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MRI of the knee

A discussion paper

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Summary

- This paper is a brief introduction to the considerations which might affect the use of Magnetic Resonance Imaging (MRI) in investigation of the knee.
- Injuries to the knee are common in Australia and are generally managed by a combination of clinical examination, assisted by X-ray, arthrogram or arthroscopic diagnosis, and arthroscopic surgery if required. It is estimated that 60,000 arthroscopic procedures are performed each year in Australia, with the highest age-specific rate (three per 1,000) occurring in males in the 20–40 year age group.
- The technical accuracy of MRI investigation of disorders of the knee has been reviewed in relation to arthrography and arthroscopy. It has been reported that the use of surface coils has increased the overall diagnostic accuracy of MRI to 90–96% compared to arthroscopy. A current view is that the use of MRI might assist in the conduct of arthroscopic procedures, particularly when investigating tears of the posterior horn of the medial meniscus.
- Given that arthroscopic services are well established in Australia, the possible clinical role of MRI in management of disorders of the knee remains to be determined, MRI examinations may have a complementary role to arthroscopy by drawing attention to a suspicious region and thus assist in obtaining better outcomes from arthroscopic surgery.
- The relative cost of the use of MRI in the management of patients with knee problems remains uncertain. Overseas studies show that the use of MRI in selected patients may reduce the number of arthroscopies performed but may result in increased costs. There is ongoing debate on this matter between professional groups with orthopaedic specialists tending to favour the use of arthroscopy and radiologists proposing the use of MRI.
- Most existing MRI services in Australia are committed to examinations of the head and spine. The availability of resources to undertake examinations of the knee is an issue which would require further consideration. There would appear to be a need for a study to determine the effect of MRI on the management of disorders of the knee, having regard to the wide availability of arthroscopic services.

Current situation in Australia

This paper is presented as a brief introduction to the issues which might affect the use of Magnetic Resonance Imaging (MRI) in investigation of the knee. The knee joint is an unstable structure and relies on the support of the ligaments. In radiological terms, it has been established that MRI has the potential to contribute to the diagnosis of disease and injury in the knee as it provides good tissue contrast and multiplanar imaging capability.⁽¹⁾ In the Australian Consensus Statement on the Clinical Efficacy of MRI⁽²⁾ it was stated that, when used as a tertiary examination by independent specialists, MRI appears to be accurate in showing diseases of joints, including the knee, and may be able to reduce or replace the need for arthrograms and arthroscopy.

As noted in the report on the MRI Assessment Program,⁽³⁾ the major use of MRI in Australia is in examination of the head and spine, as its use in these areas is considered to have an effect on patient management. In general, other diagnostic modalities are used for investigation of joints such as the knee, although a number of such cases are examined at private MRI units.

At present, examinations of the knee involve standard radiography, arthrography and arthroscopy and computed tomography. The use of radiographic techniques has the disadvantage of requiring injection of contrast material into the knee joint and the need to apply stress to a knee that is already painful in the acute period following injury. These limitations also apply to computed tomography when used to supplement arthrography in visualising the cruciate ligaments. Arthrography is a painful and invasive procedure involving ionising radiation with a level of severe complications.⁽⁴⁾ A 'normal' arthrogram may lead to further investigations of knee pain due to the continuing presence of symptoms. Examination by arthroscopy under anaesthesia is considered to be the 'gold standard' of diagnosis, although it is a method with some limitations.

The use of arthroscopy for the diagnosis and management of disorders of the knee is well established in Australia. In 1992-93, approximately 47,000 arthroscopic procedures were undertaken which attracted Medicare benefits. The great majority of procedures were for surgery rather than diagnosis. The highest age-specific rate (three per 1,000) occurs in males in the 20-40 year age group, possibly reflecting the prevalence of sports-related injuries to the knee.⁽⁵⁾ These procedures did not include services provided to public patients in public hospitals. Using the discussion by Deeble⁽⁶⁾ on the relationship between public and private utilisation of services, an estimate of approximately one-third of this total could be made for services to public patients in public hospitals, giving a national total of 60,000 arthroscopic procedures on the knee per year.

Arthroscopic procedures are well accepted and are generally considered to be effective. In the majority of cases, patients are given an X-ray examination, usually to exclude the presence of a loose body or other major abnormality, and then proceed to either diagnostic arthroscopy or to arthroscopic surgery. A computed tomography (CT) examination may be indicated if there are symptoms relating to pain in the patella.⁽⁷⁾ It is of interest that Medicare data record some 20,000 arthrograms being performed in 1992-93, but there are no data readily available on how many of these examinations were performed on the knee.

Developments in the use of MRI for knee examinations

Early work on the use of MRI for investigation of the knee was performed by Young and the Hammersmith Hospital team in London in the early 1980s.⁽⁸⁾ Following further development, the situation has been reached where software for MRI examination of the knee is now routinely provided by the majority of MRI manufacturers.

In the United States, the frequency of injury to the ligaments and meniscus in the knee has led to increased use of MRI technology. The popularity of sports such as skiing and running has led to a high rate of investigations of the knee, where arthroscopic examinations were estimated to occur at an annual rate of one per 250 persons.⁽⁹⁾

Boden et al.⁽¹⁰⁾ reported that, in the United States, MRI had gained acceptance in the diagnosis of the knee due to its ability to provide clear anatomical resolution without the use of ionising radiation. These authors noted that technical improvements, including the use of surface coils, had increased the overall diagnostic accuracy of MRI in the knee. The use of dedicated surface coils is a technological advance for MRI applications. The transmit-receive knee coil has been successful because of the high signal-to-noise ratio, homogenous signal distribution and reduced radio frequency power requirements. An advantage of MRI is that the important structures of the knee, which are located near the surface, can be readily imaged with surface coils. As coils provide improved signal-to-noise ratio, increased spatial resolution can contribute to increased diagnostic accuracy.

The use of MRI can detect such conditions as osteonecrosis, bone and soft-tissue tumours and occult fracture. Mink and Deutsch⁽¹¹⁾ have noted that the most frequently encountered bony abnormality seen with MRI is a contusion, representing a micro-fracture from trauma. As contusions can progress to osteochondritis dissecans if they are not treated with diminished weight bearing, an isolated bone contusion, with no other internal derangement, is a serious finding that requires protection.

A suggested clinical indication for MRI is as an aid to preoperative planning for cruciate ligament injuries. Demonstration of the presence and extent of cruciate ligament rupture is considered useful in designing the best operation for ligament reconstruction. Also, in acute knee injuries where physical examination is difficult because of pain and swelling, a negative MRI examination may avoid the need for a more invasive arthroscopic examination. A text by Berquist⁽¹⁾ covers such matters and outlines the use of MRI in the knee in detail, reflecting the potential for the use of the procedure.

The American Medical Association's Council on Scientific Affairs⁽¹²⁾ ranked MRI as superior to other imaging modalities for the diagnosis of disease of the knee in the areas of meniscus, tendons and ligaments, bone marrow and cartilage. However, such conclusions have not been supported by the conduct of well designed prospective studies comparing the effect of MRI on patient management and outcome with alternative diagnostic techniques. In addition,

the conclusions are based on radiological and clinical grounds rather than economic ones and do not have regard to availability of both MRI units and other investigative modalities.

MRI—how it is used in knee examinations

A brief review of the literature comparing MRI with arthrography and arthroscopy has been undertaken. In general, the use of MRI is favoured over arthrography for investigation of the knee and there is ongoing debate over the accuracy of MRI compared to arthroscopy. A current view is that the use of MRI might assist in the conduct of arthroscopic procedures, particularly when investigating tears of the posterior horn of the medial meniscus.^(13,14) The clinical literature on the use of MRI is based on overseas experience and does not necessarily have regard to factors such as the availability and cost of MRI services.

MRI and arthrography

Following the introduction of MRI into clinical practice in the mid 1980s, studies were conducted to assess the accuracy and diagnostic capabilities of MRI in patients with suspected internal derangement of the knee. A study by Crues et al.⁽¹⁵⁾ reported that MRI was slightly more sensitive for detection of meniscal tears than arthrography. The ability of MRI to visualise the interior of the meniscus, rather than just the surface, led to the visualisation of some tears that are undetectable by arthrography. It was considered that MRI was an accurate way of demonstrating the menisci and cruciate ligaments in a non-invasive manner. This work followed earlier studies comparing arthrography and arthroscopy.⁽¹⁶⁾ Because normal findings on an arthrogram fail to exclude or identify numerous causes of knee pain, additional diagnostic studies, including arthroscopy and occasionally CT scanning and radionuclide bone scanning were necessary. A fundamental advantage of MRI over arthrography was the capability of detecting the full spectrum of disorders of the knee, such as tears of the posterior cruciate ligament which are often difficult to evaluate clinically.⁽¹⁴⁾

In 1985 pre-operative arthrography was reported to be 85% to 99% accurate for diagnosing medial meniscal tears and 68% to 93% accurate for diagnosing lateral meniscal tears.⁽¹⁷⁾ Earlier studies of the diagnostic accuracy of anterior cruciate ligament evaluation by arthrography had produced variable results, with 91% reported by Pavlov et al.⁽¹⁸⁾ but 70% to 80% being representative. Reicher and others⁽¹⁹⁾ reported that MRI compared favourably, especially in the acute situation, when arthrography is difficult and painful. Mink et al.⁽⁹⁾ discontinued one prospective trial on MRI and arthrography on the grounds that MRI provided more information in a less invasive manner.

By 1987 it had been shown that MRI, although more expensive, compared favourably in accuracy with arthrography and was painless and without complications. MRI could also supply additional information in relation to causes of knee pain. However, extensive experience in the United States with the use of MRI in the knee does not relate directly to the clinical situation in Australia where availability of MRI services is more limited.

MRI and arthroscopy

Studies using MRI^(20,21,22) have shown it to be an accurate technique in the assessment of internal derangement of the knee when compared to arthroscopy. The development of arthroscopy has been rapid in the United States. Mink et al.⁽¹¹⁾ estimated one million procedures were performed per year by 1988. Because of the availability of arthroscopy, it is generally considered as the 'gold standard' against which newer technologies such as MRI are evaluated. However, arthroscopy is not an ideal technology on which to base a comparison of diagnostic accuracy. Although the accuracy of arthroscopy has been reported as 90% to 95%,⁽²³⁾ and nearly 100% in experienced hands,⁽²⁴⁾ there are known diagnostic limitations to the technique. For example, an advantage of MRI is the ability to visualise the posterior horns of the menisci which are particularly difficult to evaluate by conventional arthroscopy. In problem areas, MRI can be considered as complementary to diagnostic arthroscopy. By drawing attention to a suspicious region, MRI may be able to improve the result of surgery by leading the surgeon to search for a suspected lesion.⁽¹³⁾

As with all evaluation of diagnostic technology, problems of comparison arise if the 'gold standard' is not 100% accurate. Diagnostic arthroscopy is a procedure whose success is operator-dependent. Thus the accuracy of MRI, in comparison with arthroscopy, is dependent on the experience of the surgeon. The reporting of 'false positive' meniscal tears on MR images in the area of the posterior horns, a difficult area to examine by arthroscopy, suggests that some of the cases may be 'false negative' arthroscopic findings. Sonin and others⁽¹⁴⁾ have reported that MRI can be important in clinical decision making in areas such as the posterior cruciate ligament where arthroscopic assessment is difficult. However, an alternative view is that reliance on MRI may lead to over-diagnosis of this condition⁽¹³⁾ and the matter of a 'gold standard' remains in dispute.

A early study by Li et al.⁽²⁵⁾ comparing MRI with subsequent arthroscopy indicated high sensitivity (true-positive results 96%, 22 of 23) and high specificity (true negative results 100%, 19 of 19). MRI also has the ability to provide diagnostic information about injuries to collateral ligaments, capsule, menisci, articular cartilage and subchondral bone. A multi-centre analysis of 1,014 patients in United States by Fischer et al.⁽²⁶⁾ on the accuracy of diagnosis of MRI in the knee, reported a negative predictive value for the diagnosis of a torn meniscus of the knee of 83 to 92%. Thus a negative finding on MRI may hide the presence of a torn meniscus. In the study, the MRI diagnosis was subsequently checked at arthroscopy.

In an editorial on the study by Fischer et al., Senghas⁽²⁷⁾ quoted the case of a consultant for a Workers' Compensation insurer in United States refusing to authorise a payment for a proposed arthroscopy for a suspected torn meniscus unless the patient had a positive MRI scan. He noted that such a ruling might deny insurance coverage for a curative procedure to 17% of workers with a serious meniscal injury, as such a ruling presumes that MRI has a 100% accuracy.

In discussion, Fischer et al.⁽²⁶⁾ noted that results varied from centre to centre depending on the expertise of the radiologist, the type of MRI unit and the parameters used for imaging. While there was little difference with respect to imaging the cruciate ligaments, the opinion of the authors was that the 1.5T unit was more accurate than the 0.35T unit with regard to imaging of the medial meniscus.

MRI may also be useful in studies where arthroscopy is contraindicated or where signs are equivocal. A particular instance is a suspected diagnosis of Paget's disease in which the bones become thick and soft. In this condition, where pain is the most usual manifestation, arthroscopic examination is not indicated and MRI may be preferred. In cases where the capsule is torn, fluid used during an arthroscopic examination may escape into the popliteal space and cause neurovascular compromise.⁽²⁸⁾ MR images may help direct the surgeon to perform an arthrotomy, rather than an arthroscopy, in the case of an acute collateral ligament tear. Similarly, preoperative diagnosis of an anterior cruciate ligament tear may facilitate the planning and timing of a reconstructive procedure.

Arthroscopic procedures are not without complications. In the United States, Sherman et al.⁽²⁹⁾ reported a 4.8% rate of severe complications and an 8.2% rate of overall complications, including sepsis, nerve injury, instrument breakage and reflex sympathetic dystrophy syndrome. If MRI could suggest whether or not arthroscopy might be useful, complications of arthroscopy could be avoided in some patients.

A prospective double blind study in Germany in 1991 by Raunest et al.⁽²⁴⁾ examined 50 patients who had a suspected disorder of the meniscus. The patients were evaluated with a 1.5T MRI unit followed by arthroscopic examination. The imaging studies provided a diagnostic accuracy of 72%, a sensitivity of 88% and a specificity of 57%.

The study noted that arthroscopy can reach a diagnostic accuracy of nearly 100% in the detection of meniscal lesions but is an invasive procedure with the risk of complications. Raunest et al. commented that MRI is non-invasive, painless, does not use ionising radiation, allows imaging in various planes and is not impaired by the superimposition of osseous structures. However, it is time consuming, expensive and provides only moderate diagnostic accuracy for meniscal disorders such as tears and degeneration. They noted that the specificity found in their prospective study was lower than values reported in the literature. They suggested that the findings in other studies may not be validated at arthroscopy, leaving false-negative tests undetected. They concluded that MRI needs improvement and that increasing experience may make this a useful diagnostic tool in addition to, or in lieu of, an arthroscopic examination.

Mink et al.⁽⁹⁾ considered that MRI is complementary to diagnostic arthroscopy and by drawing attention to a suspicious region, MRI can reduce arthroscopic oversights. They also noted that diagnostic arthroscopy is a procedure whose success is highly operator-dependent. They conclude that orthopaedists will find MRI of the knee to be of value in avoiding needless violations and

improving surgical results. It is recognised that there are problems in identifying articular surface lesions on MRI⁽³⁰⁾ and prospective studies using high resolution imaging are required.

In a prospective study by Halbrecht and Jackson⁽³¹⁾ office arthroscopy was used to locate 26 areas of articular cartilage changes in 14 patients but only nine of these areas were detected by MRI (sensitivity 34.6%). Also, the one case of posterior cruciate ligament disruption was confirmed by both arthroscopy and MRI. It was concluded that office arthroscopy was an accurate and cost-efficient alternative to MRI in diagnostic evaluation of knee pathology in patients with knees that present a diagnostic dilemma or have enigmatic symptomatology. The capital cost of office arthroscopy was low (US\$20,000) and the cost of a procedure ranged from US\$600-\$800 compared with US\$800-\$1,200 for an MRI investigation.

A further conclusion was that direct visualisation and probing provided more accurate information in evaluating symptomatic post operational meniscal lesions in selected patients than MRI. However, the authors noted that the equipment should be used by experienced arthroscopists who are competent to handle complications related to the procedure.

MRI has been used as an initial diagnostic modality in Australia in examination of the knee. James and Buirski⁽³²⁾ used MRI (0.3T resistive system) in a prospective trial over a ten-month period of all patients scheduled for elective arthroscopic knee surgery for suspected internal derangement of the joint. MRI results agreed with arthroscopic data on the medial meniscus in 44 of 49 cases (overall sensitivity 82% and specificity 95%). Posterior cruciate ligament tears proved more difficult to diagnose, with overall sensitivity of 62% and specificity of 100% (50 cases). However, implications for subsequent management were not considered.

Professional issues—relative costs of MRI and arthroscopy

An issue of interest is the relative cost-effectiveness of MRI when used in the diagnosis and management of the knee. A study by Boden⁽³³⁾ of the Department of Orthopaedic Surgery at the George Washington University Medical Center, indicated that diagnostic arthroscopy would be more cost-effective than MRI if 78% of the scanned patients eventually proceeded to arthroscopic surgery. This conclusion was based on a study of 105 consecutive patients of whom 87% had arthroscopy after the MRI scan.

Ruwe et al.⁽³⁴⁾ found that MRI reduced the need for diagnostic arthroscopy of the knee on 103 patients attending a sports medicine tertiary referral clinic. After MRI, 53 patients out of 103 (51.4%) avoided a potentially unnecessary diagnostic arthroscopy. After follow-up of a mean of 22 months, 40 patients had normal function and no limitation in activity.

These findings were in agreement with a previous study by Boeree et al.⁽³⁵⁾ who suggested that the use of MRI would allow more appropriate selections of patients for arthroscopy and eliminate the need for such procedures in one-third to one-half of patients with meniscal or cruciate derangement. An earlier study by Polly et al.⁽³⁶⁾ also supported this view.

The study by Ruwe et al.⁽³⁴⁾ estimated cost savings of US\$103,000 due to 53 patients avoiding arthroscopic surgery which was costed at US\$3,900 per patient, excluding costs associated with lost work time, physical therapy and arthroscopic complications. The issue of cost and efficacy was subsequently debated by Boden⁽³⁶⁾ who suggested that conclusions made in an academic setting may be difficult to reproduce in the general community.

A more recent prospective study of 58 selected patients by Spiers et al.⁽¹³⁾ from the Nuffield Orthopaedic Centre in Oxford, UK has shown that a prior examination by MRI could have resulted in a 29% reduction in the number of arthroscopies without missing any significant meniscal lesion. The findings by the Nuffield Orthopaedic Centre, comprising both radiologists and surgeons, tend to favour the use of MRI in selected patients. Although the study noted that the use of MRI prior to arthroscopy would have led to a slight increase in cost (1.4%), this approach would have freed up theatre time and surgeons and avoided morbidity associated with arthroscopy.

A recent review of the literature indicates that debate on the cost and efficacy of the use of MRI compared with arthroscopy in the diagnosis and management of the knee has not been resolved. Orthopaedic surgeons may continue to seek to document the efficacy and cost-effectiveness of an established technique such as arthroscopy and to critically examine claims that a newer diagnostic examination has the potential to significantly reduce existing arthroscopic workloads. On the other hand, from the radiologists' point of view, the use of MRI with surface coils has successfully demonstrated the ability to diagnose conditions relating to internal derangement of the knee and by doing so has the potential to replace more traditional investigations such as arthrography and raise the possibility of avoiding some arthroscopic procedures. The selection of appropriate investigation techniques will depend on a combination of factors

including clinical assessment, availability of equipment, likelihood of satisfactory outcome and cost. In the case of the treatment of knee disorders, there may be a lack of consensus between two professional groups. It may take some time for a clearer picture to emerge as to the appropriate clinical role of the respective investigative techniques. There is a need for well-designed prospective studies.

Realities in Australia—availability of MRI units

MRI units are expensive both in terms of equipment costs and the need for specialised diagnostic and support staff. Patterns of use of MRI in examinations of the musculoskeletal system have varied in different countries, depending on factors such as the number of units installed, reimbursement practices and the availability of alternative imaging modalities.

As the pattern of use of MRI in examination of the joints has been influenced by the number of MRI units installed in each country, it is of interest to examine the availability of the technology. Marshall⁽³⁸⁾ has provided an overview of the distribution of MRI units in selected countries as at August 1992. As would be expected, there is a wide variation in availability, ranging from 12 per million in the United States to one per million in Australia. Restricted availability would have a limiting effect on the potential for the use of MRI in investigation of joints. Experience in the United States would not be directly transferable to other countries, in part because of differing patterns of diffusion of MRI and the relationship to other investigative modalities.

MRI has major application in examination of the head and spine and the MRI units in public hospitals in Australia (19 by July 1994) are mainly committed to such services. There would be only limited capacity to provide examination of joints such as the knee on these machines, although there would be some capacity on private MRI units. It might be the case that the emergence of new low-cost dedicated MRI units could have a role to play in the diagnosis of knee injuries; however, a recent paper⁽³⁸⁾ has noted the need to resolve both technical and professional issues related in the introduction and use of such technology.

Factors which will determine usage

There are many cases of untreated generalised knee and joint pain in the community, particularly in elderly persons. While many patients may be deterred at present from having such symptoms investigated by invasive modalities, they might be more willing to undergo investigation by a non-invasive examination such as MRI if it were readily available. Whether an increased level of investigation by MRI would result in improved patient management would require detailed assessment.

There is interest in Australia in establishing the efficacy of MRI in examination of joints. Supporting this interest is the potential for avoiding invasive procedures and consequential discomfort, and the potential for MRI examinations to provide more accurate results. However, in the case of the knee, there is a well established system in place in Australia for the arthroscopic management of disorders. A concern is that MRI could be additional to established diagnostic techniques and lead to further expenditure for a marginal increase in diagnostic accuracy and an undetermined effect on patient management. Evidence for improved patient management and cost-effectiveness, and for avoidance of complications, be needed before the introduction of routine use of MRI for diagnosis of disorders of the knee could be considered.

The final report of the Australian MRI Assessment Program,⁽³⁾ noted that the range of appropriate applications of MRI will continue to widen and should be kept under review. Without appropriate evidence, gathered from the Australian health system, it is difficult to develop guidelines for the use of MRI of the knee. Acceptance of the use of MRI in investigation of the knee in some countries is not necessarily an indication that this approach is appropriate for Australia.

There are a number of unresolved issues in relation to the use of MRI in examination of the knee. While excellent technical images can be produced, the accuracy of the technique and the effect on patient management have not been adequately demonstrated in well-controlled studies. As the use of MRI in the knee is sensitive to a number of factors, there would appear to be a need for a study to determine the costs and effectiveness of MRI on the management of disorders of the knee, having regard to the existence of an established system for arthroscopic services in Australia.

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