Quantifying Sodium in the Lumbar Spine *In Vivo* at 3T

M. Fenty[1], C. Wang[1,2], W. R. Witschey II[1,3], J. B. Kneeland, M.D. [4], R. Reddy, PhD[1], and A. Borthakur PhD[1]

[1]MMRRCC, University of Pennsylvania, Philadelphia, Pa, United States, [2]Bioengineering Graduate Group, University of Pennsylvania, Philadelphia, Pa, United States, [3]Biochemistry and Molecular Biophysics Graduate Group, University of Pennsylvania, Philadelphia, Pa, United States, [4]Department of Radiology, Pennsylvania Hospital, Philadelphia, Pa, United States

Objective

To measure sodium content via MRI in the intervertebral discs of the human lumbar spine *in vivo*.

Background

Lower back pain (LBP) is the second most frequent reason for a physician visit, permanently disables more than 5 million Americans and the annual costs are near $100 billion in the US [1]. Conventional T_1 and T_2 imaging techniques are useful for observing late structural morphological changes to the intervertebral discs (IVDs) but are insensitive to early biochemical changes [2]. Earlier degenerative changes occur within the IVD nucleus pulposus (NP), as large aggregating proteoglycans break down [3]. Sodium quantification has been validated as a biomarker for quantitative measurement of the proteoglycan content in cartilage tissue via a measurement of the tissue fixed charge density [4]. Previous studies have investigated sodium concentrations in the spine *in vivo* [5] however without quantifying sodium concentrations.

Materials and Methods

All experiments were performed with approval from the Institutional Review Board. MRI was performed on a Siemens 3T clinical scanner with a custom-built transmit/receive ^{23}Na surface coil. The coil diameter was 25cm and was constructed from transmission wire to ensure even capacitance around the loop. We employed a 3D GRE MRI sequence modified to detect sodium with the following imaging parameters: TE/TR/flip angle=6ms/30ms/90°, acquisition matrix 128x64x16, interpolated to 128x128x16, slice thickness = 12mm, in-plane resolution 6x6 mm^2, BW=60Hz/pixel. The scan was averaged 70 times for a total scan time of 30 minutes. CSF of the spine has a known sodium concentration of approximately 150mM and by assuming CSF and IVD's relaxation times, it is possible to compute sodium content in the IVDs.

Results

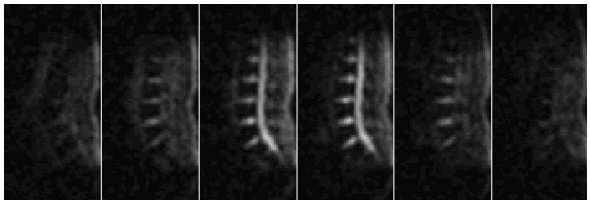

Figure 1: Representative middle 6 slices of the 16 slice 3D data set demonstrating full coverage of the entire lumbar spine in a healthy individual. The total scan time was approximately 30 minutes with SNR of the IVD sodium ~43:1

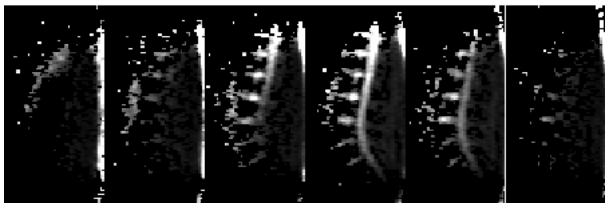

Figure 2: The same 6 images from Figure 1 after correction for signal inhomogeneity. Note the increased signal from the anterior ends of the discs (left side of each image) compared to the uncor[illegible] 1.

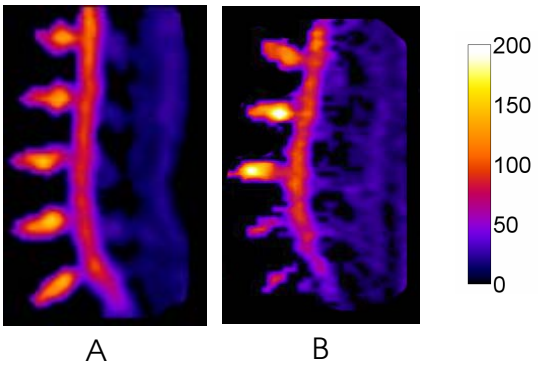

Figure 3: Sodium MRI indicates lower sodium content in a subject with lower lumbar trauma (B) in the two discs located at the bottom of the spine between L5/L4 and L4/L3 vertebrae compared to the age-matched healthy subject (A). Scale bar shows relative intensity differences.

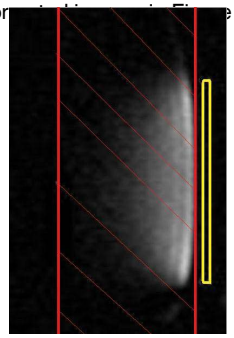

Figure 4: Sagittal scan of the center of a sodium phantom showing the signal drop-off from the surface coil (indicated as a yellow bar). The phantom dimensions are outlined in red and the diameter is 16 cm. These images were used to correct the inhomogeneity in the signal from the *in vivo* MR images

Conclusions:

Sodium MRI has been previously validated as an intrinsic biomarker for proteoglycan content within the extra-cellular matrix of cartilage. We demonstrate the utility of MRI to quantify sodium content in the discs of the lumbar spine. Work is in progress to perform additional studies to determine reproducibility of measurements and to correlate sodium content with $T_{1\rho}$ [**6**] and T_2 MRI measurements of proteoglycan content and tissue hydration *in vivo* and the utility of sodium as a biomarker for degenerative disc disease.

References

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