


# Anterolateral ligament of the knee: myth or reality?

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Received: 9 October 2015 / Accepted: 15 February 2016 / Published online: 2 March 2016  
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## Abstract

**Purpose** A ligament of the knee has recently drawn the attention: the rediscovered anterolateral ligament (ALL) of the knee. The tibial insertion of the ALL is torn off in the Segond fracture, pathognomonic of the anterior cruciate ligament tear. The ALL originates from the lateral femoral epicondyle and has fibers inserting on the lateral meniscus. It attaches distally to the tibial plateau, midway between the tip of the fibular head and Gerdy's tubercle. The purpose of this study was to evaluate the visibility of the ALL using routine MRI (1.5T) protocol.

**Materials and methods** In the first part of our study 10 cadaveric knee joints were examined using MR imaging to evaluate the visibility of the ALL. These cadaveric knees have been dissected to assess the presence of the ALL and to evaluate the accordance between MRI and anatomic dissection. In the second part of the study, 61 knee MRI of patients were examined to evaluate the visibility of the ALL using axial and coronal DP-FS weighted sequences.

**Results** In all cadaveric knee MRI, the ALL was visualized (full visualization in 75 % and partial visualization in 25 % of the cases), with 100 % accordance between MRI and anatomic dissection. Two cadaveric knees where the ALL was not viewed were excluded of the radio-anatomic analysis. The ALL was visualized in 93.4 % (95 %

CI = 84.1–98.2) of the knee MRI studies of the 61 patients included. The whole ligament was visualized in 82 % (95 % CI = 70–90.6) examinations and it was partially visualized in 11.5 % (95 % CI = 4.7–22.2).

**Conclusion** Our results show that the ALL of the knee can be identified using routine 1.5T MR imaging, which suggest that better radiological description of this underestimated anatomical structure may be beneficial in the preoperative planning of ACL tears.

**Keywords** Anterolateral ligament of the knee · MRI · Anatomical study · Segond fracture

## Introduction

A ligament of the knee has recently drawn the attention: the rediscovered anterolateral ligament (ALL). It was originally described in 1879 when Dr Paul Segond demonstrated the existence of a pearly, resistant, fibrous band at the anterolateral aspect of the knee, whose tibial insertion is torn off in the Segond fracture [5, 7, 10, 23, 25, 31].

This resulted in a confusion in its name and anatomical description: anterior band of the lateral collateral ligament [15], lateral capsular ligament [14, 21] or anterior oblique band [1]. In recently published papers, all authors agree on the common name of the anterolateral ligament of the knee.

Recent cadaveric studies have defined anatomical characteristics of the ALL. This ligamentous structure connecting the femur to the tibia originates from the lateral femoral epicondyle, near the fibular collateral ligament (FCL). The ALL has an oblique trajectory, with fibers inserting on the lateral meniscus for most authors and a distal attachment to the lateral aspect of the lateral tibial

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condyle, midway between the tip of the fibular head and Gerdy's tubercle [2, 6, 9, 30].

The Segond fracture (ALL distal avulsion) is related to a forced medial rotation trauma and is pathognomonic of the anterior cruciate ligament (ACL) tear [8, 10, 29, 31].

The ALL seems to be an anterolateral stabilizer of the knee [14, 22] injured in around 80 % of ACL ruptures for Claes et al. [4].

It has been suggested that anatomical reconstruction of ACL could result in improved results when combined with ALL reconstruction even if further studies are required to lead to improved clinical outcomes involving ACL reconstruction surgery [27].

Recently published studies have suggested that the ALL could be visible on ultrasound [3] and on magnetic resonance imaging (MRI) in variable proportions and especially on specific non-fat-saturated sequences [2, 4, 12, 20, 23, 28].

To the best of our knowledge, the ALL visibility with routine 1.5 T MRI sequences [T1-weighted, fat suppressed proton density (PD)-weighted] has not been studied to date. No radiological anatomical correlation with cadaveric dissection has been performed to date.

## Purpose

The purpose of this study was to evaluate the visibility of the ALL using routine MRI protocol (sagittal T1-weighted, coronal and axial fat suppressed PD-weighted sequences).

## Materials and methods

### Anatomical study in cadavers

In accordance with our institution's safety and ethical regulation, 10 cadaveric knee joints were examined using MR imaging (1.5T) to evaluate the visibility of the ALL.

The MR imaging protocol included coronal T1-weighted sequence and 2 mm thick reconstructions from a tridimensional SPAIR sequence.

The knees were then dissected by a team of two orthopedic surgeons (Anatomy laboratory, Faculty of Medicine of Timone, Marseille, France), blinded to MRI results, to assess the presence of the ALL of the knee and to characterize it.

### Patient selection and exclusion criteria

In accordance with our institution's safety and ethical regulation, all patients who underwent knee MRI scans

between May and July 2014 were included. Institutional review board was not required for this retrospective study.

Exclusion criteria were suboptimal MRI examination (motion artifacts, incomplete protocol), a history of knee surgery and ACL tear.

For each patient, we collected the following information: age (years), gender (male, female) and indication to perform knee MRI.

## MRI protocol

All MRI scans were performed on a 1.5T MR scanner (Philips® Achieva, Best Netherlands) using a dedicated knee coil (8-channel Sense knee array). A 15° knee flexion position was used.

The protocol included sagittal T1-weighted sequence (TR/TE: 500/18; number of excitations: 2; matrix: 512; thickness: 3.5 mm; field of view: 180 × 180 × 92 mm), axial fat suppressed PD-weighted sequence (2209/35; 3; 256; 3.5 mm; 112 × 84 × 160 mm), coronal fat suppressed PD-weighted sequence (1800/30; 3; 256; 3.5 mm; 77 × 143 × 180 mm) and tridimensional SPAIR (800/35; 3; 268; 1.24 mm; 160 × 160 × 99 mm) with 2 mm thick reconstruction (not used for ALL analysis).

## Images analysis

Two radiologists (a staff radiologist with 10 years experience (reader 1) and a resident with 1 year of experience in musculoskeletal radiology (reader 2) reviewed MRI scans in consensus.

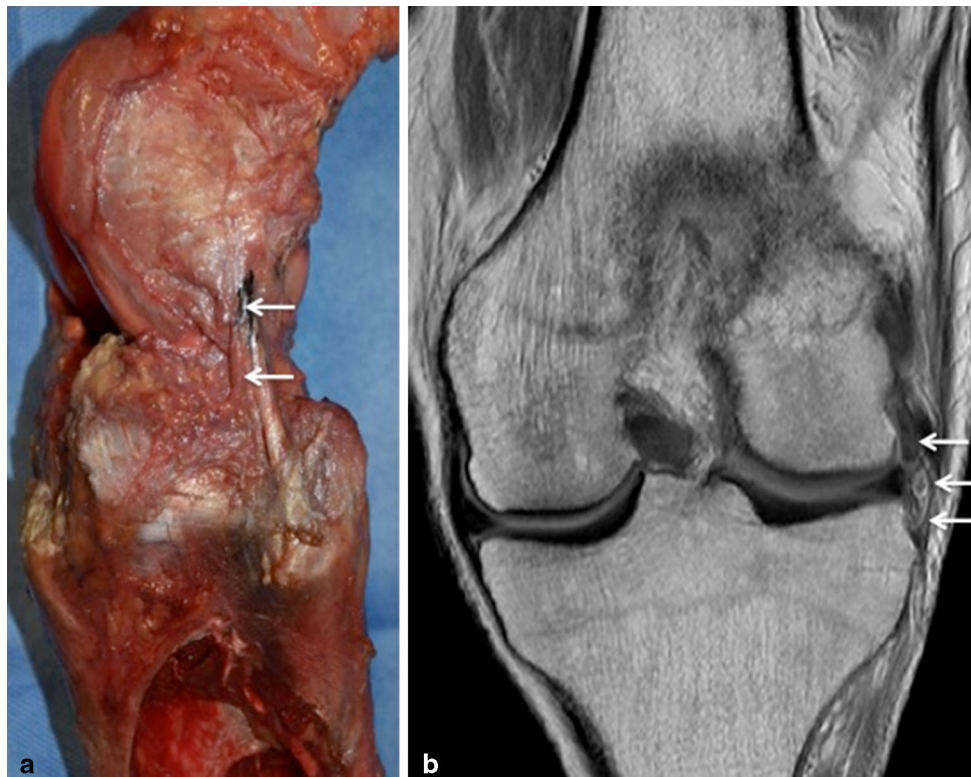
The ALL was assessed for its visibility (non-visualized, partially visualized or completely visualized). The ALL was considered as visible only if it was visible on two planes to overcome partial-volume effect or misinterpretation of structures (direct cross referencing technique).

The ALL was considered completely visible when all three portions of its length were seen, even if the insertion was not clearly individualized. If the ALL was seen on only one MRI sequence, it was not considered visible.

The ALL presents a proximal femoral portion, a middle meniscal portion next to the lateral meniscus with fibers inserting on it and a distal tibial portion inserting on the tibial plateau (Fig. 1).

## Statistical analysis

The standard deviation of the average age and the measurement of 95 % confidence intervals for ALL visibility percentages were calculated using the binomial exact method.



**Fig. 1** **a** Picture of the anatomic dissection of the ALL (inked; *arrows*) and its relationships with the FCL. **b** Correlation with cadaveric MRI: visualization of the ALL (*arrows*) on a T1-weighted coronal MRI

## Results

### Population and MRI indications (Tables 1, 2)

Exclusion criteria were a history of ACL reconstruction, 23 because of a history of knee surgery (18 ACL plasty), 9 because of a ACL tear, 10 because of an incomplete protocol and 5 because of artefacted examination.

A total of 61 patients were included.

Patient age ranged from 15 to 83 years with a mean age of 48 years (standard deviation 19 years). The MRI examinations concerned right knees in 60 % and left knees in 40 %. MRI indications were knee pain (67 %), recent trauma (11 %) and other (21 %).

**Table 1** Exclusion criteria

Exclusion criteria	<i>N</i>	%
ACL plasty	18	38.3
Other knee surgery	5	10.6
ACL tear	9	19.1
Artifacts	5	10.6
Incomplete protocol	10	21.2
Total	47	100

**Table 2** Population of the study

	<i>N</i>	%
Gender		
Male	29	47.5
Female	32	52.5
Side		
Right	37	60.7
Left	24	39.3
Indication		
Knee pain	41	67.2
Traumatism	7	11.4
Other	13	32.3

### ALL analysis on cadaveric knees

Coronal T1-weighted, coronal and axial SPAIR sequences were used in combination to identify the ALL of the knee (direct cross-referencing of images).

Two orthopedic surgeons performed independently the anatomical dissection. The ALL was identified in 80 % of the knee joints (8/10). Two knee joints where the ALL was not viewed were excluded of the radio-anatomic analysis. Knee MRI were performed and analyzed before anatomic dissection (Fig. 1). In all 8 cases, the ALL was visualized

**Table 3** Visualization of the ALL on cadaveric knee MRI

Visualization of the ALL	N	%
Visualized	8	100
Completely visualized	6	75
Partially visualized	2	25
Not visualized	0	0
Total	8	100

(full visualization in 75 % and partial visualization in 25 % of the cases), with 100 % accordance between MRI and anatomic dissection (Table 3).

### ALL analysis on patient knees MRI

Axial and coronal fat suppressed PD-weighted sequences were used in combination to identify the ALL of the knee (direct cross-referencing of images) (Figs. 2, 3). The ALL was visualized in 93.4 % (95 % CI = 84.1–98.2) of the knee MRI studies. The whole ligament was visualized in 82 % (95 % CI = 70–90.6) examinations and it was partially visualized in 11.5 % (95 % CI = 4.7–22.2). Only 8 % (CI 95 % = 1.8–15.9) of MR examinations did not demonstrate the ALL (Table 4).

ALL was identified as a thin hypointense band originating from the lateral femoral epicondyle and with a distal insertion on the lateral tibial plateau between the Gerdy's tubercle and the fibular head (Figs. 1, 4). Its origin was

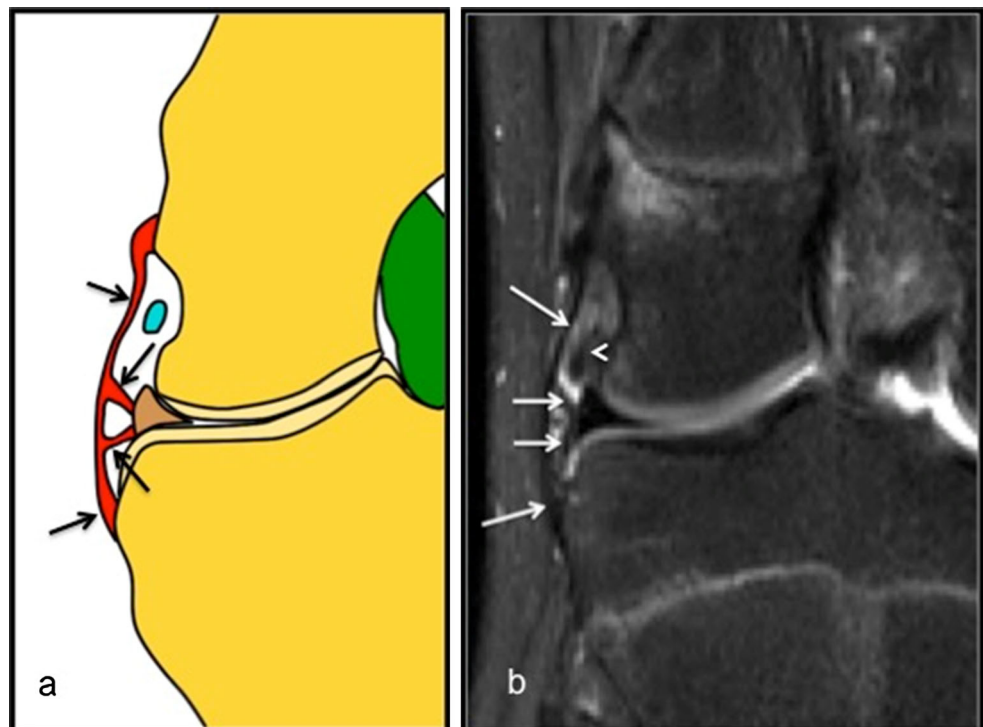
anterior or anterior-distal to the femoral origin of FCL and not always clearly distinguishable from it. The connecting fibers with the lateral meniscus were often well visible. Its distal fibers were close to the posterior fibers of the iliotibial band (ITB). No connecting fibers with popliteal tendon (PT) were observed.

### Discussion

The ALL was identified in all cadaveric studies as a distinct ligamentous structure at the anterolateral aspect of the knee, which was clearly distinct from ITB and FCL. Moreover, recent cadaveric studies precisely describe the anatomical structure of the ALL of the knee. Nevertheless some slight discrepancies remain between these studies.

The ALL is described as extra-capsular for some authors [6, 9] whereas it appears as a capsular thickening for others [2, 17, 30]. The origin of the ALL is situated at the prominence of the lateral femoral epicondyle. For some authors connecting fibers are observed between ALL and the joint capsule [9], the FCL [2, 6], and the PT [30]. According to Claes et al. and Vincent et al., the origin of the ALL is anterior to the femoral origin of the FCL [6, 30] whereas it is posterior according to Dodds et al. [9] and posterior-proximal according to Kennedy et al. [17]. According to Scott Catherine et al. the femoral origin of the ALL is somewhat variable in position, inserting either anterior-distal (60 %) or posterior-proximal (40 %) to the

**Fig. 2** Coronal (a) and axial (b). **f** Fat suppressed PD-weighted MR images: complete visualization of the three portions of the ALL (*thin straight arrows*). *ITT* (*thick curved arrow*); *FCL* (*arrowhead*); *biceps femoralis tendon* (*thick straight arrow*)





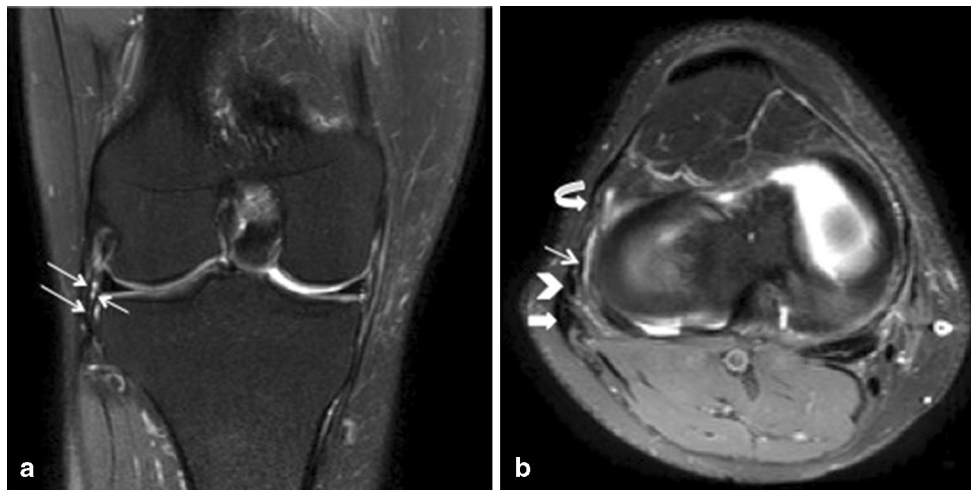


**Fig. 3** Coronal (a) and axial (b). Fat suppressed PD-weighted MR images: partial visualization tibial and meniscal portions) of the ALL (straight arrows). ITT (thick curved arrow); FCL (arrowhead); biceps femoralis tendon (thick straight arrow)

**Table 4** Visualization of the ALL on patients MRI

Visualization of the ALL	N	%	95 % confidence intervals
Visualized	57	93.4	84.1–98.2
Completely visualized	50	82	70–90.6
Partially visualized	7	11.5	4.7–22.2
Not visualized	4	6.6	1.8–15.9
Total	61	100	

femoral origin of the FCL [2]. Given the fact that the femoral origins of ALL and FCL are so closely associated, Claes et al. propose to envelop both structures in the term “lateral collateral complex” [6]: the ALL can be regarded as the lateral counterpart of the deep tibial collateral ligament [18]. According to Vincent et al. the origin of the ALL is just anterior to the popliteus tendon insertion in 90 % of cases [30] whereas it is posterior-proximal for Claes et al. [6]. The ALL has connecting fibers with the



**Fig. 4** Coronal (a) and axial (b) Fat suppressed PD-weighted MR images—partial visualization tibial and meniscal portions) of the ALL (straight arrows). ITT (thick curved arrow); FCL (arrowhead); Biceps femoralis tendon (thick straight arrow)

periphery of the middle third of the lateral meniscus which is divided into meniscofemoral and meniscotibial portions of the ALL [2, 6, 9, 30]. The lateral inferior geniculate artery and vein is situated in between the lateral meniscal rim and the ALL at the level of the joint line [6]. All authors agree that the distal insertion of the ALL is at the anterolateral side of the proximal tibia in the middle of the line connecting Gerdy's tubercle and the tip of the fibular head. Flexion of knee to 90° and internal rotation result in tightening of the structure [30].

Cadaveric studies identified the ALL in above 80 % of the examined knees with most studies indicating incidences closer to 100 % [2, 5, 6, 9, 11, 24, 30].

One case report describes the identification of the ALL by ultrasound examination with the knee in 90° flexion and slight internal rotation [3].

Radiographic landmarks of the ALL origin and insertion have been described in order to facilitate the anatomical placement of tunnels during reconstruction of this ligament, even though the authors agree that indications for such a procedure have not been defined yet [24].

Using MRI, the ALL was identified in 100 % of the examined knees in most studies [4, 23] with no further information about partial or total visualization. Helito et al. visualized at least one of the three portions of the ALL in 97.8 % of examined knees [12] while Taneja et al. visualized it in 51 % [28]. All these results were obtained with specific sequences (T2 without FS, PD without FS, three-dimensional T1), which are not performed for routine MRI in the context of traumatic knee evaluation. We know that the ALL is surrounded by adipose tissue and therefore easier to visualize on non-fat-suppressed sequences. Porriño et al. have studied the ALL with routine sequences

(coronal PD SPAIR and axial T2-weighted SPAIR) on 3T-MRI with a total visualization of the ALL in 100 % of the cases while stating that the ALL is inseparable from the adjacent FCL at their femoral attachment site and that the distal insertion is inseparable anteriorly from the posterior fibers of the ITT [23]. More recently Macchi et al. have studied the ALL of 47 patients with T1- and T2-weighted sequences on 1.5 T-MRI and visualized it in 93 % and note that ALL was more difficult to recognize in young patients [20].

In our study, we were able to visualize the ALL in 93.4 % of the knees with a routine protocol (axial and coronal fat suppressed PD-weighted sequences) and a stringent criterion of visibility in both axial and coronal planes to confirm its visualization. The whole ligament was visualized in 82 % of the case. The ALL was identified with MRI as a thin hypointense band originating from the lateral femoral epicondyle and with a distal insertion on the lateral tibial plateau between the Gerdy's tubercle and the fibula's head. Its femoral origin was rarely clearly distinguishable from the insertion of the FCL. In addition, at the tibial distal insertion, there was not always reliable plane between the ALL and the posterior fibers of the ITT. These results are also consistent with other MRI studies and the differences with results of gross anatomical dissections are easily explained by the limitation of spatial resolution of MRI.

The clinical implications of confirming the visibility of ALL on MRI with routine protocol are as follows:

First we know now that ALL distal avulsion is pathognomonic of the ACL tear [8, 10, 29, 31]: visualization on an ALL avulsion in case of uncertain ACL rupture would allow to claim the rupture.

Then, Claes et al. demonstrated a high prevalence (79 %) of ALL abnormalities on the MRI of ACL-injured knees [4].

The ALL is for some authors an important lateral knee stabilizer, controlling internal tibial rotation and preventing tibial translation [14, 16, 22], especially at high angles of flexion [22].

The ALL is not repaired in usual ACL reconstruction and its rupture is probably responsible for some chronic anterolateral instability after isolated intra-articular reconstruction of the ACL in patients without any predisposing factors (improper tunnel positioning or problems with rehabilitation). The role of extra-articular lateral reconstruction/tenodesis combined with ACL reconstruction improving postoperative knee stability has been discussed but recent studies [19, 32] and a meta-analysis [13] showed a variable (marginally to statistically significant) reduction in pivot shift in favor of the combined procedure. Sonnery-Cottet et al. describe a safe and reproducible arthroscopic technique to allow identification and examination of the ALL [26] and demonstrate that a combined ACL and ALL reconstruction can be an effective procedure without specific complications [27].

Our results show that the ALL of the knee can be identified using routine 1.5 T MR imaging, which suggest that better radiological description of this underestimated anatomical structure may be beneficial in the preoperative planning of ACL tears.

#### Compliance with ethical standards

**Conflict of interest** The authors have nothing to disclose.

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