Journal of Orthopaedics, Trauma and Rehabilitation 24 (2018) 52–56

Contents lists available at ScienceDirect

Journal of Orthopaedics, Trauma and Rehabilitation

Journal homepages: www.e-jotr.com & www.ejotr.org

Research Paper

Clinical, Magnetic Resonance Imaging, and Arthroscopic Correlation in Anterior Cruciate Ligament and Meniscal Injuries of the Knee
膝關節前交叉韌帶和半月板損傷的臨床、磁共振成像和關節鏡的相關性

Patel Ishani*, Chandru Vijay, Nekkanti Supreeth, Renukarya Ravishankar, Reddy Vishnu Vardhan, Gopalakrishna Sampathirao Vanaja

Department of Orthopaedics, JSS Hospital, Mahathma Gandhi Road, Mysore 570004, Karnataka, India

ARTICLE INFO

Article history:
Received 9 August 2016
Received in revised form
27 December 2016
Accepted 9 May 2017

Keywords:
ACL
arthroscopy
ligament injury
meniscus
MRI

ABSTRACT

Background: The aim of this study is to compare and correlate the clinical, magnetic resonance imaging (MRI), and arthroscopy findings in anterior cruciate ligament (ACL) and meniscal injuries of the knee.
Methods: This was a prospective study of 30 cases of ACL and meniscal injuries of the knee admitted between September 2014 and May 2016, who underwent clinical examination, MRI, and arthroscopy of the knee.
Results: In our study of 30 cases, there were 26 male and four female patients with age ranging from 18 years to 60 years, with most patients in between 21 years and 30 years. Clinical examination had sensitivity of 90.91%, specificity of 100%, and accuracy of 93.33% for ACL, sensitivity of 83.33%, specificity of 77.78%, and accuracy of 80% for medial meniscus, and sensitivity of 75%, specificity of 77.27%, and accuracy of 76.67% for lateral meniscus. MRI had sensitivity of 95.45%, specificity of 87.5%, and accuracy of 93.33% for ACL, sensitivity of 91.67%, specificity of 55.56%, and accuracy of 70% for medial meniscus, and sensitivity of 62.5%, specificity of 72.73%, and accuracy of 70% for lateral meniscus.
Conclusion: In conclusion, the present study supports that clinical diagnosis is of primary necessity, as the positive predictive value is high for all the lesions. MRI is an additional diagnosing tool for ligament and meniscal injuries of the knee. Routine use of MRI to confirm the diagnosis is not indicated, as the positive predictive value is low, but can be used to exclude pathology, as the negative predictive value is high for all the lesions.

中 文 摘 要

背景: 研究的目的是比較和相關膝關節前交叉韌帶和半月板損傷的臨床、磁共振成像和關節鏡檢查結果。
方法: 從2014年9月至2016年5月入院，對30例膝關節前交叉韌帶和半月板損傷患者接受臨床檢查、膝關節MRI和關節鏡檢查，進行前瞻性研究。
結果: 本研究中30例，26例男性，4例女性，年齡18至60歲，絕大多數患者為21至30歲。臨床檢查對前交叉韌帶的靈敏性為90.91%，特異性為100%，準確率為93.33% ； 內側半月板的靈敏度為83.33%，特異性為77.78%，準確率為80% ； 外側半月板的靈敏性為75%，特異性為77.27%，準確率為76.67%。而磁共振成像對前交叉韌帶的靈敏性為95.45%，特異性為87.5%，準確率為93.33% ； 內側半月板的靈敏性為91.67%，特異性為55.56%，準確率為70% ;外側半月板的靈敏性為62.5%，特異性為72.73%，準確率為70%。
結論: 本研究支持臨床診斷是首要必需的，因為所有病變的陽性預測值都很高。磁共振成像是膝蓋韌帶和半月板損傷的附加診斷工具。因為陽性預測值低，常規使用磁共振成像來確認診斷沒有必要。但因為所有病變的陰性預測值都很高，可以用於排除病變。

Introduction

The knee joint is a common site of injury due to trauma, repetitive activities, and sports activities. Clinical tests used in the diagnosis of meniscal and ligament injuries have limitations and it may be difficult to elicit objective signs repeatedly, mainly due to pain in an acute or subacute presentation. History taking regarding the mechanism of knee injury gives a vital clue to the structures injured in the knee joint. Hyperextension with an audible pop

* Corresponding author. *E-mail:* dr.ishani26@gmail.com.

http://dx.doi.org/10.1016/j.jotr.2017.05.005

would suggest an anterior cruciate ligament (ACL) tear. A direct blow to the knee from the side would point toward collateral ligament injury, and from the front, would indicate a cruciate ligament injury. Although clinical examination is most important for the diagnosis of a ligament injury, painful stress examinations are not always accurate in the acute phase of the injury. Clinical tests may be confusing and may cause a delay in diagnosis. Therefore, complementary diagnostic tools are often necessary, mainly when suspicion of multiple lesions exists.

Magnetic resonance imaging (MRI) has a better soft tissue contrast and multiplanar slice capability which has revolutionized and has become the ideal modality for imaging the complex anatomy of the knee joint.[1]

MRI is a completely noninvasive diagnostic modality and there is no ionizing radiation. Moreover, the ligaments of the knee are divided into intraarticular and extraarticular. MRI plays a most important role in their evaluation. This division is important, as the extraarticular ligaments are not visible on routine arthroscopic procedures. However, identification of meniscal tears can be difficult to interpret and can be observer dependent as well as dependent upon the sensitivity of the scanner.

Arthroscopy is considered as “the gold standard” for diagnosis of traumatic intraarticular knee lesions. Arthroscopy, being a highly sensitive and specific procedure, is both diagnostic and therapeutic, but is invasive and can cause complications like infection, haemarthrosis, adhesions, and reflex sympathetic dystrophy.

Materials and methods

This was a prospective study involving 30 patients with history of knee injuries who were admitted in the Department of Orthopaedics. Clinical examination and MRI of the knee joint was done for all these patients either before or after admission. The patients were then subjected to diagnostic and therapeutic arthroscopy by the arthroscopy team in the Department of Orthopaedics, JSS Hospital (Mysore, India) between September 2014 and May 2016.

Patients included in this study were aged between 18 years and 60 years, and had knee problems like pain, instability, and locking of the knee for more than 6 weeks.

Patients excluded from this study were those who had undergone previous meniscectomies, knee ligament repair or reconstructions and knee arthroscopies, posterior cruciate ligament injuries, knee joint neoplasm, infectious and inflammatory conditions of the knee joint, ferromagnetic implants, pacemakers, and aneurysm clips. Patients undergoing arthroscopy without MRI were also excluded from the study.

All patients gave written consent for inclusion in the study. The treatment process was explained to the patients and they were aware of his/her rights during the study. The written consent form was signed or fingerprinted by the patient. The institutional review board of JSS University approved the protocol of this study. The process of treatment did no harm to the health of the participants.

Complete examination of the knee was carried out 6 weeks post trauma, with particular emphasis on various tests. The Lachman test, anterior drawer test, and posterior drawer test were used for identifying cruciate ligament tears. McMurray's test and joint line tenderness were the diagnostic criteria considered for meniscal injuries. The tests for collateral ligament injuries were valgus/varus stress tests. Physical examination of all the patients was conducted by the most experienced orthopaedic surgeon. In case of any doubtful findings, all of the authors' opinions were sought and the final decision was then taken by the most experienced orthopaedic surgeon. X-ray of the involved knee, anteroposterior (AP) and lateral views, was done to rule out any bony injury. MRI of the knee joint was done 6 weeks post trauma and not immediately, in view of acute haemarthrosis or effusion of the knee, which would mask critical findings that would aid in diagnosis. MRI of the knee included the sequences in sagittal, coronal, and axial planes, fat suppressed T2 axial turbo spin echo, and T1 spin echo sagittal in a 3 Tesla MRI machine (Philips 3T Ingenia. Cleveland, Ohio).

Examination under anaesthesia was done to confirm the signs of instability. Patients underwent arthroscopy by a qualified and experienced orthopaedic surgeon and he was aware of the MRI findings prior to arthroscopy. Clinical, MRI, and arthroscopy findings were recorded and compared.

The composite data was tabulated and studied for correlation with clinical, MRI, and arthroscopic findings and grouped into four categories: (1) a result was considered to be true positive when the positive clinical or MRI diagnosis was confirmed by positive intraoperative arthroscopic evaluation; (2) a result was considered to be true negative when the absence of pathological findings in clinical examination or MRI could be confirmed by arthroscopy; (3) a false positive result was defined as a positive clinical or MRI diagnosis with negative arthroscopy findings; and (4) a false negative result was defined as a positive intraoperative arthroscopy finding, but clinical or MRI diagnosis was found to be negative.

Statistical analysis was used to calculate the sensitivity, specificity, positive predictive value (PPV), and the negative predictive value (NPV), in order to assess the reliability of clinical and MRI results.

Results

In our study, 26 male patients and four female patients in the age group of 18–60 years were included. The right knee joint was found to be more commonly involved (19 patients) than the left knee joint (11 patients). Domestic fall was found to be the common mode of injury.

Medial meniscus injury was more common than lateral meniscus injury in our study. A total of 14 cases of medial meniscus injury were detected on clinical examination; arthroscopy confirmed only 12 cases. The sensitivity and specificity of clinical examination with respect to arthroscopy were 83.33% and 77.78%, respectively (Table 1). MRI detected 19 cases of medial meniscus injury; arthroscopy confirmed only 12 cases. The sensitivity and specificity of MRI with respect to arthroscopy were 91.67% and 55.56%, respectively.

In our study MRI had a higher sensitivity (91.56%) and NPV (90.91%) when compared to clinical examination. Clinical examination had a higher specificity (77.78%), PPV (71.43%), and accuracy of (80%) (Figure 1) when compared to MRI for medial meniscus injury.

Eleven cases of lateral meniscus injury were detected on clinical examination; arthroscopy confirmed only eight cases. The sensitivity and specificity of clinical examination with respect to arthroscopy were 75% and 77.27%, respectively. In our study, MRI detected 11 cases of lateral meniscus injury; arthroscopy confirmed only eight cases. The sensitivity and specificity of MRI with respect

Table 1
Results for clinical examination in diagnosing anterior cruciate ligament (ACL) and meniscal tears

	ACL (%)	MM (%)	LM (%)
Sensitivity	90.91	83.33	75
Specificity	100	77.78	77.27
PPV	100	71.43	54.55
NPV	80	87.5	89.47
Accuracy	93.33	80	76.67

ACL = anterior cruciate ligament; LM = lateral meniscus; MM = medial meniscus; PPV = positive predictive value; NPV = negative predictive value.

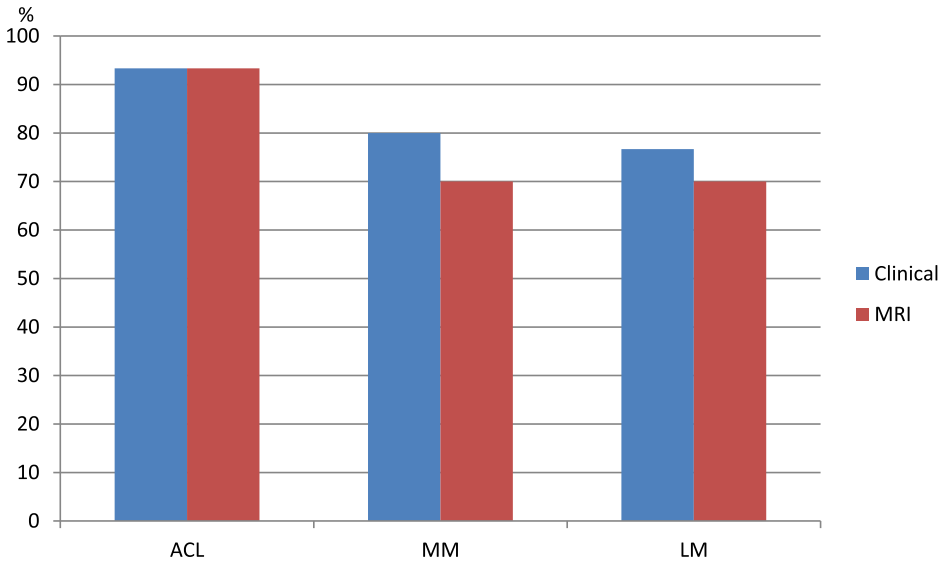

Figure 1. Diagnostic accuracy of clinical versus magnetic resonance imaging (MRI) evaluation in injuries of anterior cruciate ligament (ACL), medial meniscus (MM), and lateral meniscus (LM).

to arthroscopy were 62.5% and 72.73%, respectively (Table 2). In our study, clinical examination had a higher sensitivity (75%), specificity (77.27%), PPV (54.55%), and NPV (89.47%) when compared to MRI for lateral meniscus injury. Clinical examination and MRI had higher false positives in detecting meniscal tears. If MRI is used as the only form of preoperative screening for this condition, then there may well be unnecessary arthroscopies performed.

Among the structure involved in knee injuries, ACL injury was the most common, accounting for 20 cases (66.6%) on clinical examination, of which two were false negatives and arthroscopy detected 22 (73.3%) ACL injuries. MRI detected 22 (73.3%) ACL injuries, one of which was false positive.

The sensitivity and specificity of clinical examination with respect to arthroscopy were 90.91% and 100%, respectively (fair correlation with arthroscopy in diagnosing ACL tears). PPV was 100%. The NPV of clinical examination was 80%.

The sensitivity and specificity of MRI with respect to arthroscopy were 95.45% and 87.5%, respectively (fair correlation with arthroscopy in diagnosing ACL tears). The PPV was 95.45% and the NPV of MRI was 87.5%.

In our study MRI had a higher sensitivity (95.45%) and NPV (87.5%) when compared to clinical examination. Clinical examination had a higher specificity (100%) and PPV (100%) when compared to MRI for ACL injury.

Discussion

The purpose of this study was to compare the accuracy of clinical and MRI findings in diagnosing the meniscal and ligamentous injuries of chronic painful knees.

Table 2
Results for magnetic resonance imaging (MRI) in diagnosing anterior cruciate ligament (ACL) and meniscal tears

	ACL (%)	MM (%)	LM (%)
Sensitivity	95.45	91.67	62.5
Specificity	87.5	55.56	72.73
PPV	95.45	57.89	45.45
NPV	87.5	90.91	84.21
Accuracy	93.33	70	70

LM = lateral meniscus; MM = medial meniscus; NPV = negative predictive value; PPV = positive predictive value.

In the present study of 30 patients, 26 were males and four were females. The age ranged from 18 years to 60 years. The youngest male patient was aged 18 years and the oldest male patient was 46 years; the youngest female patient was aged 24 years and the oldest female patient was 45 years. This showed that there was a tendency of males being injured and getting operated on at an earlier age.

In the present study, males comprised the predominant number of patients who suffered knee injuries, which were mainly due to domestic falls. The maximum number of patients who suffered knee injuries was in the 20–30 years group. In our study, 18 patients fell into this age group, comprising 60% of the patients. The right knee was involved in 19 cases (63.3%) and the left knee was involved in 11 cases (36.6%); there was no bilateral involvement. Meniscal tears were classed as torn or not torn. ACLs that were completely torn were considered in this study.

Mackenzie et al[2] studied 332 patients' diagnosis before and after MRI. The diagnosis was initially based on the clinical examination and the therapeutic procedure was decided before MRI. A total of 57 from 113 clinically positive before MRI meniscal tears were not confirmed with MRI. This result led to revaluation and differentiation of treatment in 62% of the patients. From those patients programmed for surgery, only 38% finally underwent arthroscopy.

Weinstabl et al[3] randomly distributed patients with positive meniscus rupture tests into two groups. All of the patients in the first group had MRI examination before arthroscopy. In this group, only 2% of patients did not have positive findings during arthroscopy. The second group of patients underwent arthroscopy, based only on the findings of clinical examination. In this group, arthroscopy confirmed the findings of clinical examination in only 30% of patients.

The sensitivity for diagnosing isolated medial meniscal tears in a series by Rubin et al[4] was 98% and it decreased when other structures were also injured. The specificity in isolated lesions was 90%. In a multicentric analysis, Fisher et al[5] reported an accuracy of 78–97% for the ACL and 64–95% for medial meniscus tears.

The meniscus is composed of fibrocartilage and appear as low signal structures on all pulse sequences. The sensitivity and specificity of MRI in detecting meniscal tears exceeds 90%.[6]

Simultaneous injury to several supporting structures is relatively common in the knee. When more than one lesion was

present, completely correct diagnosis was rendered only 30% of the time. This phenomenon was reported by Rubin et al.[4]

In a prospective study reported by Imhoff et al[7], the NPV was 94% but the PPV was only 54%. They concluded that due to a high NPV, a normal MRI scan allows eliminating a meniscal lesion and so there is no need for a diagnostic arthroscopy. They suggested that due to the low PPV of MRI, it should not be routinely used to confirm clinical diagnosis and its use should be limited to those cases where clinical examination is inconclusive. A diagnostic arthroscopy would be a better choice in those cases.

However, in our study, MRI showed false results in a significant proportion. For example, as far as medial meniscus was concerned, there were eight false positive diagnoses and one false negative diagnosis, whereas for lateral meniscus, there were six false positive diagnoses and three false negative diagnoses (PPV 57.89% and 45.45%; NPV 90.91% and 84.21%, for medial meniscus and lateral meniscus tears, respectively).

Disruption of the ACL, a major stabilizer of the knee, leads to loss of stability of the knee and potentially significant dysfunction. Although the ACL is the most frequently torn ligament of the knee, the ACL tear has remained clinically elusive. These injuries account for a large number of referrals to hospitals. The evaluation of these lesions remains a difficult clinical problem. MRI is a frequently used diagnostic modality for these internal derangements because of being noninvasive, painless, and not associated with the risk of radiation.

As far as the cruciate ligaments are concerned, our study showed that from the 22 ACL ruptures diagnosed during arthroscopy, one of them was missed by MRI, leading to NPV of MRI for ACL ruptures of 87.5%. Causes of that target loss are easily recognised. Firstly, in cases with ligament ruptures without mucosum rupture, MRI gives false negative results. Additionally, ruptures near ligaments' insertion may be missed and MRI examination reveals an intact ACL. By contrast, false positive ACL ruptures occur in cases of intrabody mucosal or eosinophilic degeneration of ACL.[8,9]

The accuracy, sensitivity, and specificity values for knee lesions vary widely in literature. Rubin et al[4] reported 93% sensitivity for diagnosing isolated ACL tears. Similarly, several prospective studies have shown a sensitivity of 92–100% and specificity of 93–100% for the MRI diagnosis of ACL tears.[5,10,11]

Arthroscopy is a technically demanding procedure and the results vary according to the surgeon's experience, especially in difficult cases. Majority of the false positive results refer to a posterior meniscus tear. Nevertheless, the belief is that, even in these cases, the meniscal pathology existed but failed to be discovered during arthroscopy.[12,13] In particular, the inferior surface of the posterior aspect of the medial meniscus is difficult to reach with a probe and often ruptures at that point can be missed. Nowadays, the overall accuracy of arthroscopy varies between 70% and 100%, depending on the surgeon's experience.[14–17] This fluctuation inevitably raises questions regarding the reliability of the MRI results classification on true or false.[18]

In everyday practice, based on clinical examination coming first, surgeons decide whether to proceed to further laboratory tests, MRI, or conservative or surgical treatment. However, how precise can clinical examination be? There seems to be disagreement regarding the answer to this question. Investigations support the fact that the accuracy of clinical examination compared with arthroscopic findings ranges between 64% and 85%.[19,20]

Rose and Gold[9] found that clinical examination is as accurate as MRI in diagnosing meniscal tears and ACL ruptures, so they concluded that MRI, because of its high cost, is not necessary in patients with clinical suspicion of meniscus and cruciate ligament tears. A similar conclusion was reported by Boden et al[21] who supported that when clinical examination sets the diagnosis of meniscus damage, MRI will not change treatment decisions.

Jackson et al[22] concluded that negative MRI for meniscus and cruciate ligament tears can discourage diagnostic arthroscopy, even if clinical examination is positive for injury.

Conclusion

The need to accurately evaluate injuries of the knee is crucial for the correct management and outcome; otherwise it will lead to chronic debility to the patient.

MRI is of great aid in the diagnosis of knee lesions. Most diagnostic studies comparing MRI and arthroscopy have shown good diagnostic performance in detecting lesions of the meniscus and cruciate ligaments. Nevertheless, arthroscopy has remained the reference standard for the diagnosis of internal derangements of the knee, against which alternative diagnostic modalities should be compared.

Although MRI is being used with increasing frequency, it is unlikely to replace clinical diagnosis. It should be used in connection with clinical findings and history to provide a more complete picture, especially in complex injuries, as history and examination alone may be unreliable in less clinically evident situations; however, MRI still remains the only available means to diagnose in an acute/painful knee. Also, it is difficult to assess the injury status and the severity in a multiligamentous knee injury by clinical methods alone. In these situations, MRI becomes mandatory for the treating clinician. However, in situations of chronic instabilities with clinically noticeable findings, MRI may not be of significant value and hence can be avoided in clinically proven cases of knee instabilities.

In any case, what one must always bear in mind is that diagnosis alone is not the end point of the treatment and does not solve the problem. It is the beginning of new thoughts and actions one must follow to achieve accurate prognosis and correct treatment. In order to plan and apply the correct treatment pathways, cost effectiveness or the statistical data are not the most important factors. Clinical experience and adequacy of the surgeon always have the greatest value when it comes to assuring optimal treatment to the patient.

Our study found that the routine use of an MRI scan to confirm diagnosis is not indicated, as the PPV of the scan is low for all lesions. In the presence of positive clinical signs, proceeding to arthroscopy is recommended. The NPV of a scan was found to be high for all structures of the knee joint and hence a “normal” scan can be used to exclude a pathology, thus sparing patients from expensive and unnecessary surgery and also freeing up valuable theatre time. In this scenario, accurate and careful clinical examination remains the primary necessity in diagnosing ligament and meniscal injuries.

Conflict of interest

None.

References

1. Kaplan PA, Walker CW, Kilcoyne RF, et al. Occult fracture patterns of the knee associated with ACL tears: assessment with MR imaging. *Radiology* 1992;**183**:835–8.
2. Mackenzie R, Dixon AK, Keene GS, et al. Magnetic resonance imaging of the knee; assessment of the effectiveness. *Clin Radiol* 1996;**51**:245–50.
3. Weinstabl R, Muellner T, Vecsei V, et al. Economic considerations for the diagnosis and therapy of meniscal lesions: can MR imaging help reduce the expense? *World J Surg* 1997;**21**:363–8.
4. Rubin DA, Kettering JM, Towers JD, et al. MR imaging of knee having isolated and combined ligament injuries. *AJR Am J Roentgenol* 1998;**170**:1207–13.

5. Fisher SP, Fox JM, Del Pizzo W, et al. Accuracy of diagnosis from magnetic resonance imaging of the knee; a multicentric analysis of one thousand and fourteen patients. *J Bone Joint Surg Am* 1991;**73**:2–10.
6. Miller RH. In: Terry Canale S, editor. *Campbell's operative orthopaedics*. St Louis: Mosby; 1998. p. 1113–299.
7. Imhoff A, Buess E, Holder J, et al. Comparison between magnetic resonance imaging and arthroscopy for the diagnosis of knee meniscal lesion. *Rev Chir Orthop* 1997;**83**:229–36.
8. Hodler J, Haghighi P, Trudell D, et al. The cruciate ligaments of the knee: correlation between MR appearance and gross and histologic findings in cadaveric specimens. *AJR Am J Roentgenol* 1992;**159**:357–60.
9. Rose NE, Gold SM. A comparison of accuracy between clinical examination and magnetic resonance imaging in the diagnosis of meniscal and anterior cruciate ligament tears. *Arthroscopy* 1996;**12**:398–405.
10. Lee JK, Yao L, Phelps CT, et al. Anterior cruciate ligament tears: MR imaging compared with arthroscopy and clinical tests. *Radiology* 1998;**166**:861–4.
11. Mink JH, Levy T, Crues 3rd JV. Tears of the anterior cruciate ligament and menisci of the knee: MR imaging evaluation. *Radiology* 1988;**167**:769–74.
12. Spiers AS, Meagher T, Ostlere SJ, et al. Can MRI of the knee affect arthroscopic practice? A prospective study of 58 patients. *J Bone Joint Surg Br* 1993;**75**:49–52.
13. Crues III JV, Mink J, Levy TL, et al. Meniscal tears of the knee: accuracy of MR imaging. *Radiology* 1987;**164**:445–8.
14. Ireland J, Trickey EL, Stoker DJ. Arthroscopy and arthrography of the knee: a critical review. *J Bone Joint Surg Br* 1980;**62**:3–6.
15. Dandy DJ, Jackson RW. The diagnosis of problems after meniscectomy. *J Bone Joint Surg Br* 1975;**57**:349–52.
16. Jackson RW, Abe I. The role of arthroscopy in the management of disorders of the knee. An analysis of 200 consecutive examinations. *J Bone Joint Surg Br* 1972;**54**:310–22.
17. Boeve BF, Davidson RA, Staab Jr EV. Magnetic resonance imaging in the evaluation of knee injuries. *South Med J* 1991;**84**:1123–7.
18. Mackenzie R, Keene GS, Lomas DJ, et al. Errors at knee magnetic resonance imaging: true or false? *Br J Radiol* 1995;**68**:1045–51.
19. Gillies H, Seligson D. Precision in the diagnosis of meniscal lesions: a comparison of clinical evaluation, arthrography, and arthroscopy. *J Bone Joint Surg Am* 1979;**61**:343–6.
20. Simonsen O, Jensen J, Mouritsen P, et al. The accuracy of clinical examination of injury of the knee joint. *Injury* 1984;**16**:96–101.
21. Boden SD, Labropoulos PA, Vailas JC. MR scanning of the acutely injured knee: sensitive, but is it cost effective? *Arthroscopy* 1990;**6**:306–10.
22. Jackson DW, Jennings LD, Maywood RM, et al. Magnetic resonance imaging of the knee. *Am J Sports Med* 1988;**16**:29–38.