Chemical exchange saturation transfer and T_2 mapping in subjects with intervertebral disc degeneration at 3 Tesla

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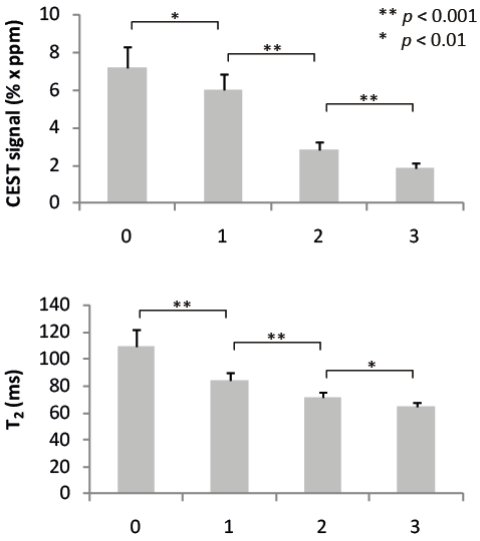
Objective: Low back pain (LBP) is a leading debilitating disease and disc degeneration is a strong etiological factors associated with LBP. The intervertebral disc (IVD) has been well acknowledged to degenerate as characterized by biochemical and morphological changes [1,2] and MRI has been commonly used to detect IVD degeneration. T_2 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 T_2 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 T_2 and CEST, has not been widely studied. In this study, we aimed to investigate the association between CEST, T_2 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 IVDs was employed. The second order shims were optimized to minimize B_0 field inhomogeneity. Imaging volume and geometry were uniform for all scans (T_2, 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 mm^2, nominal resolution = 1.96 x 2.67 mm^2, reconstructed pixel size = 1.22 x 1.22 mm^2, slice thickness = 8 mm. Single-slice axial T_2 images were obtained using a turbo spin echo sequence (TSE factor = 5) with: TR = 1000 ms, TE_1-TE_5 = 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 $CEST_{asym} = S(-freq)/S_0 - S(freq)/S_0$ where S and S_0 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 T_2-weighted (T_2w) images were obtained with: FOV = 201 x 178 mm^2, nominal resolution = 0.81 x 1.00 mm^2, reconstructed pixel size = 0.52 x 0.52 mm^2, slice thickness = 10 mm. TR = 2500-3200 ms, TE = 90 ms, number of averages = 2, total scan time = 1 min. 15 sec. Using T_2w, 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 $CEST_{asym}$ and T_2 values with increasing grade of degeneration were evident. The mean $CEST_{aysm}$ 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 T_2 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 $CEST_{asym}$ (r = -0.67, $p < 0.001$) and T_2 (r = -0.71, $p < 0.001$) (table). The correlation between CEST and T_2 values was r = 0.73 ($p < 0.01$).

Parameter	Parameter	r	*p*
CEST	T_2	0.73	< 0.01
CEST	Schneiderman grade	-0.67	< 0.001
T_2	Schneiderman grade	-0.71	< 0.001

Conclusion: Our results showed that CEST and T_2 decreases with increasing grade of disc degeneration and that CEST values significantly correlated with T_2. 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 IVDs, providing potentially a useful tool to diagnose early degenerative disc disease.

References: [1] Adams and Roughley, 2006. [2] Urban and Roberts, 2003. [3] Xia, 2000. [4] Weidenbaum et al., 1992. [5] Perry et al., 2006. [6] Chiu et al., 2001. [7] Ling et al., 2008. [8] Saar et al., 2011. [9] Kim et al., 2011. [10] Kim et al., 2009. [11] Schneiderman et al., 1987