Declaration of Conflict of Interest or Relationship

Speaker Name:  Garry E. Gold, M.D.

I have the following conflict(s) of interest to disclose with regard to the subject matter of this presentation:

- Grant/research support: NIH R01EB002524, NIH K24AR062068, NIH P01CA159992, GE Healthcare

- Consultant: Boston Scientific, Olea Medical
Protocol Principles: 3.0T

- Reduce slice thickness
- Keep TR long on PD, T2 (4000-5000 ms)
- Frequency matrix 512
- Multi-channel, parallel capable coils
- Increase bandwidth on non-fat suppressed images
- Short echo train on T1w FSE (2-3)
- “Balance” echoes around TE for FSE
High Resolution Knee Protocol

• Use: High quality knee imaging
• Goal: Keep imaging time to about 30-45 min while having outstanding quality
• Possible to scan a knee in 45 min with table turn around
• 8-channel knee coil
High Resolution Knee Protocol

- Axial PD FSE
- TR/TE = 5000/20
- Fat saturation
- 2.5 mm slices
- 416 x 320
- 2 averages
- 14 cm FOV
- 26 slices
- ETL = 8
- +/- 32 kHz BW
High Resolution Knee Protocol

- Coronal T1 FSE
- TR/TE = 1000/15
- No Fat saturation
- 2.5 mm slices
- 512 x 320
- 2 averages
- 14 cm FOV
- 18 slices
- ETL = 3
- +/- 41 kHz BW
High Resolution Knee Protocol

- Coronal T2 FSE
- TR/TE = 5000/60
- Fat saturation
- 2.5 mm slices
- 416 x 320
- 2 averages
- 14 cm FOV
- 22 slices
- ETL = 8
- +/- 32 kHz BW
High Resolution Knee Protocol

- Sagittal PD FSE
- TR/TE = 5000/15
- No fat saturation
- 2.5 mm slices
- 512 x 320
- 2 averages
- 16 cm FOV
- 30 slices
- ETL = 6
- +/- 41 kHz BW
Sagittal T2 FSE
- TR/TE = 5000/54
- Fat saturation
- 2.5 mm slices
- 384 x 320
- 2 averages
- 16 cm FOV
- 30 slices
- ETL = 8
- +/- 32 kHz BW
- Flow Comp, S Sat
High Resolution Knee Protocol

- Coronal 3D FSE
- TR/TE = 1500/35
- Fat saturation
- 0.6 mm slices
- 320 x 288
- 17 cm FOV
- 200 slices
- ETL = 35
- +/- 50 kHz BW
- Reformat at 2 mm slices
## High Resolution Scan Time Comparison

<table>
<thead>
<tr>
<th>Sequence</th>
<th>1.5T (slice, mm)</th>
<th>3.0T (slice, mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial PD</td>
<td>3:10 (4)</td>
<td>6:00 (2.5)</td>
</tr>
<tr>
<td>Cor T1</td>
<td>5:10 (4)</td>
<td>3:30 (2.5)</td>
</tr>
<tr>
<td>Cor T2</td>
<td>3:10 (4)</td>
<td>6:00 (2.5)</td>
</tr>
<tr>
<td>Sag PD</td>
<td>4:16 (3)</td>
<td>5:00 (2.5)</td>
</tr>
<tr>
<td>Sag T2</td>
<td>4:48 (3.5)</td>
<td>5:00 (2.5)</td>
</tr>
<tr>
<td>Cor 3D FSE</td>
<td>x</td>
<td>5:00 (0.6)</td>
</tr>
<tr>
<td>Total</td>
<td>20:34</td>
<td>30:30</td>
</tr>
</tbody>
</table>
Rapid Knee Protocol

- Use: Routine knee imaging
- Goal: Keep imaging time to a minimum while having acceptable quality
- Possible to scan a knee in 15 min with table turn around
Rapid Knee Protocol

- Axial PD FSE
- TR/TE = 5000/35
- Fat saturation
- 4.0 mm slices
- 320x224, 1 nex
- 14 cm FOV
- 26 slices
- ETL = 8
- 32 kHz BW
- ARC 1.8
Rapid Knee Protocol

- Coronal T1 FSE
- TR/TE = 1000/20
- No Fat saturation
- 4 mm slices
- 384x224, 1 nex
- 16 cm FOV
- 18 slices
- ETL = 4
- 32 kHz BW
- ARC 1.8
Rapid Knee Protocol

- Coronal T2 FSE
- TR/TE = 4000/54
- Fat saturation
- 4 mm slices
- 320x224, 1 nex
- 16 cm FOV
- 22 slices
- ETL = 8
- 32 kHz BW
- ARC 1.8
Rapid Knee Protocol

- Sagittal PD FSE
- TR/TE = 5000/35
- No fat saturation
- 3 mm slices
- 384x224, 1 nex
- 14 cm FOV
- 30 slices
- ETL = 8
- 32 kHz BW
- ARC - none
Rapid Knee Protocol

- Sagittal T2 FSE
- TR/TE = 6400/60
- No fat saturation
- 3 mm slices
- 320x224, 1 nex
- 14 cm FOV
- 30 slices
- ETL = 10
- 32 kHz BW
- Flow Comp, SI Sat
Scan Time Comparison

<table>
<thead>
<tr>
<th>Sequence</th>
<th>1.5T (nex)</th>
<th>3.0T (nex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial PD</td>
<td>3:10 (2)</td>
<td>1:25 (1)</td>
</tr>
<tr>
<td>Cor T1</td>
<td>5:10 (2)</td>
<td>1:43 (1)</td>
</tr>
<tr>
<td>Cor T2</td>
<td>3:10 (2)</td>
<td>2:24 (1)</td>
</tr>
<tr>
<td>Sag PD</td>
<td>4:16 (2)</td>
<td>2:30 (1)</td>
</tr>
<tr>
<td>Sag T2</td>
<td>4:48 (3)</td>
<td>2:40 (1)</td>
</tr>
<tr>
<td>Total</td>
<td>20:34</td>
<td>10:42</td>
</tr>
</tbody>
</table>
Future of Rapid Knee Imaging
2D vs 3D Slab Imaging

2D Multislice

- Shorter scan times
- Efficient when TR is long and all slices can be interleaved

3D Slab

- Averaging helps SNR
- Continuous coverage
- Better for image reformat
3D-FSE Knee at 3.0T

$0.6 \times 0.6 \times 0.6 \text{ mm (256} \times 256 \times 200\text{)}$ in 8 minutes

Coronal Acquisition  Sagittal Reformat  Axial Reformat
3D-FSE Reconstruction

ARC/Homodyne Hybrid-Space Algorithm
Compressed Sensing

76 echoes → 256 ky-lines
3.4× Acceleration

Need to minimize ETL, maximum BW to avoid blurring
3D-FSE: Coronal Source

3.0T isotropic resolution of 0.6 mm
3D-FSE: Sagittal Reformat

3.0T isotropic resolution of 0.6 mm
Meniscus Fragment at 3.0T

- T1 FSE
  - 416x320, BW 41 kHz, ETL = 3
  - 2.5 mm thick slices, 8-channel knee coil

- T2 FSE Fat Sat
  - 416x320, BW 31 kHz, ETL = 8

3D-FSE Cube Meniscus Fragment
Coil and cartilage thickness help determine MRI parameters
3D FSE $T_2$ and $T_{1p}$ Measurements

Combines cartilage morphology, meniscus damage, BML, and physiology in one measurement
Thank You