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Am J Sports Med 2012 40: 1242 originally published online April 24, 2012
DOI: 10.1177/0363546512443945

Survival Comparison of Allograft and Autograft Anterior Cruciate Ligament Reconstruction at the United States Military Academy

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Background: There is recent evidence that use of allograft tendons for anterior cruciate ligament (ACL) reconstruction in young patients may result in increased failure rates compared with autologous grafts.

Hypothesis: Allograft ACL reconstruction will result in higher failure rates in young athletes compared with autograft reconstruction.

Study Design: Cohort study; Level of evidence, 2.

Methods: A prospective cohort study of cadets at the United States Military Academy (USMA) was performed to assess performance of ACL reconstructions performed before entrance to service. Members of the classes of 2007 through 2013 who had undergone prior ACL reconstruction were identified through the Department of Defense Medical Evaluation Review Board reporting and waiver process and evaluated on the first day of matriculation. These participants were followed during their tenure at the academy with revision ACL reconstruction as the primary outcome measure of interest. Kaplan-Meier survival analysis was performed for all graft types using STATA with significance set as $P < .05$.

Results: A total of 120 cadets underwent 122 ACL reconstructions (2 bilateral) before matriculation and compose the prospective cohort. This cohort included 30 female and 90 male cadets. Of these 122 knees with prior ACL reconstructions, the grafts used were 61 bone–patellar tendon–bone (BTB), 45 hamstring, and 16 allograft. A total of 20 failures occurred among this cohort at an average of 545 days from matriculation. Of the failures requiring revision, 7 were BTB (11% of all BTB), 7 were allograft (44% of all allograft), and 6 were hamstring (13% of all hamstring). There was no significant difference in the graft failure between the BTB and hamstring autograft groups. In contrast, those who entered the USMA with an allograft were 7.7 times more likely to experience a subsequent graft failure during the follow-up period when compared with the BTB autograft group (hazard ratio = 7.74; 95% confidence interval [CI], 2.67-22.38; $P < .001$). When allografts were compared with all autografts combined, a similar increase failure was noted in the allograft group (hazard ratio = 6.71; 95% CI, 2.64-17.06; $P < .001$).

Conclusion: In this young active cohort, individuals having undergone an allograft ACL reconstruction were significantly more likely to experience clinical failure requiring revision reconstruction compared with those who underwent autologous graft reconstruction. The authors recommend the use of autograft in ACL reconstruction in young athletes.

Keywords: anterior cruciate ligament; reconstruction; allograft; autograft; revision

Anterior cruciate ligament (ACL) injuries are common in athletic and military populations.[7,9] A recent study of collegiate athletes reported a 4-year incidence of 3.24 per 100 men and 3.51 per 100 women.[7] Reconstruction is a reliable treatment that restores stability to the knee and allows a return to activity for most patients.[3,5] Rupture rates have been reported between 5% and 7%[8,10] for autograft reconstructions and between 7% and 13% for allograft reconstructions.[11]

The American Journal of Sports Medicine, Vol. 40, No. 6
DOI: 10.1177/0363546512443945

A meta-analysis by Krych et al[6] comparing bone–patellar tendon–bone (BPB) autograft and allograft noted significantly more graft ruptures in the allograft group. When they excluded the results of a study by Gorschewsky et al[4] in which the allografts used were irradiated and chemically treated by acetone drying, no significant difference between the rupture rates of the autograft and allograft groups was noted. Similarly, a meta-analysis of autograft versus allograft by Carey et al[2] excluded the Gorschewsky et al[4] study and found no significant difference in rupture rates, although there was a trend favoring autograft. None of the studies included in these 2 meta-analyses stratified outcomes according to age or used mathematical modeling to control for age or activity level.[10]

The purpose of this study was to follow a cohort of young, athletic patients after ACL reconstruction to compare the rate of failure between autograft and allograft reconstructions. The hypothesis was that ACL reconstructions using an allograft would have a higher failure rate than those using an autograft.

MATERIALS AND METHODS

Design and Setting

A prospective cohort study was conducted to assess the rate of subsequent ACL graft failure among those who entered the United States Military Academy (USMA) with a prior ACL reconstruction (ACLR) between June 2003 and June 2009. All incoming cadets are required to meet military medical fitness standards during the accession process. As part of the Department of Defense Medical Evaluation Review Board (DoDMERB) assessment, all cadet candidates must complete an extensive medical history and physical examination to ensure they meet these standards. Any prospective candidate with a prior ACLR requires a waiver of the US Army's physical induction standards before matriculation. Furthermore, for all candidates entering the USMA with a prior ACLR, an orthopaedic evaluation was conducted on the initial date of arrival at the academy, and participants were recruited into the study cohort during this evaluation. Baseline data collected upon entry into this cohort included a medical history where the graft type used for prior ACLR was documented. Graft types included BTB autograft, hamstring (HS) tendon autograft, and allograft. Eight patients were excluded because of indeterminate graft information. No data on allograft sterilization were available for any participant undergoing allograft reconstruction. An orthopaedic physical examination was performed by a sports medicine fellowship-trained orthopaedic surgeon to include Lachman examination and pivot shift. This study was reviewed and approved by the institutional review board at our institution.

Injury Definitions and Surveillance

We conducted active surveillance within the study cohort during the follow-up period to identify all subsequent ACL graft failures. All cadets receive medical care through the closed health care system at the USMA, and all injuries are evaluated through its associated sports medicine and orthopaedic clinics.[7,12,13] As a result, all ACL injuries are evaluated by the orthopaedic surgeons at our institution using standardized procedures that have been described previously.[7] These injuries are documented in multiple electronic databases, which were used for injury surveillance within this cohort. All injuries resulting in time loss to sport or physical activity and requiring presentation at a receiving clinic are documented in the Cadet Illness and Injury Tracking System (CIITS), which is an electronic injury surveillance system that captures nearly all cadet injuries at the USMA.[12,13] In addition to being documented in CIITS, all injuries are also documented in the Armed Forces Health Longitudinal Technology Application (AHLTA), which is the individual electronic medical record within the Military Health System. Finally, all cadets requiring ACL revision surgery while at the USMA are documented in the Surgery Scheduling System (S3). During the follow-up period, active surveillance included monitoring CIITS, AHLTA, and S3 to identify all ACL injuries within the study cohort. All reinjuries identified during the follow-up period were verified through magnetic resonance imaging (MRI) and/or diagnostic arthroscopy.

Outcome Measures

The primary outcome of interest in this study was the time from entry into the cohort until subsequent ACL failure during the follow-up period. Accurate follow-up time was available through the office of institutional research at our institution based on dates of entry, separation, and graduation from the academy. Follow-up time was measured in days during the study period from entry into the cohort until a participant (1) sustained a failed ACL graft requiring revision reconstruction, (2) left the USMA because of separation or graduation, or (3) reached the administrative end of the study on May 12, 2011.

Statistical Analysis

We calculated standard descriptive statistics including frequencies for categorical demographic variables and means and standard deviations for continuous demographic variables within the study cohort. Univariate and multivariable Cox proportional hazards regression models were used to estimate the time from entry into the cohort until subsequent ACL graft failure during the follow-up period. Initially, we calculated and compared hazard ratios and 95% confidence intervals between all 3 groups based on graft type, using the BTB autograft group as the referent category. We also calculated survival estimates comparing the graft types at 1 year, 2 years, and 3 years of follow-up. Because we observed no significant differences in survival between the BTB and HS autograft groups, these 2 groups were combined for further analyses comparing autograft and allograft groups by survival time. For these comparisons, we used the autograft group as the referent category.

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Presented at the 37th annual meeting of the AOSSM, San Diego, California, July 2011.

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of the US Department of Defense or the US government. The authors are employees of the US government.

The authors declared that they have no conflicts of interest in the authorship and publication of this contribution.

TABLE 1
Physical Examination Findings by Graft Type

	BTB	Hamstring	Allograft
Lachman			
Grade 0	35	24	7
Grade 1	17	14	3
Grade 2	1	0	1
Grade 3	0	0	0
Pivot shift			
None	46	31	7
Glide	9	5	4
Gross	0	0	0

Kaplan-Meier survival estimates were plotted to further compare all 3 graft types, as well as the combined autograft and allograft groups separately. Multivariable models were also used to control for the influence of sex on graft type and survival at the USMA. All data were analyzed using STATA version 10.1 (StataCorp LP, College Station, Texas).

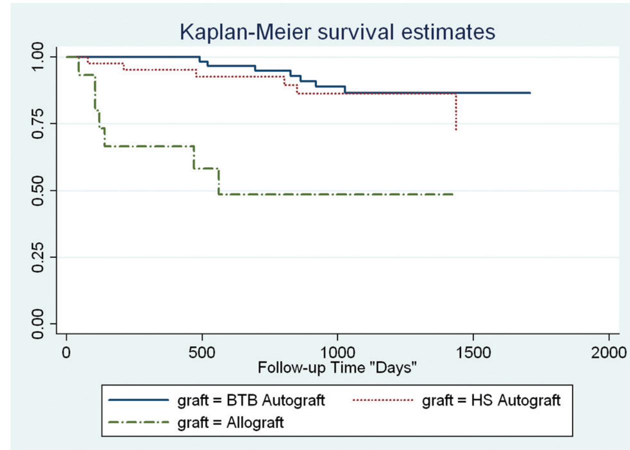

Figure 1. Kaplan-Meier survival estimates by anterior cruciate ligament graft type during follow-up. The unit of time is days from study enrollment. BTB, bone–patellar tendon–bone; HS, hamstring.

RESULTS

A total of 120 cadets had undergone 122 ACL reconstructions (2 bilateral) before matriculation and composed the prospective cohort. This cohort included 30 female and 90 male cadets. Of these participants with prior ACL reconstructions, the grafts used were 61 BTB autografts, 45 HS tendon autografts, and 16 allografts. The mean time from date of initial surgery until matriculation was not significantly different among the groups with BTB at 678.3 days, hamstring at 574.5 days, and allograft at 579.3 days. No patient reported subjective instability. Complete physical examination data were available on 102 knees (84%). Of these, the Lachman examination was graded as 0 in 66 knees, grade 1 in 34 knees, and grade 2 in 2 knees (see Table 1). A total of 84 knees had no pivot shift, including 84% of the BTBs, 86% of the hamstrings, and 64% of the allografts. A total of 18 knees had a pivot glide, including 16% of the BTBs, 14% of the hamstrings, and 36% of the allografts. No knee had a gross pivot shift. No knees were considered ACL deficient by orthopaedic surgeon evaluation, and no patients were denied admission as a result of this examination.

Overall, a total of 20 failures occurred among this cohort at an average of 545 days from matriculation. Three female participants failed (10% of all females in cohort) compared with 17 of the male participants (19%). Of the failures, 7 were BTB, 7 were allograft, and 6 were hamstring.

The Kaplan-Meier survival estimates for all 3 graft types are presented in Figure 1. Overall, there was no significant difference in the time to graft failure between the BTB and HS autograft groups (Table 2). Furthermore, survival estimates by year of follow-up were similar between those who entered the academy with BTB and HS autografts (Table 3). In contrast, those who entered the USMA with an allograft were 7.7 times more likely to experience a subsequent graft failure during the follow-up period when compared with the BTB autograft group (Table 2). Multivariable models controlling for the influence of sex on the association between graft type and time to graft failure yielded similar results. Because there was no difference in the survival estimates between the BTB and HS autograft groups, these groups were combined into a single autograft group for further analysis.

The Kaplan-Meier survival estimates comparing those who entered the academy with an autograft and those who entered with an allograft are presented in Figure 2. Cadets who entered the USMA with an allograft were 6.7 times more likely to experience graft failure (hazard ratio [HR] = 6.71; 95% confidence interval [CI], 2.64-17.06; $P < .001$) during the follow-up period when compared with those who entered with an autograft (Table 2). Survival estimates by graft type for each year of follow-up are presented in Table 4. One year after entering the USMA, 33% of the cadets who entered with an allograft had experienced subsequent graft failure, compared with only 2% of those who entered with an autograft. At the 2-year follow-up mark, more than half of those who entered the USMA with an allograft had experienced graft failure compared with only 6% of those in the autograft group (see Table 4). Similar results were observed in multivariable models after controlling for the influence of sex on the association between graft type and time to graft failure.

DISCUSSION

To our knowledge, this is the first study to examine survival estimates by ACL graft type in a young and active cohort that was healthy enough to meet the waiver criteria for active duty military service. This study demonstrates that individuals entering the US Military Academy with an allograft ACL reconstruction were significantly more likely to experience clinical failure requiring revision reconstruction when compared with those entering with autologous grafts. This finding differs from previous studies that have reported no

TABLE 2
Hazard Ratios Comparing the Time to Graft Failure by Graft Type for Univariate and Multivariable Cox Proportional Hazards Models[a]

	Model I[b]			Model II[c]		
	Hazard Ratio	95% CI	*P* Value	Hazard Ratio	95% CI	*P* Value
Graft type I						
BTB autograft	1.00			1.00		
HS autograft	1.40	0.47-4.16	.549	1.39	0.46-4.17	.548
Allograft	7.74	2.67-22.38	<.001	7.57	2.62-21.90	<.001
Graft type II						
Autograft[d]	1.00			1.00		
Allograft	6.71	2.64-17.06	<.001	6.57	2.58-16.70	<.001

[a]BTB, bone–patellar tendon–bone; CI, confidence interval; HS, hamstring.
[b]Univariate models examining the association between graft type and time to graft failure during follow-up.
[c]Multivariable models examining the association between graft type and time to graft failure during follow-up while controlling for sex.
[d]Combines BTB and HS autograft.

TABLE 3
Survival Functions for All 3 Graft Types by Year of Follow-up[a]

	Graft Type I		
Follow-up Time	BTB Autograft (95% CI)	HS Autograft (95% CI)	Allograft (95% CI)
1 year	1.000	0.953 (0.825-0.988)	0.667 (0.375-0.846)
2 years	0.948 (0.847-0.983)	0.927 (0.791-0.976)	0.486 (0.204-0.721)
3 years	0.867 (0.739-0.935)	0.863 (0.699-0.941)	0.486 (0.204-0.721)

[a]BTB, bone–patellar tendon–bone; CI, confidence interval; HS, hamstring.

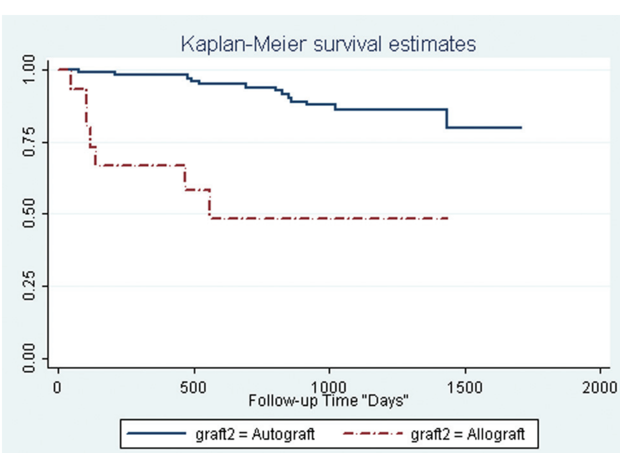

Figure 2. Kaplan-Meier survival estimates comparing autograft to allograft during follow-up. The unit of time is days from study enrollment.

TABLE 4
Survival Functions for Autograft and Allograft by Year of Follow-up[a]

	Graft Type II	
Follow-up Time	Autograft[b] (95% CI)	Allograft (95% CI)
1 year	0.981 (0.925-0.995)	0.667 (0.375-0.846)
2 years	0.939 (0.869-0.972)	0.486 (0.204-0.721)
3 years	0.862 (0.768-0.920)	0.486 (0.204-0.721)

[a]CI, confidence interval.
[b]Combines bone–patellar tendon–bone and hamstring autograft.

statistical differences in short-term outcomes between autograft and allograft ACL reconstruction.[2,6] Furthermore, Kaplan-Meier survival analysis showed that individuals entering with an allograft ACL reconstruction failed much earlier into the follow-up period when compared with those who entered with either a BTB or HS autograft in the current study. The exact reason for this early failure is unclear but may reflect increased physical activity requirements in the first 2 years of the physical program at our institution.

Our study represents a longitudinal prospective cohort study that identified and followed patients during their term at the USMA. As a result, we were able to have a long follow-up period: 4 years (classes 2007, 2008, 2009, 2010, 2011) and 2 to 3 years (classes 2012, 2013). All cadets are required to participate in organized physical activities, and if they are injured, an evaluation by a physician is required to be excused from activity. Therefore, any individual who sustains a reinjury would be readily identified and followed until graduation or transfer. We chose revision ACL reconstruction as our measure of failure as this is a clear finite end point. In our cohort, this is an accurate measure of clinical outcome because cadets with significant knee laxity or functional instability are unlikely to successfully complete the physical and military training requirements at the academy without undergoing a revision ACL reconstruction.

A major strength of this study is that all of our participants are part of a young, extremely active and athletic population. All are college-aged athletes between 18 and 23 years of age, with a mean age of 19 years. As a result, age was relatively homogeneous within the current study cohort. Carey et al[2] point out in their meta-analysis, none of the previous studies comparing autograft with allograft controlled for age or used multivariate modeling to control for age. This indicates the potential for selection bias in previous studies, as younger patients often opt for autologous grafts and older patients often choose allograft. This is borne out by the fact that in 4 of the 5 studies in their meta-analysis in which patients were allowed to choose their graft, the mean age in the autograft group was younger than that of the allograft group.[2] A recent study by Barrett et al[1] showed that young patients with high activity levels had a significantly higher failure rate with nonirradiated BTB allografts compared with BTB autografts.

Our study also examines the effect of graft choice on failure rate in a cohort of participants with very similar activity levels.[7] All cadets at USMA are required to participate in intramural, club, or intercollegiate athletics during all but 2 semesters of their 4 years at the academy. They are all required to participate in Department of Physical Education course activities, including military movement (gymnastics), combatives/self-defense training, indoor obstacle course tests, and boxing (men only). Finally, they are all required to participate in military training throughout all 4 years at the academy, including intensive field-training exercises and military schools such as Airborne and Air Assault. This results in a very homogeneous group with regard to activity level and mitigates another potentially confounding variable within the cohort studied.

As with any study, important limitations should be considered when interpreting the results of the current study. First, we did not have patient-oriented outcomes and instrumented laxity measurements for all patients in the cohort. Lysholm and Tegner scores were obtained from some of the participants, but not enough for statistical analysis. Available data from physical examination findings, instrumented laxity measures, and subjective outcome scores were comparable between the 3 graft groups at the time of enrollment into the current study. In addition, although preoperative radiographs from patients undergoing revision ACL reconstruction were available, radiographs were not obtained in our asymptomatic participants. This precluded our ability to perform an analysis of fixation devices and tunnel position. Finally, the graft source and exact method of sterilization for the allografts used in our participants could not be confirmed. The failure of an ACL reconstruction is a multifactorial event. Technical considerations include tunnel position, choice of fixation type and specific implant, and graft choice and quality. Patient characteristics such as meniscal deficiency and malalignment may also influence failure, as well as postoperative rehabilitation protocol, compliance, and return to sport. The type of allograft sterilization would also be expected to affect results. We do not have the ability to report on many technical considerations or allograft sterilization technique since we did not perform the initial ACL reconstructions. However, our study was performed prospectively with strict surveillance of a homogeneous cohort of young athletes followed in a closed health care system.

In conclusion, this prospective cohort study of prior ACL reconstruction in young athletes shows an unacceptably high failure rate with allograft tendon use. We recommend use of autologous grafts in young athletes.

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