ASSESSMENT OF COMPRESSION MODULUS, HYDRAULIC PERMEABILITY AND MATRIX CONTENT OF ENZYME-TREATED NUCLEUS PULPOSUS USING QUANTITATIVE MRI

+Périé D., PhD, Iatridis J.C., PhD, *Goswami T., PhD, **Beaudoin G., PhD, *Demers C., MSc, *Jordanova M., MSc, *Mwale F., PhD, *Antoniou J., PhD
+University of Vermont, Burlington, Vermont, USA
*McGill University, Montreal, Quebec, Canada; ++ Université de Montréal, Montréal, Quebec, Canada
delphine.perie@online.fr

INTRODUCTION

There is a strong clinical need to develop an objective, accurate, and non-invasive diagnostic tool using quantitative magnetic resonance imaging (MRI) for the detection and quantification of matrix changes (composition and integrity) in early disc degeneration. Recent evidence suggests that the physiological state of the disc, including including loading, must be mimicked when developing this method in vitro.

In the present study, we tested the hypotheses that 1) different loading conditions and enzyme treatments induce changes in MRI parameters, mechanical properties and biochemical contents of intervertebral nucleus pulposus; and 2) the mechanical properties of intervertebral nucleus pulposus are quantitatively related to MRI signal.

METHODS

Experimental Groups: Bovine caudal motion segments (n=18, 2-4 years old) were subjected to one of 2 different injections and one of 2 different loading conditions to obtain tissues with varying composition and structure. Control group: Tris buffer solution was injected into the nucleus pulposus. Trypsin group: 5mg of trypsin in Tris buffer were injected. Unloaded group: the tail was immediately embedded in paraffin. Loaded group, the tail was subjected to a cyclic compression (50N–300N–50N at 1Hz for 2 hours) before being embedded in paraffin.

MRI Procedure: The MR examinations were carried out in a 1.5T whole-body Siemens' Sonata system using the standard circularly polarized head coil. T1 and T2 relaxation times were determined from multiple inversion recovery images and multiple echo trains, respectively. The magnetization transfer MT data were obtained using a gradient echo sequence with dual acquisition. The diffusion trace TrD was measured using spin echo sequence with large gradient pulses.

Biochemical Composition: The intervertebral discs were dissected and the nucleus pulposus' Sonata system used the standard circularly polarized head coil. T1 and T2 relaxation times were determined from multiple inversion recovery images and multiple echo trains, respectively. The magnetization transfer MT data were obtained using a gradient echo sequence with dual acquisition. The diffusion trace TrD was measured using spin echo sequence with large gradient pulses.

RESULTS

Significant correlations were found between k and T1 (r=0.78, p=0.02), T2 (r=0.85, p=0.007) and between H0 and TrD (r=0.56, p=0.15). However, loading decreased the correlations between the mechanical properties and the MRI parameters (r=0.4, p=0.2).

DISCUSSION

Results indicated trypsin injection did not result in loss of GAG or collagen during this experiment where water exchange with the surrounding environment was prevented by paraffin; however, structural changes did occur as demonstrated by the significant effects of enzyme treatment on both modulus and permeability. Significant effects of trypsin treatment on mechanical properties but not on MRI parameters or biochemical contents suggested that mechanical properties were more sensitive to structural changes with trypsin treatment while significant effects of loading on T1, T2 and H0 but not mechanical properties suggested MRI parameters were most sensitive to changes in water content due to loading. Future investigations using enzymes that target other subunits of the disc matrix may shed additional light on the functional role of different matrix components in the disc.

This study demonstrates some predictive ability between permeability and MRI parameters but not between aggregate modulus and MRI parameters using this (1.5T) machine. High magnetic fields in the presence of a contrast agent using the dGEMRIC technique, were able to predict compressive modulus [2,3]. However, technical challenges with dGEMRIC due to long diffusion times and sensitivity of the relaxivity parameter to disc structure in whole discs were previously reported [4].

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REFERENCES

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