CURRENT CONCEPTS REVIEW

Current Concepts Review: Infection Following ACL Reconstruction: From Prevention to Treatment

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Abstract

Postoperative infection is a rare but serious complication following anterior cruciate ligament reconstruction (ACLR). This review integrates current epidemiological trends, risk factors, and novel diagnostic and therapeutic approaches reported in the existing literature. The estimated incidence of septic arthritis (SA) after ACLR typically ranges from 0.14% to 2.6%. Male sex, smoking, hamstring autograft use, diabetes mellitus, and elevated body mass index (BMI) are significant risk factors. Intraoperative presoaking of the graft in vancomycin, known as the 'vancomycin wrap' technique, has significantly reduced infection rates and improved prophylactic practice. Diagnosis is based on clinical suspicion and laboratory findings, including synovial fluid analysis and C-reactive protein (CRP).Management often involves urgent arthroscopic debridement and individualized antibiotic treatment, with the primary aim of preserving the ACL graft. Although graft retention is successful in many cases, persistent infection may require graft removal, which is associated with poorer outcomes.

Level of evidence: IV

Keywords: Anterior cruciate ligament reconstruction (ACLR), Instability, Postoperative infection, Septic arthritis, Surgical site infection

Introduction

Anterior cruciate ligament (ACL) reconstruction is one of the most commonly performed orthopedic procedures, and its frequency has increased noticeably in recent years. Epidemiological data from national registries and insurance databases indicate an annual incidence of 40 to 75 cases per 100,000 individuals.[1,2] The procedure, typically performed arthroscopically using autografts or allografts, allows many patients, particularly young athletes, to return to their normal level of function and performance following an injury.[3] Post-ACLR infections are rare; however, when they occur, they complicate recovery, leading to prolonged rehabilitation, possible graft failure, articular cartilage damage, and potential long-term consequences such as osteoarthritis, which may end athletic careers or reduce quality of life.[4-6]

The clinical ramifications of post-ACLR infections extend beyond physical morbidity. The psychological effects of a delayed return to activity, coupled with the financial burden of prolonged hospitalization and revision surgery, underscore the need for effective preventive and management strategies. Recent epidemiological studies indicate that hamstring autografts have a higher infection risk (1.44%) than bone-patellar tendon-bone grafts (0.49%) and quadriceps tendon grafts (0.1%).[7,8]

The microorganisms most commonly identified in ACLR infections are coagulase-negative staphylococci (CoNS), accounting for 45% of cases, and Staphylococcus aureus, accounting for 24%. Less common pathogens, such as fungi or atypical mycobacteria, may pose diagnostic challenges and require specific treatment.[1,2,9] Infections generally occur within the first two weeks after surgery and are characterized by pain, edema, fever, and restricted range of motion. In contrast, chronic infections may develop insidiously and lead to poorer outcomes due to ongoing instability.[4]

Despite advances in perioperative antibiotic treatment and surgical techniques, important limitations remain in the literature. Systematic reviews, including the 2024 meta-analysis by Lin et al., indicate that postoperative

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infection is associated with poorer outcomes after ACL reconstruction, including increased degenerative changes in the patellofemoral and lateral femorotibial cartilage and inferior graft ligamentization and maturation compared with noninfected patients.[7] Recent research published in 2024, including studies assessing the efficacy of irrigation and debridement, warrants an updated synthesis.[8]

Previous guidelines, such as those issued by ESSKA/EBJIS in 2023, provide essential guidance for treatment[10]; however, incorporating recent findings on vancomycin prophylaxis and graft-retention strategies is important for improving outcomes. This current concepts review aims to address these gaps by: (1) summarizing contemporary epidemiology and risk factors; (2) outlining evidence-based prevention and diagnostic strategies; (3) assessing management protocols, including graft retention versus removal; and (4) analyzing outcomes, rehabilitation, and future directions. By synthesizing this evidence, we aim to provide orthopedic surgeons with effective strategies to minimize risk and improve recovery in this patient population.

Main body

A focused literature search was performed to identify relevant studies addressing infection following anterior cruciate ligament reconstruction. PubMed/MEDLINE was searched using combinations of the terms "anterior cruciate ligament reconstruction," "ACL reconstruction," "infection," "septic arthritis," "risk factors," "prevention," "vancomycin presoak," and "graft soaking."

As this article was designed as a current concepts review, studies were selected based on their relevance to the topic, clinical importance, and contribution to contemporary practice.

Epidemiology and Risk Factors

The prevalence of septic arthritis after ACL reconstruction is commonly reported to range from 0.14% to 2.6% across various populations.[1,2,4,9] An infection rate of 0.65% was reported in a large database analysis of 44,501 pediatric and adolescent patients; no notable difference was found between the pediatric and young adult groups.[8]

Several risk factors have been identified in the literature:

A. Compared with bone-patellar tendon-bone (BPTB) autografts, hamstring autografts are consistently associated with a higher risk of infection.[11,12] Conversely, the use of all-soft tissue quadriceps tendon (ASTQT) autografts has been associated with a low incidence of culture-positive septic arthritis (0% in a study of 1,053 cases).[13] A comprehensive systematic review and meta-analysis identified revision surgery, simultaneous lateral extra-articular tenodesis, and prolonged operative duration as factors associated with an increased risk of surgical site infection following ACL reconstruction.[14]

B. Patient Factors: Elevated BMI, smoking, male sex, diabetes mellitus, a history of corticosteroid use, immunosuppressive medication use, and prior knee surgery are associated with an increased risk.[9] Additionally, a recent meta-analysis identified professional athletic status as a risk factor[14]. Previous research suggested a possible association between eczema and increased staphylococcal colonization; however, subsequent findings have shown that a history of dermatitis does not markedly increase the risk of postoperative infection following arthroscopic knee surgery.[15]

C. Pathogens: Staphylococcus aureus and coagulase-negative staphylococci, particularly Staphylococcus epidermidis, are the predominant etiological agents identified in most positive cultures.[2,16-18] Atypical infections, including those caused by nontuberculous mycobacteria, Salmonella, and fungi such as Aspergillus fumigatus, as well as cases of mucormycosis, have been reported and may present with more indolent or severe clinical signs.[19-22] Other pathogens, including Eggerthia catenaformis, have also been identified.[23]

A schematic overview of the multifactorial contributors to infection following ACL reconstruction is presented in [Figure 1].

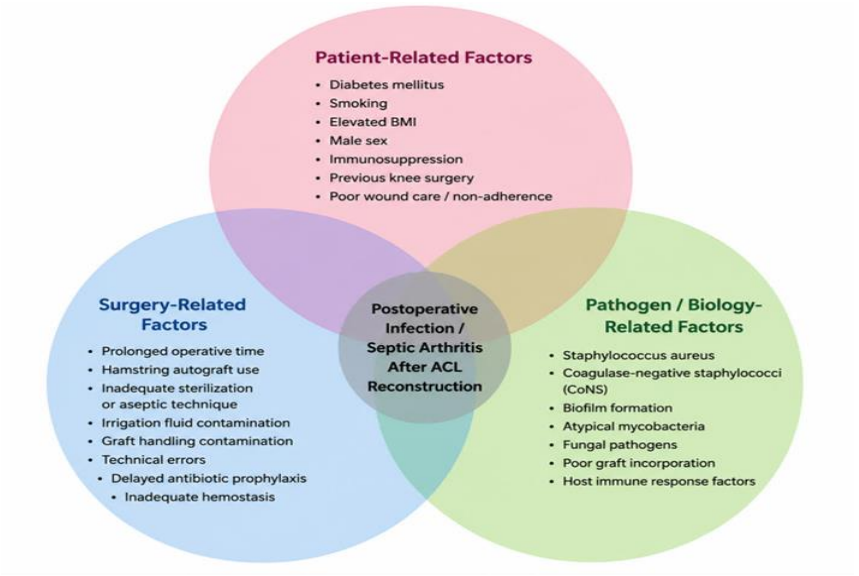

Figure 1. Contributors to Infection Following ACLR

Diagnosis may be delayed until significant bone-destructive lesions become evident. This may necessitate more extensive reconstructive procedures and result in substantial functional impairment.[22]

Prevention and Diagnostic Approaches

A major advance in prevention is the use of intraoperative antibiotic presoaking of the tendon graft.[24] Soaking hamstring grafts in a vancomycin solution (often at 5 mg/mL) has been shown to be highly cost-effective and to markedly reduce the occurrence of septic arthritis, often to nearly 0% in both hamstring and BPTB autografts.[25,26] Gentamicin has also been evaluated for graft soaking with favorable outcomes; however, vancomycin remains more widely used in contemporary clinical practice.[24,27]

Meta-analytic research demonstrates the efficacy of vancomycin presoaking in reducing infection rates following ACL reconstruction. Naendrup et al. reported no cases of septic arthritis among 2,976 vancomycin-treated grafts, compared with 44 cases among 2,099 controls (OR, 0.04; 95% CI, 0.01–0.16).[28] Xiao et al. reported significantly lower infection rates with vancomycin presoaking in 21,368 patients (0.013% vs 0.77%; OR, 0.07; P < 0.001),[29] while a subsequent meta-analysis by Hu et al. involving 31,150 patients confirmed this finding (0.09% vs 0.74%; OR, 0.17; P < 0.00001).[30] Although no apparent increase in graft failure has been reported, the available evidence is dominated by heterogeneous retrospective studies and lacks randomized controlled trials; therefore, universal use cannot yet be definitively recommended.[31]

Bartek et al. demonstrated that progressive contamination of irrigation fluid and bacterial contamination of suture material are important contributors to surgical site infection following ACL reconstruction.[32] Consequently, all infection-reduction measures, including appropriate operating-room practices, must be rigorously implemented.[10]

The complexity and duration of the surgical procedure are associated with an increased risk of postoperative infection. Orthopedic surgery requires a strictly aseptic environment to prevent joint infection because the joint is an enclosed compartment with a limited presence of immune cells.[33]

Recommendations for infection prevention are summarized in [Table 1].[2,10,34,35]

Table 1. Overview of Preventive Measures

Preventive Measure	Clinical Phase	key consideration
Graft Selection (BPTB)	Preoperative	Bone-patellar tendon-bone autografts show considerably decreased infection rates in comparison to hamstring tendon grafts.
Smoking Cessation	Preoperative	A minimum of four weeks of cessation maximizes the host's defenses against surgical site infection.
Bacterial Decolonization	Preoperative	The staphylococcal bacterial load of the patient is decreased with Mupirocin 2% ointment and chlorhexidine body wash.
IV Antibiotic Prophylaxis	Perioperative	Administration within 120 minutes following incision results in systemic protection against prominent pathogens.
Surgical Site Preparation	Perioperative	Clipping hair alternatively to shaving prevents micro-abrasions that could act as reservoirs for bacteria.
Vancomycin Wrap	Intraoperative	Using a 5 mg/mL solution to soak the autograft results in the localized eradication of bacteria on poorly vascularized tissue.
Host Optimization	Intraoperative	Maintaining normothermia and an FiO2 of 80% promotes physiological resistance to bacterial invasion.
Operative Efficiency	Intraoperative	The contamination of irrigation fluid increases considerably over time; minimizing surgical duration minimizes exposure.
Fluid Management	Intraoperative	Preventing contact with accumulated irrigation fluid in drape reservoirs inhibits the reactivation of contaminants.
Surgical Technique	Intraoperative	Appropriate management of soft tissue and precise wound closure decrease the chance of complications.
Postoperative Antibiotics	Postoperative	Two postoperative dosages are adequate.

Diagnosis

Diagnosis requires a high index of suspicion based on clinical and laboratory findings.

i. Clinical Presentation: Typical signs include persistent fever (seen in approximately 80% of patients), worsening knee pain (100%), redness, effusion, and limited range of motion.[36-38]

ii. Laboratory Markers: C-reactive protein (CRP) is considered a sensitive marker; however, its diagnostic reliability remains controversial. Although thresholds of approximately 40–50 mg/L have been suggested, clinically confirmed infections—such as fungal septic arthritis—may present with much lower values (e.g., ~19 mg/L), indicating that low CRP levels do not reliably exclude infection.[19,37,39]

iii. Joint Aspiration: Synovial fluid analysis is essential. Reported diagnostic thresholds vary across studies. Komnos et al. indicated that a synovial white blood cell cutoff of 28,000 cells/mm^3 provides the highest diagnostic accuracy for infection following ACL reconstruction, whereas other studies suggest that thresholds >25,000 cells/mm^3, with 75–90% neutrophil predominance, are indicative of septic arthritis. Conversely, Truong et al. demonstrated that a PMN proportion >90% yielded only a moderate likelihood ratio (LR 3.4), highlighting the absence of a universally accepted diagnostic threshold.[1,2,39,40]

iv. Culture Techniques: Resin-containing culture media can neutralize antimicrobial agents and improve culture yield in patients already receiving antibiotic treatment.[41]

A diagnostic and therapeutic protocol adapted from Phegan et al. is shown in [Figure 2].[42]

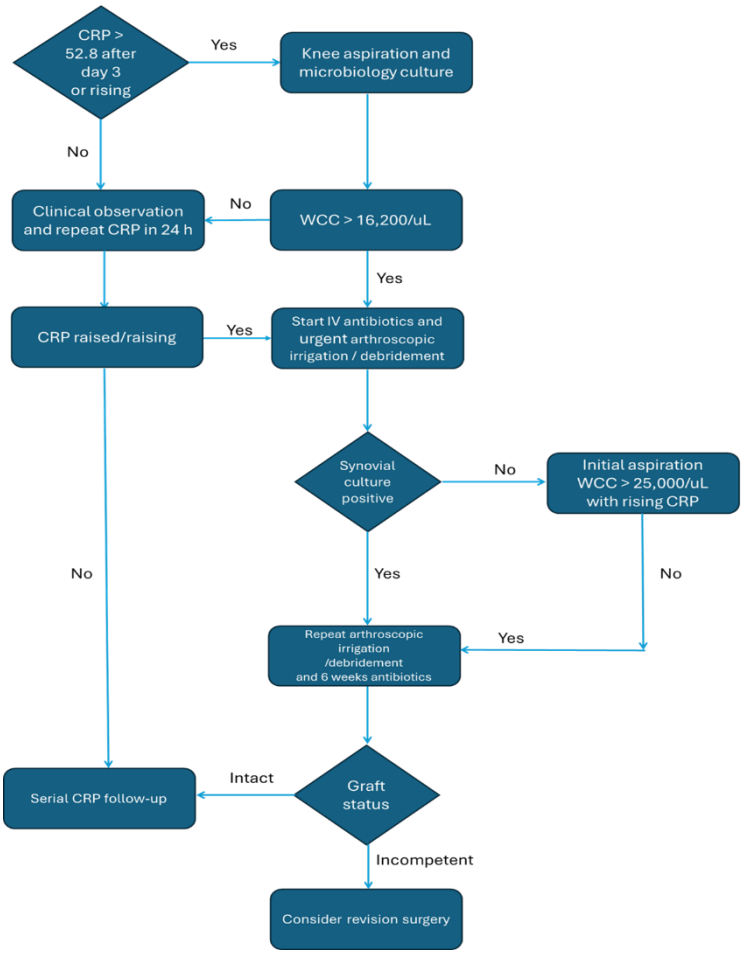

Figure 2. Adapted flowchart depicting the diagnosis and treatment of infection following ACLR based on Phegan et al. Abbreviations: ACLR = anterior cruciate ligament reconstruction; WCC = white cell count; CRP = C-reactive protein; IV = intravenous antibiotics

Management Protocols: Graft Retention vs. Removal

Acute infection

Acute postoperative infection following ACL reconstruction generally occurs within the initial two weeks.

The primary management objectives are to eradicate infection while preserving the articular cartilage and the graft.[10,34] Urgent arthroscopic irrigation and debridement are considered the standard of care for the initial management of these infections. Multiple procedures may be required to achieve infection control.[6,19] Empiric broad-spectrum intravenous antibiotics should be initiated promptly, with coverage directed primarily against staphylococcal organisms. Standard regimens include third-generation cephalosporins combined with vancomycin or gentamicin and are subsequently modified according to culture findings. Rifampicin-based regimens may be used to treat biofilm-associated infections. Antibiotics are typically administered intravenously for approximately 3 weeks, followed by

oraltherapy, for a total duration of approximately 6 weeks; treatment may be extended to 12 weeks in selected graft-retention cases.

Arthroscopic irrigation and debridement with synovectomy is the conventional initial intervention and may be repeated as required. Graft retention is typically feasible when the graft is intact and functional.

Chronic infection

Chronic infection occurs in a minority of cases (<10%), usually presenting more than two months postoperatively, and frequently requires more intensive intervention than acute infection.

Patients with persistent clinical infection despite debridement and lavage are candidates for a repeat procedure, typically arthroscopic irrigation and debridement.

In addition to arthroscopic debridement, open arthrotomy may be required when the adequacy of arthroscopic lavage is uncertain. Open arthrotomy permits extensive debridement, synovectomy, and improved visualization of infected tissues. This procedure is often combined with hardware removal and tunnel debridement. In selected cases, antibiotic-impregnated cement may be used to improve local infection control. In cases of substantial soft-tissue damage, soft-tissue coverage procedures, such as a medial gastrocnemius muscle flap, may be necessary.

In clinical practice, management decisions are frequently individualized and influenced by the timing of presentation, patient characteristics, and intraoperative findings.[4,43]

Graft instability, chronic infection after multiple debridements, and infection caused by virulent or atypical organisms (such as fungi or certain mycobacteria) are indications for graft removal.[44]

Chronic osteomyelitis

An untreated infection may progress to chronic osteomyelitis, resulting in graft failure, cartilage degradation, and joint impairment. Because typical postoperative signs (knee swelling, inflammation, and stiffness) overlap with those of infection and MRI findings may be nonspecific, diagnosis is often challenging.

A clinical case referred to our institution is presented in [Figure 3], demonstrating postoperative infection following reconstruction and emphasizing the practical challenges discussed above.

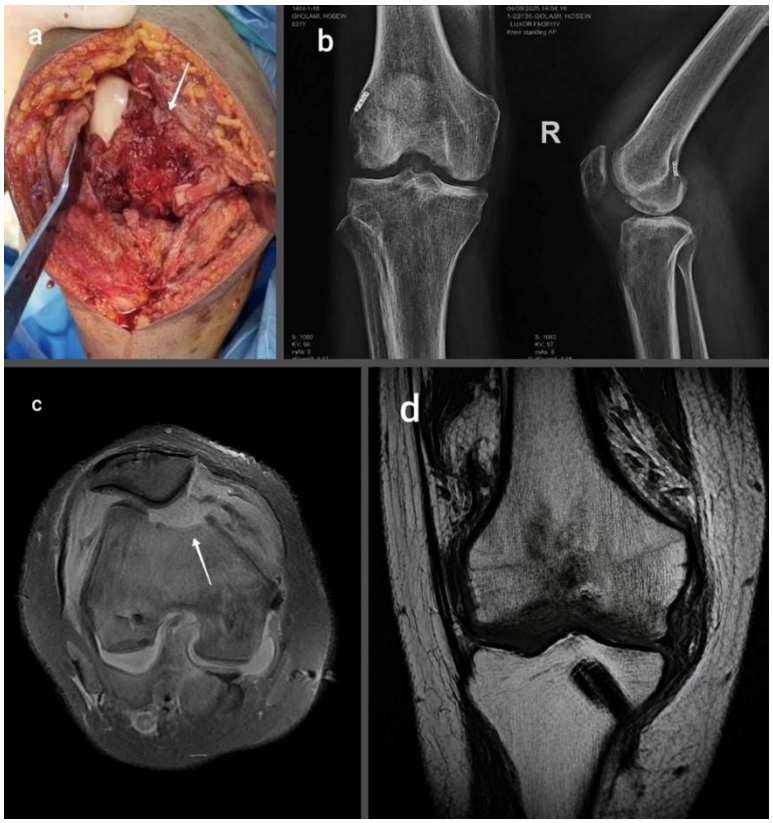

Figure 3. Post-ACL reconstruction osteomyelitis with associated cartilage and subchondral bone destruction. (A) Intraoperative photograph demonstrating the osteochondral lesion; the arrow indicates extensive loss of articular cartilage and underlying subchondral bone. (B) Anteroposterior and lateral radiographs of the knee; the arrow on the lateral view highlights the osseous defect. (C) Axial T2-weighted MRI showing the lesion involving the medial femoral condyle, while the lateral condylar cartilage remains preserved. (D) Coronal T1-weighted MRI demonstrating the extent of the osteochondral and subchondral bone involvement

Biodegradable interference screws have become increasingly common in ACL reconstruction. Their mechanical properties and biodegradability make them an attractive fixation alternative because they avoid complications associated with metallic interference screws, such as MRI artifacts, graft damage or rupture, and the need for removal during revision surgery. Despite these advantages, complications including cyst formation, tunnel widening, abscess formation, inflammatory reactions, pretibial cysts, granuloma formation, screw breakage, and implant migration have been reported with biodegradable implants.[45] [Figure 4] shows an infection associated with a bioabsorbable interference screw. The figure presents radiographs and clinical photographs of the right knee of a 34-year-old man who developed an infection at the bioabsorbable interference screw insertion site within the tibial tunnel on the medial aspect of the knee 7 months after ACLR. The patient underwent irrigation and debridement and achieved complete recovery.

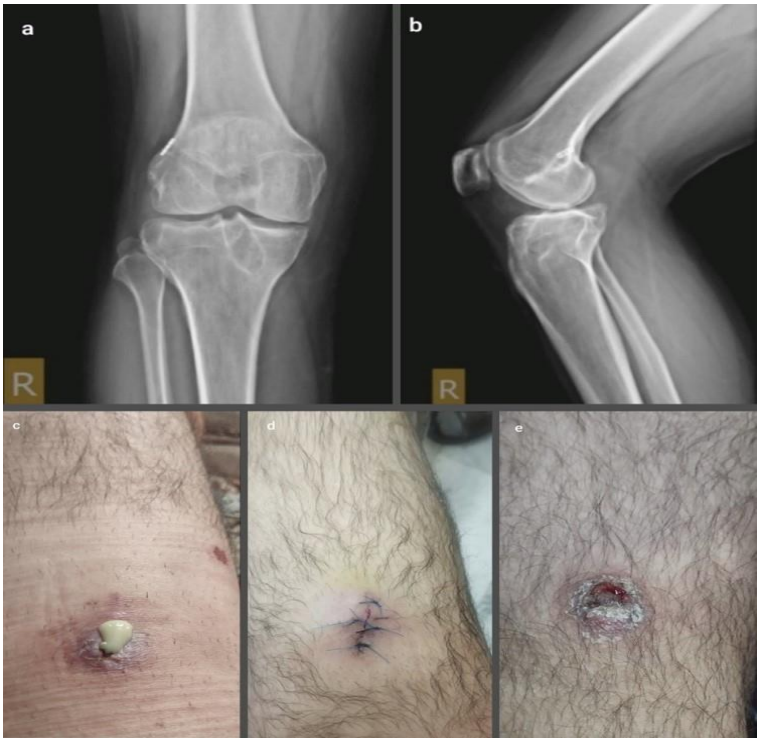

Figure 4. (A) Anteroposterior radiograph of the right knee. (B) Lateral radiograph of the right knee. (C) Purulent discharge from the tibial tunnel and bioabsorbable screw insertion site. (D) Intraoperative irrigation and debridement at the bioabsorbable screw site

Chronic distal femoral osteomyelitis following ACL reconstruction has also been reported in the literature [Figure 5].[46]

No consensus exists regarding the optimal surgical algorithm for treating chronic or persistent postoperative ACLR septic arthritis.38 Treatment is typically performed using a two-stage approach:

1. First stage (infection eradication):

This stage involves open surgical management, including arthrotomy, joint irrigation, complete synovectomy, removal of the graft and hardware, and curettage of the femoral and tibial tunnels. In selected cases, gentamicin-impregnated PMMA beads may be used as an adjunct to enhance local infection control. This is followed by systemic intravenous and oral antibiotic therapy, along with serial clinical evaluation and monitoring of inflammatory markers to confirm resolution of the infection.

2. Intermediate stage (if required):

In patients with significant bone tunnel defects or bone loss, a staged bone-grafting procedure may be performed after infection control and before definitive reconstruction.

3. Second stage (reconstruction):

Definitive ACL reconstruction is performed using an appropriate graft. Progression to this stage is considered only when full range of knee motion has been restored, no joint effusion is present, and serum inflammatory markers have returned to normal levels.

Figure 5. Chronic distal femoral osteomyelitis following anterior cruciate ligament (ACL) reconstruction in a 24-year-old man with left knee involvement. (a) Anteroposterior radiograph of the left knee demonstrating soft-tissue swelling and proximolateral placement of the Endobutton. (b) Lateral radiograph showing soft-tissue swelling with posterolateral and proximal migration of the Endobutton. (c) Clinical photograph of the sinus tract at the posterolateral aspect of the distal left femur. (d) Technetium-99m bone scan demonstrating increased late-phase uptake in the distal portion of the left femur, suggestive of an inflammatory lesion with a large soft-tissue component. (e) Coronal T2-weighted magnetic resonance image showing bone marrow edema surrounding the femoral tunnel, associated soft-tissue swelling, and a sinus tract at the lateral distal femur. (f) Axial T2-weighted magnetic resonance image demonstrating similar findings. (g) Intraoperative photograph showing the sinus tract and a floating Endobutton within the tract; the implant was removed, followed by extensive irrigation, debridement, and curettage of the involved femoral tunnel. Reproduced with permission from Ebrahimzadeh et al. (2017)

Revision ACL reconstruction

According to current research, early surgical intervention can preserve functional, uninfected grafts in 80% of cases.[47] Graft removal should be considered in cases of nonfunctional grafts, severe infection, or persistent infection associated with suspected biofilm formation.[39]

Revision ACL reconstruction is performed using a staged approach after confirmed eradication of the infection. Timing ranges from approximately 6 weeks after antibiotic treatment to 6–9 months or longer, depending on the severity and extent of bone involvement.[12,48,49]

Outcomes, Rehabilitation, and Emerging Research Directions

Patients with graft retention generally achieve better functional outcomes than those requiring graft removal.[7,43] Despite appropriate treatment, patients frequently have limited range of motion and are less likely to regain their pre-injury level of athletic performance than uninfected controls.[50]

The effect of infection on functional scores after ACL surgery remains uncertain. Early diagnosis and intervention are crucial to prevent arthrofibrosis, stiffness, and cartilage degradation.[10]

Rehabilitation

Recovery after infection is often prolonged and requires careful coordination and joint protection. Current guidelines recommend a progressive approach that prioritizes restoration of range of motion and avoids early high-load activity when the articular cartilage is compromised.[51]

For patients with infection following ACL reconstruction, the rehabilitation protocols used after primary ACL reconstruction are recommended to minimize the risk of arthrofibrosis. Physical therapy is essential for muscle strengthening and restoration of range of motion. Nevertheless, the treatment program must be adapted to the patient's symptoms and pain.[52]

Emerging Research Directions

Evidence regarding the ideal duration of antibiotic treatment for specific pathogens and the long-term effects of local antibiotics on chondrocyte viability remains limited.[47] Additional research is needed to establish standardized protocols for atypical pathogens and improve the management of culture-negative infections.[13]

Further research is needed to validate novel biomarkers and rapid assays. A new classification incorporating both arthroscopic pathoanatomical findings and systemic and

synovial proteomic parameters may improve decision-making and facilitate the development of an appropriate flowchart for managing patients with infections following ACL reconstruction.[2]

Conclusion

Postoperative infection following ACL reconstruction is an uncommon but significant complication. To reduce the risk of this serious complication, orthopedic surgeons must strictly adhere to infection-control protocols. Intraoperative vancomycin presoaking of grafts is an effective prophylactic approach.[33] Synovial fluid culture and leukocyte count constitute the gold standard for diagnosis. Timely diagnosis based on clinical assessment and synovial fluid analysis, followed by immediate arthroscopic debridement, promotes higher graft-retention rates, helps prevent complications such as osteomyelitis and arthrofibrosis, and improves outcomes after infection resolution.[50]

Early intervention enables patients to be treated successfully without recurrent infection while preserving knee stability and achieving near-full range of motion. Delayed presentation and intervention are associated with adverse outcomes.[39,53]

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