T1-T2 Cluster Analysis of Intervertebral Disc Sub-Structures

Alexander C. Wright[1], Sung M. Moon[1,2], Jonathon H. Yoder[2], Edward J. Vresilovic[2], and Dawn M. Elliott[2]

[1]Laboratory for Structural NMR Imaging, Department of Radiology, University of Pennsylvania, Philadelphia, PA, United States, [2]McKay Orthopaedic Research Laboratory, Department of Orthopaedic Surgery, University of Pennsylvania, Philadelphia, PA, United States

Introduction

The intervertebral disc consists of three major sub-structures: the nucleus pulposus (NP), the annulus fibrosus (AF), and the (superior/inferior) cartilaginous endplate (CEP). The CEP is a thin layer of hyaline cartilage between the vertebral body and the NP that provides a mechanical barrier and a nutritional conduit between the vertebral blood supply and the disc. There is evidence that with age and degeneration the CEP becomes thinner, calcifies, and may have reduced permeability [1]. MRI has been used to determine disc composition and volume [2,3] and to classify the stage of degeneration [4,5]. However, CEP geometry and relaxation times have not been quantified due to limitations in SNR and spatial resolution. The general method of cluster analysis has often been applied in the segmentation of brain structures, using the T1- and/or T2-based contrast that is well understood for brain tissues. Here we have applied a similar concept to examine the nature of T1 and T2 relaxation in sub-structures of the intervertebral disc. Apart from the simple curiosity of these results, this analysis may facilitate segmentation of disc sub-structures towards the development of anatomically accurate finite element models in the study of disc biomechanics, as well as a more detailed method for classifying the degenerative grade of a disc.

Methods

<u>Specimen</u>: A fresh frozen human lumbar motion segment (female, 28 yrs) was imaged on a 7T Siemens whole-body MRI scanner using a custom transmit/receive RF coil. The sample was thawed, sealed in an airtight bag, and embedded in 2% agarose.

<u>Imaging</u>: At 7T, the motion segment was imaged using a spin echo sequence for T2 map generation and an inversion-recovery turbo spin echo sequence for T1 mapping (voxel size = 5x5x5000 μm^3).

<u>Analysis</u>: Disc NP, AF, and CEP regions were segmented manually. Corresponding pixels were color-coded and plotted as correlation plots to illustrate the separation of clusters based on T1 and T2 differences.

Results

T2 and T1 maps of the disc motion segment (Fig. 1, with color bars in units of milliseconds), yielded highly separate clusters for the three distinct disc sub-structures. Furthermore, the general trend of the clusters is preserved for the T2- and T1-weighted images from the same data set.
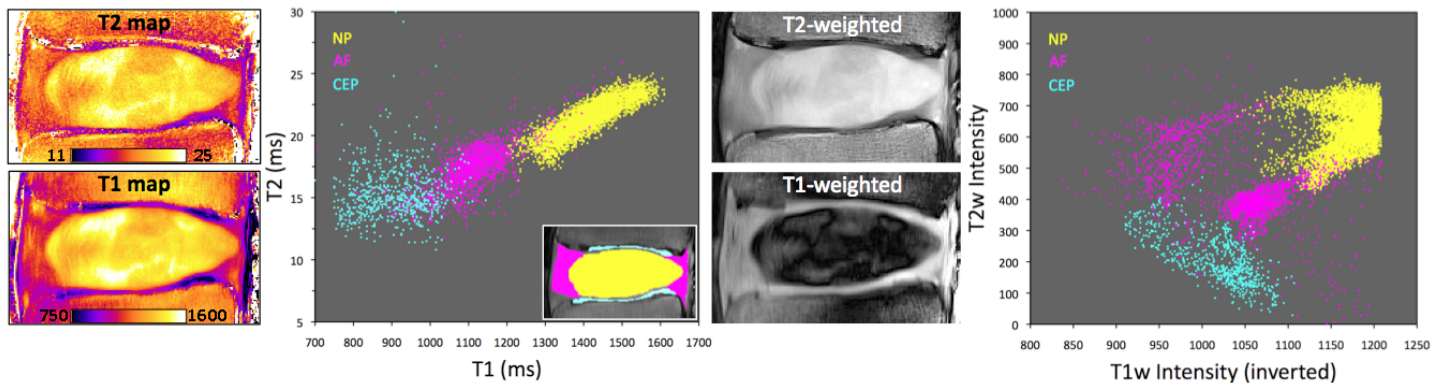

Fig. 1. (left) T2 and T1 maps of a normal disc motion segment (L4L5), obtained at 7T, and color-coded correlation plot illustrating distinct clusters. The manually segmented sub-structures are shown in the inset: NP (yellow), AF (magenta), and CEP (cyan). **(right)** The same segmented regions were applied to single T2-weighted and T1-weighted images from the mapping data sets and the corresponding pixels plotted as similarly colored points. While the AF (magenta points) here exhibits a split cluster, the distinct separation and ordered trend of the clusters are conserved.

Discussion

In this study we have found that T1 and T2 values are highly correlated in the NP, and to some extent in the AF and CEP. Cluster separation may prove useful for automatic segmentation, as well as for precision grading of disc degeneration. In vivo application appears to be straightforward.

References: [1] JPG Urban and S Roberts, *Arthritis Research and Therapy* **5**, 120-130 (2003). [2] W. Johannessen, et al., Spine 31:1253-7, 2006. [3] CWA Pfirrmann, et al., JOR: 1086-94, 2006. [4] CWA Pfirrmann, et al., Spine 26:1873-8, 2001. [5] LM Benneker, et al., Eur Spine J 14:27-35, 2005.