High-resolution 1H/23Na MR imaging of knee articular cartilage using dual-tuned knee coil at 7T

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[Introduction]

Osteoarthritis (OA), which is characterized by degradation of articular cartilage, is a common cause of disability in the aging population.. Early signs of OA involve changes in the matrix composition of articular cartilage including reduced glycosaminoglycan (GAG) concentration. The sodium concentration in cartilage on sodium MR images has been shown to correlate positively with GAG content and is used for both detecting and tracking early OA changes [1,2]. However, sodium MRI is challenging because of intrinsically low sodium concentrations in biological tissues and rapid bi-exponential signal decay. To achieve a good image quality of sodium MRI, it is imperative to maximize the sodium signal and improve the signal acquisition strategy for fast scan. Recent studies [3-5] have reported that the use of a specially designed knee coil using high-field MR improves the sodium signal and allows for the acquisition of diagnostic-quality in vivo sodium MRI of knee articular cartilage in reasonable scan times. The purpose of this study was to assess the feasibility of high-resolution proton and sodium MR imaging of the knee at 7T using a dual-tuned multi-channel $^{1}H/^{23}Na$ knee coil and quantitatively analyze the distribution of sodium signal intensity in different compartments of knee cartilage.

[Materials and Methods]

All scans were performed using a 7T human scanner (Siemens Medical Solutions, Erlangen, Germany). The knee coil consisted of four loops of proton and sodium was wrapped on a cylindrical plastic tube (Fig. 1). Each proton channel was tuned at 297.2 Mhz and each sodium channel was tuned at 78.61Mhz.

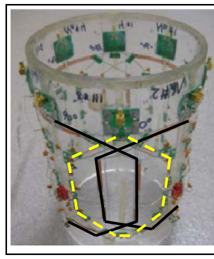

Fig. 1 Dual-tuned knee coil at 7T. Schematic diagram of coil loops of ^{1}H (*yellow-dotted line*) and ^{23}Na (*black-solid line*).

Proton and sodium imaging data was acquired from four subjects. Four calibration markers (plastic tubes with 80 mM [^{23}Na] saline) were placed on the four sides of subject's knee surface and used for sodium quantification. High resolution proton images of the knee were obtained using 3D DESS sequence (TR/TE = 15.75/5.2 ms, isotropic resolution 0.5 – 0.7 mm^3, and parallel imaging factor 2). We also acquired 3D spiral ultra-short TE proton images for one subject (TR/TE = 100/0.52 ms, isotropic resolution 1.4 mm^3, flip angle = 5°, and total acquisition 4 min). Sodium imaging of the knee was performed using 3D spiral trajectory sequence (TR/TE = 80/0.3 ms, flip angle = 90°, isotropic resolution = 2 mm^3, and total acquisition time = ~20 min). Cartilage signal intensity on the sodium images was measured at five compartments (patellar, medial femoral, lateral femoral, medial tibial, and lateral tibial) using the DESS and ultra-short TE proton images as the anatomical references.

[Results and Discussions]

Excellent image-quality DESS ^{1}H images (Fig. 2A) with isotropic resolution of 0.5 mm^3 and ^{23}Na images (Fig. 2B) with resolution of 2.0 mm^3 were obtained. Cartilage at different knee compartments and microstructures of trabecular bone were clearly depicted with superb anatomical details on the DESS images (Fig. 2A). In addition, the acquired ultra-short TE images (Fig. 2C) may play an important role as the intermediate reference image that would facilitate the accurate registration between the DESS and sodium images for precise demarcation of different cartilage regions and quantification of regional sodium signal intensity. The menisci between the femoral and tibial cartilages were visualized on the DESS, sodium and ultra-short TE images (*yellow arrowheads* in Figs. 2A-C). In each normal subject, a homogeneous and intense sodium signal was measured at five knee cartilage compartments (mean sodium signal intensity: patellar=240; medial femoral=237; lateral femoral=230; medial tibial=195; lateral tibial=190) (Fig. 2B). The mean sodium signal was measured 59 in the muscles and 196 in the popliteal vessels. The mean sodium signal at the markers was 470.

In summary, we acquired high-resolution proton and sodium images at 7T using a dual-tuned $^{1}H/^{23}Na$ coil. The sodium signal of the cartilage in the normal subjects was homogeneous and intense, and was quantitatively analyzed at different compartments. Furthermore, the 3D ultra-short-echo proton imaging may facilitate the accurate registration between the high-resolution proton and sodium images for precise quantification of regional sodium concentration.

[Reference] [1] Shapiro et al. *MRM*, 47(2): 284-91 (2002). [2] Gray et al. *J Ortho Res*, 26(30): 281-91 (2008). [3] Staroswiecki et al. *ISMRM*, p384 (2007). [4] Gold et al. *ISMRM*, p3969 (2009). [5] Wang et al. *JMRI*, 30:606-614 (2009).

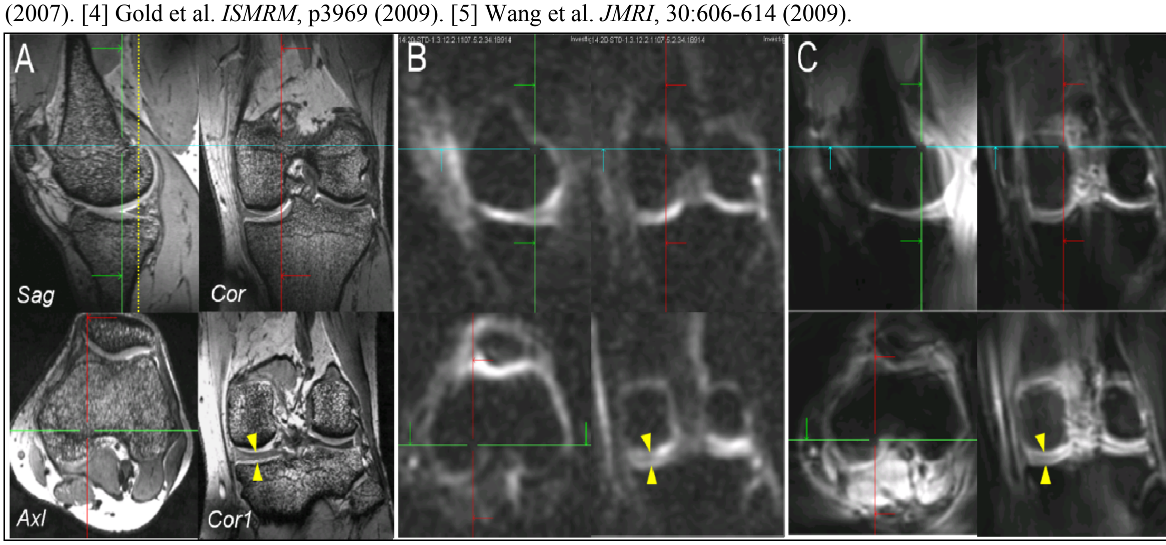

Fig. 2 $^{1}H/^{23}Na$ knee MR imaging at 7T. Proton (**A**), sodium (**B**), and ultra-short TE (**C**) images of subject 1 acquired; sagittal (*red line*), coronal (*green*), and axial (*cyan*) plane. All compartments of knee cartilage (patellar, femoral and tibial) are well demarcated on each image (**A-C**). Note the menisci and separation between femoral and tibial cartilages (*yellow arrowheads* on **A-C**)