In Vivo Sodium and Proton T1rho MR Imaging of Human Spine Disc at 3T

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[Introduction] With aging, intervertebral discs undergo biochemical and morphological changes that may lead to degenerative disc disease (DDD) [1]. Loss of proteoglycan (PG), a major component of intervertebral discs, is often associated with early disc changes in DDD. As MR imaging markers for PG in the disc, sodium concentration and proton T1rho relaxation time are reported to be sensitive to PG changes [2]. However, the association between the two markers of human discs in vivo has not been studied. Thus, in this study, we measured and compared sodium concentration and proton T1rho relaxation times in healthy human lumbar spine discs using a newly developed dual-tuned (DT) torso coil and ultra-short echo-time (UTE) spiral and spin-lock (SL) sequences.

[Methods and materials] All scans were performed using a 3T human scanner (Siemens Medical Solutions, Germany). Two normal volunteer subjects participated in this Institutional Review Board approved study. We used an in-house DT torso RF coil which consisted of 4-channel proton and 8-channel sodium (loop dimension, 150 × 180 mm² and 130 × 200 mm², respectively) (Fig. 1). Scout and proton anatomical image were acquired (Fig. 2A). Using the same shim values, sodium MR imaging was performed - 3D UTE sequence [3]; RF hard pulse of 500-μs duration, TR/TE = 150/0.27 ms, readout time = ~15 ms, resolution = 5 mm², TA = ~4 minutes, and average = 3. For the quantification of sodium concentration in discs, a homogenous 60% mM [13Na] saline phantom was used to correct B1 inhomogeneity (right in Fig. 2A). The sodium signal reduction in disc due to the partial volume effect [thickness 8 – 13 mm vs. effective resolution 10 mm (= 5-mm imaging resolution + Hanning filter)] as well as sodium T1 and T2 decay was simulated. Sodium T1, and T2 of disc was assumed to be 34.1 and 9.7 ms, respectively, on basis of 4% agarose with 153-mM [13Na] saline phantom was used to correct B1 field correction. (Lower panel) Scout and proton anatomical images, sodium concentration, and T2 and T1rho of proton over the discs were measured.

[Results and conclusions] Sodium MR imaging of lumbar spine discs was successfully acquired using a DT torso coil and UTE spiral sequence within reasonable acquisition time (< 15 min) (right in Fig. 2A). Sodium concentration of L1 to L5 ranged 190 to 235 mM (Fig. 2C), similar to values reported in a previous study [4]. The mean sodium concentration across discs was 214.9 ± 14.4 mM. Additionally, proton T1 and T1rho, mapping was consistently achieved (Fig. 3D and E). Mean T2 and T1rho relaxation times of discs were 84.0 ± 1.8 and 114.2 ± 9.5 ms, respectively (Fig. 3C). All measures were similar to those reported in other study (T2 = 92.3 ± 27.2 ms and T1rho = 133.1 ± 13.8 ms) [5]. The mean sodium concentrations and proton T1rho relaxation times across the discs were compared. Correlation was weak between sodium concentration and T1rho (r = 0.15), whereas a strong correlation (r = 0.75) was noted between T2 and T1rho. To investigate the significance of this comparative finding and clinical implication, further studies with a larger sample size of subject are essential.

In conclusion, we obtained consistent measurement of sodium concentration and proton T2 and T1rho relaxation time in lumbar discs from normal subjects using an in-house DT torso coil and UTE and SL sequences at 3T human scanner. MR-based physiological and metabolic measures of intervertebral discs may play an important role as imaging biomarkers for early diagnosis of DDD.


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Fig. 2 In-vivo sodium MR imaging of intervertebral disc from normal subject. A, (Left) Scout proton sagittal view, and (Right) the corresponding sodium MR image (maximum intensity projection) with B1 field correction. B, Simulation of sodium signal reduction due to partial volume effect [8-13 mm disc thickness vs. 10-mm effective resolution] as well as sodium T1 (34 ms) and T2 decay (9.7 ms) of 4% agar. C, Sodium concentration of intervertebral discs. Mean value was ~215 mM.

Fig. 3 In-vivo proton T2 and T1rho mapping of normal human discs. A, Sagittal image. B, T1 and T1rho curve fitting for averaged signal in all the discs. C, Bar graph of T1 and T1rho at different discs; mean value was ~86 and ~112 ms, respectively. D and E, T2 and T1rho map of intervertebral discs. T1rho value was slightly higher than T2 value in all discs. Mapping in upper- and lower-most regions (i.e., Txx and L5/S1) was incomplete due to strong susceptibility.