3D Quantitative Imaging of T1rho and T2

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Introduction: T1rho and T2 mapping have potential to provide complementary information for a number of clinical applications, such as musculoskeletal imaging for evaluating cartilage degeneration. 3D acquisition is usually desired for these applications due to the geometry of anatomy. However, the existing 3D T1rho/T2 mapping techniques have not fully addressed the following two problems: 1. relatively long scan time (1, 2), and 2. reliance of prior assumption of tissue properties for T1rho/T2 quantification (3). In our previous work (4), we showed that a pseudo steady state (PSS) 3D FSE acquisition approach (5, 6) has potential to address these problems in 3D T1rho mapping. In this work, we extend the previous technique to include both T2 and T1rho mapping, and investigated the quantification accuracy and SNR efficiency of the proposed approach on phantoms and in vivo studies.

Theory and Methods: The pulse sequence starts with a magnetization-reset module (2) followed by a certain relaxation period for signal recovery. Magnetization preparation is then played out to impart T1rho or T2 contrast, followed by a PSS 3D FSE acquisition (6). The sequence collects data sets with different amount of T1rho or T2 weighting, and the parameter map is estimated by fitting the data to a mono-exponential model. To address B1 inhomogeneity, the rotary echo approach (7) is used in T1rho RF prep and the composite 180 degree RF pulse (8) is used in T2 RF prep.

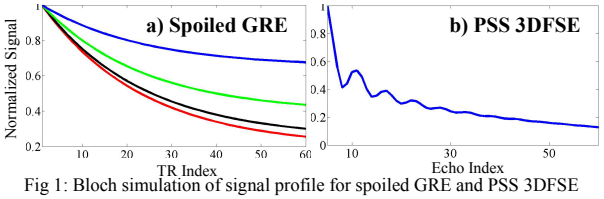

Fig 1: Bloch simulation of signal profile for spoiled GRE and PSS 3DFSE with four different initial magnetization. The signal was normalized by the initial magnetization.

A major challenge to fast 3D T1rho/T2 mapping is that T1 relaxation during data acquisition confounds mono-exponential T1rho/T2 fitting. Fig. 1 compared the Bloch simulation of the signal evolution profile (normalized by the initial magnetization) for spoiled GRE acquisition and the PSS 3D FSE acquisition. Note that the T1 relaxation effect causes the signal profile to be dependent on initial magnetization in spoiled GRE acquisition. Therefore, a prior knowledge of T1 is needed for accurate quantification of tissue properties (1). A phase cycling approach (2) has proved effective in addressing this problem, but requires 2 signal averages. The PSS 3D FSE approach employs flip angle modulation to achieve long echo train with only minimum blurring induced by T2 relaxation (5, 6). Even though refocusing pulses less than 180° are used, when the CPMG condition is met and the crusher gradient is sufficient, T1 recovery during the echo train is eliminated (Fig. 1b). Consequently, the point spread function for acquisitions with different amount of T1rho/T2 prep are identical and the relative image intensity between these acquisitions depends only on T1rho or T2 exponential decay during magnetization preparation.

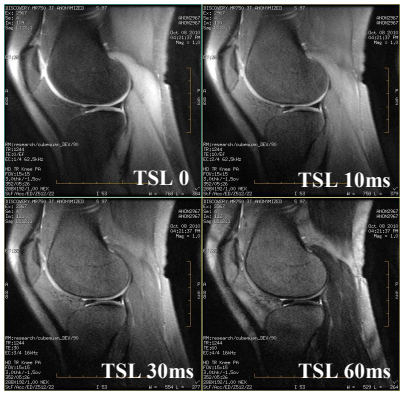

Fig 2: Source images from 3D T1rho mapping using the proposed approach.

Results and Discussion: Figure 2-5 show examples of in vivo 3D T1rho and T2 mapping using the proposed approach. The 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). The imaging parameters include: TR/TE 1240/17.4ms, NEX 1, BW±62.5kHz, FOV 15x15cm, matrix 288x192, 44 slices, slice thickness 3mm, echo train length (ETL) 35, spin-lock frequency 500Hz (T1rho), and refocusing interval 4ms (T2). ARC, a data-driven parallel imaging approach (GE Healthcare), was applied along both phase encoding and slice directions with net acceleration 2.93. The total acquisition time was 5:20 for either T1rho or T2. In contrast, MAPS (2), a relatively SNR efficient 3D T1rho/T2 mapping approach among the existing methods, requires 9min for acquisition with same resolution and FOV with similar acceleration and SNR. The proposed method provides an efficient approach to study the complementary role of T1rho and T2. Figure 6 shows the scatterplot of T1rho and T2 value on cartilage from this example. A strong cross-correlation between T1rho and T2 on cartilage was observed in this case.

We validated the accuracy of the proposed approach by comparing the T2 value measured from T2 phantoms using the proposed approach, MAPS (2), and a product multi-slice 2D T2 mapping method (GE Healthcare), as shown in Fig. 7. The data sets were collected from the same scanner using same imaging parameters as used in the in-vivo scanning with matrix 320x256. The measured T2 values agree with each other among three approaches.

Further investigation of the proposed approach includes utilizing longer ETL to further increase its SNR efficiency without introducing other artifacts in 3D FSE acquisition on T1rho/T2 quantification, and performing additional clinical testing.

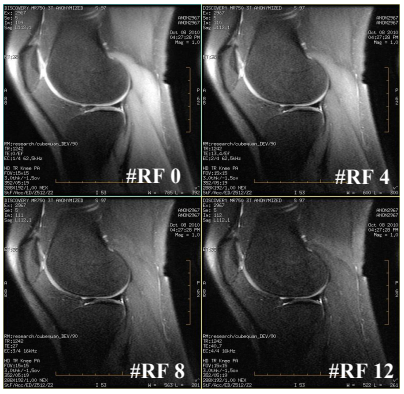

Fig 3: Source images from 3D T2 mapping using the proposed approach.

Conclusion: We developed a highly SNR efficient and robust 3D T1rho/T2 mapping method based on a pseudo steady state 3D FSE acquisition and demonstrated its accuracy in phantom and in vivo scans. This method can be useful for providing 3D T1rho and T2 measurements for quantitative assessment of disease in clinically practical scan times.

Reference: 1. Borthakur et al, JMRI 2003, p730 2. Li et al, MRM 2008 p298 3. Witschey et al, JMRI 2008 p744 4. Chen et al, ISMRM 2010, p3166 5. Busse et al, MRM 2006 p1030 6. Busse et al, MRM 2008 p640 7. Charagundla et al, JMR 2003, p113 8. Levitt et al, JMR 1981, p6

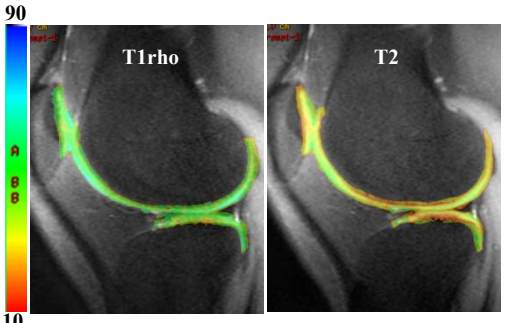

Fig 4: T1rho and T2 map acquired using the proposed approach

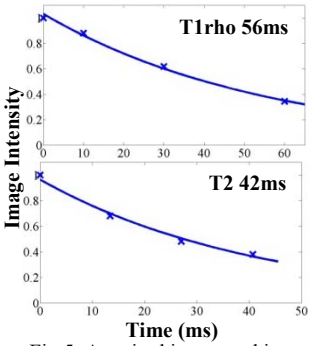

Fig 5: Acquired image and its fitting to a mono-exponential model at a pixel on cartilage.

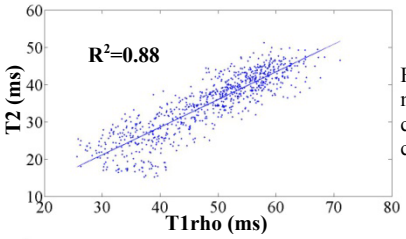

Fig 6: Scatter plot between measured T1rho and T2 on cartilage shows strong correlation between them.

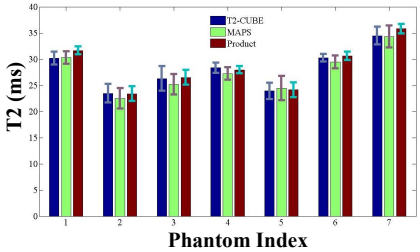

Fig 7: T2 values measured from seven T2 phantom tubes using three different approaches show agreement with each other.