In vivo MR T1rho mapping in lumbar vertebral discs at 3T: a preliminary study

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INTRODUCTION

Lower back pain is one of the most common medical problems in the western world afflicting more than 50% of all individuals during their lifetime. One of the causes of lower back pain is degenerative disc disease (DDD), which is characterized by biochemical and morphologic changes in the intervertebral disc. Current radiographic and MR imaging methods are limited to detecting morphological changes at late stages of the degeneration. It has been suggested that MR $T_{1\rho}$ relaxation time may probe changes of proteoglycan (PG) or the associated glycosaminoglycan (GAG) in articular cartilage (1), and, therefore may potentially be valuable to assess PG loss in the early stages of disc degeneration. Previously we have developed a $T_{1\rho}$ mapping technique based on spiral imaging (2,3). Although initial results using this technique were promising, acquisitions of the spine were limited to the axial orientation. In this study we aimed to develop a sagittal $T_{1\rho}$ mapping technique and to evaluate its *in vivo* imaging feasibility at 3T.

MATERIALS AND METHODS

The sequence was composed with two parts: $T_{1\rho}$ pre-encoding with spin-lock technique followed by a fast spin-echo acquisition. The spin-lock cluster consists of a hard 90^0 pulse followed by a spin-lock pulse and a hard -90^0 pulse as developed previously (2). Agarose phantoms with different concentrations (1%, 2% and 4%, g/ml) were scanned and the results were compared with a previously validated spiral $T_{1\rho}$ sequence. Six volunteers (3 female 3 male, mean age 31, range 23-44 years) were studied and four were scanned twice with repositioning between scans at a 3T GE Excite scanner with a 4-channel phased array spine coil. The parameters were FOV = 20 cm, slice thickness = 5 mm, matrix = 192*128, TR/TE = 2000/5.8 ms, echo train length = 2, time of spin-lock (TSL) = 0/10/50/110 ms, bandwidth = 35.16, spin lock frequency = 300 Hz, total acquisition time approximately 17 minutes. The imaging protocol also included a sagittal T_2-weighted fat-suppressed sequence (TR/TE = 5000/88.62).

$T_{1\rho}$ maps were reconstructed pixel-by-pixel by fitting the $T_{1\rho}$-weighted images to the equation $S(TSL) = S0 * \exp(-TSL/T_{1\rho})$. $T_{1\rho}$-weighted images with the shortest TSL were registered to high-resolution T_2-weighted images acquired in the same exam. The transformation matrix was applied to the reconstructed $T_{1\rho}$ map. The nucleus pulposus (NP) of four discs, specifically L5-S1, L4-L5, L3-L4 and L2-L3, were segmented semi-automatically with a thresholding method based on the T_2-weighted images. 3D contours for the disc NP were generated and overlaid to the registered $T_{1\rho}$ map. Mean, standard deviation, and median $T_{1\rho}$ values were calculated. The *in vivo* reproducibility was evaluated using coefficient of variation (CV) of the median $T_{1\rho}$ within each discs.

RESULTS

The median $T_{1\rho}$ values were 125ms, 81ms and 48ms for the agarose phantoms with 1%, 2% and 4% concentrations respectively, which is consistent with values acquired using the previously developed and validated method (2). Fig. 1 (a)-(d) shows the $T_{1\rho}$-weighted images in a healthy volunteer (28-year-old female) with TSL = 0/10/50/110ms, with good signal to noise ratio and no significant artifact. Fig 1(e) illustrates the reconstructed $T_{1\rho}$ map overlaid on a T_2-weighted image. The $T_{1\rho}$ values were 83.2±39.1ms, 110.4±38.2ms, 99.3±32.5ms, 85.2±31.7ms for L5-S1, L4-L5, L3-L4 and L2-L3 disc respectively. Fig. 1(f) shows a $T_{1\rho}$ map for a volunteer (44-year-old male) who complained of lower back pain and showed lower $T_{1\rho}$ in L5-S1 (66.0±18.3ms) and L4-L5 (61.5±19.3ms) discs. The average CV for the median $T_{1\rho}$ of all the 16 discs (4 discs per subjects) was 5.64%, showing a good *in vivo* reproducibility of the sequence.

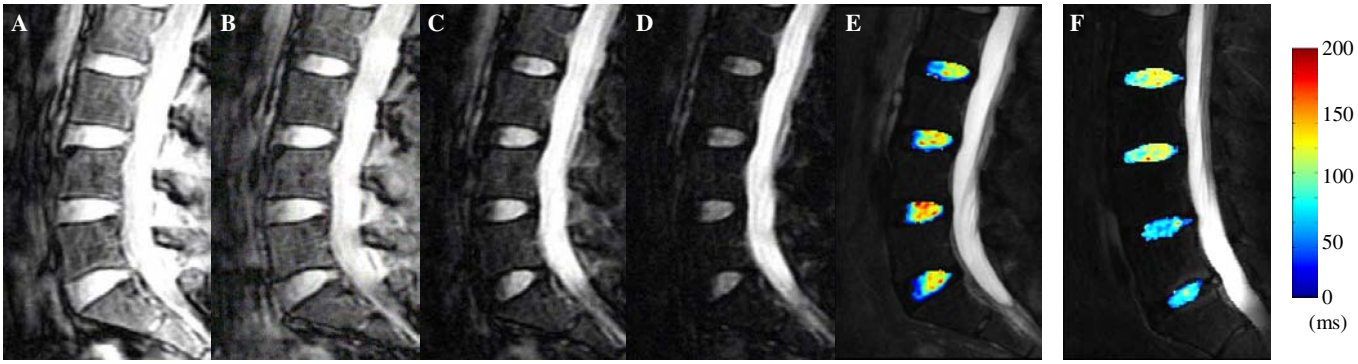

Fig. 1 *In vivo* $T_{1\rho}$ -weighted images (TSL=0/10/50/110ms) and reconstructed maps overlaid on T_2-weighted images. (a)-(e) images for a healthy volunteer; (f) The $T_{1\rho}$ map for a volunteer who complained of lower back pain and showed lower $T_{1\rho}$ values in S1-L5 and L4-L5 discs.

DISCUSSION

In this preliminary study, we have developed a reproducible $T_{1\rho}$ mapping technique based on a FSE sequence and showed the feasibility to use it for *in vivo* sagittal $T_{1\rho}$ mapping in lumbar vertebral discs at 3T. An *in vitro* study showed that $T_{1\rho}$ values were correlated with GAG contents in interertebral discs (4). This *in vivo* mapping technique may be valuable by providing non-invasive evaluation of biochemical changes in discs during degeneration. A larger cohort of patients with lower back pain will be studied and compared with healthy volunteers.

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AKNOWLEDGEMENTS: This research was supported by NIH RO1-AG17762.