CLINICAL ORTHOPAEDICS AND RELATED RESEARCH
Number 330, pp 133–142
© 1996 Lippincott–Raven Publishers

Influence of Magnetic Resonance Imaging on Indications for Arthroscopy of the Knee

Christoph Rangger, MD; Thomas Klestil, MD*; Anton Kathrein, MD*; Adi Inderster, MD*; and Laith Hamid, MD***

In a prospective study, magnetic resonance imaging was performed before arthroscopy for all patients (n = 121) with a meniscal tear (n = 125). Criteria of the study were stable cruciate and collateral ligaments, absence of pathologic radiographic findings, and absence of prior surgical interventions of the involved knee joint. In 43 knees (34%), the clinical diagnosis of a meniscal tear was discarded because of the results of the magnetic resonance imaging examination. Synovitis was diagnosed in 16 patients (13%), articular cartilage damage in 10 patients (8%), bone bruise injuries in 10 patients (8%), osteochondritis dissecans in 3 patients (2%), disruption of the inner layer of the medial collateral ligament in 3 patients (2%), and osteonecrosis in 1 patient. The use of magnetic resonance imaging in establishing diagnosis of disorders of the knee joint altered treatment in a significant proportion of patients. Magnetic resonance imaging should be done before arthroscopy of the knee in all cases in which the clinical diagnosis has been reduced to a suspected meniscus injury.

From the *Department of Traumatology, University Hospital of Innsbruck, Innsbruck, Austria; and **Lorenz Boehler Trauma Hospital, Vienna, Austria.

Reprint requests to Christoph Rangger, MD, Universitätsklinik für Unfallchirurgie, Department of Traumatology, University of Innsbruck, Anichstraße 35, A-6020 Innsbruck, Austria.

Received: July 26, 1995.

Revised: October 23, 1995; November 30, 1995; January 19, 1996.

Accepted: January 31, 1996.

In some reports, clinical investigation of meniscal injuries is afflicted with a high percentage of false positive findings.[49,62] A variety of clinical tests have been established to recognize meniscal injuries with a diagnostic accuracy varying between 35% and 95%.[49,57,62,65,67] Therefore, arthroscopy, based only on clinical evaluation may lead to diagnostic arthroscopies or even to incorrect therapeutic consequences.

Despite controversies concerning cost effectiveness, magnetic resonance imaging (MRI) recently has become a more popular diagnostic tool for evaluation of knee joint disorders.[1,15,17,45,49,62,75] In the radiologic literature, a high rate of accuracy, sensitivity, and specificity concerning meniscal disease has been reported; additionally, alterations in the surrounding tissue can be visualized on MRI scans.[7,20,52,56,64,70,75]

The purpose of the present prospective study was to evaluate the influence of MRI on the indication for arthroscopy and, consequently, on a possible reduction of the number of arthroscopies or alteration in therapy.

MATERIALS AND METHODS

From October 1993 through September 1994, 121 consecutive patients involving a total of 125 knees fulfilled the criteria of this prospective study: clinical diagnosis of a meniscus injury es-

tablished by a member of the knee clinic; stable cruciate and collateral ligaments without previous history of knee injury or previous surgery of the involved knee joint; and no pathologic radiographic findings.

Anteroposterior and lateral weightbearing radiographs of the involved knee joint and an axial view of the patella were obtained for all patients.

Detailed history of the patients' symptoms were reported. Clinical evaluation included determination of joint line tenderness, joint effusion, range of motion, meniscus tests (McMurray, Steinmann I, Steinmann II, Boehler), ligamentous stability tests, patellar tracking, and stability.

All patients with the clinical diagnosis of a meniscal injury were preliminary scheduled for arthroscopy with the same surgeon (C.R.).

Magnetic resonance imaging was conducted before surgery. Magnetic resonance imaging was performed with a 0.5 Tesla superconducting magnet (MRT-50A/20, Toshiba Medical System Factory, Nasu, Japan). Data were collected with the use of a 256 × 160 double matrix. The use of a field of view 150 to 200 mm resulted in an in-plane spatial resolution of 1.2 to 1.8 mm. Section thickness was 5 mm (intersection gap in T1, 1 mm; in T2* [FE], 0. The spin echo was used, and T2* (TR/TE: 600/22; flip angle 30°) images were obtained in the axial, coronal, and sagittal planes with 2 acquisitions. A surface coil (cervical coil, Toshiba) was used for the examinations. Magnetic resonance imaging scans were sent to Vienna without accompanying radiographs and with the diagnosis of a suspected meniscal injury. These were evaluated by an independent radiologist (L.H.), who was not aware of being part of the study at that time and who did not meet the patients. Additionally, the scans were reevaluated independently by the surgeon (C.R.). Menisci were graded on a scale of 1 to 3 according to the character of intrameniscal MRI signal.[66] Only menisci exhibiting an intrameniscal signal communicating with the meniscal articular surface (Grade 3) were considered suitable for surgery.

Whenever MRI confirmed the diagnosis of a torn meniscus, surgery was performed with the patient under general or epidural anesthesia performed by the same surgeon.

Fifty six (46%) female and 65 (54%) male patients with 62 right and 63 left knees were included in the study. Sensitivity, specificity, and accuracy as well as positive and negative predictive values of MRI evaluation of meniscal disease were determined only for patients who were treated surgically.

RESULTS

One hundred twenty-five knee joints were included in the current prospective study. Magnetic resonance imaging evaluation before surgery discarded the clinical diagnosis of a meniscal tear in 43 knee joints (34%) (Table 1).

Eighty patients (64%) required 81 surgical procedures (1 open synovectomy, 80 arthroscopies) (Table 2). There were no infections or neurovascular complications. Forty-five knee joints (36%) were treated conservatively (Table 3). Among these, 10 patients (8%) had refused surgery despite clinical and MRI findings of a meniscal injury.

In 43 knees (34%), MRI evaluation discarded the clinical diagnosis of a meniscal tear (Table 1): in 16 patients (13%), MRI did not confirm the clinical diagnosis of a meniscal tear but showed thickened or irregular synovium and free fluid of the knee joint, pertinent with the diagnosis of synovitis. For

TABLE 1. Alteration in Therapy (N = 43 [34%])

Diagnosis/No. of Patients	Altered Treatment
Synovitis n = 16 (13%)	1 open synovectomy 1 arthroscopic synovectomy
Cartilage damage n = 10 (8%)	1 drilling
Bone bruise injury n = 10 (8%)	2 bone biopsies
Osteochondritis dissecans n = 3 (2%)	1 drilling
Osteonecrosis n = 1	1 core decompression
Medial collateral ligament strain n = 3 (2%)	1 diagnostic arthroscopy

TABLE 2. Surgical Treatment (N = 81 [64%])

Surgical Treatment	No. of Patients
Arthroscopies (n = 80)	
Partial resection medial meniscus	49 (39%)
Medial meniscus repair	5 (4%)
Partial resection lateral meniscus	7 (6%)
Partial resection medial & lateral	3 (2%)
False positive MRI	9 (7%)
Drilling	2 (2%)
Bone biopsies	2 (2%)
Core decompression	1 (1%)
Synovectomy	1 (1%)
Diagnostic arthroscopy	1 (1%)
Open synovectomy (n = 1)	

MRI = magnetic resonance imaging.

these patients, serous effusion was evacuated from the knee joint and led to further serologic analysis. For 3 of these patients, changes corresponding to polyarthritis were found. For 1 patient, villonodular synovitis was suspected from the MRI scans and therefore led to open synovectomy. Nevertheless, the histologic examination merely revealed extensive nonspecific synovitis. For 1 patient, Lyme synovitis was diagnosed from the synovial fluid.

For 10 patients (8%), a diagnosis of articular surface damage was assessed on MRI scans as the only pathologic finding, which was considered responsible for patients' discomfort. For 1 patient, drilling of the intercondylar groove and consequent postoperative nonweightbearing for 6 weeks were conducted.[46] In 3 patients, MRI scans revealed the diagnosis of osteochondritis dissecans, which had not been detected on the radiographs. Two of these patients were treated conservatively. For 1 patient, osteochondritis dissecans was detected on the medial and lateral femoral condyle (Fig 1). Because of persistent pain and failure of a rehabilitation program, arthroscopy was performed. Arthroscopically, the articular surface showed no pathologic change. Softening of the cartilage on the medial femoral condyle within the area of the osteochondritis dissecans was barely detectable; no conspicuous alterations were found on the articular surface of the lateral condyle. On the medial side, the osteochondritis dissecans was located and reamed extraarticularly. No further surgical intervention was performed on the lateral side. After 6 weeks of nonweightbearing and a rehabilitation program, the patient recovered. An MRI control 12 weeks after surgery demonstrated almost complete disappearance of the edema within the medial condyle and complete resolution of the osteochondritis dissecans of the lateral femoral condyle.

TABLE 3. Conservative Treatment (N = 45 [36%])

Nonoperative treatment	No. of Patients
Conservative (n = 35) (28%)	
Synovitis	14 (11%)
Cartilage damage	9 (7%)
Bone bruise injury	8 (6%)
Medial collateral ligament strain	2 (2%)
Osteochondritis dissecans	2 (2%)
Surgery refused (n = 10) (8%)	

In 10 additional patients, MRI evaluation revealed isolated bone bruise injuries without concomitant ligamentous injuries (Fig 2). All but 2 patients had a history of a minor knee trauma. Six of 10 patients developed a serous joint effusion 2 to 4 weeks after injury. In the 2 patients who denied any prior trauma, a malignant process could not be excluded. Consequently, subchondral bone biopsy specimens were obtained from the involved side and examined histologically. Arthroscopy was performed to evaluate the knee joint and to control strict subchondral position of the cannulated drill, which was inserted extraarticularly. Articular surface, ligaments, and menisci were found intact inside the knee joint in both patients. Histologic examination of these 2 patients revealed a repair process of fractured cancellous bone within the same area, which had been interpreted as bone bruise injury on MRI scans.

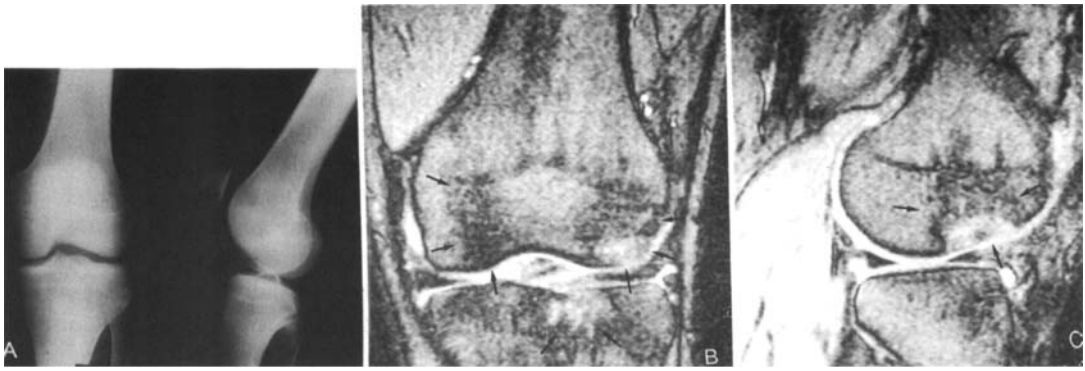

Fig 1A–C. (A) Normal preoperative anteroposterior and lateral radiograph of the knee in a 19-year-old man. (B) Preoperative coronal MRI demonstrates osteochondritis dissecans of the medial and lateral femoral condyle and of the proximal tibia (arrows). (C) Preoperative sagittal MRI showing osteochondritis dissecans of the lateral femoral condyle (arrows).

For a 53-year-old man with the clinical diagnosis of a lateral meniscus injury, MRI additionally revealed osteonecrosis of the medial and lateral femoral condyle, which had not been detectable on the radiographs (Fig 3A–C). At arthroscopy, the articular surface of the knee joint was found intact. The loose part of the lateral meniscus was resected. Osteonecrosis was treated conservatively with nonweightbearing and a rehabilitation program. However, the patient's condition did not improve. Ten weeks after arthroscopy, the patient reported increasing pain and inability to walk. At clinical examination, severe effusion was found. Magnetic resonance imaging demonstrated progression of osteonecrosis, including infarction of the articular surface of both femoral condyles. A core decompression was done under arthroscopic control. The articular surface was found to be covered with granulation tissue. Histologic examination confirmed the diagnosis. At followup after 12 months, signs of osteonecrosis had completely resolved on the MRI scans (Fig 3D). Clinically, the patient had recovered completely.

Fig 2A–C. (A) Normal anteroposterior and lateral radiographs of the knee in a 30-year-old man, who had sustained a minor twisting injury at skiing with the suspected clinical diagnosis of a lateral meniscus injury. (B) Coronal MRI shows a bone bruise injury of the lateral tibial condyle (arrows). (C) Sagittal MRI of the lateral tibial condyle reveals a bone bruise injury (black and white arrows).

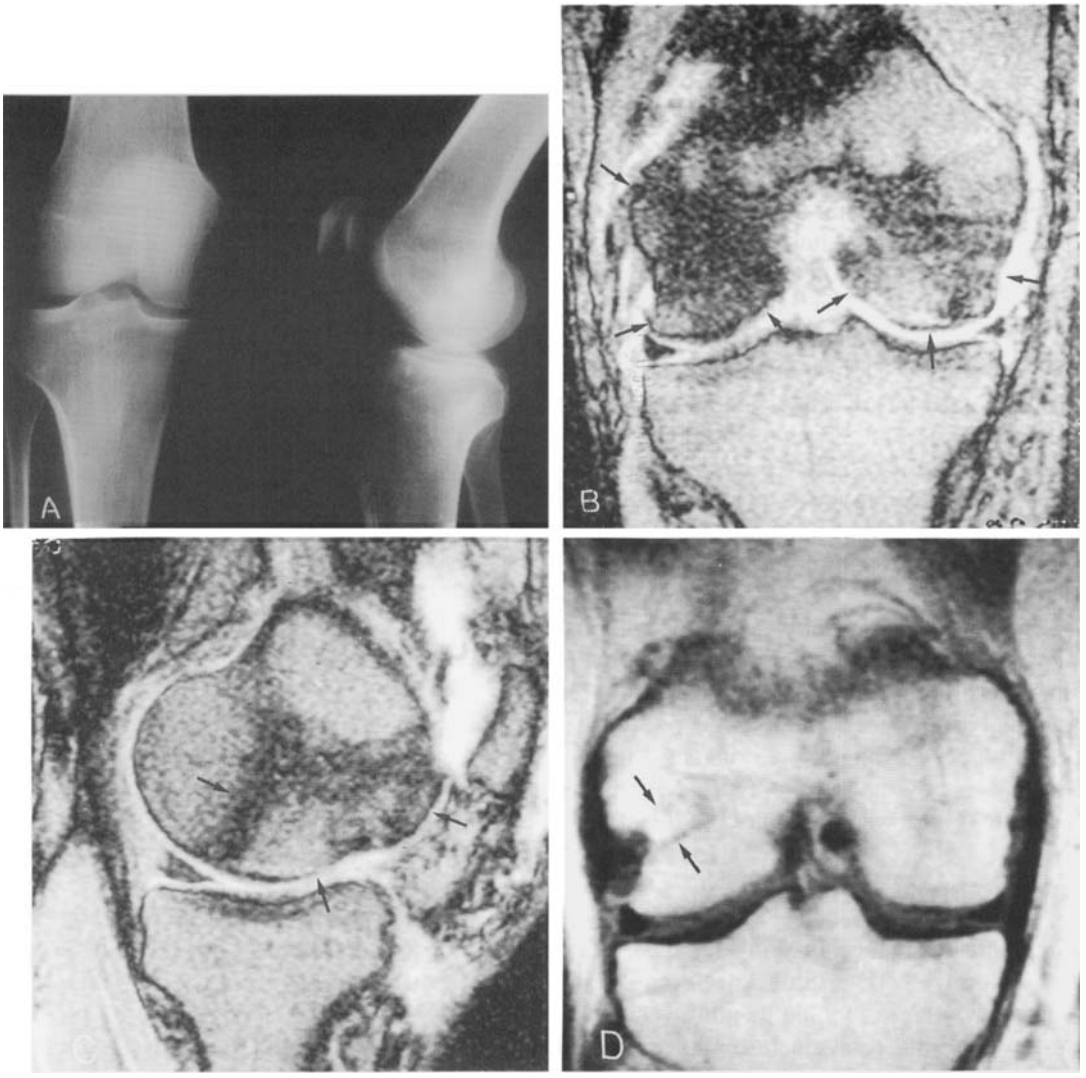

Fig 3A–D. (A) Anteroposterior and lateral radiographs of the knee in a 53-year-old man with the suspected clinical diagnosis of a lateral meniscal injury. (B) Preoperative coronal MRI demonstrates osteonecrosis of the medial and lateral femoral condyle (arrows). (C) Preoperative sagittal MRI shows osteonecrosis of the medial femoral condyle (arrows). (D) Magnetic resonance imaging 1 year after surgery demonstrates complete disappearance of osteonecrosis. Note the remains of the drill canals (arrows).

Because of false MRI results, arthroscopy had retrospectively not been indicated for 9 patients. For 5 of these patients, the only pathologic finding was articular surface damage, which did not require any further surgical measures. For 2 additional patients, incomplete disruptions of the anterior cruciate ligament appeared similar to meniscal tears on MRI scans. At arthroscopy, some fibers of the anterior cruciate ligament were found captured in the medial compartment of the knee joint without biomechanical consequences for joint stability or limitation of range of motion. For 1 patient synovitis

and for another gout arthritis were detected at arthroscopy as the only pathologic findings. In both cases, the results of serologic blood analysis before arthroscopy had been negative.

For 1 patient, diagnostic arthroscopy was done. Clinical examination indicated a medial meniscal injury, but MRI revealed a disruption of the inner layer of the medial collateral ligament. The patient developed a flexion contracture and therefore was reevaluated by MRI; again the findings were consistent with that of intact menisci. Because of continuing tenderness of the medial compartment and a resistant flexion contracture of 10°, arthroscopy was performed despite negative results on both MRI examinations; nevertheless, no pathologic alterations could be found.

Sensitivity, specificity, accuracy, and positive and negative predictive values of MRI in determining meniscal disease could be evaluated only for patients who had undergone surgery. Magnetic resonance imaging evaluations by the radiologist (L.H.) and the surgeon (C.R.) were compared (Table 4).

TABLE 4. Sensitivity, Specificity and Accuracy Statistics

MRI	%
Sensitivity	
Medial meniscus	93%
Lateral meniscus	78%
Specificity	
Medial meniscus	74%
Lateral meniscus	89%
Accuracy	
Medial meniscus	89%
Lateral meniscus	88%
Negative predictive value	
Medial meniscus	81%
Lateral meniscus	97%
Positive predictive value	
Medial meniscus	90%
Lateral meniscus	47%

MRI = magnetic resonance imaging.

DISCUSSION

Magnetic resonance imaging has been used increasingly to determine knee joint disorders. Advantages include its noninvasive nature, the ability to evaluate the knee joint in multiple planes, the absence of ionizing radiation, and the capacity to evaluate all structures and surrounding soft tissue of the knee joint.[2,7,11,12,20,51–53,56,75] Magnetic resonance imaging may be limited by costs, by misinterpretation, and by errors due to technical shortcomings.[1,17,22,39,45,49,62,69,70,73–75]

The purpose of the current study was to evaluate the influence of preoperative MRI on the decision for surgery whenever a meniscus injury was suspected. From a total of 125 consecutive knees, the number of arthroscopies was reduced in 28% of all cases and therapy was altered in 34% of all knees because of the MRI findings. This percentage is consistent with that arrived at by Spiers et al,[62] who calculated a possible 29% reduction in the number of arthroscopies in 58 patients, without missing any significant meniscal lesion, if they would have accepted preoperative MRI findings.

Magnetic resonance imaging has been found to be effective in evaluating diseases of the synovium of the knee joint.[23,25,28,30,31,33,36,37,58,60,63,75,76] In the current study, MRI evaluation revealed synovitis in 16 patients (13%). Most authors report only a few cases of synovial diseases determined by MRI.[23,28,31,33,36,37,60,63,76] In a study by Singson et al,[60] only 12 of 550 knees with significant joint effusion showed thickened or irregular synovium. Of these, the cause of synovitis was proven in 10 patients. In the current study, Lyme synovitis was diagnosed in only 1 patient.

Magnetic resonance imaging has been used to evaluate the status of articular cartilage of the knee joint.[40] Sensitivity of MRI for depicting cartilage lesions has been reported as dependent on the extent of the chondral lesion. Advanced stages of chon-

dromalacia are visualized with a high sensitivity.[2,6,21,40,41,54,56] This finding contrasts the reports of others, who have stated that cartilaginous loose bodies and rice bodies as well as defects of articular cartilage were not well identified on MRI scans.[17,45,62] In the current study, in 10 patients (8%), articular cartilage damage identified on MRI scans was considered causal for knee joint discomfort and had been incorrectly diagnosed as a meniscal injury at clinical examination. Surgery was performed for only 1 patient because of the extent of the lesion seen on MRI and the impairment of pain and swelling and failure of rehabilitation. Although arthroscopy is highly accurate in the determination of chondral lesions,[41,48,56,62] therapy usually remains conservative. In the current study, arthroscopy remained a mere diagnostic intervention for 9 patients, who had had false positive MRI findings of a torn meniscus. For 5 of these patients, only chondral lesions were found at arthroscopy.

For 3 patients, MRI detected osteochondritis dissecans, which had not been visible on radiographs and which had been considered to be meniscal injuries. For 1 patient, osteochondritis dissecans of the medial femoral condyle was reamed from an extraarticular approach, whereas osteochondritis dissecans of the lateral femoral condyle was left alone.[9,18]

Mink and Deutsch[38] defined bone bruise on T1-weighted images as a geographic and nonlinear area of signal loss involving the subcortical bone due to trauma. Bone bruise injuries have been reported with a frequency of up to 79% in association with anterior cruciate ligament injuries but also in association with other meniscoligamentous injuries.[32,38,68,72] However, Mink and Deutsch[38] additionally noted that 7 of the 30 bruises were in patients with stable knees at examination. Tung et al[68] reported bone bruises in 5 of 53 cases involving patients with normal anterior cruciate ligaments. In the current study, MRI evaluation revealed an isolated bone bruise injury in 10 patients (8%) without concomitant ligamentous injuries. Further, no bone bruise injuries associated with a meniscal injury were observed. Clinical significance of bone bruise injuries has been discussed in the literature, but treatment has not been established.[38,68,72] In the current study, 2 patients reported no prior trauma, and a malignant process could not be excluded. Consequently, subchondral bone biopsy specimens were obtained from the involved side. Histologic examination revealed a subcortical fracture of cancellous bone and a repair process within the same area which had been interpreted as bone bruise injury on MRI scans. At clinical examination, isolated bone bruise injuries should be considered, because such injuries may be misinterpreted as meniscal injuries.

Magnetic resonance imaging has been used to delineate osteonecrosis after spontaneous occurrence in association with the use of steroids, after chemotherapy, after arthroscopic surgery, and with systemic diseases.[3–6,8,13,29,34,43,44,51,55,56,77] Usually, diagnosis of osteonecrosis has been based on radiographic findings. Magnetic resonance imaging and other imaging techniques were used to describe the nature of the disease.[4,5,13,29,34,44,55,77] In contrast to the reports mentioned above, diagnosis of spontaneous osteonecrosis was based exclusively on MRI evaluation in the current study. Similarly, as reported by Forst et al,[16] radiographs did not show any signs of osteonecrosis. The presence of a lateral meniscal tear led to inadequate treatment of osteonecrosis, because initially only the torn portion of the lateral meniscus was resected. Successful treatment of spontaneous osteonecrosis of the knee joint and of the femoral head by core decompression has been reported before.[14,16,24]

Effectiveness of MRI for detecting meniscal tears visualized at arthroscopy has been reported within a range of 45% to 100%.[1,11,12,15,17,27,32,35,45,49,50,52,59,61] In the current study, sensitivity of the MRI compared with arthroscopic findings was 93% for the medial and 78% for the lateral meniscus;

specificity was 74% for the medial and 89% for the lateral meniscus; and accuracy was 89% for the medial and 88% for the lateral meniscus. These findings are consistent with the data reported earlier.[1,11,12,15,32,35,45,49,52,61] Accurate assessment of meniscal disease may be affected adversely by variations of anatomic structures of the knee joint, which may appear abnormal on MRI scans.[22,71,73,74] A variety of technologies and techniques have been described to influence the diagnostic accuracy of MRI.[11,15,19,38,39,42,45,50,69] False positive scan results have been reported before.[11,15,32,35,38,45,47,49,59] Crues et al[11] noted that of 145 menisci exhibiting a Grade 1 or Grade 2 signal, 89% were found to be normal at surgery; further, of 123 menisci exhibiting a Grade 3 signal, 94% had tears at surgery. In the current study, there were 9 false positive MRI findings; at arthroscopy, the menisci were found to be intact.

A variety of other pathologic alterations can be visualized on MRI scans but did not occur among this collective.[10,26,56,75] Therefore, it cannot be concluded from the current study that such changes might not be misinterpreted as meniscal injuries at clinical examination. Magnetic resonance imaging improved diagnostic accuracy of knee joint disorders in the current study. Nevertheless, the authors believe that MRI should not replace careful clinical examination and complete evaluation of a patient's history. However, indication for MRI before arthroscopy of the knee should be established in all cases in which clinical diagnosis has been reduced to a suspected meniscal injury.

CONCLUSION

In the current prospective study, it was shown that MRI examination of suspected meniscus injuries before the scheduled operation could reduce the total number of arthroscopies in 28% of cases. Only for 9 patients (7%) was arthroscopy retrospectively considered to be a diagnostic intervention. Magnetic resonance imaging additionally has proven to be valuable in the detection of pathologic changes located beneath the articular surface or in extraarticular spaces. These remain hidden during arthroscopy and on radiographs and can mimic meniscal injuries. Because of MRI findings, therapy was altered in 43 knees (34%).

References

1. Barronian AD, Zoltan JD, Kirk AB: Magnetic resonance imaging of the knee: Correlation with arthroscopy. Arthroscopy 5:187–191, 1989.
2. Beltran J, Noto AM, Mosure JC, et al: The knee: Surface coil MR imaging at 1.5 T. Radiology 159:747–751, 1986.
3. Bjoerkengren AG, AlRowaih A, Lindstrand A, et al: Spontaneous osteonecrosis of the knee: Value of MR imaging in determining prognosis. AJR Am J Roentgenol 154:331–336, 1990.
4. Bootsveld VK, Siewert B, Reiser M, Koch W: Spontane Nekrose des Femurkondylus—Neuartige Befunde bei T2-gewichteten Spinecho-Sequenzen und Gradientenecho-Untersuchungen. RoFo Fortschr Geb Roentgenstr Nuklearmed 156:360–364, 1992.
5. Brahme SK, Fox JM, Ferkel RD, et al: Osteonecrosis of the knee after arthroscopic surgery: Diagnosis with MR imaging. Radiology 178:851–853, 1991.
6. Burk DL, Kanal E, Brunberg JA, et al: 1.5-T surface-coil MRI of the knee. AJR Am J Roentgenol 147:293–300, 1986.
7. Burk DL, Dalinka MK, Kanal E, et al: Meniscal and ganglion cysts of the knee: MR evaluation. AJR Am J Roentgenol 150:331–336, 1988.
8. Chancelier MD, Helenon O, Page B, et al: Osteonecroses aseptiques des genoux induites par les corticoides. J Radiology 73:191–201, 1992.
9. Clanton TO, DeLee JC: Osteochondritis dissecans. Clin Orthop 167:50–64, 1982.
10. Coral A, Van Holsbeeck M, Adler RS: Imaging of meniscal cyst of the knee in three cases. Skeletal Radiol 18:451–455, 1989.
11. Crues JV, Mink J, Levy TL, Lotysch M, Stoller DW: Meniscal tears of the knee: Accuracy of MR imaging. Radiology 164:445–448, 1987.
12. Crues JV, Ryu R, Morgan FW: Meniscal pathology. The expanding role of magnetic resonance imaging. Clin Orthop 252:80–87, 1990.
13. Dey HM, Jaros RH, Swan CS, Kassamali H: Spontaneous femoral osteonecrosis: Correlation with MRI. Clin Nucl Med 13:756–758, 1988.
14. Ficat RP: Idiopathic bone necrosis of the femoral head—early diagnosis and treatment. J Bone Joint Surg 67B:3–9, 1985.
15. Fischer SP, Fox JM, Del Pizzo W, et al: Accuracy of diagnosis from magnetic resonance imaging of the knee. J Bone Joint Surg 73A:2–10, 1991.
16. Forst J, Heller KD, Adam GB: Markraumbohrung (Core-Dekompression) bei Morbus Ahlbaeck. RoFo

Fortschr Geb Roentgenstr Neuen Bildgeb Verfahr 161:142–146, 1994.
17. Grevitt MP, Pool CJF, Bodley RN, Savage PE: Magnetic resonance imaging of the knee: Initial experience in a district general hospital. Injury 23: 410–412, 1992.
18. Guhl JF: Arthroscopic treatment of osteochondritis dissecans. Clin Orthop 167:65–74, 1982.
19. Harms SE, Flamig DP, Fisher CF, Fulmer JM: New method for fast MR imaging of the knee. Radiology 173:743–750, 1989.
20. Hartzman S, Reicher MA, Bassett LW, et al: MR imaging of the knee. Part II. Chronic disorders. Radiology 162:553–557, 1987.
21. Hayes CW, Sawyer RW, Conway WF: Patellar cartilage lesions: In vitro detection and staging with MR imaging and pathologic correlation. Radiology 176:479–483, 1990.
22. Herman LJ, Beltran J: Pitfalls in MR imaging of the knee. Radiology 167:775–781, 1988.
23. Holzmueller W, Bohndorf K, Mueller JM, Walter M, Brenner U: Die pigmentierte villo-nodulaere synovialitis. Chirurg 57:514–516, 1986.
24. Hungerford DS: Die Rolle der "Core-Dekompression" als Behandlungsmethode der ischaemischen Femurkopfnekrose. Orthopade 19: 219–223, 1990.
25. Jelinek JS, Kransdorf MJ, Utz JA, et al: Imaging of pigmented villonodular synovitis with emphasis on MR imaging. AJR Am J Roentgenol 152:337–342, 1989.
26. Jelinek JS, Kransdorf MJ, Shmookler BM, Aboulafia AA, Malawer MM: Giant cell tumor of the tendon sheath: MR findings in nine cases. AJR Am J Roentgenol 162:919–922, 1994.
27. Jerosch J, Lahm A, Castro WHM, Assheuer J: Kernspin- und Computertomographie bei Meniskusverletzungen des Kniegelenkes. Unfallchirurg 94: 53–58, 1991.
28. Katz DS, Levinsohn EM: Pigmented villonodular synovitis of the sequestered suprapatellar bursa. Clin Orthop 306:204–208, 1994.
29. Kelman GJ, Williams GW, Colwell CW, Walker RH: Steroid-related osteonecrosis of the knee. Clin Orthop 257:171–176, 1990.
30. Koenig H, Sieper J, Wolf KJ: Rheumatoid arthritis: Evaluation of hypervascular and fibrous pannus with dynamic MR imaging enhanced with Gd-DTPA. Radiology 176:473–477, 1990.
31. Kottal RA, Vogler JB, Matamoros A, Alexander AH, Cookson JL: Pigmented villonodular synovitis: A report of MR imaging in two cases. Radiology 163:551–553, 1987.
32. LaPrade RF, Burnett QM, Veenstra MA, Hodgman CG: The prevalence of abnormal magnetic resonance imaging findings in asymptomatic knees. Am J Sports Med 22:739–745, 1994.
33. Limbird TJ: Arthroscopic synovectomy in sarcoid synovitis. Arthroscopy 9:599–601, 1993.
34. Madsen PV, Andersen G: Multifocal osteonecrosis related to steroid treatment in a patient with ulcerative colitis. Gut 35:132–134, 1994.
35. Mandelbaum BR, Finerman GA, Reicher MA, et al: Magnetic resonance imaging as a tool for evaluation of traumatic knee injuries. Am J Sports Med 14:361–370, 1986.
36. Mandelbaum BR, Grant TT, Hartzman S, et al: The use of MRI to assist in diagnosis of pigmented villonodular synovitis of the knee joint. Clin Orthop 231:135–139, 1988.
37. Meehan PL, Daftari T: Pigmented villonodular synovitis presenting as a popliteal cyst in a child. J Bone Joint Surg 76A:593–595, 1994.
38. Mink JH, Deutsch AL: Occult cartilage and bone injuries of the knee: Detection, classification, and assessment with MR imaging. Radiology 170: 823–829, 1989.
39. Mirowitz SA: Motion artifact as a pitfall in diagnosis of meniscal tear on gradient reoriented MRI of the knee. J Comput Assist Tomogr 18:279–282, 1994.
40. Modl JM, Sether LA, Haughton VM, Kneeland JB: Articular cartilage: Correlation of histologic zones with signal intensity at MR imaging. Radiology 181:853–855, 1991.
41. Ochi M, Sumen Y, Kanda T, Ikuta Y, Itoh K: The diagnostic value and limitation of magnetic resonance imaging on chondral lesions in the knee joint. Arthroscopy 10:176–183, 1994.
42. Peterfy CG, Janzen DL, Tirman PFJ, et al: "Magic angle" phenomenon: A cause of increased signal in the normal lateral meniscus on short-TE images of the knee. AJR Am J Roentgenol 163:149–154, 1994.
43. Pieters R, Van Brenk I, Veerman AJP, et al: Bone marrow magnetic resonance studies in childhood leukemia. Evaluation of osteonecrosis. Cancer 60:2994–3000, 1987.
44. Pollack MS, Dalinka MK, Kressel HY, Lotke PA, Spritzer CE: Magnetic resonance imaging in the evaluation of suspected osteonecrosis of the knee. Skeletal Radiol 16:121–127, 1987.
45. Polly DW, Callaghan JJ, Sikes RS, et al: The accuracy of selective magnetic resonance imaging compared with the findings of arthroscopy of the knee. J Bone Joint Surg 70A:192–198, 1988.
46. Pridie KH: A method of resurfacing osteoarthritic knee joints. J Bone Joint Surg 41B:618–619, 1959.
47. Quinn SF, Brown TF: Meniscal tears diagnosed with MR imaging versus arthroscopy: How reliable a standard is arthroscopy? Radiology 181:843–847, 1991.
48. Rangger C, Klestil T, Gloetzer W, Kemmler G, Benedetto KP: Osteoarthritis after arthroscopic partial meniscectomy. Am J Sports Med 23:240–244, 1995.
49. Raunest J, Oberle K, Loehnert J, Hoetzinger H: The clinical value of magnetic resonance imaging in the evaluation of meniscal disorders. J Bone Joint Surg 73A:11–16, 1991.
50. Reeder JD, Matz SO, Becker L, Andelman SM: MR imaging of the knee in the sagittal projection. AJR Am J Roentgenol 153:537–540, 1989.
51. Reicher MA, Bassett LW, Gold RH: High-resolution magnetic resonance imaging of the knee joint: Pathologic correlations. AJR Am J Roentgenol 145: 903–909, 1985.

52. Reicher MA, Hartzman S, Bassett LW, et al: MR imaging of the knee. Part I. Traumatic disorders. Radiology 162:547–551, 1987.
53. Reicher MA, Hartzman S, Duckwiler GR, et al: Meniscal injuries: Detection using MR imaging. Radiology 159:753–757, 1986.
54. Reiser MF, Bongartz G, Erlemann R, et al: Magnetic resonance in cartilaginous lesions of the knee joint with three-dimensional gradient-echo imaging. Skeletal Radiol 17:465–471, 1988.
55. Rudberg U, Ahlbaeck SO, Uden R, Rydberg J: Radiocolloid uptake in spontaneous osteonecrosis of the knee. Clin Orthop 287:25–29, 1993.
56. Sartoris DJ, Resnick D: MR imaging of the musculoskeletal system: Current and future status. AJR Am J Roentgenol 149:457–467, 1987.
57. Selesnick FH, Noble HB, Bachman DC, Steinberg FL: Internal derangement of the knee: Diagnosis by arthrography, arthroscopy, and arthrotomy. Clin Orthop 198:26–30, 1985.
58. Senac MO, Deutsch D, Bernstein BH, et al: MR imaging in juvenile rheumatoid arthritis. AJR Am J Roentgenol 150:873–878, 1988.
59. Silva I, Silver DM: Tears of the meniscus as revealed by magnetic resonance imaging. J Bone Joint Surg 70A:199–202, 1988.
60. Singson RD, Feldman F, Staron R, Kiernan H: MR imaging of displaced bucket-handle tear of the medial meniscus. AJR Am J Roentgenol 156:121–124, 1991.
61. Solomon SL, Totty WG, Lee JKT: MR imaging of the knee: Comparison of three-dimensional FISP and two-dimensional spin-echo pulse sequences. Radiology 173:739–742, 1989.
62. Spiers ASD, Meagher T, Ostlere SJ, Wilson DJ, Dodd CAF: Can MRI of the knee affect arthroscopic practice? J Bone Joint Surg 75B:49–52, 1993.
63. Spritzer CE, Dalinka MK, Kressel HY: Magnetic resonance imaging of pigmented villonodular synovitis: A report of two cases. Skeletal Radiol 16: 316–319, 1987.
64. Steinbrich W, Beyer D, Friedmann G, et al: MR des Kniegelenkes. RoFo Fortschr Geb Roentgenstr Nuklearmed 143:166–172, 1985.
65. Steinbrueck K, Wiehmann JC: Untersuchung des Kniegelenks. Z Orthop Ihre Grenzgeb 126:289–295, 1988.
66. Stoller DW, Martin C, Crues JV, Kaplan L, Mink JH: Meniscal tears: Pathologic correlation with MR imaging. Radiology 163:731–735, 1987.
67. Strobl M, Stedtfeld HW: Meniskusdiagnostik. In Strobl M, Stedtfeld HW (eds). Diagnostik des Kniegelenkes. Ed 2. Berlin, Springer-Verlag 166–182, 1991.
68. Tung GA, Davis LM, Wiggins ME, Fadale PD: Tears of the anterior cruciate ligament: Primary and secondary signs at MR imaging. Radiology 188:661–667, 1993.
69. Turner DA, Rapoport MI, Erwin WD, McGould M, Silvers RI: Truncation artifact: A potential pitfall in MR imaging of the menisci of the knee. Radiology 179:629–633, 1991.
70. Tyrrell RL, Gluckert K, Pathria M, Modic MT: Fast three-dimensional MR imaging of the knee: Comparison with arthroscopy. Radiology 166:865–872, 1988.
71. Vahey TN, Bennett HT, Arrington LE, Shelbourne KD, Ng J: MR imaging of the knee: Pseudotear of the lateral meniscus caused by the meniscofemoral ligament. AJR Am J Roentgenol 154:1237–1239, 1990.
72. Vellet AD, Marks PH, Fowler PJ, Munro TG: Occult posttraumatic osteochondral lesions of the knee: Prevalence, classification, and short-term sequelae evaluated with MR imaging. Radiology 178: 271–276, 1991.
73. Watanabe AT, Carter BC, Teitelbaum GP, Seeger LL, Bradley WG: Normal variations in MR imaging of the knee: Appearance and frequency. AJR Am J Roentgenol 153:341–344, 1989.
74. Watanabe AT, Carter BC, Teitelbaum GP, Bradley WG: Common pitfalls in magnetic resonance imaging of the knee. J Bone Joint Surg 71A:857–862, 1989.
75. Weissman BN, Hussain S: Magnetic resonance imaging of the knee. Rheum Dis Clin North Am 17:637–668, 1991.
76. Whitten CG, Moore TE, Yuh WTC, et al: The use of intravenous gadopentetate dimeglumine in magnetic resonance imaging of synovial lesions. Skeletal Radiol 21:215–218, 1992.
77. Zelder VJ, Benning R, Walthers E: Die spontane aseptische Osteonekrose des Knies (Morbus Ahlbaeck). RoFo Fortschr Geb Roentgenstr Nuklearmed 161:139–141, 1994.