

Non-Invasive Determination of Nucleus Pulposus Proteoglycan Content Using $T_{1\rho}$ MRI

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INTRODUCTION: MR and radiographic imaging have successfully been used to detect late-stage degenerative changes in disc morphology, height, and hydration. However these imaging methods cannot reliably detect disc constituent changes thought to contribute to early degeneration, such as loss of proteoglycan (PG) in the nucleus pulposus (NP). $T_{1\rho}$ -weighted MRI, defined as the spin-lattice relaxation in the rotating frame, is linearly correlated with proteoglycan content in articular cartilage [1] and may be able to detect PG content in the intervertebral disc. The objectives of this study were (1) to determine whether there is a relationship between $T_{1\rho}$ and PG content in human intervertebral disc tissue and (2) to demonstrate the feasibility of performing *in vivo* $T_{1\rho}$ imaging in the lumbar spine.

METHODS: Fresh-frozen cadaveric human lumbar spine sections (ages 15, 25, 45, 51, 67) were imaged on a 1.5T clinical MR scanner. A series of sagittal plane $T_{1\rho}$ -weighted images were acquired (4mm slice, $Tr/Te=3000/12$ msec, spin lock time (TSL) 15 to 75 msec). $T_{1\rho}$ was calculated on a pixel-by-pixel basis by fitting intensity data to the following exponential function: $S(TSL) = S_0 e^{-(TSL/T_{1\rho})}$. Mean $T_{1\rho}$ was taken from a 5mm circular region of interest in the center of the NP ($n = 19$ discs). A series of T_2 -weighted images (4mm slice, $Tr = 2000$, $Te = 15$ to 75) were used to generate quantitative T_2 maps. Site-matched NP samples were analyzed for water and glycosaminoglycan (s-GAG) content using the DMMB method. Linear regressions between $T_{1\rho}$, T_2 , water content, and s-GAG were performed. A volunteer (age 29, no back symptoms) underwent $T_{1\rho}$ imaging (sagittal plane, $Tr/Te = 3000/12$, TSL = 15 to 70) and a $T_{1\rho}$ map of the *in vivo* lumbar spine was generated.

RESULTS: There was a strong correlation ($r=0.7$, $p<0.01$) between $T_{1\rho}$ and s-GAG content. T_2 was moderately correlated with s-

GAG content ($r=0.5$, $p<0.05$). Neither $T_{1\rho}$ nor T_2 were significantly correlated with water content. The *in vivo* scan successfully generated a $T_{1\rho}$ map (Fig 1). $T_{1\rho}$ times (~100msec) from the *in vivo* scan were within the range of the cadaveric $T_{1\rho}$ values.

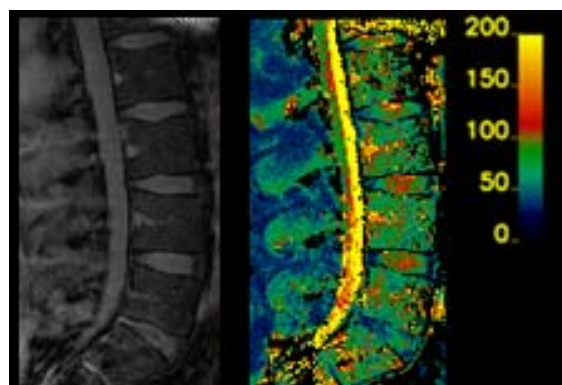


Fig.1: *In vivo* $T_{1\rho}$ image and map

DISCUSSION & CONCLUSIONS: In this preliminary study, $T_{1\rho}$ was found to vary in proportion to s-GAG content in the intervertebral disc. Thus, $T_{1\rho}$ MRI may provide a non-invasive technique to determine PG content in the intervertebral disc. $T_{1\rho}$ was better correlated with s-GAG than T_2 . Use of $T_{1\rho}$ may be an improvement upon previous attempts to determine biochemical content using quantitative MR and spectroscopy [2-4] because it does not require a contrast agent, can be performed relatively quickly in a clinical scanner, and provides a spatial map of PG content. This technique could potentially be used to diagnose early degeneration and to assess the efficacy of new biologic disc treatment strategies.

REFERENCES: ¹ U. Duvvuri et al (1997) *Mag Res Med* **38**:863-7. ² J. Antoniou et al (2004) *Mag Res Imag* **22**:963-72. ³ K. Keshari et al (2005) *Mag Res Med* **53**:519-27. ⁴ L.M. Benneker et al (2005) *Eur Spine J* **14**:27-35.

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