Magnetic Resonance Imaging Evaluation Of Traumatic Knee Injuries

Poster No.: C-1617
Congress: ECR 2015
Type: Educational Exhibit
Authors: V. S. Pande, R. Kedzierski, S. Shankar, G. Goodin; Memphis, TN/US
Keywords: Education, MR, Musculoskeletal joint, Trauma
DOI: 10.1594/ecr2015/C-1617

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
Learning objectives

1) Familiarize the reader with magnetic resonance (MR) anatomy of knee joint and mechanisms of traumatic knee injuries especially those occurring in motor vehicle accidents and sporting injuries.

2) Highlight ligamentous and myotendineous injuries, especially those involving medial and lateral corners of the knee.

Background

Traumatic knee injuries are one of the most common reasons for emergency room visits in our clinical setting. While clinical evaluation, plain film radiography and computed tomography imaging are utilized in the evaluation of osseous injuries, magnetic resonance imaging is the modality of choice for evaluating the soft tissue structures of knee joint.

Knee joint being a hinge type of synovial joint, the bones have limited contribution to the stability of the joint. The stability of knee joint hence depends upon the supporting soft tissue structures including the *joint capsule, the ligaments, the menisci and the myotendinous unit*. Traditionally the supporting soft tissues of knee have been grouped into the *medial, lateral, anterior, posterior corners* and *central* supporting structures. The table below summarizes the supporting soft tissue structures of the knee joint. (Figures 1 to 8) depict the normal MR appearance of these soft tissue supporting structures.

<table>
<thead>
<tr>
<th>Supporting structures of the knee joint</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANTERIOR</strong></td>
</tr>
<tr>
<td>Quadriceps muscles.</td>
</tr>
<tr>
<td>Patellar tendon.</td>
</tr>
<tr>
<td>Medial and lateral patellar retinacula.</td>
</tr>
<tr>
<td><strong>MEDIAL AND POSTEROMEDIAL</strong></td>
</tr>
<tr>
<td>Superficial and deep medial collateral ligament.</td>
</tr>
</tbody>
</table>
We will in brief summarize the anatomy of the above mentioned main supporting structures of the knee joint.

Central supporting structures:

**Anterior Cruciate Ligament (ACL):** Originates from the lateral femoral condyle and runs parallel to the roof of the intercondylar notch and inserts on medial and anterior aspect of the tibial plateau. It is composed of the anteromedial and posterolateral bundles. ACL resists posterior displacement of femur on tibia. Intact ACL has hypointense signal on all MR sequences but may contain some high signal within it, especially at its insertion on the tibia, also it may contain high signal if there is mucoid degeneration within it (Fig 1).

**Posterior Cruciate ligament (PCL):** Originates from the anterolateral aspect of the medial femoral condyle in region of intercondylar notch, it inserts extra articular over the back of tibial plateau. It contains anterolateral and posteromedial bundles. PCL resists...
anterior displacement of femur on tibia. PCL is much thicker than ACL and uninjured PCL has a dark signal on T1 and T2 weighted images (Fig 2).

Posterior Medial Corner:

The posteromedial corner of the knee is comprised of the deep (crural) fascia, medial collateral ligament, posterior oblique ligament, semimembranosus tendon, the oblique popliteal ligament and the posterior horn of the medial meniscus.

Medial collateral ligament (MCL): Originates on the medial aspect of the distal femur and inserts on medial aspect of the proximal tibia. It has superficial layer the MCL proper and deep layer comprising of meniscofemoral and meniscotibial attachments. The MCL fibers are intricately interlaced with the joint capsule and medial meniscus is attached to it. (Fig 3)

Posterior oblique ligament (POL): This ligament represents obliquely oriented fibers of the medial collateral ligament which originate from the adductor tubercle of the medial femur and are attached to the posterior horn of medial meniscus, the joint capsule and semimembranosus tendon sheath. (see below Fig's 24 & 25)

Oblique popliteal ligament (OPL): Connects the posterior medial and lateral knee, attaching medially to the posterior oblique ligament and the semimembranosus tendon and coursing along the posterior joint capsule attaching to the arcuate ligament and lateral head of the gastrocnemius. (see below Fig 24 and sidebar Fig 25)

Semimembranosus tendon(SM): Semimembranosus muscle, after arising from the ischial tuberosity, passes deep to semi-tendinosus to insert in a complex fashion via five tendinous expansions. It attaches to tibia, joint capsule, medial meniscus and the OPL. The semimembranosus flexes and internally rotates the joint during flexion, preventing impingement of the meniscus by opposing surfaces of the tibia and femur. (see below Fig 24 and sidebar Fig 25)
**Fig. 24:** Axial plane illustration of the knee at the level of the menisci demonstrating the components of the posteromedial corner. The semimembranosus (SM) can be seen contributing fibers to the oblique popliteal ligament (OPL) and to the posterior capsule. The posterior oblique ligament (POL) is seen between the superficial medial collateral ligament (SMCL) and the semimembranosus tendon on this view. The medial head of the gastrocnemius muscle (MG), sartorius muscle (SA), gracilis tendon (G) and semitendinosus tendon (ST) are also shown.

Axial plane illustration of the knee at the level of the menisci demonstrating the **components of the posteromedial corner**. The *semimembranosus* (SM) can be seen contributing fibers to the **oblique popliteal ligament (OPL)** and to the **posterior capsule**. The **posterior oblique ligament (POL)** is seen between the **superficial medial collateral ligament (SMCL)** and the *semimembranosus tendon* on this view. The medial head of the *gastrocnemius muscle (MG)*, *sartorius muscle (SA)*, *gracilis tendon (G)* and *semitendinosus tendon (ST)* are also shown.

Image from: http://radsource.us/posteromedial-corner-injury-of-the-knee

**Posterolateral corner structures:**

The stability of posterior lateral corner of knee is provided by *joint capsule, biceps femoris* and **popliteus tendons**, the **fibular-collateral ligament (true LCL), iliotibial band, arcuate and popliteofibular ligaments**. However there is variability with regards to presence of individual structures and their contribution to the stability of knee, also not all the structures are always visible on MRI. The structure consistently identified on MRI with some variations are the biceps tendons, the fibula-collateral ligament and the popliteus musculotendinous complex (including arcuate ligament, popliteofibular and fabello-fibular ligaments).

**Fibular collateral ligament:** Originates from external tuberosity of the lateral condyle of femur anterior to the origin lateral head of the gastrocnemius muscle. The fibulocollateral ligament together with biceps femoris tendon forms a conjoint tendon which insert's onto the proximal fibula.(Figure's 4 & 6).

The **iliotibial band** inserts onto Gerdy's tubercle on the anterior tibia. (Fig 8).

**Popliteus tendon:** Arises below the lateral collateral ligament on the lateral femoral condyle, passes under the lateral collateral ligament, descends into the popliteus hiatus, and then passes under the arcuate ligament before joining its muscle belly(Fig 5). The popliteus tendon is attached to the lateral meniscus by the **popliteal meniscal ligament** and to the styloid process of the fibula the **popliteal fibular ligament**.

**Arcuate ligament:** It is 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. The oblique popliteal ligament joins the recurrent fascicle of the semimembranosus tendon, which reinforces the capsule. Both the limbs insert on at the apex of the fibular styloid process just anterior to the fabellofibular
ligament. Arcuate ligament is usually difficult to visualize on MRI and can be considered as thickening of the posterolateral capsule. (see below Fig 26)

If the fabella is present the *fabellofibular* ligament(Fig 7) 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.

![Fig. 26: Anatomy of the posterolateral corner. 3D rendering of the posterolateral corner with the biceps femoris muscle and tendon removed demonstrates the Y-](image-url)
shaped arcuate ligament composed of the medial (blue) and lateral (red) limbs and its attachment (green) to the fibular styloid process. The biceps femoris tendon (BF), fibular collateral ligament (FCL), fabellofibular ligament (FF), popliteofibular ligament (PF), and popliteus muscle (PM) are also demonstrated. 

**References:** Michael E. Stadnick, M.D. Image from: http://radsourc.eu/posterolateral-corner-injury

Anatomy of the **posterolateral corner**. 3D rendering of the posterolateral corner with the biceps femoris muscle and tendon removed demonstrates the Y-shaped **arcuate ligament** composed of the medial (blue) and lateral (red) limbs and its attachment (green) to the fibular styloid process. The **biceps femoris tendon (BF)**, **fibular collateral ligament (FCL)**, **fabellofibular ligament (FF)**, **popliteofibular ligament (PF)**, and **popliteus muscle (PM)** are also demonstrated.

Image from: http://radsourc.eu/posterolateral-corner-injury

**Images for this section:**
Fig. 1: Sagittal T2W MR showing normal ACL, note the slight hyperintensity at the tibial attachment.
Fig. 2: Sagittal T2W MR with intact PCL
Fig. 3: Coronal Proton density fat suppressed MR depicting normal intact medial collateral ligament.
Fig. 4: Coronal Proton density Fat suppressed MR with intact fibular collateral ligament (LCL) Yellow arrows and PCL (red arrow)

Fig. 5: Coronal Proton density fat suppressed MR showing popliteus tendon (yellow arrow)
Fig. 6: Sagittal Proton density Fat suppressed MR with normal fibular collateral ligament(yellow arrow) and biceps femoris tendon(red arrow), Fibular head (black arrow)
Fig. 7: Sagittal Proton density fat suppressed MR showing intact Fabellob-fibular ligament(red arrow), Fabella(small yellow arrow)
**Fig. 8:** Coronal proton density fat suppressed MR with normal Illiotibial band(red arrow) and medial collateral ligament(yellow arrow).

**Fig. 25:** Axial proton density fat suppressed MR traumatic knee joint effusion depicting posterior medial corner structures: Posterior oblique ligament(yellow arrow), oblique posterior ligament(black arrow) and semimembranosus tendon(red arrow).
Findings and procedure details

Complex knee injuries commonly occur in sporting trauma and motor vehicle accidents. Although many factors contribute to the actual injury, combination of certain forces produces a predictable pattern of injury. The major forces acting on the knee include anterior or posterior translations, varus or valgus angulations, internal or external rotation, hyperextension, axial loading and direct blow, the pattern of injury also depends upon the relation of the tibia and femur at the time of injury.

Usually there is impaction injury at the site of the entry of the force and distraction or avulsion injury at the opposite side. Hyperextension injuries are more severe and result in bone contusions in the anterior compartment of the knee and ligamentous and soft tissue injuries at the posteromedial and posterolateral corners which represent the exit side of the force and are usually associated with injuries to the cruciate ligaments. In contrast in hyperflexion injuries the pattern of injury is dictated by the accompanying rotational forces and are frequently associated with meniscal tears.

The stabilizers of the knee are usually uniformly hypointense on all MR sequence, except ACL which may exhibit some hyperintensity as described above. Injury to the ligaments and soft tissues of knee is inferred with either heterogeneous hyperintense signal on fluid sensitive sequences or when there is an appreciable gap or defect in the continuity of the structure. The pattern of bone contusions also serves to understand the underlying mechanism of injury.

**Anterior cruciate ligament:**

ACL is the frequently injured knee ligament. Common mechanism of ACL injury are forward translation of tibia, external rotation of tibia or internal rotation of femur with valgus stress applied to flexed knee as seen in non-contact pivot shift injury (American football, skiers).

Disruption of ACL is usually obvious with, high signal intensity on T2 weighted sequences with or without non-visualization of its fibers.\*(Fig 9)*  Accuracy of MRI for the ACL is extremely high, approaching 95% to 100%. A sprain or partial tear of the ACL is mentioned when some fibers are intact and focal or diffuse high signal or laxity of the ACL is present. However caution should be exercised in reporting partial tear of ACL, and mucoid degeneration should be excluded. Osseous contusions involving the weight
bearing surfaces of the lateral femoral condyle with deepening of lateral femoral sulcus (deep sulcus sign) (Fig 11) and contusion of posterior lateral tibial plateau are often encountered. Avulsion of ACL from its tibial attachment also occur (Fig 12). High grade ACL injury can be associated with Segond's fracture (lateral tibial rim fracture) (Fig 10). Injury to medial collateral ligament (MCL), and medial meniscus tear can also be associated with ACL injuries (O'Donoghue's Triad) (Fig 17).

**Posterior cruciate ligament:**

Being a much stronger ligament complete disruption of PCL is less common and is usually associated with severe knee trauma and injuries to posterior lateral corner structures (Fig 13). Partial or intra substance tears are much more common and manifest as T2 or STIR intra substance hyperintensity with often laxity and thickening of the ligament. Additionally, avulsion fractures of the PCL from its femoral or tibial attachments which are associated with much less bone marrow contusions. Common mechanisms of PCL injury are a posteriorly directed force on anterior aspect of the proximal tibia (e.g. Dashboard injuries). Bone injuries associated with PCL injury include a reverse Segond's fracture (medial tibial rim), arcuate sign (avulsion of the proximal fibula) (Fig 22) and anterior compartment osseous contusions.

**Posteromedial corner (PMC):**

Hyperextension and valgus is usually the mechanism responsible for injury to the posteromedial corner. The PMC injuries can be divided into injuries to the ligaments (MCL and POL injuries), Menisco-capsular injury and Musculotendinous injury to the semimembranosus insertion.

**Ligament injury:** Three grades of MCL injury have been described Grade I injury is a sprain with high signal in the soft tissues medial to the MCL, Grade 2, a severe sprain or partial tear, with high signal in the soft tissues medial to the MCL with partial disruption of the MCL. Grade 3, complete tear, shows disruption of the MCL (Fig 15) and disruption of medial patellar retinaculum (Fig 16).

**Menisco-capsular injury:** MRI readily demonstrates injury of the femoral and tibial meniscal attachments as disruption and thickening of the menisco tibial and menisco femoral ligaments with or without associated marrow edema at the ligament insertion.
Musculotendinous injury: Damage to the semimembranosus insertion is common in posteromedial knee injuries. Injury to the semimembranosus tendinous expansions may include avulsion fracture of the tibial insertion, complete or partial tears of the tendon and chronic insertional tendinosis. Capsular injury manifests as thickening and hyperintensity of the posterior capsule at the level of the medial femoral condyle.

Isolated MCL injury is seldom repaired even if it is completely disrupted, unless associated with injuries to the other posteromedial corner structures resulting in anteromedial rotatory instability when surgical repair needs consideration.

Posterolateral corner injury (PLC):

The stability of the posterolateral corner of the knee is provided by capsular and noncapsular structures that function as static and dynamic stabilizers. They include iliobial band, Joint capsule, Biceps femoris tendon, Fibulocollateral ligament, Popliteus muscle and tendon, Popliteofibular and Arcuate ligaments.

The mechanism of injury is either a direct blow to the anteromedial proximal tibia, directed posterolaterally with the knee in extension, noncontact hyperextension external rotation, or complete knee dislocations from direct hyperextension (Fig 14) and varus injuries or direct blow to the proximal tibia with flexed knee as seen in dash board injuries.

There is no specific MRI criteria for defining posterolateral corner injury, however injuries to the posterolateral ligamentous structures can be classified as grade I, II, or III sprains, corresponding to minimal, partial, or complete tearing, respectively. Injury to two or more major stabilizing structures especially the popliteus myotendinous unit, fibular collateral ligament and posterior lateral joint capsule should be considered as posterolateral corner injury. Grade 3 injuries are often associated with disruption of the cruciate ligaments.

Injuries to the fibular collateral ligament are better appreciated in coronal fat suppressed proton density (PD) or coronal fat suppressed T2W images. Injuries range from partial intra substance tear to complete disruption and avulsion from bony attachment from fibular head, periligamentous soft tissue edema is often present (Fig 18). The biceps femoris tendon usually joins with the fibular collateral ligament to form a conjoint tendon, injuries to biceps femoris tendon also show similar appearance with intra substance hyperintense signal suggesting tear or avulsion from its fibular attachment with associated fibular bone marrow edema.
Popliteus myotendinous complex: The popliteus muscle is an important stabilizer of lateral knee. Avulsions from femoral attachment or complete tear of the popliteus tendon are rare, injuries of the popliteus muscle and tendon usually involve the muscle belly or musculotendinous junction with hyperintense signal in the tendon (Fig 19), fiber disarray with enlargement of muscle belly are seen. Injury to the popliteofibular ligament is seen as high signal within the ligament, disruption or avulsion from fibular head (Fig 21). Similarly when present fabellofibular ligament avulsion from the fibular styloid process can be seen frequently in association with avulsion of short head of biceps femoris tendon. As mentioned earlier the arcuate ligament is difficult to identify separately from the joint capsule and disruption of posterolateral joint capsule suggest its injury. Injury to the lateral head of gastrocnemius tendon and muscle are also infrequently observed.

The bony injuries associated with PLC injuries include marrow contusions involving the anteromedial femoral condyle, anterior medial tibial margin fracture and "Arcuate" fracture which represents avulsion fracture of the fibular styloid process (Fig 22).

It is important to recognize posterolateral corner injury as untreated injury leads to posterolateral instability, failure of ACL and PCL reconstruction grafts and early osteoarthritis. Primary repair or early reconstruction in the acute setting has a greater chance of successful outcome than surgery for chronic injuries.

Images for this section:
Fig. 9: Sagittal Proton Density(PD) Fat Suppressed MR showing disrupted ACL and PCL Ligaments.
Fig. 10: Radiograph depicting Segond fracture (thin arrow)

Fig. 11: Sagittal Proton Density (PD) Fat Suppressed MR showing "Deep sulcus" sign and bone marrow edema associated with disrupted ACL (not shown)
**Fig. 12:** Sagittal T2W MR showing avulsion of ACL’s tibial attachment, note the absence of marrow edema.
Fig. 13: Sagittal Proton density Fat suppressed MR with completely torn PCL (red arrow) and ACL (yellow arrow) also note the extensive muscular and soft tissue injuries.
Fig. 14: Radiograph with traumatic knee dislocation these are associated with lateral corner and cruciate ligament injuries.
**Fig. 15:** Coronal Proton density (PD) fat suppressed MR with medial corner injury depicting grade III MCL injury, bone contusion of lateral femoral condyle and also grade II strain of the LCL.

**Fig. 16:** Axial Proton density fat suppressed MR showing medial corner injury with disrupted medial patellar retinaculum.
Fig. 17: Coronal Proton density fat suppressed MR showing disrupted MCL (red arrow), avulsed and extruded Medial meniscus(yellow arrow) and ACL injury.(O’Donoghue’s Triad)
Fig. 18: Coronal Proton density (PD) Fat suppressed MR with high grade Lateral corner structures injuries (disrupted fibular collateral ligament) with associated soft tissue edema.
**Fig. 19:** Coronal Proton density (PD) fat suppressed MR image with disrupted popliteus tendon.

**Fig. 20:** Coronal proton density fat suppressed MR image showing avulsion fracture of the illiotibial band attachment.
**Fig. 21:** Coronal proton density fat suppressed MR with disrupted popliteo-fibular ligament.
Fig. 22: Radiograph showing "Arcuate Sign" (Avulsion fracture of fibular styloid process)
Fig. 23: Sagittal Proton density fat suppressed MR image with ruptured patellar tendon.
Conclusion

Magnetic resonance imaging plays a pivotal role in evaluation of soft tissue injuries of knee joint. Familiarity with anatomy and specific injury patterns and their correlation with mechanism of trauma is important. Correct diagnosis and early treatment are crucial in preventing resultant complications including knee instability and progressive degenerative changes.

Personal information

References