Painful Palpation of the Tibial Insertion of the Anterolateral Ligament Is Concordant With Acute Anterolateral Ligament Injury

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Background: The anterolateral ligament (ALL) has been shown to contribute to the rotational stability of the knee. However, no clinical sign specific to ALL injury has been described.

Purpose/Hypothesis: The primary aim of this study was to determine the concordance between pain elicited upon ALL palpation and ALL injury diagnosed by ultrasonography (US). The secondary aim was to look for a relationship between ALL injury and high-grade pivot shift. We hypothesized that an ALL lesion can be diagnosed clinically in an acute knee injury by palpating its tibial insertion.

Study Design: Cohort study (diagnosis); Level of evidence, 2.

Methods: A total of 130 patients (89 men, 41 women; mean age, 27.2 ± 8.3 years) with an acute, isolated anterior cruciate ligament injury who were scheduled for ligament reconstruction were enrolled in this study. ALL palpation was carried out a mean 8.8 ± 3.2 days after injury. Preoperatively, ALL integrity was evaluated with US, and the pivot shift was determined under general anesthesia. The agreement between pain upon ALL palpation and ALL injury detected on US was determined by calculating the intraclass correlation coefficient (ICC), along with 95% CIs.

Results: Distal palpation of the ALL tibial insertion elicited pain in 67 (51.5%) patients, and upon US the ALL was found to be damaged in 64 (49.2%) patients. The agreement between pain over the ALL tibial insertion and the ALL being damaged on US was excellent (ICC, 0.801; 95% CI, 0.730-0.855). Moreover, the clinical test had excellent sensitivity (92%; 95% CI, 88%-97%) and specificity (88%; 95% CI, 82%-93%). The agreement between pain at the ALL distal insertion and the pivot shift was good (ICC, 0.654; 95% CI, 0.543-0.742), and ALL palpation had excellent diagnostic accuracy for identifying rotational instability (sensitivity, 88% [95% CI, 82%-93%]; specificity, 97% [95% CI, 94%-100%]).

Conclusion: Palpation of the ALL tibial insertion highly correlates with ultrasonographic evidence of an ALL injury in the context of an acute knee injury. This simple test should become part of our standard examination when evaluating patients with acute knee injuries.

Keywords: anterolateral ligament; ACL tear; ultrasonography; pivot shift; rotational instability

There has been renewed interest in the contribution of the anterolateral ligament (ALL) to knee stability.[32] However, diagnosing ALL injuries has been challenging because no clinical sign specific to ALL injuries has been described.[40]

The relationship between ALL injury and anterolateral instability has been highlighted.[2] A significant relationship between ALL injury and a high-grade pivot shift was also reported in a pilot study.[3] However, the pivot shift is a multidimensional test evaluating overall rotational instability, not only instability attributed to ALL injury.[6,30] Thus, the pivot shift is not specific to ALL injury.

Some authors believe that ALL injury is an indication for lateral tenodesis or ALL reconstruction.[4,35] In this context of "à la carte" surgical treatment, it seems essential to define a clinical test specific to ALL injury that will allow these injuries to be diagnosed accurately.

ALL injury always occurs at the tibial insertion,[7,14] which is located halfway between the Gerdy tubercle and the fibular head.[9] This area is superficial, immediately subcutaneous, and easy to palpate. ALL injuries are often accompanied by a bone injury, with the presence of a hematoma.[3,4,25] Thus, it is likely that palpation of such an injury would elicit pain, especially when acute.

Ultrasonography (US), which has been shown to be a reliable modality for diagnosing ALL injuries,[2,4,14] especially small bone injuries such as an ultrasonographic Segond lesion,[5] can serve as a diagnostic reference tool.

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Furthermore, the in vivo relationship between ALL injury and the presence of a high-grade pivot shift has been reported in a small pilot study.[3] This finding needs to be confirmed in a large-scale study.

We hypothesized that an acute ALL lesion can be diagnosed clinically by palpating its tibial insertion in the context of an acute knee injury. The primary aim of this study was to determine the agreement between pain elicited upon ALL palpation and ALL injury diagnosed by US. The secondary aims were to quantify the relationship between clinical ALL injury (in palpation) and rotational instability and confirm the relationship between ALL injury on US and rotational instability.

METHODS

This prospective, single-center, observational study was approved by our hospital's institutional review board.

Patient Population and Clinical Examination

During the inclusion period, we treated 2080 patients with acute knee trauma for 320 anterior cruciate ligament (ACL) ruptures documented by magnetic resonance imaging (MRI). After signing an informed consent form for participation in the study, 130 consecutive patients (89 men, 41 women) were enrolled over a 1-year period (May 2018 to May 2019). The inclusion criteria were patients between 18 and 50 years with a documented isolated ACL tear (by MRI) scheduled for arthroscopic reconstruction as well as a complete clinical evaluation of the tibial insertion of the ALL within 2 weeks of the injury event. Patients with chondral or meniscal tear (medial or lateral) were included. Cases with a contralateral knee injury, other ligament tears, previous surgeries on the same knee, concurrent vascular or nerve damage, or systemic disease were excluded. The patients' demographic and anthropometric data were collected: sex, age, height, weight, and body mass index (BMI). Active tobacco use, sports activity at the time of injury, and preinjury Tegner score were recorded.

All patients underwent a full clinical examination of their injured knee. The medial and lateral collateral ligaments and the posterior cruciate ligament were evaluated meticulously, because the presence of other ligamentous tears was an exclusion criterion. ACL integrity was evaluated via the Lachman test, anterior drawer test, and pivot-shift test. We also checked for any nerve or vascular damage (exclusion criteria).

Figure 1. Manual palpation of the anterolateral ligament tibial insertion with the patient's knee slightly flexed. FH, fibular head; GT, Gerdy tubercle.

Endpoints

During the proposed clinical test, the patient was supine with the knee slightly bent to make bony landmarks more prominent. The ALL tibial insertion was identified at the midpoint between the Gerdy tubercle and the fibular head on the anterolateral aspect of the tibial plateau. The examiner then palpated the ALL tibial insertion (Figure 1). The test was graded as positive if this palpation elicited pain. To standardize the test once the manual palpation had been completed, the palpation was repeated with an algometer (Force Ten FDX digital force gauge; Wagner Instruments) to ensure the palpation pressure was the same for each patient. The ALL tibial insertion was palpated with the algometer on both knees and compared (Figure 2). The same pressure of 4 kg/cm^2 was used on both knees and was less than 4.8 kg/cm^2, which is the pain-eliciting threshold in a healthy population for a noninjured area.[17] The test was positive if palpation of the injured knee elicited pain but palpation of the contralateral knee did not. This helped to standardize the palpation test by removing measurement bias related to the examiner.

Rotational stability was evaluated on the day of the arthroscopy procedure with the patient under general anesthesia prior to the incision being made. The pivot shift

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Figure 2. Anterolateral ligament palpation was repeated using a digital force gauge to standardize the pressure applied to the patient's knee.

was graded as 0 (absent), I (glide), II (jerk), or III (subluxation).[20] Since a secondary purpose of this study was to find a relationship between high-grade pivot shift and ALL injury, we classified the pivot-shift grades as either negative (grades 0 and I) or positive (grades II and III).[20]

Ultrasonographic evaluation (Synergy MSK; Arthrex) of the ALL was performed the day of the arthroscopy procedure with the patient under anesthesia, according to a previously validated protocol.[3,4,7] The ALL was considered injured if it was not continuous over its entire length or if it was avulsed from its tibial insertion (true Segond fracture or ultrasonographic Segond lesion[5,7]). Dynamic testing in internal rotation was conducted to improve the ability to check ligament continuity.[3]

The first clinical assessment involving ALL palpation was carried out by a senior surgeon (P.T.) specialized in musculoskeletal injuries. The pivot-shift test and the US were performed in the operating suite by a second senior surgeon (E.C.) with a specialty in ACL reconstruction who was well-versed in musculoskeletal US. The second examiner did not know the findings of the ALL palpation, and the patient was anesthetized before this assessment, making assessment independent.

Statistical Analysis

Prior to the study, in order to assess the agreement between ALL palpation and US-identified ALL injury, we determined that 130 patients[28] were needed to show an intraclass correlation coefficient (ICC) significantly higher or equal to 90% with a width of the 95% CI of 5% (thus, ICC, 92.5%; 95% CI, 90%-95%).

To ensure the 2 groups (yes/no pain over ALL distal insertion) were comparable, the following patient-specific variables were assessed: BMI, tobacco use, age at surgery, time between injury and palpation, preinjury Tegner score, and meniscal lesions found during arthroscopy. These variables were compared between the 2 groups by use of the chi-square test (or Fisher exact test when necessary) for categorical variables. The Student t test was used to compare the distribution of continuous data (the Mann-Whitney test was used when the distribution departed significantly from normality or when homoscedasticity was rejected). All reported P values were 2-sided, and the significance threshold was set at less than .05. To determine the agreement between pain elicited upon ALL palpation and ALL injury diagnosed by US, we assessed the ICC (with the associated 95% CI). To be more precise in the nature of the agreement, we also assessed sensitivity and specificity of the pain elicited upon ALL palpation using ALL injury diagnosed by US as reference. The same analysis was performed to quantify the relationship between clinical ALL injury (in palpation) and rotational instability (using the pivot-shift negative [grades 0 and I] or positive [grades II and III] grades as reference). To confirm the relationship between ALL injury on US and rotational instability (pivot-shift negative [grades 0 and I] or positive [grades II and III]), ICC (with the associated 95% CI) was assessed. Statistical analysis was performed via Stata (Version 14.2; Stata Corp).

RESULTS

Pain Upon ALL Palpation

At the time of ACL reconstruction, the patients had a median age of 26 years (interquartile range [IQR], 21-31 years) and a BMI of 23.4 kg/m^2 (IQR, 21.3-25.6 kg/m^2), and 21.1% were smokers. The right knee was injured in 61 (46.9%) patients and the left in 69 (53.1%). The median time between the knee injury and ALL palpation was 8.8 days (IQR, 6-11 days). The mean time between palpation and surgery was 28.6 days. The median preinjury Tegner score was 7 (IQR, 6-9).

Palpation of the ALL distal insertion elicited pain in 67 patients (51.5%). None of the patients had pain upon palpation of the contralateral ALL. The results were the same whether the palpation was done manually or with the algometer. The demographics did not differ between the patients who had pain and those who did not except for their age, which was significantly higher by 3 years in the pain group (Table 1). This difference could be considered too small to be clinically relevant in the age group of the study population. Also, the 2 groups did not differ in the Lachman test (positive in all patients) and the anterior drawer test (positive in 94% of the patients in both groups; $P = .3791$).

Palpation and Ultrasonography Agreement

The ALL appeared injured on US in 64 patients (49.2%). Of these, 31 patients had a US-diagnosed Segond fracture and 33 patients had a discontinuity. Agreement between pain upon palpation of the ALL distal insertion and findings of ALL damage on US was excellent (ICC, 0.801; 95% CI, 0.730-0.855). The diagnostic accuracy of pain upon ALL palpation to identify an ALL injury was excellent, as the sensitivity and specificity were significantly higher than 80% (Table 2).

Palpation and Pivot-Shift Agreement

A high-grade pivot shift was found in 58 cases (44.6%). The distribution of the pivot-shift grades between the

TABLE 1
Demographics and Injury Characteristics for Both Groups With and Without Pain Elicited Upon Anterolateral Ligament Palpation[a]

	Pain Over Distal ALL Insertion		
	No (n = 63; 48.5%)	Yes (n = 67; 51.5%)	*P*
Sex, n (%)			.4802
Male	45 (71.4)	44 (65.7)	
Female	18 (28.6)	23 (34.3)	
Body mass index, kg/m^2			
Mean ± SD	23.9 ± 3.8	23.6 ± 2.9	.9059
Median [IQR]	23.3 [21.1-25.7]	23.4 [22.0-25.3]	
Smoker, n (%)			.3212
No	52 (82.5)	49 (75.4)	
Yes	11 (17.5)	16 (24.6)	
Age at surgery, y			
Mean ± SD	28.7 ± 8.4	25.8 ± 8.0	.0414
Median [IQR]	27.0 [23.0-32.0]	24.0 [19.0-31.0]	
Time from injury to palpation, d			
Mean ± SD	8.4 ± 3.2	9.2 ± 3.2	.1455
Median [IQR]	8.0 [6.0-10.0]	9.0 [6.0-12.0]	
Time from injury to ultrasonography, d			
Mean ± SD	36.4 ± 3.2	38.4 ± 3.2	.6140
Median [IQR]	32 [24-43.5]	33 [23.5-43.5]	
Tegner score, preinjury			
Mean ± SD	7.3 ± 1.8	7.7 ± 2.1	.4794
Median [IQR]	7.0 [6.0-9.0]	7.0 [6.0-10.0]	
Meniscal lesion, n (%)			.7238
No lesion	44 (69.8)	46 (68.7)	
Medial lesion	10 (15.9)	11 (16.4)	
Lateral lesion	9 (14.3)	8 (11.9)	
Medial + lateral lesion	0 (0.0)	2 (3.0)	

[a]ALL, anterolateral ligament; IQR, interquartile range.

TABLE 2
Diagnostic Accuracy of Pain Upon ALL Palpation for Identifying an ALL Injury Found on Ultrasonography[a]

	%	95% CI, %
Sensitivity	92.19	87.57-96.80
Specificity	87.88	82.27-93.49
Positive predictive value	88.06	82.49-93.63
Negative predictive value	92.06	87.42-96.71
Prevalence	49.23	40.64-57.82
Accuracy (TP+TN)/(TP+TN+FP+FN)	90.00	83.51-94.57

[a]ALL, anterolateral ligament; FN, false negative; FP, false positive; TN, true negative; TP, true positive.

yes/no ALL pain groups differed (Table 3). There were significantly more high-grade pivot-shift tests in the groups that had ALL damage on US and pain upon ALL palpation ($P < .0001$) than in the other groups (Table 3).

The agreement between pain upon palpation of the ALL distal insertion and the pivot shift was good (ICC, 0.654; 95% CI, 0.543-0.742). Moreover, ALL palpation had good discriminative ability for identifying rotational instability (Table 4).

Finally, agreement between the pivot-shift test and the US findings was excellent (ICC, 0.850; 95% CI, 0.794-0.891), and the pivot-shift test had excellent discriminative ability for identifying ALL damage on US (Table 5).

DISCUSSION

Our hypothesis was confirmed: Pain on clinical palpation of the ALL tibial insertion correlates with ultrasonographic findings of an ALL injury. The good diagnostic accuracy of ALL palpation (Table 2) means it is a suitable clinical test, especially because its high sensitivity is suggestive of an ALL injury when the palpation elicits pain. This is the first time a clinical sign specific to ALL injury has been described (specificity, 88%) (Table 1). Up to now, no specific clinical sign of ALL injury had been described.[40]

When selecting our patient population, we carefully excluded any patients with associated collateral ligament injury, as this may have caused false-positive results because of pain triggered on the lateral aspect of the knee. Furthermore, we found no lesions of the anterior portion of the lateral meniscus, which could also have been a confounding factor. The distribution of the meniscal lesions did not differ between the group that had pain upon ALL palpation and the group that did not.

We chose to enroll only patients who had a recent knee injury. We believed it was not relevant to look for this clinical sign in patients with a chronic knee injury. When the knee injury is acute, the lesion at the ALL tibial enthesis is accompanied by a hematoma, which is why palpation of this area elicits pain.[4,7] In a chronic injury, this hematoma has resorbed; thus, ALL palpation is no longer relevant. As such, our ALL palpation test can be used only in the acute context.

Since the ALL contributes to rotational stability, some authors believe that an injury to this structure is an indication for lateral tenodesis. The clinical outcomes of this strategy are very encouraging[24]; in fact, a reduced risk of retears has been reported without an increase in the morbidity related to this supplemental procedure.[11,43,44,46] Similarly, adding lateral tenodesis appear to be have a protective effect on the knee overall stability,[12,36] including meniscal structures.[41,42] This effect was also found in patients with chronic tears.[21] However, we do not know exactly the fate of the ALL after injury and, notably, its healing potential. This issue will need to be clarified in the future, as it will influence our strategy. This simple ALL palpation test can be used to plan surgical treatment during the initial consultation and to inform the patient of the treatment plan right away. Patient information is an essential element of the success of this type of surgery.[10] ALL palpation is now a part of our routine clinical examination for patients with a recent knee injury.

The pivot-shift test provides a good view of knee rotational stability.[18,33] However, the concept of knee rotational stability is multifactorial.[30,38,45] One of the secondary goals

TABLE 3
Pivot-Shift Test Grades Grouped by Whether Pain Was Elicited Upon ALL Palpation and Whether ALL Damage Was Seen on Ultrasonography[a]

	Pain Upon ALL Palpation			ALL Damage on Ultrasonography		
	No (n = 63; 48.5%)	Yes (n = 67; 51.5%)	*P* Value	No (n = 66; 50.8%)	Yes (n = 64; 49.2%)	*P* Value
Pivot-shift grade			<.0001			<.0001
0	1 (1.6)	0 (0.0)		1 (1.5)	0 (0.0)	
I	55 (87.3)	16 (23.9)		63 (95.5)	8 (12.5)	
II	7 (11.1)	45 (67.2)		2 (3.0)	50 (78.1)	
III	0 (0.0)	6 (9.0)		0 (0.0)	6 (9.4)	
Pivot shift			<.0001			<.0001
Negative (0/I)	56 (88.9)	16 (23.9)		64 (97.0)	8 (12.5)	
Positive (II/III)	7 (11.1)	51 (76.1)		2 (3.0)	56 (87.5)	

[a]Data are reported as n (%). ALL, anterolateral ligament.

TABLE 4
Diagnostic Accuracy of Pain Upon Palpation of the ALL Distal Insertion for Identifying Rotational Instability (Grade II or III Pivot Shift)[a]

	%	95% CI, %
Sensitivity	87.93	82.33-93.53
Specificity	77.78	70.63-84.92
Positive predictive value	76.12	68.79-83.45
Negative predictive value	88.89	83.49-94.29
Prevalence	44.62	36.07-53.16
Accuracy (TP+TN)/(TP+TN+FP+FN)	82.31	74.65-88.44

[a]A positive pivot shift was defined as grades II/III and a negative pivot shift was defined as grades 0/I. ALL, anterolateral ligament; FN, false negative; FP, false positive; TN, true negative; TP, true positive.

TABLE 5
Diagnostic Accuracy of the Pivot-Shift Test for Identifying an ALL Injury Found on Ultrasonography[a]

	%	95% CI, %
Sensitivity	87.50	81.81-93.19
Specificity	96.97	94.02-99.92
Positive predictive value	96.55	93.42-99.69
Negative predictive value	88.89	83.49-94.29
Prevalence	49.23	40.64-57.82
Accuracy (TP+TN)/(TP+TN+FP+FN)	92.31	86.31-96.25

[a]A positive pivot shift was defined as grades II/III and a negative pivot shift was defined as grades 0/I. ALL, anterolateral ligament; FN, false negative; FP, false positive; TN, true negative; TP, true positive.

was to analyze the in vivo link between painful palpation and a high-grade pivot shift. The agreement between a painful palpation of the ALL and high-grade pivot shift was good (ICC, 0.654; 95% CI, 0.543-0.742), but the agreement between ALL palpation and US findings was better (ICC, 0.801; 95% CI, 0.730-0.855), which is related to the multifactorial nature of rotational instability (not solely related to an ALL injury). Consequently, even if other potential causes of rotational instability were excluded from the study (such as peripheral ligament tears), we could not conclude that all high-grade pivot shifts are due to an ALL tear. Nevertheless, we advise surgeons to assess the ALL when a patient has a high-grade pivot shift. Based on this study, palpation of the ALL tibial insertion is an appropriate tool for this purpose.

In a 30-patient pilot study conducted by our team,[3] we found a correlation between high-grade pivot shift and ALL injury. This relationship was confirmed in the current study, as there was excellent agreement (ICC, 0.850; 95% CI, 0.794-0.891) between high-grade pivot shift and ALL injury in this 130-patient cohort.

To assess the plausibility of our results, we looked at the published prevalence of ALL injuries. However, it was difficult to compare the prevalence of ALL injuries between studies,[1] as the modalities and criteria differed between studies. Nevertheless, the ALL injury prevalence in our study fell within the broad range reported in other published studies (Table 6). Palpation is an examination that is simple and easy to interpret. We believe that incorporating palpation of the ALL tibial insertion in the clinical examination protocol will make interstudy comparisons more reliable in the future. The methods that we used were robust and our findings are plausible in the context of the current knowledge. However, our indications to perform an ALL reconstruction were based upon the US assessment of ALL integrity and not the physical examination. That could be another study to carry out in the future.

Limitations

The agreement between pain being elicited upon ALL palpation and the US findings of ALL injury was not perfect. Pain is a subjective sensation[48]; certain patients may not feel pain upon ALL palpation even though the structure is injured. We used a standardized method to limit the impact of different pain sensitivity thresholds between individuals.[17]

Likewise, although US is an appropriate tool for the diagnosis of ALL injury, its sensitivity is not 100%. False-positive and false-negative results are inevitable; however,

TABLE 6
Prevalence of ALL Injuries in Various Published Studies[a]

Study	N	Identification	Time Since Injury	Prevalence, %
Ferretti (2019)[16]	30	MRI	<10 d	88
Marshall (2018)[29]	50	MRI	NA	28
Helito (2017)[22]	88	MRI	<3 wk	33
Helito (2017)[23]	167	MRI	<3 wk	23
Devitt (2017)[13]	58	MRI	NA	21
Kosy (2017)[26]	277	MRI	<6 wk	11
Van Dyck (2016)[47]	90	MRI	<8 wk	42
Hartigan (2016)[19]	72	MRI	<3 wk	63
Musahl (2016)[34]	41	MRI	<2 wk	51
Song (2016)[39]	193	MRI	NA	39
Song (2016)[37]	90	MRI	<3 wk	40
Wodicka (2014)[49]	50	MRI	NA	44
Claes (2014)[8]	206	MRI	NA	60
Monaco (2019)[31]	26	Surgical exploration	<10 d	96
Ferretti (2017)[15]	60	Surgical exploration	<7 d	90
Faruch Bilfeld (2018)[14]	30	Ultrasonography	<3 mo	63
Yoshida (2017)[50]	28	Ultrasonography	<4 mo	32
Current study	130	Ultrasonography	<2 wk	49

[a]ALL, anterolateral ligament; MRI, magnetic resonance imaging; NA, not available.

the agreement was excellent.[27] Moreover, results of this study are valid if clinical examination is performed within 2 weeks of injury only, since this was the study design (<2 weeks).

We did not determine the reproducibility of our palpation test. Intrarater reliability could be negatively affected by the disappearance of the hematoma, resulting in less pain as time passes since the injury. As for interrater reliability, we used a validated protocol with an algometer to standardize our test. A single examiner assessed tenderness and conducted pivot-shift and US identification of the ALL (we did not evaluate inter- and intrarater reliability for these criteria).

Finally, it is unknown whether the ALL will heal without additional surgery. Although we can detect injury, we cannot state the need for ALL surgery. Further studies are required to clarify this point.

CONCLUSION

Palpation of the ALL tibial insertion highly correlates with ultrasonographic evidence of an ALL injury in the context of an acute knee injury. This simple test should be included in every assessment of acute knee injuries.

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