"Imaging findings in common traumatic pediatric knee injuries"

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Learning objectives

To identify common and uncommon plain radiograph and MR imaging findings in most frequent traumatic pediatric knee injuries.
Background

Knee injuries are relatively common in the pediatric population. Pattern of injury and imaging findings can differ from those found in adults.

Traumatic injuries may involve growth cartilage in pediatric patients and this is an important factor to consider in the subsequent treatment and prognosis.

Conventional radiography remains the initial imaging modality for children with knee pain but serious injuries may be overlooked. Lack of ionizing radiation, increased contrast resolution and multiplanar capabilities make MR an ideal imaging modality when clinically indicated.
Imaging findings OR Procedure details

Traumatic knee injuries can be divided into acute and chronic - overuse injuries. We reviewed the most important conventional radiography and MR imaging findings, typical patterns of injury, unique disorders and potential pitfalls in pediatric patients under 18 years of age, who underwent imaging at U-M C.S Mott Children's Hospital from June 2011 to July 2011. Most common injuries in our population were osteochondral lesion, transient patellar dislocation, avulsion fractures, cruciate ligament injuries, and specific pediatric entities such as Salter Harris type fractures and Osgood-Schlatter disease.

We show 14 cases of children aged between 9 and 17 years-old. Different conventional radiography views and MRI were obtained in each case.

Utilizing a 1.5 Tesla strenght magnet imaging system, the routine, multiplanar, multisequence non contrast University of Michigan knee protocol was performed which includes the following sequences and planes: localizer in three planes, sagittal proton density, sagittal 3D GRE, sagittal WATS, coronal and axial T2-weighted with fat-saturation.

LIGAMENTOUS INJURIES (FIG. 1)

- More frequent in adolescents than in younger children; mainly in girls likely to increased laxity, hormonal factors and relative valgus alignment.
- The most frequent ligamentous injury in the knee is a tear of the anterior cruciate ligament.
- Diagnostic criteria: Imaging findings show increased signal intensity and disruption pattern (Fig. 1 on page 8).

MENISCAL TEARS (FIG. 2, 3 AND 4)

- Rare in children with an open physis.
- Longitudinal tears and peripheral detachment are the most common injuries in pediatric patients.
- Diagnostic criteria: Similar MRI findings to those in adults, abnormal signal intensity within the meniscus.
- One type of meniscus tear is called a "bucket-handle" tear. These large tears tend to occur in younger patients, and are always traumatic injuries (compared to degenerative tears seen in patients with early signs of wear and tear in the knee). This term is related to a tear around the rim of the meniscus, causing the central portion to displace into the joint (Fig. 2 on page 8). One classic sign is "the double posterior cruciate ligament
(PCL) sign", which is seen as a low-signal-intensity band that is parallel and anteroinferior to the PCL (Fig. 3 on page 9).

- **Discoid meniscus** is a dysplastic meniscus lacking the normal morphology. It is an anatomic variant which predisposes to meniscal tears. Almost always lateral. It is a large meniscus with continuity of the anterior and posterior horns on sagittal images and medial extension into the intercondylar notch on coronal images (Fig. 4 on page 10). Covers more than 50 % of the tibial plateau.

**SALTER HARRIS FRACTURES** (FIGS. 5, 6 AND 7)

- Physeal fractures account for almost 20% of all fractures of the extremities in children. The physis is the weakest portion of immature bones.
- The Salter-Harris classification of physeal fractures classifies them according to the course of the fracture through the physis, metaphysis and epiphysis. Salter II fractures of the distal femur are the most common type diagnosed by MR imaging.
- **Diagnostic criteria:** Most physeal fractures at the knee are obvious on radiography and are seen as a radiolucent line (Fig. 5 on page 11); however, occasionally, fractures may be very subtle or occult on radiography. Salter III fracture is a fracture through growth plate and epiphysis. These fractures are seen as a linear signal abnormality within the epiphysis (low on T1-weighted, high on fluid-sensitive sequences) extending to the physis, widening with increased signal of the involved physis, adjacent bone marrow and soft tissue edema (Fig. 6 on page 12 and Fig. 7 on page 13).

**AVULSION FRACTURES** (FIGS. 8 TO 13)

- In the skeletally immature patient, the chondro-osseous tibial spine is the weakest aspect of the ACL complex. In some cases, stretching of the anterior cruciate ligament may result in avulsion of the tibial insertion (anterior tibial spine). This is a common sport-related preadolescent injury.
- Injuries of the PCL are less common than those of its anterior counterpart.
- **Diagnostic criteria:** Avulsions fractures are often subtle radiographically. A focal discontinuity of the tibial articular surface, joint effusion or a displaced bony fragment may be the only radiographic findings (Fig. 8 on page 14, Fig. 9 on page 15, Fig. 11 on page 17 and Fig. 12 on page 18). MR imaging allows visualization of the avulsed fragment in different planes. The fracture line can be appreciated on different sequences as a low signal intensity line. Ligament fibers are usually seen inserting onto the fragment (Fig. 10 on page 16 and Fig. 13 on page 19).

**IMPACTED FRACTURES** (FIGS. 14, 15 AND 16)
• An impacted fracture occurs when one end of a bone is driven into the end of another bone. These fractures are most common in children, mainly in the arms. Children are more susceptible to impacted fractures because they are more prone to falling and other impact-type accidents.

• Diagnostic criteria: Subchondral sclerosis may be the only radiographic finding (Fig. 14 on page 20). On MRI the fracture is seen as an abnormal linear low T2-weighted signal with adjacent bone marrow edema (Fig. 15 on page 21 and Fig. 16 on page 22).

**TRANSIENT PATELLAR DISLOCATION** (FIGS. 17 TO 24)

• Transient patellar dislocation occurs due to lateral dislocation of the patella from the femoral trochlea as a result of an intensive trauma. It usually occurs in adolescent patients during sport-related activities with direct trauma, valgus stress, or twisting injury of the knee. Spontaneous patellar relocation occurs in 50% to 75% of patients.

• Diagnostic criteria: Radiologic findings may be subtle and include small fractures of the medial patella or of the lateral femoral condyle, soft tissue swelling and joint effusion (Fig. 18 on page 24, Fig. 20 on page 26 and Fig. 22 on page 28).

MR imaging may detect joint effusion, bone marrow edema involving the inferomedial patella and lateral femoral condyle (Fig. 17 on page 23), cartilage injuries, and partial disruption of the medial retinaculum (Fig. 24 on page 30). Osteochondral fragments or intra-articular loose bodies are often seen (Fig. 19 on page 25, Fig. 21 on page 27 and Fig. 23 on page 29).

**STRESS FRACTURES** (FIGS. 25 AND 26)

• Stress fractures occur after repetitive trauma on a normal bone. In skeletally immature patients, the tibia is the most common site.

• Diagnostic criteria: A thick periosteal reaction and linear sclerosis in conventional radiography (Fig. 25 on page 31) and a linear low signal intensity on T1 (Fig. 26 on page 32) are important imaging findings related to stress fractures.

**OSGOOD-SCHACER DISEASE** (FIGS. 27 AND 28)

• Osgood-Schlatter disease is most common in active adolescent boys between 10 and 15 years of age participating in sports. It is usually a selflimited entity with a good prognosis, and the diagnosis is usually established clinically.

• Diagnostic criteria: Fragmentation of the tibial tubercle (Fig. 27 on page 33), high signal intensity in the tibial tubercle and thickening and edema of the adjacent patellar tendon and surrounding soft tissues (Fig. 28 on page 34).
OSTEOCHONDRITIS DISSECANS (FIGS. 29 TO 33)

- Osteochondritis dissecans is thought to be an osteochondral fracture secondary to avascular necrosis of an area of the subchondral bone and cartilage. In the knee, 75% of cases involve the posterolateral aspect of the medial femoral condyle, often extending to the intercondylar region. The peak incidence is around 12 to 13 years of age.
- **Diagnostic criteria:** Lucencies along the articular surfaces (Fig. 29 on page 35 and Fig. 31 on page 37), articular cartilage irregularities (Fig. 30 on page 36) and bone marrow edema. The presence of cystic areas within the donor site (Fig. 32 on page 38 and Fig. 33 on page 39) or free osseous fragment within the knee joint suggest instability.
**Fig. 1:** CASE 1. 14 years old female soccer player. Right knee pain and swelling when she twisted and pivoted her knee. SAGITAL PD: There is abnormal signal involving the midportion of the anterior cruciate ligament with nonvisualization of completely intact fibers (white arrow), concerning for disruption of the anterior cruciate ligament.

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**Fig. 2:** SAGITAL PD: A portion of the posterior horn of the medial meniscus (circle) is not seen in its normal anatomical position and has flipped anteromedially. Features are consistent torn posterior horn medial meniscus with flipped and displaced fragment.

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Fig. 3: SAGITAL PD: The double posterior cruciate ligament (PCL) sign is seen as a low-signal-intensity band (asterisk) that is parallel and anteroinferior to the PCL (arrowhead). It is associated with bucked-handled tears of the medial meniscus.

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Fig. 4: CASE 2. 14 years, male. Right knee pain that began when he was wrestling with one of his friends. He states he felt a pop associated with pain in the knee. CORONAL T2FS: Demonstration of lateral discoid meniscus extending into the intercondylar notch with diffuse abnormal signal abnormality (circle). Extensive medial femoral condyle bone marrow edema (asterisk).

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Fig. 5: CASE 3. 17-year-old male with history hyperextension left knee injury while he was playing soccer. FRONTAL VIEW of left knee: A nondisplaced fracture line (white arrow) is seen involving the medial growth plate (arrowhead), medial femoral condyle extending towards the intercondylar notch (Salter-Harris type III fracture).

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Fig. 6: CORONAL T2FS: There is an oblique, nondisplaced fracture (white arrow) involving the medial and anterior aspect of the medial femoral condyle. There is also extension through the distal femoral growth plate, which appears widened and with increased signal intensity. Significant adjacent bone marrow edema is noted. Mild knee joint effusion.

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**Fig. 7:** AXIAL T2FS: Findings consistent with a nondisplaced Salter-Harris III (white arrow) fracture involving the medial femoral condyle extending towards the intercondylar notch. Significant adjacent bone marrow edema.

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**Fig. 8:** CASE 4. 9-year-old girl, inability to completely extend the right knee after a trampoline accident. LATERAL VIEW of right knee: There is an osseous fragment (white arrow) in the knee joint space anterior to the tibial spine, consistent with avulsion fracture.

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**Fig. 9:** FRONTAL VIEW of right knee: Redemonstration of the bony fragment (white arrow) in the knee joint space, adjacent to the tibial spine, consistent with avulsion fracture.

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**Fig. 10:** SAGITAL PD: An ossific fragment (asterisk) anterior to the tibial spine adjacent to the ACL insertion onto the tibia consistent with avulsion injury. Fibers of the ACL (white arrow) are also seen.

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Fig. 11: CASE 5. 17-year-old young man, right knee pain after playing golf. LATERAL VIEW of right knee: Irregularity and ossific fragment (white arrow) at the intercondylar eminentia consistent with a possible PCL avulsion injury.

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**Fig. 12:** FRONTAL VIEW of right knee: Irregularity of the intercondylar eminentia (white arrow) consistent with an possible PCL avulsion injury.

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Fig. 13: SAGITAL PD: Abnormal signal intensity surrounding the tibial PCL attachment with a displacement fragment (asterisk) consistent with PCL avulsion injury. Fibers of the PCL (white arrow) are also seen.

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**Fig. 14:** CASE 6. 16-year-old female, right medial knee pain and swelling after the knee buckling and giving away while running on an indoor track. FRONTAL VIEW of right knee: Lateral tibial plateau subchondral sclerosis (white arrow) consistent with impacted fracture.

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**Fig. 15:** CORONAL T2FS: Within the lateral tibial plateau, there is abnormal linear low T2-weighted signal (white arrow), with adjacent bone marrow edema consistent with subchondral impacted fracture. There is associated signal abnormality and a frayed appearance to the overlying cartilage. However, there is no definite osteochondral lesion.

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Fig. 16: SAGITAL PD: Abnormal low signal intensity (white arrow) consistent with subchondral impaction fracture of the lateral tibial plateau.

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**Fig. 17:** CASE 7. 14 years old, male, important acute right knee pain during a basketball match. AXIAL T2FS: There is bone marrow edema involving the medial aspect of the patella (upper white arrow) and lateral femoral condyle (lower white arrow) with medial retinaculum signal abnormality that most likely represents partial tear, findings consistent with lateral patellar subluxation.

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Fig. 18: CASE 8. 14-year-old, female, right knee pain following a twisting injury to the knee while batting during a softball game. She states that she heard a pop and then fell to the ground. PATELLAR VIEW: There is a 4 mm osseous fragment (circle) adjacent to the medial aspect of the patella which likely represents a small avulsed fragment.

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Fig. 19: CORONAL T2FS: There is 10 mm osteochondral fragment (circle) adjacent to the patellar insertion of the medial retinaculum consistent with avulsion injury.

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Fig. 20: CASE 9. 15-year-old girl who was batting in softball and twisted her right knee. She had a pop anteriorly and medial onset of swelling. PATELLAR VIEW: A lenticular fragment of bone(circle) is identified within the lateral recess of the knee joint, adjacent to the lateral aspect of the lateral femoral condyle.

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Fig. 21: SAGITAL WATS: There is a large joint effusion (asterisk). The patella is laterally subluxated, in addition there is a displaced osteochondral fragment (circle) in the lateral aspect of the knee joint adjacent to the lateral femoral condyle. All these findings were consistent with lateral patellar subluxation with osteochondral avulsed displacement fragment.

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**Fig. 22:** CASE 10. Female, 15-year-old with pain and swelling left knee while playing a dancing game. LATERAL VIEW of left knee: There is a bony fragment (circle) in the left knee joint between the femoral epiphysis and patella. Moderate amount of knee joint effusion at the suprapatellar bursa with fluid-fluid level (asterisk).

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**Fig. 23:** SAGITAL PD: There is an intra articular osteochondral fragment (circle) and moderate joint effusion (asterisk).

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**Fig. 24:** AXIAL T2FS: Abnormal increased T2 weighted bone marrow signal is seen in the medial patella. There is also a displaced osteochondral fracture, with avulsion from the medial aspect of the patella (circle). Increased T2 weighted signal is present within the anterior portion of the medial retinaculum. Findings consistent with transient patellar dislocation-relocation mechanism with associated osteochondral fracture. Moderate amount of knee joint effusion with fluid-fluid level (asterisk).

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Fig. 25: CASE 11. 11 years old, male, athlete. Chronic right knee pain. LATERAL VIEW of right knee: There is thick periosteal reaction and linear sclerosis involving the proximal tibia (square) consistent with stress fracture.

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Fig. 26: CORONAL T1: There is a transverse low T1 signal abnormality to the proximal diaphysis of the right tibia (square) consistent with stress fracture.

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**Fig. 27:** CASE 12. 16-year-old, male, chronic left knee pain. LATERAL VIEW of left knee: There is irregularity and fragmentation involving the anterior tibial tuberosity with adjacent 5 mm well-corticated ossific fragment.

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**Fig. 28:** SAGITAL PD: There is irregularity at the insertion of the patellar tendon with fragmentation of the tibial tuberosity and abnormal high signal intensity in the distal patellar tendon (white arrow). Overall, findings are consistent with Osgood-Schlatter's disease.

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Fig. 29: CASE 13. 12 years-old, male, chronic left knee pain, golf player. FRONTAL VIEW of left knee: There is a lucency along the medial right femoral condyle articular surface (circle) consistent with osteochondritis dissecans. No obvious loose free osseous fragment is seen within the knee joint.

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Fig. 30: SAGITAL PD: There is a left medial femoral condyle osteochondral lesion (white arrow) with adjacent articular cartilage irregularity. There are no cystic changes or obvious free intra-articular fragments. All these findings are consisted with an stable osteochondral lesion.

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Fig. 31: CASE 14: Male, 13-year-old soccer player who has been having problems with right medial knee pain for the last 10 days. FRONTAL VIEW of right knee: Findings related to osteochondritis dissecans involving the articular surface of the medial femoral condyle near the intercondylar notch (circle).

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Fig. 32: CORONAL T2FS: Note is made of a 1.5 cm right posterior medial femoral condyle osteochondral lesion (white arrow) with adjacent articular cartilage irregularity, cystic changes and bone marrow edema suggesting unstable osteochondral lesion.

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Fig. 33: SAGITAL WATS: Osteochondral lesion involving the right medial femoral condyle with adjacent bone marrow edema. No obvious intra-articular foreign body. The presence of adjacent cystic changes (white arrows) suggests instability.

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Conclusion

Traumatic knee injuries are common in pediatric population.

Initial radiographic approach demonstrates fracture lines, cortical irregularities and malalignment. However, MR imaging is useful to detect ligamentous and soft tissue injuries as well as characterize osteochondral lesions.

The radiologist should be aware of common and often unique conventional radiographic and MR imaging findings in order to improve diagnostic accuracy.
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