GRASE (gradient and spin-echo): An alternative for T2-weighted turbo spin echo sequence in ankle joint

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Aims and objectives

The aim was to evaluate chronic ankle pain using GRASE (gradient and spin-echo) and compare with T2-weighted TSE (Turbo spin echo sequence). The primary objective was comparing GRASE and T2W TSE in assessment of anterior talofibular ligament injury, tendon injury, bone marrow edema and soft tissue edema.
Methods and materials

Institutional review board approval was obtained prior to beginning the study. A cross-sectional study was done to evaluate chronic ankle pain using plain MRI. Study group included patients with chronic ankle pain from time period August 2013 to May 2015. Sample size was 62 patients. Inclusion criteria included patient with history of chronic ankle pain for 6 weeks and more. Exclusion criteria included contraindications to MR imaging and patients refusing to participate in the study. A thorough history was taken and clinical examination done prior to imaging.

MR imaging was done in Achieva 1.5T scanner (Philips Healthcare System) with extremity surface coil which was 8 channel linear detection receive only coil. Imaging parameters used in this study were summarized in table 1. Axial and sagittal TSE T2W and GRASE with fat saturation using SPAIR were obtained in all patients. In TSE imaging, multiple k-space lines per TR are obtained by a train of 180° RF refocusing pulses. The number of RF refocusing pulses is called the turbo factor (TF). In EPI, multiple k profiles per TR are acquired by train of gradient echoes. The number of refocusing gradient is called the EPI factor (EF). Turbo factor and EPI factor (TF/EF) used in GRASE was 7/3.

Lesion visualization, image quality, and artifacts were qualitatively analyzed by two observers independently. Grading was done for lesion visualization using 3 point scale. 3-good, 2-intermediate and 1-poor. Anterior talofibular ligament was evaluated for signs of tear such as discontinuity, detachment, nonvisualization, thickening of the ligament and increased intrasubstance signal intensity on TSE T2W FS / GRASE. Complete tear was considered to be present when discontinuity, detachment or non-visualization of ligament was noted. Partial tear was considered when there was increased intrasubstance signal intensity in GRASE or T2W images without any discontinuity. Chronic tear was considered to be present when there was thickening of ligament, elongation with irregular or wavy contour. Tendon injury included peroneus longus and brevis, posterior tibial tendon and Achilles tendon. Visualization of bone marrow edema and soft tissue edema in TSE T2W and GRASE was graded using the scale described above.
<table>
<thead>
<tr>
<th>MRI sequence</th>
<th>TR(ms)</th>
<th>TE(ms)</th>
<th>Slice thickness (mm)</th>
<th>Slice gap (mm)</th>
<th>No of averages</th>
<th>Matrix</th>
<th>Time of acquisition</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSE T2W FS</td>
<td>3617</td>
<td>60</td>
<td>3</td>
<td>0.3</td>
<td>2</td>
<td>200x192</td>
<td>4 min</td>
</tr>
<tr>
<td>GRASE FS (TF factor/EPI factor) 7/3</td>
<td>2150</td>
<td>51</td>
<td>3</td>
<td>0.3</td>
<td>2</td>
<td>200x189</td>
<td>2 min 15 secs</td>
</tr>
</tbody>
</table>

**Table 1:** Table 1. Imaging parameters used in the study

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Results

A total of 61 patients were assessed during the study. The study population age ranged from 18-64 years with a mean age of 40.1 years. Out of the 61 patients, 22 patients had anterior talofibular ligament injury, 10 had tendon injury and 33 patients showed bone marrow edema and 24 patients showed soft tissue edema. MRI diagnosis of the patients are presented in table 2.

Out of 61 patients, 22 patients had ATFL injury. In T2W TSE, there were 16 cases of good and 6 cases of intermediate lesion visualization. In GRASE, 15 cases of good, 6 cases of intermediate and 1 case of poor lesion visualization. In case of tendon injury (n=10), T2W TSE and GRASE showed 10 and 8 cases of good lesion visualization respectively. For marrow edema (n=33), T2W TSE and GRASE showed 33 and 31 cases of good lesion visualization respectively. In case of soft tissue edema (n=24), T2W TSE and GRASE showed 24 and 23 cases of good lesion visualization respectively.

Comparison of TSE T2W FS with GRASE was done for lesion visualization qualitatively and grades were assigned for TSE T2W and GRASE. The results are tabulated in table 3. The results showed no statistically significant difference between two sequences for lesion visualization in ATFL injury (p value -0.679), tendon injury (p value- 0.146), bone marrow edema (p value- 0.154) and soft tissue edema (p value- 0.317). Grading was done for overall image quality with similar grading system used for lesion visualization. Comparison of TSE T2W and GRASE performed. No statistically significant difference in overall image quality difference could be demonstrated. Statistical analysis was done using Mann-Whitney test. In GRASE, 4 patients had reduced SNR, while in TSE T2W, 1 patient had reduced SNR. Inhomogeneous fat suppression and chemical shift artifact in GRASE was seen in one patient.

GRASE (gradient and spin-echo) is a hybrid of turbo spin echo (TSE) and echo-planar imaging (EPI). The GRASE technique maintains contrast mechanisms and high spatial resolution of spin echo but faster than spin echo. It avoids potential problems of echo-planar imaging including chemical shift and magnetic susceptibility heterogeneity. It has advantages of both fast gradient echo and spin echo sequences. GRASE is frequently used in brain and abdomen imaging. GRASE uses a train of refocusing 180° RF pulses in addition to gradient recalled echoes which is applied in between the RF pulses (1,2).

MRI techniques that reduce the scan time tend to decrease the signal-to-noise ratio (SNR). In EPI technique, strength of the gradient echoes can decay rapidly due to T2* effects leading to reduced SNR in the later echoes as compared to the initial echoes. However, in GRASE, the RF pulses refocus the echoes intermittently to a maximum
within the decay envelope. This helps to maintain SNR and reduce artifacts\(^2\). Optimum combination of TF and EPI factor was chosen based on the previous study done by Trattnig et al. TF/EPI factor\((7/3)\) demonstrated best results with respect to SNR, signal non uniformity and geometrical distortion\(^1\).

In addition to acquisition of quick high-resolution T2-weighted images, GRASE sequences causes less RF energy deposition when compared to TSE T2W\(^1,3\). TSE sequence with a TF factor of \(a\), reduces scan time to roughly \(1/a\). Therefore in GRASE sequence with TF of \(a\) and EPI factor of \(b\) would reduce the scan time to \((1/a \times 1/b)\) approximately\(^2\). In our study, the time taken for TSE T2W axial section in ankle is roughly 4 minutes while GRASE requires only 2 minutes 15 seconds. Significant reduction in time taken for acquisition was evident in GRASE sequence.

Fat suppression was done using SPAIR (Spectral Adiabatic Inversion Recovery). SPAIR was preferred over STIR (short inversion time inversion recovery) because SPAIR has higher SNR when compared to STIR. In SPAIR, adiabatic RF pulses spectrally separate fat and water with a small delay between short RF pulses which helps to maintain homogenous fat suppression for large field of view and high SNR\(^4-5\). In our study, fat saturation could be completely achieved in all patients except for one patient.

Lesion visualization and overall image quality were assessed qualitatively for TSE T2W and GRASE. ATFL ligament injury is the most common ligament injury in ankle joint, therefore it was considered for evaluation in this study. Complete tear (figure 2), partial tear, chronic tear and avulsion were assessed. According to study conducted by Trattnig et al., the additional gradient echoes in GRASE seemed to increase its sensitivity in the evaluation of ligamentous structures as it showed a clear delineation of partial or complete ligamentous tears\(^1\). In our study, no significant difference was identified in mean scores for TSE T2W and GRASE lesion visualization.

Magnetization transfer effect due to multiple RF pulses in the TSE sequence produces the saturation of inflamed tissue. GRASE consists of a reduced number of RF pulses since TF factor is less when compared to TSE T2W. Therefore tendon tears could be better appreciated in GRASE\(^1\). In our study, no significant difference in lesion visualization could be demonstrated (figure 3).

Bone marrow edema associated with pathologies such as osteochondral lesion of talus, arthritis, fracture and soft tissue edema in various conditions were evaluated\(\text{figure 4 and 5)\}. Mean scores were comparable for TSE T2W and GRASE. In the previous study, fat saturation was not employed. The contrast obtained with GRASE was similar to conventional SE than that in TSE T2W. This is due to intact J-coupling in GRASE\(^1\). Therefore GRASE scored higher than TSE T2W in the previous study.
The overall image quality was compared for both these sequences. No significant difference in image quality could be demonstrated. Disadvantage of GRASE includes reduced SNR. No significant difference in image noise for GRASE and TSE T2W. Inhomogeneous fat suppression and chemical shift artifact in GRASE were observed in one patient. Homogenous fat suppression could be achieved in almost all the patients. Artifacts related to EPI like distortion and sensitivity to magnetic field inhomogeneity were not encountered possibly due to RF refocusing and use of SENSE (sensitivity-encoded, parallel imaging technique in Philips) (6).
Table 2: MRI findings and diagnosis of patients with chronic ankle pain.

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Table 3: Table 3. Results of comparison between two sequences. (TSE T2W vs GRASE).

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<table>
<thead>
<tr>
<th>MRI Findings</th>
<th>TSE T2W lesion visualization</th>
<th>GRASE lesion visualization</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean score</td>
<td>SD*</td>
<td>Mean score</td>
</tr>
<tr>
<td>ATFL injury</td>
<td>2.73</td>
<td>0.456</td>
<td>2.64</td>
</tr>
<tr>
<td>Tendon injury</td>
<td>3.00</td>
<td>0.000</td>
<td>2.80</td>
</tr>
<tr>
<td>Bone marrow edema</td>
<td>3.00</td>
<td>0.000</td>
<td>2.91</td>
</tr>
<tr>
<td>Soft tissue edema</td>
<td>3.00</td>
<td>0.000</td>
<td>2.96</td>
</tr>
</tbody>
</table>

SD*-Standard deviation

Table 4: Table 4. Comparison of image quality (TSE T2W vs GRASE).

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<table>
<thead>
<tr>
<th>TSE T2W image quality</th>
<th>GRASE image quality</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean score</td>
<td>SD*</td>
<td>Mean score</td>
</tr>
<tr>
<td>2.98</td>
<td>.128</td>
<td>2.92</td>
</tr>
</tbody>
</table>

SD*-Standard deviation
**Fig. 1:** Figure 1. Schematic diagram showing GRASE (gradient and spin echo) pulse sequence.

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Fig. 2: Figure 2.(a) Axial TSE T2W showing complete tear of anterior talofibular ligament. (b) Axial GRASE showing complete tear of anterior talofibular ligament.

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Fig. 3: Figure 3. Axial TSE T2W (a) and GRASE (b) showing increased intrasubstance hyperintensity and vertical split in the posterior tibial tendon with surrounding fluid signal.

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Fig. 4: Figure 4. Axial TSE T2W (a) and GRASE (b) showing osteochondral lesion of talus with surrounding marrow edema.

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Fig. 5: Figure 5. Axial TSE T2W (a) and GRASE (b) showing fracture line in distal tibia with bone marrow edema (arrowhead) and soft tissue edema (arrow).

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Conclusion

GRASE is a new technique for fast ankle joint imaging. T2-weighted GRASE imaging offers an alternative to T2W TSE resulting in similar image quality, but acquired in short time. GRASE is a sequence that combines the strengths and weaknesses of both spin echo and gradient echo techniques.
References


