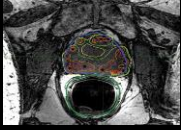


MRI-based Treatment Planning for Prostate HDR



Firas Mourtada, Ph.D., DABR, FAAPM
Helen F. Graham Cancer Center
Christiana Care Health System
Newark, Delaware



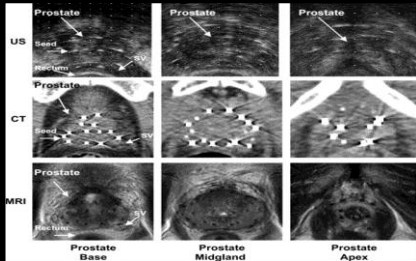
DISCLOSURE

None

Talk Objectives

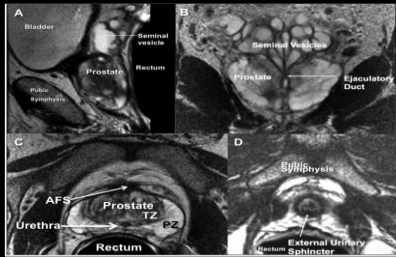
- Review prostate HDR techniques based on MRI
- Discuss the challenges and pitfalls introduced by MRI for prostate HDR brachy planning
- Review the QA process and learn about the development of clinical workflows for MRI
 - TPS

Why MRI?



Frank et al. IJROBP 2008.

Pelvic anatomy on MRI, T2-weighted images

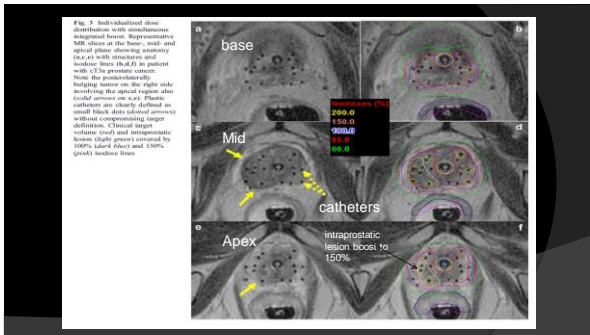


AFS, anterior fibromuscular stroma; TZ, transition zone; PZ, peripheral zone

Courtesy Dr. Frank MDACC

MRI Guidance in HDR Prostate

- ⊙ Real-time
 - Close Bore
 - 1.5T or higher → good/excellent image quality
 - 60 cm bore → tricky to implant
 - Newer 70 cm dia. bore available
 - Open Bore
 - Lower field strength (0.2-0.5T) → poor image quality
 - Easier access to place needles
- ⊙ Fuse pre- diagnostic MRI to real-time US
 - Issues with image registration, two imaging sessions



Visual QA- non quantitative

A

HDR delivery- transfer patient to vault- X-ray film QA done!

B

Fig 3 (a) Diagnostic portable X-ray showing relationship between Foley balloon and brachytherapy catheters acquired immediately before radiotherapy delivery and compared with (b) surface-rendered image generated from treatment planning MRI. No appreciable motion of catheters was noted.

"Great care was taken to prevent pelvic movement with the transfer, and immobilization was maintained" In Foley MRI contrast replaced with X-ray contrast

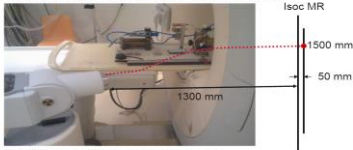
HDR Afterloading & MRI

- ⊙ There is no afterloader today that is MRI compatible
- ⊙ Hence, fraction delivery must be done in a separate vault
 - Not efficient
 - Implant motion between MRI and Delivery?

MR-compatible mobile table

Development of robot and MR compatible afterloader

Setup with treatment length 1500 mm at 50 mm beyond isocenter MR; position test with film: source position within spec (error <math><0.5\text{ mm}</math>)



The aim is to treat the patient in imaging position. This is feasible, with longer treatment cable and breaking the RF waves



Courtesy Moerland 2013

MR safety issues



5 Gauss marking on the floor for MR conditional equipment



Securing **non MRI compatible** equipment: HDR afterloader with double ropes.



© Elekta AB 2014
Medical Physics Department
University of Colorado - Boulder
Lin Hsiao, M.D.

Elekta testing: Flexitron afterloader MR conditional



Flexitron afterloader (without cover) at 30 mT line

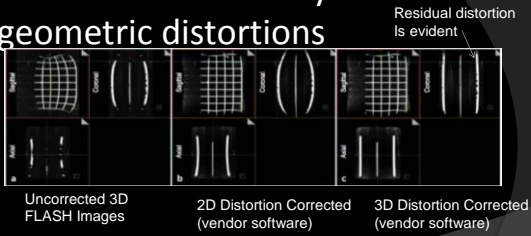
- Flexitron fully operational, not affected by magnetic and RF fields of 1.5T MRI
- Highest field strength for reliable operation at 30 mT line;
- Machine hardly attracted by MRI, no securing needed
- MRI imaging and treatment delivery **not** possible, as RF emissions of afterloader disrupt MR image quality.
 - Machine needs to be moved out of the room.

Please note that the MR capability of Flexitron has not been 510(k) cleared yet – test results need to be submitted to FDA

Potential sources of error in MRI

- ⊙ Spatial distortion
 - Due to B_0 inhomogeneity
 - Passive and active shimming methods
 - and gradient non-linearity
 - vendor software for correction
- ⊙ RF non-uniformity
- ⊙ Susceptibility induced distortion
- ⊙ Motion and organ filling (MRI → HDR Vault)
- ⊙ Metal Implants (needles, hip prosthesis)
- ⊙ Treatment Planning tools validity

Gradient Nonlinearity-induced geometric distortions



Paulson *et al.*: Comprehensive MRI simulation methodology for external beam RTP. Med Phys, Jan., 2015

Acceptable Spatial Distortion Limits

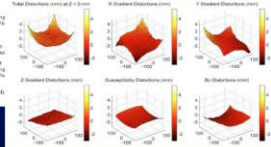
Characterization, prediction, and correction of geometric distortion in 3 T MR images

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Avenue 140, 142, Canada

Keith Wachowicz
Division of Medical Physics, Department of Oncology, University
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Charterhouse of Medical Physics, Cross Cancer Institute, 13000
Avenue 140, 142, Canada

Manuscript # 3636, received 4 October 2006; accepted 6
published 9 January 2007



Baldwin *et al* reported on spatial distortion of ~ 5mm within 20 cm radius centered at isocenter for a 60 cm 3T scanner (Med. Phys. 34(2), 2007)

5-mm spatial distortion might not be acceptable for brachytherapy!
Be careful going to 3T

MRI scan protocols considerations for brachytherapy planning

Parameter	Diag. Radiology	Brachytherapy
FOV	Reduced FOV toward ROI	Larger FOV to include OARs, body contours if MBDCA* used
Readout bandwidth (RBW)	Set w trade off fat/water shift and SNR	Set high to minimize chemical shift and susceptibility-induced spatial distortions
Slice thickness	4-5mm	2mm contiguous, better DRR quality
Geometric Distortion	tolerated	<2mm in all planes
Image Intensity Nonuniformity	tolerated	Minimal for image registration and segmentation accuracy

*AAPM TG-186: MBDCA = Model-based Dose Calculation Algorithms

Brachytherapy TPS Prerequisites Specific to MRI

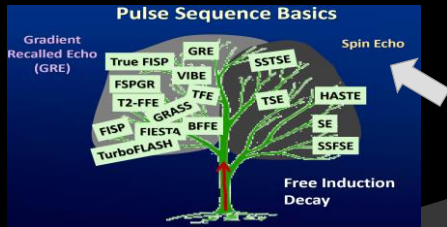
- ⦿ High fidelity images with acceptable image contrast and resolution
 - Delineate Prostate and OARs
- ⦿ Which pulse sequences to use?

Superior MRI soft tissue contrast will eventually replace CT-based planning

Most common sequences

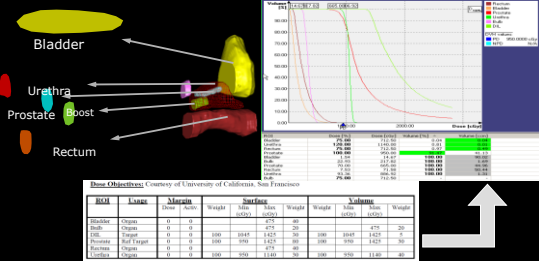
- Sagittal T2 Delineation of rectum and bladder
- Axial T2 Delineation of prostate gland and extracapsular disease (dark)
- Axial fat-suppressed T2 Delineation of intracapsular disease (dark); lymph nodes (bright)
- Axial T1 Detection of postbiopsy hemorrhage (bright)

Pulse Sequence for prostate brachy?



McGee, AAPM 2015 MRI Basics II: MR Imaging for treatment planning

Inverse Planning for Prostate HDR- IPSA



Med Phys. 2001 Lessard E, Pouliot J.

QA Procedures for MRI

- ⊙ ACR MR QC program
 - Well defined tolerances and limits
- ⊙ Insure PM is done on scanner
- ⊙ Additional phantoms needed, specific to brachytherapy planning
- ⊙ Currently, there is a void in MRI QA for brachytherapy for robust planning
 - AAPM TG is pending

Few TPS factors impacting clinical outcome quality

- Image modality quality
- ROI contouring accuracy
- Applicator registration accuracy
- HDR source registration accuracy
- Dose model assumptions
- Source decay, etc.

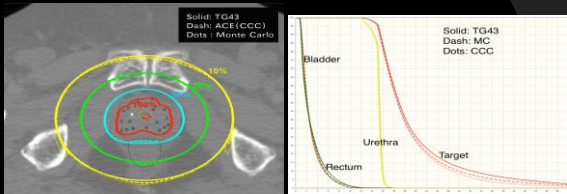
Clinical Outcome Quality?

Commission Work Guideline

- AAPM TG-53: Quality Assurance for Clinical Radiotherapy Treatment Planning
- AAPM TG-40: Comprehensive QA for Radiation Oncology
- AAPM TG-56: Code of Practice of Brachytherapy Physics
- AAPM TG-43: Dosimetry of interstitial Brachytherapy sources
- Acceptance Testing, Commissioning, Data Entry, and QA for Brachytherapy Treatment Planning Systems, M. J. Rivard, AAPM 2008

Newly AAPM TG for MRI Brachytherapy is in the works

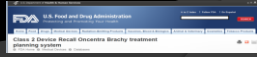
HDR Prostate implants



17 catheters; rectum set to air!

Why need to commission TPS tools?

- ⦿ Incorrect dose calculation for Regions of Interest (ROIs) defined on a secondary image series
 - Example: CT is primary, MR is secondary
- ⦿ Impact: The magnitude of the dose calculation error depends on the registration transformation and can vary between 0 and 100% of the correct dose value.



Issue occurs because the registration transformation is not applied to the dose sampling points.

IMPORTANT USER NOTICE

On which image series a ROI is defined can be checked in the case explorer of the Anatomy Modeling (AM) module by inspecting the Series column in the ROI Set tab, see Figure 1.

Figure 1 ROI Set tab in the case explorer (AM)

The type of registration that is used can be checked by inspecting the Registrations tab in the case explorer of the AM module, see Figure 2. If the registration Type reads Surface Mapping, Landmark, Mutual Information, Matrix or Manual, treatment planning may have been affected by the issue described in this important User Notice. If the registration Type reads rigid, the dose calculation issue reported in this important User Notice does not occur.

Figure 2 Registrations tab in the case explorer

Function	When applied to:	
	ROIs defined on Primary Image Series	ROIs defined on Secondary Image Series
DVH graph values	Not affected	Affected (Brachy Planning only)
DVH table values	Not affected	Affected (Brachy Planning only)
Dose statistics in case explorer	Not affected	Affected (Brachy Planning only)
IPSA	Not affected	Limited off
HiPO	Not affected	Affected (Brachy Planning only)

Conclusions

- ⦿ Improves the accuracy of target and OAR delineation, dose prescription and reporting
- ⦿ Potential to define prostate sub-volumes and dominant lesions to allow for dose administration reflecting the differential risk of recurrence.
- ⦿ Key issue for safe dissemination and implementation is establishment of qualified multidisciplinary teams and strategies for training and education

Conclusions:

- ⦿ To start your MR-based HDR Program
 - need to establish QA/QC program
 - Set standards and tolerances to meet ACR MR QC
- ⦿ Make sure to perform end to end tests and define baselines and tolerances
- ⦿ Systematic evaluation of image spatial integrity for MRI-based planning is essential
- ⦿ Other factors such as image fidelity and delineation uncertainty should be considered to further reduce uncertainty in planning
