In Vivo T_2, $T_{1\rho}$, and Sodium Imaging of Articular Cartilage at 3.0T: Initial Experience

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Introduction: Early detection of proteoglycan depletion in cartilage is important in development of treatments for osteoarthritis. $T_{1\rho}$ imaging, or relaxation of spins under the influence of a radio-frequency field, has been shown to be sensitive to changes in the cartilage matrix [1-2]. T_2 mapping is thought to reflect changes in the collagen matrix of cartilage [3]. Sodium imaging has also been used to measure proteoglycan content in cartilage [4-5]. We studied the feasibility of using these techniques *in vivo* at 3.0T.

Methods: Four volunteers (ages 34-43) were imaged in the axial plane at 3.0T on a GE Signa MRI (GE Healthcare, Milwaukee, WI) using 3-inch coil. One volunteer had a history of anterior knee pain. Measurements of $T_{1\rho}$ were made with a continuous RF spin locking pulse at the same anatomic locations with spin lock frequencies of 300, 500, 700 and 1000 Hz. The maximum spin-lock frequency in the continuous RF sequence was limited by RF power deposition limits. T_2 relaxation time at the same location was measured using a T2-prepared spiral sequence. The $T_{1\rho}$ and CPMG T_2 sequences had identical imaging parameters: TR of 2000 ms, 14 spiral arms, 4096 points, and bandwidth $\pm$125 kHz. In-plane resolution was 0.7 mm with a 16 cm FOV, 4 mm slice thickness. A single slice through the patella cartilage was acquired in 5 minutes with two signal averages. The $T_{1\rho}$ sequences acquired 4 spin lock times (TSL) of 3, 15, 35, and 80 ms. The CPMG T_2 sequence acquired 6 echoes at approximately 6, 17, 28, 49, 71 and 92 ms.

Sodium imaging was performed with a custom 3-inch surfaces coil and a short echo time "cones" trajectory [6-7]. Sodium acquisitions were obtained at a voxel size of 1.25x1.25x4 mm. Parameters for the scan were: TR/TE = 50/0.6 ms, FOV = 16x16x12.8cm, matrix = 128x128x32, readout time = 8 ms, alpha = 70 deg, and 16 averages for a total scan time of 17 min 8 s.

$T_{1\rho}$ and T_2 relaxation times for each subject were measured in 10 cartilage locations on the medial and lateral patella facets. Sodium SNR was also measured in 10 locations on the medial and lateral facets, and in an area of increased relaxation times in the subject with knee pain. Relaxation measurements and maps were created using Osirix software [8].

Results: Across the range of spin lock frequencies, $T_{1\rho}$ values significantly increased with spin lock frequency (Figure 1). Measured $T_{1\rho}$ relaxation times significantly increased from 300 Hz to 500 Hz ($p < .01$), from 500 Hz to 700 Hz ($p < .01$), and from 700 Hz to 1000 Hz ($p < .01$). This is also seen on the color maps of relaxation times in healthy volunteers (Figure 1). An area of probable cartilage damage near the apex of the patella was identified by increased T_2 relaxation times and elevated $T_{1\rho}$ values in the subject with knee pain (Figure 2). Sodium images from this region showed significantly lower SNR (12.3$\pm$0.7 vs. 10.3$\pm$ 0.5; $p < .05$) compared with the lateral facet in that subject which had similar relaxation times and sodium values to the healthy volunteers.

Conclusion: This study demonstrates that comparison of $T_{1\rho}$ imaging, T_2 mapping, and sodium imaging is feasible *in vivo* on a clinical 3.0T scanner. The optimum spin lock frequency may be higher than achievable with RF power deposition limits at 3.0T. The sodium imaging results were uniform in all healthy subjects, and showed decreased signal in the area of increased T_2 and $T_{1\rho}$ relaxation times. Further studies with these methods in subjects prior to total knee replacement will enable the comparison of cartilage histology with imaging results.

References

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Acknowledgements: The authors wish to acknowledge support from NIH 1R01-EB002524 and1R01-EB005790, and Glaxo-Smith-Kline.

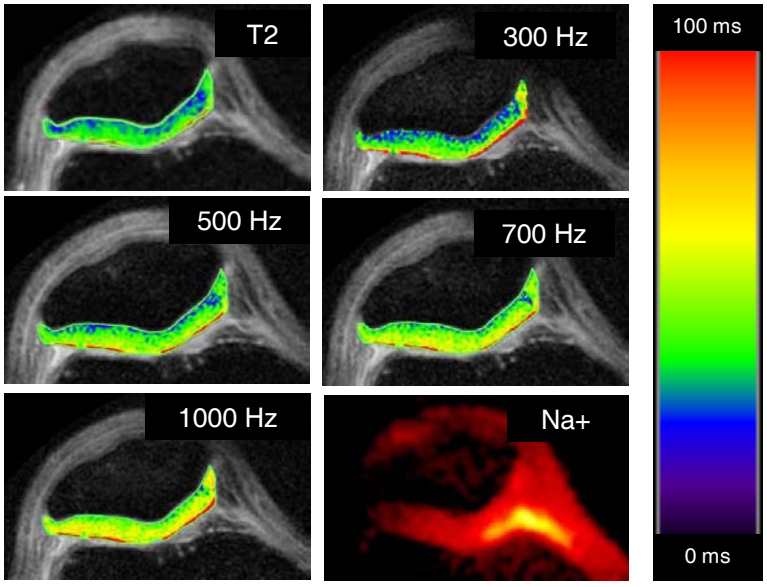

Figure 1: Comparison of the T_2, $T_{1\rho}$, and sodium images (heat scale) in a healthy volunteer.

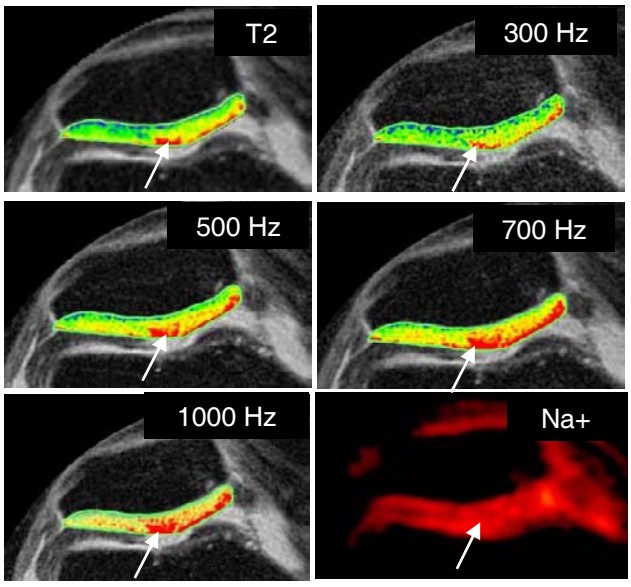

Figure 2: Comparison of the T_2, $T_{1\rho}$, and sodium images (heat scale) in a subject with cartilage damage (arrows).