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IMPROVEMENT OF CLINICAL, LABORATORY AND INSTRUMENTAL DIAGNOSTIC CRITERIA FOR SEPTIC OSTEOARTHRITIS OF THE KNEE JOINT

Shoimov Shomurod Eshpulat ugli
Trauma Surgeon, Multidisciplinary Clinic of Tashkent Medical University
Gmail: shoimovshomurod12@gmail.com

Abstract: Septic osteoarthritis of the knee is a serious infectious-inflammatory condition characterized by rapid progression of synovial inflammation, cartilage destruction, periarticular tissue involvement and, in advanced cases, osteomyelitis and systemic complications. Early diagnosis remains challenging because the clinical manifestations of septic arthritis may overlap with crystal arthropathy, rheumatoid arthritis, traumatic synovitis and exacerbation of degenerative osteoarthritis. The aim of this study was to substantiate an integrated approach to the early diagnosis of septic osteoarthritis of the knee based on clinical, laboratory and instrumental parameters. The analysis demonstrates that no single diagnostic indicator is sufficiently reliable in all patients. Clinical signs such as acute pain, swelling, local hyperthermia, restricted range of motion and joint effusion should be interpreted together with serum inflammatory markers, particularly C-reactive protein, erythrocyte sedimentation rate and leukocyte count. Synovial fluid analysis, including leukocyte count, polymorphonuclear cell percentage, Gram staining, microbiological culture and crystal examination, remains a central diagnostic component. Ultrasound provides rapid detection of effusion and facilitates aspiration, whereas magnetic resonance imaging is particularly valuable for assessing synovitis, bone marrow edema, abscess formation and associated osteomyelitis. A combined diagnostic algorithm may improve early recognition and reduce the risk of delayed treatment.

Keywords: septic arthritis, septic osteoarthritis, knee joint, early diagnosis, synovial fluid, C-reactive protein, ESR, leukocytes, ultrasound, MRI, microbiological culture, diagnostic criteria.

Introduction

Septic involvement of the knee joint represents an orthopedic and infectious emergency because progressive bacterial infection can rapidly lead to irreversible cartilage damage, joint destruction, osteomyelitis, functional impairment and systemic infection. The knee is among the most frequently affected large joints in adults, and timely recognition is essential for preservation of joint function and prevention of severe complications [1,2]. The diagnostic problem becomes particularly difficult when infection develops against a background of degenerative osteoarthritis, because pain, swelling, restricted movement and joint effusion may initially be interpreted as an exacerbation of chronic degenerative disease.

Clinical manifestations alone are insufficient for reliable diagnosis. Patients may present with severe pain, swelling, local warmth and restricted range of motion, but the classical combination of fever and marked leukocytosis is not universally present. Therefore, the absence of fever or peripheral leukocytosis should not be considered sufficient to exclude septic arthritis [2,3]. Contemporary diagnostic approaches emphasize the integration of clinical examination, inflammatory laboratory markers, synovial fluid analysis and imaging findings.

Particular attention should be paid to synovial fluid examination. Synovial leukocyte counts and polymorphonuclear cell percentage provide important diagnostic information, while Gram staining and culture contribute to etiological confirmation. In a study of patients with suspected native-knee septic arthritis, synovial fluid leukocyte count ≥30,000 cells/μL, positive Gram staining, duration of pain

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exceeding two days and clinically evident effusion were independently associated with septic arthritis. A multivariable model incorporating these parameters demonstrated high discriminatory ability, with an area under the ROC curve of 0.942 [4].

The development of diagnostic algorithms incorporating multiple parameters is therefore of considerable practical importance. Modern imaging methods, especially ultrasound and magnetic resonance imaging (MRI), can complement laboratory findings by demonstrating joint effusion, synovial hypertrophy, periarticular inflammation, abscesses and bone involvement [5,6]. MRI is particularly valuable when infection is complicated by adjacent osteomyelitis or deep soft-tissue infection.

The aim of this study was to develop a clinically applicable integrated approach to the early diagnosis of septic osteoarthritis of the knee based on the combined assessment of clinical, laboratory and instrumental criteria.

The study was based on an analytical review of contemporary scientific literature concerning the diagnosis of septic arthritis of the native knee. Priority was given to original clinical studies, diagnostic studies, systematic reviews and evidence-based guidelines published in international peer-reviewed journals indexed in major bibliographic databases, including Scopus. Particular attention was given to studies evaluating clinical predictors, serum inflammatory markers, synovial fluid parameters and imaging techniques.

The diagnostic parameters were divided into four principal groups: clinical, systemic laboratory, synovial-fluid and instrumental criteria.

The clinical assessment included the duration and intensity of knee pain, joint swelling, local hyperthermia, erythema, tenderness, limitation of active and passive movements, presence of joint effusion and general manifestations such as fever and malaise. Particular importance was assigned to an acute or subacute deterioration of symptoms in a patient with previously stable degenerative osteoarthritis.

Laboratory assessment included peripheral white blood cell count, C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR). These markers were considered supportive rather than definitive diagnostic criteria because their diagnostic specificity is limited. Previous evidence indicates that inflammatory markers may assist in determining the probability of infection but cannot independently establish or exclude septic arthritis [3,7].

Synovial fluid analysis was considered a central component of the diagnostic algorithm. The evaluated parameters included synovial leukocyte count, polymorphonuclear leukocyte percentage, Gram staining, bacterial culture and crystal analysis. Evidence indicates that synovial leukocyte count has substantial diagnostic value, although its interpretation should account for the clinical context and possible inflammatory or crystal-induced arthropathies [4,8]. The presence of crystals does not absolutely exclude concomitant septic arthritis, and therefore microbiological assessment remains necessary when clinical suspicion is high [8].

Instrumental evaluation included plain radiography, ultrasonography and MRI. Radiography was considered useful for identifying pre-existing osteoarthritis, bone destruction, fractures and other structural abnormalities. Ultrasound was used as a rapid method for identifying intra-articular fluid and for assisting aspiration. MRI was considered particularly informative for evaluating synovial inflammation, cartilage and bone involvement, bone marrow edema, periarticular soft-tissue inflammation and abscess formation [5,6].

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The diagnostic significance of each parameter was assessed in relation to its sensitivity, specificity and ability to modify the pretest probability of septic arthritis. The principal methodological concept was that the diagnosis should be based not on an isolated threshold but on a structured combination of clinical, laboratory, synovial and imaging findings.

The literature analysis demonstrated that the diagnosis of septic osteoarthritis of the knee requires a multimodal approach. The most important clinical characteristics are acute or rapidly progressive pain, swelling, local warmth, joint effusion and marked restriction of movement. However, these manifestations are not specific because they may also occur in acute exacerbation of degenerative osteoarthritis, crystal arthritis, rheumatoid arthritis and traumatic synovitis [2,4].

A clinically important diagnostic feature is the sudden deterioration of symptoms in a patient with pre-existing osteoarthritis. The appearance of intense pain disproportionate to previous symptoms, rapidly increasing effusion, local hyperthermia and severe restriction of movement should increase suspicion of secondary infection. A history of previous septic arthritis, recent invasive procedures, skin infection, bacteremia, immunosuppression or other predisposing conditions should further increase clinical suspicion.

Serum inflammatory markers provide important supportive information. CRP generally demonstrates more rapid changes in response to acute inflammation than ESR and can therefore be particularly useful for monitoring the inflammatory process. Nevertheless, normal or only moderately elevated serum markers cannot completely exclude septic arthritis. Evidence-based reviews emphasize that peripheral WBC count, ESR and CRP have limited specificity and should be interpreted within the overall clinical context [3,7].

Synovial fluid examination remains the most important diagnostic step when septic arthritis is suspected. A high synovial WBC count, particularly when associated with a high polymorphonuclear cell percentage, substantially increases the probability of infection. In the multivariable study of native adult knee septic arthritis, synovial WBC ≥30,000 cells/μL was strongly associated with septic arthritis, with an odds ratio of 90.8. Positive Gram staining and clinical effusion also showed strong independent associations [4].

However, rigid application of a single numerical threshold may result in diagnostic errors. The SANJO guideline notes that a synovial WBC count below 25,000 cells/μL decreases the probability of septic arthritis but does not exclude it. Furthermore, the optimal threshold may differ according to the patient's immune status and clinical circumstances [8].

Microbiological examination is equally important because identification of the causative microorganism allows targeted antimicrobial therapy. Importantly, administration of antibiotics before aspiration may decrease the probability of obtaining a positive Gram stain or culture. In a study of patients with septic knee arthritis, prior antibiotic administration was associated with significantly lower rates of organism identification by microscopy and culture [9].

The available evidence also demonstrates that culture-negative septic arthritis is not uncommon. In a 10-year analysis of bacterial septic arthritis of the native adult knee, cultures were positive in only 35.84% of cases. Among culture-positive cases, Staphylococcus aureus was the most frequently identified microorganism, with a considerable proportion of methicillin-resistant strains [10]. This finding emphasizes that a negative culture should not automatically terminate the diagnostic process when clinical and synovial findings strongly indicate infection.

Instrumental diagnosis complements laboratory assessment. Plain radiography is useful as a baseline investigation and can reveal pre-existing degenerative changes, joint-space narrowing,

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osteophytes or advanced bone destruction. However, radiographic findings may be normal or nonspecific during the early phase of infection [8].

Ultrasonography has particular practical value because it is rapidly available, does not involve ionizing radiation and can detect even relatively small joint effusions. Furthermore, ultrasound can facilitate accurate aspiration of synovial fluid, which is particularly valuable when the amount of fluid is limited [8].

MRI provides the most comprehensive assessment of the knee when complicated infection is suspected. Characteristic findings may include joint effusion, synovial enhancement and thickening, periarticular edema, bone marrow edema, erosive or destructive changes and soft-tissue collections. MRI is also useful for detecting adjacent osteomyelitis and deep abscesses, which may substantially influence treatment planning [5,6].

Recent research has also demonstrated the potential of predictive models for improving diagnostic accuracy. A machine-learning study involving 326 patients with suspected septic arthritis of the knee found that synovial WBC count was an important individual predictor, while an XGBoost-based diagnostic model demonstrated greater discriminatory performance than synovial WBC count alone, with an AUC of 0.831 [11]. This finding supports the concept that future diagnostic protocols should increasingly integrate multiple variables rather than depend on a single laboratory threshold.

Based on the reviewed evidence, an improved diagnostic algorithm can be proposed. At the first stage, clinical assessment should identify patients with acute inflammatory symptoms and risk factors. At the second stage, CRP, ESR and peripheral WBC should be determined. If clinical suspicion remains significant, ultrasound should be performed to assess effusion and guide aspiration. Synovial fluid should subsequently undergo WBC and differential analysis, Gram staining, culture and crystal examination. MRI should be considered when there is suspected osteomyelitis, abscess formation, extensive synovial involvement or diagnostic uncertainty.

Table 1. Integrated clinical, laboratory and instrumental criteria for early diagnosis of septic osteoarthritis of the knee

Diagnostic domain	Main parameters	Diagnostic significance
Clinical	Acute severe pain, swelling, local warmth, effusion, restricted ROM	Establishes initial clinical suspicion
Systemic laboratory	CRP, ESR, peripheral WBC	Supports assessment of systemic inflammatory response
Synovial fluid	WBC count, PMN%, Gram stain, culture, crystals	Central diagnostic component; supports infection and etiological identification
Ultrasound	Effusion, synovial thickening, periarticular collections	Rapid detection and aspiration guidance
Radiography	Joint-space narrowing, osteophytes, bone destruction	Baseline structural assessment
MRI	Synovitis, marrow edema, erosions, abscess, osteomyelitis	Detailed assessment of early and complicated infection
Integrated	Combination of clinical + laboratory +	Improves diagnostic confidence and reduces

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Diagnostic domain	Main parameters	Diagnostic significance
assessment	synovial + imaging findings	isolated-test errors

Source: compiled by the authors based on [4–8,10,11].

The principal advantage of this integrated model is its ability to reduce diagnostic delay. A patient with acute knee inflammation and elevated CRP/ESR should not be diagnosed solely with exacerbation of osteoarthritis without considering infection. Conversely, moderate elevations of inflammatory markers in the absence of supporting synovial or clinical findings should not automatically be interpreted as septic arthritis. The final diagnostic decision should therefore be based on the cumulative probability generated by all available findings.

Conclusion

Septic osteoarthritis of the knee represents a clinically challenging condition requiring rapid and comprehensive diagnostic assessment. The findings of this literature-based analysis indicate that no single clinical, laboratory or instrumental parameter is sufficiently reliable to establish or exclude the diagnosis in every patient. Clinical manifestations such as acute pain, swelling, local hyperthermia, effusion and restricted movement should serve as the initial basis for suspicion.

CRP, ESR and peripheral WBC count are valuable supportive indicators but should not be interpreted independently. Synovial fluid analysis, including leukocyte count, polymorphonuclear cell percentage, Gram staining, microbiological culture and crystal examination, remains a central component of diagnosis. Ultrasound is particularly useful for rapid identification of effusion and aspiration guidance, whereas MRI provides more detailed information about synovial inflammation, bone marrow involvement, abscesses and associated osteomyelitis.

The most appropriate strategy is therefore an integrated diagnostic algorithm combining clinical, laboratory, synovial and instrumental parameters. The application of multivariable diagnostic models and, potentially, machine-learning approaches may further improve diagnostic accuracy in patients with ambiguous presentations. Such an approach can facilitate earlier recognition of infection, reduce diagnostic errors and create a more objective basis for subsequent treatment decisions.

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