379 EVALUATION OF NEW MR IMAGING TECHNIQUES FOR ASSESSMENT OF CARTILAGE VOLUME IN THE KNEE

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Purpose: Accurate imaging of cartilage morphology is necessary to diagnose and track osteoarthritis (OA), test drug efficacy, and study surgical recovery. The gold standard in MR imaging of cartilage morphology is 3D spoiled gradient echo (SPGR). In this study, we compare two alternative imaging sequences: (1) 3D-FSE acquisition using an extended echo train acquisition and 2D-accelerated auto-calibrated parallel imaging (3D-FSE-Cube) and (2) vastly undersampled isotropic projection reconstruction (VIPR) – to SPGR with water/fat separation (IDEAL-SPGR) and parallel imaging. 3D-FSE-Cube improves upon 2D-FSE by using modulated refocusing flip angles over an extended echo train acquisition to constrain the T2 decay that leads to blurring. VIPR acquires true 3D radial sampling that begins and ends at the k-space origin in a very short TR, reducing the likelihood of banding artifact that is common to other steady-state free precession (SSFP) techniques.
Methods: Ten knees of healthy volunteers were imaged using a GE Signa HDx 3.0T MRI scanner and an 8-channel knee coil. IDEAL-SPGR was done with TR/TE 16/8 ms, BW ±31.25 kHz, 14-degree FA, 384×224 matrix, 15 cm FOV, 1 mm sections, 90 slices, acceleration factor 2, and 5:07 scan time. 3D-FSE-Cube used TR/TE 2220/24 ms, BW ±31.25 kHz, ETL 44, 256×256 matrix, 0.5 NEX, 15 cm FOV, 0.7 mm sections, 200 slices, fat-saturation, acceleration factor 3.48, and 5:00 scan time. VIPR was acquired with TR/TE 3.6/0.3 ms, BW ±125 kHz, 15-degree FA, 384×384×384 matrix, 1 NEX, 15 cm FOV, 5:00 scan time, and 3-slice averages in sagittal, axial, and coronal planes to obtain 0.39×0.39 mm in-plane resolution and 1.2 mm sections. Signal-to-noise ratio (SNR) was measured in cartilage and joint fluid, and fluid/cartilage cartilage-to-noise ratio (CNR) was calculated. SNR and CNR values were normalized to account for differences in voxel size. Cartilage volume was measured by segmentation with OsiriX. Each variable was analyzed by the Friedman test and a post-hoc paired t-test.

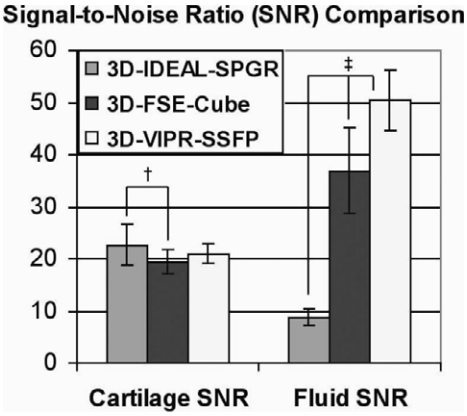

Figure 1. All three sequences have comparable cartilage SNR, with the exception that IDEAL-SPGR has higher cartilage SNR than 3D-FSE-Cube (†$p < 0.01$). VIPR has the highest fluid SNR, followed by 3D-FSE-Cube, then IDEAL-SPGR (‡$p < 0.001$).

Results: VIPR had comparable cartilage SNR (20.9±1.9) to IDEAL-SPGR (22.7±4.0, $p > 0.1$) and 3D-FSE-Cube (19.4±2.3, $p > 0.1$). IDEAL-SPGR yielded higher cartilage SNR than 3D-FSE-Cube ($p < 0.01$), likely due to its shorter TE. VIPR produced the greatest fluid SNR (50.3±5.8), followed by 3D-FSE-Cube (36.9±8.2) and IDEAL-SPGR (8.8±1.6), with related $p < 0.001$.
VIPR yielded CNR (29.4±6.1, $p < 0.001$) that was higher than the comparable CNR values of 3D-FSE-Cube (17.5±7.8) and IDEAL-SPGR (13.9±3.6, $p > 0.2$). VIPR, 3D-FSE-Cube, and IDEAL-SPGR all produced equivalent volume measurements of the femoral, tibial, and patellar cartilage (Friedman test, $p > 0.4$).
Conclusions: VIPR and 3D-FSE-Cube each has the potential to replace a 3D-SPGR/2D-FSE clinical and research imaging protocol of OA, as they are able to save time with their single isotropic acquisition. VIPR and 3D-FSE-Cube replicate the advantage of 3D-SPGR by providing accurate volume measurements. VIPR and 3D-FSE-Cube also have SNR and CNR comparable to IDEAL-SPGR, while also displaying the bright synovial fluid characteristic of 2D-FSE that may highlight cartilage surface defects and may allow for diagnosis of ligament and meniscal pathology. In conclusion, VIPR and 3D-FSE-Cube have great promise for a more rapid evaluation of OA in the knee.

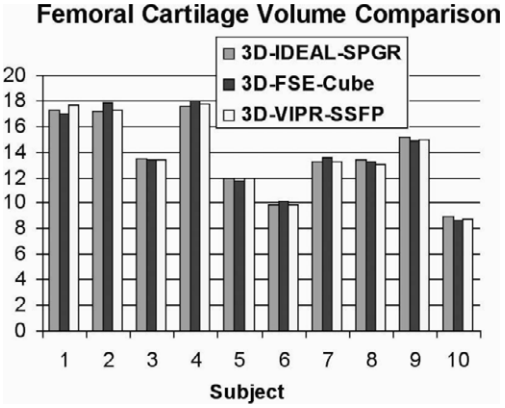

Figure 2. 3D-FSE-Cube and VIPR produced equivalent cartilage volume measurements to IDEAL-SPGR (Friedman test, $p > 0.4$) for femoral, patellar, and tibial cartilage.

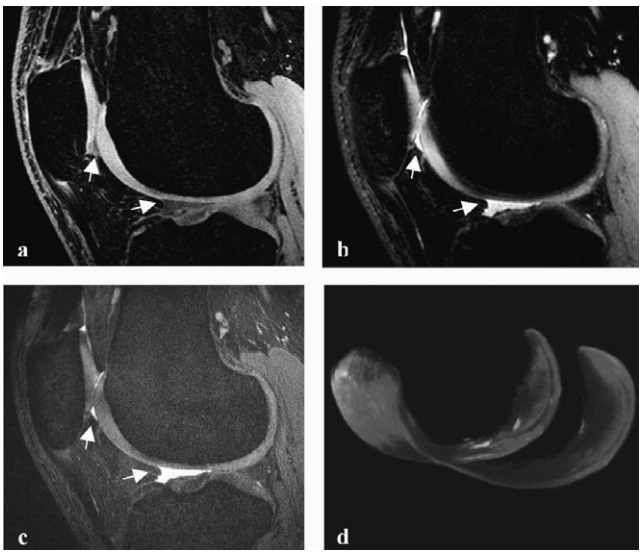

Figure 3. Images from a healthy volunteer. (a) IDEAL-SPGR water, (b) 3D-FSE-Cube, and (c) VIPR images at 3.0 T all show excellent cartilage depiction but different fluid cartilage contrast, with higher fluid signal (arrows) in 3D-FSE-Cube and VIPR than IDEAL-SPGR. (d) Model created from femoral cartilage segmentation of 3D-FSE-Cube images.

380 VALIDITY OF THE SONOGRAPHIC LONGITUDINAL SAGITTAL IMAGE FOR ASSESSMENT OF THE CARTILAGE THICKNESS IN THE KNEE OSTEOARTHRITIS

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Purpose: To compare the validity of the sonographic longitudinal sagittal image with the suprapatellar transverse axial image for assessment of thickness of femoral cartilage in osteoarthritis (OA) patients.
Methods: Fifty-one patients with knee OA were enrolled in this study. Cartilage thicknesses of medial and lateral femoral condyles were measured with longitudinal sagittal and suprapatellar transverse axial image using

sonography. Fat-suppressed 3D spoiled gradient-echo MRI was also used to get the reference value. The joint space width (JSW) and Kellgren and Lawrence (K-L) grade were measured in weight-bearing anteroposterior knee radiograph. The Kappa and intraclass correlation coefficient (ICC) were used to determine inter- and intra-observer agreement of the US measurements.

Results: In medial femoral condyle, the opportunity to obtain cartilage thickness was increased significantly using the longitudinal US scan as compared with tansverse scan (48 cases vs. 36 cases, $p < 0.05$). There was a good correlation between longitudinal US scan and MRI in the maximum and minimum cartilage thicknesses of medial condyle ($r = 0.568$; $r = 0.844$, respectively, $p < 0.01$). However, there was no correlation between suprapatellar transverse US scan and MRI in medial condyle. In lateral condyle, both US scans showed good correlations with MRI. In Bland-Altman analysis, longitudinal US scan showed good agreement with MRI except in the minimal cartilage thickness of lateral condyle. There was high overall intra- and inter-observer agreement in US scan.

Conclusions: US scan in the longitudinal plane is a more feasible method than suprapatellar transverse scan for measuring cartilages thickness of medial femoral condyle in knee OA patient.

381 SECOND HARMONIC GENERATION IMAGING AND COLLAGENEOUS MATRIX MODIFICATION IN OSTEOARTHRITIS DISEASE

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Purpose: In healthy cartilage, collagen fibers are pseudo-randomly distributed and interact with a gel of Proteoglycans. Degenerative disease like osteoarthritis can affect the organization of the extracellular matrix (ECM) surrounding chondrocytes leading to a modification or even degradation of the collagen network. The aim of this work was to characterize the remodelling of the collagen network under mechanical or biochemical stress.

Methods: Near infrared tomography (Multiphoton Excitation, Second Harmonic Generation SHG, Fluorescence Lifetime imaging Microscopy FLIM) represents an appropriate tool for cartilage imaging due to its advantages in terms of depth penetration. In the ECM collagen fibers give rise to a strong SHG signal (high non linear susceptibility) and Proteoglycans show a high level of autofluorescent after multiphoton excitation.

Under mechanical stress, a remodeling of the collagen network occurs and can be comparable to disturbance occurring in disease. To characterize structural modification on the arrangement of collagen fibers in the ECM, we used image analysis based on co-occurrence matrix (Haralick). Textural parameters can give information like homogeneity ('Angular Second Moment') or size of textural elements ('Inverse Difference Moment', 'Correlation'). We followed their evolution when samples were submitted to mechanical (compression) or biochemical (Collagenase) stress.

Results: It came out that the behavior of the collagen network was different under compression or enzymatic action.

Enzymatic action of Collagenase lead to a loss of SHG signal according to time of incubation: this evolution can either be attributed to a loss of collagen content or to a modification of collagen molecules affecting their non linear susceptibility. By this way, we proved that the SHG signal came specifically from collagen in cartilage samples.

Samples submitted to compression were characterized by higher 'Correlation', associated with a decrease of 'IDM' and 'ASM'. Those evolutions suggest the presence of long linear structures, an effect of packing of collagen fibrils and the apparition of nodes where the density of collagen is important versus areas showing a lack of molecules. Moreover the ECM seemed more dense and compact and SHG signal was even more intense.

We also were interested in the pericellular matrix of chondrocytes containing type VI Collagen. This molecule acts as a transducer of biochemical or biomechanical signals and hypothesis have been emitted about its protective role. Moreover, during osteoarthritis, its content in the pericellular area increases when compared to healthy specimens. Thus Collagen VI can be considered as a biomarker characterising disease states. FLIM associated to Spectral and SHG analysis confirmed the presence of Collagen VI in the pericellular matrix of chondrocytes.

Conclusions: SHG, FLIM and Spectral Imaging combined with multiphoton excitation enable tissue imaging at deep penetration. The association of all this imaging modalities represents a potential diagnostic tool for cartilage disease, since it enables to detect local modification of the collagen network of the ECM without any labelling (SHG) and the presence of collagen VI in the lacunae around cells. Moreover these imaging techniques can be used to validate the well functionality of bioconstructs by following synthesis of collagen for instance.

This work was partly supported by a grant of CG54 and Region de Lorraine.

382 COMPARISON OF ONE YEAR CHANGE IN MINIMUM JOINT SPACE WIDTH TO FIXED LOCATION JOINT SPACE MEASUREMENTS IN LYON SCHUSS X-RAYS FROM THE A9001140 STUDY

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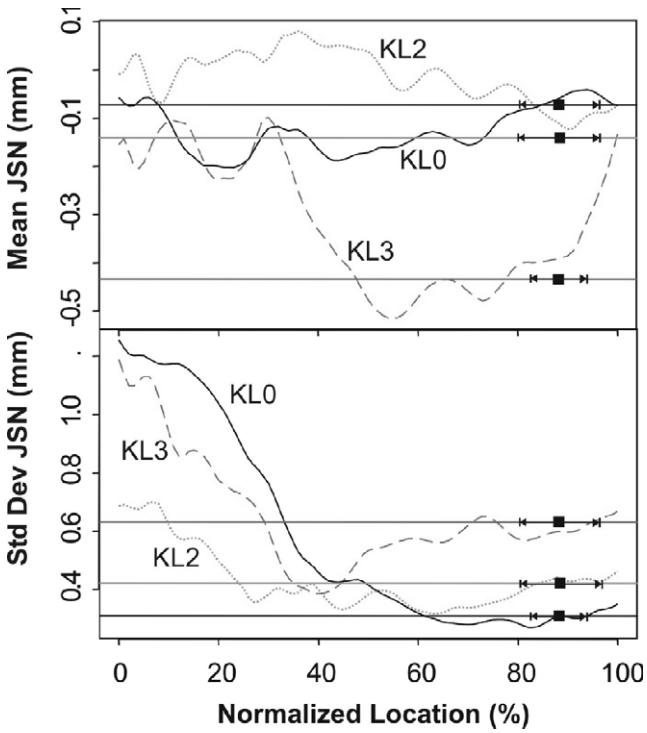
Purpose: Joint space narrowing (JSN) calculated from the change in minimum joint space width (mJSW) from x-ray has become a valuable tool for the monitoring of progression in osteoarthritis (OA). The goal of this analysis was to investigate the relative sensitivity of JSN when measured at fixed locations in Lyon schuss x-rays.

Methods: Lyon schuss x-rays from a subset of 67 subjects from the A9001140 study acquired at 7 sites at baseline and 12 months were analyzed using KneeAnalyzer (Optasia Medical), proprietary statistical model-based analysis software. The femoral and tibial margins of the medial compartment were segmented and JSW was measured along a normalized distance across the medial compartment from 0% at the tibial spine to 100% at the medial margin of the tibia. 31 subjects had Non-OA defined as Kellgren and Lawrence (KL) grades of 0 or 1. The OA subjects had KL = 2 (n = 17) or KL = 3 (n = 19). The JSN at the mJSW location and the average JSN between 51%-90% (aJSN 51−90%) were calculated along with the standard deviation (Std Dev) and the standard response mean (SRM). Significance was determined by $p < 0.05$.



Results: Figure 1 shows the mean (top) and standard deviation (bottom) of the JSN for each KL group across the medial compartment. The squares are the location of the mJSW measurement (± one Std Dev). Between 50 and about 85% the profiles are relatively flat indicating a consistent difference in JSN. However, around 90% (the approximate