Quantitative comparison of T1ρ with T2 in intervertebral disc in vivo at 3T

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Introduction: Conventional T2-weighted (T2W) images are commonly used to assess the degeneration of intervertebral discs (IVDs) by disc morphological changes and signal intensity changes, especially in the nucleus pulposus (NP) [1, 2] because the annulus fibrosus (AF) appears dark in T2W images and thus does not provide much degenerative information. However, grading system based on T2W images for disc degeneration is subjective and difficult to detect subtle changes in the IVDs. Therefore, quantitative measurements using T1ρ and T2 mapping would be more reliable, providing objective information on biochemical composition in IVDs such as water content [3] and proteoglycan content [3, 4]. The purpose of this study is 1) to compare T1ρ and T2 in different parts of the IVDs- the NP and the AF and 2) show the sensitivity of assessing disc degeneration in the NP and the AF using T1ρ and T2 mapping.

Materials and Methods: Thirteen subjects (gender: 6 males and 7 females; mean age 34.1 years, age range 25-58 years) were recruited to undergo MRI scans following approval from the Institutional Review Board. Fifty-three lumbar IVDs were scanned. Each subject was imaged on a 3T Achieva scanner (Philips Healthcare, Best, The Netherlands) with SENSE Spine coil. The grade of degeneration was determined on T2W sagittal images using Schneiderman's classification [1] by two raters. Forty-four out of 53 IVDs were graded as 0 and nine were graded as 1 or above. The T1ρ-weighted images were obtained with a 3D balanced turbo field echo (B-TFE) sequence with the following parameters: TR/TE = 4.7ms/ 2.3 ms, flip angle= 30°, FOV= 180 x 200 mm^2, slice thickness= 10 mm, acquired pixel size= 0.55 x 0.78 mm^2, reconstructed pixel size= 0.52 x 0.52 mm^2. Five subsequent T1ρ-weighted scans were performed with spin-lock durations of 1, 25, 50, 75 and 100 ms and with a scan time of 1 min. 8 sec. for each scan. Images were fitted on a pixel-by-pixel basis to the exponentially decaying T1ρ function using IDL (Research Systems, Inc., USA) to generate T1ρ relaxation map. Quantitative T2 measurement in identical geometry as that of the T1ρ image was performed using standard multi-echo spin-echo sequence with TE= 30, 60, 90, 120 and 150ms, acquired pixel size= 1.92 x 2.56 mm^2, reconstructed pixel size= 1.25 x 1.26 mm^2 and scan time= 2 min. 20 sec. Regions of interest were manually selected based on T2W images in the NP and AF in order to calculate mean T1ρ and T2 values.

Results: Figure 1 illustrates a representative T2W image and the corresponding T2 and T1ρ maps overlaid on T2W image with grade 0 at L2/L3 to L4/L5 and grade 1 at L5/S1 from a 28-year-old female subject. The degenerative L5/S1 disc graded as level 1 correlates well with decreased T2 and T1ρ values. Figure 2 shows that the correlation between T1ρ and T2 is relatively high in the NP ($R^2 = 0.57$) but low in the AF ($R^2 = 0.04$). Furthermore, apparent difference in the dynamic range of the T1ρ and T2 values is observed between the NP (70–300 ms) and the AF (30-100 ms). Figure 3 displays quantitative comparison for each paired group, showing significant difference ($p < 0.005$, using two tailed student's t test) as follows: 1) between the NP and AF for mean T2 at all grades and for mean T1ρ only at grade 0 and 2) between grade 0 and grade > 0 in the NP for both mean T2 and T1ρ. However, statistically significant difference was not found in the AF between grade 0 and grade > 0 for mean T2 and T1ρ.

Discussion: Our results demonstrate the significant correlation between T1ρ and T2 in the NP but not in the AF. The larger dynamic range of T1ρ and T2 in the NP compared to that in the AF indicates that T1ρ and T2 are more sensitive to detect subtle changes in the NP. Moreover, significantly decreased T1ρ and T2 values observed in the NP but not in the AF of degenerative discs suggest that different degenerative-related changes taking place in between the NP and the AF can be quantitatively assessed using T1ρ and T2 mapping. Based on our findings in this study, further investigation of a relationship between T1ρ and T2 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] Schneiderman, G., et al., Spine, 1987. 12(3): p.276–281. [2] Pfirrmann CW, et al. Spine (Phila Pa 1976), 2001. 26(17):p1873–1878. [3] Marinelli NL, et al., Spine (Phila Pa 1976), 2009. 1;34(5):p520-524. [4] Johannessen W, et al., Spine (Phila Pa 1976), 2006. 15;31(11):p1253-1257.
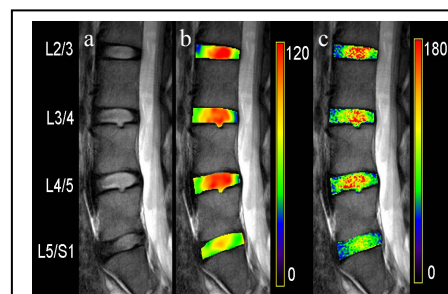
Figure 1. (a) T2W image (b) corresponding T2 map overlaid on T2W image (c) corresponding T1ρ map overlaid on T2W image with grade 0 at L2/L3 to L4/L5 and grade 1 at L5/S1.
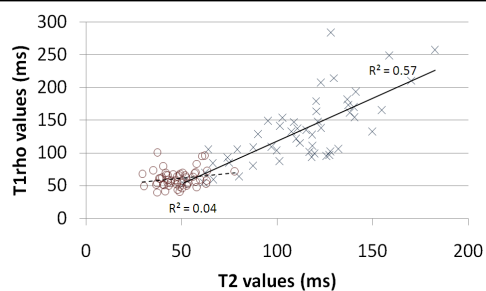

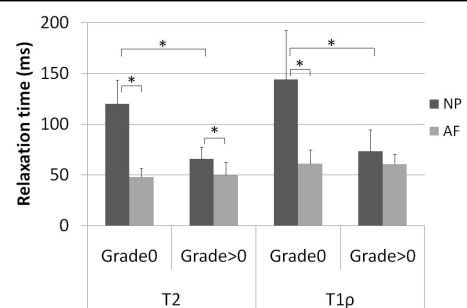Figure 2. Relationship between T1ρ values and T2 values of the NP and AF.

Figure 3. Mean T1ρ and T2 values of NP and AF for grade 0 and grade > 0. Significant differences between groups are indicated by * p < 0.005.