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Survival of the Anterior Cruciate Ligament Graft and the Contralateral ACL at a Minimum of 15 Years

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Investigation performed at North Sydney Orthopaedic and Sports Medicine Centre, Sydney, Australia

Background: The risks for primary anterior cruciate ligament (ACL) rupture have been established. What is less well known is the risk of graft rupture after reconstruction and also the risk of a primary ACL rupture in the contralateral knee.

Purpose: To determine the long-term survival of the ACL graft and the contralateral ACL (CACL) after reconstruction and to identify factors that increase the odds of subsequent ACL injury.

Study Design: Case series; Level of evidence, 4.

Methods: All patients having undergone primary ACL reconstruction in 1993 or 1994 by a single surgeon in a single unit were considered. Patients were contacted to complete a subjective interview by telephone or e-mail questionnaire at a minimum of 15 years after surgery.

Results: A total of 755 patients met the inclusion criteria, and ACL reconstruction was performed using a single-incision endoscopic technique with either autologous bone–patellar tendon–bone graft (BPTB; n = 314) or hamstring tendon graft (HT; n = 359) and metal interference screw fixation. Of these patients, 673 (89%) completed the questionnaire; 23% had sustained either a graft rupture or CACL rupture. Expected survival of the ACL graft was 95%, 93%, 91%, and 89% at a respective 2, 5, 10, and 15 years after reconstruction. Expected survival of the CACL was 97%, 93%, 90%, and 87%, respectively. Survival of the ACL graft was less favorable in men than in women (P = .007); ACL graft survival was not significantly different between the HT (88%) or BPTB (91%) groups (P = .149). Rupture of the CACL occurred twice as frequently as graft rupture in the BPTB group (graft survival, 84% vs 89%; P = .003). A positive family history of ACL rupture doubled the odds of both ACL graft and CACL rupture. The mean International Knee Documentation Committee subjective score at 15 years was 85. Return to preinjury sport levels was reported in 73% of patients, and 51% were still participating in strenuous or very strenuous activities at 15 years.

Conclusion: Fifteen years after ACL reconstruction, expected survival of the ACL graft was 89% and expected survival of the CACL was 86%. Graft choice did not affect ACL graft rupture, but using BPTB increased the risk of CACL rupture compared with HT. Men had a less favorable survival rate of the ACL graft than did women, and a family history of ACL rupture increased the risk of both ACL graft and CACL rupture.

Keywords: cruciate; long-term; graft survival; contralateral ACL; rupture rate; survivorship

Anterior cruciate ligament (ACL) rupture is a common injury among a young active population. The aim of reconstruction is to restore knee stability to prevent further intra-articular injury and to return the patient to his or her preinjury level of activity. A common question encountered by the surgeon in the perioperative consultations is, "What is the chance of this happening again?" Accurately answering this question is difficult owing to the large number of variables involved. Significant variables that have previously been reported to affect graft survival are returning to a high activity level,[2,17,18] an early return to sports,[11] younger age,[1,18] and graft type.[1,2]

In addition, a question that is not often asked by the patient and not often in the surgeon's mind is the likelihood of rupturing the contralateral ACL (CACL) after

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a return to sports. Previous studies have shown this risk to be similar to graft rupture in the short term,[17,21] but a recent review article by Wright et al[22] has shown this risk may be as high as double in the longer term. The risk factors for the CACL are less well understood and may be increasingly important, both from a patient counseling and a rehabilitation perspective.

The aim of this study was to look at how different variables affect both the ACL graft and CACL survival in a large, single-surgeon series over a minimum 15-year period.

MATERIALS AND METHODS

Patient Selection

Patients included in the study had primary ACL reconstruction performed by a single surgeon (L.A.P.) in a single unit in 1993 and 1994. The exclusion criteria were (1) patients who had had a previous CACL rupture, (2) those involved in a dispute/seeking compensation for their injury, (3) those not wishing to be involved in a research project, and (4) any patient who had had subsequent major surgery to either knee such as arthroplasty.

Patient demographics were recorded in a prospective database. These included information on side of surgery, age, sex, graft type, graft size, and meniscal injury seen at the time of surgery. Meniscectomy was recorded to be positive if greater than one-third of either meniscus had been removed.

Subjective outcome data were obtained by contacting all patients meeting the inclusion criteria via telephone or e-mail at a minimum of 15 years after the surgery. Those willing to participate in the study were then asked to complete a telephone interview or paper questionnaire, which was returned to us via post or e-mail. A research physical therapist or a clinical fellow in orthopaedic surgery, both of whom had not been involved in the original surgery, performed the telephone questionnaires.

Ethical approval was sought and granted, after submission of the study protocol, by a local independent human ethics committee (St Vincent's Hospital, Sydney, Australia).

Subjective Evaluation

All patients were requested to complete a questionnaire devised by our group. This included the full International Knee Documentation Committee (IKDC) subjective outcome analysis and additional questions relating to family history of ACL rupture, graft survival, subsequent injuries to either knee, further knee surgery, and whether return to preinjury sport was achieved. Family history was considered to be positive if the patient had a first-degree relative who had sustained an ACL rupture at any time. Information was entered into a database and statistical analysis was performed.

All patients who reported further injury not previously documented to either knee were invited to attend for further review. Graft rupture or CACL rupture was considered to have occurred only if the patient (1) had had confirmed further knee reconstructive surgery (graft rupture) or primary reconstruction (CACL) performed in our unit or by another orthopaedic surgeon, (2) had clinical examination and/or a magnetic resonance imaging scan reviewed by our unit to confirm ACL deficiency, or (3) had reported another injury characteristic of an ACL tear to either knee and had not been reviewed by us. For this last group, we assumed a graft rupture or CACL rupture for the purposes of the survival analysis as a worst-case scenario.

Operative Technique

The ACL reconstructions were performed by the senior author (L.A.P.) in all cases, using a technique previously described.[4] This was a single-incision endoscopic technique with anteromedial portal femoral tunnel drilling.

Two types of grafts were used during this period: autologous 4-strand hamstring tendon (HT) and autologous bone–patellar tendon–bone (BPTB). There was no randomization involved in graft type selection. From the beginning of 1993, the senior author (L.A.P.) had routinely been using BPTB autograft. In October 1993, he commenced using HT autograft owing to perceived problems with donor site morbidity in BPTB and after April 1994 used the HT graft exclusively. Operative techniques for both graft types were identical. Fixation in both graft types was achieved using 7 × 25-mm titanium interference screws (RCI; Smith & Nephew Acuflex, Mansfield, Massachusetts) in both the femoral and tibial tunnels. Patients were allowed to fully bear weight immediately, and no brace was used. Early accelerated rehabilitation was then commenced. Patients were allowed to return to competitive sports involving pivoting and sidestepping activity at 6 to 9 months according to objective assessment of whether the rehabilitation goals had been met.

Statistical Analysis

Statistical analysis was performed using SPSS software version 10 (SPSS Inc, an IBM Company, Chicago, Illinois). Statistical significance was set at $P < .05$. The probability of failure was estimated as a function of time using the Kaplan-Meier survival method. Survival tables at 2, 5, 10, and 15 years were collated. Comparisons of survival curves were made with univariate Cox proportional hazards. Between-group comparisons of the variables of subjective IKDC scores and IKDC activity levels were made using the Mann-Whitney U test, which assumes data are nonparametric. Factors that were significant ($P < .05$) on univariate analysis were entered into a multivariate Cox regression analysis. Factors were then eliminated one at a time in a stepwise fashion, until only the independent significant factors remained.

RESULTS

Between January 1993 and December 1994, a total of 891 patients underwent primary ACL reconstruction at our facility. The following patients were excluded: (1) those with a previous CACL injury (n = 97), (2) those seeking compensation for their injury (n = 15), (3) those who

refused to participate in a research database (n = 8), (4) those who underwent total knee arthroplasty during the study period (n = 4), (5) those who died (of unrelated causes during the study period) (n = 11), and (6) those who were unable to complete the questionnaire (n = 1, nonnative English dialect). This left 755 patients in the study group, of whom 673 (89%) completed the subjective questionnaire.

Demographics

The 673 patients completed the questionnaire at a mean of 16 years, 10 months (range, 15 years, 0 months to 18 years, 11 months) after surgery. There were 241 (36%) female and 432 (64%) male patients. The mean age at surgery was 29 years (range, 13-62 years). The mean (SD) age for women was 29.5 (10.2) years, and the mean (SD) age for men was 28.9 (8.6) years (P = .355).

There were 325 (48%) left-sided and 348 (52%) right-sided reconstructions. Surgery was performed in the acute phase (within 3 weeks of injury) in 24 patients (4%), in the subacute phase (3-12 weeks) in 393 patients (58%), and in the chronic phase (>12 weeks) in 256 patients (38%). A BPTB autograft was used in 314 cases (47%) and HT autograft in 359 cases (53%). The mean (SD) diameter of the HT graft was 7.01 (0.7) mm, and the mean (SD) diameter of the BPTB graft was 9.7 (0.6) mm.

A total of 386 patients (57%) had an ACL reconstruction only and no meniscal debridement, 176 patients (26%) required partial (>1/3) or total excision of the medial meniscus performed at the time of the reconstruction, and 171 patients (25%) required partial (>1/3) or total excision of the lateral meniscus. Sixty patients (9%) had debridement of tears both menisci.

No significant differences were found in the patient demographics (age, sex, timing of reconstruction, activity level, return to preinjury sports level, or meniscal damage) between patients with an HT graft and patients with a BPTB graft to account for possible selection bias.

Subjective Assessments

The mean overall IKDC score for patients with intact ACL grafts (n = 598) at 15 years was 85 (range, 8-100). There was no significant difference in the IKDC score between those who received the BPTB and HT grafts (P = .186) or between the sexes (P = .101).

Of the 673 patients, 493 (73%) returned to their preinjury level of sporting activity at some point over the 15-year period; this finding was approximately equal in women (72.2%) and men (73.8%) (P = .644). A total of 180 (27%) patients did not return to their preinjury sport. Of these, 128 patients (19%) reported it was due to their operated knee, and the remaining 52 patients (8%) cited other reasons.

Of the 598 patients without reported further ACL injury, 304 (51%) were participating regularly in IKDC Level 4-5 sports at 15 years after ACL reconstruction. Significantly more men (58%) reported participating in Level 4-5 sports at 15 years than did women (40%) (P = .001). The breakdown between male and female patients in the HT and BPTB groups is shown in Figure 1. The difference between female HT and female BPTB grafts was not statistically significant (P = .28). However, significantly fewer women with BPTB grafts were participating in Level 4-5 activities at 15 years compared with the other 3 groups (P = .002).

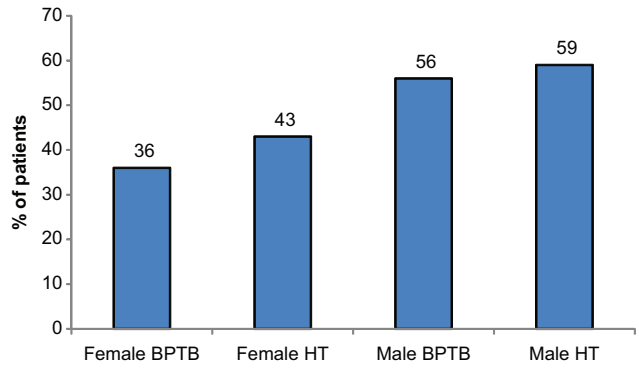

Figure 1. Percentage of patients participating in International Knee Documentation Committee (IKDC) Level 4-5 sports at 15 years.

Graft Survival

Seventy-five patients (11%) sustained a known graft rupture during the study period (see the Appendix, available online at http://ajs.sagepub.com/supplemental/). This occurred at a mean of 60 months (range, 1-192 months) from reconstruction. The overall mean (SD) time to graft rupture was 55.5 (49.9) months for men and 71.9 (67.04) months for women (P = .434) (Mann-Whitney U test).

The annualized graft rupture rate for a mean 202 months' follow-up was 0.66% per knee per year. The greatest risk period for knee injury appears to be the first 24 months after surgery, when 44% (n = 33) of the graft ruptures occurred. Adjusted annualized ACL graft rupture rates for these periods are 2.45% per year for the first 2 years and then 0.42% per year after that.

Overall graft survival was 95%, 93%, 91%, and 89% at 2, 5, 10, and 15 years, respectively. Statistical analysis of the following variables—(1) age, (2) graft type, (3) sex, (4) index side, (5) meniscectomy, (6) return to preinjury level of function, (7) family history, and (8) age and graft type when applied to graft survival—is illustrated in Table 1. Multivariate Cox regression analysis of these same variables was also performed, and the significant results are shown in Table 2.

Contralateral ACL Survival

Ninety-five patients (14%) were known to have sustained a CACL rupture during the study period (see the Appendix, available online). This occurred at a mean of 83 months (range, 6-216 months) from ACL reconstruction. The mean (SD) time to CACL rupture was 88.1 (60.6) months for men and 74.3 (55.1) months for women (P = .290; Mann Whitney test).

TABLE 1
Survival of the ACL Graft With Hazard Ratios for the Examined Variables[a]

Factor and Category	No.	Survival Rate, %				Hazard Ratio	95% CI	*P* Value
		2-Year Survival	5-Year Survival	10-Year Survival	15-Year Survival			
Age at surgery, y								
≤18	78	96	90	90	90	0.8	0.4-1.6	.596
>18	595	95	94	91	89			
Graft type								
HT	359	95	92	90	88	1.4	0.9-2.2	.149
BPTB	314	96	95	92	91			
Sex								
Male	432	94	92	88	87	2.1	1.2-3.7	**.007**
Female	241	98	96	95	94			
Index side								
Right	348	95	93	90	88	1.2	0.8-1.9	.446
Left	325	96	94	91	90			
Meniscectomy								
No	386	96	94	91	90	1.0	0.6-1.6	.990
Yes	287	95	92	90	89	1.0		
Return to preinjury sport								
Yes	493	95	94	91	89	1.0	0.6-1.7	.965
No	180	96	93	91	89			
Family history of ACL injury								
Yes	156	94	90	87	85	1.8	1.1-2.8	**.034**
No	517	96	95	92	91			
Age and graft type								
≤18 y and HT	33	94	89	85	85	3.4	0.9-12.9	.080
>18 y and HT	326	96	93	90	88			
>18 y and BPTB	269	96	95	91	91			
≤18 y and BPTB	45	98	95	93	93			

[a]Significant *P* values presented in boldface. ACL, anterior cruciate ligament; BPTB, bone–patellar tendon–bone; CI, confidence interval; HT, hamstring tendon.

TABLE 2
Multivariate Cox Regression of Significant Risk Factors for ACL Graft Rupture[a]

Risk Factor and Category	Hazard Ratio	95% CI	*P* Value
Sex			
Male	2.3	1.3-4.1	**.004**
Female			
Family history of ACL Injury			
Positive	1.9	1.2-3.1	**.008**
Negative			

[a]Significant *P* values presented in boldface. ACL, anterior cruciate ligament; CI, confidence interval.

The annualized CACL rupture rate was thus 0.84% per knee per year. Compared with graft rupture, which was greatest in the first 2 years, the greatest risk period for contralateral knee injury was between 1 and 4 years, when 42% of CACL ruptures occurred (n = 40). Comparing the 2 knees in these early years, 31 graft ruptures (5%) had occurred at 2 years compared with 16 CACL ruptures (2.4%), and then by 4 years, 42 graft ruptures (6.2%) had occurred compared with 42 CACLs (6.2%).

The adjusted annualized CACL rupture rate for this higher risk 1- to 4-year period was 1.98% per year and then 0.61% for the first year and after 4 years.

The survival rate of the CACL was 97%, 93%, 90%, and 87% at 2, 5, 10, and 15 years, respectively. Univariate analysis of the same variables as the graft rupture was performed and is illustrated in Table 3. Multivariate Cox regression analysis was also performed on these variables, and the significant results are illustrated in Table 4.

Graft Types and Injury to Either Knee

When examining the HT patients only, the incidence of ACL graft rupture (46/359, 13%) was not significantly different from the incidence of CACL rupture (41/359, 11%) ($P = .567$). In the BPTB group, the incidence of ACL graft rupture (29/314, 9%) was significantly different from the incidence of CACL rupture (54/314, 17%) ($P = .003$).

Kaplan-Meier Survival Analysis

Kaplan-Meier survival analysis for graft rupture was performed using all variables, and the results that were

TABLE 3
Survival of the CACL With Hazard Ratios for the Examined Variables[a]

Factor and Category	No.	Survival Rate, %				Hazard Ratio	95% CI	*P* Value
		2-Year Survival	5-Year Survival	10-Year Survival	15-Year Survival			
Age at surgery, y								
≤18	78	96	86	79	78	2.0	1.2-3.3	**.011**
>18	595	98	94	91	88			
Graft type								
HT	359	97	94	91	89	1.5	1.0-2.2	.061
BPTB	314	98	93	88	84			
Sex								
Male	432	98	94	90	88	0.9	0.6-1.4	.710
Female	241	97	92	89	86			
Index side								
Right	348	98	94	91	86	1.2	0.8-1.8	.443
Left	325	97	93	90	88			
Meniscectomy								
No	386	97	93	88	85	1.5	0.9-2.2	.090
Yes	287	99	94	92	89			
Return to preinjury sport								
Yes	493	97	92	88	85	2.5	1.4-4.4	**.003**
No	180	99	97	96	93			
Family history of ACL injury								
Yes	156	97	90	84	81	1.7	1.1-2.6	**.016**
No	517	98	94	91	89			
Age + graft type								
≤18 y + BPTB graft	45	96	82	73	71	2.5	1.4-4.5	**.002**
≤18 y + HT graft	33	97	91	88	88			
>18 y + BPTB graft	269	99	94	91	86			
>18 y + HT graft	326	97	94	92	90			

[a]Significant *P* values presented in boldface. ACL, anterior cruciate ligament; BPTB, bone–patellar tendon–bone; CACL, contralateral ACL; CI, confidence interval; HT, hamstring tendon.

TABLE 4
Multivariate Cox Regression of Significant Risk Factors for CACL Rupture[a]

Risk Factor and Category	Hazard Ratio	95% CI	*P* Value
Return to preinjury level of sport			
Yes	2.5	1.4-4.4	**.003**
No			
Family history of ACL injury			
Positive	1.6	1.1-2.5	**.029**
Negative			

[a]Significant *P* values presented in boldface. ACL, anterior cruciate ligament; CACL, contralateral ACL; CI, confidence interval.

statistically significant are illustrated in Figure 2 and for CACL rupture in Figure 3.

DISCUSSION

Anterior cruciate ligament rupture is unquestionably a devastating injury to young athletes, but as reconstruction techniques continue to improve, a return to a preinjury level of activity is now more likely. Of the patients contacted in this series, 73% returned to their preinjury sport at some point after their surgery. This was at a cost of 11% graft ruptures and 14% CACL ruptures. We have identified several variables that affect these further injuries.

ACL Graft Survival

At 15 years, 11% of patients were known to have sustained a graft rupture. When equating for the length of follow-up (mean, 202 months), the annualized rupture rate is only 0.66% per year, which compares favorably with annualized rates of 0.3% to 1.3% in other published series.[6,10,13,16,18] There was no significant difference between the ACL rupture rates of BPTB autografts and HT autografts (P = .149). This would suggest that both types of grafts, if used in this manner for ACL reconstruction, can produce good long-term results in the operated leg.

Two statistically significant variables affected reinjury to the reconstructed ACL. Male patients ruptured their graft more than did female patients (P = .007), and those with a positive family history (first-degree relative) ruptured more than those without (P = .034).

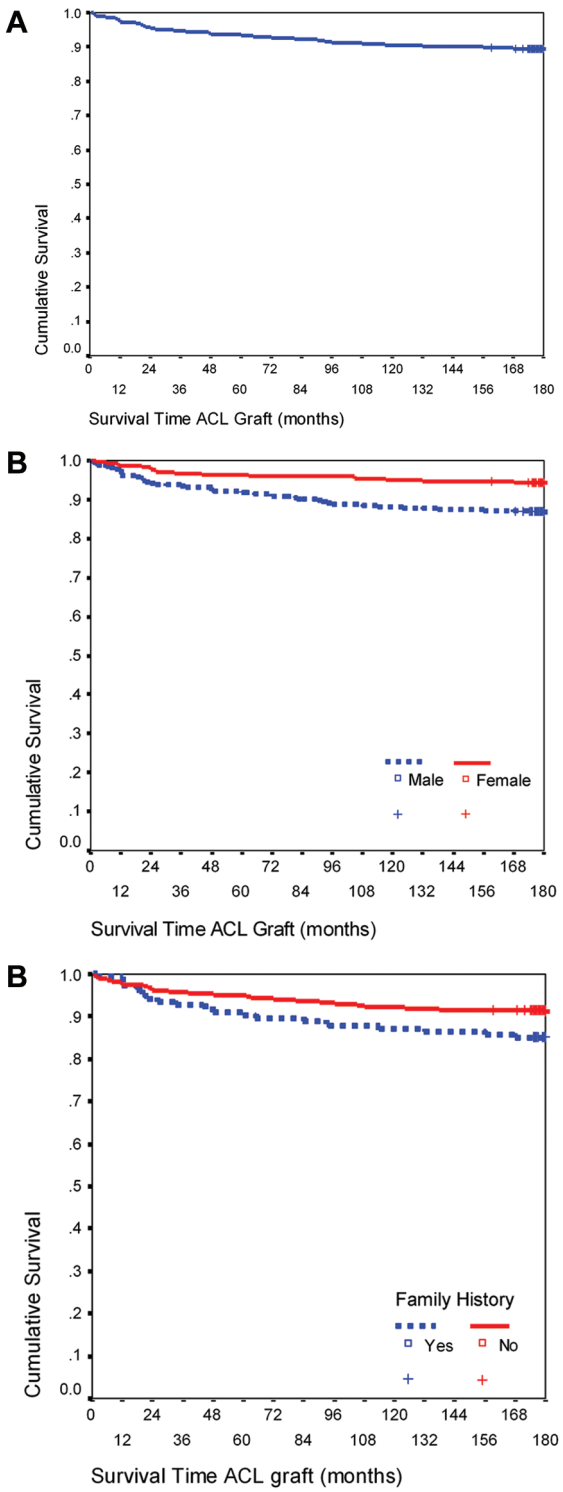

Figure 2. (A) Overall survivorship analysis of the anterior cruciate ligament (ACL) graft over time (months). (B) Survivorship analysis of the graft in male and female patients over time (months), P = .007. (C) Survivorship analysis of the graft in patients with and without a family history of ACL rupture (months), P = .034.

A higher graft rupture rate in male patients than in female patients after ACL reconstruction is an unusual finding, and this is the first medium- or long-term survival study to record this. The vast majority of studies previously published have described no discernible differences in graft rupture between men and women,[3,7,14] and indeed 1 study has reported a higher graft failure rate in women than in men,[12] but these studies involve much smaller sample sizes and shorter follow-up periods. The most likely explanation for the increased odds of injury in male patients may be the frequency of exposure to sports. Although the same number of men and women (73.8% vs 72.2%, P = .644) did at some point return to their preinjury sport, by 15 years, more men (58%) than women (40%) were regularly participating in strenuous or very strenuous activities (P = .001). Greater exposure to faster moving, cutting, and pivoting sports is likely to increase the odds of further injury.

A positive family history doubled the odds of graft rupture, and this is the first study to describe this finding. Two previous studies have found a familial tendency to primary ACL rupture,[8,9] and more recently a preponderance of collagen gene defects has been identified[15] in patients who sustain ACL ruptures compared with a control group. Anterior cruciate ligament rupture is undoubtedly multifactorial, but more information is required to identify the true effect of this gene defect.

Contralateral ACL Rupture

Injury to the CACL appears to be a significant problem after ACL reconstruction, and this has been recognized previously.[18,19,21] The explanation for this phenomenon is far from clear. In this study, the overall rupture rate of the CACL (0.84% per knee per year) was not significantly different compared with the overall graft rupture rate (0.66% per knee per year) (P = .101). There were, however, some differences seen in CACL rates between the age groups and the 2 graft types. Patients who had had a BPTB graft had a significantly greater CACL rupture rate than the graft rupture rate (19% vs 9%, P = .003), which was not seen in the HT group (11% vs 13%, P = .567). In addition, we have found more than double the odds of CACL rupture in young patients (18 years or younger) reconstructed with BPTB compared with the other groups (odds ratio [OR], 2.5; P = .002).

Traditionally, higher CACL than graft rupture rates have been attributed to the protective role of the uninjured knee that renders it vulnerable. Another possibility has been proposed by Shelbourne et al[18] in a large study of 1415 patients, 5 years after ACL reconstruction with the BPTB autograft. They found higher CACL rupture rates in young female patients (<18 years old), which they thought was due to the larger graft size of the reconstructions (10 mm) than the contralateral native ACL, which is known to be smaller in women[5] and hence has a greater tensile strength. Our series had too few patients in this age group (≤18 years old, n = 78) to draw accurate comparison to support this theory.

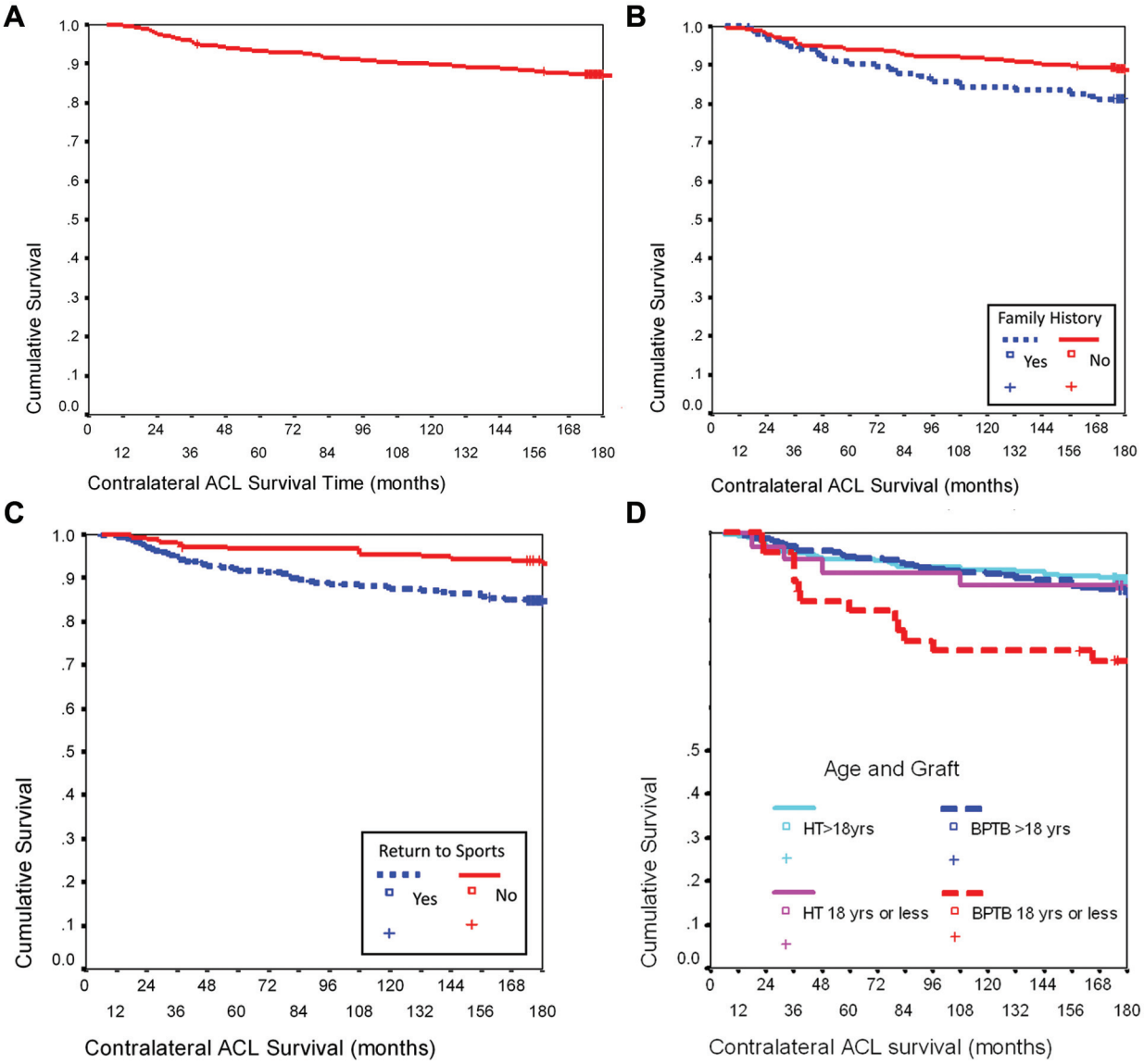

Figure 3. (A) Overall survivorship analysis of the contralateral anterior cruciate ligament (ACL) over time (months). (B) Survivorship analysis of the contralateral ACL in patients with and without a family history over time (months), $P = .016$. (C) Survivorship analysis of the contralateral ACL in those who did and did not return to their preinjury sport after ACL reconstruction over time (months), $P = .003$. (D) Survivorship analysis of the contralateral ACL in those 18 years or younger compared with those >18 years with either hamstring tendon (HT) or bone–patellar tendon–bone (BPTB) over time (months), $P = .002$.

A third proposal for the high incidence of contralateral ACL injury is that the loss of one ACL causes interruption to a central protective mechanism that affects both knees. This theory is supported by Sward et al,[19] who in review recognized that the risk of injury to the CACL is greater than sustaining a first-time ACL injury. Wojtys and Huston[20] have recorded centrally processed bilateral neuromuscular deficits 18 months after reconstruction and have suggested that this is an inhibitory effect due to loss of afferent signals from one ACL in a normal feedback loop in the central nervous system. If both knees are affected at the time of the index ACL tear and the sole focus is on the reconstructed knee during rehabilitation, the CACL is more prone to injury. Our finding that the incidence of contralateral ACL rupture is higher in the BPTB group may suggest that harvesting this graft has a greater neuromuscular "cost" to the system than HT harvest.

What is clearer is the higher risk of CACL rupture with a return to preinjury sports level ($P = .003$). This may simply be that the patient has returned to "high-risk" sports for him or her or that the contralateral knee has indeed been "put at risk" by the loss of the other ACL and is thus vulnerable. We found the period of highest risk for the other knee injury to be between 1 and 4 years after surgery (1.98% CACL rupture rate per knee per year), and this is probably the time when the patient returns to his

or her sport. The clinical significance of this finding is the potential to use modern plyometric training programs to minimize further injury.

Two weaknesses of this study are to be recognized. The first is the potential inaccuracy of recording subjective data. There may have been patients who at some stage had sustained a subclinical rupture and because of a drop in activity level had not noticed instability. We accept that this may have altered the results. To try and minimize the potential error of subjective assessment, we invited all patients with a reported further knee injury for assessment so we could confirm rupture. We were able to confirm graft or CACL rupture in 83% of the cases, and 9% were reconstructed in other orthopaedic units, which left only 8% who were not able to attend for clinical review. In an attempt to eliminate error for these unknown cases, we assumed ACL rupture in both graft and CACL groups, and so the reported graft rupture rates are a worst-case scenario.

The other weakness is potential selection bias from the nonrandomization of graft type, but we did not find any statistically significant parameters in the patient demographics to suggest there was a true difference.

CONCLUSION

Anterior cruciate ligament reconstruction using this technique is a reliable and reproducible procedure when using either the BPTB or HT autograft and allowed 73% of patients a return to their preinjury sports with an ACL graft rupture rate of less than 1% per year. Male patients have a greater odds of ACL graft rupture than do female patients. The BPTB autograft, despite producing good results for graft survival, causes an increase in odds of rupture to the CACL compared with HT. Family history should be a routine screening question when performing this surgery as it doubles the odds of injury to both the operated leg and the CACL. Male patients, those with a positive family history, and all patients 18 years and younger should be counseled carefully and advised of the increased risk of reinjury.

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