Value of imaging in posterolateral corner injuries of the knee

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Résumé
Apport de l’imagerie dans les lésions du point d’angle postéro-latéral du genou
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Abstract
Lesions of the posterolateral corner are usually post-traumatic in etiology. They are most frequently associated with tear of the ACL and/or PCL. When unrecognized, they may lead to short-term failure of cruciate ligament reconstruction or long-term knee joint degeneration. Early detection of such lesions, especially in the preoperative period, is important since more severe injuries usually require dedicated early surgical management. The anatomy of the posterolateral corner will be reviewed and the normal and abnormal imaging features on MRI and US will be illustrated. The main clinical and surgical features will also be presented.

Key words: Knee, anatomy. Knee, lesion. Knee, ligaments and menisci. Knee, MRI. Knee, US.


T he posterolateral corner of the knee (PLC) previously called the postero-external corner, corresponds, from a surgical point of view to the posterolateral capsular reinforcement of the knee. The PLC provides primary resistance to varus forces and lateral tibial rotation, and secondary resistance to posterior tibial rotation (1, 2). As a result it plays a fundamental role in both static and dynamic posterolateral and rotatory stability of the knee. Injuries to the PLC are usually traumatic and affect this stability. They are rarely isolated and nearly always associated with other meniscal ligamentous injuries, in particular, with cruciate ligament tears (3). The most severe PLC injuries require specific treatment (surgical repair or reconstruction) (2, 4). If these injuries are not identified this may result in unsuccessful ligamento-

Anatomy
The PLC is composed of eight anatomical structures that are more or less intertwined: the lateral head of the gastrocnemius muscle, the posterolateral part of the joint capsule including the mid-third lateral capsular ligament, the posterior horn of the lateral meniscus, the popliteus muscle and tendon, the popliteofibular, fabellofibular and arcuate popliteal ligaments and the iliotibial tract (fig. 1) (table I).

The lateral head of the gastrocnemius muscle inserts into the posterosuperior lateral femoral condyle and helps maintain tension in the joint capsule.

Fig. 1: PLC (posterolateral view).

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The posterolateral part of the joint capsule corresponds to a capsular thickening which lines the deep part of the lateral head of the gastrocnemius muscle. The posterior horn of the lateral meniscus is loosely attached to the joint capsule. The popliteus muscle attaches to the posterior tibia. It is an important active stabilizing element (4). It becomes a thick tendon, running obliquely above and sends stabilising fibrous expansions to the posterior horn of the lateral meniscus (still called meniscopopliteal fascicles) (5-7). The popliteus tendon is intraarticular but extrasynovial, and strongly adheres to the joint capsule (8). It terminates on the lateral side of the lateral femoral condyle in the popliteus groove.

The popliteofibular ligament extends from the musculotendinous junction of the popliteus muscle to the fibular styloid where it attaches to the arcuate and fabellofibular ligaments. It is an important passive stabilizing element (4).

The presence of the fabellofibular ligament is irregular and is absent in 32% of cases (9). It extends between the fabella (or the lateral femoral condyle when the fabella is absent) and the fibular styloid, where it attaches to the outside of the arcuate popliteal and popliteofibular ligaments.

The arcuate popliteal ligament originates at the fibular styloid, where it has attachments between the popliteofibular ligament and the fabellofibular ligament and fans over the popliteus tendon. It forms a Y with two arms: the lateral arm attaches to the joint capsule and the lateral femoral condyle while the medial arm attaches to the joint capsule and the semi-menbranous muscle, which is still called the oblique popliteal ligament.

The iliotibial tract (or iliotibial band) corresponds to the distal tendinous portion of the tensor fasciae latae muscle. It terminates on the lateral tibial condyle on Gerdy’s tubercle, after following the lateral femoral condyle, separated by fat. Before terminating, it sends fibrous expansions to the anterior third of the joint capsule and to the lateral collateral ligament (6, 10, 11).

The anatomy of the PLC is not only complex but also varies from one individual to another (2, 12-14). The popliteofibular ligament is anatomically absent in 2 to 6% of cases, the fabellofibular ligament in 32% to 60% of cases and the arcuate popliteal ligament in 30 to 86% of cases (13-16). Even when they are present, these posterolateral ligaments may be more or less developed and functional (12).

Although it is not strictly part of the PLC, the LCL and the biceps femoris tendon cannot be dissociated from the PLC and also play a role in knee stability as part of what orthopedic surgeons sometimes call the “arcuate complex” (10, 17).

The lateral collateral ligament (LCL) extends obliquely down and behind the lateral femoral epicondyle on the posterolateral side of the fibular head. Although it is extraarticular, the LCL is closely attached to the proximal articular capsule. The biceps femoris muscle is composed of a long and a short head. It attaches to the posterior ischiatic tuberosity (long head) and the lateral lip of the femoral crest (short head) then becomes a distal tendon. The latter also terminates on the posterolateral side of the fibular head. Anatomically it is closely associated with the common peroneal nerve, a branch of the sciatic nerve (fig. 2).

The LCL and the distal biceps femoris tendon attach to the head of the fibula jointly or separately, with the LCL attached in front and inside the biceps femoris tendon (13).

**Table I**

Anatomy of the posterolateral corner of the knee.

| 1) Lateral head of the gastrocnemius muscle |
| 2) Posterolateral part of the capsule including the mid-third lateral capsular ligament |
| 3) Posterior horn of the lateral meniscus |
| 4) Popliteus muscle and tendon |
| 5) Popliteofibular ligament |
| 6) Fabellofibular ligament |
| 7) Arcuate popliteal ligament |
| 8) Iliotibial tract |

**Normal imaging features**

The PLC and the intra-articular structures of the knee can be nearly completely explored with MRI and ultrasound (18, 19). Of all the anatomical structures of the PLC (table I), the posterolateral part of the joint capsule cannot be clearly visualised, although both MRI and ultrasound provide clear images of the lateral head and the deep part of the gastrocnemius muscle. The popliteus muscle and its musculotendinous junction are clear on MRI (fig. 3) but more difficult to identify on ultrasound because they are deep. On the other hand, the popliteus tendon is easy to visualise in the popliteus groove with ultrasound, and also normally with MRI (fig. 3). The posterolateral ligaments (popliteofibular, fabellofibular and arcuate popliteal) are difficult to visualise directly with MRI and even more difficult with ultrasound. Certain authors (20, 21), have suggested obtaining several coronal oblique MRI sequences, parallel to the main axis of the popliteus muscle to improve visualisation of these ligaments, although they can be seen spontaneously on the most posterior coronal sequences (fig. 4). The arcuate popliteal ligament is sometimes visible in the form of a reinforcement of the posterior capsule on axial MRI sequences that pass the femoralibial joint space (4). On ultrasound, the posterolateral ligaments are difficult to evaluate except in vitro (20). Among the other elements of the PLC, the posterior horn of the lateral meniscus can only be clearly visualised on MRI, unlike the iliotibial tract which is often easier to explore in detail on ultrasound (fig. 5). Finally, the LCL (fig. 6), the biceps femoris tendon and the common peroneal nerve can be evaluated with both techniques.

**PLC Injuries**

**Mechanisms of injury**

PLC injuries are a result of knee trauma. They are usually classified into three categories, according to severity (4):

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• Grade I injuries, corresponding to minor injuries without tears;
• Grade II injuries corresponding to partial tears;
• Grade III injuries corresponding to complete tears.
Injuries can be acute or chronic.

Acute injuries of the PLC
They are a result of trauma, from sports (contact sports, track) or other causes (traffic accidents, motorcycle accidents). These injuries are rarely isolated (1.6% of cases (22)) but are usually associated with cruciate ligament tears (anterior and/or posterior cruciate ligaments) (22, 23). Sixty-two percent of posterior cruciate ligament tears are associated with acute PLC injuries (24).

Acute, isolated PLC injuries are the result of direct posterolateral impact trauma to the anteromedial tibia, with the knee in extension or more rarely, to lateral rotation of the tibia with the knee in extension (2, 23, 25).

Acute PLC injuries associated with cruciate ligament tears are a result of extreme cases of the usual injury-causing mechanisms (lateral rotation-valgus-flexion resulting in anterior cruciate ligament tears; direct trauma to the anterior tibia, knee flexed, in posterior cruciate ligament tears) (2, 26, 27).

More rarely, acute PLC injuries may be associated with anterior or posterior knee dislocation (4).

Chronic PLC injuries
These develop progressively from recurrent accidents causing instability on chronic laxity from past cruciate ligament injuries.

Clinical features
Acute PLC injuries
Pain and posterolateral swelling may occur, but this is moderate and inconsistent. Joint fluid collection is also sometimes present because of possible associated capsule rupture (25). Severe injuries of the PLC result in the knee giving out during walking or running. Neurological symptoms due to injury of the common peroneal nerve may be found (in 13-16% of cases) (28-30). Numerous clinical manoeuvres may be used to evaluate the condition of the PLC (2, 31) by testing varus and lateral rotation during different degrees of knee flexion. The main test which is still called the “dial test” by Anglo Saxons, includes evaluating by comparison lateral tibial rotation in relation to the femur during 30° knee flexion (2, 31). Compared to the healthy side, an increased lateral rotation (of 10 to 15°) at 30° of flexion suggests PLC injury. In practice these clinical manoeuvres may be difficult to perform mainly because of pain. They are positive in patients with severe PLC injury (Grade III injuries).
Chronic PLC injuries
Initially PLC injury was poorly understood, and patients consulted for unsuccessful ligamentoplasty (PLC injuries associated with cruciate ligament tears) or later for chronic gonalgias associated with meniscal and/or osteochondral injuries (isolated PLC injuries) (2, 4).

The role of imaging
Imaging results are based on plain films which may be associated with ultrasound, and especially MRI.

Plain films
They are often normal although swelling may sometimes be found in the soft lateral tissues, with abnormal widening of the lateral tibiofemoral joint space or avulsion fractures at ligamentotcapular insertion sites:

– in the fibula (or "arcuate sign"), which indicates injury to the posterolateral stabilizing elements (9, 13, 32). This fracture occurs in 0.6% of cases (13, 33). It may be the result of an avulsion fracture of the fibular styloid (fig. 7) or more rarely, an avulsion fracture of the fibular head (fig. 8). An avulsion fracture of the fibular styloid is a sign of torn popliteofibular, fabellofibular and arcuate popliteal ligaments (8). The bone fragment is small (5-10 mm), oblong, slightly displaced, and the fracture line is often lateral (fig. 7). An avulsion fracture of the head of the fibula is a sign of a torn LCL and/or biceps femoris tendon. The bone fragment is larger (15 to 25mm), and often clearly pulled upwards due to the force of the contraction of the biceps femoris muscle (fig. 8).

– on the lateral side of the lateral femoral condyle where the popliteus tendon is attached (10).

– on the lateral side of the tibia where the iliotibial tract attaches or further back, where the articular capsule attaches (Segond fracture) (fig. 9) (10, 11, 33).
Images with a Telos® stress device or a similar device are also useful to evaluate the severity of posterior joint laxity and during varus (34) (providing indirect information about the severity of PLC lesions) and to help therapeutic management (35).

**Ultrasound**

Ultrasound can be useful as a complement to plain films to identify pieces of bone avulsion (fig. 10), or to study superficial musculotendinous ligamentous structures such as the lateral head of the gastrocnemius muscle, the popliteus tendon (in the popliteus groove) (fig. 10), the iliotibial tract (fig. 11), the LCL (fig. 12) and the biceps femoris tendon. The common peroneal nerve is also clearly visible on ultrasound and this imaging technique can reveal a mass lesion due to nerve injury from pulling. On the other hand the popliteofibular, fabellotibial and especially the arcuate popliteal ligaments are difficult to explore, especially in acute stage disease, (because of clinical swelling).

Even if ultrasound may be useful when associated with plain films, only MRI provides a detailed picture of PCL injuries and injuries to adjacent structures, whether they are PLC injuries themselves, or associated meniscal ligamentous injuries.

**MRI**

Because of its high contrast resolution, MRI can be considered the reference technique for exploring acute PLC injuries. Technically, T2-weighted MRI images with fat suppression are especially sensitive for detecting these injuries. The three most common planes and in particular axial sequences are indispensable for careful analysis of the PLC. Additional coronal oblique views (see normal imaging results) can be obtained but the examination then takes longer.

The role of MRI is three-fold:
- To identify associated meniscal ligamentous injuries. First MRI shows the condition of the cruciate ligaments by identifying tears in the anterior and/or posterior cruciate ligaments. For certain authors (4, 32), tears in the posterior cruciate ligaments are the most frequent. They are found in the main part of the ligament or at the site of tibial attachment (distal avulsion) (32). MRI can also identify associated injuries to the medial collateral ligament (sprain, tears) which are frequent, or medial meniscal tears.
- To confirm and identify the severity of PLC injury. The different elements of the posterolateral corner should be systematically analysed:
  - The lateral head of the gastrocnemius muscle is rarely involved (2, 6). Nevertheless, it may become torn from the lateral femoral condyle (fig. 13) or be injured at the musculotendinous junction;
  - The posterolateral part of the joint capsule including the mid-third lateral capsular ligament may be torn;
  - The posterior lateral meniscal horn may be torn or even sectioned, and there may be other injury to the rest of the meniscus;
  - The popliteus muscle is more often injured than the tendon. The belly of the muscle and/or the musculotendinous
junction may be partially or completely torn (10, 36, 37) (fig. 14). More rarely, there is avulsion of the tendon in the popliteus groove.

- The main body of the popliteofibular, fabellofibular and arcuate popliteal ligaments can be injured or completely torn from the fibular styloid. Although this injury may be difficult to identify on MRI (fig. 16) because of the small size of the ligaments and associated anatomical variations (4), certain indirect signs should be noted. Bone edema (high intramedullar signal intensity on T2-weighted images) of the fibular styloid is a sign of injury or tears of the popliteofibular, fabellofibular and arcuate popliteal ligaments from the fibula. Tears may also result in an avulsion fracture (fig. 17). However, this is more difficult to identify with MRI than with plain films or ultrasound because the bone fragment is small and difficult to see on fat suppressed images. A torn posterolateral joint capsule, at the level of the femoroperoneal joint space is also an indirect sign of a torn arcuate popliteal ligament (fig. 18) (4).

- The iliotibial tract is often injured near its tibial attachment and it may be torn (33). Tears are suggested by bone edema of the lateral side of the tibial condyle on coronal sequences (fig. 19).

In Grade I lesions, one or more elements of the PLC appear as high intensity signals on T2-weighted images, and they often appear thickened, while adjacent soft tissue is infiltrated. In grade II lesions there are signs of partial tears (high intensity signals on T2-weighted images, fluid collection, associated hematomas) but there is no muscular-ligamentous-tendinous retraction. Grade III, the most severe injuries, include muscular-ligamentous-tendinous loss of structural continuity with a break in the image, and proximal or distal retraction whose severity varies, associated hematoma.

Besides fibular signal anomalies strongly suggesting PLC injury, bone edema of the anterior medial femoral condyle, sometimes associated with an impaction-fracture of this same condyle, and sometimes extending to the anterior part of the medial tibial plateau, is also highly suggestive of acute PLC injury (fig. 20). In fact, this bone contusion is the result of direct trauma to the anteromedial tibia with the knee in extension (see chapter on injury to the posterolateral corner, mechanisms of injury).

• To analyse structures adjacent to the PLC. MRI can visualise the LCL, the biceps femoris muscle and tendon and the common peroneal nerve.

Fig. 11: Traumatic injury of the iliotibial tract on ultrasound.
Note the hypoechoic (dark) thickening of the iliotibial tract (asterisk) in this coronal view, compared to the normal iliotibial tract (arrows) on the opposite side. LFC = lateral femoral condyle.

Fig. 12: LCL sprain on ultrasound.
In this coronal view, the distal part of the LCL (asterisk) appears thickened and hypoechoic (dark) while the proximal part (arrows) is intact. Note the perfect correlation with the underlying MRI image, which was taken in the same position as the ultrasound image. LFC = Lateral femoral condyle; LTP = lateral tibial plateau; F = fibula.
The biceps femoris muscle can be injured at its musculotendinous junction (fig. 23) or more frequently, torn from the fibula (fig. 24) along with the LCL (10, 36). Injury to the musculotendinous junction is seen as a high intensity signal on T2-weighted images (tear) with fluid collection or not. Features of tearing include an enlarged and retracted distal tendon (fig. 24). Once again this may be associated with an avulsion fracture or edema of the fibular head. The common peroneal nerve, located behind the distal biceps femoris tendon may be injured near a tear in this tendon (32). Nerve disruption (no identifiable nerve) or post-traumatic neuroma (a mass along the nerve pathway) is sometimes seen on axial or coronal images (fig. 25). A neuroma is usually a result of nerve injury from pulling. MRI also reveals indirect signs of acute (high intensity signal on T2-weighted images of the muscles of the anterolateral compartment of the leg) (fig. 25), or chronic denervation (high intensity signal on T1-weighted images of the anterolateral compartment of the leg with atrophy or hypertrophy) (32). There are no MRI studies describing specific features of chronic PLC injury. Signal anomalies of bone marrow and soft tissue disappear and if there is no loss of tendinoligamentous structural continuity on imaging, posterolateral corner injury may not necessarily be noticed by the radiologist. MRI is especially useful to identify meniscal injuries that occur from chronic joint instability, and to a lesser extent, osteochondral injuries.

**Treatment of PLC injuries**

Therapeutic management of posterolateral corner injuries depends on the severity, how old they are, the type and whether they are isolated or not.

**Acute isolated posterolateral corner knee injuries**

Grades I and II lesions usually respond well to conservative medical treatment and physical reeducation (2, 4, 38). Long term functional results are satisfying even if moderate joint laxity may persist (in particular in grade II lesions). On the other hand, grade III injuries require
specific surgical treatment (suture or plasty of tendinoligamentous tears, staple fixation or transosseous fixation of an avulsion fracture of the lateral femoral condyle or the fibular head...) preferably within weeks after the injury (2, 39). Without surgical treatment, long term functional results are poor and can result in marked residual joint laxity, muscular weakness and post traumatic arthrosis (38). Therefore the goal of treatment is to repair, if possible, the structural elements of the posterolateral corner with open surgery or arthroscopy (2). If direct repair is impossible because of the quality of the injured tissue, surgical reconstruction is performed with allografts or tendon autografts.

Acute injuries to the posterolateral corner of the knee associated with meniscal ligamentous injuries

Severe posterolateral corner injuries (Grade III) associated with cruciate ligament tears and in particular, the posterior cruciate ligament, often require rapid surgical repair. Injury of the posterolateral corner requires specific treatment (see above) while cruciate ligament tears require ligamentoplasty, and surgery of the ACL may be performed at the same time or during a second intervention.

Meniscal injuries require repair or resection.

Isolated chronic injuries of the posterolateral corner of the knee

Treatment of these injuries is more difficult because of scarring of the injured tissue and a frequently associated varus (2). When the latter is significant it may require prior treatment by tibial valgisation osteotomy (2). Grade III injuries can be treated by surgical reconstruction. Less severe injuries can sometimes be treated with proximal surgical transposition (the posterolateral corner and the LCL are de-
Fig. 19: **Distal tear of the iliotibial tract on MRI.**
This coronal proton density MRI sequence with fat suppression shows a distal structural break in continuity (arrow) and bone edema associated with the lateral tibial condyle (asterisk). Taken from a reference (1) with permission of the author.

Fig. 20: **Bone edema suggesting posterolateral corner injury on MRI.**
On this axial proton density sequence with fat suppression, there is a high intensity signal in the anterior medial femoral condyle (asterisk). There is a moderately intense signal of the LCL, with no break in structural continuity, and a high intensity signal in the surrounding tissue. Taken from reference 1 with permission.

Fig. 21: **Complete LCL tear on MRI.**
On this coronal proton density sequence with fat suppression, the LCL is completely torn and the proximal part is barely visible (arrows) and associated with a large hematoma. The popliteus tendon (asterisk) is also injured.

Fig. 22: **Fibular tear of the LCL on MRI.**
On this coronal proton density sequence with fat suppression, the LCL (arrows) is retracted upwards.

Fig. 23: **Injury to the musculotendinous junction of the biceps femoris muscle on MRI.**
This appears as a high intensity signal on axial T2-weighted proton density images with fat suppression. Taken from reference 1 with permission.

Fig. 24: **Distal tear of the biceps femoris tendon on MRI.**
In this coronal proton density sequence with fat suppression, note the fracture of the fibular head (arrow). The tendon of the biceps femoris muscle (arrowhead) is still attached and appears retracted upwards.
tached from the femur and reinserted further up) (2, 4).

Conclusion

This posterolateral corner of the knee is an anatomically and functionally complex entity, which plays an essential role in the posterolateral and rotatory stability of the knee. Injury, which is post-traumatic, is nearly always accompanied by cruciate ligament tears. Plain films appear normal or only show apparently minor avulsion fractures, but do not show the lateral side of the articulation, in particular the fibular head. At present, MRI is the best technique to confirm posterolateral corner injury (as long as a careful and systematic exploration is performed), to define its severity and to identify any associated meniscal ligamentous injuries, so that appropriate treatment can be begun, especially in the acute stage.

References


Fig. 25: Post-traumatic injury to the common peroneal nerve on MRI. Axial proton density T1-weighted sequence with fat suppression after intravenous injection of gadolinium (a) showing increased volume of the common peroneal nerve. In this patient, the tendon of the biceps femoris and the LCL (asterisk) are visible in front of the nerve, and are respectively injured distally and completely torn. The popliteus tendon (arrow) is intact. Note the enhancement and the extension upwards of the nerve injury (arrows) on the coronal T1-weighted sequence after intravenous injection of gadolinium and fat suppression (b). In another patient, note the high intensity signal on the T2-weighted image of the anterolateral compartment of the leg (asterisk) which is an indirect sign of acute denervation.


