Imaging of Knee Ligament Injuries: From Ligament Tear to Instability Pattern

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MRI is the reference imaging technique for assessment of knee ligament injuries. The anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL) and structures of the posterolateral corner can usually be evaluated directly, while associated meniscal, osteochondral and capsular injuries can be assessed during the same examination. However, interpretation should extend beyond a checklist stating whether each ligament is intact or torn. Knee trauma produces patterns of injury determined by the direction and magnitude of applied forces. Bone contusions, meniscal tears, capsular abnormalities and small avulsion fractures frequently provide important clues to the mechanism.

ACL injuries

The ACL is the most frequently injured cruciate ligament and is commonly damaged during non-contact pivoting injuries combining valgus stress, rotation and anterior tibial translation.

A normal ACL should be identified continuously from its femoral attachment on the lateral femoral condyle to its tibial insertion. Direct signs of complete rupture include

fiber discontinuity,

abnormal orientation,

increased signal

replacement of the ligament by edema or hemorrhage.

In acute injuries, surrounding edema may make the ligament appear expanded and poorly defined. Chronic ACL tears can be more difficult. Edema disappears and the residual ligament may become scarred, attenuated or abnormally horizontal. Fibers can occasionally scar onto the PCL, potentially producing the false impression of continuity. Therefore, a continuous ligament is not necessarily a functional ligament.

Partial ACL tears: a difficult diagnosis

Partial ACL tears remain challenging on MRI. The ACL contains functionally distinct fiber bundles, classically described as anteromedial and posterolateral. Selective bundle injury may occur, although MRI does not always allow reliable functional characterization. Focal increased signal with preservation of some continuous fibers may suggest a partial tear, but similar appearances can occur with mucoid degeneration, partial-volume effects or suboptimal imaging planes. Oblique sagittal and coronal sequences aligned with the ACL can improve visualization. When uncertainty remains, the report should describe the observed morphology rather than overstating the degree of functional insufficiency.

Bone bruises: fingerprints of the injury mechanism

One of the most useful aspects of knee MRI is the ability to demonstrate bone marrow contusions. In acute ACL rupture, the classic pivot-shift pattern consists of contusions involving the lateral femoral condyle and posterolateral tibial plateau. These abnormalities reflect impact during transient anterior translation and rotation of the tibia.

Bone bruises are therefore not merely secondary findings. They are fingerprints of the trauma patterns. When an ACL appears equivocal but the characteristic bone contusion pattern is present, suspicion for ACL injury should increase. Conversely, an unusual contusion pattern should prompt consideration of a different mechanism and a search for additional ligamentous injuries.

Secondary signs of ACL insufficiency

MRI can also demonstrate secondary signs of ACL deficiency. Anterior tibial translation, excessive buckling of the PCL, uncovering of the posterior horn of the lateral meniscus and abnormal ACL orientation may support the diagnosis. These signs are particularly helpful in chronic injuries when direct ligament abnormalities are less conspicuous. However, static MRI cannot reproduce the full biomechanics of the knee. The presence or absence of instability remains a clinical concept, supported but not completely determined by imaging.

Please keep in mind that in immature skeleton, bone bruise attesting a ACL toxic trauma may be present despite a normal-looking ACL ligament due to the increased elasticity of the connective tissue in young patients.

PCL injury

PCL injuries usually result from a posteriorly directed force on the tibia, classically the dashboard mechanism, or from hyperflexion or hyperextension trauma. The normal PCL is a thick low-signal structure and is usually easier to visualize than the ACL.

Acute injury may produce increased signal, thickening, partial fiber disruption or complete discontinuity. An important difference from ACL tears is that injured PCL fibers may remain in apparent continuity despite significant functional injury. Associated injuries should be actively sought. High-energy PCL trauma may involve the posterolateral corner, MCL, menisci or other cruciate ligament. A PCL tear should therefore rarely be interpreted in isolation.

The MCL: distinguish superficial and deep components

The medial stabilizing structures are more complex than the term “MCL” suggests. The superficial MCL is the major medial stabilizer against valgus stress. The deep MCL includes meniscofemoral and meniscotibial components and has an intimate relationship with the medial meniscus.

MRI can classify injury broadly as sprain, partial tear or complete disruption. Periligamentous edema alone may indicate a low-grade injury, whereas fiber discontinuity and retraction indicate more severe trauma. The exact location of injury should be reported: femoral, midsubstance or tibial.

This is clinically relevant because some distal MCL tears may become displaced superficial to the pes anserinus—a Stener-like lesion—potentially preventing normal healing. The radiologist should therefore not simply report “MCL tear,” but specify which component is torn and where.

The posteromedial corner: do not stop at the MCL

Medial knee trauma may also involve the posterior oblique ligament, posteromedial capsule and semimembranosus-related structures. These lesions can contribute to rotational instability and are particularly important when associated with cruciate ligament injury. MRI interpretation should therefore extend posteriorly when significant MCL injury is present.

A useful general principle applies throughout the knee: The more severe the injury to one major stabilizer, the more carefully the secondary stabilizers should be examined.

The posterolateral corner

Posterolateral corner (PLC) injuries are less common but particularly important because missed lesions can result in chronic instability and failure of cruciate ligament reconstruction. The PLC includes several structures, particularly the fibular collateral ligament, popliteus tendon and popliteofibular ligament, together with capsular and musculotendinous stabilizers. Rather than attempting to identify every tiny ligament independently, the radiologist should systematically evaluate the major structures and their attachment sites.

The fibular head deserves particular attention. A small avulsion fracture from the fibular styloid—the arcuate sign—is an important marker of PLC injury. Likewise, edema or avulsion around the femoral attachment of the fibular collateral ligament and abnormalities of the popliteus complex should prompt careful assessment of the entire posterolateral corner.

Small avulsion fractures are major clues

Several characteristic avulsion fractures on radiographs can indicate important ligamentous injuries. A Segond fracture, involving the lateral proximal tibia, is strongly associated with ACL injury and reflects injury of the anterolateral capsuloligamentous structures. An arcuate-type fibular head avulsion suggests posterolateral corner injury. Tibial spine avulsion may represent the osseous equivalent of ACL disruption, particularly in younger patients. PCL injuries may similarly produce avulsion of the posterior tibial insertion. These fragments may be tiny, but their diagnostic importance is large.

Menisci

Meniscal injuries frequently accompany ligament trauma and may contribute substantially to instability. In ACL-deficient knees, particular attention should be paid to the posterior horn of the medial meniscus and its meniscocapsular attachments. Ramp lesions may be subtle on routine MRI and should be actively sought. Lateral meniscal tears are common in acute ACL injuries, while medial meniscal tears become increasingly frequent in chronic ACL-deficient knees. Meniscal root injuries are also important because loss of root function profoundly alters load transmission.

Acute versus chronic injury

The appearance of ligament injuries changes substantially with time. Acute tears are associated with edema, hemorrhage and poorly defined fibers. Subacute injuries may show partial organization. Chronic tears can become scarred, attenuated or elongated, with little surrounding edema. Secondary signs become increasingly important in chronic cases.

Chronic instability may also produce characteristic consequences: recurrent bone injuries, meniscal damage, cartilage loss and eventually osteoarthritis. Thus, MRI should distinguish not only which ligament is abnormal, but also whether the appearance suggests a recent traumatic event or chronic insufficiency.

A practical reading strategy

A systematic approach reduces missed injuries.

- First, examine the bone marrow before concentrating on the ligaments. The distribution of contusions frequently reveals the mechanism.
- Second, evaluate the ACL and PCL from attachment to attachment.
- Third, assess the medial structures, separating superficial MCL, deep MCL and posteromedial structures.
- Fourth, evaluate the lateral and posterolateral stabilizers, including the fibular collateral ligament, popliteus complex and fibular head.
- Fifth, search systematically for meniscal tears, particularly ramp and root lesions.
- Finally, look for small avulsion fractures, cartilage injuries, neurovascular abnormalities and evidence of previous transient dislocation.