In vivo high resolution imaging of the knee at 7T-potential for MRI of Osteoarthritis

S. Banerjee[1,2], R. Krug[1], D. Xu[1], R. Stahl[1], L. Carvajal[1], T. M. Link[1], D. A. Kelley[3], D. B. Vigneron[1,2], and S. Majumdar[1,2]

[1]Radiology, University of California San Francisco, San Francisco, California, United States, [2]Joint Graduate Group in Bioengineering, University of California San Francisco-University of California Berkeley, Berkeley, California, United States, [3]Healthcare, GE, San Francisco, California

Introduction: Recently, initial experience in knee imaging at 7 T with a focus towards relaxation characteristics of cartilage was reported in the literature [1]. MRI of osteoarthritis of the knee studies the interaction of articular cartilage degeneration with changes in bone structure by quantifying bone and cartilage morphology and relaxation. [2]. A gain in signal-to-noise and contrast-to-noise ratio at 7 Tesla might aid in more accurate quantification of the morphology metrics from the MR images. The compatibility of parallel imaging with high field strength might also allow rapid acquisitions without compromising on image quality.

Methods: MR scans of the knee were acquired from three volunteers on the 3 T GE Signa Echo speed MR scanner and the 7 T GE EXCITE scanner. A quadrature receiver coil (Pfizer) was used at the 3 T and a quadrature transmit/receive coil (Nova Medical) with two channels was used at 7 T. Knee cartilage was imaged with three dimensional (3D) fat suppressed Spoiled Gradient Recalled (fs-SPGR) sequence with TR(ms)/TE(ms)/BW(KHz)/flip(°) =17.1/5/32/20 at 3 T and 17.1/3.7/64/18 at 7 T. In-plane resolution and slice thickness were 0 .237 mm and 1.5 respectively for an acquisition time of 6:45 minutes. Additionally at 7 T, an accelerated cartilage scan with acceleration factor R=2 and 12 autocalibrating (AC) lines and scan time of 3:35 mins was conducted. Trabecular bone structure of the knee was imaged with 3D cycled Fast Imaging Employing Steady State Acquisition (FIESTAc) sequence with two phase cycles, partial echo, TR(ms)/TE(ms)/BW(KHz) of 13.9/2.9/32 and a flip angle of 60° at 3 T and 40° at 7 T. A two-fold acceleration with 12 AC lines was employed to yield a scan time of 9 minutes. In plane resolution and slice thickness was was .156 mm and .5 mm respectively. Accelerated images were reconstructed offline on a Sun Workstation using a GRAPPA based parallel reconstruction developed in our lab [3]. Since the receiver at 3 T has a single channel, full FOV dataset for the FIESTAc scan was reconstructed from the two undersampled phase-cycled acquisition datasets using a reconstruction algorithm similar to GRAPPA. So unlike in parallel imaging, in this case the multiple undersampled observations were provided by multiple phase-cycled acquisitions rather than multiple coils. This method has been previously referred to as the superFOV(sFOV) method [4]. Signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) (between cartilage and joint fluid) in case of SPGR sequences was measured. Blind qualitative scoring of 3T and 7 T images based on image quality and presence of artifacts was also conducted by two experienced radiologists.

Figure 1: Sharper delineation between femoral and tibial cartilage can be seen at 7T compared to 3T. Line profiles from the images are also shown

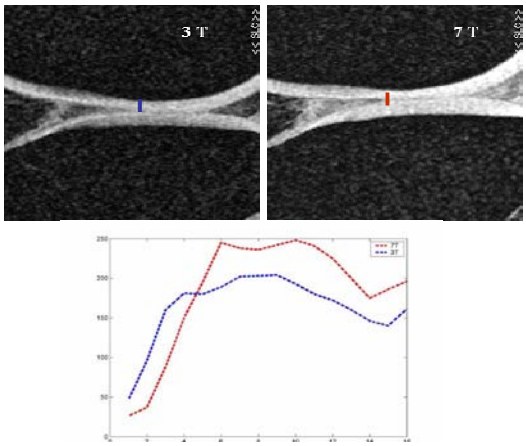


Figure2: Representative 3D fs-SPGR images of the knee acquired at 7 Tesla with R=1 (6:45 mins) and R=2 (3:35 mins)

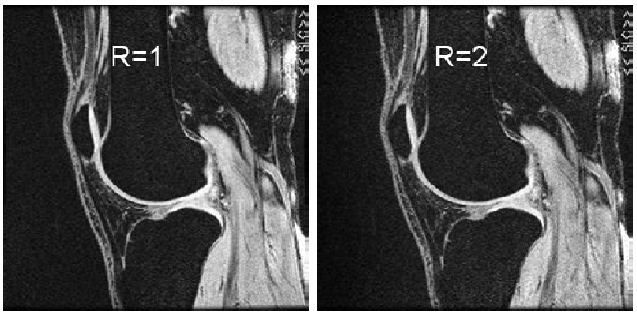
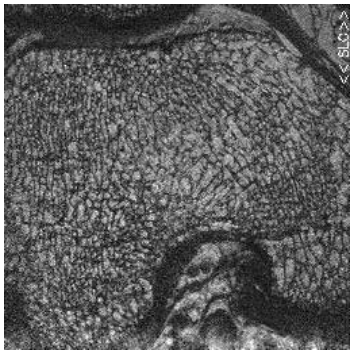


Figure 3: Representative HR image of trabecular bone structure at the knee acquired with 7 T.



Results and Discussion: Cartilage had a more homogeneous appearance and showed better delineation between femoral and tibial cartilage at 7 T compared to 3 T (Fig.1)- this might help in more accurate quantification of cartilage morphology. Radiological scoring between the two field strengths didn't have a significant difference though 7T images had a better score in the category of absence of artifacts. Mean increase in SNR and CNR of 45% and 55% for cartilage and mean SNR increase of 60% for trabecular bone was observed from 3 T to 7 T. R=2 images of the cartilage acquired at 7 T had comparable image quality to their unaccelerated counterpart (Fig. 2). Good depiction of the trabecular bone micro-architecture of the knee from a 7T acquisition is shown in Fig. 3. Regatte et al reported ~ 35-40% increase in T1 values of cartilage from 3 T to 7 T [1]. So to get full SNR advantage, longer repetition times should be used for cartilage imaging at 7 T. Broadening of bone structures at 7 T might have led to an underestimation of the SNR increase in trabecular bone. The sFOV reconstruction yielded better image quality at 7 T compared to 3 T probably because the datasets from different phase-cycled acquisitions of FIESTAc are more distinct due to dielelctric effects at 7 T. With the availability of phased array receiver arrays, rapid image acquisition at high acceleration factors can be achieved at 7 T. MRI of osteoarthritis can benefit considerably from 7 T imaging.

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References:

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