Objective: Low back pain (LBP) is a leading debilitating disease and disc degeneration is a strong etiological factors associated with LBP. The intervertebral disc (IVD) has been well acknowledged to degenerate as characterized by biochemical and morphological changes [1,2] and MRI has been commonly used to detect IVD degeneration. T2 relaxation time has been suggested to be sensitive to changes in collagen and water content in cartilage [3] and in the IVD [4]. Studies have also demonstrated that T2 decreases with disc degeneration [5,6]. Recent studies have proposed that chemical exchange saturation transfer (CEST) can be specific for glycosaminoglycans (GAGs) content (gagCEST) [7]. Investigators have quantified CEST in cartilage [7] as well as in IVD specimens in vitro [8] and have demonstrated a relationship between CEST and GAGs content [7]. However, the correlation between conventional MRI assessment and quantitative MRI measurement, such as T2 and CEST, has not been widely studied. In this study, we aimed to investigate the association between CEST, T2 and degenerative grades in IVD using in vivo MRI at 3 Tesla (3T).

Materials and Methods: After informed written consent was obtained, 21 subjects (8 females, 13 males; median age = 34; age range = 24-58 years) who did not have any previous spine surgery were recruited. All images were acquired using a 3T Achieva scanner (Philips Healthcare, Best, The Netherlands) equipped with 40 mT/m gradients. RF was transmitted using the body coil and sensitivity encoding (SENSE) reception with the 12-element spine coil for human lumbar IVDSs was employed. The second order shims were optimized to minimize B0 field inhomogeneity. Imaging volume and geometry were uniform for all scans (T2, CEST and saturation shift referencing (WASSR)): single-slice axial images were acquired at three levels of lumbar spine (L3/4, L4/5 and L5/S1) with: field of view (FOV) = 180 x 350 mm2, nominal resolution = 1.96 x 2.67 mm2, reconstructed pixel size = 1.22 x 1.22 mm2, slice thickness = 8 mm. Single-slice axial T2 images were obtained using a turbo spin echo sequence (TSE factor = 5) with: TR = 1000 ms, TE1:TE2:TE3 = 30-150 ms (30 ms interval), number of averages = 2, total scan time = 2 min. 22 sec. Single-slice axial CEST and WASSR images were obtained using TSE sequence (TSE factor = 34) with: TR = 2000 ms, TE = 6 ms, number of averages = 1, total scan time = 2 min. 26 sec. for each scan. The saturation spectral parameters for CEST and WASSR were chosen as described in Kim et al. [9]. For data analysis, a custom-written program in Matlab (Mathworks, Natick, MA, USA) was used. For each voxel, CEST curves were shifted using the frequency shift from the WASSR map [10]. The magnitude of the CEST effect was quantified as CESTsym = \( S(-\text{freq})/S_0 - S(\text{freq})/S_0 \) where S and S0 are the saturated and non-saturated intensities. CEST signal was integrated from 0.5 to 1.5 ppm, where the hydroxyl (OH) groups resonate. Additionally, multi-slice sagittal T2-weighted (T2w) images were obtained with: FOV = 201 x 178 mm2, nominal resolution = 0.81 x 1.00 mm2, reconstructed pixel size = 0.52 x 0.52 mm2, slice thickness = 10 mm. TR = 2500-3200 ms, TE = 90 ms, number of averages = 2, total scan time = 1 min. 15 sec. Using T2w, lumbar discs were graded by two spine specialists in consensus according to Schneiderman’s classification (score range: 0 to 3) [11].

Results: Figures shows that trend of decreasing CESTsym and T2 values with increasing grade of degeneration were evident. The mean CESTsym values in L3/4, L4/5 and L5/S1 discs with Schneiderman grades 0 (n = 41), 1 (n = 10), 2 (n = 7) and 3 (n = 5) were 7.17 ± 1.10 %, 6.00 ± 0.83 %, 2.85 ± 0.39 % and 1.84 ± 0.27 %, respectively. The mean T2 values in discs with Schneiderman grades 0 (n = 41), 1 (n = 10), 2 (n = 7) and 3 (n = 5) were 109.74 ± 12.40 ms, 83.84 ± 6.19 ms, 71.70 ± 3.44 ms and 65.16 ± 2.97 ms, respectively. Spearman’s rho correlations demonstrated that Schneiderman grade was correlated with both CESTsym (r = -0.67, p < 0.001) and T2 (r = -0.71, p < 0.001) (table). The correlation between CEST and T2 values was r = 0.73 (p < 0.01).

Conclusion: Our results showed that CEST and T2 decreases with increasing grade of disc degeneration and that CEST values significantly correlated with T2. Based on our findings in this study, further investigation using cadaver samples may shed light on a better understanding of underlying pathophysiological mechanism in the degenerative human lumbar IVDSs, providing potentially a useful tool to diagnose early degenerative disc disease.