MR technical requirements
- Fields and Coils -

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Prostate MRI Course
Rome, 22nd June 2012
Clinical question

Patient presentation
Prostate cancer? PSA ↑

TRUS biopsy
TRUS biopsy

Detection MRI

Screening? MRI?

neg

pos

Staging MRI

Lymph nodes neg N0
T3

Lymph nodes pos N1

T2

Lymph nodes pos N1

Lymph nodes neg N0

Staging MRI

Radiotherapy
Surgery

Hormonal therapy

Radiotherapy

Surgery

Brachytherapy
Cryo/ HIFU

Localization MRI

Localization Detection MRI

Relapse

MRI neg
TRUS biopsy
MR System

Siemens

Philips

GE
Gradient amplifiers, RF amplifier(s), TxRx chains, computers and software
Coils to receive the MR signal

Combine with pelvic phased array coil

Endorectal detection coil

Table: 16, 32 coil elements
PPA coil: 4, 8, 16, 18 elements
Essentials in set-up for prostate MRI

- Field strength: 1.5 or 3 Tesla (in 2017: 7 Tesla)
- Endorectal coil?: depends on clinical question and preference of local radiologists

- Signal to noise ratio SNR of complete MR exam
- Patient discomfort
- Additional MR time for positioning and check
- Costs (coil and MR time)
Magnetic field strength: SNR

Water and lipids contain Protons / hydrogen atoms

Protons precess
Small magnetic moment
Overall magnetisation depends on magnetic field strength:

Magnetic field → Magnetisation → MRI signal
Coils to receive the MR signal: Noise

1. Intrinsic **sample** noise
2. **Coil** noise (≈ coil radius)

**Penetration depth** of coil ≈ coil radius
Schematic coils to receive the MR signal

Penetration depth of coil $\sim$ coil radius
1. Intrinsic sample noise
2. Coil noise ($\sim$ coil radius)

filling factor

Small coil
Small sample
Little noise

Large coil
Large sample
More noise

SNR↑

Large coil
Large sample
More noise

SNR↑

SNR↓
Coils, SNR, voxel size

Penetration depth of coil ~ coil radius
1. Intrinsic sample noise
2. Coil noise (~coil radius)

Voxel size inside sample

SNR A1 >>> A2 = A3 >>> A4
SNR B3 < B1 < B2 <<< B4
Signal to noise ratio SNR

- Magnetic field, coil setup
- Spatial resolution / voxel size defines # protons
- MRI parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SNR</th>
<th>Resolution</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing Field of View</td>
<td>++</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>Increasing Slice Thickness</td>
<td>++</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>Increasing Matrix</td>
<td>--</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Increasing Number of Excitation</td>
<td>++</td>
<td>0</td>
<td>++</td>
</tr>
<tr>
<td>reducing slice thickness</td>
<td>--</td>
<td>++</td>
<td>0</td>
</tr>
</tbody>
</table>

- Averages (Nex): the SNR $\sim \sqrt{\text{(time spent)}}$
What other requirements are to be met
First steps into practice

from a spectroscopy background point of view
## Preparations

<table>
<thead>
<tr>
<th>Preparations</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contrast Injector</strong></td>
<td>Flow rate 2,5 ml/sec. KVO. 0,2mL/kg Gadolinium contrast agent, 20 cc flush with NaCl.</td>
</tr>
<tr>
<td><strong>Intra luminal rectal gel (optionally)</strong></td>
<td>The (warm) ultrasound gel is inserted into the rectum. In total ≥ 100 cc ultrasound gel is inserted (without air bubbles).</td>
</tr>
<tr>
<td><strong>Bowel movement suppression (optionally)</strong></td>
<td>Buscopan (1 mg) / Glucagon (1mg)/ none administration depends on the local situation</td>
</tr>
<tr>
<td><strong>Coils &amp; positioning</strong></td>
<td>Endorectal combined with external array (spine and body), Feet first supine</td>
</tr>
<tr>
<td><strong>Patient</strong></td>
<td>Void urine before examination</td>
</tr>
</tbody>
</table>
### Patient on table

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. t2_localizer</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Prostate</strong></td>
</tr>
<tr>
<td></td>
<td>Loads automatically into viewer</td>
</tr>
<tr>
<td></td>
<td>Automatic coil selection is on</td>
</tr>
<tr>
<td><strong>2. Localizer</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Position 2\textsuperscript{nd} localizer on prostate, patient will move to iso-center</td>
</tr>
<tr>
<td><strong>3.</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Reset Table position</strong> under Patient… From now on all positioning is fixed to this new table position, prostate in iso-center of magnet. This essential step increases chances for a good shim.</td>
</tr>
</tbody>
</table>
Coil positioning

Fast Imaging with ERC enabled e.g. HASTE

ERC tends to turn clockwise with introduction
Easily positioned too deep, especially when inflating
Coil repositioning

Reposition until correct on axial image
HF direction has larger FOV
Patient on table, **anatomy**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4. t2_localizer_ Prostate</td>
<td>Rerun localizer at new position</td>
</tr>
<tr>
<td>5. t2_tse_sag</td>
<td>No angulation! Cover entire prostate. Sat band over ventral lipids</td>
</tr>
</tbody>
</table>
The axial images have to be angulated in T-C (head-feet) direction perpendicular to the rectal wall / endorectal coil.
7. t2_tse_cor

Angle of the coronal slab perpendicular to the axial T2-weighted sequence. Note T>C angulation of T2-TSE_TRA, and fix the same number in Orientation tab as C>T with a plus and minus change.
Anatomy T₂-weighted MRI (1.5T)

3 different 2D multislice acquisitions ~10 minutes

coil

perpendicular
3D CSI: spatial resolution

Adjust the resolution (in resolution tab) in such a way that the yellow FOV has at least 1.5 to 2 voxels (green blocks) outside the white VOI. Adjust FOV, matrix size and no_averages for accurate resolution and scan time.
General rule of thumb:

- Actual CSI measurement duration 8-10 minutes
- Within this time, voxel size depends on:
  - 1.5T, Endorectal coil: 6 x 6 x 6 mm$^3$ -> 0.64 cc
  - 1.5T, External coils: 8 x 8 x 8 mm$^3$ -> 1.51 cc
  - 3T, Endorectal coil: 5 x 5 x 5 mm$^3$ -> 0.37 cc
  - 3T, External coils: 7 x 7 x 7 mm$^3$ -> 1.01 cc

2. Select the images in which the prostate has the largest diameter (axial/sagittal/coronal). Try to maximize coverage of the prostate, while minimizing inclusion of periprostatic fat.

**3D CSI: shimming**

**Manual adjustments**

<table>
<thead>
<tr>
<th>No.</th>
<th>Rec. gain</th>
<th>FWHM [Hz]</th>
<th>Int. Pj</th>
<th>T²</th>
<th>Tendency</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>High</td>
<td>27.0</td>
<td>1337</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>49</td>
<td>High</td>
<td>25.8</td>
<td>1284</td>
<td>20</td>
<td>+++</td>
</tr>
<tr>
<td>50</td>
<td>High</td>
<td>23.2</td>
<td>1308</td>
<td>20</td>
<td>++</td>
</tr>
<tr>
<td>51</td>
<td>High</td>
<td>23.8</td>
<td>1438</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>52</td>
<td>High</td>
<td>24.4</td>
<td>1280</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>High</td>
<td>26.6</td>
<td>1295</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>54</td>
<td>High</td>
<td>27.0</td>
<td>1022</td>
<td>19</td>
<td>+++</td>
</tr>
<tr>
<td>26</td>
<td>High</td>
<td>23.8</td>
<td>1307</td>
<td>22</td>
<td>Best Shim</td>
</tr>
</tbody>
</table>

**Ampl**

**Max 44**

**Max 2024**

**Sensitivity:**

- Low
- High

**Frequency**

**Transmitter**

**3D Shim**

**Interactive shim**

**VOI** is equal to adjustment volume

Supervise automatic shim, add manual shimming until:

- FWHM of magnitude signal < 20 Hz (1.5T), < 25 Hz (3T)

Remember to re-adjust frequency after shimming.
3D CSI of the prostate

- PRESS excitation
- Pulse sequence timing
- Dual-frequency water and lipid suppression
- Weighted elliptical k-space sampling
- Outer volume saturation slabs
- Repetition time
1.5T ERC data example

marker for PCa:

Cho + Cr
Cit
Endorectal coil only, axial slice
Weighted, elliptical k-space sampling

TE 145 ms, TR 750 ms, TA 9:36 min
6 ave (Hamming), 14 x 10 x 12 matrix
5 x 5 x 5 mm

Histopathology
Whole mount section

Gleason 8
Gleason 5
3T data example, **external coils only**

Array coil spectroscopy

**TE 145 ms, TR 750 ms, TA 12 min**

**6 x 6 x 6 mm**

Resolution and measurement time similar to 1.5T with ERC
Software needs

- Vendor-specific licenses for different parts of multi-parametric examination
  - Diffusion Weighted Imaging
    - spin-echo EPI with monopolar diffusion gradients
  - Spectroscopy
    - SVS – 2D CSI – 3D CSI licenses
    - ‘prostate package’
    - Post-processing software
  - Dynamic contrast Enhanced Imaging
    - Fast gradient echo with k-space sharing (TWIST)
Staging at 3T: with ERC

In-plane resolution 0.35 x 0.35 mm with ERC


<table>
<thead>
<tr>
<th>MR Imaging</th>
<th>Reader A</th>
<th>Reader B</th>
<th>Reader C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage T3</td>
<td>7</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Stage T2</td>
<td>1</td>
<td>23</td>
<td>4</td>
</tr>
</tbody>
</table>

### Table 2

#### Staging and Statistical Analysis Results for Three Readers according to Patient

**A: Histopathologic Staging Results**

<table>
<thead>
<tr>
<th></th>
<th>Reader A</th>
<th>Reader B</th>
<th>Reader C</th>
</tr>
</thead>
<tbody>
<tr>
<td>MR Imaging</td>
<td>Reader A</td>
<td>Reader B</td>
<td>Reader C</td>
</tr>
<tr>
<td>Stage T3</td>
<td>7</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Stage T2</td>
<td>1</td>
<td>23</td>
<td>4</td>
</tr>
</tbody>
</table>

**B: Statistical Results**

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Reader A</th>
<th>Reader B</th>
<th>Reader C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity†</td>
<td>88 (7/8)</td>
<td>88 (7/8)</td>
<td>50 (4/8)</td>
</tr>
<tr>
<td>Specificity†</td>
<td>96 (23/24)</td>
<td>96 (23/24)</td>
<td>92 (22/24)</td>
</tr>
<tr>
<td>Accuracy†</td>
<td>94 (30/32)</td>
<td>94 (30/32)</td>
<td>81 (26/32)</td>
</tr>
<tr>
<td>Positive predictive value†</td>
<td>88 (7/8)</td>
<td>88 (7/8)</td>
<td>67 (4/6)</td>
</tr>
<tr>
<td>Negative predictive value†</td>
<td>96 (23/24)</td>
<td>96 (23/24)</td>
<td>85 (22/26)</td>
</tr>
</tbody>
</table>

Note.—Readers A and B were experienced, and reader C was less experienced.

* Data are numbers of patients.

† Data are percentages. Numbers in parentheses were used to calculate percentages.
MRSI at 3T: with or without ERC?

ROC analysis of prospective study of 18 patients

<table>
<thead>
<tr>
<th>Reader</th>
<th>MRSI - AUC</th>
<th>MRSI + AUC</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reader I</td>
<td>0.62</td>
<td>0.65</td>
<td>.151</td>
</tr>
<tr>
<td>Reader II</td>
<td>0.59</td>
<td>0.68</td>
<td>.014*</td>
</tr>
<tr>
<td>Reader III</td>
<td>0.67</td>
<td>0.72</td>
<td>.056</td>
</tr>
<tr>
<td>Overall</td>
<td>0.63</td>
<td>0.68</td>
<td>.015*</td>
</tr>
</tbody>
</table>

Small increase in localization accuracy with ERC

T2w imaging at 7 Tesla

Patient
- Weight 98 kg
- Age 58 years

Imaging
- T2w TSE
- External body array coil
- TA < 2 min / direction
T2w imaging at 7 vs 3 Tesla ERC

- 8 channel external body array only
- TA = 1.53 min
- External body array + endorectal receive coil
- TA = 5 min

100 kg patient
Gleason 4+4 at MR-guided biopsy