Bone Contusion Patterns of the Knee at MR Imaging: Footprint of the Mechanism of Injury[1]

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CME FEATURE

See accompanying test at http://www.rsna.org/education/rg_cme.html

LEARNING OBJECTIVES FOR TEST 4

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

- Identify the typical patterns of bone marrow edema that result from five different mechanisms of injury to the knee.
- Explain how each mechanism leads to a specific pattern of bone marrow edema.
- Recognize the specific soft-tissue injuries associated with each mechanism.

Bone marrow contusions are frequently identified at magnetic resonance imaging after an injury to the musculoskeletal system. These osseous injuries may result from a direct blow to the bone, from compressive forces of adjacent bones impacting one another, or from traction forces that occur during an avulsion injury. The distribution of bone marrow edema is like a footprint left behind at injury, providing valuable clues to the associated soft-tissue injuries. Five contusion patterns with associated soft-tissue injuries occur in the knee: pivot shift injury, dashboard injury, hyperextension injury, clip injury, and lateral patellar dislocation. The classic bone marrow edema pattern seen following the pivot shift injury involves the posterolateral tibial plateau and the midportion of the lateral femoral condyle. Edema occurs in the anterior aspect of the proximal tibia following the dashboard injury. Hyperextension results in the "kissing" contusion pattern involving the anterior aspect of the proximal tibia and distal femur. The clip injury results in a prominent area of edema involving the lateral femoral condyle and a smaller area of edema involving the medial femoral condyle. Finally, lateral patellar dislocation results in edema involving the inferomedial patella and anterior aspect of the lateral femoral condyle. In many instances, the mechanism of injury can be determined by studying the distribution of bone marrow edema, which then enables one to predict with accuracy the specific soft-tissue abnormalities that are likely to be present.

Abbreviations: ACL = anterior cruciate ligament, MCL = medial collateral ligament, MPFL = medial patellofemoral ligament, PCL = posterior cruciate ligament, SE = spin echo

Index terms: Knee, ligaments, menisci, and cartilage, 452.4857 • Knee, MR, 452.121411 • Ligaments, injuries, 452.4857 • Ligaments, MR, 452.121411

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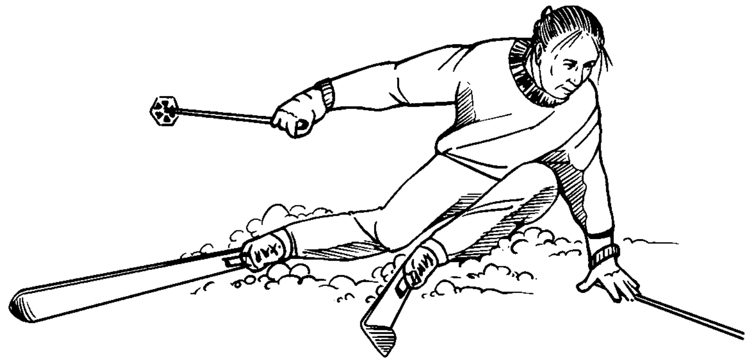

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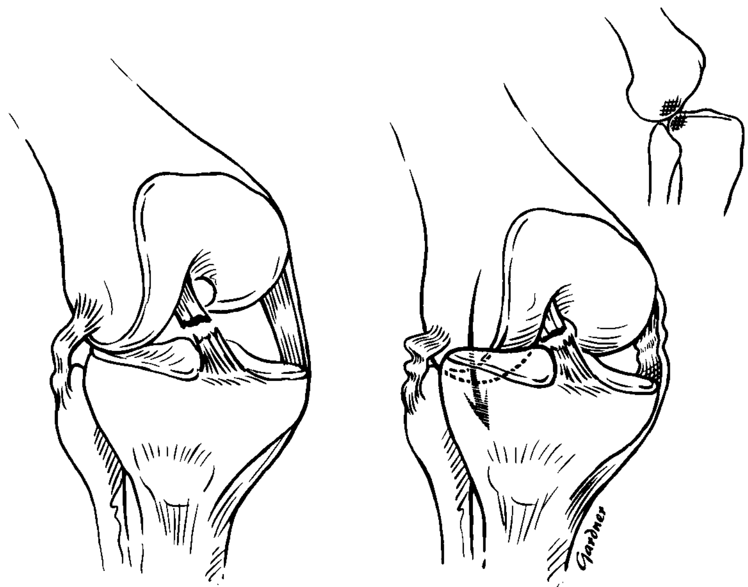

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Figure 1. Pivot shift injury. **(a)** Drawing shows a skier with a right knee pivot shift injury (knee valgus, femur internally rotated), a noncontact injury that results when decelerational-rotational-valgus stress is applied to the knee while it is in various states of flexion. **(b)** Drawing shows that, with the foot planted, the combination of valgus stress on the knee and internal rotation of the femur results in disruption of the ACL. After disruption of the ACL, the tibia is free to sublux anteriorly relative to the femur. This movement results in the impaction of the lateral femoral condyle against the posterolateral tibial plateau. Cross-hatching indicates areas of bone contusion. The degree of flexion of the knee at injury determines the exact location of the lateral femoral condyle contusion.

Introduction

Magnetic resonance (MR) imaging is an excellent means of evaluating the musculoskeletal system for the presence of soft-tissue and bone abnormalities after trauma (1). In the setting of trauma, radiographically occult osseous injuries are frequently identified at MR imaging as areas of poorly marginated signal intensity alteration (decreased signal intensity with T1-weighted sequences, increased signal intensity with T2-weighted sequences, or both) in the cancellous bone and marrow. This appearance is thought to represent areas of hemorrhage, edema, or hyperemia secondary to trabecular injury (2,3). These osseous injuries may result from a direct blow to the bone, compressive forces of adjacent bones impacting one another, or traction forces that oc-

a.

b.

c.

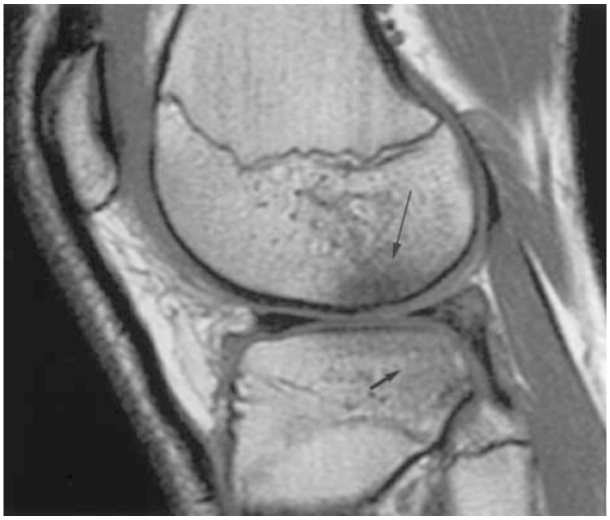
Figure 2. Pivot shift injury in a 33-year-old woman who disrupted her ACL in a skiing accident. **(a)** Coronal T2-weighted fast spin-echo (SE) MR image obtained with fat saturation demonstrates the classic bone marrow edema pattern resulting from pivot shift injury of the knee. Extensive contusion is present in the posterolateral tibial plateau (straight arrow) and, to a lesser degree, the lateral femoral condyle (curved arrow). **(b)** Sagittal proton-density–weighted MR image shows an amorphous-appearing ACL with an area of signal intensity similar to that of fluid extending completely through it (arrow), a finding that is consistent with complete disruption. **(c)** Sagittal T1-weighted SE MR image demonstrates an associated vertical tear (arrow) of the posterior horn of the lateral meniscus. A tear of the anterior horn is also present.

cur during an avulsion injury (4). The pattern of bone marrow edema is like a footprint left behind at injury (5): By studying the distribution of the edema, one can understand the mechanism of injury that occurred and thereby predict with accuracy the associated soft-tissue abnormalities that may be present. Herein, five different mechanisms of knee injury are discussed: pivot shift injury, dashboard injury, hyperextension injury, clip injury, and lateral patellar dislocation.

Pivot Shift Injury

The pivot shift injury is a noncontact injury commonly seen in skiers or American football players. This injury occurs when a valgus load is applied to the knee in various states of flexion combined with external rotation of the tibia or internal rotation of the femur (Fig 1). This type of injury usually occurs with maneuvers such as rapid deceleration and simultaneous direction change. These maneuvers load the anterior cruciate ligament (ACL) and can result in its rupture (6,7). Once the ACL is disrupted, anterior subluxation of the tibia relative to the femur occurs, which results in impaction of the lateral femoral condyle against the posterolateral margin of the lateral tibial plateau (8–10).

The resulting bone contusion pattern involves the posterior aspect of the lateral tibial plateau and the midportion of the lateral femoral condyle near the condylopatellar sulcus (Fig 2). The



a.

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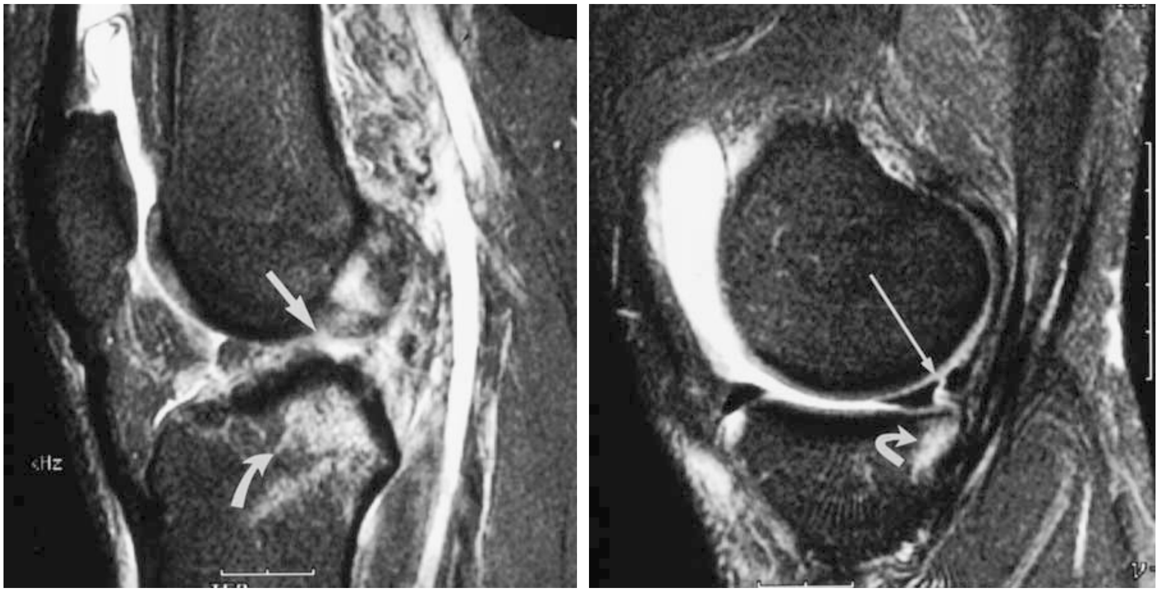
Figure 3. Relationship between degree of flexion of the knee at injury and location of the femoral condyle edema in pivot shift injury. **(a, b)** Sagittal T1-weighted **(a)** and T2-weighted **(b)** fast SE MR images (fat saturation used in **b**) of a 15-year-old boy after a pivot shift injury. The knee was in a state of moderate flexion at injury, resulting in a posteriorly located contusion of the femoral condyle (long arrow). The bone contusion also involves the posterior aspect of the lateral tibial plateau (short arrow). **(c)** Sagittal T2-weighted fast SE MR image obtained with fat saturation of a 28-year-old man after pivot shift injury. The knee was in a state of minimal flexion at injury, and, as a result, the bone contusion (arrowhead) is located more anteriorly on the lateral femoral condyle. There is deepening of the lateral femoral sulcus (which is usually less than 2.0 mm deep) (curved arrow) secondary to impaction on the posterior lateral tibial plateau. The deep femoral sulcus sign has a high specificity for ACL disruption (11). Bone contusion also involves the posterior lateral tibial plateau (straight arrow).

c.

exact location of the lateral femoral condyle injury depends on the degree of flexion of the knee at injury. Increasing degrees of flexion result in a more posteriorly located bone bruise, whereas less flexion results in a more anteriorly located edema pattern (Fig 3). Another recently described bone contusion pattern associated with the pivot shift injury is edema within the posterior lip of the medial tibial plateau. This pattern is thought to result from contrecoup forces in the medial compartment at the resolution of the forced valgus forces (12) (Fig 4).

The ACL is typically best visualized in the oblique sagittal plane. It extends from the roof of the intercondylar notch at the lateral femoral condyle to its tibial attachment site adjacent and anterior to the tibial spines. Its course should parallel the roof of the intercondylar notch. Occasionally, it is necessary to obtain images in the axial and coronal planes to confirm an intact ACL. The ACL has low signal intensity with all pulse sequences but may contain striations with signal intensity alterations noted between separate fibers of the ligament near its tibial attachment. Disruption of the ACL most commonly



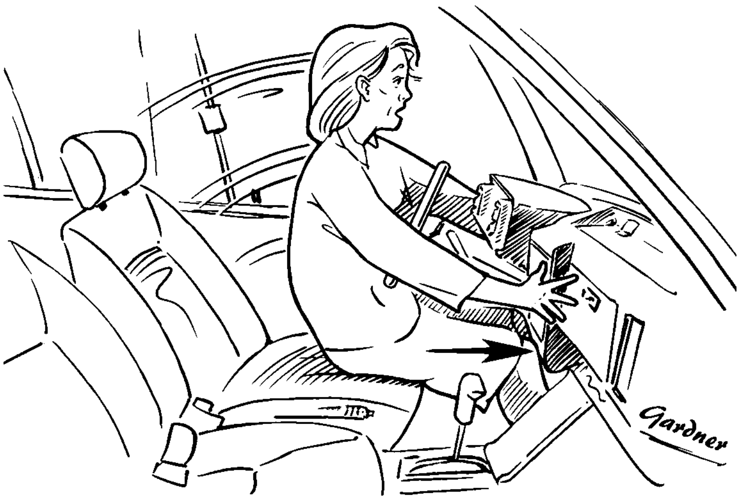
a. **b.**

Figure 4. Bone contusion involving the posterior lip of the medial tibial plateau in a 33-year-old man who sustained a pivot shift injury. Oblique sagittal T2-weighted fast SE images obtained with fat saturation show complete disruption of the ACL (straight arrow in **a**), edema (curved arrow in **a**) in the posterior aspect of the midline tibial plateau, and edema (curved arrow in **b**) in the posterior lip of the medial tibial plateau. This particular edema pattern is thought to result from contrecoup forces after a pivot shift injury and has a high specificity for ACL disruption. A vertical tear (straight arrow in **b**) through the peripheral aspect of the posterior horn of the medial meniscus is also seen. Scale is in centimeters.

Figure 5. Posterior capsule disruption in a 21-year-old man who sustained a severe pivot shift injury while playing football. On a sagittal T2-weighted fast SE MR image, the ACL appears completely disrupted and amorphous. An area of high signal intensity (white arrow) completely traverses the ligament. There is complete disruption of the posterior lateral capsule (black arrow) and extensive surrounding soft-tissue edema.

occurs in its midsubstance. The next most common location is near the femoral attachment site, and the least common location for disruption is at the tibial attachment site. Disruption is seen on MR images as complete discontinuity of the fibers with alterations in both the signal intensity and morphology of the ligament. After an acute injury, high T2 signal intensity traverses the ligament (Fig 2a); the ACL appears indistinct and may demonstrate an abnormal slope.

Other soft-tissue injuries occasionally associated with the pivot shift injury include tears of the posterior capsule and arcuate ligament, the posterior horn of the lateral or medial meniscus (Fig 5), and the medial collateral ligament (MCL). Osteochondral impaction or shear injuries may also involve the posterior tibial plateau or the lateral femoral condyle.



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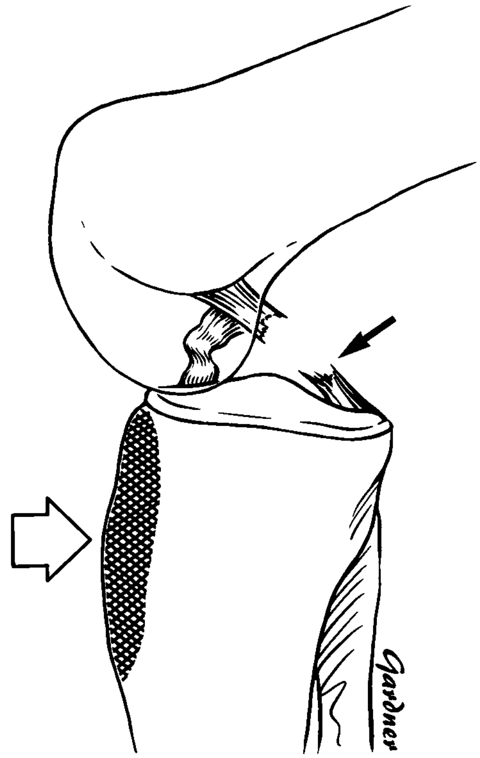


b.

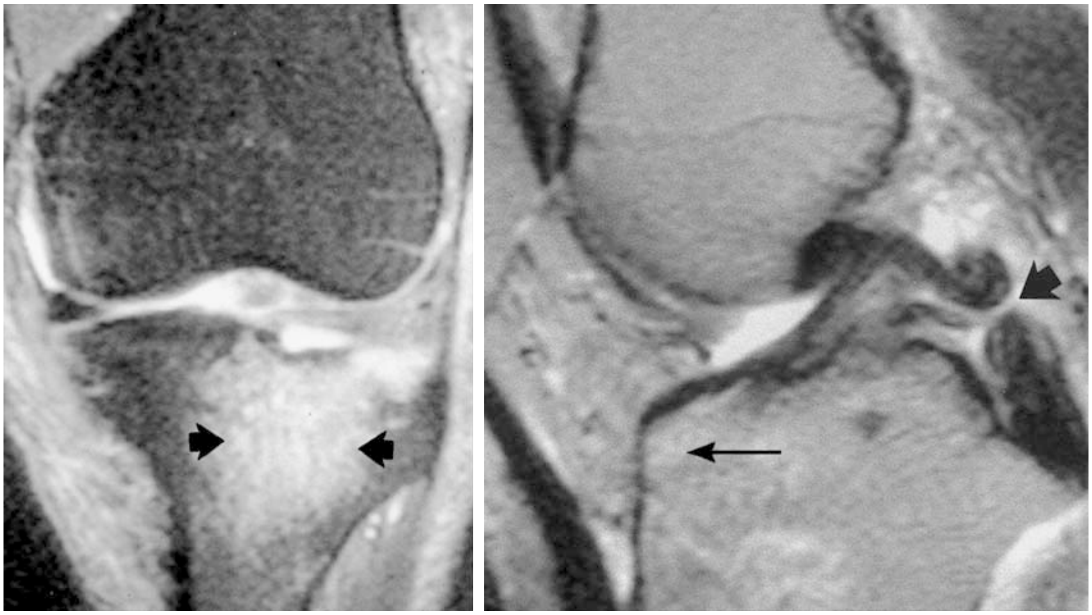
Figure 6. Dashboard injury. **(a)** Drawing shows a woman striking her knee against the dashboard during an automobile accident. This is the most common mechanism of injury resulting in disruption of the PCL. **(b)** Drawing shows that, during a dashboard injury, the tibia is forced posteriorly (open arrow) relative to the femur. The crosshatched region indicates the area of bone contusion on the anterior tibia caused by direct trauma. The PCL is usually tight when the knee is in 90° of flexion and is, therefore, at risk for disruption (solid arrow). The ACL, on the other hand, is normally lax while the knee is flexed and usually remains intact.

Dashboard Injury

Dashboard injury occurs when force is applied to the anterior aspect of the proximal tibia while the knee is in a flexed position. This injury most commonly occurs when the knee strikes against the dashboard during an automobile accident (Fig 6a), but it can also occur when the knee strikes against the ground during a fall (13). Edema is seen at the anterior aspect of the tibia and, occasionally, at the posterior surface of the patella (Fig 6b).

The associated soft-tissue injuries include disruption of the posterior cruciate ligament (PCL) and rupture of the posterior joint capsule (14) (Fig 7). The PCL is usually depicted at MR imaging as a thick, bandlike structure, has low signal intensity with all pulse sequences, and extends from the intercondylar notch at the medial femoral condyle to the posterior sloping aspect of the tibial plateau. It is typically seen in its entirety on a single oblique sagittal image of the knee and possesses a horizontal portion and a more vertical portion, which are connected by a gentle curve (the genu). A dashboard injury disrupts the PCL rather than the ACL because, with the knee flexed, the PCL is taut and the ACL is lax. In addition, the PCL usually limits posterior tibial translation, whereas the ACL limits anterior translation.

A posteriorly directed force on the anterior aspect of the proximal tibia such as that which occurs with the dashboard injury most commonly results in a tear of the midsubstance of the PCL



a. b.

Figure 7. Dashboard injury of the left knee in a 42-year-old woman. **(a)** Coronal T2-weighted fast SE MR image obtained with fat saturation demonstrates extensive bone contusion involving the anterior aspect of the proximal tibia (arrows) as a result of a direct blow to the tibia. **(b)** Sagittal T2-weighted fast SE MR image reveals complete disruption (short arrow) of the PCL, as demonstrated by discontinuity of the PCL fibers and an area of signal intensity similar to that of fluid traversing the ligament. Edema is noted in the anterior aspect of the proximal tibia (long arrow).

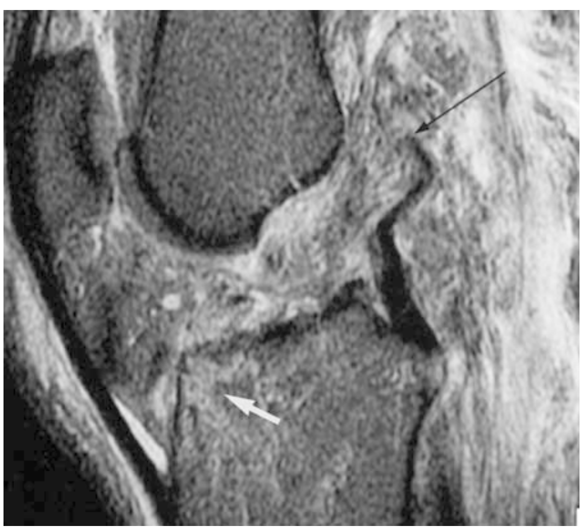
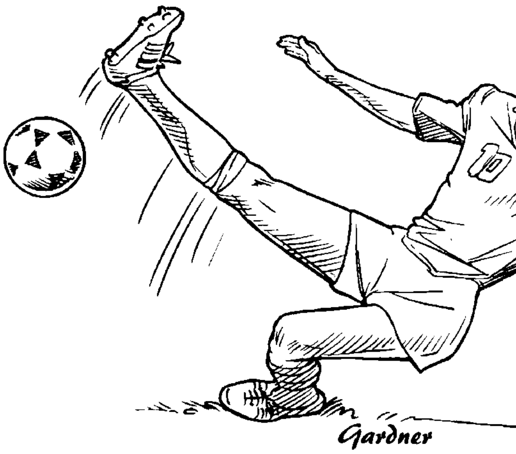


Figure 8. Dashboard injury of the left knee in a 33-year-old man. Sagittal T2-weighted fast SE image demonstrates edema in the anterior proximal tibia (white arrow) and complete disruption of the PCL (black arrow). The posterior capsule was also disrupted, and there is extensive edema in the posterior soft tissues of the knee.

at the genu. Less commonly, a tear or avulsion can occur at the femoral or tibial attachment site. Disruption of the PCL can be seen on MR images as complete discontinuity of its fibers with high signal intensity traversing the substance of the ligament (Fig 8). Partial tears can also occur and may be seen as areas of high signal intensity within the PCL on T2-weighted images, with some fibers remaining intact.

If the forces are severe, osseous injuries other than edema may result from a dashboard-type injury. These include fracture or osteochondral injury of the patella and injuries of the hip.



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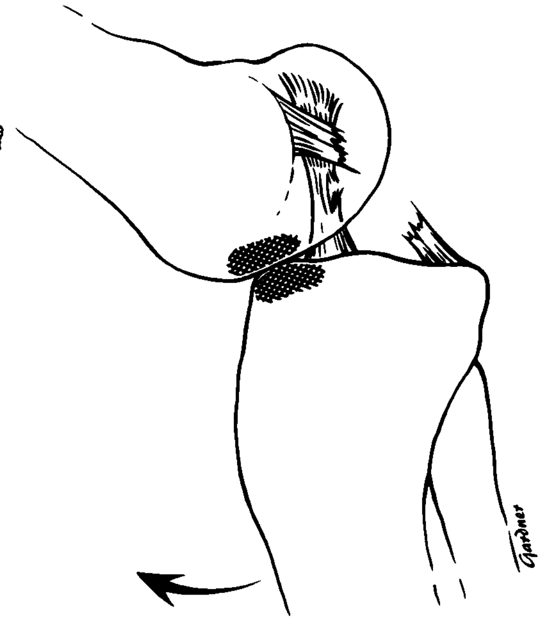

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Figure 9. Hyperextension injury. **(a)** Drawing depicts a forceful kicking motion resulting in a hyperextension injury of the right knee. **(b)** Drawing shows how very severe hyperextension of the knee (arrow) can result in the impaction of the anterior aspect of the femoral condyle against the anterior aspect of the tibial plateau. The crosshatched regions indicate the areas of bone contusion. Depending on the amount of force applied during hyperextension, tears of the ACL, PCL, or both may occur.

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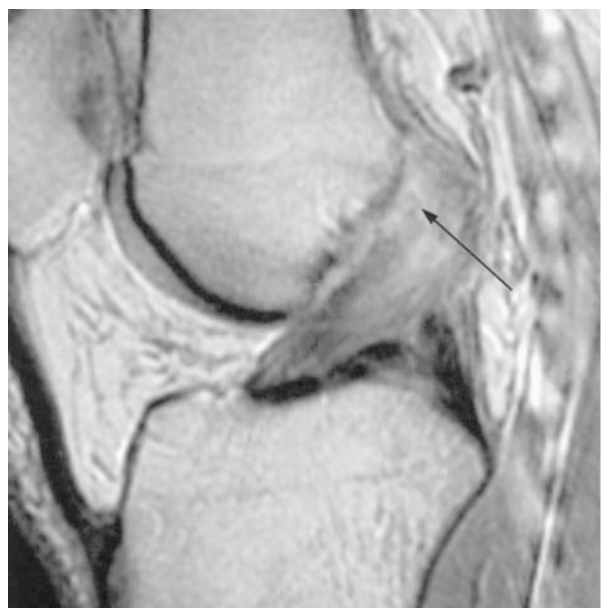
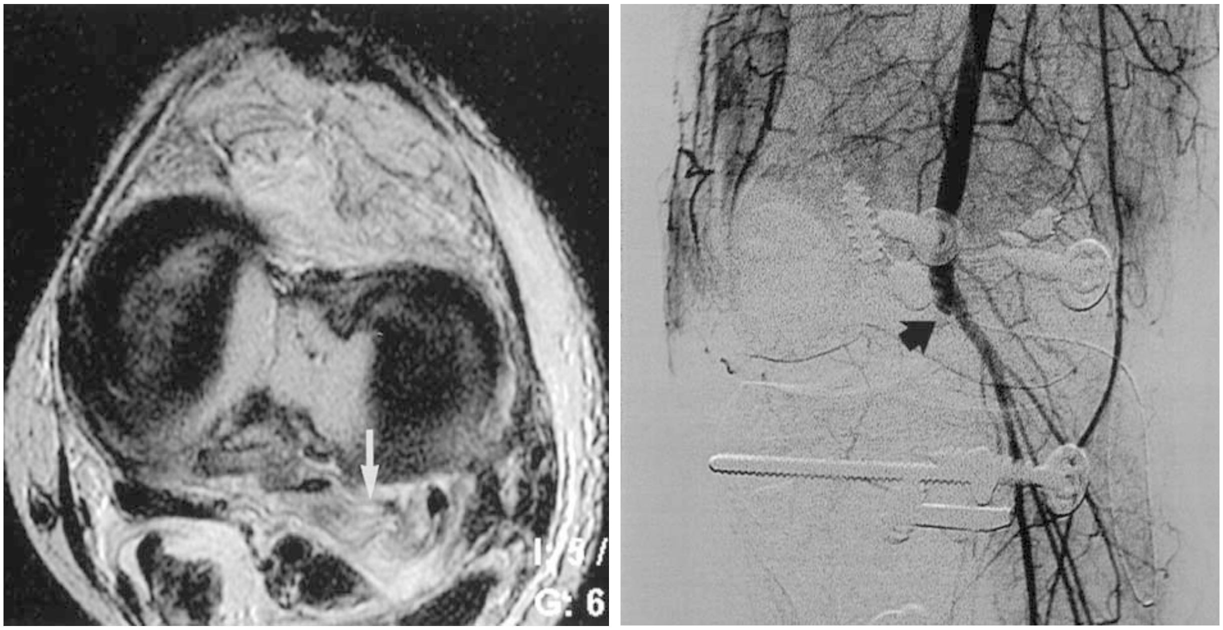


b.

Figure 10. Hyperextension injury of the knee sustained during a soccer game in a 23-year-old man. **(a)** Coronal T2-weighted fast SE MR image obtained with fat saturation reveals kissing bone marrow contusions (arrows) of the medial aspect of the anterior tibia and femur secondary to the hyperextension injury. Valgus stress occurring at the hyperextension injury resulted in the medial location of the kissing contusions. **(b)** Sagittal proton-density–weighted SE MR image demonstrates complete disruption of the proximal fibers of the ACL (arrow). The PCL (not shown) was intact.



a. b.

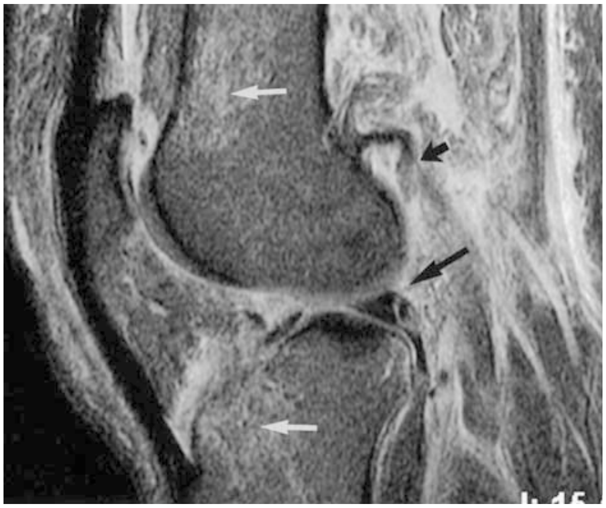
Figure 11. Severe hyperextension injury of the knee in a 23-year-old male pedestrian after being hit by a car. **(a)** Axial T2-weighted fast SE MR image obtained with fat saturation demonstrates wavy fibers and edema in the location of the posterior capsule (arrow). Complete disruption of the posterior capsule was noted at surgery. **(b)** Digital subtraction angiogram depicts the postoperative appearance of an acutely thrombosed popliteal artery (arrow).

Hyperextension Injury

Hyperextension of the knee can result when direct force is applied to the anterior tibia while the foot is planted or from an indirect force, such as a forceful kicking motion (Fig 9a). The most severe cases often result from direct injury (eg, a car bumper hitting the anterior tibia of a pedestrian). During the brief moment of hyperextension, the anterior aspect of the tibial plateau strikes the anterior aspect of the femoral condyle, resulting in the “kissing” contusion pattern of bone injury (Fig 9b). If a valgus force is also applied at hyperextension, the kissing contusions will be located medially (Fig 10a).

Depending on the amount of force applied, associated soft-tissue abnormalities may include injury to either the ACL (Fig 10) or PCL and a meniscal injury (15). MR imaging characteristics of ACL or PCL injury are similar to those described earlier. If a substantial force is applied, dislocation of the knee may occur (16–18), along with injury of the popliteal neurovascular structures (19) (Fig 11), complete disruption of the posterolateral complex (20) (Fig 12), and, possibly, gastrocnemius injury.

Figure 12. Posterior capsule disruption after a severe hyperextension injury in three separate patients. **(a)** Sagittal T2-weighted fast SE MR image shows edema (white arrows) in the anterior aspect of the distal femur and proximal tibia. The edema in the distal femur is too proximal to represent a kissing contusion secondary to hyperextension and probably occurred secondary to direct impact forces. The posterior lateral joint capsule is completely disrupted, as noted by complete absence of the posterior capsule (long black arrow) and extensive surrounding edema. The tendon of the lateral head of the gastrocnemius (short black arrow) was also disrupted. **(b)** Sagittal T2-weighted fast SE MR image demonstrates disruption of the posterior joint capsule (arrow) with extensive edema in the posterior soft tissues. The ACL and PCL were also disrupted (not shown). **(c)** On a sagittal T2-weighted fast SE MR image, discontinuity of the posterior joint capsule is seen as discontinuity of the line representing the posterior capsule (arrows). Note the extensive surrounding soft-tissue edema.



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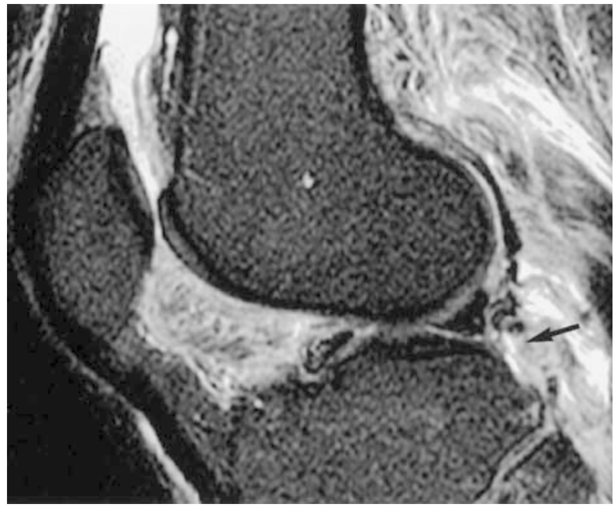

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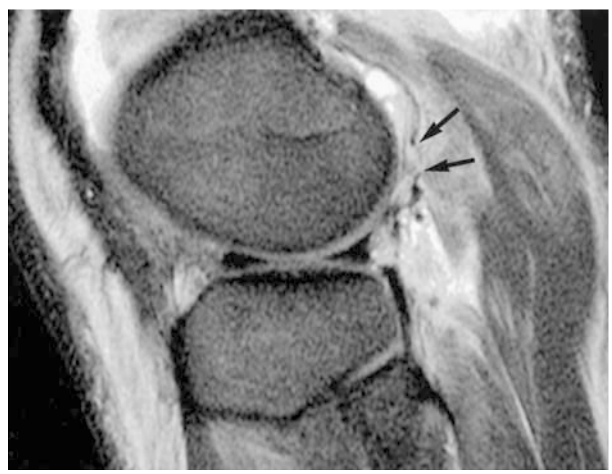
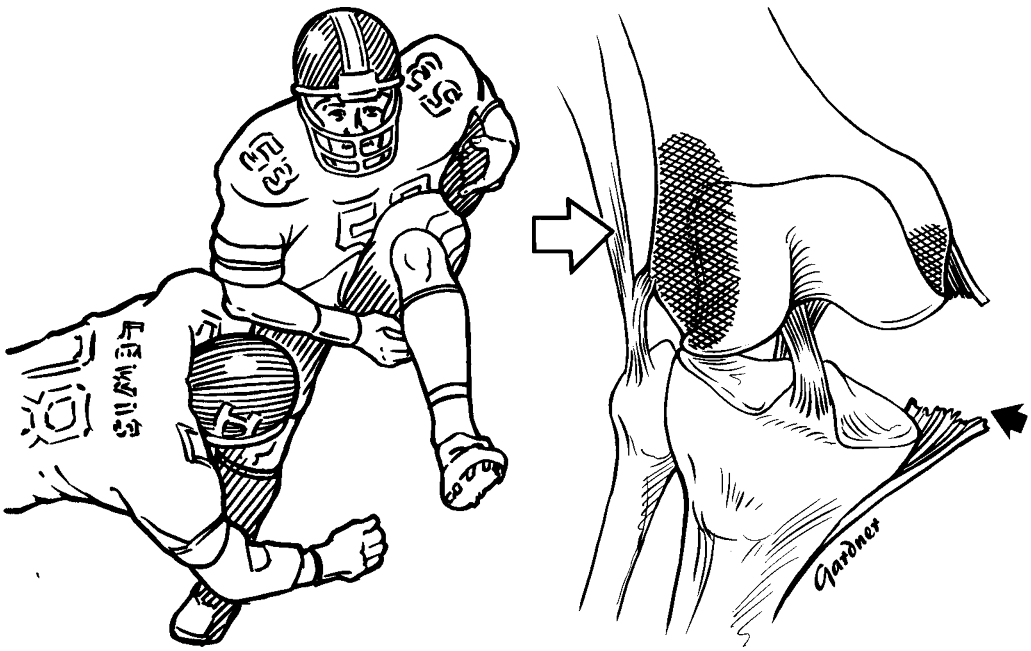


c.

Clip Injury

The clip injury is a contact injury that occurs after a pure valgus stress is applied to the knee while the knee is in a state of mild flexion (ie, 10°–30°). This injury is common among American football players (Fig 13a) (21). With clip injury, bone marrow edema is usually most prominent in the lateral femoral condyle secondary to the direct blow, whereas a second smaller area of edema may be present in the medial femoral condyle secondary to avulsive stress to the MCL (Fig 13).

Associated soft-tissue injuries can include varying degrees of sprain or disruption of the MCL (22–24). Injury most commonly involves the proximal portion of the ligament near the femoral attachment site (Fig 14). A grade I sprain of the MCL is visualized on MR images as contour irregularity and edema superficial to the MCL (Fig 15). The fibers, however, remain intact. A partial tear of the MCL is a grade II injury (Fig 14) and can be seen on MR images as a partial discontinuity of the fibers with adjacent areas of increased signal intensity on T2-weighted images in the setting of acute injury; some fibers will remain intact. Complete disruption is a



a. b.

Figure 13. Clip injury. **(a)** Drawing shows the typical mechanism of a clip injury to the right leg, resulting from a valgus force to the lateral aspect of the knee while the knee is in slight flexion. **(b)** Drawing shows that the larger area of bone contusion (large crosshatched region) results from a direct force (open arrow) to the lateral femoral condyle. A smaller area of edema (small crosshatched region) may occur within the medial femoral condyle or the medial tibial plateau due to an avulsive injury of the MCL related to the valgus stress. Stretching or disruption of the MCL (solid arrow) can occur secondary to distraction of the medial compartment.

14.

15.

Figures 14, 15. **(14)** Clip injury sustained by a 21-year-old man while playing football. Coronal T2-weighted fast SE MR image obtained with fat saturation shows a large area of contusion involving the lateral femoral condyle (long white arrow). Minimal edema is noted within the medial femoral condyle (short white arrow). The edema is distal to the attachment site of the MCL and is likely secondary to impaction. The MCL is partially disrupted (black arrow). **(15)** MCL sprain. Coronal T2-weighted fast SE MR image obtained with fat saturation demonstrates an intact MCL (curved arrow) with superficial edema (straight arrows), findings consistent with a grade I sprain.

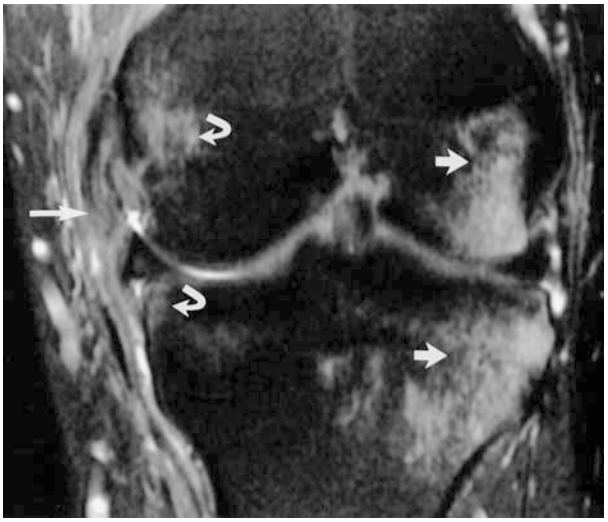


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Figure 16. O'Donoghue triad resulting from a severe clip injury sustained by a 23-year-old man while playing football. **(a)** Coronal T2-weighted fast SE MR image reveals edema (short straight arrows) in the lateral femoral condyle and lateral tibial plateau secondary to direct contusion. Minimal edema (curved arrows) is noted in the medial femoral condyle and medial tibial plateau secondary to avulsive forces. There is complete disruption of the MCL (long straight arrow). **(b)** Sagittal proton-density–weighted SE MR image reveals a complex tear (arrow) involving the posterior horn of the medial meniscus. **(c)** Sagittal proton-density–weighted SE MR image demonstrates complete disruption (arrow) of the proximal fibers of the ACL.

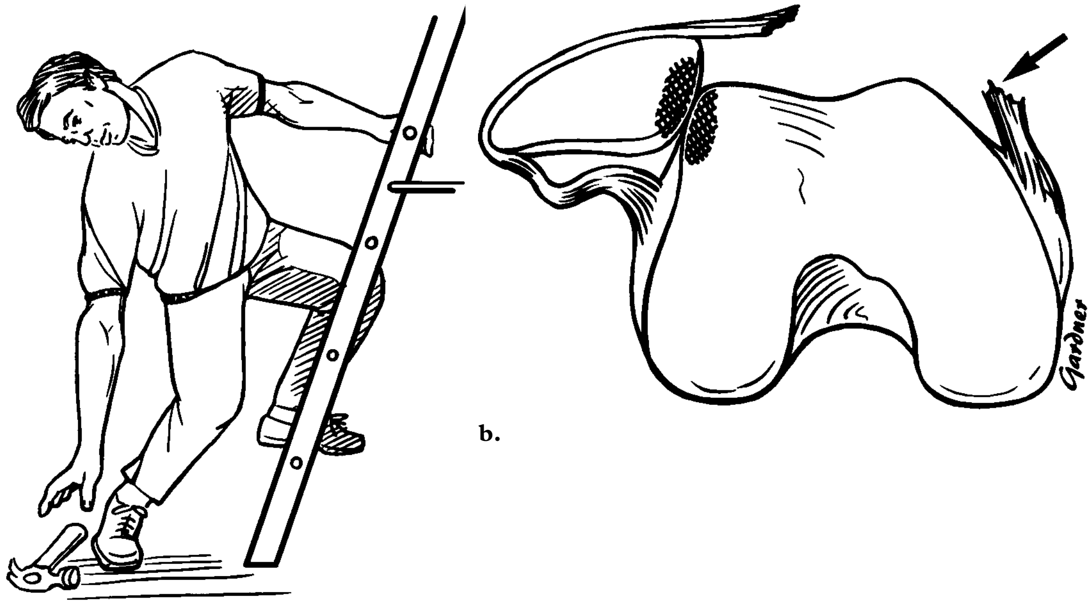
grade III injury (Fig 16a) and can be seen as complete discontinuity of the MCL fibers (25,26), with extensive surrounding high signal intensity on T2-weighted images in acute cases. Increasing degrees of flexion of the knee at injury may result in disruption of the ACL and a tear of the medial meniscus. This extensive injury combination is better known as the O'Donoghue triad (Fig 16).

Lateral Patellar Dislocation

Transient dislocation of the patella typically occurs in teenagers and young adults involved in athletic activities and results from a twisting motion of the knee while the knee is in a state of flexion (27). The femur rotates internally on a fixed tibia while the knee is flexed; contraction of the quadriceps occurs, resulting in lateral dislocation of the patella out of the trochlear groove (Fig 17). Individuals with a shallow trochlear groove are at increased risk for lateral patellar dislocation.

The classic bone contusion pattern seen after lateral patellar dislocation includes involvement of the anterolateral aspect of the lateral femoral condyle and the inferomedial aspect of the patella (28,29) (Fig 18). In rare cases, edema may also be seen in the adductor tubercle of the medial femoral condyle secondary to an avulsion injury of the medial patellofemoral ligament (MPFL) (30). The contusion of the lateral femoral condyle after lateral patellar dislocation should be differentiated from the contusion pattern involving the lateral femoral condyle after a pivot shift injury. With lateral patellar dislocation, edema of the lateral femoral condyle is located more anteriorly and peripherally, whereas

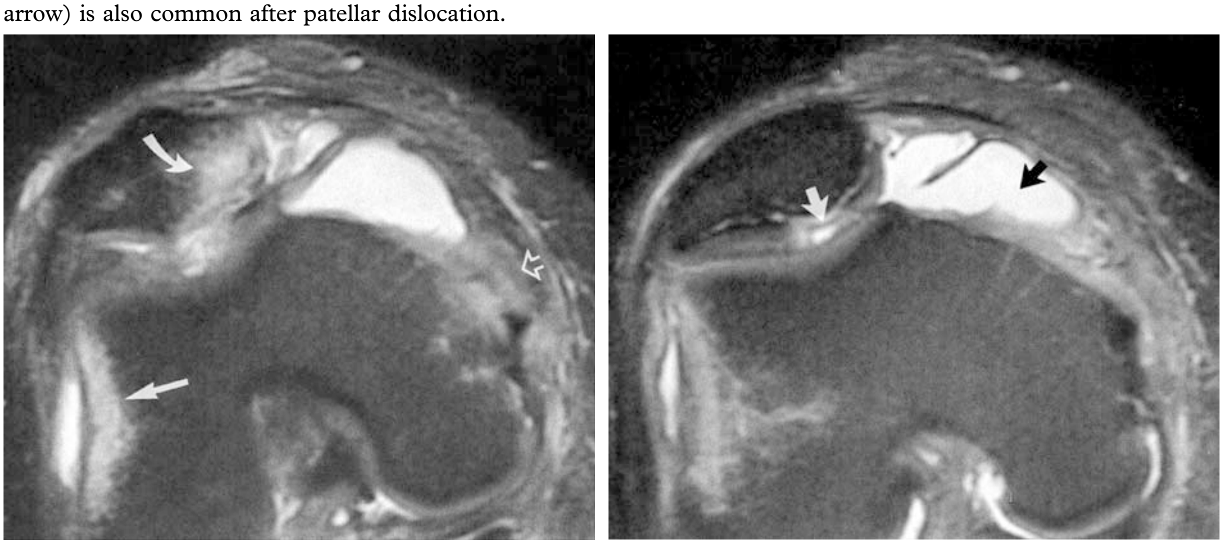
Figure 17. Lateral patellar dislocation. **(a)** Drawing shows the classic mechanism of injury: fixed tibia, internal femoral rotation, and quadriceps contraction. **(b)** Drawing demonstrates transient lateral dislocation of the patella, which results in impaction of the medial patellar facet against the lateral femoral condyle. The crosshatched regions reveal the typical areas of bone contusion involving the inferomedial patella and the anterolateral femoral condyle. The distraction forces frequently cause disruption (arrow) or stretching of the medial retinaculum and the MPFL. The dislocation is usually transient, with the patella spontaneously returning to its normal anatomic position. In many instances, the patient may be unaware of the transient dislocation, and the typical bone marrow edema pattern seen at MR imaging may be the first indication of the true nature of the injury.



b.

a.

Figure 18. Patellar dislocation in a 19-year-old man who fell from a ladder. **(a)** Axial T2-weighted fast SE MR image obtained with fat saturation demonstrates the classic bone marrow contusion pattern involving the inferior aspect of the medial patellar facet (curved arrow) and the anterior aspect of the lateral femoral condyle (straight solid arrow). The amorphous appearance of the medial retinaculum with extensive signal intensity abnormality represents disruption (open arrow). **(b)** Axial T2-weighted fast SE MR image obtained with fat saturation in the same knee but at a slightly more proximal level demonstrates an osteochondral injury (white arrow) of the patellar median eminence that occurred secondary to impaction of the patella against the lateral femoral condyle. Joint effusion (black arrow) is also common after patellar dislocation.



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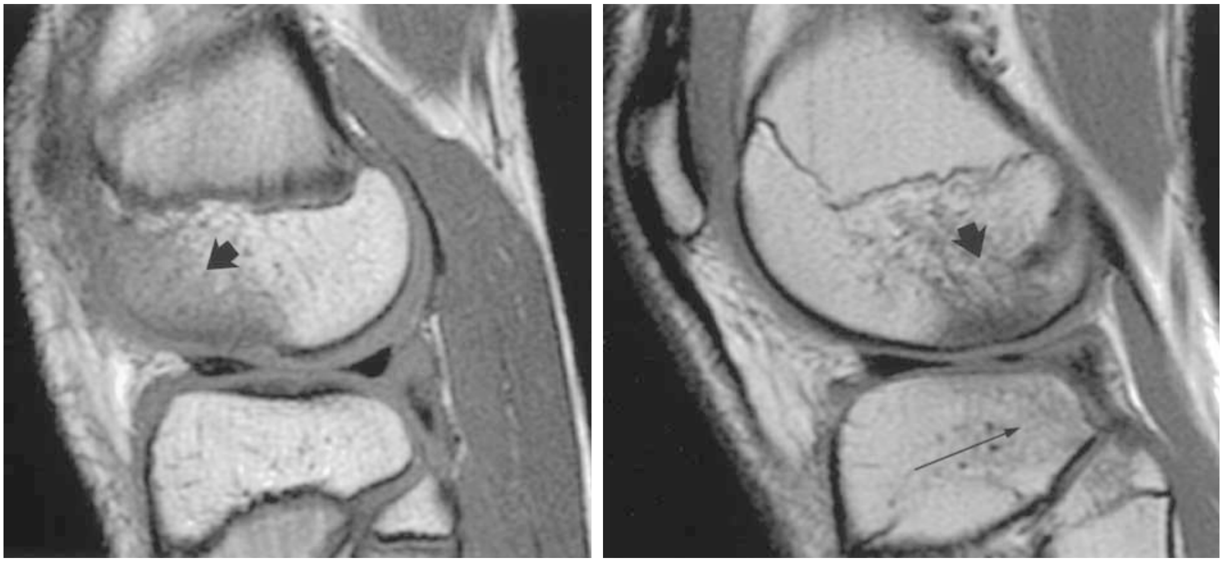


a. b.

Figure 19. Differentiation of lateral femoral condyle edema seen after lateral patellar dislocation from that seen after pivot shift injury. **(a)** On a sagittal T1-weighted SE MR image of a 14-year-old girl after lateral patellar dislocation, the edema (arrow) within the lateral femoral condyle is anteriorly and peripherally located. **(b)** Sagittal T1-weighted SE MR image of a 15-year-old boy after pivot shift injury shows that the edema (short arrow) within the lateral femoral condyle is located more posteriorly. Note also the edema (long arrow) within the posterior lateral tibial plateau.

with pivot shift injury the contusion is more centrally or posteriorly located on the lateral femoral condyle (Fig 19). As stated earlier, the exact location of the femoral edema after a pivot shift injury depends on the degree of flexion of the knee at injury. With less flexion, the femoral edema will be located more anteriorly, but it will be associated with edema of the posterior tibial plateau rather than with edema of the inferomedial patella.

Associated soft-tissue injuries include sprain or disruption of the medial soft-tissue restraints. These restraints include the medial retinaculum (31–33), the MPFL, and the medial patellotibial ligament. The MPFL has been shown to be the most important stabilizing structure of the patella preventing lateral subluxation, and recent literature suggests that, after patellar dislocation, patients with disruption of the MPFL or substantial osteochondral injury benefit from surgery (34).

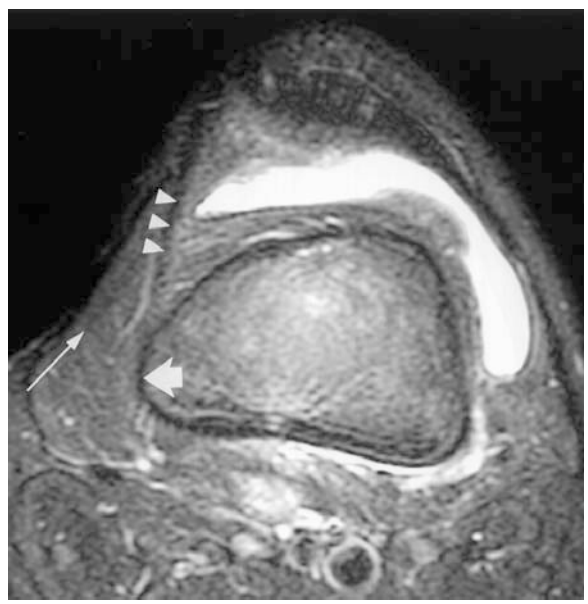
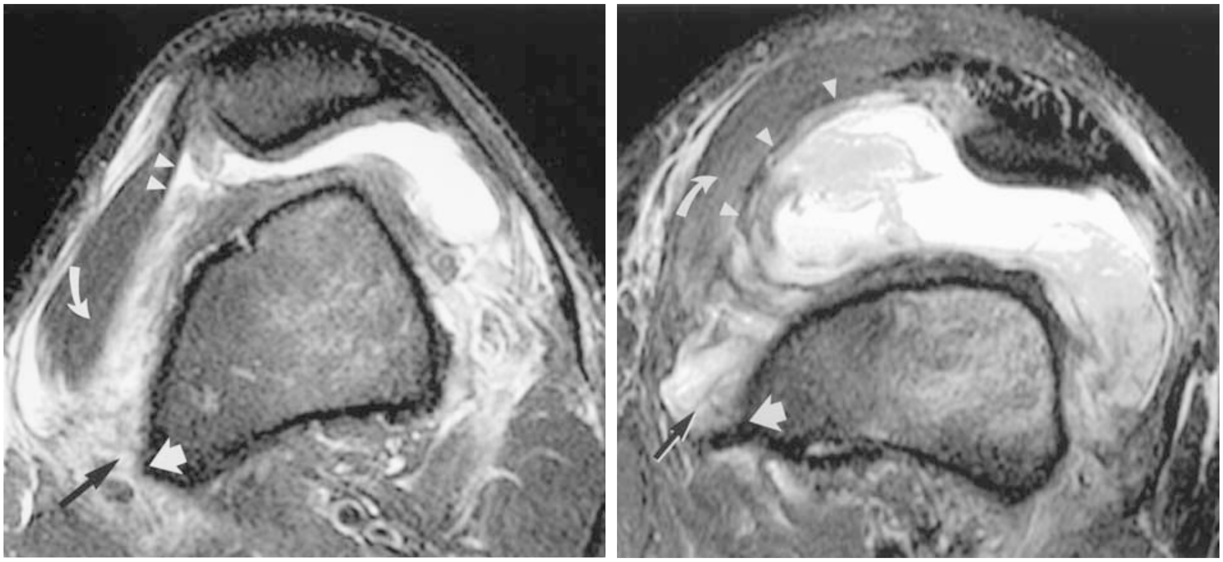


Figure 20. Normal MPFL. Axial T2-weighted fast SE MR image reveals the normal appearance of the MPFL (arrowheads) extending from the superior pole of the patella to the adductor tubercle (thick arrow) of the medial femoral condyle. The thin arrow indicates the vastus medialis obliquus muscle.



a. b.

Figure 21. MPFL disruption after lateral patellar dislocation. **(a)** Axial T2-weighted fast SE MR image of a 22-year-old man shows that the MPFL (arrowheads) is completely disrupted near its femoral attachment site on the adductor tubercle (straight white arrow). There is extensive edema (black arrow) at the normal MPFL attachment site. The most distal aspect of the medialis obliquus muscle (curved arrow) is seen superficial to the MPFL. **(b)** Axial T2-weighted fast SE MR image of a 60-year-old man also demonstrates a completely disrupted MPFL (arrowheads). The fibers are wavy and discontinuous. Extensive edema (black arrow) is present at the normal attachment site of the MPFL to the adductor tubercle (white straight arrow). The distal fibers of the vastus medialis obliquus (curved arrow) are seen superficial to the MPFL.

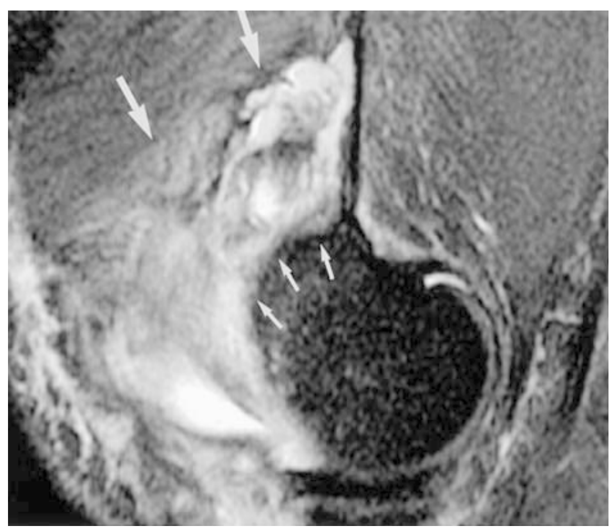
MR imaging accurately depicts the normal MPFL as a low-signal-intensity band extending from the superior pole of the patella to the adductor tubercle. On axial images, the MPFL is located just deep to the vastus medialis obliquus muscle (Fig 20). The medial retinaculum arises from the midpole of the patella and is located just distal to the MPFL. At the level of the medial retinaculum, the vastus medialis obliquus muscle should no longer be visualized (35).

The MPFL is most commonly injured near its femoral attachment site and may be sprained, torn, or avulsed off of the adductor tubercle (Fig 21). A sprain can be seen on MR images as stretching of the ligament with intact fibers and surrounding soft-tissue edema. Disruption is seen as discontinuous, wavy fibers with adjacent high signal intensity on T2-weighted images in the setting of acute injury. After avulsion of the MPFL off of the adductor tubercle, fluid is seen between the MPFL and the femoral attachment site. In addition, the vastus medialis obliquus muscle is elevated away from its normal location on top of the medial femoral condyle as seen on sagittal MR images. This elevation results from subjacent edema and hemorrhage and is an indirect sign of lateral patellar dislocation (Fig 22) (36). MR imaging can also accurately depict osteochondral injuries of the patella or lateral femoral condyle (Figs 18b, 23).

Figures 22, 23. **(22)** Elevation of the vastus medialis obliquus muscle after lateral patellar dislocation. **(a)** Sagittal T2-weighted fast SE MR image obtained with fat saturation in a 60-year-old man depicts elevation of the vastus medialis obliquus muscle (long arrows) away from its normal location on top of the medial femoral condyle (short arrows). Extensive edema and hemorrhage are present between the vastus medialis obliquus muscle and the medial femoral condyle. **(b)** Sagittal T2-weighted fast SE MR image obtained with fat saturation in a 17-year-old boy also reveals edema resulting in elevation of the MPFL (long arrows) away from the medial femoral condyle (short arrows). **(23)** Osteochondral injury after lateral patellar dislocation. Sagittal T2-weighted fast SE MR image of a 29-year-old man reveals an osteochondral defect (long white arrows) involving the anterior aspect of the lateral femoral condyle. Adjacent bone marrow edema (short white arrow) and a large joint effusion (black arrow) are also present.

22a.

23.



22b.

MR images obtained after lateral patellar dislocation should be studied closely for the presence of an osteochondral defect or disruption of the MPFL, since these injuries may be an indication of the need for surgery.

Conclusion

The pattern of bone contusion after trauma is like a footprint; by studying the distribution of bone marrow edema on MR images, one can frequently determine the type of injury that occurred. Armed with the knowledge of the mechanism of injury, one can search more diligently for the commonly associated but sometimes less conspicuous MR imaging signs of soft-tissue injuries.

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