Estimation of T1 and T2 of Deep Radial and Calcified Layers in Human Patella from Ultra Short Echo Time (UTE) Imaging on a 3T clinical system.

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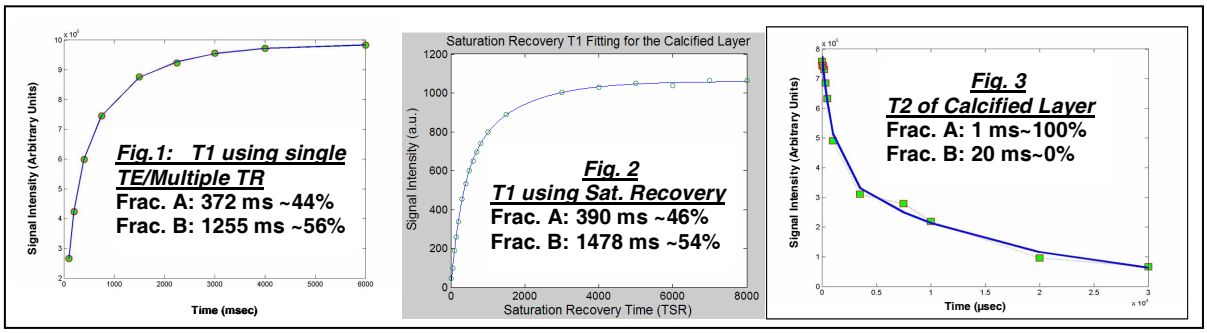
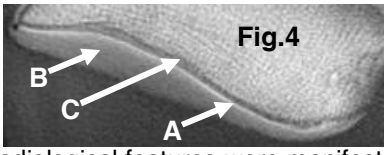
Objectives: While conventional MRI is the method of choice for diagnosis of cartilage injuries and osteoarthritis (OA), it is unable to detect signal from the deep radial and calcified layers, alterations of which probably play a critical role in the pathogenesis of OA. UTE imaging, using TEs of ~10us, allows visualization of these short T2 tissues. Our objective was to estimate the T1 and T2* of the deep radial and calcified layers of the human patella at 3T. These parameters are important prerequisites for optimizing the UTE imaging protocol for visualization of diseased cartilage.

Materials and Methods: T1 and T2* values were measured in 8 disarticulated cadaveric patella on a GE 3T Excite system, with a T/R switch allowing TEs as short as 12us using a 3" surface coil. 2D UTE sequences were implemented using a half excitation RF pulse with radial mapping of k-space from the center followed by another half excitation and repeated radial mapping with the polarity of the slice selection gradient reversed. The data from the two half excitations were added to produce a single radial line of k-space. The data generated by repeating this process through 360° in ~512 (or less) steps, were then mapped onto a 512-square grid and reconstructed by two-dimensional FT. Using this sequence, T1 was measured with two methods: (i) Keeping TE constant at 12us, images were acquired at multiple TRs of 100, 200, 400, 750, 1500, 2250, 3000, 4000, 6000 ms) (Fig.1). Other parameters were: FA=60°, BW=62.5kHz, Matrix prescribed: 512x511(actual data collected ~300x511), 2 Avg, 8 cm FOV, and 2mm slice thickness. (ii) Saturation recovery (SR) method using a UTE pulse sequence was developed with a 90° (rectangular) saturation pulse (BW=830Hz, Pulse width=600us), followed by crusher gradients. It rapidly became evident that for species with very short T2s, all signal intensity from the patellae need to be suppressed maximally, so that an accurate depiction of signal recovery is generated to accurately calculate T1 values. It was necessary to design an asymmetric SINC pulse with duration 600us and a sufficiently broad saturation bandwidth (2kHz), to optimally suppress signals from both fat and water. Other parameters were the same as (i) above, except for TR=3000ms and TSR=10, 50, 100, 150, 200, 250, 300, 400, 500, 600, 750, 1000, 1500, 2000, 2500, 3000, 4000, 5000, 6000, 8000 ms (Fig.2). For T2* measurements, a UTE sequence with a TR of 250ms and TEs of 12 µs, 50 µs, 100 µs, 200 µs, 350 µs, 500 µs, 1 ms, 3.5 ms, 7.5 ms, 10 ms, 20 ms, 30 ms, and 40 ms, with rest of the parameters the same as above, was used (Fig.3). Two-component curve fitting for the signal intensities versus the TR in (i), TSR in (ii), and TE for T2*, was performed using an in-house Matlab program. This allowed ROIs to be placed manually in the thin calcified layer and radial zone in one image, and measured the intensities within the same ROI in the rest of the images in the series.



Results and Discussion: The T1 values obtained from Method 1 (Fig. 1) closely approximated those obtained with the SR method (Fig.2) as shown only for the calcified layers above. Values of T1 and T2* thus determined for the calcified and radial layers are presented in the Table. For the calcified layer, the T2 value consistently showed a single component, with a value of ~1ms. T1 values consistently showed a short and a long T1 component. The radial component on the other hand showed a distribution of two components for both T2 and T1. Deriving an UTE imaging protocol from these estimated T1/T2* values, the following radiological features were manifest in the images of human cartilage: (1) the calcified zone (Fig.4 A) with a short T2 appeared as high signal on UTE images, and (2) the deep radial zone (Fig.4B) which does not have such a short T1 but has a short T2 (if not as short as that of the calcified layer) showed that there is a gradation of T2s from short (deep) to longer (more superficial) regions within the radial layer. (3) Compact subchondral bone (Fig.4C) can be identified as an adjacent hypointense layer between the hyperintense calcified layer and the trabecular bone which contains fatty marrow. Conventional clinical sequences are usually unable to distinguish between these three zones which are clearly demarcated by boundaries in the UTE images.

	T1 (ms)		T2 (ms)	
	Short	Long	Short	Long
Calcified	~380+/-25 (~44%)	~1300 (~55%)	1 (~80%)	~13(20%)
Radial	~220+/-40 (~15%)	1480+/-45 (~85%)	1.0 (~35%)	~45+/-6 (~65%)



Conclusion: Quantification of T1 and T2* in human cartilage in vivo is possible in a clinical setting and may be an important adjunct to radiologic features in clinical assessment of normal and diseased cartilage and subchondral bone.

References: (1) Gold GE, et al., AJR 2004; 183:343-35. (2) Gatehouse, PD *et al*., Clin. Rad. 2003; 58:1-19. (3) Brittain, JH, *et al*., Proc. ISMRM, 2004, P629. (4) Brossmann J, *et al*., Radiology 1997; 203:501-507