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
• 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

This talk
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

M.E. Ladd in Interventional Magnetic Resonance Imaging
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
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

Needle insertion

RT imaging

Radiologic evaluation

Dosimetric evaluation

Place seeds

Dose evaluation

Plan modification

Additional Needles Necessary?

Next Needle

Feedbacks:
- Geometric
- Dosimetric

Reposition needle

Additional Needles Necessary?
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
Dosmetric Feedback & Adaptive Planning

>95% PZ with apex

- PZ
- Urethra
- Ant Rect

0% 50% 100%
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