Imaging of Athletic Injuries of Knee Ligaments and Menisci: Sports Imaging Series[1]

Ali M. Naraghi, FRCR
Lawrence M. White, MD, FRCPC

Acute knee injuries are a common source of morbidity in athletes and if overlooked may result in chronic functional impairment. Magnetic resonance (MR) imaging of the knee has become the most commonly performed musculoskeletal MR examination and is an indispensable tool in the appropriate management of the injured athlete. Meniscal and ligamentous tearing are the most frequent indications for surgical intervention in sports injuries and an understanding of the anatomy, biomechanics, mechanisms of injury, and patterns of injury are all critical to accurate diagnosis and appropriate management. These will be discussed in reference to meniscal tears and injuries of the cruciate ligaments as well as injuries of the posterolateral and posteromedial corners of the knee.

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Learning Objectives:

After reading the article and taking the test, the reader will be able to:

- Define the MR criteria for unstable meniscal tears
- Discuss the anatomy of the ligamentous stabilizers of the knee
- Identify common mechanisms of injury leading to ligamentous tears
- Illustrate patterns of ligamentous injuries encountered in athletic knee injuries

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[1] From the Department of Medical Imaging, University of Toronto, Joint Department of Medical Imaging, University Health Network, Mount Sinai Hospital and Women's College Hospital, Toronto General Hospital, 200 Elizabeth St, Toronto, ON, Canada M5G 2C4. Received November 3, 2015; revision requested December 16; revision received April 22, 2016; accepted May 10; final version accepted June 3. **Address correspondence to** L.M.W. (e-mail: *lawrence.white@uhn.ca*).

Knee injuries are among the most common injuries in the athletic population. In a study of 6.6 million knee injuries presenting to emergency departments during a 10-year period, approximately 50% of injuries were related to sporting or recreational activities, with soft-tissue injuries accounting for the majority of knee injuries (1).

Essentials

- MR criteria for unstable meniscal tears include a tear greater than 1 cm in length, presence of more than one morphologic tear pattern, high T2 signal intensity within the tear plane, and presence of a displaced meniscal fragment.
- Acute anterior cruciate ligament (ACL) tears are one of the most common causes for an acute large hemarthrosis in the athletic population, and 41%–75% of acute knee injuries with a hemarthrosis have an ACL tear.
- MR imaging assessment of chronic posterior cruciate ligament (PCL) injuries is less reliable than assessment of acute injury, as continuity of PCL fibers in chronic injuries can be mistaken for a partial tear or even a normal PCL, particularly if prior imaging or accurate clinical information is lacking.
- Collectively, the posterolateral stabilizers act primarily as restraints to varus stress and external rotation of the knee; of these, the fibular collateral ligament, popliteofibular ligament, and popliteus tendon are considered the most important biomechanically and are the structures addressed in anatomic posterolateral reconstructions.
- Features that affect decision making with regard to treatment of medial ligamentous injuries include grade of injury, involvement of the posteromedial corner or cruciates, presence of osseous avulsive injury, degree of ligament retraction, entrapment of the deep medial collateral ligament (MCL) within the medial joint, and presence of a Stener lesion of the MCL.

In this article we will review the imaging evaluation of knee injuries resulting from athletic activities. We will review the pertinent anatomy, biomechanical function of ligamentous structures, mechanisms of injury, and the imaging appearances of specific ligamentous and meniscal injuries in the preoperative setting. Data regarding clinical evaluation of meniscal and ligamentous injuries are highlighted in the Table (2–5). The role of imaging in the treatment decision-making process will also be discussed where relevant. Although much of the imaging discussion will concentrate on magnetic resonance (MR) imaging, other imaging modalities will be discussed where indicated. Although chondral and osteochondral injuries are not specifically discussed in this article, it is important to recognize that they are a major consideration in treatment of knee injuries.

Imaging Technique

MR imaging enables the most comprehensive imaging assessment of the knee and when performed early after injury, MR imaging is both cost-effective (6) and can aid in predicting which patients require further treatment (7). Radiographs may demonstrate an acute fracture but commonly are either negative or may demonstrate indirect signs of an acute soft-tissue injury. Computed tomography (CT) is usually reserved for diagnosis of suspected fractures or assessment of complex fractures, although associated ligamentous injuries may be evident on CT scans obtained for evaluation of osseous injuries (Fig 1). Dual-energy CT has also been evaluated in imaging of the musculoskeletal system, principally for evaluation in patients with suspected gout (8). Preliminary studies using dual-energy CT have shown a high sensitivity and specificity for detection of bone marrow edema in traumatic knee injuries (9) and some success with imaging of ACL injuries (10). Although this technique may highlight traumatic osseous and ligamentous injuries, its role in global assessment of knee injuries remains to be determined.

MR imaging of the knee is most commonly performed with 1.5- or 3-T systems and dedicated knee coils. Standard MR studies are typically acquired in three orthogonal planes with a combination of proton density, intermediate-weighted, and T2-weighted pulse sequences with and without fat suppression. Spectral fat suppression is our preferred method of acquiring fat-suppressed images owing to superior signal-to-noise ratio in comparison with inversion recovery techniques (11). Multiple oblique imaging planes have been advocated for assessment of ligamentous injuries of the knee. These include coronal oblique and axial oblique images parallel and perpendicular to the long axis of ACL, respectively (12–14), and coronal oblique images in the plane of the popliteus tendon for assessment of the popliteofibular ligament (15). We do not routinely perform additional oblique acquisitions in our practice.

Three-dimensional isotropic fast spin-echo pulse sequences such as FSE-CUBE, sampling perfection with application-optimized contrast using different flip angle evolutions (SPACE), and volume isotropic turbo spin-echo acquisition (VISTA) provide improved through-plane resolution and the ability to perform high-quality multiplanar reformats, including multiple

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Abbreviations:
ACL = anterior cruciate ligament
FCL = fibular collateral ligament
MCL = medial collateral ligament
PCL = posterior cruciate ligament
PLC = posterolateral corner
PMC = posteromedial corner
POL = posterior oblique ligament

Conflicts of interest are listed at the end of this article.

Physical Examination Tests for Evaluation of Knee Menisci and Ligamentous Structures

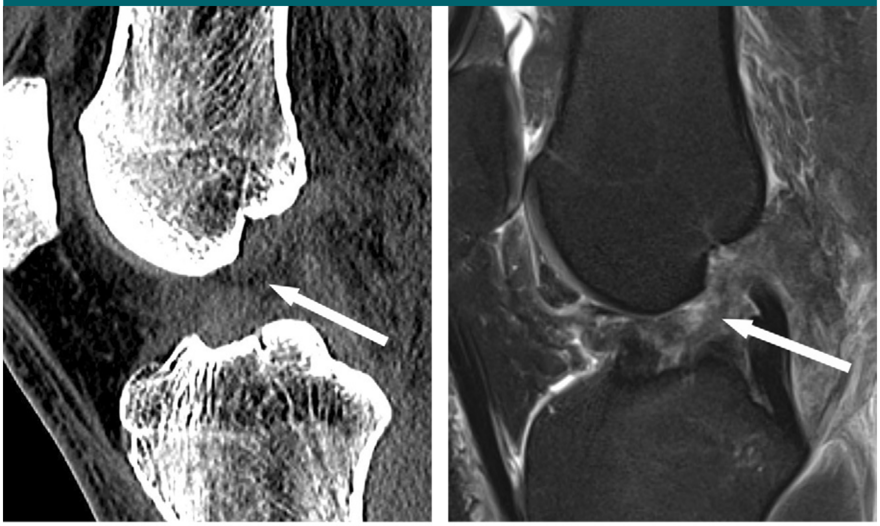
Structure Examined and Test Used	Technique	Positive Test	Sensitivity (%)	Specificity (%)
Menisci				
Joint line tenderness	Direct palpation over medial and lateral joint line	Localized tenderness	63.3*	77.4*
McMurray	Flex knee to 90° with tibia in external rotation and then extend the knee; repeat with tibia in internal rotation	Clicking or pain on extension	70.5*	71.1*
Apley grind test	Place patient prone with knee flexed to 90°; rotate lower leg while distracting or compressing the knee	Pain on rotation and compression	60.7*	70.2*
Thessaly test	Patient stands on one leg with knee at 5° or 20° of flexion and then rotates knee and body internally and externally	Pain during maneuver	15–92	45–98
ACL				
Lachman	Patient supine with knee flexed at 30°; apply anterior force to tibia	Excessive anterior draw tibia	85*	94*
Pivot shift test	Knee extended, apply valgus and internal rotation force as knee is flexed to 40°	Anterior subluxation of the tibia in extension and reduction of the tibia in flexion	24*	98*
Anterior drawer test	Knee flexed at 90° and foot planted on table; apply anterior and posterior force to proximal tibia	Anterior draw tibia	55*	92*
PCL				
Posterior sag sign	Hip flexed at 45° and knee flexed at 90°	Decreased prominence of proximal tibia	46–100	100
Quadriceps active test	Active extension of the knee from flexed position	Anterior translation of tibia	53–98	96–100
Posterior drawer test	Knee flexed at 90° with foot planted on bed; reduce tibia anteriorly and attempt to displace tibia posteriorly	Excessive posterior displacement of tibia	22–100	100
PLC				
Varus test at 0° and 30°	Stabilize thigh in extension or 30° of flexion and apply varus force	Increased lateral joint line opening	Not reported	Not reported
Dial test at 30° and 90°	Knee flexed to 30° and also 90° and the maximal degree of external rotation of the tibia in relation to the femur is recorded	Side-to-side difference of 10°–15°. Positive test at 30° only reflects PLC injury. Positive test at 30° and 90° reflects PLC and cruciate injury	Not reported	Not reported
Posterolateral drawer test	Hip flexed 45°, knee flexed 90°, foot in external rotation and apply posterior force to tibial tuberosity	Pure external rotation of the tibia: isolated PLC injury including popliteus and popliteofibular ligament. Posterior translation and external rotation: combined PCL and PLC injury	Not reported	Not reported
MCL and PMC				
Valgus stress test at 0° and 30°	Valgus stress applied to the knee at 0° and 30° and degree of medial joint line opening assessed	Increased medial opening at 30°: MCL injury. Increased medial opening at extension: MCL, PMC, and cruciate ligament injury	Not reported	Not reported
Anteromedial drawer test	Knee flexed 90°, foot in external rotation and apply anterior draw	Increased anteromedial rotation of tibia with injury to MCL and PMC	Not reported	Not reported

Note.—ACL = anterior cruciate ligament, MCL = medial collateral ligament, PCL = posterior cruciate ligament, PLC = posterolateral corner, PMC = posteromedial corner.

* Denotes pooled sensitivity and specificity data.

oblique image plane orientations. However, geometric blurring can be more pronounced, the contrast characteristics can vary from two-dimensional fast spin-echo pulse sequences, and imaging times can be significantly longer (16). To date, three-dimensional fast spin-echo pulse sequences have demonstrated similar accuracy to two-dimensional acquisitions in the assessment of internal derangement of the knee (16,17). In our practice, we routinely use three-dimensional isotropic acquisitions during examinations performed at 3 T, as we find the

Figure 1



a. b.

Figure 1: **(a)** Sagittal reformatted CT scan of the knee in a 25-year-old man with clinically suspected tibial fracture following a skiing injury shows disruption of the mid- ACL (arrow) with soft-tissue windows. **(b)** Subsequent sagittal T2-weighted fat-suppressed MR image confirms a complete tear of the ACL (arrow).

Figure 2

Figure 2: Coronal intermediate-weighted MR image in a 28-year-old male volleyball player with pain following a twisting injury on landing from a jump. There is a large flipped meniscal fragment (arrowhead) arising from the medial meniscus and displaced posteriorly in the intercondylar notch adjacent to the PCL.

improved spatial resolution useful as a problem-solving tool.

Meniscal Injuries

Acute traumatic meniscal tears are frequently seen in the athletic population either as an isolated finding or in conjunction with ligamentous injuries. There are well-established MR imaging criteria in the diagnosis of meniscal tears. In the absence of prior meniscal surgery, the criteria for a meniscal tear includes abnormal intrameniscal signal intensity on short-echo-time pulse sequence images extending to an articular surface on at least two sections, alteration of meniscal morphology, or identification of displaced meniscal fragments. The pooled sensitivity and specificity of MR imaging for meniscal tears is 93% and 88%, respectively, for the medial meniscus and 79% and 95%, respectively, for the lateral meniscus (18).

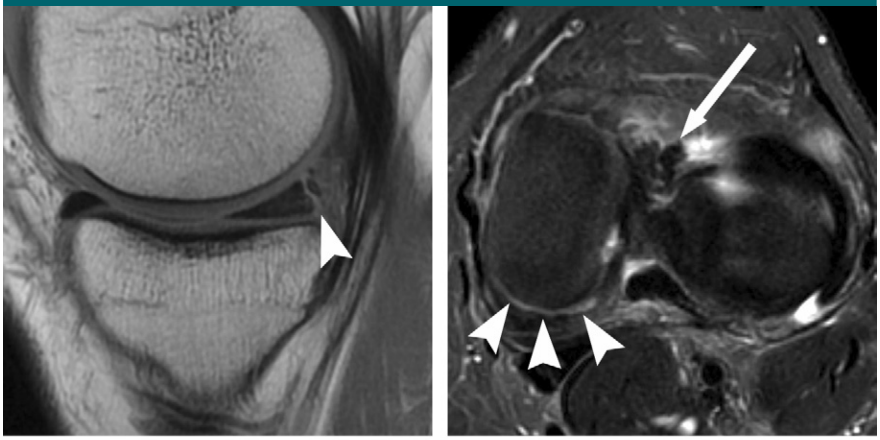
We will review the patterns of meniscal tears associated with acute trauma, the relationship of meniscal tear morphology to symptoms, associations of meniscal tears with ligamentous injuries, and the utility of MR imaging in predicting reparability and stability of meniscal injuries.

Meniscal tears can be classified as horizontal, radial, vertical longitudinal, horizontal flap, vertical flap, or complex (19). Horizontal tears are one of the most common tear morphologies, occurring in more than 30% of patients at arthroscopy, particularly in relation to the posterior horns of the medial and lateral menisci (20). Horizontal tears are frequently seen in the absence of a defined traumatic event and are more common in those over the age of 40 years (20). Radial tears may be seen with or without trauma, whereas vertical longitudinal tears are commonly seen as a result of an acute traumatic episode. The medial meniscus is involved in up to 87% of patients with flap tears, typically affecting the posterior horn or the body (21,22). The most common sites of meniscal flap displacement are the posterior intercondylar notch adjacent to the PCL (Fig 2) or into the synovial recesses of the medial and lateral gutters. Identification of displaced flap tears and acute bucket-handle tears are important because these are often treated expeditiously by means of surgery to prevent further propagation of the tear.

The location of the tear within the meniscus influences the decision-making process with regard to meniscal repair. Histologic analysis has demonstrated a peripheral vascular zone, often referred to as the red zone, and an inner margin avascular zone, often referred to as the white zone (23). Meniscal tears within 3 mm of the meniscocapsular junction are considered vascular, with a high propensity for healing, whereas tears greater than 5 mm from the periphery are located within the avascular zone, with lower rates of healing. Tears within 3–5 mm of the periphery (ie, the red-white zone) have variable vascularity (24).

Not all meniscal tears are symptomatic or require treatment. It has been shown that meniscal tears may be seen in up to 63% of asymptomatic knees (25). The incidence of asymptomatic meniscal tears is dependent on the tear morphology. Horizontal oblique tears violating only one articular surface are the most common pattern seen in asymptomatic knees (25). In contrast, vertical, radial, complex, or displaced

Figure 3



a. b.

Figure 3: **(a)** Sagittal intermediate-weighted and **(b)** axial T2-weighted fat-suppressed MR images in a 36-year-old woman with an ACL tear show a peripheral vertical longitudinal tear of the posterior horn of the medial meniscus (arrowheads). Axial image also shows torn ACL fibers flipped anteriorly in the intercondylar notch (arrow).

Figure 4

Figure 4: Coronal intermediate-weighted MR image in a 39-year-old recreational basketball player with a subacute to chronic ACL tear (not shown) shows a radial tear at the junction of the posterior horn and posterior root attachment of the lateral meniscus (arrowhead) with a horizontal extension of the tear into the posterior horn.

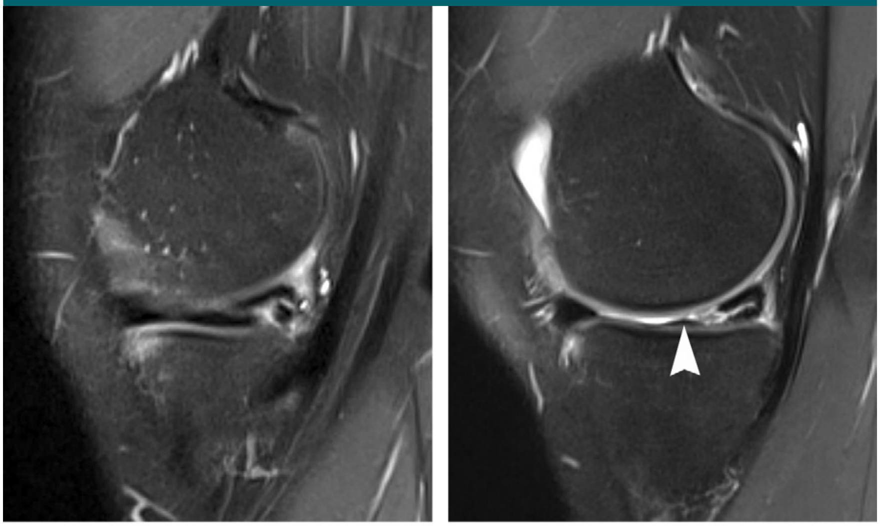
meniscal tears are less commonly encountered as asymptomatic findings (25). The presence of adjacent bone marrow or pericapsular edema in conjunction with a meniscal tear is also more likely to be associated with symptoms (25).

The association of meniscal tears with ligamentous injuries has been most extensively studied in the setting of ACL tears. A recent study demonstrated meniscal tears in 72% of patients with acute ACL tears and 85% with chronic ACL tears (26). In acute ACL tears, the lateral meniscus alone was involved in 70%, the medial meniscus alone was involved in 10%, and both menisci were involved in 20%. In contrast, in chronic ACL tears, the lateral meniscus alone was involved in 34%, the medial meniscus alone was involved in 25%, and both menisci were involved in 41% (26). Ninety percent of peripheral vertical longitudinal meniscal tears are seen in patients with ACL tears, and the presence of a peripheral vertical meniscal tear should raise suspicion for an associated ACL tear (27) (Fig 3). Following ACL injury, the sensitivity of MR imaging is reduced for detection of medial and, in particular, lateral meniscal tears, with sensitivities of 88% and 69%, respectively, in one study (27); the majority of missed meniscal tears involved the posterior horn of the lateral meniscus (28). In the setting of ACL injury, posterior horn lateral meniscal tears commonly demonstrate a cleavage plane associated with the insertion site of the meniscofemoral ligament and abnormality of the posterosuperior popliteomeniscal ligament. However, peripheral meniscal tears have a propensity for healing and may heal by the time arthroscopy is performed, resulting in an apparent "false-positive" diagnosis (29). False-positive diagnoses as a result of healed tears are more likely if the tear is at the meniscocapsular junction, only contacts the superior articular surface, is only visualized on intermediate-weighted pulse sequence images, is not of fluid signal intensity, measures less than 2 mm in width, and contains low-T2–signal intensity strands within the tear plane (29,30).

ACL tears are also associated with posterior root tears of the menisci (31) (Fig 4). Radial posterior root tears may result in alteration of the circumferential hoop stresses through the meniscus causing meniscal extrusion, increased tibiofemoral contact forces, and accelerated degenerative changes in the knee (32). The majority of such meniscal root tears are thought to be chronic in nature but acute meniscal root injuries may be encountered in conjunction with ACL tears, hyperflexion injuries, and in the specific setting of grade III MCL tearing with intact meniscocapsular attachments (32,33). The posterior root of the medial meniscus is involved in approximately 50% of meniscal root tears, and the posterior horn of the lateral meniscus is involved in 40%, with the remainder representing avulsion injuries of the anterior horn of the lateral meniscus (34). MR imaging and arthroscopic classification systems of posterior meniscal root tears have been introduced that classify tears based on relationship to the enthesis, posterior root ligament, or the junction with the posterior horn of the meniscus, as well as possible longitudinal tear extension into the posterior horn of the meniscus (34,35). Although tears through the vascular posterior root attachment are amenable to surgical repair, radial tears of the posterior horn adjacent to the root may not be reparable, highlighting the importance of accurate anatomic characterization at imaging (33).

In the setting of isolated PCL tears, meniscal tears are seen in almost 30%

Figure 5



a. b.

Figure 5: Sagittal T2-weighted fat-suppressed MR images of the **(a)** peripheral and **(b)** more central aspect of the medial compartment of the knee in a 33-year-old female field hockey player with a subacute twisting injury show a fluid signal intensity medial meniscal tear with vertical and horizontal components. There is slight displacement of the apical inner margin (arrowhead). The tear extended over 2 cm and was unstable at arthroscopy.

of patients, with a higher incidence of tearing of the anterior horn of the lateral meniscus (36). The propensity for tearing of the anterior horn of the lateral meniscus is likely related to the hyperextension mechanism of injury implicated in many cases of PCL injury.

In the young athletic population, meniscal tears are ideally repaired rather than resected, given the potential for developing premature osteoarthritis following partial meniscectomy. Surgical criteria for meniscal repair include meniscal tears greater than 10 mm in length, unstable on probing, located within 3 mm of the meniscosynovial junction, involvement of greater than 50% of the thickness of the meniscus, and an intact peripheral body or inner meniscal fragment (37). With the above criteria, MR imaging yielded a mean accuracy of 60%–74%, sensitivity of 29%–47%, and specificity of 74%–89% in predicting whether a meniscal tear is reparable at surgery (37,38).

The MR criteria for unstable meniscal tears include a tear greater than 1 cm in length, presence of more than one morphologic tear pattern, high T2 signal intensity within the tear plane, and presence of a displaced meniscal fragment (39) (Fig 5). Although the specificity and positive predictive values of these signs have been shown to be greater than 90% in diagnosing an unstable meniscal tear at MR imaging, the sensitivity ranged only between 18% and 54%, with tear length having the highest sensitivity and high T2 signal intensity of the tear cleft having the lowest sensitivity.

Anterior Cruciate Ligament Injuries

The ACL is the most commonly reconstructed knee ligament and one of the most commonly injured knee ligaments (40). ACL reconstruction has traditionally been performed with single-bundle ACL grafts, which aim to reconstruct the anteromedial bundle of the ACL. However, advances in surgical management of ACL injuries such as double-bundle reconstruction techniques as well as surgical treatment of partial tears have necessitated more accurate assessment of ACL injuries.

The ACL arises from the medial margin of the lateral femoral condyle and consists of a longer anteromedial bundle and a shorter posterolateral bundle named after their tibial insertion points. The posterolateral bundle has a more distal origin than the anteromedial bundle, with a more oblique orientation. The ACL fans out from proximal to distal, with a larger tibial footprint in comparison with its femoral origin. Consequently at MR imaging, the ACL has an elliptical homogeneous low signal intensity appearance on axial images through the proximal intercondylar notch and a heterogeneous appearance on axial and coronal images more distally through the notch where the anteromedial bundle and posterolateral bundle can be independently distinguished. The two bundles are also functionally distinct. The isometric anteromedial bundle is maximally taut in flexion and is the primary restraint to anterior tibial translation during flexion. The posterolateral bundle is maximally taut in extension, acting as a restraint to anterior tibial translation in extension as well as a restraint to tibial rotation. On sagittal MR images obtained with the knee extended, the ACL fibers are taut and run parallel or within 9° of the roof of the intercondylar notch (Blumensaat line) (41).

The highest rates for ACL injury are seen in soccer (particularly indoor soccer), Australian football, alpine skiing, handball, wrestling, rugby, and basketball (42). There is a higher incidence of ACL injury in females in most sports but particularly in basketball, soccer, and handball (42). The higher incidence of ACL tears in females is thought to be related to ligament size, limb alignment, muscle strength, and activation patterns, and possibly the intercondylar notch size. Approximately 70% of ACL tears are as a result of noncontact injuries, with 30% caused by a direct impact to the knee (43).

Noncontact ACL injuries variably occur as the result of a complex set of factors, including the position of the knee, the ground reaction force, and quadriceps loading, as well as valgus/varus and rotatory forces on the knee.

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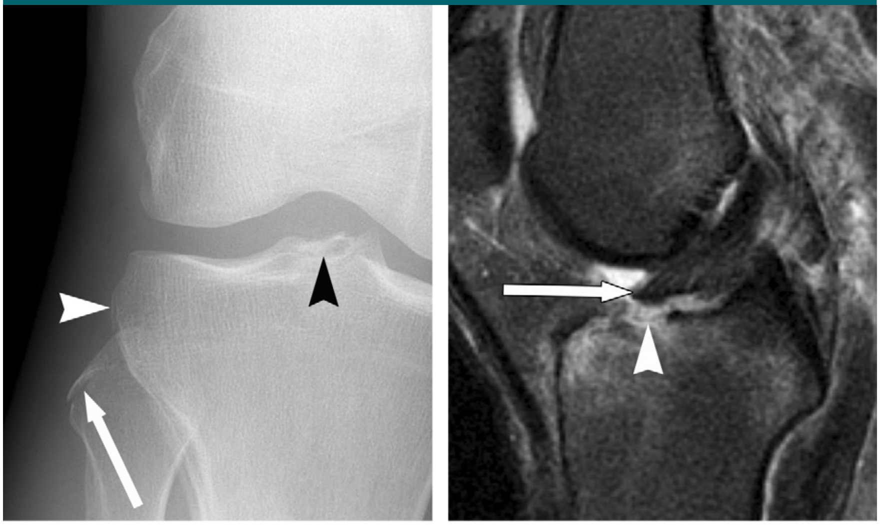
Figure 6



a. b.

Figure 6: **(a)** Anteroposterior radiograph of the knee in a 19-year-old male soccer player with an acute knee injury shows a Segond fracture (white arrowhead), ACL tibial footprint avulsion (black arrowhead), and an avulsion fracture of the fibular head (arrow) consistent with ACL and PLC injuries. **(b)** Sagittal T2-weighted fat-suppressed MR image in the same patient shows the ACL avulsion (arrow) with mild edema and loss of the cortical outline of the ACL footprint (arrowhead).

Figure 7

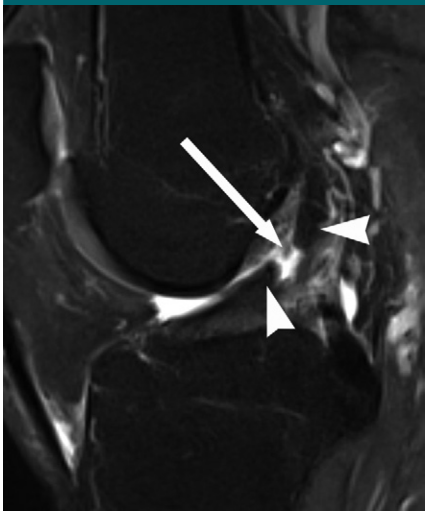


Figure 7: Sagittal T2-weighted fat-suppressed MR image in a 27-year-old male soccer player with a subacute complete ACL tear shows complete discontinuity of the mid ACL (arrow). The proximal and distal fibers (arrowheads) are more vertically and horizontally oriented, respectively.

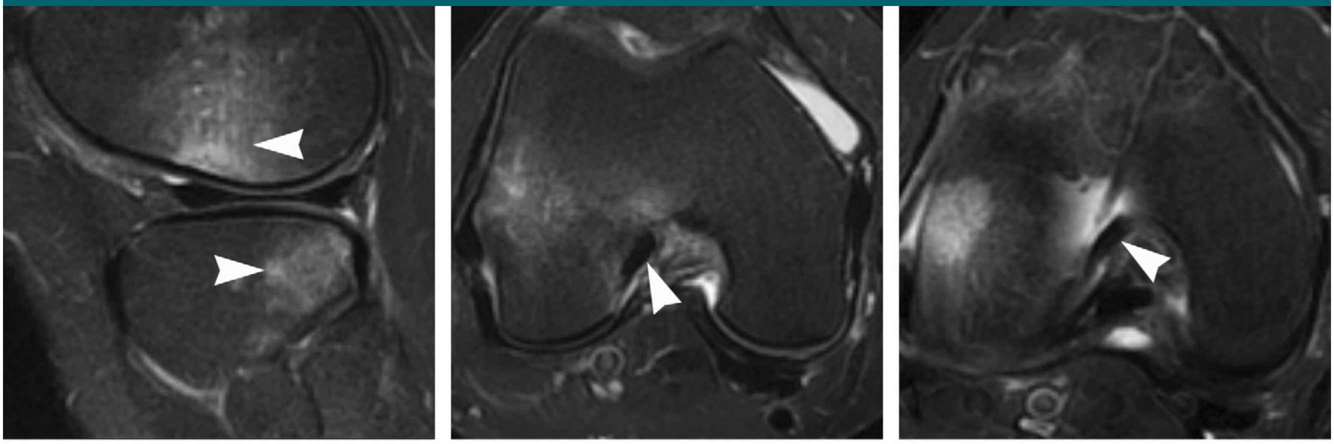
Most noncontact injuries occur during a sharp deceleration at the time of changing direction or upon landing after a jump (44). It has been shown that physiologic strain on the ACL is primarily the result of the proximal tibial anterior shear force (45), which is typically exerted through the quadriceps mechanism, and the force increases as the knee flexion angle decreases. Forces through the ACL are accentuated when anterior tibial translation is combined with either varus or valgus loading (46). Numerous noncontact mechanisms have been described in ACL injuries. The pivot shift injury composed of valgus force, quadriceps loading, and a planted foot with relative internal rotation of the tibia in relation to the femur is a common mechanism seen in sports such as soccer, in which there are abrupt changes in direction (47). This mechanism of ACL injury produces the characteristic osseous contusions of the lateral femoral condyle, posterior aspect of the lateral tibial plateau, and less commonly medial-sided contusions. A varus force with internal rotation of the tibia may also result in ACL injury and has been implicated in the etiology of the Segond fracture, involving the lateral rim of the tibia.

With contact injuries, the typical mechanisms of injury include a clip injury, whereby a valgus force is applied to the partly flexed knee, or a hyperextension injury. Clip injuries are associated with MCL and medial meniscal tears and are often associated with lateral osseous contusive injuries. Hyperextension injuries may be combined with varus or valgus force. A hyperextension varus force, with anteromedial bone bruising, can be associated with PLC injuries whereas a hyperextension valgus injury, with anterolateral bone bruising, may result in PMC injuries. Severe hyperextension injuries may result in knee dislocation with associated risk of neurovascular injuries.

Radiographs obtained early following ACL injury most commonly demonstrate distention of the joint capsule. ACL tears are one of the most common causes for an acute large hemarthrosis in the athletic population, and 41%–75% of acute knee injuries with a hemarthrosis have an ACL tear (48,49). In pivot shift injuries, there may be a deep lateral sulcus sign or subtle deformity of the posterior rim of the lateral tibial plateau. With flexion and varus injury, a Segond fracture may be evident. Such bone changes are not very sensitive but are highly specific for an ACL injury. In the adolescent population in particular, an avulsion fracture of the distal ACL footprint may be discernable on radiographs (Fig 6).

MR imaging has a pooled sensitivity and specificity of 94% for ACL tears (18). Immediately following a complete ACL rupture, the most common appearance is that of focal discontinuity or diffuse swelling and increased signal intensity within the ACL (50). An abnormal orientation of the ACL may also be seen with complete tears, with either posterior bowing of the ACL (51) or a vertical orientation of the proximal fibers and horizontal orientation of distal fibers of the torn ligament (50) (Fig 7). It is important to distinguish ligamentous tears from avulsion fractures of the distal ligament insertion, as these may be amenable to primary surgical

Figure 8



a.   b.   c.

Figure 8: **(a)** Sagittal T2-weighted fat-suppressed MR image in a 30-year-old male basketball player shows osseous contusive injury consistent with a pivot shift injury (arrowheads). **(b)** Axial T2-weighted fat-suppressed MR image through the proximal intercondylar notch shows an intact origin of the ACL (arrowhead). **(c)** Axial T2-weighted fat-suppressed MR image through the distal intercondylar notch shows only an intact anteromedial bundle (arrowhead) with nonvisualization of the posterolateral bundle.

fixation. Occasionally, the distal stump of a torn ACL may flip anteriorly and may be responsible for locking, clinically mimicking a bucket-handle tear. This has been referred to as a preoperative cyclops lesion or a bell-hammer tear and has a higher incidence with partial tears with anteromedial bundle disruption (52). A number of secondary MR imaging signs of ACL injury have been described, such as anterior translation of the lateral tibial plateau in relation to the lateral femoral condyle, uncovering of the posterior horn of the lateral meniscus, and buckling of the PCL. These are of limited additional utility to primary signs in the setting of complete ACL tears.

Partial ACL tears account for 10%–36% of surgically treated patients (53) but this is likely a significant underestimate of the incidence of partial tears and there is debate as to the accuracy of clinical evaluation of partial ACL injuries. Tears of the anteromedial bundle are more common (52) and the anteromedial bundle is more prone to injury with the knee flexed, whereas the posterolateral bundle is at risk with hyperextension and internal rotation injuries (54). MR imaging has diminished accuracy in the diagnosis of partial ACL tears in comparison with complete tears (55–57). In one study, increased intrasubstance signal, distortion, and attenuation of fibers or an abnormal orientation of the ACL were interpreted as being indicative of a partial tear, but up to 23% of partial tears could not be distinguished from a normal ligament by using the above criteria and up to 23% of partial tears could not be distinguished from complete tears (57). The performance of 3-T MR imaging appears to be better however, with sensitivity, specificity, and accuracy of 77%, 97%, and 95%, respectively, in the diagnosis of partial ACL tearing (58). Isotropic three-dimensional fast spin-echo pulse sequences and oblique coronal and oblique axial acquisitions appear to result in some improvement in diagnostic accuracy in comparison with standard orthogonal planes, although this is not always significant (14,59,60). Surgical options in patients with partial ACL tears include single-bundle or complete ACL reconstruction, and this is usually undertaken in those with symptomatic instability or those at risk for developing ACL insufficiency (54). The risk of developing ACL insufficiency is related to the severity of injury and can exceed 85% when more than 75% of the ligament is injured. In contrast, when less than 25% of the ligament is injured, the risk of developing ACL insufficiency is as low as 12% (61). As the need for surgical treatment is partly dependent on anterior instability, some studies have attempted to stratify partial tears as stable or unstable based on MR imaging appearances. With use of axial acquisitions, nonvisualization of the ACL, visualization of a single bundle (Fig 8), or demonstration of a masslike appearance was associated with unstable tears (unstable partial and complete tears) whereas attenuated fibers, intrasubstance signal intensity change, and an elongated ellipsoid appearance were associated with a stable ACL (stable partial tears and normal ligaments), with 100% sensitivity and 96% specificity. However in this same study it was not possible to distinguish a stable partial tear from a normal ACL or an unstable partial tear from a complete tear. Osseous contusive injury appears to be associated with higher grade partial tears of the ACL (62). A more recent study demonstrated a sensitivity of 77% and specificity of 92% in distinguishing between stable and unstable tears, with fiber discontinuity and abnormal ACL orientation having the highest accuracy (63). Anterior tibial translation, uncovering of the posterior horn of the lateral meniscus, and buckling of the PCL were

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Figure 9

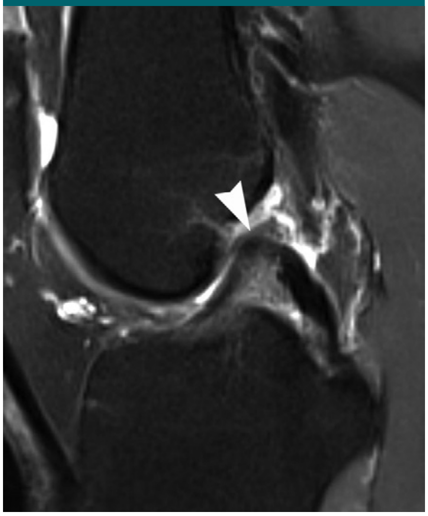


Figure 9: Sagittal T2-weighted fat-suppressed MR image in a 22-year-old man 8 weeks after a soccer injury shows a complete tear of the proximal ACL with scarring onto the PCL (arrowhead).

Figure 10

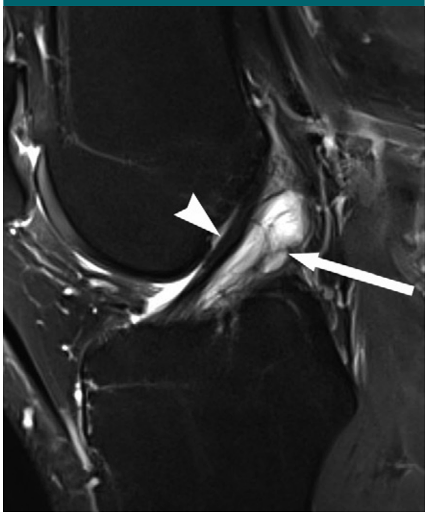


Figure 10: Sagittal T2-weighted fat-suppressed MR image in a 39-year-old man with knee pain with no recent history of trauma shows an ACL ganglion cyst (arrow) extending along the ACL. Intact ACL fibers are visualized anteriorly (arrowhead).

seen only with unstable tears (63). Most discrepancies were seen in the setting of chronic partial tears. It has been demonstrated that some chronic complete ACL tears may demonstrate end-to-end reattachment or scarring onto the PCL (Fig 9). These may be mistaken for low-grade partial tears or intact ligaments on MR images and clinically they may also demonstrate an end point and less laxity at Lachman testing (64).

ACL expansion and increased signal intensity may also be seen in ACL mucoid degeneration and ganglia (65) and can be mistaken for partial tears, especially as they can be a source of knee pain (Fig 10). The distinction from partial tears is based on continuity of fibers, best seen on T2-weighted images. Intraosseous cystic changes are commonly seen at the proximal and distal ACL attachments in mucoid degeneration and ganglion formation (65).

Posterior Cruciate Ligament Injuries

PCL injuries are relatively uncommon, with isolated PCL injuries accounting for 4% of all knee ligamentous injuries (40). However, this may be an underestimate as some isolated PCL injuries may go unrecognized, and many athletes successfully return to play despite PCL insufficiency (66). The highest incidence of PCL injuries is seen in road traffic accidents, followed by athletic injuries, particularly in soccer, football, and skiing.

The PCL originates from the lateral aspect of the medial femoral condyle anteriorly and inserts distally onto the posterior intercondyloid fossa of the tibia in close proximity to the posterior root of the medial meniscus. It consists of a larger anterolateral bundle and smaller posteromedial bundle that, similar to the ACL, have a reciprocal tensioning pattern. The PCL is the major restraint to posterior translation of the tibia, with the larger anterolateral bundle taut in flexion and the posteromedial bundle taut in extension. The PCL is also a secondary restraint to external rotation of the tibia.

Various mechanisms of PCL injury have been described, and the mechanism of injury may be inferred from the osseous contusive pattern on MR images (67). One of the most common mechanisms of PCL injury is an anterior blow to the proximal tibia, typically with the knee in flexion. This may be seen in motor vehicle accidents with dashboard injuries or with athletic injuries such as a fall onto a flexed knee resulting in bone marrow edema of the anterior tibia. Depending on the severity of the force, this may result in an isolated PCL injury or a multiligamentous injury. Hyperflexion injuries may also produce an isolated PCL tear particularly involving the larger anterolateral bundle (68). Hyperextension injuries resulting from a blow to the anterior aspect of an extended knee may produce kissing contusions of the femur and tibia anteromedially or anterolaterally and may result in multiligamentous injuries involving the PCL, ACL, PLC, or PMC structures. Rotational injuries, with relative internal rotation of the femur/external rotation of the tibia, can also injure the PCL.

Radiographic assessment of posterior knee laxity should include a lateral view in flexion, as posterior translational instability is most marked in flexion when the dominant larger anterolateral bundle would normally be the major restraint to posterior translation. Translational instability may be further aided by stress radiography with or without dedicated devices to accentuate posterior translation of the tibia. Various maneuvers including kneeling lateral radiographs or decubitus lateral radiographs with attempted active flexion of the knee against resistance at the ankle may highlight posterior tibial translation (69,70). Measurements are taken from the posterior cortex of the tibia to the posterior cortex of the femoral condyles and are compared with the unaffected knee. A side-to-side difference of 5–12 mm on stress radiographs is indicative of an isolated complete PCL tear whereas a side-to-side difference in excess of 12 mm is indicative of a multiligamentous injury (71). With PCL avulsion fractures, CT can be used to accurately assess the size, number, and displacement of bone fragments.

The PCL, in contrast to the ACL, is homogeneously of low signal intensity with all MR imaging pulse sequences. Magic angle phenomenon may be encountered in the region of genu and

Figure 11

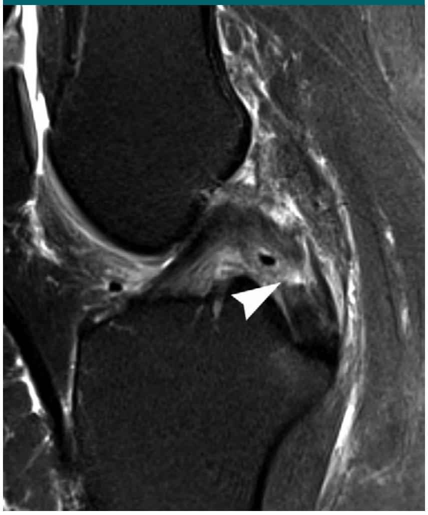


Figure 11: Sagittal T2-weighted fat-suppressed MR image in a 26-year-old male football player shows a transverse complete tear of the PCL distal to the genu (arrowhead).

Figure 12

Figure 12: Sagittal T2-weighted fat-suppressed MR image in a 29-year-old man with clinical evidence of posterior knee laxity shows an interstitial tear of the PCL with diffuse thickening.

Figure 13

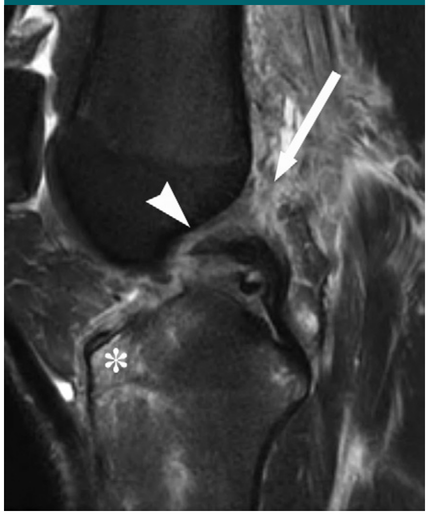


Figure 13: Sagittal T2-weighted fat-suppressed MR image in a 34-year-old male soccer player who sustained an anterior blow to the knee resulting in a hyperextension injury shows osseous contusion of the proximal tibia (*) and a complete tear of the femoral origin of the PCL (arrowhead). There is also a posterior capsular tear (arrow).

more distally on images obtained with short echo-time pulse sequences as a result of collagen fibers oriented at 55° to the main magnetic field. This can be distinguished from a partial tear by demonstration of corresponding low signal intensity on long-echo-time images and an anteroposterior thickness of the ligament, measuring less than 6 mm (72). Injury to the PCL may result in transverse or longitudinal interstitial tears (Fig 11). As such, imaging appearances of PCL tears include focal discontinuity of the PCL or diffuse increased signal intensity of the PCL violating its margins, typically with thickening of the ligament resulting in an anteroposterior dimension exceeding 7 mm (Fig 12). The increased signal intensity is commonly not of fluid signal intensity. Thickening of the PCL has a sensitivity and specificity in excess of 90% for a tear (72). Tears of the femoral origin of the PCL can be relatively subtle, with mild edema and without a significant gap (Fig 13). Ligamentous injuries of the PCL should be distinguished from osseous avulsions, as the latter are amenable to treatment by means of primary fixation. Partial tears may account for approximately 50% of PCL injuries (72). Intrasubstance mucoid degeneration of the PCL, resulting in a "tram-track" appearance, may mimic a partial or interstitial tear but in contrast to partial tears, the abnormal signal should not violate the margins of the ligament (73). In chronic tears of the PCL, the ligament may be diminutive or not visualized. However, in some series, as many as 86% of high-grade PCL injuries demonstrated fiber continuity at a mean of 3.2 years after injury (74). Up to 28% PCL tears may have a completely normal appearance at follow-up imaging (75). This is more common in the group imaged more than 6 months after injury and can be associated with improved posterior knee laxity. MR imaging assessment of chronic PCL injuries is less reliable than assessment of acute injury, as continuity of PCL fibers in chronic injuries can be mistaken for a partial tear or even a normal PCL, particularly if prior imaging studies or accurate clinical information is lacking (76). Overall MR imaging has a pooled sensitivity and specificity of 91% and 99%, respectively, for PCL tears (18).

Given the association of PCL tears with multiligamentous injuries, assessment of the posterolateral and posteromedial structures on MR images is of critical importance, as concomitant injuries to these structures may be overlooked clinically and are associated with a poorer prognosis if untreated. In PCL-deficient knees, the popliteus tendon and the posteromedial stabilizing structures act as important secondary stabilizers of the knee. In acute high-grade PCL injuries, chondral lesions are present in approximately 50% of patients, with the medial femoral condyle being the most common location (36). In chronic PCL tears, medial femoral condyle and patellofemoral chondral lesions may be seen in nearly 80% of patients (77). Patients with posterior knee instability commonly lock the knee in extension during gait to prevent posterior translation of the tibia, and this can also lead to patellofemoral chondral changes over time.

Posterolateral Corner Injuries

PLC injuries can be easily overlooked, and failure to address PLC injuries can

Figure 14

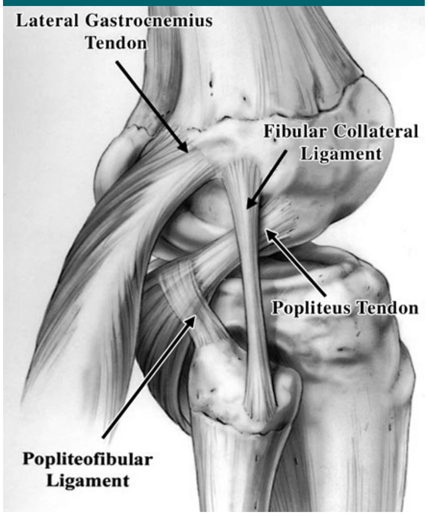


Figure 14: Illustration demonstrates the major posterolateral stabilizers of the knee. (Reprinted, with permission, from reference 78.)

Figure 15

Figure 15: Coronal intermediate-weighted MR image in a 24-year-old man with clinical evidence of isolated posterolateral instability shows a partial tear of the proximal popliteus (arrow) and a complete tear of the popliteofibular ligament (arrowhead). The cruciate ligaments were intact.

result in significant morbidity and affect the outcome of cruciate ligament reconstruction.

The anatomy of the lateral stabilizers is complex and consists of static and dynamic stabilizers (Fig 14). The static stabilizers include the fibular collateral ligament (FCL), popliteofibular ligament, arcuate ligament, fabellofibular ligament, iliotibial band, and the anterolateral ligament, while the dynamic stabilizers include the popliteus, the long and short heads of biceps femoris, and the lateral head of gastrocnemius.

The FCL originates proximal and posterior to the lateral epicondyle of the femur and inserts onto the fibular head, distal to the styloid process (78). The popliteus muscle originates distally along the posterior aspect of the tibia and the tendon extends proximally and laterally through the popliteus hiatus to insert onto the lateral femoral condyle, inferior and anterior to the origin of the FCL (78). The popliteus also serves as the attachment point of several other ligamentous structures, including the popliteomeniscal fascicles and the popliteofibular ligament. The anteroinferior, posterosuperior, and posteroinferior popliteomeniscal fascicles act as stabilizers of the lateral meniscus (79). The anterior and posterior divisions of the popliteofibular ligament are important stabilizers of the PLC. They arise from the myotendinous junction of the popliteus, posterior to the proximal tibia, and extend distally to insert onto the styloid process of the fibula with the arcuate ligament. The arcuate ligament is a Y-shaped structure inserting onto the styloid process distally with medial and lateral limbs proximally. The stronger lateral limb attaches to the lateral femoral condyle and the medial limb attaches to the posterior capsule. The biceps femoris consists of a long head and a short head, each with multiple insertions along the posterolateral aspect of the knee (80). The most important attachments of the long head of biceps are the direct and anterior arms, both attaching onto the fibular head. The short head of biceps also consists of a direct arm, inserting onto the fibular head, and the anterior arm, attaching onto the tibia posterior to the Gerdy tubercle. The iliotibial band originates from the iliac crest and inserts distally via a superficial layer onto the Gerdy tubercle at the anterolateral tibia and via a deep layer onto the lateral intermuscular septum of the lateral femoral condyle. The anterolateral ligament, previously also referred to as the mid-third lateral capsular ligament, originates from the lateral epicondyle, inserts distally onto the proximal tibia posterior to the Gerdy tubercle, and is implicated in the Segond fracture (81,82). The fabellofibular ligament originates from the fabella proximally and inserts distally along the lateral aspect of the fibular styloid.

Collectively, the posterolateral stabilizers act primarily as restraints to varus stress and external rotation of the knee. Of these, the FCL, popliteofibular ligament, and popliteus tendon are considered the most important biomechanically and are the structures addressed in anatomic posterolateral reconstructions (80). The FCL acts as the primary stabilizer of the knee to varus instability, particularly in extension and low flexion angles, as well as a restraint to internal and external rotation of the knee depending on the flexion angle (83). The popliteus and popliteofibular ligament also serve as restraints to external rotation of the knee particularly in the flexed position. The posterolateral stabilizers also act in concert as a restraint to posterior translation of the tibia particularly in extension (84).

Nine percent of acute knee injuries with a hemarthrosis at presentation will demonstrate a PLC injury, often in combination with ACL or multiligamentous injuries (49). Isolated PLC injuries are rare and account for 15%–27% of all PLC injuries (49,85) (Fig 15). Similar to posterior cruciate ligament injuries, the most common mechanisms of PLC injury are hyperextension varus injuries or a direct blow to the proximal tibia with the knee in a flexed position. External rotation injuries in hyperextension or flexion may also result in tears of the PLC.

Imaging assessment of the PLC includes standing radiographs to assess for varus malalignment and avulsion fractures, including the arcuate fracture of the fibular styloid (popliteofibular, arcuate, and fabellofibular ligaments), avulsion of the fibular head (FCL and long head of biceps femoris), and the Segond fracture (anterolateral ligament and iliotibial band) (82,86) (see Fig 6a). Stress radiography with varus force may also be used to document the degree of lateral joint space widening in PLC injuries.

MR imaging consistently demonstrates the FCL, popliteus tendon, biceps femoris, and iliotibial band, but identification of smaller ligamentous structures may be less reliable owing to their small caliber and obliquity to orthogonal imaging planes. The popliteofibular ligament, arcuate ligament, and the fabellofibular ligament are only seen on up to 50% of in vivo MR imaging studies (87). Visualization of the popliteofibular ligament is improved with isotropic three-dimensional acquisitions and may be seen on up to 91% of MR studies (88). It has been suggested that the anterolateral ligament is seen on nearly all MR studies (89). In patients with grade III PLC injuries, multiple components of the PLC are injured in 57%–100% of patients (49,90) (Fig 16). Anteromedial bone bruises are the most common site of osseous injury with acute grade III PLC injuries, and they are seen with both isolated and multiligamentous injuries but are more common with multiligamentous injuries (85).

The FCL may be injured at its origin, commonly in association with injury to the popliteus or distally at its insertion to the fibula. Partial tears are evident as altered caliber with ligamentous and periligamentous edema, in contrast to complete tears whereby there is complete disruption, typically with some degree of redundancy of the ligament. The popliteus may be injured proximally along its tendinous attachment or at its myotendinous junction. Myotendinous injuries are typically partial tears. Popliteofibular ligament injuries may be less reliably demonstrated on MR images. Injury may be evident as altered caliber or focal discontinuity of the popliteofibular ligament (Fig 17). In one study, in addition to cruciate ligament injuries, over 90% of popliteofibular ligament injuries were associated with iliotibial band injuries (91). In cases in which the popliteofibular ligament is not well visualized, edema along its expected location between the popliteus myotendinous junction and the fibular styloid should raise concern for an injury to the popliteofibular ligament and PLC. Arcuate ligament injuries may be inferred in the presence of posterolateral capsular edema and edema posterior to the popliteus tendon in the region of the popliteal hiatus (90). Edema and hemorrhage along the posterior capsule, particularly with more confluent areas of fluid signal intensity, should raise concern for a posterior capsular injury. Tears of the anterolateral ligament are also referred to as soft-tissue Segond injuries and may be seen as thickening or disruption of the ligament posterior to the iliotibial band and may contribute to ongoing instability following ACL reconstruction (92,93). In patients with clinical posterolateral instability requiring surgery, the incidence of complete tears of FCL, popliteofibular ligament, and popliteus were 86%, 72%, and 68%, respectively (90).

Figure 16

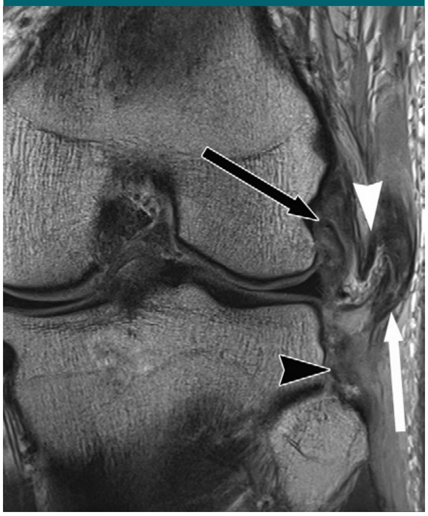


Figure 16: Coronal intermediate-weighted MR image in a 29-year-old man with an ACL tear also shows retracted complete tears of biceps femoris (white arrow) and fibular collateral ligament (white arrowhead) as well as tears of the proximal popliteus (black arrow) and the popliteofibular ligament (black arrowhead).

Figure 17

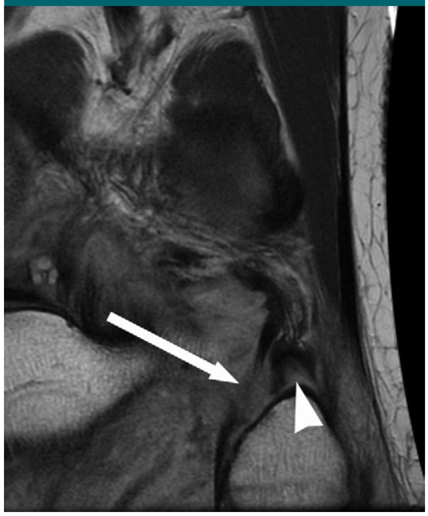


Figure 17: Coronal intermediate-weighted MR image in a 35-year-old man with a hyperextension injury and a PCL tear (not shown) shows a tear at the insertion of the popliteofibular ligament/arcuate ligament onto the styloid process of the fibula (arrowhead) and a complete tear of the myotendinous junction of the popliteus (arrow).

Accuracy of MR imaging for detection of PLC injuries is dependent on the grade of injury and the structure involved. In grade III PLC injuries, accuracy rates as high 95% have been reported for FCL, iliotibial band, anterolateral ligament, and biceps femoris tears, with accuracies of 90% and 68% for popliteus tendon and popliteofibular ligament injuries, respectively (92).

Treatment of PLC instability has typically consisted of acute repair of the PLC injury with staged cruciate ligament reconstruction, but recent data suggest that posterolateral reconstruction may have a more favorable outcome (94).

Medial Collateral Ligament and Posteromedial Corner Injuries

MCL injuries are one of the most common ligamentous injuries of the knee (40), and the majority of MCL injuries, including some complete (grade III) tears, have traditionally been conservatively treated. However, conservative treatment of MCL injury

Figure 18

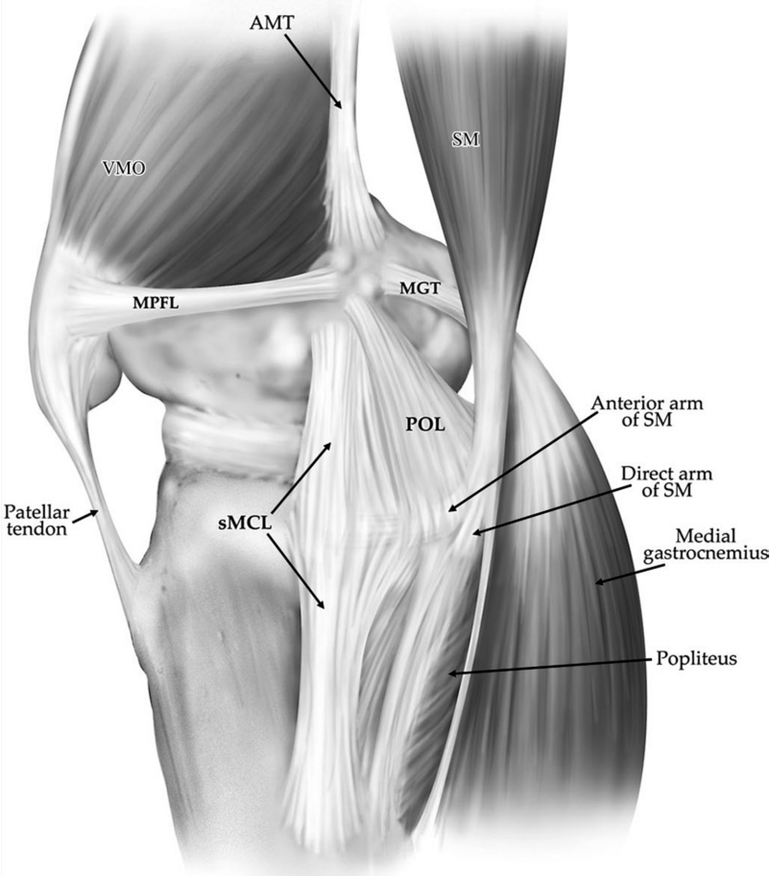


Figure 18: Illustration demonstrates the major medial and posteromedial stabilizers of the knee. *AMT* = adductor magnus tendon, *MGT* = medial gastrocnemius tendon, *MPFL* = medial patellofemoral ligament, *SM* = semimembranosus, *sMCL* = superficial MCL, *VMO* = vastus medialis obliquus muscle. (Reprinted, with permission, from reference 98.)

particularly in the setting of multiligamentous injuries may result in chronic medial instability and predispose to failure of cruciate ligament reconstruction (95). This recognition has led to detailed studies of the anatomy and biomechanics of the MCL and the PMC structures, with development of more complex and anatomic reconstruction techniques (96).

The medial and posteromedial stabilizers of the knee consist of the superficial and deep MCL, the posterior oblique ligament (POL), the semimembranosus tendon and its expansions, the oblique popliteal ligament, and the posterior horn of the medial meniscus (Fig 18). The PMC of the knee, extending from the posterior aspect of the superficial MCL to the medial aspect of the PCL, has been referred to as a synergistic muscle-ligament-meniscal unit, reflecting the complementary role of static and dynamic stabilizers (97).

The superficial MCL originates posterior and proximal to the medial epicondyle with two biomechanically distinct distal insertions onto the semimembranosus tendon and the posteromedial crest of the tibia, up to 6 cm distal to the medial joint line (98). The deep MCL, representing thickening of the medial joint capsule, consists of a longer meniscofemoral and a shorter meniscotibial component (98). The POL, which is biomechanically distinct from the MCL, originates from the femur posterior and proximal to the origin of the superficial MCL. From its origin it fans out distally inserting by way of superficial, central, and capsular arms onto the distal semimembranosus, the posteromedial capsule, the medial meniscus, the posteromedial tibia, and the medial aspect of the oblique popliteal ligament, with the central arm representing the major component of the ligament (98). The semimembranosus, which acts as a dynamic stabilizer of the PMC, has multiple attachments onto the tibia through anterior, direct, and inferior arms, with additional insertions onto the POL and along the oblique popliteal ligament (98,99).

The superficial MCL acts as the primary stabilizer to valgus force throughout the full range of motion of the knee. The superficial MCL also provides restraint to external, and to a lesser extent to internal, rotation of the tibia. The deep MCL provides secondary restraint to valgus force and acts as a restraint to internal rotation of the tibia. The POL acts as the primary restraint to internal rotation of the tibia and as a secondary restraint to external rotation in early knee flexion, as well as a restraint to posterior translation of the tibia (98,100). The posterior horn of the medial meniscus prevents anterior translation of the tibia in relation to the femur in what has been termed "the chock-block effect" (101). The semimembranosus provides tension on the POL and acts as a restraint to valgus force in knee extension and a restraint to external rotation in knee flexion (102). The PMC is particularly important in the MCL- or PCL-deficient knee, as it becomes a major restraint to valgus stress and posterior tibial translation in these scenarios, respectively.

The MCL and PMC may be injured in contact and noncontact sports. In the setting of contact sports such as football, soccer, rugby, and martial arts, a direct impact onto the lateral knee with the foot planted produces a valgus force resulting in lateral bone bruises and may result in isolated

Figure 19

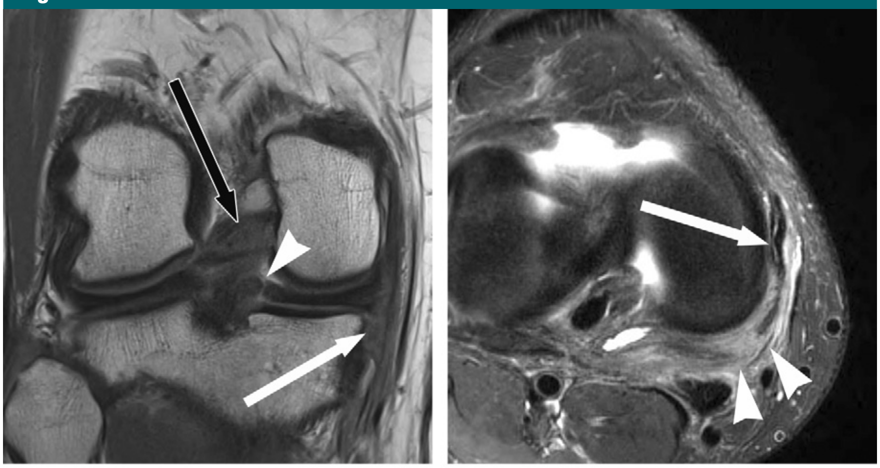
a. b.

Figure 19: **(a)** Coronal intermediate-weighted MR image in a 15-year-old male soccer player with a hyperextension valgus injury shows an avulsion of the meniscotibial component of the deep MCL consistent with a reverse Segond fracture (arrowhead) and a partial tear of the proximal PCL (arrow). **(b)** Anteroposterior radiograph obtained 5 weeks after MR imaging shows evidence of healing of the reverse Segond fracture (arrowhead).

Figure 21

Figure 21: Coronal intermediate-weighted MR image in a 32-year-old woman with a valgus injury shows a complete tear of the proximal superficial MCL (arrow) and the meniscofemoral component of the deep MCL (white arrowhead). The meniscotibial component of the deep MCL is intact (black arrowhead).

Figure 20



a. b.

Figure 20: **(a)** Coronal intermediate-weighted MR image in a 39-year-old man with a hyperextension valgus injury shows a tear of the POL (white arrow) as well as a partial tear of the PCL (black arrow) and a radial tear at the junction of the posterior horn and posterior root of the medial meniscus (arrowhead). **(b)** Axial T2-weighted fat-suppressed MR image shows a partial tear of the superficial MCL (arrow) and the tear of the POL (arrowheads).

injuries to the superficial and deep MCL. Higher impact valgus injuries can result in POL injury as well as concomitant cruciate ligament injuries. External rotation of the tibia in addition to a valgus force, seen in sports in which a cutting action is common as well as in skiing, is more likely to cause injury to the PMC in addition to tears of the superficial and deep MCL (103). Combined tears of the superficial and deep MCL as well as the PMC produce anteromedial rotatory instability (97). Anteromedial rotatory instability results in anterior subluxation of the medial tibial plateau when an external rotation force is applied to the tibia during the anterior draw test or the valgus stress test.

Radiography is of limited value in evaluation of medial injuries. A valgus injury may produce an avulsion at the femoral origin of the superficial MCL. Forced tibial external rotation and valgus force may result in avulsion of the semimembranosus insertion, which is associated with ACL tears (104). The reverse Segond fracture, representing avulsion of the tibial insertion of the meniscotibial ligament immediately distal to the medial joint line, is associated with PCL injuries (105) (Fig 19).

The superficial and deep MCL and the POL are best evaluated on coronal and axial MR images (Fig 20). Lateral osseous contusive injury may be seen

Radiology

Figure 22

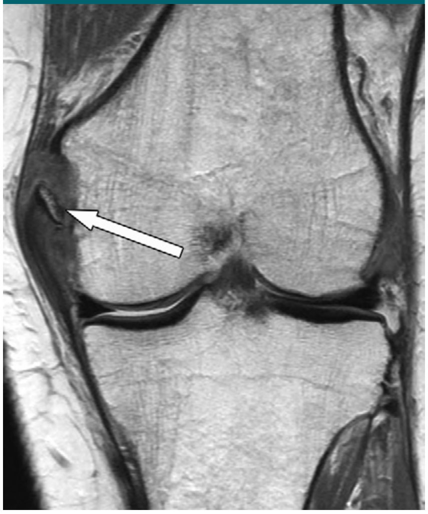


Figure 22: Coronal intermediate-weighted MR image in a 37-year-old man with a multiligamentous injury shows evidence of an osseous avulsion of the proximal superficial MCL (arrow).

Figure 23

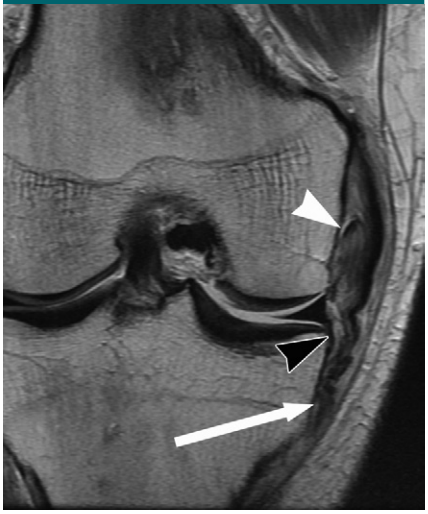


Figure 23: Coronal intermediate-weighted MR image in a 40-year-old man with valgus injury during martial arts training shows a complete retracted tear of the distal superficial MCL (arrow) and a complete tear of the meniscofemoral component of the deep MCL (white arrowhead). The meniscotibial ligament (black arrowhead) is intact.

in the setting of a direct valgus force or rotational injury. Grade I injuries demonstrate periligamentous edema on images obtained with fluid-sensitive sequences. Partial disruption of the ligamentous structures is the hallmark of grade II injuries, whereas in grade III injuries there is complete disruption of the superficial and deep MCL (Fig 21). Tears of the superficial MCL are more commonly seen through the proximal to mid-MCL. Tears of the distal superficial MCL can result in displacement of the ligament fibers anterior to the pes anserine tendons (Stener lesion of the MCL), which may impede healing. In patients with anteromedial rotatory instability, imaging will demonstrate a tear of the POL in almost all patients, injury to the semimembranosus in the majority of patients, and a tear of the posterior horn of the medial meniscus in 30% of patients (106). Features affecting the decision-making process with regard to the treatment of medial ligamentous injuries include the grade of injury, involvement of the PMC or the cruciates, the presence of osseous avulsive injury (Fig 22), degree of ligament retraction (Fig 23), entrapment of the deep MCL within the medial joint, and presence of the Stener lesion of the MCL (96,107).

Conclusion

An understanding of the complex anatomy and biomechanics of the knee is integral to the accurate diagnosis of sports injuries of the knee. Identification of injuries to intricate structures and the subtleties of ligamentous and meniscal injuries often have significant implications in surgical management of patients. An appreciation of the limitations and pitfalls of imaging tests is important in reducing interpretive errors. The mechanism of injury, inferred from osseous contusions, and recognition of patterns of injury can be helpful in highlighting the full extent of the injury.

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