Reumatismo, 2022; 74 (3): 116-121

Magnetic resonance imaging as a structural refinement to the American College of Rheumathology clinical classification criteria for knee osteoarthritis

G.A. Minetti[1], M. Parodi[2], S. Banderali[3], E. Silvestri[4], G. Garlaschi[5], M.A. Cimmino[6]

[1]Diagnostic and Interventional Radiology Unit, S. Spirito Hospital, Casale Monferrato (AL), Italy; [2]Department of Rheumatology, S.S. Antonio e Biagio and Cesare Arrigo Hospital, Alessandria, Italy; [3]Radiodiagnostic Unit, Galliera Hospital, Genova, Italy; [4]Diagnostic Imaging, Salus-Alliance Institute, Genova, Italy; [5]Imaging Diagnostics Section, Department of Experimental Medicine, University of Genova, Italy; [6]Rheumatology Clinic, Department of Internal Medicine, University of Genova, Italy

SUMMARY

Objective: To evaluate if fulfilment of the definition of osteoarthritis (OA) based on the American College of Rheumatology (ACR) clinical criteria corresponds to pathological knee findings evaluated by magnetic resonance imaging (MRI). To evaluate if any such criteria is associated with a specific MRI pattern.

Methods: Forty-six consecutive patients aged 50 years or more referred by their general practitioners (GPs) to a radiology department because of non-traumatic knee pain underwent MRI using a dedicated low field (0.2 T) machine.

Results: MRI results were compared against the ACR criteria for knee OA. Patients with knee pain fulfilling the ACR criteria showed more severe synovial fluid effusion (OR 6.2, 95% CI 2.02 to 19.1), cartilage lesions in the medial area (OR 2.4, 95% CI 1.2 to 5) and higher mean number of osteophytes (OR 2.3, 95% CI 1.1 to 4.5). The association between single criteria and MRI features was more difficult to establish. Nonetheless, crepitus at joint movement was associated with synovial fluid effusion (p=0.02); bone enlargement was more frequent in patients with lesions of the posterior cruciate ligament (p=0.0001); no palpable warmth was associated with cartilage lesions (p=0.02), and morning stiffness shorter than 30 minutes was associated with the surface of bone edema (p=0.02).

Conclusions: The ACR clinical criteria identify patients showing the most important features of OA. The association between individual clinical ACR criteria and OA pathology depicted by MRI may be difficult to explain on the basis of anatomical changes and needs further evaluation.

Key words: *Osteoarthritis, magnetic resonance imaging, ACR criteria.*

Reumatismo, 2022; 74 (3): 116-121

INTRODUCTION

The American College of Rheumatology (ACR) clinical criteria for knee osteoarthritis (OA) were developed by an ad hoc committee in 1986 (1). They are intended to be used for classification of knee OA in the clinical setting as well as for epidemiological studies (2), in which the possibility of avoiding imaging is crucial. In addition, they have been also used to select patients for magnetic resonance imaging (MRI) studies of the knee (3, 4). However, clinical criteria evaluate symptomatic disease, not structural damage. In fact, pain, loss of function, and anatomic damage are known to be often independent variables in OA (5), with OA symptoms and radiographic damage being often discordant. The relationship between every ACR criterion for knee OA and the anatomic condition of the involved joint evaluated with conventional radiology is still unclear. We wanted to ascertain if this was true also using a more sensitive imaging technique, such as MRI, a valuable method to study not only bone changes, but also soft tissue lesions in and around OA joints. This study is concerned with an MRI evaluation of the knees of a consecutive cohort of patients with non-

Corresponding author:
Marco A. Cimmino
Clinica Reumatologica, DI.M.I.,
Università di Genova
16129 Genova, Italy
E-mail: marcoamedeo.cimmino@gmail.com

traumatic pain, to evaluate if the definition of OA based on the ACR clinical criteria corresponds to MRI pathological findings. MRI features of the knee were compared in patients fulfilling or not the ACR criteria and were correlated with each of them, trying to validate MRI and clinical criteria against each other. Our hypothesis was that clinical findings included in the criteria could correlate with specific MRI findings.

PATIENTS AND METHODS

Forty-six consecutive patients aged 50 years or more referred by their GPs to a radiology department for knee MRI because of non-traumatic pain resistant to conservative anti-inflammatory and/or analgesic treatment were considered. In Italy, GPs can directly ask for articular MRI without prior specialist consultation and often before a radiograph is obtained. For the purpose of this study, non-traumatic pain was defined as pain in or around the knee without a history of knee trauma requiring medical consultation in the previous 6 months. Patients underwent clinical examination and fulfilment of the clinical ACR criteria was tested by a single observer. Of these criteria, knee pain and age over 50 years were not included in the statistical evaluation, being a prerequisite for enrolment in the study. Height and weight were measured by standard methods, and the body mass index (BMI) was calculated. The study was approved by the department's ethics committee and the patients signed an informed consent prior to their involvement in the study.

MRI was performed with a dedicated low field (0.2 T) machine (Artoscan C, ESAOTE, Genova, Italy). Sequences included Spin Echo T1-weighed (SE, three planes, 580/18/2 [repetition time msec/echo time msec/signals acquired]; flip angle 90°; field of view 20×18 cm; section thickness: 4 mm; matrix 256×180; acquisition time 2:06; 16 sections for the axial and sagittal planes; 12 sections for the coronal plane), Turbo Spin Echo T2-weighed (axial and sagittal planes, 2900/80/1 [repetition time msec/echo time msec/signals acquired]; flip angle 90°; field of view 20×18 cm; section thickness 4 mm; matrix 192×129; acquisition time 3:57; 16 sections), Gradient Echo T1-weighed (GE, coronal planes, 540/18/2 [repetition time msec/echo time msec/signals acquired); flip angle 75°; field of view 20×18 cm; section thickness 4 mm; matrix 256×180; acquisition time 3:17; 12 sections), and Short Tau Inversion Recovery (STIR, axial plane, 1900/24/1 [repetition time msec/echo time msec/signals acquired]; inversion time 85 msec; flip angle 90°; field of view 20×18 cm; section thickness 4 mm; matrix 192×129; acquisition time 4:08; 16 sections) images. The overall examination time was about 30 minutes.

The following MRI features were recorded: cartilage defects, bone edema, osteophytes, synovial fluid effusion, Baker's cysts, cruciate and collateral ligaments lesions, meniscal lesions, geodes, intraarticular loose bodies, and myxoid degeneration of the periarticular tissues. MRI images were read by consensus by two radiologists unaware of the patients' clinical characteristics. Cartilage defects were classified according to Recht et al. (6) as 0=normal cartilage, 1=inhomogeneous cartilage with or without increased thickness, 2=decreased thickness of cartilage (less than 50%), 3=decreased thickness of cartilage (more than 50%, but less than full thickness), 4=subchondral bone exposure due to full thickness loss of cartilage. These measures were taken in four areas (lateral and medial femoro-tibial joint, lateral and medial articular surface of the patella). A composite index was obtained by summing up the individual grades. Bone marrow edema was defined as diffuse subchondral low signal intensity on T1-weighed images and high signal intensity on T2-weighed images. It was measured in the medial and lateral femur and tibia and in the four patellar quadrants. Its extension was recorded by measuring the surface on the coronal GE section where it was larger. Osteophytes were assessed on the margins of the same knee areas evaluated for bone edema. The length of the largest osteophyte was measured from the base to the tip on GE images. Synovial

fluid effusion was subjectively graded as absent (grade 0), present as a thin layer of fluid (grade 1), or intense (grade 2). Edema of the cruciate ligaments was considered a grade 1 lesion. Tears of the cruciate ligaments were defined as partial interruption of their structure by abnormal signal intensity lesions (grade 2) or complete interruption or absence on T2-weighed images on the 3 planes (grade 3). In the collateral ligaments, edema and tears were independently recorded. Meniscal extrusion, degeneration, defined as intrasubstance high signal intensity, and tear, defined as linear high signal intensity extending to the articular surface, were also recorded. Geodes or subchondral cysts were assessed in the medial and lateral femoral and tibial quadrants.

Statistics included comparison of means by Wilcoxon rank sum test and of percentages by Pearson's chi square test. Association between variables was tested by Spearman's rank correlation. Variables which were able to discriminate groups with $p<0.05$ and those shown to be significant in other studies were included in a logistic regression procedure, including stepwise regression.

RESULTS

There were 30 women and 16 men with mean age 62.6±7.7 years (range 50-81 years). Of them, 28 patients (5 men, 23 women) fulfilled the ACR clinical criteria for OA. Mean BMI was 26.9±4.8 (range 20.2-43.7), with 13 (28.3%) overweight patients and 9 (19.6%) obese patients. Table I compares demographic data and MRI results in patients fulfilling or not the ACR criteria. The composite index of cartilage lesions was significantly higher in patients fulfilling the ACR criteria. In particular, they had more prominent cartilage defects in the medial femoro-tibial joint (p=0.009), and in the lateral (p=0.03) and medial (p=0.004) patellar cartilage. Bone marrow edema was slightly more common in patients fulfilling the ACR criteria. These patients also showed larger edema surfaces. When the individual knee areas were considered, bone edema was significantly more frequent only in the medial femoral area (p=0.02). Lesions of the collateral ligaments, which were present in 8.7% of the patients, intraarticular loose bodies (0%), and subchondral cysts (8.7%) were additional findings. Meniscal lesions (84.8%)

Table I - Univariate analysis of demographic and magnetic resonance imaging results in patients fulfilling or not the clinical American College of Rheumatology criteria for the classification of knee osteoarthritis.

	ACR criteria present	ACR criteria absent	p
Number of patients	28	18	
Age (years)	64±7.6	60.5±7.6	ns
Men/women	5/23	11/7	0.007
BMI	26.6±5	27.3±4.5	ns
Disease duration (months)	26.4±42.1	22.9±35.1	ns
Cartilage damage index	9.5±3.2	6.3±3.8	0.003
Patients with bone edema	16 (57.1%)	5 (27.8%)	0.05
Mean surface of bone edema (mm^2)	281.1±597.7	66.7±221.1	0.04
Patients with anterior cruciate lesion	9 (32%)	3 (16.7%)	ns
Patients with posterior cruciate lesion	4 (14.3%)	0	ns
Patients with osteophytes	14 (50%)	5 (27.8%)	ns
Mean number of osteophytes	1.1±1.5	0.4±0.8	ns
Degree of synovial fluid effusion	1.6±0.6	1.2±0.5	0.008

ACR, American College of Rheumatology; ns, not significant; BMI, body mass index.

and Baker's cysts (32.6%) were more frequent and occurred in a similar percentage of patients in the two groups. Logistic regression, weighed for gender because of the significant preponderance of women in the ACR-defined OA group, showed that synovial fluid effusion (OR 6.2, 95% CI 2 to 19.1), cartilage lesions in the medial area (OR 2.4, 95% CI 1.2 to 5) and number of osteophytes (OR 2.3, 95% CI 1.1 to 4.5) significantly predicted fulfilment of ACR criteria in patients with knee pain. This set of items correctly classified 78.3% of cases.

Table II shows the associations of MRI results with the different criteria. Knee pain and age over 50 years were not considered, being prerequisites for the enrolment in the study. Bony tenderness occurred in 22 patients (47.8%), morning stiffness less than 30 minutes in 17 (37%), crepitus in 32 (69.6%), no local palpable warmth in 34 (73.9%), and bone enlargement in 10 (21.7%). Logistic regression, weighed for gender, showed that patients with short morning stiffness had a wider surface of bone edema, those with synovial fluid effusion had more frequently crepitus at joint movement, those with no palpable warmth had a higher composite index of cartilage damage, and patients with bone enlargement were more frequently affected by lesions of the posterior cruciate ligament and by extrusion of the medial meniscus.

Table II - Stepwise regression of magnetic resonance imaging-visualized joint lesions by different American College of Rheumatology criteria.

Criterion	MRI feature	p
Bony tenderness	None	
Morning stiffness <30 min	Surface of bone edema	0.01
Bony enlargement	Posterior cruciate lesion Medial meniscus extrusion	0.0001 0.004
Crepitus	Synovial fluid effusion	0.02
No palpable warmth	Cartilage lesions	0.02

MRI, magnetic resonance imaging.

DISCUSSION AND CONCLUSIONS

Patients with knee pain fulfilling the ACR criteria are characterized on MRI by the presence of abundant intraarticular synovial fluid effusion, frequent cartilage defects of the medial compartment of the knee, and many osteophytes. These three lesions are typical of OA. The fact that direct (osteophytes) and indirect (cartilage defects corresponding to radiographic joint space narrowing) bone features of OA were more frequent in patients with ACR-defined OA is hardly surprising because radiographic findings were considered to develop the criteria. In that study (1), osteophytes were the only radiological indicator to differentiate OA from other joint conditions, including rheumatoid arthritis, seronegative spondyloarthritides, fibromyalgia and other pain syndromes, to the exclusion of periarticular soft tissue disorders. Our data confirm that these features are important even when the clinical only definition of OA is used. Our control group was more homogenous than that used in the original criteria paper because it considered only non-inflammatory pain syndromes including periarticular soft tissue disorders. By excluding inflammatory joint diseases, which may cause cartilage lesions through other mechanisms, medial cartilage damage became an important discriminator between OA and controls in our study.

Knee effusion, but not Baker's cysts, were frequent in patients with pain due to OA also in another MRI study, after allowance is made for the severity of radiographic OA (7). In addition, presence of synovitis and effusion was associated with knee OA progression, particularly among obese individuals (8). These and our results suggest that knee effusion should be included among MRI features of clinically relevant OA. Why synovial effusion was more closely associated with crepitus at joint movement is not clear, but a possible explanation is imbalance of joint mechanics facilitated by an enlarged capsule.

Lesions of the cruciate ligaments were slightly more frequent in patients with OA fulfilling the ACR criteria in the univariate analysis. In OA patients, the prevalence of cruciate tears (grade 2 and 3 lesions) was 21.4%, with 14.3% complete tears, which

figure is similar to the 22.8% of complete tears described by Hill et al. (9). Accordingly, cruciate ligament lesions could be a risk factor of knee OA. Among the ACR criteria, bony enlargement was associated with lesions of the posterior cruciate, which are much rarer than those of the anterior cruciate. The consequent instability and malalignement of the knee are probably the cause of bone enlargement. A similar mechanism could also justify why medial meniscus extrusion is associated with bone enlargement. Meniscal extrusion is strongly associated with progression of symptomatic OA and loss of medial compartment cartilage volume assessed by quantitative MRI (4). In addition, medial meniscus extrusion can overstretch the medial collateral ligament, and consequently induce a fibrous reaction in the soft tissues that could contribute to knee enlargement. This mechanism is confirmed by the highly significant correlation (p=0.008) between medial meniscal extrusion and mixoid degeneration of the soft tissues found in our study.

Bone edema is a feature of OA that was originally discovered by MRI, because it cannot be seen on conventional radiograms. Bone edema has been associated with more intense knee pain (10) but this finding has not been replicated in more recent studies (11). It was slightly more frequent and more diffuse in patients with ACR-defined OA, but this feature disappeared in multivariate analysis after adjustment for sex. The presence of bone edema was directly associated with a low degree of morning stiffness, a finding that has no clear explanation. A normal temperature of the skin overlying the joint was associated with cartilage damage, a typical finding of OA. This is in keeping with a good specificity of this criterion.

This study has some limitations: first, the number of patients was low; second, dedicated, low field MRI machines are not the standard equipment for studies of knee OA. It could be argued that their resolution was lower than that of traditional high-field machines. However, the few comparison studies between low and high field machines show that most results are comparable when the rheumatoid wrist (12) is studied. In addition, MRI detection of artificially created articular cartilage lesions in the pig was equally effective with the two systems, when standard sequences were used (13). Dedicated, low-field MRI has been already used to study OA cartilage (14). Finally, patients were not recruited from the general population but were sent for MRI by their GPs for non-traumatic knee pain. This last point is not necessarily a drawback because the patients were homogeneous and symptomatic.

In conclusion, the ACR clinical criteria identify patients showing the most important imaging features of OA. The correspondence between each of the ACR criteria and peculiar MRI findings was not easy to establish and interpret and needs further investigation. This is in part due to the fact that several criteria, such as no palpable warmth and absence of significant morning stiffness, are exclusion or negative findings, the correlation of which with positive imaging findings is difficult. Nevertheless, the good agreement between clinical ACR criteria and OA pathology depicted by MRI reinforces the widespread use of these criteria in the clinical and research settings.

Competing interests
None

REFERENCES

1. Altman R, Asch E, Bloch G, et al. Development of criteria for the classification and reporting of osteoarthritis. Classification of osteoarthritis of the knee. Arthritis Rheum. 1986; 29: 1039-49.
2. Mannoni A, Briganti MP, Di Bari M, et al. Epidemiological profile of symptomatic osteoarthritis in older adults: a population based study in Dicomano, Italy. Ann Rheum Dis. 2003; 62: 576-8.
3. Wang Y, Wluka AE, Cicuttini FM. The determinants of change in tibial plateau bone area in osteoarthritic knees: a cohort study. Arthritis Res Ther. 2005; 7: R687-93. Epub 2005 Mar 31.
4. Berthiaume MJ, Raynauld JP, Martel-Pelletier J, et al. Meniscal tear and extrusion are strongly associated with progression of symptomatic knee osteoarthritis as assessed by quantitative

magnetic resonance imaging. Ann Rheum Dis. 2005; 64: 556-63.
5. Spector TD, Hochberg MC. Methodological problems in the epidemiological study of osteoarthritis. Ann Rheum Dis. 1994; 53: 143-6.
6. Recht MP, Piraino DW, Paletta GA, et al. Accuracy of fat-suppressed three-dimensional spoiled gradient-echo FLASH MR imaging in the detection of patello-femoral articular cartilage abnormalities. Radiology. 1996; 198: 209-12.
7. Hill CL, Gale DG, Chaisson CE, et al. Knee effusions, popliteal cysts, and synovial thickening: association with knee pain in osteoarthritis. J Rheumatol. 2001; 28: 1330-7.
8. Bañuls-Mirete M, Lombardi AF, Posis AIB, et al. Effusion-synovitis worsening mediates the association between body mass index and Kellgren-Lawrence progression in obese individuals: data from the Osteoarthritis Initiative. Osteoarthritis Cartil. 2022; 30:1278-86.
9. Hill CL, Seo GS, Gale D, et al. Cruciate ligament integrity in osteoarthritis of the knee. Arthritis Rheum. 2005; 52: 794-9.
10. Felson DT, Chaisson CE, Hill CL, et al. The association of bone marrow lesions with pain in knee osteoarthritis. Ann Int Med. 2001; 134: 541-9.
11. Perry TA, Parkes MJ, Hodgson RJ, et al. Association between bone marrow lesions and synovitis and symptoms in symptomatic knee osteoarthritis. Osteoarthritis Cartil. 2020; 28: 316-23.
12. Ejbjerg BJ, Narvestad E, Jacobsen S, et al. Optimised, low cost, low field dedicated extremity MRI is highly specific and sensitive for synovitis and bone erosions in rheumatoid arthritis wrist and finger joints: comparison with conventional high field MRI and radiography. Ann Rheum Dis. 2005; 64: 1280-7.
13. Woertler K, Strothmann M, Tombach B, Reimer P. Detection of articular cartilage lesions: experimental evaluation of low- and high-field-strength MR imaging at 0.18 and 1.0 T. J Magn Reson Imaging. 2000; 11: 678-85.
14. Qazi AA, Folkesson J, Pettersen PC, et al. Separation of healthy and early osteoarthritis by automatic quantification of cartilage homogeneity. Osteoarthritis Cartil. 2007; 15: 1199-206.