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Vancomycin-Soaked Hamstring Autograft in Anterior Cruciate Ligament Reconstruction: A Strategy for Infection Prevention

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Abstract

Septic arthritis following anterior cruciate ligament reconstruction (ACLR) is a rare but potentially devastating complication, with reported incidence rates ranging from 0.14% to 1.8%. Hamstring autografts carry a disproportionately higher infection risk compared to bone-patellar tendon-bone grafts, largely attributed to skin flora contamination during harvest and preparation. Vancomycin presoaking of hamstring autografts has emerged as a promising adjunct to standard intravenous prophylactic antibiotics in reducing postoperative joint infection. This review examines the anatomical basis of ACLR, infection epidemiology and microbiology, risk factors, and the current evidence supporting vancomycin graft soaking as a safe and effective prophylactic measure.

Keywords: Anterior cruciate ligament reconstruction; hamstring autograft; vancomycin; septic arthritis; infection prophylaxis; graft soaking

Introduction

Anterior cruciate ligament (ACL) rupture is the most frequent ligamentous injury of the knee, with an annual incidence of approximately one in 3,500 people in the United States and over 400,000 reconstructive procedures performed annually. Arthroscopic ACL reconstruction has become a well-established intervention for restoring knee stability, particularly in young active patients engaged in cutting and pivoting sports, who remain at elevated risk for subsequent meniscal tears, chondral damage, and early onset osteoarthritis. Despite its favorable overall outcomes, ACLR is not without complications, and infection remains among the most consequential of these, capable of causing prolonged morbidity, articular cartilage destruction, arthrofibrosis, and graft failure. (1)

Several factors have been associated with elevated infection risk, including the use of hamstring autografts, concomitant open surgical procedures, intraarticular drains, and prior surgery on the same knee. Intravenous prophylactic antibiotics, administered 15 to 120 minutes before skin incision, have long formed the cornerstone of perioperative infection prevention in knee surgery, yet their systemic delivery does not adequately address the local contamination that may occur during graft harvesting and preparation. This recognition has driven interest in local antibiotic prophylaxis, most notably the practice of presoaking the hamstring autograft in a vancomycin solution prior to implantation. A vancomycin-soaked graft functions as a local antibiotic reservoir, eluting drug concentrations above the minimal inhibitory concentration of the most common causative organisms for approximately 24 hours. (2)

Anatomy and Biomechanics of the Anterior Cruciate Ligament

The ACL is one of two cruciate ligaments within the knee joint, forming a strong band of dense connective tissue and collagenous fibers that originates from the anteromedial aspect of the intercondylar region of the tibial plateau and extends posteromedially to attach to the lateral femoral condyle. Anatomical descriptions of this ligament date to ancient Egyptian medical texts, though the term "ligamenta genu cruciate" is attributed to Claudius Galen of Pergamon. The ligament is intraarticular but extrasynovial, enveloped by two layers of synovium, and organized

into two functionally distinct bundles: the anteromedial (AM) and the posterolateral (PL) bundles, named according to their tibial insertion sites. (3)

The AM bundle originates from the most proximal portion of the femoral attachment and inserts at the anteromedial tibial footprint, tightening with progressive knee flexion, while the PL bundle originates more distally on the femoral wall and is under greatest tension in full extension. The intraarticular length of the ACL ranges from 22 to 41 mm with a mean of approximately 32 mm, and the midsubstance width ranges from 7 to 12 mm, with a cross-sectional area considerably narrower than its femoral and tibial insertion zones, each of which is more than 3.5 times larger than the midsubstance. The collagen architecture is predominantly type I within the ligamentous substance, with type III collagen present in the surrounding loose connective tissue, and the insertion zones exhibit a four-layer chondral apophyseal enthesis structure transitioning from ligament to fibrocartilage to mineralized cartilage to subchondral bone. (4)

The vascular supply of the ACL is derived proximally from the middle genicular artery and distally from branches of the lateral and medial inferior geniculate arteries, which support a synovial plexus from which small vessels penetrate longitudinally along the collagen bundles. Avascular zones exist at the insertion sites and in the anterior portion of the distal third of the ligament, a feature directly relevant to the ligament's poor intrinsic healing capacity and its vulnerability to bacterial colonization following reconstruction. The biomechanical role of the ACL extends beyond restraint of anterior tibial translation to encompass control of internal tibial rotation and combined rotatory loads, with the PL bundle serving as the dominant restraint to tibial rotation in the near-extension range and the AM bundle assuming greater anterior load resistance at higher flexion angles. (5)

Structural testing of the femur-ACL-tibia complex in specimens aged 22 to 35 years yields a mean ultimate failure load of approximately 2,160 N and a stiffness of approximately 242 N/mm. A quadrupled hamstring graft provides a mean ultimate load of 2,422 N and stiffness of 238 N/mm at time zero, suggesting biomechanical equivalence with the native ligament, though animal models demonstrate a substantial reduction in tensile strength during the remodeling phase, falling to as low as 6.9% of initial values before recovering over a period of up to 12 weeks. Correct tunnel placement at both femoral and tibial sites is critical to restoring normal knee kinematics, and small deviations of even 3 mm in femoral tunnel position can substantially alter graft tensioning patterns and laxity outcomes. (6)

The femoral origin of the ACL lies at the posterior part of the medial surface of the lateral femoral condyle, not at the roof of the intercondylar notch, and on the tibial side the insertion covers a broad oval area between the medial and lateral tibial spines. The tibial tunnel in single-bundle reconstruction is typically directed toward the footprint of the PL bundle, creating a functional mismatch with a femoral AM tunnel, a compromise that anatomical double-bundle techniques seek to address. The notch width index and the slope of the intercondylar roof further influence surgical planning, as anterior tibial tunnel misplacement risks roof impingement and progressive graft abrasion, while posterior femoral tunnel misplacement may compromise the posterior cortical wall. (7)

Hamstring Autograft Harvest

Technique and Anatomical Considerations

The use of hamstring tendons for ACL reconstruction was first reported in 1934 using the isolated semitendinosus tendon, and subsequent technical evolution led to the adoption of a combined semitendinosus and gracilis construct folded into a quadruple-strand graft, now among the most widely used autograft options globally. Both tendons originate from the ischial tuberosity and ischiopubic ramus respectively, converging distally before inserting onto the proximal medial tibia at the pes anserinus, just medial and distal to the tibial tubercle. The harvest incision is placed midway between the tibial tubercle and the posteromedial tibial border, approximately 2 to 3 cm in length, carried through the subcutaneous tissue to the sartorial fascia using blunt dissection to minimize iatrogenic nerve injury. (8)

The gracilis lies superior to the semitendinosus at the level of the pes, while the semitendinosus has a larger diameter; both tendons are identified, dissected free from accessory bands, whip-stitched at their free ends, and individually stripped using a tendon stripper directed proximally toward the musculotendinous origin at the pelvis.

A minimum folded graft diameter of 8 mm is recommended to replicate the native ACL cross-sectional area and ensure adequate biomechanical function, and when the standard quadruple-strand construct falls below this threshold, a five-strand technique is employed, though this increases graft manipulation time and the risk of contamination. Accessory fascial bands between the semitendinosus, gracilis, gastrocnemius, and pretibial fascia are highly variable and must be thoroughly released before advancing the tendon stripper, as failure to do so is the primary cause of premature tendon amputation during harvest. (9)

The pes anserinus is in close proximity to the infrapatellar and sartorial branches of the saphenous nerve, and injury to these structures manifests as hypoesthesia, dysesthesia, or painful neuroma; in one case series of 164 patients, concomitant injuries to both branches occurred in 32% of cases. Advantages of the hamstring autograft over BPTB include reduced anterior knee pain, lower rates of patellofemoral crepitation, extension deficit, and donor site morbidity, along with smaller harvest incisions. Counterbalancing these benefits are reports of increased joint laxity, functional hamstring weakness in some comparative studies, and a consistently demonstrated higher infection risk compared to BPTB, attributed to increased soft tissue dissection, prolonged graft preparation time, and suture material positioned within the joint acting as a foreign body nidus. (10)

Infection Following ACL Reconstruction

Epidemiology and Microbiology

Septic arthritis following ACLR carries a reported incidence ranging from 0.14% to 1.70% across published series, and pooled data from seven of the largest comparative studies encompassing over 13,000 reconstructions yielded an overall infection rate of 0.50%, with rates of 0.51% for autografts and 0.49% for allografts. Staphylococci account for the majority of causative organisms in up to 90% of cases, with coagulase-negative staphylococci comprising approximately half of these and Staphylococcus aureus accounting for most of the remainder. The predominance of coagulase-negative staphylococci has been directly linked to contamination of the graft with the patient's own skin bacteria during harvest and preparation, an observation that forms the principal microbiological rationale for local antibiotic prophylaxis. (11)

Other organisms documented in postoperative ACLR infections include Propionibacterium acnes, Enterobacter species, Peptostreptococcus, Enterococcus, Pseudomonas aeruginosa, Escherichia coli, Klebsiella, and methicillin-resistant Staphylococcus aureus, with unusual pathogens including mycobacterial species and fungal organisms reported in isolated case reports. Infection classification is based on temporal presentation: acute infection occurs within two weeks of surgery, subacute infection between two weeks and two months, and late infection beyond two months, with the majority of cases presenting acutely or subacutely with increased pain and effusion, though fevers, chills, and wound drainage are not consistently present. Laboratory investigations including ESR and CRP carry high negative predictive value in the diagnostic workup; CRP is considered a more sensitive early marker because it rises and falls more rapidly than ESR, and sustained elevation beyond two weeks or a secondary rise should prompt further investigation. (12)

Synovial fluid analysis remains the most valuable diagnostic test, with polymorphonuclear cell proportions exceeding 90% highly predictive of infection, and MRI can delineate the extent of joint involvement, identify fluid collections, and demonstrate bone marrow edema or synovitis in diagnostically uncertain scenarios. Comparing infection rates between autograft and allograft, the published literature is notably inconsistent: Barker and colleagues found rates of 0.44% with allografts and 0.68% with autografts in a series of over 3,000 reconstructions, while Crawford and colleagues reported a 3.8% infection rate in 290 allografts that had not undergone sterilization versus 0% in 41 autografts, underscoring the role of processing standards rather than tissue source alone. Bacterial culture positivity of allograft tissue without clinical infection, as demonstrated with a 9.7% positive culture rate in one series in which no patient developed septic arthritis, further illustrates that microbiological contamination does not invariably translate to clinical disease in the presence of adequate systemic prophylaxis. (13)

Comparing infection rates within autograft types reveals a more consistent signal favoring lower infection risk with BPTB over hamstring grafts. Barker and colleagues found a statistically significant infection rate of 1.44%

with hamstring autografts versus 0.49% with BPTB, and Wang and colleagues identified infection in 20 of 3,536 hamstring autograft patients and none among 442 BPTB patients. Judd and colleagues similarly reported that all 11 intraarticular infections in their series of 409 patients occurred exclusively in the hamstring group, and the proposed mechanisms behind this disparity include the relatively short intraarticular hamstring graft length necessitating suture material within the joint, more extensive soft tissue dissection during harvest, longer operative times, and inadequate sterilization of tubular harvesting instruments. (14)

Risk Factors for Postoperative Infection

Multiple patient- and procedure-related risk factors have been identified in association with septic arthritis following ACLR. Patient-level factors include immunocompromised states, systemic or intraarticular corticosteroid use, prior knee infection, and significant medical comorbidities, while procedure-level factors encompass hamstring autograft use, concomitant open procedures such as inside-out meniscal repair, use of postoperative intraarticular drains, revision surgery on the same knee, prolonged tourniquet time, and extended operative duration. Wang and colleagues found that flash sterilization of surgical instruments correlated with elevated infection rates, and Tuman and colleagues specifically implicated failure to disassemble tubular hamstring harvesters prior to sterilization as a source of bacterial contamination capable of directly inoculating the graft during harvest. (15)

Judd and colleagues identified an association between the post-washer-braided suture construct used for hamstring fixation and higher infection incidence, with eight of eleven infected patients exhibiting concomitant extraarticular wound infection at the subcutaneous fixation site with cultures matching the synovial organisms, suggesting a shared inoculation source. The graft itself becomes a particularly vulnerable structure once implanted, as an avascular tissue recognized as foreign by host defenses during the remodeling phase, providing a surface amenable to bacterial biofilm formation, and the same avascularity that limits early immune surveillance also limits antibiotic penetration from systemic administration. This window of vulnerability, during which planktonic bacteria may colonize graft and implant surfaces, is estimated to span approximately 24 hours from the time of implantation, encompassing the most critical period for infection prevention and forming the central conceptual foundation for delivering antibiotic prophylaxis locally through the graft itself. (16)

Treatment of Postoperative Septic Arthritis

The management of confirmed or strongly suspected joint infection following ACLR must be approached urgently, as experimental data demonstrate that articular cartilage may lose more than half of its glycosaminoglycan and collagen content within seven days of infection onset. Prompt empirical intravenous antibiotic therapy targeting Staphylococcus aureus and coagulase-negative staphylococci should be initiated immediately after joint fluid and laboratory specimens have been obtained, with a third-generation cephalosporin or vancomycin recommended as empirical coverage pending culture results, and treatment continued even when synovial fluid cultures are negative in the setting of convincing clinical suspicion. (17)

Surgical management encompasses a spectrum from arthroscopic lavage and debridement with graft retention at one end, to staged debridement with antibiotic-impregnated polymethylmethacrylate bead placement followed by delayed revision reconstruction at the other. A survey of Sports Medicine Fellowship Program Directors found that 85% favored culture-specific antibiotics with surgical irrigation and graft retention as initial treatment for infected BPTB autografts and 64% for allografts, with graft removal reserved for cases resistant to this initial approach. Outcomes following postoperative infection are measurably inferior to those without infectious complications, with patients experiencing higher rates of arthrofibrosis, articular cartilage degeneration, persistent pain with activities of daily living, and diminished functional scores across multiple validated outcome instruments. (18)

Long-term follow-up data from patients who developed septic arthritis after ACLR showed a decline in SF-36, Lysholm, and IKDC scores alongside progressive radiographic arthritis in all affected patients at nearly 18 years of follow-up, with each patient requiring a mean of 2.75 additional procedures for infection eradication. These outcomes reinforce the primacy of prevention over treatment and highlight that even successfully eradicated

infections leave a lasting burden of joint morbidity. Patients must be counseled regarding the signs of early infection and encouraged to seek prompt evaluation, as the probability of preserving graft integrity and acceptable functional outcomes is substantially higher when treatment is initiated early in the infectious course. (18)

Vancomycin Graft Soaking

Vancomycin is a glycopeptide antibiotic with bactericidal activity against gram-positive organisms including staphylococci, enterococci, and Propionibacterium acnes, covering the organisms most frequently isolated in ACLR-related septic arthritis, and its established safety profile for local orthopaedic use has supported its adoption as a prophylactic adjunct in this setting. Grayson and colleagues established the technical basis for this intervention by demonstrating in an in vitro bovine tendon model that presoaked tendons elute vancomycin into their surrounding environment, functioning as a drug reservoir, with larger tendon dimensions providing a proportionally greater reservoir capacity. When applied clinically, this mechanism was shown to produce an important decrease in the rate of joint infection following ACLR, findings that aligned with subsequent in vivo investigations. (19)

The standard presoaking technique involves wrapping the prepared hamstring graft in a surgical sponge previously saturated in a 5 mg/mL vancomycin solution, prepared by dissolving 500 mg of vancomycin powder in 100 mL of sterile saline, for a minimum of 15 minutes during the arthroscopic phase of the reconstruction. A surgical sponge is preferred over direct graft immersion in solution to avoid fluid absorption-related changes in graft diameter. The graft wrapped in this manner acts as an antibiotic reservoir eluting vancomycin concentrations above the MIC of the target organisms throughout the 24-hour critical period of bacterial adhesion to the avascular implanted tissue. (20)

Figueroa and colleagues published the first clinical series examining this technique, comparing 285 patients who underwent ACLR with hamstring autograft and intravenous antibiotics alone against 870 patients who received both intravenous antibiotics and vancomycin-presoaked grafts. A total of four postoperative joint infections were documented in the first group, yielding an infection rate of 1.4%, while no infections were recorded in the vancomycin group, representing a rate of 0%. The strength of this study lay partly in its inclusion of five-strand graft constructs, confirming that vancomycin presoaking eliminates the additional infection risk associated with the increased manipulation required by this more complex preparation technique. (21)

Pérez-Prieto and colleagues subsequently presented an eight-year institutional experience across 1,544 primary ACL reconstructions using both hamstring and patellar tendon autografts, divided into a pre-vancomycin period of 810 patients and a vancomycin period of 734 patients. All fifteen cases of knee joint infection identified in the entire series occurred in the pre-vancomycin group, yielding an infection rate of 1.85% compared to 0% in the vancomycin group, a finding that underscored the effectiveness of the intervention across both autograft types and over an extended clinical timeframe. (22)

Vertullo and colleagues confirmed these findings in a series directly comparing 285 patients treated with intravenous antibiotics alone against 870 patients receiving vancomycin-presoaked grafts in addition to systemic prophylaxis, with four infections in the former group and none in the latter. Phegan and colleagues reported zero infections across 1,300 consecutive ACL reconstructions performed with vancomycin-presoaked hamstring grafts, a large series that added considerable weight to the cumulative evidence base. Chaturvedi reported a 2% deep infection rate in the pre-vancomycin period at his institution compared to 0% after adopting the technique, and further noted that vancomycin use did not increase the risk of graft failure, poor clinical outcomes, or arthrofibrosis. (23)

The safety of vancomycin applied locally to tendon tissue was specifically examined by Schüttler and colleagues in a porcine tendon model, where no evidence of biomechanical impairment was identified in tendons subjected to vancomycin wrapping, providing reassurance that the local antibiotic concentration achieved by this technique does not adversely affect the structural properties of the graft. A systematic review and meta-analysis by Naendrup and colleagues, pooling data across multiple studies, confirmed that vancomycin soaking of the graft significantly

reduces the incidence of septic arthritis following ACL reconstruction and supported its routine incorporation into the surgical prophylaxis protocol. (24)

Conclusion

The available evidence from multiple institutional series, comparative cohort studies, and systematic analysis consistently supports the conclusion that presoaking of the hamstring autograft in vancomycin solution, used in conjunction with standard intravenous prophylactic antibiotics, substantially reduces and in several large series eliminates postoperative septic arthritis following ACL reconstruction, without adverse effects on graft biomechanics, clinical outcomes, or rates of arthrofibrosis, making it a safe, technically straightforward, and effective addition to the standard surgical prophylaxis protocol that warrants broader adoption in routine ACLR practice. (23, 24)

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