The Effect of Magnetic Resonance Imaging Scans on Knee Arthroscopy: Randomized Controlled Trial

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Purpose: The purpose of this study was to investigate whether magnetic resonance imaging (MRI) in patients waiting for knee arthroscopy could reduce arthroscopy rates and improve patient outcome. **Methods:** A prospective randomized controlled trial was conducted in a teaching hospital setting. All participating patients had knee MRI before arthroscopy. In the intervention group the MRI report was seen by surgeons, and in the control group it was not. The primary outcome measure was the proportion of patients who did not have an arthroscopy. Secondary outcome measures included the Short Form 36, EuroQol EQ-5D, Knee Injury and Osteoarthritis Score, and Knee Society Score. **Results:** Surgeons changed both their diagnosis and management plan in 47% of patients in the intervention group compared with 1% in the control group, with no difference between groups in the proportion of patients who underwent an arthroscopy. In the intervention group 7 of 125 patients (5.6%) did not have an arthroscopy compared with 8 of 127 patients (6.3%) in the control group. In one instance a surgeon decided against arthroscopy based on the MRI report. There was no significant difference between groups in other outcome measures. **Conclusions:** We found no effect of MRI on the decision to perform arthroscopy or patient outcome. Performing MRI in patients already on the waiting list for arthroscopy may not be effective in reducing utilization of surgery. **Level of Evidence:** Level I, therapeutic randomized controlled trial with no statistically significant difference but with narrow confidence intervals. **Key Words:** Arthroscopy—Joint diseases—Knee joint pathology—Ligaments—Articular injuries—Magnetic resonance imaging—Menisci.

Clinical assessment alone has a 35% to 70% accuracy in predicting arthroscopy findings.[1-4] A small randomized controlled trial in the National Health Service (NHS) in England suggested that magnetic resonance imaging (MRI) might reduce arthroscopy rates and improve patient outcome.[5] Other observational nonrandomized studies in the United Kingdom, Austria, and the United States showed that MRI was cost-effective before knee arthroscopy, and 25% to 50% of patients on a waiting list for surgery avoided arthroscopy by the prior use of MRI.[6-13] In England approximately 80,000 knee arthroscopies were performed in the NHS in the financial year 2002-2003.[14] Orthopaedic surgery has long waiting lists in public hospitals. Consequently, the NHS in our locality decided to offer MRI to patients already on the arthroscopy waiting list to try to reduce the number of patients requiring surgery. We conducted a

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randomized controlled trial to test the hypothesis that MRI in patients waiting for knee arthroscopy in the local NHS hospital would reduce arthroscopy rates and improve patient outcome.

METHODS

Consultant orthopaedic surgeons had assessed patients at routine orthopaedic outpatient clinics. On the basis of clinical history and physical and radiographic examinations, patients had been placed on the NHS waiting list for knee arthroscopy. They were assessed again for suitability for anesthesia and indication for surgery at presurgery clinical visits done within 6 weeks of the scheduled date of surgery. Patients still deemed to require surgery were eligible to enter this trial. Surgeons excluded patients if they (1) were aged under 18 years; (2) had or were suspected of having primary synovial disease, knee infection, or tumor; (3) had undergone an arthroscopy or MRI of the affected knee within the last 12 months; (4) had a contraindication to MRI scanning; and (5) had multiple trauma.

The study was set in a teaching hospital with a core catchment population of around 500,000 persons. Surgeons operated on some patients at other local NHS or private hospitals when there was insufficient operating theater capacity at the local NHS hospital. Five consultant orthopaedic surgeons, all experienced knee arthroscopists, performed arthroscopies according to their usual practice.

Surgeons filled in MRI request cards at the presurgery clinical visits. Radiographers performed MRI on a Siemens 1-T Magnetom Impact Expert MRI system (Siemens AG, Erlangen, Germany) with standard protocols (Appendix 1, online only, available at www.arthroscopyjournal.org). The study musculoskeletal radiologist reported MRI findings at least 3 days before the date of the scheduled arthroscopy. The radiologist was blinded to patient allocation. MRI scans were stored on optical disks in the radiology department and MRI report cards in a locked filing cabinet in the trial office.

The research nurse gave surgeons both orthopaedic clinical notes and a blank MRI report card. The surgeons reviewed the information and decided whether patients should still undergo arthroscopy. They completed a questionnaire on their clinical diagnosis and subsequent management plan. If they believed that arthroscopy was no longer indicated, they reviewed patients' cases to decide a new management plan. For the experimental group, the procedure was the same as for the control group, except that surgeons received the completed MRI report.

The primary outcome was the proportion of patients who did not proceed to arthroscopy. Secondary outcomes were the EuroQol EQ-5D,[15] Short Form 36,[16] Knee Injury and Osteoarthritis Score,[17] Knee Society Score,[18] knee range of movement (assessed by a trained, independent, blinded physiotherapist), and complications. We collected data at the presurgery clinical visit, perioperatively, and both 6 weeks and 6 months postoperatively. We followed up patients who did not undergo surgery using their scheduled surgery date as proxy for their date of surgery.

Surgeons recorded their management plans after receipt of an MRI report or blank MRI report form. If the original operation was no longer planned, this was considered a complete change in plan, whereas if another procedure was planned in addition to the original one, this was considered a partial change in plan.

Patients gave informed consent for participation in the trial as well as surgery and MRI. The study was approved by the local scientific merit and research ethics committees. The trial was overseen by an academic clinician and a statistician who were not directly involved in data collection.

After MRI and before reporting, the trial manager or trial nurse allocated patients to the groups by computer. The trial manager and statistician wrote the minimization program, using minimization variables of age ($<$35 and $\geq$35 years), gender, and surgeon.[19] We blinded patients, physiotherapists, and radiologists as to allocation. Only the study statisticians and the data monitoring committee saw unblinded data, and they did not have contact with patients.

In the NHS MRI has been reported to avoid 30% to 40% of knee arthroscopies.[6-8] We considered a 15% difference in the rate of arthroscopies between the 2 groups to be clinically significant. A sample size of 350 patients, 175 in each group, was required to detect this difference with a power of 90% and a 5% significance level with 2-sided testing. The sample size was increased by 10% to allow for losses to follow-up (n = 35), giving a sample of 385 patients. Consecutive data monitoring meetings noted little reduction in arthroscopy rates in either group. A blinded analysis showed that the likelihood of detecting the target 15% difference had become negligible. Therefore the sample size was recalculated, and the data monitoring committee advised that it could be reduced to 252 to address potential differences across the range of sec-

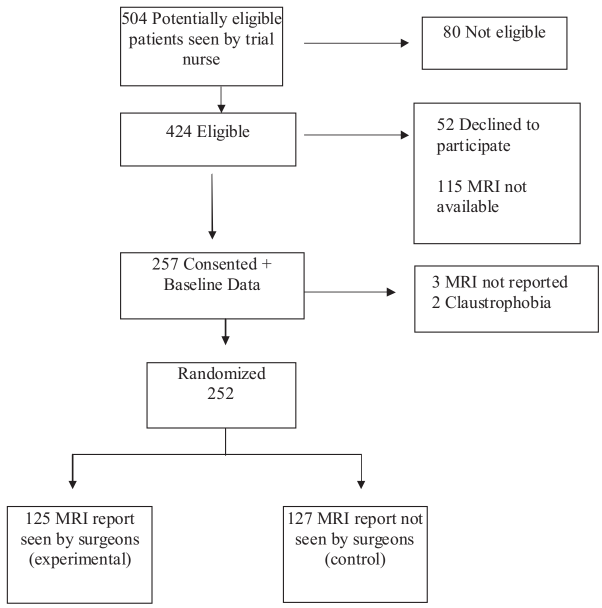

FIGURE 1. Diagram showing recruitment and patient flow through study.

ondary outcome measures with 90% power and a 5% significance level.

Analysis was performed on an intention-to-treat basis. We analyzed data by conventional statistical methods appropriate for a longitudinal randomized controlled trial involving a set of repeated correlated outcome measurements of mixed type, including (1) univariate parametric and nonparametric methods; (2) multifactor methods, such as the multiple logistic function; and (3) a linear mixed model of the generalized Laird-Ware type.[20] The Laird-Ware model allowed for baseline covariate adjustment, correlation between the repeated responses, and serial correlation in the errors. The protocol specified the inclusion of the following baseline covariates in an adjusted analysis: age, sex, and duration of symptoms. In some analyses surgical center and time to surgery were also included. The 5% significance level was used in these analyses. We assumed that missing data were missing at random.

RESULTS

Of the 424 eligible patients seen between June 4, 2001, and September 30, 2002, 115 would have participated but MRI was not available (Fig 1), 52 declined to participate, and 5 consented to participate but were withdrawn before randomization (3 because the radiologist was not available to report the MRI findings and 2 because of claustrophobia). Of the 252 participants, 125 were randomized to the experimental arm (MRI report seen by surgeons) and 127 to the control arm (MRI report not seen by surgeons). The age, gender, duration of symptoms, hospital of operation, and surgeon were similar between the 2 groups. The mean age was 43 years, the mean duration of symptoms was 46 weeks, 68% of patients were men, 59% of arthroscopies were performed in the private sector, and 2 of the 5 surgeons performed 81% of the arthroscopies.

One patient allocated to the group in which the MRI report was not seen requested to see the MRI report before surgery and withdrew before the 6-week postoperative follow-up.

Follow-up measurements were performed in 114 patients (91%) in the group in which the MRI report was seen and 120 (94%) in the group in which the MRI report was not seen (Table 1). The last follow-up measurement was made on September 17, 2003.

In the group in which the MRI report was seen, 7 of 125 patients (5.6%) did not have an arthroscopy, as compared with 8 of 127 (6.3%) in the group in which the MRI report was not seen ($\chi^2 = 0.055$, $df = 1$, $P > .05$). Of the 7 patients who did not have an arthroscopy in the group in which the MRI report was seen, 3 cancelled their arthroscopy because of work commitments, 2 stated that they no longer required arth-

TABLE 1. *Patients Seen at Follow-up According to Patient Group*

	MRI Report Seen (n = 125)		MRI Report Not Seen (n = 127)		
Time of Examination	Arthroscopy	No Arthroscopy	Arthroscopy	No Arthroscopy	Total
Baseline	94 (118)	6 (7)	94 (119)	6 (8)	100 (252)
Follow-up at 6 wk and 6 mo	63 (79)	2 (2)	75 (95)	3 (4)	71 (180)
Follow-up at 6 wk only	11 (14)	0 (0)	8 (10)	0 (0)	10 (24)
Follow-up at 6 mo only	15 (19)	0 (0)	9 (11)	0 (0)	12 (30)
No follow-up at 6 wk and 6 mo	5 (6)	4 (5)	2 (3)	3 (4)	17 (18)

NOTE. Data are presented as percentage (number).

TABLE 2. *Comparison of Selected Secondary Outcome Measures*

Secondary Outcomes	Intervention Group (Mean/SE/Median)	
	MRI Report Seen	MRI Report Not Seen
EuroQol EQ-5D		
Before MRI	71.6/1.7/76	73.35/1.5/76
6 wk	76.5/1.9/80	77.1/1.8/80
6 mo	77.6/1.9/80	79.2/1.7/80
Short Form 36: Physical Health Summary Score (%)		
Before MRI	50.6/2.5/50.0	52.0/2.5/55.0
6 wk	62.0/2.9/70.0	64.2/2.8/75.0
6 mo	67.6/3.0/75.0	68.7/2.8/75.0
Knee Society Score: Pain (%)		
Before MRI	54.6/2.0/53.1	58.4/1.9/56.2
6 wk	73.2/2.5/81.2	75.5/2.2/81.2
6 mo	75.6/2.5/84.3	77.7/2.5/87.5
Knee Society Score: Function (%)		
Before MRI	62.9/2.2/63.2	65.1/2.1/66.2
6 wk	79.7/2.2/87.5	82.3/2.0/90.4
6 mo	81.0/2.4/94.1	82.7/2.2/93.3

NOTE. These data are presented in a cross-sectional manner at each examination. The higher the score, the better the outcome. There are no significant differences between the intervention groups at any time point (*t* test and Kruskal-Wallis methods). This does not constitute a longitudinal analysis, as explained within the "Methods" section.

roscopy because their symptoms had resolved, and 1 had MRI findings reported as normal and the surgeon decided arthroscopy was no longer indicated; in addition, in 1 patient the other knee became more symptomatic and arthroscopy was performed instead.

Of the 8 patients who did not have an arthroscopy in the group in which the MRI report was not seen, 3 cancelled their arthroscopy because of work commitments, 3 stated that they no longer required arthroscopy because their symptoms had resolved, and 1 was reassessed in the hospital and placed on the waiting list for a total knee arthroplasty; in addition, surgery was mistakenly not performed in 1 patient, and when reassessed 18 months later, this patient required a revision of a femoral component of an existing total hip replacement.

After an extensive series of multivariate analyses, no significant differences between groups were found in any secondary outcome measure (Table 2). No complications were recorded in either group.

The group of patients in which the MRI report was seen waited a median of 5 months (range, 2 weeks to 16 months) between placement on the surgical waiting list and their presurgery clinical visit, whereas the group in which the MRI report was not seen waited 6 months (range, 2 weeks to 14 months).

In both groups the median time between baseline measurement and randomization was 6 days. In the group in which the MRI report was seen, the median time from randomization to arthroscopy was 13 days, and in the group in which the MRI report was not seen, it was 16 days.

Surgeons planned a meniscectomy in 66% of participants before MRI and in 66% after MRI, and they performed a meniscectomy in 49% (Table 3). They planned a washout with or without debridement in 27% of participants before MRI and 29% after MRI, and they performed one in 39%. They planned a plica resection in 1% of participants and performed one in 12%.

Surgeons changed their planned management completely in 1 participant in the group in which the MRI report was not seen, undertaking a total knee arthroplasty rather than a debridement. They changed their plans partially in another participant, when they planned a debridement in addition to a medial meniscectomy. They did not change their plans in 98% of this group.

Surgeons changed their management plans in 59 participants (47%) in the group in which the MRI report was seen, completely in 34 (27%) and partially in 25 (20%). Among the participants with a complete change in plan, surgeons changed from another procedure to meniscectomy in 7, from medial to lateral meniscectomy in 5, and from lateral to medial meniscectomy in 3. Among the participants with a partial change in plan, surgeons no longer planned a meniscectomy in 3 whereas they planned meniscectomy in 5 additional patients. There was no change in plan in 66 participants (53%). A comparison of these proportions is highly statistically significant ($\chi^2 = 71.3$, $df = 1$, $P < .001$).

In most instances in which surgeons changed their management plans, this change was consistent with the findings of the MRI report.

In the one patient in whom MRI led to the avoidance of surgery, a suspected meniscal tear was not confirmed by MRI, although osteoarthritis was reported.

The radiologist reported 12 (9.4%) of the cases in the group in which the MRI report was not seen as normal or with no significant abnormality and 16 (12.8%) in the group in which the MRI report was seen. Given a normal MRI scan, the radiologist believed that these patients were less likely to warrant surgery. Among the 12 patients in the group in which

TABLE 3. *Surgical Management Plans Before and After MRI Scanning and Recorded Arthroscopic Management*

	Surgical Management Plan Before MRI		Surgical Management Plan After MRI		Arthroscopic Management	
	MRI Report Not Seen (n = 127)	MRI Report Seen (n = 125)	MRI Report Not Seen (n = 127)	MRI Report Seen (n = 125)	MRI Report Not Seen (n = 127)	MRI Report Seen (n = 125)
Meniscal tear (any)	64 (81)	68 (85)	64 (81)	69 (86)	50 (63)	49 (61)
Lateral and medial	2 (3)	3 (4)	2 (3)	8 (10)	6 (7)	2 (3)
Lateral	13 (17)	12 (15)	13 (17)	11 (14)	16 (20)	11 (14)
Medial	48 (61)	53 (66)	48 (61)	50 (62)	28 (36)	35 (44)
Loose bodies	11 (14)	7 (9)	11 (14)	7 (9)	13 (16)	10 (12)
Plica	1 (1)	1 (1)	1 (1)	2 (2)	13 (16)	11 (14)
Lateral release	6 (8)	8 (10)	6 (8)	6 (7)	9 (12)	7 (9)
Debridement with or without washout for osteoarthritis	28 (36)	24 (31)	29 (37)	28 (35)	40 (51)	38 (48)
Investigative arthroscopy	4 (5)	4 (6)	4 (5)	7 (9)	Not applicable	Not applicable
Normal or no significant abnormality	0 (0)	0 (0)	0 (0)	0 (0)	3 (4)	1 (1)
No arthroscopy	0 (0)	0 (0)	0 (0)	0 (0)	6 (8)	6 (7)
Not recorded	0 (0)	0 (0)	0 (0)	0 (0)	2 (3)	2 (3)

NOTE. Data are presented as percentage (number).

the MRI report was not seen, surgeons suspected a medial meniscus tear alone in 10, a medial meniscal tear and plica in 1, and a lateral meniscus tear and osteoarthritis in 1. Among the 16 patients in the group in which the MRI report was seen, surgeons suspected a medial meniscal tear alone in 10, a meniscal tear and plica in 1, a lateral meniscal tear in 1, osteoarthritis in 2, and patellar maltracking in 2.

Although some noncompliance with scheduled follow-up times was observed, the distributions were very similar in both groups, and although this complicated the statistical analysis, it is unlikely to have biased the between-group comparisons.

DISCUSSION

Provision of an MRI report for a group of experienced surgeons, after the decision to operate had been made and after a presurgery clinical assessment, had no effect on the proportion of patients who underwent arthroscopy. An arthroscopy by a surgeon who was informed by an MRI report had no effect on patient outcome, although it did change planned management.

The NHS cost for arthroscopy in the financial year 2005-2006 was £985, and that for knee MRI was £220. A policy of using MRI late in the clinical pathway does not appear to be a good use of NHS resources.

This study is at variance with other randomized and observational studies in the United Kingdom, the United States, and Continental Europe suggesting that MRI can reduce the proportion of patients who undergo knee arthroscopy by 25% to 50%.[7-13,21-23] However, surgeons did change their presumptive diagnoses and management plans made at the preoperative visit in around 47% of patients in the group in which the MRI report was seen, as compared with just 2% in the group in which the MRI report was not seen. These findings suggest that, although surgeons did read and were cognizant of the MRI reports, canceling arthroscopy did not follow as a consequence.

In addition, the details of the reports might simply have encouraged rather than discouraged arthroscopy. For example, menisci reported as degenerate in about 10% of patients were considered normal for age by the radiologists.

The case mix of our study may be different from other studies. For instance, ours was the only study recruiting patients shortly before their planned date of surgery. MRI is not usually performed at a preoperative visit to refute clinical observations and cancel surgery; rather, it is used early on in the diagnostic process to confirm clinical suspicions, and this may have influenced against cancellation of operations. The patients had usually been on a waiting list for some months and would have been excluded had they recovered while on the waiting list. Therefore our cohort was likely "further down the care pathway" and hence a more selected group than the patients recruited by Bryan et al.,[21,22] who entered the study before a decision was made to perform arthroscopy. The inclusion of arthritic patients without other indications for arthroscopy is controversial, especially given that a recent trial suggested that washout and debridement may be no more effective than placebo.[24] Our surgeons might have recently changed their indications for surgery to use "washouts" more conservatively than they were when the data were being collected. We also included patients undergoing a lateral release. Such patients were excluded from the study of Bryan et al., though probably not from that of Warwick et al.[7] The MRI report might have been less likely to change the decision to perform arthroscopy in our patients awaiting an arthroscopic debridement and washout or lateral release (Table 3) compared with patients with suspected mechanical problems. However, these patients were only a minority in our study.

Subsequent to the trial, the radiologist reviewed the MRI scan reports in our study against the categories for avoidable arthroscopies of Bui-Mansfield et al.[10] Had these criteria been applied in our study, they would have prevented only 12% of arthroscopies (30/252). Most of these were in the unremarkable MRI category (n = 21): 6 patients had degenerative menisci without a discrete tear, 2 had an isolated meniscal signal, and 1 had an isolated radial tear confined to the inner third of the meniscus. Hence, we likely had a more severe case mix than other studies. Clinical decision making by surgeons early in the care pathway entails appropriately excluding patients from undergoing arthroscopy; the patients having arthroscopies on clinical grounds are very similar to those who would be included based on MRI criteria. In a recent study it was reported that clinical examination was at least as accurate as MRI in a very experienced surgeon's practice for diagnosing meniscal and anterior cruciate ligament injuries.[25]

Having already advised a patient to have an arthroscopy may have acted powerfully on surgeons to use the MRI findings in the context of a procedure already decided upon. Surgeons believed that intervening so late in the care pathway was a problem, because they thought patients expected an arthroscopy. Such an explanation for patients with a normal MRI scan or a suspected nonmechanical problem who received an arthroscopy seems reasonable. We left it to surgeons to contact patients if they believed that an arthroscopy was not indicated, so some extra effort was required to cancel a planned arthroscopy. In other studies patients were routinely seen in the clinic after their MRI scans,[7,21,22] and a clinical review alone may reduce surgery rates.[23] However, it remains unclear whether many more arthroscopies would have been avoided in our patients, given the presence of criteria in most of them suggesting that arthroscopy was indicated.

Although the NHS invested in MRI scans expecting a reduction in arthroscopies, there is little population-based work to support this assertion. In the US Medicare program, MRI rates tripled between 1993 and 1999.[26] Whereas diagnostic arthroscopy rates decreased (though they were always very low), arthroscopy rates overall increased by 20%.[26]

The use of MRI in the diagnostic process is not associated with improvement in quality of life,[22,27] although in one small randomized controlled trial, patients who had received MRI tended to have a better quality of life.[5] We found no impact of the availability of an MRI report on quality of life in this study, although a 6-month follow-up is relatively short. With limited health care resources, surgeons should continue to try to better define the value of imaging techniques to their clinical practice and patient outcomes.

A limitation of the generalizability of our study findings may be that we recruited patients at the preoperative clinic visit before their planned date of surgery, which is not usually when MRI is performed. However, recruiting at this time did mean that patients were almost certainly going to receive an arthroscopy. Our study was also limited to one center, and it is possible that different results might have been obtained elsewhere.

CONCLUSIONS

We found no effect of MRI on the decision to perform arthroscopy or patient outcome. Performing MRI in patients already on a waiting list for arthroscopy may not be effective.

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APPENDIX 1: MRI PROTOCOL

All MRI scans were performed on a fixed Siemens 1-T Magnetom Impact Expert via the dedicated knee coil. All of the images were printed out on laser film, and the data were saved on a Pioneer DC-502A optical disk (Pioneer Electronics, Beveren, Belgium) reserved for the trial. Each patient underwent the following sequences: axial localizer, sagittal T1 and gradient echo T2*, coronal short tau inversion recovery, axial fat-suppressed dual echo, and volume fat-suppressed fast low-angled shot (spoiled gradient echo) (3-dimensional volume) acquired in the sagittal projection. The latter two sequences yielded articular cartilage visualization. Details of the sequences taken are given in Appendix Table 1.

Appendix Table 1. *Sequences*

Sequences	FOV (mm)	Matrix	TR (ms)	TE (ms)	FA (°)	No. of Acquisitions	TI (ms)	Time	Thickness (mm)
Sagittal T1	200	256 × 256	532	15	90	2	—	2 min 28 s	4
Sagittal T2*	200	241 × 256	608	18	20	2	—	4 min 55 s	4
Axial T2*	220	180 × 256	616	18	20	2	—	3 min 44 s	
Coronal STIR	210	196 × 256	4,300	30	180	1	120	4 min 6 s	4
For possible ACL interruption									
Sagittal FS3D	180	168 × 256	58	11	40	1		7 min 30 s	2
Sagittal DESS	200	256 × 256	26.8	9	40	1	—	8 min 29 s	1.6
Oblique T1		256 × 256	400	15	90	3	—		3

NOTE. T1 and T2 denote "weighting" of the scan (T1 tends to be referred to as an anatomic sequence and shows adipose tissue, whereas T2 returns a water signal and tends to be good for many pathologic conditions). STIR is exquisitely sensitive to fluid, and the time chosen means that no signal emanates from fat. DESS has both T1 and T2 weighting.

Abbreviations: FOV, field of view; TR, repetition time; TE, time to echo; FA, flip angle; TI, time to inversion; STIR, short time inversion recovery; ACL, anterior cruciate ligament; FS3D, flash 3-dimensional volume; DESS, dual echo in steady state.