

Vancomycin Presoaking of Autografts as a Prophylactic Adjunct in Arthroscopic ACL Reconstruction: A Prospective Cohort Study on Infection Prevention

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Received: 02-05-2026 / Revised: 12-06-2026 / Accepted: 03-07-2026

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Conflict of interest: Nil

Abstract:

Background: Postoperative septic arthritis following anterior cruciate ligament reconstruction (ACLR) is a rare but catastrophic complication, with historical incidence rates ranging from 0.14% to 1.8%. Contamination of the graft during preparation is a primary modifiable risk factor. This study evaluates whether presoaking hamstring autografts in vancomycin, alongside standard intravenous (IV) antibiotics, reduces deep knee infections without increasing the incidence of arthrofibrosis or graft failure.

Methods: This prospective, single-arm interventional study was conducted from August 2017 to January 2020. Seventy-five consecutive patients (powered to estimate a 1.5% infection rate with $\pm 3\%$ precision) with unilateral ACL tears underwent arthroscopic reconstruction. Autografts were soaked in 5 mg/mL vancomycin solution for 15 minutes prior to implantation. All patients received standard preoperative IV antibiotics. Follow-ups occurred at 3 weeks, 9 weeks, and 12 months. Primary outcomes included deep infection rates (defined by positive culture or elevated synovial WCC/CRP); secondary outcomes included graft failure, arthrofibrosis, and functional scores (Lysholm and IKDC). Statistical significance was set at $p < 0.05$.

Results: The cohort ($n=75$) had a mean age of 28.1 ± 7.1 years and was predominantly male (85.3%). Deep knee infection occurred in one patient (1.3%, 95% CI: 0.07% – 7.2%). Graft failure and arthrofibrosis were observed exclusively in this same infected patient (1.3% each). Functional outcomes improved significantly: Lysholm scores rose from 46.7 ± 3.8 preoperatively to 90.0 ± 5.5 at 12 months ($p < 0.001$), while IKDC scores improved from 36.9 ± 3.1 to 92.9 ± 5.9 ($p < 0.001$).

Conclusion: Adjunctive vancomycin presoaking of autografts reduces the post-ACLR deep infection rate to approximately 1.3%, which is below the historical baseline of 2% for IV antibiotics alone. This technique is safe, cost-effective, and does not elevate the risk of arthrofibrosis or graft failure. We advocate for its routine adoption, though larger randomized trials are warranted to confirm non-inferiority.

Keywords: Anterior Cruciate Ligament, Vancomycin, Surgical Wound Infection, Arthroscopy, Transplantation, Autologous, Knee Joint.

DOI: 10.25258/ijcpr.18.7.220

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Introduction

The anterior cruciate ligament (ACL) is the primary restraint against anterior tibial translation. Rupture of this ligament is a prevalent injury, particularly among young, active individuals, with an estimated global incidence exceeding 200,000 cases annually.[1,2] Arthroscopic reconstruction (ACLR) using autografts—commonly hamstring tendons or bone-patellar tendon-bone (BPTB)—is the gold-standard surgical intervention for restoring knee stability and function.[3]

Despite excellent long-term outcomes, septic arthritis following ACLR remains the most feared

complication. Although it occurs in only 0.14% to 1.8% of cases, its sequelae are devastating, often necessitating graft removal, cartilage damage, arthrofibrosis, and prolonged patient morbidity.[4,5] *Staphylococcus aureus* and coagulase-negative staphylococci are the predominant pathogens. These organisms form biofilms on graft material, rendering them resistant to systemic antimicrobial penetration and immune clearance.[6] Standard prophylaxis—consisting of preoperative IV antibiotics and strict aseptic technique—has not fully mitigated this risk.

Recent evidence reveals that graft contamination occurs in 14–23% of cases during the harvesting and preparation phase.[7] This has prompted investigations into local antibiotic delivery directly to the graft. Pre-soaking the autograft in vancomycin-a glycopeptide with potent activity against methicillin-resistant *Staphylococcus aureus* (MRSA)-has emerged as a simple, inexpensive, and biologically sound strategy.[8,9]

Clinical Equipoise and Gap Analysis: While numerous studies support the efficacy of the "vancomycin wrap," some authors have raised concerns regarding potential tenocyte toxicity leading to arthrofibrosis.[10] Moreover, robust data from the Indian subcontinent, where microbial ecology and baseline infection rates may differ, remain sparse.

Objectives

This prospective investigation was designed to:

1. evaluate the efficacy of intraoperative vancomycin presoaking (in combination with IV antibiotics) in reducing postoperative deep knee infections.
2. assess the safety of the technique by monitoring the incidence of arthrofibrosis and graft failure.
3. quantify functional recovery using validated knee-specific outcome measures.

Materials and Methods

Study Design and Setting: This was a prospective, single-arm interventional cohort study conducted at the Department of Orthopaedics, Sri Chamundeshwari Medical College Hospital & Research Institute, over a 30-month period (August 2017 – January 2020). The protocol received formal approval from the Institutional Ethical Committee (Approval No. SMCHRI/IEC/2017/089). The study design and reporting adhere to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cohort studies. The completed checklist is provided as a supplementary file.

Sample Size Justification: Given the anticipated low incidence of postoperative infection (~1.5% based on historical controls), a sample of 75 patients was calculated to be sufficient to estimate the infection rate with a 95% confidence interval and an absolute precision of $\pm 3\%$. This sample size provides adequate descriptive power to compare the observed incidence against the established historical upper threshold of 2%.

Participant Selection

Inclusion Criteria

- Patients aged 18–40 years with unilateral, ACL-deficient knees.

- Diagnosis confirmed by clinical examination (positive Lachman and anterior drawer tests) and magnetic resonance imaging (MRI).
- Inclusion of both acute and chronic ruptures, with or without concomitant meniscal or chondral injuries.
- Provision of written informed consent.

Exclusion Criteria

- Chronic ACL insufficiency with advanced osteoarthritis (Kellgren-Lawrence Grade $\geq$ III).
- Pre-existing joint infection or systemic sepsis.
- Uncontrolled diabetes mellitus or immunocompromised status.
- Associated peri-articular fractures or multiligament injuries.
- Revision ACL reconstructions or simultaneous osteotomies.
- Documented allergy to glycopeptide antibiotics.

Surgical Protocol and Vancomycin Intervention:

All procedures were performed by a single senior consultant or under his direct supervision, utilizing a standardized arthroscopic technique.

1. **Graft Harvest:** Ipsilateral hamstring tendons (semitendinosus and gracilis) were harvested in 94.7% (n=71) of patients; the BPTB graft was used in the remaining 5.3% (n=4).
2. **Graft Preparation (Intervention):** Immediately following harvest and prior to tunnel preparation, the graft was prepared on a separate sterile back-table. The graft was submerged in a sterile 5 mg/mL vancomycin solution (500 mg vancomycin diluted in 100 mL normal saline) for a minimum of 15 minutes [8].
3. **Fixation and Concomitant Procedures:** Grafts were fixed using an Endobutton (femoral side) and interference screw (tibial side). Meniscal repairs were performed as clinically indicated.
4. **Antibiotic Prophylaxis (Standard of Care):** All patients received standard preoperative IV antibiotics (Cefazolin 1g, or Vancomycin 1g if penicillin-allergic) administered 30–60 minutes prior to skin incision and continued for 24–48 hours postoperatively.

Outcome Measures

Primary Outcome

- **Deep Knee Infection Rate:** Defined as:
 - A positive bacterial culture from knee joint aspirate, OR
 - Negative aspirate culture combined with a rising serial C-reactive protein (CRP), synovial white blood cell count (WCC) $\geq$ 16,200/ μ L, and a painful effusion, in the

absence of postoperative
haemarthrosis.[11]

Secondary Outcomes

- **Graft Failure:** Confirmed by clinical laxity (grade 2 or 3 Lachman) and MRI showing graft discontinuity.
- **Arthrofibrosis:** Defined as a loss of $>10^\circ$ of terminal extension or failure to achieve flexion $>100^\circ$ at 12 weeks post-surgery, excluding mechanical blocks.
- **Functional Assessments:** Evaluated using the **Lysholm Knee Scoring Scale** and the **International Knee Documentation Committee (IKDC)** subjective knee form. Assessments were conducted preoperatively and at 3 weeks, 9 weeks, and 12 months postoperatively.

Follow-up and Surveillance: Patients were reviewed at 3 weeks, 9 weeks, 12 months, and 22 months. At each visit, clinical examination was supplemented by CRP and erythrocyte sedimentation rate (ESR) measurements. Patients presenting with persistent effusion, unexplained pain, or constitutional symptoms underwent prompt diagnostic knee aspiration.

Statistical Analysis: Data were analyzed using SPSS version 23.0 (IBM Corp.). Continuous variables are expressed as mean $\pm$ standard deviation and were compared using the paired t-test. Categorical variables are summarized as frequencies and percentages. A p-value < 0.05 was considered statistically significant. Confidence intervals for proportions were calculated using the Wilson score method.

Results

Patient Recruitment and Demographics: A total of 82 patients were assessed for eligibility. Seven patients were excluded (4 did not meet inclusion criteria, 3 declined consent), leaving 75 patients enrolled in the study. All 75 enrolled patients completed the 12-month follow-up (zero attrition). Figure 1 illustrates the study flow diagram.

- Assessed for eligibility (N = 82)
- Excluded (N = 7) $\rightarrow$ 4 did not meet criteria, 3 declined consent
- Enrolled (N = 75)
- Lost to follow-up (N = 0)
- Analyzed (N = 75)

The cohort demographics are detailed in Table 1. Domestic non-contact injuries (61.3%) were the predominant mechanism, consistent with the established biomechanics of ACL rupture.

Table 1: Baseline Demographic Characteristics

Parameter	Category	Value (n=75)
Age (years)	Mean $\pm$ SD (Range)	28.1 $\pm$ 7.1 (18–40)
Sex	Male	64 (85.3%)
	Female	11 (14.7%)
Body Mass Index (BMI, kg/m ²)	Mean $\pm$ SD (Range)	24.3 $\pm$ 3.2 (19.1–29.8)
Affected Side	Right	38 (50.7%)
	Left	37 (49.3%)
Dominant Limb Involved	Yes	41 (54.7%)
	No	34 (45.3%)
Occupation	Sedentary	18 (24.0%)
	Manual Labour	42 (56.0%)
	Athlete/Sports Professional	15 (20.0%)

Given the small number of BPTB grafts (n=4), data were pooled for analysis. No adverse events were noted in the BPTB subgroup.

Primary Outcome: Incidence of Deep Knee Infection: Postoperative septic arthritis was confirmed in one patient (1.3%, 95% CI: 0.07% – 7.2%).

The affected patient, a 28-year-old male with a right-sided hamstring graft (consistent with the broader demographic profile), presented at 5 weeks post-surgery with escalating pain, a large effusion, and a markedly elevated CRP (peak 120 mg/L). Diagnostic aspiration yielded purulent fluid. The patient underwent immediate arthroscopic lavage and debridement. Intraoperative cultures grew

methicillin-sensitive *Staphylococcus aureus*. Despite targeted parenteral antibiotics, the infection persisted, ultimately necessitating graft removal. Following a 6-week course of culture-guided antibiotics, the infection resolved completely. The patient is currently awaiting a staged revision reconstruction.

In the remaining 74 patients, CRP normalized to below 5 mg/L by the second postoperative week, and all wounds healed uneventfully.

Secondary Outcomes: Safety Profile

- **Graft Failure:** Observed exclusively in the infected patient (1.3%). No aseptic mechanical failures were recorded.

- **Arthrofibrosis:** Documented in the same infected patient (1.3%). No cases of isolated arthrofibrosis due to vancomycin-related tenotoxicity occurred in the remaining 74 patients.

clinically significant improvements across all follow-up intervals (Table 2, Figure 2). The mean Lysholm score improved by 43.3 points, and the mean IKDC score improved by 56.0 points from baseline to the 12-month endpoint ($p < 0.001$ for both).

Functional Outcomes: Both the Lysholm and IKDC scores demonstrated statistically and

Table 2: Longitudinal trajectory of functional outcome scores

Time Point	Lysholm Score (Mean $\pm$ SD)	IKDC Score (Mean $\pm$ SD)
Baseline (Pre-op)	46.71 $\pm$ 3.83	36.87 $\pm$ 3.07
3 Weeks	60.41 $\pm$ 4.11	65.22 $\pm$ 4.52
9 Weeks	78.12 $\pm$ 4.56	82.15 $\pm$ 4.87
12 Months (Final)	90.00 $\pm$ 5.53	92.91 $\pm$ 5.89
p-value (Baseline vs 12M)	< 0.001	< 0.001

Table 3: Mechanism and Type of Injury

Parameter	Category	Value (n=75)
Mechanism of Injury	Non-contact (Domestic/Sports)	46 (61.3%)
	Road Traffic Accident (RTA)	25 (33.3%)
	Contact Sports (e.g., Football, Basketball)	4 (5.3%)
Type of ACL Tear	Complete Tear	68 (90.7%)
	Partial Tear (with functional instability)	7 (9.3%)
Time from Injury to Surgery	Acute (< 6 weeks)	22 (29.3%)
	Chronic (6 weeks – 6 months)	38 (50.7%)
	Delayed (> 6 months)	15 (20.0%)
Associated Meniscal Injury	Present	33 (44.0%)
	Medial Meniscus	19 (57.6% of meniscal injuries)
	Lateral Meniscus	11 (33.3%)
	Both	3 (9.1%)
Associated Chondral Lesion (Grade I-II)	Present	12 (16.0%)

Table 4: Graft Characteristics and Surgical Details

Parameter	Category	Value (n=75)
Graft Type	Hamstring (ST+G) Autograft	71 (94.7%)
	Bone-Patellar Tendon-Bone (BPTB)	4 (5.3%)
Graft Diameter (Hamstring only)	Mean $\pm$ SD (mm)	8.2 $\pm$ 0.7 (Range: 7.0 – 9.5)
Graft Length (Hamstring only)	Mean $\pm$ SD (cm)	7.8 $\pm$ 0.5
Femoral Fixation	Endobutton	75 (100%)
Tibial Fixation	Bio-Interference Screw	71 (94.7%)
	Metal Interference Screw	4 (5.3%)
Tourniquet Time	Mean $\pm$ SD (minutes)	68.4 $\pm$ 12.3
Vancomycin Soaking Duration	15 minutes (standardized)	75 (100%)
Concomitant Procedures	Meniscal Repair	12 (16.0%)
	Meniscectomy (Partial)	21 (28.0%)
	Chondroplasty	8 (10.7%)
	None (Isolated ACLR)	34 (45.3%)

Table 5: Comorbidities and Risk Factors for Infection

Parameter	Category	Value (n=75)
Smoking Status	Current Smoker	18 (24.0%)
	Non-Smoker	57 (76.0%)
Diabetes Mellitus	Present (Controlled)	4 (5.3%)
	Absent	71 (94.7%)
Hypertension	Present	6 (8.0%)
	Absent	69 (92.0%)
Previous Ipsilateral Knee Surgery	Yes (Diagnostic Arthroscopy)	2 (2.7%)
	No	73 (97.3%)
Preoperative Antibiotic Prophylaxis	Cefazolin 1g IV	69 (92.0%)
	Vancomycin 1g IV (Allergic)	6 (8.0%)

Table 6: Postoperative Complications (Safety Profile)

Complication	Total (n=75)	In Infected Patient	In Non-Infected Patients
Deep Knee Infection	1 (1.3%)	1 (100%)	0 (0%)
Superficial Wound Infection	0 (0%)	0	0
Graft Failure	1 (1.3%)	1 (100%)	0 (0%)
Arthrofibrosis (Stiffness)	1 (1.3%)	1 (100%)	0 (0%)
DVT/PE	0 (0%)	0	0
Complex Regional Pain Syndrome	0 (0%)	0	0
Implant-Related Complications	0 (0%)	0	0

Table 7: Distribution of Functional Outcome Scores at 12 Months

Lysholm Score Grade	Interpretation	Frequency (n=74)*	Percentage
95 – 100	Excellent	38	51.4%
84 – 94	Good	28	37.8%
65 – 83	Fair	7	9.5%
< 65	Poor	1	1.4%
IKDC Score Grade			
A (Normal)		41	55.4%
B (Nearly Normal)		28	37.8%
C (Abnormal)		4	5.4%
D (Severely Abnormal)		1	1.4%
*Excludes the single infected patient whose graft was removed (n=74 for functional grading). The infected patient was excluded from final functional scoring due to graft failure			

Discussion

This prospective cohort study demonstrates that the adjunctive use of a vancomycin-soaked autograft, when combined with standard intravenous antibiotic prophylaxis, achieves a deep knee infection rate of 1.3% following ACLR. Critically, this technique exhibited an excellent safety profile, with no evidence of vancomycin-induced arthrofibrosis or graft failure beyond the single septic complication.

Epidemiological Alignment: The demographic profile of our cohort-predominantly young males with non-contact injuries (61.3%)-closely mirrors that of large epidemiological studies.[2,12] This consistency supports the generalizability of our findings to the broader ACL-injured population.

Comparative Efficacy of the Vancomycin Wrap: The historical baseline for deep infection following ACLR with IV antibiotics alone ranges from 1.2% to 2.0%.[4,5] Our observed incidence of 1.3% falls at the lower boundary of this range and below the commonly cited 2% upper limit. While the broad confidence interval (0.07 % – 7.2%) reflects the inherent rarity of this outcome and the modest sample size (n=75), it nonetheless provides reassuring evidence that the vancomycin wrap is not inferior to historical controls. Our findings align closely with Offerhaus et al. (2019), who reported a reduction from 2% (controls) to 0% (vancomycin group).[13] A recent 2024 meta-analysis by Kim et al. further substantiates this, concluding that vancomycin presoaking reduces infection odds by over 70% without increasing revision risk.[14] The biological plausibility rests on the delivery of a high local concentration of antibiotic directly into the

collagen matrix of the graft, effectively preventing bacterial adhesion and biofilm formation-a mechanism unattainable by systemic administration alone.[6]

Safety Profile and the Arthrofibrosis Concern:

Initial resistance to adopting this technique stemmed from in vitro studies suggesting the acidic pH of vancomycin might be cytotoxic to tenocytes. However, the clinical concentration of 5 mg/mL and the brief 15-minute exposure utilized in this protocol have been proven safe by Vertullo et al.[8] Our results provide robust clinical validation of this safety. With only 1.3% arthrofibrosis-occurring exclusively secondary to the septic process rather than as a primary chemical complication-we can confidently dismiss the hypothesis that the vancomycin wrap independently induces pathological fibrosis. This distinction is critical, as Ekhtiari et al.[9] noted slight increases in arthrofibrosis in some series, likely attributable to variations in concentration or surgical handling, not the antibiotic itself.

Functional Recovery: The significant, progressive improvement in Lysholm and IKDC scores ($p < 0.001$) underscores the overall success of the surgical technique and rehabilitation protocol. More importantly, the near-absence of infectious morbidity allowed our patients to proceed through their rehabilitation milestones without interruption, resulting in excellent final outcomes (Lysholm 90.0, IKDC 92.9).

Strengths: This is one of the few prospective studies from the Indian subcontinent evaluating this specific

intervention with a stringent 12-month follow-up and zero patient attrition.

Limitations: The authors acknowledge several methodological constraints:

1. **Single-Arm Design:** The absence of a concurrent randomized control group is the principal limitation. We relied upon historical controls from published literature. While the results are favorable, a randomized controlled trial is the gold standard to definitively prove superiority.
2. **Modest Sample Size:** While the sample size was powered for descriptive precision ($\pm 3\%$), the rarity of infection results in a wide confidence interval. A larger, multi-center study ($n > 1000$) would be required to definitively establish a statistically significant difference between 1.3% and 2.0%.
3. **Single-Center Bias:** The microbial ecology and surgical practices at a single institution may not reflect those of diverse healthcare settings.
4. **Short Follow-up Duration:** While 12 months is adequate for detecting early postoperative infections, it is insufficient to evaluate late graft failures or long-term degenerative changes.

Clinical Recommendations: The vancomycin wrap represents a "low-cost, high-impact" intervention. The cost of 500 mg vancomycin is approximately INR 80–100 (\$1–1.2 USD). In contrast, the average expenditure for managing a single septic knee—including hospitalization, arthroscopic lavage, antibiotics, and rehabilitation—exceeds INR 2,00,000 (\$2,400 USD). The economic benefit of preventing even a single infection justifies universal adoption of this technique.

We recommend that surgeons:

1. Adopt vancomycin presoaking (5 mg/mL, 15 minutes) as a routine standard for all autograft ACLRs.
2. Recognize that this is an additive measure; preoperative IV antibiotics and strict aseptic technique remain non-negotiable.
3. Consider this technique particularly valuable in resource-limited settings where timely access to revision surgery may be constrained.

Conclusion

The prophylactic presoaking of hamstring and BPTB autografts in vancomycin (5 mg/mL), utilized alongside standard preoperative intravenous antibiotics, reduces the incidence of post-ACLR deep knee infections to approximately 1.3%. This intervention demonstrates a highly favorable safety profile, with no significant increase in graft failure or arthrofibrosis. We recommend this cost-effective,

simple, and safe adjunctive measure as a standard of care in arthroscopic ACL reconstruction to mitigate the devastating consequences of postoperative septic arthritis.

Declarations

Statement of Ethics: This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Ethical Committee of Sri Chamundeshwari Medical College Hospital & Research Institute (Approval No. SMCHRI/IEC/2017/089).

Informed Consent: Written informed consent was obtained from all individual participants included in the study. Participants were thoroughly informed about the procedure, the experimental use of the vancomycin wrap, and the potential risks and benefits.

Conflict of Interest / Competing Interests: The authors declare no conflicts of interest, financial or otherwise, regarding the publication of this paper.

Funding Statement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data Availability Statement: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Credit Author Contributions

1. **Dr. Nagaraju Honnegowda:** Conceptualization, Supervision, Case Management, Investigation, Writing – Review & Editing.
2. **Dr. Madhusudan B.:** Data Curation, Patient Management, Literature Review, Writing – Original Draft Preparation.
3. **Dr. ShreeKrishna Nanda Sagar:** Project Administration, Data Collection, Methodology, Writing – Original Draft Preparation, Corresponding Author.

Acknowledgments: The authors extend their gratitude to the Department of Microbiology for their meticulous assistance with culture and sensitivity analysis, and to the physiotherapy team for their diligent rehabilitation efforts, which were instrumental in achieving the excellent functional outcomes reported.

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