# Rapid 3D-$T_{1\rho}$ Mapping of Knee Joint at 3.0T with Parallel Imaging

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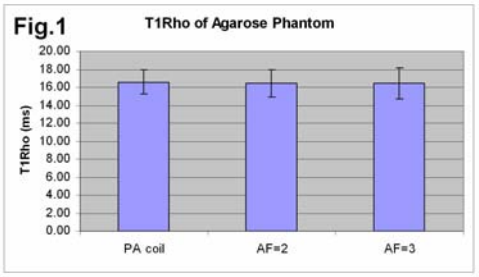
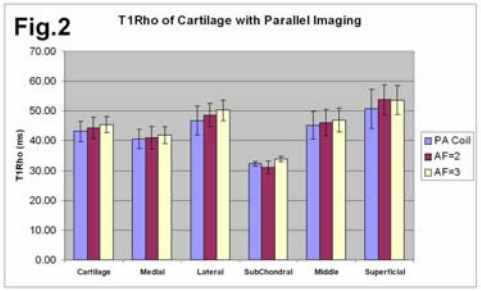
## Introduction

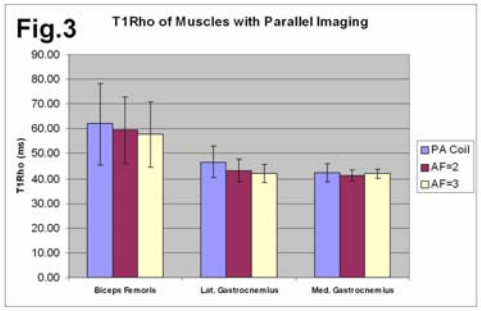
$T_{1\rho}$-weighted MRI has been shown to be sensitive to early biochemical changes in cartilage, especially proteoglycan (PG) content [1]. It has been reported that $T_{1\rho}$ elevates in OA patients when compared to age matched healthy subjects [2, 3]. However, total imaging time and RF energy deposition are two major concerns for implementing spin-lock techniques at high field strengths (3.0T). The main purpose of this work is to show the feasibility of 3D-$T_{1\rho}$-weighted MRI of knee joint with parallel imaging (GRAPPA) and to demonstrate the reproducibility of 3D-$T_{1\rho}$ maps as a function of acceleration factor (AF) in order to reduce the total imaging time and deposited RF energy.

## Methods

Phantom studies were performed using an agarose (4%) phantom. For *in vivo* studies, 3 asymptomatic subjects were recruited. The study group consisted of 2 male and 1 female volunteers whose mean age was 31 years (between 29 and 33 years). All MRI experiments were performed on a 3.0T clinical MR scanner (Magnetom Trio, Siemens Medical Solutions, Erlangen, Germany). We employed a phased-array (PA) coil (18 cm diameter 8-channel transmit-receive) in this study. 3D-$T_{1\rho}$-weighted images were acquired with a 3D GRE sequence with $T_{1\rho}$ magnetization preparation (TR/TE=175,2.9(phantom), 3.2ms(in vivo) ms; flip angle, 25°; total number of sections, 8; section thickness, 3 mm; matrix size, 256x128; bandwidth 350 Hz/pixel; one signal acquired, FOV=18x18(phantom), 15x15(in vivo) cm). The magnetization preparation is achieved by using a "self-compensating" spin-lock pulse-cluster which minimizes the effects of $B_1$ field inhomogeneities (Duration of each 90° pulse=200μs; the amplitude of the spin-lock pulse=250Hz). In order to construct $T_{1\rho}$ map, four 3D-$T_{1\rho}$-weighted images were acquired with TSLs (length of the spin-lock pulse) of 2, 10, 20, and 30 ms. We combined 3D-$T_{1\rho}$ spin-lock GRE sequence with GRAPPA [4] for parallel imaging with AFs of 2 and 3. 24 reference k-space lines were acquired for all the parallel imaging scans. The feasibility and reproducibility of $T_{1\rho}$ maps of patellar cartilage, and the three muscles, namely biceps femoris, lateral and medial gastrocnemius, were investigated. Regional analysis of patellar cartilage was also performed by analyzing lateral and medial, subchondral, middle and superficial regions separately. The reproducibility of the 3D-$T_{1\rho}$ maps were quantified using coefficient of variation (CV) and a non-parametric rank test (Wilcoxon signed rank test).




## Results and Discussion

3D-$T_{1\rho}$ maps of the phantom were constructed using the scans acquired with PA-coil and AFs 2 and 3. The median and the standard deviation of $T_{1\rho}$ for different acquisition schemes can be seen in Fig.1. CV of the median $T_{1\rho}$ of the phantom across different acquisition methods was 0.44% which shows excellent reproducibility. The standard deviation of the median $T_{1\rho}$ of patellar cartilage across different acquisition schemes was observed to be between 0.48-1.75 ms through the subjects. The standard deviation of the median $T_{1\rho}$ of patellar cartilage regions across acquisition schemes were between 0.54-1.01, 0.16-3.30, 1.04-2.47, 0.65-2.47, and 0.35-4.01ms through the subjects, for medial, lateral, subchondral, middle, and superficial regions, respectively (Fig.2). CV of median $T_{1\rho}$ of patellar cartilage among the subjects was between1.1%-4.3%. CV varied between 1.3-2.7%, 0.3-7.4%, 3.1-7.8%, 1.3-3.1%, and 0.7-8.3 for medial, lateral, subchondral, middle, and superficial regions, respectively. The standard deviation of the median $T_{1\rho}$ of biceps femoris, lateral gastrocnemius, and medial gastrocnemius across different acquisition schemes was observed to be between 0.94-4.23, 0.53-3.90, and 0.65-1.79 ms, through the subjects, respectively (Fig.3). CV of median $T_{1\rho}$ of biceps femoris, lateral and medial gastrocnemius muscles among the subjects were between 2.1-5.8%, 1.4-8.7%, and 1.5-4.1%, respectively. The differences between the median $T_{1\rho}$ acquired with different methods were statistically insignificant for all the analyzed tissues ($P \geq 0.25$ for all tissues).

Spin-lock imaging pulse sequences generally deposit considerable RF energy to the imaged body due to the long spin-lock RF pulse used for magnetization preparation. In order to construct a $T_{1\rho}$ map, several images with different amounts of $T_{1\rho}$ weighting have to be acquired by changing the length of spin-lock pulse for each acquisition. Currently, the total imaging time for spin-lock imaging is relatively long for 3D-$T_{1\rho}$ map construction. The combination of $T_{1\rho}$-weighted MRI with parallel imaging methods addresses both of these problems. As a result of application of parallel imaging, both the acquisition time and the RF energy deposition are substantially reduced.

## Conclusion

The preliminary results demonstrate that 3D-$T_{1\rho}$ maps obtained using parallel imaging (GRAPPA) are highly reproducible in an agarose phantom as well as in human knee joint *in vivo*. The resulting gain in the total acquisition time and RF energy deposition can be potentially exploited for acquiring high-resolution (both spatial and temporal) 3D-$T_{1\rho}$-weighted images in a clinical setting, even at high field strengths.

## References:

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