

Fast, high spatial resolution MRI of the ankle with parallel imaging using GRAPPA at 3.0T

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Introduction. 3.0T has been shown to improve musculoskeletal imaging compared to 1.5T (1, 2). Gains in signal and contrast to noise ratio (SNR, CNR) are particularly useful for high spatial resolution imaging of cartilage at the knee (1, 2). The additional SNR at 3.0 T might also be utilized in reducing the acquisition time using parallel imaging techniques. Especially in standard clinical musculoskeletal protocols, scan time reduction by employing parallel imaging can prevent motion artifacts as well as allow more flexibility in protocol design. Previously, studies on application of parallel imaging in clinical musculoskeletal MRI at 1.5 T have been reported in the literature. In this work we focused on small field-of-view imaging of the ankle at 3.0T with an autocalibrating parallel technique and compared it to standard acquisition at 3.0T and at 1.5T. The comparison was performed in terms of SNR, CNR, image quality, ligament, tendon and cartilage visualization as well as pathology assessment.

Material and Methods

MR images of ankles were obtained at 1.5T and 3.0T (Signa, General Electric, Milwaukee, WI) in three fresh human cadaver specimens and three human volunteers. For parallel imaging of the specimens a 4 channel receiver (NovaPaddle, USA) and for parallel imaging of the volunteers an 8-channel receiver (Medical Devices, WI, USA) was used. We applied previously optimized clinical ankle protocols consisting of axial and sagittal T1-weighted (-w), axial fat-saturated (fs) T2-w, and coronal intermediate (IM)-w fast spinecho (FSE) sequences, as well as a fs spoiled gradient echo sequence (SPGR) for dedicated cartilage imaging (Table 1). With 3D SPGR sequences, an additional variable density acquisition with reduction factor (R) = 2 – i.e. approximately half the number of phase-encodes compared to the standard sequence – was acquired. With 2D FSE no additional parallel imaging scan was conducted, but the data were decimated offline to simulate reduction factor of 2. The reduced datasets were reconstructed offline using a Generalized Autocalibrating Partially Parallel Acquisition (GRAPPA) based reconstruction technique which synthesizes the missing phase-encode lines by segmented readout and multicolumn floating node fitting (MC-FNF) (3,4). The reconstruction algorithms were programmed in MATLAB (MathWorks) and executed on a Sun Workstation. All images were assessed by two radiologists independently concerning image quality. The radiologists were blinded to specimen and volunteer number, field strength and reconstruction algorithm. Visualization of cartilage surface and internal structure were graded and cartilage pathology was assessed in the SPGR sequences. Grading of ligament visualization and assessment of ligament and tendon pathology was performed for the FSE sequences. In the cadaver specimens, macroscopic findings after dissection served as a standard of reference for the pathological evaluation. Image quality, cartilage and ligament visualization were graded on a scale of four, where 1 was considered as “poor” and 4 as “excellent”. SNR efficiency (SNR_E) was measured in every image, defined as the signal intensity (SI) of bone marrow (T1-w images), cartilage (SPGR images) or fluid (T2-w images) divided by the standard deviation (SD) of the background and the square root of the scan time in seconds. CNR efficiency (CNR_E) was calculated for the SPGR sequences and defined as SI of the cartilage minus SI of the bone marrow divided by the SD of the background and the square root of the scan time. Differences in image quality, SNR_E and CNR_E were assessed using an ANOVA analysis with a significance level of p<0.05.

Results

SNR_E and CNR_E in the GRAPPA images for R=2 were comparable to the standard acquisition at 3.0T (Table 2). The image quality was rated significantly higher at 3.0T with both normal and parallel acquisition compared to 1.5T. There was no significant difference in ligament and cartilage visualization as well as image quality between standard and GRAPPA reconstruction at 3.0T. The pathologic examination of the three ankle specimens revealed 2 cartilage and 2 tendon pathologies. The tendon pathologies were seen in all three imaging modalities, one cartilage lesion was only seen in both parallel and standard acquisition at 3.0T and not at 1.5T. The other cartilage lesion was missed in all scans.

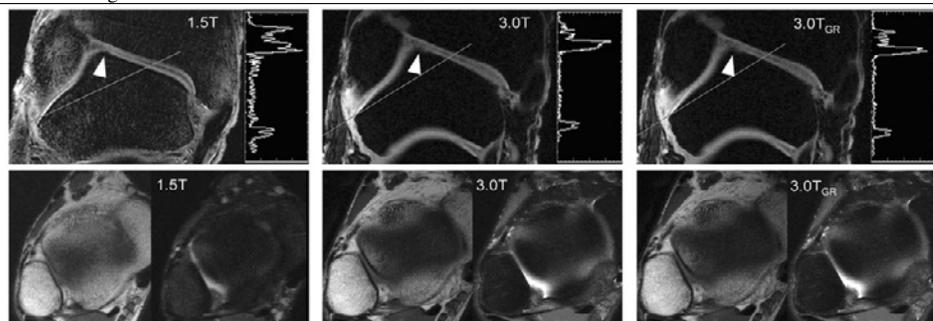


Figure 1: SPGR images (upper row, grade 3 cartilage defect (arrowhead)) as well as T1-w and T2-w images (lower row) of the ankle joint demonstrate superior image quality at 3.0T as opposed to 1.5T. No significant difference in image quality or SNR was found between the normal and parallel acquisition at 3.0T (p>0.05).

Discussion

This study has shown that higher field strength (3.0T) combined with parallel technique produces MR images of the ankle in a very short time with good diagnostic quality. In addition to scan time reduction, parallel imaging will provide more flexibility in protocol design-for 3D sequences as the technique can be used to improve volume coverage and spatial resolution without increase in acquisition time or loss of SNR compared to the standard acquisition. For 2D FSE sequences, reduction of echo train length will reduce T2 blurring and can potentially improve the SNR compared to standard acquisitions.

References

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| Sequence | | TR (ms) | TE (ms) | ETL | Matrix (pixels) | Acqu. time (min:s) |
|----------|------|---------|---------|-----|-----------------|--------------------|
| axT1 | 3.0T | 675 | 15.7 | 5 | 384x256 | 0:05:10 |
| | 1.5T | 625 | 20.8 | 4 | 320x224 | 0:05:07 |
| axT2 | 3.0T | 4500 | 42 | 16 | 512x256 | 0:05:33 |
| | 1.5T | 4000 | 40 | 12 | 320x224 | 0:05:36 |
| sagT1 | 3.0T | 675 | 15.4 | 4 | 384x256 | 0:04:41 |
| | 1.5T | 625 | 23.5 | 4 | 384x224 | 0:05:07 |
| corIM | 3.0T | 4000 | 16.7 | 9 | 384x256 | 0:04:24 |
| | 1.5T | 4000 | 15.5 | 12 | 384x224 | 0:04:24 |
| fs-SPGR | 3.0T | 19.9 | 7.20 | 1 | 512x256 | 0:06:37 |
| | 1.5T | 17.5 | 8.50 | 1 | 512x256 | 0:06:37 |

Table 1: MR sequences, additional parameters: number of acquisitions: 2; no phase wrap; bandwidth ±16.67 kHz (1.5T), ±31.25 kHz (3T); FOV: 12cm, (SPGR: 10cm); slice thickness 3mm (SPGR: 2mm); flip angle: SPGR 1.5T: 18°; SPGR 3.0T: 20°

| | 1.5T | 3.0T | 3.0T _{GR} |
|------------------------|-------|-------|--------------------|
| Image quality (SPGR) | 2.67 | 3.67 | 3.33 |
| Image quality (T1 ax) | 2.83 | 3.25 | 3.25 |
| Ligament visualization | 3.02 | 3.88 | 3.88 |
| SNR (T1 ax) | 78.80 | 96.46 | 94.30 |
| SNR (SPGR) | 10.80 | 22.48 | 20.22 |

Table 2: Differences in image quality and SNR were significant between 1.5T and 3.0T (p<0.05), but no significant difference was found between the parallel and normal acquisition at 3.0T.