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 $T_{1\text{rho}}$ relaxation time and PG loss in discs was reported in a previous study [2]. In order to systematically 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 $T_{1\text{rho}}$ 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 snugly 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 mm3 (Fig. 1A); DESS – TR/TE = 14/5 ms, resolution = 0.6×0.6×3 mm3; SE - TR/TE = 1370/12.6 – 63 ms, resolution = 0.6×0.6×3 mm3 (Fig. 1B); SL multi-segmented SSFP - TR/TE/TSL(time of SL) = 7016/1.95/10 – 150 ms, $B_1^\text{R}$ = 387 – 473 Hz depending on SAR limit, resolution = 0.86×0.86×4 mm3 (Fig. 1C). SL preparation consisted of two opposite polarity 90° RF pulses at the beginning and end of the sequence. These pulses were also added before and after the low frequency SL $B_1$ pulse between them. A composite 180° RF pulse was added before and after the low frequency SL $B_1$ pulse (see left figure 5). MR signals were fitted using a mono-exponential curve, $a_\text{exp}(\text{TE}/T_2)+b$ or $a_\text{exp}(\text{TSL}/T_{1\text{rho}})+b$ 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).

[Results and conclusions] High-resolution and high-contrast proton anatomy images of the rabbit disc were acquired in all 12 rabbits (Figs. 1A). High $T_2$ contrast in the discs was evident in the T2-weighted TSE images. $T_2$ and $T_{1\text{rho}}$ 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), 105.0 ± 3.9 (N = 10), and 138.3 ± 15.8 ms (N = 9) for $T_2$ w/ SE, $T_2$ w/ SL, and $T_{1\text{rho}}$ respectively. These measurements are similar to those reported in human lumbar discs (92.3 ± 27.2 ms for $T_2$ and 133.1 ± 13.8 ms for $T_{1\text{rho}}$) [6]. In conclusion, we successfully obtained high-resolution, high-contrast $T_2$ and $T_{1\text{rho}}$, images and measured $T_2$ and $T_{1\text{rho}}$ 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 $T_{1\text{rho}}$ 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 $T_{1\text{rho}}$ between normal and degenerative disc models in rabbits in order to validate these imaging biomarkers for degenerative disc disease.


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