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ORIGINAL STUDY

High prevalence of anterolateral ligament abnormalities in magnetic resonance images of anterior cruciate ligament-injured knees

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The purpose of this study was to identify the newly described anterolateral ligament of the human knee on magnetic resonance imaging and to describe its eventual radiological abnormalities in anterior cruciate ligament-injured subjects.

A retrospective cohort study on a series of consecutive subjects undergoing anterior cruciate ligament reconstructive surgery was performed. The MR images of 206 included knees were studied and the status of the anterolateral ligament status was judged to be either "non-visualized", "normal" or "abnormal".

Of all the visualized anterolateral ligaments, 44 (21.3%) were considered uninjured, while 162 (78.8%) knees demonstrated radiological ALL abnormalities. The majority of ALL abnormalities were situated in the distal part of the ligament (77.8%).

In conclusion, the anterolateral ligament can be identified on classic knee magnetic resonance images. Although anterior cruciate ligament injured subjects often demonstrated associated anterolateral ligament lesions, further research is needed in order to establish the clinical relevance of these highly frequent radiological abnormalities.

INTRODUCTION

In the past, some sporadic reports have suggested the potential existence of a ligamentous structure connecting the femur with the anterolateral tibia of the human knee. In 1879, Paul Segond briefly described a "pearly, resistant, fibrous band" as being attached to the eponymous Segond fracture *(11)*, while 100 years later Jack Hughston named the "middle one-third of the lateral capsular ligament" as being related with his concept of "anterolateral knee instability" *(8)*. Due to the lack of a clear anatomic description or drawing, this enigmatic structure has never gained wide acceptance in orthopedic or anatomic textbooks.

Recently however, our research group has characterized the anterolateral ligament (ALL) as a distinct ligamentous structure coursing the anterolateral aspect of the human knee *(6)*. In brief, the ALL was found to originate from the lateral femoral epicondyle, with some ALL fibers blending into the proximal part of the lateral collateral ligament

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(LCL). The ALL further showed an oblique intracapsular course displaying firm attachments to the lateral meniscus, although the lateral inferior geniculate artery and veins were invariably retrieved in between the ALL and the body of this lateral meniscus. Finally, the ALL inserted on the proximal aspect of the anterolateral tibia well posterior to Gerdy's tubercle, thus forming an capsulo-ligamentous insertional fold which was termed the "lateral tibial recess" (*6*).

On the other hand, we demonstrated in a selective ligament-cutting study using computer navigation (unpublished, under consideration) that this newly described ALL functions as an important internal rotatory stabilizer of the knee, especially between 30° and 90° of flexion. With the pivot-shift phenomenon basically consisting of a coupled anterior tibial subluxation and excessive internal tibial rotation, it was correspondingly shown that an injury to the ALL forms a prerequisite for the occurrence of a high-grade pivot-shift in the anterior cruciate ligament (ACL)-deficient knee.

The majority of ACL ruptures are caused by non-contact injuries (*3*), incited by a classic combination of knee abduction (i.e. valgus) and internal tibial torque (*9*). In this view, a recent review has suggested that the mechanism causing non-contact ACL injury "simulates the pivot-shift test in patients with ACL deficiency" (*4*). Given the aforementioned association between the ALL and the pivot-shift, we hypothesized that a clinical ACL injury might often be accompanied by a concomitant ALL injury. Therefore, an observational study was set-up to identify the ALL and its eventual injuries on pre-operative magnetic resonance images (MRI) of a consecutive cohort of ACL-reconstructed knees.

METHODS

A retrospective cohort study on all consecutive subjects undergoing anterior cruciate ligament (ACL) reconstructive surgery in our department between January 2007 and August 2011 was performed. Patients undergoing revision ACL reconstruction were excluded. Patients suffering from interfering knee pathology potentially affecting imaging of the knee's lateral compartment were also excluded (i.e. signs of ligamentous posterolateral corner injury including the lateral collateral ligament (LCL), signs of osteoarthritis ≥ Kellgren-Lawrence grade II, inflammatory arthritis, hemophilia, the presence of artifacting metallic hardware). Finally, patients with no digital pre-operative MRI images available in their respective hospital files were excluded as well.

As patients were often referred for treatment by other institutions or physicians, the corresponding MR images were obtained on various imaging machines around the country. The MR images were reviewed by two observers (SC and SB). Sagittal and axial plane reconstructions were studied to confirm the ACL-injury, while the ALL was examined on the T2-weighted coronal plane reconstructions. The ALL was considered to have been visualized if low-signal-intensity fibers were seen arising from the lateral epicondyle of the distal femur, running slightly oblique to the anterolateral border of the proximal tibia, passing laterally from the lateral inferior geniculate vessels. The ALL was determined to be abnormal in case of complete disruption of the ligament (all fibers discontinuous), if the contour of the ALL was markedly irregular (e.g. "bended out"), intra- or peri-ligamentous edema existed or a combination of these MRI features was observed. If no distinct fibers were identified at the expected location of the ALL in absence of edema, the ALL was considered as non-visualized.

Furthermore, ALL abnormalities were classified regarding the injury location. If the abnormality was seen in the region from the femoral epicondyle to the meniscofemoral portion of the ALL (*6*), the injury was defined as "proximal". ALL lesions situated from the level of the meniscal body down to the insertion on the tibia were termed "distal". Finally, bony ALL avulsions at the level of the tibia were categorized as "Segond" fractures. Figure 1 illustrates some examples of an intact ALL, together with a proximal and distal injury.

RESULTS

A total of 351 consecutive ACL reconstructive procedures were retrieved, performed in 348 subjects (108 females and 240 males, mean age at time of ACL reconstruction 32.2) After applying the above-mentioned exclusion criteria, MR images of 271 unilateral ACL-injured knees could be included for the study of the ALL. Of these MRIs, the ALL was considered as non-visualized in 65 cases (24.0%), leaving 206 of the included knees (76.0%) for further analysis.

Of all the visualized ALL's, 44 (21.3%) were considered uninjured, while 162 (78.8%) knees

Fig. 1. — Typical examples of MRI images of a normal ALL, together with a proximal and distal Injury

demonstrated radiological ALL abnormalities together with the apparent ACL rupture. With regard to location of the ALL abnormalities, the majority of ALL abnormalities were found to be situated in the distal part of the ligament (77.8%). Proximal lesions were definitely less common, accounting for only 20.4% of the ALL injuries witnessed on MRI. Finally, 3 (1.8%) knees were diagnosed with a bony ALL avulsion and thus classified as a Segond fracture. The flow diagram in Table I summarizes the most important results.

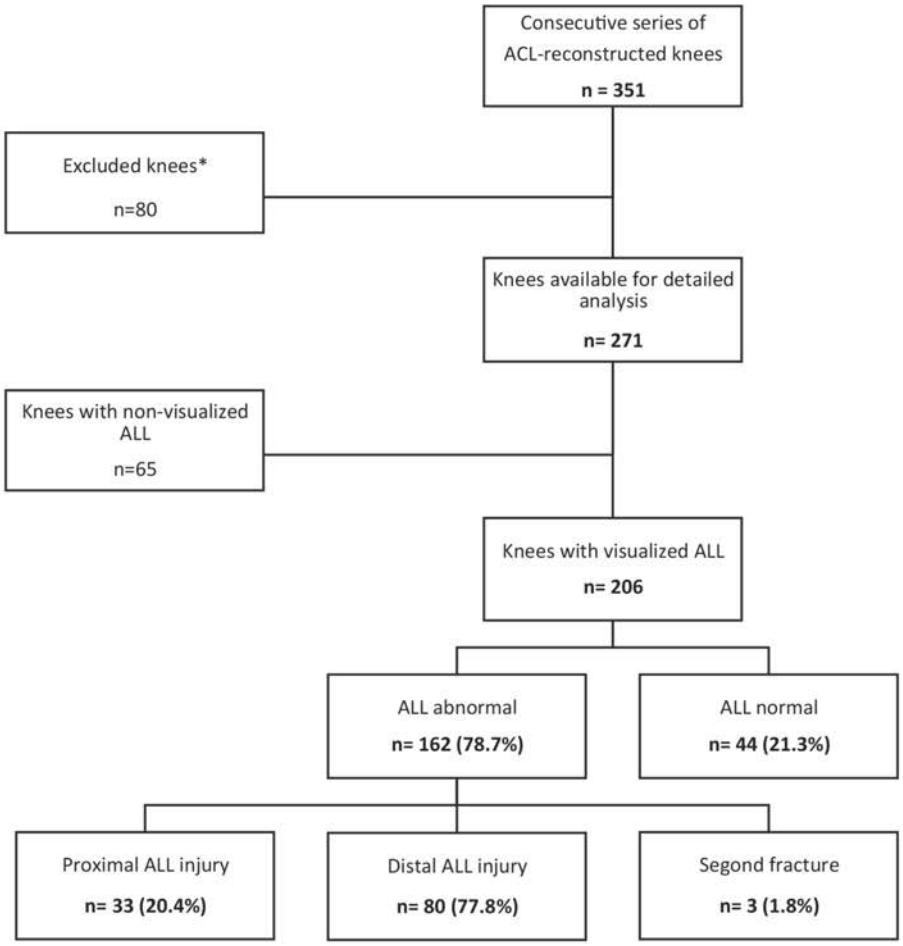
DISCUSSION

The main finding of this observational cohort study is that the ALL can be visualized on classic MRI of the knee, and that majority of ACL-injured subjects demonstrate evidence of associated damage to the ALL on MRI. Evaluation with MRI of the extra-articular ligamentous structures of the knee is generally considered effective, but remains challenging because of the anatomic variation and the thin nature of most of these structures (*2,10*). With the precise anatomy of the ALL only recently been characterized *(6,13)*, this study is the first to describe the radiological appearance of both the native and injured ALL.

Because we have demonstrated that the ALL is a ligamentous structure with a slightly oblique course on the anterolateral aspect of the knee (Fig. 2) (*6*), it was found that the classic coronal MRI reconstructions of the knee rarely depict the complete ALL on a single slice. However, in some cases where the reconstructed coronal field was (accidentally) inclined, a full-length ALL could be visualized on a single slice from its origin on the lateral femoral epicondyle to its insertion on the tibia (Fig. 3). In most other cases, the ALL was typically best seen on the coronal slices, two individual (3 mm) slices anterior to the slice showing the most anterior part of the fibular head.

With regard to the location of the radiological ALL injuries, it was found that the majority of injuries was situated in the more distal (i.e. tibial) region of the ligament. With the ALL originating on the lateral femoral epicondyle and the knee's transepicondylar axis being widely accepted as the best representation of the functional flexion-extension axis of the knee (*1, 5*), it is easily appreciated that the ALL's lever becomes larger with increasing distance from this lateral femoral epicondyle. This concept might explain the unequal distribution of the location of ALL injuries in this study. Furthermore, only 2% of all ALL injuries were determined as being Segond fractures, while some studies do suggest that Segond fractures might occur in 9-12% of all ACL injuries. (*7, 12*). We hypothesize that the use of MR images in this study caused the underestimation of Segond fractures, because MRI is widely recognized as being most

Table I. — Flow diagram summarizing the most important results of this study



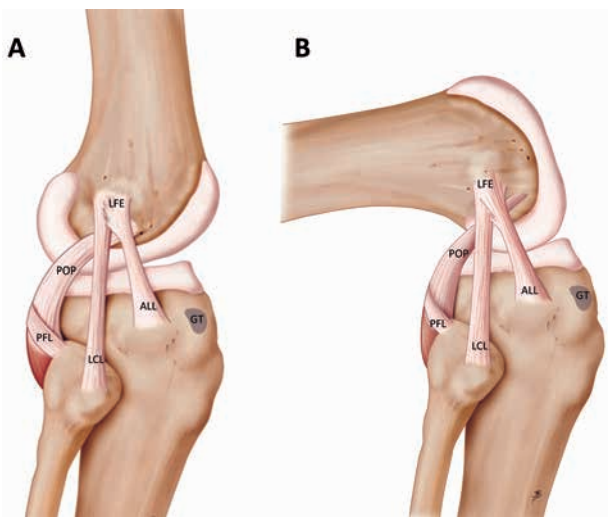


Fig. 2. — Drawing demonstrating the slightly oblique course of the human ALL and its relationship with other anatomical structures. (reprinted with permission from (6))

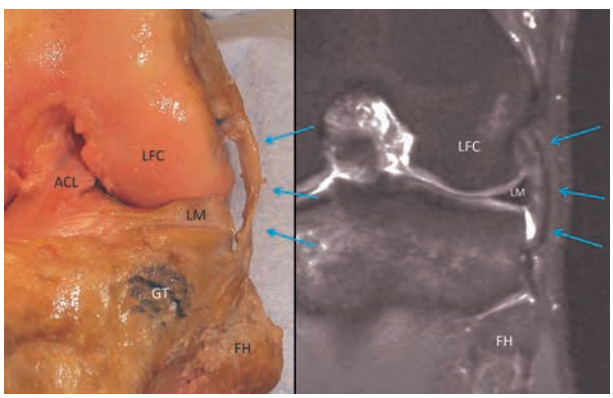


Fig. 3. — **Right** : frontal view of a dissected left knee with the ALL (blue arrows) isolated from the lateral meniscus. **Left** : Coronal T2-weighted MRI image of a left knee depicting a complete aLl from its origin to its insertion on a single slice. The parallel between the two depicted ALLs is easily appreciated.

accurate in detecting soft-tissue injuries compared to bone lesions.

As the results of this study might give an idea of the simultaneous occurrence of ACL and ALL injuries, it should be noted that the diagnosis of ALL lesions in this study was purely made on a radiological basis. With the clinical effect and natural history of the described ALL injuries not taken into account, further studies are needed to evaluate whether the high incidence of radiological ALL lesions witnessed in ACL-injured subjects indeed bear clinical repercussions with regard to knee instability patterns e.g. the pivot shift and their eventual treatment.

In conclusion, this study has shown that the newly described anterolateral ligament (ALL) can be identified on classic knee MR images. Grossly, 4 out of 5 patients diagnosed with an ACL injury demonstrated associated MRI abnormalities of the ALL, with the majority of these lesions being located in the distal (i.e. tibial) region of the ligament. Although an important role in the control of internal tibial rotation and the pivot-shift was recently attributed to the ALL in cadaveric knees, further research is needed in order to establish the clinical relevance of associated radiological ALL damage in ACL-injured knees.

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