Effect of Lateral Extra-articular Tenodesis on the Rate of Revision Anterior Cruciate Ligament Reconstruction in Elite Athletes

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Background: There is growing evidence that anterolateral procedures can reduce the risk of rerupture in high-risk recreational athletes undergoing primary anterior cruciate ligament (ACL) reconstruction (ACLR). However, this effectiveness has never been evaluated in elite athletes.

Purpose: The purpose of this study was to evaluate the effectiveness of lateral extra-articular tenodesis (LET) in reducing revision rates in primary ACLR in elite athletes. Additionally, this study evaluated whether LET had a greater effect when combined with ACLR utilizing a hamstring or patellar tendon graft.

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

Methods: A consecutive cohort of elite athletes with an isolated ACL tear undergoing autograft patellar or hamstring tendon reconstruction with or without Lemaire LET were analyzed between 2005 and 2018. A minimum 2-year follow-up was required. The association between the use of LET and ACL graft failure as defined by revision ACLR was evaluated with univariate and multivariate logistic regression models.

Results: A total of 455 elite athletes (83% men and overall age 22.5 ± 4.7 years) underwent primary ACLR with (n = 117) or without (n = 338) a LET procedure. Overall, 36 athletes (7.9%) experienced ACL graft failure, including 32 (9.5%) reconstructions without a LET and 4 (3.4%) with a LET. Utilization of LET during primary ACLR reduced the risk of graft failure by 2.8 times, with 16.5 athletes needing LET to prevent a single ACL graft failure. Multivariate models showed that LET significantly reduced the risk of graft rupture (relative risk = 0.325; P = .029) as compared with ACLR alone after controlling for sex and age at ACLR. Including graft type in the model did not significantly change the risk profile, and although a patellar tendon graft had a slightly lower risk of failure, this was not statistically significant (P = .466).

Conclusion: The addition of LET reduced the risk of undergoing revision by 2.8 times in elite athletes undergoing primary ACLR. This risk reduction did not differ significantly between the patellar tendon and hamstring tendon autografts. With these results, status as an elite athlete should be included in the indications for a LET, as they are at increased risk for ACL graft failure.

Keywords: anterior cruciate ligament injury; elite athlete; lateral extra-articular tenodesis; risk factor

There has been renewed interest over the past decade in anterolateral procedures in the setting of anterior cruciate ligament (ACL) reconstruction (ACLR).[2,7,21] Although there remains debate regarding indications and ideal surgical techniques,[12] there is growing evidence in the literature that anterolateral procedures can help protect the ACL graft while healing and upon return to activity.[1,13,17,25] Clinically, lateral extra-articular tenodesis (LET) has been shown to be effective in decreasing ACL rerupture rates in high-risk young patients[13] as well as the revision setting.[14,31] However, more research is needed to define the appropriate indications for the addition of a LET.

Elite athletes place higher demands on their ACL grafts than the average patient and unsurprisingly have higher rerupture rates.[4,9,23] Graft failure, even with subsequent revision, is potentially career-ending for an elite athlete. Thus, in 2014, after multiple cadaveric studies that demonstrated that LET offloads the ACL graft without an increase in the lateral compartment or patellofemoral forces,[7,15,19,21,22,33,35] the senior author (A.W.) began routinely performing a LET at the time of primary ACLR in elite athletes. Because of the increased morbidity, such as LET hardware irritation/pain,[13] it is vital to assess whether the addition of a LET provided clinical benefit in this setting.

The purpose of this study was to evaluate the effectiveness of LET in reducing revision rates in primary ACLR in

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elite athletes. Additionally, this study evaluated whether LET had a greater effect when combined with ACLR utilizing a hamstring graft as compared with a patellar tendon graft. Our hypothesis was that adding a LET in the setting of primary ACLR would decrease the rate of ACL revisions in elite athletes. Our secondary hypothesis was that LET would have a greater effect when combined with hamstring autograft ACLR than the patellar tendon.

METHODS

Approval to undertake the study was given by the institution involved in line with UK Health Research Authority guidelines.[16] A retrospective assessment was performed on a consecutive series of elite athletes treated by the senior author who underwent an isolated ACLR with an autograft hamstring or a patellar tendon between January 2005 and December 2018. An elite athlete was defined as one who is paid to perform one's sport or one who participates in national- or international-level competitions in amateur sports—including academy soccer and rugby players aged 15 or over. Revision ACLRs, athletes with 2 or more injured ligaments who underwent surgery, and patients not receiving an autograft hamstring or a patellar tendon graft were excluded. Two patients were excluded because of their graft choices—1 patient who insisted on having an allograft ACLR against medical advice and another who received a quadriceps tendon graft. Patients were required to have a minimum 2-year follow-up.

Demographic data included age, sex, sport played, and level of play. Preoperatively, all patients underwent a complete knee examination, anteroposterior and lateral radiographs, and a magnetic resonance imaging scan. Operative measures collected included the date of surgery, the graft type, and whether a LET was performed. The main outcome of interest was revision ACLR surgery; however, all additional surgeries after ACLR were recorded. Because the study focused on elite athletes and the senior surgeon (A.W.) served as the primary knee consultant for the majority of professional teams in his country, these data were collected through the player or team medical staff in 100% of cases.

Surgical Treatment

Athletes with an ACL rupture were offered an ACLR based on their desire to return to sports and elite sporting status. Based on the athlete's sport and position played, the decision was made to proceed with either a 6-strand hamstring autograft or a patellar tendon autograft ACLR fixed with interference screws in the anteromedial bundle position on the femur and the anterior-most anatomic position on the tibia that did not result in graft impingement.[26] Rugby players have a tradition of having the hamstring utilized, while soccer players have a tradition of having the patellar tendon utilized. Beginning in 2014, a modified Lemaire LET was added for all elite athletes undergoing primary ACLR.[35] There were no other systematic changes to the surgical technique during the study period.

Statistical Analysis

Data were analyzed utilizing Stata statistical software: release 17 (StataCorp LLC). The Shapiro-Wilk test confirmed a normal distribution. Continuous variables were expressed as mean ± SD, and categorical variables were expressed as number and percentage. Univariate logistic regression was utilized to analyze any association between the use of LET and ACL graft failures in the entire cohort and graft type subgroups. Multivariate logistic regression models were utilized to determine the effect of LET and ACL graft type while controlling for age, sex, and date of surgery. Statistical significance was set at $P < .05$.

RESULTS

A total of 455 elite athletes—79 (17%) women and 376 (83%) men—underwent primary ACLR during the study period and met the inclusion criteria. An athlete undergoing ACLR alone had a mean age of 22.9 ± 4.9 years, while an athlete undergoing ACLR with a LET was significantly younger at 21.5 ± 4.1 years ($P = .005$) (Table 1). The majority of the athletes played soccer (254 [56%]) and rugby (136 [30%]), while 65 (14%) athletes engaged in other sports such as cricket, field hockey, judo, gymnastics, and netball. Sports played did not differ significantly according to LET status ($P = .615$). Associated knee injuries, such as meniscal pathology, were not significantly different according to LET status ($P = .095$); however, there were significantly more chondral injuries in patients who were treated with a LET in addition to ACLR ($P = .006$).

ACLR utilizing hamstring autografts was performed in 272 (60%) of cases, while 183 (40%) utilized patellar tendon autografts (Figure 1). Hamstring autografts were performed with a LET in 52 (11%) of cases and alone in 220

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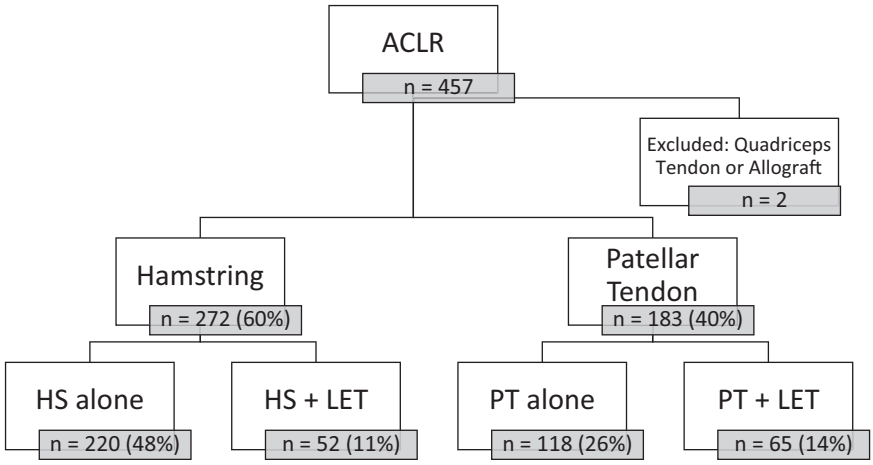

Figure 1. Flowchart of study participants depicting anterior cruciate ligament (ACL) graft type and LET procedures. ACLR, ACL reconstruction; HS, hamstring; LET, lateral extra-articular tenodesis; PT, patellar tendon.

TABLE 1
Patient and Injury Characteristics According to LET Status[a]

	ACLR Alone (n = 338)	ACLR + LET (n = 117)	*P*
Age at surgery, y, mean ± SD	22.9 ± 4.9	21.5 ± 4.1	.005
Female sex	64 (19)	15 (13)	.132
Sport			.615
Soccer	191 (57)	63 (54)	
Rugby	97 (29)	39 (33)	
Other	50 (15)	15 (13)	
Meniscal pathology			.095
Partial meniscectomy	65 (19)	15 (13)	
Repair	151 (45)	67 (58)	
Stable (left alone)	18 (5)	4 (4)	
Normal	101 (30)	29 (25)	
Associated chondral injury	25 (8)	18 (16)	.006

[a]Data are presented as n (%) unless otherwise indicated. ACLR, anterior cruciate ligament reconstruction; LET, lateral extra-articular tenodesis.

(48%) of cases. Similarly, patellar tendon autografts were performed with a LET in 65 (14%) of cases and alone in 118 (26%) of cases. Overall, a LET was performed in conjunction with the ACLR in 117 (26%) of athletes.

At a mean of 10.1 ± 3.1 months after ACLR, more than 88% (400/455) of elite athletes were able to compete at their preinjury level. However, 51 (11%) of the athletes did not return to their preinjury level and either retired from sports or returned to a lower level of competition. For 4 (1%) athletes, we were not able to determine a return to the competition level because of league changes and contract issues. Return to preinjury level of competition did not differ significantly according to LET status.

Overall, 36 out of 455 (7.9%) athletes in the study experienced ACL graft failure as defined by revision ACLR at a median of 13.2 months after primary ACLR, with 15 (3.3%) occurring at <1 year, 13 (2.9%) between 1 and 2 years, and 8 (1.8%) at >2 years (Table 2). Also, 32 of the 36 ACL graft failures occurred in athletes treated with ACLR alone and 4 failures occurred in athletes treated with ACLR and LET. Of the 7 athletes who experienced ACL graft failure before return to play, all received ACLR alone and none were treated with LET.

TABLE 2
Timeline of ACL Graft Failure Cases[a]

Time	ACLR Alone (n = 338)	ACLR + LET (n = 117)
<1 year	13 (3.8)	2 (1.7)
Before return to play	7 (2.1)	0
After return to play	6 (1.8)	2 (1.7)
Between 1 and 2 years	12 (3.6)	1 (0.9)
After 2 years	7 (2.1)	1 (0.9)
Total	32 (9.5)	4 (3.4)

[a]Data are presented as n (%). ACLR, anterior cruciate ligament reconstruction; LET, lateral extra-articular tenodesis.

Results of the univariate logistic regression analysis showed that in the athletes who underwent isolated ACLR, 32 of 338 (9.5%) underwent revision ACLR, compared with 4 of 117 (3.4%) in the ACLR with LET cohort (relative risk [RR] = 0.360; $P = .045$) (Table 3). This equated to a 2.8-times reduced risk of graft failure, and the number needed to treat to prevent 1 graft failure was 16.5 patients. Subgroup analyses by graft type yielded similar ratios but did not reach statistical significance; however, these analyses are underpowered because of the low number of ACL graft failures in the LET patient group.

Overall, 20% of athletes had subsequent knee surgery before returning to play. The indications for additional surgery were meniscal pathology (45%), limited range of motion (29%), and osteochondral pathology (9%). There were no significant differences in the indications for additional surgery before returning to play when evaluating ACL graft type ($P = .776$) or adding LET ($P = .322$). However, in the ACLR with LET group, 2 patients (1.7%) had

TABLE 3
Revision Rates for Primary ACLR[a]

	Total	No Revision, n (%)	Revision, n (%)	Statistic	*P*
ACLR alone	338	305 (90.5)	32 (9.5)	RR = 0.360	.045
ACLR + LET	117	113 (96.6)	4 (3.4)	NNT = 16.5	
Patellar tendon graft subanalysis					
PT ACLR alone	118	108 (91.5)	10 (8.5)	RR = 0.363	.176
PT ACLR + LET	65	63 (96.9)	2 (3.1)	NNT = 18.6	
Hamstring tendon graft subanalysis					
HS ACLR alone	219	197 (90)	22 (10)	RR = 0.383	.174
HS ACLR + LET	52	50 (96.2)	2 (3.8)	NNT = 16.1	

[a]ACLR, anterior cruciate ligament reconstruction; HS, hamstring tendon; LET, lateral extra-articular tenodesis; NNT, number needed to treat; PT, patellar tendon; RR, relative risk.

TABLE 4
Multivariate Logistic Regression Models Predicting the Risk of ACL Graft Failure in Patients With and Without a LET Procedure at the Time of ACLR[a]

	Model 1			Model 2		
	RR	95% CI	*P*	RR	95% CI	*P*
ACLR + LET	0.325	0.114-0.894	.029	0.345	0.120-0.953	.040
ACLR alone [Reference]	1			1		
Age at surgery, years	0.959	0.894-1.029	.245	0.960	0.895-1.029	.250
Male sex	2.352	0.828-5.180	.104	2.461	0.867-5.538	.087
Patellar tendon graft				0.768	0.382-1.490	.446
Hamstring [Reference]				1		

[a]ACLR, anterior cruciate ligament reconstruction; LET, lateral extra-articular tenodesis; RR, relative risk.

a staple removed before returning to play. The rate of athletes having a subsequent surgery due to limited range of motion—manipulation under anesthesia, cyclops lesion, or fat pad impingement—was 6% in both the ACLR with LET and ACLR-alone patient groups.

Multivariate logistic regression models were used to evaluate the effectiveness of the LET procedure to prevent ACL graft failure. The first model evaluated the effectiveness of LET while accounting for sex and age at surgery. A second model included the graft type (patellar tendon or hamstring tendon) to evaluate any change in RR. The surgery date was initially included in the models to account for subtle changes in surgical technique over time. However, surgery date and LET utilization was highly correlated (r = 0.7) and the surgery date had to be excluded from the models because of collinearity.

The first multivariate logistic model demonstrated that the addition of LET to primary ACLR significantly reduced the risk of graft rupture (RR = 0.325; P = .029) as compared with ACLR alone after controlling for sex and age at surgery (Table 4). Age and sex were not significant predictors of graft failure; however, this population consisted of elite athletes who were predominately men and between the ages of 18 and 25 years. A second model was constructed to evaluate whether LET had a greater effect when combined with hamstring or patellar tendon graft choice during ACLR. A patellar tendon graft had a slightly lower risk of failure; however, this was not significantly different from a hamstring tendon graft (RR = 0.768; P = .466), and the risk of graft failure for LET—in addition to ACLR, age at surgery, and sex—was similar in both models.

DISCUSSION

The present study demonstrated that the addition of a LET to primary ACLR led to a 2.8-times reduced risk of ACL graft failure in elite athletes, from 9.5% to 3.4%. LET had a similar effect when combined with hamstring or patellar tendon autografts. Furthermore, there were no ACL graft failures before return to play in the athletes who received a LET in conjunction with primary ACLR. The addition of a LET did not increase the number of subsequent surgeries; however, 2 patients did have a staple removed before returning to play.

The ACLR with LET failure rate of 3.4% compares favorably with the literature regarding graft rerupture in elite athletes. A recent meta-analysis reported a 5.2% rerupture rate in all elite athletes.[23] In elite soccer players, who comprised a high percentage of the present study, rerupture rates ranged[4,9] from 7.7% to 9.3%. This is in line with the rerupture rate of 9.5% in the present study when an isolated ACLR was performed, which further supports the hypothesis that LET was responsible for the decrease in the rerupture rate.

This study adds to the growing literature demonstrating that the addition of a LET can be a tool in reducing failure in high-risk primary ACLR while adding the patient's status of being an elite athlete as a potential indication for a LET.[1,13,28,30] Even though there is renewed interest in this subject, it is important to note that this is not a new procedure. The first description of the clinical benefits of LET was in 1991 when Noyes and Barber[28] reported that when treating chronic ACL ruptures, the addition of a LET decreased the rerupture rate from 16% to 3%.

The procedure fell out of favor because it was thought to be superfluous to the intra-articular reconstruction alone and with increased morbidity. Anatomic and biomechanical studies in the early 2010s again highlighted the fact that intra-articular ACLR alone fails to restore intact ACL kinematics and a realization of the importance of the function of lateral extracapsular structures in this regard.[2,7,21] This led to the biomechanical evaluation of LET, which was shown to decrease the forces applied to the ACL graft[8,25] and restore stability to the knee that cannot be restored by an intra-articular ACLR graft alone.[19,20,27,32] Two systematic reviews of clinical studies determined that the addition of a LET was effective in reducing the incidence of persistent pivot shift but did not find any difference in clinical outcomes.[5,17]

In 2020, Getgood et al[13] evaluated the effects of LET on graft rerupture in primary ACLR. The STABILITY trial was a randomized prospective controlled trial that showed that the addition of a LET to ACLR decreased the risk of rerupture from 11% to 4% in young, high-risk patients undergoing primary ACLR with hamstring autograft. While Getgood et al[13] focused on a high-risk cohort determined by a combination of the patient's age, amount of laxity, and activity level in the general population, the present study focuses on the elite athlete population. The present study supports previous reports of ACL graft failure rates, demonstrating that simply being an elite athlete places a patient in the "high-risk group,"[4,9,23] and therefore arguably being in this patient group should be an indication for supplementary LET. Later in 2020, Porter and Shadbolt[30] reported a decrease in rerupture from 14% to 0% when a LET was added to patients who had a persistent pivot shift intraoperatively after isolated hamstring ACLR. They also noted better patient-reported outcome measures in patients who had a LET. In 2020, Castoldi et al[1] reported a 19-year follow-up on their cohort of 121 consecutive patients, of whom half were randomized to receive isolated patellar tendon ACLR and the other half patellar tendon ACLR plus LET. They noted a 29% failure rate in the isolated patellar tendon group compared with 13% in the group with LET, but this did not reach statistical significance.

It is important to address concerns that are expressed by some regarding the potential for "overconstraint" with lateral extra-articular procedures. The implication of this is that LET could lead to lateral compartment degenerative change.[33] A modified Lemaire tenodesis was used in these patients because of a biomechanical study that confirmed no increase in lateral compartment articular pressures when the tenodesis was fixed at 0°, 30°, 60°, or 90° of flexion and neutral rotation and without undue tension,[19] which has subsequently been confirmed.[34] A definite potent cause of osteoarthritis is uncontrolled abnormal kinematics due to ACL deficiency.[3] In a recent meta-analysis that included 3 studies with a follow-up of more than 15 years, there was no evidence of an increase in osteoarthritis with the addition of a LET.[6,29,36,37]

Just recently, the STABILITY group[10] and Mahmoud et al[24] both reported lower graft rupture rates in patients undergoing a LET in conjunction with ACLR. These studies prompted an editorial commentary by Alan Getgood[11] to summarize the indications for a LET procedure with ACLR that included high-risk patients, defined as those aged 14 to 25 years, with $\geq$2 of the following risk factors: (1) returning to contact pivoting sport; (2) high-grade anterolateral rotatory laxity; and (3) generalized ligamentous laxity. The results of our study confirm these indications for LET; however, they also introduce a fourth risk factor—elite athletes. With the significant career consequences of ACL rerupture in elite athletes, combined with the increased risk of osteoarthritis from any persisting anterolateral instability after ACLR, the benefits of LET should be considered when treating elite athletes with an ACL injury.

Limitations are acknowledged for this study. The first limitation is the use of revision ACLR as a measure of failure. There is a possibility that some athletes could have sustained an ACL graft failure but were able to continue playing at a high level, potentially because of the stability imparted by LET. Second, this cohort of patients includes elite athletes. Although elite athletes provide a valuable source of study because of their high physical demands, the findings in this study may not apply to the general population. Because of their attachment to sports teams, elite athletes are easy to track after surgery, especially for coarse data such as graft failure, and very high follow-up rates are expected, and hence our 100% follow-up rate. It is important to note that this study does not suggest that all patients undergoing ACLR should also have a LET; rather it aims to add status as an elite athlete as a potential indication for LET. Importantly, this study did not rely on publicly available data, whose inherent biases have recently been highlighted,[18] but rather was founded on the senior surgeon's practice data.

CONCLUSION

The addition of a LET reduced the risk of undergoing revision ACLR by 2.8 times in elite athletes undergoing primary ACLR. This risk reduction did not differ significantly between the patellar tendon and hamstring tendon autografts. With these results, status as an elite athlete should be included as an indication for a LET, as they are at increased risk for ACL graft failure.

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