Rapid 3D-T1 Mapping of Cartilage Using Variable-Flip-Angle (VFA) and Parallel Imaging at 3.0T

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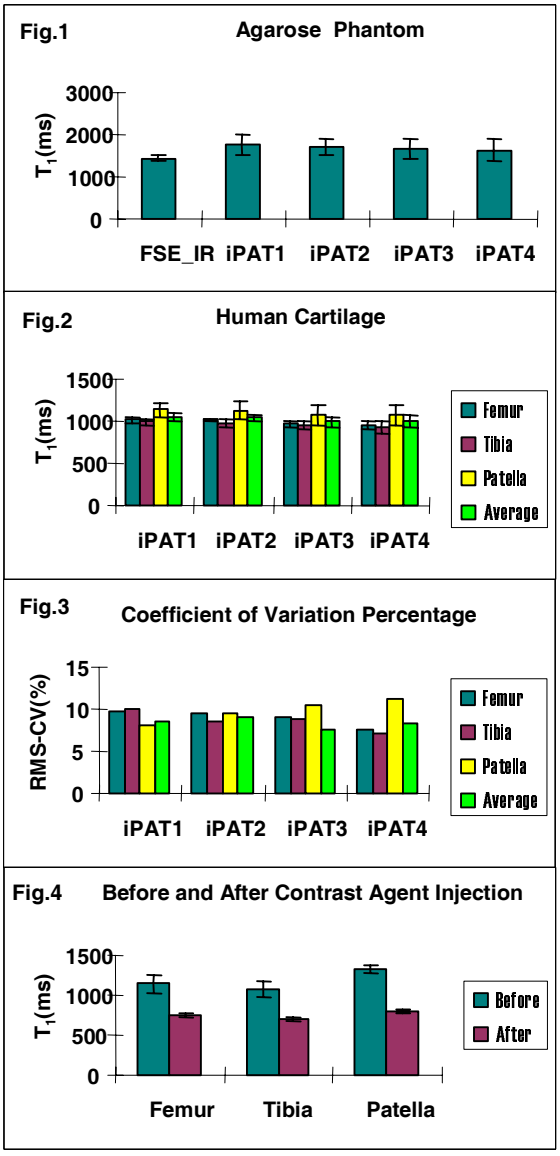
Introduction Spin-lattice relaxation time constant (T_1) has been shown to be an effective non-invasive method for cartilage imaging in the presence of contrast agent (dGEMRIC). However, most of the previously reported work on cartilage T_1 mapping has been limited to standard 2D-inversion recovery fast spin-echo (IR-FSE) sequences at 1.5T[1] with long acquisition times (~30minutes). Volume mapping of knee joint is necessary for precise quantitation of relaxation times especially for longitudinal studies. More recently, several investigators [2,3] demonstrated the feasibility of 3D methods (IR-FLASH, Look Locker, IR-True-FISP etc) for cartilage imaging in order to reduce the total acquisition times. However, the acquisition time is still relaively long even with low spatial resolution or limited number of slices. An alternative method involves determining rapid volumetric T_1 mapping from a set of two Fast Low Angle Single Shot (FLASH) images acquired with different flip angles [4,5]. The objective of the work was to demonstrate the feasibility of measuring rapid 3D-T_1 mapping of whole knee joint (with 0.7mm^3 isotropic resolution) using Variable Flip Angle (VFA) method in combination with parallel imaging (GRAPPA) at 3.0T clinical scanner.

Methods Rapid 3D-T_1 mapping is calculated from a series of FLASH images acquired over a range of flip angles with constant repetition time (TR) and parallel imaging (GRAPPA) on a 3.0T clinical MR scanner (Magnetom Tim Trio, Siemens Medical Solutions, Erlangen, Germany) employing a phased-array (PA) knee coil (18 cm diameter, 8-channel transmit-receive). Rapid 3D-T_1 mapping was first validated with 2D-FSE-IR sequence in model systems (agarose phantom, bovine cartilage) and then applied to 3 healthy (n=3 males, mean age =26 years) and 2 clinically diagnosed OA subjects (1 male, 1 female, mean age 50 years). Two optimum flip angles were selected based on 71% of Ernst signal [4]. 24 reference k-space lines were acquired for all the parallel imaging scans. Global and regional T_1 of patellar, femoral and tibial cartilage were analyzed and compared with that of conventional reference method (without parallel imaging). Total scan time to acquire a whole knee joint (FOV=13cm, NEX=2, slices=112; TR/TE=15ms/6.5ms) with 0.7mm^3 isotropic resolution was ~5 minutes with parallel imaging (acceleration factor 2). The feasibility and reproducibility of T_1 maps of femoral, tibial, and patellar cartilages were investigated. The reproducibility of the rapid 3D-T_1 maps was quantified using coefficient of variation (CV) and a non-parametric rank test (Wilcoxon signed rank test) to determine whether there were any statistically significant differences between median T_1 with different acquisition schemes.

Results and Discussion 3D-T_1 maps of the phantom were constructed using the scans acquired with PA-coil with iPAT1, iPAT2, iPAT3, and iPAT4. The median and standard deviation of T_1 for different acquisition schemes can be seen in **Fig.1**. CV of the median T_1 of the phantom across the different acquisition methods was 6.22%, which shows good reproducibility. The standard deviation of the median T_1 of femoral, tibial, patellar cartilages, and the average across different acquisition schemes was observed to be between 14.65-45.58ms, 42.84-72.73ms, 85.64-108.73ms, and 38.54-70.04ms respectively across the subjects (**Fig.2**). RMS-CV of median T_1 of femoral, tibial, patellar cartilages, and the average among the subjects was between 7.51-9.85, 7.25-9.90, 8.20-11.09, and 7.61-8.50 respectively (**Fig.3**). The differences between the median T_1 acquired with different methods were statistically insignificant for all the analyzed cartilages ($P \geq 0.34$). However, there is a statistically significant difference with contrast agent injection ($P<0.05$) (**Fig.4**)



Conclusion
The preliminary results demonstrate that the rapid 3D-T_1 mapping obtained using VFA in combination with parallel imaging are highly reproducible in an agarose phantom as well as in human knee joint *in vivo*. It is possible to quantify 3D-T_1 mapping of whole knee joint (with 0.7mm^3 isotropic resolution) under ~5 minutes with excellent i*n vivo* reproducibility at 3.0T.

References:

1) Williams A et al, AJR 2004; 182: 167-172. 2) Kimelman T et al, Invest. Rad. 2006; 41:198-203. 3) Mckenzie CA et al, JMRI 2006; 24:928-33. 4) Deoni CL. et al, MRM 2003; 49: 515-526. 5) Deoni CL. et al, MRM 2005; 53: 237-241.