Incidence and Risk Factors for Graft Rupture and Contralateral Rupture After Anterior Cruciate Ligament Reconstruction

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Purpose: The aim of this study was to determine the rates of contralateral anterior cruciate ligament (ACL) rupture and of ACL graft rupture after ACL reconstruction using either patellar tendon or hamstring tendon autograft, and to identify any patient characteristics that may increase this risk. **Type of Study:** Case series. **Methods:** Over a 2-year period, 760 endoscopic ACL reconstructions were performed in 743 patients. Bone–patellar tendon–bone autograft was used in 316 patients and 4-strand hamstring tendon in 427 patients. Those patients with a previous contralateral ACL rupture or those who underwent a simultaneous bilateral ACL reconstruction were excluded, leaving 675 knees (675 patients) for review. Persons not involved in the index operation or the care of the patient conducted follow-up assessment by telephone interview conducted 5 years after surgery. Patients were questioned about the incidence of ACL graft rupture, contralateral ACL rupture, symptoms of instability or significant injury, family history of ACL injury, and activity level according to the International Knee Documentation Committee scale. From our prospective database we obtained further information on graft source, meniscal or articular surface injury, and gender. Binary logistic regression was used to measure the relative association between the measured variables and the risk of graft rupture and contralateral ACL rupture. **Results:** Five years after primary ACL reconstruction, 612 of the 675 patients (90.7%) were assessed. ACL graft rupture occurred in 39 patients (6%) and contralateral ACL rupture occurred in 35 patients (6%). Three patients suffered both a graft rupture and a contralateral ACL injury. The odds of ACL graft rupture were increased 3-fold by a contact mechanism of initial injury. Return to level 1 or 2 sports increased the risk of contralateral ACL injury by a factor of 10. The risk of sustaining an ACL graft rupture was greatest in the first 12 months after reconstruction. No other studied variable increased the risk of repeat ACL injury. **Conclusions:** After reconstruction, repeat ACL injury occurred in 12% of patients over 5 years. Twelve months after reconstruction, the ACL graft is at no greater risk than the contralateral ACL, suggesting that adequate graft and muscular function for most activities is achieved by this time. Risk factors for repeat ACL injury identified included a return to competitive side-stepping, pivoting, or jumping sports, and the contact mechanism of the index injury. Female patients were at no greater risk of repeat ACL injury than male patients and graft choice did not affect the rate of repeat ACL injury. **Level of Evidence:** Level IV, case series. **Key Words:** ACL reconstruction—Hamstring graft—Patellar graft—Reinjury—Interference screw—Risk factors.

Anterior cruciate ligament (ACL) injuries are among the most common sporting injuries to the knee. The risk factors for, and incidence of, primary ACL injury have been explored with increasing intensity over recent years.[1-10] Variables such as activity level, female gender, and anatomic factors have been identified as increasing the risk of primary ACL injury,[10] which has been reported to occur in 1.5% to 1.7% per year in a healthy athletic population.[11,12] After ACL reconstruction, many patients are concerned about the risk of repeating the same injury. Despite this, to our knowledge, no study currently exists specifically examining the incidence of, or risk

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factors for, ACL graft rupture and contralateral ACL rupture after reconstruction.

The issue of graft choice for ACL reconstruction remains one of debate. Many surgeons consider patellar tendon autograft to be a more durable and robust reconstruction than hamstring tendon autograft, reserving hamstring tendon reconstruction for female patients and patellar tendon reconstruction for men in "high-demand" sports. However, prospective studies comparing results of hamstring and patellar tendon reconstruction have shown no difference in overall outcome.[13-18] Although the reported incidence rate of graft rupture in these studies ranges between 3% and 23%, no significant differences have been reported in the rate of ACL graft rupture or failure between the 2 graft constructs despite lack of standardized fixation techniques in some studies.[13,15,16]

This study was performed to determine the incidence of ACL graft rupture and contralateral ACL injury after reconstruction. Additionally, we sought to determine whether surgical factors such as graft type and concurrent injuries at index surgery, as well as lifestyle and demographic factors, such as gender, activity level, and family history of ACL injury, influenced the odds of ACL graft rupture or contralateral ACL injury.

METHODS

Between March 1993 and December 1994, 760 endoscopic ACL reconstructions were performed by the senior author (L.P.) in 743 patients. The initial 316 reconstructions were performed using bone–patellar tendon–bone autograft (BPTB). The subsequent 427 reconstructions were performed with autogenous hamstring tendons (HT). Those patients with a previous contralateral ACL rupture or those who underwent a simultaneous bilateral ACL reconstruction were excluded, leaving 675 patients (675 knees) for review.

Patients

At the 5-year follow-up of primary ACL reconstruction, 612 of the 675 patients (90.7%) were contacted. Sixty-three patients (9.3%) were lost to follow-up (Table 1). Thus the study group that underwent formal review consisted of 248 patients who had undergone a BPTB reconstruction, and 364 patients who had undergone a 4-strand semitendinosus and gracilis HT reconstruction. There were 383 male and 289 female patients. The median age of the study group was 28 years (range, 14 to 62 years).

Table 1. *Characteristics of Study Group and Patients Lost to Follow-up*

	HT Autograft	BPTB Autograft
Total no. of patients	427	316
Total reconstructions performed	434	326
Exclusions		
Previous contralateral ACL rupture	23	28
Simultaneous bilateral ACL reconstruction	14	20
Patients included in study	397	278
Lost to follow-up		
Unable to be located	27 (7%)	24 (9%)
Overseas	5 (1%)	7 (2%)
Deceased	1 (0.3%)	0
Patients reviewed	364 (92%)	248 (89%)

The diagnosis of primary ACL deficiency was based on a detailed history of the knee injury and the findings at surgery. The Lachman and pivot-shift tests were also performed, and results were confirmed at surgery. Plain radiographs were obtained in all patients preoperatively, but magnetic resonance imaging scans were not routinely performed. All associated injuries were documented at the time of operation. Indications for reconstruction were (1) acute injuries in young patients, (2) acute injuries in those desiring to return to a cutting or side-stepping sport, or (3) chronic injuries with persistent instability while performing sporting or activities of daily living without significant radiographic evidence of knee degeneration.

SURGICAL TECHNIQUE

The surgical technique used has been previously described.[14] Autogenous central-third BPTB or 4-strand HT were used exclusively for graft material. BPTB graft sizes measured from 8 to 10 mm in width and HT graft sizes ranged from 6.5 to 8.5 mm in diameter. Femoral and tibial tunnels of the same diameter as the graft were created using an endoscopic technique, and each end of the graft was secured in place using a round, blunt-threaded titanium interference screw (RCI; Smith & Nephew Acufex, Mansfield, MA) in each bony tunnel. All screws measured 7 mm in diameter by 25 mm long regardless of the tunnel/graft size.

TABLE 2. *Incidence and Odds Ratios of ACL Graft Rupture With Measured Variables*

	No. of Graft Ruptures/Total	Incidence of ACL Graft Rupture	Adjusted OR	95% CI for Adjusted OR Lower	Upper	*P*
Mechanism of primary ACL injury						
Contact	17/121	14%	3.0	1.4	6.1	.03
Noncontact	22/491	5%				
IKDC activity level*						
Level 1-2	27/337	8%	2.1	1.0	4.6	.05
Level 3-4	12/263	4%				
Gender						
Male	30/383	8%	0.8	0.4	1.9	.67
Female	9/229	4%				
Graft type						
HT	25/364	7%	1.2	0.59	2.4	.63
BPTB	14/234	6%				
Family history of ACL injury						
Yes	9/116	8%	1.4	0.6	3.0	.45
No	28/494	6%				
Any articular surface damage†						
Yes	8/188	4%	2.1	0.8	5.0	.11
No	31/424	7%				
Meniscal injury†						
Yes	33/446	7%	2.1	0.8	5.6	.16
No	6/166	4%				
Meniscectomy‡						
Yes	20/263	8%	1.2	0.5	2.6	.66
No	19/330	5%				

*IKDC Activity level 1-2 equates to moderate to strenuous activities. Level 3-4 equates to light to sedentary activities.
†Evident at primary arthroscopic ACL surgery.
‡Meniscectomy performed at primary arthroscopic ACL surgery.

Postoperative Rehabilitation

Postoperative braces were not used, and patients were allowed to fully bear weight immediately. Operations were performed on an outpatient basis when postoperative pain permitted. The median length of hospital stay was 1 night (range, 0 to 4). Patients were instructed to visit their physiotherapist daily for the first 2 weeks, beginning on postoperative day 1. An accelerated rehabilitation program developed under the direction of the senior author (L.P.) was followed and has been previously described.[14] Patients were allowed to begin jogging in a straight line at 6 weeks, and to begin slow progression into side-stepping activities at 3 months. Full return to sporting activity was allowed after 6 to 9 months if rehabilitation goals had been met. Patients were routinely evaluated at 1 week, 6 weeks, and 6 months postoperatively.

Follow-up Evaluation

Persons not involved in the index operation or the care of the patient conducted follow-up assessment by telephone interview. The interview was conducted by either a physiotherapist or research assistant experienced in knee research. Patients were questioned about the incidence of ACL graft rupture, contralateral ACL rupture, symptoms of instability or significant injury, and family history of ACL injury. Activity level was recorded according to the 1993 International Knee Documentation Committee scale,[19] in which the functional levels are as follows: (1) strenuous (e.g., football, hockey, basketball), (2) moderate (e.g., tennis, skiing, martial arts), (3) light recreational (e.g., jogging, cycling, swimming), and (4) sedentary, based on the demands the activity places on the knee and exposure to that functional level of at least 50 hours a year. From our prospective database, we obtained further information on graft source, gender, and meniscal or articular surface injury. Details of the circumstances of the primary and any secondary ACL injury were noted and classified as either contact or noncontact injuries. Contact injuries were defined as those that involved a direct physical force from an external source such as a tackle during a football game. Noncontact injuries were defined as arising from a maneuver without any external force, such as a side-stepping or pivoting maneuver. Timing and circumstances of injury were noted for those patients who sustained an ACL graft rupture or subsequent contralateral ACL rupture. If symptoms of instability or significant knee injury were reported, the patient was asked to come for a clinical examination to confirm an intact ACL. All patients who were classified as having suffered either a graft rupture or contralateral ACL injury were examined by an orthopaedic surgeon who confirmed the diagnosis. ACL graft rupture was defined as a traumatic episode of instability, after which the previously stabilized knee became unstable, or continuing instability after reconstruction. For those patients who had a clinical failure and underwent revision, operative details were reviewed when available to determine the site of graft failure.

Statistical Analysis

Binary logistic regression was used to measure the relative association between the measured variables and the risk of graft rerupture and contralateral ACL rupture. The Mann-Whitney *U* test was used to compare groups for significant differences. Results were considered significant at the 95% confidence interval (CI) level for all statistical analyses. Statistical analysis was performed using SPSS for Windows software v 10.0 (SPSS Inc, Chicago, IL).

RESULTS

Of the 612 patients reviewed, 71 patients (12%) suffered a further ACL injury. ACL graft rupture occurred in 39 patients (6%) at a median 20 months after the index surgery (95% CI, 15-25). Contralateral ACL rupture occurred in 35 patients (6%) at a median 28 months from surgery (95% CI, 27-36). Three patients suffered both a graft rupture and a contralateral ACL injury.

ACL Graft Rupture

Thirty-nine of the 612 patients (6.4%) sustained a rupture of their ACL graft during the follow-up period. Atraumatic graft failure occurred in 4 patients (1.1%) from the HT group and 1 patient (0.4%) from the BPTB group. Regression analysis revealed that the only significant predictor of graft rupture from among the measured variables was a contact mechanism of initial injury, which increased the odds of suffering a graft rupture 3-fold (95% CI, 1.4-6.1). As seen in Table 2, the variables of meniscal injury or meniscectomy at index surgery, gender, chronicity, type of graft, and family history of ACL injury did not affect the odds of sustaining a graft rupture. An ACL graft rupture was sustained while participating in the same sport as the index injury in 14 of the 39 graft ruptures (36%).

Table 3. *Activities Causing ACL Graft Ruptures in the First 12 Months After Surgery*

Time to Rupture (mo)	Activity	Mechanism
1	Cycling	Fall
1	None	Unknown
2	None	Unknown
2	Dancing	Fall
2	Cycling	Fall
2	Assault	Twist
3	Cricket	Twist
6	Touch football*	Tackle
7	Rugby	Side-step
10	Basketball	Jump
11	None	Fall
11	None	Unknown
11	Soccer	Twist
11	Rugby	Jump
12	Soccer	Jump
12	Touch football*	Side-step

*Touch football is a noncontact form of rugby popular in Australia.

Sixteen of the 39 ACL graft ruptures occurred in the first 12 months after surgery. Details of the mechanism of these injuries are shown in Table 3. Early graft rupture occurred during sporting activities in 11 cases. Graft failure occurred without a significant mechanism of injury in 4 cases. One patient suffered a graft rupture during an assault 2 months after surgery.

The median graft diameter at the time of reconstruction was not significantly different between those who sustained a graft rupture and those who did not (P = .84). The patients who sustained a graft rupture had a median graft diameter at the time of reconstruction of 7.8 mm (95% CI, 7.5-8.4). Those with intact ACL grafts at review had a median graft diameter of 8.0 mm (95% CI, 7.9-8.1).

Contralateral ACL Rupture

Contralateral ACL rupture occurred in 35 of the 612 patients (5.7%). Regression analysis revealed that the most significant contributor to the odds of contralat-

Table 4. *Incidence and Odds Ratios of Contralateral ACL Injury With Measured Variables*

	No. of Contralateral ACL Ruptures/Total	Incidence	Adjusted OR	95% CI for Adjusted OR		*P*
				Lower	Upper	
Mechanism of primary ACL injury						
Contact	10/121	8%	1.9	0.8	4.3	.14
Noncontact	25/491	5%				
IKDC activity level*						
Level 1-2	32/305	10%	9.8	2.9	32.9	.001
Level 3-4	3/275	1%				
Gender						
Male	20/383	5%	1.9	0.9	4.1	.10
Female	15/229	7%				
Graft type						
HT	19/364	5%	0.8	0.4	1.7	.63
BPTB	16/248	7%				
Family history ACL injury						
Yes	8/116	7%	1.1	0.5	2.5	.83
No	27/494	6%				
Any articular surface damage†						
No	26/424	6%	1.1	0.5	2.5	.85
Yes	9/188	5%				
Meniscal injury†						
Yes	23/446	5%	0.9	0.4	2.1	.75
No	12/166	7%				
Meniscectomy‡						
Yes	12/263	5%	0.9	0.4	2.3	.90
No	23/349	7%				

*IKDC Activity level 1-2 equates to moderate to strenuous activities. Level 3-4 equates to light to sedentary activities.
†Evident at primary arthroscopic ACL surgery.
‡Meniscectomy performed at primary arthroscopic ACL surgery.

eral ACL rupture is return to level 1 or 2 activities. The incidence of contralateral ACL injury increased from 1% in those who participated in level 3 or 4 activities to 10% for those participating in level 1 or 2 activities. As shown in Table 4, the other measured variables were poor predictors of contralateral ACL injury. A contralateral ACL rupture was sustained while participating in the same sport as the index injury in 20 of the 35 contralateral ACL injuries (57%).

Timing of Repeat ACL Injuries

The median time from reconstruction to graft rupture was 20 months (95% CI, 15-25) and is graphically depicted in Fig 1. There was no significant difference between the timing of ACL graft rupture between the HT group and the BPTB group ($P = .31$). The median time from reconstruction to contralateral ACL rupture was 28 months (95% CI, 27-36) (Fig 1). There was no significant difference between the timing of contralateral ACL injury between the HT group and the BPTB group ($P = .29$). Contralateral ACL injuries occurred significantly later than ACL graft ruptures ($P = .001$). In the first 12 months after surgery there was a significantly higher rate of graft rupture than contralateral ACL injury. The rate of graft and contralateral ACL

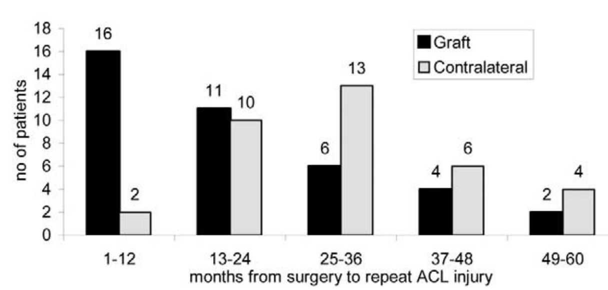

Figure 1. The number of patients suffering an ACL graft rupture (dark bars) or contralateral ACL rupture (light bars) each year after surgery.

injury followed a similar distribution 12 months after index surgery.

Details at Revision Surgery

Details of revision ACL reconstruction were available for 30 of the 39 patients who suffered a graft rupture. The location of graft rupture was midsubstance in 14 patients, proximal in 9 patients, distal in 5 patients, and unclear in 2 patients.

DISCUSSION

The primary purposes of this study were to determine the rates of contralateral ACL rupture and of ACL graft rupture after ACL reconstruction using either autogenous BPTB or autogenous HT as graft sources, and to identify any patient characteristics that may increase this risk. In this group of patients, the overall rates of ACL graft rupture (39 of 612, 6.4%) and contralateral ACL rupture (35 of 612, 5.7%) were comparable. Notably, no significant differences were identified between the BPTB and HT groups in regard to risk of ACL graft rupture or contralateral ACL rupture. The variables that increased the odds of repeat ACL injury were a contact mechanism of initial injury for graft rupture and return to sports for contralateral ACL injury.

Incidence of Repeat ACL Injuries

We found that 72 (12%) of the 612 ACL patients who underwent ACL reconstruction suffered a repeat ACL injury, over the 5-year follow-up period. In a healthy uninjured athletic population, the incidence of ACL injury is reported to be between 1.5% and 1.7% per year.[11,20] The results of the current study suggest that after ACL reconstruction the incidence of repeat ACL is increased in the first 5 years when compared with the healthy uninjured population. Similar findings have been reported by others who found that after ACL reconstruction the relative risk of repeat ACL injury is at least doubled when compared with healthy uninjured knees.[7,8] Further study is required to determine if the incidence of ACL injury after reconstruction alters with longer follow-up.

Encouragingly, we found that the incidence of injury to either the contralateral ACL or the ACL graft were the same. Rupture of the ACL graft occurred in 39 of the 612 patients over 5 years (6.4%). Contralateral ACL injury occurred in 35 of the 612 patients over 5 years (5.7%). That is, in this group of patients after ACL reconstruction, the risk of suffering a repeat ACL injury to either the reconstructed knee or the normal uninjured knee was identical. Oates et al.[7] also found similar rates of graft and contralateral ACL rupture in their study.

Studies examining bilateral ACL injuries have reported an incidence rate of between 2% and 10% after ACL reconstruction.[5,12,21,22] However, these studies have largely focused on the role of the intercondylar notch in bilateral ACL rupture and patients were collected via a review of patient files retrospectively.[12,20-22] It is unclear whether the patients were contacted to exclude contralateral ACL disruption, and annual rates of injury have not been described previously. In the current study, the incidence of contralateral ACL injury was 5.7% over a 5-year period, an average annual incidence of 1.1% per year.

There were a total of 5 patients who suffered an ACL graft rupture without any significant mechanism of injury. Two patients, both of whom had undergone reconstruction with HT graft, reruptured within 3 months of surgery—one while dancing and the other during a physiotherapy session. One patient from the BPTB group and 2 patients from the HT group denied any specific injury but reported subjective instability and were found to be ACL-deficient on examination at 12, 20, and 24 months from surgery, respectively. These patients had stable knees on Lachman and pivot-shift tests 6 months after surgery. The cause of these latter 3 failures is unclear and may be related to a biologic cause. There was no significant difference in the incidence of atraumatic graft rupture between the BPTB and HT groups as a whole, but a larger sample size would be required to further examine the cause of atraumatic failure.

Mechanism of Index Injury

A contact mechanism of initial ACL injury significantly increased the risk of rupture to the reconstructed ACL, but not the contralateral ACL. The odds of sustaining a graft rupture were increased 3-fold in patients who had suffered their initial injury from a contact mechanism, although, as the 95% CI for the odds ratio (OR) ranged from 1.5 to 6, the increased risk may be small and should be interpreted with caution. There was no significant increase in contralateral ACL injuries with a contact mechanism of injury (OR = 1.9; 95% CI, 0.8-4.3). Therefore, the increased risk is unlikely to be solely related to the act of returning to a contact sport. It may be possible that the extra trauma inflicted on the reconstructed knee during a contact mechanism of injury results in concurrent damage that compromises the knee joint and predisposes it to further injury. The presence of articular surface damage or meniscal injury that was visible at index surgery did not increase the risk of graft rupture in this study. However, others have shown with magnetic resonance imaging that significant damage to the articular cartilage and bone bruising is often associated with ACL rupture and these changes were not always visible on arthroscopic examination.[23,24] Although the mechanism by which a contact injury worsens prognosis is unclear, it is possible that when the ACL ruptures, damage to other joint structures, such as the subsurface articular cartilage or underlying bone, may adversely affect the graft or the site of bony fixation. Further study in this area is required.

Activity Level

Obviously, return to sports after ACL reconstruction increases exposure to activities that put the ACL at risk, particularly in those who return to competitive sports that require jumping, pivoting, and side-stepping of the knee. In the current study, the most significant risk factor for contralateral ACL injury was a return to level 1 or 2 sports that involved such maneuvers. This increased the odds of contralateral ACL injury by a factor of 10. Those patients who injured their contralateral ACL may represent a group who were "favoring" their reconstructed knees somewhat during sport, placing their contralateral limb under greater and more frequent stress. No data on comparative knee muscle strength before contralateral ACL rupture were available, but future studies may elucidate the role that strength plays in relative risk of contralateral injury. There was a trend toward an increased risk of graft rupture with return to level 1 or 2 sports (adjusted OR = 2.1; 95% CI, 1.0-4.6), but this finding was less marked than for contralateral ACL injury, presumably because of the influence of the atraumatic graft failures.

HT Versus BPTB Autografts

The most common grafts used for ACL reconstructions performed today are either BPTB or HT grafts. Both grafts are considered acceptable choices for ACL reconstruction by current standards.[13-15] We did not detect any significant difference between those patients who received a HT graft and those who received a BPTB graft in the rate of graft failure, traumatic graft rupture or contralateral rupture, or timing of ACL graft rupture. Despite the large number of patients in this study, we cannot exclude the possibility of a type II error occurring, that is, finding no significant difference when, in fact, a larger sample size would enable such a finding. We found a between-group difference in proportion of failures of 2%. Power calculations reveal that in order to detect a difference of such a small magnitude (1% to 2% variation) a sample size of greater than 19,000 patients is required to draw a statistically significant conclusion. However, the authors question whether a difference of this magnitude is clinically significant.

In prospective studies comparing BPTB and HT grafts for ACL reconstruction, the graft rupture rate ranges between 3% and 23%.[13-18,25] Unfortunately, many of these studies are confounded by lack of standardization between groups for variables such as graft fixation, patient selection, timing of surgery, surgeon, concurrent injuries, and rehabilitation programs.[13,15,16] Regardless, none of these studies reports significant differences in failure rates between the HT and BPTB grafts. The current study supports the evidence that there is no significant difference in failure rates between HT and BPTB grafts when an identical surgical technique and fixation method is used by a single surgeon.

Gender

It is now well accepted that females are 2 to 8 times more likely to suffer a primary ACL injury than their male counterparts.[1,26,27] It has been suggested that the disproportionate incidence of female ACL injuries may be related to extrinsic factors such as environmental features, training and conditioning factors, and intrinsic factors such as anatomic,[26,28] hormonal, and biomechanical variables.[1,10,26] Some have reported higher graft rupture rates in female patients after reconstruction with both BPTB[29] and HT autograft.[30] However, this has not been supported by other studies on patients after reconstruction with BPTB autograft where no gender differences in failure rates were identified.[4,29] The current study identified no significant difference in either graft rupture or contralateral ACL injury between male and female patients with either graft type. It appears that the factors that increase the odds of sustaining an initial ACL injury may differ from those that increase the odds of either a graft rupture or contralateral ACL injury after reconstruction.

Family History

Although a positive family history was present in almost 20% of our study group, it did not increase the likelihood of ACL graft rupture or contralateral ACL rupture. Harner et al.[5] reported a 35% incidence rate of a family history of ACL injury in 31 patients with noncontact bilateral ACL injuries compared with a 4% incidence rate in the control group. They concluded that bilaterality in ACL injuries may be related to congenital factors. More recently, Flynn et al.[31] reported that individuals with an ACL tear were 2 times more likely to have a relative with an ACL tear than individuals without an ACL injury (OR = 2.03; 95% CI, 1.14-3.63). However, because the 95% CI in this study approximated 1, the finding should be interpreted with caution.[31] Like other investigators,[26] we were unable to support this conclusion. However, we do recognize that congenital factors may have an effect on the risk of initial injury.

Timing of Repeat Injury

The median time from reconstruction to graft rupture was 20 months (95% CI, 15-25) and the median time from reconstruction to contralateral ACL rupture was 28 months (95% CI, 27-36; $P = .001$). Importantly, there was no difference between the timing of ACL graft rupture between the HT and BPTB grafts. In the first 12 months after surgery, the incidence of ACL graft rupture was significantly higher than the incidence of injury to the contralateral ACL. Early traumatic graft ruptures (i.e., during the first 12 months after surgery) may occur because of relative graft weakness while the graft is maturing through the stages of avascular necrosis, cellular repopulation, collagen remodeling, and maturation.[32-36] Rougraff et al.[37] have shown that the maturation process may take up to 3 years, but it appears that after 12 months the graft is at no greater risk than the contralateral ACL, suggesting that adequate graft and muscular function for most activities is achieved by 1 year after surgery. A similar finding was recently reported for Australian footballers by Orchard et al.[8] who found that there was a higher risk of graft rupture in the first 12 months after reconstruction than injury to the contralateral knee. After this 12-month period, the risks of sustaining a graft rupture or a contralateral ACL injury were similar.[8] Patients should be counseled that the risk for the reconstructed ACL is greatest in the first 12 months after surgery. Further study is required to determine the safest time to allow unrestricted activities after reconstruction.

It is clear that the causes of ACL injury are multifactorial. In this study, we assessed lifestyle and demographic factors that can be easily obtained from any patient in order to accurately inform them of their relative risk. Others have identified that anatomic factors such as notch width and femoral size play a role in graft failure, but these are difficult to determine without the use of repeated radiographs or computed tomography scans. Such scans are not routinely performed for all patients. Surgical variables such as tunnel placement and graft tension may also be significant.[38-40] Tunnel placement was assessed in the radiographs of 32 of the 37 graft rupture patients and there was no evidence of incorrect graft placement in this study group. The size of the graft also was not significantly different between those that sustained a graft rupture and those who did not ($P = .84$).

This study was undertaken to enable us to counsel our patients about the risks of contralateral ACL injury and graft rupture after ACL reconstruction. We were able to minimize bias in this study by using a single experienced surgeon, standard operative technique, standard graft fixation, identical rehabilitation and follow-up for all patients, and achieving a high rate of follow-up (91%) in a large group of patients. The limitations to this study warrant discussion. Follow-up assessment was conducted by a telephone interview. Physical assessment of each patient was not performed. However, patients were questioned about any symptoms of instability or episodes of knee injury by experienced knee researchers. If there was an affirmative response to either of these questions the patients were physically assessed by an orthopaedic surgeon to confirm an intact graft. Additionally, 90 of the patients with BPTB graft and 90 of the patients with HT graft with isolated ACL injuries have been reviewed on an annual basis from surgery as part of a previous study.[17] An additional 110 HT patients formed a study group assessed 7 years after surgery (Salmon et al., unpublished data). Among these patients, no instances of asymptomatic graft rupture or failure existed. Nevertheless, we concede that full clinical examination of a large number of patients would be required to definitively determine that the incidence of graft rupture or failure was not in fact higher than reported here.

It is clear that the causes of both initial and repeat ACL injury are multifactorial. In the current study, we were able to determine that repeat ACL injury occurred in 12% of patients in the first 5 years after reconstruction. Importantly, the risk of injury to either the reconstructed or contralateral ACL was identical. The factors that increased the risk of repeat ACL injury included a contact mechanism of index injury and a return to competitive sports that required side-stepping, pivoting, or jumping. Factors such as gender and family history, believed to increase the risk of primary ACL injury, were not found to influence either ACL graft rupture or contralateral ACL injury after reconstruction. When an identical operative technique and fixation was used by a single experienced surgeon, the choice of either a HT or BPTB graft did not influence the odds of sustaining a graft rupture.

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