The Anterolateral Ligament of the Knee: MRI Appearance, Association With the Segond Fracture, and Historical Perspective

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OBJECTIVE. A recent publication has drawn attention to the anterolateral ligament, a structure of the knee with which most radiologists are unfamiliar. We evaluate this structure on MRI; clarify its origin, insertion, meniscal relationship, and morphologic appearance; and identify its relationship with the Segond fracture.

MATERIALS AND METHODS. A total of 53 routine knee MRI studies interpreted as normal were reviewed to characterize the anterolateral ligament. A further 20 knee MRI studies with a Segond fracture were assessed to determine a relationship between the fracture and the anterolateral ligament.

RESULTS. In all 53 cases, a structure was present along the lateral knee connecting the distal femur to the proximal tibia, with meniscofemoral and meniscotibial components. This structure was somewhat ill defined and sheetlike, inseparable from the adjacent fibular collateral ligament proximally and iliotibial band distally. Aside from one case limited by anatomic distortion, all cases with a Segond fracture exhibited attachment of this structure to the fracture fragment (19/20 cases).

CONCLUSION. An ill-defined sheetlike structure along the lateral knee exists attaching the distal femur, body of lateral meniscus, and proximal tibia. This structure has been referenced in the literature dating back to Paul Segond's original description of the Segond fracture in 1879. The structure is identifiable on MRI and appears to be attached to the Segond fracture fragment. For the radiologist, it may be best to forgo an attempt to separate this structure into discrete divisions, such as the anterolateral ligament, because these individual components are inseparable on routine MRI.

Anatomy of the lateral aspect of the knee is complex, with numerous structures providing stability. Structures such as the iliotibial band, fibular collateral ligament, and biceps femoris tendon are readily apparent on MRI and are easy to identify. Unlike these more common structures that stabilize the lateral knee, the anterolateral ligament does not appear in many common radiology and gross anatomy texts [1, 2].

Recently, there has been much excitement about the publication of an article by Claes et al. [3], in which they provided a detailed anatomic description of an anterolateral ligament (Fig. 1). Although Claes et al. do not claim that this ligament is a new discovery, they do suggest that it is nearly always apparent on gross anatomic dissection and likely plays an important role in the pathophysiology of the Segond fracture.

Claes et al. [3] think that Dr. Paul Segond described this ligament in 1879 during his initial description of the Segond avulsion fracture. In this description, the Segond fracture occurs at the anterolateral proximal tibia as a result of forced internal rotation at the knee. Segond described a "pearly, resistant, fibrous band which invariably showed extreme amounts of tension during forced internal rotation (of the knee)" at the location of the fracture [3].

Since the Segond study, there have been numerous references to a structure along the lateral aspect of the knee connecting the distal femur to the tibia, many with claims that this structure is responsible for the Segond fracture. Unfortunately, these articles show considerable variability in nomenclature and morphologic description.

The purpose of our study was to identify the anterolateral ligament on MRI of the

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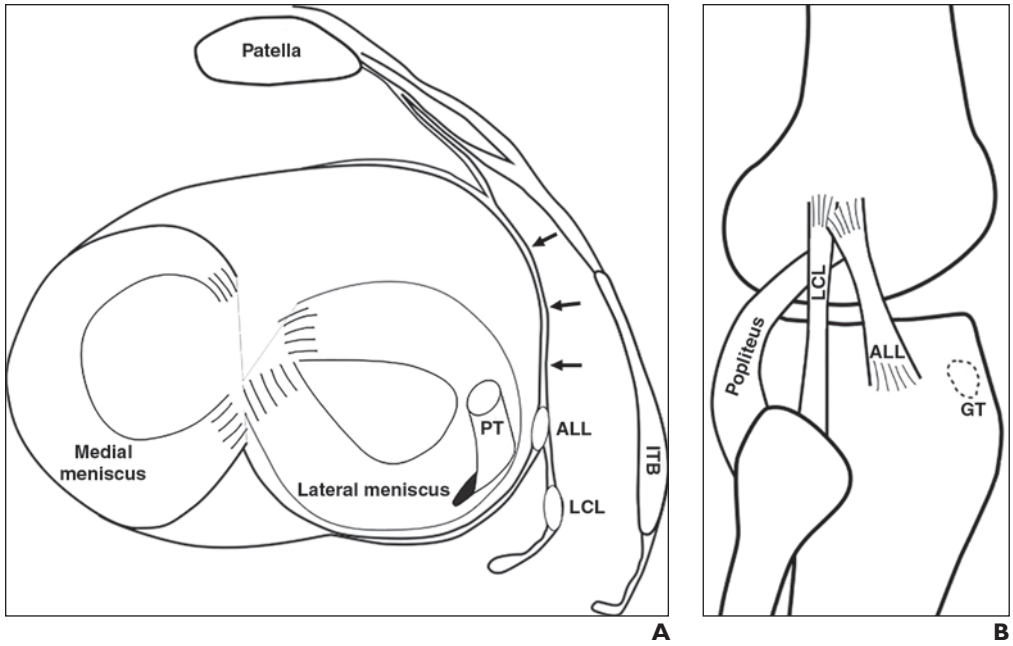


Fig. 1—Drawings modeled after diagrammatic depiction of anterolateral ligament (ALL) by Claes et al. [3]. (Adapted with permission from John Wiley and Sons)
A and **B,** Axial (**A**) and lateral (**B**) views of knee are shown. ALL is denoted in relationship to surrounding structures, including popliteus tendon (PT), fibular or lateral collateral ligament (LCL), iliotibial band (ITB), and Gerdy tubercle (GT). Notably, multiple ($n = 3$) tissue layers are depicted on axial view, from superficial to deep, partly composed of iliotibial band, lateral patellar retinaculum anteriorly, and thin lateral capsule (*arrows*, **A**) just anterior to ALL.

knee; to clarify its proximal origin, distal insertion, meniscal relationship, and morphologic appearance; and to identify the relationship between the anterolateral ligament and the Segond fracture fragment.

Materials and Methods

This study was approved by the investigational review board at the University of Washington.

Healthy Subjects

A total of 395 routine knee MRI studies were performed at the University of Washington Medical Center using magnets with 3-T field strength (two Ingenia magnets and one Achieva magnet, all from Philips Healthcare) between December 2011 and November 12, 2013. Images from these magnets were chosen because of their superior field strength and spatial resolution. Reports from these studies were reviewed, and only those studies in which the final impression was normal, or the abnormality was limited to minor hyaline articular cartilage abnormalities or minor tendinosis of the extensor apparatus, were included for interpretation. In addition, those studies subject to artifact limiting the quality of the examination, or cases in which contrast agent was present, despite the PACS designation as an unenhanced examination, were discarded. This resulted in a total of 76 remaining cases. Studies in which bone marrow abnormalities were noted, such as small enchondroma or bone infarct, were included for review because these findings have no impact on the integrity of the surrounding ligamentous structures. Patients younger than 18 years ($n = 23$) were excluded. As a result, a total of 53 unenhanced normal knee MRI studies were reviewed to identify the anterolateral ligament. The magnets used and the pulse sequences evaluated are listed in Table 1.

TABLE 1: MRI Magnets and Pulse Sequences Used to Characterize the Anterolateral Ligament and Assess for an Association of the Anterolateral Ligament With the Segond Fracture

Assessment, Magnets Used	Pulse Sequences Evaluated
Characterization of the anterolateral ligament	
3-T Ingenia (Philips Healthcare)	Axial T2-weighted spectral attenuated inversion recovery
3-T Achieva (Philips Healthcare)	Coronal proton density spectral attenuated inversion recovery
Evaluation for association of the anterolateral ligament with the Segond fracture	
3-T Achieva (Philips Healthcare)	Axial T2-weighted fat suppressed
1.5-T Achieva (Philips Healthcare)	Axial T2-weighted spectral attenuated inversion recovery
3-T Signa HDxt (GE Healthcare)	Coronal T1-weighted
1.5-T Signa Excite (GE Healthcare)	Coronal STIR
	Coronal proton density fat suppressed
	Coronal proton density spectral attenuated inversion recovery

Two fellowship-trained musculoskeletal radiologists jointly interpreted each study and tabulated their consensus opinion regarding the following questions: First, with regard to the appearance of the proximal aspect of the ligament, is there blending with the fibular collateral ligament at the proximal femoral origin, as described in the study by Claes et al. [3], and is the structure easily separable from the structure referred to by Claes et al. as the lateral capsule? Second, are there discrete meniscofemoral and meniscotibial attachments, as Claes et al. suggest, along the midportion of the structure? Third, with regard to characterization of the distal tibial insertion, is the tibial attachment cordlike, or instead fanned as Claes et al. describe, and can the distal attachment be discriminated from the posterior fibers of the iliotibial band?

Subjects With Segond Fractures

zVision software (version 1.4.80, Clario) was used to search the University of Washington PACS for routine knee MRI examinations per-

formed within the University of Washington system between November 1, 2005, and November 12, 2013, that included the word "Segond" in the finalized report. A total of 48 studies performed on a combination of 1.5- and 3-T magnets were identified. Each study was reviewed to confirm the presence of an MRI-apparent Segond fracture, and those without a discernible Segond fracture fragment on MRI (n = 14) were excluded. In addition, patients younger than 18 years (n = 1), patients with an incomplete examination (n = 1), and those with suboptimal imaging such as that seen with hardware or patient motion (n = 12) were excluded from the study. This resulted in a total of 20 unenhanced MRI studies of Segond fracture in this arm of our study (Table 1). These studies were reviewed during the same session by the same two fellowship-trained musculoskeletal radiologists to establish a relationship between the anterolateral ligament and the Segond fracture fragment. Final results were tabulated.

Results

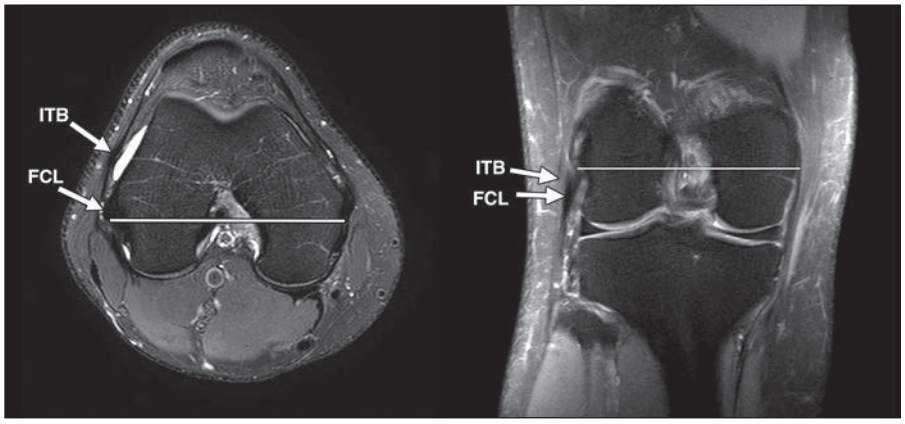
A total of 53 normal knee MRI studies were evaluated (35 women and 18 men; 29 right and 24 left knees). Patient age ranged from 18 to 59 years old. In all 53 cases, a structure was present along the lateral aspect of the knee that connects the distal femur with the proximal tibia. We were able to visualize this structure throughout its entire course, in both the axial and coronal plane.

Proximally (at the level of the distal femur), this structure is inseparable from the adjacent fibular collateral ligament at their femoral attachment site. In fact, a discrete proximal origin of the ligament is difficult to discern. Instead, just below the epicondylar origin of the fibular collateral ligament, a long (in anteroposterior dimension) but thin and somewhat ill-defined meniscofemoral attachment is present that runs deep to the iliotibial band and anterior to the fibular collateral ligament. There is no reliable division of this structure at this level to allow separation of an anterolateral ligament from an adjacent and more anterior lateral capsule. As this structure continues distally, there is a more distinct meniscotibial component that blends in a broad-based fashion onto the proximal tibia, below the level of the tibial plateau and midway between the Gerdy tubercle and the fibular head. This distal insertion is inseparable anteriorly from the posterior fibers of the iliotibial band. The structure's intimate relationship with the body of the lateral meniscus is best appreciated in the coronal plane (Figs. 2 and 3).

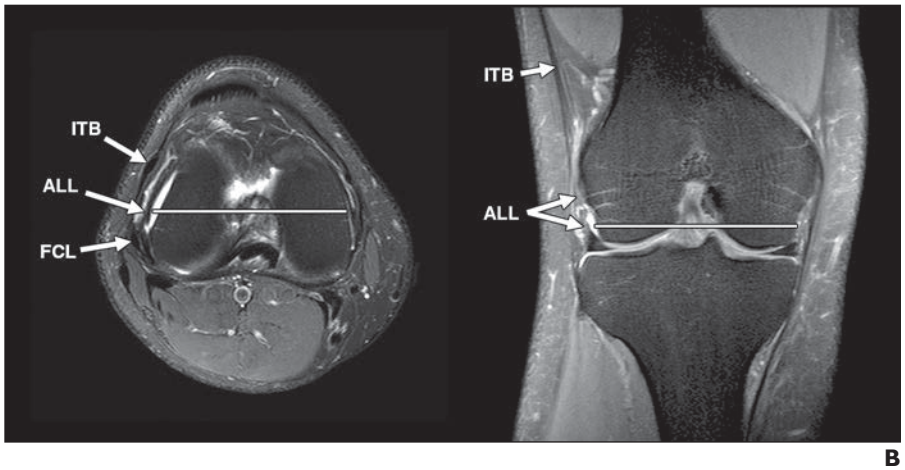
A total of 20 MRI studies with a readily apparent Segond fracture were evaluated to determine an association of the anterolateral ligament with this avulsion injury. This included 17 men and three women, with 12 right knees and eight left knees. In 19 of the 20 cases, there was clear insertion of the tibial component of the anterolateral ligament onto the Segond fracture (Figs. 4 and 5). In the lone remaining case, anatomic distortion limited assessment of a ligamentous attachment to the fragment.

Discussion

In the article by Claes et al. [3], the anterolateral ligament is described as arising from the lateral femoral epicondyle, proximal and posterior to the popliteus tendon, and with posterior fibers blending with the proximal fibular collateral ligament. The anterolateral ligament has a strong connection with the periphery of the body of the lateral meniscus by way of its meniscofemoral and meniscotibial components. Distally, the ligament inserts midway between the Gerdy tubercle and the fibular head, with distal flaring clearly apparent (Fig. 1). There is no connection of the ligament with the lateral capsule proximally or with the iliotibial band distally. The authors suggested, on the basis of the close association of the femoral origins of the fibular collateral ligament and anterolateral ligament, that the fibular collateral ligament and anterolateral ligament collectively be referred to as one structure, the lateral collateral ligament complex. On the basis of the anatomic location of the anterolateral ligament, the authors suggested that the struc-



A



B

Fig. 2—29-year-old man. T2-weighted spectral attenuated inversion recovery MR images of knee (sequentially through knee, from proximal to distal) are shown. Solid white lines represent corresponding slice levels between axial and coronal images.
A, Axial (*left*) and coronal (*right*) images show femoral origin of fibular collateral ligament (FCL). Anterolateral ligament (ALL) is not yet appreciated at this level. ITB = iliotibial band.
B, Axial (*left*) and coronal (*right*) images show ALL arising anterior to FCL, deep to ITB, and proximal to lateral meniscus. Coronal image denotes meniscofemoral component, merging with body of lateral meniscus.

(Fig. 2 continues on next page)

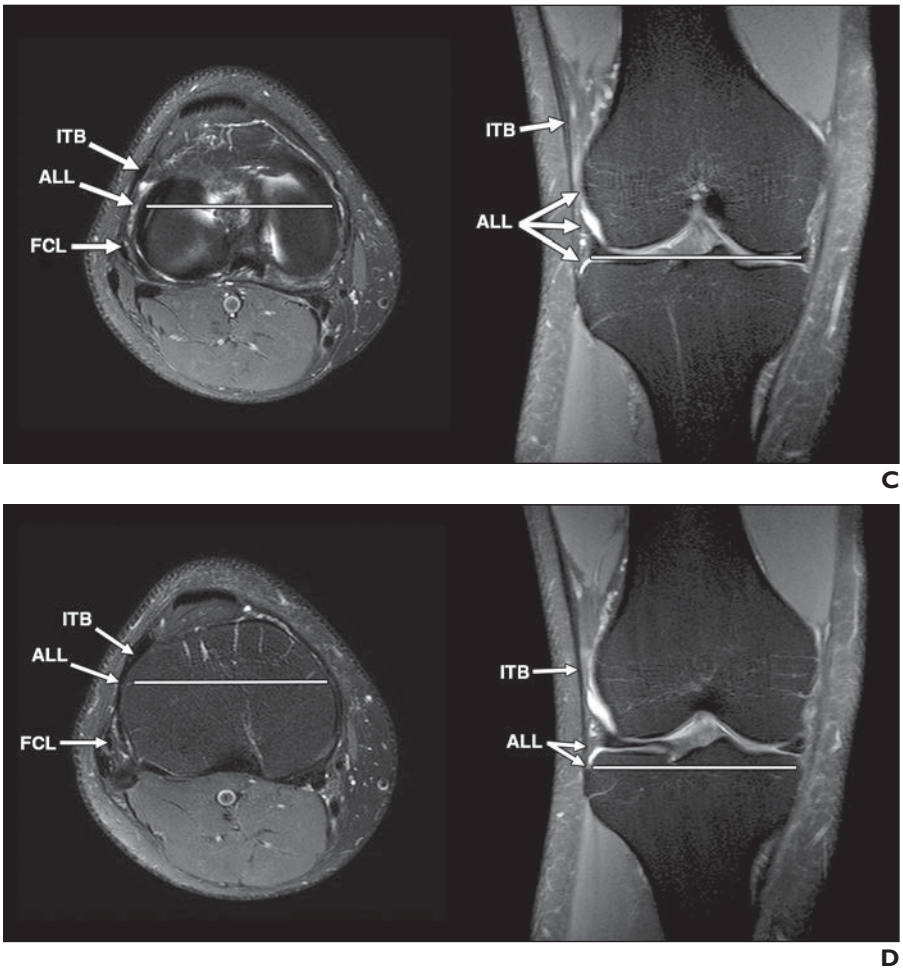


Fig. 2 (continued)—29-year-old man. T2-weighted spectral attenuated inversion recovery MR images of knee (sequentially through knee, from proximal to distal) are shown. Solid white lines represent corresponding slice levels between axial and coronal images.
C, Axial (*left*) and coronal (*right*) images show meniscotibial component of ALL just distal to body of lateral meniscus on axial slice, whereas both meniscofemoral and meniscotibial components are denoted on coronal slice, merging with body of lateral meniscus.
D, Axial (*left*) and coronal (*right*) images show ALL at tibial insertion site, midway between Gerdy tubercle and fibular head. Coronal image highlights meniscotibial component.

ture may be an important stabilizer for internal rotation and that avulsion may account for the Segond fracture [3].

We found the MRI appearance of the anterolateral ligament to be similar to that described by Claes et al. [3], although we found certain exceptions. Most discordant, there was no reliable visualized plane separating an anterolateral ligament and an immediately adjacent lateral capsule, as Claes et al. described. This results in a single thin and somewhat ill-defined structure, as opposed to a discrete cordlike structure (anterolateral ligament) and adjacent thin capsular structure (lateral capsule). In addition, at the distal tibial insertion, there is no reliable plane separating this structure from the posterior fibers of the iliotibial band. These discrepancies may well be the result of limitations in the spatial resolution of MRI when compared with that of direct gross anatomic dissection.

Nevertheless, there is clearly a lateral structure readily apparent on MRI connecting the distal femur, the body of the lateral meniscus, and the proximal tibia, exhibiting a strong association with the Segond fracture. Much of the confusion stems from the lack of standardized nomenclature and the seemingly overwhelming tendency within the literature to divide this structure into multiple individual fascicles. Some authors reference a single structure responsible for attachment of the lateral distal femur with the adjacent tibia (i.e., the lateral capsular ligament or middle-third lateral capsular ligament). Others include a description of an anterior oblique band of the fibular collateral ligament. In addition, the relationship of the iliotibial band with this structure is quite confusing on the basis of prior reports. A chronologic and systematic review of the literature in regard to this structure, as well as that of the Segond fracture, shows these inconsistencies.

Literature Review of the Anterolateral Ligament

Lateral Capsular Ligament

In a two-part landmark study performed in 1976 pertaining to the classification of knee ligament instabilities, Hughston et al. [4, 5] divided the lateral compartment ligaments of the knee into three anatomic divisions. The middle third, composed of the iliotibial band and deep capsular ligaments, extends posterior to the level of the fibular collateral ligament. Within this middle division, the lateral capsular ligament attaches proximally to the lateral epicondyle of the femur and distally to the tibial joint margin, with attachments to the meniscus divided into meniscofemoral and meniscotibial portions. Those articles provided the blueprint for the detailed anatomy that comprises the lateral aspect of the knee used by many authors thereafter [4, 5].

In a 2000 review of the MRI appearance of structures that comprise the posterolateral knee, LaPrade et al. [6] described the mid third lateral capsular ligament as a thickening of the lateral capsule of the knee, attaching to the femur in the region of the lateral epicondyle, with capsular attachments to the lateral meniscus and insertion onto the tibia posterior to the Gerdy tubercle and anterior to the popliteal hiatus. They divided this structure into meniscotibial and meniscofemoral ligament subcomponents. This anatomic description is in accordance with the studies by Hughston et al. [4, 5]. Bone avulsion of the meniscotibial ligament portion of the mid third lateral capsular ligament is termed a Segond fracture according to these authors [6].

Haims et al. [7] reviewed MRI anatomy of the lateral knee in 2003. In that study, the mid third lateral capsular ligament is depicted and described. This ligament runs vertically from the distal femur to the mid third lateral tibia on both diagrams and per their description. However, the ligament lacks an obvious femoral insertion on the provided imaging. In their discussion, bony avulsion

of this structure is responsible for the Segond fracture [7].

In an anatomic and biomechanical review of the posterolateral corner of the knee, Moorman et al. [8] in 2005 described the mid third lateral capsular ligament as the portion of the capsule that attaches to the femur and courses down to the tibia, at the site of the Segond avulsion fracture [8].

Anterior Oblique Band of the Fibular Collateral Ligament

In 1987, Irvine et al. [9] divided the fibular collateral ligament into two components while examining the Segond fracture. The fibular collateral ligament was divided into a straight band that courses from the distal femur to the fibular head, as well as an anterior oblique band that inserts onto the lateral tibial rim. In that study, results indicated that the Segond fracture may be avulsed by the anterior oblique band. [9]

In 2001, Campos et al. [10] provided a detailed review of the pathogenesis of the Segond fracture with both gross anatomic dissection and MRI. A description of the anterior oblique band of the fibular collateral ligament was provided—a firm band of tissue arising from the fibular collateral ligament in an oblique fashion, inserting at the lateral midportion of the tibia and blending with the posterior fibers of the iliotibial tract. The lateral capsular ligament was described as a separate structure—a delicate thickening of the lateral capsule at its midpoint, with a vertical orientation. The iliotibial tract, anterior oblique band, and lateral capsular ligament exhibited attachments to each other, as well as attachment to the lateral tibia. The anterior oblique band was identified on MRI in the axial plane in all six cadavers studied. The lateral capsular ligament could be identified on MRI in a coronal oblique plane only when marked preemptively with gadopentetate dimeglumine–filled tubes. There was a frequent attachment of the iliotibial tract and the anterior oblique band to the avulsed Segond fracture fragment [10].

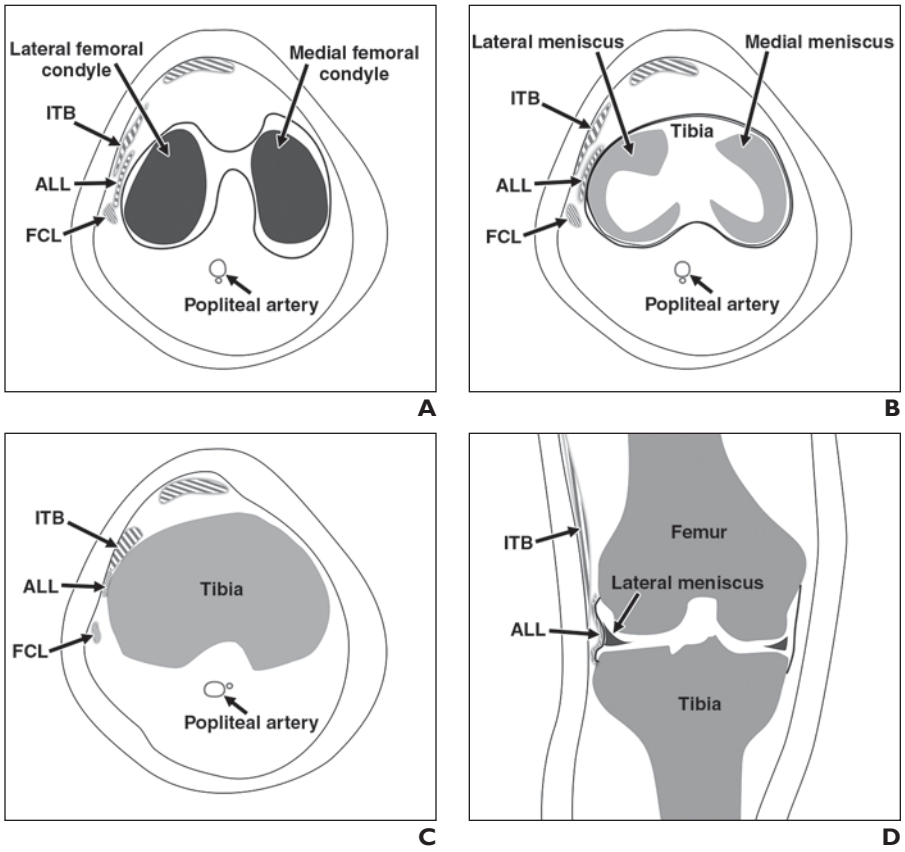


Fig. 3—Line drawings derived from axial and coronal MR images of knee. (Drawings by Maloney E)
A, Drawing shows anterolateral ligament (ALL) arising anterior and immediately adjacent to fibular collateral ligament (FCL), deep to iliotibial band (ITB), and proximal to body of lateral meniscus. This structure is thin, without clear demarcation from immediately adjacent and anterior lateral joint capsule on MRI.
B, Drawing shows ALL at level of body of lateral meniscus.
C, ALL is inserting onto tibia, midway between Gerdy tubercle and fibular head, inseparable from adjacent fibers of ITB.
D, Coronal representation of ALL shows meniscotibial and meniscofemoral components of structure.

Anterolateral Ligament

In a description of anatomy of the iliopatellar band and iliotibial tract in 1986, Terry et al. [11] referred to the capsuloosseous layer of the iliotibial tract as the anterolateral ligament because of this structure's contribution to an-

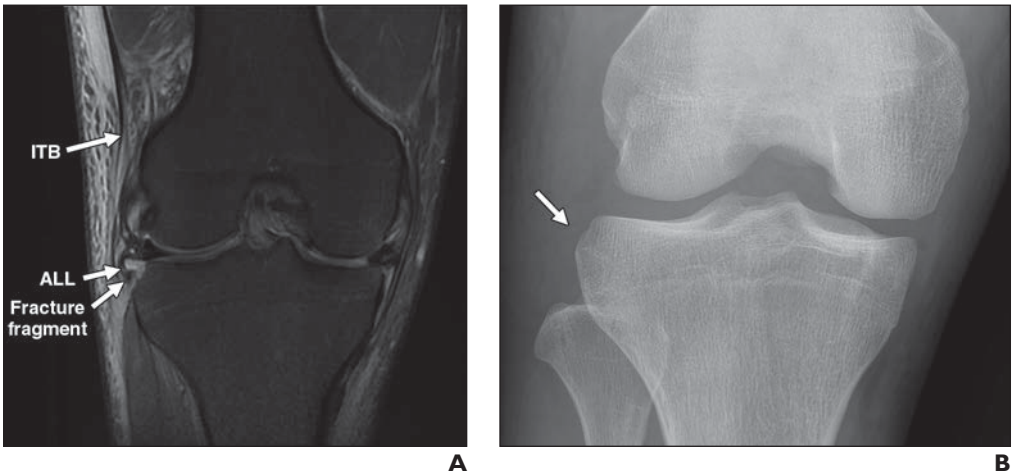


Fig. 4—28-year-old man with Segond fracture after motorcycle crash.
A, In coronal proton density–weighted fat-suppressed image, meniscotibial component of anterolateral ligament (ALL) can be seen attaching to Segond fracture fragment. ITB = iliotibial band.
B, Corresponding frontal radiograph shows nearly imperceptible displaced fracture fragment (*arrow*) adjacent to lateral tibial plateau.

terolateral stability of the knee. In this description, the capsuloosseous layer is formed proximally by a coalescence of fascia overlying the plantaris and lateral gastrocnemius to which it is intimately applied. Furthermore, at the lateral gastrocnemius, it becomes a triangular ligament attaching posterior distally to the fibula and anterior distally to the lateral tibial tuberosity. The distal tibial insertion is specifically described as being just posterior to the Gerdy tubercle, on the lateral tibial tuberosity. It should be noted that in that study, there is specific reference to an additional lateral structure about the knee referred to as the mid third capsular ligament. [11]

In a detailed anatomic study of the iliotibial tract by Vieira et al. in 2007 [12], the authors referenced the original description by Terry et al. [11] of the anterolateral ligament. They described this portion of the iliotibial tract as having a well-defined ligamentous appearance, arising from the lateral supraepicondylar region of the femur, bordering the lateral edge of the lateral epicondyle, and inserting laterally to the Gerdy tubercle of the proximal tibia [12].

In 2012, in an anatomic and histologic study of those undergoing total knee arthroplasty and in cadaveric dissections, Vincent et al. [13] described a structure that links the lateral femoral condyle, lateral meniscus, and lateral tibial plateau and referred to it as the anterolateral ligament. This structure arose from the lateral femoral condyle in the majority of cases, except for a case originating from the popliteus tendon just before its insertion. In each case, the structure was closely related to the lateral meniscus and always inserted onto the proximal anterolateral tibia. Histologically, this structure exhibited the same type of collagen orientation as that seen with tendons and ligaments and reflected fibrous tissue distinct from the lateral capsule. Vincent et al. stated that this structure is synonymous with the one described by Terry et al. [11] and later Vieira et al. [12] (capsuloosseous layer of the iliotibial tract), LaPrade et al. [6] (mid-third lateral capsular ligament), and Campos et al. [10] (lateral capsular ligament).

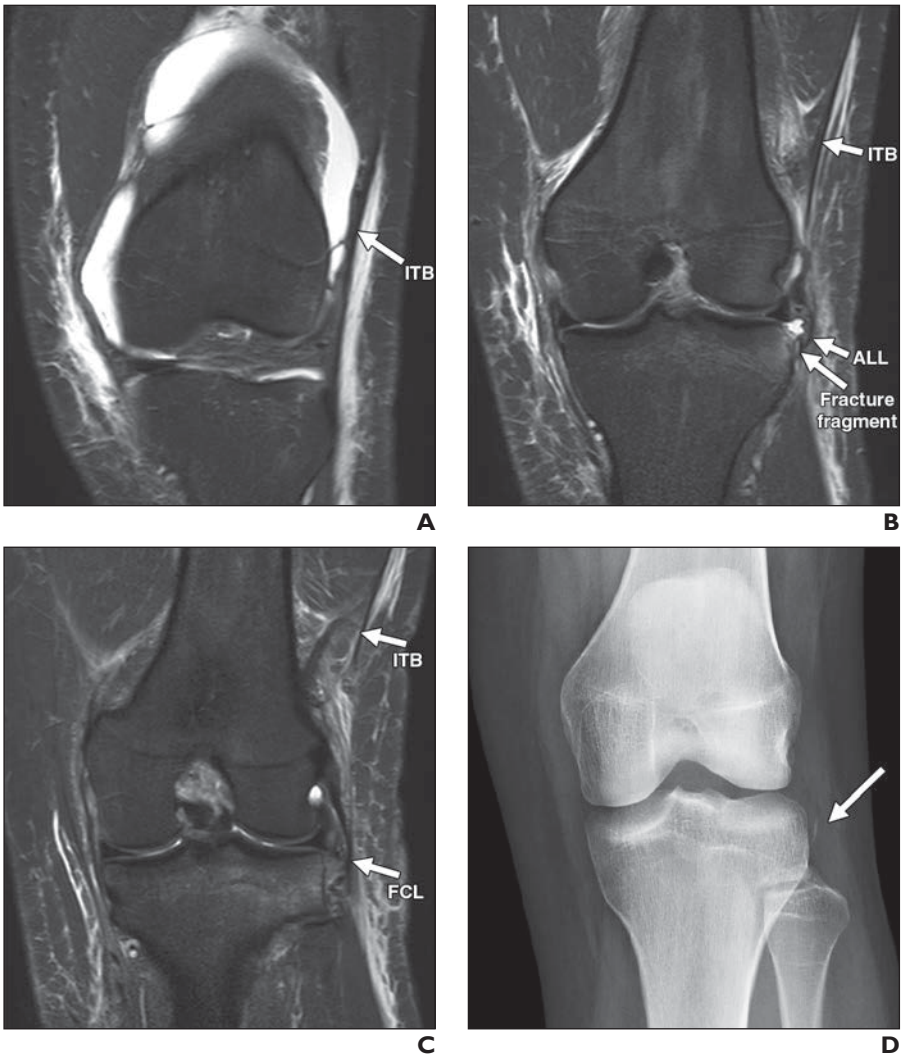


Fig. 5—19-year-old woman who experienced direct blow to knee while playing soccer
A–C, Sequential coronal STIR images of knee show Segond fracture and its relationship with anterolateral ligament (ALL), iliotibial band (ITB), and fibular collateral ligament (FCL). First image (**A**) shows knee at level of ITB. In second image (**B**), just posterior to first image (**A**), meniscotibial component of ALL is seen attaching to Segond fracture fragment. Third image (**C**), just posterior to second image (**B**), shows FCL.
D, Corresponding frontal radiograph shows Segond fracture (*arrow*).

Literature Review of the Segond Fracture

The Segond fracture is a cortical avulsion fracture of the proximal tibia, located just below the level of the lateral plateau and superior and posterior to the Gerdy tubercle. The fracture is the result of excessive internal rotation and varus stress and has a high association with tears of the anterior cruciate ligament and menisci, as well as resultant anterolateral rotary instability. The avulsed fragment is often readily apparent on an anteroposterior view of the knee, although the fracture fragment is far more difficult to identify on MRI [10, 14–18].

In 1979, Woods et al. [18] suggested that the Segond fracture reflects a fracture fragment superior and posterior to the Gerdy tubercle, related to avulsion of the meniscotibial portion of the middle one-third of the lateral capsular ligament. The middle one-third of the lateral capsular ligament is divided into meniscofemoral and meniscotibial portions. This is in accordance with the original description by Hughston et al. in 1976 [4, 5]. Woods et al. provided a brief description of their operative approach to repair. They referred to the radiographic finding as the lateral capsular sign as a result of the aforementioned anatomic description [18].

Dietz et al. [14] in 1986 performed a radiographic review of the Segond tibial condyle fracture. The fracture was differentiated from avulsion of the Gerdy tubercle. The authors explained the Segond fracture as being related to avulsion of the lateral capsular ligament, with reference to the anatomic description provided by Hughston et al. in 1976 [4, 5].

In 1988, Goldman et al. [15] performed a retrospective review of double-contrast ar-

thrograms that revealed a Segond fracture to describe the clinical and radiographic features as well as associated soft-tissue injuries. Those authors described the fracture as being the result of avulsion of the meniscotibial attachment of the middle third of the lateral capsular ligament. Again, the fracture was differentiated from an avulsion of the Gerdy tubercle at the insertion site of the iliotibial band. Diagrammatically, the lateral capsular ligament was depicted as a large broad-based structure running from the distal lateral femur to the proximal lateral tibia [15].

MRI characteristics of the Segond fracture were described by Weber et al. in 1991 [17]. The authors described the Segond fracture as a cortical avulsion of the meniscotibial portion of the middle third of the lateral capsular ligament of the knee. The avulsed fracture fragment was seen on MRI in only four of the 12 patients in the series and was seen on a single coronal image only. However, abnormal bone marrow signal at the tibial insertion of the capsular ligament and irregularity and edema of the capsule and paracapsular connective tissues were present on all cases. Although there was no MRI description of injury to the middle third of the lateral capsular ligament in that study, surgical reports described complete avulsion of the lateral capsular ligament from the lateral tibial plateau (four patients) or stretching and fraying of this ligament (three patients) in over 50% of the patients [17].

Finally, a 1994 retrospective review by Hess et al. [16] examined the relationship of the Segond fracture with concomitant tear of the anterior cruciate ligament, and the Segond fracture was described as corresponding to the distal insertion point of the lateral capsular ligament or lateral meniscotibial ligament. The authors described this as a component of the middle of the lateral joint capsule. As with prior reports, this lesion was differentiated from avulsion of the Gerdy tubercle. Notably, their diagrammatic illustration of the lateral capsular ligament depicted a thin ligamentous structure arising just anterior to the fibular collateral ligament at the femoral insertion point and inserting onto the lateral proximal tibia in a cordlike fashion. In their series of 14 patients with Segond fractures, only two exhibited an additional injury to the lateral ligament structure intraoperatively [16].

In summary, it would appear that the works reviewed here, including Claes et al. [3], have been describing, at times, different components of the same collective structure. Although the drawings published by Claes et al. depict a discrete anterolateral ligament, we could not reliably see either a discrete structure or even a consistent focal thickening of the lateral capsule in this area. For the radiologist, it may be best to forgo an attempt to separate this lateral structure into multiple components, such as the anterolateral ligament, capsuloosseous layer of the iliotibial tract, or anterior oblique band of the fibular collateral ligament, because these structures are not reliably discriminated on routine MRI. Perhaps it would be most appropriate to give credit to Hughston and colleagues [4, 5] for their detailed description of this structure in 1976 and continue to refer to this portion of the lateral knee stabilizers as the lateral capsular ligament.

Our study is limited by a lack of gross anatomic correlation, which could in theory provide a greater understanding of those authors who referenced the structure under investigation in the past. In addition, a more detailed depiction of the structure could have potentially been made if knee MRI studies were performed in partial flexion with internal rotation, a position in which this structure has been described as being under stress in previous articles. Although anatomic studies often use such optimized pulse sequences acquired in unique planes at high resolution, the purpose of our study is not to recapitulate the gross anatomic work of Claes et al. [3] through the use of MRI and prove that an anterolateral ligament exists, but instead to provide an understanding of what the routine knee MRI shows pertaining to that structure. Finally, a more comprehensive assessment of the cause of the Segond avulsion fracture would require the incorporation of cadaveric specimens and systematic mechanical data, which is beyond the scope of our study but a consideration for future research.

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