MRI teaching atlas of recent post-traumatic injuries of the knee

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Learning objectives

Illustrate by means of different cases seen in our institution the main elementary traumatic lesions seen in meniscus, ligaments, muscles, tendons as well as cartilage lesions and subcortical bone injuries, emphasizing on the most frequent specific combination of injuries to recognize on MRI depending on mechanism of trauma (combination of forces) as well as on the main elements to describe that may influence the therapeutic management.

Background

- Normal MRI radioanatomy of the knee and main pitfalls to recognize MRI findings mimicking traumatic lesions.

1) Menisci:

- Fibrocartilaginous structures thick peripherally and thin centrally, semilunar (C-shaped)

- Superior surface concave, inferior flat: maximum congruency between femur and tibia

- Medial meniscus (MM): larger, wider posterior horn, and more "open" toward intercondylar notch

- Laterla meniscus (LM): smaller, more "closed" toward the notch

- Transverse or anterior intermeniscal ligament (noted in 44 to 58% of cases): usually connecting the two anterior horns

- Vascularity of both menisci: greatest near the periphery/almost non existant near free edge peripheral tears can be repaired, while central tears cannot

Pitfalls involving both menisci:

- Transverse ligament Fig. 3 on page 7: runs in Hoffa’s fat pad from one anterior horn to another/ Pseudotear appearance on LM or MM

#following it across Hoffa’s fat pad on sequential sagittal images helps differentiating it

Pitfalls involving the posterior horn of the lateral meniscus:
- Speckled anterior horn lateral meniscus: "torn" anterior horn aspect of the LM caused by fibers of the ACL inserting into the meniscus (60% of normal patients)

- Insertion of menisco femoral ligament of Humphry Fig. 1 on page 6 or Wrisberg Fig. 2 on page 7 on posterior horn of the LM mimicking a meniscal tear # following it on sequential sagittal images from the medial femoral condyle through the intercondylar notch/ finding usually limited to the single most medial image, and on the next lateral section the meniscus appears normal

- Pulsation artifact from the popliteal artery mimicking a tear of the posterior horn of the LM # swapping the phase and frequency before scanning

- Magic angle phenomenon: hazy appearance and diffuse intermediate signal of the posterior horn of LM in proton density or T1 weighted images, due to the slope upward of the posterior horn at an angle of about 55° (angle at which high signal of collagen structures begins to be seen)# reduce the 55° angle with a knee abduction

- Popliteous tendon pseudotear: Fig. 4 on page 8 appearance of vertical meniscal tear of the posterior horn of LM caused by popliteus tendon passing between the posterior horn of the LM and joint capsule.

2) Cruciate ligaments:

- Anterior cruciate ligament (ACL):

  - running parallel to the roof of the intercondylar notch, from the posteromedial aspect of lateral femoral condyle to the anteromedial tibial plateau

  - intraarticular but extrasynovial

  - divided into anteromedial bundles and posterolateral bundles

  - main function: to restrain anterior tibial translation relative to femur (anteromedial bundle), to restrain rotation in near full extension (posterolateral bundle)

  - MR imaging: low T1 and T2 signal, striated appearance lying within the lateral aspect of the intercondylar notch; straight anterior border nearly parallel to the Blumensaat line (roof of intercondylar notch)

  - Physiologic hypersignal at its tibial insertion

- Pitfalls in ACL acute injury:

  - Volume averaging of the ACL with other structures on the intercondylar notch (fluid, fat, bone) closely examine in multiple planes
-mucoid degeneration mimicking a tear #no associated injuries
-ganglia cysts: displace normal tendon fibers, associated with previous trauma and with mucoid degeneration. No instability/asymptomatic
-Absence or hypoplasia of the ACL: normal variant

-Posterior cruciate ligament (PCL):
-larger and stronger than ACL
-main function: to restrain posterior tibial translation relative to femur
-runs from medial side and medial roof of the intercondylar notch to the midline dorsal aspect of the tibial plateau (between meniscal roots)
-intraarticular but extrasynovial
-anteralateral and posteromedial bundles
-meniscofemoral ligaments of Humphrey and Wrisberg extend from the posterior horn of the LM to the medial femoral condyle, lying respectively anterior and posterior to the PCL
-MR Imaging: low T1 and T2 signal, near the midline of the knee, extending from the the femoral intercondylar notch to the posterior tibial plateau

-Pitfalls in PCL acute injury:
-magic angle artifact: foci of increased T1 weighted signal within the PCL if it is oriented 55° to the main magnetic field #no corresponding abnormal signal on proton density or T2-weighted sequences
-double PCL sign: caused by displaced bucket-handle tear of the MM lying parallel to the PCL on sagittal images

3)Collateral ligaments:

-Medial collateral ligament (MCL):
-originates from medial aspect of the distal femur and inserts on the medial aspect of proximal tibia
-fibers intimately linked with joint capsule, and the MM is directly attached to it
-extrasynovial structure

-**Lateral Collateral Ligament (LCL):**

-made up of many structures, only three are analysed by MRI: (posterior to anterior): biceps femoris tendon, fibulocollateral ligament and iliotibial band.

-the most posterior two insert on proximal fibula whereas the iliotibial band inserts on anterior tibia

• **Functional anatomy of the knee supporting structures and biomechanics of the forces responsible for main traumatic injuries:**

-Bones of the knee: little contribution to the stability of the joint.

-Static and dynamic stability of the knee are dependent on its supporting soft tissues: menisci, ligaments, tendons, muscles, and fascia.

-Supporting structures can be divided by location: anterior, medial, lateral, posterior, and central Fig. 5 on page 8

**Two critical areas for stability:**

- posteromedial corner: attachments of the semimembranosus tendon, the posterior joint capsule, and the posterior oblique ligament.

- posterolateral corner: complex, consisting of the joint capsule, arcuate ligament, fabellolateral ligament, and popliteus muscle and tendon.

-Both corners are major resistors of rotational and translational stresses, particularly in extension. Traumatic loss of one corner may allow unstable rotation of the knee joint, with a pivoting out around the other corner. Injury at the posterolateral corner, in particular, may lead to severe disability.

- **Forces responsible for injuries:**

- Most common pattern: flexion, valgus, and external rotation nearly half of all injuries (46%).

- Next in frequency: patterns of hyperextension with varus and flexion with posterior tibial translation, followed by the patterns of pure valgus, patellar dislocation and direct trauma.
- Pure varus and flexion, varus, and internal rotation (Segond fracture): rare (1%)

  • Technical protocol of exam in acute post traumatic lesions analysis:
    - Knee in extension
    - Reference sequences: fast-spin echo proton density sequences in sagittal, coronal and axial planes
    - T1-weighted sagittal plane
    - Slice thickness: 3 to 4 mm

Images for this section:
**Fig. 1:** Humphrey menisco femoral ligament lying just anterior to the PCL and thus mimicking a meniscal tear

![Image of Humphrey menisco femoral ligament](image)

**Fig. 2:** Posterior meniscofemoral ligament of Wrisberg lying posterior to the PCL. In only one slice, feature suggestive of meniscal peripheral tear

![Image of Posterior meniscofemoral ligament of Wrisberg](image)
**Fig. 3:** Transverse ligament. Image shows that hyper signal from the loose connective tissue (small arrow) between the meniscus and the transverse ligament (large black arrow) mimics a meniscal tear. Note also a meniscofemoral Humphry ligament (arrowhead).

**Fig. 4:** Popliteus tendon above the lateral meniscus mimicking a tear of its posterior horn.
Fig. 5: Functional anatomy of the knee joint, grouped by anterior, medial, posteromedial, posterior, posterolateral, lateral, and central supporting structures.
Imaging findings OR Procedure details

• Meniscal tears:
A meniscal tear only has significance when hypersignal clearly disrupts at least an articular surface of the meniscus

#definitive diagnosis of torn meniscus in about 90% of cases

#in 10 % of cases, inability to discern definitely: clinical examination and development with conservative care may help in arthroscopy decision

Description of meniscal tears should include:

- location on posterior horn, body or anterior horn

-involving of peripheral third of the meniscus (vascularized red zone) or inner two thirds or both

-extent of the tear: which meniscal surface-length

-type of meniscal tears: horizontal (oblique), vertical (longitudinal, radial or parrot-beak) or complex

Different types of meniscal tears:

Meniscal tears can be broadly divided into horizontal, vertical circumferential and vertical radial types. Combination of the main types are not unusual. Usually vertical tears are traumatic and horizontal tears are degenerative.

- horizontal or oblique tears (synonymous): tear parallel to tibial plateau, dividing meniscus into upper and lower segments.

Fig. 8: Horizontal (oblique) meniscal tear
**References:** Imaging, 15 (2003), 217-241 E 2003 The British Institute of Radiology

- **vertical longitudinal tear**: perpendicular to tibial plateau

![Vertical Longitudinal Tear](image)

**Fig. 6:** Vertical longitudinal (circumferential) tear

**References:** Imaging, 15 (2003), 217-241 E 2003 The British Institute of Radiology

#bucket-handle tear: 10% of meniscal tears and most common lesion in the locked knee: the free inner meniscal segment "flips" usually into the intercondylar notch; involves more frequently the MM

![Bucket-handle Meniscal Tear](image)

**Fig. 7:** Bucket-handle meniscal tear
-absent bow tie sign: only one body segment on sagittal images instead of two normal images seen through the meniscus, very sensitive sign in all cases
-displaced fragment usually seen on intercondylar notch or in front of the PCL (double PCL sign)
-anterior flipped meniscus sign: when the displaced fragment flips over the anterior horn of the meniscus
-irregular edge of the peripheral meniscal remnant that will appear abnormally small
-vertical radial tears or free edge tears: occur on a plane perpendicular to the long axis of the meniscus and perpendicular to the tibial plateau; usually symptomatic Fig. 11 on page 17 Fig. 12 on page 18

Fig. 9: Vertical radial meniscal tear
-absent bow tie sign also positive, but the second body segment has only a small gap rather than the large space seen in bucket-handle fractures, and no displaced fragment is seen

-ghost meniscus sign: is seen when the tear has completely traversed the meniscus with an MRI slice parallel to the tear: intermediate or grey signal (partial volume of the adjacent meniscal tissues) instead of normal meniscus; meniscus often extrudes off of the joint

cleft sign: seen when the MRI slice is perpendicular to the tear while the radial tear takes a truncated triangle appearance when the MRI slice is parallel to the same tear with a cleft
-Particular cases:

- **vertical parrot-beak tears** are radial at the inner meniscal edge and longitudinal more peripherally within the meniscus—Detection by MR imaging difficult
- **Flap tears**: displaced fragment from the superior or inferior surface of the meniscus. The displaced portion is usually easy to see on MRI.

-complex tears: tears having either two or more tear configurations or are not categorized easily into a certain type of tear

- **Cruciate ligaments acute injuries:**
  - **Anterior cruciate ligament**:  
    - most frequently: no normal fibers of the ACL identified through the intercondylar notch Fig. 14 on page 20
    - fibers seemingly intact but angle flatter than normal, making an angle >15° - with the roof of the intercondylar notch (fibers normally parallel) Fig. 15 on page 21
    - thickening of the ACL > 8 mm
    - Partial tear: intact fibres seen with some focal or diffuse hypersignal in the posterior portion of the ligament and/or laxity of the ACL seen as wavy or curved and/or signs of minor anterior translation of the tibia Fig. 13 on page 19 Fig. 16 on page 22

    - Frequent association with bone bruises involving the lateral femoral condyle and posterior lateral tibial plateau Fig. 17 on page 23

- **Posterior cruciate ligament:**
  - infrequently torn
  - no real disruption of the fibers but stretching
  - thicker than 6 mm
  - grey appearance on DP or T1-weighted images Fig. 18 on page 24, but no high signal on T2-weighted sequences #often missed Fig. 19 on page 25
- uncommon presentation (easier to diagnose): avulsion from tibial attachment

- **Collateral ligaments injuries:**

  **Medial Collateral ligament (MCL):** Fig. 22 on page 28

  - Three grades of injury describer clinically corresponding to MR appearance:
    - Grade 1: sprain # high signal of the soft tissues medial to the MCL
    - Grade 2: severe sprain or partial tear: high signal of the soft tissues medial to the MCL + high signal or partial disruption of MCL itself
    - Grade 3: complete tear # disruption of the MCL

  - Meniscocapsular separation: fluid between the MCL and the MM # needs immobilization or surgical repair

  **Lateral Collateral ligament (LCL):**

    - Less common than tears of the MCL
    - Often associated with injuries of other structures in in posterolateral corner of the knee: lesions of arcuate ligament, popliteofibular ligament, popliteus tendon and either ACL or PCL = near emergency Fig. 21 on page 27

- **Patellar and extensor system injuries:**
  - **Patellar contusions:**
    - Contusion at the anterior lateral femoral condyle, due to impaction of patella
    - Sometimes "kissing contusion" on the medial side of patella
    - Injury of medial retinaculum
    - Key finding: patellar cartilage+++ if missing # arthroscopic procedure while conservative treatment if normal cartilage

- **Hyperextensor system injuries:**
  - Associated with tears of the anterior third of the menisci and trabecular oedema in the anterior femoral condyle and tibial plateau.
- ACL, PCL, posterior capsule and popliteus muscle tears may be present. Most obvious sign of a tear of the posterior capsule: free fluid dissecting the tissue planes posteriorly.

- **Bone Injuries:**

  - subarticular high signal on T2-weighted images
  - may indicate additional internal derangements when they have a specific pattern
  - contusion pattern specific for an ACL tears:
    # contusion involving posterolateral aspect of tibial plateau (and sometimes kissing contusion on anterior lateral femoral condyle) = *pivot-shift phenomenon*
    # contusion involving posteromedial tibial plateau and sometimes medial femoral condyle) = *contrecoup* injuries

  - Bone contusions may progress to osteochondritis dissecans (bone necrosis) if not healed

- Small areas of bone marrow edema at the margins of the tibia and femur at the sites of meniscal and capsular attachments: usually indicate adjacent avulsion injury secondary to distraction or rotation.

- **Soft tissues injuries:**

  - tears of the plantaris tendon = *tennis leg*

  - focal fluid between the calf the soleus and medial head of gastrocnemius

  - associated with injured plantaris muscle and a torn ACL

**Distinctive MR imaging patterns depending on the mechanism:**

- association between acute ACL tears and bone bruises involving the lateral femoral condyle and posterior lateral tibial plateau

- less frequent association between ACL tears and medial-sided bone bruises
-Distinctly differing bone marrow edema patterns also accompany the flexion, varus, and internal rotation mechanism, which produces the Segond fracture

-Hyperextension injuries: broad areas of contiguous bone bruising at the anterior aspect of the knee. These hyperextension injuries involve the critical posteromedial and posterolateral corners of the knee, and description of the extent of soft-tissue injury is essential.

-Injuries that occur in flexion: less extensive bone bruising: shearing and rotational forces dominate over impaction forces with secondary rotation in flexion injuries explaining more frequent meniscal tears in this group of injuries.

Images for this section:
**Fig. 10:** Sagittal T2 DP -weighted slice buckled- hand meniscal lesion Arrow: displaced fragment seen on intercondylar notch in front of the PCL (double PCL sign)
**Fig. 11:** Sagittal proton density weighted slice: vertical radial tear of the anterior horn of medial meniscus Association with CLA tear in the same patient
Fig. 12: Vertical tear of medial meniscus
**Fig. 13:** Anterior cruciate ligament acute tear: diffuse hypersignal of fibers
Fig. 14: Complete tear of the ACL
Fig. 15: ACL acute complete tear Note the indirect sign of tear: flattering of the angle of ACL with fibers no longer parallel to the intercondylar notch roof
**Fig. 16:** Partial tear of the ACL: note the hypersignal associated with normal orientation of the fibers (parallel to intercondylar notch roof)
Fig. 17: Bone bruises lesions of lateral femoral condyle :may be an indirect sign for CLA tear ( rotational lesion)
Fig. 18: Acute PCL tear: decrease of signal with grey appearance on T1 imaging
Fig. 19: PCL acute tear: thickening of the PCL in T2W image without any signal change
Fig. 20: Coronal T2 weighted DP slice: lateral collateral ligament lesion
**Fig. 21:** Coronal T2 DP weighted slice: lateral collateral ligament lesion with hypersignal of fibers
**Fig. 22:** Coronal T2 DP weighted slice: partial tear of medial collateral ligament
Fig. 23: Bone bruise of the patella may be seen in patellar lateral dislocation out of the trochlear groove.
Conclusion

MRI is the top-grade exam in exploration of recent post-traumatic lesions of the knee. Accurate description of meniscal injuries, cruciate and collateral ligaments lesions, extensor system lesions and bone lesions may determinate the prognosis and help in treatment planification.

Personal Information

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