In Vivo T2 and T1rho Mapping of Rabbit Disc using Spin-Lock sequence at 3T

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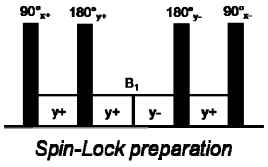
[Introduction] Loss of proteoglycan (PG), a major component of intervertebral discs, is signified in early disc changes in degenerative disc disease (DDD) [1]. A non-invasive in vivo imaging technique to detect PG change would be useful in diagnosis of early DDD. A strong association between changes in T_{1rho} relaxation time and PG loss in discs was reported in a previous study [2]. In order to systemically assess this association in an animal model [3], we developed a dual-tuned (DT) RF coil and MR sequences to measure both T_2 and T_{1rho} relaxation times in rabbit lumbar discs in vivo at 3T.

[Methods and materials] All scans were performed at a 3T human scanner (Siemens Medical Solutions, Germany). Twelve New Zealand white rabbits were studied: <1 year old, female, and 5.2 ± 0.4 kg. MR imaging was performed using an in-house multi-channel DT RF coil (designed for human knee imaging) that consisted of 4-channel transceivers with 120-mm diameter and 150-mm height [4]. Rabbits fit snuggly within the coil and were positioned supine at the center of coil. Form pads were inserted between the body and coil to minimize motion. T2-weighted TSE, DESS (data not shown), spin echo (SE), and spin-lock (SL) images with zero or nonzero B_1 SL preparation were acquired in the sagittal plane (**Fig. 1**): TSE – TR/TE = 3500/109 ms, resolution = 0.6×0.6×3 mm^3 (**Fig. 1A**); DESS – TR/TE = 14/5 ms, resolution = 0.6×0.6×3 mm^3; SE - TR/TE = 1370/12.6 – 63 ms, resolution = 0.6×0.6×3 mm^3 (**Fig. 1B**); SL multi-segmented SSFP - TR/TE/TSL(time of SL) = 7016/1.95/10 – 150 ms, B_1 = 387 – 473 Hz depending on SAR limit, resolution = 0.86×0.86×4 mm^3 (**Fig. 1C**). SL preparation consisted of two opposite polarity 90° RF pulses at the beginning and TSL, and low frequency SL B_1 pulse between them. A composite 180° RF pulse was also added before and after the low frequency SL B_1 pulse (see left figure [5]). MR signals were fitted using monotonic exponential curve, a**exp*(-TE/T_2)+b or a**exp*(-TSL/$T_{2(1rho)}$)+b in pixel-by-pixel base; likewise for the segmented lumbar L2-L7 disc regions by intensity-threshold in ROI (white box in **Fig. 1B**) (**Figs. 2A** and **B**). Three different MR relaxation times were measured and compared across the lumbar spine discs from L2 to L7 (**Figs. 2C - E**).



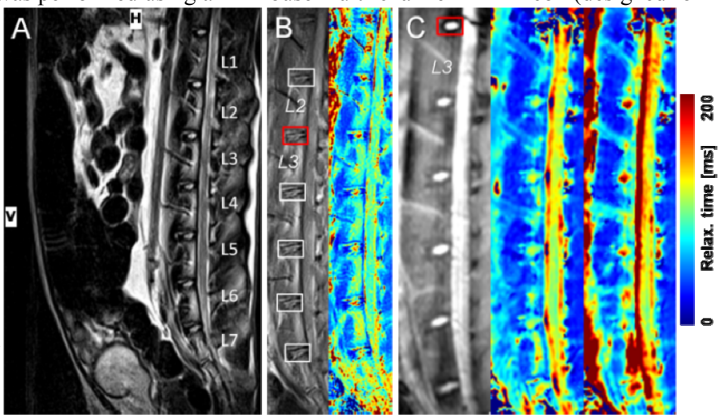


Fig. 1 In-vivo MR imaging of rabbit disc. **A**, T2-weighted TSE (TR/TE = 3500/109 ms) of lumbar spine from L1 to L7. **B**, T2 mapping with SE; left-raw, right-T2 map. **C**, T2 and T_{1rho} mapping with SL; left-raw, middle-T_2 map, right-T_{1rho} map. Note high T_{1rho} values in the discs.

[Results and conclusions] High-resolution and high–contrast proton anatomy images of the rabbit disc were acquired in all 12 rabbits (**Fig. 1A**). High T_2 contrast in the discs was evident in the T2-weighted TSE images. T_2 and T_{1rho} maps of the spine were successfully acquired (**Figs. 1B** and **C**). The measured MR relaxation times in the lumbar discs were 96.7 ± 9.5 (N = 12), 105 ±3.9 (N = 10), and 138.3 ±15.8 ms (N = 9) for T_2 w/ SE, T_2 w/ SL, and T_{1rho}, respectively. These measurements are similar to those reported in human lumbar discs (92.3 6 ± 27.2 ms for T_2 and 133.1 6 ± 13.8 ms for T_{1rho}) [6]. In conclusion, we successfully obtained high-resolution, high-contrast T_2 and T_{1rho} images and measured T_2 and T_{1rho} in normal rabbit lumbar spine discs. This was achieved using in-house dual-tuned RF coil and SL sequence at 3T. Further optimization of B_1 field homogeneity is needed for more stable T_2 and T_{1rho} mapping (e.g., using volume excitation and multi-receiving RF coil array). Further study will also be required to demonstrate the difference in T_2 and T_{1rho} between normal and degenerative disc models in rabbits in order to validate these imaging biomarkers for degenerative disc disease.

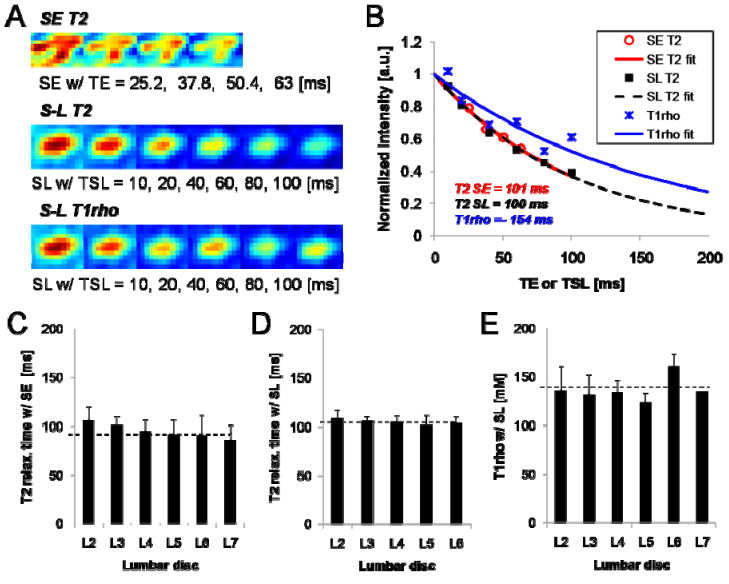


Fig. 2 T_2 and T_{1rho} measurement in the rabbit lumbar disc. **A**, Disc images (red box in **Fig. 1B** and **C**) with varying TEs and TSLs; upper-SE T_2, middle-SL T_2, lower-SL T_{1rho} image. **B**, Time plot of disc image intensity with TE and TSL. **C – E**, T_2 with SE, T_2 with SL, and T_{1rho} measurement in lumbar disc; T_2 w/ SE = 96.7 ± 9.5, T_2 w/ SL = 105 ±3.9, and T_{1rho}=138.3 ±15.8 ms. T_{1rho} values were higher than the T_2 values. T_2 measurements were similar by SE and SL sequences.

[Reference] **1**, Kent et al., *Chiropr Osteopat* 13 (2005). **2**,Wheaton et al., *MRM.* 54:1087–1093 (2005). **3**, Sowa et al., *Spine*,33:1821-8 (2008). **4**. Kim et al., *ISMRM*, 2011 submitted. **5**, He et al., *ISMRM*, 2011 submitted. **6**, Blumenkrantz et al., *MRM*, 63:1193-1200 (2010).

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