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Trends in Anterolateral Ligament Reconstruction and Lateral Extra-articular Tenodesis With ACL Reconstruction in Children and Adolescents

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Background: Anterolateral ligament reconstruction (ALLR) and lateral extra-articular tenodesis (LET) show promise in lowering the risk of rerupture after anterior cruciate ligament reconstruction (ACLR), but there are little data on surgeon practices and preferences in children and adolescents.

Purpose: To quantify surgeon practices regarding ALLR and LET in the pediatric population.

Study Design: Cross-sectional study.

Methods: An electronic survey was administered to 87 surgeons in the Pediatric Research in Sports Medicine society. The questionnaire asked several questions about surgeon and practice characteristics as well as indications, preferences, and techniques for ALLR or LET in the context of primary and revision pediatric ACLR. Chi-square and Fisher exact tests were used to evaluate factors that affect surgical preferences.

Results: A total of 63 surgeons completed the survey, of whom 62% performed ≥ 50 pediatric ACLRs annually; 56% sometimes performed anterolateral augmentation with primary ACLR, and 79% with revision ACLR. The most common indications for ALLR or LET in the primary setting were high-grade pivot shift, knee hyperextension, generalized laxity, and type of sports participation. Surgeons whose practice was $>75\%$ sports medicine were more likely to perform ALLR or LET with both primary and revision ACLR ($P = .005$ and $P < .001$, respectively). Those who had completed a sports medicine fellowship were more likely to perform these procedures than those with only pediatric orthopaedic training, in both primary (68% vs 36%; $P = .01$) and revision scenarios (92% vs 60%; $P = .002$). Of the 28 respondents who did not perform ALLR or LET with primary ACLR, 75% cited insufficient evidence as the reason. However, 96% of surgeons who did perform these procedures expressed interest in studying them prospectively, and 87% were willing to randomize patients.

Conclusion: Findings indicated that 56% of pediatric sports surgeons sometimes perform anterolateral augmentation with primary ACLR and 79% with revision ACLR. Surgeons with sports medicine fellowship training or a mostly sports practice were more likely to perform these procedures. Insufficient evidence was the most common reason given by surgeons who did not perform anterolateral augmentation. However, there was substantial willingness to prospectively study and even randomize pediatric patients to assess the impact of ALLR or LET in this population.

Keywords: anterior cruciate ligament; anterolateral ligament; lateral extra-articular tenodesis; pediatric sports medicine

The incidence of anterior cruciate ligament (ACL) injuries has increased significantly in the pediatric population, with peak incidence during high school years.^{1,3,32} Prompt, effective treatment is important given the elevated risk for subsequent cartilage or meniscal injury, as well as persistent instability and earlier-onset osteoarthritis in this young,

active age group.^{8,16} Compared with adults, children and adolescents are at increased risk for graft failure, which may require revision surgery with worse outcomes as well as substantial financial and psychosocial burdens.^{5,10} Therefore, interventions that lower the high risk of reinjury in this population merit investigation.

There is growing interest in the contribution of anterolateral structures in the setting of ACL reconstruction (ACLR). Accordingly, the literature on additional anterolateral procedures like anterolateral ligament (ALL)

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reconstruction (ALLR) and lateral extra-articular tenodesis (LET) continues to increase. While debate persists regarding the implications of these procedures, clinical data suggest that they may help lower the risk of reinjury when performed with ACLR.^{9,11,12} Such techniques could be impactful in high-risk children and adolescents, but there are little data specific to this population.

Given the debate surrounding ALLR and LET, further clinical investigation in the pediatric population may provide the evidence needed to better guide treatment. However, surgeon practices and preferences regarding these procedures are not well-established. Such information can help gauge surgeon interest in future research, as well as frame the questions that need to be addressed. Without an understanding of these practices, development of efficient, impactful clinical research may be difficult. Such data can also be used as a baseline to assess how trends in clinical practice respond to growing literature in years to come. Therefore, the purpose of this study was to assess surgeon practices and preferences regarding anterolateral augmentation procedures in pediatric ACLR while summarizing some of the recent literature in this setting.

METHODS

After receiving institutional review board approval for this study, we distributed an electronic survey to 87 surgeons in the Pediatric Research in Sports Medicine society who perform ACLRs in the pediatric population. Data were collected via Research Electronic Data Capture (REDCap) at the primary institution. We did not ask for the respondent's name, institution, contact information, or other easily identifiable data. Trainees (students, residents, and fellows) were excluded. Two reminder emails were sent to all surgeons 6 to 8 weeks apart.

For the purposes of this study, ALLR was defined as an independent procedure involving a graft with distinct attachment points on the lateral aspects of the distal femur and proximal tibia based on previous anatomic studies. LET was defined as any other independent, anterolateral procedure that seeks to provide additional stability without necessarily re-creating the anatomic characteristics of the ALL. Examples include the modified Lemaire, MacIntosh, and Ellison techniques. The Kocher-Micheli procedure, a variation of the MacIntosh technique that can be utilized as a nonanatomic primary ACLR in skeletally immature patients, was not considered a form of LET/ALLR in this study.

The survey included several different domains. Demographic questions focused on clinical training and practice background as well as quantification of pediatric ACLR volume. The next section inquired about ALLR or LET surgical technique, including the frequency at which respondents perform these procedures with primary or revision ACLR in patients aged 18 years or younger. For those who did not routinely perform these operations, we asked about the reasons that may affect this preference. Surgeons who perform 5 or more ALLR or LET procedures annually were queried about which factors they consider when performing anterolateral augmentation with primary ACLR, as well as graft type and knee position when tensioning the anterolateral graft. The final section of the survey focused on postoperative concerns, including the impact of anterolateral augmentation procedures on rehabilitation protocols and return to sports as well as complications. Finally, respondents were asked if they would be interested in participating in prospective research on this topic, as well as their willingness to randomize patients in a clinical trial where participants would be assigned to 1 of 2 study arms: (1) ACLR or (2) ACLR with ALLR or LET.

Responses were collected anonymously and analyzed independently. Statistical analysis was completed with SPSS for Mac Version 27.0 (IBM). Standard descriptive statistics were calculated for all responses. Categorical variables were analyzed using chi-square or Fisher exact tests, as appropriate. A significance threshold of $P < .05$ was applied for all statistical tests.

RESULTS

Complete survey responses were received from 63 of 87 attending surgeons (72.4%), of whom 61.9% performed ≥ 50 pediatric ACLRs annually. Most respondents practiced in a fully or partially academic setting. Survey respondent details are displayed in Table 1. In the setting of primary ACLR, 35 of 63 surgeons (55.6%) perform it combined with either ALLR or LET at least once per year (Table 2). The frequency increased to 50 of 63 (79.4%) with revision ACLR (Table 2).

Surgeons whose practice was $>75\%$ sports medicine were more likely to sometimes consider ALLR or LET with primary ACLR (27/39; 69.2%) than those with a practice that was $\leq 75\%$ sports medicine (8/24 [33.3%]; $P = .005$). This trend continued for revision ACLR (37/39 [94.9%] vs 13/24 [54.2%]; $P < .001$). Those who had completed a sports medicine fellowship (either alone or with a pediatric

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Ethical approval for this study was obtained from Ann & Robert H. Lurie Children's Hospital of Chicago (reference No. 2017-1235).

TABLE 1
Characteristics of Survey Respondents^a

	n (%)
Primary practice type	
Academic	36 (57.1)
Mix of academic and private	12 (19.0)
Private	8 (12.7)
Hospital employee	7 (11.1)
Fellowship training	
Pediatric orthopaedics and sports medicine	29 (46.0)
Pediatric orthopaedics only	24 (38.1)
Sports medicine only	9 (14.3)
None	1 (1.6)
Practice location	
West	21 (33.3)
East	20 (31.7)
South	13 (20.6)
Midwest	7 (11.1)
Outside of the United States	2 (3.2)
Years in practice	
<5	16 (25.4)
5-10	23 (36.5)
11-15	9 (14.3)
>15	15 (23.8)
Percentage of practice involving patients aged ≤18 y	
<25	2 (3.2)
25-50	3 (4.8)
50-75	5 (7.9)
>75	53 (84.1)
Percentage of practice involving pediatric orthopaedics	
<25	11 (17.5)
25-50	4 (6.3)
50-75	5 (7.9)
>75	43 (68.3)
Percentage of practice involving sports medicine	
<25	2 (3.2)
25-50	5 (7.9)
50-75	17 (27.0)
>75	39 (61.9)
No. of ACLRs performed annually in patients aged ≤18 y	
<25	11 (17.5)
25-49	13 (20.6)
50-99	28 (44.4)
100-149	10 (15.9)
>149	1 (1.6)
No. of ACLRs performed annually in skeletally immature patients	
<5	8 (12.7)
5-19	25 (39.7)
20-34	21 (33.3)
35-49	3 (4.8)
>49	6 (9.5)
Revision ACLRs performed annually	
<10	45 (71.4)
10-25	15 (23.8)
26-40	1 (1.6)
41-55	1 (1.6)
>55	1 (1.6)

^aACL, anterior cruciate ligament reconstruction.

orthopaedic fellowship) were more likely to perform anterolateral augmentation than those with only pediatric orthopaedic training in both primary (26/38 [68.4%] vs

TABLE 2
Surgical Practices and Preferences^a

	n (%)
Perform ALLR or LET with primary ACLR	
LET	22 (34.9)
Modified Lemaire	18 (81.8)
Modified MacIntosh	3 (13.6)
Other	1 (4.5)
ALLR	13 (20.6)
Neither	28 (44.4)
Perform ALLR or LET with revision ACLR	
LET	32 (50.8)
Modified Lemaire	28 (87.5)
Modified MacIntosh	4 (12.5)
ALLR	18 (28.6)
Neither	13 (20.6)
No. of ALLRs or LETs performed annually with primary ACLR	
<5	40 (63.5)
5-19	16 (25.4)
20-34	2 (3.2)
35-49	4 (6.3)
>49	1 (1.6)
Considerations for ALLR or LET with primary ACLR ^b	
Severity of pivot-shift test	20 (87.0)
Knee hyperextension	20 (87.0)
Generalized ligamentous laxity	19 (82.6)
Type of sports participation	18 (78.3)
Presence of Segond fracture	9 (39.1)
Female sex	7 (30.4)
Genu valgum	3 (13.0)
ACL graft diameter <8 mm	1 (4.3)
Lateral posterior tibial slope >8°	1 (4.3)
Graft preference ^b	
Iliotibial band	18 (78.2)
Allograft	5 (21.7)
Knee flexion when tensioning ALLR or LET graft ^b	
0°	8 (34.8)
30°	4 (17.4)
45°	2 (8.7)
60°	4 (17.4)
90°	4 (17.4)
No preference	1 (4.3)
Tibial position when tensioning ALLR or LET graft ^b	
Neutral	19 (82.6)
External rotation	2 (8.7)
Internal rotation	0 (0.0)
No preference	2 (8.7)

^aACL, anterior cruciate ligament; ACLR, ACL reconstruction; ALLR, anterolateral ligament reconstruction; LET, lateral extra-articular tenodesis.

^bThese questions were only asked of respondents performing ≥5 ALLR or LET procedures annually with primary ACLR.

9/25 [36.0%]; *P* = .01) and revision (35/38 [92.1%] vs 15/25 [60.0%]; *P* = .002) scenarios. None of the other demographic variables shown in Table 1 had an impact on surgeon preference to perform ALLR or LET.

The most common indications for anterolateral augmentation in the primary setting were high-grade pivot shift (defined as pre- or intraoperative pivot-shift grade of 3),

TABLE 3
Postoperative Practices^a

	n (%)
Impact of ALLR or LET on rehabilitation protocol	
Accelerates	0 (0.0)
Decelerates	3 (13.0)
No impact	20 (87.0)
Impact of ALLR or LET on timing of return to sports	
Accelerates	0 (0.0)
Decelerates	1 (4.3)
No impact	22 (95.7)
Complications experienced directly related to ALLR or LET	
Cosmetic issues	12 (52.2)
Knee stiffness (did not require reoperation)	8 (34.8)
Prolonged pain	7 (30.4)
Infection	4 (17.4)
Knee stiffness requiring reoperation	4 (17.4)
ALL/LET graft rupture	3 (13.0)
Implant prominence requiring reoperation	1 (4.3)
Growth disturbance	1 (4.3)

^aThese questions were only asked of respondents performing ≥ 5 anterolateral augmentation procedures annually. ALL, anterolateral ligament; ALLR, ALL reconstruction; LET, lateral extra-articular tenodesis.

knee hyperextension (defined as $>10^\circ$), generalized laxity, and type of sports participation. There was substantial variability in preferred knee position when tensioning the anterolateral graft. No surgeons listed skeletal maturity (open vs closed physes) as a factor for considering anterolateral augmentation in children and adolescents. Details regarding surgical practices and preferences are shown in Table 2. The modified Lemaire technique was most commonly preferred by those who routinely performed LET. These respondents preferred LET over ALLR for the following reasons: "I am more experienced with it" (n = 10); "I believe it is superior biomechanically" (n = 9); "Cheaper with a longer track record" (n = 1); and "The ALL is a capsular thickening, not a true ligament" (n = 1). For those who never performed ALLR or LET with primary ACLR, the following rationales were provided: "I do not believe there is sufficient evidence to warrant it" (n = 21); "I am concerned about overconstraining the knee" (n = 4); "I have not encountered the right patient for it in my practice" (n = 2); "I believe the risks of the operation outweigh the benefits" (n = 1). Postoperatively, most respondents did not alter their typical ACLR rehabilitation protocol if concomitant anterolateral augmentation was performed. The most common complication directly related to ALLR or LET was cosmetic issues (Table 3).

As previously noted, 75% of the respondents who never performed ALLR or LET with primary ACLR cited insufficient evidence as the reason. Conversely, of the surgeons who performed 5 or more of these procedures annually, 22 of 23 (95.7%) expressed interest in studying them prospectively. Twenty of the 23 surgeons (87.0%) were willing (n = 12) or possibly willing (n = 8) to randomize patients in a clinical trial on this topic. The following conditions or

reservations were expressed by those who were possibly willing to randomize: "Depends on inclusion criteria" or "details of the study"; "Exclude hypermobile patients"; and "Exclude prepubescent patients." Some of these surgeons felt uncomfortable randomizing patients they felt were at highest risk of ACL reinjury: "I would have a hard time with clinical equipoise randomizing an adolescent female soccer player. They are all getting ALLR at this point"; "Would still want to add ALLR for all that hyperextend over 10° "; and "Some measures of laxity or other risk factors suggest that LET/ALLR is necessary."

DISCUSSION

There remains little data specific to additional anterolateral procedures in the pediatric population despite the high risk of ACL reinjury in this age group.⁵ The present study found that while there is wide variation in practice, certain factors increase the likelihood of surgeons considering ALLR or LET in children and adolescents. These include high-grade pivot shift, knee hyperextension, generalized laxity, and type of sports participation as well as revision reconstruction. Surgeons who had completed a sports medicine fellowship or had a predominantly sports practice were more likely to perform combined procedures. While the surgeons who did not perform these procedures cited scarcity of evidence as the biggest deterrent, some respondents that did routinely perform them felt they are often so strongly indicated that they may be uncomfortable randomizing certain high-risk patients in a trial. Nonetheless, there was a strong interest in participating in further investigation on this evolving subject.

LET procedures such as the Lemaire or MacIntosh have regained popularity, as recent studies demonstrate added knee stability in the context of modern ACLR.^{13,15,17} In a randomized controlled trial of 618 high-risk patients with a mean age of 19 years, Getgood et al⁹ found that combined ACLR and LET significantly reduced the rate of graft failure compared with isolated hamstring ACLR. Feller et al⁶ recently described the results of the modified Ellison LET in 25 patients. Twenty of the patients were younger than 18 years of age, and only 1 experienced a graft rupture. A number of ALLR techniques have also been developed, and studies have yielded encouraging results.^{12,19,21,26} In the present study, substantial practice variability was found within surgeons who perform ALLR or LET, with the majority preferring LET. Respondent preferences for knee position during tensioning were also variable and reflected inconclusive literature on the effects of flexion angle in ALLR and LET.^{14,27} Further research is needed to better compare various surgical techniques.

There is minimal literature on anterolateral augmentation specifically in children and adolescents, and this was listed as a deterrent to performing ALLR or LET by a third of our respondents. The modified MacIntosh procedure, as popularized by Kocher and Micheli,¹⁸ is a combined intra- and extra-articular ACLR for skeletally immature patients that was developed before recent interest in anterolateral knee structures. The graft rupture rate was 6.6% in long-

term follow-up of 237 patients. Some of the success of this technique may be related to the extra-articular portion of the iliotibial (IT) band graft. Another novel procedure described by Wilson et al³⁰ utilizes a combined transphyseal hamstring autograft and extraosseous IT band graft, with both fixed within the same tibial tunnel. In a case series of 61 knees, the authors report an ACL reinjury rate of 5.3%. A physeal-sparing technique for combined LET and ALLR was recently described, but clinical outcomes are yet unknown.²³ Given the results of these techniques as well as the growing adult literature on anterolateral augmentation, there may be utility for ALLR and LET in children and adolescents.

LET and ALLR may be increasing in popularity. In 2018, Tramer et al²⁸ reported that 38.2% of surgeons in the AOSSM performed anterolateral augmentation procedures. The majority felt that the number of these procedures would stay the same or increase in the coming years. In our study, 56% of surgeons sometimes perform ALLR or LET with primary ACLR. This could be due, in part, to recent studies demonstrating clinical benefit with combined procedures.^{9,19,26} Our study is also specific to the pediatric population, which is at highest risk of ACL reinjury and therefore might lead surgeons to perform these interventions more frequently than in adults, albeit with greater concern about side effects and complications. For example, a clinical trial with long-term follow-up reported a higher rate of lateral compartment osteoarthritis in patients undergoing ACLR with LET.⁴ However, this analysis did not adjust for the presence of concomitant lateral meniscal tears, which were more frequent in patients that received LET. Similar to the variability seen in previous research on pediatric ACLR practices,²⁴ surgeons who had completed a sports fellowship or whose practice was primarily sports medicine were more likely to perform anterolateral augmentation procedures. The reasons for this are beyond the scope of the data, but it is possible that exposure to these techniques has increased during training and in specific conferences and journals, per the predictions of Tramer et al.

In this study, the most common considerations for performing ALLR or LET with primary ACLR were high-grade pivot shift, knee hyperextension, generalized laxity, and type of sports participation. Most of these factors have been associated with either residual laxity after ACLR or subsequent revision surgery. Yamasaki et al³¹ found that knee hyperextension greater than 8° was significantly associated with postoperative laxity after ACLR. In a prospective cohort study, Magnussen et al²² reported that preoperative pivot-shift grade of 3 and generalized laxity were associated with significantly higher odds of revision ACLR at 6 years of follow-up. Furthermore, damage to the anterolateral structures of the knee is an important indicator of high-grade preoperative pivot shift.⁷ This is especially noteworthy for the pediatric population, since age younger than 18 years may be a risk factor for postoperative graft laxity even without reinjury.³¹ Alm et al² noted that patients with knee laxity and grade 3 pivot shift experienced higher revision failure rates and that ACLR/LET significantly reduced rates of graft rupture in these settings. We found that 79%

of surgeons consider ALLR or LET with revision ACLR. Lee et al²⁰ reported that patients who underwent revision ACLR with ALLR had significantly better patient-reported outcome scores and a higher rate of return to previous athletic levels compared with those who underwent isolated revision ACLR. Other studies report that combining revision ACLR with LET yields significant improvements with postoperative pivot-shift and Lachman testing.^{25,29} Finally, our respondents suggested that athletes returning to specific high-risk sports³ may benefit from concomitant anterolateral augmentation.

Our investigation is not without limitations. As a survey study, it was designed to identify practices and preferences rather than make clinical conclusions. Additionally, there may be subtle factors that influence these trends that could not be accounted for in the survey, as there are myriad complex issues surrounding additional anterolateral procedures in the setting of primary ACLR. Most respondents practiced in a fully or mixed-academic environment, which may limit the generalizability of our results. The study is also subject to sampling bias, as it is possible that surgeons who hold strong opinions on ALLR or LET were more likely to respond.

CONCLUSION

Despite these limitations, our study found that just over half of pediatric sports surgeons sometimes perform ALLR or LET with primary ACLR, with high-grade pivot shift, knee hyperextension, generalized laxity, and high-risk sports participation as common indications. Additional research on anterolateral augmentation is especially needed in the high-risk pediatric population, as a large proportion of respondents in this study cited insufficient evidence as a barrier to adopting these procedures. Such research requires interest on the part of surgeons, without which meaningful studies are difficult to design. Notably, a very high percentage of respondents to this survey who perform ALLR or LET expressed interest in prospective research and were even willing to randomize patients. The results of this study help gauge surgeon interest in future research as well as frame the questions that need to be addressed. Such evidence may ultimately help guide treatment and identify the impact of additional anterolateral procedures on children and adolescents undergoing ACLR.

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