Primary Anterolateral Ligament Rupture in Patients Requiring Revision Anterior Cruciate Ligament Reconstruction: A Retrospective Magnetic Resonance Imaging Review

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Purpose: To compare the initial rate of anterolateral ligament (ALL) injury at the time of anterior cruciate ligament (ACL) rupture in patients who subsequently experienced ACL reconstruction graft failure versus patients who did not experience subsequent ACL reconstruction graft failure. **Methods:** Our institution's electronic medical record database was queried for patients who underwent primary ACL reconstruction and then experienced subsequent ACL graft rupture. Patients were included only if they presented acutely (<3 months from time of injury) and had an isolated ACL rupture with no other cruciate or collateral ligamentous injury. Exclusion criteria included lack of an available magnetic resonance imaging (MRI) scan, ACL injury greater than 3 months, previous ACL reconstruction, and age younger than 13 or older than 50 years. Each patient was paired with an age-, gender-, and graft-matched control who underwent ACL reconstruction without subsequent graft rupture. Each patient was diagnosed with an intact, partially injured, or fully ruptured ALL on initial injury MRI. The location of ALL injury was also noted. The incidence of ALL rupture and location of rupture between the 2 groups was compared using χ-square analysis. **Results:** There were 1,967 patients who underwent primary ACL reconstruction; 128 patients experienced ACL graft rupture, and 55 patients (43%) had MRI scans available for review. Of these patients, 39 fulfilled the inclusion criteria with available MRI and were matched with a control patient. In the revision ACL reconstruction group, the ALL was diagnosed as intact, partially torn, and completely torn in 17, 14, and 8 patients, respectively. In the control group, the ALL was diagnosed as intact, partially torn, and completely torn in 18, 13, and 8 patients, respectively. Pearson χ-square test revealed no difference between the groups in frequency of ALL rupture (Pearson χ-square = 0.066; $P = .968$). There was also no difference in the location of ALL rupture between the 2 groups, although the revision group had a higher trend of tibial-sided injuries. **Conclusions:** The incidence of initial ALL injury as documented on MRI was not different in patients who experienced subsequent ACL graft rupture compared with patients who did not experience ACL graft rupture after primary ACL reconstruction. The ALL was more commonly injured on the tibial side in patients with ACL graft rupture and femoral-sided lesions were more common in control patients. **Level of Evidence:** Level III, prognostic case-control study.

Surgical results after anterior cruciate ligament (ACL) reconstruction continues to improve with satisfactory outcomes reported in75% to 97% of patients.[1-5] However, ACL reconstruction failure remains a significant problem with up to 10% to 15% of patients requiring a revision surgery.[6-8] Young patients returning to pivoting and contact sports are at an especially high risk of graft rupture and need for subsequent revision surgery. Satisfactory results after revision ACL reconstruction are lower than primary

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ACL reconstruction with rates reported at 76%.[4,8] When an ACL reconstruction fails, there are many potential reasons for the failure, including technical error, chronic or acute trauma, biologic causes, or residual rotational laxity.[4,9] As more surgeons have improved their surgical technique to achieve an anatomic ACL reconstruction, other variables have gained interest as potential reasons for graft failure.

Recently, the anterolateral ligament (ALL) has gained attention as an important rotatory stabilizer for the knee joint.[10-19] First described in 1879 by Dr. Segond, more than 15 articles have confirmed identification of the ALL in cadaveric models with a more than 90% combined ability to identify the ALL in a recent systemic review.[20] However, the clinical importance and function of the ALL remains theorized.

The ALL has been implicated in prevention of the pivot shift phenomenon.[12,17-19,21] Therefore, it is possible that residual rotatory instability after ACL reconstruction may be owing to an ALL injury, yet clinical data are lacking to support this theory. Nonetheless, ALL reconstruction has been considered in the setting of revision ACL reconstruction to help prevent residual rotational laxity. Other proposed indications for ALL reconstruction include a 3+ pivot shift on examination, the presence of a Segond fracture or lateral capsular injury, athletes returning to pivoting sports, and high-level athletes.[17,22,23] However, we are unaware of any study that has investigated the presence of a primary ALL rupture in patients requiring revision ACL reconstruction surgery.

This study's purpose was to compare the initial rate of ALL injury at the time of ACL rupture in patients who subsequently experienced ACL reconstruction graft failure versus patients who did not experience subsequent ACL reconstruction graft failure. The hypothesis was that a higher rate of ALL injury at the time of initial ACL rupture would be present in patients who experienced ACL graft failure after primary ACL reconstruction.

Methods

Our institution's electronic medical record database was queried for patients who underwent ACL reconstruction between 2009 and 2015. Retrospective data were collected for all patients after receiving approval from the institutional review board. Patients who underwent ACL reconstruction were identified by a computerized search using the Current Procedural Terminology code for arthroscopic ACL reconstruction (Current Procedural Terminology 29888). These patients were cross-checked for having the *International Classification of Diseases* (ICD) version 9 and 10 diagnosis of ACL tear (ICD 9, 884.2; ICD 10, S83.511A and S83.512A). The search was limited to patients who underwent surgical treatment by 1 of the 5 sports fellowship—trained orthopedic surgeons at our institution (D.D.).

Patients from the database were included in the study if they underwent subsequent ACL reconstruction after diagnosis of ACL graft rupture, which was determined by the ICD 9 and 10 codes for ACL graft rupture (996.52 and T84.3/T84.4, respectively). Indications for revision ACL reconstruction included a ruptured ACL graft with a desire to return to a higher level of physical activity. Patients who had a chronic ACL injury for greater than 3 months, who did not have available magnetic resonance imaging (MRI) scans, who already underwent previous ACL reconstruction, or who suffered a multiligamentous knee injury were excluded from the study. Patients younger than 13 years or older than 50 years were also excluded from the study. Surgical indications for primary ACL reconstruction included subjective knee instability, desire to return to athletic or a high-demand occupational activity, and confirmed partial or complete ACL rupture at the time of knee arthroscopy, A failed ACL reconstruction was defined as an ACL graft rupture confirmed by MRI and subsequently at the time of arthroscopic revision ACL reconstruction.

The database was then searched for patients who underwent primary ACL reconstruction using Current Procedural Terminology code 29888 without a subsequent ICD 9 or ICD 10 code for ACL graft rupture, which was confirmed on chart review. Each patient who underwent revision ACL reconstruction was then paired with an age, gender, and ACL graft-matched control patient who did not experience ACL graft rupture.

Retrospective chart review was performed to identify patient demographics, mechanism of injury, and time between primary ACL reconstruction and failure. Two clinically blinded musculoskeletal radiologists reviewed initial injury MRI scans. All MRIs were performed on at least a 1.5 Tesla MRI machine. Axial T2-weighted, fat-suppressed and coronal T2-weighted or proton density fat-suppressed images were used to evaluate the integrity of the ALL similar to a previously described method.[24] For each patient and each control, the ALL was graded as intact, partially torn with increased edema signal, or completely torn (Fig 1A-C). A Segond fracture was noted when present and given a diagnosis of completely torn (Fig 2). The location of the ALL injury was also noted and assigned a location of femoral, midsubstance, or tibial. Each radiologist independently assigned a diagnosis to the ALL for each MRI. Any discrepancies after independent review were resolved by direct conversation between the 2 musculoskeletal radiologists until a consensus was obtained.

Data were recorded in an Excel spreadsheet (Microsoft, Redmond, WA), which was also used to calculate

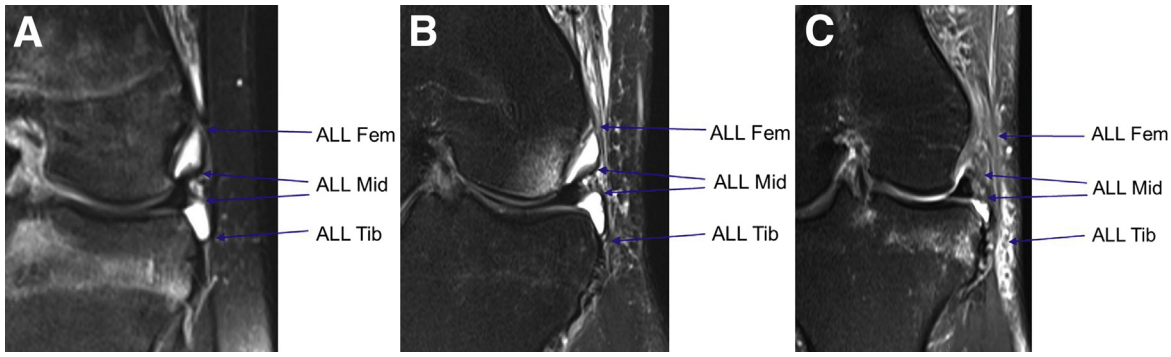

Fig 1. (A) T2-weighted, fat-saturated coronal magnetic resonance image of a left knee revealing an intact anterolateral ligament with all 3 main anatomic regions clearly visible, including the anterolateral ligament femoral attachment (ALL Fem), ALL mid-substance (ALL Mid), and ALL tibial attachment (ALL Tib). (B) T2-weighted, fat-saturated coronal magnetic resonance image of a left knee revealing a partially torn anterolateral ligament evidenced by the enhanced fluid signal along and surrounding the ligament, most notably along the femoral-sided attachment site (ALL Fem) and ALL Mid. The ALL Tib site is intact with less fluid enhancement signal. (C) T2-weighted, fat-saturated coronal magnetic resonance image of a left knee revealing a completely torn anterolateral ligament at the femoral and meniscal attachment. There is no recognizable ligament substance in the ALL Fem or the ALL Mid region. The ALL Tib shows a poorly defined ligament attachment.

summary data statistics. The incidence of ALL rupture between the ACL graft failure group and the control group was the primary outcome and was evaluated for statistical difference using the Pearson χ-square test to assess the likelihood of difference with $P < .05$ chosen for statistical significance. The location of ALL rupture was a secondary outcome that was also evaluated for statistical difference using the Pearson χ-square test with $P < .05$ chosen for significance. A power analysis was performed post hoc to determine the percentage of difference that was able to be detected between the 2 groups.

Results

A total of 1,967 patients underwent ACL reconstruction between 2009 and 2015 at our institution. Of these patients, 128 (6.5%) underwent revision ACL reconstruction because of graft rupture at our institution. An initial MRI was available for review in 55 patients who underwent revision ACL reconstruction and 39 patients met the inclusion criteria (Tables 1 and 2). There were 17 male and 22 female participants in the revision group with an average age of 21.1 years (range, 13-47 years) and average body mass index of 25.2 (range, 19.2-38.5). The control group had the same gender distribution with an average age of 20.9 years (range, 13-47 years) and average body mass index of 25.1 (range, 17.1-39.7; Table 1).

Within the revision group, the initial graft choice was hamstring autograft, bone–patellar tendon–bone autograft, and hamstring autograft combined with hamstring allograft in 25, 13, and 1 patients, respectively. The initial graft choice in the control group was hamstring autograft and bone–patellar tendon–bone autograft in 26 and 13 patients, respectively. The average time to ACL graft failure in the revision group was 2.2 years (range. 0.2-8.1 years; Table 1).

Initial MRIs revealed a similar incidence of ALL rupture between the 2 groups of patients. An intact ALL was diagnosed in 17 revision patients and 18 control patients (Pearson χ-square = 0.052; $P = .820$). A partially torn ALL was diagnosed in 14 revision patients and 13 control patients, and each group had 8 patients diagnosed with a completely torn ALL (Pearson χ-square = 0.066; $P = .968$; Table 2). Power analysis revealed 80% power to detect at least a 30% difference between the 2 groups with more than 36 patients in each group.

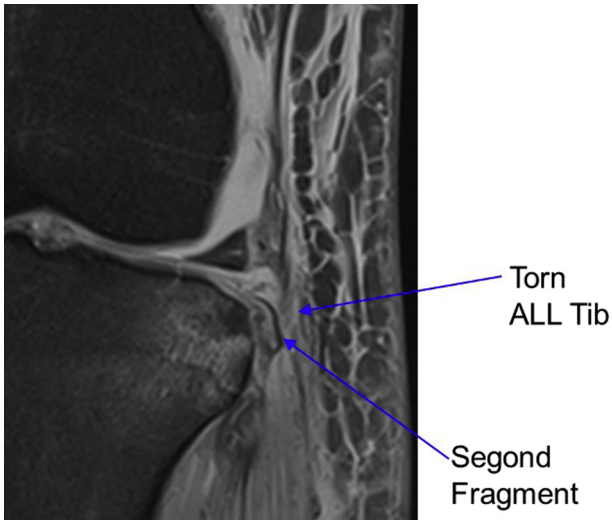

Fig 2. T2-weighted, fat-saturated coronal magnetic resonance image of a left knee revealing a Segond fracture with attachment of the tibial portion of the anterolateral ligament (ALL Tib) to the fragment.

Table 1. Demographic Data of Revision and Control ACLR Groups

Demographic	Revision Group	Control Group
Total patients	39	39
Gender (M:F)	17:22	17:22
Age, y, at primary ACLR, mean (range)	21.1 (13-47)	20.9 (13-47)
Primary graft type, n (%)		
HS autograft	25 (64.1)	26 (66.7)
BPTB autograft	13 (33.3)	13 (33.3)
HS autograft + allograft	1 (2.6)	0 (0)
Time to revision, y, mean (range)	2.2 (0.23-8.10)	N/A

ACLR, anterior cruciate ligament reconstruction; BPTB, bone–patellar tendon–bone; HS, hamstring.

A midsubstance tear of the ALL was the most common type of injury in the revision group, followed by tibial-sided and then femoral-sided injury (13, 5, and 4 patients, respectively). Three of the 5 tibial-sided lesions had an associated Segond fracture. In the control group, a midsubstance tear was also the most common pattern (13 patients), followed by femoral-sided injury (8 patients), and tibial-sided injury (1 patient). There were no Segond fractures in the control group. There was no difference in any location of injury between the 2 groups (Pearson χ-square = 4.00; $P = .135$).

Discussion

There was no difference in initial ALL rupture rates between patients who did and did not experience subsequent ACL graft rupture (56.4% vs 53.8%, respectively). Additionally, there was no difference between the 2 groups with regard to the location of the ALL injury, although the control patients had a higher incidence of femoral-sided lesions with no Segond fractures. Comparing the initial rate and location of ALL rupture in patients who did and did not experience ACL graft rupture is an important step in helping orthopaedic surgeons to better clarify indications for primary ALL reconstruction. The use of a gender, age, and graft match control group is another strength of the study.

The combined incidence of partial and complete ALL rupture in our patient population (55%) was lower than the incidence of 78.8% previously reported by Claes et al.[25] in a review of 206 knee MRIs after primary ACL rupture, yet higher than the incidence of 39.5% reported by Helito et al.[24] after review of 167 MRIs. Recently, Kosy et al.[26] reviewed 280 MRI scans after ACL injury and found only a 10.7% incidence of concomitant ALL rupture. The wide range of ALL injuries identified on MRI after ACL injury may speak to the variability among physicians in identifying ALL injury. Alternatively, the reliability of MRI to identify an ALL injury has been called into question with some authors even suggesting ultrasound examination as an improved way to identify an ALL injury. Regardless, proper identification of both an injured and uninjured ALL on advanced imaging remains a controversial topic. Hartigan et al.[27] investigated 72 knee MRIs in patients with ACL tears and found a discordant rate of reported ALL injury between 2 fellowship-trained musculoskeletal radiologists. Each radiologist could identify the ALL on 100% of the scans, but the reported rates of ALL injury was different (26% vs 62%) with poor intrarater and inter-rater reliability ($\kappa = 0.54$). Similarly, the attending musculoskeletal radiologists participating in this study (M.A., J.P.) were able to identify the ALL in every MRI scan, although multiple studies have reported lower success rates of identification of the ALL on MRIs. For example, Devitt et al.[28] reported only a 64% and 72% success rate in identifying the ALL on MRI scans of control patients and patients with ACL injury, respectively. It is unknown whether the variability in successful identification of the ALL is attributable to poor imaging techniques, observer error, or severe rupture to the ALL that renders it difficult to observe discretely.

In the current study, most patients with an ALL injury was diagnosed with a midsubstance tear. Patients undergoing revision ACL surgery had a higher rate of tibial-sided lesions and Segond fractures compared with control patients, who were more likely to have a femoral-sided lesion. These trends were not significant, which is likely attributable to the small sample size. Many studies have reported a higher rate of tibial-sided ALL injuries, followed by midsubstance tears and, rarely, femoral-sided tears, although this may be owing to bias because the ALL is often easier to visualize in the midsubstance and tibial region owing to its more distinct insertions on the tibia and meniscocapsular layer.

It is important to note that the rate of ALL rupture in the aforementioned studies is often higher than the reported rate of residual laxity after ACL reconstruction, which has been reported to be as high as 25%.[29,30] One possible explanation we propose is that the ALL and lateral capsular complex may have the ability to heal, similar to other extra-articular knee ligaments, although data are currently lacking to support or refute

Table 2. Comparison of ALL Diagnosis Between Revision and Control ACLR Groups

ALL Diagnosis	Revision Group	Control Group	Total
Intact	17	18	35
Partially torn	14	13	27
Completely torn	8	8	16
Total	39	39	78

ACLR, anterior cruciate ligament reconstruction ; ALL, anterolateral ligament.

Pearson χ-square = 0.066; $P = .968$.

this possibility. The higher rate of femoral-sided lesions in the control group along with a higher rate of tibial-sided lesions in the revision group suggests that perhaps distal lesions have less ability to heal, similar to a distal medial collateral ligament lesion. However, the current study lacks adequate power to make this determination and further study is warranted. Our findings suggest that, although the ALL is an important rotatory stabilizer about the knee joint, an injury to the ALL may not lead to a higher rate of ACL graft failure after reconstruction. This finding draws into question the need for a concomitant ALL reconstruction at the time of primary ACL reconstruction, even though biomechanically an ALL reconstruction may be advantageous in preventing residual laxity after ACL reconstruction.

Recent cadaver studies have shown the importance of the ALL complex in restoration of normal knee kinematics after ACL reconstruction.[17-19,31] In 2015, Parsons et al.[18] performed biomechanical testing of the knee joint and found that the ALL significantly contributes to internal rotation stability at flexion angles greater than 35°, but contributed minimally to anterior tibial translation between 0° and 90° of knee flexion. (Monaco et al.[31] reported increased manual laxity in pivot shift testing of cadaveric knees after severing of both the ACL and "midthird lateral capsular ligament," yet their results were not quantified objectively.) Rasmussen et al.[19] performed a biomechanical cadaver study to investigate the role of the ALL in resisting the pivot shift phenomenon using a robot with 6 degrees of freedom. They found that adding an ALL injury to an ACL-deficient knee led to a significant increase in axial plane translation and internal rotation of the tibia, confirming the role of the ALL as a significant secondary stabilizer in resisting the pivot shift test. A follow-up study performed by the same group investigated the biomechanics of the knee after ACL reconstruction with or without a concomitant ALL reconstruction.[17] When there was a combined ACL and ALL injury, ACL reconstruction alone did not restore normal stability of the knee joint, resulting in a significant residual increase in rotatory laxity. Normal knee kinematics were only restored after an ALL reconstruction was added. (Similarly, Inderhaug et al.[15] found that ACL reconstruction alone did not restore normal knee kinematics in cadaveric knees in the presence of both an ACL and ALL injury.)

These studies advocate for the importance of the ALL in resisting the pivot shift phenomenon and restoring native knee kinematics. Therefore, many authors have suggested that an unrecognized ALL or lateral capsular injury at the time of primary ACL reconstruction may lead to continued rotational laxity despite anatomic ACL reconstruction. The loss of these secondary stabilizers may account for patients who continue to have a positive pivot shift after an otherwise successfully performed ACL reconstruction. Additionally, increased postoperative laxity may lead to a higher rate of graft failure, especially in high-risk athletes who play pivoting sports, although this supposition has not been studied directly.

Based on these biomechanical data, some authors advocate for ALL reconstruction in the setting of signs or symptoms that suggest a lateral capsular injury, including a Segond fracture, a lateral femoral sulcus sign, or ALL injury identified on preoperative MRI.[13,17,23] Clinical data after combined ACL and ALL reconstruction are scarce with only a few studies reporting objective and subjective outcomes after combined ACL and ALL reconstruction.

Zhang et al.[22] reported kinematic profiles and clinical outcome scores in patients 1 year after a double bundle ACL reconstruction, single bundle ACL plus ALL reconstruction, or single bundle ACL reconstruction alone. Patients who underwent a double bundle ACL reconstruction or a single bundle ACL plus ALL reconstruction scored significantly better in anteroposterior stability, rotational stability, and knee outcome scores at 6 and 12 months compared with patients who underwent only a single bundle ACL reconstruction. The difference between the double bundle ACL reconstruction group and the single bundle ACL plus ALL reconstruction group was not significant.

In 2015, Sonnery-Cottet et al.[23] reported clinical outcome scores with a minimum of 2 years of follow-up after combined ACL and ALL reconstruction. Indications for a combined procedure were a Segond fracture, a chronic ACL lesion, grade 3 pivot shift, a high level of sporting activity, participation in pivoting sports, and a lateral femoral notch sign on radiographs. A total of 83 patients were included in final data analysis. All patients regained full knee range of motion with significantly improved clinical knee outcome scores and activity scores. Only 1 patient (1.1%) experienced graft failure; the postoperative pivot shift was grade 0 in 76 patients and grade 1 in 7 patients. Their findings suggest that a high rate of positive outcomes and activity scores are possible after combined ACL and ALL reconstruction. This finding was confirmed in a separate study by Sonnery-Cottet et al., where high-risk patients who underwent ACL reconstruction using hamstring autograft with ALL reconstruction had a significantly lower rate of subsequent graft rupture compared with patients undergoing isolated ACL reconstruction with hamstring autograft or bone—patellar tendon—bone autograft (2.5 and 3.1 times less rupture rate, respectively). Although concomitant ALL reconstruction may improve outcomes after ACL reconstruction, further clinical and imaging indications for ALL reconstruction must be elucidated.

Limitations

There are multiple limitations of the current study. First, the number of patients in each group was limited by available data within our single institution database. It is possible that the results would be different in a larger group of patients that may be more representative of the whole population. Furthermore, only 43% of potential cases were available for analysis owing to inability to obtain initial injury MRI, which may create selection bias. Given the relatively small sample size, the possibility of a type II error from lack of power remains a distinct possibility, especially if the rate of difference in ALL rupture between the 2 groups is less than 30%. Second, it is possible that patients in the control group did experience graft failure but were lost to follow-up or chose to receive care at another institution. Third, although all patients underwent ACL reconstruction at least 2 years before the final analysis, it is possible that a control patient will experience graft failure outside of the follow-up time frame. Fourth, we are only reporting MRI outcomes as opposed to clinical outcomes scores or return to play data. It is possible that patients in the control group had residual laxity, inability to return to play, or even unknown graft failure but did not seek further care at our institution. Additionally, the musculoskeletal radiologists at our institution have extensive experience identifying the ALL on MRI, although the reported accuracy of doing so on MRI studies is controversial, as discussed. Last, most patients received a hamstring autograft, which is an institutional preference, but this may be a confounding variable compared with other institutions that heavily favor other graft choices.

Conclusions

The incidence of initial ALL injury as documented on MRI was not different in patients who experienced subsequent ACL graft rupture compared with patients who did not experience ACL graft rupture after primary ACL reconstruction. The ALL was more commonly injured on the tibial side in patients with ACL graft rupture and femoral-sided lesions were more common in control patients.

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