Tip of the Iceberg: Subtle Findings on Traumatic Knee Radiographs Portend Significant Injury

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Abstract

Despite their low clinical yield, knee radiographs are among the most commonly acquired radiographic trauma studies in the emergency department. Although obvious fractures may be present, several subtler radiographic findings suggest internal derangement and significant injury.

In this review, we provide an overview of traumatic knee radiography, including anatomy, acquisition techniques, and pitfalls with associated magnetic resonance imaging correlation when available.

Despite their low clinical yield, knee radiographs are among the most commonly acquired radiographic trauma studies in the emergency department.[1,2] In a retrospective review of 1,967 patients with suspected acute knee injury, Stiell and colleagues[1] found that 74.1% had radiographs, and 5.2% were diagnosed with fractures.

Although obvious fractures may be present, several subtler findings suggest significant osseous and ligamentous injury. Avulsion injuries, commonly described in the literature, are often associated with internal derangement of the knee. Tibiofemoral dislocation, even if reduced, is highly associated with neurovascular injury.[3] Soft-tissue abnormalities, including lipohemarthrosis, may indicate radiographically occult fractures. In this review, we provide an overview of traumatic knee injuries resulting in subtle radiographic findings.

Radiographic Anatomy

An understanding of the anatomy of the knee as seen on plain radiographs is essential for the detection of both obvious and subtle injuries. Unlike magnetic resonance imaging (MRI), radiography provides less soft-tissue information, but it does provide exquisite detail of the osseous structures. Knowledge of tendinous and ligamentous insertions and origins allows the interpreting physician to predict which soft-tissue structures are involved based on avulsion patterns. Various anatomical structures should be recognized on the 2 most commonly acquired radiographic views, anteroposterior (AP) and lateral (**Figure 1**).

Standard Radiographic Views

Although authors have suggested that a normal lateral radiograph can be used to screen for a fracture after acute trauma, an AP view is often also obtained.[4] Other authors have suggested as many as 4 views for the routine evaluation of acute knee injury.[5] Each view of the knee highlights different regions of the knee and may provide better visualization of structures suspected to be injured (**Figures 2, 3**).

Avulsion and Impaction Injuries

Femur

A lateral condylopatellar sulcus impaction fracture has a high association with tearing of the anterior cruciate ligament (ACL). The radiographic sign diagnostic of this fracture is often referred to as a *deep sulcus sign* or a *lateral femoral notch sign*. The lateral femoral notch is a naturally occurring indentation resulting from the convergence of the 2 radii of curvature of the femoral articulations with the patella and tibia. To make this diagnosis on a lateral radiograph, a tangential line is drawn across the

Figure 1. Anteroposterior (AP) and lateral radiographs of the knee demonstrate the normal bony anatomy.

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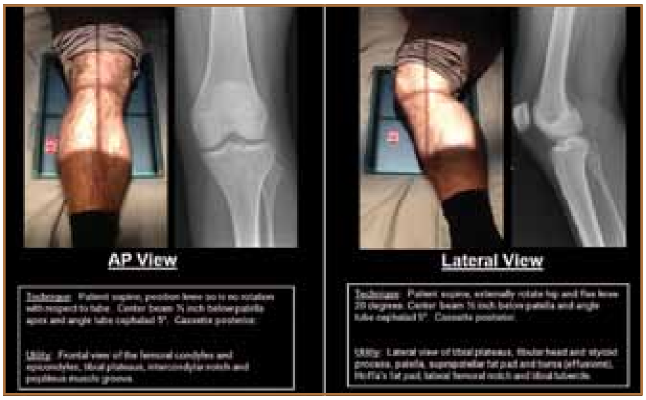

Figure 2. Method of acquisition of the AP and lateral knee radiographs and a description of each view's utility.

Figure 3. Method of acquisition of the sunrise, intercondylar fossa and oblique knee radiographs and a description of each view's utility.

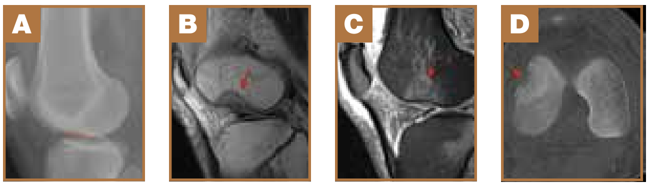

Figure 4. Lateral condylopatellar sulcus impaction fracture. (A) Line is drawn tangential to posterior-most cortex of lateral condyle across notch to other side of cortex, and then perpendicular line is drawn from that line to deepest point of notch. (B) Sagittal T_1-weighted (T1W) MRI shows impaction fracture involving lateral femoral condyle. (C) Proton-density–weighted (PDW) MRI shows same impaction fracture with high signal intensity in adjacent marrow caused by edema. There is also marrow edema in posterior lateral tibia. (D) Nonenhanced axial computed tomography (CT) confirms presence of impacted fracture involving lateral femoral condyle.

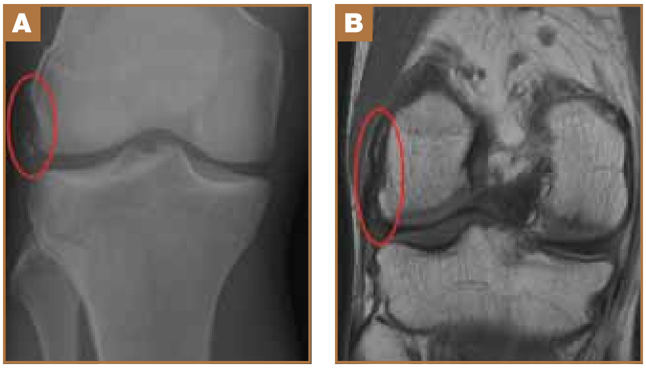

Figure 5. Popliteus avulsion fracture. (A) AP radiograph shows multiple ossific fragments (red oval) lateral to lateral femoral condyle. (B) Coronal T1W-MRI shows bone fragments (red oval) along region of popliteus muscle. At this point, injury was chronic, and little marrow edema was present. One of these fragments, in theory, could also have represented a cyamella.

notch from the anterior to posterior subchondral margins. A perpendicular line is then drawn from the tangential line to the deepest part of the notch (**Figures 4A-4D**). Normally, this perpendicular line representing the depth of the lateral femoral notch, should measure less than 1.5 mm. When the depth measures 1.5 mm to 2.0 mm, there is a 70% probability of an ACL injury.[6,7] This probability increases to nearly 100% when the notch depth exceeds 2.0 mm.[6,7] This injury may be seen in conjunction with injuries to the posterior lateral tibia in keeping with an underlying pivot-shift mechanism injury.[6]

Far less common than tears of the musculotendinous junction are bony avulsions from the proximal attachments of the popliteus muscle, which constitute less than 5% of popliteal tears; however, bony avulsions may be visible on plain radiographs (**Figures 5A, 5B**). The popliteus muscle is attached distal to the posteromedial aspect of the proximal tibial metaphysis. The muscle courses superolateral through the popliteal hiatus with its main proximal attachment at the lateral femoral condyle. The popliteofibular ligament is a slip from the popliteus tendon to the fibular styloid. There is also an attachment to the posterior horn of the lateral meniscus.[8,9] Brown and colleagues[10] reported that, in patients with popliteus injuries, 16% had ACL injuries, 29% posterior cruciate ligament (PCL) injuries, 45% medial meniscus injuries, 25% lateral meniscus injuries, and less than 10% had injuries to the medial collateral ligament (MCL) and the lateral collateral ligament (LCL).

Tibia

The iliotibial band, one of the primary stabilizers of the anterolateral knee, has a broad insertion along the anterolateral proximal tibia, including an anatomical landmark known as the *Gerdy tubercle*.[11,12] The Gerdy tubercle is seldom injured in isolation, and there is an associated risk for ACL injury, though the incidence of associated ACL injury has not been widely reported.[6,11-13] The avulsed fragment is typically more anterior than the Segond fracture (**Figures 6A-6C**).

First described in 1879 by Paul Segond, the Segond fracture is one of the most well-known traumatic avulsion fractures of the knee because of its strong association with ligamentous injury. It has been estimated that, in 75% to 100% of the cases in which this avulsion occurs, an ACL tear is present as well.[6,14] There is also a high incidence of concomitant meniscal injury, with reports ranging from 53% to 75%.[14] The AP view shows a vertically oriented sliver of

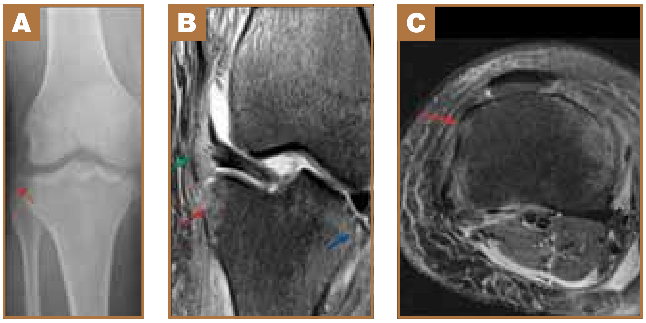

Figure 6. Gerdy tubercle avulsion fracture. (A) AP radiograph shows avulsed fragment adjacent to lateral tibial plateau (red arrow). (B) Coronal short tau inversion recovery (STIR) MRI shows marrow edema along anterolateral aspect of tibia (Gerdy tubercle) at insertion of iliotibial (IT) band (red arrow). There are irregularity and increased signal in torn IT band (green arrow). Also present are marrow edema of medial tibial plateau and, as seen in A (blue arrow), fracture of medial tibial plateau. (C) Axial STIR-MRI shows marrow edema at Gerdy tubercle (red arrow).

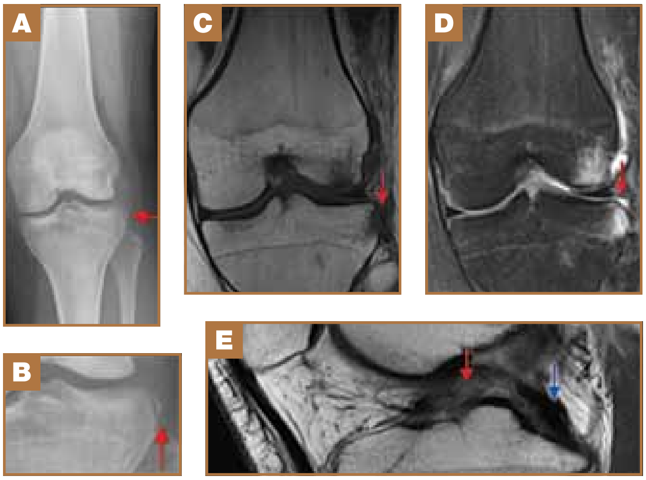

Figure 7. Segond avulsion fracture. (A) AP radiograph shows vertically oriented avulsed fragment adjacent to lateral tibial plateau (red arrow). (B) Magnified view of fracture (red arrow). (C) Coronal PDW-MRI shows corresponding cortical break and avulsed fragment (red arrow). (D) Coronal STIR-MRI shows avulsion and valgus-force–induced bone contusion pattern in this patient with pivot shift injury (red arrow). (E) Sagittal PDW-MRI shows complete tear of ACL (red arrow), commonly associated with Segond fracture. PCL is indicated by blue arrow.

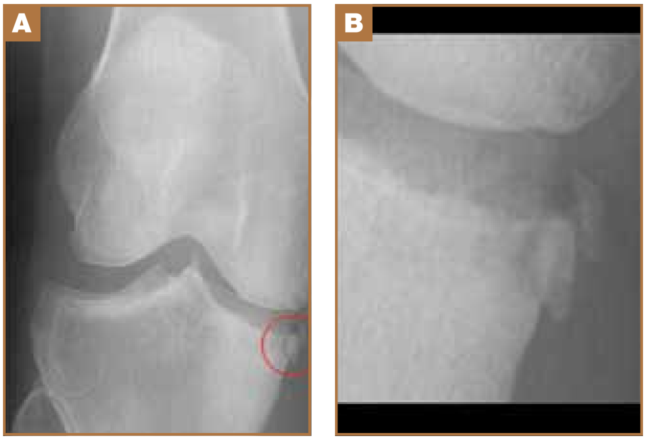

Figure 8. Medial/reverse Segond avulsion fracture. (A) AP radiograph shows vertically oriented avulsed fragment adjacent to medial tibial plateau (red circle). (B) Magnified view of A.

bone paralleling the long axis of the tibia adjacent to the articular surface of the lateral tibial plateau (**Figures 7A-7E**). MRI sensitivity in detecting the avulsed fragment is low, with 1 author reporting a range of 33% to 76%.[14] Previously, the avulsing structure thought to be responsible for the fracture was the middle third of the lateral capsular ligament.[6,11-14] However, a recent study using a cadaveric model found the Segond fragment avulsed by the anterior oblique band of the fibular collateral ligament and posterior fibers from the iliotibial band.[15] The strong association of the Segond fracture with concomitant ACL tears and meniscal injury makes it crucial for the diagnosis to be promptly made and an MRI advised. Failure to do so can result in chronic instability and osteoarthritis.[16]

One hundred seventeen years after the Segond fracture was described, Hall and Hochman[17] reported a similar–appearing avulsion fracture at the tibial insertion of the deep fibers of the MCL. This avulsion, known as the *reverse Segond* or *medial Segond fracture*, may be best seen on the AP view (**Figures 8A, 8B**).[6,12,15,17] This rare injury was described in 4 cases of patients who sustained high-energy injuries; the authors described injury to the PCL, the medial meniscus, and the MCL complex, with a rate of 100%.[15] However, the injury may also be indicative of more extensive internal derangement. Escobedo and colleagues[15] noted that, in all 3 of their patients, presence of the medial Segond fracture was seen in knees that either were dislocated or had such extensive injury they were deemed "dislocatable." As a knee dislocation can result in neurovascular injury, presence of a medial Segond fracture raises the possibility of a recent dislocation, even if the knee is reduced at time of examination.

Most cruciate ligamentous tears are intrasubstance injuries, but avulsion injuries also occur at the bony attachments. Avulsion of the ACL at its tibial attachment is more commonly seen in the pediatric population because the ligament is stronger than the physis.[6,12,18] Although both purely cartilaginous and osteochondral avulsions can occur, osteochondral injury is seen more often, and usually takes place at the tibial attachment site.[16,18,19] In adults with this avulsion, the mechanism of injury tends to be a high-energy force, as in a motor vehicle collision, and often there is structural damage beyond the ACL.[12,18] Radiographic manifestations of ACL avulsion include a fragment directly adjacent to the tibial eminence (**Figure 9A**), a fracture through the tibial eminence, or a bony defect at the tibial eminence donor site with the fragment displaced in the joint. MRI often shows an intact ACL attached to the avulsed fragment with marrow edema (**Figures 9B–9E**). Left undiagnosed, some of these injuries can heal. However, nonunion may occur if there is enough separation between the avulsed fragment and the donor site leading to chronic instability.[16,18,19] Meyers and McKeever[20] developed a classification system, based

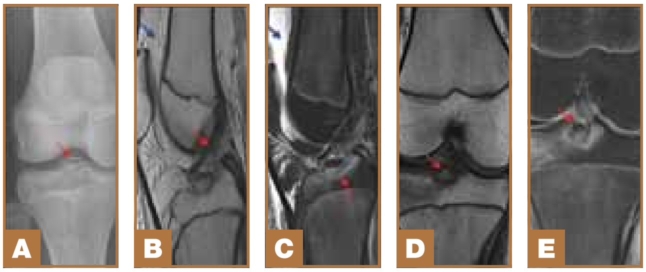

Figure 9. ACL avulsion fracture. (A) AP radiograph shows avulsed bone fragment superior to intercondylar/tibial eminence (red arrow). (B) Sagittal PDW-MRI with intact ACL (red arrow) attached to avulsed insertion site. Effusion is present (blue arrow). (C) Sagittal STIR-MRI with same findings as in B but with marrow edema better shown (red arrow). Effusion is indicated by blue arrow. (D) Coronal PDW-MRI shows avulsed bone at insertion of ACL in tibia (red arrow), which correlates with AP radiograph findings. (E) Coronal STIR-MRI with same findings as in D but with marrow edema better shown (red arrow).

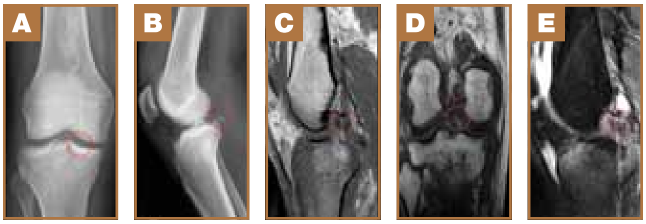

Figure 10. PCL avulsion fracture. (A) AP radiograph shows bone fragment superior to medial tibial plateau (red circle). (B) Lateral radiograph shows bone fragment posterior to tibial plateaus (red circle). (C) Sagittal PDW-MRI shows corresponding bone fragment (red circle). (D) Coronal PDW-MRI shows bone fragment superior to medial tibial spine (red circle). (E) Sagittal STIR-MRI with same findings as in C (red circle) but with edema pattern and effusion better shown.

on degree of displacement of the avulsed fragment, to determine which injuries in the pediatric population can be managed conservatively and which require either arthroscopic or open fixation. All tibial eminence fractures in adults require repair.

Figure 11. Semimembranosus avulsion fracture. Small ossific fragments (red circle) are present posterior to tibia just below joint line. Fragments are predominantly below joint line, which would be atypical for pure PCL avulsion fracture.

Although a significant emphasis has traditionally been placed on the integrity of the ACL, tears of the PCL can also lead to chronic instability.[21] This is particularly true in cases with concomitant injuries, with White and colleagues[16] reporting disruption of the posterolateral corner in up to 60% of cases with PCL tears. PCL injuries are most commonly intrasubstance tears rather than avulsions; when avulsions occur, the most common site is the tibial attachment.[22] Radiographically, the avulsed fragment is usually seen on the medial side of the joint; often, on the lateral view, it appears as a triangular avulsion just above the posterior tibial articular surface (**Figures 10A-10E**). In general, when there is an isolated PCL injury, many opt to treat conservatively. When there is concomitant ligamentous or meniscal injury detected on MRI, arthroscopic or open surgical reduction is indicated.[16]

The posteromedial corner of the knee is the territory between the medial edge of the PCL and the posterior edge of the MCL. The main components of this corner include the posterior oblique ligament, the semimembranosus tendon, the oblique popliteal ligament, and the posteromedial horn of the medial meniscus. The semimembranosus has 5 distal insertions, of which 2 insert onto the tibia and 3 insert onto soft-tissue structures. The pars reflexa courses deep to the MCL to insert on the tibia, and there is a direct insertion to the posteromedial tibia where the central tendon attaches to the infraglenoid tubercle.[12,23-25] A semimembranosus tendon bony avulsion, best seen on lateral radiographs as a thin bony fragment displaced posterosuperiorly (**Figure 11**), is associated with ACL and medial meniscal tears. Chan and colleagues[23] retrospectively reviewed cases of posteromedial tibial plateau fractures, including bony avulsions of the semimembranosus insertion, and noted a 100% association with ACL tears and a 50% association with tears of the medial meniscus.

Fibula

It is important to be familiar with the tendons and ligaments that insert on the proximal fibula in order to properly diagnose avulsion injuries. The biceps femoris tendon and inferior portion of the fibular collateral ligament merge and insert as a conjoint tendon onto the lateral fibular head. The fabellofibular ligament and arcuate ligament insert on the fibular styloid process to reinforce the posterolateral capsule. These structures, along with the popliteus muscle and tendon, the popliteofibular ligament, and the lateral gastrocnemius muscle, comprise the arcuate ligament complex, which stabilizes the posterolateral knee.[12,26] An ellipse-shaped fracture of the fibular styloid process with its long axis oriented parallel to the tibial articular surface, termed the *arcuate sign*, indicates an avulsion of the arcuate ligament complex insertion (**Figures 12A-12F**). The avulsed fragment may not be seen on the lateral view, as it is often hidden because of overlap with the tibia.[12,27] Among patients with radiographs showing the arcuate sign are reports of concomitant injury to the cruciate ligaments (89% of cases) and the menisci (50%).[27,28] In a series of 13 patients with arcuate complex avulsions after motor vehicle collisions, 100% had tears of the PCL and the MCL complex, though the authors noted that some of the MCL injuries were chronic. In this same series, there were injuries to both menisci and the LCL, though none of the patients had tears of the ACL.[27] However, injury to the ACL has also been described.[6]

When the fracture involves the more lateral aspect of the fibula, the attachment of the conjoint tendon may be involved. Although differentiating arcuate complex avulsions and fibular head avulsions can be radiographically challenging, the fibu-

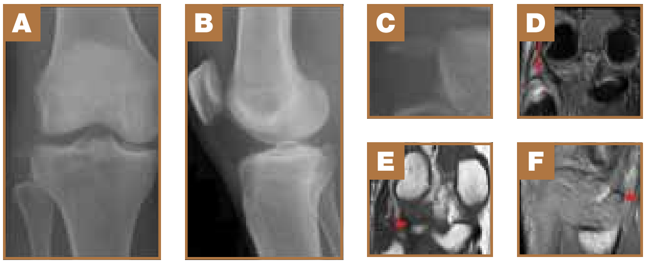

Figure 12. Fibular styloid process avulsion fracture/arcuate sign. (A) AP radiograph shows horizontally oriented, superiorly distracted avulsed fragment. (B) Lateral radiograph shows posterior irregular bone fragment. (C) Magnified view of avulsed fragment. (D) Coronal STIR-MRI shows increased signal in avulsed fragment, in fibula, and in soft-tissue at injury site (red arrow). (E) Coronal T1W-MRI shows horizontally oriented fragment distracted by arcuate ligament complex (red arrow). (F) Sagittal T1W-MRI shows distracted fracture fragment (red arrow).

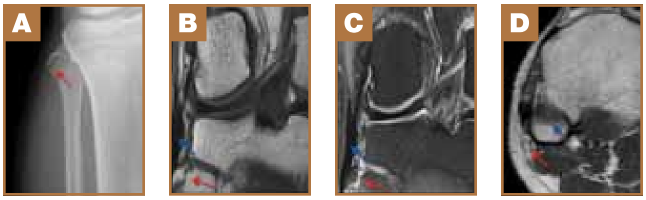

Figure 13. Fibular head avulsion fracture. (A) AP radiograph shows fracture (red arrow) along lateral margin of fibular head. (B) Coronal T1W-MRI shows obliquely oriented fracture along lateral margin of fibular head (red arrow). Conjoined tendon (blue arrow) made by tendon of long head of biceps femoris muscle and lateral collateral ligament inserts into avulsed fibular head fragment. (C) Coronal STIR-MRI shows obliquely oriented fracture along lateral margin of fibular head (red arrow). Conjoined tendon (blue arrow) inserts into avulsed fibular head fragment. Within conjoined tendon, there is no increased signal (no suggestion of tear). (D) Axial PDW-MRI shows close anatomical relationship between proximal fibula (blue arrow) and common peroneal nerve (red arrow). The patient in D is different from the patient in A–C.

lar head avulsion is usually larger and more displaced.[12,29,30] However, it can also be seen as subtler lateral fibular head avulsion (**Figures 13A-13D**). MRI can be used to evaluate the donor site and the ligamentous structures involved.[12] Presence of a posterolateral corner injury must be suggested when the arcuate sign or a fibular head fracture is identified, as missed posterolateral corner injuries are a common cause of ACL and PCL reconstruction failure.[6,12,31] In the setting of both proximal fibular fractures, there is a risk for injury to the common peroneal nerve, as it courses lateral to the proximal fibula.[12,13] In a retrospective study of 91 knees evaluated for peroneal nerve injury after dislocation, presence of a fibular head fracture had an odds ratio of 4.77 ($P = .012$) for nerve injury.[32] There have also been reports of associated anterior tibial artery damage.[12,13]

Patella

Injuries to the extensor mechanism may involve the quadriceps femoris tendon, the patella, the patellar tendon, or retinacular structures. These injuries may manifest differently for children compared with adults. In young athletes, an avulsion fracture

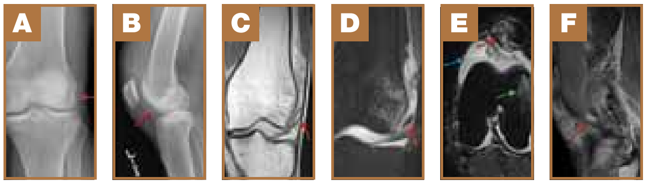

Figure 14. Transient lateral patellar dislocation. (A) Bone fragment lateral to lateral femoral condyle (red arrow). (B) Lateral radiograph shows less obvious bone fragment anterior to lateral femoral condyle (red arrow). (C) Coronal PDW-MRI shows lateral femoral condylar impaction fracture (red arrow). (D) Coronal STIR-MRI shows lateral femoral condylar impaction fracture with associated marrow edema (red arrow). (E) Axial STIR-MRI shows medial patellar impaction fracture with high-grade chondral injury (red arrow), lateral femoral condylar impaction fracture (green arrow), and lipohemarthrosis (blue arrow). (F) Sagittal PDW-MRI shows same bone fragment as seen in B (lateral radiograph).

of the superior pole of the patella indicates avulsion of the quadriceps femoris insertion caused by strong deceleration. Adults more often manifest injury to the proximal extensor mechanism at the musculotendinous junction secondary to repetitive microtrauma or systemic conditions, such as hyperparathyroidism, diabetes mellitus, gout, and collagen vascular diseases. In adults, the only radiographic finding may be thickening or discontinuity of the quadriceps femoris tendon.[12] In both adults and children, patella baja, or low patella, may also be seen. Multiple measurements have been proposed for diagnosing patella baja; one of the most widely accepted is the Insall-Salvati index. The diagnosis of patella baja is made when the ratio of the patellar tendon length to the patellar bony length is less than 0.8.[33]

Although fractures of the patellar body are easily recognized, injuries of the inferior extensor mechanism may be subtle and may warrant special attention in children. Patellar sleeve avulsions are acute injuries involving an osteochondral fracture of the inferior pole and are usually treated surgically.[12] The size of the avulsed fragment may be underestimated radiographically because the cartilage component is radiolucent. Patella alta, or a high-riding patella (Insall-Salvati ratio, > 1.2), may be seen.

Patellar dislocations are common, but their radiographic signs may not be obvious. In transient lateral patellar dislocation, the patella may spontaneously reduce by means of quadriceps muscular contraction. As a result, the medial patellar facet may fracture from compression or shearing, and there may be an associated fracture of the lateral femoral condyle.[34-36] AP radiographs of the knee may show a lateral femoral condylar impaction fracture (**Figures 14A-14F**), and sunrise/tangential radiographs of the patella may show a fracture of the medial patella.

Pitfalls

Several entities can mimic a traumatic knee avulsion fracture. The interpreting physician should be aware of these entities when determining the need for additional imaging. Evaluation for a suspected extensor mechanism injury can be challenging, especially in the absence of clinical information. A pediatric

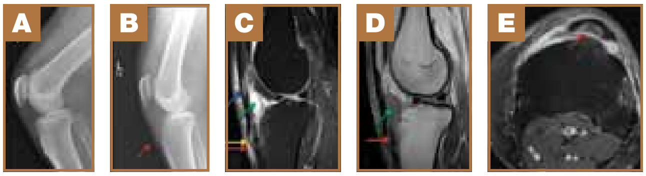

Figure 15. Tibial tuberosity injury. (A) Lateral radiograph of normal right knee for comparison. (B) Lateral radiograph of left knee with fragmentation of tibial tuberosity. Fragments are well corticated, but there is adjacent soft-tissue swelling (red arrow), and patient has point tenderness in this area after trauma. (C) Sagittal STIR-MRI shows marrow edema at tibial tuberosity, surrounding soft-tissue edema (red arrow), and fluid in infrapatellar bursa (green arrow). Near its insertion into tibial tuberosity, there is increased signal intensity within patellar tendon indicating partial tear (yellow arrow). Another partial tear is present proximally (blue arrow). (D) Sagittal PDW-MRI shows bone fragmentation (red arrow) and infrapatellar bursal fluid (green arrow). (E) Axial STIR-MRI shows avulsed fragment within patellar tendon (red arrow) and surrounding soft-tissue edema.

condition often referred to as Osgood-Schlatter disease, results from chronic traction on the anterior aspect of the tibial tuberosity.[37] The avulsion fractures originate from the epiphysis, and the overall appearance can vary from patient to patient.[13] The key imaging feature that establishes age of injury is presence of edema/soft-tissue swelling.[13,37] Detecting edema radiographically often requires comparison with the contralateral knee to determine what is normal for the patient (**Figures 15A, 15B**). It is unusual to have both tibial tuberosities injured simultaneously, though a case was reported.[38] MRI can also be used to help in the diagnosis, by noting an edema-like signal, but it is often unnecessary (**Figures 15C–15E**). In adults, a direct impact can also injure a previously fragmented tuberosity. In this case, presence of well-corticated bone fragments does not exclude the possibility of acute-on-chronic injury, and correlation with pain to palpation and the presence of edema on imaging studies aid in the exclusion of acute injury. "Jumper's knee," a tendinopathy related to repetitive stress at the patellar tendon origin, may manifest on radiographs only as thickening of the patellar tendon. A small osseous fragment at the inferior pole of the patella (**Figures 16A, 16B**), however, may indicate Sinding-Larsen-Johansson syndrome (SLJS) or a patellar sleeve avulsion injury. SLJS is a purely osseous chronic avulsion injury and is usually treated nonsurgically.

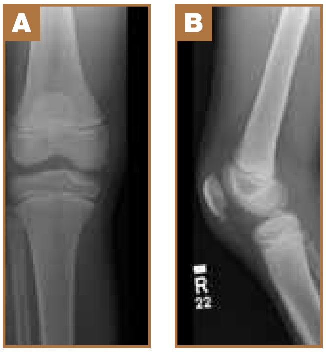

Figure 16. Sinding-Larsen-Johansson syndrome. (A) AP radiograph shows mild irregularity of inferior patella. (B) Lateral radiograph shows fragmented bone inferior to patella. There is no large effusion or significant soft-tissue swelling.

Ossicles, congenital variants and acquired nontraumatic pathology can mimic trauma. The fabella is a sesamoid bone associated with the lateral head of the gastrocnemius muscle (**Figures 17A-17D**). Uncommon in humans, the cyamella is a sesamoid associated with the popliteus tendon that may appear adjacent to the lateral femur condyle (**Figures 18A–18C**).[39] During ossification of the patella, accessory ossification centers may develop and result in the appearance of a bipartite or tripartite patella, with the superolateral bipartite patella being the most common form (**Figures 19A-19C**). In a review of 139 knees with developmental ossification center anomalies, 131 had bipartite patella, and 8 had tripartite patella.[40] Of these patellae, 81% had a small superolateral fragment with respect to the main patellar body. Pain has been associated with these patellar variants.[40] Deposition of calcium pyrophosphate in the articular cartilage of the joint (pseudogout) may result in calcific densities around the joint that could be confused with an avulsion injury. However, this calcification tends to be more linear and follows the course of the articular cartilage.[41] Rarely, a meniscal ossicle can pose a diagnostic dilemma.

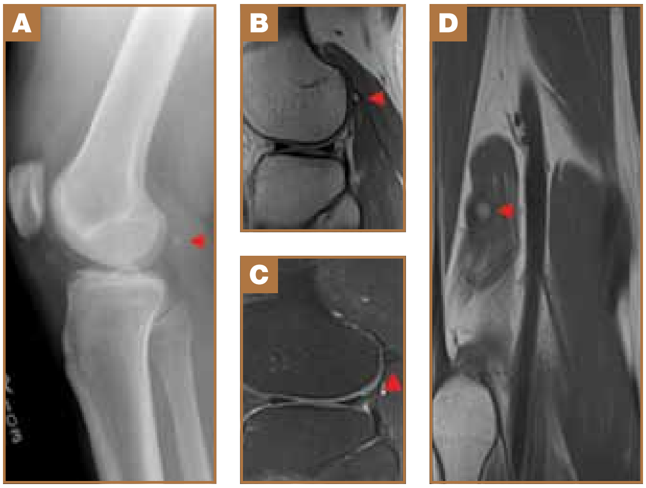

Figure 17. Fabella. (A) Lateral radiograph shows corticated posterior ossicle. (B) Sagittal PDW-MRI shows same corticated ossicle within lateral head of gastrocnemius. (C) Sagittal STIR-MRI confirms fatty marrow in ossicle. (D) Coronal PDW-MRI shows ossicle within lateral head of gastrocnemius.

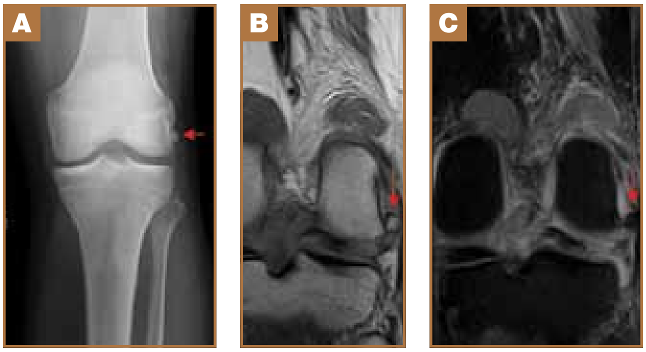

Figure 18. Cyamella. (A) AP radiograph shows corticated ossicle adjacent to popliteus muscle groove. (B) Coronal PDW-MRI shows same corticated ossicle within popliteus muscle. (C) Coronal STIR-MRI confirms fatty marrow in ossicle.

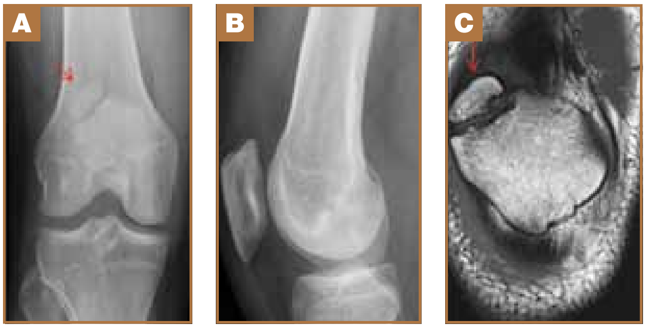

Figure 19. Bipartite patella. (A) AP radiograph shows well-corticated bone fragment superolateral to main patellar body (red arrow). (B) Lateral radiograph shows irregular contour to superior aspect of patella. (C) Coronal T1W-MRI shows well-corticated fragment in typical location of bipartite patella (red arrow).

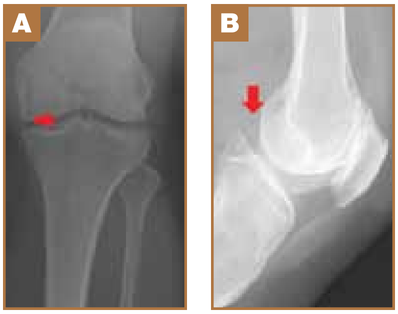

Figure 20. Meniscal ossicle. (A) AP radiograph shows well-corticated rounded ossicle projecting over medial compartment (red arrow). (B) Lateral radiograph shows well-corticated rounded ossicle projecting posteriorly over joint space (red arrow).

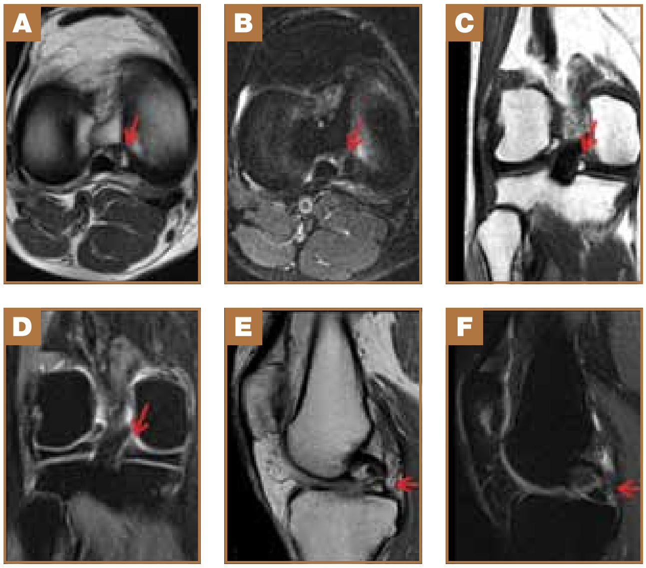

Figure 21. Meniscal ossicle (patient different from patient in Figure 19). (A) Axial PDW-MRI shows ossicle surrounded by meniscus within posterior horn of medial meniscus (red arrow). (B) Axial STIR-MRI shows same ossicle with marrow saturated (red arrow). (C) Coronal PDW-MRI shows ossicle within medial meniscus (red arrow). (D) Coronal STIR-MRI with saturation of ossicle marrow signal (red arrow). (E) Sagittal PDW-MRI shows ossicle within posterior horn (red arrow). (F) Sagittal STIR-MRI with saturation of ossicle marrow signal (red arrow).

Table. **Fracture Overview**[a]

Fracture Type	Donor	Common Concomitant Injuries	Avulsing Structure
Segond	Tibia	ACL (75%-100%) Lateral meniscus (33%)	LCL, parts of FCL and IT band, site proximal and lateral to Gerdy's tubercle
Medial Segond	Tibia	PCL (100%) Medial meniscus (100%) ACL (50%)	Meniscotibial ligament of the MCL complex
ACL avulsion	Tibia	N/A	ACL (in skeletal immature patients)
Semimembranosus avulsion	Tibia	ACL	Semimembranosus tendon
IT band avulsion	Tibia	ACL LCL	IT band
PCL avulsion	Tibia	PCL MCL LCL Medial and lateral menisci	PCL
Lateral Condylopatellar Impaction Fracture	Femur	ACL (70%-100%)	No avulsion; impaction fracture
Fibular head avulsion	Fibula	LCL Peroneal nerve Anterior tibial artery	Biceps femoris, conjoint tendon
Fibular styloid process avulsion	Fibula	ACL (72%) PCL (67%) Peroneal nerve MCL (22%) IT band (22%) Medial meniscus (28%) Lateral meniscus (6%) Popliteus muscle (33%) LCL (28%) Biceps femoris muscle tendon	Arcuate ligament complex

Abbreviations: ACL, anterior cruciate ligament; FCL, fibular collateral ligament; IT band, iliotibial band; LCL, lateral collateral ligament; MCL, medial collateral ligament; N/A, not applicable; PCL, posterior cruciate ligament.
[a]Many studies that describe percentages have small sample sizes.

This is a rare accessory ossicle within the meniscus itself, most commonly seen in the expected region of the posterior horn of the medial meniscus (**Figures 20A, 20B, 21A-21F**). Other considerations in the differential diagnosis include calcified debris within Baker cyst, loose bodies within joint or popliteus tendon sheath, chondromas of Hoffa fat pad, and osteochondromatosis.

Discussion

After trauma, presence of a subtle bone fragment around the knee may herald the presence of significant damage to the stabilizing soft-tissue structures of the knee. The **Table** lists the common radiographically detected subtle traumatic knee injuries along with structures most often concomitantly damaged. Failure to make a prompt diagnosis could result in chronic instability and predisposition to failed delayed attempts at repair. However, not every small ossific fragment around the knee indicates acute trauma or internal derangement. Awareness of the particular radiographic findings that can distinguish acute avulsion injuries from potential mimickers, coupled with clinical history and physical examination findings, should allow the treating physician to make the correct diagnosis and implement appropriate management strategies.

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References

1. Stiell IG, Wells GA, McDowell I, et al. Use of radiography in acute knee injuries: need for clinical decision rules. *Acad Emerg Med*. 1995;2(11):966-973.
2. Bachmann LM, Haberzeth S, Steurer J, ter Riet G. The accuracy of the Ottawa knee rule to rule out knee fractures: a systematic review. *Ann Intern Med*. 2004;140(2):121-124.
3. Kapur S, Wissman RD, Robertson M, Verma S, Kreeger MC, Oostveen RJ. Acute knee dislocation: review of an elusive entity. *Curr Probl Diagn Radiol*. 2009;38(6):237-250.
4. Verma A, Su A, Golin AM, O'Marrah B, Amorosa JK. A screening method for knee trauma. *Acad Radiol*. 2001;8(5):392-397.
5. Gray SD, Kaplan PA, Dussault RG, et al. Acute knee trauma: how many plain film views are necessary for the initial examination? *Skeletal Radiol*. 1997;26(5):298-302.
6. Miller LS, Yu JS. Radiographic indicators of acute ligament injuries of the knee: a mechanistic approach. *Emerg Radiol*. 2010;17(6):435-444.
7. Pao DG. The lateral femoral notch sign. *Radiology*. 2001;219(3):800-801.
8. Stäubli HU, Birrer S. The popliteus tendon and its fascicles at the popliteal hiatus: gross anatomy and functional arthroscopic evaluation with and without anterior cruciate ligament deficiency. *Arthroscopy*. 1990;6(3):209-220.
9. Bencardino JT, Rosenberg ZS, Brown RR, Hassankhani A, Lustrin ES, Beltran J. Traumatic musculotendinous injuries of the knee: diagnosis with MR imaging. *Radiographics*. 2000;20(spec no):S103-S120.
10. Brown TR, Quinn SF, Wensel JP, Kim JH, Demlow T. Diagnosis of popliteus injuries with MR imaging. *Skeletal Radiol*. 1995;24(7):511-514.
11. Campos JC, Chung CB, Lektrakul N, et al. Pathogenesis of the Segond fracture: anatomic and MR imaging evidence of an iliotibial tract or anterior oblique band avulsion. *Radiology*. 2001;219(2):381-386.
12. Gottsegen CJ, Eyer BA, White EA, Learch TJ, Forrester D. Avulsion fractures of the knee: imaging findings and clinical significance. *Radiographics*. 2008;28(6):1755-1770.
13. Capps GW, Hayes CW. Easily missed injuries around the knee. *Radiographics*. 1994;14(6):1191-1210.
14. Boutry N, Dupont S, Glaude E, Demondion X, Laffargue P, Cotten A. Segond fracture revealed by ultrasonography. *J Ultrasound Med*. 2005;24(10):1431-1435.
15. Escobedo EM, Mills WJ, Hunter JC. The "reverse Segond" fracture: association with a tear of the posterior cruciate ligament and medial meniscus. *AJR Am J Roentgenol*. 2002;178(4):979-983.
16. White EA, Patel DB, Matcuk GR, et al. Cruciate ligament avulsion fractures: anatomy, biomechanics, injury patterns, and approach to management. *Emerg Radiol*. 2013;20(5):429-440.
17. Hall FM, Hochman MG. Medial Segond-type fracture: cortical avulsion off the medial tibial plateau associated with tears of the posterior cruciate ligament and medial meniscus. *Skeletal Radiol*. 1997;26(9):553-555.
18. Bengtson H, Giangarra C. Osteochondral avulsion fracture of the anterior cruciate ligament femoral origin in a 10-year-old child: a case report. *J Athl Train*. 2011;46(4):451-455.
19. Mall NA, Paletta GA. Pediatric ACL injuries: evaluation and management. *Curr Rev Musculoskelet Med*. 2013;6(2):132-140.
20. Meyers MH, McKeever FM. Fracture of the intercondylar eminence of the tibia. *J Bone Joint Surg Am*. 1970;52(8):1677-1684.
21. Sonin AH, Fitzgerald SW, Hoff FL, Friedman H, Bresler ME. MR imaging of the posterior cruciate ligament: normal, abnormal, and associated injury patterns. *Radiographics*. 1995;15(3):551-561.
22. Xu Z, Chen D, Shi D, Jiang Q. Case report: osteochondral avulsion fracture of the posteromedial bundle of the PCL in knee hyperflexion. *Clin Orthop*. 2012;470(12):3616-3623.
23. Chan KK, Resnick D, Goodwin D, Seeger LL. Posteromedial tibial plateau injury including avulsion fracture of the semimembranous tendon insertion site: ancillary sign of anterior cruciate ligament tear at MR imaging. *Radiology*. 1999;211(3):754-758.
24. Loredo R, Hodler J, Pedowitz R, Yeh LR, Trudell D, Resnick D. Posteromedial corner of the knee: MR imaging with gross anatomic correlation. *Skeletal Radiol*. 1999;28(6):305-311.
25. Sims WF, Jacobson KE. The posteromedial corner of the knee: medial-sided injury patterns revisited. *Am J Sports Med*. 2004;32(2):337-345.
26. Recondo JA, Salvador E, Villanúa JA, Barrera MC, Gervás C, Alústiza JM. Lateral stabilizing structures of the knee: functional anatomy and injuries assessed with MR imaging. *Radiographics*. 2000;20(spec no):S91-S102.
27. Huang GS, Yu JS, Munshi M, et al. Avulsion fracture of the head of the fibula (the "arcuate" sign): MR imaging findings predictive of injuries to the posterolateral ligaments and posterior cruciate ligament. *AJR Am J Roentgenol*. 2003;180(2):381-387.
28. Juhng SK, Lee JK, Choi SS, Yoon KH, Roh BS, Won JJ. MR evaluation of the "arcuate" sign of posterolateral knee instability. *AJR Am J Roentgenol*. 2002;178(3):583-588.
29. Oh HK, Kim JH, Lee CS, Singh PK, Wang KH, Nha KW. Isolated avulsion fracture of the fibular head: a new fixation technique using a suture anchor. *Orthopedics*. 2011;34(2):100-104.
30. Strub WM. The arcuate sign. *Radiology*. 2007;244(2):620-621.
31. Fleming RE Jr, Blatz DJ, McCarroll JR. Posterior problems in the knee. Posterior cruciate insufficiency and posterolateral rotatory insufficiency. *Am J Sports Med*. 1981;9(2):107-113.
32. Peskun CJ, Chahal J, Steinfeld ZY, Whelan DB. Risk factors for peroneal nerve injury and recovery in knee dislocation. *Clin Orthop*. 2012;470(3):774-778.
33. Shabshin N, Schweitzer ME, Morrison WB, Parker L. MRI criteria for patella alta and baja. *Skeletal Radiol*. 2004;33(8):445-450.
34. Delzell PB, Schils JP, Recht MP. Subtle fractures about the knee: innocuous-appearing yet indicative of significant internal derangement. *AJR Am J Roentgenol*. 1996;167(3):699-703.
35. Nomura E, Inoue M, Kurimura M. Chondral and osteochondral injuries associated with acute patellar dislocation. *Arthroscopy*. 2003;19(7):717-721.
36. Stefancin JJ, Parker RD. First-time traumatic patellar dislocation: a sys-

tematic review. *Clin Orthop*. 2007;(455):93-101.
37. Dwek JR, Chung CB. The patellar extensor apparatus of the knee. *Pediatr Radiol*. 2008;38(9):925-935.
38. Georgiou G, Dimitrakopoulou A, Siapkara A, Kazakos K, Provelengios S, Dounis E. Simultaneous bilateral tibial tubercle avulsion fracture in an adolescent: a case report and review of the literature. *Knee Surg Sports Traumatol Arthrosc*. 2007;15(2):147-149.
39. Akansel G, Inan N, Sarisoy HT, Anik Y, Akansel S. Popliteus muscle sesamoid bone (cyamella): appearance on radiographs, CT and MRI. *Surg Radiol Anat*. 2006;28(6):642-645.
40. Oohashi Y, Koshino T, Oohashi Y. Clinical features and classification of bipartite or tripartite patella. *Knee Surg Sports Traumatol Arthrosc*. 2010;18(11):1465-1469.
41. Sagarin MJ. Pseudogout. *J Emerg Med*. 2000;18(3):373-374.

This paper will be judged for the Resident Writer's Award.