Lower Extremity Trauma: An Atlas of Radiologic Findings of ACL Injury

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Outline

- Our Patient Presentation
- Evaluation of Acute Knee Pain
- Appropriateness of Imaging for Acute Knee Pain
- Anatomy and Injuries of the ACL
- Primary Signs of ACL Injury
- Secondary Signs of ACL Injury
- Management of ACL Injury
History
- KJ is a 36-year-old male who presents to the ER with pain in his left knee
- While playing soccer yesterday, he felt his knee “twist” with part of his knee rotating in and part rotating out
- He also heard something “pop” in his knee
- No swelling or redness; just pain

Physical Exam
- Diffusely tender to palpation over knee, but without any swelling
- Positive Lachman test with significant laxity
Acute Knee Pain: Differential Diagnosis

- **Traumatic**
  - Fractures
  - Ligamentous or meniscal injury
  - Effusion or hemarthrosis

- **Non-traumatic**
  - Septic or inflammatory joint
  - Crystalline disease
  - OA
  - Bursitis
  - Patellofemoral pain syndrome
  - Baker’s cyst +/- rupture
Acute Knee Pain: Physical Exam Signs

- Inspection, Palpation, ROM
- Provocative Tests
  - MCL – Valgus Stress Test
  - LCL Complex – Varus Stress Test
  - PCL – Posterior Drawer Test
  - ACL – Anterior Drawer Test, Lachman Test
  - Menisci – McMurray Test, Apley Compression Test
  - Patella – Osmond-Clarke Test, Apprehension Test
Appropriateness of Imaging: Knee Rules

- **Ottawa Knee Rules**
  - X-rays are required for acute knee injury with any one of the following:
    - Age 55 years or older
    - Tenderness at head of fibula
    - Isolated tenderness of patella
    - Inability to flex to 90°
    - Inability to bear weight both immediately and in the emergency department (4 steps)

- **Pittsburgh Knee Rules**
  - X-rays are required for blunt trauma or a fall as mechanism of injury with either of the following:
    - Age younger than 12 years or older than 50 years
    - Inability to walk four weight-bearing steps in the emergency department
### Variant 2:

Patient any age (excluding infants): fall or twisting injury, with one or more of the following: focal tenderness, effusion, inability to bear weight. First study.

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<th>Radiologic Procedure</th>
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**Rating Scale:** 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate

**Relative Radiation Level**

### Variant 3:

Patient any age (excluding infants); fall or twisting injury with either no fracture or a second fracture seen on a radiograph, with one or more of the following: focal tenderness, effusion, inability to bear weight. Next study.

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*Relative Radiation Level*
Modalities of Imaging: X-Ray and CT

- **Plain Films**
  - Initial imaging modality of choice for evaluation of post-traumatic and acute knee pain or instability.
  - Four views (AP, lateral, merchant, and notch) may detect subtle fractures or bony avulsions caused by detachments of the cruciate or collateral ligaments and can confirm the direction of dislocation.
  - Can readily identify joint effusions

- **CT**
  - Comparable accuracy to that of MRI for the assessment of tibial plateau fractures.
  - Useful in looking for loose bodies and retro-patellar problems.
  - Multi-slice CT arthrography has a high diagnostic accuracy in detection of anterior cruciate ligament tears and associated meniscal lesions and articular cartilage pathology. However, MRI has largely replaced this modality.
Modalities of Imaging: MRI

- MRI
  - Investigation of choice for evaluation of post-traumatic and acute knee pain or instability, when available.
  - High accuracy in detection of:
    - Meniscal tears
    - Cruciate ligament tears
    - Collateral ligamentous injuries
    - Bone bruises
    - Osteochondral defects
    - Chondromalacia patellae as well as less common pathologies
  - Cost-effective in reducing the number of diagnostic arthroscopies.
  - Other advantages: non-invasive, no ionizing radiation, superior soft tissue contrast, ability to demonstrate both intra-articular and extra-articular abnormalities
  - Limitations: decreased diagnostic accuracy in patients with multiple injuries of the knee, high expense.
Our Patient: Plain Films

From PACS, BIDMC.
X-Ray: AP of Both Knees
Normal

From PACS, BIDMC.
X-Ray: Lateral of Left Knee
Normal
Increased signal within the ACL with complete disruption of ligament fibers, consistent with complete ACL Tear
Our Patient: Knee MRI 2

Increased, linear signal through the posterior horn of the medial meniscus extending to both sides of the articular surface, consistent with a tear.

From PACS, BIDMC. MRI: T2-Weighted Sagittal of Left Knee
Our Patient: Knee MRI 3

Increased signal around the MCL without disruption of fibers, consistent with Grade 1 MCL sprain

From PACS, BIDMC.
MRI: T2-Weighted Coronal of Left Knee
ACL: Anatomy and Role

- **Anatomy**
  - Originates along the medial wall of the lateral femoral condyle
  - Two bundles (anteromedial and posterolateral) that insert into the tibial plateau just anterior to the intercondyloid eminence (tibial spine)

- **Stabilization Functions**
  - Prevents anterior displacement of the tibia
  - Resists internal rotation of the knee
  - Resists hyperextension of the knee

ACL: Injuries and Mechanisms

- **Mechanism of injury**
  - Most commonly due to either significant deceleration, rotational, or hyperextension force
  - History will often include sudden stop or change of direction, landing from a jump, or trauma; patient may describe knee “giving way” or an audible “pop”
  - Pain is sudden in onset, and usually onset of effusion occurs within several hours

- **Associated injuries**
  - Important to assess all other ligaments and menisci in the knee by physical exam and imaging, as twisting or traumatic injuries will often damage other structures
  - Classically can see O'Donoghue's triad: Complete or partial tear of the anterior cruciate ligament, medial collateral ligament, and the medial meniscus
ACL: Grading Injuries

- **Grade 1 Tear**
  - aka Microscopic Tear
  - Intact ligament of normal thickness with surrounding edema

- **Grade 2 Tear**
  - aka Partial Tear
  - Thickened and/or partial disruption of the fibers of the ligament with an increased amount of surrounding edema

- **Grade 3 Tear**
  - aka Complete Tear
  - Complete disruption of the ligament with corresponding surrounding hemorrhage and edema.
Companion Patient 1: Grade 3 ACL Tear

Normal ACL

From PACS, BIDMC.
MRI: Proton-Density Sagittal of Left Knee

Grade 3 ACL Tear

From PACS, BIDMC.
MRI: Proton-Density Sagittal of Left Knee
ACL Tears: Primary Signs 1

- Discontinuity of the ACL, where the fibers of the ACL cannot be seen either in the sagittal or coronal plane.

From PACS, BIDMC.
MRI: Proton-Density Sagittal of Left Knee
ACL Tears: Primary Signs 2

- Discontinuity of the ACL, where the fibers of the ACL cannot be seen either in the sagittal or coronal plane.
- Abnormal ACL signal, consisting of isointensity on T1 and increased signal intensity on T2 either within the substance of the ACL or surrounding it.

From PACS, BIDMC.
MRI: T2-Weighted Sagittal of Left Knee
ACL Tears: Primary Signs

- Discontinuity of the ACL, where the fibers of the ACL cannot be seen either in the sagittal or coronal plane.
- Abnormal ACL signal, consisting of isointensity on T1 and an increased signal intensity on T2 either within the substance of the ACL or surrounding it.
- Abnormal contour of the ACL, demonstrated by fibers of the ACL not running parallel to the intercondylar line of Blumensaat.
ACL Tears: Secondary Signs

- Kissing Contusions
- Segond Fracture
- ACL Avulsion Fracture
- Anterior Tibial Translation
- Hyperbuckled PCL
- Uncovered Posterior Horn of Lateral Meniscus
- Deep Lateral Femoral Notch
Our Patient: Kissing Contusions

MRI: T2-Weighted Sagittal of Left Knee

Increased signal in lateral femoral condyle and posterior lateral tibial plateau

From PACS, BIDMC.
MRI: T2-Weighted Sagittal of Left Knee
Companion Patient 2: Kissing Contusions

Increased signal in lateral femoral condyle and posterior lateral tibial plateau

From PACS, BIDMC.
MRI: T2-Weighted Sagittal of Left Knee
Kissing Contusions: Anatomy and Significance

- Occurs due to anterior displacement of tibia as a result of ACL injury
- Contusion involves the mid to anterolateral femoral condyle and posterolateral tibial plateau
- Increased T2 signal attributable to subcortical microfracture, edema, or hemorrhage
Companion Patient 3: Segond Fracture

Elliptic fragment of bone adjacent to the lateral tibial plateau, with cortical irregularity of the tibial plateau

From PACS, BIDMC.
X-Ray: AP of Left Knee
Segond Fracture: Anatomy and Significance

- Small vertical avulsion of the proximal lateral tibia immediately distal to the tibial plateau, best seen on plain films as an elliptic fragment of bone parallel to the tibia
- Occurs at the tibial insertion of the middle third of the lateral capsular ligament
- Precipitating injury usually involves internal rotation combined with varus stress
- Is associated with a high incidence of coexisting ACL and meniscal injuries, likely due to mechanism of injury
- Tibial donor site should be identified to distinguish a Segond fracture from avulsion fracture of Gerdy’s tubercle
Companion Patient 4: ACL Avulsion Fracture (X-Ray)

Displaced bone fragment with cortical irregularity of adjacent tibial spine

From PACS, BIDMC.
X-Ray: Intercondylar Notch View of Right Knee
Companion Patient 4: ACL Avulsion Fracture (MRI)

From PACS, BIDMC.

MRI: T2-Weighted Sagittal of Right Knee

Displaced bone fragment with cortical irregularity of adjacent tibial spine

Increased signal surrounding bone fragment
Companion Patient 5: ACL Avulsion Fracture (MRI)

Displaced bone fragment with cortical irregularity of adjacent tibial spine

Increased signal surrounding bone fragment

From PACS, BIDMC.
MRI: T2-Weighted Sagittal of Right Knee
ACL Avulsion Fracture: Anatomy and Mechanism

- Usually occurs at the distal insertion site of the ACL just medial and anterior to the tibial eminence
- Occurs in a minority of cases, and is associated with Grade 1 & 2 injuries
- More common in children than adults, and mechanism varies
  - For children, usually occurs secondary to forced flexion of the knee with internal rotation of the tibia
  - For adults, results from severe hyperextension
ACL Avulsion Fracture: Imaging Findings

- Difficult to recognize on plain film
- When seen, appears as a tiny bone fragment in the intercondylar notch with cortical irregularity of the adjacent tibial eminence suggesting a donor site for the fragment
- Easier to see on MRI, with Meyers and McKeever classification
  - Type 1 – Minimally displaced fragment -> Conservative management
  - Types 2-4 – Increasing degrees of separation/rotation/comminution -> Arthroscopy recommended with possible internal fixation
Companion Patient 6: Anterior Tibial Translation

From PACS, BIDMC.

MRI: Proton-Density Sagittal of Left Knee

Posterior cortex of lateral tibial plateau

Posterior cortex of lateral femoral condyle

From PACS, BIDMC.
MRI: Proton-Density Sagittal of Left Knee
Anterior Tibial Translation: Imaging Findings

- Measured at the level of the midlateral femoral condyle
- Measured from the posterior cortex of the lateral tibial plateau to the posterior cortex of the lateral femoral condyle
- Distances > 5 mm are considered abnormal

MRI: Proton-Density Sagittal of Knee
Hyperbuckled PCL: Imaging Findings

- PCL is considered to be hyperbuckled if any portion of its posterosuperior border is concave.
- Alternatively, measure an angle created by lines placed parallel to the femoral portion of the PCL and tibial portion of the PCL.
  - Angle > 105 degrees is abnormal.
- Likely due to abnormal stresses on PCL after an ACL tear, particularly during hyperextension injuries.

Uncovered Posterior Horn of Lateral Meniscus: Imaging Findings

- Sign is present when a vertical line drawn tangent to the posterior cortical margin of the lateral tibial plateau intersects any part of the posterior horn of the lateral meniscus
- Related to anterior displacement of tibia during ACL injury

Depression of the lateral condylopatellar sulcus

From PACS, BIDMC.
X-Ray: Lateral of Left Knee
Depression of the lateral condylopatellar sulcus with osteochondral “step-off” defect

From PACS, BIDMC.
MRI: T2-Weighted Sagittal of Left Knee
Deep Lateral Femoral Notch: Imaging Findings

- Also known as the deep sulcus sign of the knee
- Characterized by an abnormally deep depression of the lateral condylopatellar sulcus
- Depth is calculated by drawing a tangent across the sulcus on the articulating surface of the lateral condyle, then measuring perpendicular from this line to the deepest point of the sulcus
- Depths greater than **1.5 mm** are considered abnormal
Companion Patient 7: Measurement of Deep Lateral Femoral Notch (X-Ray)

From PACS, BIDMC.

X-Ray: Lateral of Left Knee

Tangent across the sulcus on the articulating surface of the lateral condyle, with depth of sulcus measuring 2.50 mm
Deep Lateral Femoral Notch: Mechanism

- Attributed to an impacted osteochondral fracture, most often due to a complete ACL tear
  - A complete tear allows the posterior aspect of the lateral tibial plateau and the middle to anterior portion of the lateral femoral condyle to forcefully impact against one another due to anterior subluxation of the tibia. When forceful enough, this can cause an impacted fracture.

- This impaction fracture is readily apparent on lateral radiographs when present.

- Although this sign is a highly infrequent finding in patients with ACL tears, an abnormally deep lateral condylopatellar sulcus is highly suggestive of a torn ACL.
ACL Injuries: Management

- **Non-surgical treatment**
  - Braces, physical therapy
  - Often used as a bridge to surgery
  - May be only treatment necessary for the elderly, those with low physical activity, or Grade 1 tears with maintained stability

- **Surgical treatment**
  - Arthroscopic reconstruction is the definitive treatment
  - Torn ligament is replaced with tissue graft, which is often taken from either the patellar tendon, hamstring tendons, or quadriceps tendon
  - Post-surgical rehab is critical, and usually last 6+ months
Key Points

- ACL injuries commonly result from deceleration, rotational, and/or hyperextension forces.
- Evaluation of traumatic knee pain should begin with plain films, followed by MRI when appropriate.
- The three primary signs of ACL tears are best visualized on sagittal, T2-weighted or proton density knee MRI.
- There are multiple secondary signs of ACL tears, some of which, e.g. Segond fracture, can be visualized on plain films.
- Grading ACL injuries and identifying associated injuries to other knee structures using appropriate imaging techniques is vital to patient management.
References

Acknowledgements

- Dr. Jim S. Wu for providing companion cases