

MRI Simulation and Radiation Oncology

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Objectives

- Quick Overview of MRI
- MRI Safety
- MRI Simulation in Radiation Oncology
- Diagnostic MRI vs. MRI Simulation
- Benefits of MRI simulation vs CT alone
- Types of MRI Simulations done at MSK
- Brachy and MR Simulation
- Treatment planning and fusion
- Q & A

MRI Overview



Key Features

- **No Radiation**: Unlike X-rays or CT scans, MRI does not use ionizing radiation, making it safer for frequent use.
- **Soft Tissue Detail**: It is particularly effective for imaging "soft" parts of the body, such as the brain, spinal cord, muscles, ligaments, and internal organs.
- **Image Clarity**: Provides superior contrast between different types of soft tissues, helping doctors distinguish between normal and abnormal tissue (like tumors or inflammation).

MRI Zones

Some zones can extend outside the suite or room, all the way to other floors and areas because the magnetic field extends in three dimensions. That said, four main ones have been established:

Zone 1: This is the safest zone. It is essentially all areas that the general public can access freely. No hazards are posed by the magnet in these areas. The scope of this zone includes the entrance to the MR facility or hospital.

Zone 2: This is the buffer between zones one and three. At this point, the patient is with an MR personnel, under general supervision. Generally, no magnet hazards are posed here either. Areas include the dressing room, interview area, and reception area.

Zone 3: Zone Three is much more restricted, and must have a physical barrier. Here, only patients that have undergone an interview and filled out a questionnaire are allowed, alongside an approved MR personnel. Given this, field hazards should be delineated clearly. Non-MR personnel are not allowed.

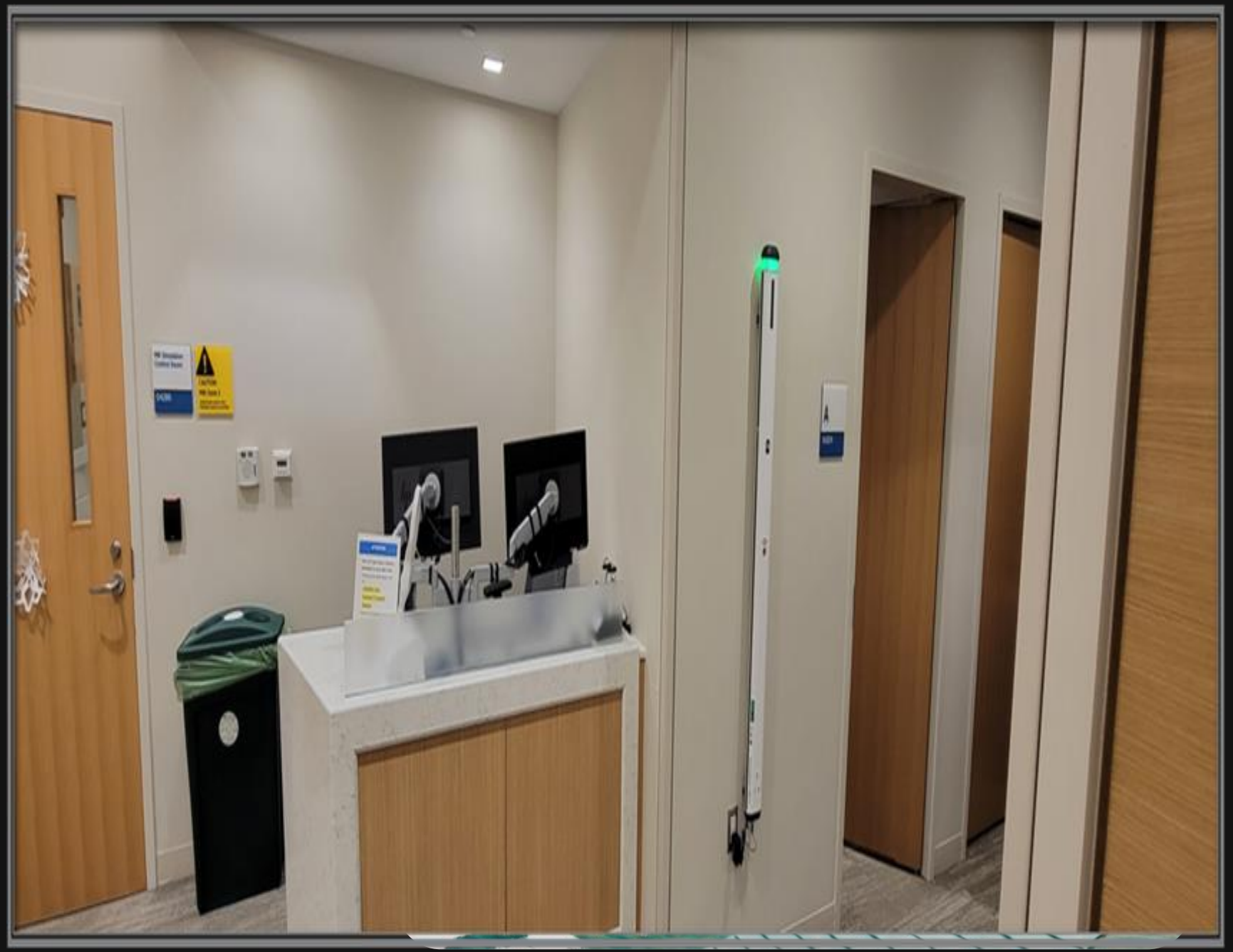
Zone 4: Sometimes called the magnet room, this is only accessible by passing Zone Three. At times, it is considered inside of Zone Three as it does not have access directly to other unrestricted areas.



Zone 1



Zone 2



Zone 3



Zone 4


WARNING
MRI Zone 4
Authorized access only
Patients must be escorted
EMERGENCY
MAGNET QUENCH
BUTTON
MR Simulation

MRI SAFETY



MR SAFE

The device/implant is non-magnetic, non-conductive, and does not react to MR levels of radiofrequency irradiation. Its presence poses no risk to patients or staff in the MRI environment.



MR CONDITIONAL

The device/implant *does* contain magnetic, conductive or RF-reactive components, but is deemed safe for use in the MRI environment provided certain strict conditions are followed.



MR UNSAFE

The device/implant contains ferromagnetic materials or has such a response to electromagnetic irradiation that it poses potential harm to MRI patients or staff under all circumstances.

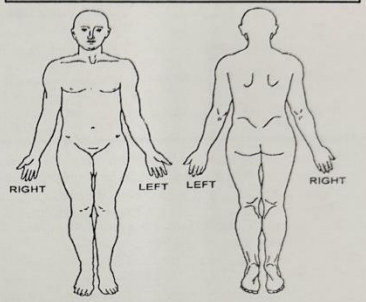
MRI Patient Screening Form

WARNING: Certain implants, devices, or objects may be hazardous to you and/or may interfere with the MR procedure (i.e., MRI, MR angiography, functional MRI, MR spectroscopy). Do not enter the MR system room or MR environment if you have any question or concern regarding an implant, device, or object. Consult the MRI Technologist or Radiologist BEFORE entering the MR system room. The MR system magnet is ALWAYS on.

Please indicate if you have any of the following:

❒ Yes	❒ No	Aneurysm clip(s)
❒ Yes	❒ No	Cardiac pacemaker
❒ Yes	❒ No	Implanted cardioverter defibrillator (ICD)
❒ Yes	❒ No	Electronic implant or device
❒ Yes	❒ No	Magnetically-activated implant or device
❒ Yes	❒ No	Neurostimulation system
❒ Yes	❒ No	Spinal cord stimulator
❒ Yes	❒ No	Internal electrodes or wires
❒ Yes	❒ No	Bone growth/bone fusion stimulator
❒ Yes	❒ No	Cochlear, otologic, or other ear implant
❒ Yes	❒ No	Insulin or other infusion pump
❒ Yes	❒ No	Implanted drug infusion device
❒ Yes	❒ No	Any type of prosthesis (eye, penile, etc.)
❒ Yes	❒ No	Heart valve prosthesis
❒ Yes	❒ No	Eyelid spring or wire
❒ Yes	❒ No	Artificial or prosthetic limb
❒ Yes	❒ No	Metallic stent, filter, or coil
❒ Yes	❒ No	Shunt (spinal or intraventricular)
❒ Yes	❒ No	Vascular access port and/or catheter
❒ Yes	❒ No	Radiation seeds or implants
❒ Yes	❒ No	Swan-Ganz or thermodilution catheter
❒ Yes	❒ No	Medication patch (Nicotine, Nitroglycerine)
❒ Yes	❒ No	Any metallic fragment or foreign body
❒ Yes	❒ No	Wire mesh implant
❒ Yes	❒ No	Tissue expander (e.g., breast)
❒ Yes	❒ No	Surgical staples, clips, or metallic sutures
❒ Yes	❒ No	Joint replacement (hip, knee, etc.)
❒ Yes	❒ No	Bone/joint pin, screw, nail, wire, plate, etc.
❒ Yes	❒ No	IUD, diaphragm, or pessary
❒ Yes	❒ No	Are you here for an MRI examination?
❒ Yes	❒ No	Dentures or partial plates
❒ Yes	❒ No	Tattoo or permanent makeup
❒ Yes	❒ No	Body piercing jewelry
❒ Yes	❒ No	Hearing aid *(Remove before entering MR system room)*
❒ Yes	❒ No	Other implant _____
❒ Yes	❒ No	Breathing problem or motion disorder

Please mark on the figure(s) below the location of any implant or metal inside of or on your body.



IMPORTANT INSTRUCTIONS

Before entering the MR environment or MR system room, you must remove all metallic objects including hearing aids, dentures, partial plates, keys, beeper, cell phone, eyeglasses, hair pins, barrettes, jewelry, body piercing jewelry, watch, safety pins, paperclips, money clip, credit cards, bank cards, magnetic strip cards, coins, pens, pocket knife, nail clipper, tools, clothing with metal fasteners, & clothing with metallic threads.

Please consult the MRI Technologist or Radiologist if you have any question or concern BEFORE you enter the MR system room.

NOTE: You may be advised or required to wear earplugs or other hearing protection during the MR procedure to prevent possible problems or hazards related to acoustic noise.

I attest that the above information is correct to the best of my knowledge. I read and understand the contents of this form and had the opportunity to ask questions regarding the information on this form and regarding the MR procedure that I am about to undergo.

Signature of Person Completing Form: _____ (Signature) Date ____/____/____

Form Completed By: ❒ Patient ❒ Relative ❒ Nurse _____ (Print name) _____ (Relationship to patient)

Form Information Reviewed By: _____ (Print name) _____ (Signature)

❒ MRI Technologist ❒ Nurse ❒ Radiologist ❒ Other_____

MAGNETIC RESONANCE (MR) PROCEDURE SCREENING FORM FOR PATIENTS

Date ____/____/____ Patient Number _____

Name _____ (Last name / First name / Middle Initial) Age _____ Height _____ Weight _____

Date of Birth ____/____/____ (month / day / year) Male ❒ Female ❒ Body Part to be Examined _____

Address _____ Telephone (home) (____) ____-____

City _____ Telephone (work) (____) ____-____

State _____ Zip Code _____

Reason for MRI and/or Symptoms _____

Referring Physician _____ Telephone (____) ____-____

1. Have you had prior surgery or an operation (e.g., arthroscopy, endoscopy, etc.) of any kind? ❒ No ❒ Yes
   If yes, please indicate the date and type of surgery:
   Date ____/____/____ Type of surgery _____
   Date ____/____/____ Type of surgery _____
2. Have you had a prior diagnostic imaging study or examination (MRI, CT, Ultrasound, X-ray, etc.)? ❒No ❒ Yes

If yes, please list:	Body part	Date	Facility
MRI	_____	____/____/____	_____
CT/CAT Scan	_____	____/____/____	_____
X-Ray	_____	____/____/____	_____
Ultrasound	_____	____/____/____	_____
Nuclear Medicine	_____	____/____/____	_____
Other_____	_____	____/____/____	_____

3. Have you experienced any problem related to a previous MRI examination or MR procedure? ❒ No ❒ Yes
   If yes, please describe: _____
4. Have you had an injury to the eye involving a metallic object or fragment (e.g., metallic slivers, shavings, foreign body, etc.)? ❒ No ❒ Yes
   If yes, please describe: _____
5. Have you ever been injured by a metallic object or foreign body (e.g., BB, bullet, shrapnel, etc.)? ❒ No ❒ Yes
   If yes, please describe: _____
6. Are you currently taking or have you recently taken any medication or drug? ❒ No ❒ Yes
   If yes, please list: _____
7. Are you allergic to any medication? ❒ No ❒ Yes
   If yes, please list: _____
8. Do you have a history of asthma, allergic reaction, respiratory disease, or reaction to a contrast medium or dye used for an MRI, CT, or X-ray examination? ❒ No ❒ Yes
9. Do you have anemia or any disease(s) that affects your blood, a history of renal (kidney) disease, renal (kidney) failure, renal (kidney) transplant, high blood pressure (hypertension), liver (hepatic) disease, a history of diabetes, or seizures? ❒ No ❒ Yes
   If yes, please describe: _____

For female patients:

10. Date of last menstrual period:____/____/____ Post menopausal? ❒ No ❒ Yes
11. Are you pregnant or experiencing a late menstrual period? ❒ No ❒ Yes
12. Are you taking oral contraceptives or receiving hormonal treatment? ❒ No ❒ Yes
13. Are you taking any type of fertility medication or having fertility treatments? ❒ No ❒ Yes
    If yes, please describe: _____
14. Are you currently breastfeeding? ❒ No ❒ Yes

Possible reasons a patient would not be able to have an MRI and/or MRI Simulation:

-Pacemaker
-Defibrillator
-Aneurysm clips
-Spinal cord stimulator
-Cochlear implant
-Other electronic various metal or electronic implants

*All implants and electronic devices are researched beforehand whether it is MR conditional or MR Unsafe and whether it can be performed with a 1.5T and/or 3.0T



MRI Simulation Overview

In oncology, "MRI-Sim" refers to using real MRI scanners specifically for **Radiation Therapy planning**.

- **How it works**: It uses MRI's superior soft-tissue visualization to accurately delineate tumor boundaries and nearby organs at risk with supreme detail.
- **Hardware adjustments**: Feature flat tabletops to precisely match the treatment table, laser positioning systems to align the patient's tattoos, and various types of immobilization devices to match the patient's treatment position during the MRI simulation

Diagnostic MRI vs. MRI Simulation

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Diagnostic MRI

- *Primary Goal* - Diagnose or monitor diseases
- Radiologists evaluate and report on the findings
- Patient position - most comfortable/optimal for imaging
- Table Design Usually curved for patient comfort
- Scanner Hardware Standard bore (60cm) Imaging
- Focus High anatomic detail and tissue contrast

MRI Simulation

- *Primary Goal* - Plan radiation therapy (Target/OAR delineation)
- Reviewed by PMD, dosimetrists, and Physicists
- Exact treatment position using immobilization devices
- Flat tabletop to match the radiation treatment couch
- Wider bore (≥70cm) and external laser systems for positioning
- High spatial fidelity and geometric accuracy

Diagnostic MRI

- Primary Focus Maximum tissue contrast and disease characterization.
- Slicing - Often thicker slices (3–5mm) to save time.
- Orientation - Oblique planes customized to specific anatomy.
- Acquisition - Typically 2D sequences are common.
- Duration - Longer sessions (45–60 min) with multiple sequences.

MRI Simulation

- Maximum geometric accuracy and spatial fidelity
- Slicing - Thin, contiguous slices (≤2mm) for precise 3D contouring
- Orientation – One Sagittal sequence and the rest axial/isotropic to match radiation beam geometry
- Acquisition - Preference for 3D volumetric sequences (e.g., T1 MPRAGE)
- Duration - Shorter sessions (25 min) with a limited subset of optimized sequences.



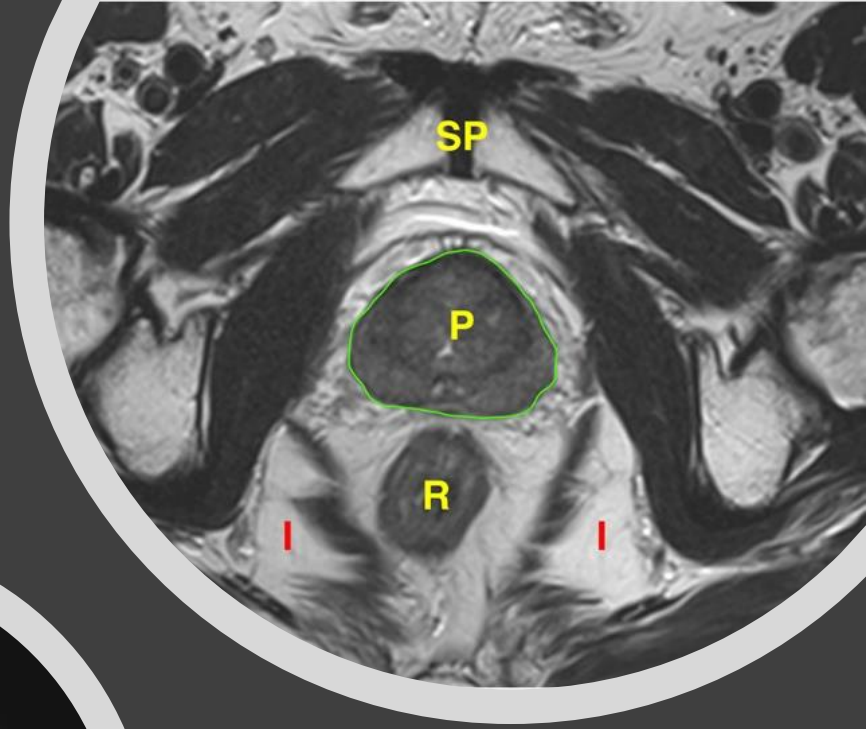
MRI Simulation Continued....

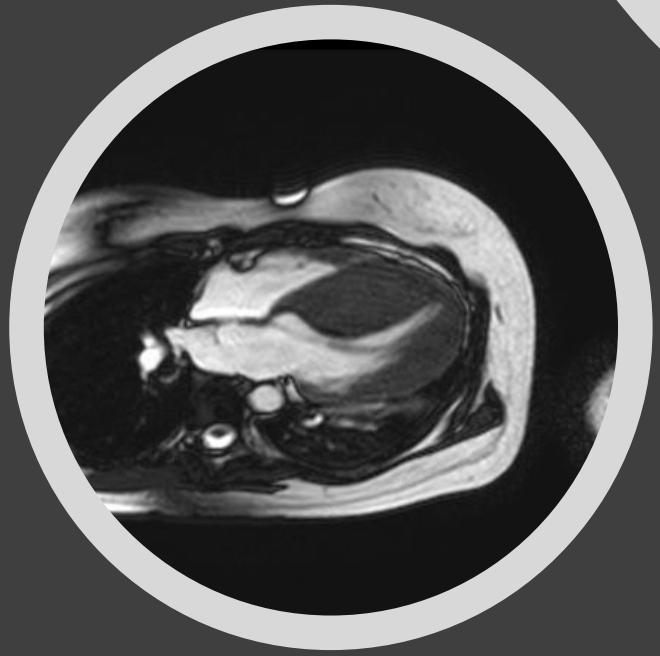
1. Geometric Distortion Correction: MR-Sim sequences are always acquired with 3D gradient nonlinearity correction turned on. This is critical because even a 2mm shift in image data can lead to radiation under-dosing the tumor.
2. High Bandwidth: MR-Sim protocols often use higher receiver bandwidths than diagnostic scans to minimize chemical shift and susceptibility artifacts.
3. Synthetic CT Generation: Advanced MR-Sim sequences (like Dixon or Zero-TE) may be added to generate "synthetic CT" data, allowing for MRI-only planning where electron density is calculated directly from the MRI.

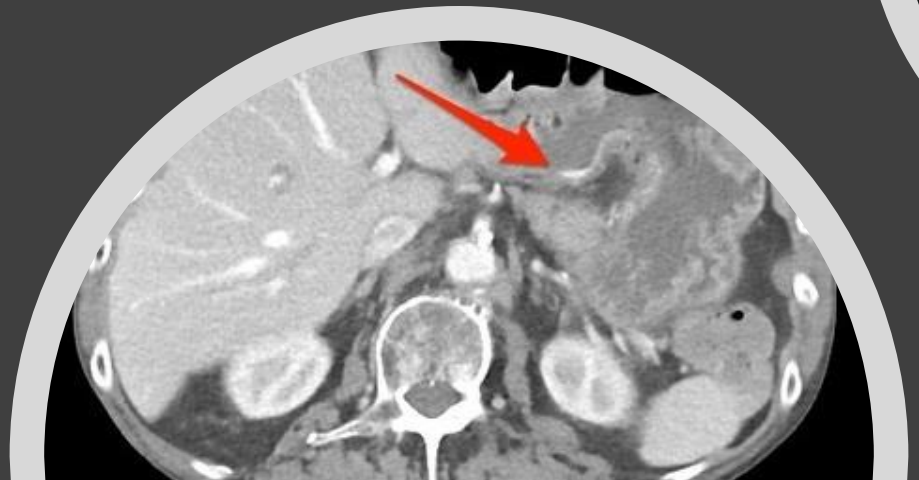
Different Type of MR SIM @ MSK

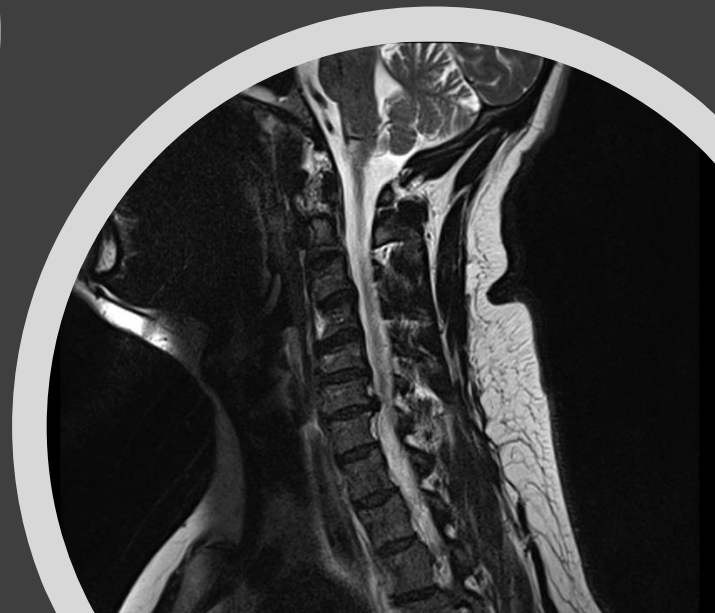
- Prostate/Prostate with Nodes
- Pelvic Node(s)
- Upper GI (Liver/Pancreas)
- Head and Neck
- Brain
- Research Scans
- Brachy











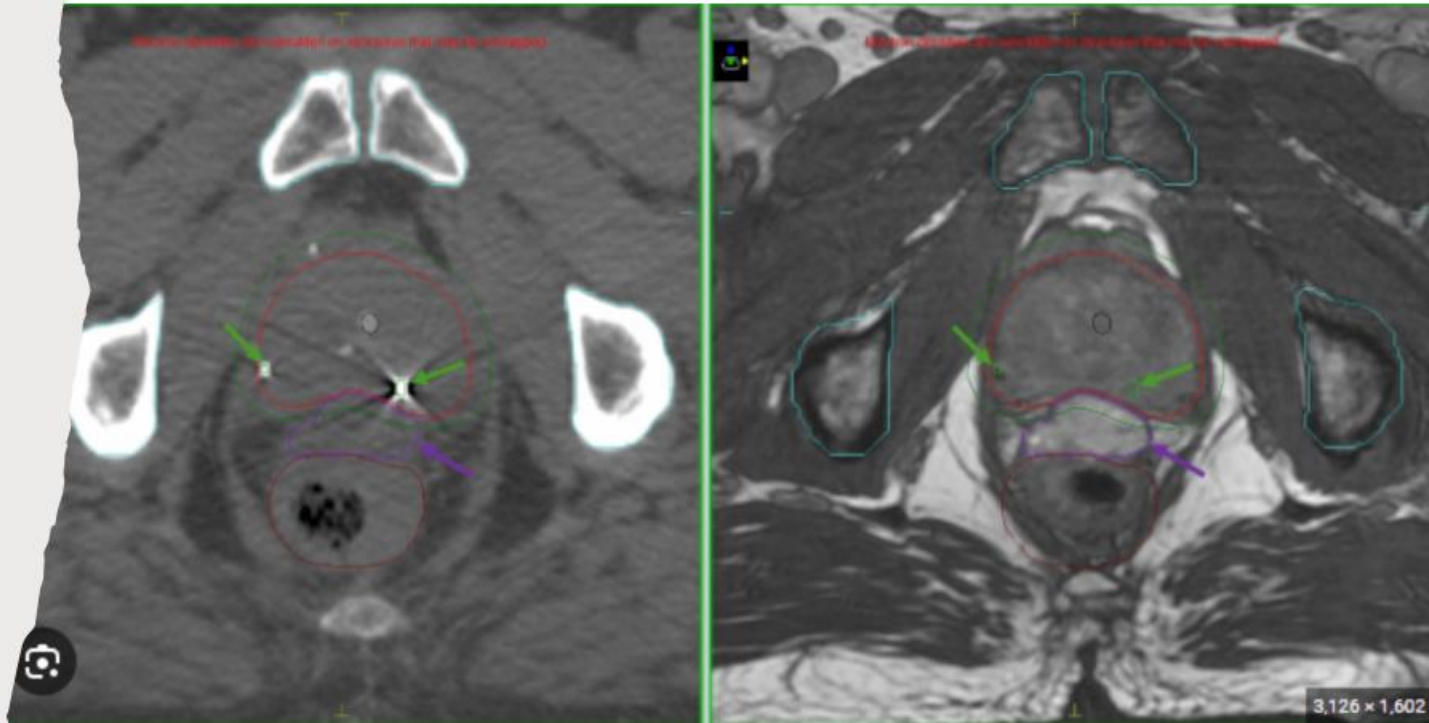


MR Sim Prostate

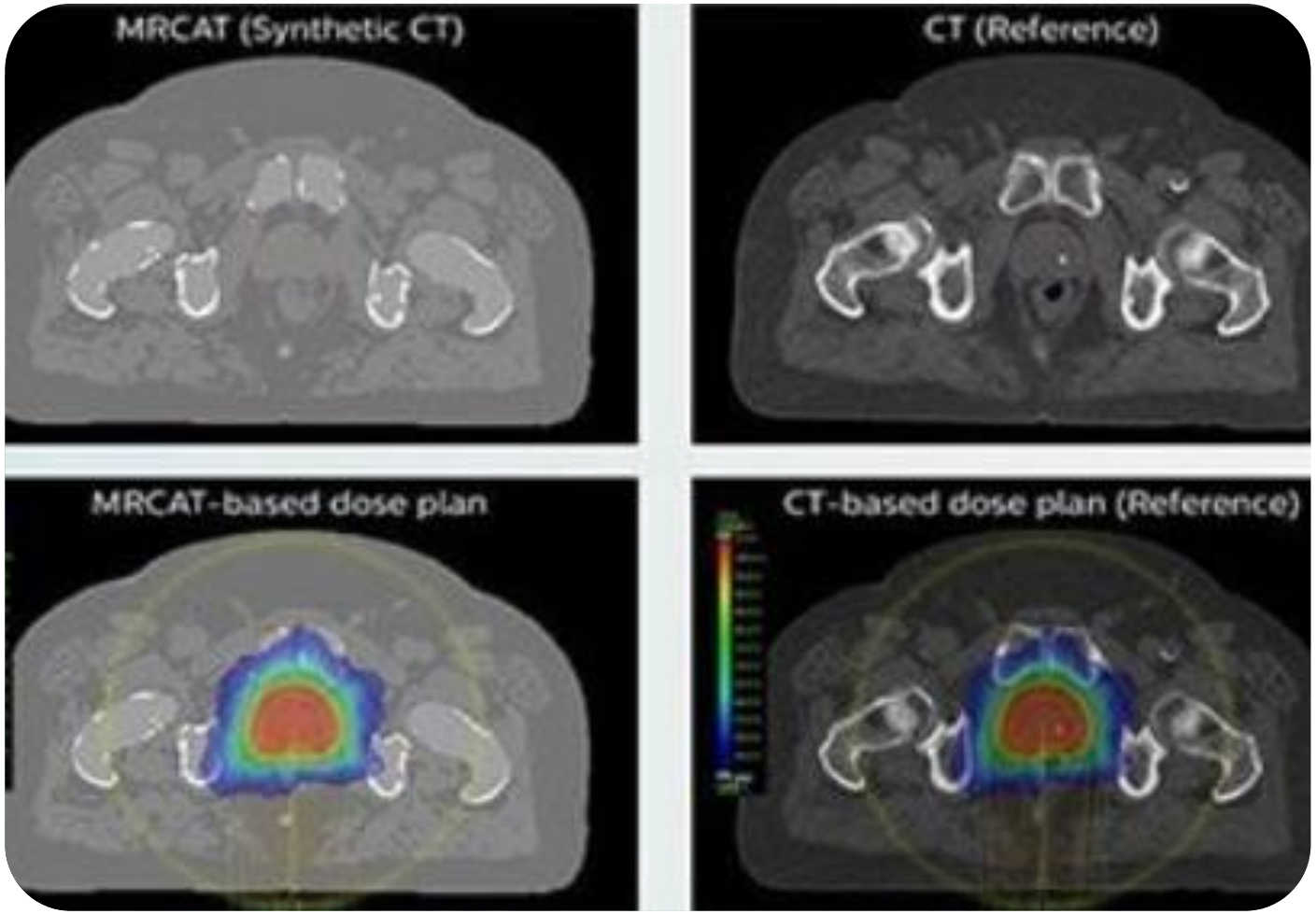
MR Fusion For Prostate Cancer

- MR fusion for prostate cancer radiation treatment planning involves combining magnetic resonance imaging (MRI) data with computed tomography (CT) data to enhance the accuracy of treatment planning. This fusion allows for a more detailed and precise visualization of the prostate gland and surrounding tissues, providing valuable information for radiation oncologists. Here are the key benefits and considerations:



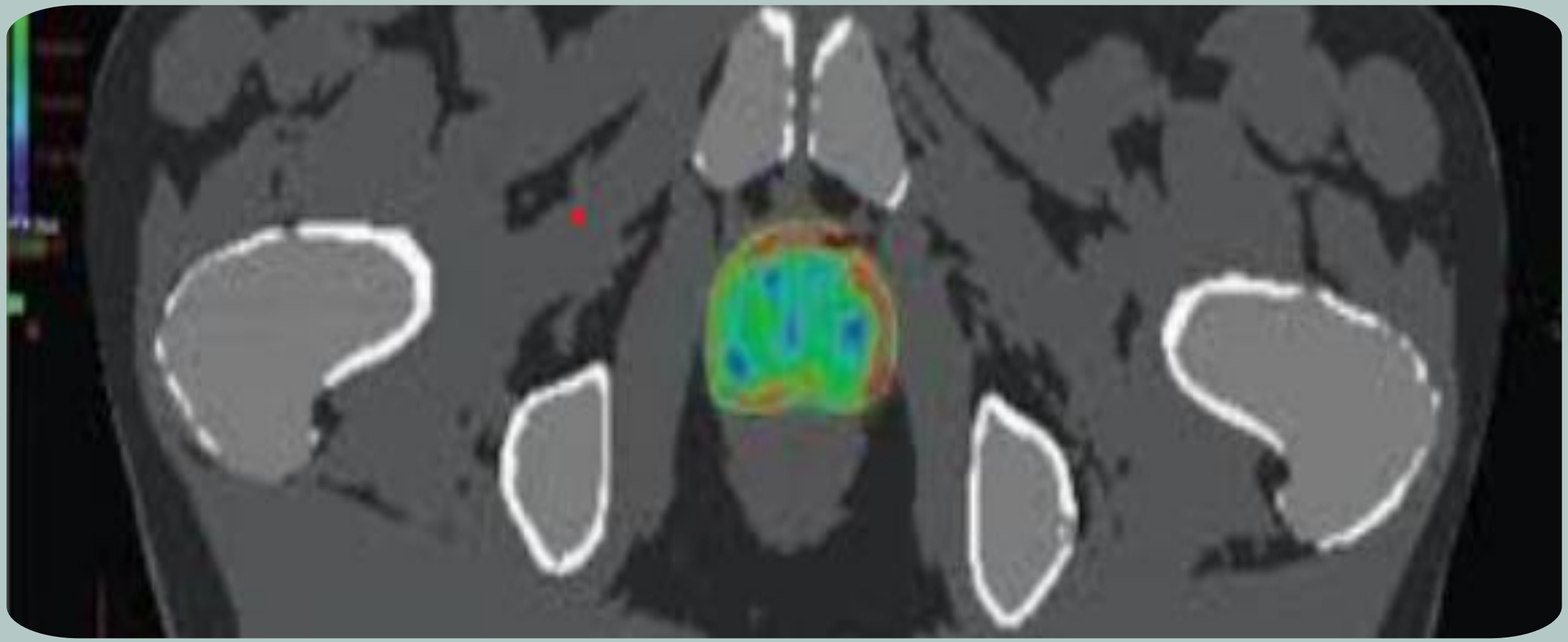


What is MRCAT?

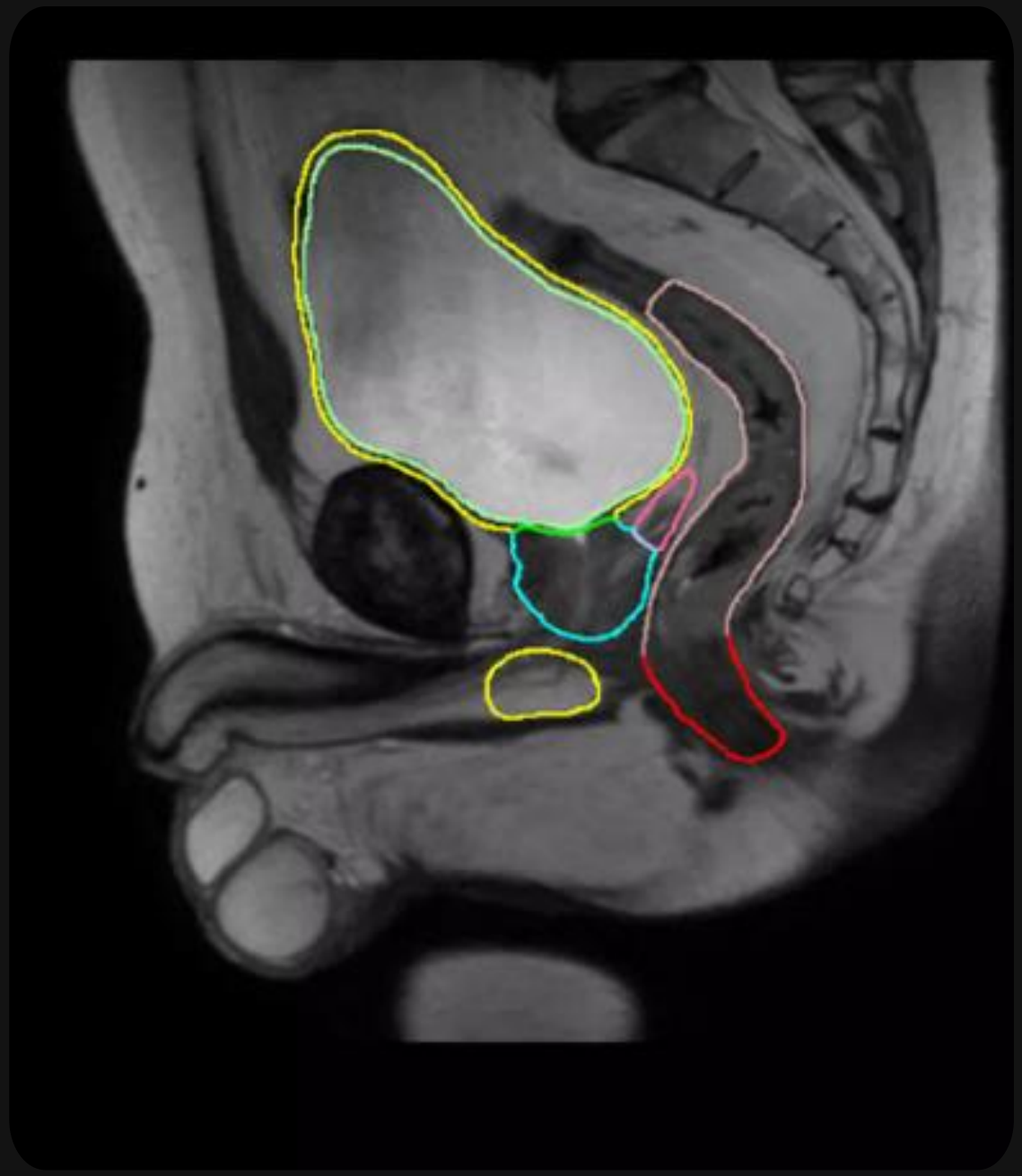


- MRCAT (MR for Calculating ATtenuation) uses artificial intelligence to generate synthetic CT images from MR scans. It enables "MR-only" radiotherapy planning, eliminating the need for separate CT scans and providing density information directly on the MR console.
- MRCAT images are exported directly to treatment planning,where they are treated exactly like a standard CT set for calculating radiation doses.

MRCAT Image used for planning

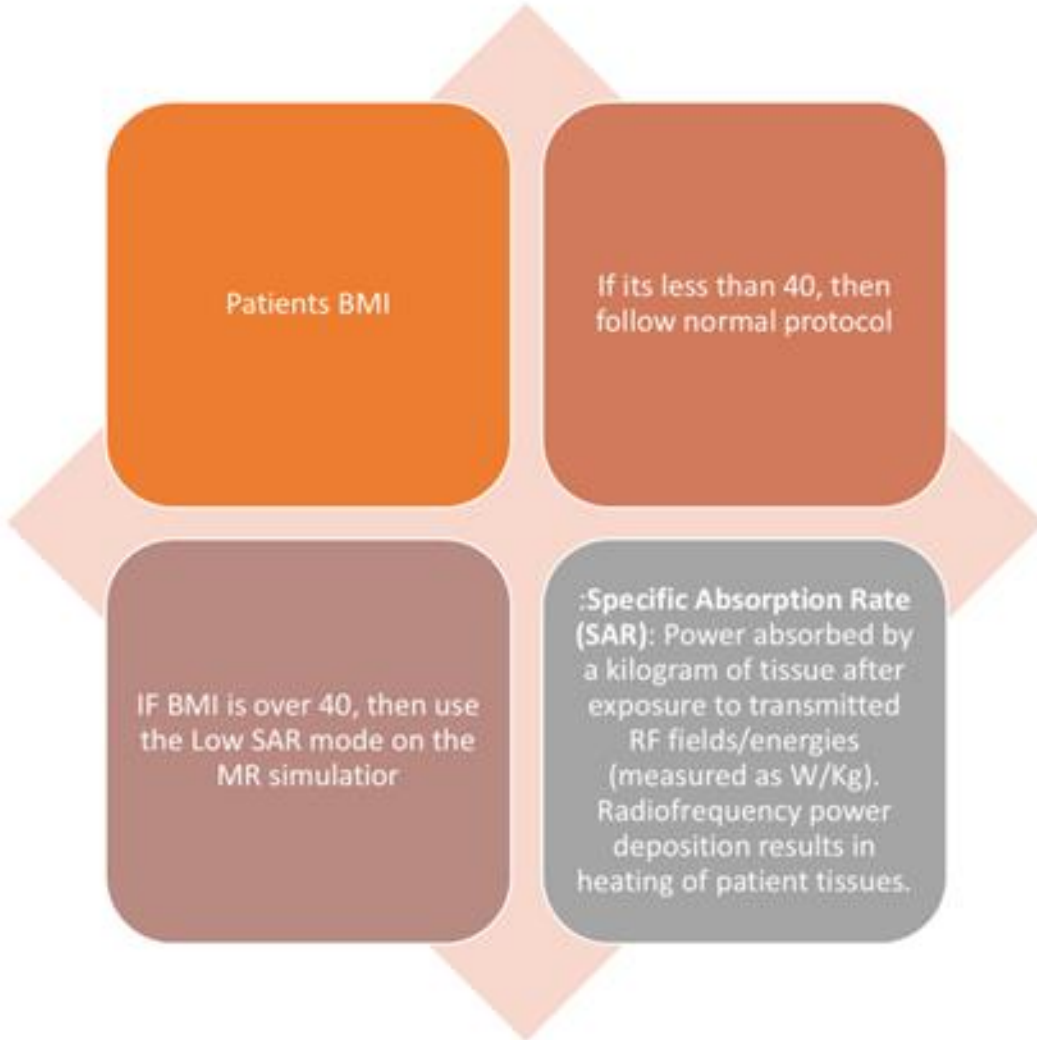


Sagittal Sequence used for MRSIM



Sagittal image showing full bladder and empty rectum.

Important Constrains for Prostate Sim



Pelvic Node MRsim

Replaces CT-Based Simulation

Highly effective in delineating soft tissue, making ideal for targeting lymph nodes.

MRCAT sequence acquired

Better visualization leads tighter, more accurate margins, allowing for reduced doses to normal tissue.

Upper GI MRI Simulation Workflow

MRL with compression

- Vaclok with Q-Fix molded in CT sim
- Arms up/down dependent upon patient
- Temporary set up marks placed on patient and mold
- Compression belt positioned and marked on patient
- Set up is reproduced in MR sim
- MR sequence used to determine degree of motion without compression vs. with compression

Non-MRL without compression

- Alphacradle with Q-Fix
- Arms up
- Motion management (DIBH)
- Contrast given in both CT and MRI

Upper GI MRI Simulation Workflow

MRL with compression continued…

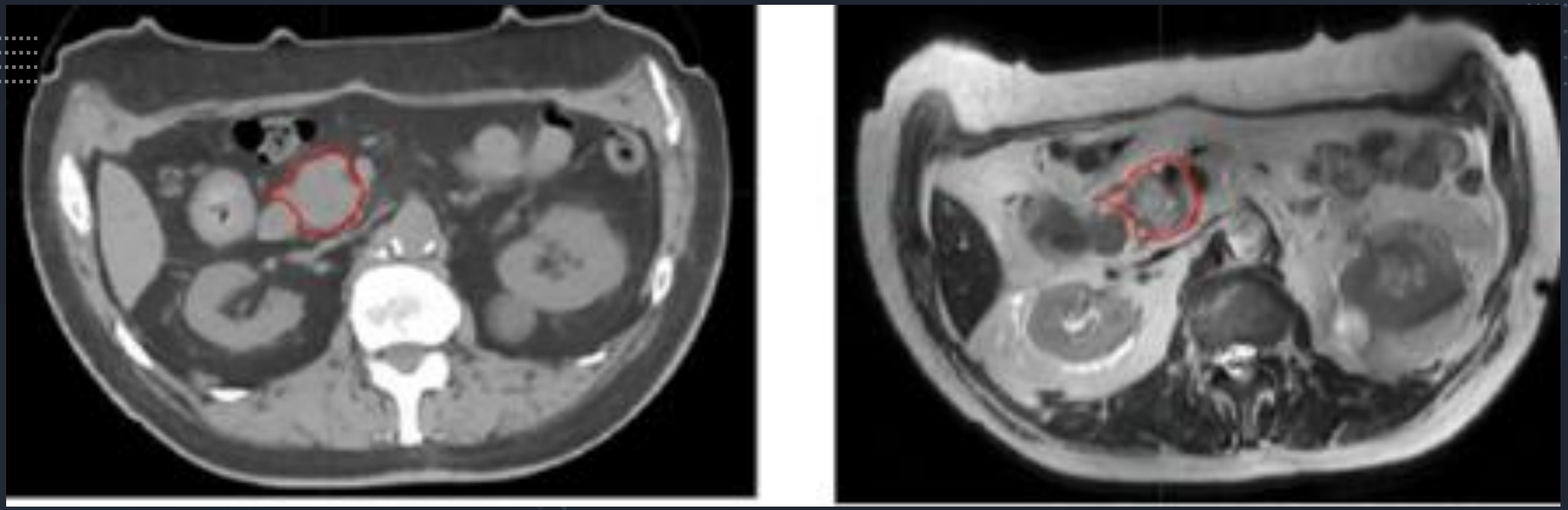
- MR sequence performed to determine degree of motion w/o compression.
- A pressure of at least 20 mmHg is added.
  - Pressure adjusted depending on patient tolerance.
- MR sequence repeated to determine degree of motion w/ compression.
- Respiratory motion documented
  - Targeted goal is within 1cm
- Patient returns to CT sim after MRI
- Set up is reproduced in CT sim
- Iso placement and final markings are completed
  - (tattoos, tabletop, board level, etc.)



Upper GI MRI Simulation Patient Positioning

UPPER GI Patient positioning in MRI SIM

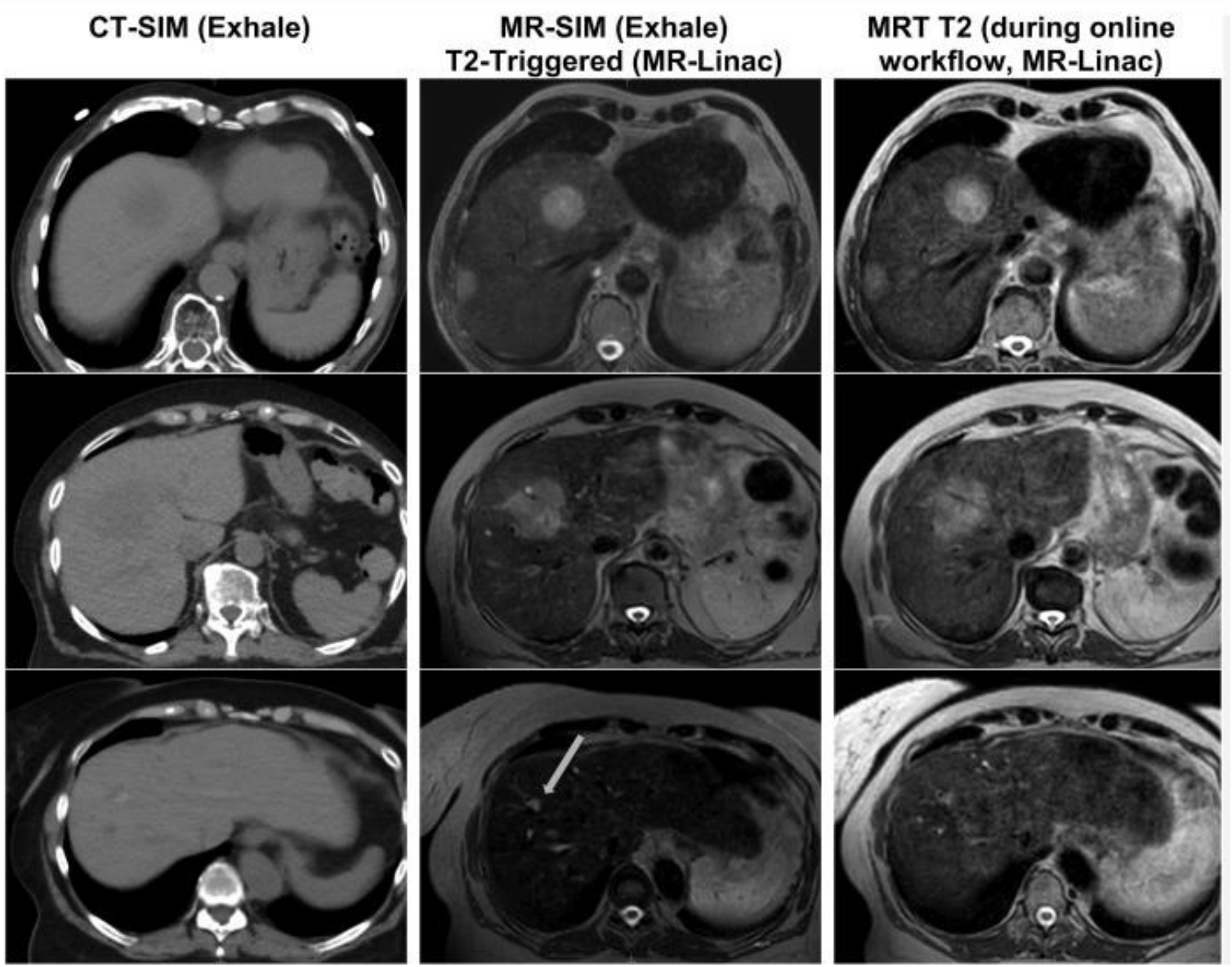




Upper GI MRI Simulation

- CT Scan vs. MRI images with compression belt

Upper GI MR Sim vs CT only imaging



Head and Neck Simulation Protocol

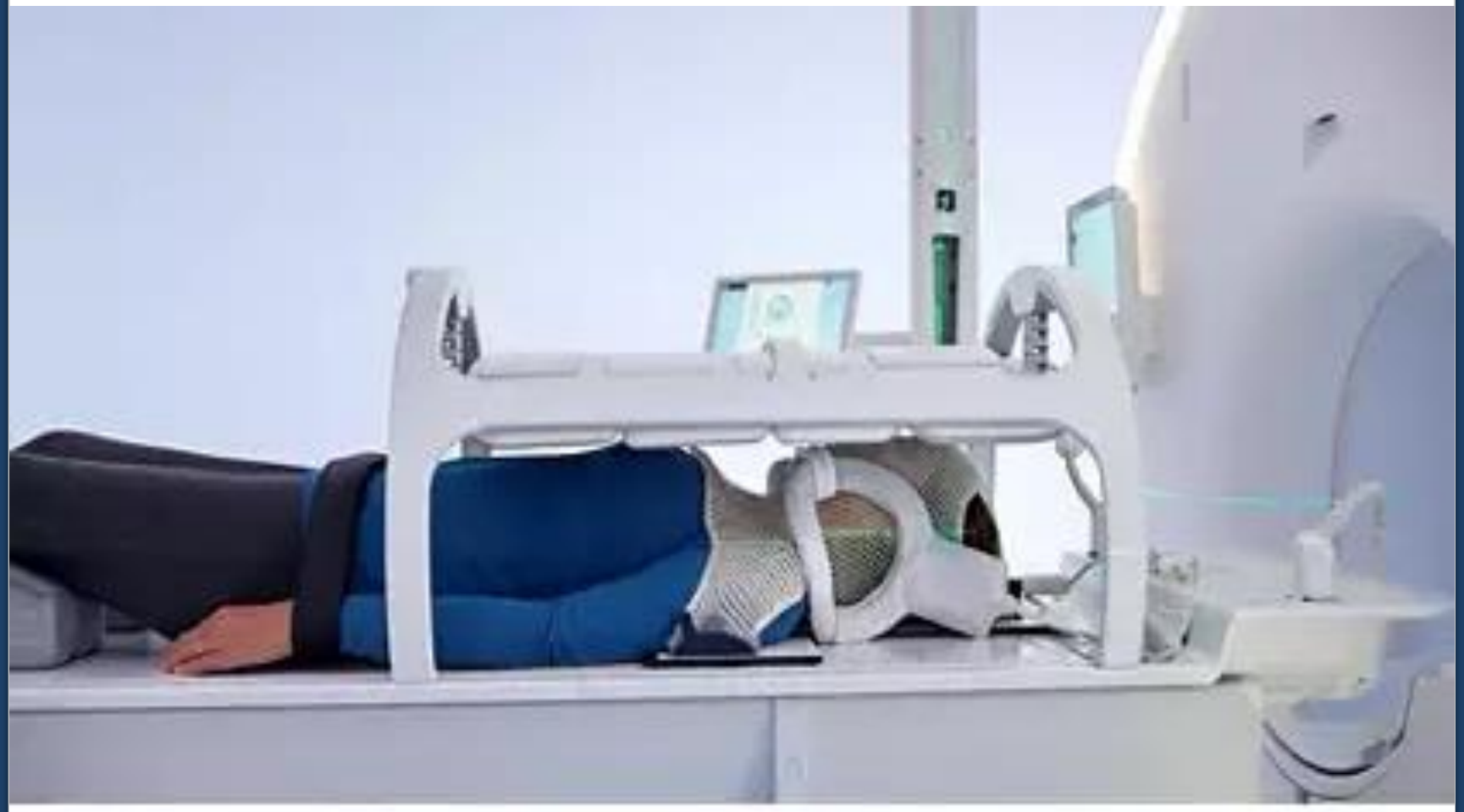
First 2 initial sequences are done in the mask on the Orfit board and designated head holder

Check to see if the patient has a bite block or mouth guards

Center patient at the chin

Instruct the patient to remain still and reduce swallowing

After those particular scans are completed, the patient will come off of the table and a standard set-up with the head coil is used for the remaining sequences



Head and Neck Simulation

←

-First 2 sequences

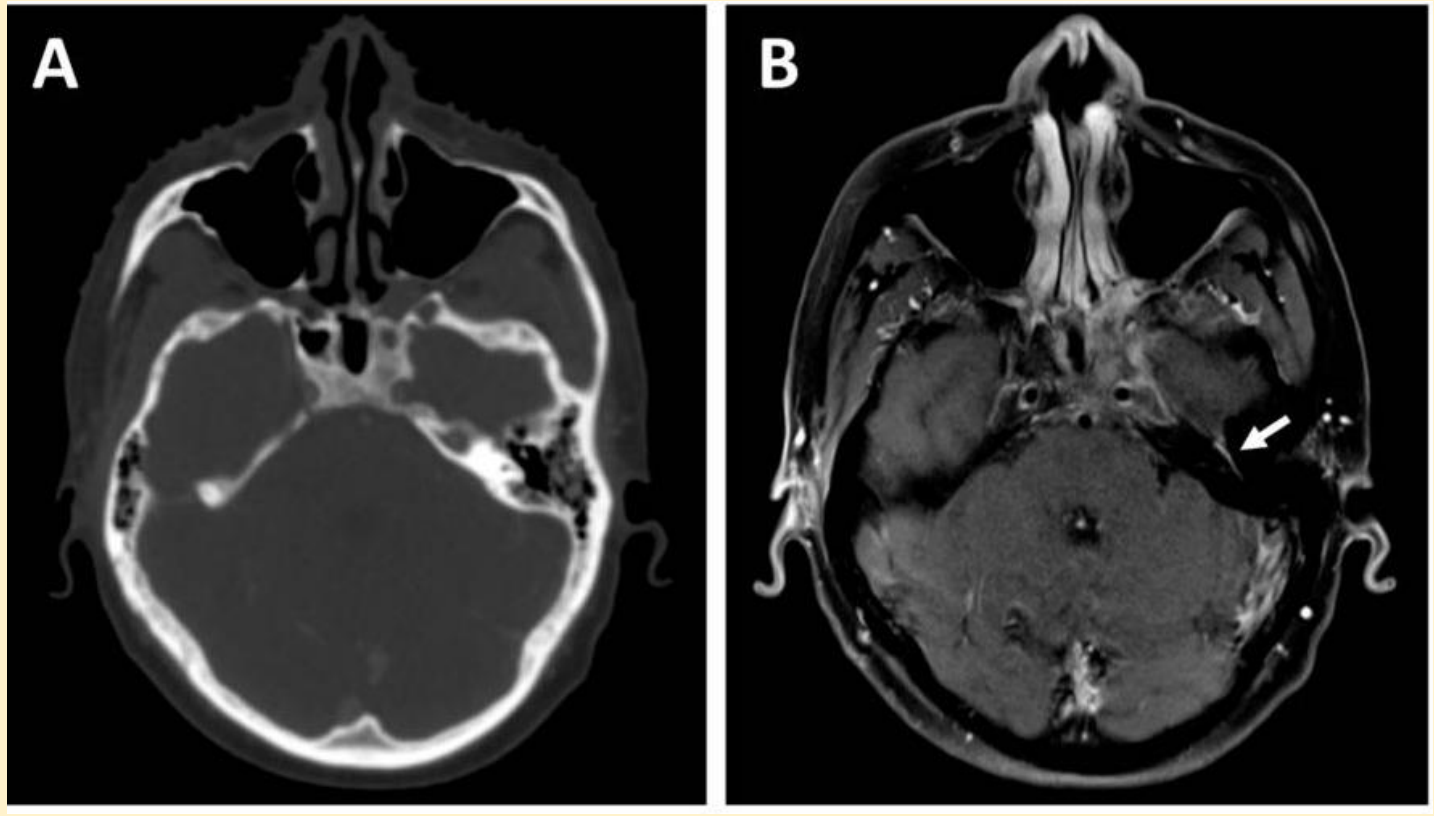


Head and Neck Simulation

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-Remaining sequences, including post contrast

Head and Neck Simulation CT/MR image comparison




CT
3D T2W TSE MRI
usa.philips.com

Brain

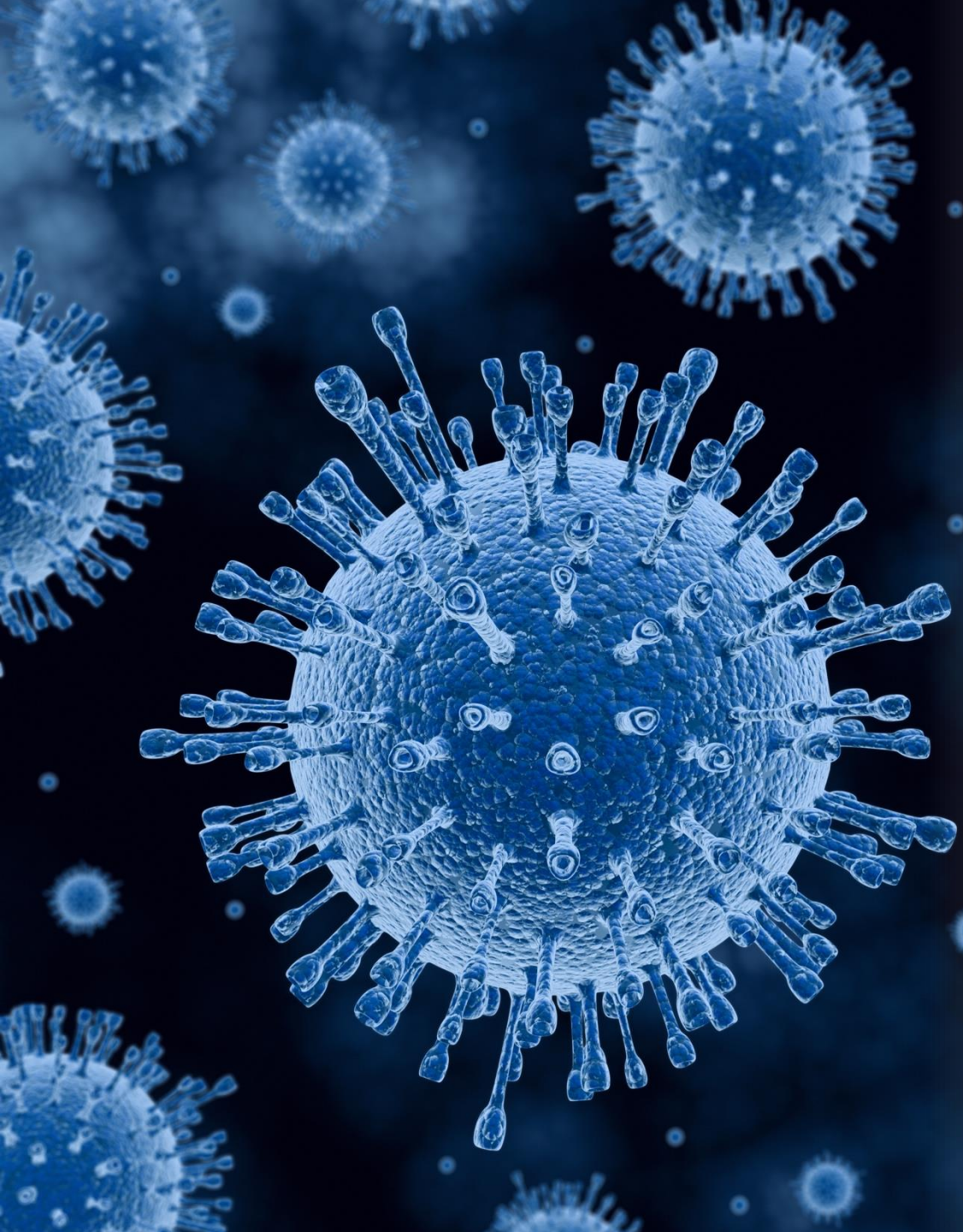


MR Sim/Research Scans

- PMD coordinates with research team to determine who qualifies for the research study, the timeframe of the scans, and whether or not they need contrast.
- Research scans can be used for planning before treatment, used for adaptive planning during their radiation treatment course, and post treatment to follow progression and outcome.

Types of Research scans @ MSK

- Head and Neck
- Prostate
- Rectum
- GYN
- Upper GI
- Low Dose for Arthritis*



Head and Neck Research

- Current MSK research protocols
  - 22-215
  - 17-409
  - 18-063
  - 21-434
- Depending on the research protocol, patients will have an MR scan pre-treatment, during RT, and post RT
  - For example - Protocol 22-215 requires a scan pre-treatment, week1, week 2, week 3, week 4 etc. , and post RT at 3 month, 6 month, and 1 year intervals
- Research team and MD decide if contrast is needed
  - For example – Protocol 22-215 typically requires contrast for the pre-txt and week 2 appointments . The remaining appointments are without contrast
  - Protocol 21-434 typically requires contrast for every appointment

MRI and Brachytherapy

MRI scans are obtained after applicator placement,
Protocol includes multiplanar T2-weighted fast spin-
echo sequences and high-
resolution isotropic sequences (e.g., SPACE) for 3D volumeplanning.
MRI is used to:
Visualize applicator geometry and placement.
Assess tumor residual volume.
Ensure safety (detect perforations, detect adjacent organ proximity).

MRI and Brachytherapy

- **Pre-Brachytherapy Imaging and Patient Preparation**:
- MRI is typically performed after **applicator insertion** to capture accurate anatomy with devices in place.
- Safety screening is mandatory for MR compatibility of applicators and transport devices.
- **Patient positioning** should replicate treatment posture to minimize motion during transfer to HDR treatment rooms.
- For gynecologic brachytherapy, no vaginal gel is generally required; bladder filling protocols may vary.

MRI and Brachytherapy

MRI plays a crucial role in the planning and execution of brachytherapy, especially for cervical cancer. Here are some key points regarding its use:

Image-Guided Therapy: MRI provides high-resolution images that help in accurately locating the tumor and surrounding structures. This is essential for ensuring that the radioactive sources are placed precisely where they are needed.

Treatment Planning: MRI can be used to assess the extent of the tumor and to plan the brachytherapy treatment effectively. It allows for dose escalation to the tumor while minimizing the dose to adjacent organs at risk (OARs).

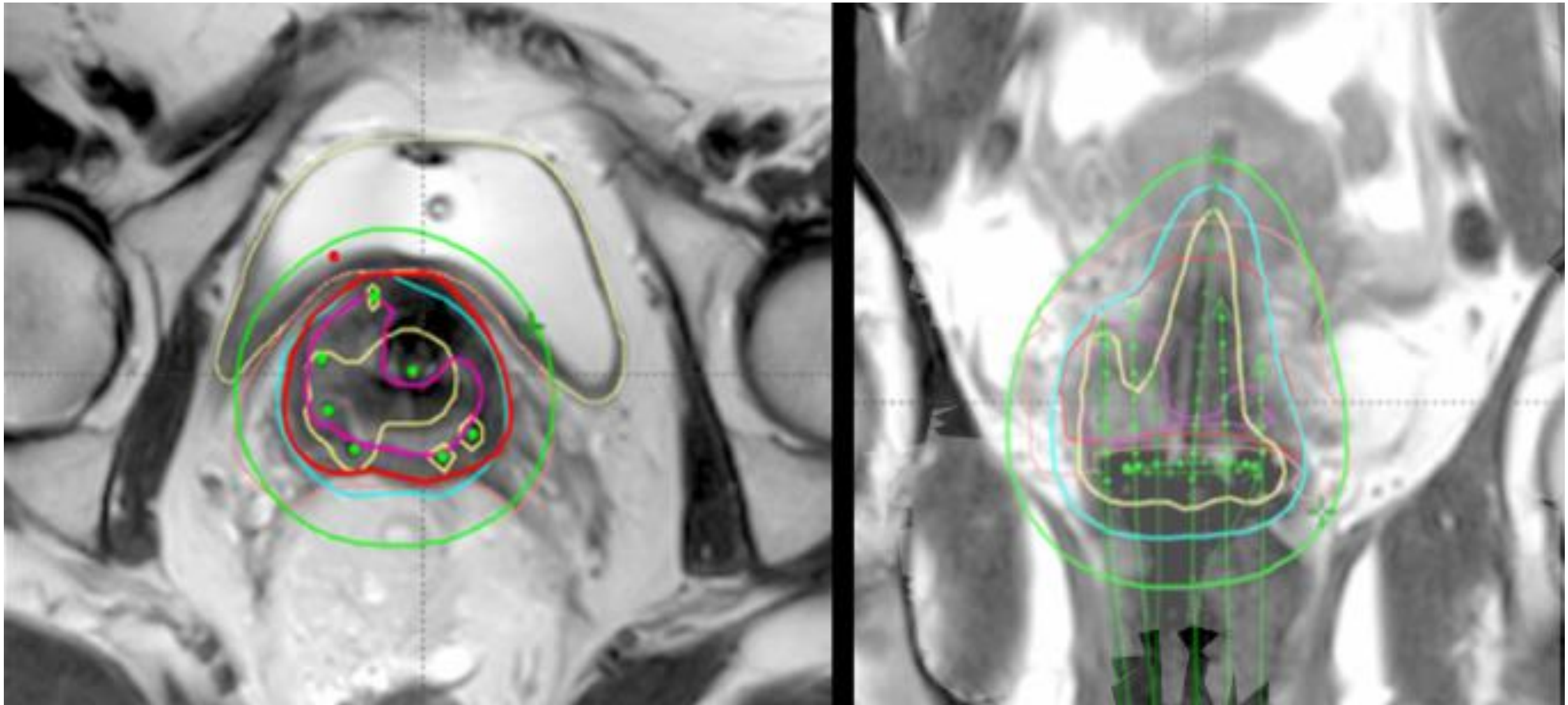
Real-Time Guidance: During the brachytherapy procedure, MRI can assist in verifying the position of applicators and the distribution of the radioactive source, reducing the risk of complications such as uterine perforation.

Enhanced Outcomes: The integration of MRI in brachytherapy has been shown to improve treatment outcomes by allowing for more personalized and precise radiation delivery, which is particularly beneficial in complex cases.

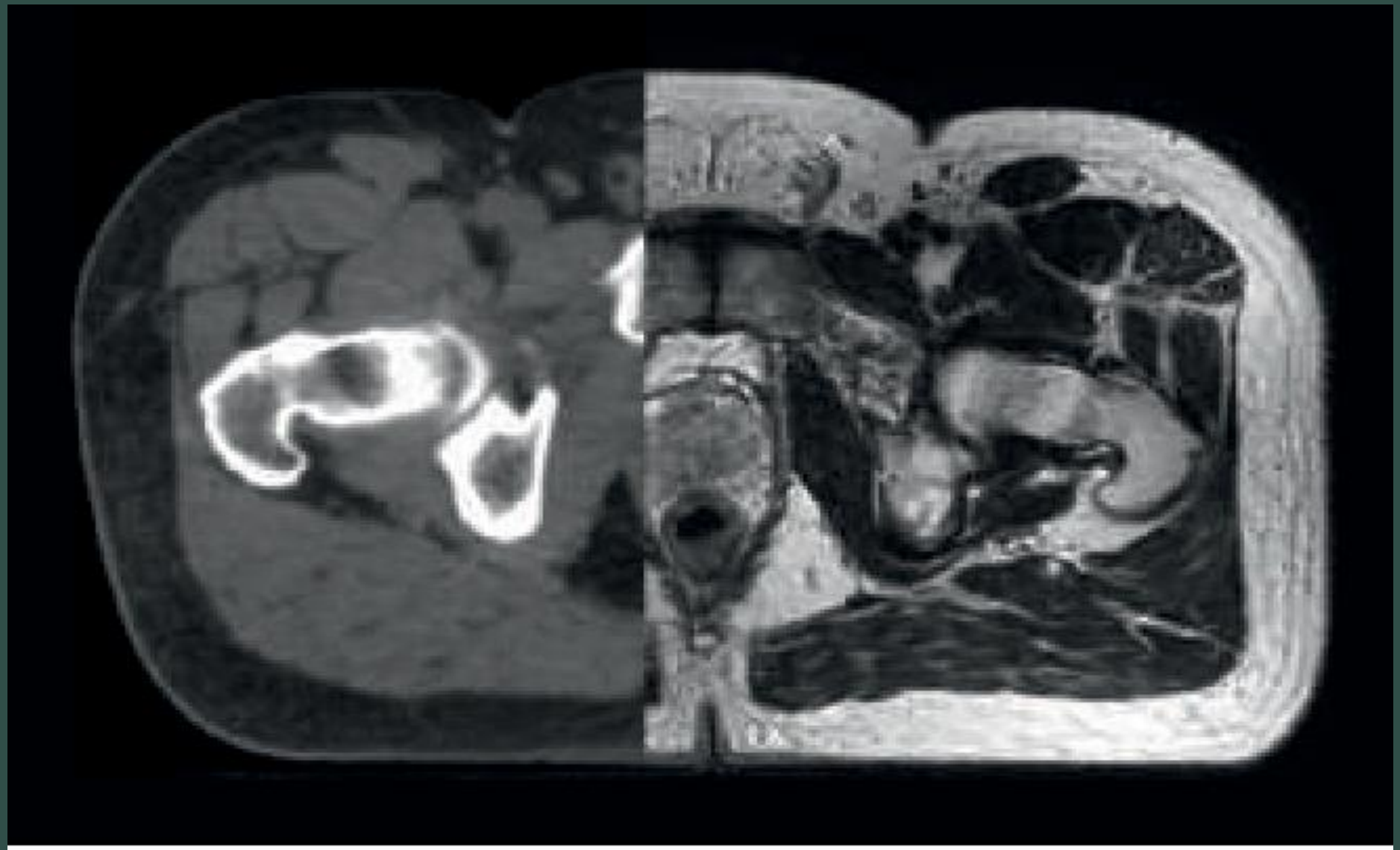
MRI and Brachytherapy



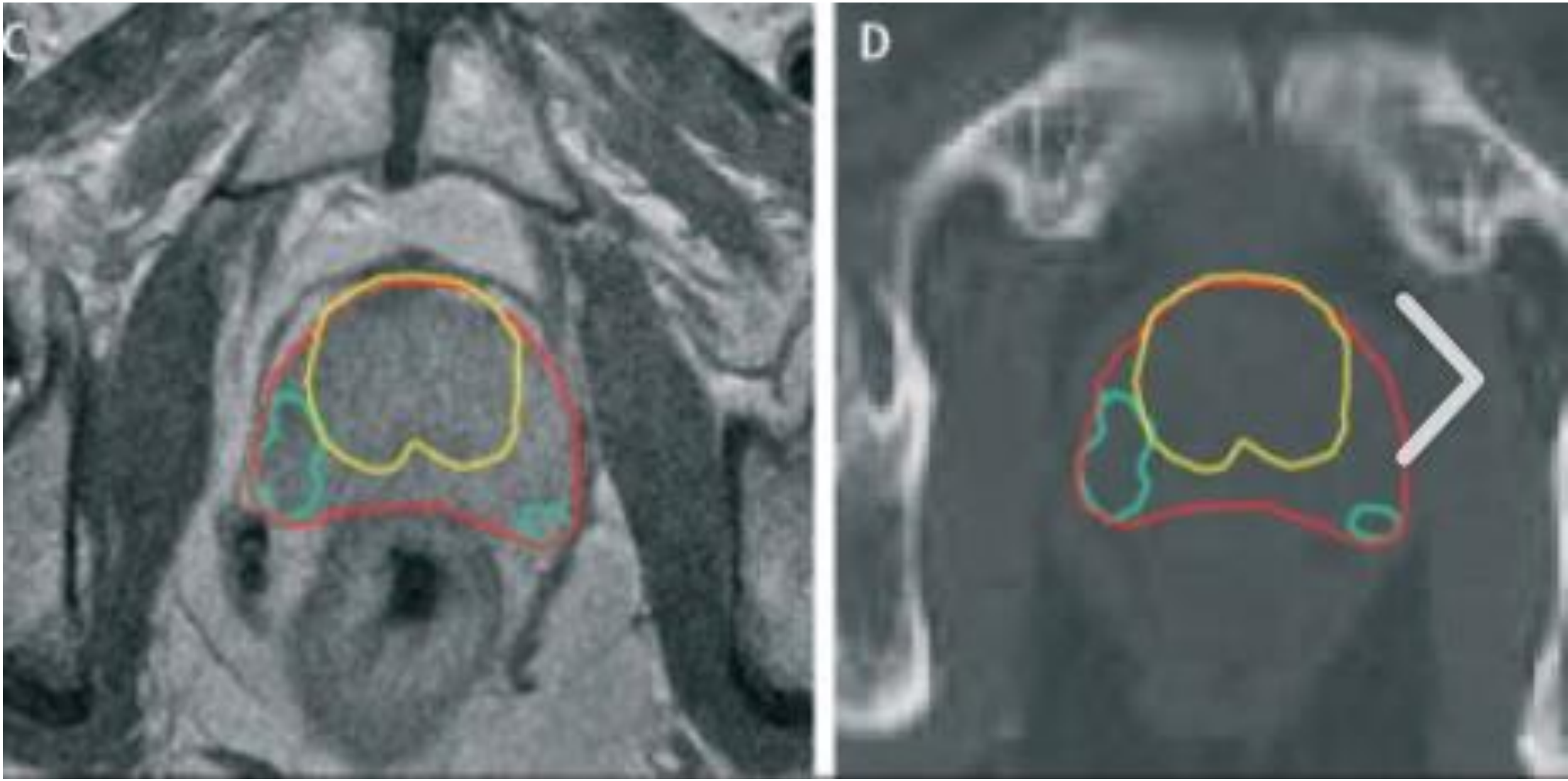
MRI and Brachytherapy



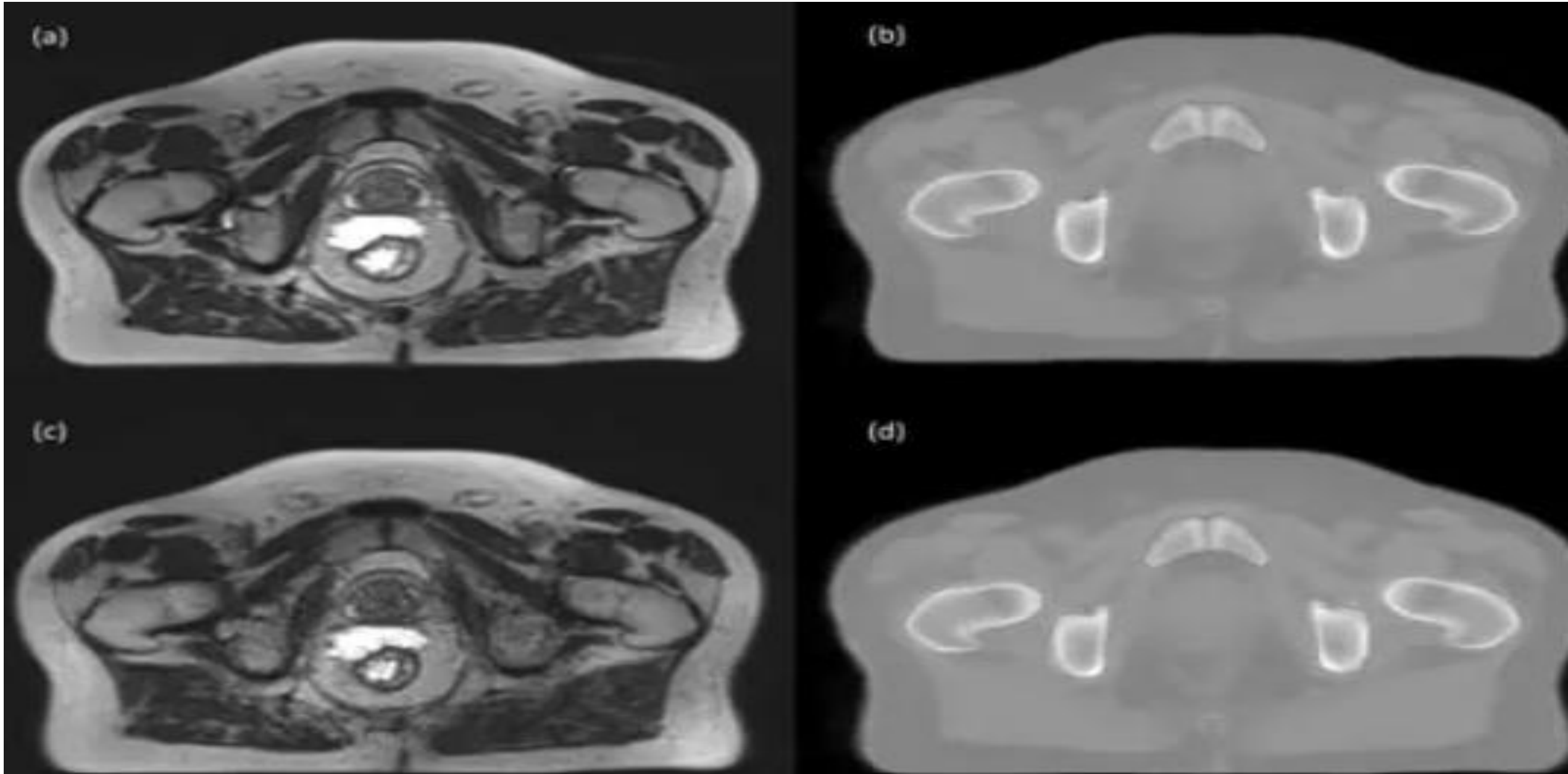
MRI vs. CT only for Radiation Planning

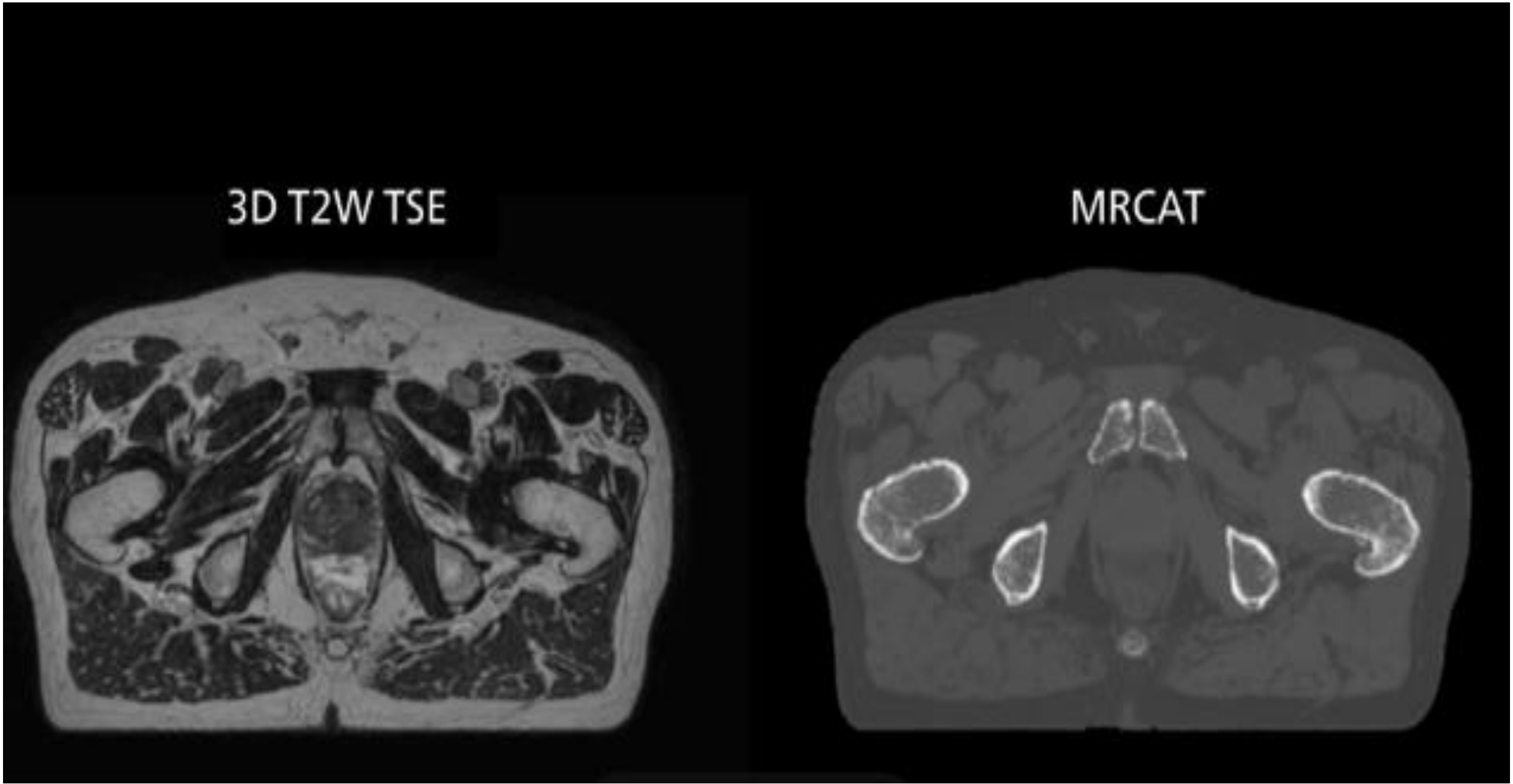


images



MR SIM used for planning vs CT alone for planning




3D T2W TSE
MRCAT

Simulation in hospitals and clinics

Most facilities used CT only simulations for direct radiation therapy planning

Diagnostic MRI and PET images are used for fusion during the planning process

Patient positoning will be different in the diagnotic setting, which creates challenges and limitation in the treatment planning process.



Q & A

How to handle audience questions effectively