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Magnetic resonance imaging versus arthroscopy in the diagnosis of knee pathology, concentrating on meniscal lesions and ACL tears: a systematic review

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Purpose: Magnetic resonance imaging (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 menisci 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.

Methods: We took arthroscopy to be the 'gold standard', and we undertook a systematic review of MRI and arthroscopy in the diagnosis of internal derangements of the knee. We used Coleman scoring methodology to identify scientifically sound articles in a reproducible format.

Results: MRI is highly accurate in diagnosing meniscal and anterior cruciate ligament (ACL) tears. It is the most appropriate screening tool before therapeutic arthroscopy. It is preferable to diagnostic arthroscopy in most patients because it avoids the surgical risks of arthroscopy. The results of MRI differ for medial and lateral meniscus and ACL, with only 85% accuracy.

Conclusions: Study design characteristics should also be taken into account whenever a study on MRI assessing its diagnostic performance is designed or reviewed.

Level of evidence: II, systematic review of level II studies.

Keywords: MRI/arthroscopy/patient outcome/systematic review

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Introduction

Although surgeons often decide to proceed with arthroscopy on clinical assessment alone, the accuracy of such assessment in predicting findings of arthroscopy is between 35 and 70%.[1–4] In England, approximately 80 000 knee arthroscopies were performed in the National Health Service in the financial year 2002–2003.[5]

Although magnetic resonance imaging (MRI) scans are often considered to give the ultimate diagnostic certainty, in reality, the performance of MRI as a diagnostic tool of internal derangement of the knee when compared with arthroscopy has not been tested in a systematic and reproducible fashion. Studies assessing MRI versus arthroscopy have not been reliably compared, making it harder to decide the correct level of clinical significance to the published data.

We therefore set out to critically assess the methodology of the studies using a scoring system as part of a systematic review and to provide a framework with which all MRI and arthroscopy studies can be accurately compared. We were interested to see whether the studies that scored higher in their methodology also had the best results.

Materials and methods

A MEDLINE search not limited to English literature was performed using the keywords arthroscopy, MRI, meniscal lesions, meniscal tears and knee pathology, over the years 1966–2006 to identify the studies that used both MRI and arthroscopy in the diagnosis of knee injuries. All journals were considered, and all relevant articles were retrieved. Closer analysis indicated that relevant material was drawn from the years 1986–2006. Materials on this subject in the library of the Department of Trauma and Orthopaedic Surgery of Keele University Medical School, University Hospital of North Staffordshire were searched manually, and the relevant articles were also included in this study.

Papers were included if they were based on the knee pathology and used MRI and arthroscopies in some of their patients. Abstracts were excluded.

The criteria originally developed by Coleman *et al.*[6] for comparing surgical techniques were adopted and used to blindly assess the methods of each article twice. After twice blindly determining the Coleman score for each study, any discrepancies were given the higher Coleman score to show the study in the best light.

The original Coleman scoring system had 10 criteria, which were each scored out of 10 giving a maximum total mark of 100.

We modified the Coleman criteria by removing sections such as recovery time after surgery and surgical complications, also adding a score which includes the number of radiologists who assessed the MRI scans. This made them reproducible and relevant for the systematic review of arthroscopies and MRI scans. Each study was scored for each of the five criteria adopted (listed in Table 1) to give a total Coleman methodology score between 0 and 100. A perfect score of 100 would represent a study design that largely avoids the influence of chance, various biases and confounding factors.

Meniscal tears were classed as torn or not. We did not specifically look into the difference between types of tears (radial versus horizontal). Anterior cruciate ligaments (ACLs) were either completely torn or not, and we did not look into partial tears as there was not enough information to make it statistically significant. Any other knee pathologies including posterior cruciate ligament (PCL) tears, bone oedema and chondral lesions were grouped together as other pathology.

Statistics

Descriptive statistics were calculated. We used Cohen's kappa to assess reproducibility of the Coleman score. Spearman's correlation coefficient was calculated as appropriate, and significance was set at $P < 0.05$.

Table 1 Coleman methodology score.

Adapted Coleman criteria	
Study size (number of MRI)	>60 = 20 41–60 = 14 20–40 = 8 <20 (or not stated) = 0
Number of radiologists	1 = 20 2 = 12 >2 (or not stated) = 0
Type of study	Randomized control trial = 20 Prospective cohort study = 10 Retrospective cohort/case series = 0
Diagnostic certainty/arthroscopy to confirm diagnosis	In 100% = 20 In 80% = 14 In 60% = 8 In >60% (or not stated) = 0
Description of MRI given	Very good (type of machine and full details given) = 20 Good (type of machine and some details given) = 14 Fair (type of machine given) = 8 Not given = 0

Results

The studies reviewed used different approaches to assess the differences between MRI and arthroscopy in the diagnosis of knee pathology. Fifty-nine articles were retrieved reporting on 7367 MRI scans and 5416 arthroscopies, with an age range of 3–87 years.

Methods

When the methods of each article were blindly assessed twice, the methods scores were highly reproducible. Cohen's kappa was 0.99κ, indicating the highly reproducible nature of this scoring. The Coleman methodology scores for the studies showed a mean score of 54.46 ($\pm$SD 18.33; range 10–90) (Fig. 1).

Type of study

Only one of the articles was a randomized control trial,[7] with a Coleman score of 34. This trial investigated whether MRI impacts on the clinical management of patients rather than how accurate it is in diagnosis.

Forty-seven of the articles were prospective studies; the remaining 11 were a mixture of retrospective cohort studies, audits, outcome reviews and case series.

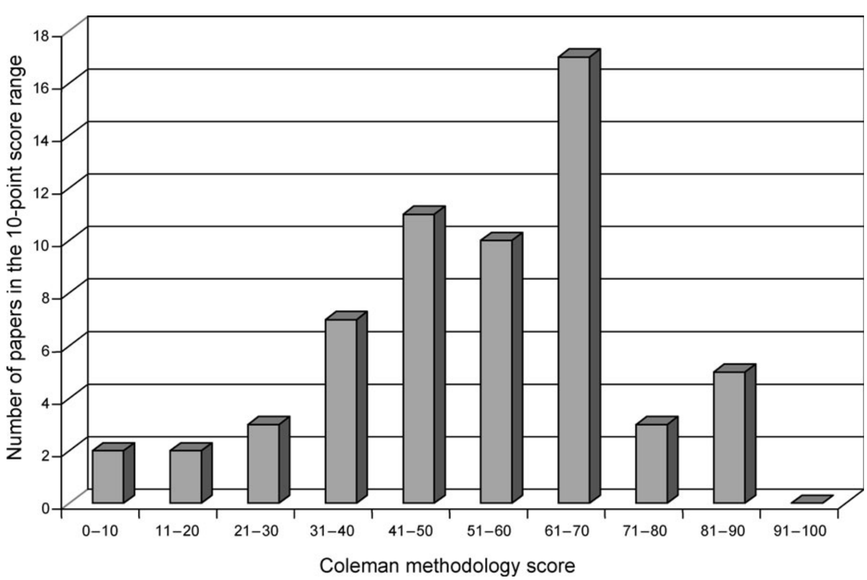

Fig. 1 Split of Coleman methodology scores across the papers.

Correlation

The Coleman scores were correlated with the reported accuracy recorded for meniscal lesions by MRI, using arthroscopy results as gold standard (Fig. 2). There is a positive trend, implying that the higher the Coleman methodology scores, the greater the accuracy. The majority of the accuracy listed is greater than 80%. One data point was removed from the graph as it overly skewed the results (Fig. 3). The data point had a Coleman score of 10 and an accuracy of 57%. The article reported the results of an audit,[8] which probably justifies why the Coleman score for that publication was so low. Figure 3 showed a Spearman's correlation coefficient of 0.0809; $P = 0.64$. Figure 4 showed the percentage accuracy that a study produced for ACL tears correlated against Coleman scores. The line of best fit shows a positive trend.

When the year of publication was correlated with the reported accuracy recorded for meniscal lesions by MRI, using arthroscopy results as gold standard (Fig. 5), the line of best fit showed a negative trend (Spearman's correlation coefficient, -0.274; $P = 0.131$) (Fig. 6).

Figure 6 shows how the Coleman scores varied. For example, the Coleman scores for publications between 1986 and 1995 range from 10 to 90 and from 28 to 90 in the period 1996–2006. There is a negative trend displayed by the line of best fit, with the most recent studies having lower overall scores. This may be due to the fact that studies are no longer just comparing arthroscopy and MRI results to ascertain whether MRI should be used in the diagnosis of knee injures. As

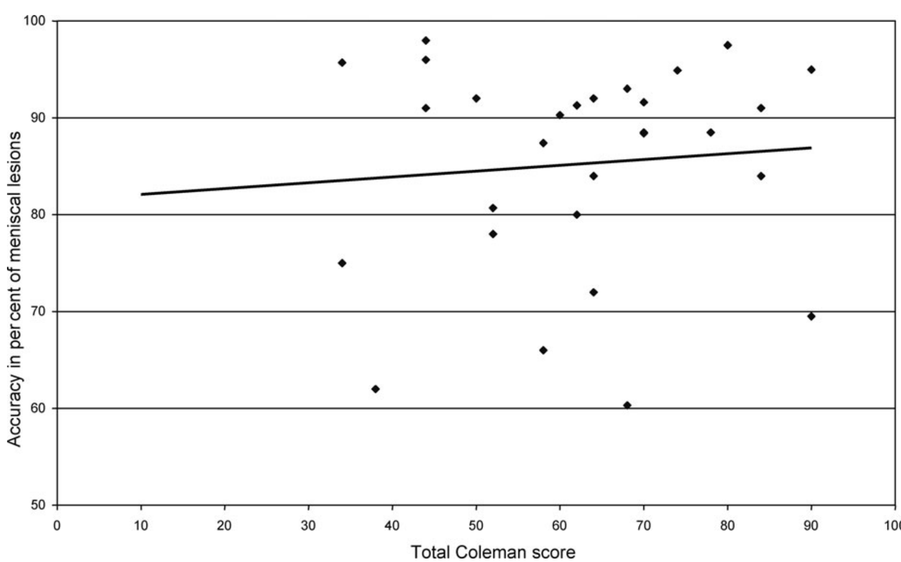

Fig. 2 Percentage accuracy of meniscal lesions against Coleman scores using all studies.

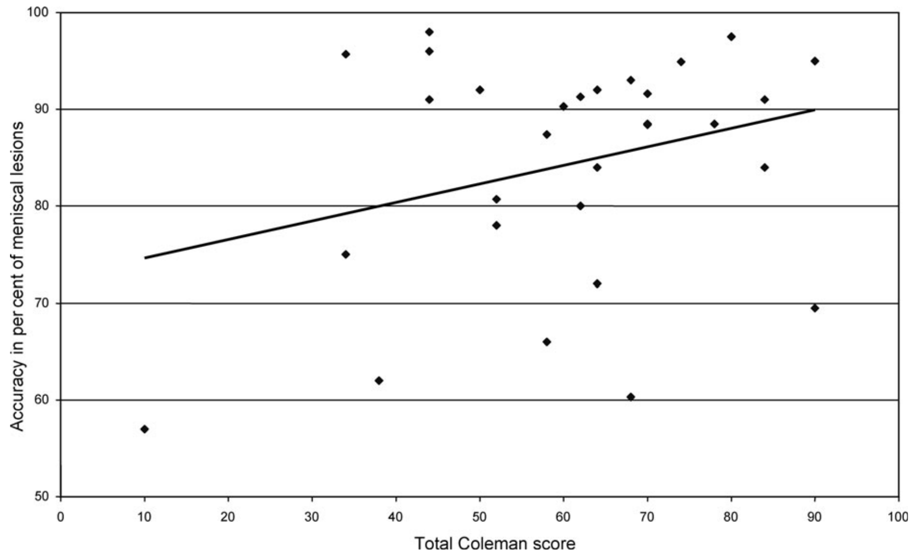

Fig. 3 Percentage accuracy of meniscal lesions against Coleman scores removing one of the study which skewed the results.

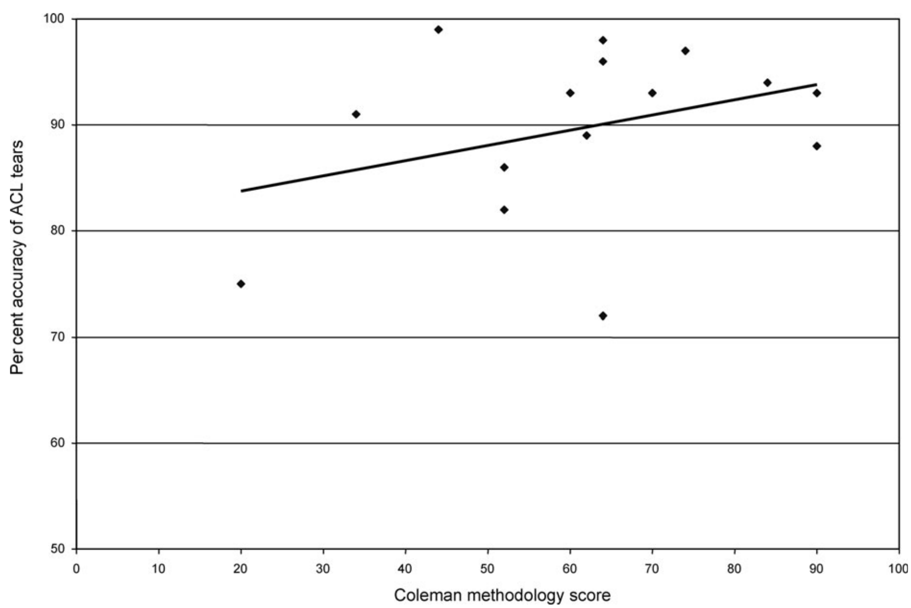

Fig. 4 Per cent accuracy of ACL tears against Coleman score.

studies are interpreting different aspects of MRI, patients who have a negative MRI result may not progress to have arthroscopies, thus reducing the studies overall Coleman score (Spearman's correlation coefficient, -0.173; $P = 0.19$).

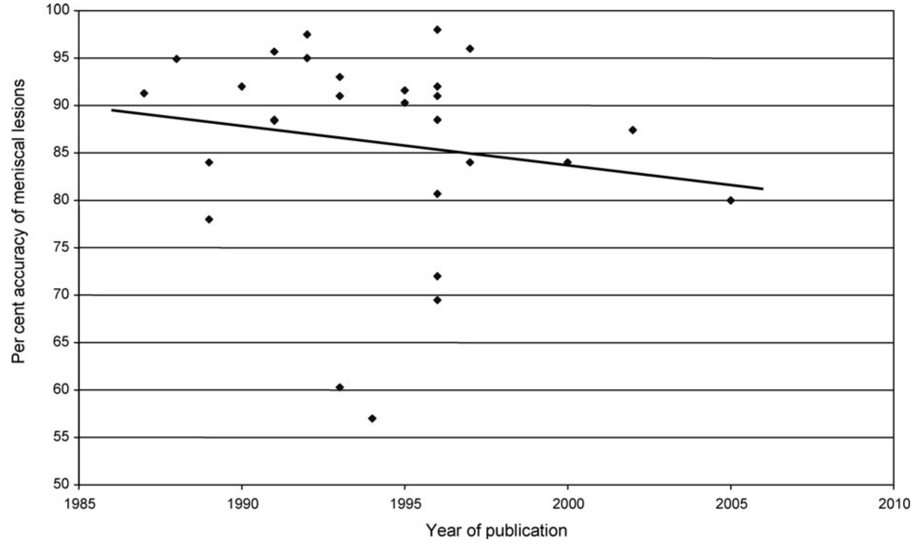

Fig. 5 Accuracy of MRI with arthroscopy as gold standard for meniscal lesions.

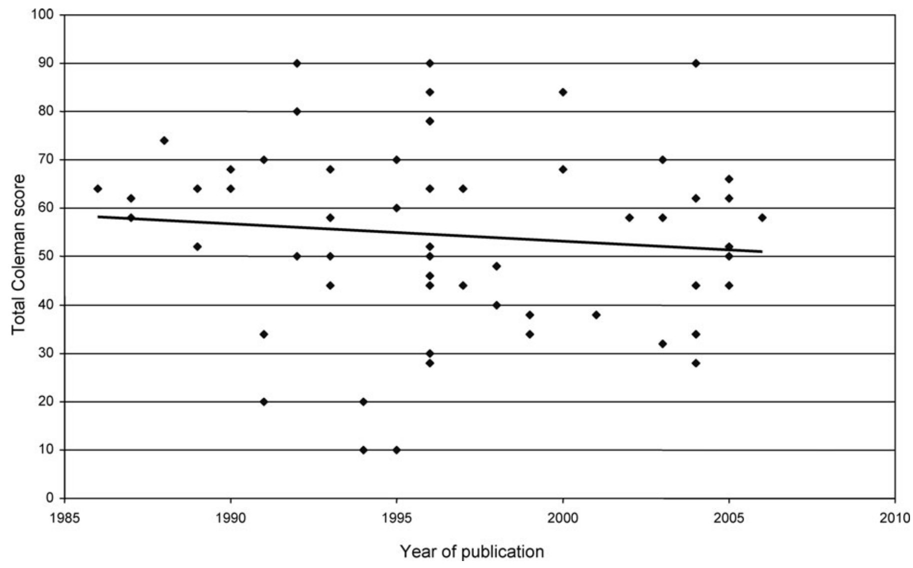

Fig. 6 Total Coleman score against year of publication.

Studies reviewed

We have grouped the findings of all the interpretations, which are classified into three categories:

1. 43 studies that interpreted meniscal and ACL injuries[1,9–48];
2. 23 studies that interpreted other aspects of MRI and arthroscopic diagnosis of knee pathology.[1,7,14,15,22,25,40,42,44,49–62] A few studies

Table 2 True positives (TP), true negatives (TN), false positives (FP) and false negatives (FN) values for studies in groups 1 (meniscal and ACL injuries) and 2 (other aspects of MRI and arthroscopic diagnosis of knee pathology).

Results	Total TP	Total TN	Total FP	Total FN	Total
Medial meniscus	1207	1043	243	114	2607
Lateral meniscus	525	1801	128	166	2620
ACL	372	1533	77	58	2040
Combined MM, LM, ACL	2104	4377	448	338	7267
Other knee pathology	443	1973	42	202	2660
Total (combined + other)	2547	6350	490	540	

Table 3 Accuracy, sensitivity, specificity, NPV and PPV for groups 1 (meniscal and ACL injuries), 2 (other aspects of MRI and arthroscopic diagnosis of knee pathology) and 3 (all results combined) and separately for medial meniscus, lateral meniscus and ACL tears.

Results	Accuracy (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Medial meniscus	86.3	91.4	81.1	83.2	90.1
Lateral meniscus	88.8	76.0	93.3	80.4	91.6
ACL	93.4	86.5	95.2	82.9	96.4
Combined MM, LM, ACL	89.2	86.2	90.7	82.4	92.8
Other knee pathology	90.8	68.7	97.9	91.3	90.7
Total	89.6	82.5	92.8	83.9	92.2

interpreted both meniscal and ACL injuries and other aspects of MRI and arthroscopic diagnosis of knee pathology[14,15,22,25,40,42,44];

3. all the results combined together.

From the studies in groups 1 and 2, we extracted the relevant data, where available, and we calculated true positive, true negative, false positive and false negatives values (Table 2). In some instances, this meant that these data had to be calculated from other values such as specificity and sensitivity by rearranging the equations.

The accuracy, sensitivity, specificity, negative predictive value (NPV), and positive predictive value (PPV) were calculated using the following equations for the three groups and separately for medial meniscus, lateral meniscus and ACL tears (Table 3):

$PPV = TP/(TP + FP)$, $NPV = TN/(TN + FN)$, $sensitivity = TP/(TP + FN)$, $specificity = TN/(FP + TN)$ and $accuracy = (TP + TN)/(TP + TN + FP + FN)$.

MRI is better in identifying patients with a medial meniscus tear than those without them. MRI is nearly 20% better in identifying patients without lateral meniscus tears than those with them. Both menisci have similar NPV and PPV results.

The group labelled 'other knee pathology' (which includes aspects such as bone oedema and osteonecrosis) has a low sensitivity, implying that MRI is more accurate in identifying meniscal lesions and ACL tears. It has a very high specificity of ~98%.

Overall, MRI has a higher specificity (92.8%) than sensitivity (82.5%), and a higher NPV (92.2%) than the PPV (83.9%).

The studies that provided their results for findings such as bone oedema (listed together in the group labelled other knee pathology) had a higher average Coleman methodology score than the average for all the studies combined. This may be because the stronger studies listed all their results, whereas the weaker ones did not.

Discussion

The goals of the study were to adapt and implement a reproducible system for evaluating the methodology of studies comparing arthroscopy and MRI scans in the diagnosis of intra-articular knee pathology using an adapted version of the Coleman scoring system.

The Coleman scoring system is a method of analysing the quality of the studies reviewed, and it is accurate and reproducible in systematic reviews.[6,64] Also, we devised the system, and have used it successfully for several years. In addition, it has been validated outwith of our research centre.[65]

We were also interested in the trend between-studies Coleman score in relation to its results. The present investigation has highlighted a positive correlation between accuracy of MRI results for ACL and meniscal lesions, and a higher Coleman score assigned to a given study (Figs 2–4).

Overall, the Coleman scores of the studies varied considerably (range 10–90). This highlights the wide range of accuracy displayed in published research studies. If this variability is linked to accuracy of results, then the accuracy portrayed by a given paper may be misleading.

The year of publication was correlated with the reported accuracy recorded for meniscal lesions by MRI (Fig. 5), using arthroscopy results as gold standard. This negative trend was surprising. It might be explained by the fact that earlier studies focused on MRI accuracy for meniscal injury. More recently, it can be seen that this has not been the main focus of further studies. There are nine points below the line of best fit and 19 above it, although we acknowledge that the line of best fit might not be the best representation, as few studies with a lower accuracy exert an undue effect on the results as a whole.

MRI is able to detect most internal derangements of the knee efficiently. MRI has a higher specificity (i.e. correctly identifies the absence of an internal derangement of the knee) than sensitivity (i.e.

accurately identifying an internal derangement of the knee). It has a higher NPV (reliability of a negative MRI result) than PPV (reliability of a positive MRI result). Thus, if a patient is given a result of a negative MRI scan, the high specificity and NPV of the scan mean that this is likely to be a true negative result.

MRI has a high sensitivity in the medial meniscus, where it was accurate in detecting a tear in 91.4% of cases. MRI has a lower specificity in the medial meniscus than in the lateral meniscus: if MRI is used as the only form of pre-operative screening for this condition, then there may well be unnecessary arthroscopies performed.

False positives and false negatives

MRI studies have higher false positive than false negative results.[22] We also found this to be true when examining the combined results from meniscal lesions and ACL tears, but not when other knee pathologies such as bone oedema were considered (Table 2).

Radial meniscal tears are difficult to visualize on MRI; hence, they account for a large number of tears missed by MRI. Radial tears involve the free edge of the meniscus. Thus, the key to interpretation of this injury is the recognition of absence or blunting of the inner point of the meniscal triangle.[63] This study did not specifically compare the results between the different types of meniscal tears, as most articles reviewed did not specify the type of meniscal lesion.

False positive MRI scans seen in the posterior horn of the medial meniscus may reflect an inability to completely visualize the area at arthroscopy, and tears that extend to the inferior surface of the meniscus may be difficult to see.[15] Some false positive findings on MRI can be attributed to inadequate visualization of the meniscus at surgery and to the fact that the diagnosis of a tear can be subjective.[33]

Some of the results listed in Table 3 were unexpected. For example, the high accuracy of the 'other knee pathology' results in comparison with the meniscal results is unusual. This might be explained because there were fewer results available for assimilation in this area.

Sixteen per cent of asymptomatic patients have evidence of meniscal tears on MRI, with the incidence increasing to 36% for patients over 45.[66] Therefore, it is likely that some arthroscopies will be performed unnecessarily and that, in some patients, an arthroscopy is not carried out when it should be.

It should be appreciated that the sensitivity and specificity of MRI are not 100%, particularly where the lateral meniscus is involved. One of the investigations reviewed in the present study is a case series of eight bucket handle tears of the lateral meniscus in athletes which were missed on MRI scanning leading to five of the patients returning to sport prematurely.[27]

MRI is the non-invasive imaging technique of choice in evaluating knee pain.[16] The high NPV and high specificity confirm the use of MRI as a screening tool highly predictive in avoiding unnecessary arthroscopies.[17,51]

The MRI examination techniques recommended in the literature at present are not able to replace arthroscopy for diagnosis of cartilage damage in the knee.[51]

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.

Retrospective studies are easier to perform, take less time to conduct and are cheaper. They also provide the weakest evidence for establishing causation. They are still valuable tools in assessing clinical outcomes. Prospective studies of a large size are more costly.

It is surprising that MRI is so widely used and, nevertheless, there have not been more randomized control trials to assess its diagnostic efficacy. It is improbable that numerous randomized controlled trials will now be undertaken to investigate the use of MRI in the diagnosis of meniscal and ACL tears. MRI in conjunction with clinical examinations is used day to day for the diagnosis of these knee injuries. There is still more research to be performed into the use of MRI in the diagnosis of other knee pathologies.

Clinical examination, when combined with MRI, provides the most accurate non-invasive source of information currently available for pathological findings in the menisci and the ACL.[19] MRI films need to be carefully examined because a meniscal tear is unlikely when MRI scans show a focus of high signal in a meniscus that does not unequivocally extend to involve the surface of the meniscus.[23] Grade 1 and 2 signals are focal or linear areas of high signal confined to the substance of the meniscus with intact outer contour lines: these are not visible at arthroscopy[23] and would be classed as a false positive result.

MRI is not the most reliable tool for diagnosing recurrent meniscal tears, detecting only 66% (27/41) compared with 88% (36/41) with arthrography. The accuracy also varies with the extent of the original resection and the presence of an effusion tracking into the meniscal tear.[9] There is an increased prevalence of meniscal radial tears in the post-operative knee, with 32% in post-operative knees in comparison with 14% in normal knees. MRI might not be the optimal screening procedure in a post-operative knee.[28]

MRI is a useful diagnostic tool in detecting radial tears of the posterior horn of the medial meniscus, which are common in elderly patients who also often have osteoarthritis that masks their symptoms. If the tear is treated, then there is specific symptom relief.[11]

MRI is non-invasive. Arthroscopy has surgical risks, with a complication rate of 2.5% in arthroscopic meniscal surgery,[67] including saphenous and peroneal nerve injures, deep infections, superficial infections, vascular injuries and pulmonary embolism. Sometimes, arthroscopy reveals no abnormality or possibly minor non-pathological lesions such as plicae or chondromalacia patellae. This means that a patient could be exposed to surgical risk with no symptom benefit.

The use of MRI has increased, whereas diagnostic arthroscopies have decreased. In the USA, between 1993 and 1999, there was a 144% rise in MRI scanning of the knee. Diagnostic arthroscopy decreased by 54%, and therapeutic arthroscopies increased by 27%.[68]

MRI in the diagnosis of other knee pathology

Acute PCL injuries can be successfully detected with MRI, but MRI is not used in the diagnosis of chronic PCL injuries. The findings of seven radiologists on the scans of 10 chronic PCL injury patients were compared: 57% of chronic PCL injuries were detected by radiologists. The highest number identified by a single radiologist was eight of 10, the lowest number was four of 10.[59] The Coleman score of this study was 28. In the Results section, we combined PCL injuries with other knee pathologies in a group, which excluded meniscal and ACL injuries (Table 2), as there were no enough data to make comparisons statistically significant on their own.

The extent of cartilage abnormalities can be concealed when MRI is used as the only diagnostic tool. Arthroscopic evaluation is more useful than radiographs or MRI to grade osteoarthritis and assess surface cartilage abnormalities.

MRI is useful to diagnose bone injuries in patients with acute knee effusions who had no ligament laxity on examination and normal findings on plain radiograph. Bone injury is the most common cause of acute effusion in this group of patients.[50]

An MRI study examined the link between internal derangement of the knee and the amount of fluid present in the knee joint. An anterior–posterior measurement of 10 mm of fluid or less in the lateral aspect of the suprapatella pouch is a reasonable threshold value for distinguishing a physiologic from pathologic amount of fluid in the knee joint.[56]

Changes found beneath the articular surface or in extra-articular spaces, which remain hidden at arthroscopy, are more likely to be detected with MRI.[37] MRI identifies deep chondral lesions, but not superficial ones, and also helps locate subchondral lesions undetectable by arthroscopy.[55]

Strengths and weaknesses of the study

This study includes a comprehensive cross-section of studies comparing arthroscopy and MRI. It includes a wide range of patient ages. All studies were assessed by one reviewer, so there is no inter-observer bias. The results of Coleman scoring highlight the importance of adequate study design. A high Coleman score positively correlated with the accuracy of research findings. Research studies do not always include all the information required for a comprehensive Coleman score. For example, when considering the scoring related to radiologists:

Number of radiologists $1 = 20$

$2 = 12$

>2 (or not stated) $= 0$

39 studies mentioned how many radiologists reviewed the MRI scans and 20 did not. If a study did not state how many radiologists assessed the MRI scans, that study was given zero points for that section. Had they used only one radiologist (and stated expressly that they had done so), that study could have scored the maximum 20 Coleman methodology points for that section. Radiologist reliability was not measured. Of those 39 studies, 13 relied on just one radiologist. This makes the observer bias equal for all the films reviewed. Conversely, it also means that if the diagnosis is performed by just one individual, then the accuracy depends solely on that radiologist.

When more than one radiologist reviewed the films, many of the studies did not state whether the films were reviewed with the radiologists together coming to a consensus, or whether the films were reviewed randomly by the separate professionals. The Coleman score was based just on the number of radiologists and did not take into account the possible advantage of a group consensus. A group consensus with the same group of radiologists interpreting all the films together should give the least biased and most accurate outcome.

The Coleman score did not take into account the number of MRI scanners used per study. The Coleman scoring for MRI scanners depends on how detailed the description of the machine was, not on the number of scanners used. If all MRI scanners used in a study had an equally good description, then they were scored accordingly.

Of the 51 studies that documented which MRI scanners they used, 12 studies[10,17,23,24,26,28,34,38,43,44,51,59] used more than one MRI scanner and one multi-centre study using 12 scanners.[34]

One centre used two different scanners over the course of the study. They found a difference in reliability of the MRI units of $<3\%$ when assessing cruciate ligaments.[18] This may well be acceptable, but it is still a variable that may affect results. Differences in the reliability of the centres may be attributed to many variables: expertise of the radiologist, type of MRI unit and parameters used for imaging, to mention a few.

The number of true positive MRI results was artificially lowered in some instances by clinicians fast-tracking patients with obvious meniscal injuries for surgery without MRI. Some studies took the patients with an obvious clinical diagnosis and added them on to the surgery waiting list without having an MRI, especially those patients with locked knees,[40,42,43] but also those who had obvious meniscal injury.[42,43] Fast tracking patients for a locked knee are understandable (for pain and functional purposes). However, those with obvious meniscal injuries on clinical examination may have obvious meniscal injuries on an MRI scan. Hence, their exclusion reduces the overall accuracy results for that study and would reduce the number of true positive MRI results.

All studies were assessed by the same person, with the high kappa result suggesting that intra-observer bias was minimal. To increase the accuracy, more testers could have been used and their results were compared, but practical restraints did not allow for this.

The most obvious problem in this field is that some studies are never published. If the reasons why studies remain unpublished are associated with their outcome, then the result of a systematic review could be seriously biased. Studies with positively significant results are more likely to be published than those with non-significant results. Hypothetically, with a treatment that has no actual effect on a disease, studies suggesting a beneficial effect might be published, whereas an equal mass of data pointing the other way might remain unpublished. In this situation, a systematic review of the published data would identify an unauthentic beneficial treatment effect.

Language bias

Systematic reviews published in English language journals are often exclusively based on trials published in English. Investigators working in a non-English speaking country might publish some of their work in local journals. The authors may perhaps be more likely to report

Table 4 Comparison of the results by Oei *et al.*[69] and the results from the present study.

	Medial meniscus		Lateral meniscus		ACL	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
Oei *et al.*	93.3	88.4	79.3	95.7	94.4	94.3
Present study	91.4	81.1	76.0	93.3	86.5	95.2

positive findings in an international (i.e. English language) journal and negative findings in a local journal. It has therefore been confirmed by a member of the research team fluent in Italian, French, Spanish and Portuguese that no relevant studies were excluded from this review.

Oei *et al.*[69] systematically reviewed 29 studies interpreting just meniscal and cruciate injuries in 3683 knees in the years 1991–2000. That study had very stringent inclusion and exclusion criteria. Overall, Oei *et al.*[69] found higher sensitivities and specificities, especially when comparing the sensitivities for ACL tears (Table 4).

Duchateau *et al.*[70] reviewed 29 articles using a scale of methodological quality for clinical studies developed by Arrive *et al.*[71] They found that standards were rarely met in the literature reviewed (relating to the methodology of the studies and the inter- and intra-observer reliability). Duchateau *et al.* did not interpret the sensitivities and specificities of the studies reviewed, and so these results cannot be compared with those in the present investigation.

MRI is highly accurate in the diagnosis of tears of the menisci and ACL. MRI has now made diagnostic arthroscopy redundant in most settings, and it is more appropriately used as a screening tool for therapeutic arthroscopy. Fast three-dimensional MRI allows identification of all relevant intra-articular pathologies of the knee joint within a few minutes, with high accuracy comparable to arthroscopy.[20] The diagnostic performance of MRI differs for the lateral and medial menisci.

The results of this study support the use of MRI in the diagnosis of internal derangements of the knee, when used in conjunction with a full history and clinical examination. MRI is not 100% accurate: if an MRI is reported as negative but the patient is still complaining of ongoing symptoms, then arthroscopy should be considered.

Conclusion

MRI is highly accurate in diagnosing meniscal and ACL tears. It is the most appropriate screening tool for therapeutic arthroscopy. It is preferable to diagnostic arthroscopy in most patients because it is faster and avoids surgical risks. An area of future research is the use of specific MRI sequences to identify problems in each of the various tissues in and around the knee (ligaments, menisci, tendons, articular surface and bone), while keeping the investigation within acceptable times and costs.

From the present study, it is clear that the diagnostic performance results of MRI differ for the medial and lateral meniscus and the ACL, although all were above 85% accuracy. Study design characteristics should also be taken in account whenever a study on MRI assessing its diagnostic performance is designed or reviewed. There is scope for more research in this area, particularly on knee pathology other than menisci and ACL.

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References

1 Oberlander MA, Shalvoy RM, Hughston JC (1993) The accuracy of the clinical knee examination documented by arthroscopy. A prospective study. *Am J Sports Med*, **21**, 773–778.
2 Selesnick FH, Noble HB, Bachman DC, Steinberg FL (1985) Internal derangement of the knee: diagnosis by arthrography, arthroscopy, and arthrotomy. *Clin Orthop*, **198**, 26–30.
3 Lawson GM, Nutton RW (1995) A prospective audit of knee arthroscopy: a study of the accuracy of clinical diagnosis and therapeutic value of 325 knee arthroscopies. *JR Coll Surg Edinb*, **40**, 135–137.
4 Solomon DH, Simel DL, Bates DW, Katz JN, Schaffer JL (2001) Does this patient have a torn meniscus or ligament of the knee: value of the physical examination. *JAMA*, **286**, 1610–1620.
5 (2004) Department of Health, England. *Hospital Episode Statistics*. Http://www.hesonline.nhs.uk/Ease/servlet/DynamicPageBuild?siteID=1802&categoryID=192&callingCatID=325 (date last accessed, 7 July 2005).
6 Coleman BD, Khan KM, Maffulli N *et al*. (2000) Studies of surgical outcome after patellar tendinopathy: clinical significance of methodological deficiencies and guidelines for future studies. *Scand J Med Sci Sports*, **10**, 2–11.
7 Bryan S, Bungay HP, Weatherburn G, Field S (2004) MRI imaging for investigation of the knee joint: a clinical and economic evaluation. *Int Technol Assess Health Care*, **20**, 222–229.
8 Birch N, Powels D, Dorrell H, Brooks P (1994) The investigation and treatment of disorders of the knee: indications and a cost-comparison of arthroscopy and MRIs. *Health Trends*, **26**, 50–52.
9 Applegate GR, Flannigan BD, Tolin BS, Fox JM, Del Pizzo W (1993) MR diagnosis of recurrent tears in the knee: value of intraarticular contrast material. *Am J Roentgenol*, **161**, 821–825.
10 Barronian AD, Zoltan JD, Bucon KA (1989) MRI of the knee: correlation with arthroscopy. *Arthroscopy*, **5**, 187–191.
11 Bin SL, Kim JM, Shin SJ (2004) Radial tears of the posterior horn of the medial meniscus. *Arthroscopy*, **20**, 373–378.

12 Boeree NR, Ackroyd CE (1991) Assessment of the menisci and cruiciate ligaments: an audit of clinical practice. *Injury*, **22**, 291–294.
13 Boeree NR, Ackroyd CE, Johnson C, Watkinson AF (1991) MRI of meniscal and cruiciate injuries of the knee. *J Bone Joint Surg (Br)*, **73**, 452–457.
14 Bui-Mansfield LT, Youngberg RA, Warme W, Pitcher DJ, Nguyen PLL (1997) Potential cost saving of MRI obtained before arthroscopy of the knee: evaluation of 50 consecutive patients. *Am J Roentgenol*, **168**, 913–918.
15 Chissell HR, Keightley A, Allum RL (1994) MRI of the knee: its cost effective use in a DGH. *Ann R Coll Surg Engl*, **76**, 26–29.
16 Crues JV, Mink J, Levy TL, Lotysch M, Stoller DW (1987) Meniscal tears of the knee: accuracy of MRI imaging. *Radiology*, **164**, 445–448.
17 Elvenes J, Jerome CP, Reikeras O, Johnsen O (2000) MRI as a screening procedure to avoid arthroscopy for meniscal tears. *Arch Orthop Trauma Surg*, **120**, 14–16.
18 Fischer SP, Fox JM, Del Pizzo W, Friedman MJ, Snyder SJ, Ferkel RD (1991) Accuracy of diagnoses from MRI of the knee. A multi-center analysis of 1014 patients. *J Bone Joint Surg Am*, **73**, 2–10.
19 Glashow JL, Katz R, Schneider M, Scott WN (1989) Double-blind assessment of the value of MRI in the diagnosis of ACL and meniscal lesions. *J Bone Joint Surg Am*, **71**, 113–119.
20 Gluckert K, Klandy B, Blank-Schol A, Hofmann G (1992) MRI of knee joint with a 3D gradient echo sequence. *Arch Orthop Trauma Surg*, **112**, 5–14.
21 Gobbi A, Tuy B, Mahajan S, Panuncialman I (2003) Quadrupled bone—semitendinosus anterior cruciate ligament reconstruction: a clinical investigation in a group of athletes. *Arthroscopy*, **19**, 691–699.
22 Heron CW, Calvert PT (1992) 3D gradient echo MRI of the knee: comparison with arthroscopy in 100 patients. *Radiology*, **183**, 839–844.
23 Kaplen PA, Nelson NL, Garvin KL, Brown DE (1991) MR of the knee: the significance of high signal in the meniscus that does not clearly extend to the surface. *Am J Roentgenol*, **156**, 333–336.
24 Jah AAE, Keyhani S, Zarei R, Moghaddam AK (2005) Accuracy of MRI in comparison with clinical arthroscopic findings in ligamentous and meniscal injuries of the knee. *Acta Orthop Belg*, **71**, 189–196.
25 Lundberg M, Odensten M, Thuames KA, Messner K (1996) The diagnostic validity of MRI in acute knee injuries with hemarthosis. *Int J Sports Med*, **17**, 218–222.
26 Lawson GM, Nutton RW (1995) A prospective audit of knee arthroscopy: a study of the accuracy of clinical diagnosis and therapeutic value of 325 knee arthroscopies. *J R Coll Surg Edinb*, **40**, 135–137.
27 Makdissi M, Eriksson KO, Morris HG, Young DA (2005) MRI—negative bucket-handle tears of the lateral meniscus in athletes: a case series. *Knee Surg Sports Traumatol Arthrosc*, **26**, 1–5.
28 Magee T, Shapiro M, Williams D (2004) Prevalence of meniscal radial tears of the knee revealed by MRI after surgery. *Am J Roentgenol*, **182**, 931–936.
29 Mackenzie R, Dixon AK, Keene GS, Lomas DJ (1995) Errors at knee magnetic resonance imaging: true or false? *Radiology*, **68**, 1045–1051.
30 Mackenzie R, Dixon AK, Keene GS *et al*. (1996) MRI of the knee assessment of its affectiveness. *Clin Radiol*, **51**, 245–250.
31 Pereira ER, Ryu KN, Ahn JM, Kayser F, Bielecki D, Resnick D (1998) Evaluation of the anterior cruciate ligament of the knee: comparison between partial flexion true sagittal and extension sagittal oblique positions during MR imaging. *Clin Radiol*, **53**, 574–578.
32 Polly DW, Callaghan J, Sikes RA, McCabe JM (1988) The accuracy of selective MRI compared with findings of arthroscopy of the knee. *J Bone Joint Surg*, **70**, 192–198.
33 Quinn SF, Brown TF (1991) Meniscal tears diagnosed with MRI versus arthroscopy: how reliable is arthroscopy? *Radiology*, **181**, 843–847.
34 Miller GK (1996) A prospective study comparing the accuracy of the clinical diagnosis of meniscus tear with MRI and its effect on clinical outcome. *Arthroscopy*, **12** 406–413.
35 Murray AR, Hartzman S, Bassett LW *et al*. (1987) MRI of the knee; part 1. Traumatic disorders. *Radiology*, **162**, 547–551.

36 Murray AR, Hartzman S, Duckwiler GR *et al*. (1986) Meniscal injuries; detection using MRI. *Radiology*, **159**, 753–757.
37 Rangger C, Klestil T, Kathrein A, Inderster A, Hamid L (1996) Influence of MRI imaging on indications for arthroscopy of the knee. *Clin Orthop*, **330**, 133–142.
38 Rose NE, Gold SM (1996) A comparison of accuracy between clinical examination and MRI in the diagnosis of meniscal and ACL tears. *Arthroscopy*, **2**, 398–405.
39 Rappeport ED, Wieslander SB, Stephensen S, Lausten GS, Thomsen HS (1997) MRI preferable to diagnostic arthroscopy in knee joint injuries. A double-blind comparison of 47 patients. *Acta Orthop Scand*, **68**, 277–281.
40 Ruwe PA, Wright J, Randall LR, Lynch JK, Jokl P, McCarthy S (1992) Can MRI effectively replace diagnostic arthroscopy? *Radiology*, **183**, 335–339.
41 Spiers ASD, Meagher T, Ostlere ST, Wilson DJ, Dood CAF (1993) Can MRI of the knee affect arthroscopic practice. *J Bone Joint Surg*, **75**, 49–52.
42 Trieshmann HW, Mosure JC (1996) The impact of MRI of the knee on surgical decision making. *Arthroscopy*, **12**, 550–555.
43 Vincker PWJ, Braak BPM, Erkell AR, Rooy TPN (2002) Effectiveness of MRI in selection of patients for arthroscopy of the knee. *Radiology*, **223**, 739–746.
44 Uppal A, Disler DG, Short BW, McCawley TR (1998) Internal derangements of the knee: rates of occurrence of MRI in the patients referred by orthopedic surgeons compared with rates in patients referred by physicians who are not orthopedic surgeons. *Radiology*, **207**, 633–636.
45 Warwick DJ, Cavanagh P, Bell M, Marsh CH (1993) Influence of MRI on knee arthroscopy waiting list. *Injury*, **24**, 380–382.
46 Williams RC, Williams LA, Watura R, Fairclough J (1996) Impact of MRI on knee arthroscopy waiting list. *Ann R Coll Surg Engl*, **78**, 450–452.
47 Weinstabl R, Muellner T, Vecsei V, Kainberger F (1997) Economic considerations for the diagnosis and therapy of meniscal lesions: can MRI help reduce the expense? *World J Surg*, **21**, 363–368.
48 James P, Buirski G (1990) MRI of the knee: a prospective trial using a low field strength magnet. *Australas Radiol*, **34**, 59–63.
49 Blackburn WD, Bernreuter WK, Rominger M, Loose LL (1994) Arthroscopic evaluation of knee articular cartilage: a comparison with plain radiographs and MRI. *J Rheumatol*, **21**, 675–679.
50 Duncan JB, Hunter R, Purnell M, Freeman J (1996) Injured stable knee with acute effusion MRI evaluation. *J South Orthop Ass*, **15**, 13–19.
51 Friemert B, Oblerlander Y, Schwarz W *et al*. (2004) Diagnosis of chondral lesions of the knee joint: can MRI replace arthroscopy? *Knee Surg Sports Traumatol Arthrosc*, **12**, 58–64.
52 Gardner MJ, Yacoubian S, Geller D *et al*. (2006) Prediction of soft-tissue injuries in Schatzker II tibial plateau fractures based on measurements of plain radiographs. *J Trauma*, **60**, 319–324.
53 Gudas R, Kalesinskas RJ, Kimtys V, Stankevicius E, Toliusis V, Bernotavicius G, Smailys A (2005) A prospective randomized clinical study of mosaic osteochondral autologous transplantation versus microfracture for the treatment of osteochondral defects in the knee joint in young athletes. *Arthroscopy*, **21**, 1066–1075.
54 Henderson I, Francisco R, Oakes B, Cameron J (2005) Autologous chondrocyte implantation for treatment of focal chondral defects of the knee—a clinical, arthroscopic, MRI and histologic evaluation at 2 years. *Knee*, **12**, 209–216.
55 Irie K, Yamada T, Inoue K (2000) A comparison of magnetic resonance imaging and arthroscopic evaluation of chondral lesions of the knee. *Orthopedics*, **23**, 561–564.
56 Kolman BH, Daffner RH, Sciulli RL, Soehnlen MW (2004) Correlation of joint fluid and internal derangement on knee MRI. *Skelet Radiol*, **33**, 91–95.
57 Nho SJ, Freedman KB, Bansal SL *et al*. (2005) The effect of radiofrequency energy on nonweight-bearing areas of bone following shoulder and knee arthroscopy. *Orthopedics*, **28**, 392–399.
58 Schneider U, Schelegel U, Bauer S, Siebert CH (2003) Molecular markers in the evaluation of autologous chondroctye implantation. *Arthroscopy*, **19**, 397–403.

59 Servant CTJ, Ramos JP, Thomas NP (2004) The accuracy of magnetic resonance imaging in diagnosing chronic posterior cruciate ligament injury. *Knee*, **11**, 265–270.
60 Sumen Y, Ochi M, Deie M, Adachi N, Ikuta Y (1999) Ganglion cysts of the cruciate ligaments detected by MRI. *Int Orthop*, **23**, 58–60.
61 Vallotton JA, Meuli RA, Leyvraz PF, Landry M (1995) Comparison between MRI and arthroscopy in the diagnosis of patellar cartilage lesions. *Knee Surg Sports Traumatol Arthosc*, **3**, 157–162.
62 Wessel LM, Scholz S, Rusch M *et al*. (2001) Hemarthrosis after trauma to the pediatric knee joint: what is the value of magnetic resonance imaging in the diagnostic algorithm? *J Pediatr Orthop*, **21**, 338–342.
63 Tuckman GA, Miller WJ, Remo JW, Fritts HM, Rozansky MI (1994) Radial tears of the menisci: MR findings. *Am J Roentgenol*, **163**, 395–400.
64 Tallon C, Coleman B, Khan KM, Maffulli N (2001) Outcome of surgery for chronic Achilles tendinopathy: a critical review. *Am J Sports Med*, **29**, 315–320.
65 Jakobsen RB, Engebretsen L, Slauterbeck JR (2005) An analysis of the quality of cartilage repair studies. *J Bone Joint Surg Am*, **87**, 2232–2239.
66 Boden SD, Davis DO, Dina TS *et al*. A prospective and blinded investigation of magnetic resonance imaging of the knee. Abnormal findings in asymptomatic subjects. *Clin Orthop Relat Res*, **282**, 177–185.
67 Small NC (1990) Complications in arthroscopic meniscal surgery. *Clin Sports Med*, **9**, 609–617.
68 Glynn N, Morrison WB, Parker L, Schweitzer ME, Carrino JA (2004) Trends in utilization: has extremity MR imaging replaced diagnostic arthroscopy? *Skelet Radiol*, **33**, 272–276.
69 Oei EHG, Nikken JJ, Verstijnen ACM, Ginai AZ, Hunink MGM (2003) Magnetic resonance imaging of the menisci and cruciate ligaments: a systematic review. *Radiology*, **226**, 837–848.
70 Duchateau F, Vande Berg BC (2002) MR imaging of the articular cartilage of the knee with arthroscopy as gold standard: assessment of methodological quality of clinical studies. *Eur Radiol*, **12**, 2977–2981.
71 Arrive L, Renard R, Carrat F *et al*. (2000) A scale of methodological quality for clinical studies of radiologic examinations. *Radiology*, **217**, 69–74.