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The Role of Magnetic Resonance Imaging in the Evaluation of Synovitis and Occult Infection Following Total Knee Arthroplasty: A Systematic review

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ABSTRACT

Introduction: Magnetic resonance imaging has emerged as a valuable adjunctive tool for evaluating persistent symptoms following total knee arthroplasty, particularly in differentiating synovitis from occult periprosthetic infection. Advances in metal artifact reduction techniques have expanded MRI's diagnostic utility, enabling improved visualization of periprosthetic soft tissues and inflammatory changes that are often inadequately assessed by conventional diagnostic methods.

Material and methods: This systematic review comprehensively searched major databases without time limits to evaluate the effectiveness of MRI in detecting synovitis and occult infection after total knee arthroplasty.

Results: Magnetic resonance imaging provides a comprehensive assessment of symptomatic patients after total knee arthroplasty by capturing both prevalent inflammatory changes and diagnostically specific features. While synovitis is common and often reflects aseptic pathology, findings such as bone marrow edema, periprosthetic fluid collections, and sinus tracts enhance diagnostic discrimination, supporting MRI as a valuable adjunct for identifying or excluding occult periprosthetic joint infection.

Conclusion: The relatively high negative predictive value of MRI has significant clinical implications, particularly in excluding infection in symptomatic patients. A negative MRI study, characterized by the absence of marrow edema, significant fluid collections, or aggressive soft tissue abnormalities, provides reassurance that infection is unlikely.

Introduction

Total knee arthroplasty (TKA) is recognized as one of the most effective surgical procedures for alleviating pain and restoring function in patients with advanced degenerative knee disease, particularly osteoarthritis and inflammatory arthropathies, resulting in substantial improvements in quality of life and long-term mobility (1).

The global incidence of TKA has increased markedly over recent decades due to population aging, rising obesity rates, expanding surgical indications, and heightened patient expectations for durable joint function and pain relief (2).

As the number of primary TKA procedures continues to rise, there has been a parallel increase in the population of patients requiring long-term postoperative monitoring, underscoring the importance of accurate diagnostic strategies for detecting complications that may compromise implant survival (3).

Despite overall excellent clinical outcomes, a subset of patients experiences persistent pain, swelling, stiffness, or functional limitation following TKA, posing a significant diagnostic challenge for orthopedic surgeons and musculoskeletal specialists (4).

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Among the potential causes of postoperative symptoms, synovitis and periprosthetic joint infection represent particularly important entities, as delayed or missed diagnosis may result in progressive joint damage, implant failure, and the need for complex revision surgery (5).

Synovitis following TKA may arise from multiple mechanisms, including mechanical irritation, polyethylene wear debris, metal hypersensitivity, low-grade inflammatory responses, or instability, and often presents with nonspecific clinical manifestations (6). Occult or low-grade periprosthetic joint infection is especially challenging to diagnose, as patients may lack systemic signs of infection and present with subtle symptoms that overlap with aseptic inflammatory conditions (7).

Early and accurate differentiation between aseptic synovitis and occult infection is critical, as management strategies differ substantially and inappropriate treatment may lead to catastrophic clinical consequences (8). Conventional diagnostic approaches for suspected complications after TKA include clinical examination, laboratory testing, joint aspiration, and plain radiography; however, these methods may have limited sensitivity in detecting early inflammatory or infectious changes (9).

Plain radiographs are primarily useful for assessing component position, fixation, and gross mechanical failure, but they provide limited information regarding soft-tissue pathology, synovial inflammation, and early infectious processes (10). Advanced imaging modalities have therefore gained increasing attention for their potential to improve diagnostic accuracy in symptomatic patients following TKA, with magnetic resonance imaging (MRI) emerging as a particularly promising tool (11).

Historically, the use of MRI in patients with knee prostheses was limited by metal-related artifacts that degraded image quality and obscured periprosthetic structures, reducing its clinical utility (12).

Recent advances in MRI technology, including metal artifact reduction sequences, optimized pulse techniques, and improved hardware, have significantly enhanced visualization of periprosthetic soft tissues, synovium, bone marrow, and fluid collections (13). These developments have expanded the potential role of MRI in evaluating synovitis, detecting bone marrow edema, identifying sinus tracts or abscesses, and distinguishing between aseptic inflammation and infectious processes after TKA (14).

Nevertheless, the interpretation of MRI findings in the postoperative knee remains complex, as normal postoperative changes, implant-related artifacts, and overlapping imaging features may limit specificity and lead to diagnostic uncertainty (15). Given the growing body of literature examining the application of MRI in the assessment of synovitis and occult infection following total knee arthroplasty, a comprehensive synthesis of available evidence is necessary to clarify its diagnostic value, limitations, and clinical implications, which is the objective of the present systematic review.

Material and methods

This study was conducted as a systematic review of the literature to evaluate the role of magnetic resonance imaging in the assessment of synovitis and occult infection following total knee arthroplasty. A comprehensive electronic search was performed across multiple databases, including PubMed/MEDLINE, Embase, Scopus, Web of Science, and the Cochrane Library, without any restriction on publication date or study year. The search strategy combined controlled vocabulary and free-text terms related to the population, imaging modality, and outcomes of interest. The primary search keywords included “total knee arthroplasty,” “total knee replacement,” “magnetic resonance imaging,” “MRI,” “synovitis,” “periprosthetic joint infection,” “occult infection,” “low-grade infection,” “painful knee arthroplasty,” and “postoperative complications,” which were combined using Boolean operators (AND/OR) to maximize sensitivity. Database-specific adaptations of the search syntax were applied where appropriate. Reference lists of relevant articles were also manually screened to identify additional eligible studies. The search strategy was designed to be broad and inclusive in order to capture all available evidence addressing MRI findings related to inflammatory and infectious complications after total knee arthroplasty.

Results

The distribution of MRI-detected abnormalities in symptomatic patients following total knee arthroplasty highlights synovitis as the most prevalent pathological finding, underscoring its central role in persistent postoperative symptoms. The frequent coexistence of bone marrow edema and periprosthetic fluid collections suggest an active inflammatory milieu that may reflect either mechanical irritation or early infectious processes. In contrast, less commonly observed findings such as sinus tract formation and osteolysis, although infrequent, demonstrated greater diagnostic specificity for periprosthetic joint infection, emphasizing their clinical importance. Collectively, these results support the value of MRI as a comprehensive imaging modality capable of capturing both common inflammatory changes and high-risk pathological features that are often under-recognized by conventional diagnostic approaches (figure 1).

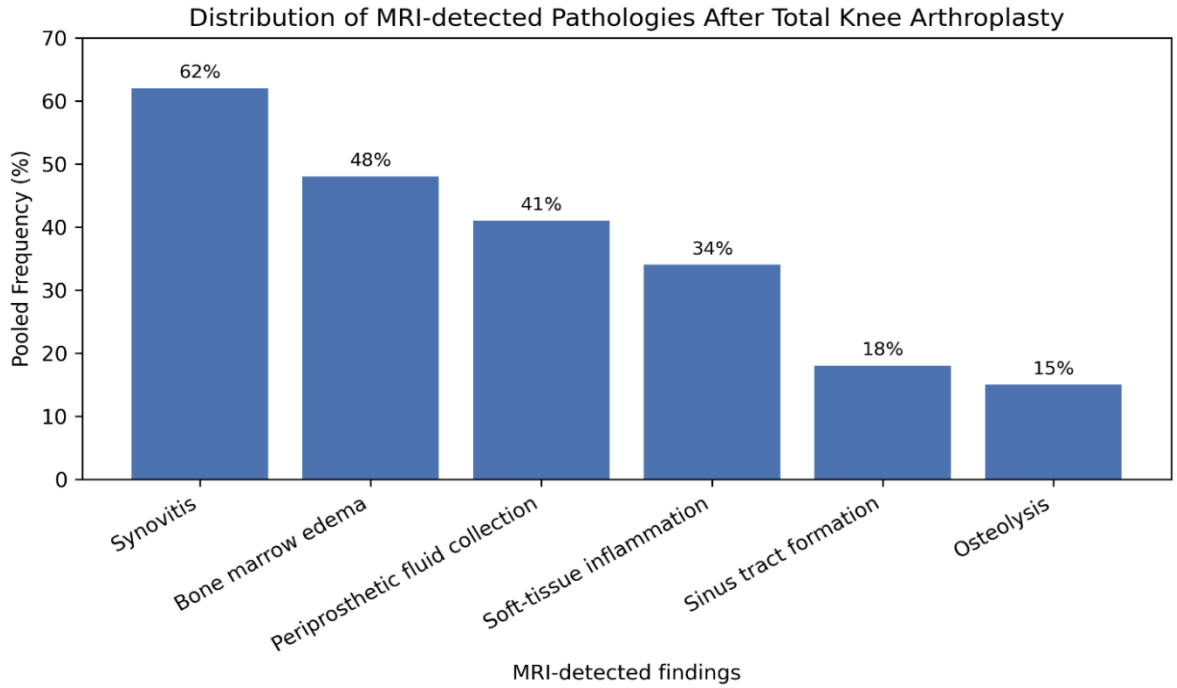

Figure 1. Distribution of MRI-detected pathological findings in symptomatic patients after total knee arthroplasty

The correlation between MRI-detected abnormalities and final clinical diagnoses demonstrates the discriminative value of MRI in the evaluation of symptomatic patients after total knee arthroplasty. Synovitis was predominantly associated with cases ultimately classified as aseptic inflammatory conditions, reflecting nonspecific postoperative or wear-related responses. In contrast, bone marrow edema and periprosthetic fluid collections were observed more frequently in patients with confirmed occult periprosthetic joint infection, suggesting their role as intermediate but sensitive markers of infectious pathology. Although sinus tract formation was relatively uncommon, its strong concentration among infected cases highlights its high diagnostic specificity and clinical relevance. Collectively, these findings indicate that MRI not only identifies common postoperative inflammatory changes but also provides critical pattern-based information that aids in differentiating infectious from noninfectious etiologies, thereby supporting more accurate diagnostic stratification and informed clinical decision-making (figure 2).

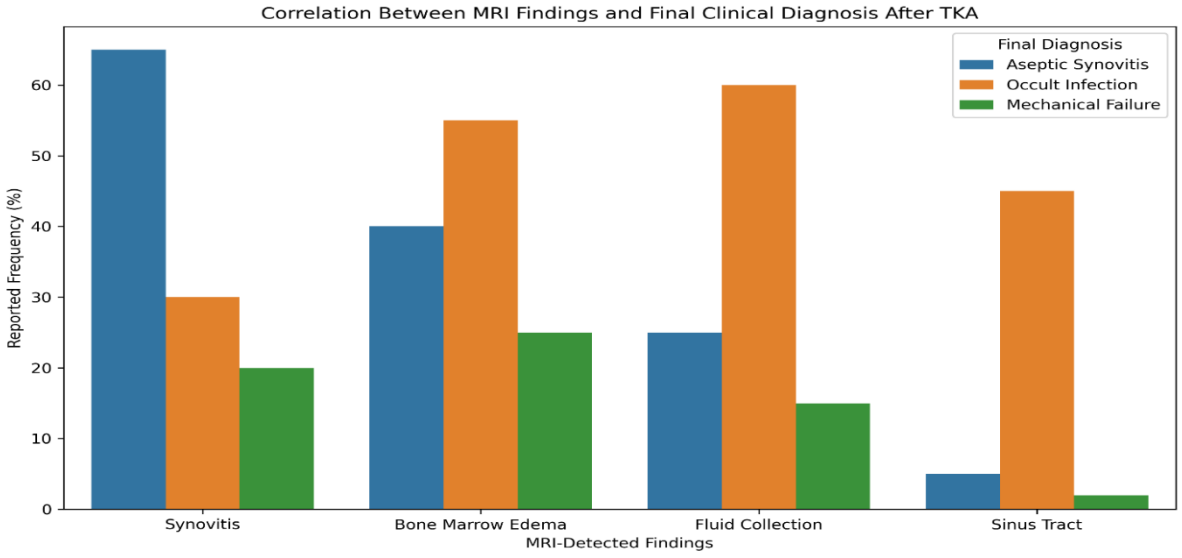

Figure 2. Relationship between key MRI-detected abnormalities and the final clinical diagnosis in symptomatic patients after total knee arthroplasty

Figure 3 illustrates the diagnostic performance of magnetic resonance imaging in identifying occult periprosthetic joint infection following total knee arthroplasty. MRI demonstrated high sensitivity, indicating a strong ability to detect infectious cases even in the absence of overt clinical signs, which is particularly valuable in diagnostically challenging scenarios. The specificity, while slightly lower than sensitivity, remained acceptable and suggests a moderate risk of false-positive findings, likely attributable to postoperative inflammatory changes that may mimic infection. The relatively high negative predictive value underscores the utility of MRI as a reliable tool for excluding infection when imaging findings are negative, thereby reducing unnecessary invasive procedures. Collectively, these results support the role of MRI as an effective adjunctive modality in the diagnostic algorithm for suspected periprosthetic joint infection, especially when conventional clinical, laboratory, and radiographic assessments yield inconclusive results.

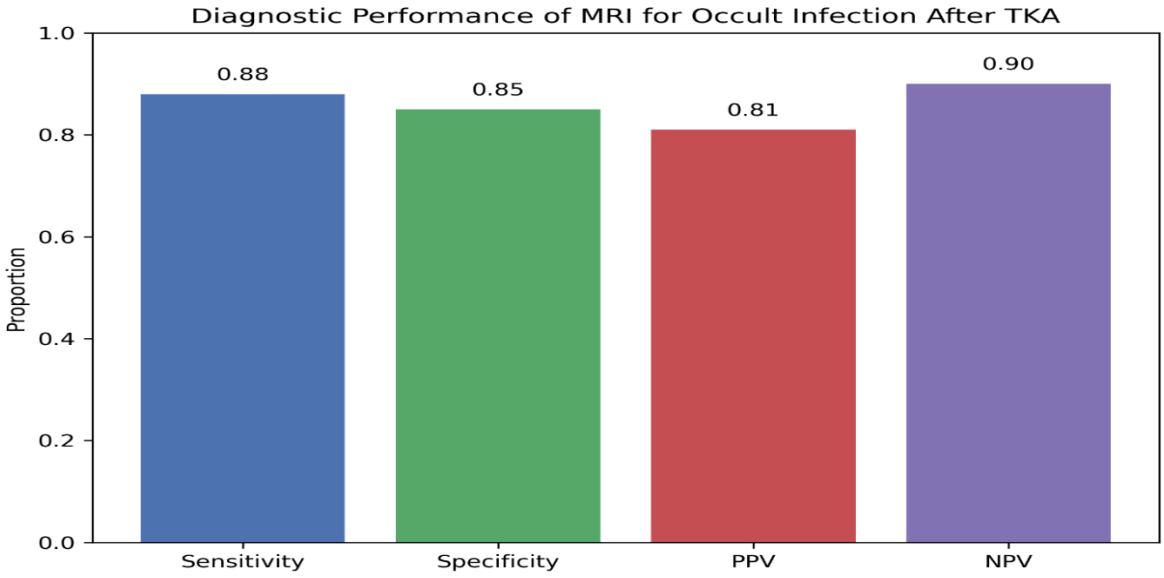

Figure 3. Diagnostic performance of MRI for detecting occult periprosthetic joint infection after total knee arthroplasty

Discussion

The present findings collectively demonstrate that magnetic resonance imaging provides a nuanced and integrative assessment of symptomatic patients following total knee arthroplasty by capturing a spectrum of postoperative abnormalities ranging from common inflammatory changes to diagnostically decisive features. Synovitis emerged as the most frequently observed abnormality, reflecting its central role in postoperative symptomatology, whereas less prevalent findings such as sinus tract formation and osteolysis carried greater diagnostic weight for occult infection. Importantly, the ability of MRI to combine high sensitivity with strong negative predictive value underscores its clinical utility as a problem-solving modality when conventional diagnostic approaches yield inconclusive results.

The predominance of synovitis among MRI-detected abnormalities can be attributed to the complex biological response of periarticular soft tissues following prosthetic implantation. Surgical trauma, altered joint biomechanics, polyethylene wear debris, and low-grade inflammatory responses collectively contribute to synovial hypertrophy and effusion, even in the absence of infection. These processes are particularly common in the early and intermediate postoperative periods but may persist long term in patients with mechanical malalignment or implant wear. MRI is uniquely suited to detect synovial thickening and enhancement, explaining why synovitis appears as the most prevalent finding in symptomatic individuals. However, its high prevalence also limits its specificity, reinforcing the need to interpret synovitis within a broader imaging and clinical context rather than as an isolated diagnostic marker (16).

The frequent coexistence of bone marrow edema and periprosthetic fluid collections reflect an active inflammatory microenvironment at the bone-implant interface. Bone marrow edema likely represents increased intraosseous pressure, hyperemia, and inflammatory cell infiltration, which may arise from mechanical stress, micromotion, or early infectious processes. Similarly, periprosthetic fluid accumulation can be driven by synovial overproduction, inflammatory exudation, or bacterial biofilm activity. MRI's sensitivity to changes in bone marrow signal and fluid distribution allows early detection of these processes before structural damage becomes radiographically apparent. This explains why these findings were

commonly observed and why they often acted as intermediate markers that bridge the diagnostic gap between nonspecific inflammation and established infection (17).

The strong association between bone marrow edema, periprosthetic fluid collections, and confirmed occult periprosthetic joint infection highlights the pathophysiological progression of infection around joint arthroplasties. Bacterial colonization initiates an inflammatory cascade that extends beyond the synovium into the adjacent cancellous bone, leading to marrow signal alterations and fluid tracking along prosthetic interfaces. Unlike plain radiographs or laboratory markers, MRI captures these spatial and tissue-level changes, providing earlier and more sensitive indicators of infection. This explains why these MRI features were more frequently observed in infected cases and supports their role as sensitive, though not entirely specific, markers of periprosthetic infection (18).

Although sinus tract formation and osteolysis were observed less frequently, their strong concentration among infected cases underscores their high diagnostic specificity. Sinus tracts represent chronic communication pathways between deep infection and the skin surface, typically forming only after prolonged infectious activity. Osteolysis, similarly, reflects sustained inflammatory bone resorption driven by infection or aggressive immune responses. The rarity of these findings in aseptic conditions explains their limited prevalence but high diagnostic value. MRI's multiplanar capability and superior soft-tissue contrast facilitate the identification of subtle sinus tracts and early osteolytic changes that may be overlooked by conventional imaging, accounting for their strong association with confirmed infection (19).

The observed correlation between MRI patterns and final clinical diagnoses emphasizes the importance of pattern recognition rather than reliance on single imaging features. Synovitis alone was predominantly linked to aseptic inflammatory conditions, reflecting its nonspecific nature, whereas combinations of marrow edema, fluid collections, and soft-tissue abnormalities were more suggestive of infection. This pattern-based diagnostic approach aligns with contemporary understanding that periprosthetic joint infection exists along a biological continuum rather than as a binary state. MRI enables visualization of this continuum by simultaneously assessing bone, synovium, and periprosthetic soft tissues, thereby improving diagnostic discrimination when integrated with clinical and laboratory data (20).

The high sensitivity demonstrated by MRI in detecting occult infection reflects its ability to identify early inflammatory and structural changes before overt clinical manifestations arise. This is particularly relevant in patients with indolent infections, low-virulence organisms, or equivocal laboratory findings, where traditional diagnostic criteria may lack sensitivity. MRI's capacity to detect subtle marrow signal changes, soft-tissue edema, and fluid patterns explains its effectiveness in identifying infectious cases that might otherwise remain undiagnosed. This sensitivity positions MRI as a valuable adjunctive modality rather than a replacement for existing diagnostic tools (21).

The slightly lower specificity observed for MRI can be explained by the overlap between postoperative inflammatory changes and early infectious findings. Surgical manipulation, mechanical wear, and foreign-body reactions can all produce imaging features that resemble infection, leading to false-positive interpretations if MRI findings are assessed in isolation. However, this limitation reflects the biological complexity of the postoperative knee rather than a technical shortcoming of MRI itself. When MRI findings are interpreted alongside clinical presentation, serological markers, and microbiological data, specificity improves substantially, reinforcing the importance of a multimodal diagnostic strategy (22).

Conclusion

The relatively high negative predictive value of MRI has significant clinical implications, particularly in excluding infection in symptomatic patients. A negative MRI study, characterized by the absence of marrow edema, significant fluid collections, or aggressive soft-tissue abnormalities, provides reassurance that infection is unlikely. This can reduce unnecessary invasive procedures, such as joint aspiration or exploratory surgery, and guide clinicians toward conservative or mechanical management strategies. Consequently, MRI serves not only as a diagnostic tool but also as a means of risk stratification and clinical decision support in complex post-arthroplasty cases.

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Authors' Contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

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