Evaluation of the Articular Cartilage of the Knee Joint at 3T Using Vastly Undersampled Isotropic Projection Steady-State Free-Precession (VIPR-SSFP) Imaging

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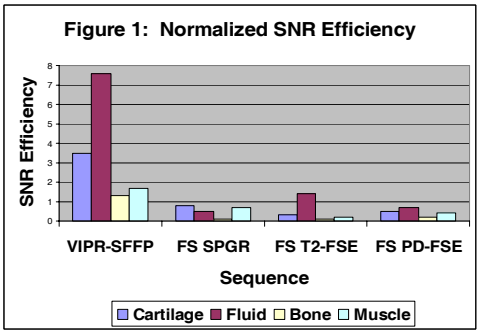
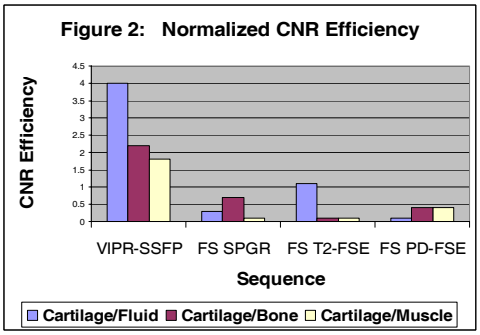
Objective: The vastly undersampled isotropic projection steady-state free-precession (VIPR-SSFP) sequence has been shown to be highly effective for evaluating articular cartilage on 1.5T imaging systems. (1, 2) Adapting the technique to 3T imaging systems is not straight forward because the optimal TR of 1.2 msec at 3T for fat-water separation using linear combination SSFP will not allow adequate time for spatial encoding. Skipping a passband with a TR of 3.6 msec at 3T allows for a much longer time to achieve higher resolution than is possible at 1.5T. Using multiple-echoes and tracking the phase of the desired signal component, usually water, between echoes also allows a Dixon-like capability that removes unwanted fat signal that leaks into the image volume from the skipped passband. (3) This study was performed to determine the ability of a newly developed 3T version of the VIPR-SSFP sequence to evaluate the articular cartilage of the knee joint.

Methods: An MR examination of the knee of was performed on 7 asymptomatic volunteers and 3 patients with osteoarthritis using a GE 3T scanner (v14.0, GE Healthcare, Waukesha, WI) and an 8-channel phased array extremity coil. All MR examinations consisted of a VIPR-SSFP sequence (0.47 mm x 0.47 mm x 0.47 mm voxel size and 5:00 min scan time), a fat-suppressed spoiled gradient recalled-echo (FS SPGR) sequence (0.38 mm x 0.71 mm x 1.20 mm voxel size and 4:25 min scan time), a fat-suppressed T2-weighted fast spin-echo (FS T2-FSE) sequence (0.36 mm x 0.63 mm x 3.50 mm voxel size and 3:53 min scan time), and a fat-suppressed proton density-weighted fast spin-echo (FS PD-FSE) sequence (0.36 mm x 0.63 mm x 3.00 mm voxel size and 3:16 min scan time). The signal-to-noise (SNR) efficiency of articular cartilage, synovial fluid, subchondral bone, and muscle and the contrast-to-noise (CNR) efficiency between articular cartilage and synovial fluid, subchondral bone, and muscle were calculated for all sequences. SNR and CNR efficiency measurements were normalized to account for differences in the voxel size between the sequences. Paired t-tests were used to compare the normalized SNR and CNR efficiency measurements.

Results: The VIPR-SSFP sequence had significantly higher ($p<0.05$) normalized cartilage SNR efficiency and significantly higher ($p<0.05$) normalized CNR efficiency between articular cartilage and synovial fluid, subchondral bone, and muscle than the FS SPGR, FS T2-FSE, and FS PD-FSE sequences (Figures 1 and 2). The VIPR-SSFP sequence provided excellent visualization of the articular cartilage of the knee joint in all subjects. On VIPR-SSFP images, the intermediate signal intensity articular cartilage was well distinguished from the adjacent high signal intensity synovial fluid and low signal intensity subchondral bone (Figure 3A). The high signal intensity synovial fluid on VIPR-SSFP images created an arthrogram-like effect which allowed excellent visualization of cartilage defects (Figure 3B). Due to the isotropic resolution of the VIPR-SSFP sequence, cartilage defects could be visualized in multiple planes following a single acquisition (Figures 3C and 3D).





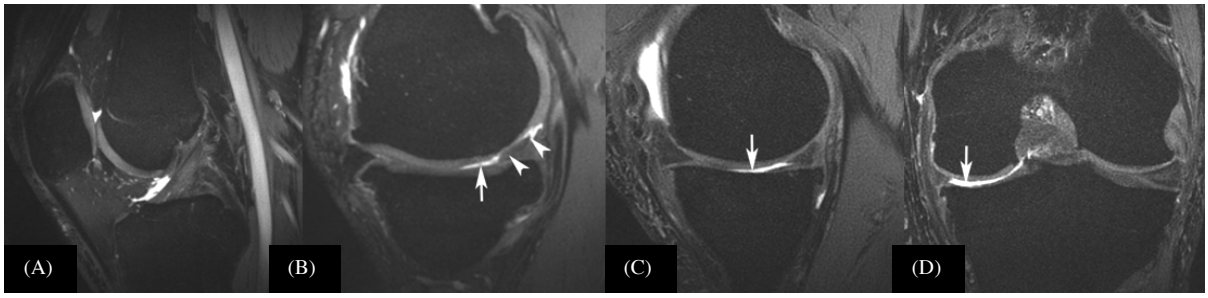


Figure 3: (A) Sagittal VIPR-SSFP reformat image of the knee in an asymptomatic volunteer shows excellent visualization of articular cartilage. (B) Sagittal VIPR-SSFP reformat image of the knee in a patient with osteoarthritis shows partial-thickness cartilage loss anteriorly (arrow) and full-thickness cartilage loss posteriorly (arrowheads) on the medial femoral condyle. (C) Sagittal VIPR-SSFP reformat image and (D) coronal VIPR-SSFP reformat image of the knee in another patient with osteoarthritis show full-thickness cartilage loss on the medial tibial plateau.

Conclusions: The VIPR-SSFP sequence produces high quality multi-planar images of the knee with 0.47 mm isotropic resolution at 3T which provide excellent visualization of articular cartilage. VIPR-SSFP images have significantly higher cartilage SNR and significantly greater contrast between articular cartilage and synovial fluid, subchondral bone, and muscle than images obtained using currently available cartilage imaging sequences.

References: 1) Kijowski, et. al, J Magn Reson Imaging, 24:168-75, 2006. 2) Lu, et al., Magn Reson Med, 54:1051-7, 2005. 3) Jashnami, et al. ISMRM 2006, p.3607.