

## High resolution 3D $T_{1\rho}$ MRI of Knee Joint at 3.0T with Parallel Imaging

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### Introduction

Spin lattice relaxation time ( $T_{1\rho}$ ) has been shown to be a sensitive diagnostic tool for quantifying early biochemical changes in cartilage that occurs at the early stages of osteoarthritis (OA) [1]. However, 3D- $T_{1\rho}$  MRI that was reported in most of earlier papers was acquired with low spatial resolution (256X128 acquisition matrix with 3 mm slice thickness) at 1.5T [2]. The main reason for the choice of low resolution is low signal-to-noise ratio (SNR) and acquisition time constraints in 3D- $T_{1\rho}$  sequences at 1.5T. However, high resolution 3D- $T_{1\rho}$ -weighted MRI is highly desirable and perhaps necessary for accurate assessment of 3D- $T_{1\rho}$  relaxation times in early OA patients. High field strengths (3T) with 8-channel phased-array knee coil and parallel imaging capability should be able to simultaneously improve SNR and decrease imaging times. Therefore, the purpose of this study was to demonstrate the feasibility of acquiring high resolution 3D- $T_{1\rho}$ -weighted MRI (~100% improvement in spatial as well as temporal resolution) as well as quantify the relaxation times in human knee joint at 3.0T employing 8-channel phased-array coil and parallel imaging.

### Methods

Eight subjects (n=5 control and n=3 early OA) were evaluated. All MRI experiments were performed on a 3.0T clinical MR scanner (Magnetom Trio, Siemens Medical Solutions, Erlangen, Germany) using an 8-channel phased-array coil (18 cm diameter transmit-receive). High resolution 3D- $T_{1\rho}$ -weighted images were acquired with a 3D GRE sequence (TR/TE=175/3.2 ms; flip angle, 25°; total number of sections, 8; section thickness, 1.5 mm; matrix size, 512x256; bandwidth 350 Hz/pixel; one signal acquired, FOV=150x150 mm).  $T_{1\rho}$ -weighting was achieved by magnetization preparation using a "self-compensating" spin-lock pulse-cluster which minimizes the effects of  $B_1$  field inhomogeneities (Duration of each 90° pulse=200 $\mu$ s; the amplitude of the spin-lock pulse=250Hz). Four 3D- $T_{1\rho}$ -weighted images were acquired with TSLs (length of the spin-lock pulse) of 2, 10, 20, and 30 ms, in order to construct the high resolution  $T_{1\rho}$  map. We combined 3D- $T_{1\rho}$  spin-lock GRE sequence with GRAPPA [3] for parallel imaging with an acceleration factor (AF) of 2. 24 reference k-space lines were acquired for all the parallel imaging scans. Total imaging time for the acquisition of a 3D- $T_{1\rho}$ -weighted image was 3 min 20 s. Thus, 3D- $T_{1\rho}$ -high resolution map was acquired in ~13 min.

### Results and Discussion

Two representative slices from 3D- $T_{1\rho}$ -weighted image (acquired with TSL=2 ms) of the healthy subject is displayed in Fig. 1. The overlaid  $T_{1\rho}$  map on a representative slice can be seen in Fig. 2A. The overlaid  $T_{1\rho}$  map on a slice from 3D- $T_{1\rho}$ -weighted image of the patient can be seen in Fig.2B. There is ~50-60% increase in  $T_{1\rho}$  in early OA subject when compared to age matched healthy subject. Regional analysis of patellar cartilage was performed for both the healthy subject and the patient. The patellar cartilage regions of both subjects are divided first into medial and lateral, then into subchondral, middle, and superficial regions. The median  $T_{1\rho}$  of these regions of both subjects can be seen in Fig. 3. One of the difficulties associated with spin-lock imaging is the long acquisition times due to limits on TR in order to keep the SAR levels below the mandated SAR limits. Generating high resolution  $T_{1\rho}$  maps is quite time-consuming with conventional methods, which are overcome with this technique modification. Without parallel imaging, the total imaging time of 3D- $T_{1\rho}$ -high resolution map would be ~24 min. Thus, combining spin-lock imaging with GRAPPA increases the temporal resolution by a factor of 2, while improving resolution. The voxel size we used in this study is ~8 fold smaller than that of previously reported data (compared to an acquisition matrix of 256x128x8 with 3 mm slice thickness) [4]. Another problem with high-resolution  $T_{1\rho}$  is the high RF energy deposition to the imaged body. Using parallel imaging with AF=2 also reduced the RF energy deposition by a factor of ~2.

### Conclusion

We implemented and demonstrated high resolution 3D- $T_{1\rho}$ -mapping at 3.0T employing an 8-channel phased-array coil and parallel imaging (GRAPPA with acceleration factor 2). High resolution  $T_{1\rho}$  images are acquired and high resolution 3D- $T_{1\rho}$ -maps are computed for both healthy subjects and OA patients by combining spin-lock imaging with GRAPPA. The capability of generating high resolution  $T_{1\rho}$  maps shows promise for accurate localization of areas with elevated  $T_{1\rho}$  values in early OA subjects and potential detailed follow-up.

### References:

1) Akella SVS *et al* Mag Reson Med 2001;26:419-423. 2) Regatte RR *et al.*, Acad Radiol 2004;11:741-749. 3) Griswold MA *et al*, Magn Reson Med 2003;47:1202-1210. 4) Li *et al* MRM 2005;54: 929-36.

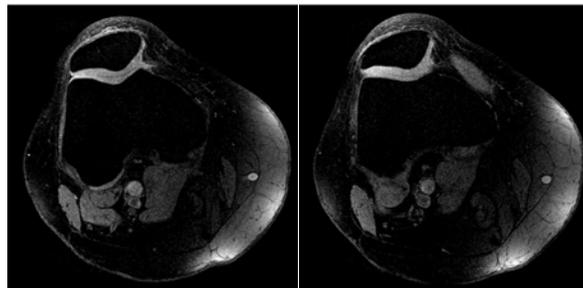


Fig. 1: Two representative slices from 3D- $T_{1\rho}$ -weighted high resolution knee image of the healthy subject.

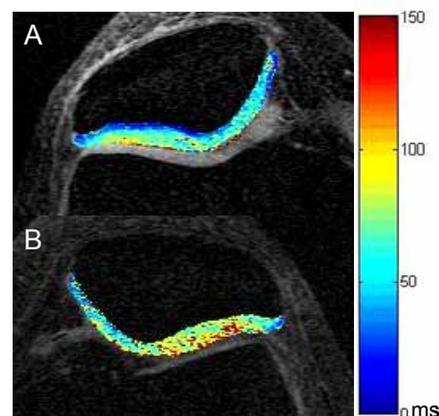


Fig. 2: High resolution  $T_{1\rho}$  maps of the patellar cartilage of (A) the healthy subject, and (B) the early OA patient.

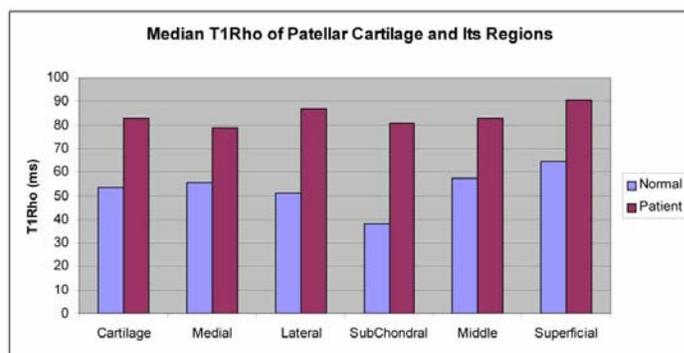


Figure 3: Results of the regional analysis of patellar cartilage  $T_{1\rho}$

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