Experimental Investigation into the Relationship between T2* and T2 in Cartilages at 3T

Y. Qian[1], A. A. Williams[2], C. R. Chu[2], and F. E. Boada[1]
[1]Radiology, University of Pittsburgh, Pittsburgh, PA, United States, [2]Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, PA, United States

INTRODUCTION

Compared with T_2 relaxation time determined by internal Brownian motion of spins in tissue, T_2* time is affected by both internal events (Brownian motion of spins and local change of tissue microstructures) and external fields (main field B_0 and encoding gradients). An equation has been established to connect T_2* to T_2 by including field effects via a quantity T_2' (1): $1/T_2^* = 1/T_2 + 1/T_2'$. It is supposed that T_2* value approaches to T_2 value when the external effects are minimized. However, T_2* may not do so when the local field effect is much larger than the effect of Brownian motion. This is usually the case in osteoarthritis (OA) cartilages where collagen disorganization is expected to have much larger effect on local field than in normal cartilage. In this work we show that T_2* value is dominated by internal events in cartilage once external field effects are minimized. T_2* time is then an independent quantity and might be more sensitive to cartilage degeneration than T_2.

METHODS AND EXPERIMENTS

Methods As $1/T_2^* = 1/T_2 + \gamma\Delta B$ in a voxel with field inhomogeneity $\Delta B = \Delta B_{ex} + \Delta B_{in}$. It has been known that reducing voxel size (or increasing spatial resolution) will reduce the magnitude of total field inhomogeneity ΔB across the voxel and thus push T_2* value closer to T_2 if ΔB is dominated by the external field inhomogeneity, ΔB_{ex} (1). Otherwise, the ΔB is dominated by internal field inhomogeneity, ΔB_{in}. We implemented T_2 and T_2* mapping at different spatial resolutions to determine which inhomogeneity (ΔB_{ex} or ΔB_{in}) affects T_2* more. The T_2* mapping was implemented at two distinct resolutions: a low resolution of 0.71mm at matrix size 128 and a high resolution of 0.36mm at matrix size 256, while the T_2 mapping was implemented only at the low resolution. ***Experiments*** An tibial cartilage explant of human knee (asymptomatic adult) was scanned on a 3T MRI scanner (Magnetom Trio Tim, Siemens Medical Solutions, Erlangen, Germany) with an extremity coil. For T_2 mapping, multi-contrast spin echo sequence (se_mc) was used with 11-TEs (8.8-96.8ms), TR=3500ms, slice thickness = 1mm, resolution = 0.71mm, and BW=326 Hz/pix. For T_2* mapping, AWSOS sequence was used (2), with 13-TE acquisitions (0.3-70ms), TR=100ms, slice thickness =1mm, resolution= 0.71/0.36mm. ***Data Processing*** Mono-exponential fitting was employed for T_2 and T_2* mapping. For T_2* mapping two TE groups were used: one is normal TEs matching that for T_2 mapping but the other is UTE having all the 13-TEs. Alignment of the T_2* map to T_2 map was performed before comparing them at individual voxels.

RESULTS AND DISCUSSION

Results Fig. 1 shows the maps of T_2* and T_2 times, demonstrating visible distinction between them across the cartilage. Quantitative correlations between T_2* and T_2 at individual voxels are shown in Fig. 2. Increasing spatial resolution from 0.71mm to 0.36mm did not improve the correlation significantly: 10% at low resolution and 14% at high resolution for normal TE mapping (Fig. 2a-b), and 5.2% to 1.5% for UTE mapping (Fig. 2c-d). The ratio of the internal to external field inhomogeneity ($\Delta B_{in}/\Delta B_{ex}$) at an individual voxel was estimated as 41.6, showing that ΔB_{in} was much larger than ΔB_{ex}. [Details: $\gamma\Delta B = (1/T_2^* - 1/T_2) \approx (1/37ms - 1/58ms) = 9.8Hz$, across a voxel. The measured shim linewidth was <60Hz, leading to $\gamma\Delta B_{ex} < 60Hz$ across FOV, and thus $\gamma\Delta B_{ex} < 60/256 = 0.23Hz$ across a voxel. Consequently, $\Delta B_{in}/\Delta B_{ex} \approx (9.8-0.23)/0.23 = 41.6$]. ***Discussion*** The reason for low correlation between the T_2* and T_2 (Fig. 2a-b) might be microstructures in the cartilage that make local magnetic field inhomogeneous at any vozxel sizes and thus can not be reduced through increasing spatial resolution. Lower correlation of the UTE T_2* to T_2 (Fig. 2c-d) may reflect short-T_2* component of dominative impact on resultant T_2* values, leading to UTE-T_2* values more distinct from T_2 values. **In conclusion**, both the very low correlation between the T_2* and T_2 and the very large ratio of ΔB_{in} to ΔB_{ex} clearly showed that the T_2* value was an independent quantity relative to T_2 value in the cartilage explant studied. The UTE-based T_2* further enhanced this independency.

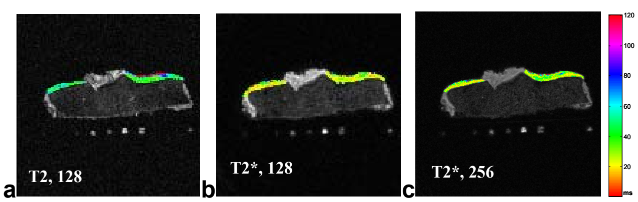

Fig. 1. T_2 (**a**) and T_2* (**b**) mapping at low resolution (res=0.71mm, matrix=128, mean T2*=36ms, mean T2 = 58ms) and high resolution (**c**) (res= 0.36mm, matrix=256, mean T2* = 37ms).

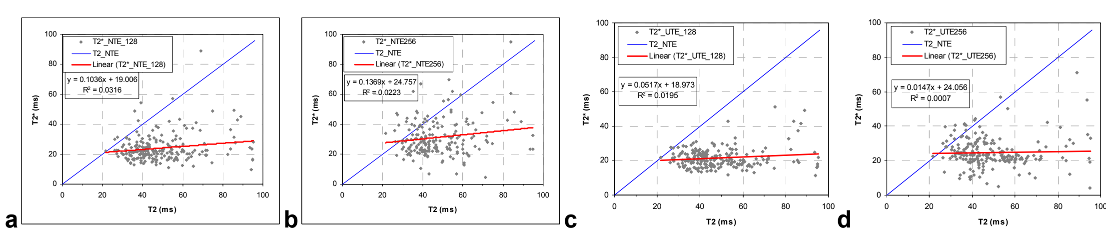

Fig. 2. Correlation between T_2* and T_2 at individual pixels at normal TEs (a, b) and UTEs (c, d) at low (a, c) and high (b, d) resolutions. The correlations are very low for both resolutions (10% at low resolution and 14% at high resolution, respectively). High resolution did not close much the gap between T_2* and T_2.

REFERENCES: [1] Haack EM, etc. 1999; 914 p. [2] Qian Y, etc. US patent 7,750,632. 2010.