High Prevalence of Anterolateral Ligament Abnormalities on MRI in Knees With Acute Anterior Cruciate Ligament Injuries

A Case-Control Series From the SANTI Study Group

Andrea Ferretti,* MD, Edoardo Monaco,* MD, Andrea Redler,*† MD, PhD, Giuseppe Argento,‡ MD, Angelo De Carli,* MD, Adnan Saithna,§ MD, Paulo Victor Partezani Helito,‖ MD, and Camilo Partezani Helito,‖ MD

Investigation performed at Sant'Andrea Hospital, University of Rome Sapienza, Rome, Italy

Background: Broad variation in the reported rate of magnetic resonance imaging (MRI)–detected abnormalities of the anterolateral structures of the anterior cruciate ligament (ACL)–injured knee suggests a lack of reliability that has limited the use of MRI in clinical decision making.

Purpose/Hypothesis: The aim of this study was to use MRI to determine the prevalence and spectrum of abnormalities of the anterolateral structures in acute ACL-injured knees, using the contralateral uninjured knee as a reference. We hypothesized that MRI evaluation of the acutely injured knee (using the uninjured knee as a reference) would allow reliable identification of abnormalities of the anterolateral structures.

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

Methods: Patients with acute ACL injury underwent MRI scan of both knees. Images were evaluated by 3 observers. Inter- and intraobserver reliabilities were determined for MRI parameters of anterolateral ligament (ALL) injury by use of the kappa (κ) test. Univariate and multivariate analyses were conducted to test associations between ALL abnormality and associated injuries.

Results: A total of 34 patients were evaluated. Of these, 30 patients (88.2%) had at least 1 ALL abnormality in the ACL-injured knee (increased signal: n = 27[79.4%]; increased thickness: n = 15[44.1%]; tapering: n = 7[20.6%]; irregularities in the path of the ALL fibers: n = 21[61.7%]). Asymmetries of the genicular vessels were observed in 21 patients (61.7%). ALL abnormality was significantly associated with lateral joint capsular tears ($P < .001$). No correlation was found between ALL lesions and iliotibial band lesions ($P = .49$). Inter- and intraobserver reliabilities were very good concerning ALL signal changes and femoral and tibial bone bruises (κ coefficient, 0.81-1).

Conclusion: MRI evaluation of the ALL was associated with good and very good inter- and intraobserver reliabilities, and it demonstrated abnormalities of the ALL in the majority of acutely ACL-injured knees. The index of suspicion for ALL injury should be elevated by the presence of lesions of the lateral capsule. This suggests that the ALL is part of a wider area of the lateral capsule that is often injured simultaneously in an acute ACL tear.

Keywords: anterolateral knee injury; ACL rupture; MRI

The anterolateral capsule and ligament, in combination with the anterior cruciate ligament (ACL), have an important role in the rotatory stability of the knee, as proven by numerous clinical and biomechanical studies.[16,17,20-22,30] However, the anatomic features of the anterolateral structures of the knee remain imprecisely defined, as various structures have been identified and several names used.[14,15,18,19,32] Claes et al[5] provided a detailed description of the anterolateral ligament (ALL), which they described as a distinct structure running from the lateral femoral epicondyle to the tibia, midway between the Gerdy tubercle and the fibular head. In contrast, other authors have argued that the ALL is an inconstant entity of low biomechanical importance.[2,16] Moreover, some authors have used the term *anterolateral complex*, referring to a capsular region including the ALL itself and the thickened capsule closely anterior and posterior to the ALL.[7,14]

The Orthopaedic Journal of Sports Medicine, 7(6), 2325967119852916
DOI: 10.1177/2325967119852916

TABLE 1
Parameters Used in the MRI Sequences[a]

	Sagittal PD	Sagittal T2 FATSAT	Coronal T2 FATSAT	Coronal T1	Axial T2 FATSAT
Field of view, mm	180	180	180	180	180
Repetition time, ms	2800	3950	2950	3110	2940
Echo time, ms	33	30	30	33	33
Thickness, mm	3	3	3	3	3
Spacing, mm	2	2	1.5	1.5	2

[a]FATSAT, fat saturation; MRI, magnetic resonance imaging; PD, proton density.

Magnetic resonance imaging (MRI) is a frequently used modality for investigation of pathological changes in the extra-articular soft tissues of the knee, for which MRI demonstrates high sensitivity and specificity. However, the current literature shows a broad variability in the rate of MRI identification of the normal ALL and also the rate of injury (40%-80%) in acutely ACL-injured knees.[4,12,13,33] Reasons for such wide variation include the lack of a standardized and validated MRI protocol for evaluation of the ALL, differing MRI magnet strengths, the inclusion of acute and chronically injured knees, and differing expertise of authors in ALL evaluation. However, the rate of acute injury to the anterolateral structures reported during open exploration by Terry et al,[32] and more recently by Ferretti et al,[8] was somewhat higher (at around 90%) than reported in MRI studies.

Some authors advocate adding a lateral extra-articular procedure to intra-articular ACL reconstruction because of the associated significant reductions in the rates of graft rupture, persistent pivot shift,[9,23-25,30] and reoperation for failed medial meniscal repair when compared with isolated ACL reconstruction.[26,29,31] Despite these improved clinical outcomes, the current indications for adding any type of lateral extra-articular procedure are based only on parameters such as the severity of the pivot-shift test, the activity level of patients, or the personal experience of the surgeon; more objective findings such as imaging evaluation, including MRI, are less often used.[10,11,28] However, it seems logical to postulate that the patients most likely to benefit from a lateral extra-articular procedure might be those who have a demonstrable injury to the anterolateral structures of the knee. It is therefore appropriate to evaluate the role of imaging modalities to identify these particular patients.

The aim of this study was to use MRI to determine the prevalence and spectrum of abnormalities of the anterolateral structures in acute ACL-injured knees using the contralateral uninjured knee as a reference. The study hypothesis was that by using the uninjured knee as a direct control, radiologists and knee surgeons could more easily identify abnormalities.

METHODS

Between May 2015 and May 2016, patients treated at the emergency department of a single institution who had a history of acute (<10 days) knee injury and physical examination findings consistent with ACL injury were prospectively considered for study enrollment. Patients were excluded if they had a previous history of either ipsilateral or contralateral knee injury/surgery or infection, multiligament injury, or inability to undergo MRI. All patients underwent ACL reconstruction within 10 days, which is the standard of care for acute ACL injuries in our institution. Ethical approval for this study was granted by an institutional review board, and all patients provided written consent to participate.

After clinical evaluation, patients underwent MRI of the injured knee. If this image confirmed the clinical suspicion of an ACL injury, then patients also underwent MRI of the contralateral knee. The MRI scans were performed on a 1.5-T device (Siemens Maestro Sonata, gradient 40 mT, software Syngo A35), with the parameters as shown in Table 1.

Magnetic resonance imaging scans were evaluated by 3 independent and blinded observers (2 musculoskeletal radiologists [G.A. and P.V.P.H.] with 15 and 8 years of experience, respectively, and 1 orthopedic surgeon [C.P.H.] with 10 years of experience of interpreting MRI scans of the knee in daily practice). The blinding was performed with respect to patient identification and demographic data, but blinding of the injured versus uninjured sides was not possible owing to obvious imaging features of an acute ACL injury. Imaging assessment was performed by each observer on 2 separate occasions in order to allow determination of both inter- and intraobserver reliabilities.

†Address correspondence to Andrea Redler, MD, PhD, Orthopaedic Unit and Kirk Kilgour Sports Injury Centre, S. Andrea Hospital, University of Rome Sapienza, Via di Grottarossa 1035-1039, 00189 Rome, Italy (email: andrearedler@gmail.com).
*Orthopaedic Unit and Kirk Kilgour Sports Injury Centre, S. Andrea Hospital, University of Rome Sapienza, Rome, Italy.
‡Department of Radiology, S. Andrea Hospital, University of Rome Sapienza, Rome, Italy.
§Sano Orthopedics, Kansas City, Missouri, USA.
‖Department of Orthopaedics and Traumatology, Hospital and Clinics, Faculty of Medicine, University of Sao Paulo (IOT-HCFMUSP), Sao Paulo, Brazil.
One or more of the authors has declared the following potential conflict of interest or source of funding: A.F., E.M., and A.D.C. are consultants for Arthrex. A.S. is a consultant for Arthrex and Smith & Nephew. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
Ethical approval for this study was obtained from the University of Rome Sapienza, Rome, Italy.

For intraobserver reliability, the second evaluation of the imaging was performed with a minimum interval of 2 weeks. Although the observers studied the imaging independently, they used a standardized approach to imaging evaluation, described by Helito et al.[12]

The ALL was evaluated by use of coronal images, with the axial and sagittal planes used mainly for anatomic orientation. The ALL was defined as the low signal band originating from the posterior-proximal region of the lateral epicondyle of the femur and crossing the proximal surface of the lateral collateral ligament, deep to the iliotibial band (ITB), to its tibial insertion between the Gerdy tubercle and the fibular head.[10] Differences in the MRI signal and the thickness and appearance of the fibers of the ALL in the ACL-injured knee compared with the contralateral uninjured side were recorded. The fibers were considered abnormal when they presented irregular contours, a wavy aspect, or areas of discontinuity. The signal from the injured side was characterized as increased or equal and the thickness as increased, equal, or reduced compared with the contralateral ALL. In addition, the path and caliber of the inferior lateral genicular vessel (GV) were evaluated and compared with the contralateral knee.

Other imaging findings evaluated were osseous contusions in the femur and tibia (related to the trauma or knee sprain), the presence of lateral capsular tear, and the presence of lesions of the ITB. The latter were evaluated by use of the criteria established by Mansour et al.[18] Joint capsule tear was defined by thickening and increased signal in T2-weighted sequences, as well as the presence of periarticular fluid. The ITB was considered abnormal in the presence of thickening, signal change in its fibers, or edema of adjacent planes, even if observed in a discrete manner. Bone contusions were graded according to the criteria established by Song et al.[27]

Statistical Analysis

The chi-square test was used to assess whether a significant difference was present between the key ALL parameters evaluated on MRI in the ACL-injured knee compared with the contralateral uninjured knee. Univariate and multivariate analyses were conducted to test associations between MRI-proven injury of the ALL and other abnormalities, including GV asymmetry and lateral capsular and/or ITB tears. Association tests between capsular and/or ITB tears with GV asymmetry were performed with the Pearson chi-square test. For all variables, results with a P value less than .05 were considered statistically significant. Inter- and intraobserver agreements were evaluated through use of the kappa (κ) test. All calculations were made via SPSS software (v 20.0; IBM Corp).

RESULTS

A total of 36 patients met the eligibility criteria and were enrolled in the study. However, in 2 patients (5.5%) it was not possible to visualize the ALL in the uninjured knee and so these patients were excluded from the overall statistical analyses. Thus, 34 patients formed the final study population; the demographics of the group are reported in Table 2.

TABLE 2
Demographics and Patient Characteristics of the Study Population (N = 34)[a]

Age, y, mean ± SD (range)	26.7 ± 7.1 (17-46)
Sex, n	
Male	24
Female	10
Body mass index, mean ± SD (range)	20.2 ± 1.3 (19-23.5)
Days from injury to MRI, mean ± SD (range)	4 ± 3 (1-7)
Days from injury to surgery, mean ± SD (range)	4.5 ± 2.3 (1-10)
Preoperative (under anesthesia) pivot-shift grade, n	
Grade 0	0
Grade 1	2
Grade 2	18
Grade 3	14
Mechanism of injury, n	
Noncontact	30
Contact/trauma	4

[a]MRI, magnetic resonance imaging.

TABLE 3
Prevalence of Anterolateral Ligament Abnormalities and Associated Lesions in Knees With Acute Injury of the Anterior Cruciate Ligament

Abnormality	n (%)
Any abnormality	30 (88.2)
Signal change	27 (79.4)
Thickness and thinness	22 (64.7)
Fiber path	21 (61.7)
Genicular vessel asymmetry	21 (61.7)
Capsular tear	30 (88.2)
Iliotibial band tear	12 (35.3)

Overall, 30 (88.2%) patients had at least 1 ALL abnormality in the ACL-injured knee. In 27 (79.4%) patients, this was manifest as increased signal within the ALL. In 22 (64.7%) patients there were differences in the thickness of ALL fibers, with increased thickness in 15 (44.1%) patients and tapering in 7 (20.6%) patients. In 21 (61.7%) patients, irregularities were noted in the path of the ALL fibers. No cases of complete transection of the ALL or of bony avulsion were found in this series. Asymmetry of the GV was observed in 21 (61.7%) patients (Table 3 and Figures 1 and 2).

All of the ACL-injured knees that had a concomitant ALL lesion were also found to have a joint capsule abnormality (joint capsule tears, or stretch or signal alteration of the joint capsule); thus, in only 4 (11.8%) patients was the capsule considered completely normal in the ACL-injured knee. Stretch or signal alteration of the joint capsule was observed in 12 (35.3%) patients, and capsular tear with extravasation of synovial fluid was observed in another 18 patients (11 cases posterior and 7 cases including both the anterior and posterior capsule).

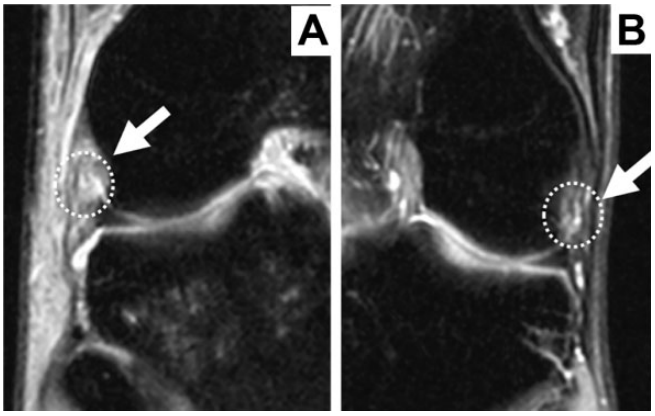

Figure 1. Coronal T2-weighted magnetic resonance images (MRIs) with fat saturation of the (A) injured right knee and (B) uninjured left knee of a patient. The arrows and dotted circle indicate the anterolateral ligament. MRI of the right knee demonstrated a slightly thickened anterolateral ligament with increased signal compared with the contralateral side.

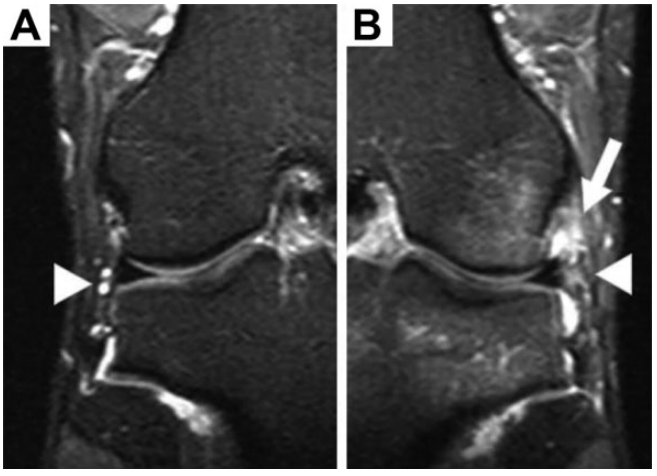

Figure 2. Coronal T2-weighted magnetic resonance images with fat saturation of the (A) uninjured right knee and (B) injured left knee of a patient. The arrow indicates the anterolateral ligament, and the arrowheads indicate the inferior lateral genicular vessels. MRI of the left knee demonstrated decreased thickness and increased signal of the anterolateral ligament compared with the contralateral normal ligament. Proximal fibers were also irregular. Note that the inferior lateral genicular vessels are asymmetric and are better depicted on the uninjured side (A).

No cases of complete ITB rupture were found, but in 12 (35.3%) patients it was possible to observe a discrete stretch or signal alteration of the ITB. Finally, all but 1 of the ACL-injured knees had an associated tibial bone contusion, and all but 3 also had a femoral bone contusion (Table 4). Bone contusions in the tibia were classified as minimal (n = 13), moderate (n = 19), or severe (n = 1). Most of the femoral bone contusions were moderate (n = 18), followed by minimal (n = 10) and severe (n = 2) according to the classification described by Song et al.[26]

TABLE 4
Association Between Anterolateral Ligament (ALL) Abnormalities and Other Lesions[a]

	ALL Abnormality (n = 30/34)	Normal ALL (n = 4/34)	*P*
Genicular vessel asymmetry	20/30 (66.7)	1/4 (25)	.10
Capsular tear	30/30 (100)	0/4 (0)	<.001
Iliotibial band tear	12/30 (40.0)	1/4 (25)	.49
Femoral bone bruise	27/30 (90.0)	3/4 (75)	.09
Tibial bone bruise	29/30 (96.7)	4/4 (100)	.71

[a]Values are expressed as n (%).

ALL abnormality was significantly associated only with lateral joint capsular tears ($P < .001$). No correlation was found between ALL lesions and ITB lesions ($P = .49$) or between ALL lesions and GV asymmetry ($P = .10$) (Table 4). ITB lesions also did not correlate with GV asymmetry ($P = .49$).

Even though ALL and capsular tears presented a high incidence of combined femoral and tibial bone contusions, they did not show any correlation ($P = .71$ for tibial contusion, $P = .09$ for femoral contusion). Abnormalities of the ITB also showed no correlation with tibial ($P = .45$) or femoral ($P = .64$) bone bruises.

The inter- and intraobserver reliability data as determined by the kappa statistic are reported in Table 5. These values were calculated for each diagnostic parameter to include signal change within the ALL, side-to-side differences in the thickness of the ALL, abnormality of the ALL fibers, abnormality of the inferior lateral GV, bone bruising, capsular tear (anterior and/or posterior), and injury to the ITB.

DISCUSSION

The most important finding of the present study is that ALL abnormalities were demonstrated in 88.2% of acutely ACL-injured knees when evaluated with 1.5-T MRI. The most common alterations were of signal and thickness changes of the ALL fibers compared with the contralateral uninjured knee. Furthermore, the abnormalities of the ALL were significantly associated with lateral joint capsule tears ($P < .001$) but not with ITB lesions ($P = .64$). Another important finding was that the ALL could be identified and evaluated in the contralateral uninjured knee in all but 2 of the initial 36 patients, thus confirming the ability of routine 1.5-T MRI to detect the ALL as a distinct structure in almost all normal knees.[3,6,23] In contrast, several previous authors have reported difficulty in clearly identifying the ALL on MRI.[4,12,13,33] This has been attributed to the small size of the ALL, its oblique orientation, and to its close relation to other structures, such as the lateral collateral ligament, ITB, and popliteus tendon.

TABLE 5
Inter- and Intraobserver Reliabilities (Kappa Coefficient) for Evaluation of Each Imaging Parameter[a]

					Bone Bruise			
	Signal	Thickness	Fibers	GV	Femur	Tibia	Capsular Rupture	ITB
Interobserver	0.81	0.75	0.69	0.69	1	1	0.47	0.54
Intraobserver 1	0.75	0.76	0.92	0.68	1	1	0.61	0.67
Intraobserver 2	0.83	0.75	0.84	0.6	1	1	0.68	0.58
Intraobserver 3	0.86	0.90	0.92	0.83	1	1	0.83	0.83

[a]Kappa values were interpreted according to the classification described by Altman[1]: very good, 0.81-1 (dark gray shading); good, 0.61-0.8 (gray shading); moderate, 0.41-0.6 (no shading). GV, genicular vessel; ITB, iliotibial band.

In the current study, moderate to very good inter- and intraobserver reliabilities of 1.5-T MRI were demonstrated in the evaluation of the lateral extra-articular structures. For specific ALL-related parameters such as signal change, thickness, fiber, and GV abnormalities, the kappa coefficient was consistently good or very good. For the evaluation of capsule and ITB abnormalities, the interobserver reliability was only moderate (Table 5).

The majority of previous MRI studies of the ALL have focused on describing its normal appearance, but only a few studies have investigated the prevalence of ALL abnormality in the ACL-injured knee, and the results have been controversial. Claes et al[4] reported ALL abnormalities in 80% of cases, but in other studies the rate was approximately 50%.[3,6,12,13,23,33] There are several potential reasons for this broad variation in the reported rates of ALL injury. One of the main reasons is that no clearly defined, validated MRI evaluation protocol for the ALL exists. In this study, the use of the uninjured contralateral side as a reference likely helped the evaluators to more easily detect abnormalities, resulting in a higher rate than other studies. Further reasons for a higher rate of ALL abnormalities detected in this study include evaluation of images by expert musculoskeletal radiologists who had previous experience in the field of ALL imaging, as well as restriction of the study population to patients with acutely ACL-injured knees. It has been suggested that the ALL, much like the medial collateral ligament, has some intrinsic potential for healing,[20] and thus the inclusion of nonacute injuries may have resulted in a lower rate of ALL abnormality.

The prevalence of ALL abnormalities detected by MRI in the present study is consistent with the rate detected at surgical exploration by Ferretti et al[8] in patients undergoing ACL reconstruction within 10 days from injury (same interval as used in the present study). These findings suggest that clinicians should have a high index of suspicion for ALL injury when evaluating MRI scans of the acutely ACL-injured knee, as changes can be identified in the majority of cases (about 90%). An appropriate index of suspicion for ALL injury can also be held by evaluating the MRI for associated abnormalities of other structures. In this study, a significant association with lateral joint capsule tears was identified. It therefore seems logical to carefully scrutinize the ALL if these abnormalities are apparent. Considering the strong correlation with lateral joint capsule abnormalities, we can speculate that the ALL acts as a part of a wider ligamentous structure involving the whole lateral compartment. We found no correlation between ALL injury and ITB abnormalities, but ALL injury occurred in many cases without ITB injury.

The present study confirms the high prevalence of bone bruising of the lateral femoral and tibial condyles in acute ACL injury. Some authors have postulated that the bone bruise detected on MRI could be due to the rotational stress[27,25] occurring during a pivot shift–like mechanism of injury. Moreover, the almost constant association between lateral bone bruising and abnormalities of the ALL or lateral capsular ligament supports the hypothesis that this occurs because of a sudden bone impact during forced internal rotation.[3,25]

The results of this study highlight the frequency and spectrum of ALL abnormality in the acutely ACL-injured knee. It is hoped that this finding may help to establish a recognized spectrum of injury and a standardized protocol for diagnosis of ALL lesions, which in turn could potentially help clinicians identify patients in whom an isolated ACL reconstruction may fail to restore normal knee kinematics and in whom repair or reconstruction of these structures is indicated.

Limitations

The main limitation of this study is that the imaging findings were not correlated with a lateral extra-articular surgical exploration, and therefore the sensitivity and specificity of MRI for evaluation of ALL lesions remain undefined. However, in contrast to previous studies, this limitation was mitigated to some extent by use of the contralateral uninjured knee for comparison. It is reassuring to note that the imaging protocol used in the current study revealed a prevalence of ALL injury that was broadly comparable with the rate previously reported during surgical exploration by Ferretti et al,[8] but further study is needed to more completely validate the role of MRI in this setting.

Additional limitations of the study include the relatively small number of knees evaluated, the lack of previous studies evaluating the normal spectrum of side-to-side variation in GV symmetry in uninjured knees, the fact that chronic ACL-injured knees were not included (which may have a different profile of ALL injury because of the potential for spontaneous healing), and the lack of comparison between the different types of ALL lesions and the severity of the

pivot shift at clinical examination. However, the majority of patients had a positive pivot-shift grade of 2 or 3 at preoperative examination, and comparison with lower grades was therefore not possible. Another limitation is that no sex-related evaluation was performed owing to the small number of patients. Further, MRI of the contralateral uninjured knee is not performed in routine clinical practice, and it is unknown whether the same inter- and intraobserver reliabilities could be achieved if the injured knees were evaluated in isolation.

CONCLUSION

In this study, 1.5-T MRI evaluation of the ALL was associated with good and very good inter- and intraobserver reliabilities and demonstrated abnormalities of the ALL in the majority of acutely ACL-injured knees. The index of suspicion for ALL injury should be elevated by the presence of tears of the lateral capsule, given their strong association.

REFERENCES

1. Altman DG. Statistics in medical journals: developments in the 1980s. *Stat Med*. 1991;10(12):1897-1913.
2. Caterine S, Litchfield R, Johnson M, Chronik B, Getgood A. A cadaveric study of the anterolateral ligament: re-introducing the lateral capsular ligament. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(11):3186-3195.
3. Cavaignac E, Faruch M, Wytrykowski K, et al. Ultrasonographic evaluation of anterolateral ligament injuries: correlation with magnetic resonance imaging and pivot-shift testing. *Arthroscopy*. 2017;33(7):1384-1390.
4. Claes S, Bartholomeeusen S, Bellemans J. High prevalence of anterolateral ligament abnormalities in magnetic resonance images of anterior cruciate ligament-injured knees. *Acta Orthop Belg*. 2014;80(1):45-49.
5. Claes S, Vereecke E, Maes M, Victor J, Verdonk P, Bellemans J. Anatomy of the anterolateral ligament of the knee. *J Anat*. 2013;223(4):321-328.
6. Faruch Bilfeld M, Cavaignac E, Wytrykowski K, et al. Anterolateral ligament injuries in knees with an anterior cruciate ligament tear: contribution of ultrasonography and MRI. *Eur Radiol*. 2018;28(1):58-65.
7. Ferretti A. Beyond the anterolateral ligament: letter to the editor. *Am J Sports Med*. 2017;45(6):NP17.
8. Ferretti A, Monaco E, Fabbri M, Maestri B, De Carli A. Prevalence and classification of injuries of anterolateral complex in acute anterior cruciate ligament tears. *Arthroscopy*. 2017;33(1):147-154.
9. Ferretti A, Monaco E, Ponzo A, et al. Combined intra-articular and extra-articular reconstruction in anterior cruciate ligament-deficient knee: 25 years later. *Arthroscopy*. 2016;32(10):2039-2047.
10. Getgood A, Brown C, Lording T, et al. The anterolateral complex of the knee: results from the International ALC Consensus Group Meeting. *Knee Surg Sports Traumatol Arthrosc*. 2019;27(1):166-176.
11. Helito CP, Demange MK, Helito PV, et al. Evaluation of the anterolateral ligament of the knee by means of magnetic resonance examination. *Rev Bras Ortop*. 2015;50(2):214-219.
12. Helito CP, Helito PVP, Costa HP, et al. Assessment of the anterolateral ligament of the knee by magnetic resonance imaging in acute injuries of the anterior cruciate ligament. *Arthroscopy*. 2017;33(1):140-146.
13. Helito CP, Helito PVP, Leão RV, Demange MK, Bordalo-Rodrigues M. Anterolateral ligament abnormalities are associated with peripheral ligament and osseous injuries in acute ruptures of the anterior cruciate ligament. *Knee Surg Sports Traumatol Arthrosc*. 2017;25(4):1140-1148.
14. Herbst E, Albers M, Burnham JM, et al. The anterolateral complex of the knee: a pictorial essay. *Knee Surg Sports Traumatol Arthrosc*. 2017;25(4):1009-1014.
15. Hughston JC, Andrews JR, Cross MJ, Moschi A. Classification of knee ligament instabilities, part II: the lateral compartment. *J Bone Joint Surg Am*. 1976;58(2):173-179.
16. Kittl C, El-Daou H, Athwal KK, et al. The role of the anterolateral structures and the ACL in controlling laxity of the intact and ACL-deficient knee. *Am J Sports Med*. 2016;44(2):345-354.
17. Lutz C, Sonnery-Cottet B, Niglis L, Freychet B, Clavert P, Imbert P. Behavior of the anterolateral structures of the knee during internal rotation. *Orthop Traumatol Surg Res*. 2015;101(5):523-528.
18. Mansour R, Yoong P, McKean D, Teh JL. The iliotibial band in acute knee trauma: patterns of injury on MR imaging. *Skeletal Radiol*. 2014;43(10):1369-1375.
19. Muller W. *The Knee: Form, Function and Ligament Reconstruction*. Berlin, Germany: Springer-Verlag; 1982.
20. Muramatsu K, Saithna A, Watanabe H, et al. Three-dimensional magnetic resonance imaging of the anterolateral ligament of the knee: an evaluation of intact and anterior cruciate ligament-deficient knees from the Scientific Anterior Cruciate Ligament Network International (SANTI) study group. *Arthroscopy*. 2018;34(7):2207-2217.
21. Musahl V, Getgood A, Neyret P, et al. Contributions of the anterolateral complex and the anterolateral ligament to rotatory knee stability in the setting of ACL injury: a roundtable discussion. *Knee Surg Sports Traumatol Arthrosc*. 2017;25(4):997-1008.
22. Parsons EM, Gee AO, Spiekerman C, Cavanagh PR. The biomechanical function of the anterolateral ligament of the knee. *Am J Sports Med*. 2015;43(3):669-674.
23. Porrino J Jr, Maloney E, Richardson M, Mulcahy H, Ha A, Chew FS. The anterolateral ligament of the knee: MRI appearance, association with the Segond fracture, and historical perspective. *AJR Am J Roentgenol*. 2015;204(2):367-373.
24. Rezende FC, de Moraes VY, Martimbianco AL, et al. Does combined intra- and extraarticular ACL reconstruction improve function and stability? A meta-analysis. *Clin Orthop Relat Res*. 2015;473(8):2609-2618.
25. Sahoo K, Garg A, Saha P, et al. Study of imaging pattern in bone marrow oedema in MRI in recent knee injuries and its correlation with type of knee injury. *J Clin Diagn Res*. 2016;10(4):TC06-11.
26. Song GY, Hong L, Zhang H, Zhang J, Li Y, Feng H. Clinical outcomes of combined lateral extra-articular tenodesis and intra-articular anterior cruciate ligament reconstruction in addressing high-grade pivot-shift phenomenon. *Arthroscopy*. 2016;32(5):898-905.
27. Song GY, Zhang H, Wang QQ, Zhang J, Li Y, Feng H. Bone contusions after acute noncontact anterior cruciate ligament injury are associated with knee joint laxity, concomitant meniscal lesions, and anterolateral ligament abnormality. *Arthroscopy*. 2016;32(11):2331-2341.
28. Sonnery-Cottet B, Daggett M, Fayard JM, et al. Anterolateral Ligament Expert Group consensus paper on the management of internal rotation and instability of the anterior cruciate ligament-deficient knee. *J Orthop Traumatol*. 2017;18(2):91-106.
29. Sonnery-Cottet B, Saithna A, Blakeney WG, et al. Anterolateral ligament reconstruction protects the repaired medial meniscus: a comparative study of 383 anterior cruciate ligament reconstructions from the SANTI study group with a minimum follow-up of 2 years. *Am J Sports Med*. 2018;46(8):1819-1826.
30. Sonnery-Cottet B, Saithna A, Cavalier M, et al. Anterolateral ligament reconstruction is associated with significantly reduced ACL graft

rupture rates at a minimum follow-up of 2 years: a prospective comparative study of 502 patients from the SANTI study group. *Am J Sports Med*. 2017;45(7):1547-1557.
31. Sonnery-Cottet B, Thaunat M, Freychet B, et al. Outcome of a combined anterior cruciate ligament and anterolateral ligament reconstruction technique with a minimum 2-year follow-up. *Am J Sports Med*. 2015;43(7):1598-1605.
32. Terry GC, Norwood LA, Hughston JC, Caldwell KM. How iliotibial tract injuries of the knee combine with acute anterior cruciate ligament tears to influence abnormal anterior tibial displacement. *Am J Sports Med*. 1993;21(1):55-60.
33. Van Dyck P, Clockaerts S, Vanhoenacker FM, et al. Anterolateral ligament abnormalities in patients with acute anterior cruciate ligament rupture are associated with lateral meniscal and osseous injuries. *Eur Radiol*. 2016;26(10):3383-3391.