Acta Biomed 2019; Vol. 90, Supplement 1: 116-122 DOI: 10.23750/abm.v90i1-S.7977

Original article

Role of low field MRI in detecting knee lesions

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Summary. *Objective:* The aim of this work is to evaluate the diagnostic accuracy of 0.3T sectoral MR imaging, compared with arthroscopy, for meniscal, cruciate ligaments and chondral knee lesions. *Materials and Methods:* We conducted a retrospective study analyzing all the consecutive knees subjected to arthroscopy at our institution between January 2014 and June 2017 and preceded within 3 months by knee MR examination at our institution with 0.3 T equipment. Patients with history of a new trauma in the time interval between MR exam and arthroscopy were excluded from the study. Two independent experienced radiologists evaluated in double blind the MR findings of menisci, cruciate ligaments and articular cartilage. Both radiological findings were independently compared with those of the arthroscopic report considered as gold standard. For each of the examined targets we calculated the following parameters: sensitivity, specificity, accuracy, positive and negative predictive value; interobserver concordance statistically calculated using Cohen's Kappa test. *Results:* 214 knees (95R/119L) of 214 patients (143M/71F) aged from 18 to 72 years (mean 44) were included and analyzed. We found a good diagnostic accuracy of the low field MR in identifying the injuries of the menisci (93%) and the crossed ligaments (96%), but a lower accuracy for the articular cartilage (85%). Sensitivity resulted 90% for menisci, 73% for ligaments and 58% for cartilage. Specificity was 91% for menisci, 97% for ligaments and 92% for cartilage. Inter-observer concordance resulted to be excellent for cruciate ligaments (K of Cohen's test = 0.832), good (K = 0.768) for menisci, modest to moderate for articular cartilage (K from 0.236 to 0.389) with worse concordance for tibial cartilage. *Conclusions:* Low-field MR sectoral device with dedicated joint equipment confirms its diagnostic reliability for the evaluation of meniscal and cruciate ligaments lesions but is weak in evaluating low grade chondral lesions. (www.actabiomedica.it)

Key words: Low field MRI, MR, Magnetic Resonance, knee, arthroscopy, meniscal lesion, chondral lesion, ligament lesion, diagnostic accuracy, cartilage, 0.3T MR, sensitivity, specificity, predictive value, concordance

List of abbreviations:
MR = Magnetic Resonance
MRI = Magnetic Resonance Imaging
T = Tesla
STIR = Short Tau Inversion Recovery
GRE T1 = GRadient Echo T1
SE T1 = Spin Echo T1
FSE T2 = Fast Spin Echo T2
AMA = American Medical Association
SS = Sensitivity
SP = Specificity
ACC = Accuracy
PPV = Positive Predictive Value
NPV = Negative Predictive Value
ACL = Anterior Cruciate Ligament
PCL = Posterior Cruciate Ligament

* Both authors contributed equally to the paper and thus are both to be considered 1st author

Introduction

Magnetic Resonance (MR) is the best non-invasive imaging method for evaluating the anatomical structures of the knee (1); its diagnostic accuracy, which varies according to the equipment used and the anatomical tissue studied, can be comparable to that of arthroscopy (2-6), considered the gold standard in the diagnostic evaluation of meniscal and cruciate ligaments lesions.

Most of the scientific studies aimed at assessing the sensitivity and specificity of the MR were carried out with high intensity field equipment (>1T) but even low-field studies (<0.5T) (3,7,8) have shown an overlapping diagnostic reliability concerning the pathology of meniscal fibrocartilages and cruciate ligaments.

High intensity field MR devices provide better signal/noise ratio, better contrast and better spatial resolution with faster acquisition time than low magnetic fields (8); however, considering the lower purchase and maintenance costs, the ease of installation in not too wide environments (9) and the diagnostic performance for ligaments and menisci similar to that of the high-intensity field MR (8), it would be generally desirable to use low-field equipment.

Moreover, despite the availability of high-intensity field "open" machines, low-intensity sectoral equipment is preferred by claustrophobic patients and children for whom no sedation is required (10).

To date the reliability of the information about the articular cartilage condition obtained with low intensity magnetic fields is still doubtful; in particular mild chondral lesions seem to be not easy to be detected by these low field devices (3).

Purpose

The primary aim of this work was to evaluate the diagnostic accuracy of a low-field (0.3T) sectoral MR device, compared with arthroscopy, for meniscal, cruciate ligaments and chondral knee lesions. Secondary aims were the estimation of sensitivity, specificity, positive and negative predictive values and inter-observer concordance.

Materials and methods

We conducted a retrospective study analyzing all the knees consecutively subjected to arthroscopy at our institution between January 2014 and June 2017 and preceded by knee MR examination within 90 days from arthroscopy at our institution with 0.3 T equipment with dedicated coil (Oscan, Esaote, Genova, Italy). The MR examinations were performed with the knee in slight flexion and intra-rotation with the STIR, GRE T1, SE T1, FSE T2 acquisitions in the three planes of the space (Table 1).

Exclusion criteria concerned all the patients examined by other MR devices, to have a uniform MR evaluation; moreover patients undergone arthroscopy more than 90 days after MR and patients with history of a new trauma in the time interval between MR examination and arthroscopy were also excluded from the study to avoid possible modifications of the tissues which could vary and false the MR-Arthroscopy comparison.

All patients included in the study expressed a written consent to undergo MR examination and arthroscopy and to treat personal data.

Table 1. 0,3 T MR parameters

	TR	TE	Etl	Thickness (mm)	Gap (mm)	Matrix	Nex
SE T1	1040	24	1	4	0,4	256x256	1
FSE T2	5460	100	10	4	0,4	256x256	2
GRE T1	505	16	1	4	0,4	512x512	2
STIR*	1920	25	1	4	0,4	256x256	1

*TI = 90

TR: repetition time; TE: echo time; Etl: long echo train lenght; Gap: slice intervals; Nex: number of excitation.

Two independent experienced radiologists evaluated, in blind of the other radiologist and of the arthroscopic report, the MR findings of the menisci, the cruciate ligaments and the articular cartilage, classifying the lesions according respectively to Lotysch for menisci (3 degrees) (Table 2) (11), American Medical Association (AMA) for ligaments (3 degrees) (Table 3) (12), and Outerbridge for cartilage (4 degrees) (Table 4) (13); moreover, in evaluating the cartilage, the articular surfaces were divided into medial and lateral condyle, medial and lateral tibial plateau, femoral trochlea and patella.

Table 2. Lotysch meniscus injuries grading

Grading	Aspect
I	small focal area of hyperintensity, no extension to the articular surface
II	linear areas of hyperintensity, no extension to the articular surface
III	abnormal hyperintensity extends to at least one articular surface (superior or inferior), and is referred as a definite meniscal tear

Table 3. AMA ligament injury classification

Grade	Description
I	Mild, minor tearing of ligament fibers and no demonstrable increase in translation on examination
II	Moderate, partial tear of the ligament without complete disruption, with a slight to moderate increased translation upon examination
III	Severe, complete tear of the ligament, with a marked increase in translation upon examination

Table 4. Outerbridge articular cartilage defect grading

Grade	Description
I	Focal areas of hyperintensity with an intact surface
II	Shallow superficial ulceration, fibrillation, or fissuring involving less than 50% of the depth of the articular surface
III	Deep ulceration, fibrillation, fissuring, or a chondral flap involving 50% or more of the depth of the articular cartilage without exposure of subchondral bone.
IV	Full-thickness chondral wear with exposure of subchondral bone

Both series of radiological findings were independently compared with those of the arthroscopic report considered as gold standard and for each of the examined targets the following parameters were calculated:

- Sensitivity (SS): the percentage of patients for whom the diagnosis detected by MR was confirmed by arthroscopy
- Specificity (SP): the percentage of patients for whom the negative diagnosis detected by MR was confirmed by arthroscopy
- Accuracy (ACC): the percentage of patients for whom the MR scan diagnosis was found to be the same at arthroscopy;
- Positive Predictive Value (PPV): percentage of patients with positive MR findings also positive at arthroscopy;
- Negative Predictive Value (NPV): the percentage of patients with negative MR findings confirmed as negative by arthroscopy;
- Inter-observer concordance statistically calculated using Cohen's K test.

Results

Sample characteristics

214 knees, 95 (44 %) right and 119 (56 %) left, of 214 patients, 143 (67 %) males and 71 (33 %) females, aged from 18 to 72 years (mean 44) were included and analyzed.

Arthroscopic findings

The following lesions were found at the arthroscopic inspection:

- 155 medial meniscal lesions (Figures 1 and 2), 53 lateral meniscal lesions;
- 42 Anterior Cruciate Ligament (ACL) lesions (Figure 3), 3 Posterior Cruciate Ligament lesions (PCL) (Figure 4);
- 242 cartilage lesions (Figure 5) of which 30 patellar, 70 tibial and 142 femoral-trochlear (Figure 1).

MR findings

At MRI the *first reader* recognized:

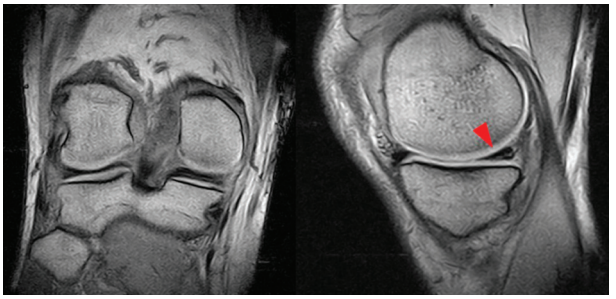

Figure 1. Longitudinal lesion of the medial meniscus posterior horn

- 194/208 meniscal lesions, misunderstanding 14 (9 of lateral meniscus and 5 of medial meniscus);
- 41/45 cruciate ligaments lesion, misunderstanding 4 (3 of the ACL and 1 of the PCL);
- 136/242 cartilage injuries, misunderstanding 106 (9 on the patella, 49 on the tibia and 48 on the femur) (Figure 2 and 3).

The *second MR reader* detected:

- 185/208 meniscal lesions, misunderstanding 23 (3 of the lateral meniscus and 20 of the medial meniscus);
- 37/45 injuries of the cruciate ligaments, misunderstanding 8 (7 for the ACL and 1 for the PCL);

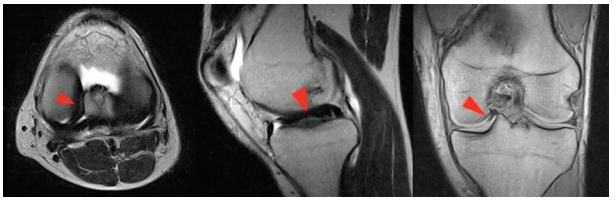

Figure 2. Bucket-Handle lesion of the medial meniscus

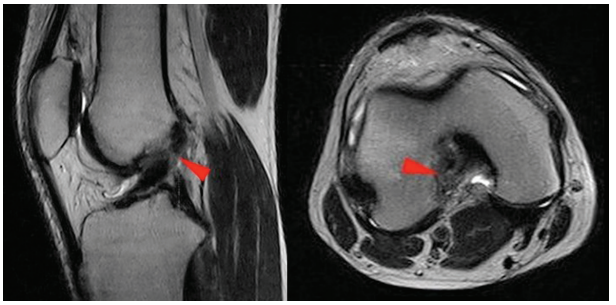

Figure 3. Full proximal (femoral) lesion of the anterior cruciate ligament

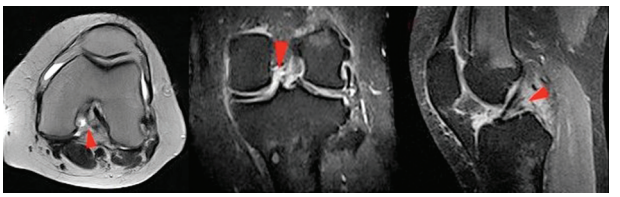

Figure 4. Full lesion of the posterior cruciate ligament

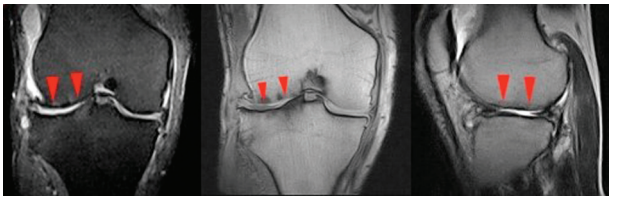

Figure 5. III-IV degree chondropathy of the lateral compartment

- 126/242 cartilage injuries, misunderstanding 116 (7 on the patella, 62 on the tibia and 54 on the femur) (Figure 4 and 5).

MR-Arthroscopy comparison (Table 5)

- *Meniscal* injuries revealed 90% of sensitivity, 91% specificity and a diagnostic accuracy of 93% (mean values between the two observers vs arthroscopy);
- crossed *ligaments* lesions showed 73% sensitivity and 97% specificity with an accuracy of 96%;
- for articular *cartilage* we obtained a mean sensitivity of 58%, 92% specificity and 85% diagnostic accuracy: in particular 82% patella, 90% tibia and 84% femur.

Inter-observer concordance resulted to be excellent for cruciate *ligaments* (K of Cohen's test = 0.832), good (K = 0.768) for *menisci*, modest to moderate for articular *cartilage* (K ranging from 0.236 to 0.389) with worse concordance for tibial cartilage.

Discussion

Over the years, with the evolution of machines and study protocols, MR has been confirmed as a non-invasive and highly sensitive instrument in the evalua-

Table 5. Results of the comparison between MR and arthroscopy findings.

	SS1	SS2	SP1	SP2	PPV1	PPV2	NPV1	NPV2	ACC1	ACC2
Medial Meniscus	97	87	85	97	95	87	90	97	94	95
Lateral Meniscus	83	94	97	83	90	94	95	85	93	91
PCL	67	50	100	99	100	50	100	99	100	99
ACL	91	84	97	92	89	72	98	96	96	90
Patellar cartilage	73	86	80	85	40	21	94	99	79	85
Tibial cartilage	27	55	98	98	70	67	87	96	86	95
Femoral cartilage	65	44	94	96	77	83	90	81	88	81
Total	74	73	94	93	81	77	91	91	89	88

SS sensitivity; SP specificity; PPV positive predictive value; NPV negative predictive value; ACC accuracy. 1 = Reader 1; 2 = Reader 2. PCL = Posterior Cruciate Ligament; ACL = Anterior Cruciate Ligament

tion of osteo-ligamentous structures, articular surfaces and peri-articular knee tissues (1).

Arthroscopy, on the other side, is a highly sensitive and specific procedure for evaluating endocapsular structures (2-5) but invasive and no more accepted as sole diagnostic instrument.

As mentioned above, high-intensity field devices (>1T) allow for spatial and contrast resolution and a signal-to-noise ratio not obtainable with low-field equipment (<0.5T), if not increasing scanning time at the expense of increasing artifacts from movement (14,15).

Here we emphasize the use of low-field equipment dedicated to the joints, cheaper and more versatile than the large and expensive high-field equipment of proven diagnostic quality (4,16-20).

Our results are in line with literature as regards the evaluation of pathological findings on menisci (2,5,14,21) and cruciate ligaments (2,5,6,21-24) with a good (93% and 96% respectively) diagnostic accuracy and a good to excellent inter-observer concordance (Table 5).

Riel et al. (5) correctly identified, using the low field MR, the 3 lesions of the PCL present in their own study, as well as Lokannavar et al. (24) correctly identified two kind of lesions in their own study. Although our results were in line with these studies about the PCL injuries, it is still difficult to draw statistical conclusions with such small size samples.

The low diagnostic accuracy associated with the low inter-observer concordance found in detecting cartilage lesions reveals a weakness in diagnosing cartilage injuries by the 0.3T MR equipment. In our experience, the major discrepancies between radiological and arthroscopic findings are referred to grade I-II chondral injuries, mostly about patella (average error 24.5%), and less (15% and 14.5% respectively) for tibia and femur (trochlear cartilage) (Figure 6).

Scarcity of studies on articular surface evaluation by low-field MR makes it difficult to compare our data with literature. In particular Lee et al. (3) comparing their chondral lesions findings between low-field MRI and arthroscopy, obtained 8% of sensitivity and 94% of specificity, while Riel et al. (5) evaluating only grade III chondral lesions and comparing them with arthroscopy obtained 72% of sensitivity and 100% of specificity.

Best results in the field of chondral lesions are obtained with machines capable of developing more intense fields (> 1T); especially, the recent use of 3T equipment has allowed good diagnostic reliability also with 76% of sensitivity and 95% of specificity (16,18,19).

Conclusions

The present study confirms the reliability of the MR examination performed by low-field equipment for meniscal and ligamentous lesions, while demonstrates the limitations of the tool in detecting mild chondral lesions. Especially, the diagnostic accuracy of

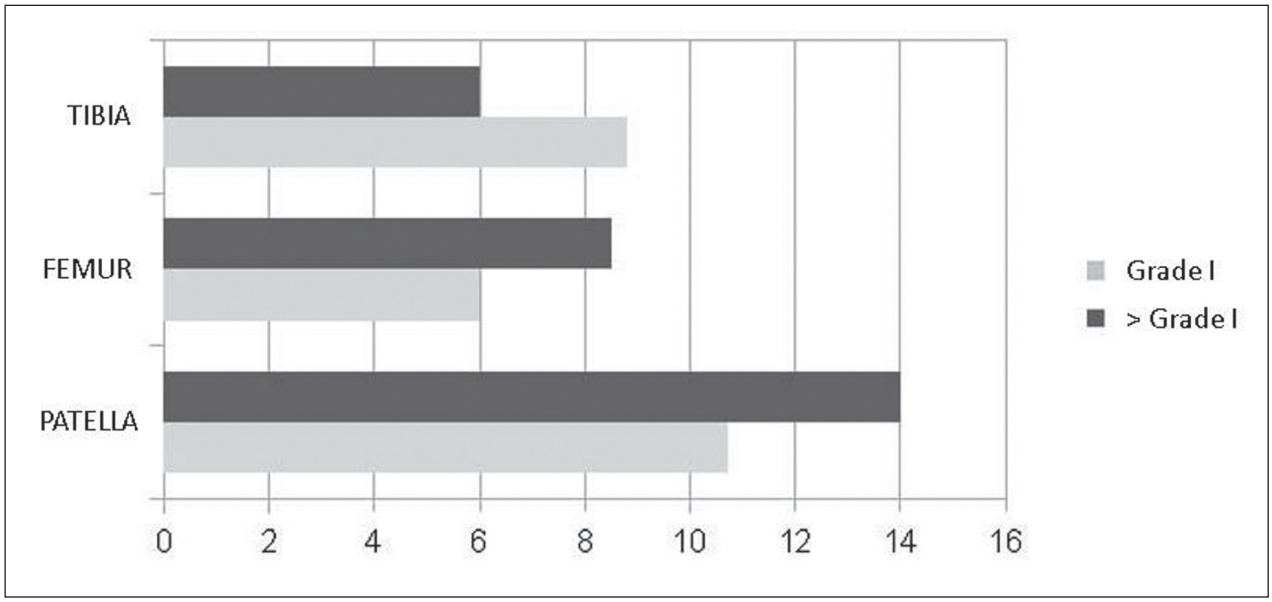

Figure 6. Visual representation of percentages of diagnostic errors for cartilage divided in degree I or degrees II-III-IV (according to the Outerbridge classification)

the latter is positively affected by the increase of the magnetic field of the latest MR equipment; however the low availability of the same and the highest cost of purchase and management makes their use not convenient except in selected cases.

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Received: 26 October 2018
Accepted: 10 December 2018
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