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for Health Services Research

# WORKING GROUP ON ACUTE PURCHASING

# Magnetic Resonance Imaging (MRI) in the Management of Knee Disorders

**April 1999**

## GUIDANCE NOTE FOR PURCHASERS 99/05

## Series Editor: Nick Payne

**InterDEC No: 14/1999**

# Trent Development and Evaluation Committee

The purpose of the Trent Development and Evaluation Committee is to help health authorities and other purchasers within the Trent Region by commenting on expert reports which evaluate changes in health service provision. The Committee is comprised of members appointed on the basis of their individual knowledge and expertise. It is chaired by Professor Sir David Hull.

The Committee recommends, on the basis of appropriate evidence, priorities for:

- the direct development of innovative services on a pilot basis;
- service developments to be secured by health authorities.

The statement that follows was produced by the Development and Evaluation Committee at its meeting on 13 April 1999 at which this Guidance Note for Purchasers (in a draft form) was considered.

## MAGNETIC RESONANCE IMAGING (MRI) IN THE MANAGEMENT OF KNEE DISORDERS

**AUTHORS:** Beard S M, Perez I, Touch S, Bickerstaff D. Trent Institute for Health Services Research, Universities of Leicester, Nottingham and Sheffield 1999. Guidance Note for Purchasers: 99/05.

**EXPERT ADVISORS TO TRENT DEC:** Dr I Perez, Senior Registrar in Public Health Medicine, Nottingham Health Authority; Mr S M Beard, Senior Operational Research Analyst, The School of Health and Related Research (ScHARR)

*(The recommendations made by the Committee may not necessarily match the personal opinions expressed by the experts)*

**DECISION: On the information presented to it, the Committee was unable to make recommendations on the place of MRI in the management of knee disorders. It appeared that the more expert the clinician, the less need there was for MRI. The Committee hoped that evidence would be collected so that guidance could be prepared on when referral for MRI was appropriate.**

**April 1999**

# MAGNETIC RESONANCE IMAGING (MRI) IN THE MANAGEMENT OF KNEE DISORDERS

***S M Beard***
***I Perez***
***S Touch***
***D Bickerstaff***

**Series Editor: Nick Payne**

Trent Institute for Health Services Research
Universities of Leicester, Nottingham and Sheffield

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***Conflict of Interest*** None of the authors of this document has any financial interests in the drug or product being evaluated here.

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## ABOUT THE TRENT INSTITUTE FOR HEALTH SERVICES RESEARCH

The Trent Institute for Health Services Research is a collaborative venture between the Universities of Leicester, Nottingham and Sheffield with support from NHS Executive Trent.

The Trent Institute:

- undertakes Health Services Research (HSR), adding value to the research through the networks created by the Institute;
- provides advice and support to NHS staff on undertaking HSR;
- provides training in HSR for career researchers and for health service professionals;
- provides educational support to NHS staff in the application of the results of research;
- disseminates the results of research to influence the provision of health care.

The Directors of the Institute are: Professor R L Akehurst (Sheffield);
Professor C E D Chilvers (Nottingham); and
Professor M Clarke (Leicester).

Professor Clarke currently undertakes the role of Institute Co-ordinator.

A Core Unit, which provides central administrative and co-ordinating services, is located in Regent Court within The University of Sheffield in conjunction with The School of Health and Related Research (ScHARR).

## FOREWORD

The Trent Working Group on Acute Purchasing was set up to enable purchasers to share research knowledge about the effectiveness and cost-effectiveness of acute service interventions and determine collectively their purchasing policy. The Group is facilitated by The School of Health and Related Research (ScHARR), part of the Trent Institute for Health Services Research, the ScHARR Support Team being led by Professor Ron Akehurst and Dr Nick Payne, Consultant Senior Lecturer in Public Health Medicine.

The process employed operates as follows. A list of topics for consideration by the Group is recommended by the purchasing authorities in Trent and approved by the Health Authorities and Trusts Chief Executives (HATCH) and the Trent Development and Evaluation Committee (DEC). A public health consultant from a purchasing authority leads on each topic assisted by a support team from ScHARR, which provides help including literature searching, health economics and modelling. A seminar is led by the public health consultant on the particular intervention where purchasers and provider clinicians consider research evidence and agree provisional recommendations on purchasing policy. The guidance emanating from the seminars is reflected in this series of Guidance Notes which have been reviewed by the Trent DEC, chaired by Professor Sir David Hull.

In order to share this work on reviewing the effectiveness and cost-effectiveness of clinical interventions, The Trent Institute's Working Group on Acute Purchasing has joined a wider collaboration, InterDEC, with units in other regions. These are: The Wessex Institute for Health Research and Development, The Scottish Health Purchasing Information Centre (SHPIC) and The University of Birmingham Department of Public Health and Epidemiology.

**Professor R L Akehurst,**

**Chairman, Trent Working Group on Acute Purchasing.**

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## EXECUTIVE SUMMARY

Disorders within the knee are collectively referred to as ‘derangement of the knee’. Around 50% of such disorders are likely to be meniscal injuries or involve loose bodies within the knee structure. A further 25% are related to injuries to the anterior cruciate ligament, with the remaining 25% split between posterior cruciate ligament and cartilage damage. There are no good routine data on the epidemiology of knee disorders. A 'typical' district of 500,000 population should expect to see around 430 patients with knee disorders per annum, presenting to orthopaedic units for arthroscopy.

The use of Magnetic Resonance Imaging (MRI) in the diagnostic investigation of acute and chronic knee injury/disorder is well documented. There are now increasing pressures for MRI to be used as a routine pre-screening diagnostic process, rather than relying solely on the diagnostic results of arthroscopy. The reference standard to which MRI is most often compared is that of arthroscopy. The advantages of arthroscopy are the ability to observe directly the internal knee structure and the opportunity to carry out therapeutic interventions at the same time. However, it is the case that some knee injuries can remain hidden to arthroscopy. The overall accuracy of arthroscopy has been commonly quoted as being between 70-100%. The theoretical advantage of using MRI, as a supplement to a clinical examination of the knee, is that a number of subsequent arthroscopies can be avoided which would otherwise result in no further therapeutic action. However, the scale of this impact is greatly debated.

A number of studies have attempted to evaluate the diagnostic accuracy of clinical examination compared to a blinded, or independent, MRI scan. Some reveal that clinical diagnosis can often miss knee disorders, leading to more diagnostic uncertainty and further exploratory arthroscopies. Others, particularly those from specialist clinics, report very similar findings between clinical examination and MRI. From these studies it is clear that MRI is certainly not a substitute for a thorough clinical examination, and should only be considered as an addition to an initial clinical diagnosis.

A number of blinded and unblinded studies have considered the relative diagnostic accuracy of MRI, compared to arthroscopy. Overall, the published evidence suggests that MRI provides an equivalent diagnostic performance to arthroscopy in cases of meniscal and cruciate knee disorder.

In considering the relative importance of MRI field strength, evidence suggests that field strength is not a significant determinant of diagnostic reliability for MRI assessment of internal derangement of the knee. Therefore, low field strength machines (<1 Tesla) should be expected to produce a diagnostic accuracy and image quality that is comparable to high field strength machines (>1 Tesla). The advantages are the potential for smaller operating costs and more flexibility and comfort for patients through dedicated machines.

A moderate number of studies consider whether the addition of MRI to the diagnostic process can have any influence on eventual patient management. There is a very wide range of opinion on this issue, with the reported impact of different studies ranging from less than 10%, to around 60-70% reductions in the number of arthroscopies eventually conducted. It is very difficult given the available data, to make any direct comparisons between the studies and to be clear on the precise patient groups involved. However, the majority of the studies do report between 30-50% reductions in arthroscopies, with some reporting additional reductions in waiting lists.

It remains difficult to evaluate accurately the potential cost implications of MRI, as it is clearly dependent on the amount of avoidable arthroscopies. This, in turn, will vary between centres and individual clinicians, on the basis of both case mix and experience. However, the authors' analysis suggests that, if over 40% of arthroscopies are avoided through additional use of MRI in all patients, then there will be potential cost savings to the NHS. For a 'typical' district with 60% avoidable arthroscopies, this saving could reach £100,000 if it is possible to target MRI usage to 70% of patients. Given much lower rates of avoidable arthroscopy, around 5%, then the blanket use of MRI would increase annual costs by around £70,000.

## 1. INTRODUCTION

Magnetic Resonance Imaging (MRI) has fast become a leading medical technology allowing non-invasive diagnostic imaging of many parts of the body, including the musculo-skeletal regions. Its use in the diagnostic investigation of acute and chronic knee injury/disorder is well documented and supported in the published literature.[1,2,3] There are now increasing pressures to move towards an MRI based pre-screening diagnostic process, rather than relying solely on the diagnostic results of arthroscopy. This is particularly relevant in cases where diagnosis remains uncertain despite a thorough clinical examination. It is widely believed that, if adopted as a supportive diagnostic step, MRI scanning could avoid a significant proportion of those arthroscopies which result in either negative findings, or where therapeutic surgical intervention is not required. Some clinicians argue further for a blanket coverage of MRI pre-screening for all knee injuries as part of the diagnostic process. However, many orthopaedic surgeons believe that a thorough clinical examination, performed by an experienced clinician, can produce clear indications for surgical intervention in many cases. The published literature reflects these differences in opinion with regard to the benefits and role of MRI scanning for knee disorders.

A previous Wessex DEC report considered the evidence and potential role of MRI scanning in the diagnosis of knee disorders.[4] This review concluded that MRI would only be cost saving if more than 50% of arthroscopies were truly avoidable (i.e. were only diagnostic in nature and resulted in no therapeutic element). The report indicated, however, that this break-even point could be influenced by the relative costs of MRI and arthroscopy at a local level. It also highlighted that the inclusion of patient-borne costs would work strongly in favour of MRI, with reduced impact of in-patient stays and recovery times from surgery. The report recommended the use of MRI scanning for a sub-set of selective cases:

- suspected meniscal lesions;
- unusual signs/symptoms;
- patients with high surgical risk;

- areas of difficulty for arthroscopy (posterior horn of menisci);
- persistent symptoms after negative arthroscopy.

Since the publication of the Wessex report in 1993, there has been a continued debate around the precise role of MRI scanning in the diagnostic process, the numbers of patients who are likely to benefit, the patient benefits that may be achievable, the number of potentially avoided arthroscopies and the overall relative cost impact that MRI may represent. A number of additional reviews and trials have also been published, allowing the diagnostic accuracy and management impact of MRI to be assessed further.

This Guidance Note revisits this literature evidence base comparing MRI with arthroscopy in the specific diagnosis of meniscal tears and cruciate ligament damage. The objective is to address the following research questions, all relating to the impact of MRI scanning on the effective management of knee disorder:

1. Issues related to the diagnostic performance of MRI:
- How accurate is MRI when compared to clinical diagnosis alone?
- How accurate is clinical examination in diagnosing knee disorder? Is it sufficient alone?
- Can low field strength machines produce a diagnostic accuracy that is comparable to high field strength machines?

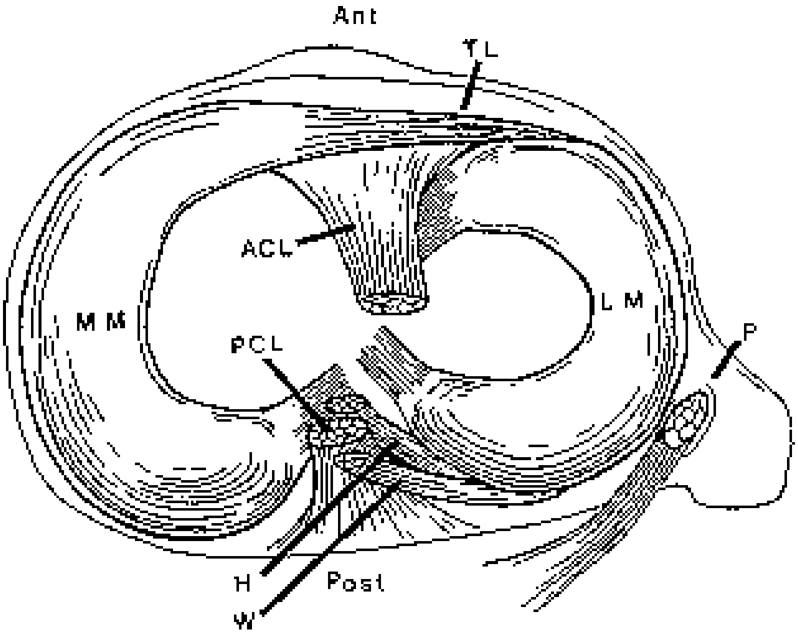
2. Issues related to the influence of MRI on patient management:
    - Can MRI prevent arthroscopies?
    - Can MRI reduce the waiting list for surgery?

3. What is the likely impact of MRI on patient outcome?
4. What are the cost and benefit implications of adopting MRI scanning?
5. Is there any recommended sub-set of patients for which MRI is more appropriate?

### 1.1 Scope of Knee Injuries

The knee is the largest joint in the body and sits between the tibia and femur. The main meniscal and cruciate structures within the knee joint are represented in Figure 1 (and also in Appendix A: Lateral/Medial Views of the Knee Joint)

**Figure 1 Meniscal/Cruciate Structures of the Knee**




Ant = anterior; Post = posterior; MM = medial meniscus; LM = lateral meniscus; ACL = anterior cruciate ligament; PCL = posterior cruciate ligament; P = popliteus tendon; H/W = meniscofemoral ligament

* The menisci are semi-lunar fibrocartilage structures which perform a load bearing and distribution function within the knee. They also act as a shock absorber, providing a secondary stabilisation alongside the ACL. The two structures, medial and lateral, are attached to each other via the meniscal ligament and are seen at MRI as a typical bow-tie or double triangle darkened image.

* The ACL travels upwards and backwards within the knee, both preventing hyper-extension of the joint and assuring rotary control and, as such, performs a primary stabilising function.

* The PCL is a shorter, but thicker, ligament structure located at the rear of the knee and, as such, is more difficult to access surgically at arthroscopy. As the PCL is stronger than the ACL, injuries are less common and are typically associated with high energy injury mechanisms.

* The medial and lateral collateral ligaments also perform a stabilising role and can be partially or fully torn following trauma.

* The articular cartilage also acts as a shock absorber.

Injuries to the structures within the knee are collectively referred to as 'derangement of the knee' and are covered within the ICD-10 codes as M23, and ICD-9 as 717.[5,6]
Within this general diagnosis, disorders break down into the following specific types:

- medial meniscus tears;
- medial collateral ligament tears (MCL);
- articular cartilage damage;
- anterior cruciate ligaments (ACL) lesions;
- posterior cruciate ligaments (PCL) lesions;
- lateral meniscus tears;
- lateral collateral ligament tears (LCL);
- meniscal cysts;
- cysts of semilunar cartilage;
- loose bodies.

There also exist a number of other types of knee disorder, such as, unicompartmental arthritis, congenital disease and bone deformations, for which MRI scanning may provide some benefit. However, for the purpose of this report we have focused on the evidence related to the more common forms of knee derangement, as identified above. Injuries to the menisci or cruciate ligaments represent the majority of knee disorders and would, therefore, be expected to have the largest impact in terms of potential MRI activity and cost.
(See Table 1).

**Table 1 Typical Breakdown of Presenting Knee Injuries**

| Knee Structure | Proportion (%) | Patients p.a. |
|---|---|---|
| Menisci/ Loose Bodies | 50 | 400 |
| ACL | 25 | 200 |
| PCL | 5 | 40 |
| MCL/LCL | 20 | 160 |
| **Total for an Average Referral Centre** | **100** | **800** |

Source : (Northern General Hospital Sheffield )

## 1.2 Epidemiology of Knee Disorder

It is very difficult to provide exact measures of the annual incidence rates for these types of disorder. The Wessex DEC report[4] suggested that, based on national records of hospital in-patient episode (HIPE), an incidence rate of 3.4 per 10,000 should be expected per year. This analysis used ICD-9 (717) coding to define the disorder type. A more recent examination of Hospital Episode Statistics (HES) 1994-95 reveals that 40,704 finished consultant episodes (FCEs) related to knee derangement in England. For Trent the published figure is 4,284 FCEs. In an updated search of the Trent Patient Information System (PIS) 1996-97 data, consideration was given to all in-patient episodes marked with an ICD-10 (M23) 'Internal derangement of the knee' coding. The data identifies 4,041 knee injured patients, involved in 4,202 day-case or in-patient episodes, equating to an underlying annual incidence rate of 8.6 patients per 10,000 population. Knee derangement as a primary diagnosis accounted for 3,725 of the 4,202 episodes identified. The diagnosis codes clearly show that meniscal injury is the most common cause of knee derangement (See Table 2).

**Table 2 Trent PIS - Breakdown of Primary Diagnosis Codes**

| ICD-10 M23 | Description | Primary No | Primary % |
|---|---|---|---|
| .0 | cystic | 42 | 1 |
| .1 | meniscus (congenital) | 9 | 0 |
| .2 | meniscal derangement (old tear/injury) | 1,798 | 48 |
| .3 | meniscal derangement other | 522 | 14 |
| .4 | loose body in knee | 246 | 7 |
| .5 | chronic instability of knee | 98 | 3 |
| .6 | spontaneous disruption of ligaments | 133 | 4 |
| .8 | laxity of ligament / snapping of knee | 744 | 20 |
| .9 | unspecified derangement | 133 | 4 |
| M23.* | internal derangement of the knee | 3,725 | 100 |

Source : Trent PIS 1996/97 data

The problem with both these estimates is that some patients will undoubtedly be treated as out-patients only and escape recording. Also, there are problems in the consistency of coding of episodes across patient records generally. Therefore, it is likely that these estimates are conservative.

The 1991 Morbidity Statistics from General Practice estimate that 32 per 10,000 population per annum consult their GP with knee disorders, generating on average 1.5 consultations per person.[7] This is almost four times the level of recorded in-patient activity. Almost 80% of these patients are new consultations rather than presenting with ongoing chronic problems. Some of these patients will be managed solely by the GP, whilst some will be referred either to orthopaedic surgeons for investigation or the GPs themselves may request an MRI scan. These figures re-enforce the likelihood of the in-patient data representing an under-estimate of the true incidence.

Using the recent Trent PIS data as a measure of annual incidence, around 430 knee derangement patients are expected to present to secondary care per annum for a 'typical' health authority of 500,000 population. These patients would undergo some form of diagnostic procedure (clinical diagnosis, arthroscopy, MRI), which may lead to a later surgical therapeutic intervention.

### 1.3 Current Diagnostic Services for Knee Injuries

The diagnosis of knee injuries is currently based around three modes of approach:

- thorough clinical examination *(typically conducted by an orthopaedic surgeon);*
- arthroscopy *(surgical visualisation of the disorder);*
- MRI scan *(non invasive imaging of the knee joint).*

*Clinical Examination*: With many knee disorders a definite diagnosis is possible after careful consideration of the clinical history and a thorough external clinical examination of the patient. Patients can then be moved on to appropriate management which may involve therapeutic arthroscopy, where indicated, or may be based on non-surgical approaches.

*Arthroscopy*: There exists a smaller, but significant, proportion of disorders where diagnosis, based on clinical examination alone, can remain inconclusive. In such cases a typical approach has been to conduct an arthroscopy, in order to take an internal view of the knee. Arthroscopy can confirm the existence and severity of the disorder and treatment of the disorder can often be conducted immediately, avoiding a second therapeutic intervention. This benefits the patient in terms of avoided pain and general inconvenience.

However, there are associated patient risks with such a surgical procedure. Estimates of arthroscopy-related infection rates vary between 0.47%[8] and 3%[9], depending on the exact definition of severity. There are also associated risks from the use of general anaesthesia itself, which rise with the age of the patient. Second arthroscopies can also be necessary where the nature of the disorder reveals a need for general anaesthetic, or where symptoms persist. There is also a sub-set of patients in whom arthroscopy reveals injuries that are likely to heal without the need for surgical intervention. Finally, there is the possibility of injuries remaining hidden to arthroscopy.

*MRI Scanning*: In cases of non-therapeutic, or diagnostic arthroscopy, the surgical procedure could potentially have been avoided, if an initial MRI scan had identified accurately such patients. This appears to be particularly true of the posterior third of the menisci with PCL injuries difficult to visualise at arthroscopy. Also, MRI has the potential to identify patients where arthroscopically negative findings mask a hidden disorder.

For these reasons MRI scanning of the knee joint, supplementing a thorough clinical examination, has become an increasingly common diagnostic approach. This may be particularly true if an orthopaedic surgeon has limited experience of treating knee disorders. The effectiveness of MRI depends heavily on the likely proportion of patients who would, without its use, undergo an unnecessary arthroscopy. Both failure to identify a disorder (false-negatives) and the suggestion of a disorder where none is present (false-positives) will also have impact in terms of patient care and overall cost-effectiveness.

### 1.4 Description of MRI Scanning

MRI is non-invasive and does not use ionising radiation (See Table 3). The patient is placed in a strong static magnetic field, causing hydrogen protons to align with the field. The tissues are then exposed to pulsed radio-waves. Emitted signals can be detected and used to construct an image.[10] MRI scanners are produced with a variety of magnetic field strengths. Field strengths are measured in a unit called the Tesla (T), and machines range from 0.2 to 2.0T. High field strength systems have the greatest range of imaging capabilities, but many mid-field scanners of 0.5-1.0T can provide excellent performance at a much reduced cost. The following provides a brief overview of the pros and cons of MRI scanning and imaging techniques.

**Table 3 MRI Scanning - Pros and Cons**

| |
|---|
| **Pros** |
| • It is non-invasive. |
| • MRI does not involve exposure to ionising radiation and has no known significant clinical side effects.[11,12] |
| • Magnetic resonance images can be acquired with equal clarity in any orientation: axial, sagittal, coronal or oblique. |
| • MRI does not require the injection of contrast medium in most situations. |
| • Soft tissue contrast is better with MRI than other techniques. |
| • MRI without contrast can be done during pregnancy, if necessary. |
| • Paramagnetic contrast agents are safer than the iodinated contrast agents used with computed tomography (CT), although both are contraindicated in pregnancy. |
| • For spine/joints, the image quality is superior to that which is achieved with traditional invasive techniques.[11,12] |
| **Cons** |
| • MRI requires more patient co-operation than CT. |
| • MRI cannot be used for some people because of the powerful magnetic field. Pacemakers, many cerebral aneurysm clips, intraocular metal and cochlear implants are definite contraindications to MRI. Other vascular clips, vena cava filters, and most metallic implants require individual patient consultation.[13] |
| • Most MRI scanners require the patient to be positioned in a tunnel within the magnet housing. Claustrophobic patients may refuse to undergo the procedure. Evidence suggests that between 1% and 10% of patients experience panic and claustrophobic responses.[14,15] |
| • MRI shows incidental anatomical abnormalities that can be misinterpreted as causing a patient's symptoms, e.g. incidental spinal column abnormalities whose prevalence increases with age.[8] |
| • Magnetic resonance scanners are costly to install and operate. |
| • The long-term effect of magnetic fields is not known. |

The main imaging techniques adopted when conducting MRI investigation of the knee are listed below in Table 4 in a summary form. [3,10,16,17]

**Table 4 Glossary of MRI Techniques**

| Technique | Abbr. | Description |
|---|---|---|
| Spin echo sequences | SE | Traditional form of MRI knee investigation varying proton density, T1 and T2 times to visualise different tissue forms. |
| Fast spin sequences | FSE | Produces similar but faster images to SE, with more blurring of fine detail at shorter T2. |
| Gradient echo sequences | GE-2D | Again faster images than SE, but less resolution. |
| Gradient echo sequences | GE-3D | Very high resolution image which can be manipulated on screen in any plane, however, time consuming. |
| Fat suppression techniques | - | Help focus on high signal intensity areas. |
| T2 relaxation time | T2 | Time taken for the strength of signal to decay. |
| T1 relaxation time | T1 | Time taken for the protons to align. |

## 2. MAGNETIC RESONANCE IMAGING IN THE MANAGEMENT OF KNEE DISORDERS: SUMMARY OF EVIDENCE OF EFFECTIVENESS

### 2.1 Search Strategy

In identifying the evidence of effectiveness, papers/studies covered by the following standard data sources were considered:

- Medline
- EmBASE
- BIDS
- Cochrane
- CRD DARE
- CRD NEED

The period 1984 - July 1998 was focused on in a search for both reviews and published studies covering both diagnostic accuracy and performance of MRI and its potential impact in terms of patient management decisions. The original Wessex report acted as a source of literature references, covering a period up to, and including, 1993.[4] In considering the literature review, particular attention was placed on the time period post-1996 as this period had not been within the scope of the identified systematic reviews.

### 2.2 Diagnostic Performance Indicators

In considering the performance of any diagnostic procedure, it is important to clarify the exact measures by which new and existing technologies are to be judged. The following provides a definition for sensitivity, specificity, and positive/negative predictive value of a diagnostic test - in this case the focus is on knee disorder as an example.

**Table 5 Diagnostic Performance Indicators**

| Diagnostic Test Result | Disorder Status | | Total |
|---|---|---|---|
| | Present | Not Present | |
| **Positive** | a | b | a+b |
| **Negative** | c | d | c+d |
| **Total** | a+c | b+d | a+b+c+d |

a = true positive; b = false positive; c = false negative; d = true negative

| ***Performance Statistic*** | ***Calculation*** | ***Definition*** |
|---|---|---|
| Sensitivity | a / (a+c) | Indicates the probability of testing positive if disorder is present. |
| Specificity | d / (b+d) | Indicates the probability of testing negative if disorder is not present. |
| Positive predictive value (PPV) | a / (a+b) | Indicates the probability of disorder present if test is positive. |
| Negative predictive value (NPV) | d / (c+d) | Indicates the probability of no disorder present if test is negative. |
| Accuracy | (a+d)/(a+b+c+d) | Indicates the probability of the results of the test (+ or -) being correct. |

**NB:** Both PPV and NPV are strongly influenced by the prevalence of the disorder or disease under investigation. If the condition is rare, the test may have high NPV whilst still being a poor test in terms of its accuracy.

## 2.3 Evidence of Diagnostic Accuracy

### 2.3.1 Arthroscopy as a 'Gold Standard'

The reference standard by which MRI of the knee has been generally measured is that of arthroscopy. This implies that arthroscopy is 100% accurate, having a sensitivity and specificity of 1 (i.e. it enables visualisation and evaluation of all lesions). However, this is clearly not always the case and some knee injuries can certainly remain hidden to diagnostic arthroscopy, i.e. the sensitivity is actually lower than 1.[9,18,19,20] Overall accuracy for arthroscopy has been commonly quoted as being somewhere between 0.7 and 1, depending on the experience of the arthroscopist, with arthroscopy providing a correct + or - diagnosis in between 70-100% of cases.[21,22,23]

One reason for variation in diagnostic performance is that results of arthroscopy depend very much on the individual skill of the surgeon. A knee specialist would be expected to achieve better outcomes than a generalist orthopaedic surgeon. (There is also a parallel issue of radiologist expertise in interpretations of MRI scans). An important issue relates to the practical problems associated with accessing the deeper internal structures of the knee, in particular the posterior regions. Whilst different access portals can be used in combination with improved arthroscopy techniques, 'hidden areas' almost certainly still remain.[24] [25] It has been reported that the false-positive rate of MRI was 6% when compared with arthroscopy conducted by knee specialists and 16% when arthroscopy was conducted by general orthopaedic surgeons.[26] Such false-positive results would typically result in negative arthroscopies. This highlights the parallel diagnostic inaccuracies of MRI and this issue is addressed in later discussion points.

Despite the potential for missing a small proportion of disorders, it is against arthroscopy as a standard diagnostic modality that the potential role of MRI must be evaluated practically. The vast majority of studies considering MRI scanning for knee disorder use arthroscopy as a 'gold standard' and these issues of comparability must be remembered.

### 2.3.2 Clinical Examination vs. Diagnostic Investigation

Whilst many radiologists and clinicians claim that MRI can add value and influence clinical diagnosis and management, others remain sceptical and see no added diagnostic advantage to conducting MRI scans. In many cases of knee disorder it is very likely that clinical examination alone will be sufficient to reach a reliable diagnosis and for the surgical/non-surgical management of the disorder to be planned accordingly. However, for other presentations of knee disorder and injury, there remains controversy about the strength of clinical assessment in diagnosis of knee problems. The accuracy of clinical diagnosis is strongly correlated to clinical expertise of knee disorders. A number of studies have been published which attempt to evaluate the diagnostic accuracy of clinical examination compared to a blinded, or independent, MRI scan. (See Appendix B). The research question remains: *'How accurate is clinical examination in diagnosing knee disorder, and is it sufficient alone?'*

In a commonly quoted study, Fowler et al.[27] considered the value of clinical signs for meniscal tears in a study of 161 patients with a proven history of knee pain. Comparing standard clinical tests (McMurray, flexion pinch, Apley grind, joint extension tenderness, extension block) with findings at arthroscopy, the authors concluded that clinical diagnosis had limitations when considering and confirming meniscal lesions.[27]

A following audit conducted by Boeree et al.[9] involving 203 patients, suggested that physical signs proved insufficiently sensitive in detecting menisci and cruciate abnormalities. Patients were seen by orthopaedic consultants 'with a particular interest in knee surgery'. The study suggests that clinical examination alone would be expected to miss approximately 30% of medial meniscus tears, 70-75% of lateral meniscus tears and over 30% of ruptured ligaments. However, the authors also noted a high level of unneccesary arthroscopies (following diagnosis using MRI). This was particularly true in cases of ‘suspected’ meniscal tears linked with ACL injuries. Overall, the authors concluded that reliance upon clinical judgement alone, compared to additional investigations via MRI, would have resulted in an 89% increase in arthroscopic procedures. These findings are closely supported in a further study by Boden et al.[28].

In a recent prospective blinded comparison with MRI, clinical examination was found to have a diagnostic accuracy of only 44% in cases of meniscal tears.[29] There was a high level of false-positives, with a specificity as low as 6%. Diagnostic performance was much improved under a blinded MRI scan with specificity of 75% and accuracy of 79%. The sensitivity of clinical examination for meniscal tears was very high at 100%.

Yoon et al.[30] evaluated the accuracy of clinical evaluation alone in a prospective study in 200 knee injuries. Approximately 50% of cases were found to have more than one lesion. Importantly, although correct diagnosis was made in 70% of cases where only a single lesion was present, cases of multiple lesions had a drastically reduced diagnostic accuracy of 23-48%, with the number of lesions related to poorer diagnosis. The results of clinical examination indicate that ACL injuries are difficult to assess accurately with a sensitivity of almost 80% (i.e. 20% of injuries are missed with clinical examination alone). The authors also identified a significant relationship ($p<0.01$) between partial ACL tears and the risk of being recorded as a false-negative or missed disorder.

A number of further review papers reflect on the limitations of clinical diagnosis alone as an indication for surgical intervention.[2,3,31]

However, there are contrasting views which are more positive about clinical examination alone as a diagnostic process. These studies are generally conducted in the setting of sports injury clinics, possibly reflecting more experience of knee surgery and, as such, reflect a more accurate performance from clinical examination.

In a study of 206 patients Terry et al.[32] showed that the results of clinical assessment were comparable or superior to published reports of arthrography, Computed Tomography (CT) and MRI. The authors concluded that a thorough clinical assessment can provide sufficient information for the surgeon to make a definitive primary pre-operative diagnosis, and that arthroscopy should not be performed without a complete pre-operative examination.

A recent prospective study (Gelb et al.)[33] evaluated the clinical value of MRI of the knee in 72 patients in a sports medicine referral practice. This study showed that clinical evaluation had a sensitivity and specificity of 100% for diagnosis of anterior cruciate ligament (ACL) injuries, whereas MRI was 95% sensitive and 88% specific. For isolated meniscal lesions, the clinical assessment had a sensitivity and specificity of 91% compared with 82% and 87% respectively for MRI. For evaluation of articular surface damage, the positive predictive value was 100% for clinical assessment and 33% for the MRI. The authors conclude that clinical assessment equals, or surpasses, MRI in accuracy. They also claim that MRI is overused in the evaluation of knee disorders and is not a cost-effective method for evaluating disorders when compared with the results of a skilled examiner.

Miller et al.[34] conducted a single-blinded study in 57 patients with suspected meniscal tears in order to compare the diagnostic performance of MRI against clinical examination, using arthroscopy as a standard reference. Blinded MRI (i.e. with no knowledge of the clinical examination) was found to produce very similar results to clinical examination alone, when considering meniscal tears.

Muellner et al.[35] also report on a similarly blinded series of 36 athletes who faced clinical examination and MRI scan independently. The series showed that both MRI and clinical examination predicted meniscal lesions with an 89% accuracy rate.

*Conclusion*

It is difficult to draw definite conclusions from such a broad range of studies. Overall, it is clear that MRI is certainly not a substitute for a thorough clinical examination and should only be considered as an addition to an initial clinical diagnosis.

It would also appear that in many sports injury clinics, the results of a skilled examiner equal or surpass those of MRI. This most likely reflects an increased experience of knee injury surgery, as compared to that of a general orthopaedic surgeon. It is also possibly a reflection of the type/severity of disorders faced by such clinics. Therefore, it is likely that the use of MRI would be most appropriate as an addition to clinical examination when conducted by general orthopaedic surgeons.

### 2.3.3 MRI vs Arthroscopy

There have been numerous published studies, designed to evaluate the diagnostic power of MRI in identifying knee disorders. As previously discussed, the vast majority of these studies compare the findings of MRI scanning to those of follow-up arthroscopies, i.e. they use arthroscopy as a 'gold standard' reference point. The research question remains: *“How accurate is MRI when compared with arthoscopy?”*

In considering the effectiveness for MRI there are a number of challenges in making valid comparisons and contrasts across study data.

*1. Lack of Study Blinding, Leading to Over Estimates of Diagnostic Performance*

It is a fact that very few of the earlier studies are truly double-blinded in nature. If a surgeon is made aware of previous clinical diagnosis/MRI results this may lead him to conduct a more thorough surgical examination, improving the accuracy of arthroscopy. Likewise, an unblinded radiologist may identify more lesions from an MRI scan than may have been the case. Lack of blinding is likely to lead to overestimation of the performance of either diagnostic approach. Blinding provides a much more clinically realistic view of diagnostic performance.

*2. Variation in Strength and Techniques of MRI Between Studies*

The studies vary in terms of the MRI field strength and techniques adopted. In principle, a higher powered system should provide clearer images and lead to an improved performance. However, this issue is still under debate in the literature.

*3. Variation in the Skills of the Radiologists/Surgeon*

The individual skill and experience of the clinician will affect the performance of both the MRI and the arthroscopy in formulating a diagnosis.

*4. Variation in the Case Mix of Disorder Leading to Bias in Lesion Prevalence*

It is also true that most of the studies involve patients with specific disorder types, mostly meniscal tears and/or ACL lesions, rather than a general representative case mix of patients. The selection criteria for studies plays a major role in influencing the end-points. If patients are selected only if they have already had arthroscopy (retrospective studies) or who show clinical indications for arthroscopy (prospective studies), then potential bias will be evident with more lesions than would typically be the case. This makes the evaluation of specificity difficult as the majority will have lesions present.

Despite these problems in comparing and contrasting the results of diagnostic performance studies, it is still possible to comment on the comparative accuracy of MRI and arthroscopy. There have been a number of recently published reviews which have critically appraised and summarised the evidence of diagnostic accuracy for MRI scanning.

*Boeve et al. 1991*

Boeve et al.[36] analysed 10 published studies in 1991, comparing MRI and arthroscopy in the detection of meniscal and anterior cruciate ligament tears. Sensitivity, specificity, positive predictive value and negative predictive value for medial meniscus tears, lateral meniscus tears and anterior cruciate ligament tears were either obtained or calculated from each article. The authors concluded the combination of high negative predictive value and high sensitivity for MRI suggests that diagnostic arthroscopic surgery is not necessary in the evaluation of patients with negative MRI studies.

*MacKenzie et al. 1996*

More recently Mackenzie et al.[23] considered the published diagnostic performance statistics for MRI in cases of menisci and cruciate ligament injury. The authors reviewed 22 studies, (2 double blinded, 10 single blinded), all of more than 35 patients and identified over a time-period covering 1983-1994. All studies provided arthroscopic confirmation of MRI findings and presented sufficiently detailed results to allow recalculation of performance statistics and confidence intervals. Studies were restricted to English language text only. Importantly, the authors raise the issue of confidence intervals around performance statistics, and the fact that such information was found in only two of the 22 identified studies. Mackenzie et al. recalculated the confidence intervals for all studies before summing and averaging the results as an overall assessment of diagnostic accuracy (See Table 6).

On the basis of this evidence, the authors concluded that MRI of the menisci and ACL/PCL appeared to be fairly accurate in correctly assessing both the presence and absence of injury/disorder. The summary statistics suggest that the least sensitive application of MRI was in the diagnosis of lateral meniscal tears.

**Table 6 MRI Diagnostic Accuracy (MacKenzie Review)**

| Anatomical Region | Overall MRI Results | | | | | Sensitivity | | Specificity | | Accuracy | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | TP | TN | FP | FN | (%) | 95% C.I. | (%) | 95% C.I. | (%) | 95% C.I. |
| Medial meniscus | 2,104 | 1,039 | 82 | 153 | 830 | 93 | 91-94 | 84 | 82-87 | 89 | 97-90 |
| Lateral Meniscus | 2,095 | 379 | 117 | 91 | 1,508 | 76 | 73-80 | 94 | 93-95 | 90 | 89-91 |
| Both Menisci | 982 | 372 | 45 | 43 | 522 | 89 | 86-92 | 92 | 90-95 | 91 | 89-93 |
| ACL | 2,076 | 408 | 50 | 90 | 1,528 | 89 | 86-92 | 94 | 93-96 | 93 | 92-94 |
| PCL | 1,360 | 44 | 3 | 9 | 1,304 | 94 | 86-10 | 99 | 99-10 | 99 | 99-10 |
| Total | 8,617 | 2,242 | 297 | 386 | 5,692 | 88 | 87-90 | 94 | 93-94 | 92 | 91-93 |

NB : TP = True positive; TN = True negative; FP = False positive; FN = False negative

Details of the individual study results can be found in Appendix C.

*Rappeport et al. 1996*

In a similar review of diagnostic accuracy Rappeport et al.[19] considered 20 studies, published during the period 1986-1995 and involving more than 40 patients. Only four were assessed as true prospective double-blinded studies. Again, studies were restricted to MRI findings validated against follow-up arthroscopy. The review provides details of diagnostic performance for meniscal tears, ACL, PCL and articular cartilage injuries.

Overall, Rappeport et al. concluded that the published studies supported the hypothesis that MRI is equal to the diagnostic performance of arthroscopy in cases of injury in the major knee structures, as listed above. There are also additional advantages in term of providing information on sites hidden to traditional arthroscopy.

**Table 7 MRI Diagnostic Accuracy (Rappeport Review)**

| Anatomical Region | Sensitivity | | Specificity | | Accuracy | |
|---|---|---|---|---|---|---|
| | Range | Median | Range | Median | Range | Median |
| Menisci | 71-100% | 85% | 65-100% | 90% | 72-93% | 90% |
| ACL | 61-100% | 95% | 80-100% | 95% | 82-98% | 93% |
| PCL (low incidence) | 100% | 100% | 98-100% | 99% | na | na |
| Articular cartilage | 18-100% | - | 50-100% | - | 68-98% | 85% |

*NB : Where studies were clustered around or above clear vales these have been shown*

Details of the individual study results can be found in Appendix C.

*Later Diagnostic Performance Studies (1996-1998)*

Both MacKenzie and Rappeport provide good semi-systematic reviews of the current literature covering the decade prior to 1996. However, there have been a number of key studies published since this date. It is important to include these studies as the pace of improving technology means that the accuracy of MRI should be expected to improve over time. The rigour of the studies may also be improved in terms of blinding of clinicians and patient inclusion criteria.

The literature search process employed for this Guidance Note identified eight such studies, all of which made a direct comparison of MRI scans to subsequent arthroscopic examination (See Appendix C). These studies reflected a range of different MRI field strengths, surgical experience and settings. Overall, they appear to confirm the general accuracy of MRI scanning. However, some of the series are reported from more specialist clinics and show similar levels of diagnostic accuracy to clinical examination alone.

*Conclusions*

In cases of suspected meniscal tears diagnostic performance levels of MRI appear high, although most studies confirm a lower sensitivity in cases of lateral meniscal disorder.

In cases of ACL disorder the sensitivity of MRI regularly exceeds 90%, with some studies reporting a 100% sensitivity (i.e. all positive cases were identified by MRI). With similar levels of specificity reported, (> 90%) MRI appears to provide a good assessment of ACL disorders.

It is a fact that PCL injuries are seen in far less numbers than other knee disorders. This is mainly due to the amount of energy required to cause such a tear to a major knee structure. As such, the number of studies which specifically identified PCL disorder were greatly reduced. Although sensitivity and specificity levels of 98-100% suggest a high level of accuracy, the low prevalence brings more uncertainty into the interpretation of these results. It appears that, with this caveat in mind, MRI is a very effective diagnostic tool in the case of PCL disorders.

Finally, sensitivity and specificity for articular cartilage injuries were noted across a wide range (50-100%) with one outlier study reporting sensitivity levels of 18%. Rappeport et al.

concluded that MRI was likely to be beneficial in the surgical management of patients with more severe cases of cartilage damage.

Overall, the evidence would seem to suggest that MRI provided an equivalent diagnostic performance to arthroscopy in cases of meniscal and cruciate disorder.

### 2.3.4 Low vs High Field Strength MRI Systems

As well as studies investigating the relative merits of MRI compared to arthroscopy, there is also debate regarding the comparative quality of low and high field strength MRI machines. The advantage of low field strength MRI systems is that they are less expensive, in terms of the initial investment, and also that the use of dedicated small-joint systems may represent a more flexible and potentially user-friendly resource. The research question remains: *'Can low field strength machines produce a diagnostic accuracy that is comparable to high field strength machines?'*

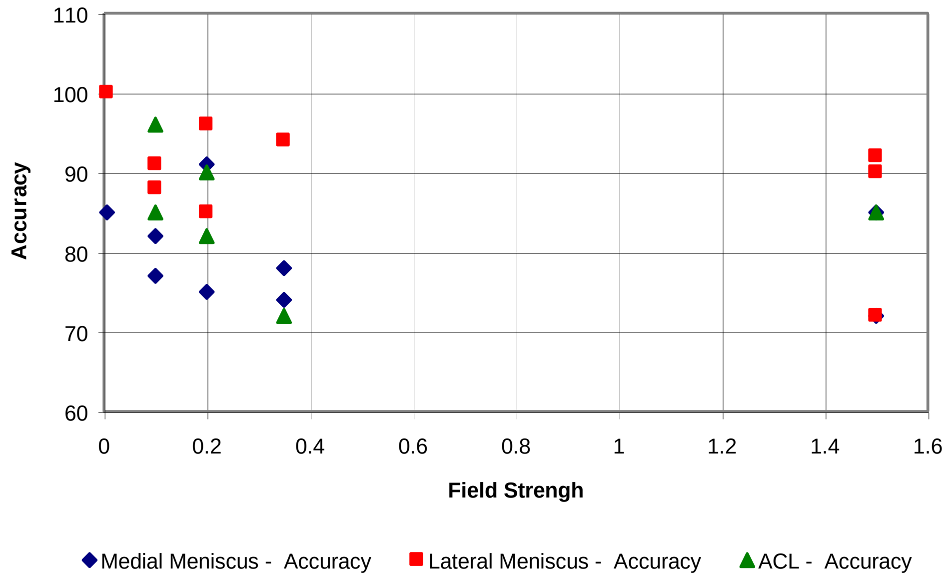
In publishing their own series of low field MRI performance statistics, Rappeport et al.[37] concluded that there was no proven major difference between the performance of high, medium and low strength MRI systems in knee disorders on the basis of previously published double blinded trials (see Table 8 and Figure 2). Similarly MacKenzie et al.[23] could not identify any significant differences in accuracy rates when comparing results from studies using either low or high field strength MRI systems (ranging between 0.064T-1.5T).

**Table 8 Diagnostic Performance of MRI by Field Strength (Rappeport Review)**

| Year | Reference | Double Blinded | Field Strength (Tesla) | Medial Meniscus (%) | | | Lateral Meniscus (%) | | | ACL (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Se | Sp | Acc | Se | Sp | Acc | Se | Sp | Acc |
| 1992 | D'erme et al.[38] | Yes | 0.006 | 92 | 86 | 85 | - | - | 100 | 80 | 82 | - |
| 1994 | Kinnunen et al.[39] | Yes | 0.100 | 88 | 80 | 82 | 25 | 97 | 88 | 83 | 85 | 85 |
| 1992 | Grevitt et al.[40] | | 0.200 | 92 | 90 | 91 | 88 | 98 | 96 | 100 | 80 | 82 |
| 1995 | Kersting-Sommerhoff et al.[41] | Yes | 0.200 | 73 | 76 | 75 | 33 | 98 | 85 | 95 | 87 | 90 |
| | | Yes | 1.500 | 87 | 87 | 85 | 44 | 94 | 90 | 86 | 87 | 85 |
| 1989 | Glashow et al.[42] | Yes | 0.350 | 77 | 71 | 74 | 93 | 94 | 94 | 61 | 82 | 72 |
| 1989 | Barronian et al.[43] | Yes | 0.350 | 88 | 72 | 78 | - | - | - | - | - | - |
| 1991 | Raunest et al.[44] | Yes | 1.500 | 94 | 37 | 72 | 78 | 69 | 72 | - | - | - |
| 1993 | Spiers et al.[31] | Yes | 1.500 | 100 | 71 | - | 100 | - | 92 | 100 | 98 | - |
| 1997 | Rappeport et al.[37] | Yes | 0.100 | 86 | 73 | 77 | 40 | 98 | 91 | 89 | 97 | 96 |

NB : Se = sensitivity; Sp = specificity; Acc = Accuracy

**Figure 2 Diagnostic Performance of MRI by Field Strength**




A number of other more recent field strength studies exist which all conclude that low-field strength MRI is comparable to standard high-strength systems. These studies are detailed in Appendix D.

Franklin et al.[45] considered the merits of dedicated in-office MRI systems, where field strength (0.2T) is much lower than the fixed MRI systems (1.5T) traditionally used in knee diagnostic studies. In total 35 patients were evaluated by MRI-ARTOSCAN, all of whom had a subsequent arthroscopy. In a larger prospective study of 210 patients, Kersting-Sommerhoff et al.[41] also considered the diagnostic accuracy of an MRI-ARTOSCAN system. Barnett et al.[46] compared the scan findings of 118 patients at 0.5T MRI with similar data from 11 recently published 1.5T MRI studies. All three studies concluded comparable sensitivity, specificity and accuracy when compared with published rates for high field strength machines of 1.5T.

In a prospective study of 22 patients, Kladny et al.[47] evaluated a 1.5T MRI system against a lower field strength machine of 0.2T. Although the results were slightly lower in terms of specificity for meniscal tears, the authors concluded that both systems provided high levels of accuracy in diagnosing knee disorders. A similar prospective double-blind study of 33 patients found that the performance of 0.1T MRI in lesions of medial meniscus, lateral meniscus, anterior cruciate tears and posterior cruciate tears equalled that for high field strength MRI, the only exception being the sensitivity for lateral meniscus lesions.[39] Passariello et al.[48] report on three years' experience of using a dedicated MRI system in the evaluation of small joint disorder including knee. They claim high levels of accuracy when compared to reported results of high strength machines and reflect on the lower unit costs of a dedicated system.

Parizel et al.[49] studied prospectively 10 subjects showing image quality and diagnostic performance, as assessed by four radiologists, to be equivalent for both 0.2T and 1.5T systems. The authors concluded that a low field system is a cost-effective alternative with a 40% reduction in operating costs.

*Conclusion*

The results suggest that MRI field strength is not a significant determinant of diagnostic reliability for MRI assessment of internal derangement of the knee. Therefore, it seems that low field strength machines can produce a diagnostic accuracy and image quality that is comparable to high field strength machines. The advantage is that operating costs likely to be up to 40% less in lower strength machines. Obviously, if existing high field machines are already in operation, providing enough capacity for other joint diagnostic work, then the economic advantage would be different. Whilst the findings remain consistent with supportive expert opinion, criticisms can be levelled as some sample sizes are rather small, and the quality of the methodology is not always robust.

### 2.3.5 Abnormal Findings in Asymptomatic Subjects

Several studies have investigated the prevalence of abnormal findings in asymptomatic subjects when carrying out an MRI scan, in order to consider and identify the level of specificity in MRI scanning of knee disorder. If specificity is low, then false-positive tests may result in unnecessary arthroscopies.

Boden et al.[28] conducted a prospective and blinded study on 74 asymptomatic volunteers without history or symptoms of knee disorder. Overall, the MRI scan identified 16% of people as having abnormalities consistent with tears, this percentage increased with age to >36% in people aged over 45 years. The authors emphasised the importance of access to relevant clinical data when interpreting MRI scans of the knee.

Another study by LaPrade et al.[50] found that the prevalence of meniscal tears in asymptomatic knees was 5.6%. The authors recommend that clinicians match clinical signs and symptoms with MRI *before* instituting surgical treatment.

Again, it must be emphasised that a false-positive result from MRI may still, in a proportion of cases, represent actual injuries which remain hidden even after repeat arthroscopy.

### 2.4 Impact of MRI on Patient Management

Accurate diagnosis is not an end in itself and therapeutic impact also needs to be considered. There are many prospective studies in the literature demonstrating the high accuracy of knee MRI against an arthroscopic standard, but little is being written on whether this accuracy can influence patient management. Reflecting on the experience of MRI over the last decade, Dixon et al. highlight the potential of MRI to influence patient management in cases of uncertain diagnosis, which almost certainly result in diagnostic arthroscopy.[25] In cases where clinical examination provides clear indication of disorder, Dixon et al. argue that the role of MRI is less relevant. Table 9 summarises the results of studies designed to evaluate the impact of MRI on patient management.

Warwick et al.[51] reported on the impact of MRI on the arthroscopy waiting list. MRI scans were performed on 155 patients who had been placed on a diagnostic arthroscopy waiting list for between 4-18 months previously. In total 32% of patients were removed from the waiting list, of whom 22% of the total were directly attributable to the results of the MRI. A total of 24 patients (15.5%) improved spontaneously. The proportion of patients on the arthroscopy waiting list who improved spontaneously has been reported previously by Hede et al.[52] to be as high as 25%. Warwick et al.[51] concluded that the use of MRI can reduce diagnostic arthroscopy, but that the ideal time for MRI and arthroscopy is not clear. They also felt that arthroscopy very soon after presentation might be unjustified in those patients who improve spontaneously. Also MRI itself soon after presentation may be misleading.

Mackenzie et al.[21] conducted a prospective observational study on all patients referred to a regional unit for knee MRI over a six month period. The objective was to quantify how MRI influences clinicians' diagnoses, diagnostic confidence and management plans in patients with knee problems and to investigate whether these changes can bring about an improvement in health. The study revealed significant increases in clinicians' diagnostic confidence for both meniscal ($z = -6.6$, $p<0.01$) and ACL lesions ($z = -2.1$, $p<0.05$). For the medial meniscus, only 56 out of 113 pre-imaging diagnoses were retained. For the ACL, 35 diagnoses were made, but only 21 of these were still being considered after MRI. Most importantly, the study identified 62% (136 of 219) of originally planned arthroscopies that were avoided after a re-evaluation of diagnosis using MRI scan. The authors concluded that MRI significantly influences clinicians' diagnosis and management plans.

In a year-long prospective audit of all arthroscopies of the knee, Birch et al.[53] studied 279 patients for whom the intended arthroscopy was categorised as diagnostic or therapeutic, dependent on pre-operative indications. The study indicated that selective MRI would be cost beneficial in up to 40% of patients, i.e. those with uncertain diagnosis. However, to achieve cost savings, at least 14% of patients, who would otherwise receive diagnostic arthroscopy, would need to be excluded from surgery.

Another study by Ruwe et al.[54] performed on 103 patients, aimed to determine whether MRI was cost saving and whether it reduced the need for diagnostic arthroscopy of the knee. In their study, 51.4% of patients avoided a potentially unnecessary diagnostic arthroscopy and there were net savings of 26% of the costs.

Carmichael et al.[55] reported on experience of four orthopaedic consultants. They experienced 324 arthroscopies and 66 MRI scans. Based on the experience of a knee surgery specialist, it was estimated that 37 out of 57 patients (>60%) avoided arthroscopy through MRI scanning.

Williams et al.[57] reports the results of an MRI study on 69 patients all of whom had been placed on an arthroscopy waiting list for meniscal tears. Following MRI interpretation by a team of five radiologists and a senior registrar, around 60% of patients were successfully removed from the waiting list, with 40% of patients indicated as never having needed to have been scheduled for arthroscopy.

Spiers et al.[31] conducted a study involving 58 patients who had suspected derangement of the knee following a detailed clinical examination and consideration of patient details. All the patients had an initial MRI scan and subsequent arthroscopy. Using arthroscopy as a 'gold standard', it was estimated that 29% of arthroscopies could be avoided, for an overall 1.4% increase in costs. This, they argued, would be more than balanced by extra potential savings of freed surgical and theatre time.

**Table 9 Potential Impact on Patient Management of MRI Scanning**

| Year | Reference | Setting | Design | Orth | Rad | n | Impact on Management |
|---|---|---|---|---|---|---|---|
| 1997 | Carmichael et al.[55] | UK | ret | 3c<br>1ks | 1c | 324 | 65% reduction in arthroscopies |
| 1996 | Trieshmann et al.[56] | US | pro | - | 5r | 208 | 29% reduction in arthroscopies due to incorrect clinical diagnosis<br>22% increase in arthroscopies due to incorrect clinical diagnosis<br>64% reduction in arthroscopies for patients with acute symptoms of <8 days duration |
| 1996 | Mackenzie et al.[21] | UK | pro | 11c | 2r | 288 | 62% of arthroscopies discharged or reviewed due to MRI<br>21% new diagnosis due to MRI |
| 1996 | Williams et al.[57] | UK | pro | 1sr | 5r | 58 | 40% reduction in waiting list<br>60% reduction in arthroscopies |
| 1994 | Ruwe et al.[58] | US | | - | - | 103 | 57% reduction in arthroscopies |
| 1994 | Chissell et al.[59] | UK | ret | 1c | 1c | 175 | 54% reduction in arthroscopies |
| 1992 | Ruwe et al.[54] | US | pro | 2o | 3r | 103 | 51% reduction in arthroscopies |
| 1991 | Boeree et al.[9] | UK | ret | c/ks | - | 203 | 40-50% reduction in arthroscopies |
| 1997 | Maurer et al.[60] | US | pro | 2ks | - | 840 | 37% reduction in arthroscopies |
| 1997 | Weinstabl et al.[61] | AUSTRIA | pro | - | - | 201 | 30% unnecessary arthroscopies |
| 1994 | Birch et al.[53] | UK | pro | - | - | 279 | 28% reduction in arthroscopies |
| 1993 | Spiers et al.[31] | UK | | - | - | 58 | 29% reduction in arthroscopies |
| 1993 | Warwick et al.[51] | UK | pro | - | 2r | 155 | 22% reduction in arthroscopies |
| 1996 | Gelb et al.[33] | US | pro | - | - | 72 | 19% contribution to management<br>4% change in diagnosis<br>no reduction in arthroscopies |
| 1990 | Boden et al.[62] | | | | | | 13% reduction in arthroscopies |

?=information not listed; pro=prospective; ret=retrospective; r=radiologist; c=consultant; sr=senior registrar; ks=knee surgeon

*Conclusion*

There are a moderate number of studies addressing whether the accuracy of MRI can influence patient management. Table 9 shows the reported impact of different studies ranging from <10% to 64% reductions in the number of conducted arthroscopies. However, the majority report between 30-50% reductions. It is difficult in all these studies to be clear on the precise patient group. Some studies describe patients as justifying diagnostic arthroscopy, without clearly describing the reasons why. This is important when trying to interpret a proportional reduction. Other studies quote theoretical reductions in arthroscopy by assuming that if MRI had not been conducted, then arthroscopy would have followed. A search by the authors revealed very few studies which measured the impact of MRI on arthroscopy waiting lists.

The availability and quality of the case-series descriptive data does not allow us to examine the impact of MRI on patient management, on the basis of either surgical expertise or overall throughput. This level of analysis would be very informative, if possible.

### 2.5 Effect of MRI on Patient Outcomes

There is little evidence to support the hypothesis that the accurate diagnosis provided by MRI affects the overall quality of life of the patient. Hollingworth et al.[63] conducted an observational study to assess some aspects of the validity of the Rosser Index by comparing it with the SF-36 and the EuroQol. The three questionnaires were used to measure health change in 332 patients referred for MRI of the knee. SF-36 and EuroQol questionnaires recorded significant improvements in patients' health at six months. The authors concluded that MRI is associated with a positive impact on quality of life of patients with knee disorders. However, it will remain difficult to attribute such improvement to the use of MRI alone without a randomised trial.

Mackenzie et al.[21] used an SF-36 to track patients' quality of life with an initial response rate of 87% and 62% for follow-up post imaging. Improvements in patients' self reported health status were noted, but could not be attributed to the use of MRI specifically.

*Conclusion*

The only conclusion the authors can reach is that more research in this area is necessary.

## 3. COST AND BENEFIT IMPLICATIONS OF ADOPTING INTERVENTION

### 3.1 Usage of MRI and Arthroscopy

Nationally, there has been a substantial growth in the utilisation of MRI, resulting in growing waiting lists. There is evidence in many parts of the country that imaging of the spine, head and knee accounts for the bulk of MRI investigations (See Table 10).

**Table 10 The Major Uses of MRI Examinations in 1993**

| Area | % |
|---|---|
| Spine | 39 |
| Head | 30 |
| Knee | 16 |
| Other | 15 |

(*Source: Survey of all MRI machines in Wales. Welsh Health Planning Forum Survey 1994.)*

In a recent audit conducted in Nottingham, the percentage of MRI investigations on the knee was only around 3%. However, there is a general feeling among professionals that this percentage is increasing. Examples of the typical levels of service provision for MRI scanning of knee disorder within the Trent Region is detailed in Table 11. Waiting lists for MRI are typically six months and costs range between £130-£210.

**Table 11 Trent MRI Usage for Knee Investigations**

| Examples of Trent Centres | No of Knee MRIs p.a. | Field Strength of MRI System | MRI Cost | Waiting Time (weeks) |
|---|---|---|---|---|
| Derbyshire Royal Infirmary | 458 | 0.5T | £135 | 25-30 |
| Sheffield - Northern General Hospital/Central Sheffield University Hospitals | 380 | 1.5T | £185 | 26 |
| Leicester Royal Infirmary | not known | 1.0T | £207 | 26 |

Using patient information taken from the Trent PIS database consideration was given to the number of therapeutic/diagnostic arthroscopies conducted in patients with internal derangement of the knee (ICD10 - M23). The analysis was limited to cases where the primary procedure code indicated arthroscopy of the knee (See Table 12). The data clearly show that the majority of arthroscopies are therapeutic in nature with only 513 cases of diagnostic arthroscopy. However, there are very substantial coding concerns here (i.e. are diagnostic arthroscopies entered correctly?).

**Table 12 Trent PIS Arthroscopy for Knee Derangement**

| Procedure | Episodes | Patients |
|---|---|---|
| All Arthroscopy | 3,787 | 3,723 |
| Diagnostic Arthroscopy | 513 | 511 |
| Therapeutic Arthroscopy <u>only</u> | 3,274 | 3,212 |

Table 13 shows the reported arthroscopy activity obtained directly from a number of orthopaedic centres within the Trent Region. The table presents data on diagnostic/therapeutic arthroscopy and also indicates the proportion of patients treated with general anaesthesia and as in-patients. However, the current data do not allow us to stratify by disorder type (meniscal, ACL etc). These data show that patients almost always have a general anaesthetic and are more likely to have a day-case than an in-patient stay. However, it is interesting to note the variation in the levels of arthoscopies identified as diagnostic in intent. Without a detailed analysis of cases it is difficult to draw any firn conclusions from this.

**Table 13 Trent Arthroscopy Usage for Knee Derangement**

| Eamples of Regional Centres | No of Knee Arthroscopies p.a. | | | Anaesthesia | | Setting | | Average Cost (£) | | Average Waiting time |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diag | Ther | Total | Gen | Loc | Day | In | Day | In | (mths) |
| Derbyshire Royal Infirmary | 91 (13%) | 609 (87%) | 700 | >95% | <5% | 75% | 25% | £375 | £404 | 3-4 |
| Sheffield - Northern General Hospital | 343 (53%) | 301 (47%) | 644 | - | - | 53% | 47% | £534 | £744 | - |
| Nottingham City Hospital | 121 (64%) | 67 (36%) | 188 | 87% | 13% | 55% | 45% | £661 | £731 | <6 (day) <12 (in) |

## 3.2 Costs of MRI and Arthroscopy

The typical costs of MRI scanning, identified through the sample of data from the Trent Region, clearly show a reasonably wide range between £135-207 (See Table 11). There have also been a number of published studies, both UK and US based, which have quoted typical MRI costs (See Table 14). The UK studies in particular cover a time period of 1993-1994, and appear to suggest a similar range to that of the Trent data.

By comparison, the UK published costs for arthroscopy (day-case) vary much more widely, ranging between £250-£600. Again a similar variation is seen in the Trent cost data (See Table 13).

US costs for both MRI and arthroscopy tend to be higher, by around three times, reflecting the inclusion of a broader cost base: physician, hospitalisation, etc. However, they also indicate a higher proportional cost of arthroscopy compared with MRI.

For the purpose of the cost analysis the cost of MRI was estimated to be £180, based on an averaging of costs as suggested by both Trent data and published studies. The cost of arthroscopy was estimated at £450, roughly 2.5 times the cost of MRI, again reflecting the scale of price difference found in the published data. This cost per arthroscopy represents an average figure, calculated using the average costs, as per the published studies, and the expected proportions of arthroscopies conducted on a day-case basis within the UK.

Importantly, sensitivities around these assumptions on costs were also explored in order to enable the study to be generalised to local situations (arthroscopies may vary in price due to local service provision issues and, likewise, MRI could potentially be cheaper per patient, given existing local capacity/staffing).

**Table 14 Published Costs of MRI and Arthroscopy**

| Year | Ref | MRI | Arthroscopy | |
|---|---|---|---|---|
| | | | Day Case | In-patient |
| | | UK Studies | | |
| 1993 | Spiers[31] | £185 | £600 | |
| 1993 | Warwick[51] | £120 | £250 | £475 |
| 1994 | Chissell[59] | £210 | £400 | |
| 1994 | Birch[53] | £250 | £450 | £700 |
| 1996 | Williams[57] | £150 | £522 | |
| 1997 | Carmichael[55] | £120 | £375 | |
| | | US Studies (£1 = US$1.6) | | |
| 1990 | Boden[62] | £438 | £2,000 | |
| 1992 | Ruwe[54] | £625 | £2,438 | |
| 1994 | Crowe/Hailey[64] | £750 | £500 | |
| 1996 | Gelb[33] | £750 | - | |

NB : These costs have not been adjusted for inflation

### 3.3 Cost and Benefit Modelling

In combining the costs and benefits of MRI scanning, three separate scenarios have been considered:

1. A low level of avoidable arthroscopies (possibly reflecting a specialist centre where more acute knee disorders are treated through a knee surgeon specialist).
2. An average level of avoidable arthroscopies (possibly reflecting a general orthopaedic unit treating a wide range of different knee disorders).
3. A high level of avoidable arthroscopies (possibly reflecting a general orthopaedic unit with a low throughput of knee disorders).

Within these scenarios the following have been considered:

- Blanket coverage of all cases (i.e. 100% receive an MRI scan);
- More focused use in cases of diagnostic uncertainty (i.e. trying to limit the use of MRI assuming a sub-set of patients can be identified).

*Key Assumptions*

- Complication rates for arthroscopy have been assumed to be 3% at an estimated total cost of £1,000, representing four in-patient days (£200 unit cost), two out-patient attendances (£100 unit cost), as previously assumed in the Wessex DEC Report[4] taken from Boeree et al.[9]
- The low number of avoidable arthroscopies is 5%.[33]
- The average number of avoidable arthroscopies is 30%.[31,56,60]
- The high number of avoidable arthroscopies is 65%.[21,55]
- The total number of arthroscopies for a 'typical' district is assumed to be 430 (based on Trent data returns).

The following analysis of costs suggests that if only 5% of arthroscopies are truly avoidable (i.e. are being conducted for diagnostic purposes only), then the use of MRI scanning is unlikely to result in any overall cost reductions, even if MRI is tightly targeted at specific patient groups (See Table 15). However, if more than 30% of arthroscopies are avoidable, cost reductions become far more likely, even if MRI is used in all cases (which is unlikely as specialist knee surgeons often do not require MRI).

Data on arthroscopies conducted within Trent seem to support the suggestion that there can be variations in the proportions of arthroscopies conducted with diagnostic intent (see Table 15).

**Table 15 Scenario 1 - Low Level Avoidable Arthroscopy**

| | Unit Cost | With No MRI Scanning | | | With MRI Scanning | | | Marginal Cost |
|---|---|---|---|---|---|---|---|---|
| | | Proportion | n | Total Cost | Proportion | n | Total Cost | |
| **Arthroscopy Patients** | | 100% | 430 | - | 100% | 430 | - | |
| **Diagnostic Arthroscopy** | £450 | 5% | 21.5 | £9,675 | 0% | 0 | - | |
| **Therapeutic Arthroscopy** | £450 | 95% | 408.5 | £183,825 | 95% | 408.5 | £183,825 | |
| **Complications** | £1,000 | 3% | 12.9 | £12,900 | 3% | 12.3 | £12,300 | |
| **Arthroscopy Sub-Total** | | | | £206,400 | | | £196,125 | |
| **MRI Scanning Blanket @ 100%** | £180 | | | | 100% | 430 | £77,400 | |
| **MRI Scanning Targeted @ 50%** | £180 | | | | 50% | 215 | £38,700 | |
| **MRI Scanning Targeted @ 25%** | £180 | | | | 25% | 107.5 | £19,350 | |
| **TOTAL COST MRI @100%** | | | | £206,400 | | | £273,525 | £67,125 |
| **TOTAL COST MRI @ 50%** | | | | £206,400 | | | £234,825 | £28,425 |
| **TOTAL COST MRI @ 25%** | | | | £206,400 | | | £215,475 | £9,075 |

Based on the assumptions of unit costs, the marginal cost of providing MRI scanning is calculated at £67,125 if all the arthroscopic patients are scanned prior to surgery, with an avoided 5% of arthroscopies.

**Table 16 Scenario 2 - Average Level of Avoidable Arthroscopy**

| | Unit Cost | With No MRI Scanning | | | With MRI Scanning | | | Marginal Cost |
|---|---|---|---|---|---|---|---|---|
| | | Proportion | n | Total Cost) | Proportion | n | Total Cost | |
| **Arthroscopy Patients** | | 100% | 430 | - | 100% | 430 | - | |
| **Diagnostic Arthroscopy** | £450 | **30%** | 129 | £58,050 | 0% | 0 | - | |
| **Therapeutic Arthroscopy** | £450 | 70% | 301 | £135,450 | 70% | 301 | £135,450 | |
| **Complications** | £1,000 | 3% | 12.9 | £12,900 | 3% | 9 | £9,000 | |
| **Arthroscopy Sub-Total** | | | | £206,400 | | | £144,450 | |
| **MRI Scanning Blanket @ 100%** | £180 | | | | 100% | 430 | £77,400 | |
| **MRI Scanning Targeted @ 70%** | £180 | | | | 70% | 215 | £38,700 | |
| **MRI Scanning Targeted @ 40%** | £180 | | | | 40% | 107.5 | £19,350 | |
| **TOTAL COST MRI @ 100%** | | | | £206,400 | | | £221,850 | £15,450 |
| **TOTAL COST MRI @ 70%** | | | | £206,400 | | | £183,150 | -£23,250 |
| **TOTAL COST MRI @ 40%** | | | | £206,400 | | | £163,800 | -£42,600 |
| | | | | | | | | |

Based on the assumptions of unit costs, the marginal cost of providing MRI scanning is calculated at £15,450 if all the arthroscopic patients are scanned prior to surgery, with an avoided 30% of arthroscopies.

**Table 17 Scenario 3 - High Level of Avoidable Arthroscopy**

| | Unit Cost | With No MRI Scanning | | | With MRI Scanning | | | Marginal Cost |
|---|---|---|---|---|---|---|---|---|
| | | Proportion | n | Total Cost | Proportion | n | Total Cost | |
| **Arthroscopy Patients** | | 100% | 430 | - | 100% | 430 | - | |
| **Diagnostic Arthroscopy** | £450 | **60%** | 258 | £116,100 | 0% | 0 | - | |
| **Therapeutic Arthroscopy** | £450 | 40% | 172 | £77,400 | 40% | 172 | £77,400 | |
| **Complications** | £1,000 | 3% | 12.9 | £12,900 | 3% | 5.2 | £5,200 | |
| **Arthroscopy Sub-Total** | | | | £206,400 | | | £82,600 | |
| **MRI Scanning Blanket @ 100%** | £180 | | | | 100% | 430 | £77,400 | |
| **MRI Scanning Targeted @ 80%** | £180 | | | | 80% | 215 | £38,700 | |
| **MRI Scanning Targeted @ 70%** | £180 | | | | 70% | 107.5 | £19,350 | |
| **TOTAL COST MRI @ 100%** | | | | £206,400 | | | £160,000 | £-46,400 |
| **TOTAL COST MRI @ 80%** | | | | £206,400 | | | £121,300 | £-85,100 |
| **TOTAL COST MRI @ 70%** | | | | £206,400 | | | £101,950 | -£104,450 |
| | | | | | | | | |

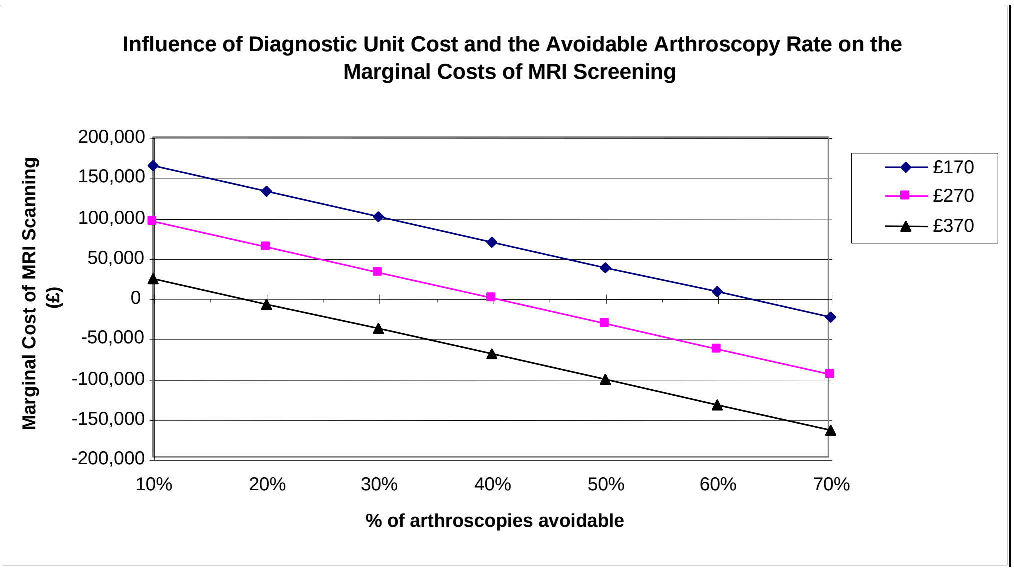
Based on the assumptions of unit costs, the marginal cost of providing MRI scanning is calculated at -£46,400 (representing a cost saving) if all the arthroscopic patients are scanned prior to surgery, with an avoided 60% of arthroscopies.

## 3.4 Sensitivity Analysis

The three cost and benefit scenarios allow us to consider the relative economics of MRI scanning given three possible levels of avoidable (or diagnostic) arthroscopy. As previously discussed, these might be expected to be more in the case of a general orthopaedic unit than in a specialist knee unit. The economic conclusions are also dependent on the unit costs and the assumptions in terms of the ability to define a sub-set of patients for MRI scanning, as opposed to scanning all planned arthroscopies.

The following graph (See Figure ) presents the overall marginal cost of MRI screening measured at different rates of avoidable arthroscopy. The graph shows three data series, representing different levels of cost difference between arthroscopy and MRI. As this cost difference decreases, the advantages of MRI diminish and the effectiveness line rises up the y-axis. If the cost gap increases (for example MRI gets cheaper through the use of low field systems) then the line moves in the opposite direction. The middle of the three series shown represents the default value used in our scenario calculations. On this basis it can be seen clearly that, given the unit cost assumptions and a 100% coverage of scanning, MRI becomes cost neutral at the point where about 40% of arthroscopies are avoidable.

**Figure 3 Sensitivity of MRI Marginal Cost**




NB : Each series corresponds to the marginal cost of arthroscopy compared to MRI, i.e. the amount by which the cost of arthroscopy exceeds the cost of MRI.

## 4. OPTIONS FOR PURCHASERS AND PROVIDERS

There are four options available:

**Option 1 - No Change to Current Policy:** Clinicians would remain free to request MRI scans as they deem them to be clinically appropriate. There are likely to be no reductions in the number of arthroscopies performed with a possibility of steadily increasing MRI requests and waiting lists.

**Option 2 - Routine Use of MRI For All Knee Disorders:** Every case of knee disorder has an MRI scan, irrespective of the clinical examination, as part of the diagnostic process, supplementing clinical judgement.

**Option 3 - No Routine Use of MRI Scanning:** Use arthroscopy rather than MRI to supplement clinical judgement in cases of uncertain diagnosis, accepting that some arthroscopies will result in no therapeutic procedure.

**Option 4 - Adopt a Targeted Use of MRI in Selective Cases:** This would be achieved by specifying and agreeing appropriate referral guidelines for MRI scanning. The purpose of the guidelines would be to define the type of injury/diagnostic uncertainty which require MRI scan and/or referral to a knee specialist.

An example of such a guideline is the treatment plan for knee injuries from the Department of Orthopaedics at Wexham Park Hospital. Based on their study, Chissell et al.[59] developed a protocol for the treatment of knee injuries, which they claimed helped to reduce the number of arthroscopies. In their protocol, the indications for MRI were:

- Convincing symptoms, but no signs, e.g. history of locking or giving way, but normal examination.
- Unresolved significant symptoms after conservative treatment, e.g. joint line pain persisting after 12 weeks of conservative treatment.

In discussing purchasing options, the Trent Working Group on Acute Purchasing also raised two further issues which they felt needed consideration.

1. The Group felt that the evidence revealed a very real issue of choice between increasing the numbers of specialist knee surgeons, requiring less MRI support, and providing additional access to MRI scanning for general orthopaedic surgeons. The evidence clearly shows that general orthopaedic surgeons often require additional support to their clinical expertise in making diagnosis of certain knee disorders.

2. The group felt that, although many studies explored the impact of MRI on patient management, none of the studies could be seen to reflect adequately local circumstances, in terms of current waiting lists etc. There was a suggestion that a regional prospective study of the use of MRI scanning, funded as a waiting list initiative project, could address this issue.

## 5. DISCUSSION AND CONCLUSIONS

Most of the literature looks at the diagnostic accuracy of MRI. Very few studies consider the diagnostic impact and hardly any speculate on patient outcomes.

### *Conclusions Related to Diagnostic Accuracy of MRI*

The majority of studies use arthroscopy as the 'gold standard'. However, it is recognised that this is not a fully reliable reference point. The evidence suggests that general orthopaedic surgeons are likely to miss a sub-set of injuries which would be expected to be identified by knee specialists at arthroscopy. Therefore, both the sensitivity and specificity of clinical examination and arthroscopy are likely to be influenced by the skills and expertise of the clinician. Taking this into account, the evidence suggests that, for the vast majority of patients, MRI is as accurate as arthroscopy in diagnosing knee derangement.

The relatively high levels of abnormal findings in asymptomatic subjects indicate the danger in relying on MRI as a diagnostic test without careful consideration of clinical signs and symptoms. Overall, it is clear from the studies that MRI is not a replacement for a thorough clinical examination and should only be considered as an addition to the initial clinical diagnosis.

The literature seems to indicate strongly that low/medium field strength MRI systems can provide an acceptable diagnostic accuracy comparable to traditional high field strength machines. This has obvious implications in terms of cost and patient comfort.

### *Conclusions Regarding the Impact of MRI on Patient Management*

There are few studies which address the issue of the influence of MRI on patient management. Some of these studies indicate that MRI can reduce the number of and, hence, the waiting lists for arthroscopies, with associated cost savings and patient benefits. However, none of these studies is robust enough to make definite conclusions, with no randomisation and often confusion over clinical experience.

It appears that, in general, there is a difference of opinion between specialist knee surgeons, general orthopaedic surgeons and radiologists. The view of local specialist surgeons is that, for the majority of the patients with knee problems, a good clinical diagnosis is all that is needed to indicate the need for surgical intervention. A surgical intervention is still required even if the original pathology diagnosis proves incorrect. In these cases MRI is felt to provide very little additional benefit and would not alter the eventual patient management. However, the view of many radiologists and general orthopaedic surgeons is that MRI can significantly alter patient management, as was shown in Table 9.

Before requesting MRI, clinicians should consider whether the results would be likely to change the management of their patient and whether there are simpler and less expensive assessments which would provide the same information, such as, good clinical history. There is evidence that MRI can reduce the need for arthroscopy, and most clinicians agree that for some sub-set of patients MRI would be helpful.

### *Conclusions Regarding the Impact of MRI on Patient Outcome*

There is little evidence available to support the hypothesis that the addition of MRI to the diagnostic work-up affects the quality of life of the patient. At the moment, the only conclusion that can be reached is that more research is needed in this area. However, if it does reduce the need for surgery, it will result in less pain, disability and complications, even if all these are short-lived.

### *Conclusions Related to Cost Benefit Implications*

The literature identified and reviewed in this Guidance Note suggests that the effectiveness and cost-effectiveness of MRI as a diagnostic tool depend upon a number of factors:

- the type of knee abnormality;
- the level of clinical expertise;
- MRI's ability to avert arthroscopies;
- MRI's ability to reduce waiting lists.

### *Issues for the Future*

There is a general feeling among local clinicians from within the Trent Region, that more MRI scans are requested by general orthopaedic surgeons than by knee specialists. The reason given for this is more accurate diagnostic performance claimed by knee specialists, with a reduced need for MRI to confirm initial clinical diagnosis. There is also a general feeling of a higher diagnostic to therapeutic arthroscopy ratio in general orthopaedic surgeons, with knee specialists expecting very little, if any, diagnostic arthroscopy. In our search we found no studies that specifically address the impact of the surgeon's expertise in the management of the patient. Some questions still need to be answered:

- "Are there any systematic differences in ratios of diagnostic to therapeutic arthroscopy?"

- “Do general surgeons request more MRI scans than specialists?”

The wording of both the referral letter and the radiologist report are factors which have been said to be of influence on diagnostic performance of both MRI and arthroscopies. This is an issue not addressed in this Guidance Note.

Another key issue which has been raised is the importance of expertise and knowledge in both interpreting MRI scans and conducting arthroscopy.

- “Should all knee injuries be seen by a knee specialist?”
- “Should uncertain diagnosis be referred on to a knee specialist?”
- “Should orthopaedic surgeons themselves interpret the MRI?”
- “What should the working definition of a specialist be based on: knee only, lower limb or number of patients per year?”

At the moment it is difficult, with the data available, to form any conclusion on what the true impact of MRI on patient management is. Perhaps a regional audit would clarify this. Such an audit could also provide information on case mix, the proportion of patients with definite diagnosis following MRI scan and the proportion of patients whose diagnosis changes following scanning.

*Key Summary Points*

- MRI has an effective diagnostic performance when compared to arthroscopy in cases of knee derangement.
- MRI is more accurate for medial meniscal, PCL and ACL injuries than lateral meniscal tears.
- MRI does not replace a careful history and competent physical examination.
- There is a lack of scientific rigorous studies comparing the results of MRI with other imaging techniques.
- Clinical diagnosis can give the wrong pathology in around 20% of cases, but remains a very accurate predictor (~100%) of the need for surgical intervention, when conducted by knee specialists.

Evidence suggests that MRI has a role to play in supporting the clinical diagnosis of patients when under the care of a general orthopaedic surgeon. However, its relevance for a knee specialist is more limited to cases where the need for surgery, irrespective of suspected disorder, is questionable.

## GLOSSARY

**Anterior cruciate ligament (ACL)** - the ligament that limits the glide of the tibia on the femur, thus providing anterior-posterior (front to back) stability of the knee.

**Arthroscopy** - direct visualisation of a joint by means of an instrument used to view the interior of the joint and for correcting certain abnormalities.

**Articular cartilage** - a smooth, non-vascular connective tissue that permits the gliding motion of the joint.

**Femur** - the thighbone; the longest and strongest bone in the body.

**Fibrocartilage** - a type of tough cartilage containing collagen fibers.

**Knee** - the articulation between the femur and tibia.

**Lateral meniscus** - a nearly circular, crescent-shaped fibrocartilage attached to the lateral articular surface of the superior end of the tibia.

**Medial meniscus** - a crescent-shaped fibrocartilage attached to the medial articular surface of the superior end of the tibia.

**Meniscus** - a crescent-shaped structure that serves as a cushion between two bones meeting in a joint.

**Orthopaedics** - branch of medicine concerned with the preservation and restoration of functions of the skeletal system and associated structures.

**Osteoarthritis** - a chronic disorder marked by degeneration of articular cartilage and hypertrophy of bone, accompanied by pain that appears with activity and usually subsides with rest. Also called degenerative joint disease.

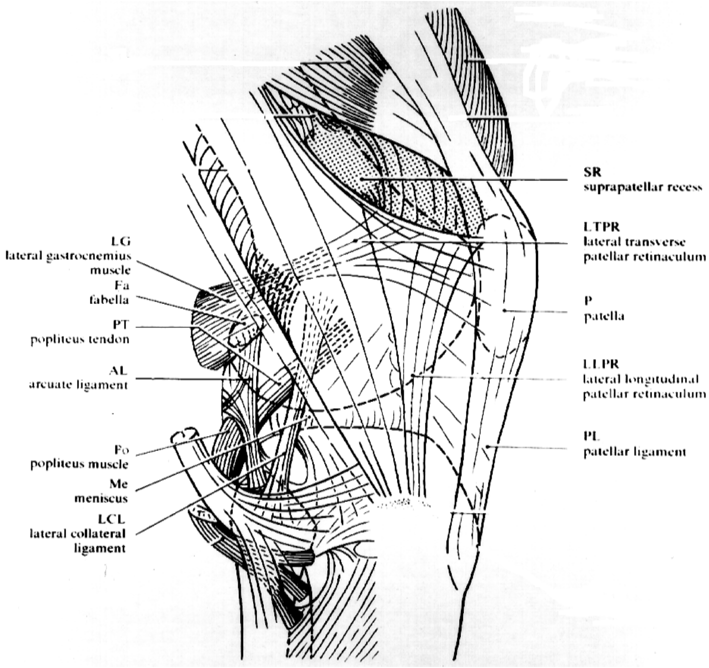
**Patella** - triangular bone located in the front of the knee joint.

**Posterior Cruciate Ligament (PCL)** - the ligament which is located at the rear of the knee. It is shorter than the ACL, but is thicker and stronger.

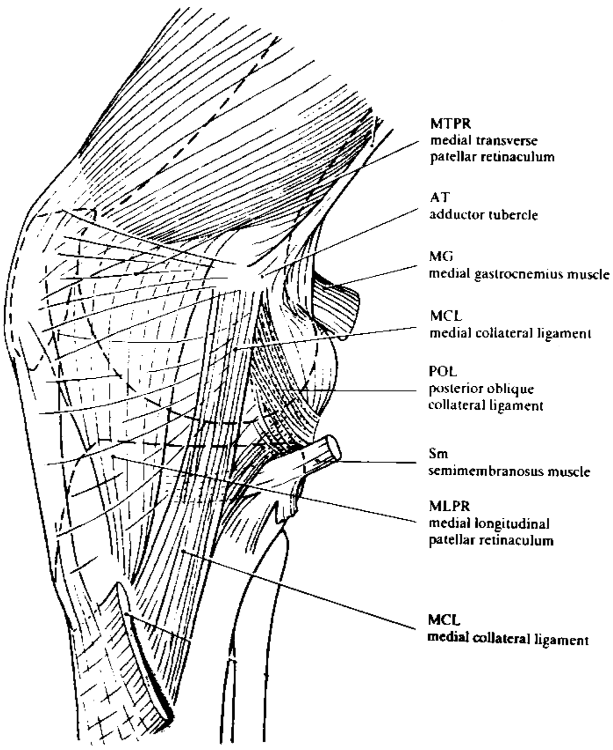
**Tibia** - the larger and medial of the two bones of the leg between the knee and the ankle, commonly called the shinbone.

## APPENDIX A Lateral/Medial Views of the Knee Joint

### Lateral Meniscus




### Medial Meniscus



## APPENDIX B Clinical Examination Accuracy Studies

| Year | Trial | Clinical | | N | Medial Meniscus (%) | | | | | Lateral Meniscus (%) | | | | | ACL (%) | | | | | Arterial cartilage (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | N | Experience | (pts) | Se | Sp | Acc | PPV | NPV | Se | Sp | Acc | PPV | NPV | Se | Sp | Acc | PPV | NPV | Se | Sp | Acc | PPV | NPV | _1998 |
| 1997 | Yoon et al.[30] | 1 | not known | 200 | 87 | 93 | 90 | 92 | 88 | 81 | 93 | 90 | 82 | 92 | 76 | 97 | 92 | 90 | 92 | - | - | - | - | - |
| 1996 | Miller et al.[34] | 1 | specialist | 50 | 100 | - | 81 | 81 | - | # | # | # | # | # | - | - | - | - | - | - | - | - | - | - |
| 1996 | Rose et al.[65] | 1 | specialist | 100 | 73 | 79 | 75 | 87 | 60 | 35 | 100 | 69 | 100 | 63 | 92 | 99 | 98 | 92 | 99 | - | - | - | - | - |
| 1991 | Boeree et al.[9] | >1 | specialist | 144 | - | - | 63 | - | - | - | - | 75 | - | - | - | - | 81 | - | - | - | - | - | - | - |

# = combined meniscal data

(accuracy confirmed by arthroscopy in all studies)

## APPENDIX C MRI Diagnostic Accuracy Studies

**Mackenzie Reviewed Studies**

| Year | Ref | MRI Field | Blinding | n | Medial Meniscus (%) | | | | | Lateral Meniscus (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Se | Sp | Acc | PPV | NPV | Se | Sp | Acc | PPV | NPV |
| 1986 | Mandelbaum et al.[66] | 0.3T | - | 80 | 96 | 82 | 90 | 88 | 93 | 75 | 95 | 91 | 80 | 94 |
| 1987 | Reicher et al.[67] | 0.3T | - | 61 | 100 | 64 | 85 | 80 | 100 | 75 | 84 | 81 | 64 | 90 |
| 1987 | Crues et al.[68] | 1.5T | br | 134 | 87 | 91 | 89 | 93 | 84 | 88 | 98 | 94 | 96 | 92 |
| 1988 | Silva et al.[69] | 0.35T | - | 44 | 62 | 53 | 59 | 72 | 42 | na | na | na | na | na |
| 1988 | Polly et al.[70] | 1.5T | br | 50 | 96 | 100 | 98 | 100 | 96 | 67 | 95 | 90 | 75 | 93 |
| 1988 | Jackson et al.[71] | 1.5T | br | 87 | 98 | 89 | 93 | 89 | 98 | 85 | 99 | 97 | 92 | 97 |
| 1989 | Glashow et al.[42] | 0.35T | br/bs | 50 | 77 | 71 | 74 | 68 | 80 | 93 | 94 | 94 | 87 | 97 |
| 1990 | Crues et al.[72] | 1.5T | - | 171 | 98 | 100 | 99 | 100 | 99 | 84 | 97 | 95 | 87 | 96 |
| 1991 | Raunest et al.[44] | 1.5T | br/bs | 50 | 94 | 37 | 72 | 71 | 78 | 78 | 69 | 72 | 58 | 85 |
| 1991 | Kelly et al.[73] | 0.5T | - | 60 | 97 | 77 | 88 | 85 | 95 | 90 | 87 | 88 | 79 | 94 |
| 1991 | Boeree et al.[74] | 0.5T | br | 129 | 97 | 91 | 94 | 91 | 97 | 96 | 98 | 98 | 93 | 99 |
| 1991 | Quinn et al.[18] | 1.5T | - | 219 | 92 | 82 | 89 | 94 | 78 | 70 | 95 | 87 | 86 | 88 |
| 1991 | Fischer et al.[75] | varied | - | 911 | 93 | 84 | 89 | 86 | 92 | 68 | 94 | 88 | 76 | 92 |
| 1993 | Spiers et al.[31] | 1.5T | bs | 58 | 100 | 76 | 86 | 75 | 100 | 100 | 96 | 97 | 82 | 100 |

br = blinded radiologist; bs= blinded surgeon

Se = sensitivity; Sp = specificity; Acc = Accuracy; PPV = positive predictive value; NPV = negative predictive value

**Mackenzie Reviewed Studies cont.**

| Year | Ref | MRI Field | Anterior Cruciate Ligament (%) | | | | | | Posterior Cruciate Ligament (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | n | Acc | Se | Sp | PPV | NPV | n | Acc | Se | Sp | PPV | NPV |
| 1986 | Mandelbaum et al.[66] | 0.3T | 83 | 100 | 100 | 100 | 100 | 100 | - | - | - | - | - | - |
| 1988 | Polly et al.[70] | 1.5T | 37 | 100 | 100 | 100 | 100 | 100 | - | - | - | - | - | - |
| 1988 | Lee et al.[76] | 1.5T | 41 | 98 | 94 | 95 | 100 | 96 | 41 | 98 | 94 | 100 | 100 | 96 |
| 1988 | Jackson et al.[71] | 1.5T | 87 | 97 | 100 | 96 | 70 | 100 | - | - | - | - | - | - |
| 1988 | Mink et al.[26] | 1.5T | 242 | 95 | 92 | 95 | 78 | 98 | - | - | - | - | - | - |
| 1989 | Reeder et al.[77] | 1.0T | 50 | 92 | 82 | 95 | 82 | 95 | - | - | - | - | - | - |
| 1989 | Reeder et al.[77] | 1.0T (GE) | 50 | 92 | 64 | 100 | 100 | 91 | - | - | - | - | - | - |
| 1989 | Glashow et al.[42] | 0.35T | 50 | 72 | 61 | 81 | 74 | 71 | - | - | - | - | - | - |
| 1991 | Niitsu et al.[78] | 1.5T | 52 | 79 | 71 | 88 | 87 | 72 | 52 | 98 | 100 | 98 | 80 | 100 |
| 1991 | Niitsu et al.[78] | 1.5T (Cine) | 52 | 94 | 93 | 96 | 96 | 92 | 52 | 98 | 100 | 96 | 66 | 100 |
| 1991 | Kelly et al.[73] | 0.5T | 60 | 93 | 88 | 94 | 70 | 98 | - | - | - | - | - | - |
| 1991 | Vahey et al.[79] | 1.5T | 81 | 93 | 92 | 93 | 96 | 87 | - | - | - | - | - | - |
| 1991 | Boerre et al.[74] | 0.5T | 95 | 96 | 100 | 96 | 33 | 100 | - | - | - | - | - | - |
| 1991 | Fischer et al.[75] | varied | 997 | 93 | 93 | 93 | 76 | 98 | 1014 | 99 | 80 | 99 | 57 | 100 |
| 1992 | Heron et al.[80] | 1.5T | 242 | 94 | 88 | 96 | 88 | 96 | - | - | - | - | - | - |
| 1992 | Gross et al.[81] | 0.3T | - | - | - | - | - | - | 201 | 100 | 100 | 100 | 99 | 100 |

## Rappeport Reviewed Studies

| Year | Reference | Blinding | Medial Meniscus (%) | | | Lateral Meniscus (%) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Se | Sp | Acc | Se | Sp | Acc |
| 1987 | Reicher et al.[67] | No | 89 | 64 | - | 67 | 67 | - |
| 1987 | Crues et al.[68] | No | 87 | 91 | 91 | 87 | 97 | 91 |
| 1988 | Mink et al.[26] | No | 97 | 89 | 4 | 92 | 91 | 92 |
| 1989 | Redder et al.[77] | No | 87 | 98 | - | - | - | - |
| 1989 | Glashow et al.[42] | Yes | 77 | 71 | - | 93 | 94 | - |
| 1991 | Raunest et al.[44] | Yes | 94 | 37 | 72 | 78 | 69 | 72 |
| 1991 | Niitsu et al.[78] | No | 71 | 96 | - | - | - | - |
| 1991 | Kelly et al.[73] | No | 97 | 77 | 88 | 90 | 87 | 88 |
| 1991 | Quinn et al.[18] | No | 92 | 81 | 88 | 70 | 94 | 88 |
| 1991 | Fischer et al.[75] | No | 93 | 84 | 89 | 69 | 94 | 88 |
| 1992 | Derme et al.[38] | Yes | 91 | 86 | 84 | - | - | 84 |
| 1992 | Heron et al.[80] | No | 97 | 94 | - | - | - | - |
| 1992 | Quinn et al.[82] | No | 90 | 95 | 92 | 80 | 97 | 93 |
| 1993 | Araki et al.[83] | No | 100 | 100 | - | - | - | - |
| 1993 | Sanchis-Alfonso[84] | No | 78 | 95 | 91 | - | - | 91 |
| 1993 | Spiers et al.[31] | Yes | 100 | 71 | n/a | 100 | 92 | n/a |
| 1993 | Barnett et al.[46] | No | 93 | 90 | 92 | 81 | 97 | 93 |
| 1993 | Mesgarzadeh[85] | No | 95 | 74 | n/a | 86 | 90 | n/a |
| 1993 | De Smet et al.[86] | No | 93 | 86 | n/a | 83 | 92 | n/a |
| 1994 | Haramati et al.[87] | No | 100 | 62 | n/a | 92 | 90 | n/a |

| Year | Reference | Blinded | ACL (%) | | | PCL (%) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Se | Sp | Acc | Se | Sp | Acc |
| 1988 | Lee et al.[76] | No | 94 | 100 | - | - | - | - |
| 1988 | Mink et al.[26] | No | 92 | 95 | 95 | - | - | - |
| 1989 | Redder et al.[77] | No | 82 | 100 | - | - | - | - |
| 1989 | Glashow et al.[42] | Yes | 61 | 82 | - | - | - | - |
| 1990 | Grover et al.[88] | No | - | - | - | 100 | 100 | - |
| 1991 | Niitsu et al.[78] | No | 96 | 92 | | 100 | 98 | - |
| 1991 | Kelly et al.[73] | No | 87 | 94 | 93 | - | - | - |
| 1991 | Vahey et al.[79] | No | 92 | 93 | 93 | - | - | - |
| 1991 | Fischer et al.[75] | No | 93 | 93 | 93 | - | 99 | 99 |
| 1992 | Derme et al.[38] | Yes | 100 | 80 | 82 | - | - | - |
| 1992 | Heron et al.[80] | No | 92 | 96 | | 100 | 100 | - |
| 1993 | Sanchis-Alfonso et al.[84] | No | 96 | 100 | 98 | - | - | - |
| 1993 | Spiers et al.[31] | Yes | 100 | 98 | - | 100 | 100 | - |
| 1993 | Tung et al.[89] | No | 96 | 94 | - | - | - | - |
| 1993 | Barnett et al.[46] | No | 100 | 97 | 97 | - | - | - |
| 1994 | Haramati et al.[87] | No | 93 | 82 | - | - | - | - |
| 1994 | Gentili et al.[90] | No | 93 | 97 | - | - | - | - |
| 1994 | Robertson et al.[91] | No | 95 | 85 | - | - | - | - |
| 1994 | Chan et al.[92] | No | 90 | 94 | - | - | - | - |

**MRI Diagnostic Accuracy Studies 1996 - July 1998**

| Year | Reference | Design | Blinding | Setting | MRI Radiologist | | Surgeon | | MRI | | N | Medial Meniscus (%) | | | | | Lateral Meniscus (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | N | Experience | N | Experience | Field | Pulse | (Pts) | Se | Sp | Acc | PPV | NPV | Se | Sp | Acc | PPV | NPV | _1998 |
| 1997 | Rappeport[37] | pro | bs/br | general | 2 | not known | - | orth specialist | 0.1T | GE3/GE2 | 47 | 86 | 73 | 77 | 57 | 92 | 40 | 98 | 91 | 67 | 93 |
| 1997 | Muellner et al.[35] | pro | bs/br | sports | 1 | not known | 3 | knee 10/30 yrs | 1.5T | SE/GE | 36 | 98 | 86 | 96 | 97 | 92 | # | # | # | # | # |
| 1997 | Cheung et al.[94] | ret | unclear | general | 50 | mixed | >1 | not known | 1.5T | SE/FSE | 289 | 89 | 84 | 87 | 85 | 88 | 72 | 93 | 86 | 84 | 87 |
| 1996 | Miller et al.[34] | pro | br/bc | sports | 17 | not known | 1 | knee specialist | 0.35-1.5T | SE | 57 | 76 | 90 | 81 | 91 | 63 | 40 | 95 | 81 | 88 | 82 |
| 1996 | Rose et al.[65] | pro/ret | bc | general | 4 | not known | 1 | knee specialist | 1.5T | SE | 100 | 73 | 79 | 75 | 87 | 60 | 35 | 100 | 69 | 100 | 63 |
| 1995 | Chen et al.[95] | ret | ba | general | - | not known | - | not known | 1.5T | SE/GE | 50 | 87 | 86 | 86 | 72 | - | 85 | 90 | 88 | 85 | - |

ret = retrospective study ; pro = prospective study; ba = blinded analyst; br = blinded radiologist; bs= blinded surgeon; bc =binded clinical diagnosis

GE2 = gradient echo 2D; GE3 = gradient echo 3D; SE = spin echo; FSE = fast spin echo; ath = athletes

# = combined meniscal data

| Year | Reference | ACL (%) | | | | | Arterial cartilage (%) | | | | | PCL (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Se | Sp | Acc | PPV | NPV | Se | Sp | Acc | PPV | NPV | Se | Sp | Acc | PPV | NPV |
| 1998 | Ha et al.[93] | 96 | 98 | 98 | 95 | 99 | - | - | - | - | - | - | - | - | - | - |
| 1998 | Munk et al.[29] | 44 | 96 | 82 | 78 | 83 | 0 | 97 | 56 | 0 | 57 | - | - | - | - | - |
| 1997 | Rappeport et al.[37] | 89 | 97 | 96 | 89 | 97 | - | - | - | - | - | - | - | - | - | - |
| 1997 | Muellner et al.[35] | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1997 | Cheung et al.[94] | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1996 | Miller et al.[34] | 59 | 98 | 86 | 91 | 84 | - | - | - | - | - | - | - | - | - | - |
| 1996 | Rose et al.[65] | 92 | 99 | 98 | 92 | 99 | - | - | - | - | - | - | - | - | - | - |
| 1995 | Chen et al.[95] | 95 | 89 | 92 | 88 | - | | | - | - | - | 100 | 100 | 100 | 100 | - |

**APPENDIX D   Low vs High Field Strength Studies**

| Year | Reference | Design | Blinding | MRI Field | N (pts) | Meniscal | | | Lateral meniscus | | | ACL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Sp | Se | Acc | Sp | Se | Acc | Sp | Se | Acc |
| 1997 | Franklin et al.[45] | pro | br/bs | 0.2T (A) | 35 | 86 | 100 | 91 | 89 | 100 | 97 | - | - | - |
| 1996 | Kersting-Sommerhoff et al.[41] | pro | | 0.2T(A) | 210 | 82 | 77 | 79 | 70 | 93 | 90 | 90 | 100 | 98 |
| 1996 | Kersting-Sommerhoff et al.[41] | pro | | 0.2T(A) | 20 | 73 | 76 | 75 | - | - | - | 95 | 87 | 90 |
| | | pro | | 1.5T | 20 | 87 | 87 | 85 | - | - | - | 86 | 87 | 85 |
| 1995 | Passariello et al.[48] | ret | | ? | 145 | | | | | | | | | |
| | | | | 0.5T | 222 | | | | | | | | | |
| 1995 | Parizel et al.[49] | | | 0.2T | 10 | | | | | | | | | |
| 1995 | Kladny et al.[47] | pro | br | 0.2T | 22 | 75 | 97 | - | # | # | - | 100 | 75 | - |
| 1994 | Kinnunen et al.[39] | | | 0.1T | 33 | 88 | 80 | - | 25 | 97 | - | 83 | 85 | - |
| 1993 | Barnett et al.[46] | | | 0.5T | 118 | 93 | 90 | 92 | 81 | 97 | 93 | 100 | 97 | 97 |

A = ARTISCAN; br = blinded radiologist; bs= blinded surgeon; ret = retrospective study ; pro = prospective study

# = combined meniscal data

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