The American Journal of Sports Medicine

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Przemyslaw M. Kamien, Josie M. Hydrick, William H. Replogle, Linda T. Go and Gene R. Barrett

Am J Sports Med 2013 41: 1808 originally published online June 28, 2013

DOI: 10.1177/0363546513493896

Age, Graft Size, and Tegner Activity Level as Predictors of Failure in Anterior Cruciate Ligament Reconstruction With Hamstring Autograft

Przemyslaw M. Kamien,*†‡ MD, Josie M. Hydrick,‡ BS, William H. Replogle,§ PhD, Linda T. Go, MD, and Gene R. Barrett,‡ MD
Investigation performed at Mississippi Sports Medicine and Orthopaedic Center, Jackson, Mississippi

Background: Patient age, Tegner activity level, and graft size could be factors that influence the outcome of anterior cruciate ligament reconstruction (ACLR) with hamstring autografts.

Hypothesis: Decreased graft size, higher Tegner activity score, and younger age are associated with an increased failure rate of ACLR, represented by continued knee laxity and revision surgery.

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

Methods: A total of 98 patients who had undergone ACLR with hamstring tendon autografts between 2000 and 2007 were identified from a computerized relational database. Inclusion criteria consisted of a minimum of 2 years of follow-up, all age groups, and all activity levels. Exclusion criteria consisted of treatment with other grafts or previous ligament surgery, previous ACL repairs, bilateral ACL injuries, and associated ligament tears. Failure was defined as a 2+ Lachman result, positive pivot shift, and 5-mm difference or more on KT-1000 arthrometer measurement.

Results: Fifteen of the 98 ACLRs (15.3%) were defined as failures. Of the failures, 12 of 48 (25%) occurred in patients aged 25 years and younger, whereas 3 of 50 (6%) occurred in patients older than 25 years. There was a statistically significant association when comparing failure rate and age groups (P = .009); however, a significant association was not found between graft size and failure rate in the entire study population (P = .135) or within the different age groups (age $\leq$25 years vs $>$25 years) based on failure rate (P = .390 and P = .165, respectively). No statistical significance was found when Tegner activity level and failure rate were compared in the overall study population (P = .463) or within age groups ($\leq$25 years, P = .707; $>$25 years, P = .174).

Conclusion: In this study population, younger patients ($\leq$25 years) demonstrated a higher failure rate compared with the over-25 age group. A statistically significant difference was not found in terms of graft size and activity level correlating with failure rate in ACL reconstruction with hamstring autograft.

Keywords: ACL reconstruction; hamstring autograft; graft size; age

Hamstring tendons remain a popular choice for autograft in anterior cruciate ligament reconstruction (ACLR).[19] Multiple studies have shown that successful ACLR can be achieved with hamstring tendon autograft.[7,8,15,16,18,21,24,27] Biomechanical superiority shown in studies and the lower harvest site morbidity compared with patellar tendon autograft continue to support the use of hamstring autograft.[14,25] Randomized controlled clinical trials have shown no difference between clinical outcome and laxity between these 2 types of commonly used autografts.[21,24,27] However, increasing evidence has recently shown that hamstring autograft could have an inferior outcome in younger, more active patients and in female patients.[1,3,20,26]

Technical errors resulting in nonanatomic tunnel position have been implicated in the failure of ACLR. In the case of hamstring autograft, attention has also been given to graft incorporation and fixation since it is an all–soft tissue graft as opposed to bone–patellar tendon–bone autograft. There is also interest in graft size because of the large variability

*Address correspondence to Przemyslaw M. Kamien, MD, Indiana University Health, LaPorte, 1325 E. Fortification Street, Jackson, MS, 39202 (e-mail: mattkamien@gmail.com).
†Indiana University Health, LaPorte, Indiana.
‡Mississippi Sports Medicine and Orthopaedic Center, Jackson, Mississippi.
§University of Mississippi Medical Center, Jackson, Mississippi.

Presented at the 38th annual meeting of the AOSSM, Baltimore, Maryland, July 2012.
The authors declared that they have no conflicts of interest in the authorship and publication of this contribution.

The American Journal of Sports Medicine, Vol. 41, No. 8
DOI: 10.1177/0363546513493896

in size of the graft harvested. In regard to this variability, biomechanical studies have shown inferior biomechanical properties of smaller grafts.[14] Animal studies have also shown an inverse relationship between the amount of anterior-posterior translation and the cross-sectional area of the graft.[9,11] However, the relationship of graft size to the load of the graft to failure was not always linear, and some small grafts fail at higher load than do larger ones.[25] Clinically, grafts with a diameter less than 7 mm have been associated with an increased rate of early revision.[20]

The large variability of graft size obtained during surgery and its possible significant influence on the outcome of surgery, especially in women and younger active people, led to the search for characteristics that would help predict the size of hamstring tendon autograft. The roles of height, weight, body mass index (BMI), and size of the lower extremity as predictors for hamstring tendon autograft in both sexes were analyzed.[28,31,32] Magnetic resonance imaging (MRI) was also reported to be clinically useful in predicting the size of the hamstring autograft expected at the time of reconstruction.[5,13,35] Interest in graft size has been fueled by early biomechanical studies and more recent clinical evidence of its importance in outcome.[14,20]

The purpose of this study is to determine whether patient age, Tegner activity level, and graft size are associated with recurrent instability and revision surgery. We hypothesized that decreased graft size, higher Tegner activity level, and younger age are associated with increased failure rate of the ACLR as represented by continued knee laxity and revision surgery.

MATERIALS AND METHODS

Patient Selection

A total of 98 consecutive patients who underwent primary, quadruple-looped hamstring tendon (semitendinosus and gracilis) ACLR from January 2000 to July 2007 who met inclusion criteria were identified by a computerized relational database (Access 2000; Microsoft Inc, Redmond, Washington). Inclusion criteria consisted of 24 months of follow-up, acute injuries (<3 months from the date of surgery), chronic injuries (>3 months from the date of surgery), and both contact and noncontact injuries. Patients with bilateral ACL injury, previous ligament surgery (ACL repairs, extra-articular reconstruction), and associated ligament injuries (medial collateral ligament, lateral collateral ligament, posterior cruciate ligament, posterolateral corner) were excluded. Detailed forms were used at initial visit, surgery, and at follow-up visits at 3, 6, 9, 12, 18, and 24 months. An objective examination was done at the time of visit consisting of a Lachman test, pivot-shift test, measurement of range of motion, and evaluation with KT-1000 arthrometer. Subjective data that were collected included Tegner activity scores. Graft sizes were obtained from a review of operative reports and were available for 95 patients (96.9%). Failure was defined as any pivot shift, a 2+ Lachman grade (no palpable end point), 5 mm or larger side-to-side difference in KT-1000 arthrometer testing, and/or revision surgery. Forty-eight patients were age 25 years and younger, with a mean age of 16.99 years (range, 12-25, years), and 50 patients were over the age of 25 years, with a mean age of 38.52 years (range, 26-52 years).

Operative Procedure

All procedures were performed by a single senior surgeon (G.R.B.) at a single institution. After routine 10-minute preparation and draping of the ACL-deficient knee, an examination under anesthesia and a complete diagnostic arthroscopy were performed. Any associated lesions were addressed. Injured menisci were either resected or repaired by use of an inside-out technique depending on type and location of the tear. All patients with associated ligament injury were excluded from the study. Hamstring tendons (semitendinosus and gracilis) were harvested through a 3-cm oblique incision on the anteromedial tibia. After tendons were identified, commercially available tendon strippers were used to harvest a graft, and all muscle tissue was removed. Tendons were tensioned and looped to form a 4-strand graft and were sized. Graft sizing tubes (Smith & Nephew Endoscopy, Andover, Massachusetts) with 0.5-mm increments were used.

The tibial guide was used to place a tibial guide pin into the ACL footprint of the tibia. Once the guide pin position was deemed to be correct, it was overreamed with a reamer to the graft size as previously measured by graft sizers. Next, a 5-mm offset guide was used through this tibial tunnel and placed over the top of the posterior notch. It was then rotated down the lateral wall to position the pin more anatomically. The guide pin was then advanced through the guide once it was in the desired position corresponding to the anatomic footprint. Femoral tunnel was reamed to desired size (same as prepared graft).

An EndoButton (Smith & Nephew Endoscopy) was used for femoral fixation. Interference screws were used to secure the graft in the tibia.

A compression dressing was applied and a drain was used for 23 hours. Initially emphasis was placed on passive range of motion exercises and swelling control. Full weightbearing was allowed between 2 and 4 weeks depending on patient comfort. Progressive quadriceps and hamstring rehabilitation was started at approximately 4 weeks. Return to sport was allowed at 6 months or later depending on achieving equal quadriceps size and passing sport-specific tests.

Statistical Analysis

Tests of association between nominal scales were made using the chi-square statistic. An independent t test was used to test for mean differences between groups. An alpha level of .05 was used to determine statistical significance.

RESULTS

There were 15 failures (15.3%) as determined by the definition used. Patients aged 25 years and younger had a significantly higher failure rate (12 of 48; 25.0%) compared with

TABLE 1
Number of Patients per Graft Size

	Graft Size, mm									
	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0
No. of patients	1	10	3	29	5	33	4	8	1	1

patients older than 25 years (3 of 50; 6.0%) (*P* = .009). The mean Tegner activity level score for the ≤25-year age group was 5.58 (range, 3-8) and the mean Tegner activity level score for the >25-year age group was 4.28 (range, 2-7) (*P* = .066). The mean Tegner activity level score for patients with failed reconstructions was 5.53 (range, 3-7), and the mean Tegner activity level score for the nonfailure patient group was 4.81 (range, 2-8). The difference did not reach statistical significance (*P* = .463). Patients 25 years and younger in the failure group had a mean Tegner score of 5.83 (range, 3-7), and those in the nonfailure group had a mean Tegner activity score of 5.50 (range, 3-8) (*P* = .707). Patients older than 25 years in the failure group had a mean Tegner score of 4.33 (range, 4-5), and those in the nonfailure group had a mean Tegner activity score of 4.28 (range, 2-7) (*P* = .174).

The graft sizes ranged from 6.5 to 11 mm. The number of patients with each graft size is shown in Table 1. The mean graft size of the nonfailure group was 8.54 mm (range, 7-11 mm) and the mean graft size of the failure group was 8.43 mm (range, 6.5-10 mm) (*P* = .135). Mean graft size and failure/nonfailure in groups divided by age (≤25 and >25 years) failed to show a statistically significant difference (*P* = .390 and *P* = .165, respectively). In analysis of failure rates in patients with graft sizes ≤7 and >7 mm in the entire study population, as well as divided by age (≤25 and >25 years), there was no statistical significance difference, with the *P* values being .665 and .172, respectively. Similar findings were also shown when failure versus nonfailure groups (*P* = .861) and graft sizes ≤8 and >8 mm (*P* = .390) were compared.

The mean graft size in female patients was 8.15 mm (range, 6.5-10 mm) and in males 8.68 mm (range, 7-11 mm); however, the difference was not significant (*P* = .300). The failure rate in male patients was 17.6% and 10.0% in females, but the difference was not significant (*P* = .543). Mean graft size did not correlate with failure in male (*P* = .180) or female (*P* = .322) patients.

DISCUSSION

Younger age and higher activity level previously have been shown to be associated with a higher failure rate of ACLR.[1,2,17,20] This association was shown to be true for many different graft types and techniques, including hamstring tendon autograft.[1,2,17,20] Younger, more active patients put more demand on the graft and are more prone to reinjury. This association of the younger active patient with ACLR failure and revision is becoming increasingly important since many patients are staying active at an older age.

This study found a statistically significant, higher rate of recurrent instability in the younger patients. Failure rate in this age group (≤25 years) was 25% compared with 6% in older patients (*P* = .011). An increased failure rate in younger patients was previously reported when patellar tendon autograft and allografts were used.[1] Additionally, the failure rate in this age group was higher in the allograft and hamstring autograft group in comparison with patellar tendon autograft.[1] Shelbourne et al[29] reported higher reinjury rates in younger patients after ACLR with patellar tendon autograft. This association of age and activity level with reinjury, failure, and revision rates has been shown by several studies with different graft types.[6,25,20,29]

Magnussen et al[20] recently evaluated early revision rate of the hamstring autograft in 256 patients. The revision rate in the younger population, defined as younger than 20 years, was 14.3% compared with 0.7% in the 20 years and older group. Although the definition of failure was revision only, it clearly demonstrates that younger age could be a factor in hamstring autograft failure, as revision rate could be higher in the younger patients with recurrent instability. In the Magnussen et al[20] study, the revision rate was significantly higher in patients with grafts sized 7 mm or smaller. This threshold was higher for patients younger than 20 years old and was found to be 8 mm.

Interestingly, Tegner activity level did not correlate statistically with ACLR failure in our study. We expected to find an association, since younger patients tend to demonstrate higher activity levels, represented by higher Tegner scores.[30] An increased activity level is generally implicated in the higher failure rate in this population, but a higher frequency of reinjury likely also plays a role. This association was previously described by Shelbourne et al[29] and Borchers et al.[6] Although the mean Tegner activity score was higher in the younger patients compared with older patients (5.58 vs 4.28), the difference between them approached but did not reach statistical significance (*P* = .066). The biggest difference in the mean Tegner activity score between failures and nonfailures was in the entire study population (5.53 vs 4.81), followed by the patients aged 25 years and older (5.83 vs 5.50). The mean Tegner activity scores between failure and nonfailure groups in older patients were quite similar at 4.33 and 4.28, respectively. All study groups had Tegner scores that were higher in the failure group, but no statistical significance was found in the differences.

Graft size has long been implicated in the failure of ACLR in biomechanical studies.[10,11,14,23] Size is especially important for hamstring autograft, since the size of the graft cannot be controlled by the surgeon to the same degree as other grafts. There is also large variability in the size of the autograft obtained. This situation led to interest in finding ways to predict graft size expected during surgery. Multiple patient characteristics including height, weight, BMI, and sex have been evaluated.[28,32,33,37] Recently there is interest in estimating expected graft size by use of preoperative MRI.[5,13,35] This shows that many surgeons believe that size does matter in hamstring autograft reconstruction. Evidence from biomechanical studies and common sense expectations support that belief.

We have failed to find an association between graft size in our patients with hamstring autograft ACLR and failure. This was true when we looked at differences in the mean graft size as well as the failure rates for grafts ≤7 mm and ≤8 mm for all study groups. Mean graft size in the failure group for all patients and older patients was smaller but did not reach statistical significance. Interestingly, the mean graft size was exactly the same in failure and nonfailure groups for younger patients. We made similar observations when comparing grafts ≤8 mm with grafts >8 mm. Our failure to find such association could be explained by lack of sufficient power since the number of patients with very small graft sizes in both failure and nonfailure groups was limited. In contrast to Magnussen et al,[20] we used a different definition of failure, including all patients with recurrent instability in this group in addition to all revisions. This could explain our larger failure rate of 15.3% versus 7.0%. Similar differences were found in failure rates in groups divided by age and graft size.

Initial graft size accounts for time-zero stability. The graft undergoes a whole range of transformation, including size, during incorporation and healing.[12] This process likely plays a more important role in the final outcome and stability than does the initial size of the graft. Other factors, including patient characteristics and, most important, tunnel position, likely play a far more important role.

Bedi et al[4] in a biomechanical study showed that increasing graft size did not increase stability at the time of reconstruction. They also showed that increasing graft size did not compensate for poor stability produced by malposition of the tunnels. The main conclusion from this study is that anatomic reconstruction is far more important than graft size at least for the time-zero stability.

Two studies attempted to compare biomechanical properties of the hamstring tendon with those of the patellar autograft. Both showed biomechanical superiority of the quadrupled hamstring autograft over the patellar tendon graft.[14,25] However, their findings differ in terms of the relationship between the graft size and maximum load to failure. Hamner et al[14] reported a strong positive linear relationship between maximum load to failure and the graft cross-sectional area. Wilson et al[36] failed to find a strong linear relationship between these graft properties. Interestingly, some smaller grafts failed at higher load than the larger grafts. Those findings suggest that inherent properties of the host could significantly affect the biomechanical properties of the graft.

In our study there was only 1 graft smaller than 7 mm (6.5 mm), and it failed. Many 7-mm grafts (8/10; 80%) did well, even in younger patients. However, some larger grafts also failed, including three 10-mm, four 9-mm, and five 8-mm grafts. The failed grafts were not distributed evenly, with some larger graft sizes showing a much larger failure rate than smaller grafts, likely caused by the small number of patients with certain graft sizes.

This unclear direct relationship of certain biomechanical properties to graft size was described in an earlier animal study.[34] Another showed some biomechanical advantages but at the cost of reduced range of motion and arthrosis with larger grafts.[10] This should be taken into consideration, especially with very large grafts, since some increase in the diameter may occur during incorporation.[12] In such situations, the resulting impingement may be more disadvantageous than beneficial for a larger graft. The other issue related to concentrating on just biomechanical properties is that even a smaller graft can provide enough stability to produce a good outcome in most patients. Even if there is an initial increase in the anterior-posterior translation with smaller grafts, it can diminish with time.[10] Once again this brings up the point that patient factors, including compliance, postoperative protocol, and, most important, technical factors leading to nonanatomic reconstruction, may play a far more important role. Perhaps some patients, especially the younger and more active and those at risk of receiving a very small graft, might be better served by a different type of graft, such as the patellar tendon autograft.[1]

Female sex also has been studied as a possible cause of increased failure of ACLR.[3,22] This is especially important given that females have been shown to have smaller diameter hamstring tendons, leading to smaller grafts.[28,32,33] The situation is further complicated because patient factors such as height and weight should be taken into consideration. In our study population, we did not find a statistical difference in graft size between male and female patients, although mean graft size was slightly smaller in females. There was also no difference in the failure rate between male and female patients. Smaller graft size was not associated with increased failure rate in either male or female patients,

Although this study is a retrospective review, all the data come from an ACL database that was entered prospectively. All patients had been treated by a single surgeon (G.R.B.) at a single institution. Failure was defined as 2+ Lachman, positive pivot shift, and 5-mm or larger difference on the KT-1000 arthrometer measurement or revision surgery, as opposed to only revision surgery.

There are several weaknesses of our study. One of those is the retrospective nature of the review. The small number of patients, especially in the failure group, limits our ability to detect differences. The other problem is the number of patients with small diameter grafts (<8 mm)—the vast majority of patients had grafts of 10 and 11 mm in both failure and nonfailure groups. This did not give us enough power to detect differences, if such exist, in the failure rates between smaller and larger grafts. We also did not account for other possible causes of failure, the most important being the tunnel and graft position. This could be important since all the surgeries were done with a transtibial technique previously implicated in less anatomic femoral tunnel position that affects ACL graft position. We did not control for any differences in patient compliance, rehabilitation protocol, return to sport, and full unrestricted activity or history of injury. Postoperative Tegner activity level and stability were the only outcome measures used in this study.

CONCLUSION

Younger patients (≤25 years) had a statistically significant, higher rate of failure after ACLR with hamstring autograft. Size of the hamstring autograft and the postoperative Tegner activity score had no correlation on the failure rate in the entire study population or groups divided by age ($\leq$25 or $>$25 years).

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