Advanced Patellar Tendinopathy Is Associated With Increased Rates of Bone–Patellar Tendon–Bone Autograft Failure at Early Follow-up After Anterior Cruciate Ligament Reconstruction

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Background: Revision anterior cruciate ligament (ACL) reconstruction can be potentially devastating for a patient. As such, it is important to identify prognostic factors that place patients at an increased risk for graft failure. There are no data on the effects of patellar tendinopathy on failure of ACL reconstruction when using a bone–patellar tendon–bone (BPTB) autograft.

Purpose/Hypothesis: The purpose of this study was to investigate the association of patellar tendinopathy with the risk of graft failure in primary ACL reconstruction when using a BPTB autograft. The hypothesis was that patellar tendinopathy would result in higher rates of graft failure when using a BPTB autograft for primary ACL reconstruction.

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

Methods: All patients undergoing ACL reconstruction at a single institution from 2005 to 2015 were examined. A total of 168 patients undergoing primary ACL reconstruction with a BPTB autograft were identified. Patients' magnetic resonance imaging scans were reviewed for the presence and grade of patellar tendinopathy by 2 musculoskeletal fellowship–trained radiologists; both were blinded to the aim of the study, patient demographics, surgical details, and outcomes. Patients were divided into 2 groups: failure (defined as presence of symptomatic laxity or graft insufficiency) and success of the ACL graft. Statistical analyses were run to examine the association of patellar tendinopathy with failure of ACL reconstruction using a BPTB autograft.

Results: At a mean follow-up of 18 months, there were 7 (4.2%) patients with graft failure. Moderate or severe patellar tendinopathy was associated with ACL graft failure ($P = .011$). Age, sex, and side of reconstruction were not associated with the risk of graft failure, although the majority of patients who failed were younger than 20 years. The use of patellar tendons with moderate to severe tendinopathy was associated with a relative risk of ruptures of 6.1 (95% CI, 1.37-27.34) as compared with autograft tendons without tendinopathy.

Conclusion: Moderate or severe patellar tendinopathy significantly increases the risk of graft failure when using a BPTB autograft for primary ACL reconstruction. Patellar tendinopathy should be considered when determining the optimal graft choice for patients undergoing primary ACL reconstruction with autograft tendons.

Keywords: patellar tendinopathy; bone–patellar tendon–bone autograft; graft failure; anterior cruciate ligament reconstruction

Graft failure after primary anterior cruciate ligament (ACL) reconstruction is a dreaded complication, often requiring revision surgery. While ACL reconstruction is a common operative procedure in the United States, with nearly 200,000 cases performed annually, the failure rate for primary ACL reconstruction using an autograft is reported at an average of 3.6%.[35] Primary ACL reconstruction has reported rates of satisfaction of greater than 90%; however, the outcomes for revision surgery, such as return to play, patient satisfaction, and functional testing scores, are typically worse.[10,24,37] As such, efforts have been made to identify the predictors of graft failure after primary ACL reconstruction.

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Failure of ACL reconstruction has been considered as the presence of pain, stiffness, and/or persistent instability, leading to abnormal activities of daily living or sports performance.[30] A number of factors have been associated with failure. Patient factors including younger age, higher activity levels, use of allografts, meniscal deficiency, and cutting sports are associated with an increased rate of failure.[26,33,38] Technical factors, such as tunnel malpositioning, laxity, impingement, and infections, among others, are also associated with higher rates of graft failure.[30] Graft selection has also been proposed as a possible predictor of ACL graft failure. While it is well established that, in both the primary and revision setting, autografts remain the superior choice over allografts,[9,17,20,21] the specific choice of autograft remains murky. Some studies indicate that the bone–patellar tendon–bone (BPTB) autograft has lower overall rates of failure than reconstruction with a hamstring autograft or allograft.[33] Recent work has emphasized that smaller hamstring grafts are related to increased failure rates[11,22]; however, the quality of patellar tendon autografts and its impact on outcomes are unclear.

Prior literature has established a correlation between tendinopathy and native tendon ruptures, including the extensor carpi ulnaris and Achilles tendons, which has been hypothesized to be caused by tendon degeneration and breakdown.[23,34] While anterior knee pain and patellar tendinopathy are recognized complications after the use of a BPTB autograft,[29] the role of patellar tendinopathy before ACL reconstruction is not as well elucidated. The relationship between patellar tendinopathy and outcomes in ACL rescontruction with BPTB has not been extensively studied.[2] The goal of this study was to investigate the influence of patellar tendinopathy on the rate of graft failure in ACL reconstruction when using a BPTB autograft. We hypothesized that patellar tendinopathy would result in higher rates of graft failure, possibly because of a weaker tendon secondary to chronic degenerative changes within the autograft.

METHODS

Procedures

This retrospective study received approval from an institutional review board. Between January 2005 and January 2015, the charts of all patients undergoing ACL reconstruction by 1 of 3 fellowship-trained sports medicine surgeons (C.T.M., A.P.T., and D.C.T.) were reviewed. Patients were included if they (1) had undergone primary ACL reconstruction using a BPTB autograft from the central third of the patellar tendon of the ipsilateral leg, (2) had preoperative magnetic resonance imaging (MRI) scans of the primary ACL reconstruction site available for review, and (3) had a minimum follow-up of 6 months (or earlier in cases of graft failure).

Cases of primary ACL reconstruction that did not use a BPTB autograft, such as hamstring autografts or tendon allografts, were excluded. Once the patients were identified, a data collection spreadsheet was created to obtain demographic information (age, sex, side of reconstruction), imaging history (preoperative MRI scans available), length of follow-up, presence of graft failure, and details on subsequent surgical interventions. Although failure of ACL reconstruction has been considered to be the presence of pain, stiffness, and/or persistent instability, leading to abnormal activities of daily living or sports performance,[30] for the purpose of this study, failure was considered to be the presence of symptomatic laxity or graft insufficiency (by physical examination or MRI). A separate spreadsheet with the MRI-related variables for patellar tendinopathy, not including the other study variables, was created for the radiologists' blinded evaluation.

Patients

A total of 168 patients met the inclusion criteria. The mean follow-up was 18 months (range, 6-120 months), with a mean age of 21.8 years. There were 106 male patients (63.1%) and 62 female patients (36.9%) (Table 1). Surgery

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Ethical approval for this study was obtained from the Duke University Institutional Review Board for Clinical Investigations (No. Pro00052597).

TABLE 1
Patient Characteristics

Characteristic	Total, n	Success, n	Failure, n	*P*
Age, y				.27
10-19	90	85	5	
20-29	54	54	0	
30-39	14	13	1	
40-49	10	9	1	
Sex				.74
Male	106	102	4	
Female	62	59	3	
Side of reconstruction				.82
Left	89	85	4	
Right	79	76	3	

was performed on 79 right knees (47.0%) and 89 left knees (52.9%) (Table 1). The surgical procedures were performed by 3 different surgeons (A.P.T., C.T.M., and D.C.T.). In all cases, single-bundle anatomic reconstruction was performed by either a transtibial technique or by independent drilling of the femoral tunnel. The harvest site was the ipsilateral knee in all cases.

MRI Evaluation

Two fellowship-trained musculoskeletal radiologists independently evaluated preoperative MRI scans of patients undergoing ACL reconstruction with a BPTB autograft. The radiologists were blinded to the study purpose, patients' treatment, and failures or complications. They were told that a study on patellar tendinopathy was being planned and that their job would consist of reaching a consensus on the reading and classification of this condition, assessing a number of MRI scans independently, and filling a data collection spreadsheet. The radiologists evaluated for the presence or absence of bone bruising (at the patellar or tibial tubercle sites) and patellar tendinopathy in the middle third (harvest area) as defined by the following procedure: First, images were evaluated for the absolute presence or absence of tendinopathy in the proximal part, middle part, distal part, or diffuse. Then, images were graded from 0 to 3 in accordance with the scheme established by Johnson et al[16] (Figure 1), where grade 0 represents a normal tendon appearance, grade 1 (mild) represents signal intensity in <25% of the axial cross-sectional tendon width, grade 2 (moderate) represents signal intensity in 25% to 50% of the axial cross-sectional tendon width, and grade 3 (severe) represents signal intensity in >50% of the cross-sectional tendon width. Any images suggesting a tendon tear and its location were also collected. Once the 2 independent radiologists completed data collection, the researchers checked the evaluation of patellar tendinopathy for each case. Cases were excluded from statistical analyses when there was no consensus between the radiologists. Success or failure of the graft was compared according to age (stratified), sex, side of reconstruction, presence/absence of patellar tendinopathy, and classification of patellar tendinopathy (grades 0 or 1 vs grades 2 or 3).

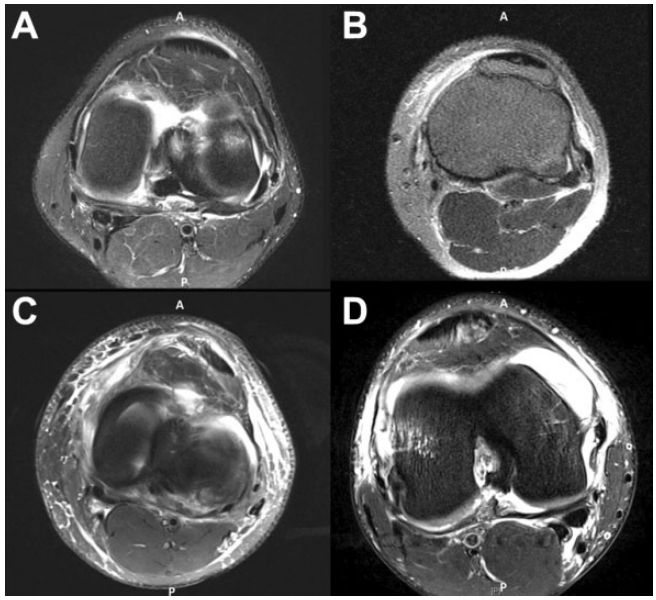

Figure 1. Axial T2-weighted magnetic resonance imaging of the patellar tendon in cross-section demonstrating examples of (A) normal (grade 0), (B) mild (grade 1), (C) moderate (grade 2), and (D) severe (grade 3) patellar tendinopathy.

Statistical Analysis

Descriptive statistics were used to summarize the variables collected for this study. The agreement in the classification of patellar tendinopathy for each patient between the 2 independent radiologists was evaluated using the kappa coefficient. A univariate analysis using the chi-square test was conducted to compare the subgroups. Multivariate methods were used to create a model controlling for sex, age, follow-up time, and tendinopathy in examining the association with the failure rate. All statistical analyses were carried out using JMP (SAS Institute). The alpha level was set at 0.05.

RESULTS

Of the 168 study patients, 7 (4.2%) had graft failure. Four failures occurred from a contact injury, while 3 occurred from a noncontact mechanism of injury. The kappa coefficient of agreement between both radiologists for bone edema of the patella, bone edema of the tibial tubercle, or partial tendon tears on MRI was 0.38, 0.41, and 0.65, respectively ($P < .001$ for each); this indicated weak, minimal, and moderate agreement, respectively. Radiologist 1 identified 10 (6.1%) cases of bone edema in the patella, 6 (3.6%) cases of bone edema in the tibial tubercle, and 8 (4.8%) cases of a partial tendon tear on MRI; there were no statistically significant differences in their distribution between the success and failure groups

TABLE 2
Outcomes Stratified by Classification of Tendinopathy[a]

	Success, n			
Tendinopathy	Yes	No	Total, n	*P*
Moderate to severe	7	2	9	.01
None to mild	133	5	138	
Total	140	7	147	

[a]Includes 147 patients for whom a consensus between the 2 radiologists could be reached.

($P = .46$, .57, and .30, respectively). Radiologist 2 identified 9 (5.5%) cases of bone edema in the patella, 5 (3.1%) cases of bone edema in the tibial tubercle, and 10 (6.1%) cases of a partial tendon tear on MRI; there were no statistically significant differences in their distribution between the success and failure groups ($P = .38$, .61, and .59, respectively).

When patellar tendinopathy was classified as none or mild versus moderate or severe, there was still a statistically significant difference in concordance (kappa = 0.39; $P < .001$). Twenty-one patients (12.5%) were excluded from this subgroup comparison because no consensus between the radiologists could be reached on the degree of patellar tendinopathy (Table 2). When comparing the remaining 147 patients with none to mild patellar tendinopathy versus those with moderate to severe patellar tendinopathy, there was a statistically significant difference in the failure rate, with patients with moderate to severe tendinopathy having higher rates of failure ($P = .011$) (Table 2). The risk of ruptures for patients with moderate to severe tendinopathy was 6.1 (95% CI, 1.37-27.34) times greater than for those with none to mild tendinopathy. Even after controlling for sex, age, and follow-up time, tendinopathy remained statistically significant ($P = .017$).

DISCUSSION

The principal finding of this study was that moderate or severe patellar tendinopathy is associated with an increased risk of graft failure when using a BPTB autograft for primary ACL reconstruction. Therefore, a contralateral BPTB autograft or other tendon autograft is recommended in cases of moderate or severe patellar tendinopathy.

Previous studies have identified a number of risk factors for graft failure, such as younger age, higher activity levels, use of allografts, smaller graft size, concomitant meniscal deficiency, and patient sex.[1,3,5,6,17,26-28] A study by Ponce et al[28] retrospectively analyzed 2898 patients to identify risk factors for revision surgery in ACL reconstruction; they found that female sex was significantly correlated with higher rates of revision surgery. This has been suggested by other studies as well.[1,6,14] In a study of the MOON (Multicenter Orthopaedic Outcomes Network) cohort however, female sex was not correlated with either ipsilateral or contralateral ACL disruption after ACL reconstruction. Still other studies have supported the notion that, although female sex seems to be associated with higher rates of native ACL disruption, female patients do not appear to have higher rates of graft failure.[5,12,27,36] Our study did not find an association between sex and graft failure in 168 patients undergoing ACL reconstruction using a BPTB autograft.

Younger age and higher activity levels have also been correlated with higher rates of revision surgery after ACL reconstruction, as Kaeding et al[18] reported after prospectively examining 2488 patients from the MOON cohort. This finding has been confirmed by other authors,[36] including a study utilizing a large cohort from the Norwegian Cruciate Ligament Registry.[27] While previous studies have demonstrated meniscal deficiency and allograft use as predictive of graft failure,[17,26] our study was not specifically designed to evaluate these factors.

Tendinopathy has been proposed as a contributing factor for ruptures in other tendons. A study by McQueen et al[23] used MRI to evaluate the prognostic significance of extensor carpi ulnaris tendinopathy in 42 patients with rheumatoid arthritis; they found that higher tendinopathy scores correlated with tendon ruptures at 6 years. Achilles tendinopathy has also been proposed as a contributing factor for ruptures.[34] As such, it stands to reason that pathological changes in the patellar tendon before implantation may compromise the integrity of reconstruction using an autograft. Work by Alentorn-Geli et al[2] supports this notion, suggesting that patellar tendinopathy indeed increases the rate of BPTB failure. Our findings support this premise and agree with the findings of this prior study. It should be noted that, while moderate to severe patellar tendinopathy was associated with graft failure, 77.8% of patients with moderate to severe patellar tendinopathy did not have evidence of failure. In comparison, however, only 3.6% of patients with none to mild patellar tendinopathy failed, which is consistent with the reported rates of failure in the literature,[35] further supporting the notion that failure is associated with more severe patellar tendinopathy. It is also possible that patellar tendinopathy may be a surrogate for other factors, such as jumping sports or overtraining, that may predispose to graft failure.

When considering tendinopathy as a possible risk factor for graft ruptures when using a BPTB autograft, it is also pertinent to discuss graft healing. BPTB grafts have been found to heal by a process of ligamentization.[4] Initially, the healing response is marked by an inflammatory phase in which the graft undergoes necrosis and becomes hypocellular. This results in the release of inflammatory markers and cytokines that signal for an influx of inflammatory cells and the beginning of the healing response.[4,7,8,19] Subsequently, the graft enters a proliferative phase at 1 to 3 months, in which it undergoes revascularization and recellularization.[15,31,32] It is during the proliferative phase that the graft is felt to be at its weakest; some studies have suggested that this process of revascularization may even take up to 1 year to complete.[25] Finally, at approximately 3 to 6 months, the graft begins to undergo ligamentization, in which it is remodeled to have similar biomechanical strength and morphology of a normal cruciate ligament.[4,31]

It is unclear what effect the healing process would have on an autograft that had previously demonstrated tendinopathy and vice versa. Certainly, it is possible that the effects of tendinopathy are mitigated by the actual healing response of the graft, which would diminish the effect of tendinopathy on long-term rupture rates. Unfortunately, we did not have data on the time to graft failure in our patients, so we could not determine whether patellar tendinopathy affected a specific period in the ligamentization process. What is certain is that there is a lack of data investigating the role of tendinopathy on graft healing in both humans and animal models.

This study is not without its limitations. First, the study was retrospective in design, which poses a risk of selection bias. Data on failure were gleaned from a retrospective chart review and clinical data from clinic visits; follow-up questionnaires and radiographic assessments were not utilized. Second, an a priori power analysis was not conducted for this study, which entails a theoretical risk of type II errors. Data on the expected rate of failure for patients with patellar tendinopathy is not well established. While our sample size was smaller than in previous studies using the Norwegian[27] or Scandinavian[13] registries, with 12,643 and 45,998 patients, respectively, these large registry studies were not specifically conducted to evaluate the role of patellar tendinopathy as a risk factor for graft failure. While an insufficient sample size could affect nonsignificant findings, ours is the first study to report on such a topic and provides an estimate for more highly powered studies in the future.

Third, it was observed in this study that patellar tendinopathy may be a challenge to grade, even for fellowship-trained musculoskeletal radiologists. We attempted to control for this factor by excluding patients in whom agreement could not be reached. While we utilized the grading scheme previously established by Johnson et al,[16] the current study demonstrates that a thorough definition and classification for MRI-based patellar tendinopathy are warranted. What is more, the development of a more reliable and reproducible classification system may be of benefit. Fourth, the present study did not control for the many other possible causes of graft failure. Therefore, it might be argued that graft failure was not only explained by the presence of patellar tendinopathy but also related to other factors. As such, future studies in the form of prospective comparative analyses with even larger patient cohorts are warranted to help examine the role of patellar tendinopathy in graft failure after ACL reconstruction using a BPTB autograft.

Despite these limitations, we feel that this study has merit. Importantly, it is the first to observe that patellar tendinopathy may affect the outcomes of primary ACL reconstruction when using a BPTB autograft. This has clinical relevance, as obvious patellar tendinopathy changes (moderate or severe) can be readily identified on all preoperative MRI scans and can be used to influence decision making in terms of graft selection. Given the potentially devastating impact of revision ACL surgery, this is an important prognostic factor to consider.

CONCLUSION

Moderate or severe patellar tendinopathy has a significant association with an increased risk of graft failure when using a BPTB autograft for primary ACL reconstruction. Therefore, we recommend that an alternative graft (hamstring tendon, contralateral patellar tendon, quadriceps tendon, etc) be considered for cases of moderate or severe patellar tendinopathy. Future studies with larger sample sizes and prospective study designs are warranted to help examine the role of patellar tendinopathy in graft failure after ACL reconstruction using a BPTB autograft.

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