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Efficiency of Magnetic Resonance Imaging in Regional Diagnosis and Classification of Advanced Chondropathies of Knee Joint

Diz Ekleminde Geç Dönem Kondropatilerin Bölgelere Göre Tanisi ve Siniflandirilmasinda Manyetik Rezonans Görüntülemenin Etkinliği

Abdullah Soydan Mahmutoğlu[1], Müjdat Bankaoğlu[2], Şükrü Mehmet Ertürk[2], İrfan Çelebi[2], Alper Özel[2], Özdeş Mahmutoğlu[2], Muzaffer Başak[2]

Abstract / Öz

Objective: Today, magnetic resonance imaging (MRI) procedures used to detect and measure articular hyaline cartilaginous defects are being increasingly investigated. In this study, we evaluated the sensitivity and diagnostic efficiency of MRI in the detection of particularly advanced cartilage pathologies compared to the arthroscopic results.

Methods: In this study, we enrolled 16 male (%38.1) 26 female (%61.9) patients who applied to Şişli Hamidiye Etfal Education and Research Hospital with complaints of throbbing knee pain after long walks and uneasiness during climbing stairs and whose arthroscopies were already scheduled. Forty-two knee joints were evaluated using routine fat-saturated T2-weighted fast spin echo (FSE), sagittal T1, sagittal fat-suppressed proton density (PD) FSE, and coronal short inversion time inversion recovery (STIR) sequences. The MRI results were retrospectively analyzed and compared with the arthroscopic outcomes.

Results: The comparison of advanced cartilage lesions at the specified six regions of the knee joint detected using sagittal fat saturated T2- and axial T2-weighted sequences with arthoscopic results revealed that 199 out of 252 regions results showed concordance. At a total number of 38 regions, MRI results failed to detect cartilage lesions, and at 15 regions, the MRI evaluated pathologic results, while arthroscopy revealed normal results. The success of MRI in grading cartilage defects and its concordance with arthroscopy were higher at the medial condyl of the femur and patellar facets.

Conclusion: Although MRI is the leading imaging modality due to its high sensitivity and diagnostic efficiency, particularly in detecting advanced cartilage pathologies, the magnetic power of the device and the sequences used are important to obtain optimal images. Although the success rates of different sequences in different planes in detecting and grading chondropathy vary in studies, MRI reaches high accuracies in detecting and grading advanced cartilage lesions with the use of appropriate sequences.

Keywords: Cartilage, chondropathy, knee joint, magnetic resonance imaging

Amaç: Hyalen artiküler kartilaj defektlerinin ölçümü ve tespit edilmesi için MR görüntüleme yöntemleri günümüzde artarak araştırılmaktadır. Çalışmamızda MR incelemenin, özellikle ileri evre kartilaj patolojilerinin tespitindeki duyarlılık ve tanısal etkinliğini, artroskopi sonuçları ile karşılaştırma yoluyla değerlendirdik.

Yöntemler: Çalışmamızda hastanemizde takip edilen, dizde uzun yol yürüdükten sonra zonklama, merdiven çıkarken zorlanma, şikayetleri ile gelen ve artroskopi planlanan 16 erkek (%38,1), 26 kadın(%61,9) hasta incelendi. 42 diz, rutin fat sat T2 FSE, sagittal T1, sagittal FS PD FSE ve coronal STIR sekansları kullanıldı. MRG sonuçları retrospektif olarak değerlendirildi. MR bulguları artroskopi sonuçları ile verifiye edildi.

Bulgular: Sagittal Fat Sat T2 ve Aksiyel T2 ağırlıklı sekanslarda dizlerde tespit ettiğimiz geç dönem kartilaj lezyonlarının dizde belirlediğimiz altı bölgedeki artroskopi bulgularıyla karşılaştırılmasında; 252 bölgenin 199 unda MR bulguları ile artroskopi bulguları uygunluk göstermekteydi. Toplam 38 bölgede kıkırdak lezyonlarının gösterilmesi ve sınıflamasında MR başarısız iken, 15 bölgede artroskopide normal kabul edilen alanlar MR incelemede patolojik olarak rapor edilmişti. Femur medial kondil ve patella faset yüzlerde MR ve Artroskopinin uygunluğu ve gradeleme başarısının daha fazla olduğu gözlendi. İleri evre kondromalazilerde MR ile artroskopi arası uyum daha yüksek bulunmuştur.

Sonuç: Özellikle ileri evre kartilaj patolojilerinin tespitinde MR inceleme yüksek duyarlılık ve tanısal etkinliği nedeni ile tercih edilen görüntüleme yöntemi olmakla birlikte optimum imajları elde etmekte MR cihazının manyetik gücü ve kullanılan sekanslar önem taşır. Değişik planlardaki, değişik sekansların kondropati saptama ve sınıflandırmadaki başarıları çalışmalarda değişkenlik gösterse de MRG, uygun sekanslarla, geç dönem kıkırdak lezyonlarının gösterilmesi ve derecelendirilmesinde yüksek doğruluğa ulaşmaktadır.

Anahtar Kelimeler: Kartilaj, kondropati, diz eklemi, manyetik rezonans görüntüleme

[1]Department of Radiology, İstanbul Training and Research Hospital, İstanbul, Turkey
[2]Department of Radiology, Şişli Hamidiye Etfal Training and Research Hospital, İstanbul, Turkey

Address for Correspondence
Yazışma Adresi:
Abdullah Soydan Mahmutoğlu
E-mail: asmahmutoglu@yahoo.com

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Introduction

Chondromalacia is caused by decreased sulfated mucopalysaccharides in the extracellular matrix ingredient of cartilage (1). Chondropathy or chondromalacia defines a progressive cascade of events, including softening, fibrillation, thinning, focal blisters, ulcerations, chondral defects, and subchondral erosive changes (1).

Magnetic resonance imaging (MRI) should provide a high spatial resolution with image contrast to detect small cartilage defects and signal changes in the diagnosis of articular cartilage. It should also be capable of reliable distinction of cartilage from synovial fluid and subchondral bone together with the shape and thickness of the cartilage (2).

MRI is the best radiologic imaging method for the visualization of articular cartilage. Different MRI pulse sequences, such as T1-weighted (W), proton density-W (PDW), T2W spin echo (SE), fat saturation sequences, 2D and 3D gradient echo (GRE) sequences, and magnetization transfer contrast (MTC) sequences were studied to examine hyaline cartilage in several reports. However, there is no clearly defined single MRI sequence yet (3). SE and GRE sequences are known to be useful in the diagnosis of ligamentous and meniscal pathology. MRI imaging methods to detect and measure hyaline articular cartilage defects are more frequently investigated in recent years (4).

The objective of imaging is to grade early cartilage degeneration before morphological findings become obvious and to follow medical treatment response.

Recent progresses in new surgical methods and drugs enable to help delay chondral degeneration and possibly heal post-traumatic chondral changes (5). Therefore, detailed high-resolution diagnostic methods are becoming an obligation to grade and differentiate cartilage pathologies of the knee joint in early and advanced stages.

In this study, we aimed to evaluate the sensitivity and diagnostic efficiency of MRI in the detection of particularly advanced cartilage pathologies compared with the arthroscopic results.

Methods

We investigated 16 males (38.1%) and 26 females (61.9%) who had been under follow-up at our hospital for 6 months and presented with complaints of throbbing in the knee after walking long distances, difficulty in climbing stairs, and for whom arthroscopy was planned. The age range of the patient group was 31-70 years, and the mean age was 50.8±10.8 years. For 42 knees, routine fat saturated T2W fat SE (FSE), sagittal T1-W, sagittal fat-suppressed (FS) PD FSE, and coronal short inversion time inversion recovery (STIR) sequences were used. The MRI results were retrospectively assessed. No physical effort was applied during MRI. Two different radiologists evaluated the MR images with consensus in case of different results and then compared with the arthroscopy results, regarded as the "gold standard."

A 1,5 Tesla Picker MR Unit (Philips Medical Systems Eindhoven, Netherlands) and superficial knee Q coil was used for the MRI investigations. Repetition time (TR): 300-550 ms; echo time (TE): 8-18 ms; cross-sections: 4 mm thick; field of view (FOV) 15-30 cm; and matrix: 192-256 pixels were obtained.

Six articular surfaces were assessed in total, including medial and lateral femoral condyls, medial and lateral tibia plateau surfaces, and medial and lateral patella facets. An outbridge MR grading system was applied: Grade O: normal, Grade 1: abnormal signal intensity, Grade 2: surface irregularity; Grade 3: partial loss of thickness that does not reach the bone, and Grade 4: complete loss of thickness that does not reach the bone and reactive change in the subchondral bone. Figures 1-5 represent the different grades of chondropathies diagnosed in the study group.

Images were assessed blinded to clinical data. On different planes, individual assessment, grading, and labeling was applied for each knee. Images on the axial and sagittal planes were collected and classified; the results were listed according to each patient's name.

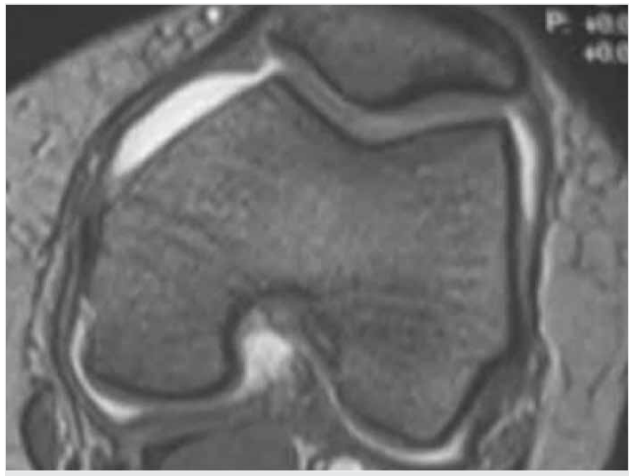


Figure 1. Axial T2W MR image; patellar facets and cartilage is normal (Grade 0)



Figure 2. Axial T2W MR image; focal hyperintensity can be seen in the medial patellar facet cartilage (Grade 1; white arrow)

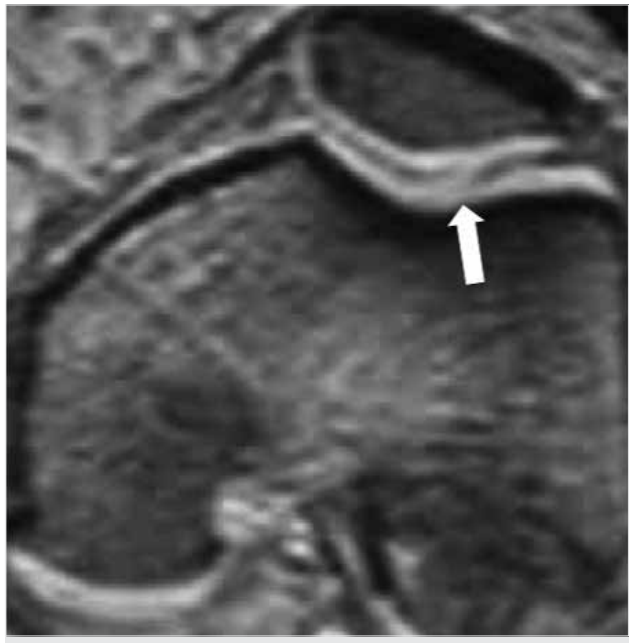


Figure 3. Axial fat saturated T2W MR image; Oblique fissural defect can be seen in the lateral femoral condyl cartilage (Grade 2; white arrow)

Arthrosocopies were performed under general anesthesia using a standard procedure. The duration between MRI investigations and arthroscopic procedure did not exceed 15 days.

The ratios of sensitivity, specificity, and accuracy were evaluated for imaging results using arthroscopy as the gold standard.



Figure 4. Sagittal FSE fat saturated T2W MR image; advanced cartilage loss can be seen in MFC cartilage where bony cortex is intact (Grade 3; white arrows)

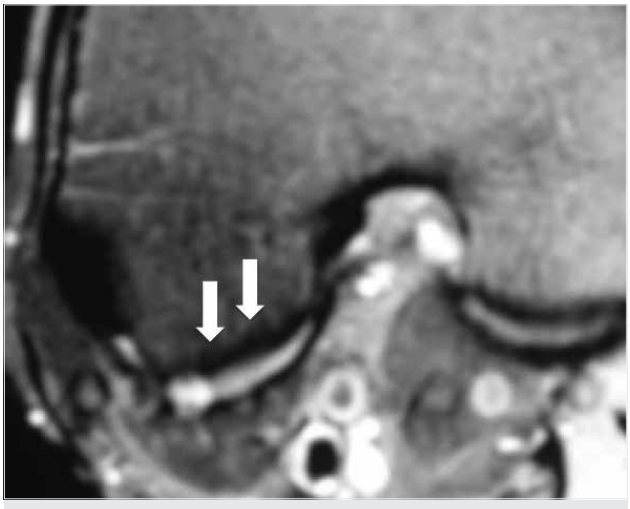


Figure 5. Axial FSE fat saturated T2W MR image; cartilage defect that reaches subcortical bone at lateral femoral condyl can be seen (Grade 4; white arrows)

The study was approved by the ethical committee of our institution. Informed consent was waived due to the retrospective study design.

Statistical Analysis

The Statistical package for social sciences for Windows 10.0 software (SPSS Inc. SPSS Statistics for Windows, Version 10.0. Chicago, IL, USA) was used for statistical analyses. Descriptive statistical methods (frequency distribution), diagnostic screening tests (sensitivity, specificity, and positive prediction value) were used for comparing quantitative data. Results were evaluated at 95% confidence interval (CI).

Results

In comparison with the late-stage cartilage lesions detected in the sagittal fat saturated T2 and axial T2-weighted sequences to the arthroscopy findings detected in 6 regions in the knee, we observed that MRI findings were consistent with the arthroscopy results in 199 of 252 sites. While MRI was unsuccessful in showing and classifying the cartilage lesions in 38 regions in total, sites that were considered normal in 15 regions upon arthroscopy were reported to be pathologic at MRI investigation. The compliance of MRI and arthroscopy and the success of grading were observed to be higher on the medial femoral condyl (MFC) and patella facet surfaces. The sensitivity, specificity, and precision were calculated at 95% CIs. Arthroscopy revealed advanced-stage chondromalacia in 139 of 252 sites in total (images 1-5 represent MRI and arthroscopy images of 5 different stages of cartilage pathologies). The total sensitivity in detecting cartilage abnormalities of MRI was 72.7% (101/139; 95% CI: 64.7%-79.4%); total specificity was 86.7% (98/113; 95% CI: 79.3%-91.8%), and total accuracy was 78.9% (199/252; 95% CI: 70.5%-83.6%). Table 1 shows comparison of sensitivity, specificity and accuracy values of different chondropathy regions.

The highest sensitivity and accuracy values were detected as MFC (93.3%) and lateral patellar facet (LPF; 84%).

The highest number of fake (+) assessments was detected for medial tibial plateau with 5 cases (total fake [+]: 15). No fake (+) assessments were made in MFC. The highest number of fake (-) assessments was in lateral tibial plateau with 17 cases (total fake [-]: 43). The compliance between MRI and arthroscopy was calculated using the kappa statistics in early chondromalacia (Grade 1 and Grade 2) and late-stage chondromalacia (Grade 3 and Grade 4).

κ was 0.1532 (0-0.3311) for stages 0, 1, and 2, while κ was 0.4753 (0.3513-0.5993) for stages 3 and 4; the compliance between MRI and arthroscopy was detected to be higher in advanced-stage chondromalacia.

Table 1. Comparison of sensitivity, specificity and accuracy values of different chondropathy regions

	MFC	LFC	MTP	LTP	LPF	MPF
Sensitivity	93.3%	52.6%	70%	42.9%	84%	79.2%
Specificity	100%	82.6%	77.3%	80.9%	94.1%	91.4%
Accuracy	95%	69%	73%	61%	88%	85%

MFC: medial femoral condyl; LFC: lateral femoral condyl; MTP: medial tibial plateau; LTP: lateral tibial plateau; LPF: lateral patellar facet; MPF: medial patellar facet

Discussion

MRI is the most commonly used modality in investigating chondromalacia due to high soft tissue contrast, ability to directly visualize the joint cartilage, and multiplanar imaging capacity. Despite many studies presented, there is yet no consensus on the pulse sequences to be selected for articular cartilage assessment. Conventional SE T1, PD and T2-weighted images, GE sequences obtained using 2D or 3D imaging, and MTC sequences are the sequences that are reported for investigating chondral pathologies. While the sensitivity and specificity ratios can be as low as 31% and 50%, respectively, they may also be as high as 100% (5).

Although FS 3D spoiled GE MRI was shown to be sensitive and specific in detecting the hyaline cartilage defects in the knee, at the early stages of the cartilage degeneration, it is weakly sensitive for isolated matrix injury. It is sensitive to metallic artifacts (6). These are the sequences that need to be adjusted using software before interpretation. Due to low-contrast resolution, it was reported to be non-beneficial in characterizing the other intra- and extra-articular diseases (7).

In a study by Bredella et al. (3), FS 3D spoiled GE MRI was reported to be of higher value in detecting morphologic changes compared to spatial resolution T2W FSE FS images .

Mc Cauley et al. (8) reported that it was difficult to differentiate from the cartilage fluid in PDW images . They concluded that the conventional SE technique was more beneficial in detecting chondromalacia patella and finding focal signal abnormalities than finding contour abnormalities.

Bredella et al. (3) showed in their studies that hyaline cartilage defects in the knee could be clearly assessed using T2W SE and FSE sequences used in the clinical practice. In this study, T2W FSE fat-saturated and T2W SE sequences showed high values in detecting articular cartilage defects (94%) . Particularly, it was shown to be sensitive in the early stages of chondromalacia. In this trial, 16 of 18 arthroscopy investigations were detected to show Grade 1 lesion; however, on MRI, only 11 showed compliance in grading. It showed a compliance between MRI and arthroscopy at 50% in Grade 2 lesions and at 83% in Grade 3 lesions. T2W FSE is sensitive in detecting Grade 4 lesions at advanced stages of chondromalacia. In this study, 18 of 19 lesions (95%) were detected; however, only one-half of the lesions showed (53%) compliance with arthroscopy.

In our study, T2W FSE FS sequences showed high sensitivity and specificity in assessing articular cartilage pathologies in the knee.

In their study conducted using non-fat-suppressed FSE proton density-weighted MRI imaging, Sonin et al. (4) detected a sensitivity of 73.5%, a specificity of 86.7%-90.5%, and an accuracy of 79.6%-86.1%, and the results were similar to those results obtained using cartilage-specific sequences . The results from this trial showed that previously described cartilage-specific sequences and FSE PDW MRI exhibited a comparable precision in the ability to detect articular cartilage and that they provided valuable data on other knee structures, such as ligaments or meniscus (9).

In our study, T2W FSE fat saturated was sensitive in detecting the presence of hyaline cartilage defects; 72.7% of the lesions were compliant with arthroscopy. Conventional T2W SE sequences are time consuming and usually provide groundless signal-noise ratio. However, T2W FSE provide a heavy T2 weight and high resolution (10). T2W FSE images provide more contrast between the cartilage and the fluid from FS T1W images. Nevertheless, spatial resolution is lower than that in FS 3D spoiled gradient echo MRI.

On T2W images, collagen loss in degenerated cartilage and increased water content is associated with reduced T2 relaxation and increased proton density. Both lead to increased signal intensity in T2W FSE fat saturated images (11). Fat suppression is usually included in the clinical image protocols to increase sensitivity in bone marrow abnormalities. Articular cartilage reduces the chemical shift artifacts that exaggerate the thickness (12).

Radlbauer et al. (13) pointed out that incorporation of a DRIVE pulse into a standard T1weighted FSE sequence significantly increases the diagnostic value in the evaluation of anatomical structures and pathologies, within the same acquisition time .

In their study, Bae et al. (14) concluded that with the use of ultrashort time-to-echo (UTE) MRI techniques, it is possible to directly visualize and characterize some important musculoskeletal soft tissues that have intrinsically short T2 values .

Friedrich et al. (15) found that when using 3 tesla MRI, individually weighted double-echo steady-state is the most promising sequence for the evaluation of cartilage .

In a study by Andreisek et al. (16), it is said that although a relatively new method for the compositional assessment of the articular cartilage T2* mapping shows a good test-retest as well as inter-reader and intra-reader reliabilities .

In our study, the comparison of the late-stage cartilage lesions detected in the knees on sagittal fat saturated T2 and axial T2W sequences with the arthroscopy findings obtained in 6 pre-specified regions of the knee showed full compliance between MRI findings and arthroscopy findings in 199 of 252 regions.

Conclusion

New surgical and medical approaches enable post-traumatic chondral treatment and delay chondral degeneration. Thus, it is crucial to diagnose and differentiate between early and advanced chondral lesions of the knee. Although MRI is the leading imaging modality due to its high sensitivity and diagnostic efficiency, particularly in detecting advanced cartilage pathologies, the magnetic power of the device and the sequences used are important to obtain optimal images. Although the success rates of different sequences in different planes in detecting and grading chondropathy vary in studies, MRI reaches high accuracies in detecting and grading advanced cartilage lesions with the use of appropriate sequences.

The study was approved by the institutional ethics committee and the requirement for informed consent was waived due to the retrospective study design.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Şişli Hamidiye Etfal Training and Research Hospital.

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