Reduced Magic Angle Effects Using Ultrashort Echo Time Magnetization Transfer (UTE-MT) for Quantification of Human Rotator Cuff Tendon

Eric Y Chang[1], Jiang Du[2], Reni Biswas[2], Betty Tran[2], Sheronda Statum[2], Won C Bae[2], and Christine B Chung[1]

[1]*Radiology Service, VA San Diego Healthcare System, San Diego, CA, United States,* [2]*Department of Radiology, University of California, San Diego Medical Center, San Diego, CA, United States*

Introduction: Similar to other tendons, the "magic angle effect" in rotator cuff tendon (RCT) can cause remarkably large orientation-dependent changes in MRI signal intensity[1,2]. The magnitude of change may exceed the amount of change that is produced by disease states. For tendons such as the Achilles, which have a more constant orientation in clinical imaging, this may be less problematic with regards to quantitative MRI[3]. However, RCT course is varied and always courses through the magic angle. In porcine menisci, magnetization transfer (MT) ratio has been suggested to be less sensitive than T2 to magic angle effects[4]. Recently, ultrashort TE (UTE) has been combined with magnetization transfer to study the tissues with rapid transverse decay, such as tendon[5]. The purpose of this study is to quantify human RCT using T2, T2*, and MT techniques and compare orientation-dependent value changes.

Methods: *Samples*: 7 cadaveric rotator cuff tendons (3 supraspinatus and 4 infraspinatus tendons) from 4 donors (84.5 ± 10.8 years, mean age ± standard deviation; 2 females, 2 males) were used for this study. Tendons were dissected free from surrounding tissues with maintenance of osseous attachments. *Imaging*: A 3T clinical scanner (Signa HDx, GE Healthcare, Milwaukee, WI) was used with imaging protocol which included the following three sequences for T2, T2*, and off-resonance saturation ratio (OSR) quantification, respectively: 1) 2D-CPMG (TR=2000 ms, TE=15, 30, 40, 50, 70, 80, 90, 100 ms, FOV=8 cm, matrix=320x256, slice thickness=3 mm), 2) 4 sets of 4-echo 3D-UTE-Cones (TR=48ms, TE=0.03/4.9/14/24, 0.4/6/16/26, 0.8/8/18/28, 1.6/10/20/40 ms, FOV=8 cm, matrix=256x256, slice thickness=3 mm), and 3) 3D-UTE-Cones-MT (TR=50, TE=30 µs, FOV=8 cm, matrix=256x256, slick thickness=3 mm, Fermi pulse duration=8 ms, pulse power=670°, frequency offset=1.5 kHz). Coronal images were obtained and tendons were imaged in a clinically-anatomic position (humeral shaft parallel to B_0) and again after 90° counterclockwise rotation (humeral shaft orthogonal to B_0). *Data Processing*: Manual regions of interests (ROIs) were carefully placed within each tendon near the enthesis, ~1 cm from the enthesis (critical zone of Codman), and ~1.5-2 cm from the enthesis (tensile portion) by a musculoskeletal radiologist using a combination of osseous landmarks and electronic calipers. An in-house MATLAB code was used to calculate mono-exponential T2 and T2*. Off-resonance saturation ratio (OSR) was calculated as $(S_0-S_{SAT})/S_0$, where S_0 denotes mean signal intensity without a saturation pulse and S_{SAT} denotes mean signal intensity after saturation pulse. At each anatomic location, the percent of change was calculated by subtracting the quantitative MR measures of the anatomic and 90° rotation positions, dividing by the measure in the anatomic position, multiplying by 100, and using the absolute value. Additionally, pixel maps were created.

Results: T2 mean percent change was 38, 25, and 36% at the enthesis, critical zone of Codman, and tensile portions, respectively. T2* mean percent change was 37, 92, and 40% at the enthesis, critical zone of Codman, and tensile portions, respectively. OSR mean percent change was 12, 12, and 15% at the enthesis, critical zone of Codman, and tensile portions, respectively. Pixel maps visually confirmed the dramatic differences in change for T2 and T2* values compared with OSR (**Figure 1**).

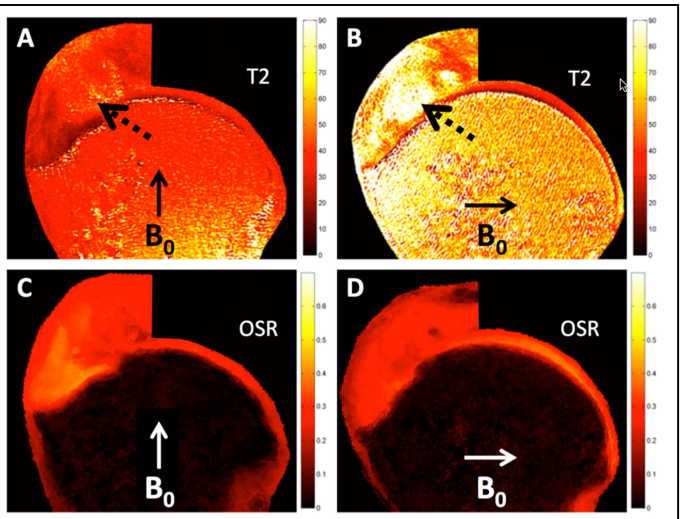

Figure 1. T2 and OSR maps from representative sample. With a 90° orientation difference, the T2 map with 0-90 ms scale (A and B) shows dramatic difference relative to OSR map (0-0.7 unit scale). Critical zone of Codman indicated with dashed arrow.

Conclusion: OSR measured with the UTE-MT technique may be more useful than T2 and T2* due to the strong dipolar-dipolar influence on the latter two biomarkers.

References: **[1]** Krasnosselskaia LV et al. Magn Reson Med. 2005;54(2):280-8. **[2]** Chang EY et al. AJR. 2014;202:W376–W378. **[3]** Juras V et al. Eur Radiol. 2013;23(10):2814-22. **[4]** Hopfgarten C et al. Proc. Intl. Soc. Mag. Reson. Med. 2012(20):1397. **[5]** Grosse U et al. Magn Reson Med. 2013;70(1):184-92.