SPIN-LOCK Prepared MRI of a Spontaneous Animal Model of Disc Degeneration

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Introduction:

Intervertebral disc (IVD) degeneration has been implicated as a major etiological component of low back pain [1,2], a condition with tremendous disability, activity limitation, and economic loss. The disc consists of three anatomically distinct regions: nucleus pulposus (NP), annulus fibrosus (AF) and cartilaginous end plates (EP). The earliest biochemical changes in the disc are loss of glycosaminoglycans (GAG) and decrease in water content in the NP with some structural changes (denaturation) of collagen [3]. The conventional MRI techniques such as T_1, T_2, and magnetization transfer (MT) are excellent for detecting the gross morphological changes (late stage) of the IVD disorders [3,4]. However, these techniques are particularly not sensitive enough to detect early degenerative changes associated with GAG loss, in the disc. Although, sodium MRI is highly specific to GAG, it inherently has low sensitivity, low resolution, and requires high static fields for clinical applications. Due to limited diffusion of contrast agents into IVD, MR techniques based on exogenous contrast agents such as dGEMRIC are not useful for measuring GAG in IVD [5, 6]. The spin-lattice relaxation in the rotating frame ($T_{1\rho}$) is an alternative approach, which is sensitive to the slow macro-molecular interactions with the bulk water, and has been shown to sensitive to GAG changes in cartilage. [7,8]. There are numerous animal models, both naturally occurring and experimentally induced, to study disc degeneration. One specialized and naturally occurring model is the sand rat, which is an attractive small rodent model for spontaneous age-related disc degeneration and diabetes research. The age dependent disc degeneration in sand rat model has been extensively characterized by gold standard techniques (histo-pathology, radiographic signs and fixed charge density) [9,10]. Characterization of this model by non-invasive techniques opens a new possibility for evaluating disc degeneration. However, to the best of our knowledge, no MRI evaluation of IVD of sand rat model was reported. In the present work, we demonstrated the feasibility of acquiring high-resolution $T_{1\rho}$-weighted images and quantify spatial variation of the basal $T_{1\rho}$ relaxation times in sand rat IVD specimens.

Materials and Methods:

IVD specimens (n=3) of sand rat spine (~3-4 months of age) were used for MR imaging. All the experiments were performed on an Oxford 4.7T horizontal bore magnet interfaced to a UNITY INOVA spectrometer (Varian, Palo Alto, CA) equipped with 12-cm gradients having a maximum strength of 25 gauss/cm. A 3.0 cm custom-built, solenoid radio-frequency (RF) coil tuned to 200.78 MHz was employed. High-resolution $T_{1\rho}$-weighted images were acquired with $T_{1\rho}$ preparatory pulse cluster appended to a spin-echo (SE) sequence [7]. $T_{1\rho}$ maps were computed by fitting the signal intensity to an appropriate signal expression using a linear least-squares method.

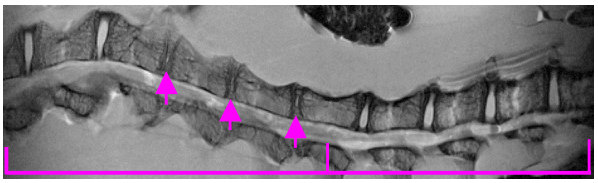

Fig. 1. Representative long axis $T_{1\rho}$ -weighted image (sagittal plane) of sand rat spine acquired at 500Hz. The imaging parameters are TR/TE=4000ms/(TE+TSL)=20ms, FOV=5cm×2.5cm, matrix=512×256 in--plane resolution =97μm×97μm, slice thickness =1.0mm, acquisition time for each image=34 minutes, number of averages=2. The arrows show the compression of lumbar spine and absence of normal

Results and Discussion:

Representative high-spatial resolution $T_{1\rho}$-weighted images of sand rat IVD (**97μm×97μm in sagittal plane and 58μm×58μm in axial plane)** are shown in Fig. 1 & 2. $T_{1\rho}$-weighted images acquired at 500 Hz provided ~150% higher signal to-noise ratio (SNR) and improved contrast between NP and AF when compared to conventional T_2-weighted images. The $T_{1\rho}$ relaxation numbers in NP and AF are in the range of 100-120ms and 50-60ms, respectively at 500Hz. $T_{1\rho}$ relaxation times in sand rat IVD are ~100-200% higher when compared to T_2 relaxation times (T_2 data not shown).

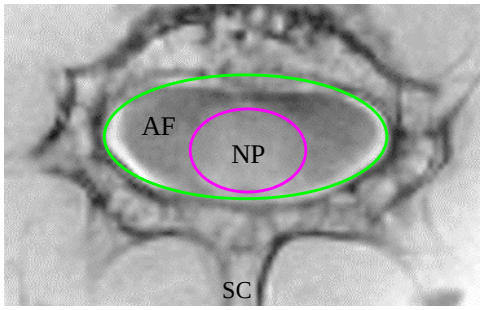

Fig. 2.Representative short axis $T_{1\rho}$-weighted image acquired with spin-lock frequency of=500Hz. The imaging parameters are TR/TE=2000ms/(TE+TSL)=20ms, FOV=1.5cm×1.5cm, matrix=256×256, in -plane resolution =58μm×58μm, slice thickness =0.5mm, acquisition time for each image=34 minutes, number of averages=4. Spinal cord (SP) can also be observed under the disc.

Conclusions:

The preliminary work demonstrate the feasibility of acquiring $T_{1\rho}$- weighted images in sand rat model of disc degeneration. The results demonstrate that $T_{1\rho}$ relaxation has higher dynamic range in both AF and NP of IVD compared to T_2 relaxation. Higher dynamic range not only provides higher SNR and improved contrast between AF and NP but also improves the precision of the measurement. These characteristics of $T_{1\rho}$ imaging may be exploited in quantifying PG changes in the NP of sand rat model for disc degeneration. Further studies are underway using this MRI approach and animal model to assess the age-related progression of disc degeneration and evaluation of novel therapeutic interventions.

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