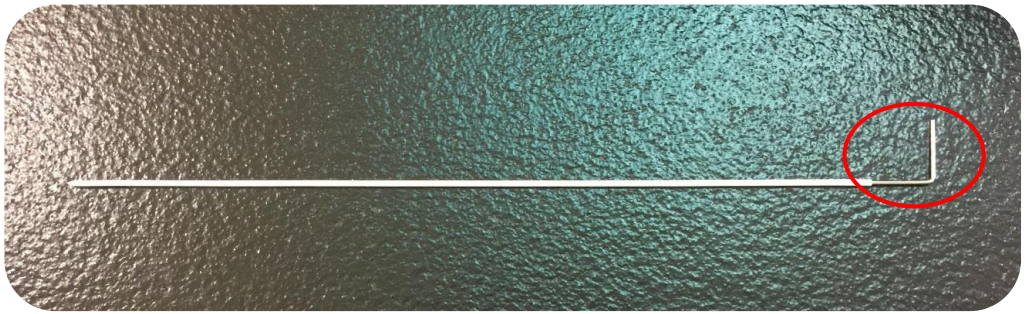
Checklist for Preparation of MRI Compatible Equipment

1. Interstitial catheters
2. MRI line markers
3. Interstitial templates
4. Immobilization and transportation equipment

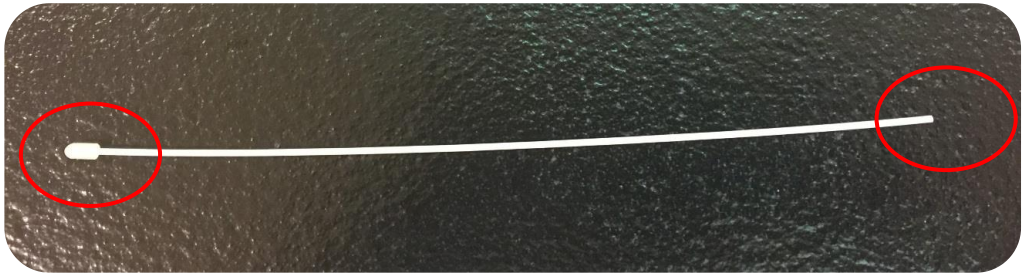
Interstitial Catheters

- Some radiation oncologists prefer to use metal catheters for IBT, because metal catheters are rigid and easier to insert than the more flexible plastic catheters.
- However, titanium needles are delisted from MRI compatible equipment in USA for IBT, because they were found to cause image perturbation. Therefore, plastic needles must be used.

Interstitial Catheters



An interstitial catheter with the metal obturator

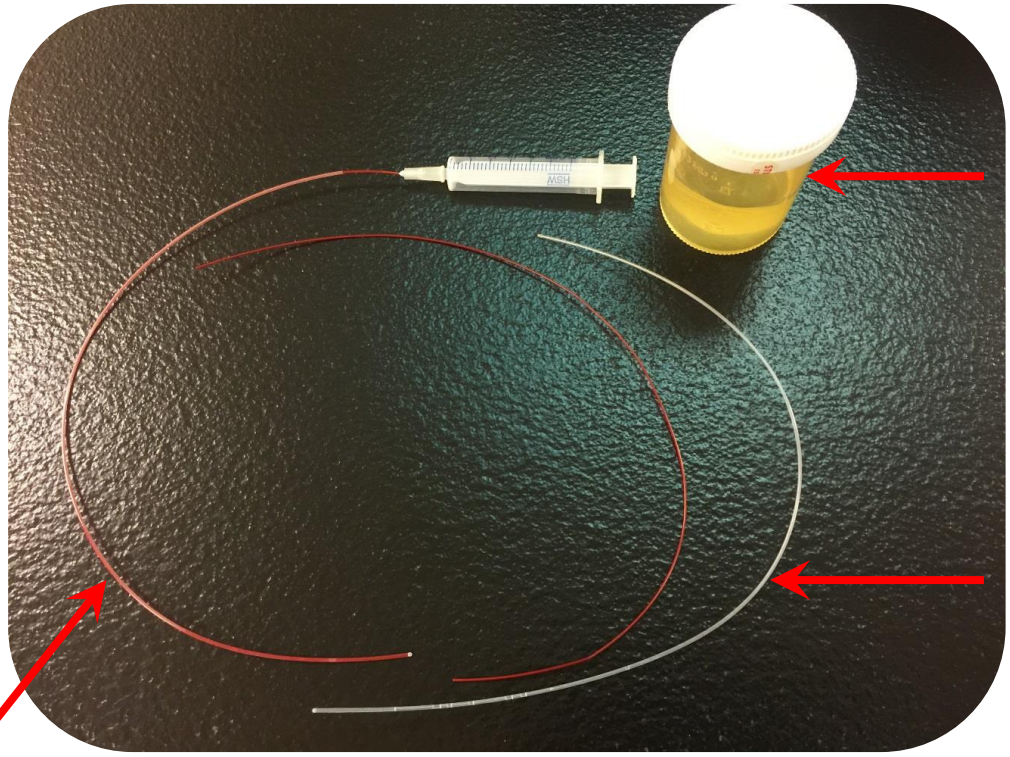


An interstitial catheter with the protective cap and the obturator removed

MRI Compatible Line Markers

- T2 MRI image is recommended for gynecologic brachytherapy.
- Plastic needles cannot be differentiated from the surrounding tissues in T2 MRI images without the visualization assistance of MRI line markers. Therefore, preparing MRI line markers is an important component for the procedure required.

MRI Line Markers and Filling Device



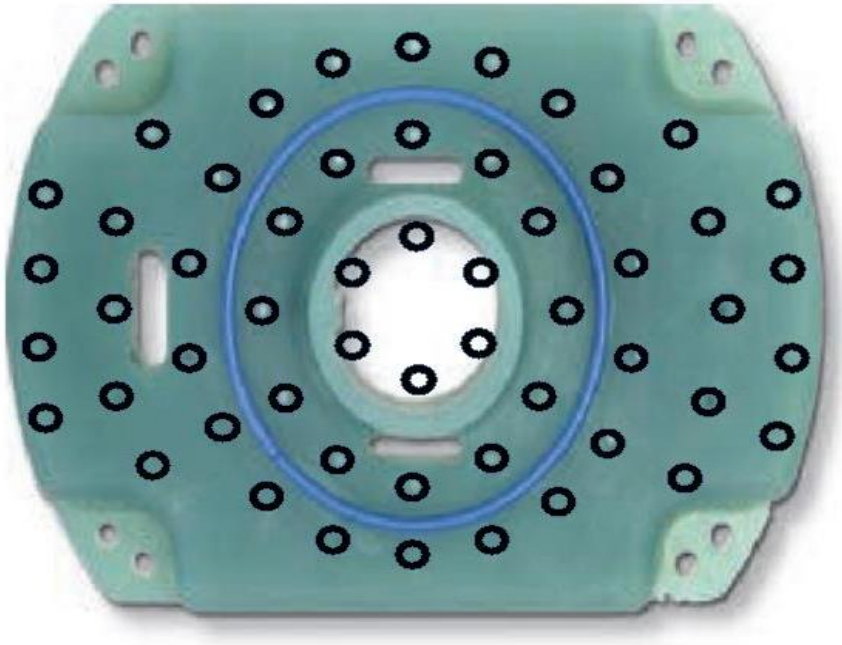
T2 Contrast Agent: Medical saline plus several drops of iodine

MRI Line Marker

Tool used for filling saline into the line marker via the syringe

MRI Compatible Templates

- An MRI compatible interstitial template is needed to guide the needle insertion.
- A variety of MRI compatible templates are available for IBT treatments.



Plastic Syed Template

Immobilization and transportation equipment

- MRI height-adjustable hydraulic stretcher / trolley / non-magnetic

MRI Image Acquisition

- Several MRI sequences can be acquired during MRI scan, per requirement of radiation oncologist and gynecologist.
- Based on the GEC-ESTRO recommendation, the sequence of Axial 3D T2-weighted MRI is the primary scan utilized for brachytherapy planning.
- The slice thickness is 1 mm for better spatial resolution, and the MR scan takes 6-9 minutes.

MRI Scanning Range

Sagittal view

Coronal view

Make sure to have sufficient margin (5 cm) above the uterus.

Checklist for MRI Imaging

- Make sure that the patient is transported between the cart and the MRI scanner couch in a fashion that minimizes catheter disruption to avoid altering patient position or moving the implant.
- Check that the MRI line markers are fully inserted into the catheters before scanning.
- Verify that the patient is scanned head-first since this is the default setting for most radiation oncology treatment planning systems (TPS).
- Confirm the MRI sequences are from the gynecologic brachytherapy MRI imaging protocol.

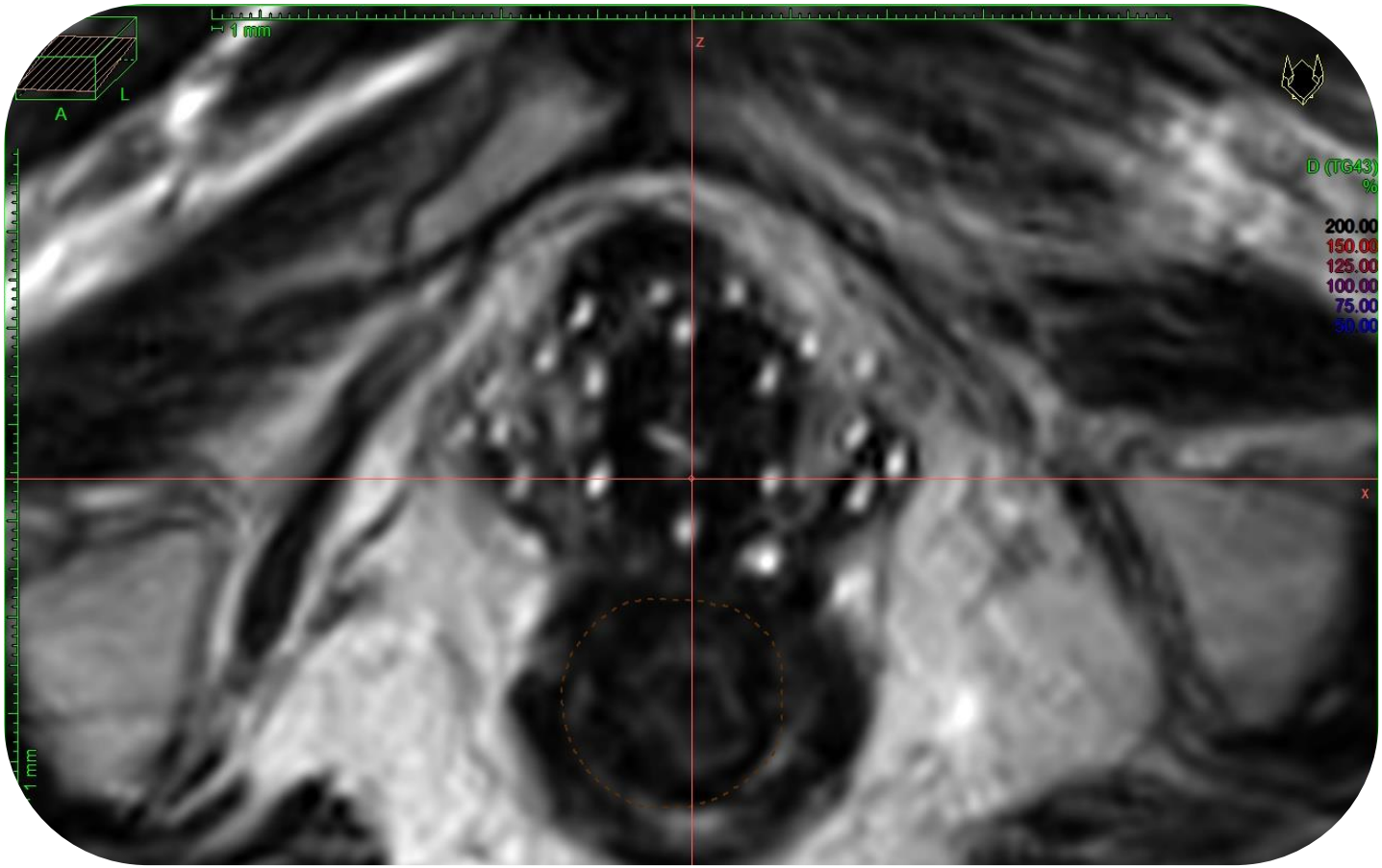
Checklist for MRI Imaging (cont.)

- Check that the MRI scanning range is large enough to cover the whole pelvis. The upper field border should extend 5 cm superior to the uterus. The lower field boarder should include the template plate.
- Make sure that the patient images are collected at a non-oblique axial orientation, especially important for the T2 weighted image set used for treatment planning.
- Make sure the line markers are visible in the T2 image.
- Make sure all slices of the axial T2 image were sent to brachytherapy TPS.

Checklist for Handling MRI Images in Brachytherapy TPS

- The primary image must be loaded into the TPS first.
- If the catheters can be tracked in the T2 MRI image
  - Primary image: T2 MRI image (no CT image needed)
    - Reconstruction of catheters
    - Delineation of target volumes & OARs
    - Development of treatment plans
- If the catheters cannot be tracked in the T2 MRI image
  - Primary image: CT image
    - Reconstruction of catheters
    - Delineation of OARs
    - Development of treatment plans
  - Secondary Image: T2 MRI image
    - Delineation of target volumes

Catheters in MRI T2 Image



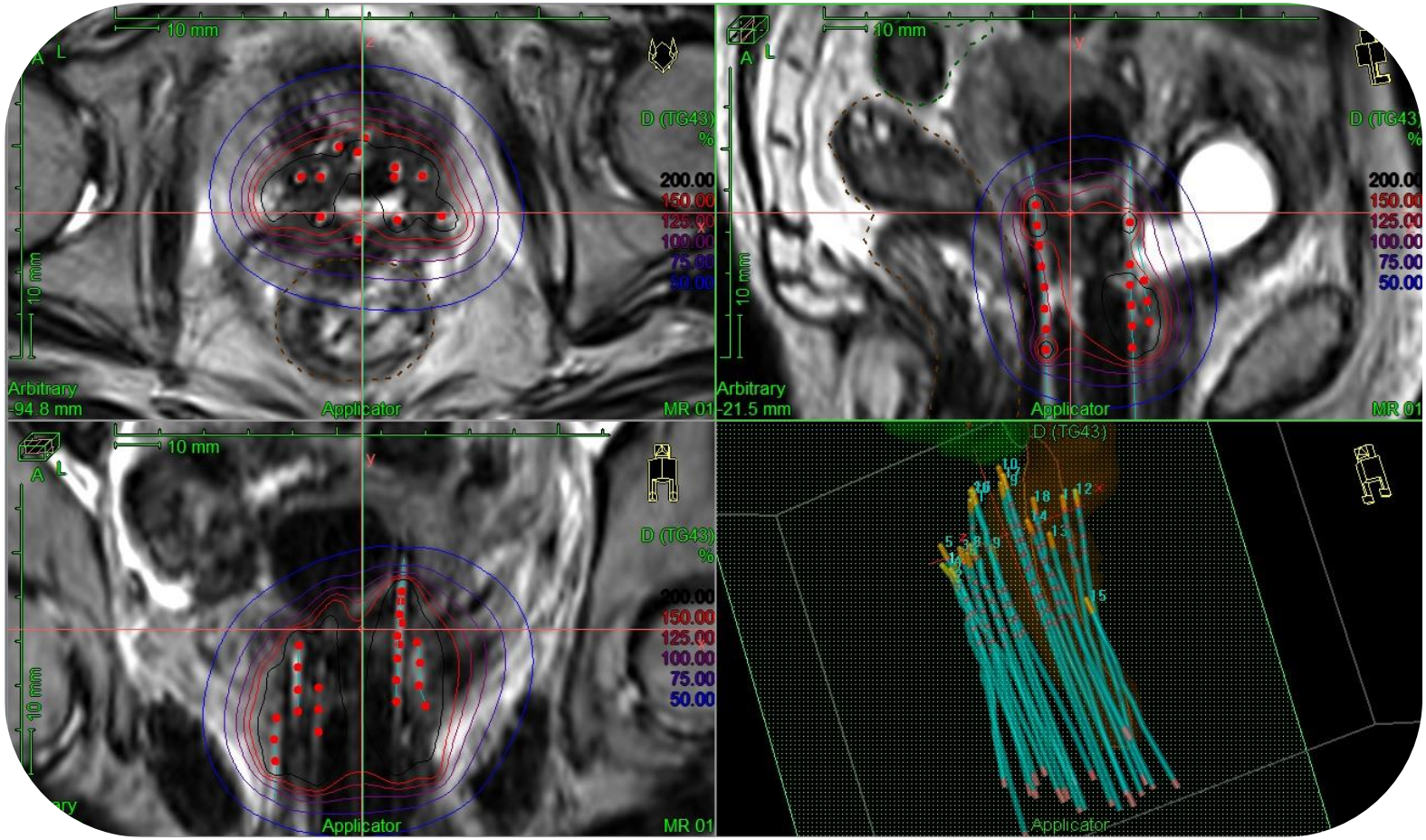
Catheters visualized by MRI line markers in an axial T2 MRI image

Checklist for Target Volumes and OARs Delineation

GEC-ESTRO recommended contouring:

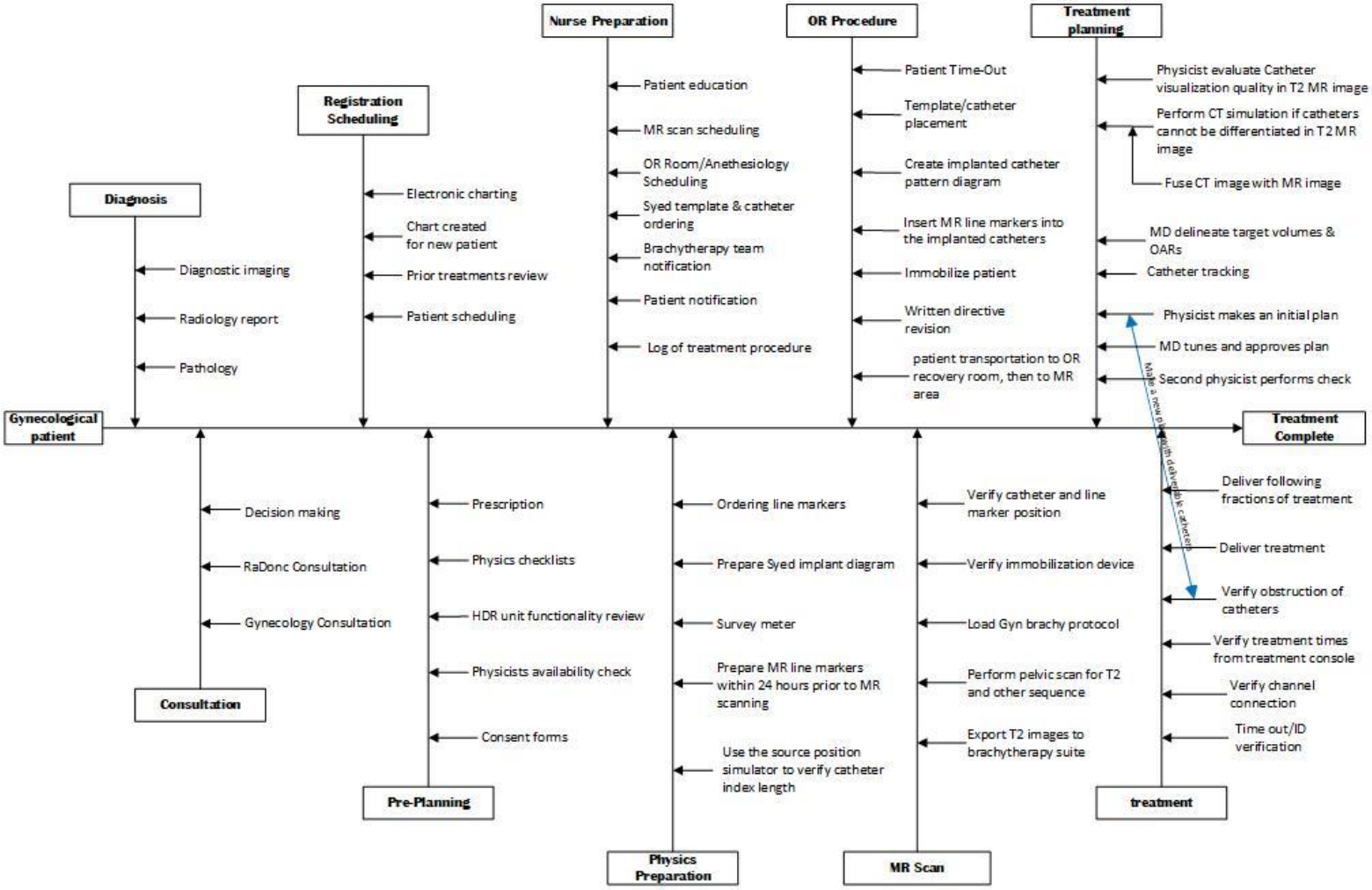
- GTV, HR-CTV, IR-CTV, bladder, rectum, sigmoid, bowel-bag
- IR-CTV is created by expanding the HR-CTV with a margin of 1 cm excluding the OARs.

MRI Images with Needles

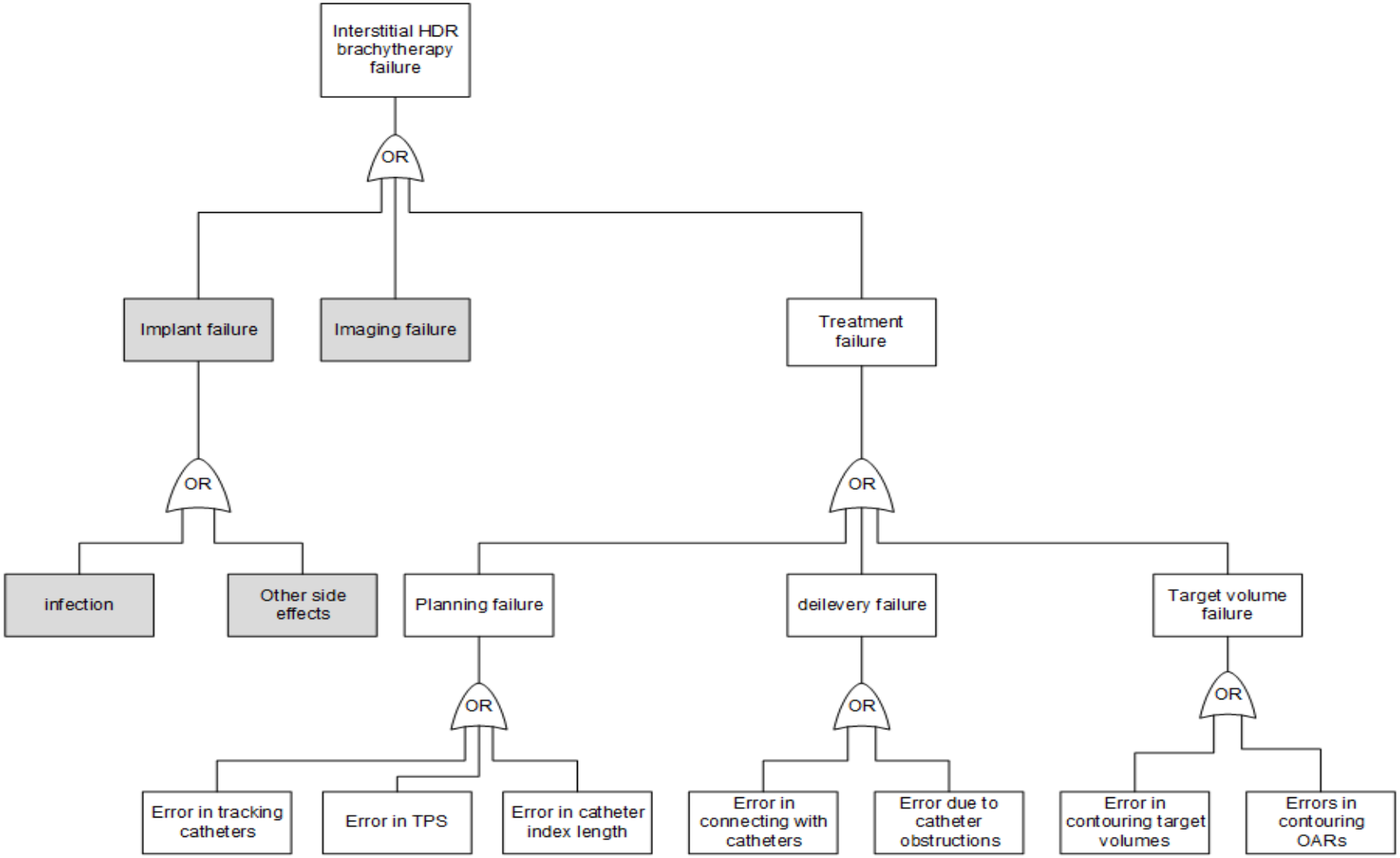


A typical MRI-HDR-IBT plan seen in a TPS

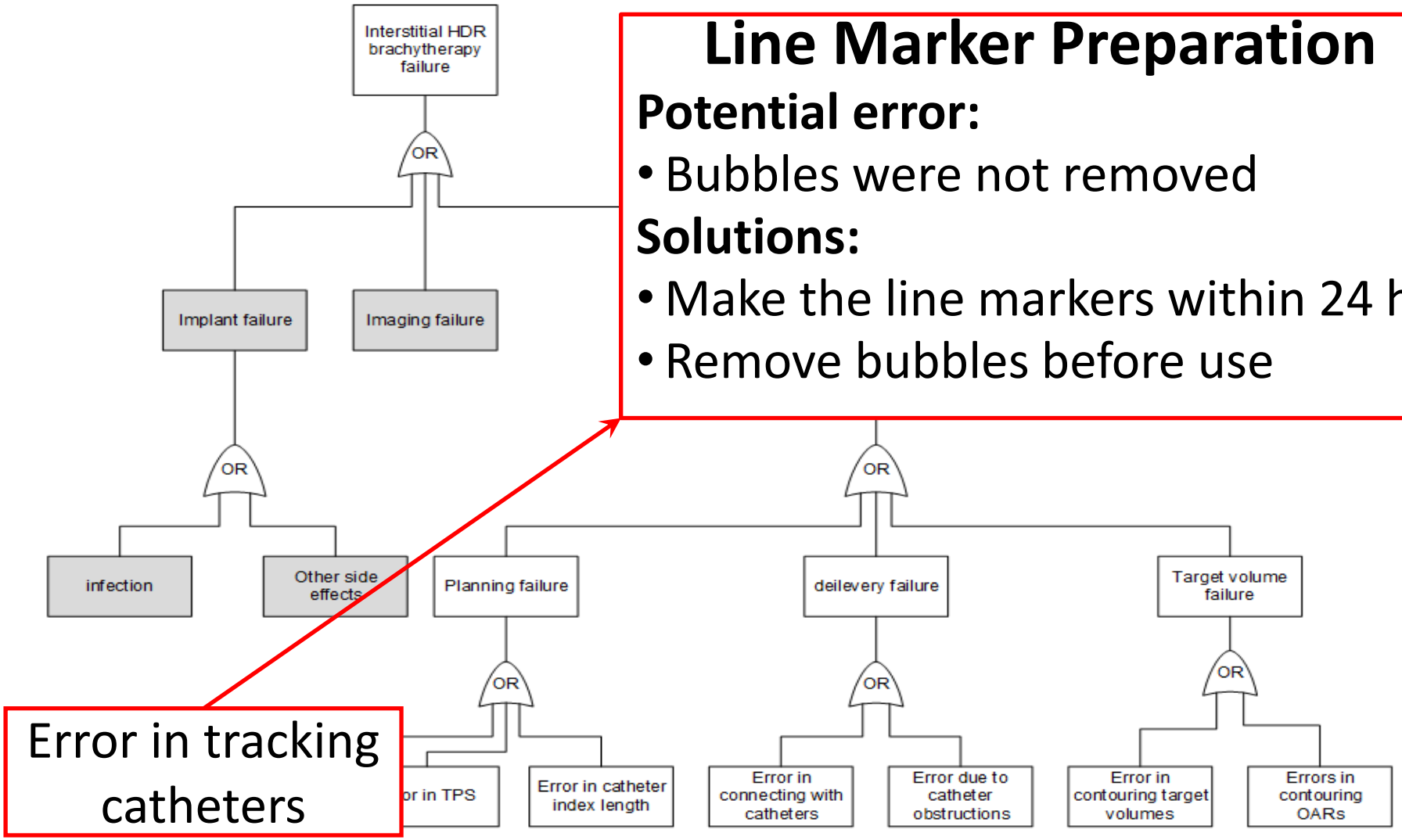
An Example of MRI-HDR-IBT Workflow



An Example of Fault Tree Analysis



An Example of Fault Tree Analysis



Line Marker Preparation

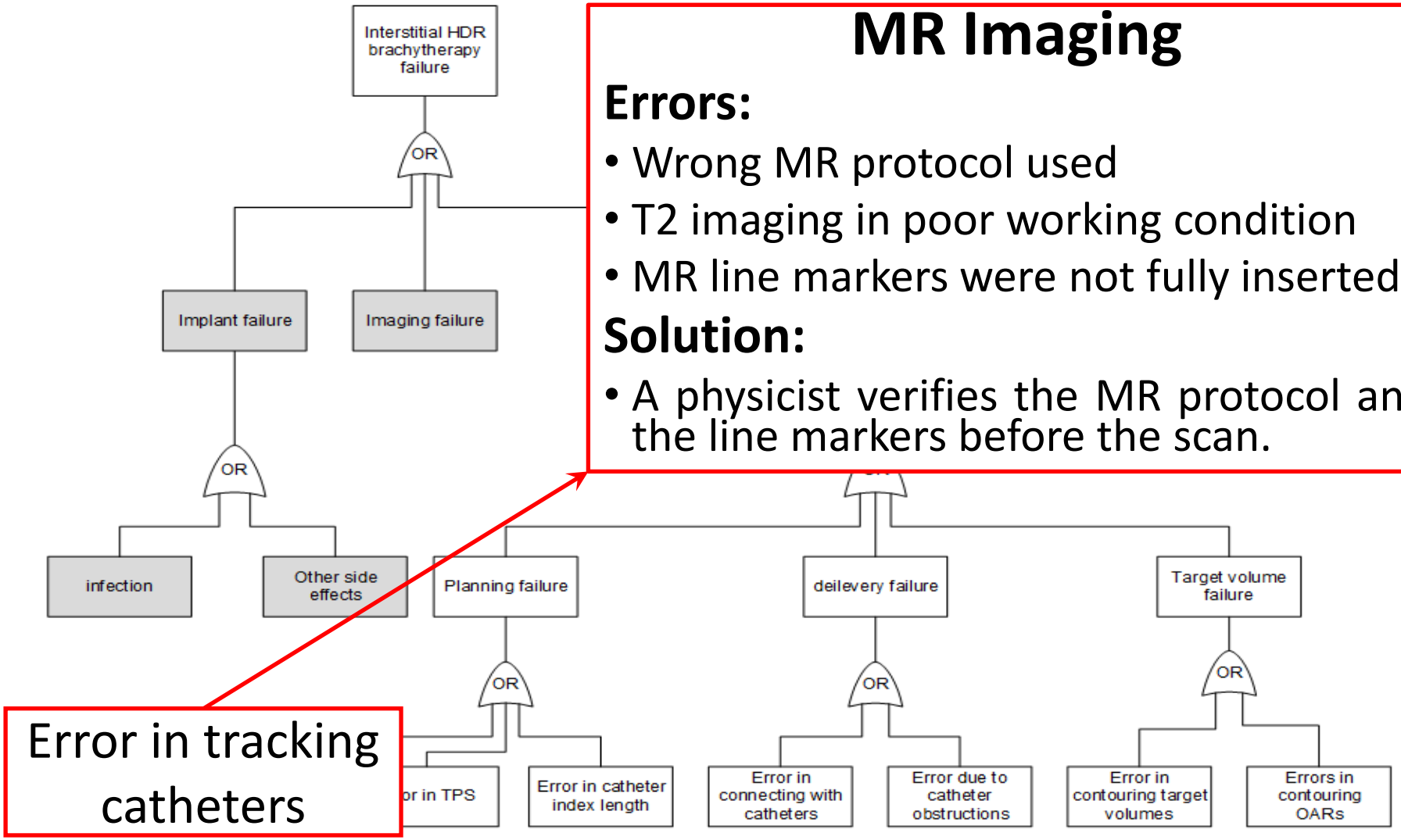
Potential error:

- Bubbles were not removed

Solutions:

- Make the line markers within 24 hr
- Remove bubbles before use

An Example of Fault Tree Analysis



MR Imaging

Errors:

- Wrong MR protocol used
- T2 imaging in poor working condition
- MR line markers were not fully inserted

Solution:

- A physicist verifies the MR protocol and the line markers before the scan.

Error in tracking catheters

Conclusion

- MRI-based interstitial brachytherapy is achievable in most radiation oncology clinics if the required equipment is available.
  - MRI scanner
  - CT scanner (only needed when MRI functioned poorly on the treatment day)
  - HDR afterloader
  - OR / procedure room
  - MRI compatible IBT catheters and templates

Conclusion (cont.)

- Careful physics equipment preparation and planning following checklists will facilitate the implementation of the MRI-HDR-IBT procedure, and therefore improve the treatment experience of the patient and the brachytherapy treatment team.

References

1. **Hualin Zhang, Eric D. Donnelly, Jonathan B. Strauss et al. Clinical implementation, logistics and workflow guide for MRI image based interstitial HDR brachytherapy for gynecological cancers. J Appl Clin Med Phys. 2019;20(11):37-49.**
2. Eric D. Donnelly, Sean Sachdev, Hualin Zhang, et al. Development of a Gynecologic Brachytherapy Curriculum and Simulation Modules to Improve Radiation Oncology Trainees Skills and Confidence. Brachytherapy 2020;19(6):732-737.
3. Haie-Meder C, Potter R, Van Limbergen E, et al. Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group (I): concepts and terms in 3D image based 3D treatment planning in cervix cancer brachytherapy with emphasis on MRI assessment of GTV and CTV. Radiother Oncol. 2005;74:235–245.
4. Potter R, Haie-Meder C, Van Limbergen E, et al. Recommendations from gynaecological (GYN) GEC ESTRO working group (II): concepts and terms in 3D image-based treatment planning in cervix cancer brachytherapy-3D dose volume parameters and aspects of 3D image-based anatomy, radiation physics, radiobiology. Radiother Oncol. 2006;78:67–77.
5. Hellebust TP, Kirisits C, Berger D, et al. Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group: considerations and pitfalls in commissioning and applicator reconstruction in 3D image-based treatment planning of cervix cancer brachytherapy. Radiother Oncol. 2010;96:153–160.
6. Dimopoulos JC, Petrow P, Tanderup K, et al. Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group (IV): Basic principles and parameters for MR imaging within the frame of image based adaptive cervix cancer brachytherapy. Radiother Oncol. 2012;103:113–122.

Questions?

Zhilei (Julie) Shen, PhD, DABR
zhilei.shen@med.usc.edu

Hualin Zhang, PhD, DABR
hualin.zhang@med.usc.edu