Bacterial Septic Arthritis of the Adult Native Knee Joint

A Review

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Abstract

» Acute bacterial septic arthritis of the knee is an orthopaedic emergency and, if left untreated, can result in substantial joint degradation.

» Important risk factors for development of septic arthritis include age of >60 years, recent bacteremia, diabetes, cancer, cirrhosis, renal disease, drug or alcohol abuse, a history of corticosteroid injection, a recent injury or surgical procedure, a prosthetic joint, and a history of rheumatoid arthritis.

» The diagnosis is primarily based on history and clinical presentation of a red, warm, swollen, and painful joint with limited range of motion. Laboratory values and inflammatory markers from serum and joint fluid may serve as adjuncts when there is clinical suspicion of septic arthritis.

» The initial and general antibiotic regimen should cover methicillin-resistant *Staphylococcus aureus* and gram-negative and gram-positive organisms. The antibiotic regimen should be specified following the culture results of the infected joint.

» Operative management involves either arthrotomy or arthroscopy of the knee with thorough irrigation and debridement of all infected tissue. The Gächter classification is useful in establishing a prognosis or in determining the need for an extensive debridement.

Septic arthritis is defined as a joint infection caused by a pathogenic inoculation via direct or hematogenous routes[1]. Acute bacterial septic arthritis is an orthopaedic emergency requiring prompt diagnosis and treatment because of the potential for serious morbidity and mortality[2-5]. The diagnosis can be challenging, as a warm and painful knee can be due to an infectious cause and many non-infectious causes such as osteoarthritis, crystalline arthropathy, local intra-articular injection, and several systemic inflammatory disorders. Therefore, the accurate diagnosis of a patient with septic arthritis in the knee is a culmination of a patient's clinical picture, objective values, and clinician experience.

The current diagnostic algorithm involves a thorough history, physical examination, and serum and synovial laboratory values (Fig. 1)[3,6]. However, there are inconsistencies with clinical and laboratory diagnostic values routinely used to aid in diagnosis[3,7,8]. The mainstay of treatment for bacterial septic arthritis is timely joint irrigation and debridement followed by a targeted course of antibiotics. Historically, several techniques have been utilized. These include repeated aspirations, closed irrigation systems with or without instillation of antibiotics, open

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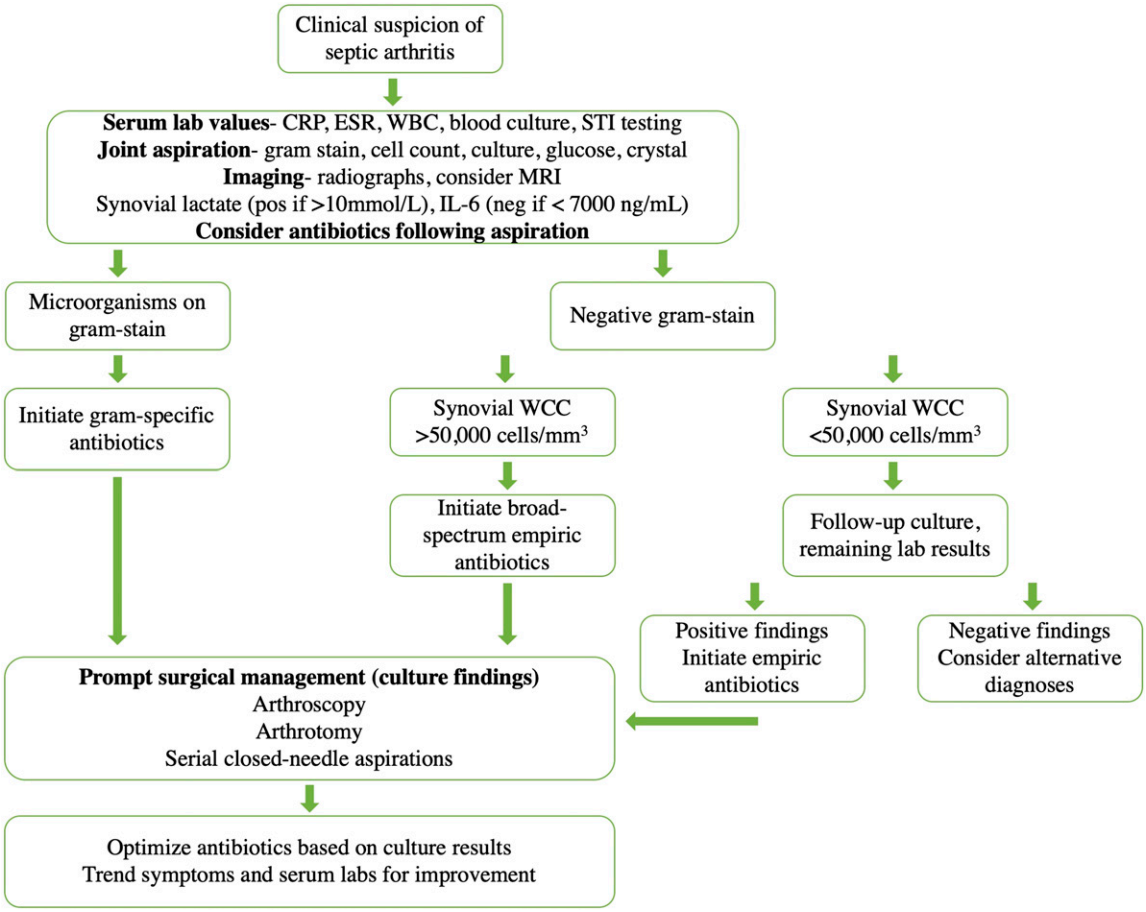

Fig. 1

Treatment algorithm for the diagnosis and management of suspected septic arthritis of the knee. STI = sexually transmitted infection, pos = positive, and neg = negative.

irrigation and debridement via arthrotomy, and more modern techniques including arthroscopic irrigation and debridement[9-14]. Because of the inconsistency of reporting measures, confounding variables, and a paucity of well-designed prospective studies, no technique has shown superiority[15-19]. This article sought to review the current multitude of literature with regard to the clinical, diagnostic, and laboratory workup of native knee joint septic arthritis and different surgical techniques utilized to obtain optimal results.

Epidemiology

The annual incidence of septic arthritis in the general population has been estimated to be around 2 to 10 cases per 100,000 people per year[8]. Patients with a history of prosthetic joint replacement, rheumatoid arthritis, systemic lupus erythematosus, crystalline arthropathy, diabetes mellitus, and use of immunosuppressive medications are at increased risk for developing septic arthritis[2,6]. *Staphylococcus aureus* is the organism most commonly responsible for septic arthritis, followed by other gram-positive organisms, notably streptococcal species[5,7,20,21]. Certain populations are known to have an increased susceptibility for unusual organisms. These include patients with a history of intravenous drug abuse, in which atypical bacterial and fungal infections should also be considered[5].

Pathophysiology

Acute septic arthritis of the knee can develop by the following mechanisms: hematogenous inoculation, direct inoculation, contiguous spread from an adjacent source of infection, and iatrogenic inoculation[5,22-24].

Hematogenous inoculation, being the most common mechanism, occurs when bacteria and bacteria-laden phagocytes lodge in the synovial membrane. The synovial membrane is a complex network of connective, vascular, and lymphatic tissues organized to deliver ultra-filtrated plasma known as synovial fluid into the joint[4]. Blood vessels enter the membrane and branch to form anastomotic plexi, which ultimately become the innermost layers of the synovium[25]. The vessels of the synovial intima lack a basement membrane, thus allowing the passage of large molecules. In physiologic circumstances, hyaluronic acid and other molecules enter the joint and function to lubricate and nourish the articular cartilage. The dense vascularity of the synovial membrane

allows this filtration process to occur. The absent basement membrane and dense vascularity also mean that the synovial membrane is in constant communication with the bloodstream. It is theorized that these features may allow for the passage of phagocytes loaded with bacteria into the synovium in states of bacteremia[4,22]. Recent literature over the past decade has suggested a role for the synovial lymphatic system in the pathogenesis of septic arthritis[26]. The lymphatic system represents a highly regulated and permeable monolayer of cells. During periods of inflammation, the primary processes of lymphangiogenesis coordinate immune cell migration. The increased flow of cells and macromolecules through this system may lead to leakage into the interstitium, resulting in joint effusions and the elevated pressures observed in septic arthritis. Persistent inflammation may result in damage to the lymph vessels, reduced permeability, lymph node collapse, and, ultimately, severe synovitis and joint erosion[26].

Once bacteria enter and adhere to the joint, the synovial milieu acts as an ideal culture medium for the bacteria. Direct inoculation of the knee is characteristically seen in the setting of a traumatic or iatrogenic knee penetration. Iatrogenic inoculation can occur following arthrocentesis, intra-articular injections, and arthroscopic procedures[23,27]. Geirsson et al. reported a septic arthritis frequency of 0.14% after arthroscopy and 0.037% after arthrocentesis[28]. For example, anterior cruciate ligament (ACL) reconstruction can introduce pathogens resulting in septic arthritis[29], with an estimated risk of 0.14%, which is in accordance with the rate reported in the study by Geirsson et al.[28]. Regardless of the mechanism bacteria use to enter the joint space, the bacteria will have the opportunity to infect the knee and activate the immune response, which will eventually lead to joint destruction.

Infection of the synovial membrane results in hyperemia and recruitment of immune cells, which in turn releases a number of pro-inflammatory factors into the joint space. This leads to redness, warmth, swelling, and pain. As the immune response continues, the synovial cells begin to secrete proteolytic enzymes[30]. Cartilage damage starts to occur as early as 8 hours after infection[31]. As this destructive process proceeds, proteoglycans are broken down by day 5 and collagen is degraded by day 9 after the inoculation[32]. As the infection progresses, the intra-articular pressure rises, resulting in compression and thrombosis of the synovial vasculature and further destruction of articular cartilage[33].

Clinical Presentation

The presentation of native knee septic arthritis in the adult patient is often subacute and can be difficult to diagnose. The current gold standard for diagnosis does not rely on laboratory values alone but relies also on clinical suspicion from an experienced physician[1]. Thus, collecting a detailed medical history is critical for diagnosis. The typical signs and symptoms include a hot, swollen, and tender knee with limited and severely painful active and passive motion on examination[1,21,34]. The knees of patients with septic arthritis are held in 30° of flexion with external rotation; in contrast, patients with prepatellar septic bursitis are able to obtain >90° of flexion, although extension is limited past that point[3]. Symptoms can be present for 2 weeks by the time of presentation[34].

There is no accurate criteria-based method for diagnosis of septic arthritis. The Kocher criteria form a commonly used clinical prediction algorithm used to differentiate septic arthritis from transient synovitis in the pediatric hip[35]. Although the Kocher criteria are commonly used in diagnosing septic arthritis in adult patients[36], these criteria have not been validated for use in children. Borzio et al. performed a retrospective review of 458 patients treated for septic arthritis, and specifically evaluated the utility of the Kocher criteria in the diagnosis of septic arthritis in an adult population[37]. The study found that, to achieve 90% specificity, synovial white blood-cell (WBC) counts had to be at least 64,000 cells/mm^3. The authors concluded that the synovial WBC count was a valuable diagnostic tool and the application of the Kocher criteria in adults was of limited utility.

Because clinical presentation has been found to be unreliable, the physician must take into account risk factors and laboratory findings in diagnosing septic arthritis.

Risk Factors

The risk factors associated with septic arthritis include an age of >60 years, recent bacteremia, diabetes, malignancy requiring chemotherapy or immunosuppressive therapy, cirrhosis, renal disease, drug or alcohol abuse, a history of corticosteroid injection, long-term corticosteroid therapy, refractory sinusitis treated with methylprednisolone, recent dental procedures or tattoos, genital trauma, and injury or surgical procedure involving the joint (Table I)[1,6,38,39]. Of particular importance, patients with rheumatoid arthritis are at risk for septic arthritis, with as much as 4 to 15 times greater risk than in the general population[1,5,6,24]; this increased risk could be related to the disease process itself as well as the immunosuppressive therapies used to treat it[6,24]. In particular, comorbidities with immunomodulation or those requiring immunomodulating treatment are associated with an increased risk of septic arthritis. Comorbidities linked with hospitalization for septic arthritis include diabetes mellitus, hyperlipidemia, hypertension, coronary heart disease, gout, osteoarthritis, renal failure, and heart failure[40].

Intra-articular steroid injection rarely results in septic arthritis, with a reported risk of 1:3,000 to 1:50,000[23]. Most of the commonly cited sources with regard to the rates of septic arthritis following intra-articular steroid injection are outdated[23,28,36], and newer prospective studies are limited. Geirsson et al. reported the estimated risk of septic arthritis following arthrocentesis in their

TABLE I Risk Factors for Development of Septic Arthritis

Age of >60 years
Recent bacteremia
Injury or surgical procedure involving the joint
Joint prostheses
History of corticosteroid injection
Rheumatoid arthritis
Diabetes
Malignancy (receiving chemotherapy or immunosuppressive therapy in the past 6 to 12 months)
Reduced immunocompetence (e.g., through treatment with anti-tumor necrosis factor medication)
Cirrhosis
Renal disease
Drug abuse
Alcohol abuse
Chronic prostatitis
Long-term corticosteroid therapy (e.g., asthma, chronic obstructive pulmonary disease, seasonal allergies)
Refractory sinusitis receiving methylprednisolone
Recent dental procedures
Recent tattoo
Genital trauma through sexual practices

Icelandic cohort as 3 infections per 7,900 procedures, or 0.037% per injection[28]. In comparison, the incidence rates of septic arthritis following hyaluronic acid injections are estimated to be 2.7 per 100,000 in men and 4.2 per 100,000 in women, based on a Korean insurance registry[41]. Patients with rheumatoid arthritis undergoing immunosuppressive therapy have been shown to have a higher risk of septic arthritis following steroid injection, with rates reported as high as 1 in 2,000 within 3 months following an injection[42].

Similar to steroid injection risks, elective arthroscopy rarely results in septic arthritis[4,21,43]. In their review on septic arthritis as a complication of elective arthroscopy, Kirchhoff et al. reported a risk of approximately 0.42%[27]. They concluded that, although this was a rare entity, it is essential to recognize early as timely diagnosis is a key factor in control of morbidity and mortality[27]. Even though infection is unlikely, surgeons should have a high index of suspicion and patients presenting with unusual knee pain after arthroscopy should have a workup for septic arthritis[4].

Diagnosis

Several conditions such as gout, pseudogout, and rheumatoid arthritis can mimic acute septic arthritis and can present with a red, warm, swollen knee with a painful range of motion[3]. The initial evaluation should begin with a history, physical examination, imaging, and laboratory studies including blood cultures. If a high clinical suspicion exists, joint aspiration with synovial fluid analysis is essential[2-4,6]. A holistic analysis of findings and symptoms is necessary for diagnosis, as there is a reported high incidence of false-negative results in Gram stain microscopy, particularly in the presence of crystals or clotting[44]. If trained personnel are available, ultrasound-guided synovial biopsy may be utilized to improve diagnostic efficiency in cases in which a false-negative aspiration is suspected[45].

A detailed history and a physical examination are vital portions of every patient encounter; however, the predictive value of a single examination finding for septic arthritis appears to be weak[3,46,47]. Any violation of the dermis and subdermal environment, such as with piercings, is important to note during examination. Couderc et al. performed a prospective study to determine the sensitivity and specificity of clinical signs and laboratory values in suspected septic arthritis[47]. A multivariate analysis of their findings found that no clinical sign or laboratory test alone (excluding positive synovial fluid culture) is conclusive for diagnosing septic arthritis. The only clinical finding that they found to be associated with a diagnosis of septic arthritis was chills. They concluded that the association of several factors (clinical, laboratory, and radiographic) may combine to be suggestive of septic arthritis and that future prospective studies could aid in the creation of a score to estimate the probability of septic arthritis and to guide treatment.

The clinician has an array of imaging modalities to assist in the diagnosis of septic arthritis. A complete diagnostic workup includes orthogonal radiographs of the joint involved. Early changes in septic arthritis include effusion, joint-space widening, and soft-tissue swelling. Lateral knee radiographs may also contain air and/or air-fluid levels. Juxta-articular osteoporosis, erosions, and joint-space narrowing with cortical destruction are late findings[48]. Additionally, ultrasound is an attractive imaging tool due to its ability to provide real-time information to the technician and no radiation exposure to the patient. With concerns over growing hospital costs, it also benefits from being relatively inexpensive.

Magnetic resonance imaging (MRI) is excellent in detecting irregularities in soft tissue and osseous edema and is useful in identifying coexistent osteomyelitis[2]. Although it is very sensitive in detecting synovial hypertrophy and joint effusion, there is substantial overlap in the findings seen between the

septic and non-septic inflamed joint, and no 1 sign or combination of signs is pathognomonic for septic arthritis[49]. For these reasons, as well as its expense and its unavailability to most practitioners in an expedient manner, we cannot recommend its use on a routine basis. Overall, imaging studies assist the clinician in identifying structural abnormalities, effusions, and the extent of inflammation, but cannot provide a definitive diagnosis of septic arthritis. Advanced imaging studies should therefore be used judiciously when clinical suspicion is high so as to not delay surgical intervention.

Physicians have routinely used laboratory tests and blood cultures to aid in the diagnosis of septic arthritis. The sensitivity of these modalities in diagnosing septic arthritis has been a topic of research. Ideally, blood cultures should be drawn prior to the initiation of antibiotic therapy. Weston et al. evaluated all patients admitted to a U.K. hospital over a 10-year period with confirmed septic arthritis[7]. Of the 242 patients identified with positive synovial fluid cultures, 58 (24%) were also found to have positive blood cultures. Overall, the study supported the notion that a negative blood culture should not preclude the diagnosis of septic arthritis.

Laboratory tests routinely include a complete blood-cell count, complete metabolic panel, erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP). Li et al. completed a retrospective study which identified 61 (84%) of 73 patients with culture-proven septic arthritis[50]. Of these patients, they found that the sensitivities were 48% for peripheral WBC count (>11,000 cells/mm^3), 64% for synovial white cell count (WCC) (>50,000 cells/mm^3), and 96% for ESR (>30 mm/hr). The synovial WCC has been explored as a measurement with the potential use of definitively diagnosing septic arthritis. The ranges for all 3 of these values were broad among the 61 patients and were not reliable. More than one-third of their patients with culture-proven septic arthritis had a synovial WCC of <50,000 cells/mm^3. Overall, the authors concluded that traditional serum markers are extremely variable and that laboratory tests including synovial WCC were not able to rule out septic arthritis with reliability.

Carpenter et al. performed a systematic review in an effort to evaluate the efficacy of clinical and laboratory values in the diagnosis of septic arthritis[46]. They found that history, physical examination, and peripheral WBC, ESR, and CRP were not able to provide a definitive diagnosis. They utilized a stratified approach in their analysis of synovial WCC. Their reported likelihood ratios were 0.33 for a synovial WCC of 0 to 25,000 cells/mm^3, 3.59 for a synovial WCC of 25,000 to 50,000 cells/mm^3, and infinity for a synovial WCC of >100,000 cells/mm^3. The authors concluded that a synovial WCC of >50,000 cells/mm^3 is specific but not sensitive in the diagnosis of septic arthritis and should be applied in conjunction with each patient's overall clinical presentation. CRP is most routinely trended following treatment and is expected to normalize between 1 and 2 weeks following the initiation of antibiotics or irrigation[51,52]. Although ESR may also be trended, serum values may still be elevated for days to weeks after the resolution of inflammation[53].

More recent studies have focused on the identification of novel diagnostic values that can be utilized in assessment of a patient with possible septic arthritis. Hügle et al. performed a prospective study that included a total of 42 patients, 14 with confirmed septic arthritis, and sought to evaluate the effectiveness of serum procalcitonin in differentiating septic arthritis from non-septic arthritis as causes of arthropathy[54]. The investigators found that patients with septic arthritis had statistically higher procalcitonin concentrations compared with patients without septic arthritis. In addition, they found that, at a cutoff of 0.1 ng/mL, the sensitivity for septic arthritis was 93% and the specificity was 75%. Notably, upon exclusion of patients without septic arthritis who also had concomitant infection, the specificity rose to 93%. This small, yet promising, study identified a marker with potentially high sensitivity and specificity. Further trials are required to fully elucidate the value of procalcitonin in the diagnosis of septic arthritis.

Lenski et al. performed a retrospective study that included 119 patients with suspected septic arthritis[55]. Of the 119 patients, 62 (52%) were found to be culture-positive. Analysis of the synovial fluid samples from these patients included interleukin (IL)-6, total protein, glucose, lactate, and synovial WCC. The markers with the highest predictive value were synovial lactate, which had a sensitivity of 74.5% and a specificity of 87.2%, followed by IL-6, which had a sensitivity of 92.5% and a specificity of 64.1%. The investigators found that synovial fluid lactate levels of >10 mmol/L nearly proved septic arthritis, with an interval likelihood ratio of 20.4. Synovial IL-6 levels of <7,000 pg/mL almost ruled out infection, with an interval likelihood ratio of 0.12. The investigators performed a follow-up retrospective study involving 719 patients that further investigated the diagnostic value of several serum and synovial inflammatory markers. This study supported their previously reported result that synovial lactate levels of >10 mmol/L strongly support a diagnosis of septic arthritis[56].

These new laboratory values demonstrate exciting potential in their ability to simplify the diagnosis of septic arthritis. However, more extensive research is required before these values can be routinely utilized. Additionally, laboratory testing of new markers may not be available in some clinic sites. Clinicians should consider the use of these studies on a case-by-case basis and as an adjunct when making a clinical diagnosis of septic arthritis.

Medical Management

It is critical to initiate antibiotics as soon as possible when septic arthritis is suspected (Table II). It is appropriate to obtain blood cultures and synovial fluid

TABLE II Antibiotic Treatment Regimen According to Organism in the Treatment of Septic Arthritis

Organism	Antibiotic Regimen
MRSA	Vancomycin 1 g every 12 hours or linezolid 600 mg every 12 hours
Coagulase-negative Staphylococcus species	Vancomycin 1 g every 12 hours or linezolid 600 mg every 12 hours
Methicillin-sensitive *S. aureus* (MSSA)	Nafcillin 2 g every 6 hours or clindamycin 900 mg every 8 hours
Coagulase-negative Staphylococcus species	Nafcillin 2 g every 6 hours or clindamycin 900 mg every 8 hours
Group A streptococci, *S. pyogenes*	Penicillin G 2 million units every 4 hours or ampicillin 2 g every 6 hours
Group B streptococci, *S. agalactiae*	Penicillin G 2 million units every 4 hours or ampicillin 2 g every 6 hours
Enterococcus species	Ampicillin 2 g every 6 hours or vancomycin 1 g every 12 hours
Escherichia coli	Ampicillin-sulbactam 3 g every 6 hours
Proteus mirabilis	Ampicillin 2 g every 6 hours or levofloxacin 500 mg daily
P. vulgaris, P. rettgeri, Morganella morganii	Cefotaxime 2 g every 6 hours, imipenem 500 mg every 6 hours, or levofloxacin 500 mg daily
Serratia marcescens	Cefotaxime 2 g every 6 hours
Pseudomonas aeruginosa	Cefepime 2 g every 12 hours, piperacillin 3 g every 6 hours, or imipenem 500 every 6 hours
Neisseria gonorrhea	Ceftriaxone 2 g daily or cefotaxime 1 g every 8 hours
Bacteroides fragilis	Clindamycin 900 mg every 8 hours or metronidazole 500 mg every 8 hours

samples prior to initiation[4,5], but these tests should be performed in an expedient manner. Stengel et al. performed a meta-analysis that demonstrated no advantage between various initial regimens[57].

Most recommendations with regard to initial antibiotic regimens are currently based on expert opinion. The current recommendation is that an initial regimen be based on the suspected organisms while keeping in mind common flora for a given region[1,4,5,8,24]. One must consider the Gram stain result as well as the possible risk of a sexually transmitted infection. Generally, in the absence of a sexually transmitted infection, coverage is achieved with antibiotics with gram-negative, gram-positive, and methicillin-resistant *S. aureus* (MRSA) coverage[4,24]. Antibiotic regimens should be specified on the basis of cultures, preferably in conjunction with an infectious disease specialist. In patients with a high suspicion for septic arthritis who have negative cultures but respond to empiric antibiotics, completing a full course of therapy may be prudent and should be decided by the clinician on a patient-by-patient basis[24].

Surgical Management

Acute native joint septic arthritis is an orthopaedic emergency, and delays in treatment can result in joint degradation, osteonecrosis, and instability[39]. The goals of surgical treatment include decompression, lavage, debridement, and, in some cases, synovectomy[58,59]. There is debate with regard to the optimal surgical method to achieve these goals. Options currently include open treatment via arthrotomy, arthroscopic debridement, or serial closed-needle aspiration[15-18,59-61].

The treatment of septic arthritis by excisional debridement is a staple in the field of surgery. In the pre-antibiotic era, aspiration or exploration were the only available methods to eradicate a joint infection. Willems was one of the first to advocate for wide arthrotomy followed by early active mobilization in patients with septic arthritis[62]. In 1941, Heberling reported on his series of patients who underwent an arthrotomy for septic arthritis, followed by placement of a subcutaneous drain and early active motion[63]. He, among other authors, concluded that early diagnosis and treatment were pivotal to successful outcomes and limiting morbidity and mortality[12,64]. Although their contributions to recognizing the importance of early diagnosis and treatment cannot be overstated, advances in diagnostic and outcome measures make it difficult to generalize their findings to the patient populations seen today.

Serial closed-needle aspiration is 1 method of treating native joint septic arthritis that is commonly cited in the rheumatology and medical literature[18,60]. Ravindran et al. retrospectively compared 32 patients who received medical treatment (serial closed-needle aspiration) or surgical treatment (arthroscopy or arthrotomy with joint lavage) for culture-proven native joint septic arthritis[61]. They found that the medical treatment group trended toward greater odds of complete recovery compared with the surgical treatment group, but this finding was not significant. A limitation of the study was that the authors did not provide guidelines for patient treatment allocation, thus increasing suspicion of a selection bias. It is possible that the patients with a more severe infection were treated surgically, and those with lower-grade infections were treated medically. The investigators recommended medical treatment only for "uncomplicated" native joint septic arthritis[54]. The use of serial aspiration for the definitive management of septic arthritis is not widely accepted in the orthopaedic literature[65,66].

Many authors have advocated for arthroscopic management of native joint septic arthritis[15,16,19,59]. Ivey and Clark reported on 1 of the first prospective

TABLE III Gächter Classification of Septic Knee Arthritis

Stage	Arthroscopic Findings	Radiographic Findings
I	Opacity of fluid, redness of the synovial membrane	No radiographic changes
II	Severe inflammation, fibrinous deposition, pus	No radiographic changes
III	Thickening of the synovial membrane, compartment formation	No radiographic changes
IV	Aggressive pannus with infiltration of the cartilage, undermining the cartilage	Subchondral osteolysis, possible osseous erosions, and cysts

cohorts evaluating arthroscopic management of native knee septic arthritis[13]. Their study included 10 patients with 11 infected knees who underwent arthroscopic excisional debridement. In their series, no patient required a second debridement, and all patients returned to their former levels of activity. The authors were encouraged with the early results and thought that functional recovery was more complete because of less scarring of the joint surface. Proponents of arthroscopic management of septic arthritis of the knee cite the ability to perform a complete debridement of necrotic synovium and a thorough joint assessment with minimal operative morbidity[13].

This improved visualization, when adequate suction is achieved, allows the surgeon to better evaluate the knee and determine the stage of infection as defined by the Gächter classification (Table III)[15-17,19,59,67]. Staging of the joint based on this classification may direct surgical treatment and has prognostic implications. Studies have found that arthroscopic management of Gächter stage I to II is effective, typically with 1 procedure[15,16,19,59]. Gächter stage III can also effectively be managed with arthroscopy, but typically requires a more extensive synovectomy to clear any necrotic or purulent-appearing areas[15,16,19,59]. Gächter stage IV is defined by osseous involvement with cartilage necrosis; therefore, open treatment is recommended to allow for appropriate debridement of affected extra-articular structures[16,19]. Arthroscopy has also been shown to reduce rates of reoperation, to improve postoperative range of motion and function, and to achieve shorter hospital stays[15,16,19,59].

Balabaud et al. proposed an algorithm used at their institution for the treatment of acute bacterial arthritis of the native knee joint[68]. In their retrospective cohort of 40 patients, 21 arthroscopic debridements and 19 open debridements were performed in infected knees of various etiologies[68]. In concordance with other studies, the authors saw a significant relationship between intra-articular joint damage, as defined by an increasing Gächter stage, and ultimate functional outcomes. They identified that this relationship was also directly correlated with a delay in treatment. From their findings, they recommended aggressive arthroscopic debridement as the routine treatment for native knee septic arthritis. Additionally, they recommended synovectomy during the initial primary procedure when substantial synovial hypertrophy is present (Gächter stages III or IV) or in the instance of failure of more conservative treatment.

Even with surgical debridement, patients with certain risk factors may develop recurrent infection. Hunter et al. reviewed 132 native joints in 128 patients with acute septic arthritis and found that 49 of these patients (38%) underwent a failed single surgical debridement[39]. They isolated 5 clinical factors that were most predictive of failure of a single surgical debridement. These included a history of inflammatory arthropathy, the involvement of a large joint (knee, shoulder, or hip), a synovial-fluid cell count of >85,000 cells/mm^3, the isolation of *S. aureus,* and a history of diabetes.

Overall, there is a lack of well-designed prospective studies comparing surgical treatment modalities for native knee septic arthritis. Most of the available studies are small, retrospective series with important methodological flaws. Although open debridement via arthrotomy is considered an effective treatment option, arthroscopic debridement may also be advantageous in select populations. The use of the Gächter classification may aid in acknowledging which patients may require extensive synovectomy and which patients are at a higher risk for requiring a second debridement. Both open and arthroscopic techniques can typically eradicate infection with 1 procedure in patients who are diagnosed early and are also receiving appropriate antibiotic therapy[15,39].

Several topics with regard to musculoskeletal infection remain in need of further study. The International Consensus Meeting (ICM 2018) on Musculoskeletal Infection designated 38 research questions as high priority for further study, which included topics of acute infection compared with chronic infection, host immunity, antibiotics, diagnosis, research caveats, and modifiable factors[69]. Research with regard to biofilms relevant to clinical practice was also deemed relevant and includes the topics of surface modifications to prevent or inhibit biofilm formation, therapies to prevent and treat biofilm infections, polymicrobial biofilms, diagnostics to detect active and dormant biofilm in patients, methods to establish a minimal biofilm eradication concentration for biofilm bacteria, and novel anti-infectives that are effective against biofilm bacteria[70].

Conclusions

Acute bacterial septic arthritis of the knee is an orthopaedic emergency that requires prompt diagnosis and early initiation of treatment. Diagnosis is best achieved by a summation of each patient's overall clinical presentation, risk factors, and laboratory values. It is essential to identify patients with risk factors such as rheumatoid arthritis, diabetes, alcoholism, and a history of corticosteroid injections as they are at increased risk for septic arthritis.

Although variability exists in the overall ability of each physical examination and clinical laboratory factor to independently diagnose septic arthritis, when used in conjunction with clinical experience, it will most often allow for accurate diagnosis. When high suspicion exists, it is important to obtain blood cultures and synovial fluid aspiration. Most studies have indicated that a synovial WCC of $>$50,000 cells/mm^3 is specific for bacterial septic arthritis, but values of $<$50,000 cells/mm^3 do not necessarily allow the clinician to rule out septic arthritis. Therefore, these values should be used in conjunction with other values such as peripheral WCC, ESR, and CRP to make clinical decisions. Other laboratory factors such as serum procalcitonin, synovial IL-6, and synovial lactate levels have shown promise in aiding with diagnosis but have yet to be proven with randomized controlled trials.

Prompt treatment is essential. This includes the initiation of antibiotics in addition to surgical irrigation and debridement. Arthroscopic approaches have been shown to be as effective as traditional open approaches, with the added benefit of reduced hospital stay and improved postoperative recovery. These findings are the result of many retrospective reviews but have yet to be validated with randomized controlled studies. The decision for an arthroscopic approach is left to the comfort and decision of the clinician.

The mainstay of management of acute septic arthritis is timely diagnosis, initiation of systemic antibiotics, and surgical decompression and debridement. Although serial aspiration and closed irrigation systems have been described, they are not widely accepted as definitive treatment. Whether to perform an open or arthroscopic debridement with or without synovectomy is a topic of debate. The choice of technique is dependent on patient variables, severity of disease, and surgeon preference. Prompt debridement, whether open or arthroscopic, typically results in effective resolution of infection. A high clinical suspicion and thorough diagnostic evaluation in addition to early initiation of medical and surgical management are essential for the successful management of native knee septic arthritis.

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