Quantitative Imaging of Selective Relaxation Component in Cartilage

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Introduction: Osteoarthritis (OA) is a prevalent disease with symptoms of progressive degradation and loss of articular cartilage. There is great interest in using MR imaging methods for non-invasive early detection of OA. Among these methods, quantitative T1rho and T2 imaging are appealing due to the advantages of no contrast agent, no hardware modification, and convenient workflow. However, despite the evidence that T1rho and T2 are sensitive to changes of matrix composition in cartilage, their specificity to particular matrix component is yet inconclusive. Recently multi-exponential relaxation analysis was reported to have improved specificity of matrix assessment in cartilage (1). However, quantification of more than one component of T1rho or T2 significantly increases scan time and is impractical in the clinical setting. In this work, we investigate mono-exponential relaxation methods to quantify relaxation property of a single relaxation component by suppressing signal from other components. Such methods are feasible in terms of clinical scan time, and have potential to achieve improved specificity to matrix component in cartilage compared to conventional mono-exponential relaxation analysis.

Theory and Methods: Cartilage matrix may consist of components with ultrashort, intermediate, and long T2. The signal from tissue with ultrashort T2 decays away in common T2 quantification methods and will not interfere with T2 or T1rho quantification of the other two components. To quantify long T2 component without excessive data collection for bi-exponential relaxation analysis, we can simply increase the length of magnetization prep to let signal from intermediate T2 component decay away. For quantification of only intermediate T2 component, we proposed two approaches to suppress signal from long T2 component as illustrated in Figure 1. The first approach – subtraction approach (Fig 1A) is to acquire an additional data set with relative long magnetization prep and subtract it from the other data sets with relatively short magnetization prep, and then fit the data to a mono-relaxation model. In the second approach – RF prep approach (Fig 1B), a T2-prep is inserted during T1 relaxation time. The long T2 component experiences both 90 degree RF pulses, and therefore is inverted after T2 prep, whereas the intermediate T2 component only experiences 90 degree RF flip. We then start magnetization prep at the T1 nulling time of long T2 component. This method has been previously proposed by Wong et al (2) to improve SNR in FLAIR imaging. Note the proposed long T2 suppression is different to those used in UTE imaging. The intermediate T2 component usually has T2 from 5 to 20 ms, which is much longer than those investigated in UTE filed (< 1ms). Therefore, the long T2 suppression used in UTE is inapplicable here.

Figure 1: The proposed methods to suppress long T2: a) Approach 1- the subtraction approach, and b) Approach 2 - the RF prep approach

Both phantom and in vivo knee data sets were collected from a Discovery MR750 3T scanner (GE Healthcare, Waukesha, WI) using a transmit-receive 8-channel knee coil (Invivo Inc., Gainesville, FL). Informed consent was obtained for in vivo scans. The phantom data sets were collected using a magnetization prepped 2D spiral sequence (3). For in vivo scan, 3D MAPSS (4) was used for test of the subtraction approach with 5 TEs for T2 prep (0, 6.8, 13.7, 20.5, 4 1ms). The 5th T2 prep was then subtracted from the other four TEs before applying fitting. For comparison, we also collected eight TEs of T2 prep in the same exam (TE = 0, 6.8, 13.7, 20.5, 27.3, 41, 54.7, 68.4m s) and use this data for bi-exponential analysis. For the RF prep approach, the magnetization prepped 2D spiral sequence (3) was used to collect four TEs (TE = 0, 6.8, 13.7, 27.3ms) of T2 prep. We also collected eight TEs in the same scan without any long T2 suppression for comparison (TE = 0, 6.8, 13.7, 27.3, 41, 54.7, 68.4, 82 ms).

Figure 2: a) The proposed approach 2 suppressed long T2 (~50ms), and b) Both phantoms can be seen when long T2 suppression RF pulses were turned off.

Results: Figure 2 demonstrate that the RF prep approach can suppress long T2 (shown here T2~50ms) meanwhile preserving signal from relative short T2 (shown here T2~25ms). Figure 3 compared T2 quantification on cartilage using three different methods: the subtraction approach, conventional mono-exponential analysis, and short T2 component from bi-exponential analysis. Note the result from the subtraction approach is much closer to the short T2 component measurement from bi-exponential fitting compared to the result from conventional mono-exponential fitting.

Figure 3: T2 map of cartilage from: a)Mono-exponential fitting using 4 TEs. b) Proposed Approach 1 c) Short T2 component from bi-exponential fitting using 8 TEs.

Figure 4 compared an in vivo scan using the RF prep approach and conventional mono-exponential analysis. To check whether the short TEs of T2 prep used in the RF prep approach can cause lower T2 quantification, we also measured the T2 using the same four TEs but without long T2 suppression RF pulse. Note despite the impact on quantification from choice of TEs, the impact on quantification from long T2 suppression is obvious (blue arrows). Note the blood vessels were suppressed in Fig 4a) due to long T2 suppression (red arrows). The RF prep approach also created image contrast different to the contrast from conventional T2-prep.

Figure 4: T2 map of cartilage from: a) the proposed approach 2, b) conventional mono-exponential T2 mapping using 8 TEs, and c) conventional mono-exponential T2 mapping using 4 TEs same as those used in a)

Discussion: The long T2 suppression RF pulses proposed in the RF prep approach can decrease SNR. Care should be used when performing quantification at low SNR. For the subtraction approach, the fitting model we use is an approximation rather than an accurate model. Therefore, the quantification result from the subtraction approach is only an approximation to the actual T2 relaxation. One limitation of the RF prep approach is that we used an estimate of T1 to calculate T1 nulling time when acquiring the results shown in Figure 4. A more accurate T1 value of the long T2 component in cartilage can improve its signal suppression. The RF prep approach does provide image contrast different to conventional methods. The anatomy image with this contrast might have useful diagnostic information. We only show T2 results here. Same methods can be applied to T1rho quantification with potential improvement on its specificity to cartilage matrix component.

Wang et al (5) recently reported that the existence of multi-component T2/T1rho relaxation relates to magic angle effect. By quantification of single selected T2/T1rho component, the proposed methods might have potential to reduce the dependency of T1rho or T2 value on subject orientation, and therefore, reduce magic angle effect.

Conclusion: We proposed methods for selective T2 component analysis in cartilage. The scan time of these methods are clinically feasible. The proposed methods have potential to provide T1rho and T2 quantification with improved specificity to cartilage matrix component compared to the conventional methods.

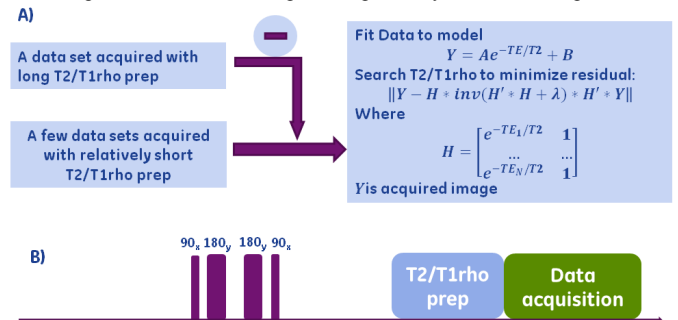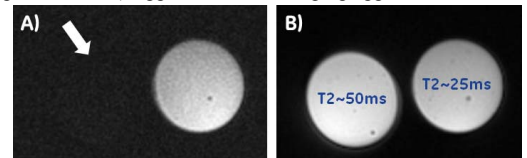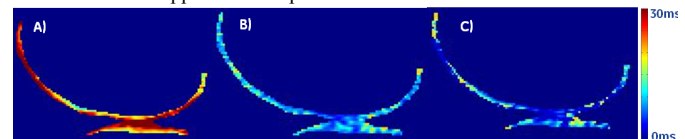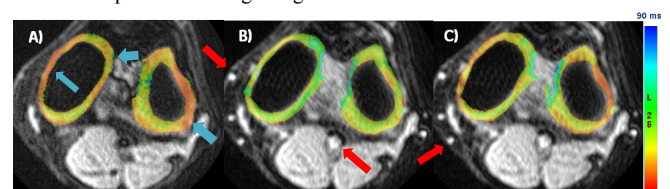**Reference:** 1. Reiter et al, MRM 2011, p377 2. Wone et al, MRM 2001, p529 3. Li et al, MRM 2005 p929 4. Li et al, MRM 2008 p298 5. Wang et al, JMR 2011 p124