

# MRI Guided Brachytherapy

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# Learning Objectives

- Highlight rationale for MR brachytherapy
- Discuss technical challenges
  - MR based planning
  - MR guided implants
- Indicate current developments & efforts

# Outline

- Subjects to be ignored
- Benefits of MR for brachytherapy
- MRI Based Planning
  - Permanent implants
  - Rigid applicators
- MRI Guided Implants
  - Geometric (HDR)
  - Dosimetric (permanent)

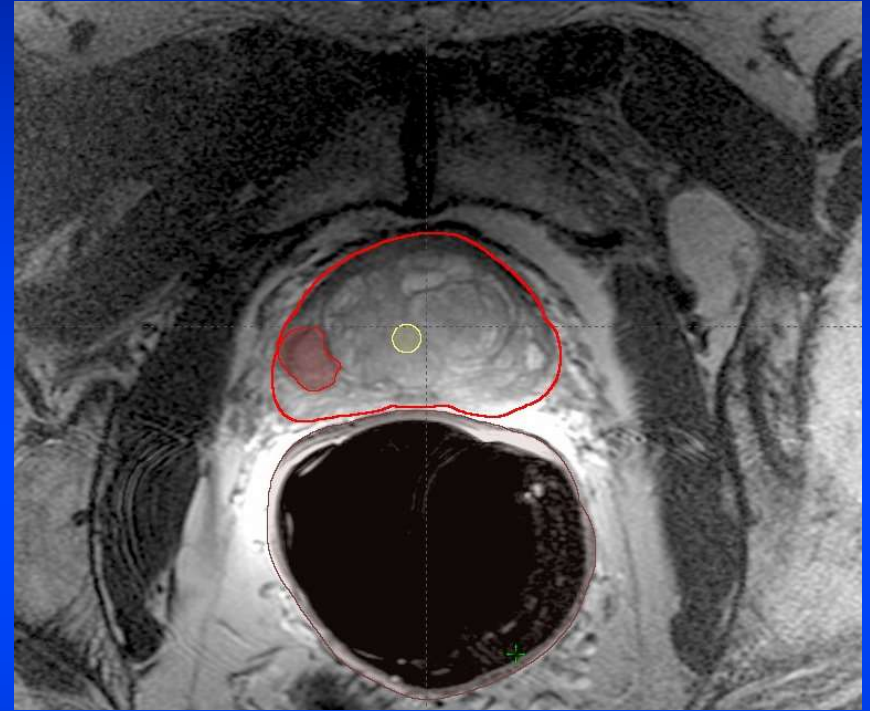
# What we do not consider

- MR safety
- Radiation Safety
- MR scanner QA This talk
- Brachytherapy QA
  - HDR
  - Applicators
  - Sources
  - TPS
- MR sequences for target definition
- Choice of isotope/dose rate
- Boy, 6, Dies of Skull Injury During M.R.I.
  - July 31, 2001
- Radiation Offers New Cures, and Ways to do Harm
  - January 23, 2010

**The New York Times**

# Why MRI? (prostate)

- Prostate
  - Visualization of capsule and substructure
    - T1, T2
  - Identification of primary tumor
    - MRS, DCE, DWI
  - Excellent identification of bladder, urethra and rectum



# Why MRI? (gyn)

- Target visualization
- Normal structures
- Target definition guidelines



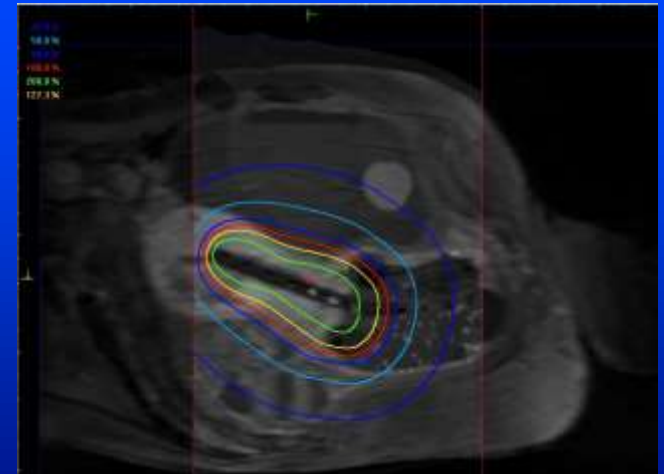
# Brachytherapy Examples

- HDR (gyn)
  - Preplanning
  - Implant
    - Applicator placement
    - Needle guidance
      - Blind
      - Image guided
      - Quantitatively guided
  - Planning
  - HDR delivery
- Permanent (prostate)
  - Biopsy
  - Volume study
    - Preplanning
  - Implant
    - Planning
    - Needle guidance
    - Adaptive
  - Post implant evaluation



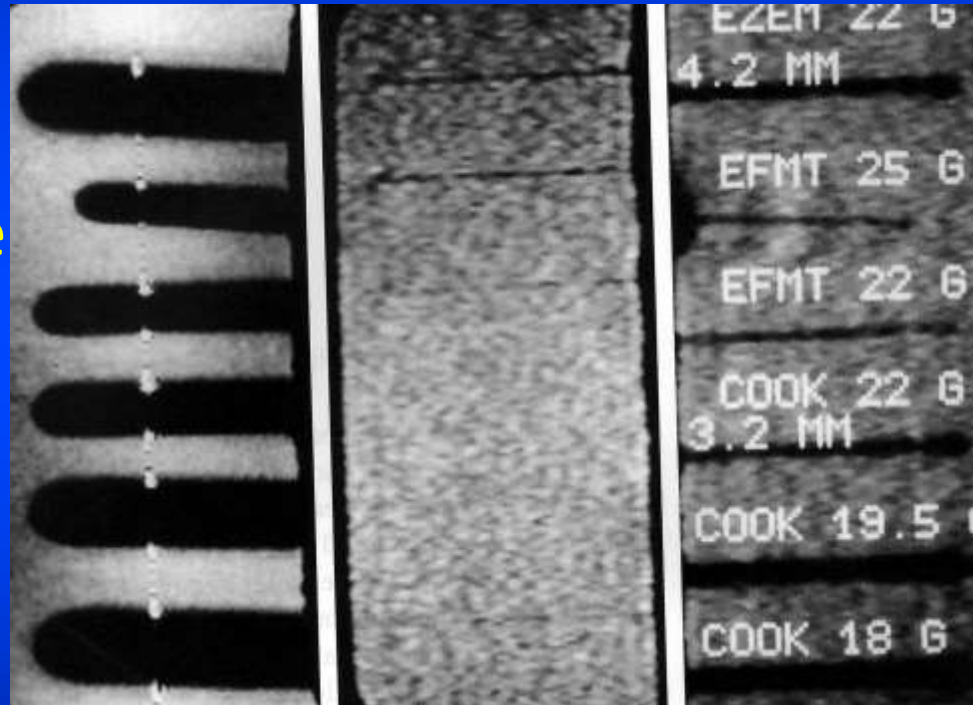
# Components of Brachytherapy

- Applicators or sources placed in patient
- Imaging with devices in place
- Applicators localized wrt anatomy
- Treatment planning in MR



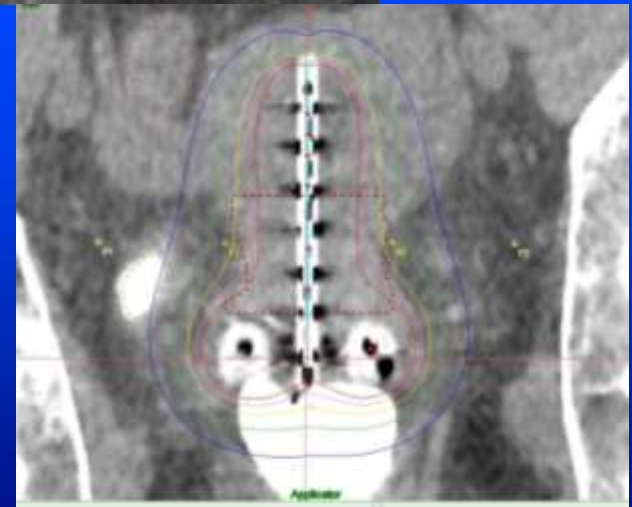
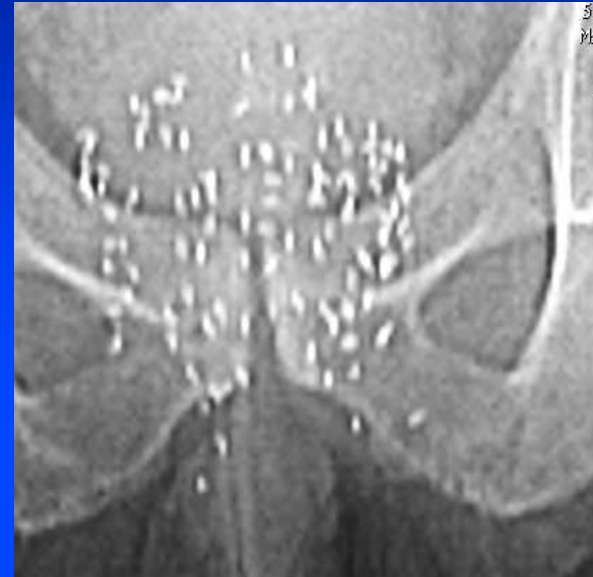
# Devices in MR

- Safe vs. compatible
- HDR applicators offered in MR versions
- Accessories may be safe but not compatible
- Compatibility may be pulse sequence dependent
- Image with devices in scanner



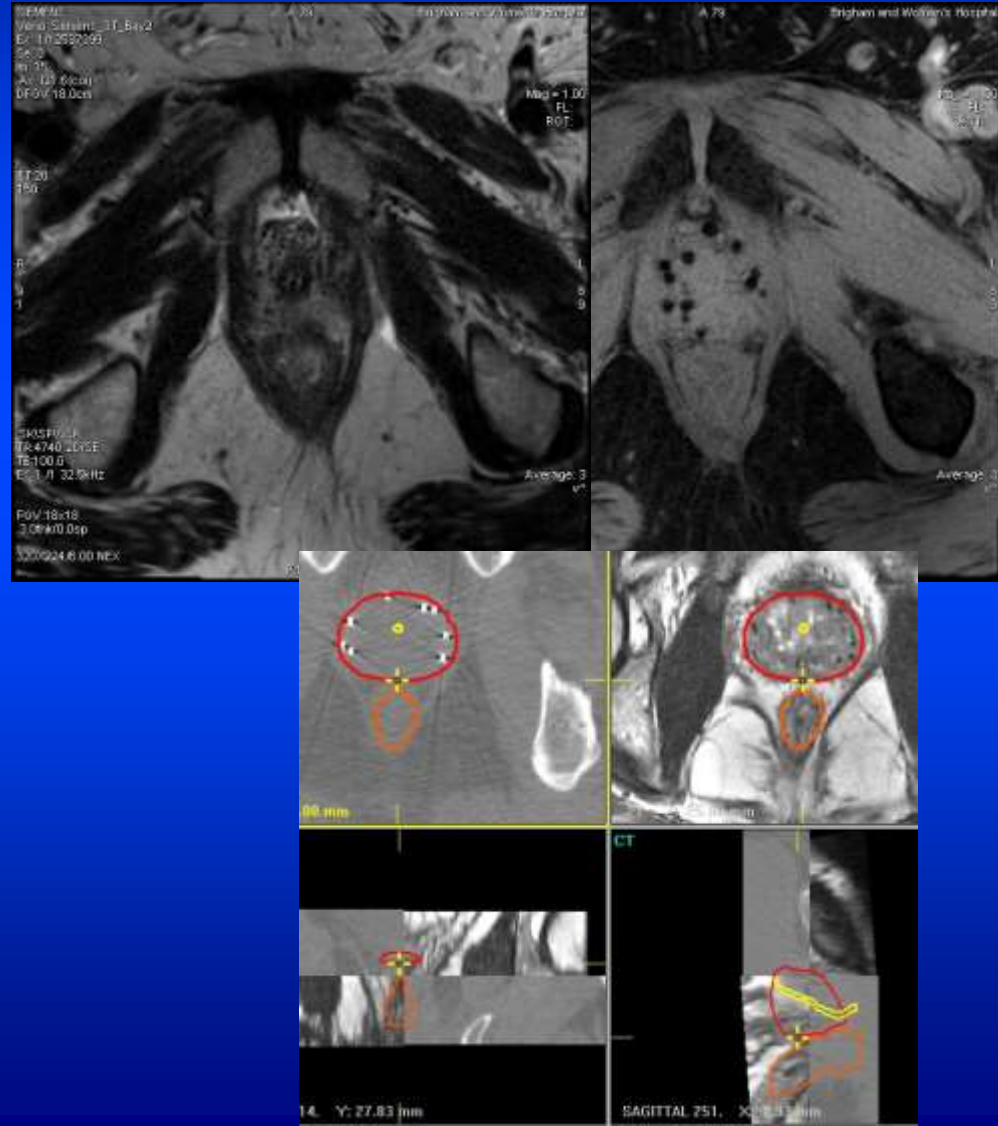
# Image Based Tasks for Brachy Planning

- Sources
- Applicators & Needles
- CT may not visualize target well, but:
  - Excellent spatial accuracy
  - Excellent device separation
  - Scout provides independent data
  - Scanning the entire implant is straightforward
  - Quick, multiple scans easy



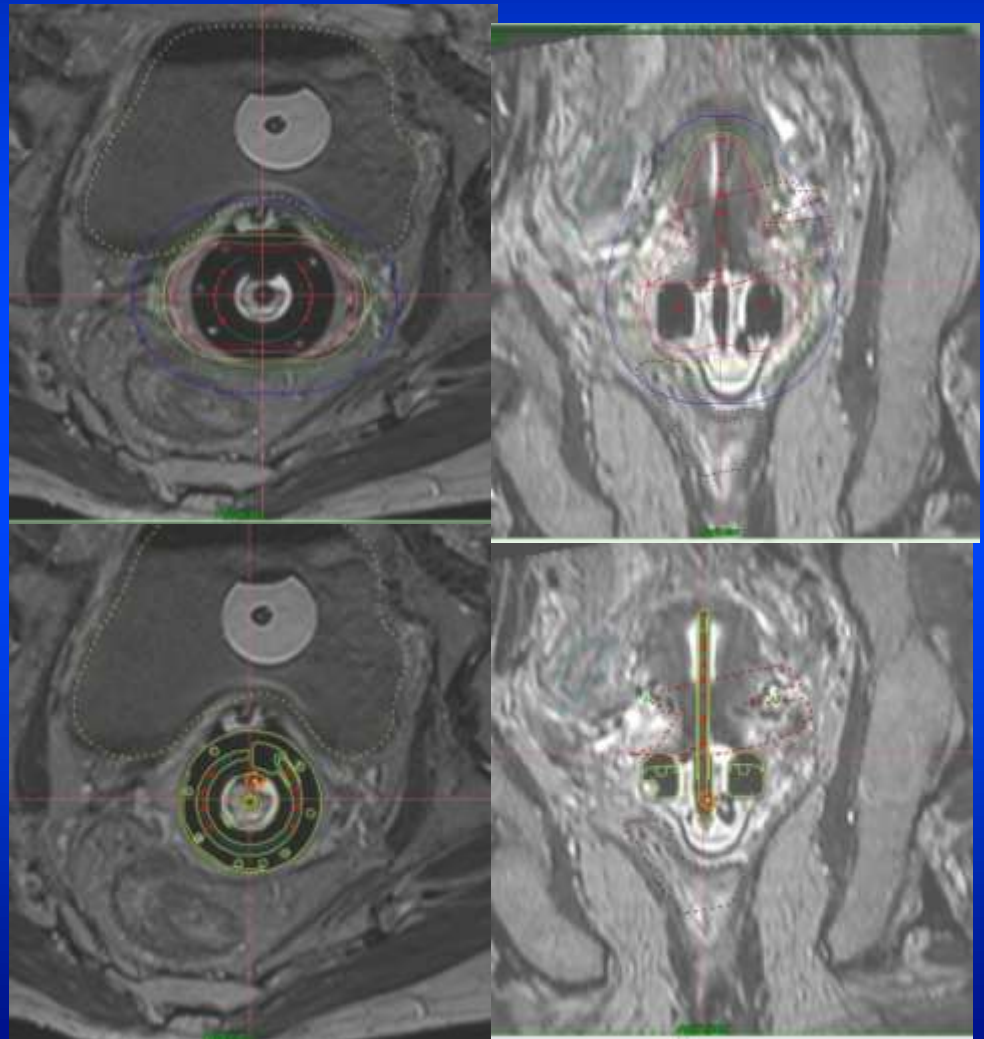
# MR Based planning: Post-implant Evaluation

- Image guided implant
- Multiple MR sequences
  - Anatomy T2
  - Sources T1 (artifacts merge)
- CT source identification
- Implanted objects provide means of registration



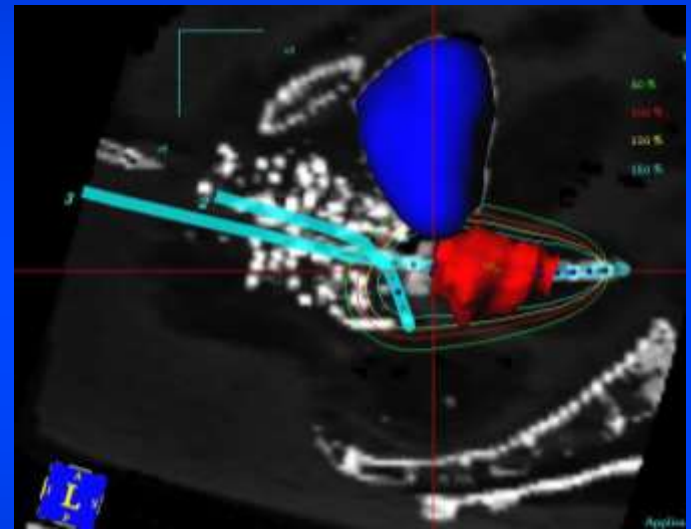
# MR Based Planning: Rigid Applicators

- Rigid applicators
  - Dwell locations
  - Channel assignments
  - Normal tissues
  - Target delineation
- Model based applicator localization: dwells inherent
- Multiple sequences
  - Applicator
  - Anatomy



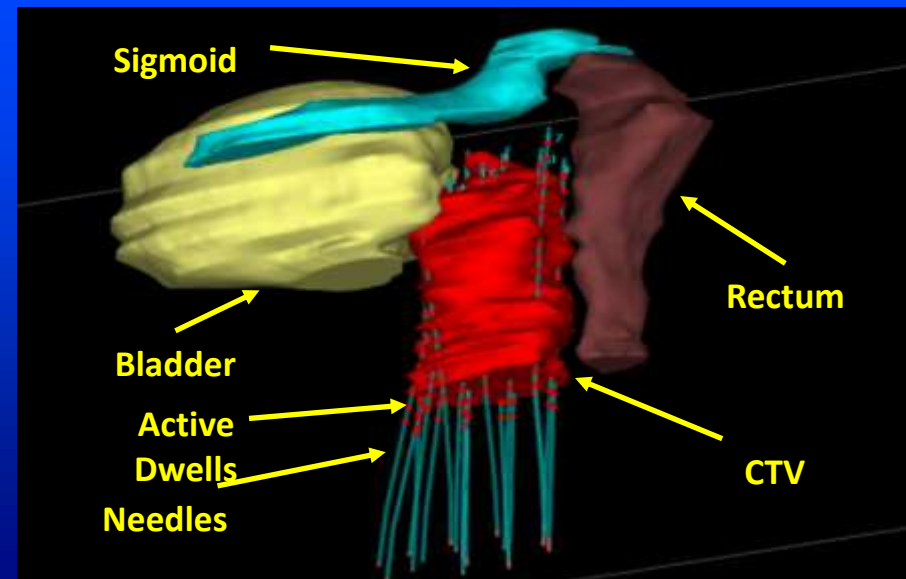
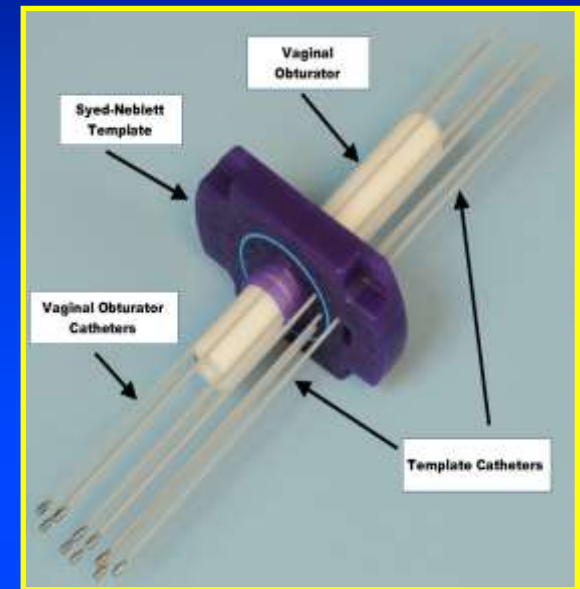
# MR Based planning: T&R,T&O

- Target definition is most relevant to MR
  - GEC-ESTRO recommendations
  - HR CTV
- MR compatible applicator differences
  - Channel diameters
  - Lack of shielding
- Applicator enable fusion



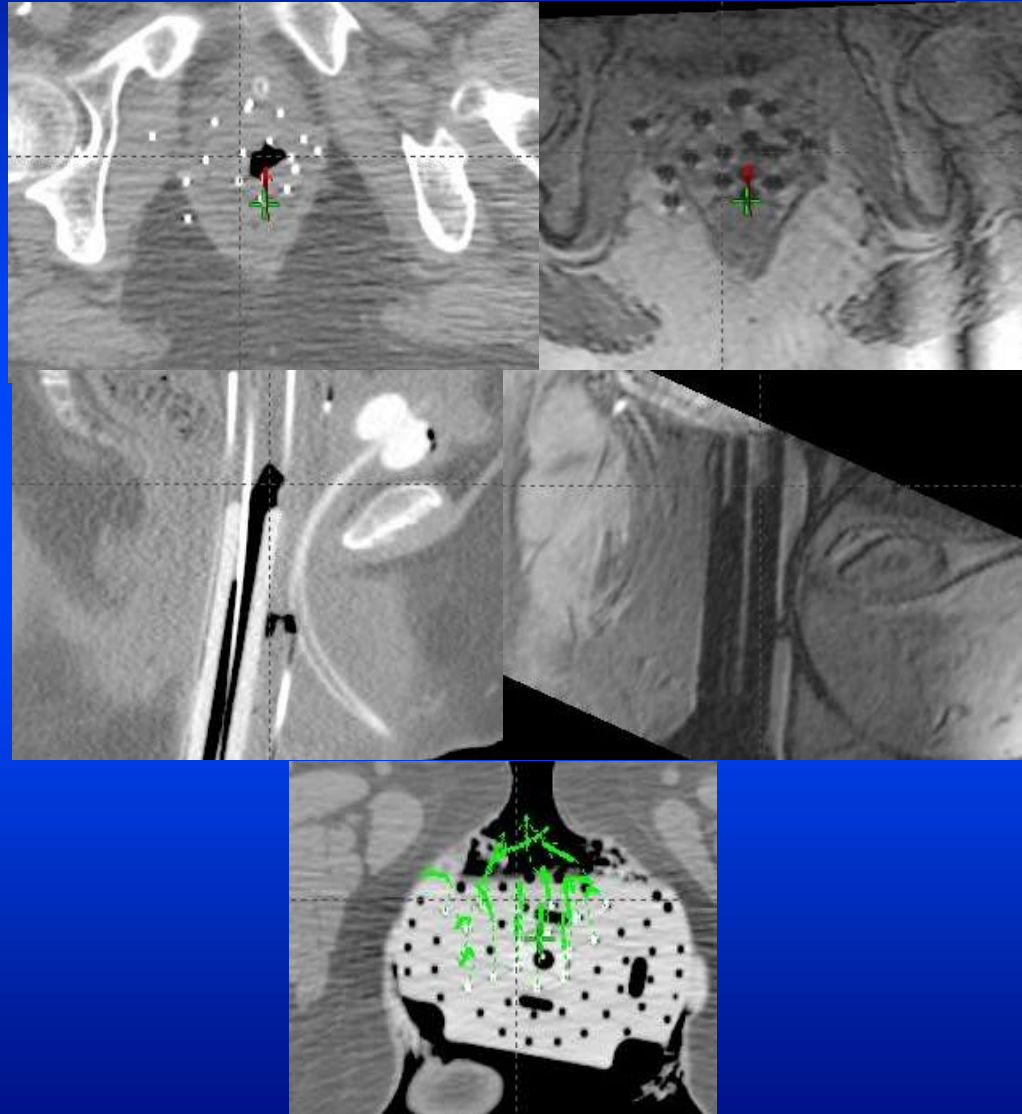
# MR Based Planning: Interstitial GYN

- 10-30 needles
- Assume HDR with post-implant planning
- Most devices plastic, **!NOT QUITE!**
- Relatively large irregularly shaped tumors



# Needle localization and identification

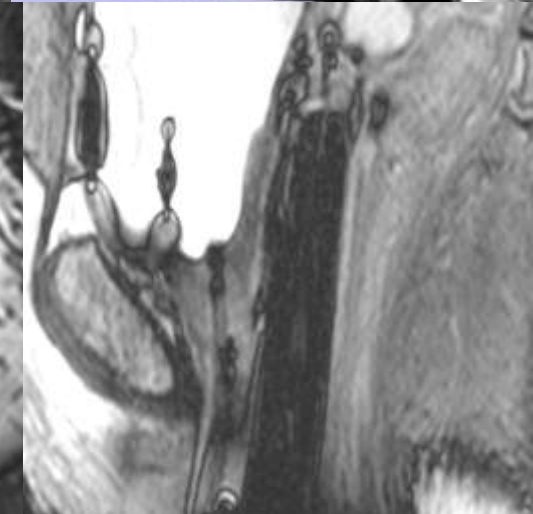
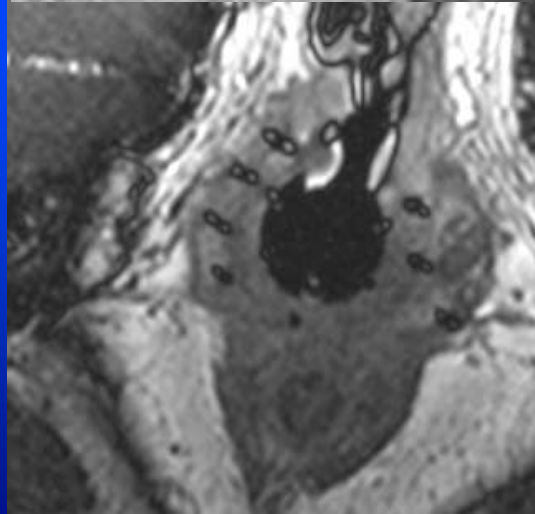
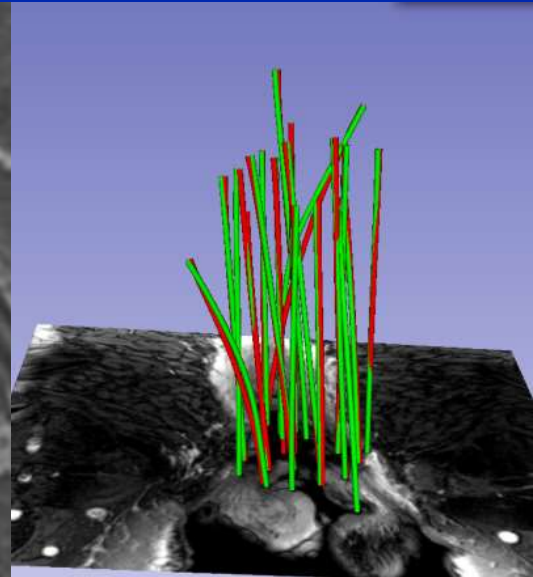
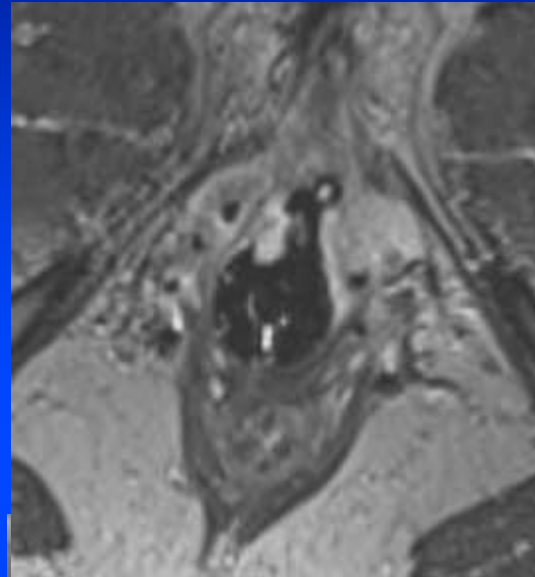
- Localization
  - MR artifacts larger than CT
  - Tip
  - Approaching needles
- Identification
- Verification
- CT
  - Dummies
  - Signal beyond pt
  - Smaller artifacts





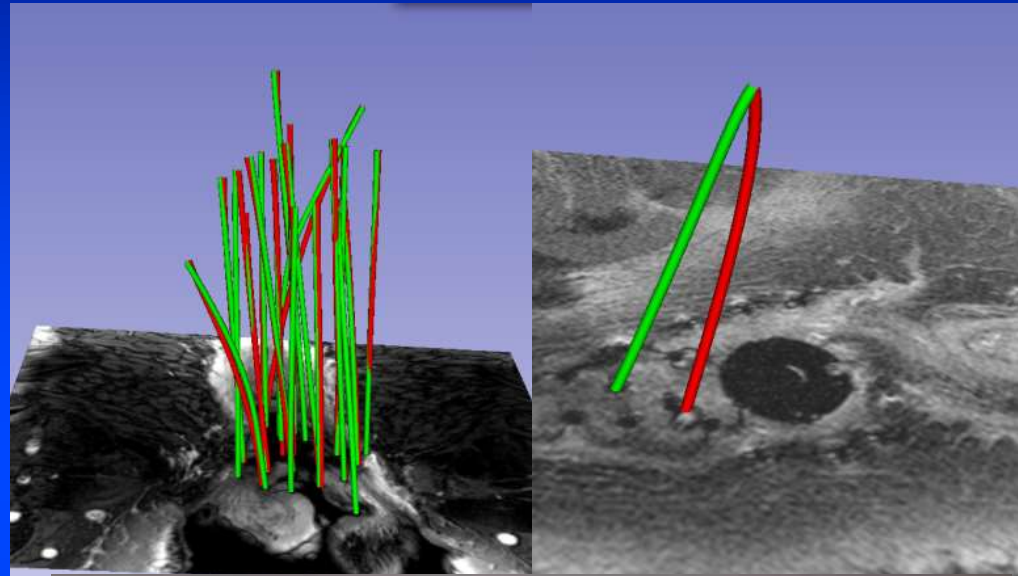
# Needle Localization

- MR artifacts larger/ambiguous compared to x-ray or CT
- MR dummies not readily available
- CT fusion assists
  - Less (not none) artifact
  - Tip identification
  - Channel identification



# Catheter Identification

- CT Scouts provide independent assessment
- X-ray dummies help reduce ambiguities
- Tracking technology provides both functions without ionizing radiation

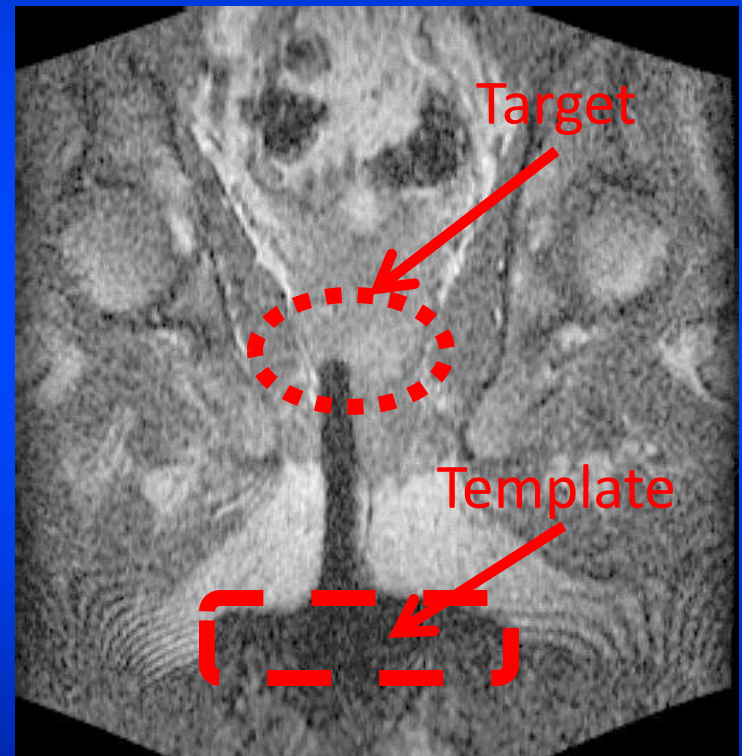


# Summary: MR Based Planning

- MR safety vs. MR compatibility
- MR applicators generally differ from predecessors: shielding, gauge, geometry, adaptability
- Multiple sequences to achieve needed information
- Applicator identification/verification more challenging than x-ray or CT
- Need for independent verifications

# MR Guided Brachytherapy

- Brachytherapy is dominated by placement
- Optimization can make a good implant better but cannot make a poor implant good
- Placement is controlled at a distance
- How do we use MR to improve placement?



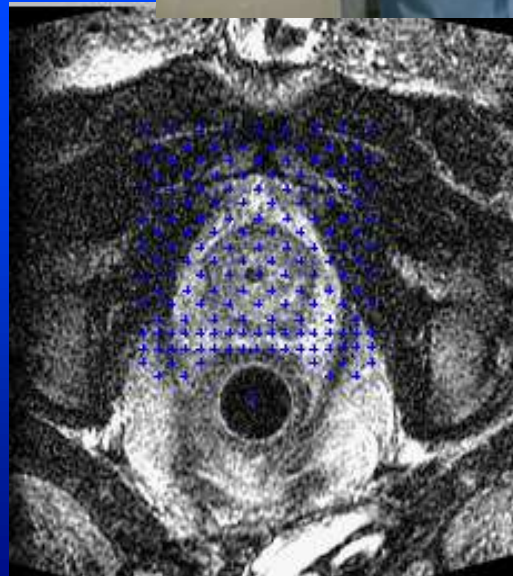
# Insertion under MR guidance

- Magnet design
  - Open
  - Closed
- Interstitials
  - Geometry
  - Dosimetry



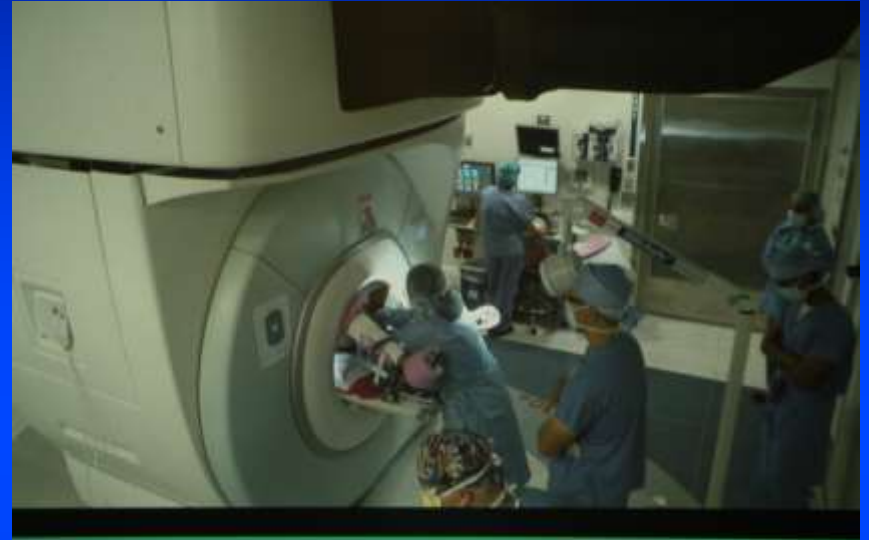
# Open Magnet Insertion

- MR guided targeting
  - Biopsy
  - Brachytherapy
    - Geometric
    - Dosimetric
- Requires localization of needle guidance device
  - Template
  - Image based
  - External system
    - Optical
    - Mechanical



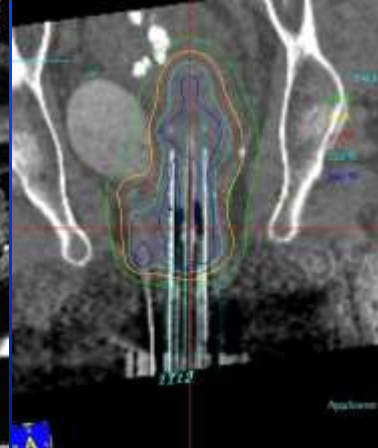
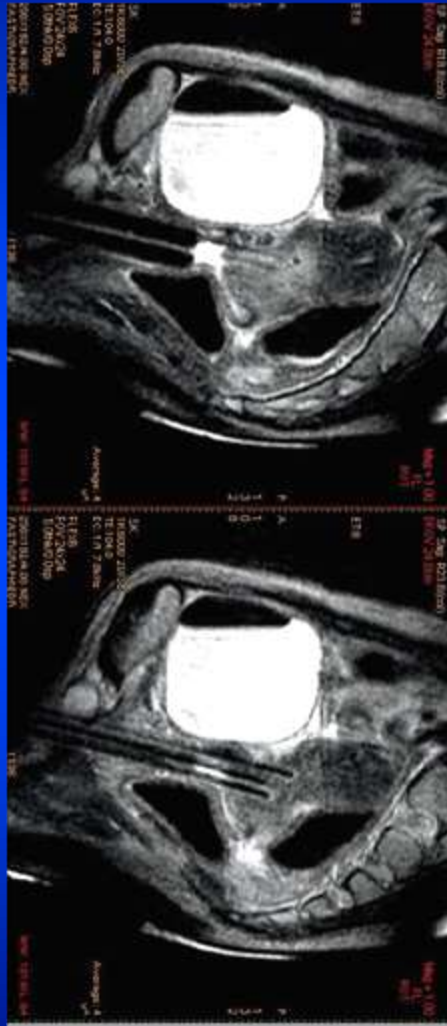
# Closed Magnet Insertion

- Limited access
- Table coordinates
- Multiple patient positioning



# MR Guided Needle Placement

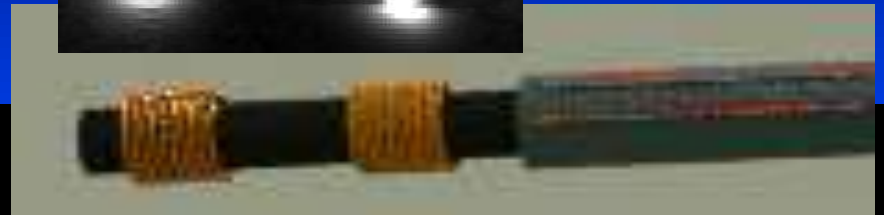
- ~real time imaging
- Allows visualization of needle wrt
  - Target
  - Normal structures
- Needles degrade image
- Target shifts
- Tends to focus on needle not configuration
  - Catheter spacing
  - Multiple depths
- Allows easier needle placement





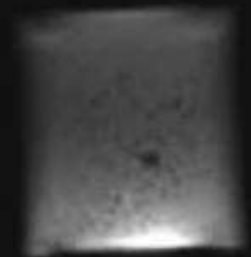
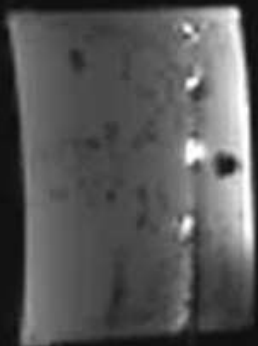
# Real Time Imaging with Active Tracking

Images: 2 frames/sec



WWTracking\_060713

IMA 13

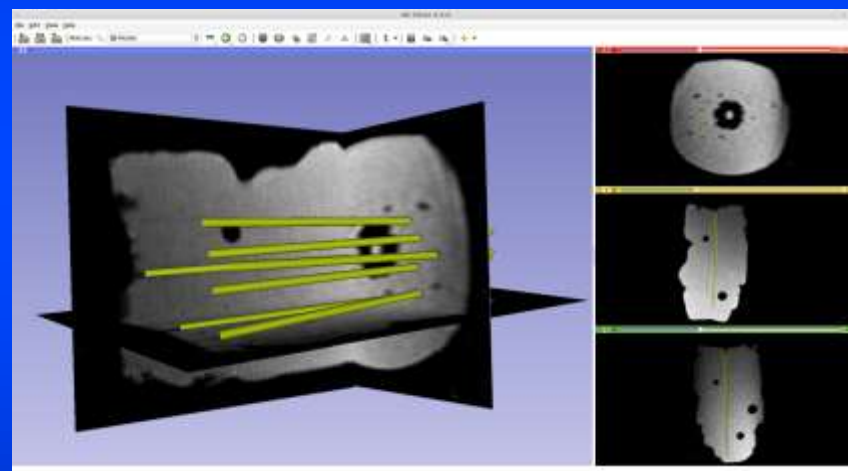


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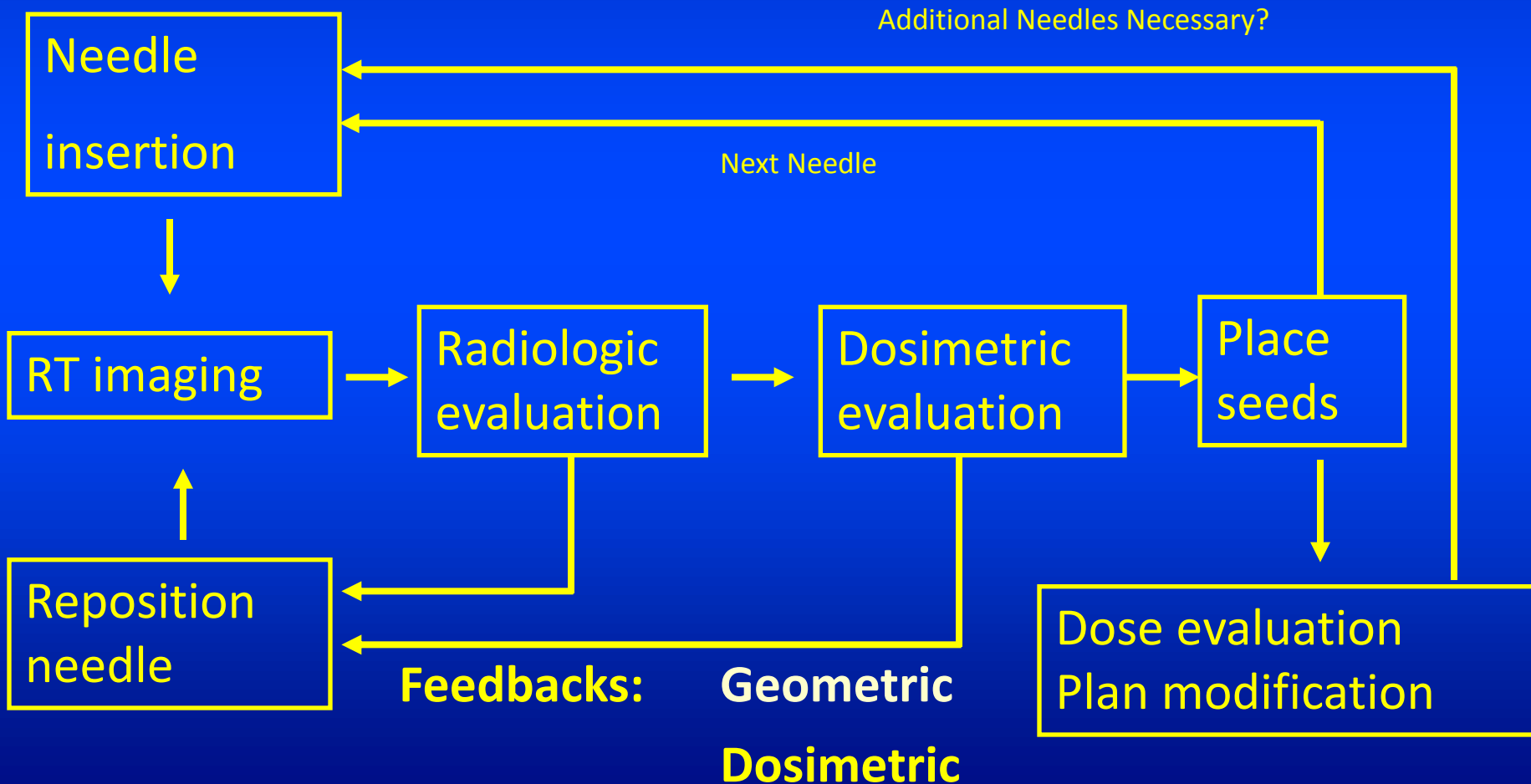
# MR Tracking: Needle Identification

- MR Tracker
- Capture location along length of needle
- User identifies channels
- Tracker used to resolve ambiguities in artifact localization



# MR Dosimetry Guided Implants

- Permanent implants
  - Seed identification challenging
  - Needles as surrogates
- No repositioning of pt
- Scanner coordinate system
- Template/robot registration



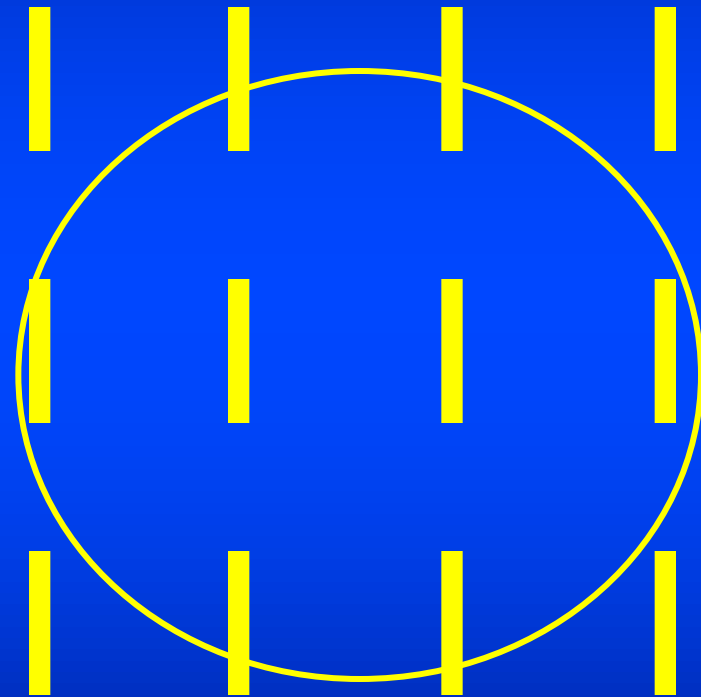
# Adaptive Planning

- Desired location not achieved
- Actual location observed and incorporated in dosimetry
- Loss of coverage 5-15%



# Dose Distributions Based on Source Locations

**Preplan  
(Intraoperative)**

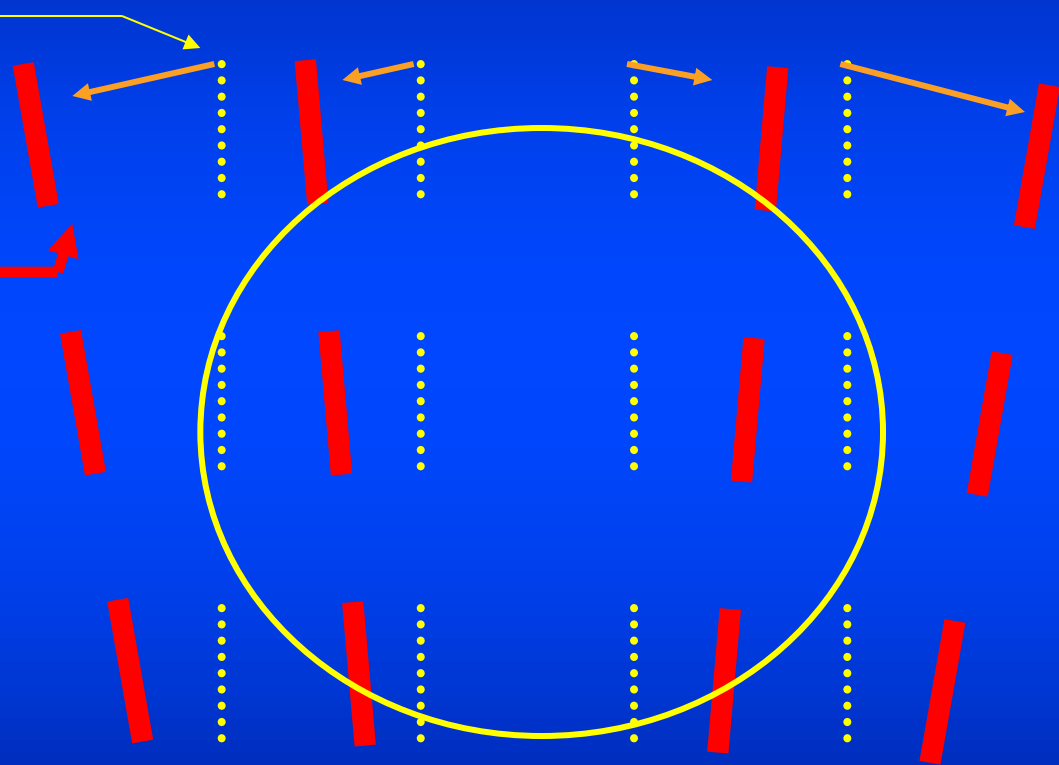


# Geometric vs Dosimetric

**Preplan**

**Intermediate:**  
with observed  
trajectories  
based on RT  
imaging

divergence

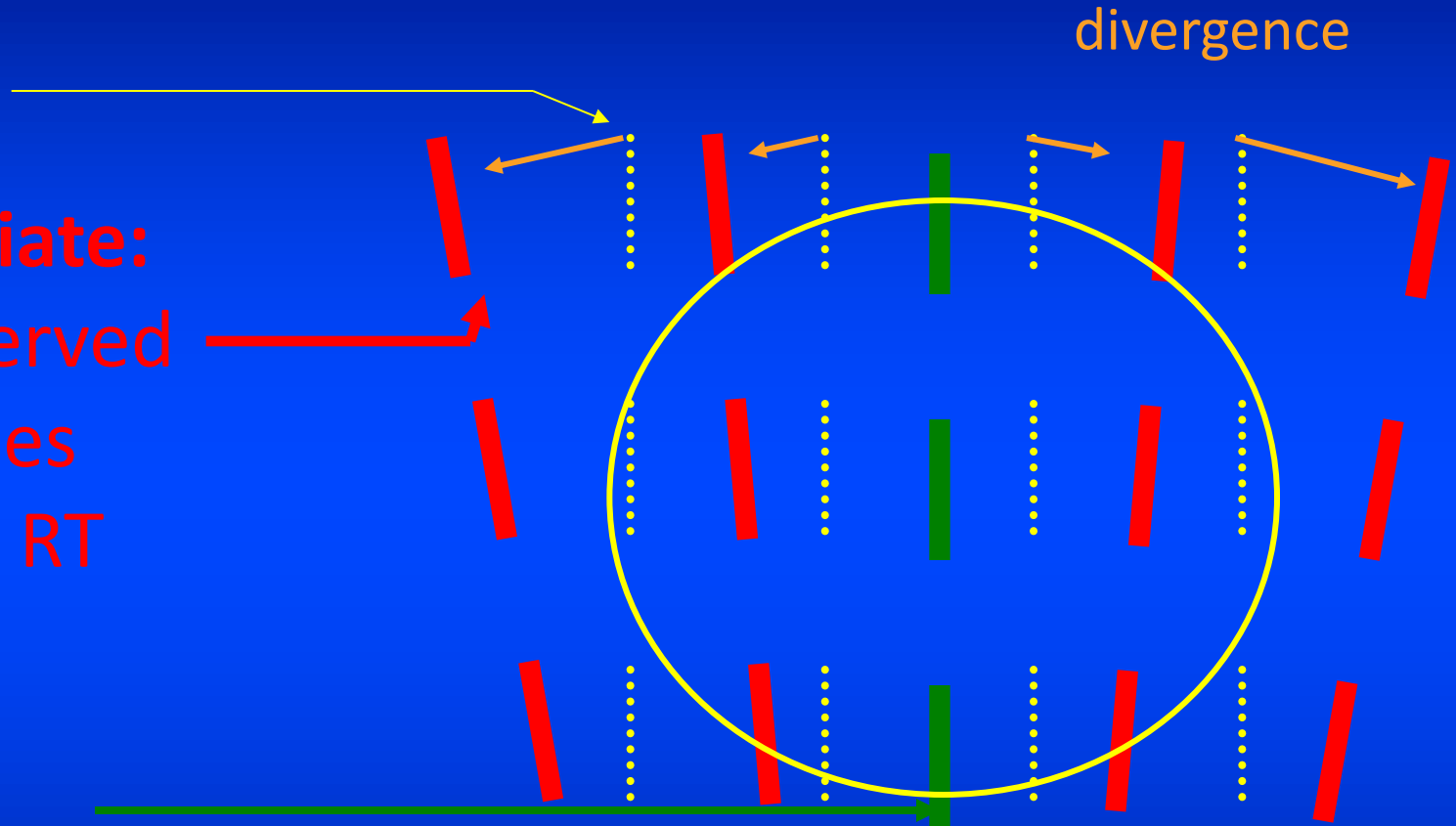


# Dosimetric Feedback

**Preplan**

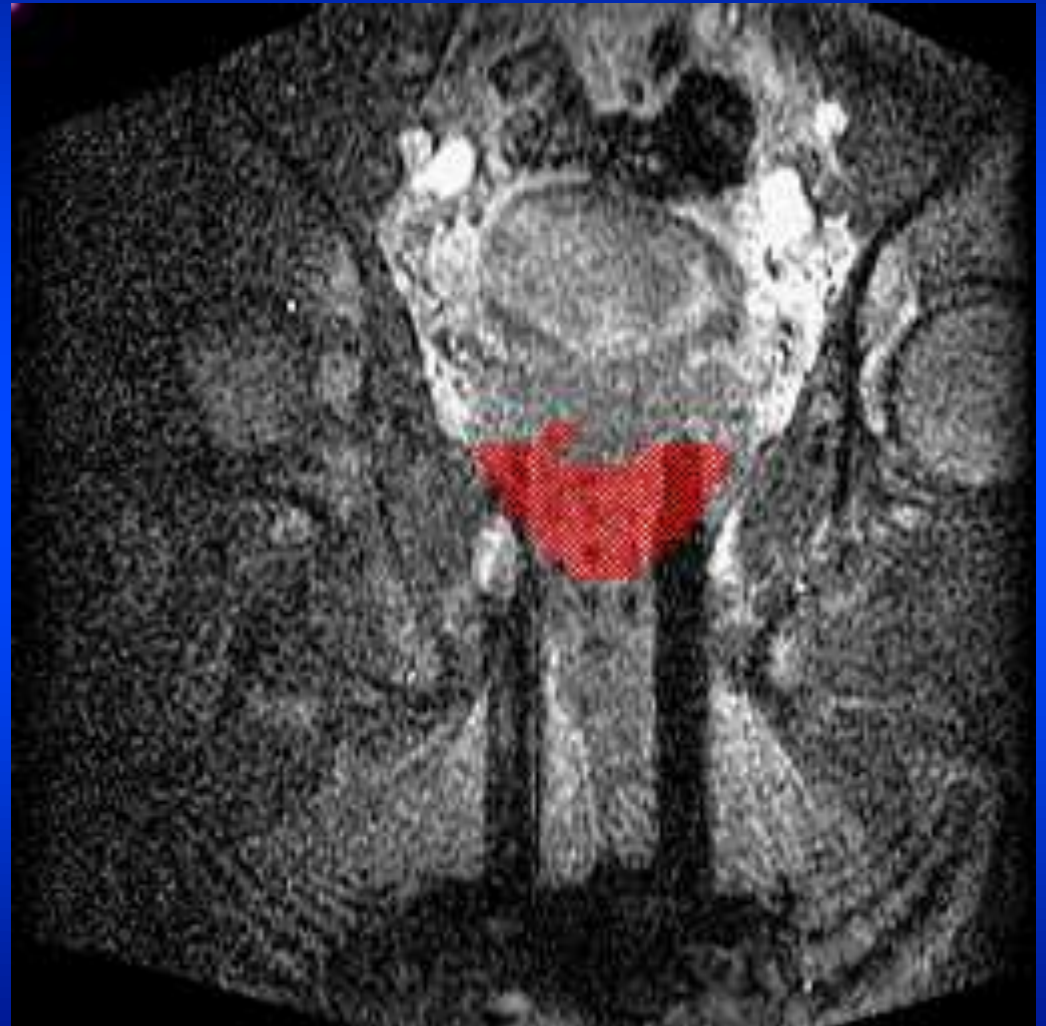
**Intermediate:**  
with observed  
trajectories  
based on RT  
imaging

**Final:**  
intermediate  
+ additional  
sources



# Imaging Feedback

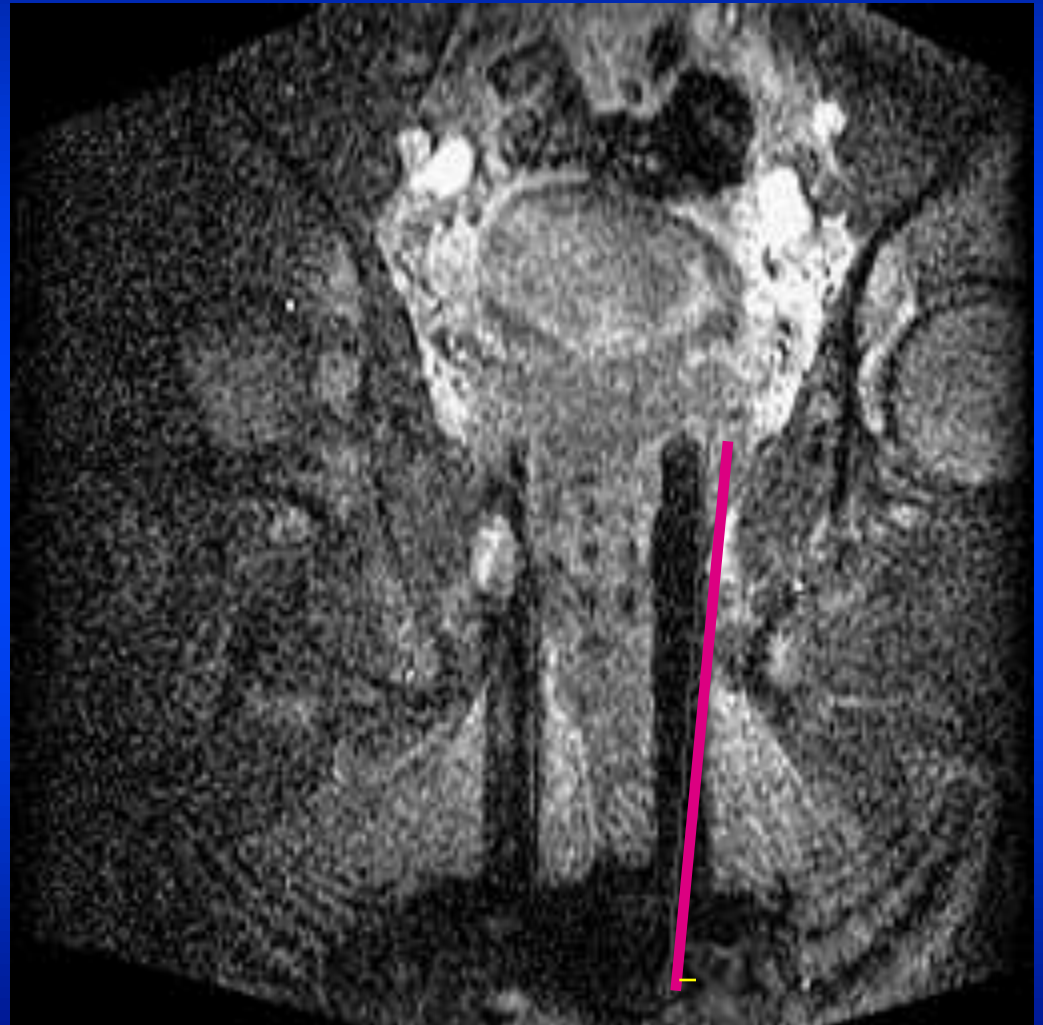
- Coronal view
- Contoured anatomy overlaid
- 2 needles placed



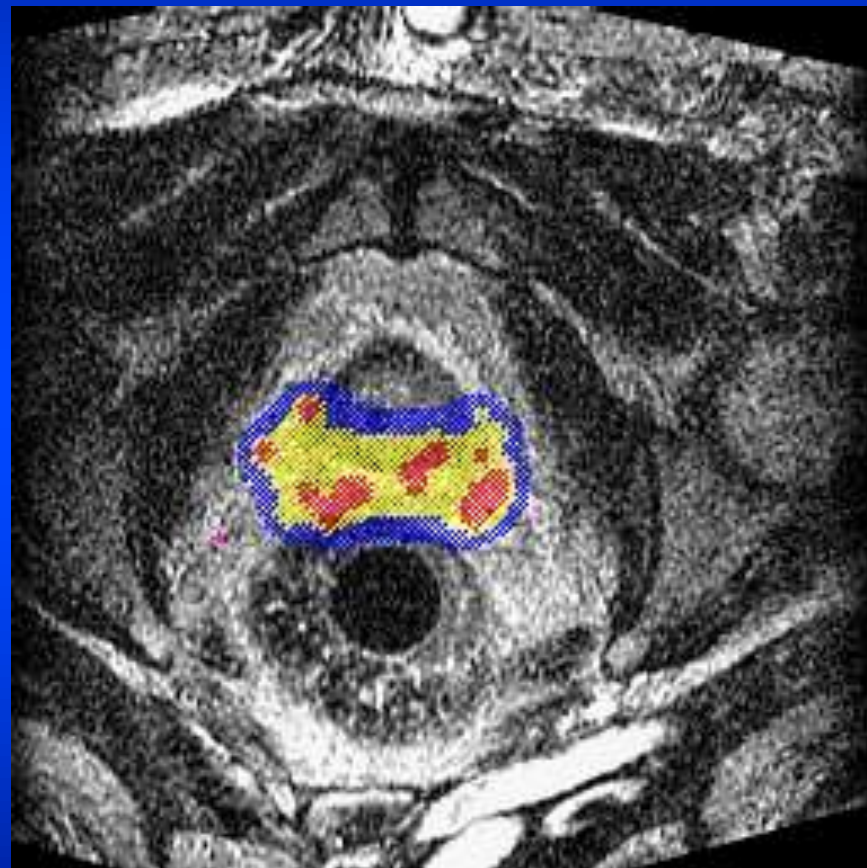
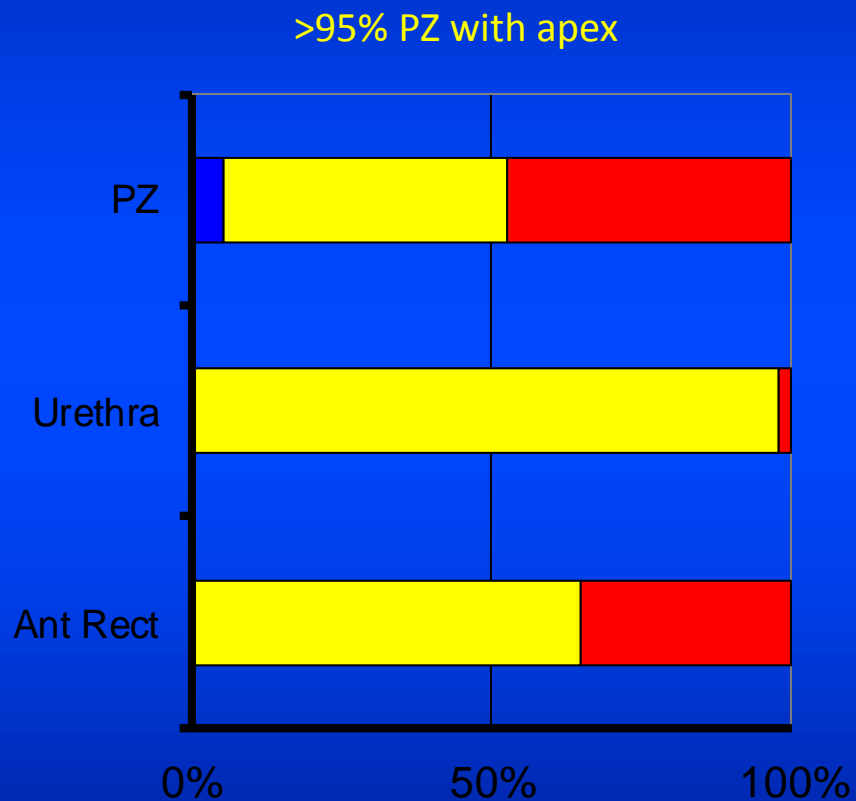


# Geometric Feedback

- In arbitrary image plane
- Compare needle with planned trajectory

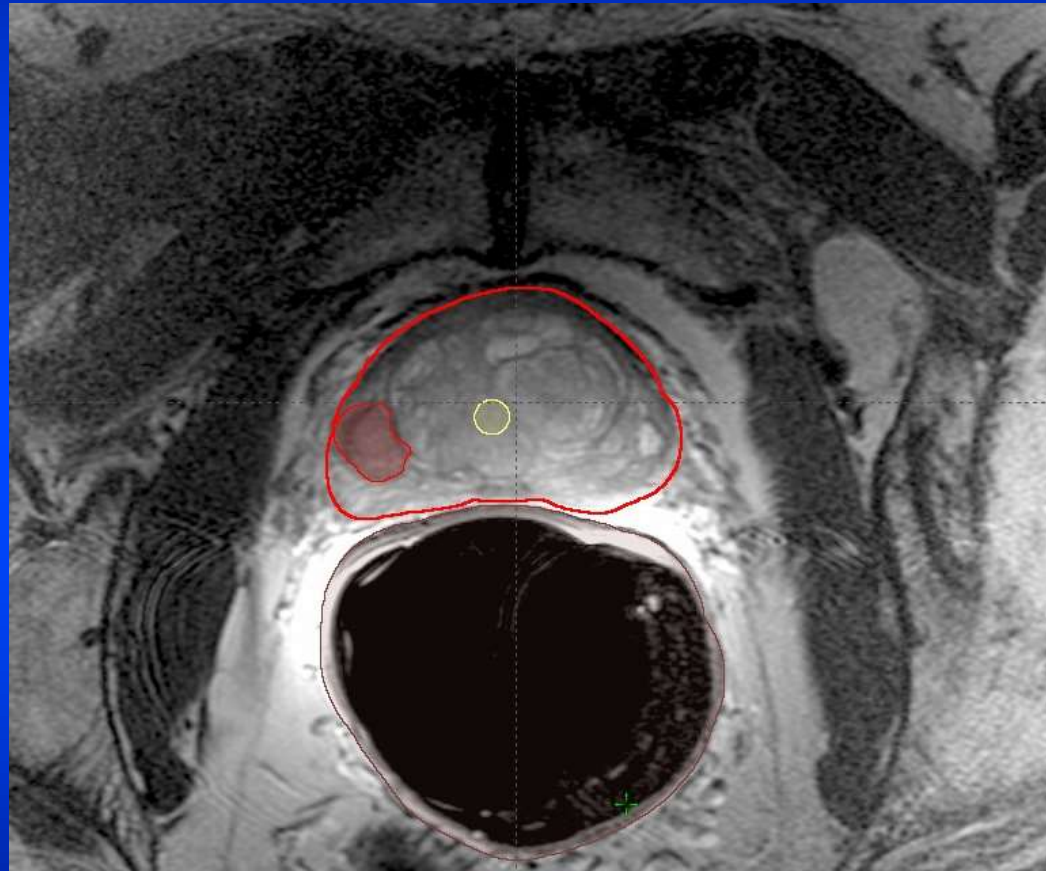


# Dosimetric Feedback & Adaptive Planning



# Identification of Tumor

- Multiparametric MR imaging
  - T1,T2
  - Dynamic contrast
  - Diffusion weighted
  - Spectroscopy
- Focal brachytherapy
  - Alternative to active surveillance with minimal restriction on future treatments
  - Potential for sub-volume boost of standard RT



# Conclusions

- MR is an ideal image guidance modality for brachytherapy. Outstanding visualization of pelvic anatomy
- MR can be involved in brachytherapy at various levels of complexity
- MR involves an increased level of safety concerns
- Challenges
  - Cost
  - Source/applicator localization identification
  - Constrained environment