Infections Following Arthroscopic Anterior Cruciate Ligament Reconstruction

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Purpose: Infection after anterior cruciate ligament (ACL) reconstruction is a serious but uncommon complication. Optimal management has not been established. The purpose of our case series was to review our experience and published reports to identify risk factors, evaluate physical and laboratory findings, compare different treatments, and assess clinical outcomes. **Methods:** Retrospective review of all the arthroscopic ACL reconstructions performed at our institution between 1994 and 2002. Patients with intra-articular infections were evaluated and, when available, comparisons were made between patients with extra-articular infections and uncomplicated postoperative ACL reconstructions. **Results:** Eleven postoperative infections were identified, all in patients who had hamstring autograft. Previous knee surgery, especially previous ACL reconstruction and tibial ACL graft fixation with a post and washer, was associated with increased infection. Laboratory data revealed elevated erythrocyte sedimentation rate (average, 67), C-reactive protein (average, 14), and intra-articular blood cell count (average, 52,000). All infections were eradicated with serial arthroscopic incision and drainage (average, 2.4 procedures) and intravenous antibiotics (duration, 14 to 42 days). The graft was retained in 10 of 11 patients. At an average follow-up of 22 months, the average Lysholm functional knee score was 71.6 out of 100 points (range, 36-99). Of the 5 patients with fair/poor results, the most common chief complaint was pain and stiffness. **Conclusions:** Long-term goals for treatment of patients with postoperative ACL infections are to protect the articular cartilage and to maintain knee function. Timely initiation of treatment, including joint lavage, debridement, and antibiotics, are essential to treatment. Graft and hardware retention can successfully accomplish these long-term goals. However, if early clinical response is not acceptable, strong consideration should be given to expedient graft and hardware removal. Excellent outcomes can be obtained, but results are usually lower than with uncomplicated cases. **Level of Evidence:** Level IV, case series. **Key Words:** Anterior cruciate ligament reconstruction—Infection—Treatment—Complications.

Arthroscopic anterior cruciate ligament (ACL) reconstruction is an effective method of restoring stability to the knee after injury to the ACL. Postoperative septic arthritis is an uncommon but potentially serious complication with a reported incidence rate of between 0.14% and 0.78%.[1-7] However, optimal clinical management guidelines have not been completely established.[1-7] Published recommendations have differed for graft retention, open versus arthroscopic treatment, type and duration of antibiotics, and time to revision.[1-7] Additionally, the functional outcomes after eradication of postoperative infection have been variable.[2-7] In this report, we review our experience with postoperative ACL reconstruction infections (11 of 1,615 cases), identify potential risk factors for this complication, describe our treatment, and present the patients' outcomes. The purpose of our case series

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was to attempt to identify ways to prevent, identify, and optimally treat this complication. A review of published reports is also presented.

METHODS

A retrospective review was performed of all arthroscopic ACL reconstructions performed at our institution from January 1994 to December 2001. Postoperative intra-articular infections were defined as a positive culture from a knee aspiration or a cell count consistent with intra-articular infection (>10,000 cells/mL) in patients who presented with symptoms consistent with septic arthritis. Workup for infections was performed at the discretion of the attending physician, typically in conjunction with an infectious disease consultant.

The charts were reviewed to identify the operative procedure, type of graft fixation, presentation and treatment, and results at the latest follow-up. We analyzed operative reports of all ACL reconstructions performed for operative variables and patient demographics. The relative risk was determined by dividing the incidence of the operative variable being evaluated in the infected cohort by the noninfected cohort. During follow-up evaluations, patients' knees were assessed for range of motion, joint-line tenderness, patellofemoral pain, and ligamentous stability. They completed a knee function questionnaire including the Lysholm knee score.[8,9] Patients unavailable for follow-up in person completed questionnaires by telephone interview. Weight-bearing anteroposterior and lateral radiographs were taken at follow-up and were reviewed by an independent board-certified musculoskeletal radiologist.

This surgical procedure, including graft harvest and preparation, used essentially the same techniques described in published texts, and no breaks in sterile techniques were reported.[10] The surgeon generally shaved the skin with a razor before surgical prep. The surgical prep included a povidone iodine scrub and paint performed by the operating room nurse. A 4- to 5-cm longitudinal incision was made over the pes anserinus to allow identification and harvest of the semitendinosus and gracilis tendons and creation of the tibial tunnel through the same incision. The graft was then prepared on the back table and placed on a tensioning device (GraftMaster; Smith & Nephew, Andover, MA). The tibial tunnel was made with an Arthrex drill guide (Arthrex, Naples, FL) and the femoral tunnel with a transtibial technique with the goal of a 1- to 2-mm back wall. The incisions were closed in layers, with absorbable braided Vicryl sutures (Ethicon, Somerville, NJ). No. 0 suture was used for deep fascial tissue and No. 2-0 Vicryl for the subcutaneous layer, and either skin staples or subcuticular monofilament suture for the skin. All patients received preoperative antibiotics for infection prophylaxis, remained in the hospital overnight, and received antibiotics for 24 hours postoperatively. The postoperative dressing was changed at the first follow-up visit, generally between postoperative days 3 and 5. Our standard postoperative rehabilitation protocol involves weight bearing and range of motion as tolerated immediately postoperatively. The patients' rehabilitation was supervised by a physical therapist who instructed them on specific ACL rehabilitation exercises preoperatively, in the hospital before discharge, and within 3 to 6 days after discharge. A structured rehabilitation protocol, typically 2 to 3 times a week, was started immediately after the first postoperative visit. The patients' wore a range-of-motion brace for weight-bearing activities until adequate quadriceps strength was achieved (typically 4 to 6 weeks),

We selected patients with extra-articular infections that occurred during our study period to compare with the intra-articular infection group to assess for differences on physical examination and laboratory studies that may assist in establishing the correct diagnosis. Inclusion into the extra-articular infection group required a postoperative complication that necessitated local wound incision, debridement, and antibiotics. Laboratory studies were obtained at the discretion of the attending physician based on clinical suspicion. Postoperative complications of erythema, local cellulitis, and suture abscesses were not included. Additionally, we compared laboratory results with the 12 patients who underwent uncomplicated ACL reconstruction followed by serial erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) laboratory tests, which were collected as part of a separate study performed at our institution.[11]

RESULTS

Out of the 1,615 ACL reconstructions performed between January 1994 and December 2001, 11 patients (0.68%) were identified with postoperative septic arthritis. However, the 11 intra-articular infections all occurred during a 3-year period between 1999 and 2001, resulting in an incidence rate of 2.6%. We analyzed the operative reports of all 418 ACL reconstructions performed during this period of increased incidence of infection for operative variables and pa-

Table 1. *Graft Type*

All reconstructions (n = 418)	
BPTB	217
Hamstring	193
Allograft	8
Intra-articular infection	
Hamstring	11
Extra-articular infection	
BPTB	8
Hamstring	4

Abbreviation: BPTB, bone–patellar tendon–bone.

tient demographics. Additionally, based on our inclusion criteria, 12 patients who developed isolated extra-articular infections during this time were also evaluated.

Despite a nearly equal use of patellar and hamstring autografts in the overall ACL reconstruction group and extra-articular infection group, all the intra-articular infections were found in the ACL reconstructions performed with hamstring autografts (Table 1).

Other operative variables found to be associated with a higher incidence of postoperative intra-articular infection were prior knee surgery (relative risk, 1.90), especially if the prior knee surgery was ACL reconstruction (relative risk, 5.1) (Table 2). For the intra-articular infection group, there were 8 men and 3 women with an average age of 28 years (range, 22 to 35 years). In our series, age, gender, surgical side, tourniquet use, and additional procedures at the time of ACL reconstruction did not differ between the 3 groups.

Fixation of a bone-tendon-bone autograft was performed using metallic interference screws in the vast majority of cases; other fixation devices included BioScrews (Linvatec, Largo, FL) on the femur, and BioScrew and staple fixation on the tibia. Hamstring autografts were secured with either a BioScrew, open looped EndoButton (Smith & Nephew), or TransFix (Arthrex) device on the femoral side, and BioScrew, BioScrew and post/washer, or ligament button for tibial side fixation. Evaluation of femoral and tibial graft fixation revealed a higher incidence of infection associated with the use of a post and washer fixation on the tibia (19% use overall *v* 63% intra-articular infection group; relative risk, 3.2; Table 3). This method of fixation makes use of a bicortical 6.5-mm screw in the proximal tibia over which braided nonabsorbable sutures connected to the graft limbs are tied. Alternatively, if the graft is long enough, a spiked washer secures the graft directly to bone. We also found an increased association of intra-articular infections with femoral tunnel fixation involving EndoButton fixation (10% use overall ACL reconstruction *v* 45% intra-articular infection group; relative risk, 4.5). Extra-articular infections were not found to be associated with a use of fixation significantly different from the overall ACL reconstruction group.

Comparison of the patients' clinical presentation between the intra- and extra-articular infection groups showed similar signs and symptoms (Table 4). However, knee effusion, painful range of motion, and fever were more common with the intra-articular infection group, with knee effusion and painful range of motion being statistically significant ($P < .01$). The average time to presentation after ACL reconstruction was 14.2 days (range, 6 to 45 days) for the intra-articular infection group and 22.9 days (range, 12 to 33 days) for the extra-articular infection group; this was statistically significant ($P < .01$). The vast majority of intra-articular infections presented between 7 and 14 days. In our series, 2 patients presented after 2 weeks, 1 at 18 days, and the other at 45 days. In 8 patients, the diagnosis was made and surgical treatment was started on the day of initial presentation. In 3 patients, the diagnosis and treatment was delayed. The delays were usually 2 days; however, in the 1 patient whose graft was removed, the delay was 5 days.

Comparison of laboratory data, obtained through peripheral vein blood sample, revealed a normal white blood cell count (WBC), but elevated ESR and CRP. Intra-articular cell count, obtained through sterile knee aspiration, was elevated in both the extra-articular and intra-articular infection groups (Table 5). However, ESR, CRP, and cell count were statistically higher in the intra-articular infection group compared with the extra-articular infection group (ESR 67 *v* 23, $P = .05$; CRP 14 *v* 8, $P = .05$; cell count 52,000 *v* 4,170, $P <$

Table 2. *Previous Knee Surgery*

All ACL reconstructions (n = 418)	
ACL	29 (6.9%)
Meniscal repair	7 (1.7%)
Arthroscopy	21 (5%)
Intra-articular infection (n = 11)	
ACL	4 (36%)
Arthroscopy	2 (18%)
Extra-articular infection (n = 12)	
ACL	1 (8.3%)
Arthroscopy	1 (8.3%)

NOTE. Relative risk: previous surgery, 1.6 intra-articular, 0.2 extra-articular. Previous reconstruction, 5.1 intra-articular.

TABLE 3. *Graft Fixation*

	Femoral Tunnel	Number of Patients	Tibial Tunnel	Number of Patients
All ACL reconstructions (n = 418)	IS	174	IS	166
	BS	149	BS	126
	EB/BS	42	BS/PW	81
	TF	32	BS/LB	20
	OT	22	OT	25
Intra-articular infections (n = 11)	EB/BS	5	BS/PW	5
	BS	4	BS	3
	EB	2	PW	2
			PW/LB	1
Extra-articular infections (n = 12)	IS	7	IS	7
	BS	3	BS/PW	3
	BS/EB	2	PW	1
			BS	1

NOTE. Fixation by graft type. BPTB (217 patients): Femur, IS 80%, BS 20%. Tibial, IS 77%, BS 20%, staple 3%. Hamstring (193 patients): Femur, BS 54%, EB/BS 20%, TF 15%, OT 11%. Tibial, BS 42%, BS/PW 38%, BS/LB 11%, OT 9%. Allograft (8 patients): Femur, EB/BS 50%, TF 50%. Tibial, BS/PW 100%.

Abbreviations: IS, metallic interference screws; BS bioabsorbable interference screw; EB, EndoButton; TF, TransFix; PW, post and washer, LB, ligament button; OT, other.

.0001). Normal values in our laboratory are ESR 0 to 10 and CRP <0.5.

Evaluation of the average postoperative laboratory values in uncomplicated ACL reconstruction revealed an initial postsurgical bump in both ESR and CPR. The CPR returns to near normal levels by 2 weeks and the ESR remains mildly elevated up to 4 weeks postoperatively (Table 5). Comparison of the noninfected group and the infected group at 2 weeks revealed statistically significant differences in both groups with regard to the CRP ($P = .05$). The ESR was significantly elevated in the intra-articular infection group only ($P = .05$).

The white blood cell count and ESR were obtained in all patients, and the CRP in 9 of 11 intra-articular infections, and 7 of 12 extra-articular infections. The cell count was only obtained in 4 of the 12 extra-articular infections. Coagulase-negative *Staphylococcus epidermidis* (CNSE) was the most common organism cultured in the intra-articular infection group. *Staphylococcus aureus* was the most common in the extra-articular group and CNSE the second most common in the extra-articular group. Of note, additional sites of extra-articular infections were found in 9 of 11 patients in the intra-articular infection group; 8 of these 9 additional sites of infection were at the hamstring graft harvest site at the proximal tibia.

After diagnosis was established, all intra-articular infections were eradicated with a combination of serial arthroscopic joint and local surgical wound irrigation and debridement. Arthroscopic lavage and debridement included the posterior compartment of the knee, with an average of 2.4 procedures (range, 1 to 4 procedures) and intravenous antibiotics for an average of 28 days (range, 14 to 42 days) (Table 6). Arthroscopic treatment was performed based on intraoperative findings and included lavage with at least 9 liters of lactated Ringer's solution, debridement, synovectomy, and evaluation of the graft for competence and signs of infection. During arthroscopic evaluation, the graft often had a thin fibrinous coating but seemed

TABLE 4. *Patient Presentation*

	Days to Presentation (Average)	Physical Examination Findings (No. of Patients With Finding)
Intra-articular infections (n = 11)	14.2	Effusion 11* Pain at wound 8 Pain with knee motion 7* Erythema 6 Drainage 6 Fever 5†
Extraarticular infections (n = 12)	22.9	Pain at wound 11 Erythema 6 Drainage 6 Effusion 2 Fever 1 Pain with knee motion 1

*$P < .01$.
†$P = .069$.

TABLE 5. *Laboratory Values*

	Intra-articular (n = 11)	Extra-articular (n = 12)	Control POD 14 (n = 8)
WBC	9.8 (4.9-17.7)	7.7 (5.5-10.2)	—
ESR	67 (25-124)	23 (7-42)	21.7 (6-50)
CRP*	13.7 (5.5-19.4)	7.7 (1.2-10.4)	0.79 (<0.3-3.3)
Cell count†	52,735 (25,400-72,800)	1,133 (427-2,850)	—

Abbreviations: WBC, white blood cell count; ESR, erythrocyte sedimentation rate; CPR, C-reactive protein; POD, postoperative day.
*Intra-articular n = 9, extra-articular n = 7.
†Extra-articular n = 4.

otherwise normal and took up appropriate tension. In 1 patient, the graft was removed because it was found to be incompetent on probing and had purulent exudate. The graft was retained in the remaining 10 of 11 patients (91%). Soft-tissue debridement consisted of removal of all necrotic tissue and irrigation with pulse lavage. The suture and post were left intact and the wounds were allowed to heal by secondary intention.

After appropriate laboratory studies were obtained and based on recommendations by infectious disease consultants, all patients were started on empirical intravenous antibiotic therapy, usually cefazolin or vancomycin. In 2 cases, the intravenous antibiotics were switched to oral antibiotics when culture and sensitivity results revealed sensitivity to available oral antibiotics. Bacteria were resistant to initial antibiotics used in 6 of 11 patients. Only 1 of 11 bacterium was sensitive to cefazolin whereas 11 of 11 were sensitive to vancomycin.

At an average of 22 months (range, 10 to 48 months), in 9 of 11 patients available for follow-up, the average modified Lysholm functional knee score was 71.6 points (range, 36-99) (Table 7). Two patients were lost to follow-up. Three patients were unable to return to the clinic, and the questionnaires were completed by telephone interview. Five of 9 patients felt that their knee functioned normal/nearly normal and 4 of 9 felt that their function was abnormal or severely abnormal. Of these 4 patients, the most common chief complaint in 3 was pain and stiffness, followed by pain and instability in the 1 patient in whom the graft was removed. He chose not to undergo revision ACL reconstruction.

Six patients were available for follow-up physical examinations. In the 3 patients with Lysholm scores over 90 points, there was no evidence of patellofemoral or joint line pain. Range of motion was symmetric to the contralateral leg. Lachman test and pivot-shift tests revealed no evidence of ACL laxity. Of the 2 patients with Lysholm scores of 65 and 70, 1 had moderate patellofemoral pain and a range of motion from 0° to 110° of flexion. The other had mild patellofemoral crepitance, a range of motion of 0° to 120°, and a pivot glide. The final patient available for physical examination, in whom the graft was removed, had a Lysholm score of 40. His range of motion was 0° to

TABLE 6. *Treatment of Postoperative ACL infections*

Patient	Postoperative Day	Number of Procedures	Organism	Definitive Antibiotic	IV Antibiotic Duration (days)
1	12	2	*S epidermidis*	Vancomycin	21
2	9	3	*S epidermidis*	Vancomycin and rifampin	28
3	45	1	*Propionibacterium acnes*	Clindamycin	21
4	16	4	*S epidermidis*	Vancomycin and rifampin	42
5	9	2	*Enterobacter aerogenes*	Ciprofloxacin (PO)	21 (3 wks PO)
6	8	2	*S aureus*	Cephalexin (PO)	14 (4 wks PO)
7	10	2	*S epidermidis*	Vancomycin	28
8	18	2	*S epidermidis*	Vancomycin and rifampin	21
9	14	3 (graft removed)	*S epidermidis*	Vancomycin and rifampin	42
10	11	2	*S epidermidis*	Vancomycin	28
11	14	3	*S epidermidis*	Vancomycin	42
Average (range)	15.1 (8-45)	2.4 (1-4)			28 (14-42)

TABLE 7. *Results of Postoperative ACL infections*

Patient	Follow-up (mo)	Scale 1-100	Lysholm	Function	Activity
1	10	95	95	Normal	Does not interfere
2	30	98	99	Normal	Does not interfere
3	16	65	68	Abnormal	Interferes moderately
4	48	40	56	Severely abnormal	Interferes a great deal
5	10	85	91	Nearly normal	Interferes only slightly
6	20	50	50	Nearly normal	Interferes moderately
7	31	93	95	Normal	Does not interfere
8	13	70	54	Abnormal	Interferes moderately
9	18	40	36	Severely abnormal	Interferes a great deal
Average (range)	21.8 (10-48)	70.7 (40-98)	71.6 (36-99)		

145° with pain at the extremes of flexion on the affected side and −5° to 150° on the nonoperative leg. He had a positive +2 Lachman, positive pivot-shift, and a KT-1000 side-to-side difference of 12 mm.

Follow-up radiographs available in 8 patients showed no evidence of degenerative joint disease in 5 and mild degenerative changes in 3, in 1 of whom previous degenerative changes were present preoperatively. All 4 patients with Lysholm scores above 90 had normal radiographs.

Time to return to physical therapy for postoperative ACL reconstruction rehabilitation protocol averaged 10.9 days (range, 1 to 30 days), which corresponds to an average of 5 physical therapy sessions lost. Comparison of patients' functional scores with the time interval between initiation of treatment and the return to rehabilitation showed that the 5 patients with Lysholm scores less than 70 were associated with a longer delay in return to physical therapy (16 days compared with 4 days for the 4 patients with Lysholm scores greater than 70).

DISCUSSION

In a review of the literature, we identified 5 published case series addressing postoperative ACL infections.[2-4,6,7] Data from these reports are summarized in Tables 8 and 9. Most investigators reported similar patient presentations, with classic signs of joint infections, rapid increase in effusion, knee pain, local ery-

TABLE 8. *Literature Review: Septic Arthritis After ACL Reconstruction*

Study	Number (Incidence)	Graft	Average Age in Years	Concomitant Open Procedures	Previous Knee Surgery	Average Days to Presentation	Average Number of Treatments*
Williams[2]	7 (0.3%)	4 BPTB 3 Hamstring	31 (17-50)	6 of 7	Not reported	21 (3-79)	1.6 (1-2)
McAllister[3]	4 (0.48%)	3 BPTB 1 Hamstring	26 (20-34)	2 of 4	3 of 4	11.2 (8-18)	2.7 (2-4)
Indelli[6]	6 (0.14%)	4 BPTB 2 Allograft Achilles	32 (20-51)	0 of 6	Not reported	20 (9-34)	2.3 (1-4)
Burks[7]	8 (0.42%)	7 Hamstring 1 BPTB	27 (15-40)	5 of 8	Not reported	24 (20-29)	2
Viola[4]	14 (0.78%)	14 BPTB	21 (17-29)	2 of 14	3 of 14	7.7 (2-20)	1†
Current study	11 (0.62%)	11 Hamstring	28 (22-35)	0 of 11	6 of 11	14.2 (6-45)	2.4 (1-4)
Total	50 (0.14%-0.78%)	26 BPTB 22 Hamstrings 2 Allografts	27 (15-51)	15 of 50	12 of 29	15.4 (2-79)	2 (1-4)

NOTE. Except where indicated, numbers in parenthesis indicate range.

*Treatments consisted of arthroscopic and/or open joint irrigation and debridements and, where appropriate, local wound irrigation and debridements.

†Antibiotics started initially: 6 patients failed to improve and were treated with arthroscopic incision and drainage after 2 weeks of antibiotics.

TABLE 9. *Literature Review: Septic Arthritis After ACL Reconstruction*

Study	Time from Presentation to Treatment	Lab Results (average)	Cell Count	Graft Retention	Organism	Antibiotics Duration	Results (follow-up time)
Williams[2]	Not reported	WBC 10.8 ESR 82	75,400 (27,000-136,700)	3 of 7	4 *S aureus* 1 *S epidermidis* 1 *S aureus* and *S epidermidis* 1 *S aureus* and Peoptostreptococcus 6 of 7 with extra-articular sites of infection	IV antibiotics 4-6 wk One patient developed osteomyelitis several months after finishing antibiotics	7 of 7 ADLs 100%, athletics 57% 1 pain with ADLs 6 minimal to negligible pain All patients used knee braces 6 of 8 were satisfied with their level of function (29 mo, 7-71)
McAllister[3]	Within 24 hr	WBC 9.74 ESR 79 CRP 26	50,817 (7,689-81,236)	4 of 4	4 *S aureus*	IV 4.75 wk (2-6) Oral antibiotics 3 wk (2-4)	Lysholm 78 (73-88) 3 abnormal 1 severely abnormal (11 mo, 7.5-20)
Indelli[6]	7.5 d	Not reported	91,000 (64,000-129,000)	4 of 6	3 *S aureus* 2 *S epidermidis* 1 nonhemolytic streptococcus	6 wk IV antibiotics	2 normal 1 nearly normal 2 normal 1 patient converted to total knee replacement (3 yr, 2-8)
Burks[7]	Not reported	WBC 8.4 ESR 48	60,750 (18,000-100,000)	1 of 8	3 *S aureus* 1 *Pseudomonas aeruginosa*	6 wk IV antibiotics	Lysholm 92 (76-100) in revision group of 4 patients (21 mo, 14-31) Lysholm of 57 in 1 patient graft retention No report of 3 patients who elected not to have revision
Viola[4]	2 wk	WBC 10.2 ESR 86.8 CRP 10	Not reported	14 of 14	11 Cultures negative 2 *S epidermidis*	PO antibiotics for 15-90 d until lab data normalized	Lysholm 93 (80-100) 3 normal 8 nearly normal 2 abnormal (14.4 mo, 5-43)
Present study	0.9 d	WBC 9.8 ESR 66.9 CRP 13.7	52,735 (30,130-95,800)	10 of 11	8 *S epidermidis* 1 *S aureus* 1 *Entgerobacter aerogenes* 1 *Propionibacterium acnes* Extra-articular sites of infection 9 of 11 patients	4-6 wk IV antibiotics 2 patients switched to oral antibiotics for 3-4 wk	3 normal 2 nearly normal 2 abnormal 2 severely abnormal (22 mo, 1-48)

thema, and incisional drainage. As noted by others, the diagnosis may not be as obvious and classic signs of knee sepsis can be masked by postoperative changes; in addition, local wound problems can further complicate the clinical presentation.[7] Findings of knee effusion, painful range of motion, and fever all strongly suggest intra-articular infection (Table 4), but are seen with extra-articular infections and probably some noninfected postoperative patients, but we do not have these data. Based on our comparison with isolated extra-articular infections, the diagnosis of septic arthritis is often suspected based on a careful history and physical examination; however, there is overlap between the groups, and laboratory data are generally needed to establish the correct diagnosis.

Previous knee surgery and concomitant open surgical procedures were often, but not universally, found to be associated with postoperative infections.[2-4,6,7] Potential causes for these associations were thought to be increased operative time, tourniquet use, additional and/or longer incisions, and/or increased foreign body load.[2,3,7]

Most investigators did not comment on the method of graft fixation. In our series, hamstring grafts had a higher incidence of infection. This may be attributable to the choice of graft fixation or additional soft-tissue dissection rather than the graft itself. Previous knee surgery, tibial fixation with a metallic post and washer, and femoral-side EndoButton fixation were associated with an increased risk of infection. Viola et al.[4] also reported the use of a post–braided suture construct in their series, but did not comment on whether they encountered extra-articular infections at this site as well. Possibly the soft-tissue injury involved in harvesting the hamstring tendons and creation of a tibial tunnel, combined with the relatively subcutaneous position of the metallic post/washer/braided suture construct predisposes this area to wound complications. Our results support this as 8 of 11 of our patients in the intra-articular group had a concomitant extra-articular wound infection at this site with the same causative organism isolated on intra-articular cultures.

EndoButton fixation has not been reported to be associated with increased infection. However, given the high correlation of infecting organisms between intra-articular infections and the tibial wound site, we believe that EndoButton fixation is probably less clinically relevant than our statistical analyses imply.

Treatment rendered was very similar among the case series and generally followed the recommendation initially described by Williams et al.[2] who advocated serial arthroscopic joint irrigation and debridement, open irrigation, and debridement of surgical incisions, with graft and hardware retention unless there were signs of contamination. Descriptions of the ACL graft on intra-articular examination varied, but most investigators noted a fibrous material coating the graft and, in select cases, gross contamination was encountered. If signs and symptoms of infections persisted, they recommended graft and hardware removal at the second-look surgery.

Williams et al.[2] reported on the results of 7 patients with postoperative infections. In 4 patients, approximately 1 week after initial irrigation and debridement, a secondary joint and/or local wound irrigation and debridement was performed. The graft was removed in 4 patients (57%). Pathologic evaluation of 3 of the grafts revealed the presence of necrosis, acute inflammatory cells in 2, and no evidence of deep infection in 1. They commented that the ACL graft could serve as a nidus for infection and recommended removal at second-look arthroscopy if signs or symptoms of persistent infection were present. Physical therapy was resumed 1 to 2 weeks after wound healing, and repeat ACL reconstruction was considered at 1 year. One patient did have a repeat ACL reconstruction using this protocol and returned to professional sports. One patient who was treated with 1 washout, graft removal, and 4 weeks of antibiotics developed osteomyelitis and repeat knee sepsis several months after treatment.

McAllister et al.[3] presented the cases of 4 patients with postoperative infections in whom the graft was retained. They found, during follow-up arthroscopy for hardware removal after eradication of the infections, a viable ACL graft that performed normally on intraoperative evaluations. Although their patients noted minimal to no pain during activities of daily living, they did report lower overall functional assessment scores than patients who had uncomplicated ACL reconstructions. In addition, they observed evidence of full-thickness cartilage lesions and diffuse chondral thinning on postoperative magnetic resonance imaging scans in all of their patients and believed these articular cartilage changes were the most likely cause of their patients' inferior outcomes.

Burks et al.[7] described 8 patients with postoperative infections and reported excellent results in 4 young patients with an average age of 17.5 years who had graft removal, local wound and arthroscopic joint irrigation and debridements, and early revision ACL reconstruction after antibiotic treatment. They compared their results with that of 1 patient who had

similar treatment, but with graft retention and a poor result. They also expressed concerns about a retained ACL graft as a potential nidus for persistent infection, as well as sterile microbial fragments and inflammatory mediators that might pose the risk of persistent chondrolysis. No loss of joint space was observed on follow-up radiographs, but no comment was made about the condition of the cartilage during revision ACL reconstruction. The authors recommended graft removal if it appeared infected or if there was any difficulty controlling the infection, and advocated early revision once antibiotic therapy was completed and the infection was eradicated.

Indelli et al.[6] reported on 5 postoperative infections they treated, 2 of which were allografts. None of the patients had secondary procedures performed.[6] Two grafts were removed because of purulent exudate encountered at the time of initial arthroscopy. At follow-up, 1 patient with mild to moderate preoperative degenerative changes had been converted to a total knee arthroplasty. Another patient had a revision ACL reconstruction at 1 year and was able to return to athletic activity despite mild tricompartmental degenerative changes. They reported a 7-day delay in onset of symptoms to diagnosis, and noted their best results occurred in patients who were treated early and in those infected with *S epidermidis*. All 3 patients with excellent results had their original graft retained. The authors emphasized early treatment with irrigation, debridement, and antibiotics, because early treatment with antibiotics has been shown to decrease the amount of articular cartilage loss.[12] The also suggested that less virulent bacteria such as *S epidermidis* may allow for graft retention and excellent results because the less virulent bacteria cause less articular cartilage damage.[13] They also believed their poor results were caused by articular cartilage damage.

Viola et al.[4] reported on 13 patients (14 knees) who were treated for postoperative infections. Initial diagnosis was made based on clinical and laboratory workup. However, only 2 positive cultures of intrasynovial fluid were obtained. The remaining 11 cultures were negative. Antibiotics were initially administered to all patients. Six patients who failed to improve on antibiotics alone underwent arthroscopic irrigation and debridement. Because 10 of 14 of their infections occurred over a 4-month period (10 of 70 ACL reconstructions performed during this period), an epidemiologic workup was performed that revealed that 2 contaminated prepackaged "sterile" inflow catheters had been used for ACL reconstruction. After changing this device, their rate of infection dropped dramatically. Excellent results were reported in all 13 patients included in their study without specifying which were the results for those patients treated operatively or with positive cultures.

Because of our increased incidence of infection between 1999 and 2001, thorough evaluations were performed by our infectious disease and preventive medicine departments of all the arthroscopic equipment, surgical instruments, sterilization procedures and equipment, prepackaged and sterilized items from the manufacturers, and operative room personnel. However, no source of infection was identified. Additionally, multiple surgeons and residents were involved in the cases and there was no increased incidence of infection noted in other surgical procedures, including knee arthroscopy for indications other than ACL reconstruction. However, given that the majority of our infections were from natural skin flora and associated with concomitant extra-articular sites for infection at the hamstring graft site, we assume that inoculation may have occurred at the time of surgery or shortly thereafter.

After analysis of our results, we have paid particular attention to the hamstring harvest site to minimize surgical trauma during graft harvest, and we perform a meticulous layered wound closure. Our choice of graft fixation has evolved with the newer implants available. Presently we primarily use hamstring autografts with a TransFix or closed-loop EndoButton device for femoral fixation and a BioScrew for tibial fixation, typically backed up with a post and washer construct. Fortunately, we have not had any further ACL infections.

Based on the reported case series, eradication of infection can reliably be accomplished with arthroscopic and open surgical wound irrigation and debridement and 4 to 6 weeks of antibiotic therapy. A decision on graft preservation should be made on a case-by-case basis, but if the patient continues to show signs of infection after an initial irrigation and debridement, serious consideration should be given to graft removal. In patients with concomitant extra- and intra-articular infection, because of the high incidence of resistance to cefazolin antibiotic in our series, we recommend vancomycin as the empiric antibiotic of choice pending culture results.

Follow-up results can be excellent, but overall results are much less satisfactory than for patients without postoperative infections.[2-4,6,7] Reported outcomes reflect the potential devastating results of this complication and emphasize the need for careful management. The ability of patients to perform pain-free

activities of daily living is likely. However, a full return to athletic activities is less certain. Articular cartilage damage caused by infection and a delay in returning patients to physical therapy may contribute to poor results. After pain, arthrofibrosis was the most common cause of unsatisfactory results and an early return to physical therapy might help mitigate this complication.

A limitation of our study is that 2 patients were lost to follow-up after they left the armed service and 3 had been transferred to a different duty station and were unable to have a follow-up physical examination, although they were able to complete questionnaires by telephone interview. Because of the overall low numbers in our case series, if these patients have significantly different findings than the other patients, the conclusions of our study could be skewed.

CONCLUSIONS

The long-term goals of treatment of patients with postoperative ACL infections are to protect the articular cartilage and to maintain knee function. Graft retention and eradication of infection are not sufficient measures of successful treatment. Timely initiation of treatment, including joint lavage, debridement, and administration of antibiotics, are essential to remove bacterial contamination and to minimize chondrolysis. Based on our experience and literature review, graft and hardware retention can successfully accomplish these long-term goals if treatment is initiated early and the graft and hardware appear normal on evaluation. However, when treatment is delayed, a more virulent organism is present, early clinical response is not acceptable, or the graft or hardware appear contaminated, strong consideration should be given to expedient graft and hardware removal. After successful treatment and completion of antibiotic therapy, patients who undergo revision ACL reconstruction can do well, whether performed immediately after treatment or delayed.

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