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Effect of Graft Selection on the Incidence of Postoperative Infection in Anterior Cruciate Ligament Reconstruction

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Background: Knee joint infection is a potentially devastating complication of anterior cruciate ligament (ACL) reconstruction. There is a theoretical increased risk of infection with the use of allograft material.

Hypothesis: An allograft ACL reconstruction predisposes patients to a higher risk of bacterial infection.

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

Methods: All primary ACL reconstructions performed at our institution between January 2002 and December 2006 were reviewed; 3126 total procedures were identified. A retrospective medical record review was performed to determine the incidence of infection, offending organism, time after surgery until presentation, infection treatment, and graft salvage as an outcome of graft choice.

Results: Of the 3126 ACL reconstructions, 1777 autografts and 1349 allografts were performed. Eighteen infections were identified (0.58%). Infections occurred in 6 of the 1349 allografts (0.44%), 7 of the 1430 bone-patellar tendon-bone (BPTB) autografts (0.49%), and 5 of the 347 hamstring autografts (1.44%). Five grafts were removed because of graft incompetence or loosening: 3 hamstring tendon, 1 BPTB, and 1 allograft. The most common organism isolated was *Staphylococcus aureus*. Hamstring tendon autograft had an increased incidence of infection compared with both BPTB autograft and allograft ($P < .05$), with a trend toward a more common need for graft removal ($P = .09$). Allograft reconstructions were equally likely to have graft salvage as autograft reconstructions.

Conclusion: Hamstring tendon autografts have a higher incidence of infection than BPTB autografts or allografts. The use of allograft material in ACL reconstructions does not increase the risk of infection or the need for graft removal with infection.

Keywords: anterior cruciate ligament; infection; allograft; complications

Arthroscopic ACL reconstruction is used to restore knee stability after an ACL rupture. Knee joint infection is a rare but potentially devastating complication of ACL reconstruction, with a reported incidence of 0.14% to 1.70% of patients.[4,7,8,12,15,23,25] Because of the rare occurrence of septic arthritis after ACL reconstruction, the literature is limited to case reports, and there are few data on the effect of graft selection on the incidence of infection and on the probability of graft salvage.

Allograft tendons are now commonly used for ACL reconstructions. Proponents cite the ability to avoid donor-site morbidity, ease of use, availability, wide variety of graft size options, and decreased operation time.[1,17,21] Additionally, clinical results with the use of allograft material have been equivalent to traditional autograft selection.[5,13,16,17] Some concerns with the use of allograft tissue include longer incorporation time[2] and increased risk of infection, both viral and bacterial. A literature review reveals limited and conflicting data on whether allograft ACL reconstruction increases risk of infection.[6,11] The purpose of this study was to retrospectively review our experience with infection after ACL reconstructions and to determine the effect of graft selection on both incidence of infection and ability to perform graft salvage.

MATERIALS AND METHODS

A retrospective medical record review was completed for all patients who had ACL reconstructions performed at our institution from January 2002 until December 2006. No patients were excluded. A detailed database kept on all operations performed at our institution was used to initially determine number of ACL procedures performed

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as well as graft selection for each procedure. A total of 3126 ACL reconstructions was identified. To determine the number of infections over this 5-year interval, 3 methods were used. First, as per hospital protocol, all infections are reported to the infectious disease department, and records are kept based on procedures. This detailed database of all postoperative infections is maintained by a nurse practitioner. This database identified 18 patients with postoperative ACL infections. Next, the medical record database was queried for all cases with Current Procedural Terminology (CPT) code 29888 (arthroscopically aided ACL repair/augmentation or reconstruction) performed over the 5-year time period. The CPT codes 27310 (arthrotomy, knee, with exploration, drainage, or removal of foreign body) and 29871 (arthroscopy, knee surgical; for infection, lavage, and drainage) were then matched to CPT code 29888. Finally, the International Statistical Classification of Diseases and Related Health Problems (ICD-9) code of 717.83 was used to identify ACL reconstructions. This code was then matched to ICD-9 codes 998.5 (postoperative infection), 996.6 (infection due to internal prosthetic device), and 996.7 (other complications of internal prosthetic device, implant, and graft). All patients identified through the use of CPT codes as well as ICD-9 codes were accounted for in the initial list of 18 patients from the infectious disease department.

A complete chart review was then performed on all 18 patients identified as having a postoperative infection. General patient details collected included age, gender, comorbidities, prior ACL surgery, prior knee surgery, and graft type. Surgical details were reviewed to determine length of surgery, tourniquet time, associated procedure, and graft contamination. Infection details that were reviewed were symptoms, organism, erythrocyte sedimentation rate, C-reactive protein, both the joint and systemic white blood cell count, number of days after surgery until presentation, graft salvage, and type of treatment.

At our institution all patients are instructed to perform a home preparation (an antiseptic, antimicrobial wash) of the surgical site before presentation at the hospital. Once at the hospital, in the presurgical holding area, the site is shaved with a razor (as needed) and an alcohol-based solution is used for a preliminary preparation. Once in the operating room, a surgical preparation is initially performed with a povidone iodine scrub by the operating nurse. The leg is then kept sterile while the surgeon performs a second povidone iodine scrub with paint sticks on the leg. All patients received weight-appropriate antibiotics before surgery consisting of cefazolin or vancomycin (significant penicillin or cephalosporin allergy). Sterilization of instruments was performed as per standard hospital protocol.

Methods of graft harvest, preparation, and fixation were left to the individual discretion of the attending surgeon. Postoperative rehabilitation protocols also varied according to graft fixation method, graft type, surgeon preference, and concomitant procedures. All patients had consultation by an infectious disease specialist within a week of the diagnosis of infection. Length of treatment with antibiotics, monitoring of laboratory values, and need for irrigation and debridements were based on agreement between attending orthopaedic surgeon and infectious disease specialist.

All allograft tissue was obtained from the Musculoskeletal Transplant Foundation, American Red Cross Tissue Services, or Community Tissue Services. The use of antibacterial detergents, antiviral detergents, and gamma irradiation was performed at each of these organizations as per their individual standard protocols. All allograft tissues were fresh-frozen and stored at −80°C at our institution before use in surgery. The decision to use an allograft or an autograft was made based on the discretion of the attending surgeon after lengthy discussion with the patient regarding risks and benefits of each. In general, the majority of surgeons at our institution use allografts in patients over the age of 35 years and autografts in patients under 35 years. More than 95% of allograft tissue used in our institution for ACL reconstruction is Achilles tendon allograft with calcaneal bone plug. The decision to use hamstring tendon autograft or bone-patellar tendon-bone (BPTB) autograft was made based on patient desire and surgeon's preference. There were multiple surgeons in each graft type group.

Statistical analysis of the data consisted of a descriptive evaluation using means and standard deviations for continuous variables and frequencies and percentages for discrete variables. All potential risk factors were evaluated for a univariate association with ACL infection using Fisher exact test for discrete variables and 1-way analysis of variance for continuous variables. Fisher exact test was used to determine if there were associations between graft type and graft salvage as well as between graft type and type of infection. One-way analysis of variance was used to determine if differences existed between graft types and type of infection with respect to mean length of surgery. Finally, rate ratios were calculated to compare the incidence rates of infection between graft types. Unadjusted odds ratios and their respective 95% confidence intervals were calculated and presented for the discrete variables and means (± standard deviations) and their respective P values were calculated and presented for the continuous variables. Statistical significance was defined as a P value of $<.05$ and a trend to significance was defined as a P value of $<.10$. All calculations were done using SPSS version 14.0 (SPSS Inc, Chicago, Illinois).

RESULTS

In the 5-year study period between January 2002 and December 2006, a total of 3126 ACL reconstructions were performed at our institution. Eighteen infections were identified (0.58%). The average age of the patients with an infection was 34.1 years; there were 14 men and 4 women (Table 1). All patients had undergone their primary surgery at our institution. Overall, there were 1777 autograft and 1349 allograft reconstructions performed. Infections occurred in 6 of the 1349 allografts (0.44%; all were Achilles tendon allografts), 7 of the 1430 BPTB autografts (0.49%), and 5 of the 347 hamstring tendon autografts (1.44%). There was no statistically significant difference between total allograft and

TABLE 1
Patient Demographics Including Age, Gender, Additional Procedures At Time of ACL Reconstruction, and Specific Graft Details

Patient No.	Age, y	Gender	Additional Procedures	Graft Type[a]
1	34	M	None	BPTB autograft
2	41	F	Excision of nodule	Achilles allograft
3	35	M	Attempted hamstring harvest	BPTB autograft
4	45	M	Medial meniscal repair	Achilles allograft
5	45	F	Partial medial meniscectomy, chondroplasty of left medial femoral condyle	Hamstring autograft
6	21	M	None	Hamstring autograft
7	48	M	Medial femoral condyle microfracture	BPTB allograft
8	33	M	Partial medial meniscectomy	Hamstring autograft
9	16	F	Overdrilling of proximal tunnel requiring Endobutton[b] use	Hamstring autograft
10	40	M	Medial meniscal repair, patella chondroplasty	Achilles allograft
11	52	M	Partial medial and lateral meniscectomies	Hamstring autograft
12	29	M	None	BPTB autograft
13	48	M	None	Achilles allograft
14	18	M	Partial medial meniscectomy	BPTB autograft
15	32	M	Patella chondroplasty, partial lateral meniscectomy	BPTB autograft
16	25	M	None	BPTB autograft
17	26	F	Partial lateral meniscectomy	BPTB autograft
18	26	M	HTO, partial medial and lateral meniscectomies	Achilles allograft

[a]BPTB, bone-patellar tendon-bone; HTO, high tibial osteotomy.
[b]Endobutton is a product of Smith & Nephew Endoscopy, Andover, Massachusetts.

total autograft and risk of infection ($P = .40$). There was a statistically increased risk of infection with hamstring tendon autograft compared with BPTB autograft ($P < .05$) and hamstring tendon autograft compared with allograft ($P < .05$). Overall, the rate of incidence of hamstring autograft infection is 3.34 times higher (95% confidence interval: 1.18, 9.47) compared with the rate of the rest of the study population ($P = .02$).

Three of the 18 patients with infections had undergone previous knee surgery: 2 ACL reconstructions and 1 partial medial meniscectomy. Only 1 patient with an infection had a concomitant open procedure consisting of an allograft reconstruction and a high tibial osteotomy (HTO) performed in a 26-year-old woman (Table 1). Nine of 18 patients had arthroscopic meniscal surgery at the time of reconstruction (2 meniscal repairs, 7 partial meniscectomies). The average length of surgery was 107 minutes and was defined as skin incision until skin closure was complete (range, 72-176 minutes in the patient with an HTO). A tourniquet was used in 13 of the patients, and average tourniquet time was 47 minutes (range, 18-85 minutes in the patient with an HTO). Use of a tourniquet and the inflation protocol were based on surgeon preference. No patient had documented intraoperative graft contamination and there were no reports of breaks in sterile technique as per both nursing record and surgeon operative note. No grafts were cultured before use.

The most common presenting symptoms for infection as documented by the surgeon were fever, defined as temperature 38.5°C or more (10 patients) and pain (10 patients) (Table 2). Other common symptoms at time of presentation included erythema (8 patients), swelling (6 patients), and drainage (3 patients). Seventeen (94%) of the patients had 2 or more symptoms. Time after surgery until presentation of symptoms of infection varied from 5 to 205 days (mean, 32 days). There were 5 acute infections (defined as <2 weeks), 11 subacute infections (2 weeks to 2 months), and 2 late infections (>2 months).

Erythrocyte sedimentation rate was available for review in 12 of the 18 patients and was obtained at time of presentation with infection (Table 2). The average erythrocyte sedimentation rate was 80 (range, 15-118). C-reactive protein was available for review in 9 patients and was also obtained at time of presentation with infection, with an average value of 17.5 (range, 4.5-38.1). Aspiration results before surgical management were available in 10 patients. The average white blood cell count in the joint was 115 000 (there were only 2 patients with a value of <50 000). Finally, systemic white blood cell values were reviewed before surgical management in all patients and there was an average value of 9.6 (range, 6.0-13.8).

All patients were treated with at least 6 weeks of antibiotics and at least 1 irrigation and debridement procedure (Table 3). Seven of the 18 patients required 2

TABLE 2
Patient-Specific Laboratory Data and Signs and Symptoms of Infection[a]

Patient No.	Symptoms	Organism	ESR	CRP	Joint WBC Count (% PMN)	Systemic WBC Count (% PMN)	Presenting POD
1	Erythema, drainage, fever, chills	MRSA	*	*	*	11.4 (77.3)	5
2	Erythema, pain, swelling	MRSE	*	*	22 750 (80)	9.3 (85.8)	28
3	Fever, pain, swelling	No growth	*	*	*	8.8 (70.9)	7
4	Pain	MRSA	101	18.8	194 500 (94)	8.4 (76.4)	7
5	Fever, swelling	No growth	77	38.1	52 000 (89)	8.1 (79.9)	17
6	Pain, swelling	MSSE	15	*	66 000 (100)	9.4 (72.3)	14
7	Fever, chills, erythema	No growth	114	10.5	*	7.2 (75.5)	21
8	Fever, chills, erythema	No growth	89	25.3	189 000 (86)	10.9 (77)	11
9	Fever, pain, swelling	*P acnes*	90	20.2	*	6.0 (67)	22
10	Fever, chills, erythema	MSSE	47	7.9	*	8.1 (72.8)	6
11	Lethargy, fever, chills	No growth	118	*	92 000 (97)	11.2 (76.7)	19
12	Drainage, pain	MSSA	*	*	*	8.4 (69.3)	36
13	Drainage, pain	MSSA	*	*	*	13.0 (80.5)	90
14	Pain, swelling	*P. acnes*	81	10.1	231 000 (92)	8.0 (62.4)	28
15	Pain, erythema	MSSA	45	4.5	750 (24)	13.8 (74.5)	9
16	Pain, erythema	MSSA	*	*	*	6.9 (62.1)	122
17	Fever, erythema	No growth	101	*	145 000 (90)	11.9 (60.6)	30
18	Fever	MSSE	80	22.4	154 200 (100)	10.9 (60.5)	29

[a]ESR, erythrocyte sedimentation rate; CRP, C-reactive protein; WBC, white blood cell; PMN, polymorphonuclear neutrophilic leukocyte; POD, postoperative day; MRSA, methicillin-resistant *Staphylococcus aureus;* MRSE, methicillin-resistant *Staphylococcus epidermidis*; MSSE, methicillin-sensitive *S epidermidis*; MSSA, methicillin-sensitive *S aureus; P acnes, Propionibacter acnes;* *, not obtained or data unavailable.

irrigation and debridement procedures, and 1 patient required 3 irrigation and debridement procedures. The results of intraoperative culture included 6 methicillin-sensitive *Staphylococcus aureus* organisms, 4 methicillin-resistant *S aureus* organisms, 2 *Propionibacter acnes* organisms, and in 6 patients the intraoperative cultures had no growth. There was no statistically significant relationship between organism and graft selection.

The decision to retain the graft was made by the discretion of the attending surgeon. On the basis of the operative notes, the surgeons used appearance of the graft, graft competency, and ability to take up tension as the major determinants for graft retention. Graft retention occurred in 13 of 18 patients (72%). All 5 grafts that were not retained had presented between 10 and 30 days after surgery (11, 17, 22, 28, and 30 days). One BPTB autograft, 1 allograft, and 3 hamstring autografts were not able to be retained. There was a trend toward increased need for graft removal with hamstring tendon autograft compared with BPTB autograft and allograft ($P = .09$).

TABLE 3
Patient-Specific Treatment Regimen and Impact on Graft Salvage[a]

Patient No.	Graft Salvage	Treatment
1	Yes	I&D, IV Abx × 6 weeks
2	No	I&D, IV Abx × 6 weeks
3	Yes	I&D, IV Abx × 6 weeks
4	Yes	I&D × 2, IV Abx × 6 weeks
5	No	I&D × 2, IV Abx × 6 weeks
6	Yes	I&D, IV Abx × 6 weeks
7	Yes	I&D, IV Abx × 6 weeks
8	No	I&D × 2, IV Abx × 6 weeks
9	No	I&D, IV Abx × 6 weeks
10	Yes	I&D × 3, IV Abx × 6 weeks
11	Yes	I&D × 2, IV Abx × 6 weeks
12	Yes	I&D, IV Abx × 6 weeks
13	Yes	I&D × 2, removal of tibial screw, IV Abx × 6 weeks
14	Yes	I&D, IV Abx × 6 weeks
15	Yes	I&D, delayed primary closure, IV Abx × 6 weeks
16	Yes	I&D, IV Abx × 6 weeks
17	No	I&D × 2, IV Abx × 6 weeks
18	Yes	I&D × 2, removal of HTO hardware, IV Abx × 6 weeks

[a]I&D, irrigation and debridement; IV, intravenous; Abx, antibiotics; HTO, high tibial osteotomy.

DISCUSSION

Septic arthritis after an arthroscopic procedure is rare, and thus only limited case series exist in the literature. To our knowledge, this study represents the largest series of postoperative ACL infections in the literature to include allograft data. Our results do not support theoretical concerns of increased bacterial infection with the use of allograft tissue and document that allograft tissue can be retained following infection. Furthermore, we had no documented cases of viral infection or seroconversion after allograft ACL reconstruction. The rate of infection in

allograft ACL reconstruction (0.44%) and overall ACL reconstruction (0.58%) correspond to previous studies in the literature.[4,7,8,12,15,23,25]

Katz et al,[11] in 2008, reviewed 801 ACL reconstructions and found 2 of 170 autograft infections (1.2%) and 4 of 628 allograft infections (0.06%). Possible proposed reasons for decreased risk of infection with use of allograft include shorter surgical time, less extensile dissection, and less graft preparation. The authors were able to retain infected allograft material, and our findings support limited need for graft removal with allograft infections, as 5 of 6 infected allograft ACL reconstructions were retained. Indelli et al[8] reviewed 3500 arthroscopic ACL reconstructions, of which 40% were BPTB autografts and 60% were allografts. Only 6 postoperative infections were discovered, with 4 of 1400 BPTB infections and 2 of 2100 allograft infections. There was no documented statistical analysis of allograft versus autograft in this article. These results are contrary to the widely held dogma that all foreign material should be removed to clear infections. Additionally, our data, as well as the previously described work by Katz et al[11] and Indelli et al[8] contradict previous work by Crawford et al,[6] who reported 11 infections in 290 allograft procedures (3.8%) and no infections in 41 autograft surgeries (not statistically significant). In the study by Crawford et al, none of the allografts involved in the postoperative infections had undergone sterilization procedures. All of our allografts as well as all allografts in the recent literature underwent sterilization with both a washing agent as well as gamma irradiation.

This study demonstrated a statistically significant increased risk of infection with hamstring tendon autograft compared with both allograft and BPTB autograft. Judd et al[10] found similar results when reviewing 217 BPTB autografts and 192 hamstring autografts. A total of 11 intra-articular infections occurred in the hamstring group with no intra-articular infections in the BPTB group. Katz et al[11] also had 0 of 52 BPTB autograft infections and 2 of 118 hamstring autograft infections. Many earlier studies[15,23,25] did not delineate incidence of infection between hamstring and BPTB, leaving little data in the literature. A case series of 3 hamstring autograft infections was recently described by Tuman et al[22] in which it was determined that infection was due to the hamstring graft harvester sterilization process. They proposed that the technique of not fully disassembling hamstring harvesters before sterilization may lead to increased risk of infection.

In this study, the clinical presentations were similar for each patient, and the signs and symptoms were similar to those previously described by other authors.[8,10,18,25] All but 1 patient had at least 2 major classic symptoms of joint infection, defined in this study as fever, pain, erythema, swelling, or drainage. Fever and pain were the most common symptoms. All patients had a documented peripheral white blood cell count before surgical intervention. Our finding of a laboratory average of 9.6 cells/μL is consistent with previous studies,[4,10,15,23] demonstrating the majority of values of high normal. In the patients for whom synovial fluid white blood cell count was available for review, our average value of 115 000 cells/μL is higher than that seen in previous studies in which average values have ranged from 50 000 to 91 000 cells/μL.[4,8,15,25] The average erythrocyte sedimentation rate of 80 mm/h in our patients corresponds to previous series (range, 48-87 mm/h).[4,8,10,15,23,26] There is limited reporting of C-reactive protein values in previous series; however, our value of 17.5 mg/dL falls in the average range in the literature (range, 10-26 mg/dL).[10,15,24]

The ultimate goal of treatment of any infection is eradication with preservation of graft function, if possible. The current algorithm for treatment of ACL reconstruction infections at our institution is based on previous work by Williams et al[25] and has been in use for over 15 years. Fundamental to this algorithm is knee joint aspiration to obtain cultures, intraoperative cultures, emergent irrigation and debridement,[9] and appropriate intravenous antibiotics for 6 weeks' duration. The role of repeat operative management after the initial irrigation and debridement is based on clinical symptoms and was needed in 33% of our patients. This value is consistent with other series in the literature.[8,10,15,23,25] The ability to retain the ACL graft was based on gross inspection of the graft at the time of all initial irrigation and debridement procedures. Overall, 72% of our grafts were salvaged. In a review of 118 cases of ACL infection reported in the literature, including our own series, 76 grafts were retained (64%).[4,8,10,11,15,19,23–26] Additionally, Matava et al[14] sent out a questionnaire to 74 surgeons with 5 different treatments proposed for deep infection and found that the majority of surgeons chose initial debridement with graft retention.

There are several major limitations to this study. This series represents a variety of surgical techniques, and variations in hardware used with each graft type were not analyzed. Additionally, erythrocyte sedimentation rates, C-reactive protein values, and white blood cell counts from synovial fluid were not present for all patients. This is largely because several patients initially were seen at outside offices or emergency departments that were not affiliated with our institution. Additionally, there is the possibility that a patient with a postoperative infection chose to follow up with a surgeon outside our institution. Three different methods of capturing postoperative infections were employed, and there was no evidence of patients lost to follow-up. Finally, to our knowledge there was no viral transmission (human immunodeficiency virus [HIV], hepatitis B, hepatitis C) with the use of allograft tissue; however, we did not rigorously evaluate this in our postoperative patients. To date, there is not a documented case of HIV transmission through musculoskeletal allograft tissue since the increased testing protocols were implemented, but this remains a theoretical concern.[20] With appropriate screening, testing, and freezing of connective tissue allografts, the estimated risk of HIV transmission is 1:8 000 000.[3] Finally, this study lacks clinical follow-up and is unable to address potential differences in long-term function after allograft or autograft infections.

In conclusion, infection after ACL reconstruction remains a rare but potentially devastating complication. Our study demonstrated that the use of allograft material in ACL reconstructions does not increase the risk of infection or the need for graft removal with infection.

Additionally, while previous studies have shown higher overall values of hamstring autograft infections compared with BPTB autografts, this study is the first to demonstrate a statistically significant difference. We believe that this information should help diminish theoretical concerns of increased risk of infection with allograft tissue for both surgeons and patients.

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