Buy One, Get Two for Free: Simultaneous Knee T2 Mapping and Morphological Analysis On Synthetic Images Using GRAPPATINI

Marion Roux, Tom Hilbert, Jean-Baptise Ledoux, Fabio Becce, Tobias Kober, Patrick Omoumi

1 - Department of Radiology, University Hospital (CHUV), Lausanne
2 - Advanced Clinical Imaging Technology (HC CMEA SUI DI BM PI), Siemens Healthcare AG, Lausanne
3 - LTSS, École Polytechnique Fédérale de Lausanne, Lausanne
Background

• Most commonly used contrasts to assess morphological joint abnormalities are [1]:
  – Intermediate-weighted TSE (IW)
  – T2-weighted TSE (T2w)

• Quantitative T2 mapping gained interest recently
  – Clinical Relevance: quantitative T2 is a good biomarker of early degenerative disease of cartilage and meniscus [2-4]

• The acquisition of both morphological and quantitative sequences is however time consuming, hindering their spread in clinical use.

The GRAPPATINI sequence

Standard sequences

GRAPPATINI sequence
Objective

• Validation of:
  – (1) **T2 values**
    • phantom experiment
  – (2) **image quality**
    • quantitative and qualitative assessment
    • 5 healthy volunteers
    • in comparison to the consecutive acquisition of morphological and quantitative sequences
1) Phantom experiments – Methods

- Validation of the T2 estimation with GRAPPATINI
  - Phantom: Tubes filled with different concentrations of agar and gadolinium
  - Experiment: Same hardware and protocols (MESE and GRAPPATINI) used as in in-vivo experiments
  - Reference: Low resolution single slice, single spin-echo sequence
1) Phantom Experiments – Results

- MESE > GRAPPATINI > SSSE (stimulated echoes)

2) In vivo experiments – Methods

- Single-center prospective study, performed from September 2015 to January 2016
- **5 healthy volunteers** (3 males, age 30.2±3.3 years)
- 3T (MAGNETOM Skyra, Siemens Healthcare, Germany), 15-channel knee coil
- Acquisition of the **GRAPPATINI sequence**
  - Generation of additional synthetic contrasts with TE=34ms and TE=80ms
- Acquisition of **standard morphological TSE images**
  - IW (TE=34ms) and T2w (TE=80ms)
2) In vivo – Methods – MRI protocol

- 3T (MAGNETOM Skyra, Siemens Healthcare, Germany)
- 15-channel knee coil
- All sequences were acquired in the sagittal plane.

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Resolution</th>
<th>Number of Slices</th>
<th>TR</th>
<th>TE</th>
<th>Fat Suppression</th>
<th>TA</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRAPPATINI</td>
<td>0.4x0.4x3mm³</td>
<td>36</td>
<td>4880 ms</td>
<td>34 / 80 ms</td>
<td>On</td>
<td>6:22 min</td>
</tr>
</tbody>
</table>

Total Acq. Time: **6:22 min**

<table>
<thead>
<tr>
<th>IW - TSE</th>
<th>0.4x0.4x3mm³</th>
<th>36</th>
<th>3790 ms</th>
<th>34 ms</th>
<th>On</th>
<th>2:52 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2w - TSE</td>
<td>0.4x0.4x3mm³</td>
<td>36</td>
<td>3790 ms</td>
<td>80 ms</td>
<td>On</td>
<td>2:52 min</td>
</tr>
<tr>
<td>MESE</td>
<td>0.5x0.5x3mm³</td>
<td>36</td>
<td>1630 ms</td>
<td>ΔTE 13 ms</td>
<td>Off</td>
<td>7:09 min</td>
</tr>
</tbody>
</table>

Total Acq. Time: **12:13 min**
2) In vivo – Methods – Analysis

• Comparison of synthetic morphological images versus conventional TSE images
  – Quantitative analysis: SNR, CNR
  – Qualitative analysis (2 radiologists blinded to employed sequence, Five-grade scale):
    • Global image quality
    • Image quality of each of the following anatomical structures: cartilage, menisci, cruciate ligaments, bone marrow, muscle, joint fluid, quadricipital and patellar tendons
• Visual image contrast
• Visual noise
• Artifacts

-2: first image significantly worse than second,
-1: moderately worse,
0: no difference,
+1: moderately better,
+2: significantly better
Synthetic Image (TE=34 ms)

Standard IW TSE (TE=34 ms)
2) In Vivo Experiments – Results

• Quantitative Analysis
  – No significant difference in SNR and CNR

  – SNR :
    • average SNR = 9.9 for both synthetic and conventional sequences, p=0.99

  – CNR :
    • cartilage/fluid: 6.2 vs. 6.6, p=0.62
    • meniscus/fluid: 11.3 vs. 11.6, p=0.81
2) In Vivo Experiments – Results

• Qualitative Analysis
  – No difference in **global image quality** or of any of the anatomical structures that were evaluated
    • average score of 0, 95%CI=[0; 0.4]
  
  – **Artefact** scores were slightly higher for the synthetic sequences
    • average of -0.1, 95%CI=[-0.002; -0.6]
  
  – **Visual noise** and **contrast** were slightly better for the synthetic sequences
    • average score of 0.1 for both, 95%CI=[0.002; 0.6]
Limitations

- Number of included patients (volunteers)
- Implication in diagnosis imaging
Conclusion

• T2 map, IW and T2w images can be acquired with one GRAPPATINI sequence in 6.22 min instead of 12.13 min (sum of the acquisition times obtained with the standard techniques)

• GRAPPATINI provides...
  – Accurate T2 values
  – Synthetic IW and T2w images quantitatively and qualitatively similar to conventional TSE images
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The GRAPPATINI sequence

• **T2 Map Acquisition:**
  – 10-fold undersampled multi-echo spin-echo sequence (MESE)

• **T2 Map Reconstruction:**
  – GRAPPATINI [7]: Subsequent application of parallel imaging (GRAPPA) [5] and model-based reconstruction (MARTINI) [6]

• **Synthetic T2 weighted Images:**
  – Applying the forward signal Model to simulate TSE contrast with arbitrary echo-time TE

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