Acute trauma of the knee ligaments: Following the contusion pattern.

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Authors: W. Aponte, E. Salinas, L. K. Cifuentes, L. Brun, D. Sossa, O. Rivero, R. Gómez; Bogotá/CO
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Learning objectives

• To review the anatomy of the knee ligaments throughout illustrations and figures.
• To describe and schematize bone contusion patterns in acute trauma of the knee.
• To show representative cases and schemes of traumatic knee ligament pathology on magnetic resonance imaging (MRI) and the associated bone contusion patterns.
Background

Acute trauma of the knee ligaments: Following the contusion pattern.

The anterior cruciate ligament (ACL) is the most frequently affected ligament in knee trauma. This injury is most frequently related to the pivot shift mechanism of injury. Posterior cruciate ligament (PCL) injury is associated with the dashboard mechanism of trauma. The pure valgus injury of the knee, known as "Clip injury", is the most commonly associated mechanism to the medial collateral ligament (MCL). The "kissing lesion", a hyperextension injury, is associated with PCL and ACL injuries.

Medial retinaculum injuries are associated with injuries of the medial patellofemoral ligament (MPFL). The "clip injury" mechanism of trauma is associated with the O'Donoghue’s triad. In acute knee trauma, is more common to find multiple ligament and meniscal injuries rather than an isolated ligament injury.

ANATOMY OF THE KNEE LIGAMENTS

The ACL is an intraarticular and extrasynovial structure that gives sagittal and rotational stability to the knee. It prevents anterior translation. The ACL originates in the medial aspect of the lateral femoral condyle and inserts on the tibial plateau adjacent to the anterior tibial spine.

The ACL has a lateral to medial and posterior to anterior course. It is composed of two bundles of fibers (anteromedial and posterolateral). The ACL bundles have low signal intensity on all MRI sequences and may have fat or fluid in between their fibers, particularly to the tibial attachment site. It is best viewed in MRI, in the oblique sagittal plane. The axial and coronal images help confirm the integrity of the fibers.

The posterior cruciate ligament (PCL) is bigger and stronger than the ACL, it is an extrasynovial, intraarticular structure and prevents subsequent translation of the tibia and provides posterolateral rotational stability. It arises from the posterior aspect of the medial femoral condyle and is inserted into the posterior aspect of the tibial plateau. It can be divided into two functional bundles, the anterolateral and the posteromedial bundles. On MRI the PCL is seen as a broadband, with low signal intensity on T1 and T2, near to the midline of the knee.
The medial collateral ligament complex (MCL) consists of deep (internal) and superficial (external) portions. The deep component is composed of the meniscofemoral and meniscotibial ligaments. The superficial component is the medial collateral ligament. The deep portion is strongly attached with the medial meniscus in its intermediate region. Both layers are separated by fat and the medial collateral bursa. The MCL originates from the anterior medial femoral condyle near to the adductor tubercule, is inserted into the anteromedial aspect of the proximal tibial metaphysis, distal to the pes anserine.

The MCL is the primary stabilizer of the knee in the anteromedial region and restraint the external rotation of the tibia. It is best viewed in the axial and coronal Magnetic Resonance (MR) planes. This ligament shows low intensity signal on all MRI sequences.

The lateral collateral ligament (LCL) is the largest posterolateral knee stabilizer. The LCL arises in the external tuberosity, directly above the origin of the lateral Gastrocnemius in the lateral femoral condyle. The LCL is inserted along with the biceps tendon in the fibular head as a whole tendon. The LCL is best viewed in the coronal plane. The LCL have low signal intensity on all sequences of MRI. The lateral collateral ligament complex includes the LCL, the biceps tendon, the meniscopopliteal and arcuate ligaments.

The patellofemoral retinaculum are part of the knee stabilizers. The patellofemoral retinacula reinforce the front of the joint capsule at the top and bottom, along with some fibers of the lateral and vastus medial obliquus muscle. They are a layer of fibrous connective tissue and have obliquely and transverse course from the superior pole of the patella to the femoral condyles. The MPFL represents a condensation of three layers of fibers, the most inner layer receives contribution of the deep femoral fascia, the intermediate layer is formed by the MPFL and the outer layer is formed by fibers of the MPFL and fibers of the joint capsule. The MPFL on MRI is visualized as a thin linear structure that shows low intensity signal on all MRI sequences.

The following scheme illustrates the normal anatomy of the knee ligaments (Fig. 1 on page 7). Also, there is a table (Table 1) which summarizes the sites of origin and insertion of each ligament.

Anatomy of the knee ligaments
Fig. 1: Scheme of the anatomy of the knee ligaments. Lateral, frontal and axial view.

**Origin**

- ACL: Lateral femoral condyle at intercondylar notch
- PCL: Mid portion of medial femoral condyle at intercondylar notch
- MCL: Adductor tubercle of medial femoral condyle
- LCL: Lateral femoral condyle
- MPFL: Adductor tubercle of medial femoral condyle

**Insertion**

- ACL: Anteromedial tibial spine and adjacent plateau
- PCL: Posterior aspect of the tibial plateau
- MCL: Medial aspect of the proximal tibia, adjacent to the pes anserinus insertion site
- LCL: Fibular head with the biceps tendon to form the conjoint tendon
- MPFL: Superior pole of patella
Table 1. Anatomy of the knee ligaments. Origin and insertion site of the different knee ligaments.
Fig. 1: Scheme of the anatomy of the knee ligaments. Lateral, frontal and axial view.

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Findings and procedure details

KNEE LIGAMENTS TRAUMATIC INJURIES

Knee ligament injuries are classified into three grades: grade I is the sprain, grade II is the partial-thickness, and grade III is the full-thickness tear. The grade III lesion is associated with instability and loss of function.

The ACL tear occurs more frequently in the middle third, followed by the adjacent femoral insertion ruptures. The least common site of tear is the distal insertion. On MRI, ligament tears are identified for fiber morphology and signal intensity changes, with partial or complete disruption. Acute injuries are displayed on T2 sequences with high signal intensity. It is difficult to visualize the ligament fibers and to identify an abnormal fiber orientation.

The PCL is injured less often than the ACL. PCL ruptures occur often in the middle portion of the ligament, which can be partial or a full thickness tear. The PCL injuries have a high association with other injuries. It has been reported an incidence of microfractures or bone bruises from 32% to 83%, which may be of variable location. Up to half of PCL ruptures are associated with rupture of the medial collateral ligament and meniscus. The PCL full thickness tear may be associated with posterior subluxation of the tibia due to lack of stability of the knee. PCL injuries are associated with lesions of the posterolateral corner.

MCL tears occur most frequently in the proximal portion of the ligament, near to the femoral attachment. On MRI, ligament tears are identified for fiber morphology and signal intensity changes, with associated partial or complete disruption. If the injury is acute, there will be an increase in the signal intensity on T2 sequence.

The LCL injuries occur in association with lateral collateral complex lesions. Isolated LCL injuries are rare. On MRI, ligament tears are identified for fiber morphology and signal intensity changes, with partial or complete disruption. If the injury is acute, there will be an increase in the signal intensity in liquid sensitive sequences.

The medial patellofemoral ligament (MPFL) is often affected in lateral subluxation of the patella. The injuries of the lateral retinaculum are less frequent, related to a surgical procedure.
Mechanisms of injury and bone contusion pattern

PIVOT SHIFT

- **Mechanism of trauma**: This pattern is caused by a valgus stress applied to the knee in flexion, with internal rotation of the femur against a fixed tibia. It is caused by fast deceleration forces combined with changes in the direction. It is related to sports like skiing and football.

- **MRI findings**: bone marrow edema in the lateral femoral condyle and in the posterior aspect of the lateral tibial plateau (Fig. 2 on page 20).

![Fig. 2: Coronal fat-suppressed PD MRI (A,B,C) and scheme (D), three different cases that show bone marrow edema in the lateral femoral condyle and posterolateral aspect of the tibial plateau, full-thickness rupture of the proximal third of the ACL and complete rupture of the distal insertion of the MCL with increased joint fluid and soft tissue edema.](image-url)
Associated injuries: the main injury is the ACL injury. Additional findings are MCL injuries, rupture of the posterior horn of the medial or lateral meniscus, joint capsule or arcuate ligament rupture, and osteochondral lesion of the tibial plateau and femoral condyle. The following figure shows an example of the most common associated injuries (Fig. 3 on page 20).

Fig. 3: Sagittal PD T1-weighted MRI (A), Coronal fat-suppressed PD (B) and scheme (C) demonstrating rupture of the MCL and medial meniscus (O'Donoghue's triad) by pivot shift trauma mechanism.

References: Department of Radiology, Fundación Santa Fe de Bogotá - Bogotá/CO

CLIP INJURY
• **Mechanism of trauma:** This pattern occurs when a force of pure valgus is applied, while the knee is in slight flexion (10-30 °). The clip injury mechanism of trauma is related to soccer, football, basketball and skiing.

• **MRI findings:** bone marrow edema in lateral femoral condyle and lateral tibial plateau (Fig. 4 on page 21).

![Fig. 4](image)

**Fig. 4:** Coronal fat-suppressed PD MRI of three different patients and scheme (D) pointing out the bone marrow edema in the femoral condyles. (A) Full-thickness tear of the MCL in its femoral insertion. (B) and (C) showing a partial tear of the MCL and associated soft tissue edema.

**References:** Department of Radiology, Fundación Santa Fe de Bogotá - Bogotá/CO

• **Associated injuries:** the MCL is most commonly affected. Additionally, there are associated injuries such as ACL tear, medial meniscus injuries, the meniscocapsular separation, the medial retinaculum tears, and semimembranosus, and vastus medialis obliquus muscle injuries. (Fig. 5 on page 22)
Fig. 5: Coronal fat-suppressed PD (A) and scheme (B) showing bone marrow edema in the patellar medial facet and lateral femoral condyle. A partial-thickness tear of the medial retinaculum.

References: Department of Radiology, Fundación Santa Fe de Bogotá - Bogotá/CO

DASHBOARD INJURY

• Mechanism of trauma: occurs when an external force is applied to the anterior aspect of the proximal tibia while the knee is flexed. It often occurs when the knee hits the backboard of the car during a car accident or when the knee hits the ground during a fall.

• MRI findings: bone marrow edema in the anterior aspect of the proximal tibia and occasionally in the inferior pole of the patella (Fig. 6 on page 23).
Fig. 6: Sagittal fat-suppressed PD MRI. (A) Bone marrow edema in the tibial tuberosity. Full-thickness tear of the PCL. Sagittal fat-suppressed PD and Sagittal T1-weighted. (B) and (C): Bone marrow edema in the tibial tuberosity and full-thickness tear of the femoral insertion of the PCL. Scheme (D) Dashboard mechanism of trauma.

References: Department of Radiology, Fundación Santa Fe de Bogotá - Bogotá/CO

- **Associated injuries:** The primary injury is the PCL rupture. The posterior joint capsule tear, fracture or osteochondral injury of the patella are other associated injuries. It may be associated with hip injuries such as fractures and dislocations (Fig. 7 on page 24).
**HYPEREXTENSION INJURY**

- **Trauma mechanism:** Occurs when a force is applied directly or indirectly to the anterior tibia while the foot is fixed, or an indirect movement such as a blunt trauma.

- **MRI findings:** Bruised "Kiss" (Kissing lesion), bone marrow edema in the anterior aspect of the proximal tibia and in the anterior aspect of the femoral condyle (Fig. 8 on page 25).
**Fig. 8:** Coronal fat-suppressed PD MRI (A): Bone marrow edema of the lateral aspect of the external femoral condyle and superior and lateral aspect of the tibial plateau. Coronal fat-suppressed PD MRI (B), sagittal PD T1-weighted MRI (C) and scheme (D): Bone marrow edema of the lateral femoral condyle and superior and lateral aspects of the tibial plateau with a PCL tear of its medial third.

**References:** Department of Radiology, Fundación Santa Fe de Bogotá - Bogotá/CO

- **Associated injuries:** The primary injury is the PCL tear, in more severe cases it can be associated with rupture of the ACL. Additionally, it can present rupture of the posterior capsule, meniscal injuries and dislocations (**Fig. 9** on page 26).
**Fig. 9**: Sagittal PD T1-weighted MRI (A) and scheme (B): PCL full-thickness tear and ACL partial-thickness tear due to hyperextension mechanism of trauma.

**References**: Department of Radiology, Fundación Santa Fe de Bogotá - Bogotá/CO

**LATERAL PATELLAR DISLOCATION**

- **Mechanism of trauma**: occurs as a result of a twisting motion of the knee while it is bent.

- **MRI findings**: bone marrow edema in the anterolateral aspect of the lateral femoral condyle and in the inferomedial aspect of the patella (Fig. 10 on page 27).
**Fig. 10:** Axial fat-supressed PD MRI (A): Bone marrow edema of the medial patellar facet and the external femoral condyle with a lateral dislocation of the patella and proximal disruption of the medial retinaculum. Axial fat-suppressed PD (B), coronal (C) and scheme (D) showing edema of the medial patellar facet, external femoral condyle, lateral dislocation of the patella, medial retinaculum rupture and vastus medialis obliquus muscle tear.

**References:** Department of Radiology, Fundación Santa Fe de Bogotá - Bogotá/CO

- **Associated injuries:** The primary injury is the rupture of the medial patellofemoral retinaculum. It is associated with osteochondral lesion of the patella or lateral femoral condyle injury, also with the presence of intra-articular bodies and vastus medialis obliquus muscle injury (Fig. 11 on page 28).
Fig. 11: Sagittal fat-suppressed PD MRI (A) and scheme (B): Lateral dislocation of the patella with edema of its inferior and medial aspects and vastus medialis tear.

References: Department of Radiology, Fundación Santa Fe de Bogotá - Bogotá/CO

Summary of knee ligaments traumatic injuries

<table>
<thead>
<tr>
<th>Mechanism of trauma</th>
<th>Bone marrow edema</th>
<th>Primary injury and associated lesions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pivot-Shift</td>
<td>Lateral femoral condyle and posterior aspect of the lateral tibial plateau</td>
<td>ACL</td>
</tr>
<tr>
<td>Clip injury</td>
<td>Lateral femoral condyle and lateral tibial plateau</td>
<td>MCL, posterior horn of the meniscus, joint capsule</td>
</tr>
<tr>
<td>Trauma Mechanism</td>
<td>Location</td>
<td>Associated Lesions</td>
</tr>
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<td>----------------------</td>
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<tr>
<td>Dashboard</td>
<td>Anterior aspect of the proximal tibia.</td>
<td>ACL, Medial meniscus, MPFL</td>
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<td>PCL</td>
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<td></td>
<td></td>
<td>Posterior capsule, fracture or osteochondral injury of the patella, hip fracture or dislocation</td>
</tr>
<tr>
<td>Hyperextension</td>
<td>Anterior aspect of the proximal tibia and anterior aspect of the femoral condyle</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>ACL, posterior capsule, meniscus, popliteal neurovascular injury</td>
</tr>
<tr>
<td>Lateral patellar dislocation</td>
<td>Anterolateral aspect of the lateral femoral condyle and inferomedial aspect of the patella</td>
<td>MPFL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Osteochondral lesion, intra-articular body, medial retinaculum, vastus medialis obliquus muscle injury</td>
</tr>
</tbody>
</table>

**Table 2.** Knee ligaments traumatic injuries. Summary of the different mechanism of trauma, their primary injury and associated lesions.
Fig. 2: Coronal fat-suppressed PD MRI (A,B,C) and scheme (D), three different cases that show bone marrow edema in the lateral femoral condyle and posterolateral aspect of the tibial plateau, full-thickness rupture of the proximal third of the ACL and complete rupture of the distal insertion of the MCL with increased joint fluid and soft tissue edema.

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Fig. 7: Sagittal PD T1- weighted MRI (A) and scheme (B) that illustrate PCL tear and subchondral fracture of the anterior tibial tuberosity.

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Conclusion

The bone contusion pattern analysis is the initial step in addressing acute traumatic knee injury in MRI. It allows us to suspect which ligament could be injured. It is essential to know the anatomy of the knee ligaments when addressing traumatic pathology for a proper evaluation of lesions of these structures, and to avoid overlooking injuries that may have long-term consequences, such as post-traumatic osteoarthritis. The finding of an initial injury and the mechanism of trauma should raise suspicion of damage to additional soft tissue structures.
Personal information

Aponte, Wilmer, MD, Santa Fe de Bogotá Foundation. El Bosque University, Bogotá. Colombia; email: woaponteb@gmail.com.

Salinas, Emmanuel, MD, Santa Fe de Bogotá Foundation. El Bosque University, Bogotá. Colombia; email: emmanuels7@gmail.com

Cifuentes, Karen, MD, Santa Fe de Bogotá Foundation. El Bosque University, Bogotá. Colombia; email: krncfnts@hotmail.com

Brun, Lucia, , Los Andes University. Santa Fe de Bogotá Foundation, Bogotá. Colombia; email: marialuciabrun@gmail.com.
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