Prostate MRI Protocols

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Declaration of Financial Interests or Relationships

I have no financial interests or relationships to disclose with regard to the subject matter of this presentation.
Introduction

- Multiparametric magnetic resonance imaging (mpMRI)
  T2-weighted (T2W) Imaging  Diffusion-Weighted Imaging (DWI)  Dynamic Contrast-Enhanced (DCE)

- Prostate Imaging – Reporting And Data System (PI-RADS v.2.1)
  - Improves detection, localization, characterization, and risk stratification of prostate cancer (Pca)
  - Standardizes mpMRI acquisition, interpretation and reporting
  - Establishes minimum acceptable technical parameters

Technical Specifications for mpMRI (PI-RADS v2.1)

- Tailored to specific patients, clinical questions, and MRI equipment
- Magnetic Field Strength
  - Both 3T and 1.5T – adequate and reliable
  - 3T – superior
    - Increased signal-to-noise ratio (SNR)
    - Increased spatial resolution, temporal resolution, or both
  - 1.5T – the choice for patients with implants (safety or image artifact)
  - Lower magnetic field strength (< 1.5T) not recommended

https://www.acr.org/Clinical-Resources/Reporting-and-Data-Systems/PI-RADS
Technical Specifications for mpMRI (PI-RADS v2.1)

- **Coils**
  - Pelvic phased-array coils commonly used
  - Endorectal Coil (ERC)
    - Increased SNR, advantageous for larger patients
    - Increased exam time and cost, image artifacts, and patient discomfort
- **Specialized post-processing software**
  - Not required but may improve workflow
  - Provide quantitative measurements
  - Facilitate MR targeted biopsy

## Specifications for Prostate mpMRI Protocol (PI-RADS v.2.1)

<table>
<thead>
<tr>
<th></th>
<th>T2-Weighted (T2W) Imaging</th>
<th>Diffusion-Weighted Imaging (DWI)</th>
<th>Dynamic Contrast-Enhanced (DCE)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pulse sequence</strong></td>
<td>2D RARE, fast-spin-echo (FSE) or turbo-spin-echo (TSE)</td>
<td>2D spin-echo echo-planar imaging (EPI) with spectral fat suppression</td>
<td>3D T1-Weighted (T1W) gradient echo (GRE)</td>
</tr>
<tr>
<td><strong>Imaging planes</strong></td>
<td>Axial (straight or oblique); Sagittal and/or Coronal</td>
<td>Axial (match T2W)</td>
<td>Axial (match T2W)</td>
</tr>
<tr>
<td><strong>Slice thickness</strong></td>
<td>3 mm, no gap</td>
<td>≤ 4 mm, no gap</td>
<td>3 mm, no gap</td>
</tr>
<tr>
<td><strong>Field of View (FOV)</strong></td>
<td>12–20 cm</td>
<td>16–22 cm</td>
<td>12–20 cm</td>
</tr>
<tr>
<td><strong>Pixel size</strong></td>
<td>≤ 0.7mm (phase) x ≤0.4 mm (frequency)</td>
<td>≤ 2.5mm (phase and frequency)</td>
<td>≤ 2mm (phase and frequency)</td>
</tr>
<tr>
<td><strong>Specific Recommendation</strong></td>
<td>3D axial acquisition as adjunct to 2D not a replacement</td>
<td>TE ≤ 90 msec; TR ≥ 3000 msec</td>
<td>TE &lt; 5 msec; TR &lt; 100 msec</td>
</tr>
<tr>
<td></td>
<td>Appropriate echo train length to avoid T2 blurring</td>
<td></td>
<td>Temporal resolution ≤ 15 sec</td>
</tr>
<tr>
<td></td>
<td>Apparent Diffusion Coefficient (ADC) maps: low b-value 0-100 sec/mm² (preferably 50-100 sec/mm²); intermediate b-value 800-1000 sec/mm²</td>
<td>Low molecular weight gadolinium-based contrast agent (GBCA) Dose: 0.1mmol/kg Injection rate: 2-3 cc/sec</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High b-value ≥ 1400 sec/mm²: acquired or calculated</td>
<td>Total scan time ≥ 2 min (before, during, and after GBCA injection)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Additional b-values (100-1000 sec/mm²) for accurate ADC and high b-value calculations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
“Everyday” Clinical Prostate mpMRI at UTSW

- Magnetic Field Strength
  - 3T preferred
  - 1.5T for patients with implants not safe for 3T, or bilateral hip replacements
- Pelvic phased-array coils and Endorectal coil (ERC)
  - Protocol for without ERC: more signal averages, compromised spatial resolution
- DynaCAD (invivo) and syngo.via (Siemens)
  - Segmentation of the prostate and the lesion for biopsy targeting
  - DCE analysis

**Clinical Prostate mpMRI Examination**

- Philips: 3T and 1.5T Ingenia, 3T and 1.5T Achieva
- Siemens: 3T Skyra; 1.5T Avanto, Aera, and Sola

<table>
<thead>
<tr>
<th>3T Ingenia Scan</th>
<th>Imaging Plane</th>
<th>TE/TR (msec)</th>
<th>FOV (cm)</th>
<th>Pixel size (mm)</th>
<th>Slice thickness/Gap (mm)</th>
<th>Accel. factor</th>
<th>Phase encoding</th>
<th>NSA</th>
<th>Scan Time (min:sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2W SSTSE</td>
<td>3-Plane</td>
<td>80/1000</td>
<td>44 x 44</td>
<td>2 x 4</td>
<td>20/10</td>
<td>0</td>
<td>--</td>
<td>1</td>
<td>0:15</td>
</tr>
<tr>
<td>T2W TSE</td>
<td>SAG</td>
<td>120/3800</td>
<td>25 x 25</td>
<td>1 x 1</td>
<td>3/0.3</td>
<td>2</td>
<td>FH</td>
<td>1</td>
<td>2:26</td>
</tr>
<tr>
<td>T2W TSE</td>
<td>Obl AX</td>
<td>110/3938</td>
<td>18 x 18</td>
<td>0.45 x 0.6</td>
<td>2.5/0</td>
<td>2</td>
<td>RL</td>
<td>1</td>
<td>3:33</td>
</tr>
<tr>
<td>DWI SS-EPI</td>
<td>Obl AX</td>
<td>87/2425</td>
<td>16 x 16</td>
<td>1.25 x 1.32</td>
<td>3/0.3</td>
<td>4</td>
<td>RL</td>
<td>2</td>
<td>6:50</td>
</tr>
<tr>
<td>T2W TSE</td>
<td>Obl COR</td>
<td>110/2500</td>
<td>16 x 16</td>
<td>0.38 x 0.42</td>
<td>2.5/0</td>
<td>1.6</td>
<td>RL</td>
<td>1</td>
<td>4:50</td>
</tr>
<tr>
<td>T1W DCE</td>
<td>Obl AX</td>
<td>2.3/4.6</td>
<td>25 x 25</td>
<td>0.9 x 1</td>
<td>3/0</td>
<td>4</td>
<td>RL</td>
<td>1</td>
<td>5:46</td>
</tr>
<tr>
<td>T1W Post</td>
<td>AX</td>
<td>1.3/2.3/3.6</td>
<td>40 x 35</td>
<td>1.6 x 1.7</td>
<td>4/0</td>
<td>2.8</td>
<td>AP</td>
<td>1</td>
<td>0:21</td>
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Obl = oblique
Verify Endorectal Coil (ERC) Position

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SSTSE = Single-shot turbo spin-echo

 ERC placed by technologist
 ERC inflated with barium

Prostate Zonal Anatomy on T2-Weighted Images

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<td>RL</td>
<td>1</td>
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Diffusion-Weighted Imaging (DWI)

- Single-shot SE-EPI with b-values of 0, 100, 1000, 1500, 2000 (3T) s²/mm, with corresponding NSA of 2, 2, 4, 6, 6
- ADC maps: monoexponential model

T1-Weighted Dynamic Contrast-Enhanced (DCE) Imaging

- T1W DCE
  - 3D spoiled gradient echo sequence (11 s/dyn)
  - Variable flip angle T1 mapping (optional)
- T1W post-contrast
  - 3D two-point DIXON gradient echo sequence
  - Evaluation of lymph nodes and bone lesions

\[ \text{ADC} \]
**Susceptibility Artifacts of EPI DWI**

- Geometric distortion reduced by parallel imaging and high receiver bandwidth\(^1\)
- Reduced FOV DWI with 2D focused excitation and parallel transmission\(^2\)
- Siemens 3T Skyra
- PROPELLER DWI\(^3\)
- GE 1.5T MR450

\(^1\)Donato, Acad Radiol 21 (2014); \(^2\)Rosenkratztz, Curr Prob Diag Radiol 47 (2018); \(^3\)Czarniecki, Eur J Radiol 102 (2018)

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**MRI Targeted Biopsy**

- MRI-transrectal ultrasound fusion biopsy
  - Improves lesion targeting
- MRI-guided in-bore biopsy
  - Target the center of a small lesion or the lowest ADC area of a heterogeneous lesion

\textit{Costa, RadioGraph 35 (2015)}
## MRI Protocol for In-bore Biopsy

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Scan</th>
<th>Sequence</th>
<th>TE/TR (ms)</th>
<th>FOV (cm)</th>
<th>Acq Voxel (mm)</th>
<th>Scan time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device gross position</td>
<td>3-plane localizer</td>
<td>2D bFFE</td>
<td>2/4</td>
<td>30 x 30</td>
<td>1.3 x 2.1 x 10(20)</td>
<td>30sec</td>
</tr>
<tr>
<td>Needle guide position</td>
<td>SAG T2</td>
<td>2D SSTSE</td>
<td>80/1300</td>
<td>26 x 26</td>
<td>0.9 x 1.1 x 3/0.3</td>
<td>19sec</td>
</tr>
<tr>
<td><strong>Prebiopsy planning</strong></td>
<td>SAG T2</td>
<td>2D TSE</td>
<td>110/3400</td>
<td>23 x 21</td>
<td>0.7 x 0.8 x 3/0.3</td>
<td>3min 30sec</td>
</tr>
<tr>
<td></td>
<td>Straight AX T2</td>
<td>2D TSE</td>
<td>110/2500</td>
<td>20 x 20</td>
<td>0.6 x 0.8 x 3/0.3</td>
<td>2min 45sec</td>
</tr>
<tr>
<td>Needle guide verification</td>
<td>SAG T2</td>
<td>2D SSTSE</td>
<td>80/1300</td>
<td>26 x 26</td>
<td>0.9 x 1.1 x 3/0.3</td>
<td>19sec</td>
</tr>
<tr>
<td>Needle placement</td>
<td>AX T2</td>
<td>2D TSE</td>
<td>110/2300</td>
<td>20 x 20</td>
<td>0.8 x 0.9 x 3/0.3</td>
<td>1min 38sec</td>
</tr>
</tbody>
</table>

### MR-guided Transurethral Ultrasound Ablation

- Linear array of 10 transducer elements
- Continuous sweeping ultrasound beam
- Real-time MRI thermometry feedback control
- Cooling of urethra and rectum

**TULSA-PRO® (Profound)**
MRI Protocol for TULSA Therapy

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Scan</th>
<th>Sequence</th>
<th>TE/TR (ms)</th>
<th>FOV (cm)</th>
<th>Acq Voxel (mm)</th>
<th>Scan time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device gross position</td>
<td>3-plane localizer</td>
<td>2D bFFE</td>
<td>2/4</td>
<td>30 x 30</td>
<td>1.3 x 2.1 x 5.0</td>
<td>30sec</td>
</tr>
<tr>
<td>Device alignment</td>
<td>SAG T2 (straight)</td>
<td>3D TSE</td>
<td>370/1800</td>
<td>30 x 30</td>
<td>1 x 1 x 2 (→1)</td>
<td>3min</td>
</tr>
<tr>
<td>Treatment planning</td>
<td>AX T2</td>
<td>2D TSE</td>
<td>110/2500</td>
<td>26 x 26</td>
<td>0.8 x 0.8 x 3/2</td>
<td>3min</td>
</tr>
<tr>
<td>Temperature mapping</td>
<td>AX Thermometry</td>
<td>2D GRE-EPI FS</td>
<td>12/25</td>
<td>26 x 26</td>
<td>2 x 2 x 5/0.4</td>
<td>5 sec/dyn</td>
</tr>
<tr>
<td>Post-treatment evaluation</td>
<td>AX T1 pre/post Gd</td>
<td>3D DIXON</td>
<td>1.5/2.7/4.3</td>
<td>35 x 30</td>
<td>1.1 x 1.3 x 3</td>
<td>1min 23sec</td>
</tr>
</tbody>
</table>

TULSA Procedure

1. T2W
2. Temperature Map
3. Ablation Volume
Summary

- High-quality prostate mpMRI depends on
  - Hardware, software, scanning parameters, and patient-related factors
- Implementation of prostate MRI protocols
  - PI-RADS technical specifications as guidelines
  - Preloaded sequences by MR vendors
- Optimization of prostate mpMRI protocols
  - Tailored to each scanner and institution
  - High image quality at a patient level
  - Development of novel and advanced MRI technology

Thank You!

- UT Southwestern Medical Center
  - Dr. Daniel Costa, Dr. Taemee Pak (Radiologists)
  - Adrian Gaspar, Heather Shelley, Orlando Morales (MRI Technologists)
  - Debbie Travalini (PA-C)
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  - Dipti Joshi (Lead Clinical Product Expert)
- UT MD Anderson Cancer Center
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  - Dr. Jingfei Ma