Knee Pain Case Studies

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Acute Burning Knee Pain

History

A 34-year-old male with history notable for severe factor VIII deficiency (on factor VIII prophylaxis, 3 times a week) presented with new bilateral knee pain, right greater than left, during a follow-up visit. The pain is deep within the knee joint, stiff and burning in quality, and keeps the patient awake at night. It is unalleviated by position changes. He has tried NSAIDs 1–2 times a day for the past few weeks with minimal relief. The patient has had chronic right ankle pain in the past attributed to hemophilic arthropathy, worsened by walking and training. He has taken NSAIDs and oral steroids in the past with minimal to moderate pain relief, and underwent ultrasound guided corticosteroid injec-

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tion with moderate improvement. He also has had occasional hemarthroses in various joints (including the knee) that eventually resolved with factor VIII injection.

Review of systems:
No fever, chills, cough, paresthesia, weakness, bowel/bladder changes or falls

Past medical Hx/surgeries:
- Severe FVIII deficiency
- Right ankle corticosteroid injection

Medications:
- Factor VIII solution
- Diclofenac gel
- Celecoxib
- Lidocaine patches
- Meloxicam
- Emicizumab (monoclonal antibody for factor VIII)

Family history:
None

Social history:
The patient is a professional table tennis player and trains 3–4 times per week

Physical exam findings:
BMI of 23 kg/m^2
General: Not in acute distress, well developed
Skin: No rash, swelling, ecchymoses, erythema, or warmth

Knee:
Inspection: No bony abnormalities, no muscular atrophy
Palpation:
- No effusion or hemarthrosis
- No pain with manipulation or palpation to joint lines, bursa, tendons, bony prominences

Range of motion:
- Bilateral knees unable to fully extend with hard stop, non-painful
- Positive crepitus bilaterally

Strength: 5/5 in bilateral lower ext.
Sensation: Intact to light touch in lower ext.

Gait:
- Antalgic with right toe walk
- Left lower limb discrepancy

Provocative maneuvers:
Negative Lachman/anterior or posterior drawer
Negative Thessaly
Negative McMurray
Negative varus/valgus stress or laxity

Differential Dx (Table 10.1)

Imaging

Bilateral Knee X-Ray

See Fig. 10.1.

Diagnostic Discussion

In this patient with acute, bilateral knee pain in the setting of chronic intra-articular bleeds due to severe hemophilia, and severe degenerative arthropathy seen on imaging at a young age (Fig. 10.1), the most likely diagnosis is hemophilic arthropathy. While the patient may have an episode of acute hemarthrosis, the lack of swelling or warmth on physical exam, and the bilateral nature of his pain makes this less likely. Patellofemoral pain syndrome may secondarily contribute to his pain from a rigorous training schedule. Crystal arthropathies such as gout and pseudogout would present with more severe pain on manipulation and

Table 10.1 Differential diagnosis and associated key findings

Differential	Key findings
Hemophilic Arthropathy	Osteoarthritic changes on imaging, pain worsened with activity
Acute hemarthrosis	Swelling, warmth, pain, and stiffness in the setting of recent trauma or a known bleeding disorder
Crystal arthropathy	Joint inflammation, erythema, and intense pain with a history of similar episodes in other joints (toes, ankles, fingers)
Patellofemoral pain syndrome	Common among athletes due to overuse, aching pain in front of the knee
Bursitis	Swelling, warmth, and pain on palpation localized to a bursa
Ligament tear	Knee trauma accompanied with swelling and a "popping" sensation, leading to joint instability on exam, non-weight bearing

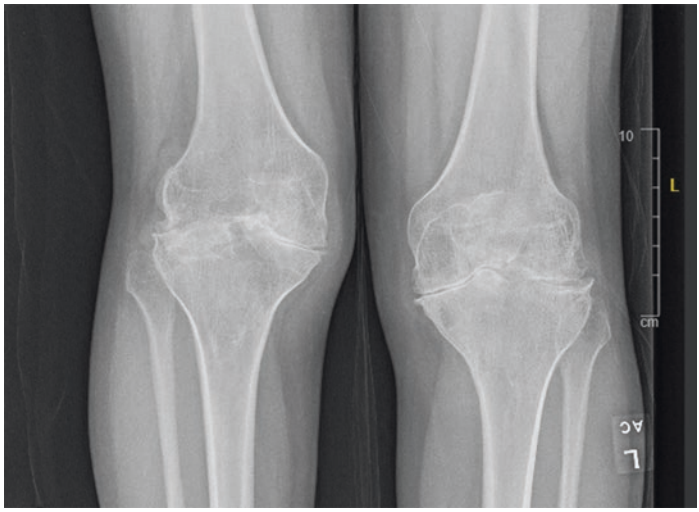

Fig. 10.1 Bilateral Knee X-Rays: Both knees show advanced arthritic changes with chronic erosions and loss of articular surfaces. No substantial effusions on either side

localized erythema. Bursitis or a ligamentous tear are less likely, as the patient does not have any effusions, lacks any pain on manipulation, and has not experienced recent trauma to the knee, or evidence of joint instability.

Hemophilic arthropathy (HA) is a degenerative joint disease (DJD) caused by repeated intra-articular bleeding events. Initial bleeding episodes have been proposed to cause toxicity for articular chondrocytes due to iron overloading, leading to impaired chondrocyte function and survival. Chronic bleeding has also been shown to cause synovial hypertrophy, leading to an increase in the number of fibroblast-like synoviocytes and macrophages promoting a cycle of further inflammation. The early phases of HA have been likened to the synovial hypertrophy and inflammation seen in rheumatoid arthritis (RA), with later stages resembling degenerative arthropathies such as osteoarthritis (OA) [1]. Patients with severe Factor VIII or IX deficiency will have spontaneous joint bleeding in childhood, leading to a high percentage

of adults (30–50% of patients) with hemophilia presenting with clinical arthropathy despite access to prophylactic factor replacement since childhood [2].

MRI has been the preferred modality for diagnostic imaging in children due to its direct visualization of hemosiderin deposits, joint effusions, marrow edema, and therefore detection of potentially reversible pathology, while radiography can only capture irreversible late-stage disease.

Stages of Hemophilic Arthropathy

This patient already has evidence of advanced stage arthritis (Fig. 10.2) from chronic hemophilic arthropathy, making MRI less consequential in informing disease management. Musculoskeletal ultrasound (MSKUS) has also been used in clinical practice for the imaging of hemophilic joints: comparison of MSKUS to MRI has shown comparable detection of soft tissue and osteochondral abnormalities, cartilage destruction, and effusions. Additionally, MSKUS modalities such as power doppler allow for more dynamic assessments of synovial blood flow and demarcation of synovitis from fluid [2].

Management

Management of hemophilic arthropathy can be separated into prevention of further bleeding events (beyond factor replacement) and treatments that decrease further joint inflammation and degeneration, as well as pain control.

Bleeding Reduction

- Radioactive synoviorthesis is a procedure in which radioactive isotopes are injected into the synovium to fibrose sub-synovial blood vessels and reverse synovial hypertrophy, leading to a reduction in the incidence of hemarthrosis (Fig. 10.3). This is currently the standard of care in patients with recurrent bleeds, is effective in more than 90% of patients, and can be performed in the ambulatory setting.

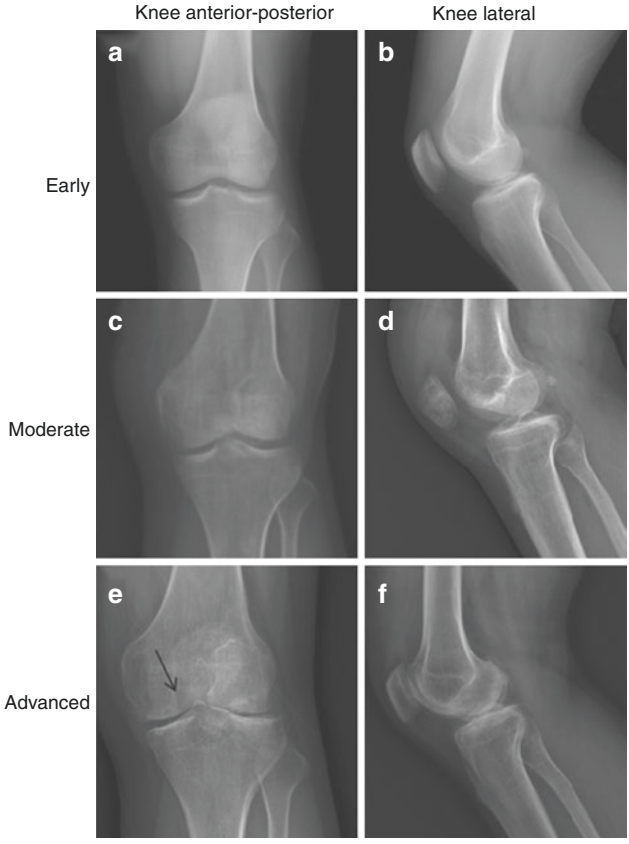

Fig. 10.2 Figure (**a**, **b**) show early stage of hemophilic arthropathy in knee joint: AP and lateral view. Note no osteoporosis, no enlarged epiphysis, no irregular subchondral surface, no narrowing of joint space, no subchondral cyst formation, no joint margin erosion, no gross incongruence of articulating bone ends, and no joint deformity. Figure (**c**, **d**) show moderate stage of hemophilic arthropathy in knee joint: AP and lateral view. Note the osteoporosis, no enlarged epiphysis, no irregular subchondral surface, narrowing of joint space (>1 mm), no subchondral cyst formation, no joint margin erosion, no gross incongruence of articulating bone ends and no joint deformity. This is Patterson grade 2. Figure (**e**, **f**) show advanced stage of hemophilic arthropathy in knee joint: AP and lateral view. Note the osteoporosis, no enlarged epiphysis, partially irregular subchondral surface, narrowing of joint space (<1 mm), 1 subchondral cyst formation (black arrow, e), no joint margin erosion, slight gross incongruence of articulating bone ends and no joint deformity. This is Patterson grade 6 [3]

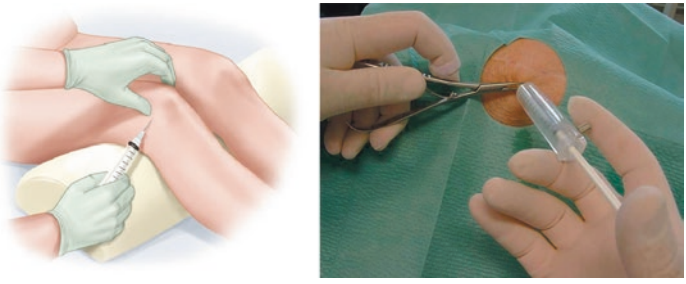

Fig. 10.3 Knee synoviorthesis (lateral suprapatellar approach) [4]

Inflammation Reduction, Tissue Regeneration, and Pain Control

- Selective Cox-2 Inhibitors such as celecoxib have been found to be effective in children with hemophilic arthropathy in a small study, showing a reduction in chronic synovitis and pain. Because these selective NSAIDs avoid exacerbating platelet dysfunction, they function as a safer option compared to traditional NSAIDs in reducing joint inflammation, especially among those with hemophilia [5].
- Tramadol has often been used in OA to diminish pain severity, leading to functional improvement without complications such as gastrointestinal bleeding or renal impairment seen in NSAIDs. Its use in late stage hemophilic arthropathy may be appropriate if other medications are contraindicated. Data regarding their efficacy and safety is still scant in this patient population, therefore they should not be regularly utilized even with severe, chronic articular pain [6].
- Intra-articular hyaluronic acid injections have been shown to have some efficacy in reducing chronic articular pain and improving functional status, usually lasting between 6 months and 1 year. However, there is a lack of robust evidence demonstrating its clinical benefits over placebo in randomized control trials. These injections are typically considered as second-line interventions after selective cox-2 inhibitors [7].

- Intra-articular corticosteroids injections (most often methylprednisolone or triamcinolone) have also been shown to relieve joint pain refractory to NSAIDs, albeit over several weeks to a month, compared to hyaluronic acid injections [7, 8]. Although the rate of adverse effects for corticosteroid injections in the short term are low, longer-term use (every 3 months for 2 years) may lead to structural damage such as cartilage loss as seen in its use for OA [9]. Therefore, corticosteroids are typically not recommended for the chronic management of hemophilic arthropathy.

Consideration 1: Comparing Intra-Articular Injections

It is important to note that strict comparisons between hyaluronic acid and corticosteroid injections regarding efficacy and side effects is challenging. First, their mechanisms of action are different: While corticosteroids help reduce the inflammatory processes associated with bleeding and synovitis, hyaluronic acid improves the viscoelastic properties of synovial fluid. Second, there is little to no research looking at these interventions in specific patient populations. Until more robust RCTs are conducted, the efficacy of these injections may vary widely across a heterogenous patient cohort.

Consideration 2: Safety of Intra-Articular Injections in Hemophilic Patients

First, it is necessary to assess whether a patient's knee pain is caused by an acute hemarthrosis (swelling, warmth, pain) or due to a chronic hemarthropathy. Patients with acute hemarthrosis require IV infusion of coagulation factor preferably within 2 h from the start of articular bleed (most patients will have factor concentrates at home), local cryotherapy to induce vasoconstriction, and joint aspiration within 2 days of bleeding to reduce joint impairment [6]. For those with chronic hemarthropathy, patients should have previous hematologic factor coverage to be consid-

ered for intra-articular injections to reduce bleeding risk [8]. Intra-articular injection of corticosteroids or hyaluronic acid may be considered after joint aspiration for acute hemarthrosis or afterwards from a safety perspective.

Knee Replacement

For those with severe hemophilic arthropathy refractory to the treatments listed above, total knee arthroplasty (TKA) should be considered for patients optimized for the procedure. Both the short- and long-term outcomes of TKA in these patients are favorable, with a high prosthesis survival rate (10-year survival achieved in 97.1% of procedures among 56 patients) and significant increases in the range of motion and functional scores [10].

Areas of Research

- Intra-articular injections of platelet-rich plasma or mesenchymal stem cells are hypothesized to aid in tissue regeneration through the addition of platelet derived growth factors in the former, and multipotent stem cells in the latter. However, they currently lack robust evidence in reversing hemolytic arthropathy and are not currently recommended [7].
- The role of certain biologics such as TNF-α is currently being investigated in addressing the early inflammatory stages of HA, as they have shown efficacy in treating rheumatoid arthritis and other inflammatory arthropathies [1].

Key Takeaways

1. Hemophilic arthropathy is a degenerative joint disease caused by repeated intra-articular bleeds often seen in patients with hemophilia, with initial presentation similar to rheumatoid arthritis and chronic degeneration leading to OA.
2. MRI and MSKUS are both modalities that can help assess the degree of early pathology, while radiographs will be sensitive only to late-stage disease.

3. Radioactive synoviorthesis is the standard of care for reducing intra-articular bleeds, while selective cox-2 inhibitors are first line in reducing inflammation. Intra-articular hyaluronic acid and corticosteroid injections are second line, while TKA is the definitive treatment for late stage arthropathy.

Non-traumatic Knee Pain with Effusion

History

The patient is a 55-year-old female with a history of thyroid disease who presented to the clinic with right-sided knee pain. The pain is localized to the right anterolateral knee, is characterized as an intermittent tingling pain graded 4/10 in severity and began a few weeks ago with no inciting event. At the beginning of the year, she started a new job that required more walking. The pain is aggravated by walking, bending the knee, going down hills and is alleviated by rest and sitting. She has tried turmeric tea, ibuprofen, and ice packs with some alleviation and has not attended physical therapy.

The patient reports having similar symptoms in the past and is not sure if she was diagnosed with arthritis at the time. The last time she had knee pain was 4 years ago, which improved with physical therapy. The pain is significantly impacting the patient's ability to perform activities of daily living.

Review of systems:
No fever, chills, cough, paresthesia, weakness, bowel/bladder changes or falls

Past medical Hx/surgeries:
- Thyroid disease
- History of thyroidectomy

Medications:
- None

Family history:
- None

Social history:
- Drinks alcohol once a week
- Recently started a new job requiring more walking

Physical exam findings:
BMI of 28 kg/m^2
Gen: Not in acute distress, well developed

Knee:
Inspection: No bony abnormalities, no muscular atrophy
Palpation:
- Right knee with effusion and warmth
- Tender to palpation to lateral joint line along area of effusion, mildly tender to distal quadriceps tendon attachment to patella
- Nontender to palpation over the prepatellar bursa, infrapatellar bursa, pes anserine, or patellar tendon

Range of motion:
- Right knee limited in flexion with pain, has full extension, no crepitus

Strength: 5/5 in lower extremities
Sensation: Grossly intact to light tough
Reflexes: 1+ bilateral patellar and Achilles
Tone: Normal

Gait: Antalgic gait

Specialized exam maneuvers:
- Pain on right Thessaly test
- Pain on right McMurray laterally
- Negative Lachman, ant. and post. drawer test
- Negative for varus/valgus laxity or stress pain

Differential Dx (Table 10.2)

Work Up: Imaging

Right Knee X-ray (AP View and Lateral View)

See Fig. 10.4.

Diagnostic Discussion

In this patient with anterolateral knee pain with associated effusion, the differential can be narrowed through the presence or absence of inciting factors, the location and severity of pain and effusion, and exam maneuvers that help pinpoint specific struc-

Table 10.2 Differential diagnosis and associated key findings

Differential diagnoses	Key findings
Meniscal tear	Caused by forceful twisting of the knee, catching sensation, knee swelling, joint line tenderness, positive McMurray and Thessaly tests
Crystal arthropathy	Joint inflammation, erythema, and intense pain with a history of similar episodes in other joints (toes, ankles, and fingers)
Quadriceps or patellar tendinopathy	Occurs over weeks to months due to overuse, pain along the superior pole (quadriceps) or inferior pole (patellar) of the knee joint, minor swelling, calcification may be present
Patellofemoral pain syndrome	Associated with joint overuse or onset of new strenuous activity involving the knee joint. Presents as an aching pain in front of the knee
Intra-articular fracture	Often caused by valgus stress on the knee, associated with rapid swelling and pain, lateral joint line tenderness and instability
Osteoarthritis	Depending on the stage of osteoarthritis, pain can be intermittent and sharp with associated stiffness, with or without chronic aching pain. Worsened by joint use and relieved by rest. Joint deformity and swelling can also be present

tural damage. The absence of notable trauma on history makes a significant ligament or tendon tear unlikely. Absence of joint laxity on anterior and posterior drawer test further supports the integrity of the ACL and PCL, while absence of varus and valgus laxity shows preservation of the MCL and LCL. Bursitis is also unlikely as the patient endorses pain along the lateral joint line as opposed to the knee bursae. An intra-articular fracture is also unlikely without significant trauma to the knee, however, could be considered due to the presence of an intra-articular body on radiograph along with joint line tenderness.

Degenerative joint disease such as osteoarthritis (OA) should also be considered in post or peri-menopausal females with activity induced joint pain and stiffness. Radiography can help discern the degree of joint space loss as well as osteophyte formation. This patient has minor OA affecting her medial joint space more than her lateral, unlikely to be the cause of her recent symptoms (Fig. 10.4). Tenderness along the distal quadriceps tendon associated with increased ambulation at work may reveal some degree of quadriceps or patellar tendinopathy.

Based on patient history, a crystal arthropathy such as gout or pseudogout should be strongly considered in the setting of acute to subacute joint pain with swelling, without any inciting trauma.

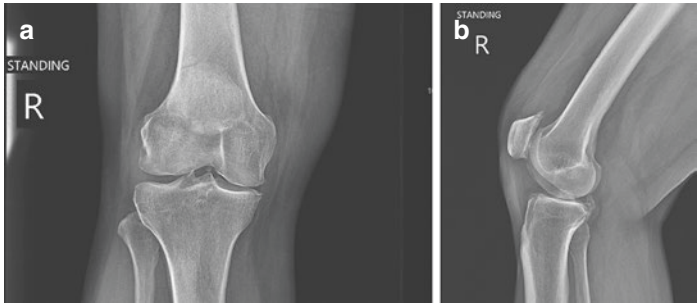

Fig. 10.4 Right knee X-rays: Medial joint compartment narrowing with small osteophytes. The lateral compartment is preserved. There are small patellofemoral osteophytes and small to moderate knee joint effusion. There is an intra-articular body in the posterior aspect of the knee. (**a**) Right knee X-ray (AP View). (**b**) Right knee X-ray (Lateral View)

Confirmatory testing is done through joint aspiration to evaluate for the presence of uric acid or calcium pyrophosphate crystals.

Procedures and Lab Tests

Ultrasound guided joint aspiration was performed at the prepatellar space. 30 cc of clear yellow joint fluid was aspirated without evidence of blood. The joint fluid was analyzed under polarized light without any crystals visualized.

The absence of crystals rules out a crystal arthropathy from our differential.

A minor meniscal tear is the most likely cause of this patient's knee pain and effusion. Pain on Thessaly and McMurray tests point towards a meniscal pathology that may have occurred during an unnotable event involving sudden pivoting or kneeling (Fig. 10.5). Joint line tenderness and effusion due to reactive synovitis area are also common findings [12].

While meniscal injuries often occur in sports and areas of profession that involve rapid changes in direction, older patients may induce minor tears with little to no trauma. Confirmatory testing for meniscal pathology can be done through MRI, especially for small defects. Radiograph and ultrasound are appropriate initial imaging modalities but are limited by their inability to visualize deeper structures. In this patient with a probable small meniscal tear, it is unlikely that obtaining an MRI would change management unless symptoms continued to persist after conservative treatment.

Management

Conservative, nonoperative management of meniscal tears is preferred in patients who do not have severely restricted range of motion, locking, or instability of the knee. A regimen for this patient may include the following, with gradual resolution of symptoms over 6 weeks [13].

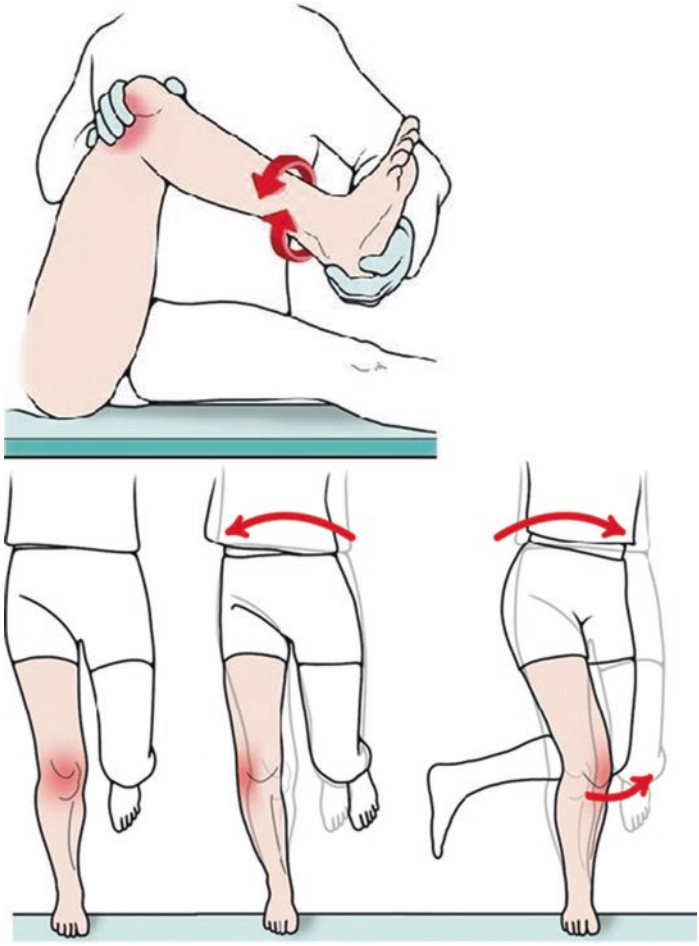

Fig. 10.5 McMurray and Thessaly tests for evaluation of meniscal injury [11]

- Rest, ice, and compression of the knee.
- Offloading until fully weight bearing.
- NSAIDs for pain relief.
- Physical therapy.

- Controlling and managing swelling while maintaining range of motion.
- Quadriceps and hamstring strengthening.
- Proprioceptive training.

If there is no improvement in symptoms after undergoing conservative therapy, it is reasonable to obtain an MRI of the knee to further assess the degree of meniscal injury, or the presence of a separate concomitant injury.

Operative management could be considered with failure of conservative therapy and meniscal lesions on MRI amenable to partial meniscectomy or direct repair. Regarding clinical characteristics attributed to successful repair, this patient's older age (>40) is a negative prognosticator while most positive prognosticators depend on the nature of the tear (acute tears, vertical tears, red-red zone tears, no mechanical misalignment, and tears longer than 1 cm but shorter than 4 cm) [13].

While partial meniscectomies are a common orthopedic procedure, no RCTs have supported its superiority compared to nonsurgical management, with several studies showing an increased risk of future OA. If the patient has a meniscal tear not appropriate for direct repair, then meniscectomy could be discussed regarding risks, benefits, and variability in success [13].

Intra-articular steroid injections can also be performed in patients who have concomitant mild OA, such as in this patient [12].

Areas of Research

- Platelet Rich Plasma and Mesenchymal Stem Cells have shown promising results in promoting meniscal recovery and healing with and without surgical intervention. These orthobiologics may address at treatment gap for patients who fail conservative

management and are not candidates for surgical intervention [13].

Key Takeaways

1. Meniscal tears are often caused by sudden changes in direction that cause forceful pivoting of the knee joint. However, minor meniscal tears can occur in older patients with little to no trauma, and can present with joint line tenderness, effusion, and pain on ambulation.
2. Physical exam maneuvers such as the Thessaly and McMurray tests are useful in diagnosing a meniscal pathology. Confirmatory testing with MRI is indicated in patients who fail conservative management over 4–6 week period.
3. Conversative management is preferred in patients who do not have joint instability or severe restrictions in range of motion. Operative management (direct repair vs. partial meniscectomy) should be decided based on the patient's age, degree and location of meniscal injury, and other concomitant conditions such as OA.

Left Knee Swelling for 1 Month

History

Patient is an active 37-year-old female with no significant past medical history, who presents to the orthopedics clinic for evaluation of left knee swelling for 1 month. She had a motorcycle accident 1 month ago, in which she was traveling at about 50–60mph at the time of the accident and was wearing a helmet. She was seen at an ER and was found to have a left shoulder dislocation, which was reduced at this time. She also had left knee pain and swelling after the accident; however, patient states no imaging of the knee was done at the time. She continues to have persistent swelling of the left knee, which is exacerbated by deep bending and alleviated with extension of the knee. When she

bends her knee, she feels "pressure within the knee." She denies any trauma prior to the accident, surgery, or injection to the left knee. She denies numbness, tingling, decreased ROM, or buckling.

Review of systems: No fever, chills, cough, paresthesia, weakness, bowel/bladder changes or falls *Past medical Hx/surgeries:* No significant past medical history No past surgical history *Medications:* None *Family history:* No significant family history *Social history:* Patient works as a carpenter. She enjoys playing yoga, cycling, and playing tennis. She smokes cigarettes 1–2× weekly and drinks alcohol socially	*Physical exam findings:* **Wt**: 75.8 kg (167 lb) **BMI** 22.65 kg/m^2 **General:** In no acute distress *Musculoskeletal exam*: ***Left knee*:** **Inspection**: Large anterior effusion, no deformity, no erythema, skin intact **Palpation**: Non-tender to palpation. **Movement**: ROM: 0–135, within normal limits. Negative crepitus **Strength**: 5/5 strength **Sensation**: Intact to light touch, well perfused **Special exam maneuvers:** Lachman: Positive compared to other side but with endpoint Negative McMurrays Negative Thessalys Negative valgus/valgus stress Negative patellar grind Negative patellar apprehension Positive dial test at 90, negative at 30 **Gait**: Normal gait **Right knee exam unremarkable**

Differential Dx (Table 10.3)

Work Up: Imaging

The patient obtained an MRI of the left knee with the following results (Fig. 10.6):

Table 10.3 Differential diagnosis and associated key findings [14]

Differential	Key findings
Anterior cruciate ligament (ACL) tear	Sudden change in direction or landing from a jump (usually audible "pop" at time of injury), positive Lachman and/or anterior drawer test, history of direct trauma to knee, rapid swelling, instability with weight bearing, decreased ROM
Morel-Lavallee lesion	Caused by rotational (shearing) force, often from a motor vehicle collision. Localized swelling, contusion, abrasion, and/or decreased sensation may also be present
Prepatellar and infrapatellar bursitis	Recurrent trauma to anterior knee, seen in individuals who kneel frequently ("housemaid's knee"). Can also be caused by infection, gout, or arthritis. Relief with flexion of knee. Presents with swelling and tenderness over anterior knee
Lipoma	Present as soft, painless subcutaneous nodules of mature fat cells enclosed by thin fibrous capsules. Rarely, may involve fascia or deeper muscular planes. Most frequently occur on trunk and upper extremities, and usually patients have multiple
Subcutaneous hematoma	Presents with pain, drop in hemoglobin, or fluid collection on imaging Studies. May see enlarging mass on exam
Soft tissue sarcoma	Presents as gradually enlarging, painless mass, most commonly in extremities. May have paresthesias or edema. Rarely symptoms of fever and/or weight loss

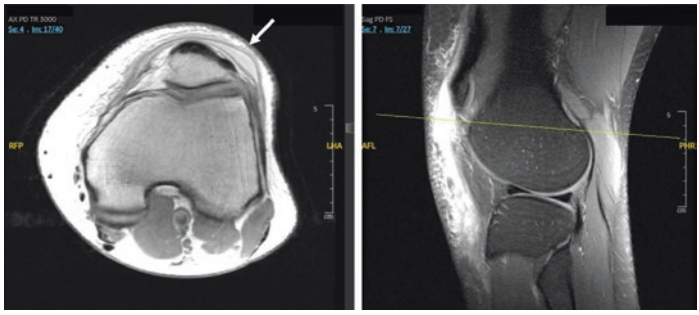

Fig. 10.6 MRI of left knee

Impression:

1. Small peripheral undersurface tear of the body of the medial meniscus.
2. Mild to moderate chondromalacia of the patellar articular cartilage, greater laterally than medially.
3. Mild patella alta and findings of mild soft tissue secondary to abnormal patellar tracking.
4. Joint fluid/cysts: Small complex Baker's cyst. Subcutaneous edema predominantly in the prepatellar and infrapatellar soft tissues with more confluent fluid collection in the prepatellar space. Thin prepatellar fluid collection extends proximally, superficial to the quadriceps tendon and vastus medialis, and distally superficial to the patellar tendon, beyond expected confines of pre-patellar bursa, and likely represents sequela of prior trauma with possible hemorrhage into and rupture of the prepatellar bursa with subsequent loculation (Fig. 10.7).
5. No fracture or bone contusion.

Diagnostic Discussion

Degloving soft tissue injuries occur when the skin and subcutaneous fatty tissue are abruptly separated from the underlying deep fascia in the setting of severe trauma, most commonly motor vehi-

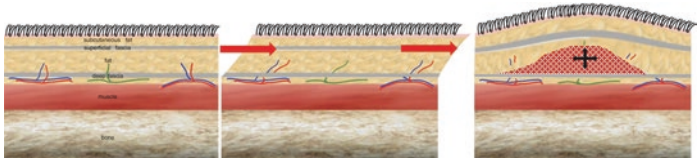

Fig. 10.7 Shearing between the subdermal plane and the fascia leading to distended cavity

cle collisions. As a result, there may be cavity formation following disruption of the lymphatics and subdermal capillaries; the cavity may consist of lymphatic fluid, debris, and subdermal fat (Fig. 10.7) [15]. This collection of fluid may spontaneously resolve or persist if it becomes encapsulated [16]. When degloving injuries do not involve a break in the skin (closed injury), they are called Morel-Lavallee lesions. These lesions classically occur in the hip (i.e. greater trochanter of the femur) and proximal thigh, but can occur in any area in which there is severe mechanical force such as over the lumbar spine, the scapula, or the pre-patellar knee [17].

The typical presentation is an enlarging, painful lesion following trauma, which usually occurs within hours to days of the event [18]. Contusions, abrasions, and/or decreased sensation may also be present [17, 18]. A small study showed Morel-Lavallee lesions can form as early as a few hours after trauma, or as late as 13 years from the time of injury, with a median time of presentation of 1.4 years [19]. Data shows one-third of acute lesions are missed or considered insignificant, especially when more severe injuries are present [17].

MRI is the modality of choice for diagnosis, which can clearly demonstrate fluid collection and the associated underlying fascia [18]. CT scan can be useful at showing fluid–fluid levels and capsule formation, while ultrasound can be used to identify fluid, internal debris such as fat globules, and capsule formation (Fig. 10.8) [15]. Morel-Lavallee lesions are typically compressible and have no vascularity on ultrasound [16, 18]. The Mellado-Bencardino classification system characterizes Morel-Lavallee lesions based on shape, signal and enhancement, and the presence or absence of a capsule observed on MRI [20].

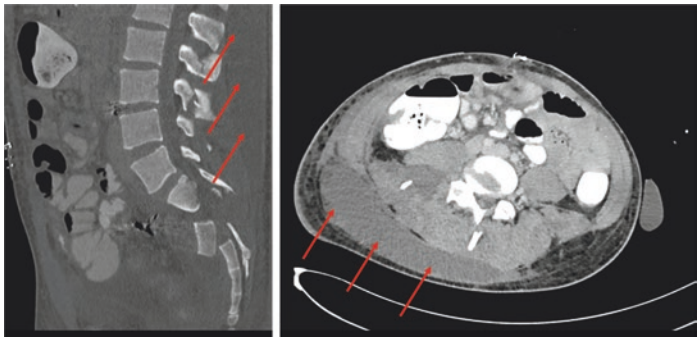

Fig. 10.8 CT demonstrating Morel-Lavellee lesion after high-energy fall

Management

Prompt identification of Morel-Lavallee lesions is essential, as delay in diagnosis or a missed lesion can lead to infection, extensive soft tissue necrosis, loss of limb, or death [20, 21]. There is currently no universally accepted treatment algorithm for the management of Morel-Lavallee lesions, however, studies have shown for small lesions without an identified capsule, conservative treatment with compression is recommended [20, 22]. Data shows treatment with compressive elastic bandages or corsets for patients with small fluid accumulation had successful healing within an average of six weeks [23]. However, other data has suggested that healing time is significantly less for patients who receive surgical intervention over those where compression is used alone [24].

Percutaneous aspiration is another option for treatment; however, majority of lesions recur following aspiration. Studies have shown if there is percutaneous aspiration of more than 50 mL of fluid from Morel-Lavallee lesions, there is a higher likelihood of recurrence, and surgical intervention would be recommended [17]. The use of sclerosing agents to close off pathological cavities has also been applied to the treatment of these lesions and is often recommended when percutaneous aspiration alone fails. Doxycycline is the most used agent, in addition to erythromycin,

bleomycin, vancomycin, absolute ethanol, tetracycline, and talc. Most of these agents work by causing cell destruction within the periphery of the lesion, which obliterates the cavity and induces fibrosis [24]. Studies show sclerodesis has an efficacy of 95.7% in treating Morel-Lavallee lesions and is recommended as first line treatment for acute lesions or chronic lesions up to a volume of 400 mL [24, 25].

In circumstances where patients have lesions with overlying skin that is necrotic, then debridement of the dead tissue is required with reconstruction. If the overlying skin is viable, open drainage is another option for treatment, which involves curettage of the cavity to induce fibrosis. Quilting sutures, fibrin sealant, and low suction drains have also proved to be successful adjuncts to this method. Lastly, mass resection is typically indicated for lesions with an intact capsule and when other measures have failed and/or fluid volume is greater than 400 mL [24].

Patient Conclusion

The patient above was referred to physical therapy for her left knee and left shoulder and instructed to start a home exercise program. An MRI of the left knee was ordered due to concern for ACL/PCL injury given the ligamentous laxity and large effusion of the left knee, and she was advised to ACE wrap her left knee during the day and ice as needed until her MRI results came back. Patient returned to the clinic 1 month later and stated her left knee swelling had significantly improved and noted that she was back to most of her normal activities. On exam of the left knee, there was mild residual swelling and the Morel-Lavallee lesion diagnosed on MRI was resolving without any additional therapies.

Key Takeaways

1. Degloving soft tissue injuries occur when the skin and subcutaneous fatty tissue are abruptly separated from the underlying deep fascia in the setting of severe trauma, creating a collection of fluid.

2. When degloving injuries do not involve a break in the skin (closed injury), they are called Morel-Lavallee lesions.
3. They present as an enlarging, painful lesion following trauma, which usually occurs within hours to days of the event.
4. MRI is the modality of choice for diagnosis, which can clearly demonstrate fluid collection and the associated underlying fascia; however, CT scan and ultrasound can also aid in identification of fluid accumulation and capsule formation.
5. Prompt identification of Morel-Lavallee lesions is essential, as delay in diagnosis or a missed lesion can lead to infection, extensive soft tissue necrosis, loss of limb, or death.
6. Conservative treatment includes compressive elastic bandages or corsets for patients with small fluid accumulation.
7. While percutaneous aspiration may also be used for treatment, sclerodesis has shown the greatest efficacy in treating Morel-Lavallee lesions and is recommended as first line treatment for acute lesions or chronic lesions up to a volume of 400 mL.
8. Open drainage with the adjunctive use of quilting sutures, fibrin sealant, and low suction drains has also proved to be effective.
9. Mass resection is indicated for lesions with an intact capsule, and when other measures have failed and/or fluid volume is greater than 400 mL.

Diffuse Knee Pain and Decline in Ambulation

History

Patient is a 62-year-old female with past medical history of hypertension, diabetes mellitus, multiple sclerosis, polymyositis, morbid obesity, who presents to the orthopedics clinic for follow-up of worsening bilateral diffuse knee pain and loss of mobility. She states her knee pain has limited her ability to use the toilet or shower, and she often uses a rolling office chair to get around her

home due to painful standing and walking. She has received seven bilateral steroid knee injections and four bilateral hyaluronic acid knee injections over the past 3 years with moderate relief lasting a few months.

Review of systems:
No fever, chills, cough, paresthesia, weakness, bowel/bladder changes or falls.
Past medical Hx/surgeries:
Hypertension
Diabetes mellitus
Multiple sclerosis
Polymyositis
Morbid obesity
Chronic osteoarthritis
No significant surgical history
Medications:
Amlodipine 5 mg tablet
Lopressor 50 mg tablet
Gabapentin 600 mg tablet
Tramadol 50 mg tablet
Lidocaine patch
Voltaren 75 mg tablet
Voltaren topical gel
Tylenol 500 mg
Family history:
No significant family history
Social history:
Works as a schoolteacher (on disability). Former smoker (quit date: 09/27/1992), 0.5ppd, 8 pack years. Does not drink alcohol

Physical exam findings:
Ht: 5′5″
Wt: 151 kg (333 lb)
BMI: 55.41 kg/m^2
Gen: Not in acute distress, morbidly obese
Musculoskeletal exam:
Inspection:
Bilateral knees: Joint effusion observed. No obvious bony deformities or varus/valgus alignment, however limited by body habitus
Palpation:
Bilateral knees: No tenderness to palpation over medial or lateral joint lines.
Movement:
Bilateral knees: ROM of the knees restricted by body habitus. Pain in both flexion and extension. Crepitus bilaterally.
Strength: 5/5 in bilateral lower extremities
Sensation: Grossly intact to light touch
Special exam maneuvers:
Negative straight leg raise
Negative anterior and posterior drawer test
Negative Lachman's test
Negative McMurray's test
Gait: Sit to stand time increased. Antalgic gait, only able to tolerate a few steps

Differential Dx (Table 10.4)

Work Up: Imaging

See Fig. 10.9.

Diagnostic Discussion

Osteoarthritis (OA) is the most common form of arthritis in the knees, hips, and hand joints, and is one of the most prominent causes of pain, functional limitation, and reduced quality of life worldwide. Knee OA accounts for approximately 80% of the dis-

Table 10.4 Differential diagnosis and associated key findings [26]

Differential	Key findings
Osteoarthritis	Middle-aged or older patients. Usually bilateral knees. Pain in joints typically worse after activity. Radiographs show joint space narrowing, osteophytes, and subchondral erosions. Absence of RF and CCP (see below)
Rheumatoid arthritis	Middle-aged or older patients. Stiffness of joints typically worse after rest. Presence of rheumatoid factor (RF), antibodies to cyclic citrullinated peptide (CCP), and elevated ESR, CRP
Infectious arthritis	Single joint with tenderness, redness, warmth, swelling, and restricted ROM. Inability to weight bear. Patients often febrile. Synovial fluid with >20,000 WBCs
Crystalline arthritis or gout	Severe pain, redness, warmth, swelling, and restricted ROM. Flares often occur at night. Synovial fluid with monosodium urate (MSU) crystals. Tophi on exam and radiographs
Ligamentous or meniscal tear	Typically involves trauma to the knee, such as sudden change in direction, landing, twisting or direct force. Positive special tests (i.e., Lachman or anterior drawer test for ACL tear). Rapid swelling, instability with weight bearing, decreased ROM

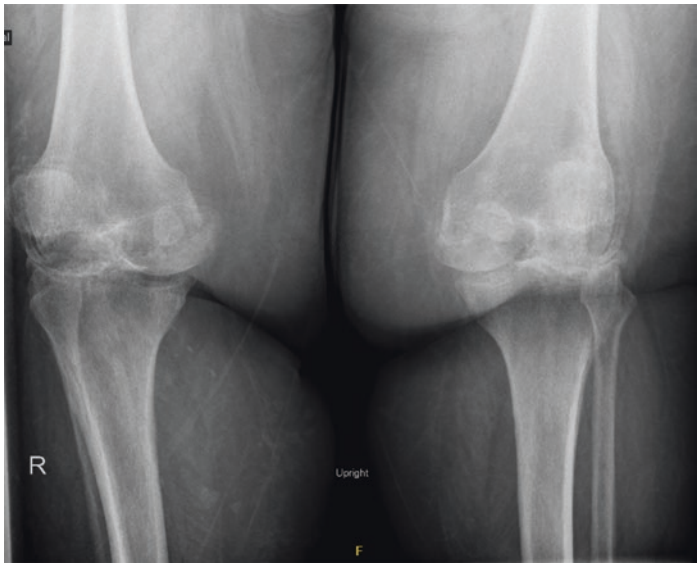

Fig. 10.9 Bilateral knee X-rays: Severe end stage tricompartmental OA and osteophytes

ease and most commonly affects the patellofemoral and medial tibiofemoral joints [26, 27].

It is caused by localized loss of cartilage in the joint, subsequent remodeling of adjacent bone, and associated inflammation [28]. The most notable risk factor for OA is age, where the mechanism of joint damage is poorly understood but thought to be multifactorial (oxidative damage, thinning cartilage, muscle weakening, reduction in proprioception, etc.) [29]. "Chondrosenescence" describes the age-dependent deterioration of chondrocytes, the cells responsible for cartilage formation, and this can lead to the cartilage dysfunction seen in OA. The term "inflammaging" has also been used to describe the low-grade inflammation that occurs as people age and is a major contributing factor to the progression of OA [30]. Obesity also plays an important role in the development of OA, especially in weight-bearing joints such as the knees and hips. Data shows that indi-

viduals with BMI > 30 kg/m^2 were 6.8 times more likely to have knee OA than controls with normal-range BMIs [31]. Modifiable risk factors such as obesity, comorbidities (i.e., diabetes, cardiovascular disease), and sedentary lifestyles have been shown to heavily influence the course of disease progression [30].

Prevalence of OA is also associated with previous joint injury and abnormal loading of the joints. Studies have shown that anterior cruciate ligament (ACL) tears are associated with early-onset knee OA in 13% of cases after 10–15 years. When ACL tears also involve injury to cartilage, subchondral bone, collateral ligaments and/or menisci, the prevalence of OA increases to 21–40% [29]. Furthermore, data suggest that people with occupations that involve frequent squatting, kneeling, stair climbing, crawling, and/or bending had increased risk of developing knee OA. Such occupations include workers in construction, firefighting, agriculture, fisheries, forestry, and mining [32].

Osteoarthritis usually presents as joint pain (often at the end of the day), stiffness, limited motion, swelling, and in some cases joint deformity depending on advancement of disease [26]. Diagnosis of osteoarthritis is typically clinical; however, imaging can be useful when the diagnosis is unclear. Radiographs are the most widely used form of imaging and can identify key features of OA such as osteophytes, joint space narrowing, cysts, and subchondral sclerosis [33] (Fig. 10.9). One limitation of radiographs, however, is that they can be insensitive in early disease. While an MRI is not typically necessary for diagnosis, it can identify OA at earlier stages and rule out OA when there is suspicion for other pathologies, such as ligamentous and/or meniscal tears [34].

Management

Management of knee osteoarthritis varies depending on the severity of the disease. For patients with mild to moderate OA, symptoms are usually controlled with nonpharmacologic therapies such as exercise therapy, muscle strengthening, and weight loss. Exercises that strengthen the quadriceps femoris are thought to be the most effective method both for the treatment and prevention of

knee OA, as this muscle maintains the stability of the knee joint and allows for its extension [35]. Studies show that exercise therapy has the same pain-relieving effect as NSAIDS and 2–3× the effect of acetaminophen in patients with knee OA, without the side effects or risk of dependence associated with pharmacologic therapies. Furthermore, exercise therapy is essential in the management of OA, not only for its positive impact on joint pain and function, but because of its role in the prevention and/or improvement of chronic conditions that are often associated with OA. Studies show 2/3 of patients with knee and hip OA have one or more comorbidities, including type 2 diabetes, hypertension, and depression, and physical activity can help these patients maintain good health [36]. Recreational or moderate intensity exercises such as walking, long-distance running, swimming, biking, and Tai chi are recommended for patients with OA. Elite level activities, particularly contact sports, which can lead to injury or post-traumatic OA are not recommended [30].

If symptoms persist, it is recommended to add topical therapies (i.e., diclofenac gel, capsaicin cream or patches) or oral analgesics as needed [37]. Studies have also shown that some nutritional supplements, such as curcumin and *Boswellia serrata*, can be beneficial for the treatment OA due to their anti-inflammatory and analgesic properties, however, research on their efficacy is limited [38, 39]. For moderate to severe OA, treatment also starts with nonpharmacologic treatment as above, with emphasis on aquatic over land-based exercise due to reduced load on the knees [40]. Other supportive measures include knee braces, specialized footwear, assistive walking devices (i.e., canes), and cognitive behavioral therapy for pain coping.

Alternatives for treatment include the addition of oral NSAIDS, intra-articular steroids, duloxetine, and eventually surgery if indicated [37]. For patients with inadequate response to oral NSAIDS or concomitant comorbidities in which oral NSAIDS are contraindicated, duloxetine is the next suggested treatment. Intra-articular glucocorticoids are not recommended unless patients have moderate to severe pain and there has been failure of relief with the other treatment options. Triamcinolone or methylprednisolone are most commonly used, although betamethasone can

also be used. Studies show that serial injections every 3 months is not recommended due to findings of increased cartilage volume loss measured on MRI and no effect on knee pain long-term compared to controls with saline injections [41]. Other studies have shown that intra-articular glucocorticoid injections do provide short-term relief for up to 6 weeks post-injection, however, after this period the effects on knee pain and function were similar to the placebo injections [42]. Additionally, physical therapy was shown to be more effective for pain relief and improvement in functional debility compared to glucocorticoid injections after 1 year [43].

Lastly, surgery is recommended for patients after significant symptoms persist despite nonsurgical interventions. Total knee replacement is the most common type of surgery, and osteotomy is an option for younger patients with varus or valgus deformity [36, 44].

Patient Conclusion

The patient above had bilateral methylprednisolone injections on the day of her visit. Physical therapy had been recommended; however, she did not feel comfortable going out frequently on her own and is wheelchair bound. It was determined by the clinician that this patient requires bilateral total knee replacement, however, she was not a good candidate due to her body habitus. Patient was encouraged to increase physical activity and to initiate a weight loss program.

Key Takeaways

1. Osteoarthritis (OA) is the most common form of arthritis in the knees, hips, and hand joints, and knee OA accounts for approximately 80% of the disease.
2. The most notable risk factors of OA are age, obesity, previous joint injury, and abnormal loading of the joints.

3. Osteoarthritis of the knee usually presents as joint pain (often at the end of the day), stiffness, limited motion, swelling and in some cases joint deformity.
4. Diagnosis of osteoarthritis is typically clinical. Radiographs are the most widely used form of imaging and can identify key features of OA such as osteophytes, joint space narrowing, cysts, and subchondral sclerosis.
5. For mild OA, symptoms are usually controlled with nonpharmacologic therapies such as exercise, muscle strengthening, weight loss, topical therapies, and nutritional supplements.
6. Exercise therapy has been shown to be safer and more effective than pharmacologic treatments and can help with prevention and/or improvement of chronic conditions that are often associated with OA.
7. For moderate to severe OA, persistent symptoms involve the addition of supportive measures such as knee braces, specialized footwear, and assistive walking devices, as well as oral NSAIDS, duloxetine, and intraarticular steroids.
8. Surgery is recommended for patients after significant symptoms persist despite nonsurgical interventions. Total knee replacement is the most common type of surgical intervention.

Chronic Knee Pain in a 12-Year-Old

History

A 12-year-old male presents to clinic with complaint of anterior left knee pain and popping that was first noted roughly 1 year ago. The pain has gradually worsened over time from a dull ache to moderate pain after physical activity causing him to limp. The pain is exacerbated by jumping, running, and climbing stairs. He has no recent trauma or injury.

Review of systems: No fever, chills, cough, paresthesia, weakness, bowel/bladder changes or falls. *Past medical Hx/surgeries:* ADHD *Medications:* Concerta *Family history:* None *Social history:* Patient lives at home with his mother and brothers. He attends seventh grade and enjoys basketball, baseball, and football	*Initial physical exam findings:* **BMI:** 19.6 **Height:** 4′ 11″ **Gen:** Not in acute distress, well developed *Left knee:* **Inspection:** Mild swelling of the left knee located anterior and inferior to patella **Palpation:** • No tenderness to palpation over medial or lateral joint lines, or over pes anserine • Mild tenderness to palpation over the tibial tubercle • General tenderness to palpation over anterior knee, including patellar tendon **Movement:** 0–140 degrees of flexion without significant pain **Strength:** 5/5 in bilateral lower extremities **Sensation:** Grossly intact to light touch *Special exam maneuvers:* Negative Lachman, anterior/posterior drawer test Negative valgus stress or laxity test Negative varus stress or laxity test Negative McMurray's test

Differential Dx (Table 10.5)

Work Up: Imaging

Left Knee X-ray: AP Lateral View

See Fig. 10.10.

Table 10.5 Differential diagnosis and associated key findings

Differential	Key findings
Patellofemoral pain syndrome	Associated with joint overuse or onset of new strenuous activity involving the knee joint. Presents as an aching pain in front of the knee
Osgood-Schlatter disease	Osteochondrosis caused by traction of the proximal tibial tubercle secondary to repetitive contractions of the quadricep muscle. Often presents as pain and swelling at the tibial tubercle
Sinding-Larsen-Johansson disease	Osteochondrosis caused by traction of inferior pole of the patella due to repetitive quadricep contractions, similar mechanism to Osgood-Schlatter. Associated with pain at the inferior border of the patella
Quadriceps/patellar tendinopathy	Occurs over weeks to months due to overuse, pain along the superior pole (quadriceps) or inferior pole (patellar) of the knee joint, minor swelling, calcification may be present
Prepatellar/infrapatellar bursitis	Swelling, warmth, and pain on palpation anterior to the patella or patellar tendon. Often caused by direct, repetitive trauma to the knee such as kneeling
Fat pad impingement	Impingement of the infrapatellar fat pad between the inferior poles of the patella and femur, leading to diffuse pain over the patella exacerbated by knee extension

Bilateral Knee X-ray: AP Merchant View

See Fig. 10.11.

Diagnostic Discussion

Chronic knee pain in a pediatric patient (lasting longer than 6 weeks) should be evaluated for the following etiologies: pain onset related to excessive activity, impaired healing after an acute injury, congenital/anatomical anomalies, and systemic causes.

Fig. 10.10 Enthesopathy of left knee seen on the distal aspect of the patella

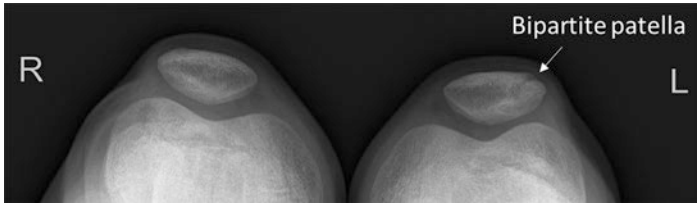

Fig. 10.11 Bipartite patella on the left

This patient's worsening knee pain over the past year is associated with physical activity without any notable trauma. The physical exam does not show any evidence of joint laxity or decreased range of motion which would point more towards a ligamentous or meniscal injury. As such, the differential can be narrowed to several pathologies relating to joint overuse injury, tendinopathy, and bursitis. Localization to the anterior knee is more reflective of patellar or quadricep involvement, or bursitis in the anterior com-

partment. Iliotibial band injury (typically localized to the lateral knee) or pes anserine bursitis (typically localized to the medial knee) are less likely.

Patellofemoral pain syndrome is one of the most common causes of anterior knee pain among physically active patients, often associated with ascending, descending stairs, squatting, and jumping. Overuse of the knee joint can lead to tightening and weakening of surrounding connective tissue, causing inflammation between the femoral and patellar joint space secondary to misalignment or excessive compressive forces on the synovial space.

Osgood-Schlatter disease and Sinding-Larsen-Johansson disease are also common overuse injuries in the pediatric population due to traction on the proximal tibial tubercle and inferior pole of the patella respectively. Symptoms typically arise in adolescents (ages 12–15) during their growth spurt and within highly active children [45]. Radiographic evaluation can be helpful in elucidating the primary contributor to this patient's knee pain.

Quadriceps or patellar tendinopathy is also associated with overuse but is typically associated with localizable pain to either the superior or inferior pole of the knee joint. Prepatellar or infrapatellar bursitis is less likely due to lack of erythema or warmth. Fat pad impingement is also unlikely as the patient's pain is not exacerbated by knee extension.

This patient has radiographic evidence of osteochondrosis both at the proximal tibial tubercle (Osgood-Schlatter) and the inferior pole of the patella (Sinding-Larsen-Johansson), as well as a bipartite patella seen on merchant view which may contribute to the patient's anterior knee pain (Figs. 10.10 and 10.11). Repetitive strain on the insertion sites of the patellar tendon can result in small avulsion fractures which result in sclerosis and fragmentation of the tibial tubercle or patella [45].

Management

Both Osgood-Schlatter and Sinding-Larsen-Johansson syndrome are usually self-limited with most adolescents responding well to

conservative treatment over several months. This includes rest from sports-related/strenuous activity, anti-inflammatory medications, and physical therapy geared towards hamstring and quadricep stretches, range of motion exercises, and core stability. Symptoms typically resolve at skeletal maturity with closure of the apophysis, which may range from several months to 1–2 years [46].

For patients who continue to have disabling symptoms after closure of the apophysis, surgical intervention may be warranted. Persistent pain can usually be attributed to the presence of free ossicles and enlargement of the anterior portion of the tibial tubercle (Fig. 10.12). Both endoscopic and open operative approaches are available to remove these ossicles or reduce the enlarged tubercle with beneficial outcomes [48].

Areas of Research

While corticosteroid injections are not recommended in the pediatric population due to increased risk for atrophy and tendon rup-

Fig. 10.12 Typical clinical appearance of Osgood Schlatters with marked tibial tubercle swelling [47]

ture, joint injections with hyperosmolar dextrose and lidocaine have been explored in improving symptoms, especially during sports-related activity [49, 50].

Key Takeaways

1. Chronic knee pain in the pediatric population can often be categorized by the following considerations: pain onset with activity, impaired healing after trauma, congenital anomalies, and systemic conditions.
2. Anterior knee pain worsened by physical activity can often be attributed to one or more of the following conditions: Osgood Schlatter disease, Sinding-Larsen-Johansson disease, patellofemoral pain syndrome, or quadriceps/hamstring tendinopathy.
3. Both Osgood Schlatter disease and Sinding-Larsen-Johansson disease are characterized by joint overuse leading to traction apophysitis of the tibial tubercle or inferior patella respectively. Radiographic imaging may show associated osteochondrosis with small avulsion fractures and free ossicles.
4. These conditions are typically self-limiting and improve with conservative management. While most cases resolve with closure of the apophysis, refractory cases may warrant surgical intervention.

Posterior Knee Pain

History

A 88-year-old-female with history notable for a right nondisplaced femoral neck fracture (with closed reduction and percutaneous pinning) presented with worsening chronic bilateral knee pain. The pain is localized to her posterior knees and is worsened with flexion and prolonged standing. She has difficulty with ambulation and takes acetaminophen four times a day for pain alleviation. She reports no recent history of knee trauma. She reports her knee was drained four times and she has received four steroid injections in the past 2.5 years with initial improvement in pain lasting for 1–2 weeks.

Review of systems:
No fever, chills, cough, paresthesia, weakness, bowel/bladder changes or falls.
Past medical Hx/surgeries:
Coronary artery disease
History of cardiac stent placement
Type 2 diabetes mellitus
Hypertension
Deep vein thrombosis
Right nondisplaced femoral neck fracture (with closed reduction and percutaneous pinning)
Medications:
- Apixaban
- Furosemide
- Gabapentin
- Diclofenac gel
- Aspirin (81 mg)
- Atorvastatin
- Hydrochlorothiazide
- Metoprolol succinate
- Metformin
- Quinapril

Family history: Non-contributory

Physical exam findings:
BMI: 35.5
General: Not in acute distress, well developed
Cardiovascular: Well perfused
Knees:
Inspection:
Left knee varus deformity
Diffuse bony overgrowth of bilateral knees
Palpation:
No erythema/edema
Tenderness to palpation to posterior left knee; crepitus in bilateral knees
Movement:
Right knee flexion 100 degrees
Left knee flexion 120 degrees
Bilateral knee extension 0 degrees
Strength: 5/5 in lower extremities
Sensation: Grossly intact to light touch
Gait: Slowed cadence, antalgic, ambulates with walker
Special exam maneuvers:
Positive anterior drawer test bilaterally
Negative McMurray's test
Negative for varus/valgus laxity or stress pain

Differential Dx (Table 10.6)

Work Up: Imaging

Left Knee MRI (Fig. 10.13)

Left knee MRI results: Tricompartmental osteoarthrosis, most pronounced in the medial joint compartment. Moderate joint effusion with synovitis. Intra-articular body in the posterior aspect of the knee. Degenerative tearing of the medial and lateral menisci. Chronic complete rupture of the ACL. Mild degenerative change of the PCL and MCL. Small Baker's cyst.

Table 10.6 Differential diagnosis and associated key findings

Differential	Key findings
Anterior cruciate ligament tear	Sudden change in direction or landing from a jump (usually audible "pop" at time of injury), positive Lachman and/or anterior drawer test, history of direct trauma to knee, rapid swelling, instability with weight bearing, decreased ROM
Popliteal Baker's cyst	Joint fluid contained in a cyst localized to the posterior capsule, worsened by activity typically involving repetitive knee flexion. Presents as posterior knee pain and a palpable cyst in the popliteal fossa (with knee in extension)
Osteoarthritis	Depending on the stage of osteoarthritis, pain can be chronic or intermittent with associated stiffness and reduced range of motion. Worsened by joint use and relieved by rest. Joint deformity and swelling can also be present
Popliteus/biceps femoris tendinopathy	Can be caused by acute or chronic trauma, most associated with downhill activities. Pain to palpation at the tendon insertion site, anterior to the lateral femoral condyle
Popliteal artery aneurysm	Seen in patients with cardiovascular risk factors. Claudication leading to chronic or acute posterior knee pain, associated with a pulsatile mass in the popliteal fossa

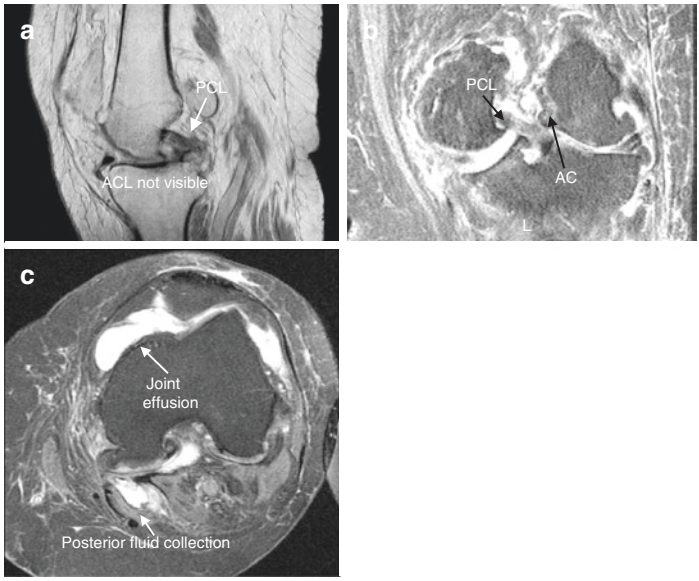

Fig. 10.13 (**a**) Sagittal View (**b**) Coronal View, (**c**) Axial View

Right Knee MRI (Fig. 10.14)

Right knee MRI results: Tricompartmental osteoarthrosis, most pronounced in the medial and lateral joint compartments. Small joint effusion with synovitis. Degenerative tearing of the medial and lateral menisci. Chronic complete rupture of the ACL. Partial tear of the MCL. Degenerative change of the LCL. Small Baker's cyst.

Along with the patient's severe osteoarthritis, she has several degenerative changes (meniscal, PCL, MCL) including complete tears of her ACL bilaterally. ACL tears are commonly seen more in younger populations engaged in sports-related activity (deceleration, jumping, pivots, direct trauma), but many other mechanisms can cause ACL damage leading to an eventual tear [51]. Considering the patient's advanced age, her ACL tears are most likely due to non-contact injuries throughout her lifetime that were not intervened on. These chronic ligament tears have contributed to this patient's advanced osteoarthritis, leading to chronic joint effusion and recurrent Baker's cysts.

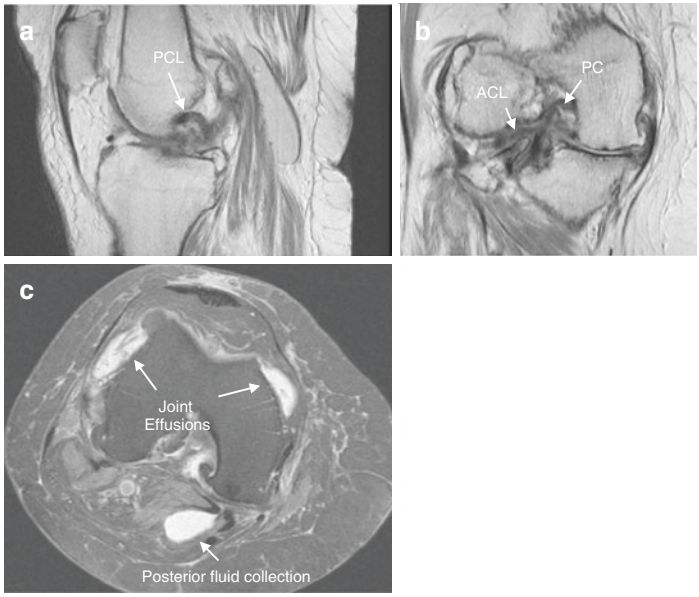

Fig. 10.14 (**a**) Sagittal View (**b**) Coronal View, (**c**) Axial View

Diagnostic Discussion

Baker's cysts typically develop due to a communication between the cyst and joint space, with sequestration of fluid caused by repeated knee flexion/extension. These cysts are typically found between the semimembranosus and medial gastrocnemius muscles. Popliteal cysts are relatively common even in asymptomatic individuals—anywhere from 4.7% to 37% depending on the population. They are often found in association with other intra-articular or inflammatory conditions such as osteoarthritis, rheumatoid arthritis, and meniscal or ligament tears [52]. For patients where the diagnosis is uncertain on physical exam and history, ultrasound and plain radiographs are recommended. While ultrasound can identify cysts and adjacent effusions, radiographs can help identify other pathologies associated with cyst formation and maintenance. MRI is often used to evaluate soft tissues structures and areas of fluid collection (Fig. 10.15).

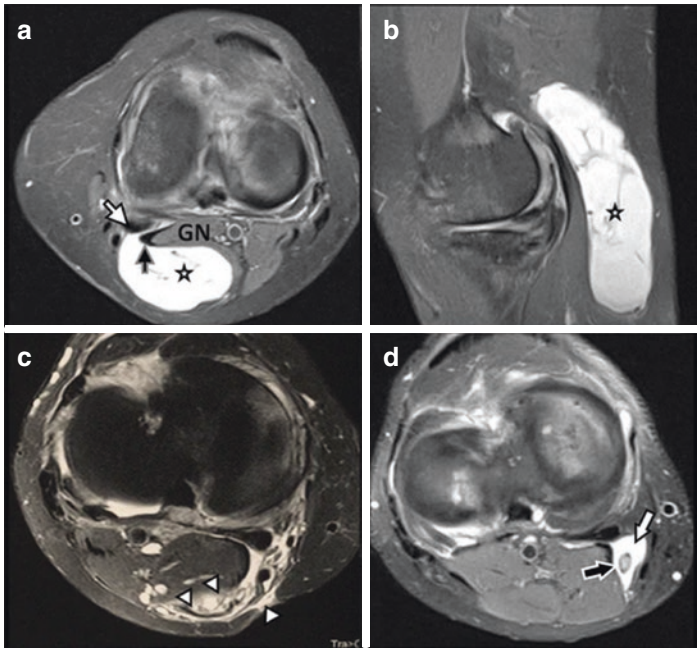

Fig. 10.15 Popliteal cysts. The axial (**a**) and sagittal (**b**) fat saturated proton density weighted images show a large multiseptated popliteal cyst (asterisks) emerging between the medial gastrocnemius tendon (black arrow) and the semimembranosus tendon (white arrow) and abutting the medial gastrocnemius muscle belly (GN). The axial (**c**) fat saturated proton density weighted image shows a ruptured popliteal cyst (arrowheads). The axial (**d**) fat saturated proton density weighted image demonstrates a Baker's cyst (white arrow) with a single loose osteocartilaginous body inside the cyst (black arrow) [53]

In this older patient with chronic bilateral knee pain, recurrent joint effusion and Baker's cysts, and a history of femoral neck fracture, osteoarthritis should be highly suspected as a primary cause for this patient's recurrent cysts. However, it is important to rule out other reversible causes. This patient's positive findings on anterior drawer test bilaterally pointed towards ACL pathology and warranted further imaging.

Other diagnoses to consider include popliteal or biceps femoris tendinopathy, which are localized to the posterior knee due to their attachment sites, though less likely in this patient who has not endorsed any aggravating activities. And in a patient with several cardiovascular comorbidities (coronary artery disease, hypertension, prior stent placement), vascular pathologies such as a popliteal artery aneurysm should also be evaluated for.

Management

This patient has severe osteoarthritis with bilateral, chronic ACL tears presenting with recurrent Baker's cysts. Baker's cysts are typically managed by identifying a source of cyst formation as well as treating the cyst if symptomatic. In this case, the patient's bilateral ACL tears, ligament degeneration, meniscal degeneration, and severe osteoarthritis are all potential contributors.

ACL tears can be managed conservatively or surgically depending on a patient's activity level, extent of injury, and the presence of arthritic changes. ACL reconstruction in active, older patients (ages 40+ and 60+) without arthritis have been shown to restore function and knee stability with similar complication rates compared to younger patients [54]. While this patient ultimately deferred surgical treatment, her eligibility would depend on the surgeon's judgment regarding expected return of function and pain relief in the setting of existing severe osteoarthritis and ligament/meniscal degeneration. Non-operative management includes rehabilitation and bracing that helps control knee range of motion (such as a hinge knee brace) to avoid further joint instability.

Management of symptomatic Baker's cysts include knee joint arthrocentesis and intra-articular injection with glucocorticoids for symptom relief and to reduce the rate of recurrence. Direct aspiration of the cyst can also be attempted with ultrasound guidance. The same management can be followed for ruptured cysts [55]. For cysts refractory to repeat aspirations and injections, further imaging and evaluation should be performed to evaluate reversible causes as mentioned prior, with few patients requiring surgical excision.

Areas of Research

While the frequency of surgical intervention remains low, more options have been explored for patients with refractory cysts. For patients with or without one-way valve lesions contributing to cyst maintenance, arthroscopic cystectomy has been shown to provide good outcomes in reducing pain and recurrence [56]. New techniques such as arthroscopic communication enlargement (valvular opening between the semimembranosus and medial gastrocnemius) may produce better outcomes in future studies [57].

Key Takeaways

1. Popliteal (Baker's) cysts are often asymptomatic and are commonly found incidentally on imaging. Patients with symptomatic cysts typically present with posterior knee pain and palpable cyst in the popliteal fossa made more detectable on knee extension.
2. Osteoarthritis, rheumatoid arthritis, and meniscal/ligamentous pathology can contribute to symptomatic Baker's cysts, which can be managed through cyst aspiration, steroid injection, and less commonly cystectomy in refractory cases.
3. ACL tears in older individuals are often managed conservatively with rehabilitation and bracing due to lower physical demands. ACL reconstruction is still a viable option for all active patients regardless of age, after assessing the extent of injury and severity of arthritis.

Knee Trauma After Motor Vehicle Collision

History

A 35-year-old female with no significant past medical history, presents with right knee pain and weakness after a motor vehicle collision. She was riding a moped going 5–10 mph, hit an open car door, and fell onto her right lower extremity. She had immediate pain localized to the right knee. She attempted to ambulate after the fall but was unable to bear weight due to weakness in the right knee. She denies numbness or tingling in the right lower extremity. She denies head injury or loss of consciousness.

Review of systems:
No fever, chills, cough, chest pain, SOB, paresthesia, dizziness, loss of consciousness, or lightheadedness
Past medical Hx/surgeries:
Abnormal pap smear
Gonorrhea
Ovarian cyst (ruptured)
Anemia
No past surgical history
Medications:
None
Allergies:
Sulfa
Family history:
No relevant family history
Social history:
Patient is a social worker.
Denies smoking or drug use.
Drinks alcohol socially

Physical exam findings:
Constitutional: Alert. Oriented to person, place, and time. No distress
HEENT:
Head: Normocephalic and atraumatic
Cardiovascular: Normal rate. 2+ dorsalis pedis pulses bilaterally
Pulmonary/chest: Effort normal and breath sounds normal. No respiratory distress
Skin: Skin is warm and dry. Non-diaphoretic
Musculoskeletal exam:
Inspection:
Right lower extremity: Mild effusion superior and medial to patella. No visible ecchymosis or bony deformities. Hip, calf, and ankle without abnormalities
Left lower extremity: No abnormalities noted
Bilateral upper extremities without abnormalities
Palpation:
Right lower extremity: Limited right knee passive ROM 3–80 degrees due to pain. Mild right knee medial joint line tenderness. Right hip, calf and ankle non-tender to palpation
Left lower extremity: Non-tender to palpation
Bilateral upper extremities non-tender to palpation
Sensation:
Bilateral upper and lower extremities neurovascularly intact
Strength:
Right lower extremity: Unable to assess due to pain
Full strength of the left lower extremity and bilateral upper extremities
Gait:
Unable to bear weight on the right lower extremity due to weakness secondary to pain
Special exam maneuvers:
Right lower extremity:
Straight leg raise with minimal lag
Grade 2 posterior drawer
Soft endpoint with Lachman
Mild laxity with valgus stress
Negative McMurray
Negative dial test
Left lower extremity: Negative

Differential Dx (Table 10.7)

Work Up: Imaging

See Fig. 10.16.

X-rays of the right knee were obtained (Fig. 10.16) which showed:

Fracture fragments detected at the lateral femoral condyle and posterior to the fibular head, highly suspicious for comminuted traumatic fractures of the lateral femoral condyle and/or lateral tibial plateau. No significant suprapatellar effusion.

Table 10.7 Differential diagnosis and associated key findings

Differential	Key findings
Tibial plateau fracture	High energy trauma, most often motor vehicle collisions, also seen in sports injuries. Acute pain, swelling. Ligamentous and meniscal injuries often accompany due to mechanism of injury
Fibular head or neck fracture (Maisonneuve fracture)	High energy trauma with direct blow to fibula; also seen with severe medial ankle sprains or medial malleolar fractures; lateral knee pain that may present with or without swelling; focal bony tenderness at fibular head or neck
Knee (tibiofemoral) dislocation	High energy trauma with direct blow to anterior knee causing hyperextension; often involves multiple knee ligaments, and can compromise vascular supply to lower leg; trauma often related to motor vehicle collisions and sports; swelling, pain, and instability
Bone contusion	Commonly associated with PCL injuries, in which there is direct knee trauma to tibia and hyperextension. Can cause significant pain, disability, and restricted ROM. Negative posterior drawer test when an isolated injury
Patellar fracture	Caused by direct trauma to the anterior knee; presents with pain, swelling and ecchymosis localized to directly over patella; PCL tears often accompany due to mechanism of injury

Table 10.7 (continued)

Differential	Key findings
Patellar dislocation	Usually caused by twisting force to planted, flexed knee. Presents as acute swelling, tenderness to palpation on medial edge of patella. May be audible "pop" or tear at time of dislocation. Often instability with weight bearing followed by severe pain. Patella typically palpable laterally if not reduced
Anterior cruciate ligament (ACL) tear	Sudden change in direction or landing from a jump (usually audible "pop" at time of injury), positive Lachman and/or anterior drawer test, history of direct trauma to knee, rapid swelling, instability with weight bearing, decreased ROM
Posterior cruciate ligament (PCL) tear	History of direct trauma to knee (usually direct blow to proximal anterior tibia), positive posterior drawer test, posterior knee pain, instability with weight bearing, knee may feel like it hyperextends
Medial/lateral collateral ligament strain	MCL: Twisting of leg or direct blow to medial knee, Medial knee pain; medial knee feels unstable with lateral movements; focal tenderness over MCL; positive valgus stress test; often accompanied by medial meniscus tear LCL: Twisting of leg or direct blow to lateral knee, lateral knee pain; lateral knee feels unstable with lateral movements; focal tenderness over LCL; positive varus stress test; often accompanied by ACL and PCL injury due to greater required force
Meniscus tear	Sudden, forceful twisting of knee with foot planted, tearing/popping sensation, pain/swelling, effusion, joint line tenderness; positive McMurray and/or Thessaly test

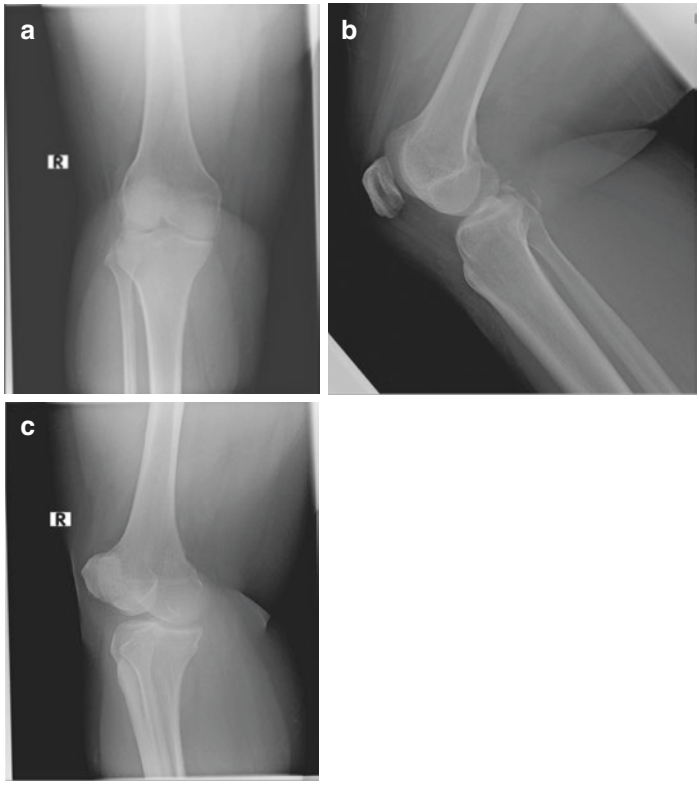

Fig. 10.16 (**a**) AP View, (**b**) Lateral View, (**c**) Oblique External View

CT right knee w/o contrast was obtained which showed (Fig. 10.17):

Comminuted traumatic fracture of the posterior mid and medial tibial plateau. Lateral subluxation of the patella.

MRI Right Knee was obtained which showed (Fig. 10.18):

1. Comminuted posterior tibial plateau fracture.
2. Large osteochondral defect weightbearing lateral femoral condyle as above.

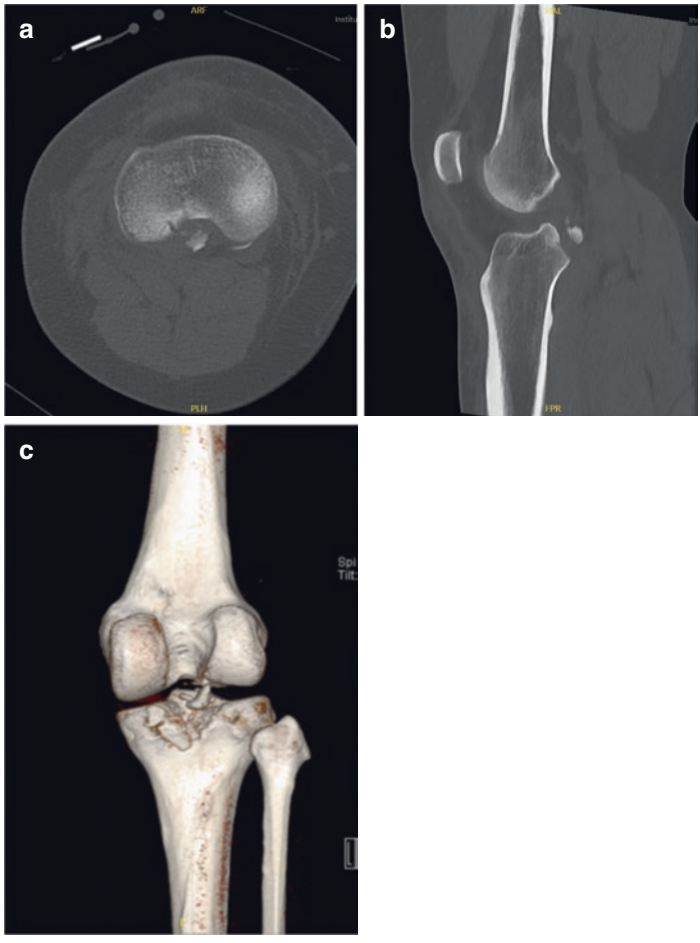

Fig. 10.17 (**a**) Axial View, (**b**) Sagittal View, (**c**) 3D Spin View

3. Complete avulsion posterior root lateral meniscus. Avulsion of posterior meniscocapsular attachments.
4. Complete tear ACL and distal PCL.
5. Complete tear superficial and deep MCL.

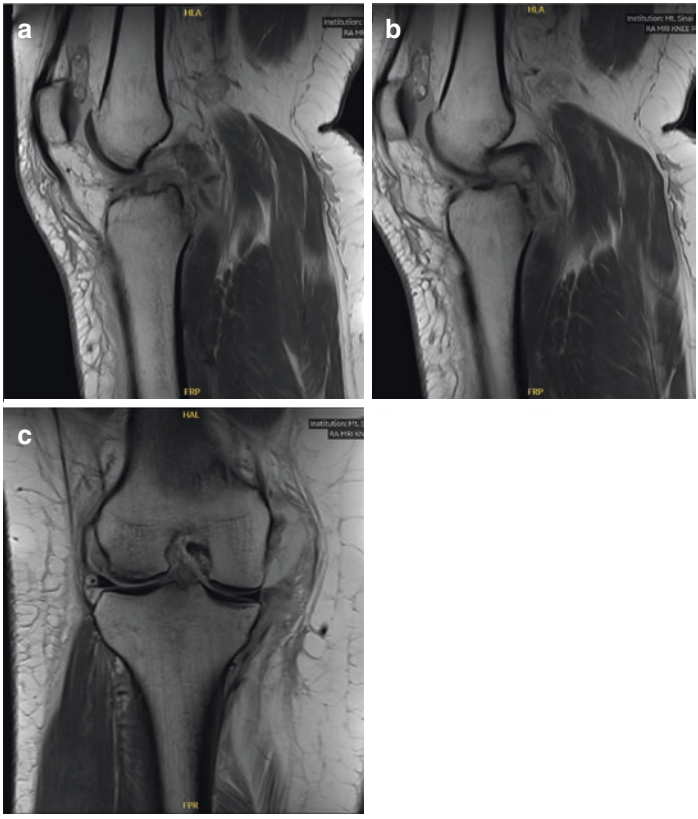

Fig. 10.18 (**a**) Sagittal view, notable for ACL tear, (**b**) Sagittal view, notable for PCL tear, (**c**) Coronal View

6. High-grade sprain proximal LCL with associated lateral femoral epicondyle avulsion fracture.
7. Mild popliteus muscle strain.
8. Large joint effusion containing fracture fragments/loose bodies posteriorly.

Diagnostic Discussion

The proximal portion of the tibia, also known as the tibial plateau, is the most common site of tibial fractures compared to the distal and midshaft tibia [58]. Tibial plateau fractures account for about 1% of all fractures and occur most often in situations that involve significant direct trauma to the knee, such as motor vehicle collisions, vehicle-pedestrian collisions, and contact sport injuries [59]. The lateral tibial plateau is affected in 60% of fractures, likely because most injuries involve a lateral to medial force. Medial tibial plateau fractures occur 15% of the time, while bicondylar lesions occur in 25% of cases. Injury often presents on exam as swelling and tenderness over the proximal tibia, as well as skin abrasions and/or contusions. Complications such as compartment syndrome, peroneal nerve dysfunction, and ligamentous or meniscal instability may also be seen [60].

Ligamentous and meniscal injuries often occur with tibial plateau fractures, likely because the proximal tibia forms the lower surface of the knee joint and serves as an attachment site. A recent study which evaluated MR scans of 29 patients with acute tibial plateau fractures, showed that tibial (medial) collateral ligament tears (55%) and lateral meniscal tears (45%) were the most common. 41% of patients had anterior cruciate ligament injuries, compared to 28% of posterior cruciate ligaments. Furthermore, medial meniscal tears were noted in 21% of cases, while lateral collateral ligament tears were seen 34% of the time [61].

The Schatzker classification system divides tibial plateau fractures into six types: lateral plateau fracture without depression (type I), lateral plateau fracture with depression (type II), lateral plateau fracture with central depression (type III), medial plateau fracture (type IV), bicondylar plateau fracture (type V), and plateau and proximal shaft fracture (type VI). CT and MRI are the most accurate method for Schatzker classification of tibial plateau fractures (Fig. 10.19) [62–64].

AP and lateral radiographs are usually sufficient for the diagnosis of proximal tibial fractures. CT scans can better define the fracture when radiographs are unremarkable but clinical suspi-

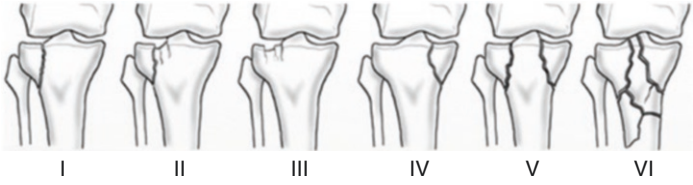

Fig. 10.19 Schatzker classification system of tibial plateau fractures [62]

cion is high, while MRI is most useful for displaying meniscal or ligamentous injuries [61]. Ultrasound may be useful for showing knee effusions or soft tissue injury [65].

Management

Initial management of tibial plateau fractures involves compression, icing, splinting of knee in extension, elevation, non-weight bearing, and analgesics. If there is an uncomplicated fracture without displacement, or ligamentous/meniscal injury, management may be non-operative. This usually includes weekly radiographs to monitor healing, non-weight-bearing for about 6–8 weeks and knee immobilizer for 8–12 weeks until radiographs show complete healing. Patients usually regain full function of the lower extremity after 16–20 weeks with physical therapy [66].

Orthopedic referral is indicated within 48 h in the setting of open or displaced tibial plateau fractures, signs of vascular compromise, acute compartment syndrome, or involvement of ligamentous or meniscal injury. Most of these fractures will require surgical intervention with open reduction and external fixation (ORIF) [66]. Total knee arthroplasty may be indicated in older patients with significant osteoporosis or osteoarthritis and younger patients with severe tibial plateau destruction [67]. Return to full sporting activity is usually attainable in about 6 months, if indicated [68].

Studies have shown that severe open fractures of the tibia often require amputation due to considerable soft tissue injuries; how-

ever, proximal tibia fractures comprised the lowest percentage of amputation (19.3%) compared to midshaft tibial (46.8%) and distal tibial (34.0%) fractures [69].

Outcomes and Complications

Overall, the outcome following treatment of tibial plateau fractures is good. However, because tibial plateau fractures often occur with high impact force such as motor vehicle collisions, the patient usually sustains other severe injuries or complications. These include acute compartment syndrome (ACS), infection, nonunion, malunion, and this may cause a delay in their return of daily function and cause long-term morbidity [66].

Gait abnormality is also a significant long-term complication that has been observed following tibial plateau fractures. In one study, 22 patients were evaluated 3 years after high energy tibial plateau fractures. Findings showed these patients walked slower by 18%, and had a shorter step length by 11% in the affected leg and shorter step length by 12% in the unaffected leg. This study also assessed for quality of life in patients with tibial plateau fractures, which showed a Physical Health Score 65% lower compared to healthy controls and Mental Health Score 40% lower compared to healthy controls [70].

Another study analyzed the long-term functional results following surgical repair of tibial plateau fractures using ORIF. It was found that the most significant factor for variation in functional outcome was age, where patients under 40 had a high rate of functional outcome (>92%) regardless of fracture type. Patients over 40 showed a much poorer functional outcome, and still experienced lower extremity pain, stiffness, and decreased physical function compared to the younger age group [71]. Lastly, studies have shown that patients with tibial plateau fractures that required surgery had a 5.3× increase in the likelihood of also needing a total knee arthroplasty after 10 years [72].

Patient Conclusion

The patient above underwent surgical repair of the ACL, PCL, medial and lateral meniscus, and medial collateral ligament. Post-op instructions included instructions for home exercises, and a physical therapy referral.

Key Takeaways

1. Tibial plateau fractures occur most often after significant direct trauma to the knee, such as motor vehicle collisions, vehicle-pedestrian collisions, and contact sport injuries.
2. Ligamentous and meniscal injuries are often associated with tibial plateau fractures. Therefore, physical exam and imaging should rule out these potential pathologies when a patient presents with a tibial plateau fracture.
3. Orthopedic referral is indicated within 48 h in the setting of open or displaced tibial plateau fractures, signs of vascular compromise or acute compartment syndrome, or involvement of ligamentous or meniscal injury. Most of these fractures will require surgical intervention with open reduction and external fixation (ORIF).
4. For uncomplicated fractures, initial management involves compression, icing, splinting of knee in extension, elevation, and non-weight bearing, and analgesics. Regaining full function of the lower extremity usually takes 16–20 weeks with physical therapy and return to full sporting activity usually takes about 6 months.
5. While the outcome following treatment of tibial plateau fractures is typically good, there are often other severe injuries or complications that may cause a delay in a patient's return of daily function and cause long-term morbidity.

Knee Trauma from a Ski Crash

History

A 14-year-old female presented to the urgent care 2 days prior after crashing while competing at a ski race. She could not describe moments leading up to the event but endorsed acute swelling of the right knee and was unable to bear weight immediately. At urgent care, she was diagnosed with a Salter 1 distal femur fracture of the right leg and was placed in a knee immobilizer. Patient would like to return to skiing and playing soccer.

Review of systems: No fever, chills, cough, paresthesia, weakness, bowel/bladder changes or falls. *Past medical Hx/surgeries:* None *Medications:* None *Family history:* None *Social history:* Eighth grade in middle school Lives at home with her mom, dad, and sister Plays soccer and participates in ski races	*Initial physical exam findings:* **Evaluation while on ski hill** **Gen:** Not in acute distress, well developed *Right knee:* **Inspection:** Mild swelling of the right knee with associated erythema **Palpation:** Tenderness to the right distal lateral femur and lateral aspect of proximal tibia No tenderness to palpation of the patellar tendon, quadricep tendon, medial joint line, popliteal fossa, or hamstring tendon *Gait*: Unable to bear body weight on right leg Antalgic gait while using crutches

Follow-Up Physical Exam Findings

Evaluation at outpatient clinic.

BMI: 19.5.

Height: 5′ 3″.

Right Knee

Inspection:

Mild swelling of the right knee.
Patella in appropriate position.

Movement:

Right knee flexion and extension limited to 30* due to pain.
Able to do straight leg raise with both legs.

Strength: 5/5 in bilateral hips and dorsi & plantar flexors.

Sensation: Grossly intact to light touch.

Special Exam Maneuvers

Positive Lachman test.

Negative posterior drawer test.

Negative valgus laxity or stress test.

Negative varus laxity or stress test.

Unable to perform McMurray due to pain.

Differential Dx (Table 10.8)

Diagnostic Discussion

Acute, traumatic injuries to the knee can cause multiple pathologies (fractures, ligament tears, dislocations, and subluxations) necessitating a thorough workup to dictate proper management. While imaging such as MRI is often needed, the patient's initial history and physical exam findings are useful in guiding treatment following initial follow-up. In this patient with a knee effusion after collision during a ski race, an isolated femur fracture would

Table 10.8 Differential diagnosis and associated key findings

Differential	Key findings
Anterior cruciate ligament tear Posterior cruciate ligament tear	Associated with a popping sensation localized to the knee at time of injury followed by acute swelling and joint instability **ACL:** Commonly caused by a direct lateral impact to the knee, or deceleration of the knee causing valgus stress. Positive on anterior drawer test and Lachman's test **PCL:** Can be caused by a direct impact to the proximal anterior tibia but often presents as subacute/chronic symptoms not associated with trauma. Positive on posterior drawer test
Medial collateral ligament tear Lateral collateral ligament tear	**MCL:** Can be caused by direct (blow to lateral aspect) or indirect valgus stress (abduction/rotation) to the knee. Positive on valgus stress test **LCL:** Least commonly injured. Can be caused by direct (blow to medial aspect) or indirect varus stress to the knee. Positive varus stress test
Meniscal tear	Caused by forceful twisting of the knee; catching sensation, knee swelling, joint line tenderness, positive McMurray and Thessaly tests.
Patellar dislocation	Associated with a popping sensation at the knee followed by acute swelling and joint instability. Lateral displacement of the patella is most common, palpable on physical exam with knee flexed to 30 degrees
Quadriceps or patellar tendon tear	Can also be associated with a popping sensation and acute swelling with sharp pain at the knee. Focal tenderness at the anterior knee just above the patella (quadriceps tendon tear) or below the patella (patellar tendon tear). Patients cannot maintain a straight leg or extend their knees
Intra-articular fracture	Often caused by valgus stress on the knee, associated with rapid swelling and pain, lateral joint line tenderness, and instability

unlikely be the only cause for her pain and lack of weight bearing. In addition to her inability to bear weight due to the femur fracture, a knee ligament sprain or tear should be highly suspected: a positive Lachman's test indicates ACL pathology that warrants further imaging. Other injuries such as a concomitant ligament tear, meniscal injury, or intraarticular fracture should also be evaluated for as they often occur concurrently with an ACL tear [73, 74].

Patellar dislocation or subluxation is less likely in this patient, as the patella is appropriately positioned, and the patient does not endorse localized pain to palpation on manipulation. While limited by pain, the patient is able to flex and extend their knee to 30 degrees, making a quadriceps or patellar tendon tear less likely.

Work Up: Imaging

Right Knee Radiograph from Urgent Care (Fig. 10.20)

Right Knee MRI (Fig. 10.21)

Management

In this adolescent with an ACL tear seen on MRI, the acute management involves pain control, reducing inflammation, and achieving full range of motion. A hinged knee brace and crutches are also indicated if there is joint instability, evidenced by excessive range of motion beyond a joint's intended movement. Deciding on an operative versus non-operative approach depends on several key factors, the following of which would lean towards operative:

1. Patient desires to resume athletic, high impact activity.
2. Presence of other concomitant injuries: meniscal tears, collateral ligament injuries.
3. Presence of severe joint instability.

In a young adolescent who is interested in returning to athletic activity, an operative approach such as ACL reconstruction is considered standard of care. Preparation for surgery depends primarily on the condition of the injured knee, which should exhibit absence of effusion, adequate strength, and full range of motion [75]. In this patient with only a slight effusion and full strength and range of motion on subsequent follow-up, ACL reconstruc-

Fig. 10.20 Right knee X-ray: No definitive fracture seen. Growth plates visible but nearly closed

tion was appropriately planned for 1–2 weeks after the incident using a quadricep tendon autograft.

For other patients who may require longer periods of preparation, these considerations should be tempered by the conse-

Fig. 10.21 Right knee MRI: Grade 3 full thickness tear of the junction of the proximal and middle thirds of the ACL. The distal ACL exhibits an atypically horizontal spatial orientation. Secondary findings suggestive of ACL instability

quences of extended delays in surgery. Studies have shown that delaying ACL reconstruction in pediatric or adolescent patients for greater than 12 weeks significantly increased the risk of meniscal injuries, and nonoperative management leads to higher rates of residual knee instability, increased risk of meniscal tears, and comparatively lower rates of return to sports. Both early and delayed operative treatment have been shown to achieve satisfactory knee stability [76]. Therefore, young active patients who elect for nonoperative care may still undergo delayed reconstruction within 3 months and have similar outcomes.

Consideration 1: Pediatric Vs. Adult Patients

In comparison to pediatric patients, adult patients have been shown to have more flexibility regarding timing of ACL reconstruction. Active adults who delayed ligament reconstruction for 6 months showed similar functional outcomes at 5 year (compared to adults who had early reconstruction and rehab) [77]. For patients who are not participating in athletic activity or are overall less active (such as geriatric patients), non-operative management (strength training, activity modification, stability training) can be a reasonable alternative.

Following ACL surgery, a personalized rehabilitation program is essential in improving treatment results and return-to-play. While the phases of rehabilitation may vary, all should incorporate the following: pain control, early weight bearing and range of motion exercises, reducing joint effusion, and increasing quadriceps muscle activation [75]. Closed kinetic chain exercises (squats, lunges) are initially emphasized to strengthen the quadriceps and hamstring muscles while maintaining joint stability, followed by open kinetic chain exercises [78].

The large majority of young individuals who undergo ACL reconstruction are able to return to sports: 81–92% return to any sport, 65–79% return to their preinjury level, and 55–81% return to competitive sports [75, 79]. A patient's return-to-play timeline can vary widely depending on the timing and type of surgery, patient symptoms, functional testing, properly structured rehabilitation, and psychologic readiness. Across this heterogeneity, bet-

ter outcomes typically occur after 9 months post-reconstruction [75]. Patients who return to sports prematurely significantly increase their risk for reinjury and graft failure [79], as well as increased risk for osteoarthritis [80]. Therefore, return to full activity sports should depend on return of normal strength, ability to achieve full range of motion, adequate performance on functional tests (strength tests, hop tests, movement quality) and sports specific movements [81].

Areas of Research

- While ACL reconstruction has been considered the gold standard for operative intervention, more surgeons are revisiting primary ACL repair due to improvements in imaging, arthroscopic modalities, and techniques that augment the mechanical/biological environment to allow for primary healing [82].

Key Takeaways

1. High impact trauma to the knee (as seen in athletic activity, sports, and motor vehicle accidents) can often lead to several concomitant injuries, requiring a thorough history, physical exam and follow-up imaging. Injuries may include ligament tears, tendon tears, meniscal tears, fractures, and dislocations.
2. ACL tears are often accompanied by a popping sensation, acute pain, and joint swelling. Tears are best visualized on MRI, along with any other concomitant ligament or tendon injuries.
3. Patients have the option of choosing either operative or non-operative intervention, depending on their desired activity level, presence of other injuries, and extent of joint instability. Most young athletes will elect to undergo ACL reconstruction, which has been shown to decrease residual knee instability, decrease risk of meniscal tears, and lead to higher rates of return to sports compared to physical rehabilitation only.
4. The success of ACL reconstruction depends heavily on a personalized rehabilitation regimen post-procedure, which should include pain control, early weight bearing and range of motion

exercises, reducing joint effusion, and increased quadriceps muscle activation. The large majority of athletes will be able to return to their desired sport, with large heterogeneity between individuals regarding length of rehab.

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