

Lateral Stabilizing Structures of the Knee: Functional Anatomy and Injuries Assessed with MR Imaging¹

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The lateral aspect of the knee is stabilized by a complex arrangement of ligaments, tendons, and muscles. These structures can be demonstrated with routine spin-echo magnetic resonance (MR) imaging sequences performed in the sagittal, coronal, and axial planes. Anterolateral stabilization is provided by the capsule and iliotibial tract. Posterolateral stabilization is provided by the arcuate ligament complex, which comprises the lateral collateral ligament; biceps femoris tendon; popliteus muscle and tendon; popliteal meniscal and popliteal fibular ligaments; oblique popliteal, arcuate, and fabellofibular ligaments; and lateral gastrocnemius muscle. Injuries to lateral knee structures are less common than injuries to medial knee structures but may be more disabling. Most lateral compartment injuries are associated with damage to the cruciate ligaments and medial knee structures. Moreover, such injuries are frequently overlooked at clinical examination. Structures of the anterolateral quadrant are the most frequently injured; posterolateral instability is considerably less common. Practically all tears of the lateral collateral ligament are associated with damage to posterolateral knee structures. Most injuries of the popliteus muscle and tendon are associated with damage to other knee structures. MR imaging can demonstrate these injuries. Familiarity with the musculotendinous anatomy of the knee will facilitate accurate diagnosis with MR imaging.

Index terms: Knee, anatomy, 452.121411, 452.92 • Knee, injuries, 452.485 • Knee, ligaments, menisci, and cartilage, 452.485, 452.92

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Introduction

The lateral compartment of the knee contains many ligamentous and tendinous structures, which are the primary restraint against varus angulation as well as external-internal rotation and anterior-posterior translation of the tibia (1–5).

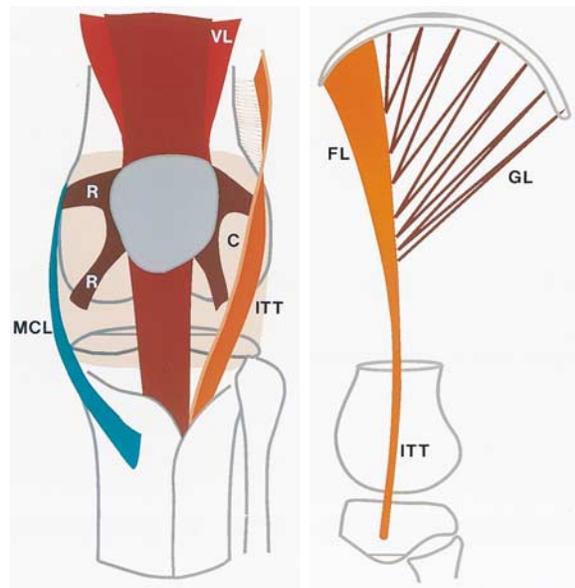
Isolated damage to these structures is rare; injuries are frequently interlaced and combined with cruciate ligament tears or damage to the stabilizing structures of the medial side of the knee (4–8). Although lateral compartment lesions are less common than those on the medial side of the joint, they may be more disabling. The wide range and complexity of these injuries cause difficulties in clinical diagnosis, and some damaged structures may go undetected at clinical examination. In fact, clinically unrecognized posterolateral injuries have been suggested as a cause of chronic instability of the knee after trauma and postsurgical failure of the cruciate ligaments (2,9,10).

Magnetic resonance (MR) imaging is a widely recognized technique for the evaluation of knee abnormalities. It is also useful in diagnosis of lateral compartment lesions; however, knowledge of the complex anatomy and biomechanics of this area is essential for detection and understanding of the injuries associated with lateral instability.

In this article, we present the functional anatomy and injuries of the lateral compartment as seen at MR imaging. The article is based on the MR images of 10 asymptomatic volunteers and 20 patients with external knee structure damage. The injuries were isolated in only two of the patients; the other 18 patients had a combination of lateral and medial compartment lesions with or without cruciate ligament tears.

Functional Anatomy

The lateral aspect of the knee is stabilized by a complex arrangement of ligaments, tendons, and muscles. These structures provide anterolateral and posterolateral stabilization. They can be dem-



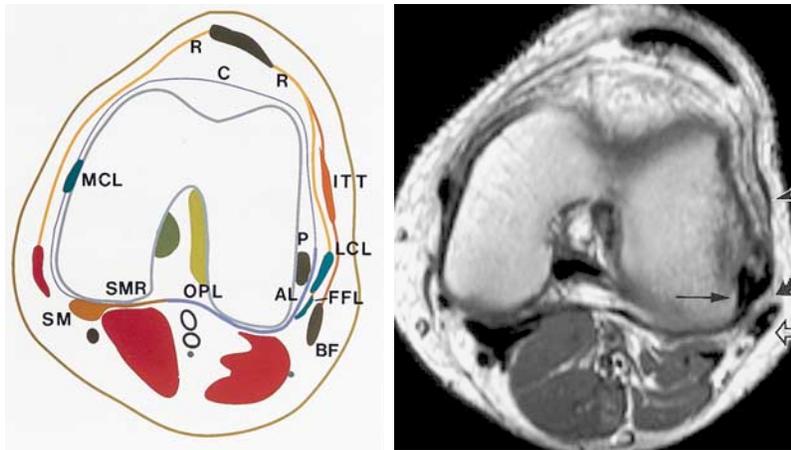
a. **b.**
Figure 1. Anatomy of the iliotibial tract. **(a)** Coronal diagram shows the capsule (*C*), iliotibial tract (*ITT*), medial collateral ligament (*MCL*), retinacula (*R*), and vastus lateralis muscle (*VL*). **(b)** Sagittal diagram shows the fascia lata (*FL*), gluteus muscle (*GL*), and iliotibial tract (*ITT*).

onstrated with routine spin-echo MR imaging sequences performed in the sagittal, coronal, and axial planes.

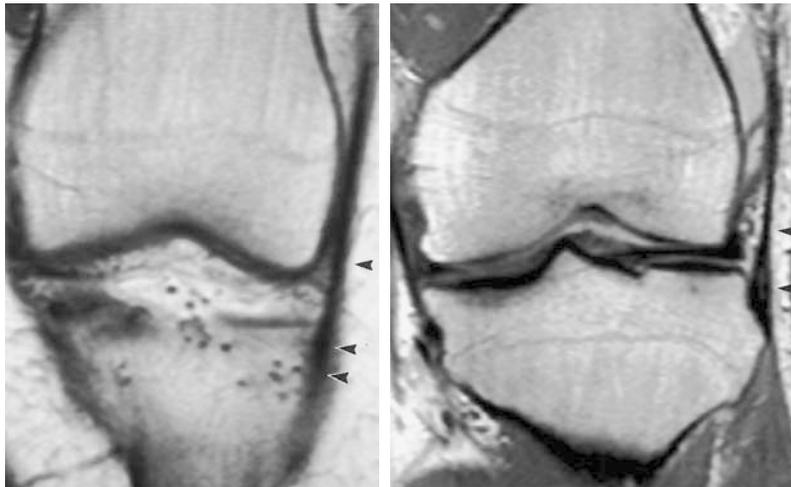
Anterolateral Stabilization

Anterolateral stabilization is provided by the capsule (capsular ligament) and iliotibial tract (5,6,11) (Figs 1–3). The capsule also contributes to anterior and posterolateral stabilization. The anterior part of the capsule is reinforced by the superior and inferior retinacula and the vastus lateralis muscle (Fig 1).

The iliotibial tract is an extension of the fascia lata and ends at the Gerdy tubercle, which is located on the anterolateral surface of the tibia (Figs 1–3). Before this tract inserts on the tibia, some of its anterior fibers attach to the lateral retinaculum and some of its posterior fibers insert on the lateral femoral condyle (6,11–16) (Figs 1, 4).



a. **b.**
Figure 2. Axial plane anatomy of the lateral structures of the knee at the level of the femoral condyles. **(a)** Axial diagram shows the arcuate ligament (*AL*), biceps femoris tendon (*BF*), capsule (*C*), fabellofibular ligament (*FFL*), iliotibial tract (*ITT*), lateral collateral ligament (*LCL*), medial collateral ligament (*MCL*), oblique popliteal ligament (*OPL*), popliteus muscle and tendon (*P*), retinacula (*R*), semimembranosus tendon (*SM*), and recurrent fascicle of the semimembranosus tendon (*SMR*). **(b)** Axial proton-density-weighted MR image shows the iliotibial tract (arrowhead), lateral collateral ligament (curved arrow), popliteus muscle and tendon (straight solid arrow), and biceps femoris tendon (open arrow).



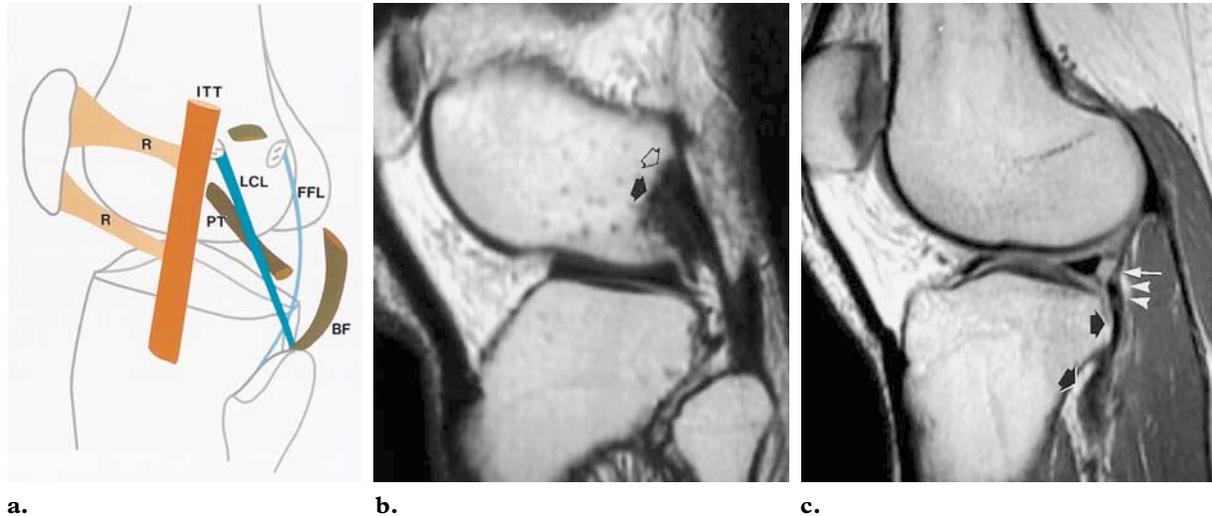
a. **b.**
Figure 3. Anatomy of the iliotibial tract. Coronal proton-density-weighted MR images show the iliotibial tract (arrowheads) attached to the anterior **(a)** and posterior **(b)** aspects of the tibia.

Posterolateral Stabilization

Most surgeons view the posterolateral region of the knee as a functional tendoligamentous unit, which is termed the *arcuate ligament complex* (2,6). This complex encompasses the lateral collateral

ligament; biceps femoris tendon; popliteus muscle and tendon; popliteal meniscal and popliteal fibular ligaments; oblique popliteal, arcuate, and

Figure 4. Sagittal plane anatomy of the lateral structures of the knee. **(a)** Sagittal oblique diagram shows the biceps femoris tendon (*BF*), fabellofibular ligament (*FFL*), iliotibial tract (*ITT*), lateral collateral ligament (*LCL*), popliteus muscle and tendon (*PT*), and retinacula (*R*). **(b)** Sagittal proton-density-weighted MR image shows the lateral collateral ligament (open arrow) and the popliteus muscle and tendon (solid arrow). **(c)** Sagittal proton-density-weighted MR image shows the popliteus muscle and tendon (black arrows) and arcuate ligament (white arrow). There is only fat behind the popliteus tendon (arrowheads). The coronal oblique plane is parallel to the long axis of the popliteus tendon.



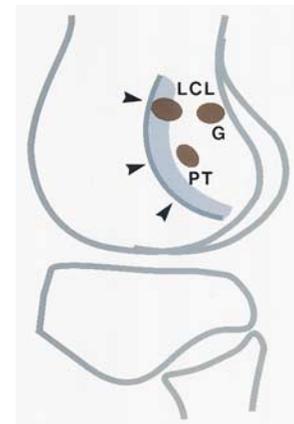
fabellofibular ligaments; and lateral gastrocnemius muscle (1,17–19) (Figs 4–6).

The posterolateral structures may not always appear on images obtained with routine MR imaging protocols. Yu et al (20) propose use of a coronal oblique plane; with a coronal plane slanted parallel to the direction of the popliteus tendon (Fig 4c), they were able to achieve better visualization of the arcuate, fabellofibular, and popliteal fibular ligaments.

The lateral collateral ligament originates from the external tuberosity of the lateral femoral condyle, directly anterior to the origin of the lateral head of the gastrocnemius muscle (Fig 5). The biceps femoris tendon descends behind the iliotibial tract. The lateral collateral ligament and biceps femoris tendon end by inserting on the head of the fibula as a conjoined tendon (6) (Fig 6). The function of the biceps femoris tendon, along with the popliteus muscle and the iliotibial tract, is to be a strong dynamic knee stabilizer and an external rotator of the tibia (16).

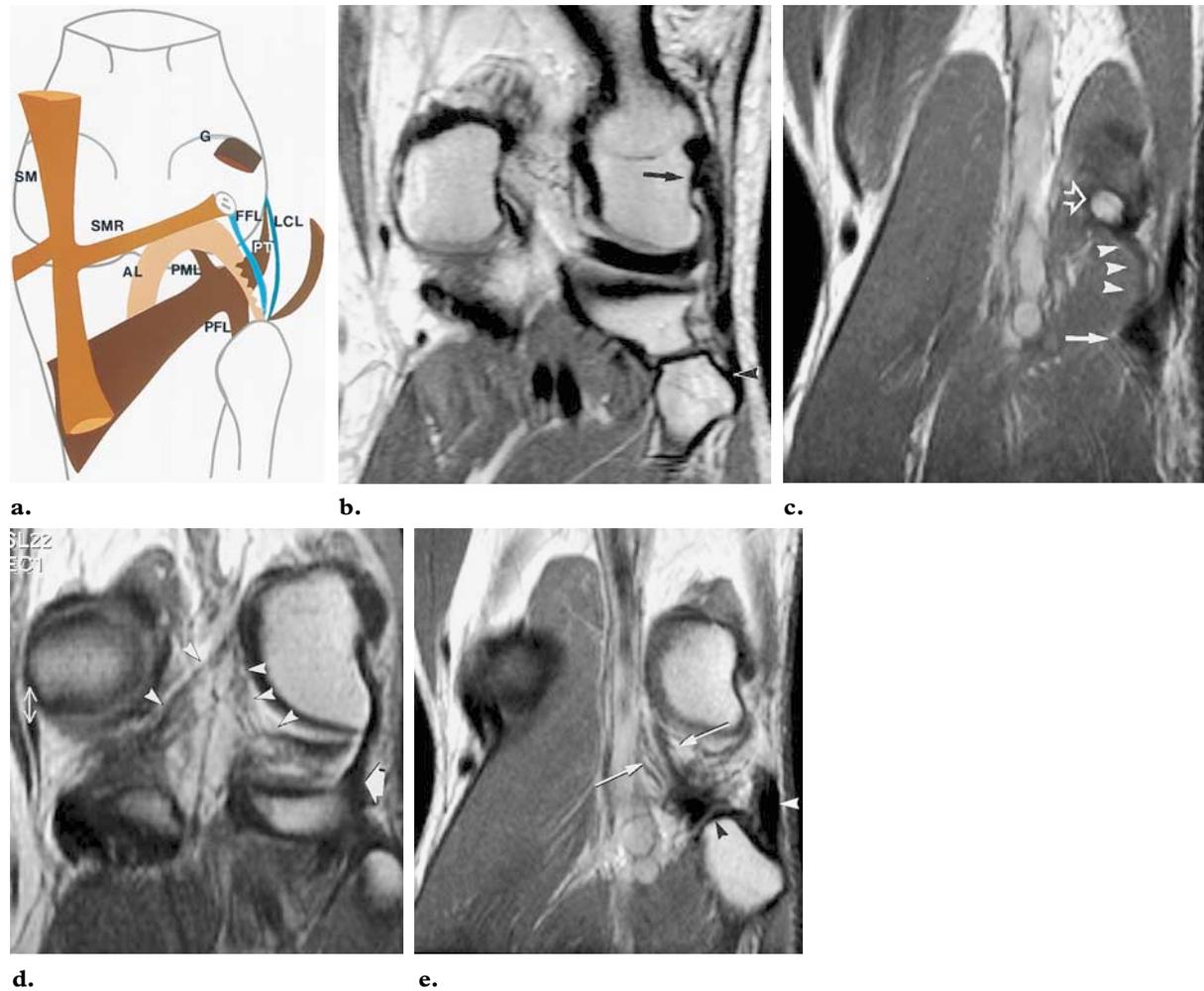
The popliteus tendon arises below the lateral collateral ligament in a small sulcus on the lateral femoral condyle, passes under the lateral collateral ligament, descends into the popliteus hiatus, then

Figure 5. Attachments on the lateral femoral condyle. Sagittal diagram shows the external tuberosity (arrowheads) and the attachments of the gastrocnemius muscle (*G*), lateral collateral ligament (*LCL*), and popliteus tendon (*PT*).



passes under the arcuate ligament and becomes extraarticular before finally joining its muscle belly, which attaches to the posteromedial surface of the proximal tibia (Figs 4–6). The popliteus tendon sends attachments to the lateral meniscus (the popliteal meniscal ligament) and to the styloid process of the fibula (the popliteal fibular ligament) (21–24) (Fig 6). The popliteus muscle is the main lateral stabilizer of the knee and also an internal rotator of the tibia (23–26). The popliteal meniscal ligament prevents the lateral meniscus from excessive forward displacement during extension of the knee (21,22,24). The popliteal fibular ligament acts as a pulley, fixing the muscle in position during contraction (27).

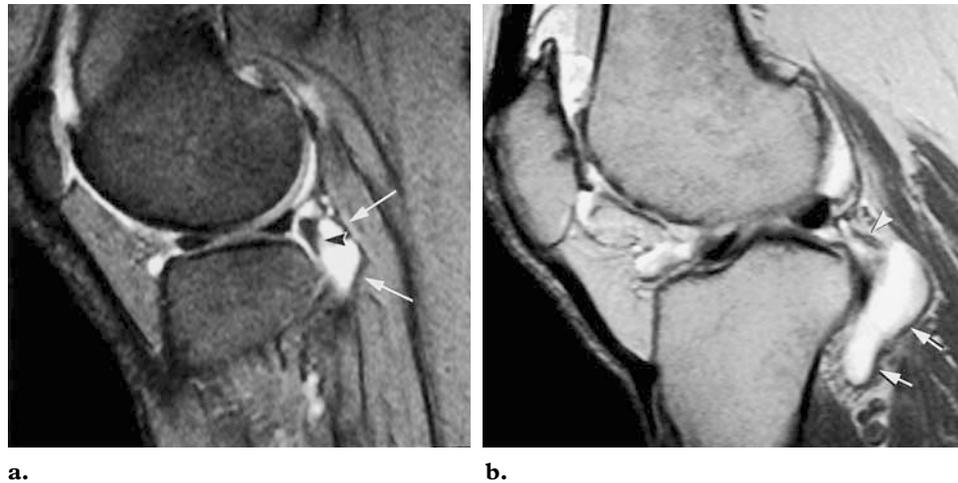
Figure 6. Coronal plane anatomy of the posterolateral structures of the knee. **(a)** Coronal diagram shows the arcuate ligament (*AL*), fabellofibular ligament (*FFL*), gastrocnemius muscle (*G*), lateral collateral ligament (*LCL*), popliteal fibular ligament (*PFL*), popliteal meniscal ligament (*PML*), popliteus muscle and tendon (*PT*), semimembranosus tendon (*SM*), and recurrent fascicle of the semimembranosus tendon (*SMR*). **(b)** Coronal oblique proton-density-weighted MR image shows the lateral collateral ligament (arrow) merging with the biceps femoris tendon to form a conjoint tendon (arrowhead) that attaches to the lateral aspect of the fibular head. **(c)** Coronal oblique proton-density-weighted MR image shows the fabellofibular ligament (arrowheads), which extends from the fabella (open arrow) to the styloid process of the fibula (not shown). Solid arrow = fibular attachment of the biceps femoris tendon. **(d)** Coronal oblique proton-density-weighted MR image shows the arcuate ligament (arrowheads) as a Y-shaped thickening of the capsule. The popliteus tendon (arrow) passes under the arcuate ligament. **(e)** Coronal oblique proton-density-weighted MR image shows the arcuate ligament (arrows) and the conjoint tendon formed by the lateral collateral ligament and biceps femoris tendon (arrowheads).



The arcuate ligament is a Y-shaped thickening of the capsule. The medial limb curves over the popliteus muscle and tendon and joins the oblique popliteal ligament. The lateral limb ascends to blend with the capsule near the lateral gastrocnemius muscle in its condylar insertion. The oblique popliteal ligament joins the recurrent fascicle of the semimembranosus tendon, which reinforces the capsule (1,17–19) (Fig 6). If the fabella is

present, which is the case in 20% of the population, the fabellofibular ligament extends from the styloid process of the fibula to the fabella; if the fabella is absent, the fabellofibular ligament extends to the lateral femoral condyle (18,19) (Figs 4, 6).

Figure 7. Popliteal bursa. Sagittal T2-weighted (a) and T1-weighted (b) MR arthrograms of the knee show a contrast material-filled popliteal bursa (arrows) around the popliteus tendon (arrowhead).



The popliteal bursa is an extraarticular extension of the synovial membrane of the knee joint. The course of this bursa extends from the popliteal hiatus along the proximal part of the popliteus tendon (21). On T2-weighted images, a fluid-filled popliteal bursa appears as a well-defined area of high signal intensity surrounding the popliteus muscle and tendon (Fig 7). This bursa may be confused with a tear of the popliteus muscle and tendon or of the posterior capsule.

Injuries

Injuries of the lateral compartment of the knee are less common than injuries of the medial compartment. However, injuries of the lateral structures are subjected to greater force during gait (8,16,28). The physiologic varus angulation of the limb axis increases and reaches maximum with full extension of the knee during the stance phase of the gait cycle, in which the lateral structures are stretched.

Lateral compartment injuries are complex, and multiple elements can be damaged at the same time. To make these complex injuries understandable, the knee can be divided into quadrants and a central pivot (the cruciate ligaments) (Fig 8). According to the traumatic mechanism (varus, valgus, or both), structures in different quadrants may be

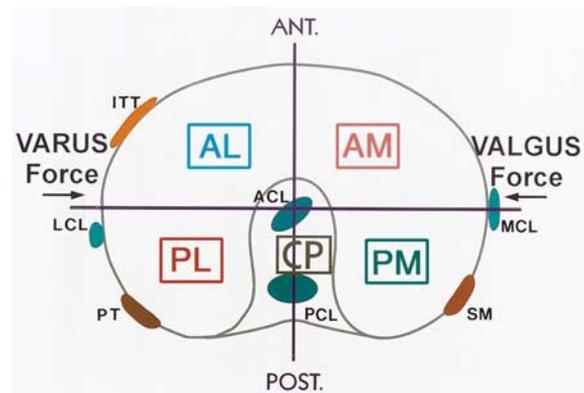
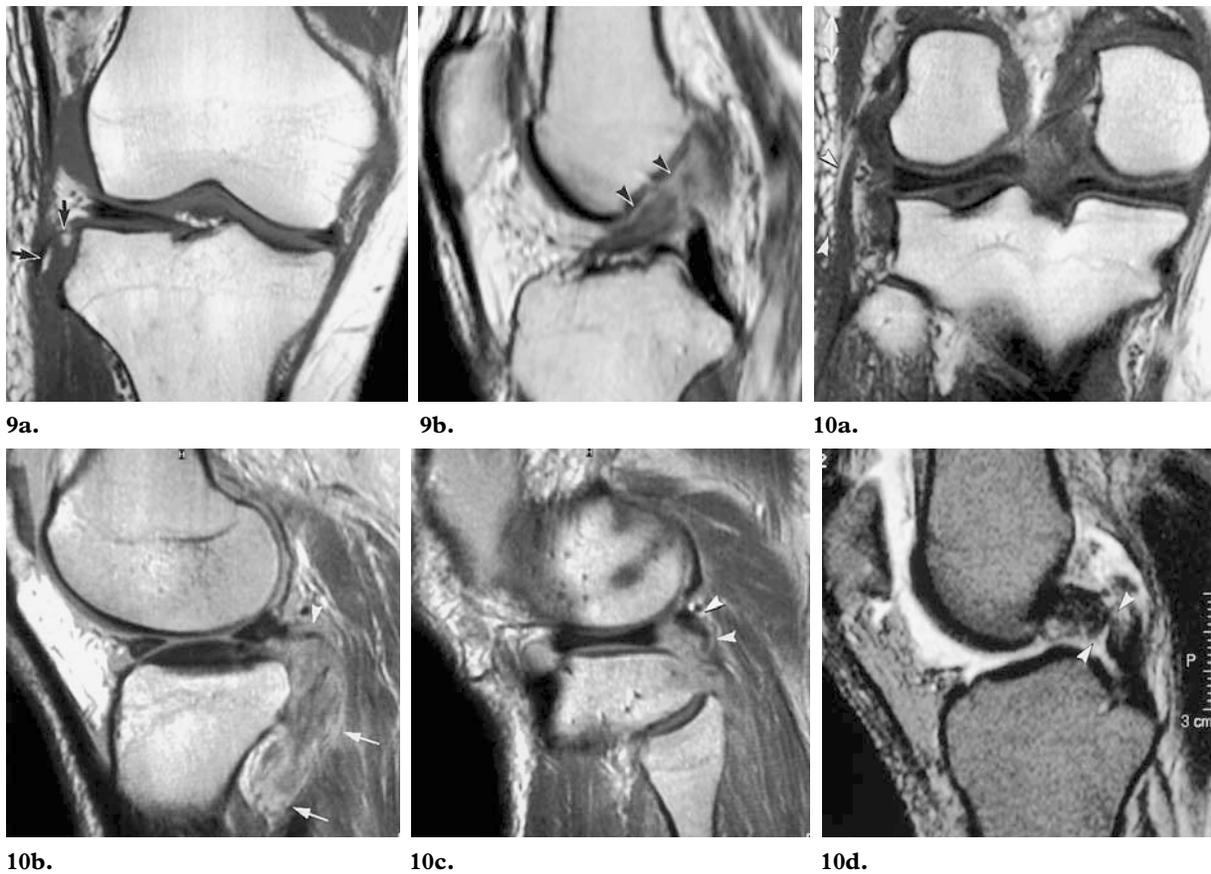


Figure 8. Method of visualizing knee instability. Diagram shows the tibial plateau divided into quadrants—anterolateral (AL), anteromedial (AM), posterolateral (PL), posteromedial (PM)—and a central pivot (CP). ACL = anterior cruciate ligament, ANT = anterior, ITT = iliotibial tract, LCL = lateral collateral ligament, MCL = medial collateral ligament, PCL = posterior cruciate ligament, POST = posterior, PT = popliteus muscle and tendon, SM = semimembranosus tendon.

injured: anterolateral, anteromedial, posterolateral, posteromedial, or any combination. There may be associated injury of the central pivot (3,5,6,16).

Multiple combinations of injuries can occur: anterolateral instability with or without damage to the anterior cruciate ligament (Fig 9); posterolateral instability with or without damage to the cruciate ligaments (Fig 10); combined anterolateral, anteromedial, posterolateral, and central pivot instability (Fig 11); and combined antero-



Figures 9, 10. (9) Acute anterolateral instability. (a) Coronal T1-weighted MR image shows an avulsion fracture of the Gerdy tubercle (arrows). (b) Sagittal proton-density-weighted MR image shows a tear of the anterior cruciate ligament (arrowheads), which appears thickened and has increased signal intensity and a wavy contour. (10) Acute posterolateral instability. (a) Coronal proton-density-weighted MR image shows thickening and increased signal intensity of the lateral collateral ligament (arrowheads), an appearance suggestive of a partial tear. (b, c) Sagittal proton-density-weighted MR images show a torn and displaced popliteus tendon at the level of the popliteal hiatus (arrowheads) and high signal intensity within the popliteus muscle (arrows). (d) Sagittal T2-weighted MR image shows disruption of the posterior cruciate ligament (arrowheads).

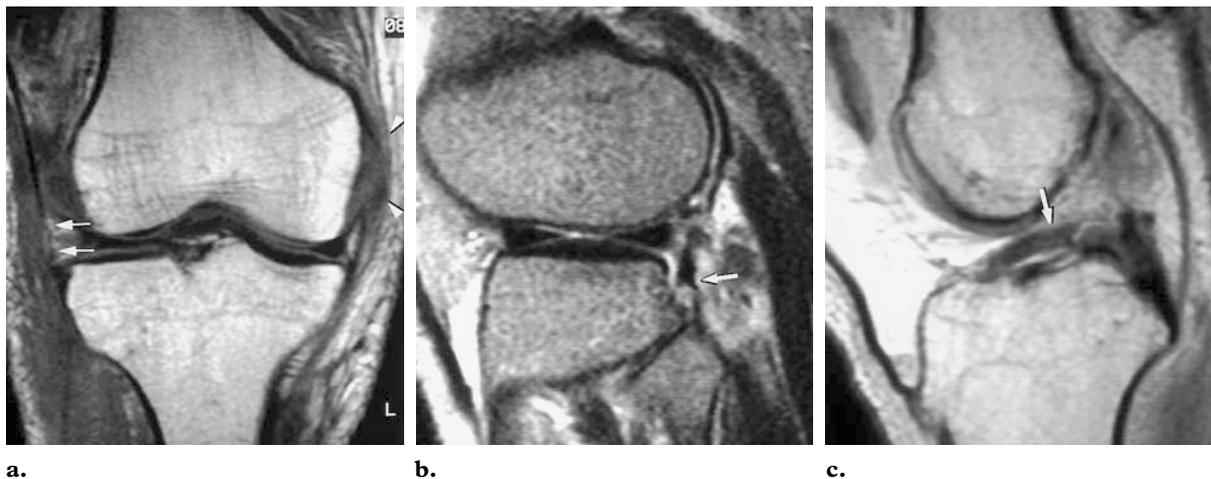


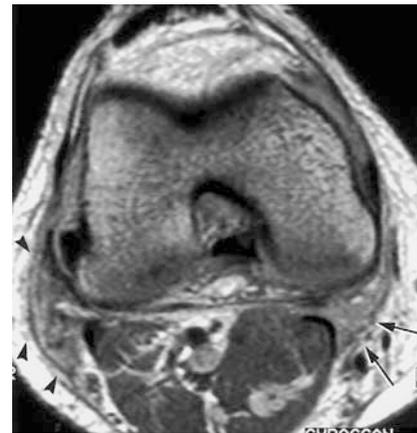
Figure 11. Acute anterolateral, anteromedial, posterolateral, and central pivot instability. (a) Coronal T1-weighted MR image shows an interruption of the iliotibial tract (arrows). There is an increase in the thickness and signal intensity of the medial collateral ligament (arrowheads), findings indicative of a partial tear. (b) Sagittal T2-weighted MR image shows thinning and an irregular contour of the popliteus tendon at the myotendinous junction (arrow). (c) Sagittal proton-density-weighted MR image shows that the anterior cruciate ligament is also torn (arrow).



Figure 12. Acute anterolateral, posterolateral, posteromedial, and central pivot instability. **(a)** Coronal T1-weighted MR image shows an interruption of the iliotibial tract (arrowheads). **(b)** Coronal T1-weighted MR image shows high-signal-intensity edema within the expected course of the lateral collateral ligament and biceps femoris tendon (arrowheads). **(c, d)** Sagittal **(c)** and axial **(d)** proton-density-weighted MR images show high signal intensity in the semimembranosus tendon (arrows), an appearance indicative of a partial rupture. The lateral collateral ligament and biceps femoris tendon are also injured (arrowheads). The anterior cruciate ligament (not shown) was also injured.

lateral, posterolateral, posteromedial, and central pivot instability (Figs 12, 13). In severe trauma, all the stabilizing structures of the knee may be disrupted. In these serious situations, the common peroneal nerve and gastrocnemius muscle can also be injured (3,5,6,8,29).

Structures of the anterolateral quadrant are the most frequently injured. These injuries are usually associated with damage to the anterior cruciate ligament. The injury is caused by varus force with internal rotation of the tibia (Fig 14). Most commonly, the posterior fibers of the iliotibial tract are damaged. This injury is seen on coronal images as an interruption distally near the tibial attachment. An avulsion fracture of the Gerdy tubercle may also occur (29,30) (Fig 9).



d.

Figure 14. Mechanism of anterolateral quadrant injuries. Diagram shows a fall forward with the knee in varus angulation and the tibia in internal rotation.



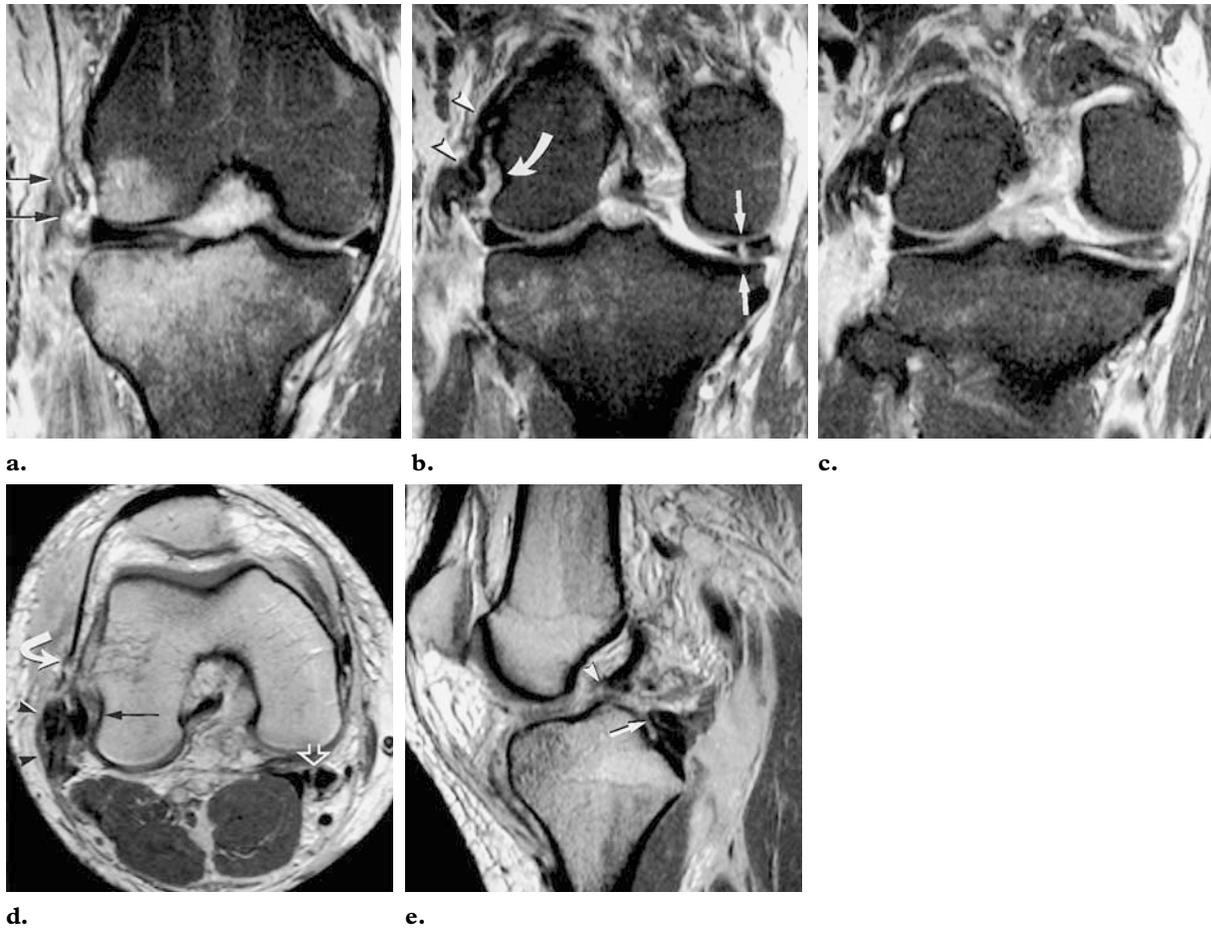


Figure 13. Acute anterolateral, posterolateral, posteromedial, and central pivot instability. **(a)** Coronal short tau inversion-recovery MR image shows a tear of the iliotibial tract (arrows). **(b, c)** Coronal short tau inversion-recovery MR images (**b** obtained anterior to **c**) show a complete tear of the lateral collateral ligament (arrowheads), detachment of the popliteus tendon from its femoral insertion (curved arrow), a tear of the medial meniscus (straight arrows), and high-signal-intensity edema in the soft tissue and bone marrow. **(d)** Axial proton-density-weighted MR image shows injuries of the iliotibial tract (curved arrow) and the lateral collateral ligament and biceps femoris tendon (arrowheads), as well as detachment of the popliteus tendon from its femoral insertion (straight solid arrow). There is also fragmentation of the semimembranosus tendon (open arrow), a finding indicative of a partial rupture. **(e)** Sagittal proton-density-weighted MR image shows complete tears of the anterior (arrowhead) and posterior (arrow) cruciate ligaments.

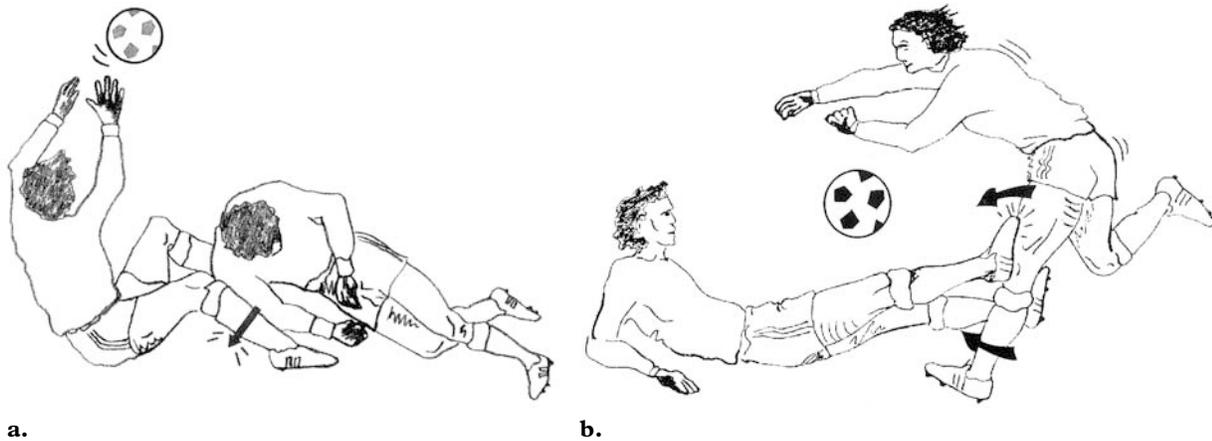
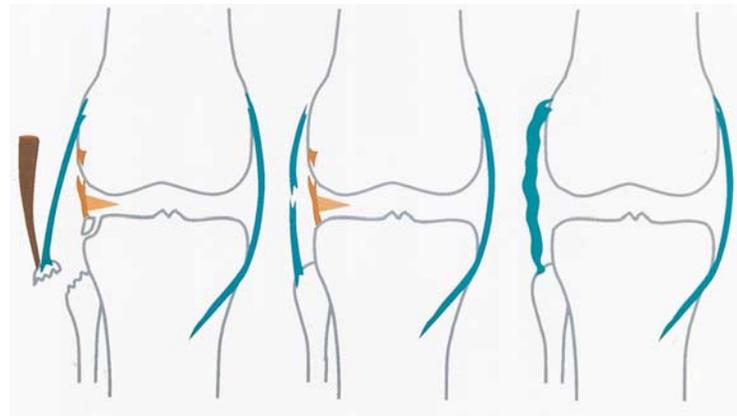


Figure 15. Mechanisms of posterolateral quadrant injuries. Diagrams show a direct blow with the knee flexed while the tibia is externally rotated (**a**) and a fall with the knee in hyperextension and the tibia internally rotated (**b**).

Figure 16. Lateral collateral ligament tears. Coronal diagrams show an avulsion fracture at the ligament-bone attachment (left diagram), a complete ligament tear (middle diagram), and a partial ligament tear (right diagram).

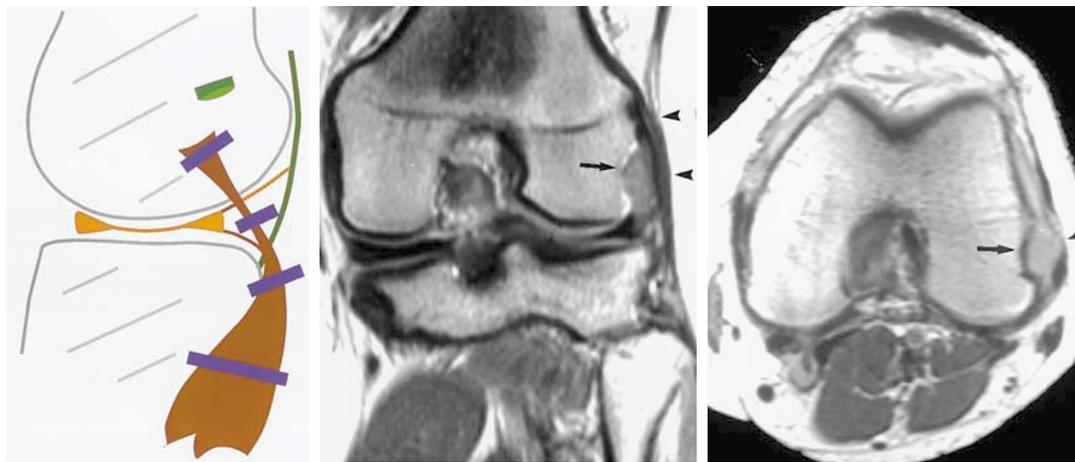


Posterolateral instability is considerably less common than anterolateral instability (5,28). The mechanism of posterolateral injury is either direct varus force while the tibia is externally rotated or sudden hyperextension of the knee (Fig 15). This type of instability is frequently overlooked at clinical examination. Clinical signs may be subtle and might remain masked by the more extensive symptoms due to cruciate ligament damage (1–3,7). In fact, clinically unrecognized posterolateral injury has been suggested as a cause of postsurgical cruciate ligament failure or chronic instability of the knee (2,9,10).

Practically all tears of the lateral collateral ligament are associated with damage to posterolateral knee structures: capsular tears, detachment fracture of the superior rim of the tibia (Segond

fracture), biceps femoris tendon tears, popliteus tendon lesions, cruciate ligament tears, and so on. Instead of a lateral collateral ligament tear, an avulsion fracture of the fibular insertion of the lateral collateral ligament and biceps femoris tendon can occur (29–32) (Fig 16). At MR imaging, complete disruption of the ligament appears as an interruption of its normal contour, whereas a partial tear appears as thickening and high signal intensity within its midsubstance (15,30) (Figs 10, 12).

The majority of popliteus tears are extraarticular, involving the muscular or myotendinous portion, although they can be intraarticular at the level of the popliteal hiatus and at or near the femoral insertion. Such injuries can also be a mixture of intraarticular and extraarticular (33–36) (Figs 10, 17).



17.

18a.

18b.

Figures 17, 18. (17) Popliteus muscle and tendon tears. Sagittal diagram shows tears at different levels: intraarticular and extraarticular. (18) Isolated popliteus tendon injury. Coronal (a) and axial (b) T1-weighted MR images show absence of the popliteus tendon at the popliteal sulcus (arrow), a finding indicative of avulsion from the femoral attachment. The lateral collateral ligament is intact (arrowheads).

Most popliteus muscle and tendon injuries are associated with damage to other knee structures: injury to other elements of the arcuate ligament complex, cruciate ligament tears, meniscal tears, bone fractures, and so on (Figs 10, 11, 13). Less than 10% of popliteus tears are isolated (33–36). At MR imaging, popliteus lesions have different appearances depending on the level and grade of damage. They may appear as an avulsion of the popliteus tendon from its femoral attachment (Fig 18), as an irregular contour of the tendon at the popliteal hiatus with surrounding high-signal-intensity edema, or as swelling and high-signal-intensity changes within the popliteus muscle (Figs 10, 11). A complete popliteus tendon tear may be seen as an interruption and possibly as retraction of the muscle belly, which may appear as a “mass” surrounded by fluid (15,30,37). Only fat should be present behind the popliteus tendon (Fig 4). Therefore, the presence of fluid posterior to the tendon should suggest a capsular tear if the existence of a fluid-filled popliteal bursa is taken into account (15).

Conclusions

Injuries of the lateral compartment of the knee are less common than injuries of the medial compartment but may be more disabling. Moreover,

injuries of lateral structures can easily be overlooked at clinical examination. They are frequently associated with cruciate ligament and medial compartment injuries. MR imaging is best suited for evaluation of lateral compartment lesions, but a thorough knowledge of the anatomy is necessary for image interpretation.

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