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Role of magnetic resonance imaging in the diagnosis of the painful unicompartmental knee arthroplasty

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ABSTRACT

Background: Unicompartmental knee arthroplasty (UKA) is a well established method for the treatment of single compartment arthritis; however, a subset of patients still present with continued pain after their procedure in the setting of a normal radiographic examination. This study investigates the effectiveness of magnetic resonance imaging (MRI) in guiding the diagnosis of the painful unicompartmental knee arthroplasty.
Methods: An IRB-approved retrospective review identified 300 consecutive UKAs performed over a three years period with 28 cases of symptomatic UKA (nine percent) with normal radiographic images.
Results: MRI examination was instrumental in finding a diagnosis that went undetected on radiographs. Based on MRI findings, 10 (36%) patients underwent surgery whilst 18 (64%) were treated conservatively.
Conclusion: This study supports the use of MRI as a valuable imaging modality for managing symptomatic unicompartmental knee arthroplasty.
Level of evidence: Case series

1. Introduction

Unicompartmental knee arthroplasty (UKA) is an effective method for treating single compartment arthritis. It provides advantages over total knee arthroplasty (TKA) in terms of kinematics, function, range of movement and recovery time [24,27], whilst reports have shown comparable long-term survivorship [10,28,33,34]. However, the national registries tend to show a higher revision rate of the UKA. A leading cause of revision is unexplainable pain following UKA. Various reports describe that between 4%–23% of patients experience pain post-operatively without any obvious cause [3–5,8,16,19].

There are a variety of etiologies that can contribute to painful UKA, including infection, synovitis, osteolysis, component loosening and further degenerative change in the opposite compartment [2,3,8,31]. Conventional radiographs are the first line of investigation for patients presenting with symptomatic UKA, but these may fail to identify the cause and are ill-suited in rendering accurate images of the periprosthetic soft tissues [7,42,46]. The effectiveness of standard radiographs in analyzing component positioning, predicting component loosening, and assessing osteolysis has been called into question [9,29,30,40,43,48–50]. Magnetic resonance imaging (MRI) is becoming increasingly used in investigating painful TKA due to its accuracy and specificity in diagnosing the etiology of post-operative pain in comparison to radiographic imaging [1,7,21,29–31,36,41–43,48,50]. However, the use of MR imaging in evaluating symptomatic UKA has not been investigated.

The purpose of this study is to assess the role of MRI in the evaluation of patients with symptomatic UKA. We hypothesize that MRI will serve as a useful modality in determining the etiology of the symptoms.

2. Materials & methods

After approval by the Institutional Review Board, a retrospective review of 300 consecutive UKAs was undertaken. All UKAs were performed over a three years period between January 2008 and January 2011 by two experienced orthopedic surgeons (ADP, ASR). During routine follow-up visits any cases of symptomatic UKA were identified. These patients were initially evaluated by standard anteroposterior (AP), lateral, merchant, and Rosenberg radiographs by both orthopedic surgeons and an experienced musculoskeletal radiologist. If radiographic analysis failed to provide definitive information regarding the etiology of the patient's post-operative symptoms or if the patient's symptoms persisted, then the patient underwent MRI. Patients who presented with other obvious causes of pain (e.g. lumbar spine stenosis, hip osteoarthritis, complex regional pain syndrome (CRPS)) were excluded. The final study group consisted of patients presenting with persistent symptoms following UKA who had normal physical examination, negative radiographic imaging, and normal routine postoperative blood work, and an unidentified etiology causing symptoms. Patient notes, radiographs and MR images were reviewed to determine the degree of time to diagnosis from standard AP radiographs, the nature of

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the patients' symptoms, and any subsequent operative or conservative interventions.

Magnetic resonance imaging was performed using a clinical 1.5 T Surface Coil unit (General Electric Healthcare, Milwaukee, Wis.). Images were obtained with a knee coil with sagittal inversion recovery followed by additional optimized coronal, sagittal and axial fast spin echo sequences (Fast spin echo XL, General Electric Healthcare), which were obtained using a four-channel phased array receive-only shoulder coil (Med Rad phased array, Indianola, Pa), with a repetition time of 3000 to 5000 ms/echo time of 30 to 36 ms, with a wider receiver bandwidth of 62.5 to 100 kHz over the entire frequency direction. Field of view ranged between 17 and 20 cm, and slice thickness was three to four millimeters with no gap; matrix was 512 × 320 to 384 at four to six excitations, yielding a maximum in-plane resolution of 332 μ. Initial coronal fast inversion recovery sequence had a field of view 35 cm, repetition time 17 ms (effective), inversion time 150 ms, receiver bandwidth 62.5 kHz (over the entire frequency range), and slice thickness five millimeters with no interslice gap. Total imaging time ranged between 25 and 40 minutes, depending upon patient size and the need for repetition of pulse sequences due to involuntary motion. MRIs were reviewed by musculoskeletal radiologists for the presence of any effusion, osteoarthritis in adjacent compartments, and synovitis. Osteolysis was also assessed by the fluid signal versus intermediate signal intensity, maximum thickness of the fibrous membrane, presence of stress reaction in the bone, integrity of the articular cartilage in the non-operative compartment and the presence of occult fractures.

Patients with suspected signs of infection on MR images post-operatively had additional tests ordered for workup. Standard serology was ordered, which included erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP). Aspiration of the joint was also performed with the joint aspirate fluid sent for microbiologic culture, synovial fluid white blood cell count and differential. All descriptive statistics (mean, standard deviation [SD], and mean standard error) were performed with SPSS 16.0 (SPSS Inc., Chicago, IL).

Fig. 1. Radiographs of a symptomatic right UKA with no overt pathology seen.

3. Results

Twenty-eight patients were identified with symptomatic UKA. There were 16 females and 12 males, with a mean age of 57 years (range 34–87 years) (Table 1). All surgery was performed using identical techniques through a medial para-patellar incision. Of the 28 patients, 23 had a UKA performed on the medial compartment and five on the lateral. 96% of cases were robotically-assisted UKAs (n = 27 patients). The tibial components used included 16 all-polyethylene and 12 metal-backed implants. Twenty-seven were fixed bearing and one was mobile bearing.

3.1. Radiographic assessment

None of the initial radiographs demonstrated radiolucencies, evidence of fracture, loosening or mechanical failure (Figs. 1 & 2).

3.2. Magnetic resonance imaging

The average time between index surgery and MRI was 275 ± 182 days (range 77–741 days). The average time between the radiograph and MRI evaluation was 48.6 days ± 69.7 days (range 0–335 days). MRI found osteoarthritis in 100% patients (n = 28) with varying degrees of OA in different compartments (Table 2). Other overlapping findings included effusion in 13 patients (46%) (Fig. 3), synovitis in 16 patients (57%), osteolysis in three patients (11%) (Fig. 4), loosening in three patients (11%), a sinus tract in one patient (four percent) (Fig. 5) and a non-displaced proximal tibial fracture in one patient (four percent) (Fig. 6). Signs of infection were found in two patients (seven percent) (Fig. 7). Other findings included the presence of a cyst (seven percent), meniscal tears (18%) and bursitis (eight percent) (Table 2). Radiograph and MRI findings as well as subsequent clinical treatment are listed in Table 3. Based on the clinical presentations and MR findings, 10 patients were advised to undergo operative treatment whilst 18 were recommended for conservative treatment.

Table 1
Demographic data.

	Mean ± SD (range)
Male:female	12:16
BMI	28.3 ± 6.6 (18.9–42.8)
Mean age (years)	56.1 ± 10.9 (34–79)
UKA	
Medial	23
Lateral	5
Mean follow-up (years)	1.4 ± 0.9 (0.3–2.8)

3.3. Periprosthetic infection work-up

After MRI detected signs of infection in two patients, blood work was ordered and joint aspiration was performed. ESR was 63 mm/h and 25 mm/h and CRP was 2.8 mg/dL and 5.6 mg/dL. Synovial fluid white blood cell counts were 65,000/μL and 3225/μL, both highly suggestive of infection [44].

3.4. Treatment following MRI

Of the 10 patients advised for surgical intervention after MR imaging, two underwent arthroscopic debridement, one underwent manipulation under anesthesia, one underwent revision UKA, four were converted to a TKA, one had an irrigation and debridement with polyexchange, and one underwent a two-stage revision. Seven patients (70%) experienced improvement in pain and function after their second surgical intervention. Of the 18 patients who were treated conservatively, 11 patients (61%) experienced improvement in pain and function. Patients were prescribed anti-inflammatories or physical therapy.

4. Discussion

In this study, we have found that MRI is an effective imaging technique that provides greater insight into the etiology of the symptomatic patient following UKA. Our data suggests that MRI examination was instrumental in finding a diagnosis that went undetected on radiographs for all 28 symptomatic UKA patients. The pathologies for the 10 patients advised for surgical intervention included loose bodies, osteolysis, tibial loosening, synovitis, stress fractures, and infection. For the 18 patients who were managed conservatively, the pathologic findings included stress fracture, meniscus tear, sinus tract, synovitis, and patellofemoral

Fig. 2. Radiographs of a symptomatic right UKA with no overt pathology seen.

(PF) OA. Although our numbers are small, our data highlights the usefulness of MRI in the diagnosis of the symptomatic patient following UKA where traditional radiographic evaluation and physical examination do not indicate any pathological explanation.

Management of the symptomatic UKA can be both complex and difficult due to the nature and variety of causative factors. Similar to managing the painful TKA, a systematic approach is required and is comprised of a thorough history, physical examination, laboratory testing, and radiographic imaging [7]. Traditionally, imaging modalities have been limited to plain radiographs, arthrography, and nuclear medicine bone scans [21,42]; however, numerous studies have reported inadequacies in assessing the residual structures of the knee and the

Table 2
Incidence of pathology seen on MRI.

Pathology	Incidence (%)
Other compartment arthritis	100%
Superficial wear	4% (n = 1)
Fibrillation	4% (n = 1)
Grade 2	11% (n = 3)
Grade 3	43% (n = 12)
Grade 4	39% (n = 11)
Synovitis	61% (n = 17)
Effusion	68% (n = 19)
Osteolysis	32% (n = 9)
Loosening	11% (n = 3)
Cyst	14% (n = 4)
Presence of stress reaction in bone	14% (n = 4)
Chondromalacia patella	4% (n = 1)
Meniscal tear	14% (n = 4)
Infection	7% (n = 2)

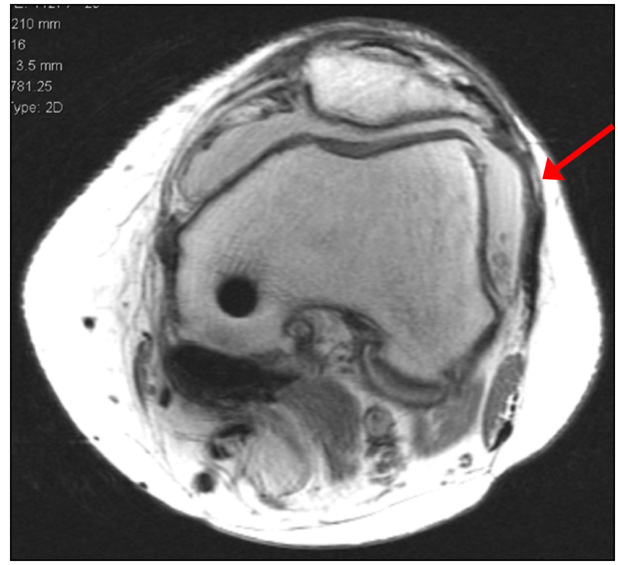

Fig. 3. Axial fast spin echo magnetic resonance image of a patient presenting with effusion and particulate synovial debris. The patient was treated conservatively.

surrounding soft tissue, such as ligaments, tendons, and the pseudocapsule [1,42]. MRI is the gold standard in evaluating soft tissue pathology with its diagnostic sensitivity well-documented following numerous orthopedic procedures, including TKA and THA [1,2,6,12,17,21,29,32,37,39,41–44,48–50].

Although MRI has traditionally not been considered as a diagnostic tool in the setting of arthroplasty due to metallic susceptibility artifact, modern, modified MR imaging techniques allow the amount of artifact around prosthetic implants to be reduced significantly [41]. Heyse et al. showed that with a protocol tailored to reduce metallic susceptibility artifact, MRI can have good reproducibility in the analysis of the bone implant interface at the tibia and patella after TKA and can be helpful in the diagnosis of loosening [14]. More recently, Heyse et al. also showed

Fig. 4. Coronal fast spin echo magnetic resonance image of a patient with osteolysis as indicated by intermediate signal intensity. Patient was revised to a TKR.

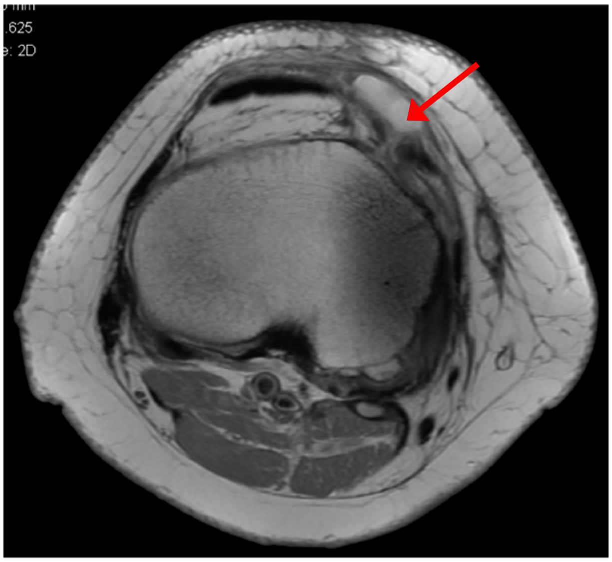

Fig. 5. Axial fast spin echo magnetic resonance image of a patient presenting with a sinus tract who was treated conservatively.

good reproducibility when analyzing component rotation for femoral and tibial UKA implants, which can provide useful information when evaluating symptomatic UKA [15]. Furthermore, Sofka et al. showed that MRI provided accurate evaluation of periprosthetic structures after TKA when conducted with an appropriate protocol that is available on most commercial MRI units [42]. These findings were also confirmed by Heyse et al. who reported a series of cases where MR examination was a useful addition in the evaluation of symptomatic patients following TKA [13].

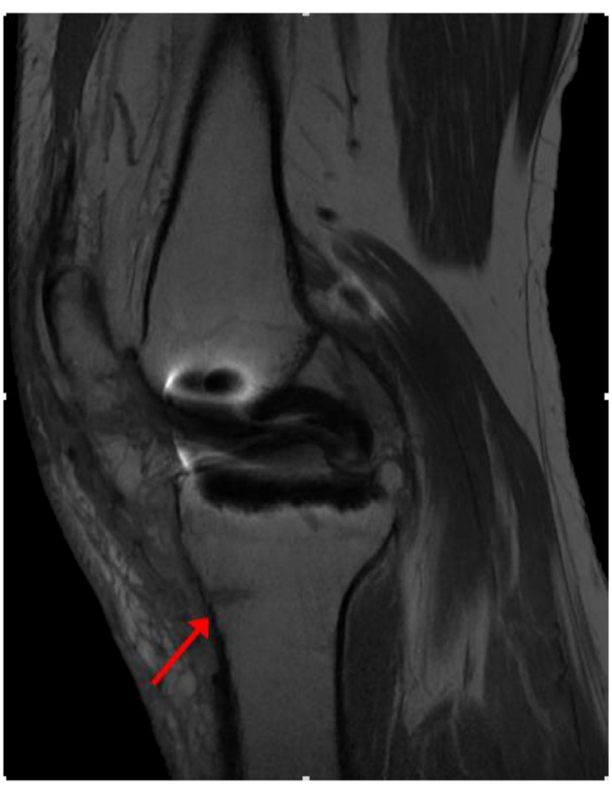

Fig. 6. Sagittal fast spin echo magnetic resonance image of a patient presenting with a non-displaced tibial plateau fracture following a fall. Patient was treated conservatively.

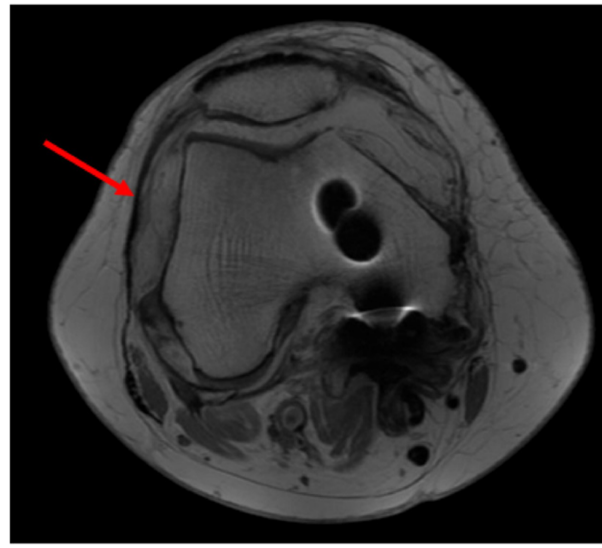

Fig. 7. Axial fast spin echo magnetic resonance image shows a slightly lamellated type architecture at the superior aspect of the suprapatellar recess. Findings were suggestive of infection, which was confirmed by OR cultures. Patient was treated with a two stage revision.

Historically, radiographs are used to evaluate prosthesis alignment, positioning, overhang, stress fractures, implant loosening, osteolysis, wear and heterotropic ossifications [18]. Standard radiographs can help detect gross prosthetic malposition, radiolucencies and fractures [26]. However, they have little value in the detection of the more common but subtle osseous abnormalities such as early loosening, minor implant malposition, infection, stress fractures, or early stage OA [7,18,26,46]. Numerous studies have proven that MRI is a valid examination for the early detection of OA [20,22,38]. It is highly sensitive to early morphologic alterations, such as cartilage, bone marrow, and ligament degeneration, which are the earliest structural changes of OA and are not as evident on traditional radiographic examination. These findings are consistent with the results of our study. In multiple patients from our study cohort, we could not diagnose the progression of OA of the non-operated compartment on plain radiographs, whereas MRI was able to detect OA (Table 2 & 3). Furthermore, multiple studies show that components and interfaces are not well visualized on the conventional radiographs [7,30] and component rotation cannot be assessed [15]. Evidence of component loosening is often evaluated by comparing radiographs over time. However, minor changes in the alignment of the X-ray beam to the component can obscure the diagnosis and therefore make the examination unreliable [30].

Radiographic lucencies are a frequent finding on radiographs following arthroplasty and can be indicative of implant loosening. However, multiple studies report that they have low diagnostic value for joint pathology [30,45,46]. In an attempt to answer the question of whether non-pathological radiolucent lines have a relationship with clinical outcome, Gulati et al. studied the incidence and clinical outcome of 161 Oxford UKAs five years following implantation. They found that 30% of UKAs had a complete line, 32% had partial, and 37% had no radiolucent lines. Furthermore, they concluded that the presence of physiological radiolucency under the tibial tray can be ignored since they noted no significant relationship to clinical outcome [11]. None of the patients included in our study showed any signs of radiolucencies, which could have been caused by the relative short follow-up in comparison to the report by Gulati et al.

Fluoroscopy and oblique views are two other additional radiographic examinations in the assessment of the symptomatic UKA. They may enhance plain radiographs but many studies have reported the inaccuracy and insensitivity of this conventional, two-dimensional imaging

Table 3
Patient MRI findings & subsequent treatment.

Patient	UKA	MRI findings	Final diagnosis	Treatment
1	R med	Mild lateral/PF degenerative joint disease; Meniscus tear	Mild lateral OA	Scope debridement; sympathetic blocks
2	R lat	Loose body & PF OA	Loose body, PF OA	Knee arthroscopy; removal of loose body
3	L med	Effusion, mild lateral & PF chondral loss, peripatellar scar	Arthrofibrosis	Manipulation under anesthesia
4	L med	Effusion, tibial loosening, lateral compartment OA	Tibial loosening and progressive arthritis	Revision to onlay UKA
5	L med	Progressive lateral compartment degeneration	Progressive arthritis	Revised to TKR
6	R med	Marrow edema, effusion with fine particulate synovial debris, mild tibial osteolysis	Proximal tibial stress rxn & progressive arthritis	Revised to TKR
7	L med	Progressive lateral & femoral degenerative joint disease	Progressive arthritis	Revised to TKR
8	R med	Tibial component osteolysis and loosening, synovitis	Tibial loosening & progressive arthritis	Revised to TKR
9	L med	Joint effusion, synovitis, lateral meniscal tear, loosening	Infection	Irrigation & debridement with polyexchange
10	R med	Marrow edema, joint effusion, synovitis	Infection	2-Stage revision
11	R med	Effusion, fine particulate synovial debris	PF OA, reactive synovitis	Conservative treatment
12	R med	Semimembranosus bursitis, lateral meniscus degeneration	Lateral meniscal degeneration	Conservative treatment
13	R med	Effusion, fine particulate synovial debris, meniscus tear	Synovitis	Conservative treatment
14	L lat	Effusion, fine particulate synovial debris	Synovitis	Conservative treatment
15	L med	Popliteal cyst, effusion, fine particulate synovial debris	Synovitis	Conservative treatment
16	R lat	Synovitis, meniscus tear, PF and medial OA	PF & medial OA	Conservative treatment
17	L med	PF OA, medial synovial scar	PF OA	Conservative treatment
18	R lat	Scarred extensor mechanism, PF OA, synovitis	PF OA, reactive synovitis	Conservative treatment
19	R med	Effusion, lateral chondral loss, Hoffa fat pad edema & scar	Hoffa fat pad edema & scar, stress reaction	Conservative treatment
20	R med	Pre-patellar bursitis, PF and lateral OA	PF & lateral OA, reactive bursitis	Conservative treatment
21	L med	Effusion & fine particulate synovial debris, meniscal tear	Meniscus tear, synovitis	Conservative treatment
22	R med	PF OA & synovitis	PF OA & synovitis	Conservative treatment
23	R med	Mild lateral subluxation, patella alta, PF chondromalacia	PF chondromalacia	Conservative treatment
24	L med	Effusion & fine particulate synovial debris, lateral compartment chondral loss, PF OA	PF & lateral OA, synovitis	Conservative treatment
25	L med	Osteolysis, synovitis	Osteolysis, synovitis,	Conservative treatment
26	R med	Effusion & linear synovial debris, healing tibial impaction fx	PF OA, synovitis	Conservative treatment
27	R lat	High grade cartilage wear, large joint line, inner marginal osteophytes	Loose bodies, medial compartment degeneration	Conservative treatment
28	L med	PF OA, synovitis, popliteal cyst	Synovitis	Conservative treatment

modality in detecting soft tissue pathology, especially when estimating the degree of periprosthetic osteolysis, a major complication following knee arthroplasty [29,41–43,48–50]. Numerous reports have proven that modifications in MR imaging technique have allowed the MRI to become a valuable addition in the evaluation of osteolysis. In a cadaver study, Walde et al. compared the specificity of radiography, CT and MRI in assessing periacetabular osteolytic lesions. MRI was a significantly more effective tool (95%) in detecting lesions than CT (75%) or radiographs (52%) [49]. The accuracy of MRI in identifying and quantifying osteolysis has also been confirmed intra-operatively [29,48]. Several studies have reported the superior sensitivity and specificity of MRI in assessing the degree of osteolysis around TKA, which is commonly underestimated with radiographs [1,21,29,40,42,43,47,48]. One other study has investigated the use of MRI after medial UKA, but only in terms of safety and the reproducibility of the residual knee anatomy [1].

One of the most challenging complications following knee arthroplasty is treating periprosthetic infections (PPI) [48,49]. In our retrospective cohort, there were two patients where MRI helped confirm infection. In both cases, suspicion of PPI was very low, since both patients presented with atypical symptoms. Physical and radiographic examinations were not aberrant or suggestive for PPI and aspiration resulted in equivocal blood work. Furthermore, both patients presented with a late onset of symptoms, where MR imaging was respectively performed 371 and 225 days following surgery (Table 3). Due to the unclear diagnosis, MRI was obtained which was suggestive for infection and confirmed the diagnosis. The variable presentation of PPI can make diagnosis difficult and there is scant literature to guide the diagnosis of PPI in UKA patients. Radiographic findings indicative of infection are generally found in the later stages of infection. Plodkowski et al. reported the sensitivity and specificity of lamellated hyperintense synovitis in the MRI of knee arthroplasty patients with infection [36]. Comparing 28 patients with a proven infected TKA with 28 patients with a non-infected TKA, they concluded that the presence of lamellated hyperintense synovitis at MR imaging had a high sensitivity (0.85–0.87) and specificity (0.85–0.87). Similarly in this study, the detection of lamellated synovitis instigated knee aspirations in two patients, which eventually confirmed the suspected infections. MR results influenced the treatment for both patients who both reported an improvement in pain and function at follow-up. Thus, we believe that MRI can be a helpful adjuvant to help diagnose PPI in patients who may have equivocal blood workup or present with atypical symptoms of PPI.

This study is not without limitations. First, this study was limited by its relatively small sample size due to the narrow indication for use of MR imaging. Secondly, time between the obtained radiographs and MR imaging varies due to logistical issues, such as difficulties with obtaining approvals from insurance companies, making sure patients can have a special MRI sequence done, and scheduling the MRI based on the patient's schedule. Thus, in some cases, the time between the two exams is relatively long. Lastly, since this is the first study to report about the use of MRI for the symptomatic UKA patient, the potential influence of metallic artifacts on the diagnosis has not been extensively investigated. The majority of our patients however showed improvement following their treatment based on MR findings.

Although physical examination and traditional radiographs remain the cornerstone in the imaging of postoperative unicompartmental knee arthroplasty, it is to our belief that MRI should be used as a supplemental diagnostic imaging modality for patients experiencing painful UKA. MRI can provide superior evaluation of periprosthetic soft tissues, joint effusion, component integrity, and bony pathology without exposing the patient to additional radiation. The results of our study support the use of high quality MRI for patients presenting with painful UKA. This in conjunction with sound clinical judgment can have a significant impact on operative and conservative treatment decisions, providing a more effective method of managing the symptomatic UKA patient.

References

[1] Aliprandi A, Sconfienza LM, Randelli P, Bandirali M, Tritella S, Di Leo G, et al. Magnetic resonance imaging of the knee after medial unicompartmental arthroplasty. Eur J Radiol 2011;80:416.

[2] Baker K, Grainger A, Niu J, Clancy M, Guermazi A, Crema M, et al. Relation of synovitis to knee pain using contrast-enhanced MRIs. Ann Rheum Dis 2010;69:1779.
[3] Baker PN, Petheram T, Avery PJ, Gregg PJ, Deehan DJ. Revision for unexplained pain following unicompartmental and total knee replacement. J Bone Joint Surg Am 2012;94(17):e126.
[4] Chou DT, Swamy GN, Lewis JR, Bahde NP. Revision of failed unicompartmental knee replacement to total knee replacement. Knee 2012;19(4):356.
[5] Clement ND, Duckworth AD, MacKenzie SP, Nie YX, Tiemessen CH. Medium-term results of Oxford phase-3 medial unicompartmental knee arthroplasty. J Orthop Surg (Hong Kong) 2012;20(2):157.
[6] Cooper JH, Ranawat AS, Potter HG, Foo LF, Jawetz ST, Ranawat CS. Magnetic resonance imaging in the diagnosis and management of hip pain after total hip arthroplasty. J Arthroplasty 2009;24(5):661.
[7] Dennis DA. Evaluation of painful total knee arthroplasty. J Arthroplasty 2004;19(4):35.
[8] Edmondson MC, Isaac D, Wijeratna M, Brink S, Gibb P, Skinner P. Oxford unicompartmental knee arthroplasty: medial pain and functional outcome in the medium term. J Orthop Surg Res 2011;5:52.
[9] Fehring TK, McAvoy G. Fluoroscopic evaluation of the painful total knee arthroplasty. Clin Orthop Relat Res 1996;331:226.
[10] Foran JRH, Brown NM, Della Valle CJ, Berger RA, Galante JO. Long term survivorship and failure modes of unicompartmental knee arthroplasty. Clin Orthop Relat Res 2013;471:102.
[11] Gulati A, Chau R, Pandit G, Gray H, Price AJ, Dodd CA, et al. The incidence of physiological radiolucency following Oxford unicompartmental knee replacement and its relationship to outcome. J Bone Joint Surg Br 2009;91-B(7):896.
[12] Hayter CL, Koff MF, Potter HG. Magnetic resonance imaging of the postoperative hip. J Magn Reson Imaging 2012;35(5):1013.
[13] Heyse TJ, Chong le R, Davis J, Haas SB, Figgie MP, Potter HG. MRI diagnosis of patellar clunk syndrome following total knee arthroplasty. HSS J 2012;8(2):92–5.
[14] Heyse TJ, Chong le R, Davis J, Boettner F, Haas SB, Potter HG. MRI analysis of the component bone interface after TKA. Knee 2012;19(4):290–4.
[15] Heyse TJ, Figiel J, Hahnlein U, Schmitt J, Timmesfeld N, Fuchs-Winkelmann S, et al. MRI after unicondylar knee arthroplasty: rotational alignment of components. Arch Orthop Trauma Surg 2013;133:1579–86.
[16] Heyse TJ, Khefacha A, Peersman G, Cartier P. Survivorship of UKA in the middle-aged. Knee 2012;19(5):585.
[17] Hill CL, Hunter DJ, Niu J, Clancy M, Guermazi A, Genant H, et al. Synovitis detected on magnetic resonance imaging and its relation to pain and cartilage loss in knee osteoarthritis. Ann Rheum Dis 2007;66:1599.
[18] Hirschmann MT, Konala P, Iranpour F, Kerner A, Rasch H, Friederich NF. Clinical value of SPECT/CT for evaluation of patients with painful knees after total knee arthroplasty — a new dimension of diagnostics? BMC Musculoskelet Disord 2011;12:36.
[19] Hofmann S, Seitlinger G, Djahani O, Pietsch M. The painful knee after TKA: a diagnostic algorithm for failure analysis. Knee Surg Sports Traumatol Arthrosc 2011;19:1442.
[20] Jungmann PM, Li X, Nardo L, Subburaj K, Lin W, Ma CB, et al. Do cartilage repair procedures prevent degenerative meniscus changes? Longitudinal t1rho and morphological evaluation with 3.0-T MRI. Am J Sports Med 2012;40:2700.
[21] Kosy JD, Eyres KS, Toms AD. The value of magnetic resonance imaging in investigating a painful total knee arthroplasty. J Arthroplasty 2011;26(6).
[22] Kumar D, Schooler J, Zuo J, McCulloch CE, Nardo L, Link TM, et al. Trabecular bone structure and spatial differences in articular cartilage MR relaxation times in individuals with posterior horn medial meniscal tears. Osteoarthritis Cartilage 2013;21:86.
[24] Laurencin CT, Zelicof SB, Scott RD, Ewald FC. Unicompartmental versus total knee arthroplasty. Clin Orthop Relat Res 1991;273:151.
[26] Mandalia V, Eyres K, Schranz P, Toms AD. Evaluation of patients with a painful total knee replacement. J Bone Joint Surg Br 2008;90B:265.
[27] McKeon BP, Rand JD. Treatment of osteoarthritis of the middle-aged athlete. Sports Med Arthrosc Rev 2013;21(1):52.
[28] Mercier N, Wimsey S, Saragaglia D. Long-term clinical results of the Oxford medial unicompartmental knee arthroplasty. Int Orthop 2010;34:1137.
[29] Mosher TJ, Davis III CM. Magnetic resonance imaging to evaluate osteolysis around total knee arthroplasty. J Arthroplasty 2006;21(3):460.
[30] Mukherjee K, Pandit H, Dodd CA, Ostlere S, Murray DW. The oxford unicompartmental knee arthroplasty: a radiological perspective. Clin Radiol 2008;63:1169.
[31] Murakami AM, Hash TW, Hepinstall MS, Lyman S, Nestor BJ, Potter HG. MRI evaluation of rotational alignment and synovitis in patients with pain after total knee replacement. J Bone Joint Surg 2012;94-B(9):1209–15.
[32] Nadaud MC, Fehring TK, Fehring K. Underestimation of osteolysis in posterior stabilized total knee arthroplasty. J Arthroplasty 2004;19(1):110.
[33] Newman JH, Pydisetty RV, Ackroyd CE. Unicompartmental or total knee replacement? 15 year results of a prospective, randomized controlled trial. J Bone Joint Surg Br 2009;91-B:52.
[34] O'Rourke MR, Gardner JJ, Callaghan JJ, Liu SS, Goetz DD, Vittetoe DA, et al. The John Insall Award: unicompartmental knee replacement: a minimum twenty-year followup, end-result study. Clin Orthop Relat Res 2005;440:27.
[36] Plodkowski AJ, Hayter CL, Miller TT, Nguyen JT, Potter HG. Lamellated hyperintense synovitis: potential MR imaging sign of an infected knee arthroplasty. Radiology 2013;266(1):256.
[37] Potter HG, Foo LF, Nestor BJ. What is the role of magnetic resonance imaging in the evaluation of total hip arthroplasty? HSS J 2005;1(1):8.
[38] Prasad AP, Nardo L, Schooler J, Joseph GB, Link TM. T(1)rho and T(2) relaxation times predict progression of knee osteoarthritis. Osteoarthritis Cartilage 2013;21:69.
[39] Raphael B, Haims AH, Wu JS, Katz LD, White LM, Lynch K. MRI comparison of periprosthetic structures around zirconium knee prostheses and cobalt chrome prostheses. Am J Roentgenol 2006;186.
[40] Reish TG, Clarke HD, Scuderi GR. Use of multi-detector computed tomography for the detection of periprosthetic osteolysis in total knee arthroplasty. J Knee Surg 2006;19:259.
[41] Sofka CM, Potter HG. MR imaging of joint arthroplasty. Semin Musculoskelet Radiol 2002;6(1):79.
[42] Sofka CM, Potter HG, Figgie M, Laskin R. Magnetic resonance imaging of total knee arthroplasty. Clin Orthop Relat Res 2003;406:129.
[43] Solomon LB, Stamenkov RB, MacDonald AJ, Yaikwavong N, Neale SD, Moss MJ, et al. Imaging periprosthetic osteolysis around total knee arthroplasties using a human cadaver model. J Arthroplasty 2012;27(6):1069–74.
[44] Sperling JW, Potter HG, Craig EV, Flatow E, Warren RF. MRI of the painful shoulder arthroplasty. J Shoulder Elbow Surg 2002;11(4):315.
[45] Toms AD, Davidson D, Masri A, Duncan CP. The management of peri-prosthetic infection in total joint arthroplasty. J Bone Joint Surg (Br) 2006;88-B(2):149.
[46] Toms AP, Marshall TJ, Cahir J, Darrah C, Nolan J, Donell ST, et al. MRI of early symptomatic metal-on-metal total hip arthroplasty: a retrospective review of radiological findings in 20 hips. Clin Radiol 2008;63(1):49.
[47] Trampuz A, Hanssen AD, Osmon DR, Mandrekar J, Steckelberg JM, Patel R. Synovial fluid leukocyte count and differential for diagnosis of prosthetic knee infection. Am J Med 2004;117:556–62.
[48] Vessely MB, Frick MA, Oakes D, Wenger DE, Berry DJ. Magnetic resonance imaging with metal suppression for evaluation of periprosthetic osteolysis after total knee arthroplasty. J Arthroplasty 2006;21(6):826.
[49] Walde TA, Weiland DE, Leung SB, Kitamura N, Sychterz CJ, Engh Jr CA, et al. Comparison of CT, MRI, and Radiographs in assessing pelvic osteolysis: a cadaveric study. Clin Orthop Relat Res 2005;437:138.
[50] Weiland DE, Walde TA, Leung SB, Sychterz CJ, Ho S, Engh CA, et al. Magnetic resonance imaging in the evaluation of periprosthetic acetabular osteolysis: a cadaveric study. J Orthop Res 2005;713.