Imaging of the Knee Extensor Mechanism

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Introduction:

This handout accompanies a presentation at the Knee Imaging Multisession Course on Tuesday, 11/29/11 at the RSNA Annual Meeting. Due to time limitations, there will be no discussion of most abnormalities of the patella, including acute fractures, osteochondritis dissecans, and dorsal defect of the patella. Undoubtedly, the remaining information in this handout will be more complete than I will be able to be in my 20-minute presentation.

Anatomy, Normal Appearance, and Function:

The primary structures of the knee extensor mechanism are the quadriceps tendon and the patellar ligament/tendon. The quadriceps tendon is a multi-layered tendon that receives contributions from the four muscles that comprise the quadriceps femoris: the rectus femoris, the vastus medialis, the vastus intermedius, and the vastus lateralis. The layers of the distal quadriceps tendon are often interspersed with fibrofatty connective tissue, so the appearance on magnetic resonance (MR) imaging will not be homogenously black, as with some tendons, but will have longitudinal streaks of intermediate signal on most sequences. Most of the fibers of the quadriceps tendon insert on the superior pole of the patella; however, some of the fibers contributed by the rectus femoris continue over the anterior surface of the patella, forming an aponeurosis that connects to the patellar ligament. As such, the patella is considered a sesamoid bone within the extensor mechanism tendons.

The infrapatellar component of the extensor mechanism is the patellar ligament, also known as the patellar tendon. The patellar ligament originates at the lower pole of the patella, where it has contributions from the aponeurosis mentioned above, and inserts on an anterior prominence of the proximal tibia, the tibial tubercle. Because of magic angle phenomenon and interspersed non-tendinous fibers, the proximal portion of the patellar ligament may also have heterogeneous signal on MRI and not be completely low signal, especially along its posterior margin.

The medial patellar restraints include the vastus medialis obliquus (VMO, most distal portion of the vastus medialis), medial patellofemoral ligament, medial retinaculum, and medial patellotibial ligament; these will be discussed in more detail in the section on

transient dislocation of the patella. The primary lateral restraints are the lateral retinaculum and lateral patellofemoral ligament.
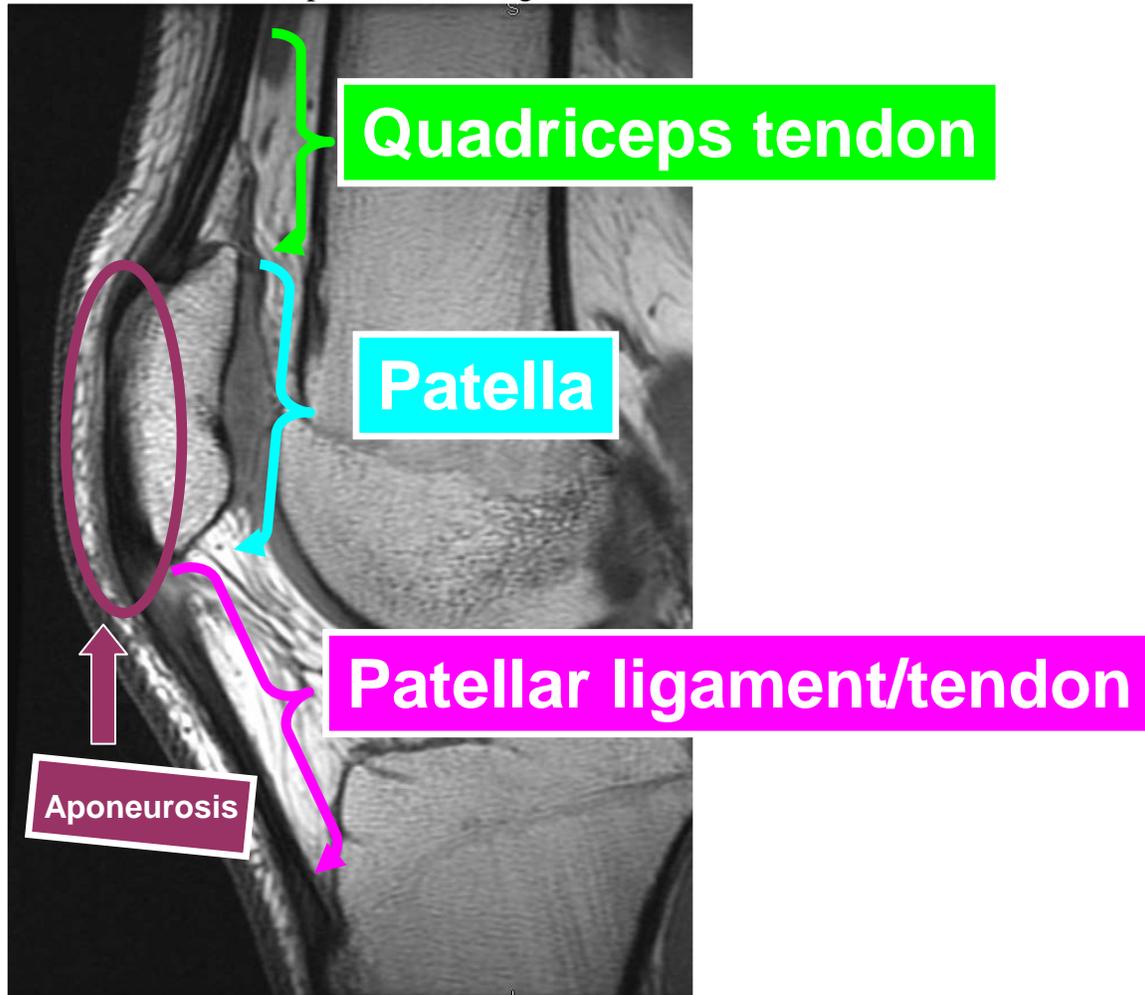

Figure 1: Anatomy of the extensor mechanism

As its name implies, the primary function of the extensor mechanism is to extend the knee. The extensor mechanism also stabilizes the knee joint, especially during deceleration and when ambulating downhill. The patella fits into the groove of the trochlea on the anterior femur and its smooth cartilage surfaces allow the extensor mechanism to glide safely over the front of the knee.

Tendon/Ligament Injuries:

The tendinous portions of the extensor mechanism may suffer acute or chronic injuries, or both.

Acute Injuries:

Acute tears of the quadriceps tendon usually happen at the attachment to the superior pole of the patella or just proximal to this. Complete tears typically occur in patients over the age of 40 and are not the result of direct trauma. These tears usually take place in the setting of chronic tendinopathy and often happen in patients with predisposing factors such as diabetes mellitus, gout, hyperparathyroidism, connective tissue disorders, and corticosteroid use. They are usually clinically obvious based on the history of the injury and physical exam demonstrating lack of active extension capability and a palpable gap in the tendon. Partial tears may be higher or lower grade. For both partial and complete tears, many will require imaging with MRI or ultrasound (U/S). Complete tears demonstrate an obvious gap between the tendon and the top of the patella or the distal stump fibers, with extensive hemorrhage in the gap. Partial tears will demonstrate variable percentages of intact fibers throughout the length of the tendon; intact fibers should be low signal on all sequences. Dictations should include a rough percentage of intact fibers in partial tears or describe the size of the gap/degree of retraction in complete tears.
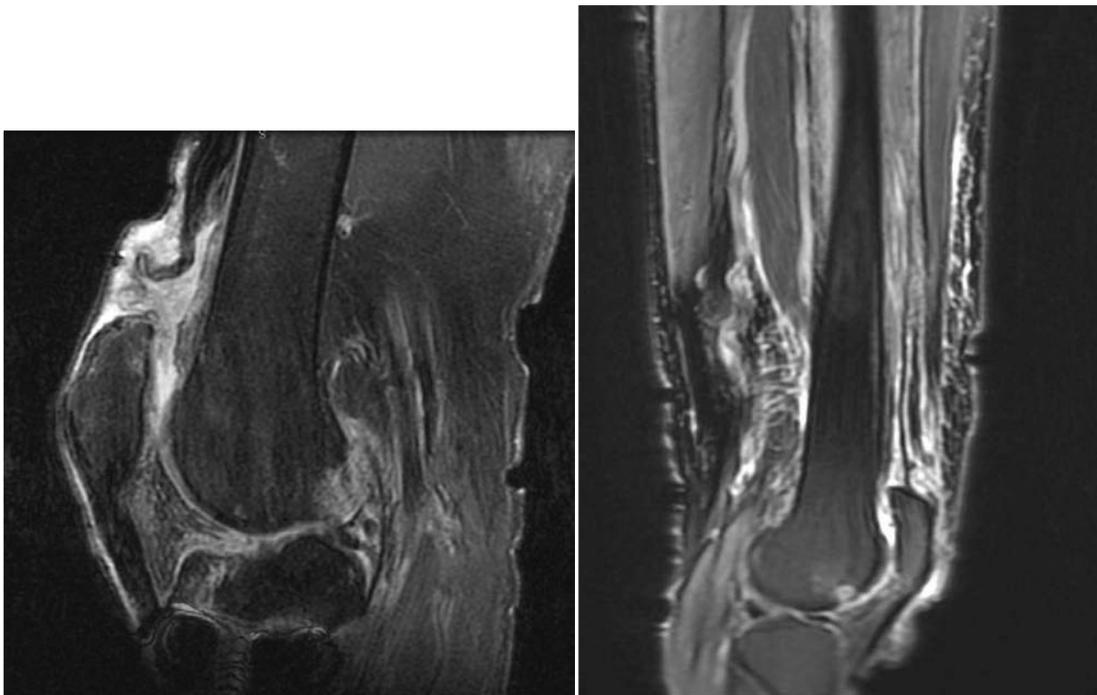

Figure 2: Sagittal T2 images in 2 different patients. The patient on the left has a complete tear of the quadriceps tendon at its attachment to the patella with complete disruption of fibers. The patient on the right has a high grade partial tear.

Patellar ligament tears usually occur in younger patients without a predisposing condition, typically resulting from direct trauma. These tears generally occur near the patellar origin and are much less common than quadriceps tendon tears.

In patients who are not skeletally mature, the weakest link is the cartilage at the attachment of the patellar ligament to the inferior pole of the patella. Some children will

sustain a patellar sleeve fracture after violent contraction of the extensor mechanism against resistance. This injury is an osteocartilaginous avulsion of the inferior pole of the patella. On radiographs, one will identify a thin flake of bone avulsed from the inferior or anteroinferior tip of the patella with associated soft tissue swelling. In young children with substantial unossified patellar cartilage, there may be a much larger fragment of cartilage that is disrupted; hence, MRI is indicated to evaluate the extent of the injury. In patients with large cartilage fragment avulsions, surgeons will reattach the fragment.

Figure 3: Lateral radiograph of the knee demonstrates a patellar sleeve avulsion at the inferior pole of the patella. This patient was skeletally mature enough that he did not have substantial unossified cartilage to injure, as described in the text.

Chronic injuries:

Chronic overuse injuries to the extensor mechanism are usually associated with sports activities in younger patients. The exception may be quadriceps tendinopathy, but this is not a widespread clinically significant phenomenon. Approximately 75% of bipartite patellae occur in the superior lateral corner of the patella, and may be symptomatic if traumatized or abnormally stressed. Symptomatic bipartite patellae may demonstrate T2 high signal along the synchondrosis with the adjacent patella and within the marrow of either/both pieces, surrounding soft tissue edema, and focal articular cartilage defects at the interface. In fact, some authors suggest that a bipartite patella is the result of an overuse syndrome at the attachment of the vastus lateralis obliquus tendon in young children, analogous to Osgood-Schlatter disease.

Jumper's knee is the label often applied to patellar tendinosis, an overuse injury that occurs at the attachment of the patella tendon/ligament to the inferior pole of the patella. The result of repetitive mechanical overload, patellar tendinosis (tendinopathy) demonstrates mucoid degeneration, fibrosis, and neovascularization at pathology. Jumper's knee affects teenage and young adult athletes who are skeletally mature and participate in sports that require frequent jumping and similar activities. The maximal stress is placed at the enthesis when landing after a jump. Activity related focal anterior knee pain may progress to constant pain if activities are not restricted. MRI demonstrates increased focal T2 signal and swelling of the proximal portion of the patellar ligament, often with edema in the adjacent bone and fat. Findings are most prominent in the posterior portion of the ligament and may be accompanied by small partial tears. At U/S, the tendon will be thickened and heterogeneously hypoechoic with increased flow. The normal fibrillar pattern will be disrupted.
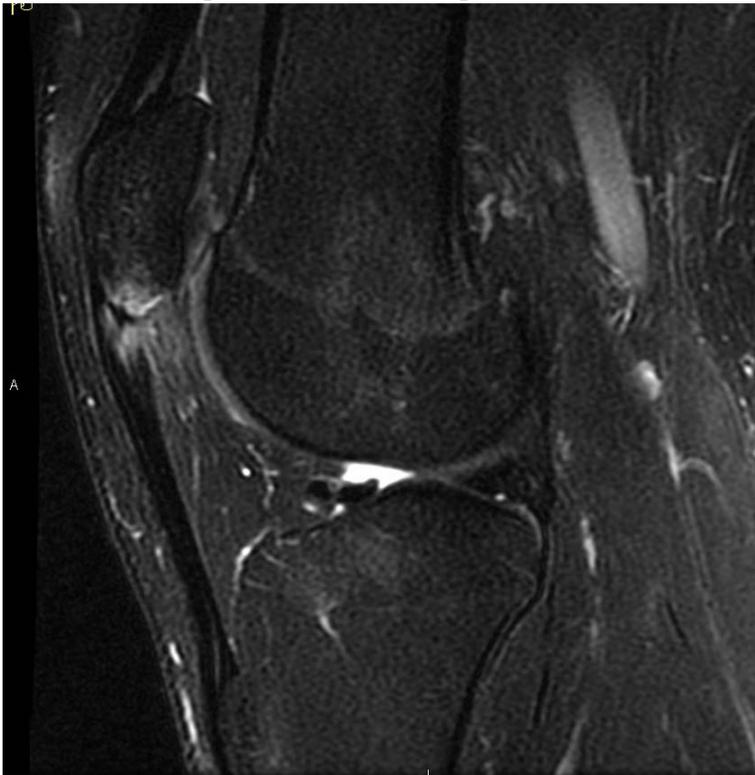

Figure 4: Sagittal T2 image in a patient with patellar tendinopathy (jumper's knee) demonstrates high signal and thickening of the posterior portion of the proximal patellar ligament with adjacent marrow edema in the patella.

Sinding-Larsen-Johannson (SLJ) disease is analogous to jumper's knee, but occurs in skeletally immature athletes. Because of the amount of unossified cartilage present at the margins of the patella in some children, SLJ is often referred to as a traction apophysitis. The proximal patellar tendon is markedly thickened in SLJ, a finding that typically is visible on radiographs. Many patients will also demonstrate ossific fragments in the proximal ligament. These fragments may be due to avulsed margins of the patella (cortex or cartilage that ossifies) or may be dystrophic fragments that develop in the tendon due to longstanding overuse. MRI findings mimic those of jumper's knee but also may

demonstrate the intra-tendinous bone fragments, and the degree of swelling is often greater than that of jumper's knee. U/S findings similarly mirror those of jumper's knee. Though SLJ is said to be a self-limited condition that resolves within 12 to 18 months, many patients remain symptomatic into adulthood and continue to demonstrate radiologic abnormalities.
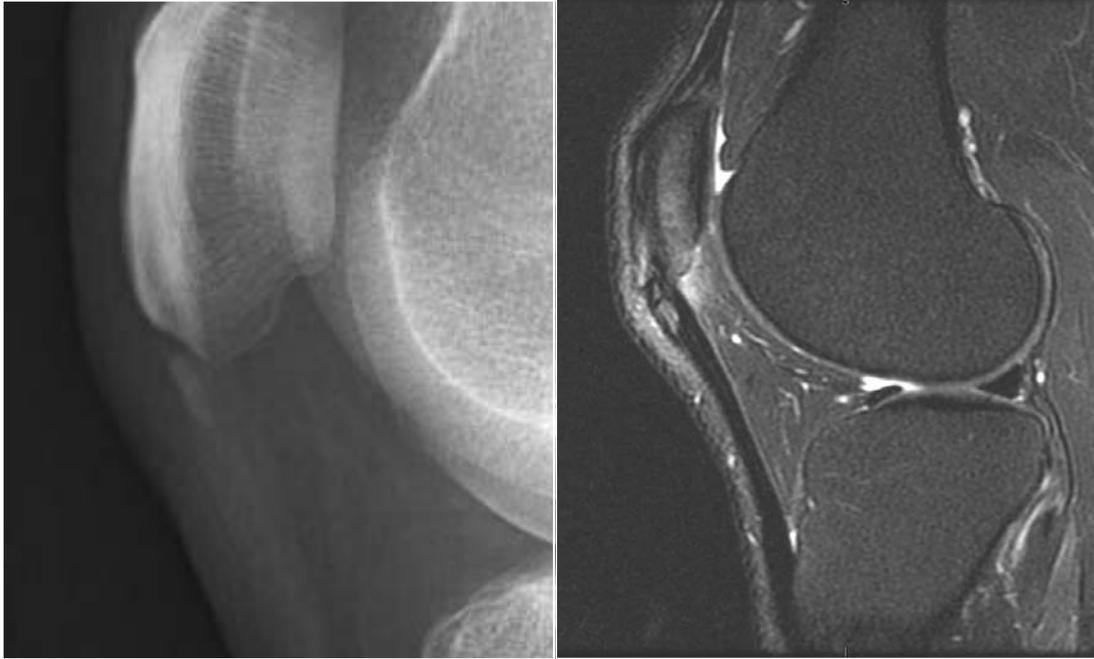

Figure 5: Lateral radiograph and sagittal T2 image in a patient with residual stigmata of SLJ despite skeletal maturity. The radiograph demonstrates soft tissue swelling and the intra-ligamentous bone fragment. The MR image demonstrates the extensive surrounding edema. This patient's pain persisted despite prolonged conservative treatment.

An essentially identical condition affects the distal end of the patellar ligament, known as Osgood-Schlatter disease (OSD). OSD is more common than SLJ but produces the same radiologic findings and has a similar clinical course. Intraligamentous ossicles are present in approximately 50% of cases of OSD; however, similar osseous fragments may be present as normal variants. As such, one should not diagnose OSD on the basis of the bone fragments alone; instead, swelling must be present along with clinical evidence of the condition.

Figure 6: Lateral radiograph and T2 image in a patient with OSD demonstrates identical findings to SLJ, but at the insertion of the patellar ligament on the tibial tubercle.
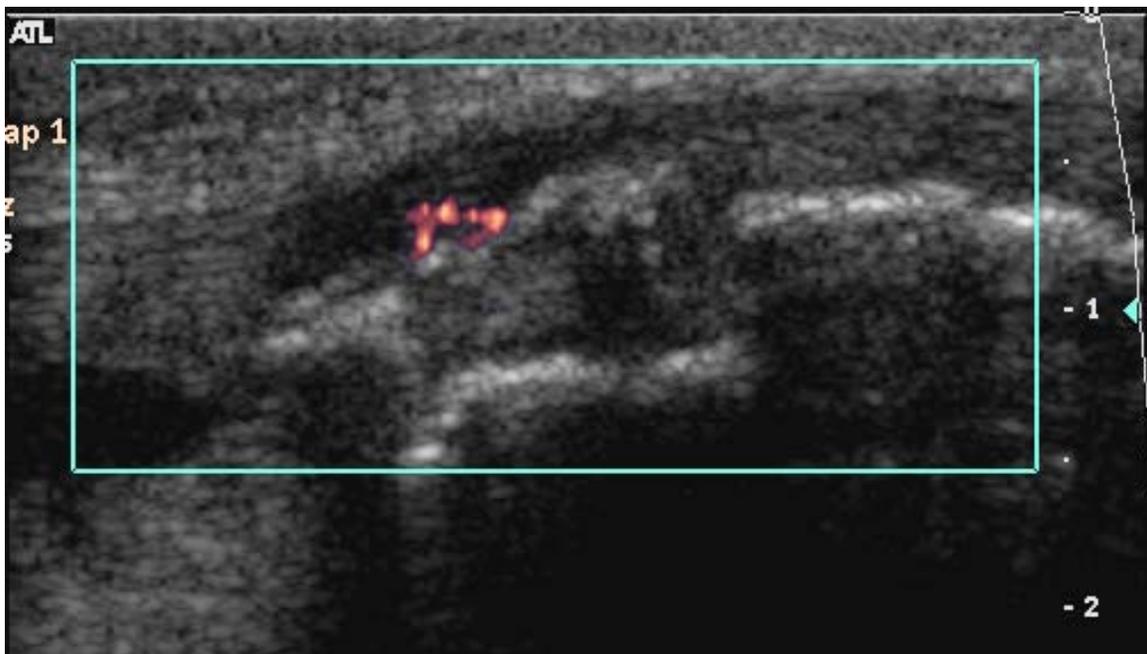

Figure 7: Longitudinal power Doppler image of the distal patellar ligament in a teenaged patient with OSD demonstrates the increased flow that is common, along with ligament thickening and heterogeneity and shadowing calcifications.

Transient Dislocation of the Patella:

Patellar dislocation occurs in a lateral direction, typically as a result of a twisting injury when one has a fixed foot and a flexed knee. Because the dislocation almost always reduces spontaneously, it is referred to as, transient dislocation of the patella (TDP). TDP afflicts teenagers and young adults. Especially in younger patients, up to 50% of patients will be unaware of the exact nature of the injury. Because these injuries usually result in characteristic findings on MRI, radiologists will often be the first to diagnose the injury. TPD almost always results in a sizable joint effusion, so the lack thereof should call this diagnosis into question if the injury occurred within a week or two of imaging. In teenagers, moderate or large joint effusions resulting from an injury should raise the question of TDP, anterior cruciate ligament tear, or tibial plateau fracture.

Some patients may be predisposed to TDP based on dysplastic anatomic features. A couple of these findings that radiologists may be able to identify include patella alta and a shallow trochlea. Though measuring the depth of the trochlea can be variable based on degree of flexion of the knee, one should probably know how to measure the sulcus angle on MRI. On the axial image on which the trochlea appears deepest, draw an angle from the highest points of the medial and lateral femoral condyles down to the intercondylar sulcus. An angle greater than 145° is said to indicate trochlear dysplasia.

A number of other imaging methods have been proposed to evaluate for patellar maltracking and predisposing knee dysplasia. Some practitioners will perform serial single-image CT scans through the patellofemoral joint with the patient in variable degrees of flexion from 0-45° to evaluate for maltracking. Surgeons contemplating realignment of the tibial tubercle may request measurement of the Tibial Tubercle-Trochlear Groove (TT-TG) distance on CT. To obtain the TT-TG, one draws a line through the trochlear groove that is perpendicular to a line drawn across the backs of the femoral condyles. At the level of the tibial tubercle, a second line is drawn though the tibial tubercle exactly parallel to the trochlear groove line. The distance between these two lines is the TT-TG distance, normally 10-15 mm. Drawing these lines is easiest if one is able to superimpose the two images on each other.
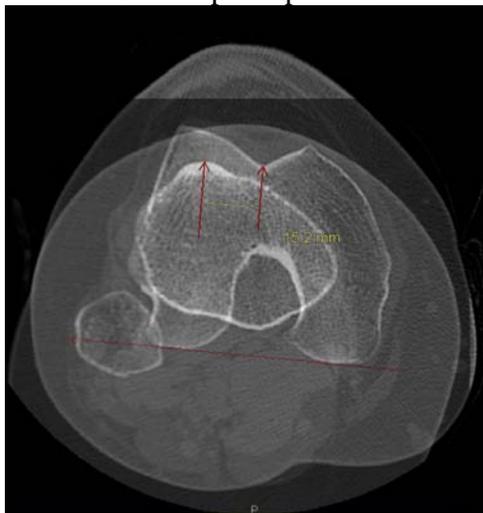

Figure 8: Method of measuring TT-TG distance.

Classic osseous findings of TDP include contusion of the peripheral surface of the lateral femoral condyle (LFC) in 80%, contusion of the medial surface of the patella in 60%, and impaction fracture of the medial inferior pole of the patella in 45%. Though the last finding is less common, it is the most specific. Edema of the medial patella may also reflect avulsion of the medial retinaculum at its patellar attachment or avulsion of a small flake of bone at this site. Once one has recognized the classic findings of TDP, one must search for chondral injuries also. Focal cartilaginous defects sometimes occur in the LFC along the posterior margin of the contusion edema. These cartilage fragments also may be displaced with an underlying crescent of cortex. In that instance, the osteochondral fracture fragment will be visible on radiographs. Shear injuries also may affect the patellar cartilage, particularly along the median ridge or medial facet.
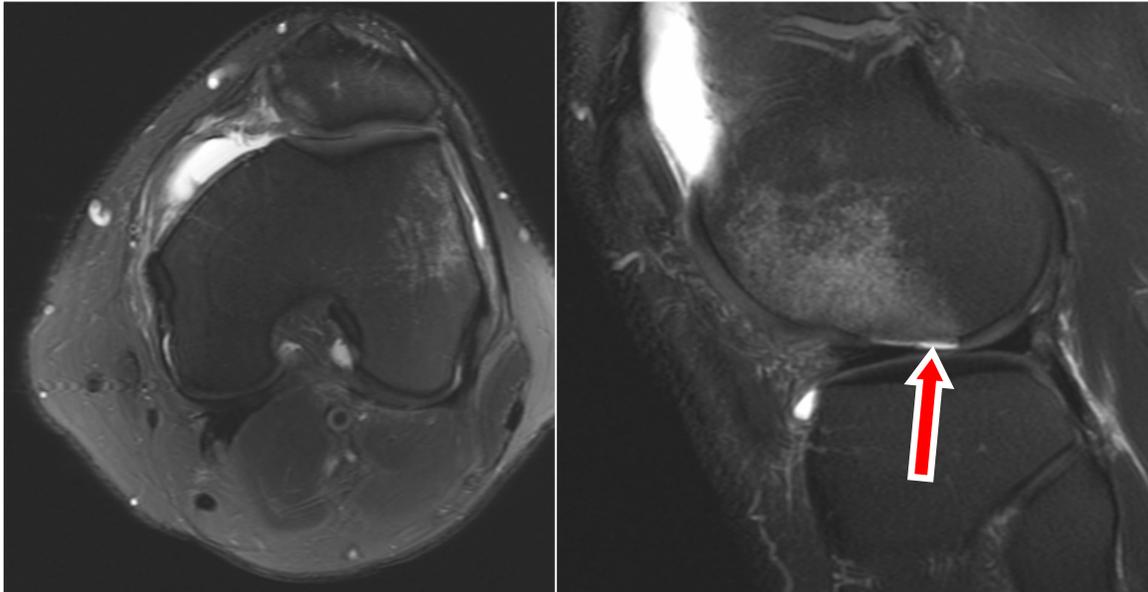

Figure 9: Axial T2 image demonstrates the classic edema pattern of TDP: medial patella and peripheral LFC. On the sagittal T2 image, note the articular cartilage defect (arrow) along the posterior extent of the LFC contusion.

Naturally, for the patella to dislocate laterally one would expect the medial soft tissue restraints to be injured. Indeed, the medial retinaculum is often partially or completely disrupted near its patellar attachment. However, the retinaculum is not a very important stabilizer. Much more important is the medial patellofemoral ligament (MPFL), which provides 50-65% of the medial restraint to the patella. The MPFL originates from the medial femoral epicondyle, just distal to the adductor magnus tendon insertion onto the adductor tubercle and just proximal to the origin of the superficial medial collateral ligament. As the MPFL passes forward to attach to the superior half to two-thirds of the medial patella, it underlies the distal portion of the VMO muscle. The fibers of the MPFL blend with the VMO and are often imperceptible more posteriorly/medially. The MPFL is more recognizable near its patellar attachment. Because the MPFL is difficult to discern near its origin, which is where it usually tears during patellar dislocation, one must rely on secondary signs to diagnose MPFL injuries. When there are classic signs of TPD, one should search for fluid at the expected origin of the MPFL, disrupted ligament

fragments, and elevation of the VMO off the femur by fluid—these findings indicate injury to the MPFL that a surgeon may want to reconstruct.
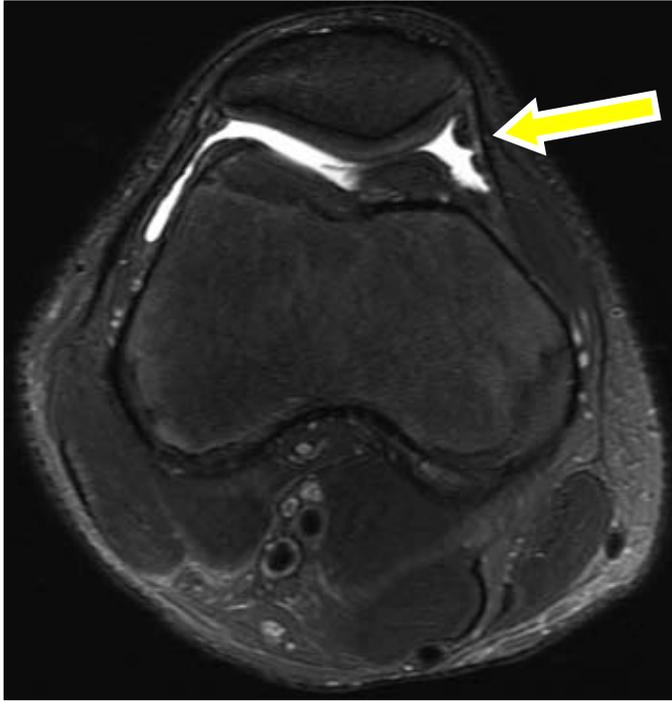

Figure 10: Axial T2 image demonstrates a normal MPFL. The more anterior portion near the patellar attachment is easily visualized (arrow); the more posterior portion underlies and blends with the VMO.
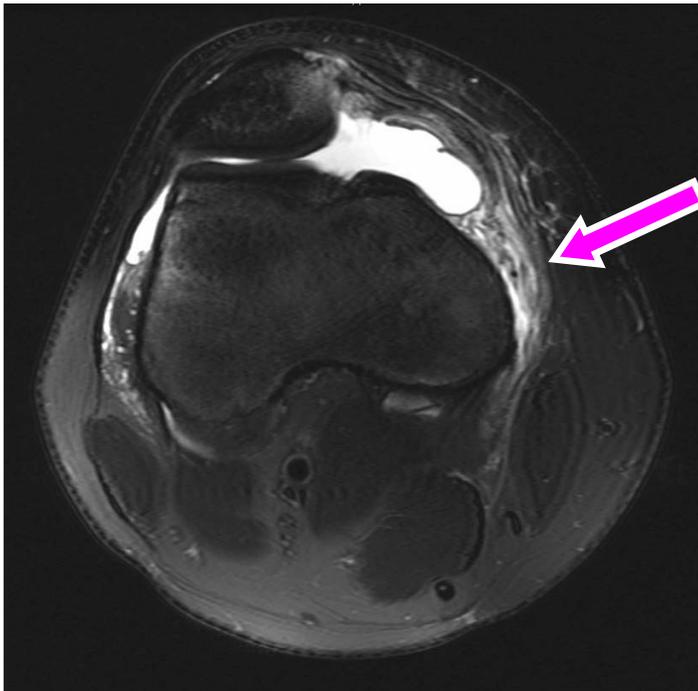

Figure 11: Tear of the MPFL on an axial T2 image with fluid replacing the ligament.

Adjacent Soft Tissue Conditions:

Superficial and deep soft tissue structures surround the extensor mechanism. Conditions of these structures are intimately associated with the extensor mechanism.

Anterior Bursitis:

Three bursae of the anterior knee may become inflamed and cause pain. The prepatellar bursa occurs directly anterior to the patella but may extend inferiorly over the patellar ligament if the volume of bursal fluid is substantial enough. Prepatellar bursitis, sometimes referred to as, "housemaid's knee" or "washer-woman's knee," may be an occupational affliction or related to sports such as wrestling. More common is pretibial (superficial infrapatellar) bursitis, sometimes called, "preacher's knee" or "carpet-layer's knee." This condition afflicts laborers and athletes who spend time on their knees and occurs over the tibial tubercle. MRI or U/S of the knee in patients with prepatellar or pretibial bursitis will demonstrate focal fluid collections, sometimes hemorrhagic, with increased Doppler flow or surrounding enhancement. One should not diagnose bursitis if the findings only reflect edema and not a collection of fluid. In this instance, whether to mention the findings as friction related and possibly symptomatic may rest on the degree of edema present.
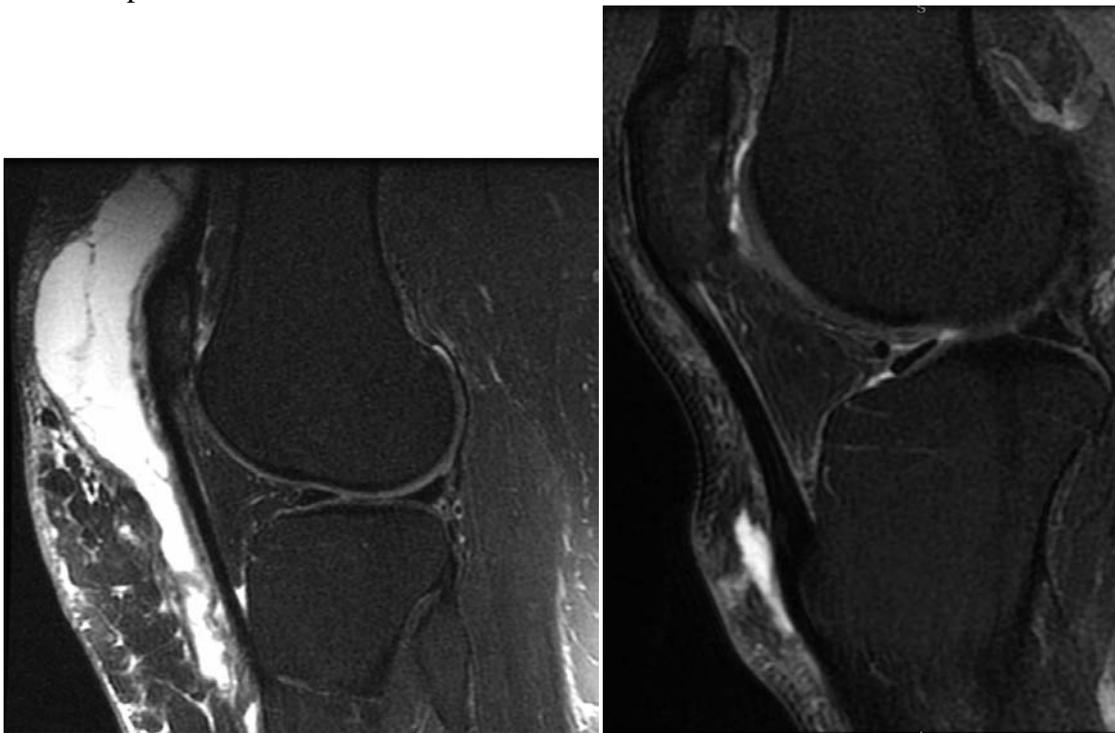

Figure 12: Sagittal T2 images of the knee in two different patients demonstrate superficial focal fluid collections representing prepatellar (left image) and pretibial (right) bursitis. The patient on the right is a landscaper and deck builder.

Deep infrapatellar bursitis underlies the patellar ligament as it attaches to the tibial tubercle. A small amount of fluid here is normal and may communicate with the joint; larger quantities reflect bursitis, sometimes related to OSD.

Fat Pad Syndromes:

Hoffa's fat pad, or the infrapatellar fat pad, lies behind the patella ligament and anterior to the intercondylar notch and the anterior cruciate ligament. Injury to this fat pad is purported to lead to edema and hemorrhage followed by granulation and scarring; the resultant swelling renders the fat pad prone to entrapment between the femur, tibia, and/or patella, increasing the degree of injury, swelling, and pain. This painful fat pad impingement is termed, "Hoffa's disease." On MRI, the fat pad will demonstrate considerable streaky edema in its midst. Surgical removal of the fat pad is usually curative. A more focal edematous condition of Hoffa's fat pad occurs in the superolateral aspect of the fat pad, just distal to the lateral corner of the patella. This focal form of Hoffa's disease is also thought to be due to impingement but the degree of correlation with symptoms remains uncertain.
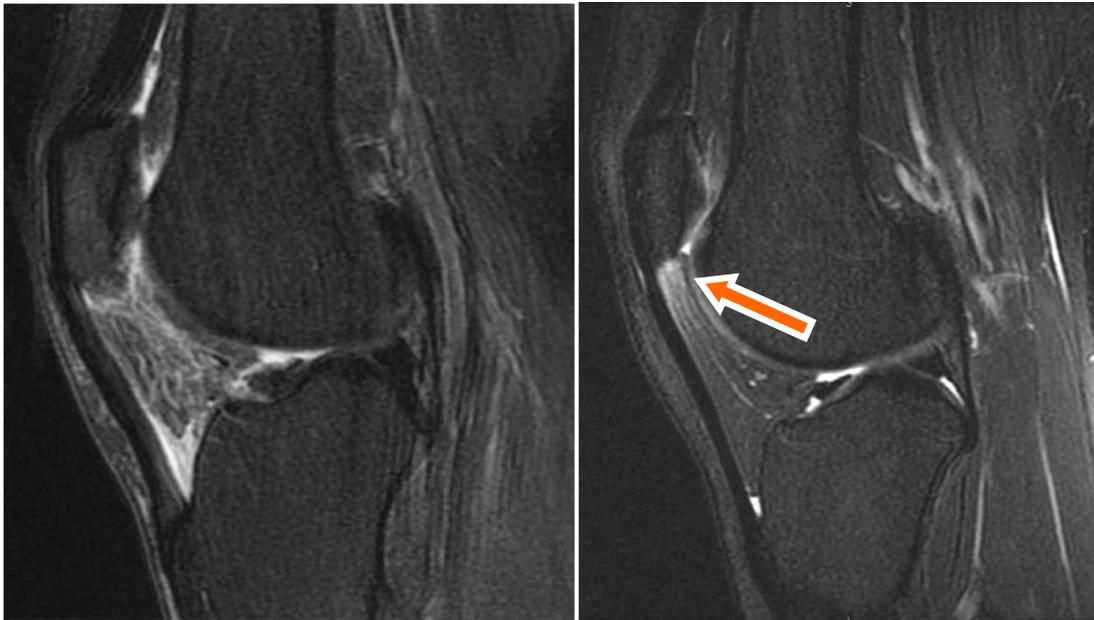

Figure 13: Diffuse (left) and focal (right—arrow) Hoffa's fat pad syndrome in two different patients.

Another more focal fat pad syndrome afflicts the suprapatellar or quadriceps fat pad. This fat pad rests between the distal quadriceps tendon anteriorly, the patella distally, and the suprapatellar recess of the joint posteriorly. Edema is relatively common in this site; however, when edema is prominent here and the fat pad is swollen enough to produce posterior convexity and mass effect on the suprapatellar recess, one should be alert to the possibility of a painful entrapment dubbed, "quadriceps fat pad syndrome." As with focal Hoffa's disease, there is very little proof in the literature how often quadriceps fat pad syndrome is symptomatic.

Figure 14: Sagittal T2 image demonstrates edema and swelling of the suprapatellar fat pad with posterior mass effect on the joint recess, consistent with quadriceps fat pad syndrome. This 46-year-old male was exquisitely tender at the site.

Plica Syndrome:

Plicae are normal variant infoldings of the synovium into the knee joint. Most plicae are asymptomatic. Lateral plicae are rare. Superior plicae are more common, but thought to be symptomatic only rarely. The inferior plica, or ligamentum mucosum, extends from the intercondylar notch and anterior margin of the anterior cruciate ligament into Hoffa's fat pad and sometimes up to the inferior pole of the patella. Though the inferior plica is occasionally blamed for anterior knee pain, MRI findings of thickening and T2 high signal have not correlated well with clinical symptoms or surgical results. The most common plica to cause pain is the medial plica. Researchers have not been able to determine a thickness cutoff at which point one should suggest medial plica syndrome but it is generally accepted that thicker ligaments are more likely to be symptomatic. Ligaments may become entrapped and presumably symptomatic. Occasionally one will recognize the plica draping over the anterior junction of the trochlea and medial femoral condyle; this appearance should be mentioned as a potentially impinged plica. Medial plicae have also been implicated as causing cartilage defects in the medial facet of the patella, which should be mentioned in MRI reports. Ultimately, diagnosing symptomatic plicae is challenging and surgical exploration remains the final arbiter.
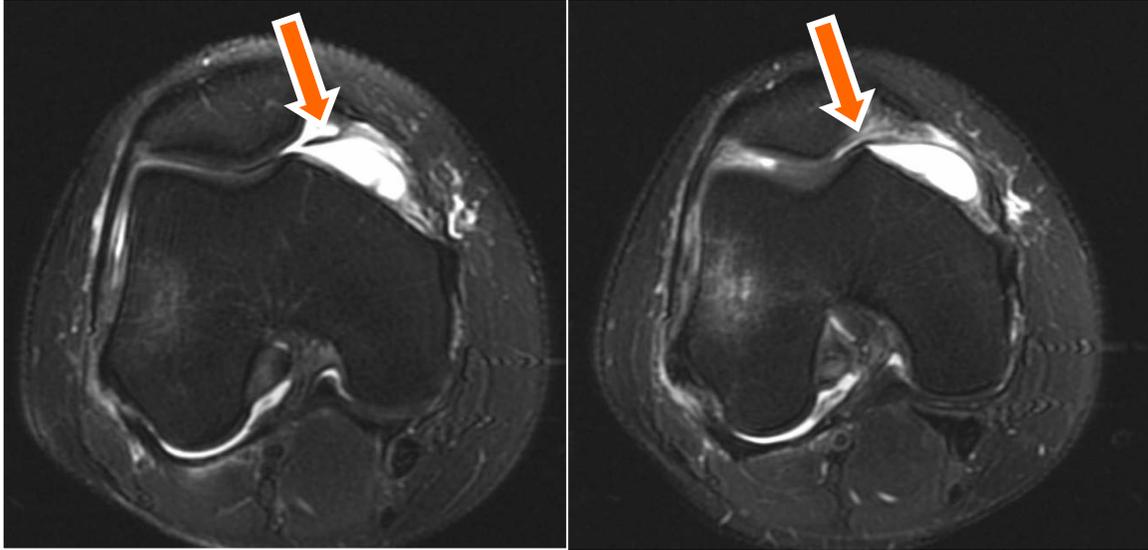
Figure 15: Axial T2 images demonstrate the medial plica, which is at most borderline thickened. However, it is draped over the trochlea on the right image, predisposing it to impingement, confirmed at surgery.

Summary:

There are a myriad of conditions that afflict the anterior knee and specifically the extensor mechanism. While many of the causes of anterior knee pain can be mysterious, others, including those in this handout, often have clinical, radiographic, MRI, and U/S findings that will lead one to the diagnosis.

Suggested Readings

Bates DG, Hresko MT, Jaramillo D. Patellar Sleeve Fracture: Demonstration with MR Imaging. *Radiol* 1994; 193:825-827.

Beasley LS, Vidal AF. Traumatic Patellar Dislocation in Children and Adolescents: Treatment Update and Literature Review. *Curr Opin Pediatr* 2004; 16:29-36.

Chung CB, Skaf A, Roger B, Campos J, Stump Z, Resnick D. Patellar Tendon-Lateral Femoral Condyle Friction Syndrome: MR Imaging in 42 Patients. *Skelet Radiol* 2001; 30:694-697.

Colvin AC, West RV. Patellar Instability. *J Bone Joint Surg Am* 2008; 90:2751-2762.

Elias DA, White LM, Fithian DC. Acute Lateral Patellar Dislocation at MR Imaging: Injury Patterns of Medial Soft-Tissue Restraints and Osteochondral Injuries of the Inferomedial Patella. *Radiol* 2002; 225:737-743.

Haas SB, Callaway H. Disruptions of the Extensor Mechanism. *Orthop Clin N Am* 1992; 23:687-695.

Kramer J, White LM, Recht MP. MR Imaging of the Extensor Mechanism. *Semin Musculoskel Radiol* 2009; 13:384-401.

Lopis EL, Padon M. Anterior Knee Pain. *Eur J Radiol* 2007; 62:27-43.

Panni AS, Biedert RM, Maffulli N, Tartarone M, Romanini E. Overuse Injuries of the Extensor Mechanism in Athletes. *Clin Sports Med* 2002; 21:483-498.

Peace KAL, Lee JC, Healy J. Imaging the Infrapatellar Tendon in the Elite Athlete. *Clin Radiol* 2006; 61:570-578.

Roth C, Jacobson J, Jamadar D, Caoili E, Morag Y, Housner J. Quadriceps Fat Pad Signal Intensity and Enlargement on MRI: Prevalence and Associated Findings. *AJR* 2004; 182:1383-1387.

Saddik D, McNally EG, Richardson M. MRI of Hoffa's Fat Pad. *Skelet Radiol* 2004; 33:433-444.

Sanders TG, Morrison WB, Singleton BA, Miller MD, Cornum KG. Medial Patellofemoral Ligament Injury Following Acute Transient Dislocation of the Patella: MR Findings with Surgical Correlation in 14 Patients. *JCAT* 2001; 25:957-962.

Zaidi A, Babyn P, Astori I, White L, Doria A, Cole W. MRI of Traumatic Patellar Dislocation in Children. *Pediatr Radiol* 2006; 36:1163-1170.