$R_1\rho$ ($1/T_1\rho$) dispersion measurement in knee cartilage at 3T

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Introduction: $T_1\rho$ sensitive imaging is sensitive to early biochemical changes in the extracellular matrix of cartilage, and has been previously used to evaluate cartilage state in healthy and osteoarthritic subjects [1-3]. $T_1\rho$ variations with spin-locking strength (= the $T_1\rho$ dispersion) can in principle provide a more complete characterization of tissue composition and the physicochemical changes associated with pathology, but only very few $T_1\rho$ dispersion studies in biological tissues have been reported previously, and mostly these have been at lower magnetic field strengths [4, 5]. At higher fields, $T_1\rho$ dispersion may be dominated by chemical exchange effects so that information on specific constituents and pH can be derived. In this work, *in vivo* $R_1\rho$ (=$1/T_1\rho$) dispersion of human knee cartilage (articular and epiphyseal) was studied at 3T, and our preliminary results show pronounced $R_1\rho$ dispersion over practical locking fields; the mean exchange rate was measured at ~992 Hz when fitting the data to the Chopra model [6]. To the best of our knowledge, this is the first $R_1\rho$ dispersion measurement in human articular/epiphyseal cartilage, and forms the basis for more quantitative evaluation of cartilage disorders.

Methods: Six healthy volunteers (ages 24-71, median=39 years) participated in this study. Imaging was performed on a Philips Achieva 3.0T MR scanner with an eight-channel knee coil (Philips Healthcare, Cleveland OH, USA). A B_0/B_1 inhomogeneity self-compensated $T_1\rho$ pre-pulse sequence [7] was implemented to create $T_1\rho$ contrast followed by a Turbo Spin Echo (TSE) data acquisition. A single axial slice covering cartilage was chosen for imaging, with FOV: 180×146mm^2, pixel size: 0.5×0.5mm^2, slice thickness: 4mm, TR/TE=3300ms/10ms, TSE factor=15, NEX: 1. Five spin-locking times (TSL) [2ms, 22ms, 42ms, 62ms, 82ms] were combined into a single scan for $T_1\rho$ calculations, resulting in a scan time of 5min16sec. For the $R_1\rho$ dispersion data, the scan was repeated at different spin-locking frequency within the coil capacity and SAR limits: [0Hz, 50Hz, 100Hz, 150Hz, 200Hz, 250Hz, 300Hz, 350Hz, 400Hz, 450Hz, 500Hz]. After acquisition, a $T_1\rho$ map at each spin-locking frequency was calculated by fitting the signal intensity v TSL to a three-parameter mono-exponential model. An ROI was then drawn manually on the articular/epiphyseal cartilage of each subject to generate the $R_1\rho$ curve v locking amplitude. Finally, the average $R_1\rho$ dispersion curve was fit to a three-parameter Chopra model [6] $R_{1\rho} = \left(R_2 + \frac{R_{1\rho}^{\infty} w_1^2}{k_{ex}^2}\right) / \left(1 + \frac{w_1^2}{k_{ex}^2}\right)$ with a non-linear least-squares method to estimate the exchange rate [8]. Data processing was based on custom Matlab (version 2013a) scripts.

Results: Figure 1 (A) shows an example $T_1\rho$ color-map in the cartilage region overlaid on a structural image. The six subjects' $R_1\rho$ dispersion curves are plotted in Figure 1 (B). Clear R1ρ dispersion is observed within the spin-locking frequency range of 0-550Hz, although there are some local variations on the measured dispersion curves. In Figure 1 (C), the average dispersion and its fit to the Chopra model are displayed. The fitted parameters are: R_2 ≈38Hz, $R_{1\rho}^{\infty}$ ≈14Hz, and exchange rate k_{ex} ≈992Hz.

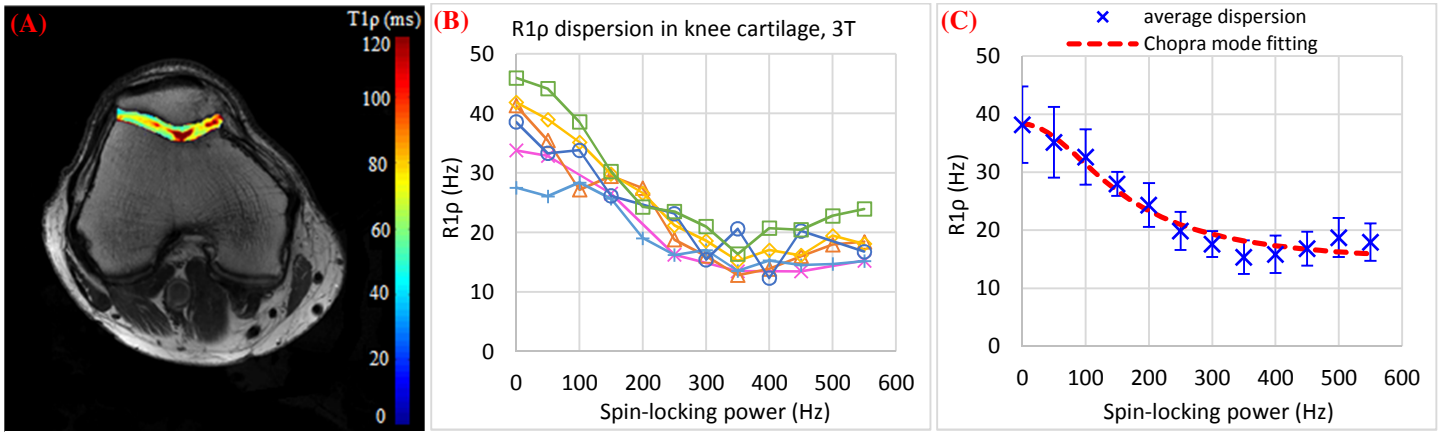

Figure 1. (A) A representative knee slice with $T_1\rho$ map overlaid on the cartilage region. (B) $R_1\rho$ dispersion curves of the six volunteers, and (C) Fitting the average $R_1\rho$ dispersion of the six volunteers to the Chopra model.

Discussion: Most tissues show little dispersion even at 3T, but where there are significant populations of exchanging protons such as proteoglycan hydroxyls the dispersion of $R_1\rho$ is dominated by exchange effects. The data here show that exchange processes are detectable within cartilage and the kinetics of that exchange can be measured. Changes in these exchange contributions are expected if there are changes in the concentrations of exchangeable species or in the exchange rate, caused by changes in pH or other effects. In a larger population study we anticipate investigating the variation of these parameters with disease and with normal aging.

Conclusion: Clear $R_1\rho$ dispersion is observed in articular and epiphyseal cartilage within a spin-locking frequency range of 0-550Hz. The exchange rate k_{ex} ≈992Hz was estimated from the Chopra model fitting.

References: [1] Regatte *et al*. JMRI 2006; 23:547. [2] Goto *et al*. Eur J Radiol 2012; 81: e796. [3] Cobb *et al*. JMRI 2013; 38:299. [4] Borthakur *et al*. JMRI 2004; 19:403. [5] Du *et al*. MRM 2010; 64:834. [6] Chopra *et al*. JMR 1984; 59:361. [7] Witschey *et al*. JMR 2007; 186:75. [8] Cobb *et al*. MRM 2012; 67:1427.