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TIBIOFEMORAL JOINT OSTEOARTHRITIS ONE YEAR AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: A MAGNETIC RESONANCE IMAGING EVALUATION

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Purpose: Radiographic tibiofemoral joint (TFJ) osteoarthritis (OA) is known to be common more than five years after anterior cruciate ligament injury and reconstruction (ACLR). Magnetic resonance (MR) imaging enables evaluation of early, pre-radiographic features of OA, which may be important for individuals at high risk of OA. Specifically, MR imaging may be useful to assess the onset of OA at an earlier stage after ACLR. A recently proposed tool to assess OA features and prevalence of TFJ OA from MR images is the MR Imaging Osteoarthritis Knee Score (MOAKS). This study aimed to (i) establish the reliability of the MOAKS in novice readers; (ii) describe the prevalence of OA features and TFJ OA one year after ACLR; and (iii) investigate the relationship between meniscal or cartilage damage at the time of ACLR and the presence of meniscal or cartilage damage one year later.

Methods: One hundred and eighteen participants (65% male; age 31±9 years; BMI 26.1±4.0kg·m-2; median time from injury to surgery 3 months) who were approximately one year post ACLR with a single bundle hamstring tendon autograft were recruited from two orthopaedic surgery clinics. High field MR imaging at 3 Tesla was performed on all participants and the MOAKS was used by two novice readers (medical students), following an intensive training regimen by a musculoskeletal radiologist, to score specific features of OA and to evaluate the prevalence of TFJ OA based on published criteria. Inter-rater reliability was calculated using the kappa statistic. Binary logistic regression analysis was used to study the relationship between meniscal or cartilage damage at time of surgery and meniscal or cartilage damage on MR imaging one year later.

Results: Most measures of inter-rater reliability from the MOAKS were substantial (78% of kappa values > 0.6). Osteoarthritis features appeared slightly more prevalent in the medial compartment than in the lateral compartment. Prevalence of bone marrow lesions in the medial and lateral compartment were 62% and 48%, respectively, with articular cartilage lesions (21% and 15%), osteophytes (30% and 26%) and meniscal damage (32% medial and 30% lateral) also frequently observed in both compartments. Of the 118 participants 17 (14%) met the criteria for TFJ OA, following the MOAKS scoring system. Cartilage damage one year post ACLR was predicted by cartilage damage present at time of surgery. Meniscal damage one year post ACLR observed from MR images was predicted by meniscal damage seen at time of surgery, age and gender.

Conclusions: Inter-rater agreement between the two novice readers using the MOAKS instrument to evaluate OA features in the TFJ one year after ACLR was high. These results add to other data recently published on the MOAKS and indicate that the MOAKS may be used by different researchers with varying levels of experience and at the early stages of OA disease. Although TFJ OA and OA features identified on MR imaging are evident as early as one year after ACLR, the stability of these features, particularly BMLs, which may resolve or progress over time, is not well understood. Further research investigating whether these features are risk factors for disease progression is therefore warranted.

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IMAGE QUALITY CONSIDERATIONS FOR ACCURATE QUANTITATIVE T1ρ MAGNETIC RESONANCE IMAGING

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Purpose: T1ρ relaxation arises from interactions of protons between free water and macromolecules. T1ρ is emerging as an imaging biomarker as its measurement can serve as an indicator of the biochemical state of tissue, finding use in joints to assess cartilage degeneration in the knee and spine. Quantitative T1ρ measurements require acquisition of multiple images with varying T1ρ preparation weightings for derivation of relaxation maps. T1ρ imaging protocols must balance time efficiency with image quality sufficient to generate accurate quantitative information. The purpose of this study was to investigate the interplay of imaging characteristics such as signal-to-noise ratio (SNR) and selection of T1ρ weightings to assess efficient protocols for quantitative T1ρ imaging.

Methods: Imaging experiments used a special phantom to assess T1ρ measurements across a range of protocols (see image below). The phantom contained concentric Plexiglas rings separating compartments filled with 1% carrageenan and varying levels of agarose gel doped with gadolinium trichloride to vary expected T1ρ over a physiologic range. Scans were performed on a Siemens 3T Tim Trio equipped with a 15-channel transmit/receive extremity coil. T1ρ weighted images derived from a segmented 3D gradient-echo-based pulse sequence with a conventional T1ρ preparation block (+90° tip-down, spin lock durations of 10, 20, 40, and 60ms at 400Hz amplitude, -90° tip-up and crusher gradient) applied prior to acquisition of segments of 16 centrically ordered k-space lines. Additional imaging parameters were intrasegment TR/TE = 9.4/4.7ms, intersegment repetition time = 1000ms, FOV = 16cm x 16cm with 256x128 matrix covering 16 slices, BW=260 Hz/pixel for a scan time of 2:10 per spin lock time (8:40 total). Images were acquired sagittally, corresponding to typical use in knee imaging. To assess varying SNR, volumes with 4mm, 2mm, and 1mm slices were acquired at identical center locations, yielding images with correspondingly reduced SNR. T1ρ relaxation times were calculated for the central slice of each volume using a monoexponential nonlinear least squares fit with all four acquired spin lock times as well as only two times (10ms and 60ms). The 4mm thick slice with four relaxation times was considered the standard against which the other five combinations were compared by normalized RMS error (NRMSE) over a 10x60 voxel region of interest (ROI).

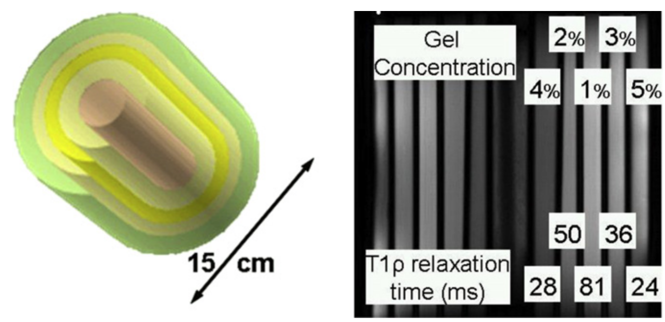

Table 1 shows the calculated mean T1ρ and measured SNR for the 10ms and 60ms images, and NRMSE over the ROI compared to full thickness and full set of spin lock times for each slice thickness (SNR condition) and number of points included in the curve fit computation. SNR values generally followed the expected trends, though there was some spatial variation arising from non-uniform coil sensitivity. Mean T1ρ measurements did not vary significantly for any of the 4-point measurements. For reference, the standard deviation of T1ρ measured in the reference scan was <2% of the mean value for all gels.

Conclusions: Accurate estimation of T1ρ relaxation times requires images of sufficient quality over the range of acquired spin lock times. As expected, NRMSE increases with decreased SNR, though for 4-point fits, the error does not grow beyond 5% even for SNR levels down to 15. The use of 2 points for T1ρ calculations appears acceptable when both images have high SNR, but measurements degrade rapidly when the

Table 1
T1ρ, SNR, NRMS error values compared to 4 point full thickness standard.

Gel	Slice thickness	Mean T1ρ (ms)	SNR 10/60ms	NRSME (4 pts)	NRMSE (2 pts)
1%	4 mm	81.2	275/123	–	0.59%
	2 mm	83.1	153/68	3.08%	3.28%
	1 mm	81.6	88/43	4.21%	4.64%
2%	4 mm	50.1	239/72	–	1.10%
	2 mm	50.0	133/40	2.50%	2.53%
	1 mm	49.7	75/26	4.48%	4.90%
3%	4 mm	35.7	261/53	–	2.78%
	2 mm	36.3	146/30	2.43%	3.03%
	1 mm	35.8	83/19	3.53%	5.34%
4%	4 mm	27.5	188/27	–	3.29%
	2 mm	27.2	101/15	3.11%	6.26%
	1 mm	27.4	57/9	5.22%	9.02%
5%	4 mm	23.9	276/30	–	3.19%
	2 mm	24.1	154/16	2.08%	3.66%
	1 mm	24.2	88/11	3.27%	6.09%

longer spin lock image has low SNR. This highlights the need for acquisition of spin lock times that cover the full range of the decay curve for the range of T1ρ relaxation times expected. Robust curve fitting methods may help to minimize the effect of low-quality images arising from long spin lock times with short T1ρ tissues. The results shown here quantify the increase in measurement error as SNR and number of spin lock times decrease. This information will help guide design of efficient and robust protocols for quantitative T1ρ imaging in vivo.

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SUPERIORITY OF KNEE ULTRASOUND OVER RADIOGRAPHS IN OSTEOPHYTE DETECTION IN KNEE OSTEOARTHRITIS

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Purpose: Osteophytes are important signs in knee osteoarthritis as they are one of the diagnostic criteria and in the assessment of the disease severity (Kellgren-Lawrence grading). Musculoskeletal ultrasound (MSUS) is being adopted by a growing number of rheumatologists because of its cost-effectiveness and the absence of radiation exposure. The aim of the study was to evaluate the concordance of radiographs and MSUS in terms of detecting osteophytes in knee osteoarthritis.

Methods: A cross-sectional study in outpatients presenting with knee osteoarthritis, according to the 1990 ACR criteria for knee osteoarthritis. Radiographs of the knees (anteroposterior incidence) and MSUS of the knee have been performed for each patient. Two rheumatologists trained in MSUS (S.S and A.H) have done MSUS examinations, and had no access to patients' radiographs. Radiographs were sent and read by an independent rheumatologist (B.I) in another rheumatology center. Osteophytes were searched on 4 sites, chosen because of their easy access by both radiographs and MSUS: medial and lateral femoral condyles; medial and lateral superior tibial extremities. Osteophytes of the femoropatellar compartment have not been assessed because they require strict lateral radiographs and are not easily accessible on MSUS, thus a concordance assessment could not be reliable on this site. Concordance has been assessed using Kappa concordance coefficient.

Results: We have examined 192 knees of 102 patients, 76.5% females, mean age 65.2 ± 9.7 years. Radiographic analysis allowed the detection of osteophytes in 35.9% cases, with a mean number of 1.6 osteophyte per knee, while MSUS detected osteophytes in 86.5% cases, with a mean number of 2.7 osteophyte per knee. The Kappa coefficient between radiographs and MSUS was 0.183 (95% CI: 0,138-0,228). Most of the detected osteophytes on MSUS (60.5%) were located on the femoral condyles.

Conclusions: Concordance between radiography and MSUS in the detection of osteophytes is poor, due to a much higher level of detection of MSUS (2.5 more osteophytes detected with MSUS). This was made possible since new high resolutions machines were made available. The place of knee MSUS is still to be defined in the diagnostic procedure of knee pain, may be in case of normality of radiographs. To do this, studies assessing sensitivity/specificity of knee MSUS in detecting infra-radiographic knee osteoarthritis are required.

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LONG TERM PATIENT REPOSITIONING REPRODUCIBILITY OF CARTILAGE VOLUME ON KNEE MRI

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Purpose: Quantitative measurement of cartilage volume in MRI image data may be an important imaging biomarker in knee osteoarthritis (OA) but relies on reproducible patient re-positioning and image acquisition across time points. We previously developed a fast and responsive method to measure cartilage volume at focal regions in the femur. Figure 1 shows an example of this region in the medial compartment. The purpose of the current study was to examine long-term patient repositioning reproducibility of this method, and to investigate systematic changes in cartilage volume in subjects without OA or risk factors for OA.

Methods: The dominant knee image of 42 randomly selected subjects from the OAI Control Cohort was selected from patients present at the baseline, 12 month and 48 months visits. Since duplicate scans obtained the same day were not available, we used Control Cohort subjects and assumed no change in cartilage volume due to OA progression.

Change in cartilage volume

Visit time	Medial Volume		Lateral Volume	
	RMSSD	CV	RMSSD	CV
BL-12 mo	14.4 mm^3	9.6%	15.3 mm^3	8.8%
BL-48 mo	13.9 mm^3	9.2%	17.5 mm^3	10.2%

Change in normalized cartilage volume

Visit time	Normalized medial volume		Normalized lateral volume	
	RMSSD	CV	RMSSD	CV
BL-12 mo	8.0 mm^3	5.2%	9.7 mm^3	5.6%
BL-48 mo	7.8 mm^3	5.0%	11.7 mm^3	6.8%

Double echo steady state (DESS) 3D sagittal images were obtained on a 3T Siemens Trio MR system (0.365 mm x 0.365mm, 0.7 mm slice thickness, TR 16.5 ms, TE 4.7 ms). The reader used the method to segment two fixed regions of cartilage in the medial and lateral compartments of the knee determined with respect to a 3D cylindrical coordinate system defined by the software. Readings were performed fully blinded to subject ID and time point. Cartilage volume at fixed locations in the medial and lateral compartments was measured between two time point pairs: baseline (BL) to 12 month, and BL to 48 months. A second metric, reflecting cartilage thickness, was defined as the cartilage volume normalized to a measure of the region surface area. Reproducibility was measured using the root mean square SD (RMSSD) and coefficient of variation (CV). To investigate possible biases or any consistent change over time, Bland Altman plots were also produced.

Results: Results from the raw volume measurements are shown in Table 1 and for normalized volume measurement in Table 2. The reproducibility was substantially better for the normalized compared to the raw volume measurements. Bland Altman plots of the normalized volume revealed no systematic bias in the normalized volumes (Figures 2-5) or in raw volume (data not shown).

Conclusions: We observe excellent long-term reproducibility using a normalized volume measurement. The reproducibility is degraded when using the raw volume suggesting a bias from the cartilage region selection component of the method. The Bland Altman plots reveal no systematic shift, indicating a robust method and that no true cartilage volume change occurred.

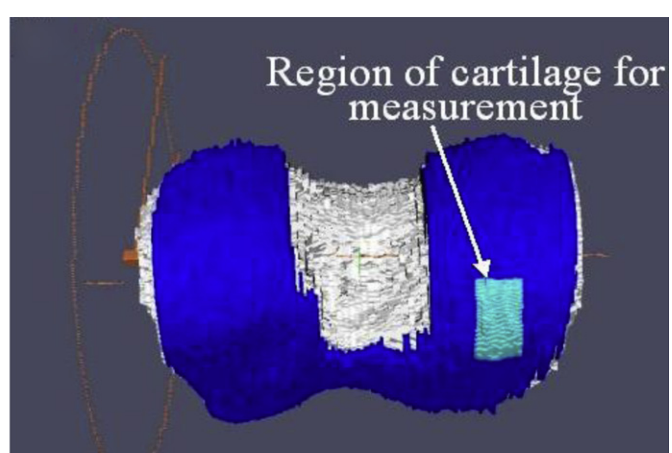

Fig. 1. Region of cartilage for measurement.