Acta Orthop. Belg., 2005, **71**, 189-196

ORIGINAL STUDY

Accuracy of MRI in comparison with clinical and arthroscopic findings in ligamentous and meniscal injuries of the knee

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Rapidly progressing medical technology sometimes obscures the importance of history and physical examination. This study was designed to assess the value of MRI and clinical examination in the diagnosis of ligamentous and meniscal knee injuries in comparison with arthroscopic findings.
In the year 2003-2004, we conducted a prospective, single blind study to assess ligamentous and meniscal injuries of the knee in patients with acute knee trauma. The mean age was 27.9 years. The sex distribution was 81.4% male and 18.6% female ; 42.9% of injuries affected the right knee and 57.1% the left knee. All the included patients were ordered a MRI, executed in five separate centres. All patients underwent arthroscopy by the author. Arthroscopic findings were the diagnostic reference.
Clinical examination was accurate in 91.4%, and MRI in 88.5% of anterior cruciate ligament injuries. For posterior cruciate ligament injuries, clinical accuracy was 100% and MRI 94.6%. Clinical examination was accurate in 96.9% and MRI in 85.9% of medial meniscal injuries. For lateral meniscus injuries, clinical accuracy was 85.4% and MRI 73.8%. MRI findings showed the lowest correlation with arthroscopic findings in lateral meniscus injuries (r = 0/47). Clinical diagnostic performance was poorest in case of combined cruciate ligament and meniscal injuries.
We found an excellent correlation between MRI and clinical findings. However, when MRI is normal, high clinical suspicion and a skilled clinical examination are more reliable.

INTRODUCTION

The introduction of MRI led to a revolutionary change in medical diagnosis. The comparison of MRI diagnosis and surgical/clinical findings has always been a challenge for the health professions (*3, 9, 15, 17, 22*). Many publications addressed the accuracy of MRI in orthopaedic diagnosis, but few reports have correlated clinical and arthroscopic findings with MRI (*1, 3, 8-12, 16, 18, 20, 22-24*).

In Iran, the use of MRI has spread widely during the last four years. This has also created an immense area of controversy among physicians. We conducted a prospective, single blind study, to compare diagnostic accuracy of clinical examination with MRI findings in assessing patients with acute traumatic internal derangement of the knee.

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PATIENTS AND METHODS

During the years 2003 and 2004, two examiners (a senior resident in orthopaedic surgery and the main author) both examined 110 eligible patients with acute traumatic knee complaints at the university referral hospital, AKHTAR Hospital in Tehran.

Clinical examination included history (onset of effusion, presence of pop, locking, giving way and subjective instability) and physical examination (presence of effusion, range of motion, joint line tenderness, three plane stability, McMurray test, squat test, Apley test, anterior drawer test, Lachman test, posterior drawer test and quadriceps active test). We excluded 21 patients whose histories did not suggest meniscal and cruciate ligament injury, or who had had prior knee surgery or knee trauma. We classified the injury as a meniscal injury if there was an appropriate history, joint line tenderness and a positive McMurray test (*21*). We classified the injury as a cruciate ligament injury in patients with an appropriate history and a positive anterior or posterior drawer test, with or without a positive Lachman test (*21*).

This left 89 patients with a suspected meniscal or cruciate injury.

When the two examiners reached a consensus, we were confident of the clinical findings. Where clinical consensus was not reached, a third orthopaedic surgeon, who was unaware of the other examiners' diagnoses, examined the patients, following the same protocol. If two interpretators came to an identical clinical conclusion, this conclusion was accepted.

Three cases were excluded because conventional radiography demonstrated osteochondral or tibial plateau fractures. The remaining 86 knees were reassessed after three weeks in a posterior splint and non-weight bearing. We lost 13 patients to follow-up. The same three examiners examined the residual 73 patients, following the same protocol. Sixteen patients, whose initial diagnosis was dismissed at the second examination, were grouped as group A. We informed these patients of our modified diagnosis, and asked them to sign an agreement, to undergo arthroscopy in spite of their improved status. Two of them refused to sign and were excluded from the study. Finally 71 were planned to undergo arthroscopy.

A total of 71 patients were sent for MRI at five different centres. We selected five well-equipped MRI centres. All of their MR imaging studies were performed using a standard knee protocol on a 1.5-Tesla MR scanner with a phased array knee coil. We let the patients select the centre they were more comfortable to go. All of the patients had T1 and T2 weighted coronal and sagittal plane images, without contrast. Parameters used were slice thickness of 3 mm with a 0.5 cm interslice interval, 14 × 20 cm FOV (field of view), 256 × 320 matrix for all sequence. TR/TE was (400/30 ms) in T1 and (3500/90 ms) in T2 images respectively. MR pulse sequences included fast spin echo (FSE) and fast recovery (*4, 13*).

A blinded radiologist reported the MRI findings. Meniscal tears were radiologically graded from I to IV. Grades III and IV were considered as positive findings. Complete as well as partial lesions of the anterior and posterior cruciate ligaments were interpreted as ruptures. Again we excluded one patient with an occult osteochondral fracture, which was revealed only by MRI. Finally, 70 patients were included in this study and underwent arthroscopy even if they did not have any clinical knee problem anymore (the mentioned 14 patients of group A).

All arthroscopic procedures were performed in a standard manner by one experienced arthroscopic surgeon (E.J.) who was blinded to the radiologist's diagnosis, using an infero-lateral portal and supero-lateral drainage. The arthroscopic findings were considered as the reference diagnostic data (*7, 20*).

The diagnostic findings were compared at three levels : clinical versus arthroscopic, clinical versus MRI and MRI versus arthroscopic findings.

We calculated positive predictive value, negative predictive value, sensitivity, and specificity. Furthermore, we analyzed the data to understand the role of concomitant injury on the MRI reports.

We used the chi-square test in the area of nominal variable and the Fisher exact test for comparison between accuracy, sensitivity, specificity, positive predictive value and negative predictive value. Furthermore, we used Phi and Cramer's correlation to reveal the correlation among the findings.

RESULTS

We assessed an acute knee injury in 57 males (81.4%) and 13 females (18.6%), ranging in age from 17 to 51 years (mean = 27.9).

The right knee was involved in thirty cases (42.9%) and the left knee in 40 (57.1%). The mechanism of trauma was a non-professional sports injury in 55 patients, a motor car accident in 10 patients and a fall in 5 patients.

Table I. — Accuracy of clinical findings, using arthroscopic finding as the reference data

Component / Test	ACL %	PCL %	MM %	LM %
Accuracy	91.4	100	96.9	85.5
Positive predictive value	90	100	92.3	68.7
Negative predictive value	94	100	100	96.3
Sensitivity	85.7	100	100	84.6
Specificity	95.9	100	95.6	91.2

Table II. — Accuracy of MRI findings, using arthroscopic findings as the reference data

Component / Test	ACL %	PCL %	MM %	LM %
Accuracy	88.5	94.6	85.9	73.8
Positive predictive value	90	100	92.3	50
Negative predictive value	90	96.7	81.8	92.6
Sensitivity	78.3	81.8	75	66.6
Specificity	95.7	100	94.7	86.2

Clinical, MRI, and arthroscopic findings

In 7 patients, the two clinical examiners failed to reach a consensus and the third examiner participated to reach a verdict : 6 of them were arthroscopically documented combined injuries.

We diagnosed clinically 21 anterior cruciate ligament injuries, 9 posterior cruciate ligament injuries, 24 medial meniscal injuries and 13 lateral meniscal injuries in 56 patients.

MRI detected 23 anterior cruciate ligament injuries, 11 posterior cruciate ligament injuries, 32 medial meniscal injuries and 12 grade III and IV lateral meniscal injuries. There were also 3 grade II lateral meniscal injuries that appeared to have been underestimated arthroscopically. Arthroscopy revealed 20 anterior cruciate ligament injuries, 9 posterior cruciate ligament injuries, 26 medial meniscal and 16 lateral meniscal injuries. Tables I and II illustrate in detail accuracy, PPV, NPV, sensitivity, and specificity of clinical and MRI findings. Table III illustrates the true positive, true negative, false positive and false negative clinical and MRI findings.

Combined injuries

We saw 17 cases of concomitant injuries at arthroscopy. The predominant pattern was anterior cruciate ligament rupture and medial meniscus tear (5 patients), followed by anterior cruciate ligament and lateral meniscus (4 patients), or anterior cruciate ligament + medial meniscus + lateral ligament (4 patients), posterior cruciate ligament + lateral meniscus (3 patients), and medial meniscus + lateral meniscus (1 patient).

MRI also reported 17 cases of combined injuries. The predominant pattern was ACL+MM (n = 6), followed by ACL + MM + LM (n = 3), ACL + LM (n = 2), ACL + PCL (n = 2), MM + LM (n = 2), and ACL + PCL + LM (n = 1), ACL + PCL + MM (n = 1). Details and overlap between MRI and arthroscopic findings are illustrated in table IV on combined injuries.

Group A patients

In 14 patients the initial diagnosis was revoked (20%) after 3 weeks of splinting and non-weight-bearing. MRI reports of 14 patients revealed 7 grade I meniscal injuries (5 MM & 2 LM) and 3 grade II meniscal injuries (2 MM & 1 LM). Arthroscopy did not change these diagnoses.

Statistical analysis

Re-evaluating the initial result of the two interpretators in 70 remaining patients, revealed a significant difference in number of arthroscopically documented concomitant cruciate and meniscal injury (cruciate/meniscus) between the group in which 2 examiners reached consensus (63 patients : 53 with single injuries and 10 with combined injuries) and the group in which 2 examiners failed to reach a consensus (1 with a single injury and 6 with concomitant injury) ($p < 0.0005$) indicating the potential role of concomitant injury in erroneous clinical diagnosis.

Table III. — True positive, true negative, false positive and false negative of clinical and MRI findings, using arthroscopic finding as the reference data

Test	True positive	True negative	False positive	False negative
ACL clinical finding	18	47	3	2
ACL MRI finding	18	45	5	2
PCL clinical finding	9	61	0	0
PCL clinical finding	9	59	2	0
MM clinical finding	24	44	0	2
MM MRI finding	24	36	8	2
LM clinical finding	11	52	2	5
LM MRI finding	8	50	4	8

We compared lateral meniscus and medial meniscus MRI findings in order to reveal the cause of lateral meniscus injury missed by MRI.

Arthroscopically documented lateral meniscus injuries were divided into 2 groups. Those with combined lesion on MRI comprised group one and the patients without a single MRI lesion comprised group two. Then, we analysed sensitivity, specificity, PPV, and NPV in these 2 groups. Fischer exact test revealed significant differences between these two groups in sensitivity (62.5% Vs 37.5%, $p < 0.01$), specificity (55.5% Vs 0%, $p < 0.005$) and PPV (55.5% Vs 37.5%, $p < 0.02$) indicate that MRI is performing better for the lateral meniscus in combined lesions (group I). Vice versa in area of Npv we face with better result in the group without concomitant injury (62.5% Vs 90%, $p < 0.005$). The true positive, true negative, false positive and false negative MRI findings of lateral meniscus in cases with or without combined injuries is illustrated in table V.

Arthroscopically documented medial meniscus injuries were similarly divided into 2 groups. Fischer exact test showed significant differences between group one and two in specificity (55.5% Vs 88.5%, $p < 0.005$), Ppv (63.6% Vs 80.9%, $p < 0.007$) and Npv (83.3% Vs 96.7%, $p < 0.002$). However, the test did not show any significant difference in sensitivity between the groups (87.5% Vs 94.4%, $p < 0.14$). MRI is performing better in detection of medial meniscus tears in cases without combined injury. The true positive, true negative, false positive and false negative of medial meniscus MRI findings in cases with or without concomitant injury is illustrated in table V.

To identify the cause of clinically missed meniscal tears, patients were again classified into two groups. Group one who had no arthroscopically documented cruciate injury (intact ACL and PCL) and group two had an arthroscopically documented cruciate injury (ACL, PCL or both). We missed only 2 meniscal injuries (in 2 different patients) in 53 patients of group one and missed 5 meniscal injuries (in 5 different patients) among the 17 patients of group two. The Pearson chi-square test shows this to be highly significant (3.8% Vs 29.4%, $p < 0.002$). In combined knee injuries meniscal lesions are easily missed.

Next the correlation between clinical/arthroscopic and MRI/arthroscopic findings, using phi/ Cramer's nominal test, was evaluated. Correlations and their significant differences are illustrated in table VI. Neither MRI nor clinical examinations are superior. In lateral meniscus injuries clinical examination was more accurate than MRI, but without statistical significance.

Stratification effects of MRI centres were examined. Using ANOVA test, the different results of each MRI centre (using the same MRI technique, as detailed above) show no significant difference in accuracy ($p > 0.05$, table VII).

DISCUSSION

This is not the first report to stress the superiority of repeated and controlled skilled clinical examination over MRI, nor will it be the last. Feller *et al* (*8*) and Hostetter *et al* (*10*) reported similar findings, but Zairal *et al* (*24*) reported diverging findings. Alioto *et al* (*1*), Trieshmann *et al* (*23*), and

Table IV. — Details of concomitant injury

Cases' number	MRI finding	Arthroscopic finding	Concomitant finding
1	ANTERIOR CRUCIATE LIGAMENT + LM	ANTERIOR CRUCIATE LIGAMENT + MM + LM	MRI & ARTHROSCOPY
2	ANTERIOR CRUCIATE LIGAMENT + MM	ANTERIOR CRUCIATE LIGAMENT + MM + LM	MRI & ARTHROSCOPY
3	ANTERIOR CRUCIATE LIGAMENT + MM	ANTERIOR CRUCIATE LIGAMENT + MM + LM	MRI & ARTHROSCOPY
4	ANTERIOR CRUCIATE LIGAMENT + MM + LM	ANTERIOR CRUCIATE LIGAMENT + LM	MRI & ARTHROSCOPY
5	ANTERIOR CRUCIATE LIGAMENT + LM	ANTERIOR CRUCIATE LIGAMENT + LM	MRI & ARTHROSCOPY
6	ANTERIOR CRUCIATE LIGAMENT + POSTERIOR CRUCIATE LIGAMENT + LM	POSTERIOR CRUCIATE LIGAMENT + LM	MRI & ARTHROSCOPY
7	ANTERIOR CRUCIATE LIGAMENT + POSTERIOR CRUCIATE LIGAMENT	POSTERIOR CRUCIATE LIGAMENT + LM	MRI & ARTHROSCOPY
8	ANTERIOR CRUCIATE LIGAMENT + POSTERIOR CRUCIATE LIGAMENT + MM	ANTERIOR CRUCIATE LIGAMENT + MM	MRI & ARTHROSCOPY
9	ANTERIOR CRUCIATE LIGAMENT + MM + LM	ANTERIOR CRUCIATE LIGAMENT + LM	MRI & ARTHROSCOPY
10	ANTERIOR CRUCIATE LIGAMENT + MM	ANTERIOR CRUCIATE LIGAMENT + MM	MRI & ARTHROSCOPY
11	ANTERIOR CRUCIATE LIGAMENT + MM	ANTERIOR CRUCIATE LIGAMENT + MM	MRI & ARTHROSCOPY
12	MM	ANTERIOR CRUCIATE LIGAMENT + MM + LM	ARTHROSCOPY
13	ANTERIOR CRUCIATE LIGAMENT + MM	ANTERIOR CRUCIATE LIGAMENT + LM	MRI & ARTHROSCOPY
14	ANTERIOR CRUCIATE LIGAMENT	ANTERIOR CRUCIATE LIGAMENT + LM	ARTHROSCOPY
15	MM	MM + LM	ARTHROSCOPY
16	POSTERIOR CRUCIATE LIGAMENT	POSTERIOR CRUCIATE LIGAMENT + LM	ARTHROSCOPY
17	MM	ANTERIOR CRUCIATE LIGAMENT + MM	ARTHROSCOPY
18	ANTERIOR CRUCIATE LIGAMENT + MM	ANTERIOR CRUCIATE LIGAMENT	MRI
19	MM + LM	MM	MRI
20	MM + LM	– – – – –	MRI
21	ANTERIOR CRUCIATE LIGAMENT + MM + LM	– – – – –	MRI
22	ANTERIOR CRUCIATE LIGAMENT + POSTERIOR CRUCIATE LIGAMENT	– – – – –	MRI

Table V. — The true positive, true negative, false positive and false negative of lateral and medial meniscus MRI findings in cases with or without concomitant injury, using radiologist report as the point reference

Test	True positive	True negative	False positive	False negative
Medial meniscus MRI finding in concomitant injury	7	5	4	1
Medial meniscus MRI finding in non concomitant injury	17	31	4	1
Lateral meniscus MRI finding in concomitant injury	5	5	4	3
Lateral meniscus MRI finding in non concomitant injury	3	45	0	5

Table VI. — The Phi/Cramer's correlation

Type of injury	Arthroscopic finding
Anterior cruciate ligament clinical finding	0.82†
Anterior cruciate ligament MRI finding	0.76†
Posterior cruciate ligament clinical finding	1.00†
Posterior cruciate ligament MRI finding	0.89†
Medial meniscus clinical finding	0.94†
Medial meniscus MRI finding	0.72†
Lateral meniscus clinical finding	0.70†
Lateral meniscus MRI finding	0.47†

† Non- significant difference.

Table VII. — Accuracy of ACL, PCL, MM, and LM in different MRI centres

MRI centres	Accuracy of ACL	Accuracy of PCL	Accuracy of MM	Accuracy of LM
#1	90%	97.6%	82%	77.5%
#2	92%	94.6%	88.3%	73.2%
#3	88.6%	93.5%	84.2%	75.3%
#4	88%	96%	86.7%	71.5%
#5	85.3%	89.7%	89.1%	70%

Bryan *et al* (*6*) reported the role of MRI in decreasing unnecessary diagnostic arthroscopy. On the other hand, Runkle *et al* (*20*) emphasised the importance of the expertise of the MRI interpreter in increasing the accuracy of diagnosis. Generally, our protocol of clinical examination (in two sessions and with two examiners) suggests slightly better accuracy, but fails to show a significant superiority over MRI finding (*11*).

Solomon *et al* (*21*) stated "While most meniscal or ligamentous knee injuries heal with non-operative treatments, a subset should be treated with arthroscopic or open surgery". We believe that our clinical protocol including a second examination after 3 weeks of splinting can reduce the number of unnecessary MRI's or arthroscopic procedures, and should be particularly considered when the patient is not a professional sportsman, or is willing to wait for three weeks. However, in case of a high clinical suspicion of osteochondral damage and/or bony lesion, early MRI, or arthroscopy may be required.

An area of controversy is inadequate arthroscopic evaluation of the knee joint (*12*). Since we performed all of our arthroscopic procedures under the supervision of another orthopaedic surgeon, whose role was to watch out for missed lesions, we retain confidence in our arthroscopic findings.

Our clinical or MRI diagnostic accuracy in cruciate ligaments and meniscal injuries is similar to that reported elsewhere (*8, 14, 24*). Our clinical and even more our MRI accuracy in the diagnosis of lateral meniscus tears has been slightly inferior. Rubin (*19*) and Blankenbaker *et al* (*4*) report the variation of lateral meniscus sensitivity in MRI studies (68-86%). It is obvious that the MRI reports are highly dependent on the skills and experience of the radiologist and his/her equipment. Our MRI reports missed a considerable number of lateral meniscal injuries, but less so in combined injuries. We believe that the concomitant findings were triggers for radiologists to pay additional attention to other potential intra-articular lesions. Kreitner *et al* (*12*) report on "over-interpretation of central signal intensities with contact to the meniscal surface, but without disturbance of the meniscal contour" as the prime aetiology of missed meniscal injuries in their study (two cases in our series). Moreover, they mention the "magic angle phenomenon" as a cause of missing tears on MRI. Li *et al* (*13*) report a medium risk of magic angle phenomenon for FSE (fast spin echo). The magic angle phenomenon has had an influence in our readings since our MRI centres use FSE. Some lesions could have been missed due to large spacing for imaging (0.5 cm). Overlooked MRI sheets may be the cause of a missed tear. And finally, the results show that it is unwise to trust negative MRI reports in the face of high clinical suspicion.

Our data support the claim that combined injuries may affect the diagnosis of meniscus lesions (*2*) : we missed some injured menisci in our clinical examination, especially lateral ones in the group of patients with combined cruciate ligament and meniscal injuries. Also, it was in patients with combined injuries that the two examiners most often failed to reach agreement.

The accuracy of diagnosis of injured menisci, or cruciate ligaments, will depend on the quality of imaging equipment and on the skills and experience of the clinical examiner, the radiologist and the arthroscopist. Assuming that MRI study is carried out correctly and assessed by an experienced radiologist, the accuracy of MRI for meniscus diagnosis is almost equivalent to that by arthroscopy (*20*). When in doubt about the technical quality of an MRI and a negative report of the radiologist in a new patient with knee problems, our results show that it is safe to trust a skilled clinical examination and go straight to arthroscopy, rather than order a second MRI. In countries with poor health resources, it is important to consider the economic burden of MRI for patients. Therefore, it is important for an orthopaedic surgeon to choose the best MRI setting and radiologist, in order to save time and reduce patient costs.

In our view, the great variation in published reports is related to case selection. We selected acute injuries and re-examined them after three weeks of non-weight-bearing and splinting and sent for MRI those selected for surgery. We did not refer the patients with a non-surgical plan. Furthermore, we planned to perform surgery on the basis of clinical examination, so we used MRI to possibly contradict our decision.

Kocher *et al* (*11*) mention that selective MRI does not provide an enhanced diagnostic utility over clinical examination. MRI should be reserved for cases where the clinical diagnosis is uncertain and when the input of MRI is likely to alter the treatment plan. Brooks *et al* (*5*), in a prospective study, assessed the agreement between preoperative clinical/arthroscopic and MRI/arthroscopic findings (79% versus 77% agreement, respectively) and concluded that MRI did not reduce the number of negative arthroscopic procedures. Bryan *et al* (*6*) reported contradictory findings. They demonstrated that MRI could decrease the rate of surgery in chronic knee problems, especially in those in whom surgery was already planned ; furthermore, they found that it did not increase the overall cost. There was no significant difference between different magnetic resonance imaging centres. This finding is similar to Kocher's (*11*).

CONCLUSION

The strength of correlation between MRI and arthroscopic findings confirms the value of MRI in assessing internal knee structures. However, skilled clinical examination rates similarly to MRI. Whereas modern imaging techniques can be invaluable in diagnosis, a competent and preferably repeated physical examination can sometimes play the same role. It is important to consider the economic load of MRI for patients, especially in countries with poor welfare state and poor insurance coverage. In addition, it is wise to doubt clinical accuracy in case of suspected combined injuries.

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