Reproducibility of a novel 3D pulse sequence for mapping $T_{1\rho}$ in inter-vertebral disc

M. Fenty[1], W. Witschey[1,2], C. Wang[1,3], R. Reddy, PhD[1], J. B. Kneeland, MD[4], and A. Borthakur, PhD[1]

[1]MMRRCC, University of Pennsylvania, Philadelphia, Pa, United States, [2]Biochemistry and Molecular Biophysics Graduate Group, University of Pennsylvania, Philadelphia, Pa, United States, [3]Bioengineering Graduate Group, University of Pennsylvania, Philadelphia, Pa, United States, [4]Department of Radiology, Hospital of the University of Pennsylvania, Philadelphia, Pa, United States

Background:

Lower back pain (LBP) is the second most frequent reason for a physician visit, permanently disables more than 5 million Americans and the annual costs are near $100 billion in the US. [2-5]. Conventional T_1 and T_2 imaging techniques are useful for observing late structural morphological changes to the intervertebral discs (IVDs) but are insensitive to early biochemical changes. These late structural changes are often clinically identified as late-stage DDD [6]. Earlier degenerative change occurs within the IVD nucleus pulposus (NP), as large aggregating proteoglycans break down [7]. The $T_{1\rho}$ relaxation time has enhanced sensitivity to the interaction between bulk water molecules and extracellular matrix macromolecules [8], such as the proteoglycans in the NP.

Materials and Methods:

All experiments were performed with approval from the Institutional Review Board. MRI was performed on a Siemens Sonata 1.5 T clinical scanner with the vendor-supplied transmit/receive 8-channel spine array coil. A novel 3D $T_{1\rho}$ MRI pulse sequence [9] was used with the following imaging parameters: T_E/T_R/flip angle = 3.7ms/7.4 ms/30°, acquisition matrix = 256x128x16, interpolated to 256x256x16, slab thickness = 80mm, in-plane resolution = 0.8x0.8 mm^2, T_{DELAY} = 6s, BW = 130Hz/pixel. The pulse sequence of our 3D $T_{1\rho}$ MRI consists of a spectrally selective fat saturation, $T_{1\rho}$ preparation, and a magnetization readout with a centrically encoded balanced steady-state free precession (b-SSFP) pulse train (N_{pulses} = 128), followed by a recovery delay. The pulse sequence is repeated for each slice encode for scan duration of under 3 minutes. Five separate acquisitions were performed with different spin lock pulse durations (5-40ms). $T_{1\rho}$ maps are then calculated by applying linear-regression on a pixel-by-pixel basis in all five images to the exponentially decaying function. Afterwards, a region of interest was selected by a single observer to calculate each intervertebral disc's bulk mean $T_{1\rho}$ and standard deviation values using NIH's ImageJ. $T_{1\rho}$ maps of the discs are then overlaid on a high resolution anatomical image. Three male volunteers (ages 23-26) were scanned three separate times. Two were deemed to be healthy/normal while one individual had a history of lower lumbar trauma. Reproducibility was measured as the coefficient of variation (standard deviation/ mean) of $T_{1\rho}$ in a region of interest in the nucleus pulposus in each disc.

Results:

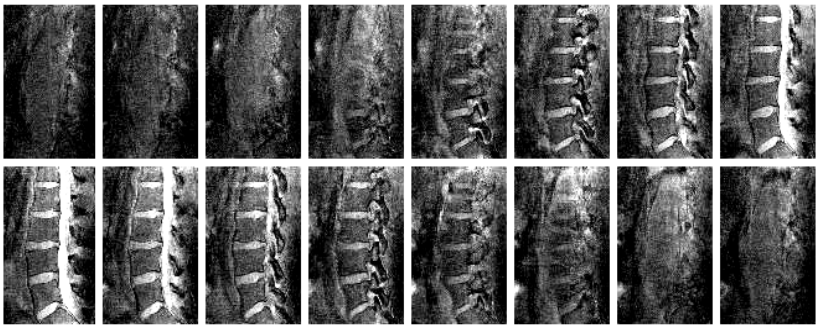

Figure 1: Typical 16-slice 3D data set demonstrating full coverage of the entire lumbar spine in a healthy individual. The total scan time was less than 3 minutes so that 5 data sets used for mapping $T_{1\rho}$ in the discs required less than 15 minutes.

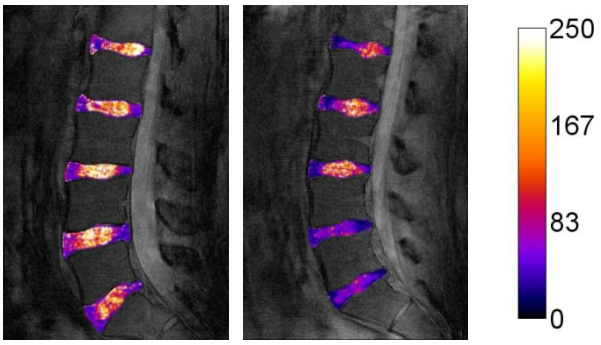

Figure 2: Normal volunteer's $T_{1\rho}$ map overlaid in color (A) on the grayscale anatomical image, and that of the patient with lower lumbar trauma (B). Color bar (C) (in milliseconds) indicates lower $T_{1\rho}$ values in the bottom two discs of the patient.

Conclusions:

SLIPS has the ability to quickly generate $T_{1\rho}$ maps within the lower lumbar discs. With a mean CoV of 10%, reproducibility has been determined to be feasible for our purposes. Our sequence can now be used in further studies to correlate $T_{1\rho}$ values with various degrees of disc degeneration.

Disc	*Subject 1*	*Subject 2*	*Subject 3*
L4/L5	*0.07*	*0.06*	*0.18*
L3/L4	*0.06*	*0.05*	*0.08*
L2/L3	*0.09*	*0.09*	*0.06*
L1/L2	*0.06*	*0.08*	*0.21*
T12/L1	*0.10*	*0.13*	*0.19*

Table 1: Coefficients of variation of $T_{1\rho}$ values in the nucleus pulposus of each volunteer's lumbar spine discs. The average CoV was 10%.

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