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

Qi Liu1,2, Ning Jin1, Zhayao Fang1, Yutaka Natsuaki1, Wafa Tawackoli1, Dan Gazit1, Gadi Pelled1, and Debiao Li1,3

1Biomedical Imaging Research Institute, Cedars-Sinai Medical Center, Los Angeles, CA, United States, 2Biomedical Engineering, Northwestern University, Chicago, IL, United States, 3Siemens Medical Solutions, Columbus, OH, United States, 4Siemens Healthcare, Los Angeles, CA, United States, 5University of California, Los Angeles, Los Angeles, California, United States

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 implemented 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 (transmitted 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 (S0) were acquired. WASSR method was used to correct for B0 inhomogeneity [1]; 11 images with offsets evenly distributed between -1.0ppm and +1.0ppm were acquired; saturation was achieved by two 40°, 30-ms Gaussian pulses. 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=1.8x1.8mm2. For full FOV, 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 S0 and B0-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 MTRsyst were calculated and averaged for further analysis. Thus the Sum of Absolute Difference (SAD) over all MTRsyst 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.

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 up to 150mM, well above physiological concentration. The nonlinearity at 300mM 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.


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 MTRsyst 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.

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

Fig. 2. Relationship between MTRsyst and GAG concentration.

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