

in vivo Quantification of Intervertebral Disc Collagen Content Using Magnetization Transfer Ratio Mapping

C. Wang^{1,2}, W. Witschey³, A. Goldberg⁴, M. Elliott², J. Calabro⁵, A. Borthakur², and R. Reddy²

¹Bioengineering, University of Pennsylvania, Philadelphia, PA, United States, ²Radiology, University of Pennsylvania, Philadelphia, PA, United States, ³Biochemistry and Molecular Biophysics, University of Pennsylvania, Philadelphia, PA, United States, ⁴Radiology, Hospital of the University of Pennsylvania, Philadelphia, PA, United States, ⁵Siemens Medical Solutions

Objective: in vivo Quantification of Intervertebral Disc Collagen Content Using Magnetization Transfer Ratio Mapping

Introduction:

An important contrast in MRI is the enhancement of bulk water proton spin relaxation via dipolar cross relaxation between bulk water protons and protons on macromolecules [1]. Under this magnetization transfer (MT) mechanism, a saturation pulse applied off-resonance on a homogeneously broadened macromolecule-bound proton magnetization will also saturate the bulk water (on-resonance) proton magnetization via dipolar cross relaxation. Recent studies have determined that the hydroxyl, amine, and possibly carboxyl groups on the surfaces of macromolecules act as sites of MT process [2]. Furthermore, it has been demonstrated that in cartilage the MT effect is entirely dominated by collagen-bound protons rather than PG-bound protons [3]. Therefore quantification of MT effect may lead to the quantification of collagen content in the intervertebral disc (IVD).

Materials and Methods:

Two male volunteers were recruited for this study in accordance with the regulations of the Institutional Review Board (IRB) of our institution. Each subject provided written consent prior to the experiment. The subjects were imaged on a 1.5 T Siemens Sonata clinical MRI scanner (Erlangen, Germany). Siemens supplied spine-array RF coil was used to acquire all images of the spine. The MT imaging sequence was a modified 2D turbo-spin-echo (TSE) sequence, with an off-resonance saturation RF pulse applied before each TR. The echo train of each TR was centrally encoded to maximize the MT contrast. A series of gradient-echo (GRE) images were first acquired to localize the mid-sagittal slice of each subject's lumbar and thoracic spine. After localization, MR images were acquired according to the following parameters: TE/TR = 13/2000 ms, FOV = 25 x 25 cm, matrix size = 512 x 512, slice thickness = 5 mm, bandwidth = 296 Hz/Pixel, echo train length = 3, signal average = 3. Two images were collected for each subject, one with the off-resonance saturation preparation (M_s) and the other one without it (M_o). The off-resonance saturation pulse was applied +6.4 kHz downfield of the free proton resonance frequency, at an amplitude of 200 Hz for a duration of 150 ms. The large off-resonance frequency was chosen to minimize direct saturation effect on the free water peak. The magnetization transfer ratio (MTR) was subsequently calculated according to $MTR = (M_o - M_s)/M_o$.

Results:

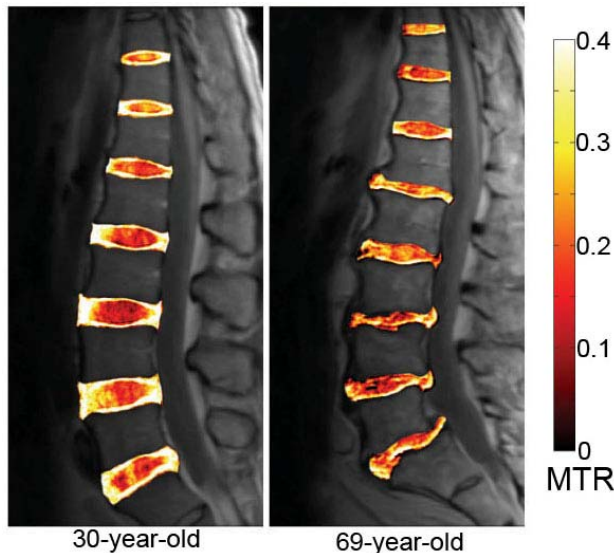


Fig 1. Sagittal MTR color maps overlaid on the grayscale M_0 images of two subjects. Note the overall clarity in demarcation between the AF and the NP compartments in the IVDs of the 30-year-old subject when compared to those of the 69-year-old subject.

In the MTR map of the healthy IVDs of the 30-year-old subject in Fig 1., there was a clear boundary between the AF with high MTR and the NP with low MTR. This MTR difference between the AF and the NP was due to the greater fraction of collagen in the AF compared to the NP. The signal of the collagen-rich AF decreased significantly more than the signal of the PG-rich NP after the application of the off-resonance saturation pulse. In Fig 2., the MTR value of the NP increased with age, which corresponded to increased collagen content in IVD NP.

Conclusions:

In conclusion, our study demonstrated that the MT effect in IVD is dominated by the presence of collagen in IVD. In a healthy IVD, the MT contrast was most prominent in the collagen-rich AF. However, as a result of aging or trauma related degeneration, we also observed elevated MTR in the NP region of the IVD. Currently we are acquiring and processing the MT MRI images of additional subjects. ROI analysis of the IVD MTR maps is also being conducted. The average MTR values will then be compared to Pfirrmann grades determined from sagittal T_2 -weighted MR images of the same subjects. Since the Pfirrmann grade is currently the accepted measurement of IVD degeneration, a linear regression analysis between IVD MTR value and Pfirrmann grade will answer the question of whether collagen content increases in IVD with degeneration.

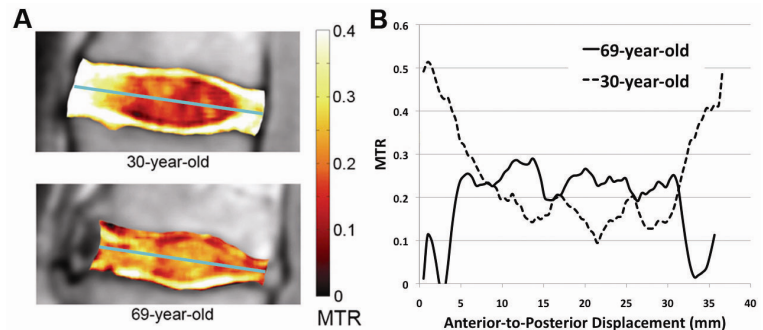


Fig 2. (A). The MTR maps of the L2/L3 IVDs overlaid on top of the grayscale M_0 images for a pair of young and old subjects. The green lines mark the locations from which the anterior-to-posterior MTR profiles were computed. (B) The anterior-to-posterior MTR profiles of the same IVDs from (A).

1. WOLFF, S.D. AND R.S. BALABAN. MAGN RESON MED, 1989. 10(1): P. 135-44.
2. CECKLER, T.L., ET AL. JOURNAL OF MAGNETIC RESONANCE, 1992. 98: P. 637-45.
3. KIM, D.K., ET AL. MAGN RESON MED, 1993. 29(2): P. 211-5.