Quantification of Relaxation Times of Metabolite Resonance in Intervertebral Disc Using MR Spectroscopy

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Introduction

Intervertebral disc degeneration (IVDD) related back pain is a leading health problem. However, the causes and the progression of IVDD remain poorly understood. Traditional imaging techniques rely on disc morphology while actual disc degeneration begins with internal biochemical and biomechanical changes. Proton magnetic resonance spectroscopy (^{1}H-MRS) is a powerful non-invasive tool that has been used for the assessment of metabolites in tissues. Therefore, applying ^{1}H-MRS to studying IVDD may provide a straightforward way to understand the causes of the disease and to monitor its progression. Initial studies have been performed on bovine discs and human cadaver discs to study the feasibility of the technique [1]. When using MRS to evaluate disc degeneration, it is critical to choose appropriate TR and TE that will produce the largest contrast in metabolites levels between normal and degenerated discs. The optimal TR and TE are known to be determined by the longitudinal and transverse relaxation times. In addition, quantification of relaxation times might provide valuable information related to disc degeneration. Great efforts had been made previously to map relaxation times in the disc using MR imaging (MRI). However, no studies have been performed to measure metabolite relaxation times. The aim of this study was to evaluate T1 and T2 relaxation times of choline, N-acetyl and lactate within the intervertebral disc using a single-voxel MRS technique.

Method

Quantitative T1 and T2 measurements were performed on 6 fresh-frozen bovine caudal discs on a 3 Tesla GE Excite Signa whole body MR scanner (General Electric Medical Systems, WI) using an 8 channel phase array knee coil (GE). A single voxel point-resolved spectra selection (PRESS) sequence with a three-pulse chemical shift selective (CHESS) saturation for water suppression was chosen to acquire the spectra. A 4 × 16 × 14 mm^3 voxel was placed at the center of the disc. For T1 mapping, TE= 28ms, TR = 800/1000/1600/3200 ms; For T2 mapping, TR =1600ms, TE=28/56/84/112ms. The spectra were acquired with 1024 data points, 2000 Hz spectral width and 384 repetitions. Unsuppressed water spectra were acquired in each scan to obtain estimates of coil sensitivities for the combination of the eight-channel data.

All post-processing was performed on a Sun workstation (Sun Microsystems, Palo Alto, CA). The acquired data were corrected with respect to phase and frequency using an internal water reference, and apodized with a 3-Hz Lorentzian function. Multiple channel data were then combined using the unsuppressed water signal, followed by a Fourier transform to the frequency domain and a baseline correction. Three spectral regions were identified and measured in each acquired spectrum based upon previous literature [2]: the choline head group region (Cho) (3.15-3.30ppm), the N-Acetyl region (N-Acetyl) (1.90-2.10ppm) and the lactate region (Lac) (1.15-1.40ppm). A peak-fitting program developed in-house was then applied to provide robust and reliable estimation of the metabolite peak areas and peak heights. Peak heights of Cho, N-Acetyl and Lac were extracted from the spectra and fitted to calculate the relaxation times. T1 relaxation times were calculated from data partial saturation using a two-parameter least-squares fitting routine to the equation $S/S_0 = 1\text{-}2*\exp[-(TR\text{-}TE/2)/T1]+\exp(-TR/T1)$ [3], where S is the signal intensity, S_0 is the fully relaxed signal intensity. A Levenberg-Marquardt monoexponential fitting algorithm was employed to calculate T2: $S(TE) \propto \exp(-TE/T2)$, where S is the signal intensity.

Results

Figure 1 shows representative MR spectra acquired from a T2 measurement in the disc. Note the clear reduction of the metabolite peak heights as TE increases. The calculated T1 and T2 for the metabolite groups are listed in Tab. 1. The Cho group has the longest T1 and T2. The T1 and T2 of N-acetyl and Lac are in the same range.

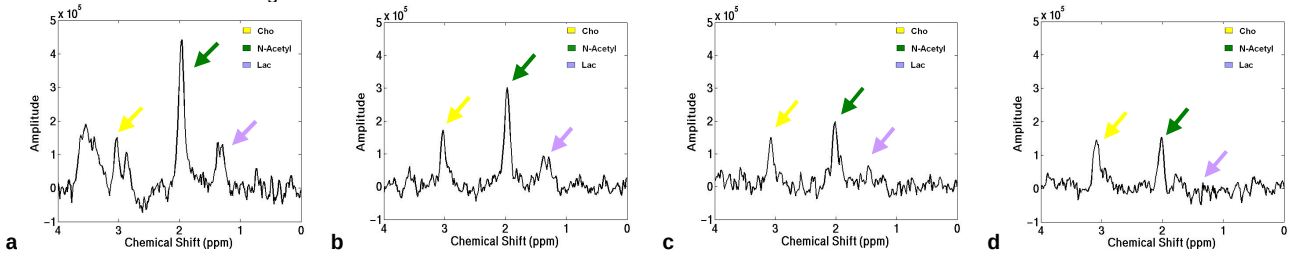

Fig.1 Representative MR spectra acquired in a bovine disc with TR= 1600ms, TE= 28ms (**a**), TE = 56ms (**b**), TE = 84ms (**c**), and TE = 112ms (**d**).

Discussion

Water spin-lattice (T1) and spin-spin (T2) relaxation times have been previously studied in tissue using MR imaging method to characterize disc and cartilage [4-5]. Correlations have been found between T1 and water content as well as T2 and water content, for more hydrated tissue has a longer T1 and T2. This study measured the T1 and T2 of metabolites using MRS of the disc for the first time. The measured T1 and T2 are in the same range as those measurements that were reported earlier using a high-resolution magic angle spinning (HR-MAS) spectroscopy method [2]. Both studies indicated a lower T1 and T2 compared to those measured for the brain [6] due to less water content in the disc. In addition, disc degeneration shortens the relaxation times. This reduction might also be attributed to tissue water loss. Further quantification of T1 and T2 of metabolites in discs with different degeneration grades might provide another approach to assess disc degeneration. The current study provided reference values to optimize future MRS studies. For example, the measurements of T1 indicated that the maximum signal to noise ratios (SNR) of N-acetyl and Lac could be achieved with a TR=750ms. Combining this information with scanner gradient limits, as well as the specific absorption rate (SAR) is essential to achieving an optimized SNR. Further studies are warranted to provide more information about the relationship between T1 and T2 and disc degeneration both in vitro and in vivo.

	Cho	N-acetyl	Lac
T1 (ms)	**885±355**	**594±31**	**622±138**
T2 (ms)	**162±85**	**51 ±6**	**40±10**

Tab.1 Measured T1 and T2 for metabolites.

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