Rates of Septic Arthritis After ACL Reconstruction

A Single-Center Analysis Highlighting Quadriceps Tendon Grafts

Emre Anil Özbek,*†‡ MD, Sahil Dadoo,† BS, Audrey Chang,§ BA, Lauren Simonian,§ BS, Romano Sebastiani,§ BS, Zachary Herman,† MD, Armin Runer,†‖ MD, Kathleen M. Poploski,¶ PT, DPT, Clair N. Smith,† MS, James J. Irrgang,†¶ PT, PhD, and Volker Musahl,† MD
Investigation performed at University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania, USA

Background: Although the infection rates for bone–patellar tendon–bone autograft (BTB), hamstring tendon autograft (HT), and allograft have been reported previously, there are limited data available for a large cohort of individuals undergoing anterior cruciate ligament (ACL) reconstruction (ACLR) using quadriceps tendon autograft (QT).

Purpose: The aims of this study are (1) to compare rates of septic arthritis after primary and revision ACLR with QT, BTB, HT, and allograft and (2) to evaluate the association between an infection after ACLR and potential risk factors in a large single-system analysis.

Study Design: Cohort study; Level of evidence, 3.

Methods: All ACLR cases performed by 10 high-volume sports medicine fellowship–trained ACL surgeons between January 2000 and January 2022 were retrospectively analyzed. Minimum follow-up was 90 days after ACLR, and all multiligament reconstructions were excluded. Demographic information, surgical variables, infection characteristics, and rate of ACL graft retention were collected for all included patients. Independent samples *t* test, chi-square test, or Fisher exact tests with adjusted Benjamini-Hochberg post hoc procedure were used for group comparisons.

Results: In total, 6652 patients were included in this study. The most commonly used graft was allograft (n = 2491; 37.4%), followed by HT (n = 1743; 26.2%), BTB (n = 1478; 22.2%), and QT (n = 940; 14.1%). The overall postoperative rate of septic arthritis was 0.34% (n = 23). Septic arthritis rates based on graft type were 0.74% (n = 13) for HT, 0.24% (n = 6) for allograft, 0.20% (n = 3) for BTB, and 0.10% (n = 1) for QT. While a statistically significant difference with regard to graft type ($P = .01$) was observed, no significant relationships were found between postoperative septic arthritis and age, sex, revision ACLR, ACLR surgical technique, and accompanying intra-articular procedures for all septic arthritis patients ($P > .05$). The average time from the onset of the symptoms of infection to surgical irrigation and debridement (I&D) was 2 days (minimum, 0; maximum, 6). ACL grafts were retained during I&D procedures in all patients with postoperative septic arthritis.

Conclusion: The postoperative rate of septic arthritis was 0.1% after use of the QT autograft. While graft choice may affect rates of septic arthritis after ACLR, patient characteristics, ACLR technique, revision ACLR, and accompanying intra-articular procedures during ACLR were not associated with postoperative septic arthritis with the numbers available for analysis.

Keywords: ACLR; septic arthritis; infection; quadriceps tendon; graft

Septic arthritis after arthroscopic anterior cruciate ligament (ACL) reconstruction (ACLR) is a rare complication with reported rates of 0.32% to 1.8%.[18,19,25] However, it can be devastating, resulting in graft failure, loss of function, increased cost of surgery, and extensive antibiotic therapy.[2,18,19,24,25] Due to the rarity of this complication, the current literature may be insufficient to report the risk factors, infection rates, treatment options, and results based on graft choice.[19]

The frequency of using a quadriceps tendon (QT) autograft ACLR is gradually increasing.[5] Studies reporting functional, biomechanical, and graft survival rates that

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are comparable with bone–patellar tendon–bone (BTB) and hamstring tendon (HT) autografts, which are among surgeons' other autograft preferences, play a major role in the increased frequency of use of this autograft.[7,23] The rates of septic arthritis have been studied in several large-scale studies.[2,18,19] While the HT graft is associated with the highest postoperative septic arthritis rates, BTB grafts have shown the lowest rates of septic arthritis.[14,19] However, the inclusion rates of ACLR surgeries performed with the QT autograft are observed to be low, which is inconsistent with current clinical practice.

Treatment of concomitant meniscal and cartilage pathologies is performed in 26.3% to 43.7% of individuals undergoing ACLR[10] and may prolong the total surgical time.[6] In addition, revision surgery, periarticular osteotomy, and other extra-articular procedures may also affect the total surgical time for ACLR. It has been reported that longer surgery time (time $\geq$70 minutes) is an independent risk factor for septic arthritis after ACLR.[12] While revision ACLR has been found to be a relative risk factor for septic arthritis,[19,22] the relationship between concomitant intra- or extra-articular procedures and septic arthritis after ACLR is still unknown. However, it has been previously reported that 16.6% to 27.1% of patients with septic arthritis after ACLR had an accompanying procedure.[2,19]

The aims of this study are (1) to compare rates of septic arthritis after primary and revision ACLR with QT, BTB, HT, and allograft and (2) to evaluate potential risk factors for septic arthritis after ACLR in a large single-institute analysis. We hypothesized that using the QT autograft and performing isolated ACLR surgery may be associated with lower rates of septic arthritis.

METHODS

This retrospective study was granted institutional review board approval at the University of Pittsburgh (No. STUDY20050226). Patients who underwent primary or revision ACLR surgery by 10 fellowship-trained high-volume ACL surgeons between January 2000 and January 2022 were included in our study. Throughout the study population, all surgeons had experience using each graft option, individualizing the graft choice based on patient needs and previous surgeries. Exclusion criteria were follow-up <90 days, patient age <14 years, and multiligamentous reconstruction surgeries. Patient characteristics, body mass index (BMI), laterality, graft choice, and ACLR surgical techniques (single bundle, double bundle, over-the-top technique) and hybrid fixation (over-the-top technique for anteromedial bundle, femoral bone tunnel for posterolateral bundle) were collected for all included patients. Accompanying intra-articular procedures including medial and/or lateral meniscal surgery (meniscectomy, repair, root repair, ramp lesion repair, meniscal allograft transplantation), cartilage surgery (microfracture, osteochondral autograft transfer system, matrix-induced autologous chondrocyte implantation, osteochondral allograft transplantation), and extra-articular procedures (lateral extra-articular tenodesis, high tibial osteotomy, distal femoral osteotomy) were also collected for all included patients. Postoperative septic arthritis was diagnosed by the presence of $\geq$1 of the following criteria within 90 days of ACLR surgery: (1) purulent drainage from a deep incision, (2) knee joint aspiration suggestive of a bacterial infection, (3) culture-positive aspiration, and (4) positive physical examination findings consistent with septic arthritis.[19] For patients determined to have septic arthritis after ACLR, additional information was collected, including previous knee surgeries, smoking history, time from ACLR to symptom onset, time from symptom onset to irrigation and debridement (I&D), blood C-reactive protein, erythrocyte sedimentation rate, white blood cell (WBC) count, synovial fluid sample data, culture results, antibiotic type and dose, and graft retention or removal.

For the index ACLR, all patients were administered cefazolin or vancomycin 30 minutes before ACLR surgery at a dose appropriate for their weight and allergy history. Hair removal at the surgical site was performed in the operating room before surgery, if necessary, and all patients were thoroughly disinfected with an alcohol-based and povidone-iodine solution. The graft used for the surgeries was selected via a combination of patient preference and surgeon experience. While allograft was used more frequently in earlier surgeries, autograft was used more frequently in recent years. All allograft tissue was fresh frozen and stored at –80°C before use in surgery. Antibacterial detergents, antiviral detergents, and gamma irradiation were used for each allograft depending on the providing company's protocols.

Synovial fluid samples were taken from patients with suspected septic arthritis under sterile conditions and sent to the laboratory for cell count and culture. All

*Address correspondence to Emre Anil Özbek, MD, Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, University of Pittsburgh, 3200 S. Water ST. Fredie Fu Sports Complex, Pittsburgh, PA 15203, USA (email: anl_ozbek@hotmail.com).
†Department of Orthopedic Surgery, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania, USA.
‡Department of Orthopedics and Traumatology, Ankara University, Ankara, Turkey.
§University of Pittsburgh Medical Center, University of Pittsburgh, Pittsburgh, Pennsylvania, USA.
‖Department for Orthopaedic Sports Medicine, Klinikum rechts der Isar, Technical University of Munich, Munich, Germany.
¶Department of Physical Therapy, University of Pittsburgh, Pittsburgh, Pennsylvania, USA.
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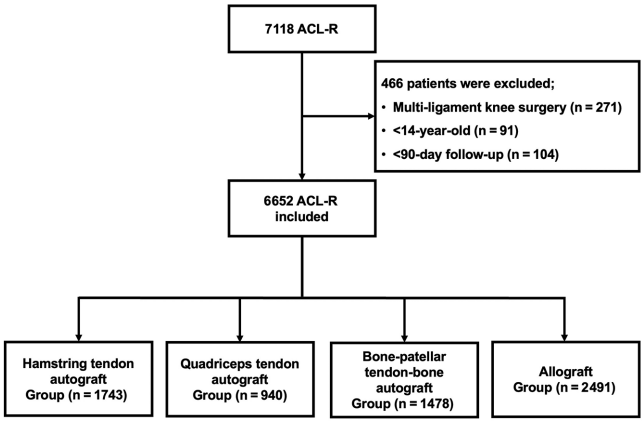

Figure 1. Group Allocation Based on Graft Types.

patients diagnosed with septic arthritis underwent arthroscopic I&D surgery at least once. The decision to retain or remove the graft was ultimately determined based on graft appearance and surgeon preference during I&D surgery. After initial I&D surgery, the decision to undergo subsequent I&D surgeries was based on patient appearance and laboratory values. Antibiotic therapy for patients with septic arthritis was determined in consultation with infectious disease specialists, who provided antibiotic therapy based on cultures obtained from the synovial fluid in conjunction with current practice guidelines at the time of the diagnosis.

Statistical Analysis

Categorical variables were summarized with frequencies and percentages, and continuous variables were summarized with the mean and standard deviation. Age was compared between groups (infection vs no infection) with an independent-samples *t* test. All other variables were compared with the chi-square or Fisher exact test. Post hoc comparisons were adjusted with the Benjamini-Hochberg procedure.[20] Because only 1 variable was associated with infection, no multivariable regression was conducted for risk factor analysis. Significance was set at .05. Analysis was performed in SAS Version 9.4 (SAS Institute).

RESULTS

A total of 7118 patients were identified for analysis, of whom 6652 were included based on the study inclusion (Figure 1). The most commonly used graft was allograft (n = 2491; 37.4%), followed by HT (n = 1743; 26.2%), BTB (n = 1478; 22.2%), and QT (n = 940; 14.1%). Complete patient characteristics, number of primary and revision surgeries, type of femoral fixation, and concomitant procedures are reported in Table 1.

The overall postoperative rate of septic arthritis was 0.34% (n = 23). Each of the 10 surgeons included in the study experienced $\geq$1 case of septic arthritis, and no surgeon experienced >3 cases of septic arthritis. Patient characteristics and operative details comparing the noninfected and infected groups are displayed in Table 2. Age, sex, BMI, and laterality did not differ statistically between the infected and noninfected groups ($P > .05$). Furthermore, primary or revision ACLR, surgical technique, and the performance of concomitant extra-articular or intra-articular procedures were not statically significant different between both groups ($P > .05$). The differences in infection-based graft type were statistically significant. However, when looking at pairwise comparisons and after adjustments for multiple comparisons, there were no detectable differences between the type of graft used for ACLR due to lower power caused by the small number of infections.

When examining the cohort of patients with postoperative septic arthritis, no patients had a diagnosis of diabetes mellitus, 17.4% (n = 4) of the patients had a history of smoking, 4.3% (n = 1) had comorbid disease (Crohn disease), and 4.3% (n = 1) had a previous knee surgery (meniscectomy). The mean WBC count of the patients with postoperative infection symptoms was 10 (minimum, 6.1; maximum, 25.2), the mean blood C-reactive protein was 11.69 mg/dL (minimum, 1; maximum, 21.41), and the mean erythrocyte sedimentation rate was 57 (minimum, 22; maximum, 102) at the time of admission. Infection symptoms were detected in the patients at an average of 27 days (minimum, 5; maximum, 79) after the first surgery. When broken down by graft type, on average, symptoms were detected postoperatively in the HT group at 32 days, QT group at 26 days, BTB group at 21 days, and allograft group at 25 days. The average time from the onset of symptoms to the I&D surgery was 2 days (minimum, 0; maximum, 6). When aspirating the knee under sterile conditions, frank purulence was observed in 8 (34%) patients, and the mean WBC count in the synovial fluid was 60,778 (minimum, 500; maximum, 165,550). Ten, or 43%, of the patients with postoperative infection had positive cultures from synovial fluid, of which the following microorganisms were obtained: *Staphylococcus aureus* (n = 3), *Enterococcus faecalis* (n = 2), *Streptococcus pneumoniae* (n = 2), *Serratia marcescens* (n = 2), and *Escherichia coli* (n = 1). In addition, 43% (n = 10) of the patients with postoperative infection underwent 1 I&D procedure, while 52% (n = 12) underwent 2 I&D procedures. One patient underwent 5 I&D procedures during a single hospital admission. The ACL grafts were retained during I&D procedures in all patients (n = 23) with a postoperative infection.

DISCUSSION

The primary finding of the study was that the postoperative rate of septic arthritis was 0.1% after use of the QT autograft. While the use of the QT autograft in ACLR surgery is increasing, information on septic arthritis that may occur in patients receiving this graft is limited.[5] In a cohort study that included only patients who had undergone revision ACLR surgery, the QT autograft was used in 634

TABLE 1
Patient Characteristics and Operative Details by Graft Type[a]

Characteristic	Total (N = 6652)	HT (n = 1743)	QT (n = 940)	BTB (n = 1478)	Allograft (n = 2491)
Age, y	26.0 ± 10.6	22.9 ± 8.5	23.0 ± 7.5	21.6 ± 6.5	31.9 ± 12.2
Female	2839 (42.9)	882 (50.6)	371 (39.9)	470 (31.8)	1116 (45.0)
BMI	26.7 ± 5.4	26.1 ± 5.2	26.0 ± 5.1	26.3 ± 5.0	27.7 ± 5.9
Laterality					
Right	3222 (48.4)	839 (48.0)	456 (48.7)	741 (50.1)	1186 (47.7)
Left	3430 (51.6)	904 (52.0)	484 (51.3)	737 (49.9)	1305 (52.3)
Primary vs revision surgery					
Primary ACLR	5656 (85.2)	1686 (96.8)	794 (84.8)	1344 (90.8)	1832 (73.7)
Revision ACLR	996 (14.8)	57 (3.2)	146 (15.2)	134 (9.2)	659 (26.3)
ACLR technique					
Single bundle	4793 (71.8)	1336 (75.8)	761 (80.9)	1237 (83.7)	1459 (58.3)
Double bundle	1029 (15.3)	145 (8.1)	65 (6.9)	0 (0)	730 (29.2)
Hybrid	641 (8.2)	187 (10.5)	103 (10.9)	196 (13.2)	155 (6.2)
OTT	278 (4.7)	75 (5.5)	11 (1.3)	45 (3.1)	147 (6.3)
Concomitant procedures					
ACLR only	3230 (48.7)	960 (54.6)	354 (38.0)	679 (46.3)	1237 (50.1)
ACLR + intra-articular procedure[b]	3321 (49.8)	811 (44.8)	574 (59.9)	780 (52.8)	1156 (48.6)
ACLR + extra-articular procedure[c]	101 (1.5)	4 (0.2)	32 (3.3)	19 (1.3)	46 (1.8)

[a]Data are presented as mean ± SD or n (%). ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; BTB, bone–patellar tendon–bone autograft; HT, hamstring tendon autograft; OTT, over-the-top ACLR technique; QT, quadriceps tendon autograft.
[b]Meniscal or cartilage procedure.
[c]Lateral extra-articular tenodesis or osteotomy procedures.

patients, and the rate of infection was reported as 0.16%.[21] The rate of septic arthritis in patient groups receiving other auto- and allografts used in ACLR surgery has been reported in detail in many studies. The rate of infection after the use of the HT autograft during ACLR is reported to be between 0.61% and 2%, while the rate of postoperative infection of another frequently used autograft, BTB, is reported to be between 0.23% and 0.72%.[2,4,18,19,24] During ACLR, the rate of infection after allograft use is reported to be between 0.27% and 0.6%.[2,11,18,19] Our study results parallel the literature and show a higher rate of infection in the HT group, while patients receiving allograft and BTB experienced infection at lower rates.

The overall infection rate was 0.34% in our study. This rate is among the 0.32% to 1.8% post-ACLR septic arthritis rates reported in the literature in studies with large patient populations.[2-4,8,11,18,19,21,24,25] In a cohort study of 11,451 patients, the rate of postoperative septic arthritis was reported as 0.42%, and the most frequently isolated microorganism was *S aureus*, while it is reported that no growth was detected in the culture in 18% of the patients.[19] In a study involving 10,626 patients, *S aureus* was also reported to be the most frequently isolated microorganism, while 48% of the patients reported no growth in culture.[25] In a large cohort study, which reported that culture could not be detected in 26% of patients who developed postoperative septic arthritis, it was reported that the most frequently isolated microorganism was *S aureus*.[18] In other studies reporting the results of septic arthritis after ACLR, the rate of culture-negative patients is reported to be between 6.6% and 33%.[2,3,24] Some potential causes for not detecting the infecting microorganism, such as infections caused by organisms that require a long incubation period, lack of enriched culture media, and suppression by antibiotic therapy in vivo, may cause culture-negative infections.[13] In our study, the most frequently isolated microorganism was *S aureus*, while no microorganism was isolated in the cultures of 13 patients. In culture-negative patients, a diagnosis of septic arthritis was made with physical examination and findings of the laboratory tests that were consistent with septic arthritis such as purulent drainage from the surgical wound and/or high blood infection markers.[19]

Although septic arthritis is rarely observed after ACLR, the complication may occur more frequently with some graft choices compared with others.[19] Many studies have reported that HT autograft use is a risk factor for the development of postoperative septic arthritis.[1,4,11,14,18,19] Although the exact reason is unknown, reasons such as the need for deeper dissection to harvest the HT autograft and the proximity of the donor site to the tibial tunnel have been reported in the literature.[18] According to our research, there is no clear theory in the literature as to why a lower incidence of infection may exist after use of the QT autograft compared with the HT autograft. Possible explanations include less skin contact during QT autograft harvesting and that the harvesting area is far from the bone tunnels and has thicker soft tissue coverage. There was a significant difference in infection rates when statistical testing was performed across the 4 graft types. However, when looking at pairwise comparisons and after adjustments for multiple comparisons, no statistical differences were detected between each graft combination due to lower power caused by the overall small number of infections.

TABLE 2
Patient Characteristics and Operative Details by Infection Status[a]

Characteristic	Total (N = 6652)	Noninfected Group (n = 6629)	Infected Group (n = 23)	*P* Value
Age, y	26.0 ± 10.6	26.0 ± 10.6	24.0 ± 10.1	.38[b]
Sex				.71[c]
Male	3813 (57.1)	3799 (99.6)	14 (0.4)	
Female	2839 (42.9)	2830 (99.7)	9 (0.3)	
BMI, kg/m^2 (n = 4601)	26.7 ± 5.4	26.7 ± 5.4	25.5 ± 2.7	.81[b]
Laterality				.95[c]
Right	3222 (48.4)	3211 (99.7)	11 (0.3)	
Left	3430 (51.6)	3418 (99.7)	12 (0.3)	
Primary vs revision surgery				.77[c,d]
Primary ACLR	5656 (85.2)	5637 (99.7)	19 (0.3)	
Revision ACLR	996 (14.8)	992 (99.6)	4 (0.4)	
Graft choice				**.01**[c,e]
HT	1743 (26.2)	1730 (99.3)	13 (0.7)	
QT	940 (14.1)	939 (99.9)	1 (0.1)	
BTB	1478 (22.2)	1476 (99.8)	3 (0.2)	
Allograft	2491 (37.4)	2485 (99.8)	6 (0.2)	
Femoral fixation				.55[d]
Single bundle	4793 (71.8)	4775 (99.6)	18 (0.4)	
Double bundle	1029 (15.3)	1025 (99.6)	4 (0.4)	
Hybrid	552 (8.2)	552 (100)	0 (0)	
OTT	278 (4.7)	277 (99.7)	1 (0.3)	
Concomitant procedures				.85[c]
ACLR only	3230 (51.3)	3218 (99.6)	12 (0.4)	
ACLR + intra-articular procedure[f]	3221 (49.8)	3210 (99.6)	11 (0.4)	
ACLR + extra-articular procedure[g]	101 (1.5)	101 (100)	0 (0)	

[a]Data are displayed as mean ± SD or frequency (%). Bold value represents statistical significance (<.05). ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; BTB, bone–patellar tendon–bone autograft; HT, hamstring tendon autograft; OTT, over-the-top ACLR technique; QT, quadriceps tendon autograft.
[b]*P* values were calculated using the *t* test.
[c]*P* value calculated using the chi-square test.
[d]*P* value calculated with Fisher exact test.
[e]Post hoc comparisons were adjusted with the Benjamini-Hochberg procedure and did not show any statistical significance between grafts.
[f]Meniscal or cartilage procedure.
[g]Lateral extra-articular tenodesis or osteotomy procedures.

Another potential risk factor for septic arthritis reported in the literature is revision ACLR surgery.[9] Marom et al[19] reported the relative risk ratio for the development of postoperative septic arthritis for revision ACLR as 3.13, while Schuster et al[22] reported this rate as 2.5. Proposed reasoning for this association is the need for a longer intraoperative time with revision ACLR surgery.[6] In addition, although there is a study reporting that young patient age is a relative risk factor for the development of septic arthritis, another study in the literature reports that there is no relationship between patient age and postoperative infection.[3,19] In our study, no significant difference was found between the infected and noninfected groups in age, sex, and surgical technique. In addition, the relationship between revision ACLR surgery, which was reported as a relative risk factor in the literature, and septic arthritis was not found in our study. This may be due to the small number of patients in the infected group included in our study and the inclusion of ACLRs performed by only high-volume sports medicine fellowship–trained ACL surgeons in our study, thus shortening the surgical time.[12]

One of the most important steps in the treatment of septic arthritis after ACLR is the decision to retain or remove the existing graft. In the literature, graft retention rates after septic arthritis have been reported to be between 69% and 97%.[2,15,17-19,22,25] Delay in the time from the onset of septic arthritis symptoms to I&D surgery and >2 I&D surgeries has been reported as a risk factor for graft removal.[16,19] In a recent study reporting that the graft was retained in 69% of patients who developed septic arthritis after ACLR, the mean time from the onset of infection symptoms to I&D surgery was reported to be 5 days.[19] Another study indicated that 78% of grafts could be retained, in which the mean time from symptom onset to I&D surgery was 2.6 days.[17] Schuster et al[22] included 7096 patients in their study and reported a graft retention rate of 97.3%, with a mean time from symptom onset to I&D surgery of 2.5 days. Our study found a higher rate (100%) of graft retention than what has previously been reported in the literature. A possible explanation for this is that the mean time from the onset of septic arthritis symptoms to I&D surgery in our study was 2 days (0-5 days), and only 1 patient required more than 2 I&D surgeries.

Our study has several limitations. First, this is a large single-institute study, and there will inevitably be loss of follow-up for patients who were seen and treated at other institutions after ACLR. Specifically, as referenced in Figure 1, 104 patients were lost to follow-up within 90 days postoperatively. This may have a direct effect on the rate of septic arthritis after ACLR, as well as the rate of graft retention or removal. Second, although all 10 surgeons included in this study are fellowship-trained, high-volume ACL surgeons, each surgeon may have different graft preferences, graft preparation, and surgical techniques. However, all surgeons included routinely use all 4 graft types based on patient indications and desires. Third, while the rate of infection after the QT autograft was 0.1% in our study, the use of QT has risen only in recent years, and the observed lower infection rate may be due to improvements in surgical technique that minimize risk of infection. Fourth, although surgical time is one of the most influential factors for infection after ACLR,[12] the actual surgical time could not be evaluated for some patients during this study because of the long-term retrospective study design. Fifth, it has been reported recently in the literature that soaking the graft in vancomycin during graft preparation significantly reduces infection rates.[14] However, while vancomycin soaking was used in some cases, it was not utilized during the full (20-year) study period, and data could not be uniformly collected for the entire study population. Thus, vancomycin soaking data were not collected in our study. Sixth, although comorbid disease, which may influence the development of postoperative septic arthritis,[19] was collected for the infection group, this variable could not be collected for all patients. Seventh, the low number of infections likely limited the power of the study to detect associations with other factors, such as revision ACLR and accompanying intra-articular procedures. Furthermore, with only 1 infection in the QT autograft group, the precise rate of infection after QT autograft use is fragile. Finally, multiple regression analysis could not be performed in our study due to the small number of patients in the septic arthritis group.

CONCLUSION

The postoperative rate of septic arthritis was 0.1% after QT autograft use. While graft choice may affect rates of septic arthritis after ACLR, patient characteristics, ACLR technique, revision ACLR, and accompanying intra-articular procedures during ACLR were not associated with postoperative septic arthritis with the numbers available for analysis. Surgeons can use this information when choosing grafts for ACLR and managing the complication of septic arthritis, as well as when informing patients of the potential complications after ACLR.

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ORCID iD

Emre Anil Özbek https://orcid.org/0000-0002-8502-9798

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