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Magnetic Resonance Imaging of the Knee: Assessment of Effectiveness

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***Objectives*: To quantify how magnetic resonance imaging (MRI) influences clinicians' diagnoses, diagnostic confidence and management plans in patients with knee problems. To investigate whether these changes can bring about an improvement in health.**

***Methods*: This was a prospective observational study on all patients referred to a regional unit for MRI of the knee over a 6-month-period. Data on diagnosis, diagnostic confidence and proposed management before MRI was compared with diagnoses and actual management after MRI. In addition, short form 36 item (SF-36) health survey data was collected at referral and again 6 months later.**

***Results*: Three hundred and thirty-two patients were entered into the study. MRI led to previously unsuspected diagnoses in 69 of 269 patients with available data. When MRI confirmed the clinical diagnosis, significant improvements in clinicians' diagnostic confidence were found ($P < 0.01$ for medial meniscus, $P < 0.05$ lateral meniscus, $P < 0.05$ anterior cruciate). MRI led to a change in management in 180 (63%) of 288 patients (where data available). There was a significant shift away from surgical management after MRI ($P < 0.01$). SF-36 results were available in 206 patients. There was a significant improvement over time in five of the eight SF-36 scales (four at $P < 0.001$, one at $P < 0.01$).**

***Conclusions*: Magnetic resonance imaging significantly influences clinicians' diagnoses and management plans. These patients, examined by MRI, also recorded an improvement in health related quality of life.** Mackenzie, R., Dixon, A.K., Keene, G.S., Hollingworth, W., Lomas, D.J. & Villar, R.N. (1996). *Clinical Radiology* **51**, 245–250. Magnetic Resonance Imaging of the Knee: Assessment of Effectiveness

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The NHS has identified magnetic resonance imaging (MRI) as a priority for health technology assessment (HTA). HTA is defined as 'assessment of the costs, effectiveness and broader impact of all methods used by health professionals to promote health, prevent and treat disease and improve rehabilitation and long term care' [1,2]. This definition encompasses the concept of effectiveness; the extent to which a health technology 'influences favourably' the outcome of disease when applied in clinical practice [3–5].

For preventative or therapeutic technologies, 'influence favourably' can be readily interpreted in terms of the potential for preventing or directly altering the course of disease. However, for diagnostic technologies, the situation is complicated because it is not immediately obvious how the technology affects the health of the patient. An imaging examination provides information from which a trained observer makes a detailed report. The clinician combines this report with clinical findings and other results to make or refine diagnoses and plan therapy. Assessment of the effectiveness of imaging therefore depends on measurement of a chain of events between the application of the technology and any potential influence on the disease [6,7]. A framework for assessing this chain of events has been described and its five level evaluative hierarchy is widely acknowledged as appropriate for the assessment of diagnostic imaging (Fig. 1) [3,7–13]. This framework clearly differentiates between features inherent to MRI (technical and diagnostic performance) and those that influence patients' subsequent diagnosis, management and health.

The aim of this study was primarily to assess the diagnostic and therapeutic impact of MRI of the knee in routine clinical practice. The basis for the arrangement of the evaluative hierarchy in Fig. 1 is that the clinical value of MRI should ultimately be measured against the benefit to patients that comes from its use. This implies that the MRI result can influence management decisions and that these may result in improvement in health. Accordingly, an additional aim was to investigate whether the use of imaging improves the health of the patient [14]. Examination of the knee is the commonest musculoskeletal application of MRI (excluding spinal imaging) and is now considered an established diagnostic technique [15–17]. Although technical [18] and diagnostic [19–21] performance of MRI for knee problems have been clearly demonstrated, there have been few assessments of either the diagnostic and therapeutic impacts or impacts on health.

PATIENTS AND METHODS

Over a 6-month-period, purpose designed MRI request forms were used to collect information on

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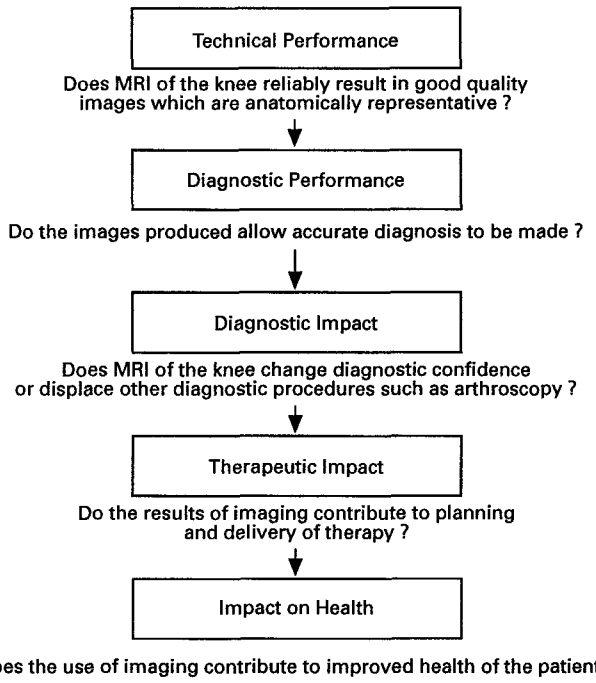

Fig. 1 – The five stage evaluative framework (originally developed by Fineberg *et al.* [8]) adapted here for MRI of the knee. The arrows indicate that each level depends on the demonstration of a favourable influence at the preceding level.

diagnosis, diagnostic confidence and proposed management for all patients referred for imaging of the knee. Diagnoses were specified in terms of the probable anatomical site of the lesion under investigation and the working diagnoses for that lesion. Clinicians' confidence in each diagnosis was measured using 10 cm visual analogue scales (VAS) [22].

Patients referred over the study period were sent an appointment letter and a short form 36 item (SF-36) health survey [23–25] (with instructions to return it on the day of their MRI appointment). MRI examinations were performed on either a Picker 2055 HP system operating at 1.5 Tesla (T) or an IGE Signa Advantage 0.5T system, both using appropriate coils for knee imaging. For all patients, the clinical details were known at the time of MRI, thereby allowing a tailored examination using routine image sequences chosen according to the clinical problem. The images were viewed by a consultant radiologist with at least 3 years experience in MRI of the knee and a report dictated in the usual way. After MRI, follow-up cards were sent to the referring clinician along with the images and MRI report. These cards asked for the diagnoses being considered (and degree of confidence thereof) in the light of the MRI report. Clinicians did not have access to their original MRI request form at this stage.

Six months after the referral for MRI, a second SF-36 postal survey was conducted. Nine months after referral, the case notes were reviewed (covering the 12 month period commencing 3 months before the original referral). All notes were checked by two people using a structured review form. The principal aims of this review were to verify the information on the request and follow-up forms and to identify patients who had proceeded to arthroscopy and record the operative findings (for an evaluation of diagnostic performance).

A purpose designed database was used to collate and handle the data generated by the study. Common pre-imaging diagnoses were grouped according to the probable anatomical site of the lesion under investigation (i.e. medial meniscus, lateral meniscus, unspecified meniscus and anterior cruciate ligament). Pre- and post-imaging diagnoses were compared with the MRI diagnoses and the results quantified in terms of new (previously unsuspected) diagnoses made by MRI, clinical diagnoses refuted by MRI and those confirmed by imaging. For those diagnoses confirmed by imaging and retained by clinicians at follow-up, changes in diagnostic confidence were assessed. In the analysis of diagnostic confidence, VAS measurements were interpreted according to Table 1.

The Wilcoxon signed rank test [26] was used to test the hypothesis that there were more positive than negative shifts in diagnostic confidence for those diagnoses confirmed by MRI (the null hypothesis being that if MRI was having no effect on confidence, the numbers of positive and negative shifts would be equal). As regards therapeutic impact, pre-imaging therapeutic plans and the actual management decisions taken at the post-imaging follow-up appointment were placed into one of three groups: discharge, review or arthroscopy. The first category included discharge and no further action. The second included review, symptomatic treatment (including physiotherapy), further investigations and second opinions. The most important change in management plans concerns whether patients proceed to arthroscopy or not. The McNemar change test [26] was used to test the hypothesis that after MRI, there would be a greater proportion of changes from surgical to non-surgical management. The null hypothesis being that amongst those clinicians who change their management plan, the probability that one will switch from surgical to non-surgical management would equal the probability that one would switch from non-surgical to surgical management.

Returned SF-36 questionnaires were scored by the same method as previous studies [24,25,27,28]. Pre- and post-imaging SF-36 results were compared with British general population scores [27,28] and then analysed for changes over the 6-month-period between questionnaires. In the comparison with normative data, the mean SF-36 scale scores were standardised by calculating the difference between the mean score and the published normal score; the differences being expressed as standard deviations from the general population mean. The significance of observed changes in mean SF-36 scale scores over time was investigated using paired *t*-tests.

RESULTS

Over the 6-month-period, 332 patients were referred for MRI of the knee by 32 consultants (11 of whom

Table 1 – Interpretation of visual analogue scales for diagnostic confidence

Measurement (mm)	*Grade*	*Meaning*
96–100	A	Very certain
66–95	B	Certain
36–65	C	Moderately certain
6–35	D	Uncertain
0–5	E	Very uncertain

Table 2 – Changes in clinicians' grades of confidence in diagnoses involving the medial and lateral menisci

Medical meniscus									
Pre-imaging grade	*Post-imaging grade*								*Totals*
	A	*B*	*C*	*D*	*E*	*R*	*N*	–	
A	0	0	0	0	0	0	0	0	0
B	13	7	1	1	0	17	6	2	47
C	5	10	3	4	0	22	4	1	49
D	3	6	0	3	0	18	5	3	38
E	0	0	0	0	0	0	0	0	0
–	0	0	0	0	0	0	2	0	2
Totals	21	23	4	8	0	57	17	6	136
Lateral meniscus									
A	0	0	0	0	0	0	0	0	0
B	0	1	0	0	0	8	2	0	11
C	2	0	1	0	0	10	5	0	18
D	1	2	0	2	0	12	4	1	22
E	0	0	0	0	0	0	0	0	0
–	0	0	0	0	0	1	2	0	3
Totals	3	3	1	2	0	31	13	1	54

See Table 1 for interpretation of grades. R, removed from clinicians differential diagnosis after MRI; N, no follow-up card completed; –, VAS not completed.

(34%) accounted for 272 (82%) of referrals). There were 205 men aged between 9 and 72 years (median 33 years) and 127 women aged between 11 and 76 years (median 33 years). Correctly completed MRI request forms were returned for 293 patients (88%). The mean interval between referral and the MRI appointment was 24 days (SD 12, $n = 332$). For a variety of reasons, MRI was only performed on 324 patients (98%). Patients were reviewed by the clinician an average of 33 days (SD 34, $n = 284$) after imaging and follow-up forms were completed for 269 patients (81%). Nine months after referral, case notes could be reviewed for 317 patients (95%). Even if the request forms, follow-up forms and notes reviews were incomplete, some data was available for analysis on all patients. Many patients had more than one suspected diagnosis (both in terms of anatomical site of lesion and suspected pathology). In total, 529 working diagnoses were given. Accordingly, the relevant number of patients and diagnoses varies for each of the following analyses.

Diagnostic Impact

Three anatomical sites accounted for 404 (76%) of the pre-imaging clinical diagnoses: meniscus in 246 (46%), patellofemoral joint in 98 (18%), and cruciate ligament in 61 (12%). In those patients with patellofemoral joint and extensor mechanism problems, MRI was usually requested to exclude other intra-articular pathology rather than for primary diagnostic classification. The diagnostic results for these patients are therefore not considered here.

For the medial meniscus, it was possible to analyse changes for 113 pre-imaging diagnoses (such as tears, cysts and degenerate lesions). After MRI, 57 of these were no longer being considered while 56 were retained. There was a positive and significant shift in clinicians' diagnostic confidence regarding these retained diagnoses ($z = -6.6$, $P < 0.01$). For the lateral meniscus, 40 diagnoses could be analysed. Thirty-one diagnoses were no longer considered after MRI; nine were retained. Despite the small numbers, there was also a positive and significant shift in clinicians' diagnostic confidence amongst these nine retained diagnoses ($z = -2.1$, $P < 0.05$). These results are summarized in Table 2. The medial or lateral meniscus was not specified in 34 diagnoses (perhaps indicating a low diagnostic confidence from the outset). Twenty-six of these diagnoses

Table 3 – Comparison of proposed management if MRI had been unavailable and actual management decision at follow-up (numbers of patients)

Proposed management	*Management decision at follow-up*					
	Discharge	*Review*	*Arthroscopy*	–	*DNA*	*Total*
Discharge	10	6	7	0	1	24
Review	20	15	11	2	3	51
Arthroscopy	73	63	83	17	5	241
–	5	2	4	4	1	16
Totals	108	56	105	23	10	332

DNA, did not attend for follow-up; –, no data available.

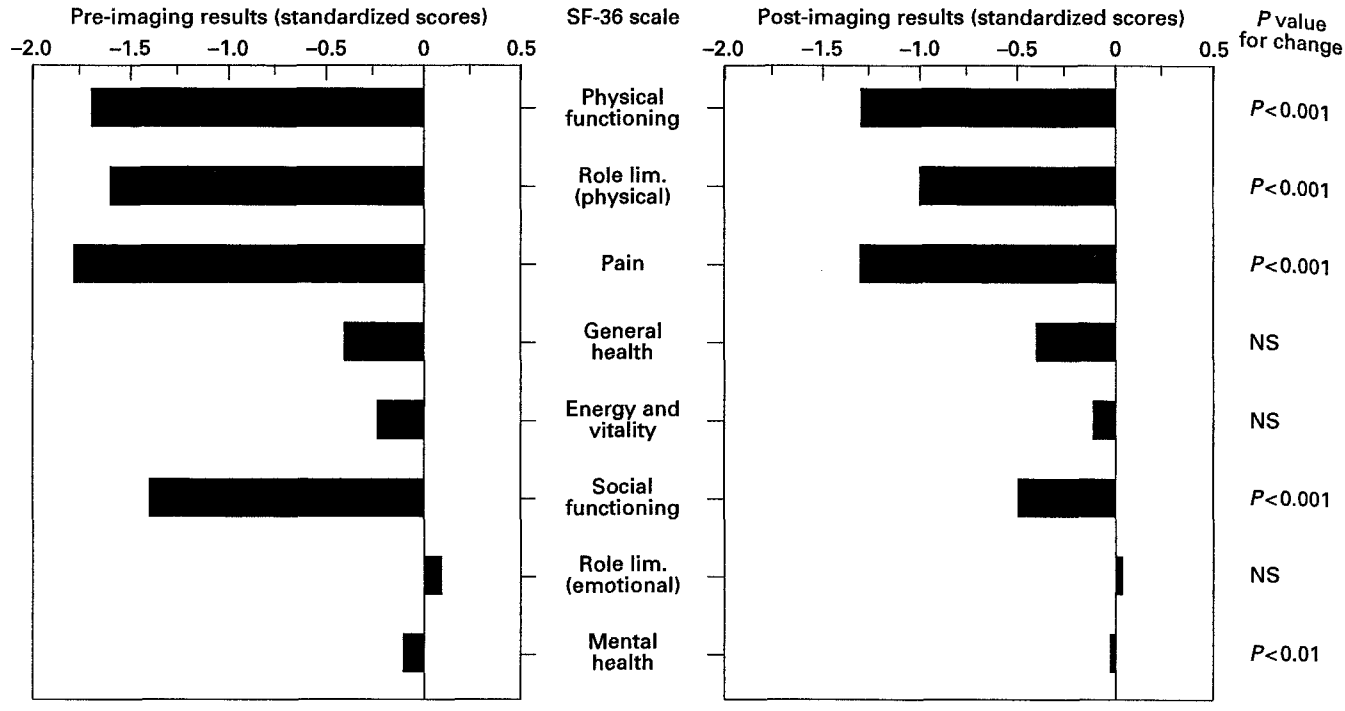

Fig. 2 – SF-36 results before and 6 months after MRI for 206 patients. SF-36 scale scores are expressed as standard deviations from the normal scores [27,28] (zero line). Significance of change over time was tested using paired, two-tailed *t*-tests.

were no longer considered following MRI while nine were confirmed and retained at follow-up. Although there was also a positive shift in confidence for these, this was not significant. For the anterior cruciate ligament, 35 diagnoses (such as tears and partial tears) could be analysed; 14 of these were no longer being considered after MRI while 21 were retained. There was a positive and significant shift in clinicians' diagnostic confidence regarding these diagnoses ($z = -2.1$, $P < 0.05$). There were too few posterior cruciate ligament lesions to merit formal analysis.

In addition to refuting clinical diagnoses and improving clinician's confidence in those diagnoses confirmed by MRI, new, previously unsuspected diagnoses were made by MRI in 69 (21%) of the 324 patients examined.

Therapeutic Impact

Pre-imaging management plans were stated for 316 patients. The management decision taken at the post-imaging outpatient appointment was known for 299 patients. The management plan was changed in 180 of the 288 patients (62%) for whom both sets of data were available; the major change being that 136 of the 219 patients (62%) for whom arthroscopy was the proposed management were either discharged or reviewed. Thus, only 83 of the 219 patients (38%) for whom arthroscopy was proposed retained this management plan after imaging. The comparison between the proposed management if imaging had been unavailable and the actual post-imaging management is shown in Table 3. The observed shift away from arthroscopy was highly significant (McNemar change test, $P < 0.001$).

Impact On Health

SF-36 questionnaires were returned by 290 patients (87%) before imaging. Only those patients who had returned the first questionnaire were sent a second questionnaire 6 months later; 206 of these second questionnaires were returned. Comparison of the SF-36 scores with normative data [27,28] reveals the extent to which these knee problems affected respondents' perceptions of their health-related quality of life, not only in terms of physical well-being (physical functioning, role limitation due to physical problems and pain) but also with regard to social functioning (Fig. 2).

Two hundred and six patients completed both pre and post-imaging questionnaires. There were 124 men (median age 35) and 82 women (median age 36.5). The changes in each of the eight SF-36 scales over the 6-month-period for these 206 patients are shown in Fig. 2. Five of the eight scales showed a significant improvement over time: physical functioning, role limitation due to physical problems, pain, social functioning and mental health (all at $P < 0.01$).

DISCUSSION

Although this study has produced considerable data on many aspects of the diagnosis and management of disorders of the knee, the principal aim was to gain insight into the diagnostic and therapeutic impact of MRI. The presentation of the results reflect that aim. Several aspects of the study merit further discussion.

The involvement of our referring clinicians in the design of the MRI request form was clearly of benefit and is reflected by the high completion rate (88%). There was, however, a considerably poorer response to the follow-up forms. Although some 81% were returned, several were incomplete. Accordingly, there were numerous diagnoses without full follow-up confidence scores.

The study was not primarily designed to assess the

diagnostic performance of the two MRI systems used. In fact, for the purposes of this study, the diagnostic performance of these two systems was considered equivalent (an old 1.5T system and a modern 0.5T system). Nevertheless, a potential criticism is that the study was not controlled for MRI system or protocol. A further issue of methodology concerns observer variability in interpreting images. A recurrent problem with evaluating new technologies such as MRI is the paucity of observers with sufficient experience to interpret images correctly. All the images in this study were reported by one of two consultant radiologists with considerable experience of knee MRI. In addition, many examinations were discussed with other radiologists attending the MRI unit. Accordingly, the MRI report usually represented a consensus opinion. On this point it is worth noting that our overall accuracy for meniscal and cruciate lesions (94% as judged by arthroscopic correlation [29]) is comparable with other centres [30].

The study was observational and therefore the detected shifts in diagnostic confidence and therapeutic plans cannot be attributed to the use of MRI alone, especially in view of the interval between MRI and follow-up. However, given that no patients had further investigations between the MRI and follow-up appointments, the shift in diagnostic confidence is likely to be attributable to MRI. This is consistent with improvements in diagnostic confidence observed in evaluations of MRI of the head and spine [31–33]. In addition, new diagnoses were made by MRI in 21% of patients and were generally adopted by clinicians (49 of 55 diagnoses (89%) with follow-up available). The acceptance of new diagnoses made by MRI and the improvement in confidence amongst diagnoses confirmed by MRI provides further evidence of a diagnostic impact for MRI of the knee.

Assessment of therapeutic impact was restricted to observation of differences between proposed management if MRI was unavailable and actual management at follow-up. Although management at follow-up was broadly categorized into three groups (discharge, review or arthroscopy), review of the case notes revealed patients did not always remain in one of these groups. Some of those who were discharged returned with further symptoms whilst some of those who were scheduled for arthroscopy became asymptomatic while on the waiting list and were subsequently discharged. However, it was considered that the impact of MRI on management decisions was likely to be greatest at the first follow-up appointment. There was certainly a significant shift away from surgical management at this initial review. A further point is that there is variation between clinicians in what is considered the most appropriate management for many knee disorders. By sampling a large number of referring clinicians, it was hoped that any potential bias introduced by individual differences in management strategies would be minimised.

The high avoidance of arthroscopy is the most important finding in our study. Interestingly, similar results were found in a small randomized study conducted within our unit before MRI gained wide acceptance: only 38% (20 of 52) of patients for whom arthroscopy was proposed on clinical grounds actually proceeded to arthroscopy [34]. The interval between MRI and follow-up in the randomized study was approximately 42 days compared with the mean interval of 33 days in the observational study. It seems, therefore, that review of patients after this interval is appropriate and may, itself, contribute to therapeutic impact. There are of course other factors (such as physiotherapy) which may have an influence during this interval and which were not controlled for.

These figures for 'avoidance' of arthroscopy (62%) are higher than has been found in other series [35–37]. Although analysis of the financial aspects of the various procedures was not an objective of this study, this high avoidance of arthroscopy lends some financial justification to the use of MRI [38]. In addition, this result provides some measure that most of the MRI requests were appropriate, although it was surprising that there were 24 patients for whom the proposed initial alternative management was discharge.

The use of MRI for patellofemoral joint and extensor mechanism problems is another controversial area. There is considerable variation in both clinical assessment and nomenclature in these patients. This had not been anticipated. The main difficulty was that in many cases, imaging was being used to exclude lesions for which the clinician did not have any pre-imaging diagnostic confidence, and to demonstrate lesions for which the technical and diagnostic performance of MRI is still being established [39–44].

Measurement of health-related quality of life with self-completed questionnaires relies on adequate responses from the study sample. Overall, the initial response (87%) was very good. The lower post-imaging response (62%) is typical of a postal survey. The non-respondents did not differ substantially from the respondents in terms of age, sex or clinical problem.

The SF-36 was able to differentiate patients from the normal population in ways that could be related to the clinical problem. As might have been expected, the differences between patients with knee problems and the healthy sample surveyed by Jenkinson *et al.* [27,28] were mainly in the physical well-being aspects of health (physical functioning, role limitation due to physical problems and pain). An interesting feature was the poor social functioning consistently recorded by these patients. This result can be related to the high proportion of patients who are referred for assessment of leisure or sports related injuries as opposed to other disease processes. Normal social functioning in these patients may have included participation in such activities, as emphasized by the large number of written comments such as 'most of my hobbies and social life revolve around sport'. The most important result however was that patients' self reported health status improved over time, with the greatest improvements in the areas where patients had been furthest removed from the normal population. The observational nature of the study does not allow the improvement in health to be attributed to the use of MRI, but the fact that changes are occurring (and are detectable) supports the use of instruments such as the SF-36 to measure changes in health in future experimental studies. Several independent variables may have influenced the change in SF-36 scores over time observed in this study. These include differences according to duration of symptoms, diagnostic impact of imaging, post-imaging management (surgery or discharge within 6 months of imaging), age and sex. Pre- and post-imaging SF-36 results are currently being analysed for each of these variables [14,45].

This study has confirmed that MRI in routine clinical use establishes new diagnoses and significantly influences the diagnostic confidence in lesions of the menisci and anterior cruciate ligament. These effects on diagnosis are likely to be responsible for the observed shift away from surgical management, although other factors also play a part. Furthermore, these patients, examined by MRI, recorded an improvement in health related quality of life. Further research to confirm these effects should now be directed towards controlled trials of management strategies for specific knee problems which include MRI.

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