Accelerated T1rho relaxation quantification in intervertebral disc using limited spin-lock times

Pu-Xuan Lu[1], Feng Zhao[2], Jing Yuan[2], Greta SP Mok[3], James F Griffith[2], and Yi-Xiang Wang[2]

[1]*Department of Radiology, the Shenzhen Third People's Hospital, Shenzhen, Guangdong, China,* [2]*Department of Imaging and Interventional Radiology, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong,* [3]*Department of Electrical and Electronics Engineering, University of Macau, Macau, Macau*

Introduction: T1rho relaxation measurement, which probes the interaction between water molecules and their macromolecular environment, is suggested to have the potential to identify early biochemical changes in the intervertebral disc [1-4]. For traditional T1rho MR imaging applications like spine, multiple spin-lock times (SLT), often ~5 SLTs, are used to ensure the accuracy and robustness of T1rho mapping [1-4]. In the meantime, it will be advantageous to use fewer SLT points if comparable accuracy of T1rho mapping can be achieved. Recently we documented that using 3 SLTs of 1, 20, and 50 ms can be an acceptable alternative for liver T1rho measurement, while 2 SLTs of 1 and 50 ms do not provide reliable measurement [5]. We also documented that while in nucleus pulposus (NP) T1rho and T2 decrease in a similar pattern following disc degeneration, T1rho is better suited for evaluating nucleus pulposus (NP) in degenerated disc than T2 [6]. In this study, the feasibility of using 3 SLT points to measure intervertebral disc T1rho relaxation time is explored.

Materials and Methods: In total there were 12 subjects (6 females and 6 males; mean age: 49.8 years; age range: 30-75 years old) randomly selected from the data base of 52 subjects we previously reported [6]. All subjects were confirmed to have no other spine diseases except disc degeneration. All subjects underwent imaging in the morning. MRI was performed on a 3-T clinical system (Philips Healthcare). A 12-channel receive-only spine coil was used as the signal receiver to cover the lumbar spine, and the built-in body coil was used as the signal transmitter. Volume shimming was employed to minimise B0 heterogeneity. For T1rho measurement, a rotary echo spin-lock pulse was implemented in a 3D balanced fast field echo (b-FFE) sequence. Spin-lock frequency was set as 500 Hz and the SLTs of 1 ms, 10 ms, 20 ms, 40 ms and 60 ms were used for acquisition and T1rho mapping [6]. TE and TR for b-FFE acquisition were 2.3 ms and 4.6 ms respectively. FOV= 200 mm, pixel = 1.0 mm ×1.0 mm. Seven sagittal slices were acquired and the slice thickness was 4 mm. The flip angle was 40° and the number of signal averages (NSA) was one. A sensitivity-encoding (SENSE) factor of 2 was applied for parallel imaging. T1rho maps were computed on a pixel-by-pixel basis using a mono-exponential decay model with a home-made Matlab program. T1rho maps were generated by fitting each pixel's intensity as a function of TSL using a non-negative least-square fitting algorithm, respectively. T1rho was calculated as the inverse of the slope of the corresponding straight-line fit. Images were analysed in the mid-sagittal section of the lumbar spine. There were 60 discs included in the study. T1rho maps were re-constructed using all 5 SLT points of 1, 10, 20, 40, and 60ms, and three SLT points of 1, 20, and 60 ms respectively. With T2-weighted images as reference, regions of interest (ROIs) were manually drawn over T1rho map of the discs simultaneously on the image constructed using 5 SLTs and 3 SLTs. ROIs included NP, anterior AF and posterior AF (Fig 1). Values of anterior AF and posterior AF were averaged as the value for AF. Agreement of liver T1rho measurements using different SLT points was assessed using intra-class correlation coefficient (ICC) on absolute agreement as well as Bland and Altman plot. According to Fleiss [7], ICC values >0.75 represent good agreement, and values between 0.4 and 0.75 represent fair to moderate agreement. Statistical analyses were done using SPSS 14.0 (Chicago, IL).

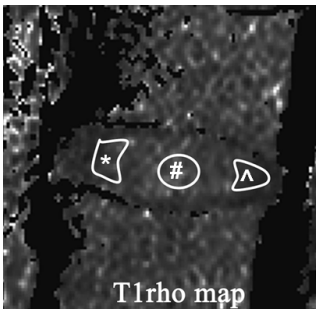

Fig. 1, *An example of placement of regions-of-interest (ROIs) over nucleus pulposus (#), anterior annulus fibrosus (*) and posterior annulus fibrosus (^) in one disc.*

T1rho values (ms) in disc

Region	5-SLT T1rho measurement	3-SLT T1rho measurement	p-value#
NP (n=60)	81.0 ± 23.4 ms (48.4-137.4 ms)	80.8 ± 23.4 ms (46.3-135.2 ms)	0.63
AF (n=60)	55.6 ± 9.2 ms (38.8-80.6 ms)	55.4 ± 9.4 ms (37.05-83.25 ms)	0.31

Table. 1, *The T1rho values measured by 5-SLT and 3-SLT in nucleus pulposus (NP) and annulus fibrosus (AF). #: by paired-t test.*

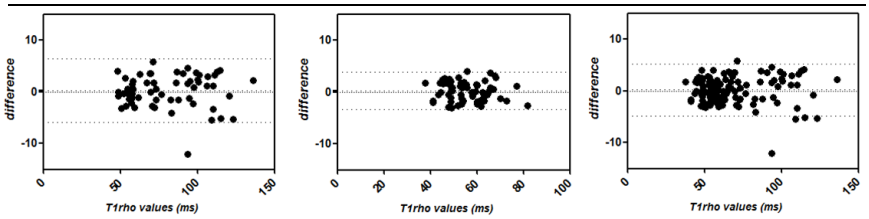

Fig. 2 *The Bland and Altman plots for the comparison of measurement by 5-SLT and 3-SLT in NP (left), AF (middle), and NP & AF (right) .*

Results: There was no significant difference for T1rho values by 5-SLT measurement and 3-SLT measurement in both NP (p=0.63) and AF (p=0.31) (Table.1). The ICC for 5-SLT T1rho measurement vs 3-SLT T1rho measurement was 0.991 and 0.981 respectively for NP and AF T1rho relaxation time. The Bland and Altman plots for the comparison are shown in shown in Fig 2, with mean difference of 3.14 (95% limits of agreement: -5.96, 6.36) and 1.83 (95% limits of agreement: -3.35, 3.83) for NP and AF respectively. Polling the T1rho values for NP and AF in 60 discs together, the ICC for 5-SLT T1rho measurement vs 3-SLT T1rho measurement was 0.993. The Bland and Altman analysis showed a mean difference of 2.56 (95% limits of agreement: -4.80, 5.24) (Fig.2).

Discussion: Accurate and precise T1rho mapping is challenging under the scan time constraint because multiple SLTs are usually required and a long delay time is also often necessary in the spin-lock pulse sequence for longitudinal magnetization restoration. The reduction of the applied SLT numbers is an apparent strategy to enhance T1rho imaging efficiency as long as the accuracy and reliability of T1rho mapping could be maintained. Examinations with fewer SLTs are also helpful to reduce the total RF energy deposition into the patient bodies and so mitigate the safety concern. Our current study suggests that adopting 3 SLTs of 1, 20, and 60 ms can be an acceptable alternative for the disc T1rho measurement.

References: [1] Johannessen W, et al. Spine. 2006; 31:1253-7. [2] Blumenkrantz G, et al. Magn Reson Imaging. 2006; 24:1001–1007. [3] Auerbach JD, et al. Eur Spine J. 2006; 15:338–344.[4] Blumenkrantz G, et al. Magn Reson Med. 2010; 63:1193-200. [5] Zhao F, et al. Korean J Radiol. 2012;13:736-42. [6] Wang YX, et al. Eur Radiol. 2012 Aug 4. [Epub ahead of print] [7] Fleiss JL (1986) Reliability of measurement. The design and analysis of clinical experiments. John Wiley & Sons, New York