3D distribution of T1ρ relaxation times in the human knee joint

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Introduction: Previous studies have shown the MR relaxation time T1ρ is a surrogate biomarker for changes in the extracellular matrix of articular cartilage and may be sensitive to osteoarthritis (OA) progression (1). T1ρ increases in controlled degradation studies in ex vivo bovine plugs (2), porcine (3) and guinea pig (4) models of arthritis. In this study, we present the first 3D assessment of T1ρ among all regions of the knee joint articular cartilage in a subset of asymptomatic subjects (N=17) of the early OA T1ρ clinical trial.

Methods: Each subject was scanned on a 1.5 T clinical MRI system equipped with 40 µT/mm gradients (Siemens AG; Erlangen, Germany; Sonata Model) and an 8-channel transmit/receive 1H RF coil (Philips; Amsterdam, Netherlands; previously Invivo; Latham, NJ). The patella was centered with the leg flexed in the RF coil and scanned using the imaging protocol listed in Table 1. T1ρ images were acquired with a previously described T1ρ prepared balanced gradient echo sequence. Cartilage segmentation was performed using a LiveWire algorithm in 3DViewnix (MIPG; University of Pennsylvania; Philadelphia, PA) and imported into a custom image processing software constructed in Matlab (Natick, MS) to extract T1ρ by cartilage layer (superficial, middle, deep zones), side (medial, lateral), and location (patellar, femoral and tibial articular cartilage). A musculoskeletal radiologist evaluated all images for bony cysts, meniscal tears, cartilage thinning, loss and other irregularities.

Sequence	Orientation	Contrast	Acquisition Type	TE/TR/flip (ms/ms/degrees)	Resolution (mm)	Imaging Matrix	Duration (min)	Slices	Thickness (mm)
b-SSFP	Triplane	T1	2D	2.56/5.12/70	1.17x1.17	256x256	0.5	10*3=30	3.0
b-SSFP	Sagittal	T1	2D	2.56/5.12/70	0.55x0.55	256x256	0.5	30	3.0
FSE	Axial	T2	2D	25/2850/90-180	0.55x0.55	256x256	2.0	25	3.0
FSE	Coronal	T2	2D	25/2850/90-180	0.55x0.55	256x256	2.0	25	3.0
MP-RAGE	Sagittal	T1	3D	18.6/37.1/90	0.55x0.55z0.55	256x256x208	8.2	208	0.55
SLIPS	Axial	T1ρ	3D	3.7/7.4/ 20	0.55x0.55x3.0	256x128x30	15.0	30	3.0
SLIPS	Coronal	T1ρ	3D	3.7/7.4/ 20	0.55x0.55x3.0	256x128x30	15.0	30	3.0

Results: Among the 17 asymptomatic subjects ages 30-60, T1ρ was significantly different between patellar, femoral and tibial regions (p<0.001) and between the superficial, middle and deep zones of the cartilage (p<0.01). Fig.1 depicts mean T1ρ for all subjects, medial and lateral sides of the knee and shows patellar cartilage T1ρ is elevated, but with greater variance than the middle and deep zones. Medial and lateral mean T1ρ were 44.6 ± 14.0 and 45.3 ± 14.0 ms, respectively. Superficial, middle and deep zone T1ρ were 47.9 ± 15.1, 43.7 ± 13.4, and 42.3 ± 13.2 ms, respectively. Patellar, femoral and tibial T1ρ were 55.7 ± 16.9, 43.2 ± 8.5, and 36.0 ± 6.2 ms, respectively. No significant difference in T1ρ was detected by side or age. Elevated T1ρ was confirmed in one subject corresponding with focal loss of the articular cartilage on the medial patellar facet with an underlying bony cystic change as shown in Fig. 2.

Discussion: T1ρ is lower in tibial and femoral cartilage compared to the patellar cartilage likely reflecting differences in loading and associated changes in molecular content. The T1ρ gradient from superficial to deep zones likely reflects the increasing concentration of proteoglycan from the joint space surface to the subchondral bone. The complete characterization of T1ρ relaxation times among all regions of the knee articular cartilage will aid diagnosis of cartilage lesions and progression of early OA symptoms as shown in Fig. 2.

References: (1) Borthakur, et al. NMR Biomed, 2006. (2) Wheaton AJ, et al. Magn. Res. Med. 2005. (3) Wheaton, AJ, et al. Acad. Radiol. 2004. Witschey II W.R.T., et al. Rapid 3D T1p-weighted Imaging (JMRI: accepted for publication).
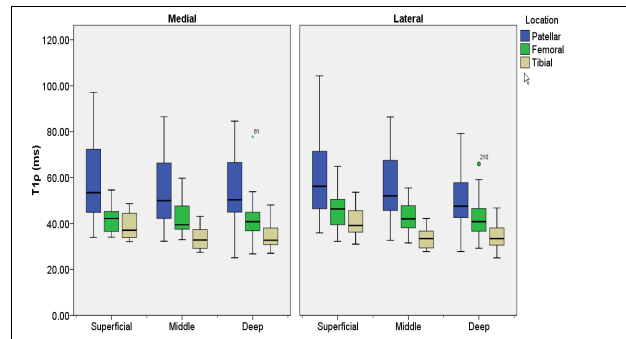

Fig.1: Average, confidence intervals and standard deviation in T1ρ among different cartilage regions in 17 asymptomatic subjects.
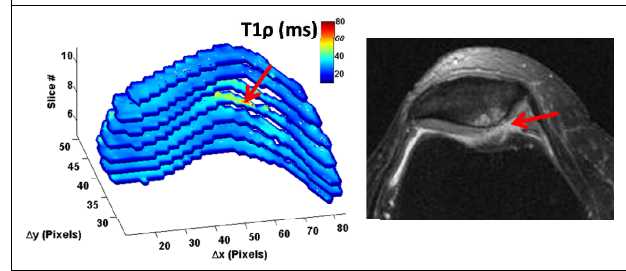

Fig. 2: 3D crossections of the patellar cartilage in a subject with focal cartilage loss and bony cyst (arrow) and corresponding 2D T2 slice.