Joint anatomical and biochemical imaging using 3D FSE

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Introduction: Intermediate- or T2-weighted FSE sequences are commonly used in clinical MRI for detection of joint abnormalities such as meniscus tears (1, 2), ligamentous injury (3), or cartilage damage (4, 5). Current standard MRI is used for diagnosis of anatomy change only. T1rho and T2 mapping have been reported to have potential for early detection of biochemical symptoms of osteoarthritis. Recently, a new technique based on 3D fast spin echo acquisition has been reported as a highly efficient approach for 3D T1rho or T2 mapping (6). In this abstract, we investigated the feasibility of applying this technique for high resolution joint biochemical and intermediate- or T2-weighted 3DFSE anatomy imaging with clinically reasonable scan time.

Methods and Results: The pulse sequence is based on the technique reported in (6). Source images are acquired with different amount of T1rho or T2 weighting and a 3D T1rho or T2 map is calculated using a mono-exponential relaxation model from the source images. We linearly combine the source images to create intermediate- or T2-weighted images with high SNR as the diagnostic anatomy image. T1rho or T2 map is naturally fully registered with the anatomy image since they are acquired with one acquisition. The noise at low SNR regions can introduce bias to T1rho/T2 quantification. This bias is more likely to appear in acquisitions with high spatial resolution due to SNR decrease. To increase the robustness of T1rho/T2 quantification in our applications, we apply a wavelet denoising technique using Stein's Unbiased Risk Estimate (SURE) (7) which has the potential to increase SNR without image blurring before T1rho/T2 calculation.
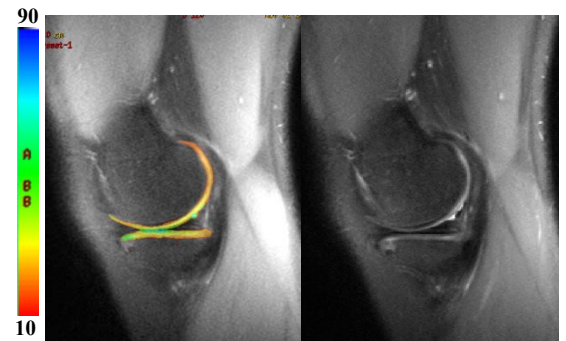

Figure 1: Joint T2-weighted 3D FSE anatomy imaging and 3D T2 mapping in one acquisition. 15x15cm FOV with 320x256 matrix. Full knee coverage with 3mm thickness. Total scan time: 5:30 min.

The in vivo 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: fat sat, TR/TE 1316/17.4ms, NEX 1, BW±62.5kHz, FOV 15x15cm, matrix 320x256, 44 slices, slice thickness 3mm, echo train length (ETL) 45, 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 direction with net acceleration 3.14. The total acquisition time was 5:30min for either T1rho or T2. Figure 1 shows the reconstructed T2-weighted knee anatomy image and the T2 map. Four source images were acquired with T2-prep duration 0, 16, 32, and 48ms, respectively. The anatomy image was reconstructed by summing the four source images. Note high SNR and good fluid-cartilage contrast in the anatomy image. Figure 2 shows the reconstructed T1rho-weighted anatomy image and the T1rho map. Four source images with time-of-spinlock (TSL) 0, 10, 30, 60ms were acquired, respectively, for this example.

Estimation of relaxation parameters by least-square fitting to a mono-exponential model is prone to overestimate T2 at low SNR regions (8). Figure 3 shows the results with and without wavelet denosing (7) applied to the source images. T2 map estimated without denosing applied to source images has relatively higher value at regions with low actual T2 value, which likely is overestimation due to low SNR at these regions.
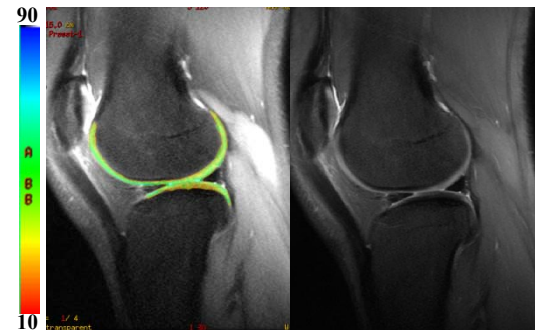

Figure 2: T1rho-weighted 3D anatomy image and 3D T1rho mapping in one acquisition. 15x15cm FOV with 320x256 matrix. Full knee coverage with 3mm thickness. Total scan time: 5:30 min.

Discussion and Conclusion: The high efficiency of the sequence under investigation in this work enables this approach for high resolution 3D biochemical imaging. Since this approach is based on 3DFSE acquisition, the source images can be utilized to provide T2-weighted anatomy images without additional imaging time. To increase robustness of this approach for T1rho/T2 quantification at low SNR area, we combined this method with wavelet denoising of source images before relaxation parameter quantification. The scanning efficiency of the proposed approach, however, still has room to improve by increasing the echo train length in the employed 3DFSE approach, although this must be balanced against image blurring. The image blurring induced by T2 relaxation during long echo train can be addressed by advanced flip angle modulation. In summary, 3D T1rho/T2 mapping based on 3D FSE acquisition is a promising approach for joint high resolution biochemical imaging and T2-weighted anatomy imaging with clinical reasonable scan time.
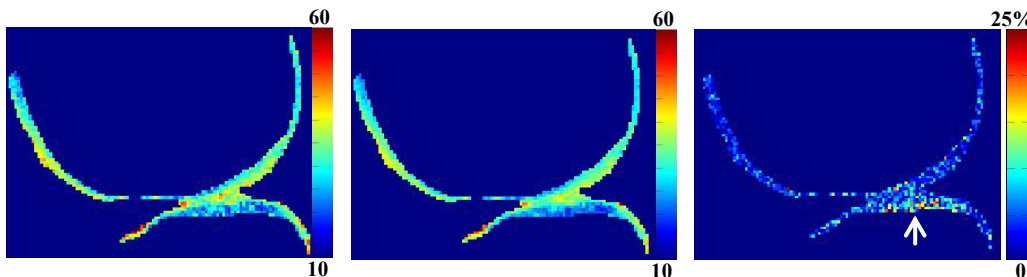

Figure 3: T2 mapping of cartilage a) original, b) after denosing on source images acquired using the proposed approach, and c) the absolute percentage change between a) and b). Note larger percentage change at regions with low T2 value due to lower SNR at these areas. The average absolute percentage within an ROI around this area (white arrow) is about 8.6%.

Reference: 1. Escobedo et al, AJR 1996, p1223 2. Jee et al, AJR 2003, p93 3. Schaefer et al, Eur J Radiol 2006, p 411 4. Sonin et al, AJR 2002, p1159 5. Bredella et al, AJR 1999, p1073 6. Chen et al, ISMRM 2010, p3166 7. Donoho et al, J. Amer. Statstical Assoc, 1995, p1200 8. Raya et al, MRM 2010, p181