INTERVERTEBRAL DISC CEST IMAGING WITH IMPROVED RELIABILITY USING REDUCED-FOV TSE

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Introduction:

Low back pain (LBP) is a disease with wide prevalence and significant burden, and is closely associated with degeneration of the intervertebral disc (IVD). Various MRI methods have been used to study IVD degeneration [1-2] , yet these methods either fail to provide objective quantitative measurement, or provide little insight into changes in biochemical composition. Loss of glycosaminoglycan (GAG) is regarded as an early sign of degeneratoin, and has recently been assessed in vivo by chemical exchange saturation transfer (gagCEST) using a turbo-spin-echo (TSE) based sequence [3]. However this method suffers from severe bowel movement artifacts that limit its accuracy and clinical applicability. In this study, a reduced-field-of-view (rFOV) TSE method is used to measure IVD gagCEST signal in vivo by reducing bowel movement artifacts on a 3.0T clinical scanner. The proposed method is verified by a phantom study, and is compared with the conventional full-FOV CEST technique on nine volunteers.

Methods:

Pulse Sequence & Imaging: A rFOV TSE CEST sequence (Fig. 1) is impletmented on a 3.0T system (Verio, Siemens) by applying the gradients for the 180° refocusing pulses in the phase-encoding direction. Using this rFOV technique and centric-encoding, all k-space lines were acquired within a single excitation, minimizing artifacts from bowel movement. CEST-preparation was achieved by using a train of 8 Gaussian pulses and a 50% duty cycle (transimited by a body coil), with each pulse lasting 90ms and having a flip angle of 1440°. 31 images with saturation offsets evenly distributed between -4.5ppm and +4.5ppm, and one image without saturation (S_0) were acquired. WASSR method was used to correct for B_0 inhomogeneity []: 11 images with offsets evenly distributed between -1.0ppm and +1.0ppm were acquired; saturation was achieved by two 40°, 30-ms Gaussian pulses.

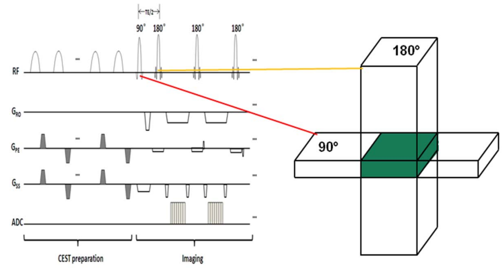

Fig 1. Pulse sequence. Shaded zone indicates regions being imaged.

Phantom studies: To verify the ability of the proposed method in differentiating GAG concentrations, four samples with GAG concentrations of 50, 100, 150, and 300mM were prepared from chondroitin sulphate A (Aldrich-Sigma, St Louis) in a standard solution of phosphate-buffered saline and subsequently titrated to a pH of 7.0. Volunteer studies: Nine healthy volunteers (3 female, 6 male; mean age 39.1±11.9) were recruited. The study was approved by our Institutional Review Board and informed consent was obtained from all volunteers. For each volunteer one L3/L4 transverse IVD slice were acquired, with the same image position and slice thickness of 3mm for both full and rFOV CEST imaging. For rFOV, TE/TR=8.9/2500ms, ETL=32, bandwidth=300Hz/pixel, 32 phase-encoding lines were acquired, in-plane resolution=1.8×1.8mm^2. For full FOV technique, 128 phase-encoding lines were acquired with total acquisition time of 310s and the FOV was 4 times that of the rFOV method; other parameters were the same as rFOV CEST. Each imaging method was repeated twice. Data analysis: All images were first normalized by S_0 and B_0-corrected by WASSR pixel by pixel, and only data between -4.2ppm and +4.2ppm were kept. One ROI containing nucleus pulposus was drawn in the center of the IVD and MTR_{asym} were calculated and averaged for further analysis. When there is random bowel movement, bowel movement will lead to signal difference between repeated acquisitions. Thus the *Sum of Absolute Difference(SAD)* over all MTR_{asym} data points between the two repetitions for each method were used to quantify image artifacts due to bowel movement. Higher SAD means more bowel movement. Paired-t test at α=0.05 was used to test SAD differences.

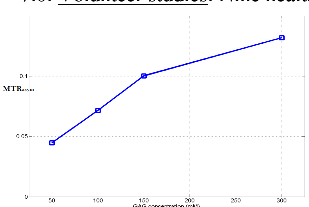

Fig 2. Relationship between MTR_{asym} and GAG concentration.

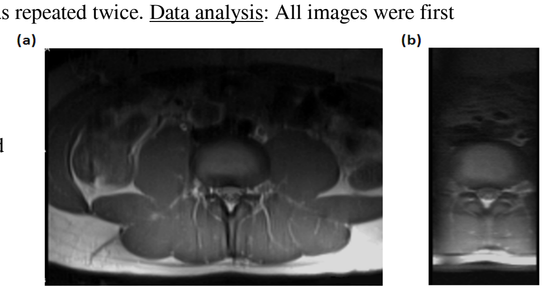

Fig 3. Typical full-FOV (a) and rFOV CEST (b) image.

Results:

Phantom study (Fig. 2) demonstrated that rFOV CEST signal has a linear relationship with GAG concentration up to 150mM, well above physiological concentration. The nonlinearity at 300mM can be explained by decreased T1. This relationship indicates rFOV CEST might be used as a biomarker for GAG concentration and IVD degeneration. Typical conventional full-FOV and rFOV CEST volunteer IVD images are shown in Fig. 3. Close inspection can identify bowel movement artifacts in the full-FOV image but not in the rFOV image. A typical mean MTR_{asym} curve and Absolute Difference MTR_{asym} curve is shown in Fig 4a&b. With only nine volunteers, compared with full-FOV technique, rFOV CEST showed (Fig 5) significantly decreased SAD (0.14 vs. 0.45, p=0.002<0.05), implying it is a more reliable and accurate gagCEST technique. The average MTR_{asym} difference for a single frequency-offset was 0.94% and 3.01% for rFOV and full-FOV, respectively.

Volunteer#	Sum of Absolute Difference Over All Points	
	Conventional TSE	rFOV TSE
1	0.484644	0.156927
2	0.170286	0.134029
3	0.976823	0.293104
4	0.735659	0.134777
5	0.337325	0.088691
6	0.289394	0.067653
7	0.288192	0.095172
8	0.319542	0.210327
9	0.470296	0.082312
Mean ± Std	0.4525 ± 0.2551	0.1403 ± 0.0724

P=0.002<0.05

Fig 5. Comparison of SAD between full-FOV and rFOV CEST results for 9 volunteers.

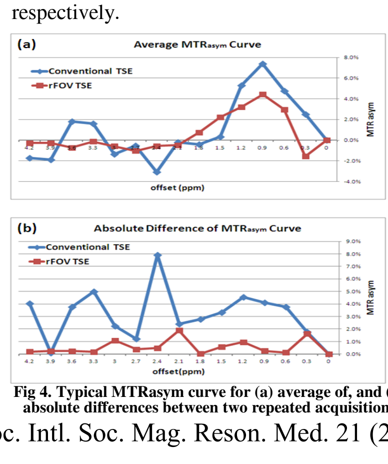

Fig 4. Typical MTRasym curve for (a) average of, and (b) absolute differences between two repeated acquisitions

Discussion and Conclusions:

We have demonstrated a method for reliable gagCEST measurement *in vivo* by minimizing bowel movement artifacts. With the propose method, a variation of less than 1% in MTR_{asym} can be achieved, which opens doors for 1) accurate IVD degeneration quantification in a clinical setting and 2) measuring smaller CEST signals in IVD such as those from –NH protons which are sensitive to pH.

References: [1] J Bone Joint Surg Am (2001); 83-A(9):1306-11. [2] J Bone Joint Surg Br (1992); 74(3):431-5. [3] NMR Biomed. 2011 Nov;24(9):1137-44. [4] Magn Reson Med. 2009 Jun;61(6):1441-50.