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Magnetic Resonance Imaging of Total Knee Arthroplasty

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Evaluation of painful total knee arthroplasty can be clinically difficult, and traditional imaging techniques such as conventional radiographs, arthrography, and bone scintigraphy are limited by poor contrast resolution and specificity. Traditional magnetic resonance imaging techniques often are nondiagnostic because of significant metal artifact. Forty-one patients (46 knees) had magnetic resonance imaging, tailored to reduce metallic susceptibility artifact, after total knee arthroplasty, and the findings and clinical and surgical followup were reviewed. All studies consistently showed the integrity of the periprosthetic soft tissues. Magnetic resonance imaging findings led to surgical or other therapeutic interventional procedures in 20 patients, and influenced clinical treatment in all patients. Optimized magnetic resonance imaging, in which the metallic artifact is diminished, is a clinically useful adjunct to traditional imaging techniques in evaluation of patients with painful total knee arthroplasty.

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Traditionally, magnetic resonance imaging (MRI) has played a limited role in the evaluation of patients after arthroplasty, primarily because of the metallic susceptibility artifact, which is the different susceptibility of the soft tissues and metallic implants to become magnetized when exposed to a high magnetic field. Imaging evaluation of the painful knee after arthroplasty typically has been limited to conventional radiographs,[4,8] arthrography, and nuclear scintigraphy, yet the findings on such images often are nonspecific,[1,6] or the test is insensitive to pathologic features.[13] Arthrography, moreover, is an invasive test, and essentially is limited to diagnosing infection in the joint or loosening of the prosthesis; the periprosthetic soft tissues cannot be evaluated. More recently, given improved transducer technology, ultrasound has showed promise in evaluating the soft tissues about the knee, including the polyethylene component[19]; however, this technique is highly operator-dependent and possible intraosseous pathologic features (fractures, cement failure, osteolysis) cannot be discerned.

Modifications of traditional MR sequences, using the commercially-available software found on most high field strength units, can be used to circumvent much of the artifact generated by joint prostheses. These have proven useful in evaluating the spine after surgery,[10,14,17] and earlier works have suggested their useful-

ness in reducing susceptibility artifact from other orthopaedic hardware,[2,3,9,12,16] including total hip arthroplasty[18] and shoulder arthroplasty.[15]

The current authors reviewed their experience with MRI of total knee arthroplasty, evaluated the conspicuity of the periprosthetic soft tissue and osseous components, and correlated findings with their influence on clinical treatment.

MATERIALS AND METHODS

A retrospective review of all images of patients with total knee arthroplasty who had MRI examination at the authors' institution from 1996 to 2001 was done followed by a chart review. Variables including patient age, indications for initial joint replacement, clinical assessment before and after MRI, and revision surgery, if done, then were recorded.

Magnetic resonance imaging scans were acquired with a 1.5 T superconducting magnet (Horizon LX; GE Medical Systems, Milwaukee, WI). The patients were imaged supine, and a standard send-receive linear or phased-array extremity coil (phased-array extremity coil, Med Rad, Indianola, PA) was used. Sagittal inversion recovery images were obtained with an inversion time of 150 ms, a repetition time (TR) of 4000 to 5000 ms, an echo time (TE) of 17 ms (4000–5000/17), a 256 × 224 matrix, a 20- to 22-cm field of view, 4-mm thick sections with no intersection gap, and two excitations. The receiver bandwidth was 32 kHz. Sagittal fast spin echo images were obtained with a TR/TE of 4000 to 5000/34, 12- to 18-echo train length, 3.5-mm slice thickness with no interslice gap, 32- to 83-kHz bandwidth, 512 × 288 matrix, 18-cm field of view, 4 to 5 excitations. Axial and coronal fast spin echo images were obtained with similar parameters, but with a field of view of 16 cm and slice thickness of 3 mm with no interslice gap. Standard nonweightbearing anteroposterior (AP), lateral, and Merchant radiographs were taken in all patients within 3.5 months of the MRI examination (range, 0–99 days; average, 49.5 days).

RESULTS

Forty-one patients with total knee replacements (46 knees) had MRI examination between 1996 and 2001 at the authors' institution. Patient's ages ranged from 34 to 85 years. There were 26 women and 15 men. The majority of patients (n = 38) initially had total knee arthroplasty for degenerative joint disease (43 knees). Other indications for primary joint replacement included osteosarcoma (n = 1), Ehlers Danlos syndrome (n = 1), and pigmented villonodular synovitis (n = 1). Prospective and retrospective evaluation of conventional plain radiographs were noncontributory regarding the patients' symptoms, in that there was no radiographic evidence for infection, loosening of the prosthesis, or fracture.

In all patients, the periprosthetic soft tissues, including the collateral ligamentous complexes, popliteus, patellar, and quadriceps tendons could be evaluated on MRI (Fig 1). The more recent MRI examinations (after 1998 [n = 41]), with higher receiver bandwidths and decreased interecho spacing, showed reduced metallic susceptibility artifact generated by the prosthesis, subjectively increasing the conspicuity of the periprosthetic soft tissues, the polyethylene component, and the metal-bone interface (Fig 1).

Magnetic resonance imaging findings were varied and often were multiple in the same patient (Table 1). The most common MRI finding postoperatively in the series was dense scar in the infrapatellar fat pad (n = 7). In three of these cases, the patients returned to the operating room for surgical debridement or manipulation under anesthesia, and two of the three patients had symptoms of mechanical locking (n = 1) or flexion contracture (n = 1).

Particle reaction with inflammatory synovitis, with or without gross osteolysis, was observed in seven patients, four of whom returned to the operating room. One of these patients who had revision surgery 1.5 months after the MRI examination had multifocal cystic changes about the femoral component, prospectively diagnosed on MRI as osteolysis, and had significant osteolysis confirmed about the femoral component at surgery (Fig 2). Plain radiographs failed to show any suspicious lucencies suggestive of osteolysis in any of these patients. The remaining three patients

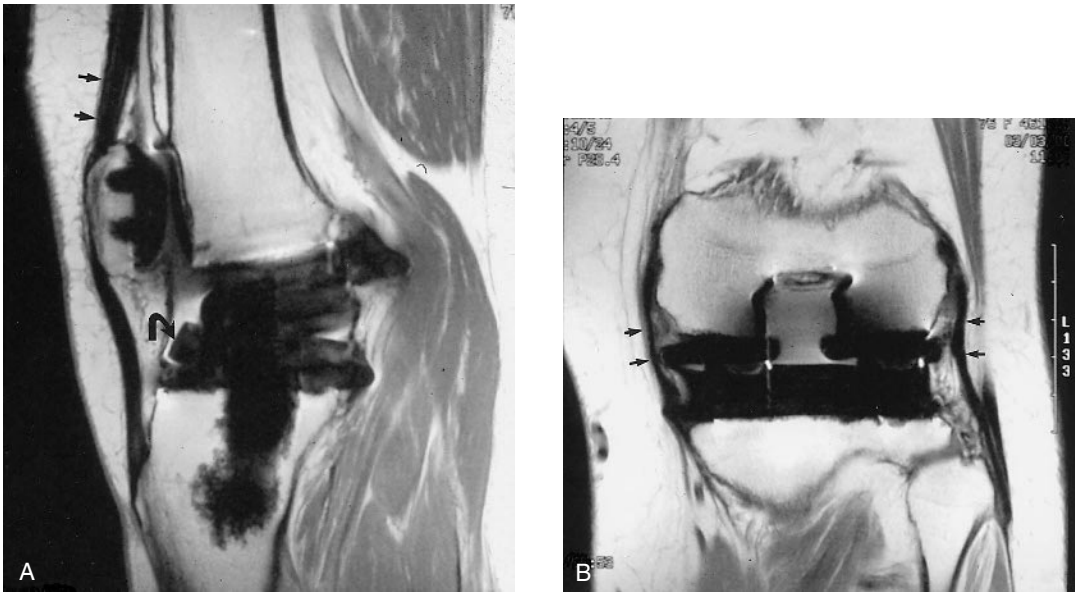

Fig 1A–B. (A) A sagittal fast spin echo sequence in a 77-year-old woman obtained 8 years after total knee arthroplasty shows the normal postoperative appearance. The normal slight posterior tilt of the polyethylene component (curved arrow), and the intact extensor mechanism (small arrows) are shown. (B) A coronal fast spin echo sequence shows the intact medial and lateral collateral ligamentous complexes (small arrows).

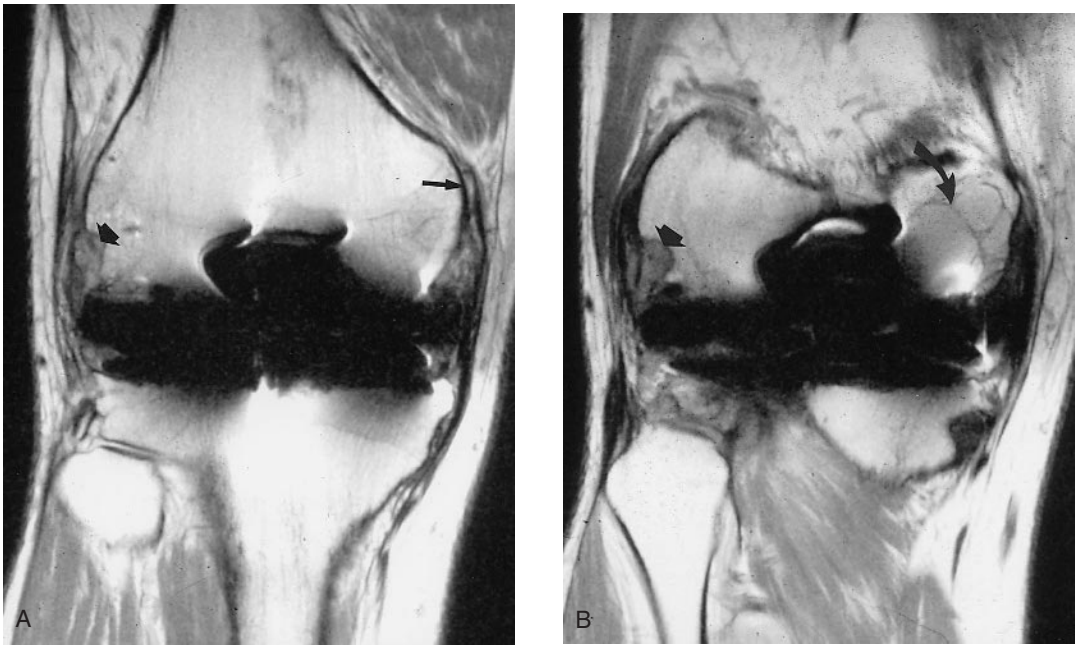

Fig 2A–B. (A) A coronal image of a 43-year-old man with pain and instability taken 8 years after total knee arthroplasty shows a high-grade tear of the proximal medial collateral ligament (long arrow) and absence of the popliteus tendon attachment (short arrow). (B) A slightly more posterior image again shows disruption of the popliteus tendon (short arrow), and a multilobular cystic focus in the posteromedial femoral condyle, consistent with focal osteolysis (curved arrow). The patient subsequently had a total knee revision, at which time a large area of osteolysis in the posterior aspect of the medial femoral condyle, with loss of almost the entire posterior femoral condyle, was seen and grafted. Conventional radiographs failed to show the lesion.

TABLE 1. Selected Examples of Positive Magnetic Resonance Imaging Findings

Patient	Clinical Findings	Conventional Radiographs	MRI Findings	Subsequent Clinical Treatment
1	Nonfocal pain	Negative	Osteolysis, partial tear MCL	TKA revision; significant osteolysis confirmed about femoral component
2	MCL insufficiency	Valgus stress films—Negative	Nonacute tear MCL, quadriceps dehiscence	TKA revision
3	Decreased ROM: posterior pain, ? popliteal cyst	Negative	Inflammatory synovitis	Given NSAIDs, patient's pain improved
4	Swelling, drainage, ? infection	Negative	Intraosseous and soft tissue polyethylene granulomas	Curettage of granulomas; aspiration negative for infection
5	Pain	Negative	Inflammatory synovitis	Treated conservatively
6	Pain, decreased ROM	Negative	Insertional patellar tendinosis	Manipulation under anesthesia for decreased ROM
7	Swelling with prior history of PVNS	Negative	Recurrent PVNS with mass effect on neurovascular structures in popliteal fossa	Cryosurgery
8	Pain	Negative	Prepatellar bursitis	Treated conservatively
9	Pain, decreased ROM	Negative	Scar posterior capsule	Arthroscopic debridement and manipulation under anesthesia
10	Quadriceps tenderness	Negative	Partial tear quadriceps	Treated conservatively
11	Lateral pain; ? peroneal nerve disorder	Negative	No scar encasement of peroneal nerve; suprapatellar scar	Lateral release, debridement of suprapatellar scar
12	Locking	Negative	Dense scar infrapatellar fat	Surgical debridement, symptoms resolved
13	Flexion contracture	Negative	Scar tethering the posterior margin of the extensor mechanism	Surgical debridement, ROM increased
14	Pain	Negative	Nonacute partial patellar tendon tear	Treated conservatively
15	Pain, instability	Negative	High-grade tear MCL, disruption of the popliteus tendon, focal osteolysis in the femur	TKA revision with constrained implant; large focus of osteolysis curettaged and grafted
16	Pain	Negative	Disrupted iliotibial band	Treated conservatively
17	Pain	Negative	Nonacute proximal MCL tear	Treated conservatively
18	Limited ROM	Negative	Fat pad scar tethering patella or tibia	Surgical debridement of scar tissue
19	Swelling; ? infection	Negative	Septic arthritis; hematoma medial head of the gastrocnemius	TKA removal for infection with staged reimplantation
20	Pain	Heterotopic bone seen laterally	Inflammatory synovitis; heterotopic ossification deviating popliteus muscle-tendon junction	Treated conservatively

(*continues*)

TABLE 1. Selected Examples of Positive Magnetic Resonance Imaging Findings (*Continued*)

Patient	Clinical Findings	Conventional Radiographs	MRI Findings	Subsequent Clinical Treatment
21	? Recurrent PVNS	Negative	Aggressive tumor of fibrous origin originated from PVNS	Histologic analysis showed malignant fibrous histiocytoma; patient died from lung metastases
22	Patellar instability	Negative	Tear medial retinaculum, patellofemoral ligament, distal VMO and quadriceps	Revision of the patellar component and retinacular reconstruction

MCL = medial collateral ligament; PVNS = pigmented villonodular synovitis; TKA = total knee arthroplasty; ROM = range of motion; VMO = vastus medialis oblique; NSAIDs = nonsteroidal antiinflammatories

had polyethylene granulomas curettaged; one of the granulomas recurred 4 years after initial curettage as a large anterior soft tissue mass that had to be excised surgically.

Other findings included medial collateral ligament tears (n = 5) and various tendon injuries, including one quadriceps dehiscence, one popliteus disruption (Fig 2), one distal iliotibial band disruption, one partial tear of the quadriceps tendon, and one patellar tendon rupture. A medial patellar retinacular injury secondary to chronic instability was seen in a patient with Ehlers-Danlos syndrome; the patellar tendon rupture and patellar retinaculum injury were treated surgically.

Fluid collections also were common, with one hemarthrosis compressing the posterior neurovascular bundle (n = 1) and one distending the anterior pseudocapsule, causing a mass effect on a recently placed anterior latissimus dorsi muscle flap. One patient in the series had recurrent pigmented villonodular synovitis seen on MRI scans and eventually had total radical synovectomy and cryosurgical resection (Fig 3).

DISCUSSION

The evaluation of patients with nonspecific knee pain after total knee arthroplasty often is challenging, even in the hands of an experienced orthopaedic surgeon. Diagnostic etiologies are varied and include infection, prosthetic loosening, periprosthetic soft tissue, or intraosseous disorders. Conventional imaging options available to the clinician have been limited to conventional radiographs, arthrography, and nuclear medicine bone scans. Although plain radiographs provide analysis of the gross alignment of the prosthesis and the

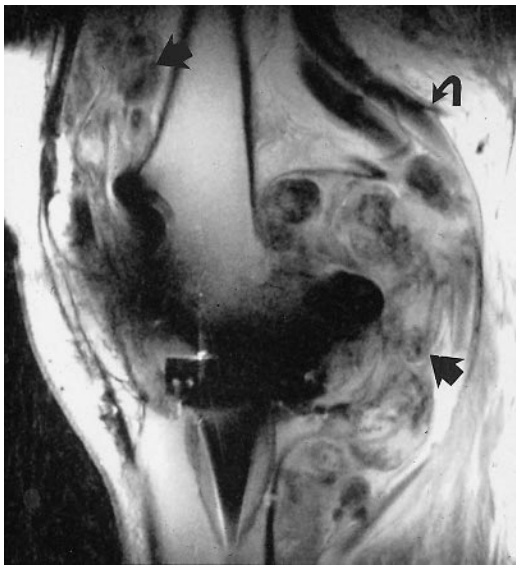

Fig 3. A sagittal fast spin echo sequence in a 68-year-old patient taken 5 years after total knee arthroplasty shows extensive recurrence of pigmented villonodular synovitis (straight arrows), distending the posterior pseudocapsule and the suprapatellar pouch. The posteriorly displaced popliteal vessels (curved arrow) can be seen.

cement interface, they do not allow evaluation of the periprosthetic soft tissues, including ligaments, tendons, and the pseudocapsule. Nuclear medicine bone scans, although sensitive in detecting foci of osseous remodeling, thereby suggesting loosening or infection, are nonspecific as there may be increased radiotracer uptake about the tibial component years after initial arthroplasty placement, often not contributing significantly to the clinician's decision-making process.[5]

Radiologists and orthopaedic surgeons traditionally have been reluctant to choose MRI as an imaging modality for the painful total knee arthroplasty, fearful of the abundant metallic susceptibility artifact generated by the hardware, often resulting in a nondiagnostic examination. Newer software options, however, available on most commercial MRI units can significantly reduce the artifact generated by total joint prostheses. These modifications include increasing receiver readout bandwidths, decreasing interecho spacing, reducing effective echo times to maintain signal to noise, and the use of fast spin echo pulse sequencing to limit the signal loss secondary to diffusion.[18]

Many imaging centers routinely use gradient echo sequences when imaging joints; however, gradient-echo sequences are extremely sensitive to magnetic field inhomogeneities, making them particularly useful when searching for metallic foreign bodies or paramagnetic effects from hemoglobin degradation products (as seen in cases of pigmented villonodular synovitis), but they are problematic when metallic hardware is present, given the lack of 180° refocusing pulses (Fig 4). Such sequences yield increased intravoxel phase dispersion, or large foci of diminished signal intensity, which obscures the surrounding soft tissue in the presence of metallic implants.

Fast spin echo sequences, as opposed to conventional spin echo imaging, have improved the imaging of orthopaedic hardware. The multiple 180° refocusing pulses in fast spin echo imaging correct for signal loss caused by diffusion.[18]

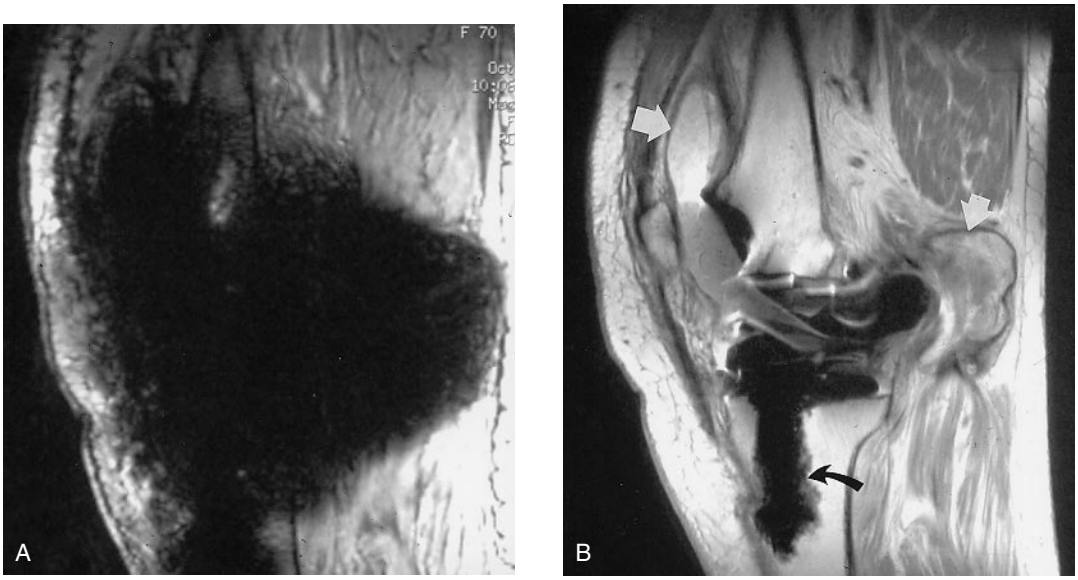

Fig 4A–B. (A) A sagittal gradient recalled image of a 70-year-old woman taken 4 months after total knee arthroplasty shows a significant metallic susceptibility artifact that renders the image nondiagnostic. (B) A sagittal fast spin echo image in the same patient shows a tense synovitis containing particulate debris distending the posterior pseudocapsule, and the suprapatellar pouch (white arrows), which subsequently was debrided. The cement interface of the tibial component (curved arrow) can be seen.

Shorter interecho spacing and decreased effective echo times decrease the time for signal loss before each refocusing pulse, while simultaneously filling multiple lines of k-space, allowing for more rapid image acquisition.[3,11,17]

Magnetic resonance imaging with optimized pulse sequence parameters available on most commercial MR units can circumvent much of the susceptibility artifact generated by total knee arthroplasty, yielding diagnostic information about the arthroplasty, the periprosthetic soft tissues, and the adjacent osseous structures. In the current study, all images provided diagnostic information relevant to the clinical treatment of patients with painful total knee arthroplasty, often leading to secondary interventional procedures.

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