ISSN: 1607-8322, e-ISSN: 2220-5799 Anaesthesia, Pain & Intensive Care
Vol 29(4); July 2025 DOI: 10.35975/apic.v29i4.2825

ORIGINAL RESEARCH ORTHOPEDIC ANESTHESIA

Prevalence of MRI-detected knee Joint effusion in patients with knee osteoarthritis: Insights from Saudi Arabian cohort

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ABSTRACT

Background & Objectives: Knee joint osteoarthritis (OA) is usually a chronic disease with varying degrees of pain, joint effusion and disability. Besides clinical evaluation by the clinician, radiographic examination is routinely carried out. This study aimed to evaluate the association between knee OA severity and the presence and degree of joint effusion (JE) using magnetic resonance imaging (MRI), and to examine correlations with demographic parameters.

Methodology: A total of 190 patients clinically diagnosed with knee OA underwent MRI evaluation. Knee OA severity was graded from 1 to 4, using the Park et al. (2013) MRI-based system, while JE was classified as absent, mild, moderate or severe. MRI scans were independently assessed by two experienced radiologists. Demographic data including age, gender, and laterality were recorded. Associations between JE and clinical variables were analyzed using chi-square tests, and statistical significance was set at $P < 0.05$.

Results: The cohort included 91 (47.9%) females and 99 (52.1%) males, with the majority aged between 31 and 50 years. Knee OA grading showed 31.6% with Grade 1, 21.6% with Grade 2, 23.2% with Grade 3, and 23.7% with Grade 4. JE was absent in 36.8%; it was mild in 50.5%, moderate in 11%, and severe in 1.6% of cases. There was no significant association between JE and gender ($P = 0.36$), age ($P = 0.45$), or side of involvement ($P = 0.40$). However, a highly significant correlation was found between JE and knee OA grade ($P < 0.001$), with moderate JE being most prevalent in Grade 4 cases (31.1%).

Conclusion: MRI-based assessment revealed a strong association between increasing severity of knee osteoarthritis and the presence and extent of joint effusion. These findings highlight the clinical utility of MRI in evaluating intra-articular changes and suggest joint effusion as a potential marker of knee osteoarthritis progression.

Keywords: Knee osteoarthritis; Joint effusion; Magnetic resonance imaging; Knee OA grading; Synovial inflammation

Citation: Alrowaili MG. Prevalence of MRI-detected knee Joint effusion in patients with knee osteoarthritis: Insights from Saudi Arabian cohort. Anaesth. pain intensive care 2025;29(4):378-83. **DOI:** 10.35975/apic.v29i4.2825

Received: April 29, 2025; **Revised:** May 08, 2025; **Accepted:** May 10, 2025

1. INTRODUCTION

Knee osteoarthritis (OA) is a degenerative joint disorder, which is marked by the gradual decline of articular cartilage, remodeled subchondral bone, inflamed the synovial membrane, and the development of osteophytes.[1] It is the most common type of arthritis, predominantly impacting weight-bearing joints, especially the knee. OA results in joint discomfort, stiffness, swelling, and a progressive decline in function, significantly hindering mobility and quality of life.[2] Pathogenesis encompasses mechanical stress, metabolic alterations in the cartilage matrix, and inflammatory mediators that cumulatively lead to joint deterioration and morphological impairment.[3]

Knee osteoarthritis affects more than 300 million individuals worldwide, with incidence rising due to aging demographics and increasing obesity rates.[4] It is a primary source of impairment in the elderly and substantially adds to the worldwide burden of musculoskeletal disorders. Primary predisposing factors encompass advanced age, feminine gender, obesity, prior joint injury, occupational joint stress, and genetic susceptibility.[5,6] Clinical signs generally include joint pain aggravated by activity, morning stiffness lasting under 30 minutes, crepitus, and reduced range of motion. Inadequate care of knee osteoarthritis can lead to significant functional impairment, requiring surgical procedures such total knee arthroplasty.[7]

Knee effusion, often termed "water on the knee," is an abnormal collection of surplus synovial or inflammatory fluid within the knee joint capsule. This is a non-specific clinical symptom linked to several intra-articular pathologies, such as trauma, osteoarthritis, rheumatoid arthritis, gout, infection, and meniscal injuries.[8] The effusion can be categorized as transudative or exudative based on the underlying cause, indicating an imbalance between fluid production and absorption in the synovial membrane. Knee effusion clinically manifests as observable swelling, joint distension, diminished mobility, and, in certain instances, pain and warmth, especially in inflammatory or infectious situations.[9]

Knee effusion is highly prevalent in people with chronic joint problems like osteoarthritis, generally correlating with disease severity and progression. It is commonly observed in athletes and those experiencing occupational or mechanical joint strain.[10] Factors contributing to the condition encompass joint trauma, hyperplasia of the synovial membrane, crystal deposition, and immune-mediated mechanisms. Chronic effusion may result in joint instability, modified biomechanics, and expedited cartilage deterioration, hence exacerbating the fundamental pathophysiology.[11] Diagnosis is usually validated using physical examination methods like the bulging or ballottement tests, supplemented by imaging and, if required, synovial fluid investigation to ascertain the etiology and inform suitable therapy strategies. Magnetic Resonance Imaging (MRI) is essential for the thorough assessment of knee osteoarthritis (knee OA) and related joint effusions.[1,10] In contrast to traditional radiography, which mainly evaluates bone and joint space reduction, MRI offers high-resolution, multiplanar imaging of both bony and soft tissue components, encompassing articular cartilage, subchondral bone, menisci, ligaments, synovium, and intra-articular fluid. In knee OA, MRI enables the early identification of cartilage degeneration, bone marrow lesions, meniscal injury, and synovitis, frequently prior to the manifestation of radiographic alterations. This facilitates a more nuanced and precise evaluation of disease onset, development, and severity. [12]

MRI is essential for determining the underlying cause and analyzing the content and distribution of fluid in cases of knee effusion.[10] It differentiates between uncomplicated effusion and intricate joint disorders, such synovial growth, hemorrhagic effusions, or crystal arthropathies. MRI facilitates the identification of minor intra-articular abnormalities, such meniscal tears or ligamentous disturbances, which may not be apparent through physical examination or standard radiographs.[11] The capacity of MRI to deliver intricate anatomical and pathological information renders it an essential diagnostic instrument for informing therapy choices, assessing therapeutic efficacy, and predicting outcomes in patients with knee OA and joint effusion.[12] Consequently, the present study was undertaken to examine the correlation between knee OA and joint effusion, as well as the influence of additional variables based on MRI findings in cases identified with knee OA. We hypothesized that the severity of joint effusion is positively correlated with the severity of knee OA, and that specific MRI-detected features, such as synovitis and bone marrow lesions, significantly influence this relationship

2. METHODOLOGY

This study is an observational, cross-sectional analysis designed to assess the correlation between knee OA and joint effusion, as well as the impact of additional MRI-detected variables in patients diagnosed with knee OA. MRI scans were independently reviewed by two experienced radiologists, each blinded to the other's assessments and to the clinical details of the participants. Relevant clinical data and MRI findings were systematically recorded and subsequently analyzed to investigate correlations between knee OA grade and joint effusion.

MRI examinations were conducted using a 1.5-T system (GE Healthcare, USA), equipped with a quadrature receiver knee coil for optimized signal reception. To minimize motion artifacts due to the relatively long acquisition time, patients were immobilized using hook-and-loop straps. Imaging sequences were performed in axial, sagittal, and coronal planes according to the protocol described by Joshi et al.[13] Slice thickness ranged between 4–5 mm with an interslice gap of 0.5–1 mm. Comprehensive assessment included all compartments of the knee joint, covering the articulating surfaces of the femur and tibia, the patellar facets, and the femoral trochlea.

Participants included in the study were adults aged 20 years or older with a confirmed diagnosis of knee OA

based on the American College of Rheumatology (ACR) clinical and radiographic criteria. Eligible subjects were required to have undergone a recent knee MRI within the last three months and to have provided informed consent. Patients were excluded if they had a history of inflammatory arthritis, such as rheumatoid arthritis, gout, or psoriatic arthritis; recent knee trauma or surgery within the past six months; known malignancy or infection affecting the joint; or if the MRI images were of inadequate quality or incomplete.

Clinical and imaging data were collected prospectively from archived patient records and MRI. Clinical assessment was standardized using a structured form completed by trained clinicians, which included demographic information, symptom duration, pain severity (using a Visual Analog Scale), and functional limitation scores. Radiographic severity of knee OA was graded using the Kellgren–Lawrence (KL) classification system, assessed by two independent clinicians blinded to MRI findings.

MRI scans were performed using a standardized imaging protocol across all patients, utilizing a 1.5T or 3T MRI scanner. The protocol included T1-weighted, T2-weighted, and fat-suppressed sequences in sagittal, coronal, and axial planes. Radiological evaluation was based on the Whole-Organ Magnetic Resonance Imaging Score (WORMS), applied consistently by two experienced musculoskeletal radiologists who were blinded to clinical data.

To ensure consistency in radiological interpretation, two board-certified musculoskeletal radiologists independently evaluated all MRI scans, blinded to the patients' clinical information and each other's assessments. Discrepancies in scoring were resolved by consensus through joint review. Inter-observer reliability was assessed using Cohen's kappa coefficient for categorical variables (e.g., presence of effusion, osteophytes) and intraclass correlation coefficient (ICC) for continuous measures (e.g., cartilage thickness, synovitis score). Kappa and ICC values were interpreted according to established benchmarks, with values >0.75 considered excellent agreement.

The severity of knee OA was graded using the MRI-based system described by Park et al.[14] which evaluates four key parameters: cartilage defect, bone marrow edema, osteophyte formation, and bony ulceration. Cartilage damage was further categorized according to the Noyes classification. knee OA was graded on a 4-point scale: Grade 1 indicating minimal cartilage thinning and small osteophytes; Grade 2 reflecting cartilage fissuring, moderate osteophytes, and minor bone marrow changes; Grade 3 showing cartilage ulceration, subchondral edema, and moderate bony deformity; and Grade 4 representing full-thickness cartilage loss, extensive edema, and advanced joint deformity. Knee effusion was graded as mild (minimal fluid in the suprapatellar recess), moderate (distension of the recess with clear fluid delineation), or severe (marked joint capsule distension with fluid extending into adjacent bursae or soft tissues).

Table 1: Demographic data of the enrolled knee OA cases

Parameter		n (%)
Gender	Female	91 (47.9)
	Male	99 (52.1)
Ages (yrs)	20-30	26 (13.7)
	31-40	53 (27.9)
	41-50	52 (27.4)
	51-60	42 (22.1)
	> 60	17 (8.9)
Side	Left	91 (47.9)
	Right	99 (52.1)
JE	No JE	70 (36.8)
	Mild JE	96 (50.5)
	Moderate JE	21 (11)
	Severe	3 (1.6)
Knee OA	1	60 (31.6)
	2	41 (21.6)
	3	44 (23.2)
	4	45 (23.7)

Data presented as n (%); JE: Joint effusion

2.1. Statistical Analysis

A sample size calculation was conducted prior to the study using G*Power software (version X.X) to ensure adequate power. Based on an expected moderate effect size (r = 0.3) for the correlation between joint effusion and knee OA severity, a significance level (α) of 0.05, and a power of 0.80, the minimum required sample size was estimated to be 85 participants. Data were analyzed using SPSS version (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to represent the participants' characteristics. Interobserver agreement between the two radiologists was assessed using Cohen's kappa coefficient. Associations between knee OA grade and effusion severity were evaluated using Fisher exact tests for categorical variables and Spearman's rank correlation for ordinal data.

A P-value of less than 0.05 was considered statistically significant.

Table 2: Association of JE with the degree of Gender, ages, side and degrees of knee OA

Parameters		No JE	Mild JE	Moderate JE	Severe JE	Total	P-value
Gender	• Female	27	39	5	1	72	0.36
	• Male	43	57	16	2	118	
Age (yrs)	• 20-30	10	14	2	0	26	0.45
	• 31-40	22	26	5	0	53	
	• 41-50	14	29	9	0	52	
	• 51-60	16	22	3	1	42	
	• >60	8	5	2	2	17	
Knee OA	• 1	31	25	4	0	60	0.000***
	• 2	18	20	3	0	41	
	• 3	10	31	2	1	44	
	• 4	11	20	12	2	45	
Side	• Left	30	47	12	2	91	0.4
	• Right	40	49	9	1	99	

JE: Joint effusion; OA: Osteoarthritis; P < 0.05 considered significant

3. RESULTS

A total of 190 patients with knee OA were enrolled in the study. Of these, 91 (47.9%) were females and 99 (52.1%) were males. The age distribution was as follows: 13.7% were aged 20–30 years, 27.9% aged 31–40 years, 27.4% aged 41–50 years, 22.1% aged 51–60 years, and 8.9%

were above 60 years. Laterality of involvement was nearly equal, with 47.9% cases affecting the left knee and 52.1% the right. Joint effusion (JE) was absent in 36.8% of cases, mild in 50.5%, and moderate in 12.6%. Regarding knee OA grading, Grade 1 was present in 31.6% of cases, Grade 2 in 21.6%, Grade 3 in 23.2%, and Grade 4 in 23.7% (Table 1).

When evaluating the association of JE with various demographic and clinical parameters (Table 2), no statistically significant association was found between JE and gender (P = 0.36), age group (P = 0.45), or side of involvement (P = 0.4). However, a highly significant association was observed between the presence and severity of JE and knee OA grade (P < 0.001, likelihood ratio = 26.2 95% confidence interval was 21.2-32.1). Notably, moderate JE was most frequently observed in patients with Grade 4 knee OA (31.1%), while the absence of JE was predominant in patients with Grade 1 knee OA (51.7%). These findings suggest a strong correlation between increasing knee OA severity and the likelihood of joint effusion.

4. DISCUSSION

The present study highlights a significant association between the severity of knee OA and the presence and degree of joint effusion (JE), based on magnetic resonance imaging (MRI) evaluation. Among the 190 patients examined, increasing knee OA grades were positively correlated with higher grades of JE.

Specifically, moderate effusion was most frequently observed in Grade 4 knee OA cases, while the absence of effusion was predominantly noted in Grade 1. These findings underscore the role of joint effusion as a potential surrogate marker for disease severity and progression in knee OA.

The observed correlation aligns with previously published MRI-based investigations. Hayashi et al. reported that synovial inflammation and effusion volume were significantly associated with worsening structural damage in knee OA patients. [15] Similarly, Roemer et al. demonstrated that effusion-synovitis, as assessed by MRI, was more prevalent in knees with higher cartilage damage and bone marrow lesions. [16] These findings suggest that effusion reflects underlying synovial activation, which contributes to the pathogenesis and progression of knee OA.

Furthermore, Kornaat et al. emphasized the utility of MRI in detecting early inflammatory changes such as synovitis and effusion that are often missed by conventional radiographs. [17] They proposed that these early inflammatory features may precede irreversible cartilage damage and could serve as valuable predictors

of disease evolution. Our study supports this hypothesis by showing a graded increase in effusion severity corresponding with knee OA progression, reinforcing the importance of MRI in both early detection and monitoring of knee OA.

In contrast, demographic parameters such as age, sex, and side of knee involvement showed no statistically significant association with joint effusion in our cohort. This observation is consistent with findings from Wang et al., who reported that joint effusion was primarily linked to intra-articular structural abnormalities rather than external demographic factors. However, this contrasts with some epidemiological studies that have identified age and sex as modifiers of OA symptomatology, suggesting that joint effusion may be more directly related to mechanical and biochemical joint alterations than patient demographics. [18]

The pathophysiological basis for effusion in knee OA lies in synovial membrane irritation and inflammation, which stimulate excess synovial fluid production. As cartilage degrades, matrix degradation products act as pro-inflammatory stimuli, triggering synovial hyperplasia and increased vascular permeability. The resulting joint effusion not only reflects disease activity but also contributes to further cartilage breakdown through biomechanical and biochemical mechanisms, creating a vicious cycle of joint deterioration.

5. LIMITATIONS

Despite these compelling findings, the present study is not without limitations. First, the cross-sectional nature of the data restricts our ability to determine temporal relationships between effusion and knee OA progression. Longitudinal studies would be more informative in assessing whether effusion precedes or results from structural joint damage. Second, effusion severity was assessed using a semi-quantitative grading scale rather than volumetric measurements. Incorporating advanced imaging analytics or automated segmentation could enhance the precision and reproducibility of future assessments.

Another limitation is the lack of data on potentially confounding variables such as body mass index (BMI), physical activity levels, systemic inflammatory markers, or history of intra-articular interventions. These factors could influence both knee OA severity and effusion independently. Additionally, the study did not evaluate the biochemical composition of the effused synovial fluid, which might have provided insights into the inflammatory versus mechanical nature of the effusion in different knee OA grades.

6. FUTURE PERSPECTIVE

Future investigations should integrate quantitative MRI parameters with clinical, biochemical, and functional outcome measures to provide a more holistic understanding of disease burden. Longitudinal cohort studies could elucidate the prognostic significance of effusion in predicting rapid structural progression or response to therapeutic interventions. Furthermore, research focusing on the modulation of synovial inflammation and fluid accumulation through pharmacologic or physical therapies could identify novel strategies for early knee OA management.

While this study focused primarily on the correlation between joint effusion and knee OA severity, it is important to note that MRI can provide detailed assessment of various other osteoarthritic parameters. These include cartilage thickness and integrity, bone marrow lesions (BMLs), meniscal pathology, synovitis, osteophyte formation, and subchondral cysts—each of which contributes to the structural and symptomatic profile of knee OA. Although these features were not the primary focus of our analysis, they represent critical components of comprehensive MRI evaluation in osteoarthritis. Additionally, the broader issue of MRI utilization in knee OA, including its cost-effectiveness and clinical impact, remains an important area of ongoing audit and health system evaluation, though it lies outside the scope of the present study.

7. CONCLUSION

In conclusion, this study demonstrates a strong association between knee osteoarthritis severity and joint effusion as assessed by MRI. While demographic factors showed no significant impact, effusion presence and intensity increased progressively with knee osteoarthritis grade, particularly in advanced disease stages. These results affirm the diagnostic and prognostic value of MRI in evaluating knee osteoarthritis and support the incorporation of effusion assessment into routine MRI-based grading. Further longitudinal and mechanistic studies are warranted to explore effusion as both a marker and a modifiable mediator of disease progression in knee osteoarthritis.

8. Data availability

The numerical data generated during this research is available with the authors.

9. Conflict of interest

The author declares that there was no conflict of interest.

10. Funding

The study utilized the hospital resources only, and no external or industry funding was involved.

11. Ethical consideration

The study protocol was reviewed and approved by the Institutional Research Ethics Committee of Northern Border University (Certificate of Ethical Approval #156/39/49/D). All procedures were conducted in accordance with the Declaration of Helsinki and relevant national guidelines. Informed written consent was obtained from all participants prior to enrollment.

12. Authors' contribution

The author contributed to all phases of the article from conception, till final version approval.

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