Rapid 3D-Sodium MRI of Knee Joint In-vivo at 7T

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Introduction Loss of glycosaminoglycans (GAG) is a signature of early osteoarthritis (OA). Although sodium MRI has been shown to correlate linearly with GAG concentration (1, 2), it poses major challenges at clinical magnetic field strengths (1.5T/3.0T) in terms of low signal-to-noise (SNR), poor spatial resolution and long acquisition times due to low natural abundance, low sodium concentration and non-vanishing residual quadrupolar interaction results in rapid bi-exponential signal T_2 decay when compared to proton MRI. High and ultra high field systems (4.0T-9.4T) with improved gradient hardware and pulse sequences have potential in improving the spatial-temporal resolution of sodium MRI of knee in vivo in clinically acceptable scan times. Therefore, the aim of this study was to demonstrate the feasibility of acquiring high resolution, isotropic 3D-sodium MRI of whole knee joint in less than 15 minutes at 7T via 3D-radial acquisition with ultra short echo times.

Methods Five healthy controls (4 males, 1 female; mean age 28) and five OA patients (3 males, 2 females; mean age 52) underwent ^{23}Na–MRI on a 7T whole body imager equipped with multi-nuclei options (Siemens Medical Solutions, Erlangen, Germany). Approval for this study was obtained from our institutional review board (IRB) and informed consent was obtained from all the subjects. All the MRI experiments were performed utilizing a quadrature ^{23}Na knee coil (Rapid MR International, LLC, OH) and a 3D-GRE imaging sequence with radial acquisition (TR/TE = 80 ms/0.16 ms, BW = 130 Hz/pixel, signal averages = 10, with spatial resolutions = 1.5mm - 4mm, radial projections= 512-1024, acquisition times = 13:42 minutes). Five cylindrical calibration phantoms consisting of known sodium concentrations (100 - 300mM) were simultaneously imaged to obtain calibration data to compute cartilage Na^+ concentration as previously described (2). Compartment wise (Patella, femoral-tibial medial joint, and femoral-tibial lateral joint) sodium concentration was measured in healthy and OA patients. The Student's t-test was calculated to determine the statistical significance.

Fig.1

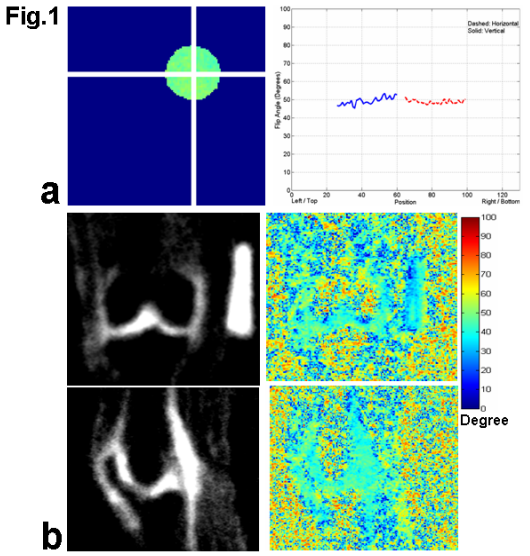
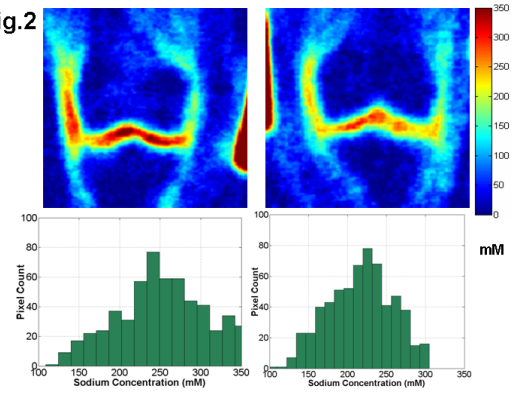


Fig.2



Results and Discussion There are only mild variations of flip angle distribution in the regions of interest of agarose phantom (Fig.1 (a)) and human cartilage in the coronal and sagittal planes (Fig. 1 (b)). Our results confirmed that sodium MR imaging is relatively insensitive to B_1 at 7T, although B_1 inhomogeneity, susceptibility, and chemical shift artifacts are all major concerns at higher field strengths in the case of proton MRI. The average SNR for different spatial resolutions (1.5mm - 4mm) varies from ~30 - 64 respectively. The left column of Fig.2 shows representative sodium concentration map of a healthy human cartilage at 7T with an isotropic resolution of 1.5 mm and the corresponding histogram of sodium concentration in the femoral-tibial knee joint. Likewise, the right column of Fig.2 shows the case from an OA patient. The mean sodium concentration of healthy and OA subjects ranged from ~240 to 280 mmol/L and ~180-240mmol/L, respectively. There is a significant difference in sodium concentration between healthy subjects and OA patients ($P < 0.05$).

Conclusion This is the first study that demonstrates the feasibility of acquiring high resolution, isotropic 3D-sodium knee images of healthy and OA patients at 7T in less than 15 minutes using a volume coil. The preliminary results suggest that the sodium imaging at 7T may be a viable potential alternative for OA imaging.

References

1). Bashir et al MRM, 41 (1999) 857-65. 2). Shapiro et al JMR 142 (2000) 24-31.