Disc Location Dependence of the Proteoglycan (PG) T2 value in Human Lumbar Intervertebral Disc

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INTRODUCTION: The intervertebral disc degeneration (IVDD) is considered to be the root cause of back pain, which is a common disease that causes suffering and distress among the aging population (1,2). Anatomical MRI can routinely depict morphological changes in exquisite details during the late stage of IVDD. Quantitative MRI studies report that T2 decrease correlates with disc hydration and to a lesser extent with proteoglycan (PG) and collagen contents (3,4). Previous in vivo MRS study also revealed the potential relationship between spectroscopy derived PG concentrations (N-acetyl resonance around 2.0ppm) and disc degeneration levels (5). In this study, we hypothesized that the disc matrix degradation would affect the spin-spin relaxation of macromolecule proton and lead to an increase in the macromolecule T2 value, i.e. the PG T2 values in this study. Clinical experiences revealed that the lower lumbar discs are generally more degenerated than the upper discs, hence we measured the PG T2 value in different disc levels to explore the feasibility of using the PG T2 value as a probe of disc degeneration**.**

MATERIALS AND METHODS: A total of 7 healthy volunteers (ages 22-28, male, body weights 60-75kg) were examined using a 3 Tesla Philip human scanner. A stimulated-echo (STEAM) based single-voxel MRS sequence with chemical shift selective (CHESS) saturation for water suppression was chosen to acquire the spectra. The typical MRS voxel size was 14×18×5mm^3, covering ~80% of total disc volume. Both the PG and water T2 value were measured using 2 different TEs. The parameters used were: TR = 840ms, TE = 10/40ms. The spectra were acquired with 1024 data points, 2000 Hz spectral width and 192 repetitions. Each scan took nearly 3 minutes. The unsuppressed water spectra were extracted to calculate the relaxation times of water signal. 4 different disc levels (L2-3, L3-4, L4-5 and L5-S1) were targeted for the T2 measurement. Total experiment time was kept below 60 minutes. Spectral analysis was performed using the JMRUI and TOPSPIN software package. The N-acetyl resonance (1.9-2.1ppm) was quantified as the PG signal by fitting the spectrum to the Lorentzian line shape using the QUEST algorithm. The PG and water content was corrected by their T2 values and the PG over water ratio was computed. Results were considered significant when p<0.05. (Two-tailed paired t-test, *p<0.05;**p<0.01;***p<0.001).

Disc Level	L2-3	L3-4	L4-5	L5-s1
Sample Size	2	7	7	4
PG T2 (ms)	33.19±0.41	38.64±6.68	49.32±7.10	54.05±10.34
Water T2 (ms)	89.95±16.89	92.69±17.33	91.74±16.28	86.30±18.32
PG/Water (×10^{-3})	7.09±2.98	5.99±1.16	5.24±1.21	5.57±0.89

Table 1. The PG and water T2 value, PG/water ration (mean±SD)

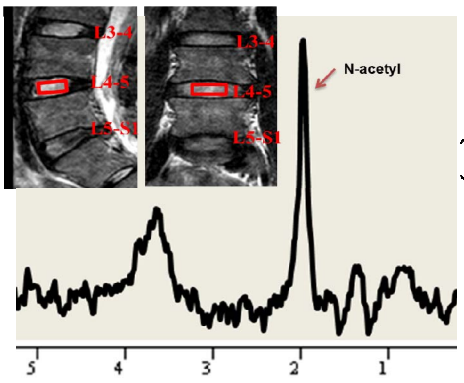

Fig.1 Representative spectrum acquired from a healthy subject on L4-5 disc. The MRS voxel covered both NP and AF parts of the disc.

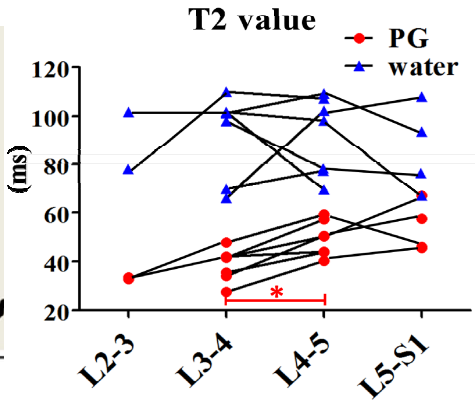

Fig.2 The T2 value of PG and water in different disc levels. The different discs of the same subject are connected by the line. The star stands for the significant difference between L3-4 and L4-5 (P<0.05)

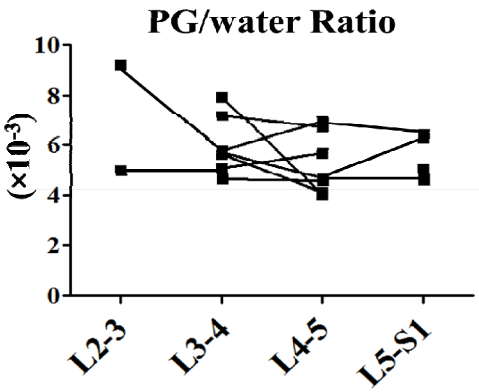

Fig.3 The PG/water ratio in different disc levels. The different discs of the same subject are connected by the line.

RESULTS: Fig. 1 shows the typical the spectra acquired from a healthy subject (the L4-5 disc, TE/TR=10/840ms). The corresponding T2-weighted (coronal and sagittal) images are shown at the upper left part. The voxel covered a relative large portion of the disc, not only the nucleus pulposus (NP) region but also covered some of the annulus fibrosus (AF) parts. The PG signal was identified as the N-acetyl group resonance at 2.0ppm which comes from the repeating disaccharide units of GAG chains in PGs. In some subject the L2-3 and L5-S1 disc had not been measured, because their disc sizes in those disc levels were not large enough to generate sufficient SNR. The averaged PG and water T2, as well as the PG/water ratio are given in table 1.The individual plot of both the PG and water T2 values of all subjects is shown in Fig. 2. An increasing trend of PG T2 values from upper disc level to lower disc level can be observed while the water T2 from the same MRS voxel shows no clearly trend. Significant difference of PG T2 value was found between L3-4 disc and L4-5 disc. At the same time, a slight decreasing trend of PG/water ratio from disc L3-4 to disc L4-5 is implied in Fig. 3, though no significant difference of PG/water ratio between this two disc levels was found.

DISCUSSIONS AND CONCLUSION: The reproducibility of the T2 measurement was checked in 2 subjects by repeating the measurement for 3 times on 2 different discs. The inter-measurement variation is 9.6%. The T2 PG measurement accuracy is limited by both the scan time and the disc size. Generally the relatively taller subject would provide a larger disc thus the voxel could be localized in the central region of the disc where the better shimming quality can be achieved. In this study, the data quality is to some extent compromised by the subject disc size. The PG and water T2 values, as well as the PG/water ratios (table1) are generated from a voxel partially covered the AF region. Given the previous knowledge about the regional difference of the water T2 and PG content between AF and NP part (6), both the water T2 value and PG/water ratio should be slightly higher in the NP region than the values shown in table 1. Lumbar disc disease (disc herniation, bulging and IVDD) happens at the lower lumbar spine, especially at the L4-5 and L5-S1 levels. The lower lumbar discs, which are more compressed by the body weight, are usually more degenerated that the upper discs. The increasing PG T2 value from upper disc level to lower disc level can be explained as the result of increased degeneration level in the lower disc levels. This suggests the elevated PG T2 value could be the reflection of disc degeneration taken place. Demonstrated by this preliminary study, the PG T2 measurement on clinical scanner is highly feasible and the PG T2 value might be a potential marker for the early detection of disc degeneration.

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