Acute Knee Injuries

CHAPTER 27

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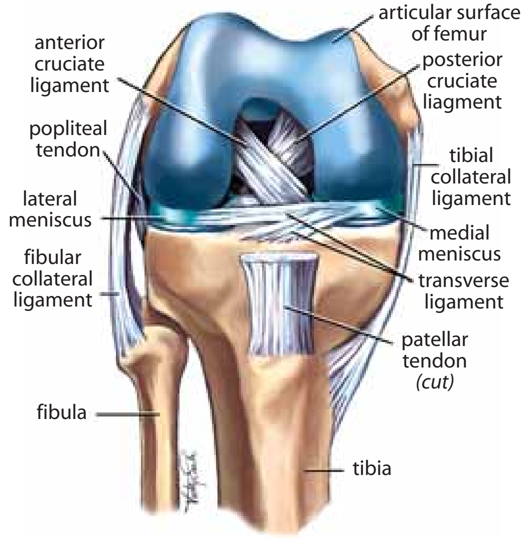
Acute injuries affecting the knee joint cause considerable disability and time off sport. They are common in all sports that require twisting movements and sudden changes of direction, especially the various football codes, basketball, netball and alpine skiing.

Functional anatomy

The knee contains two joints: the tibiofemoral joint with its associated collateral ligaments, cruciate ligaments and menisci; and the patellofemoral joint, which obtains stability from the medial retinaculum and the large patellar tendon passing anteriorly over the patella. We refer to the tibiofemoral joint as the knee joint.

By understanding the role of the different ligaments and menisci in the knee joint, the clinician can better understand the mechanisms of injury, and also the likely consequences of injuries. The anatomy of the knee joint is shown in Figure 27.1.

The two cruciate ('cross') ligaments, anterior and posterior, are often referred to as the 'crucial' ligaments, such is their importance in sporting activity. They are named anterior and posterior in relation to their attachment to the tibia. The anterior cruciate ligament (ACL) runs posteriorly and superiorly from its attachment near the front of the tibial plateau to



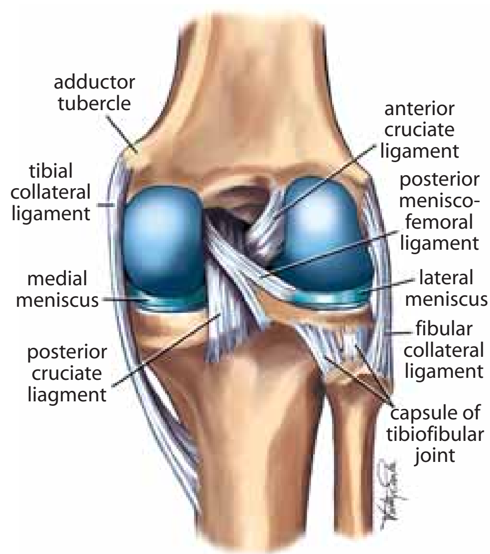


Figure 27.1 Anatomy of the knee joint

(a) The knee joint (anterior view)

(b) The knee joint (posterior view)

its femoral attachment at the posterolateral aspect of the intercondylar notch. The role of the ACL is to prevent forward movement of the tibia in relation to the femur, and to control rotational movement.

The posterior cruciate ligament (PCL) attaches on the posterior part of the tibial plateau and runs anterosuperiorly to its femoral attachment at the medial aspect of the intercondylar notch. The PCL prevents the femur from sliding forwards off the tibial plateau.

The ACL is essential for control in pivoting movements. Without an intact ACL, the tibia may rotate under the femur in an anterior–lateral direction. This is most common when an activity such as landing from a jump, pivoting or a sudden deceleration is attempted. The PCL serves to stabilize the body (femur) above the tibia. In its absence the femur wants to shift forward on the tibia. This shift forward is accentuated when one tries to run down an incline plane or down stairs.

The two collateral ligaments, the medial and lateral, provide medial and lateral stability to the knee joint. The superficial medial collateral ligament (MCL) originates from the medial epicondyle of the femur 3 cm (1.5 in.) above the joint line and passes downward as a thickened band to attach to the anteromedial aspect of the tibia about 8 cm (4 in.) from the joint line. This portion of the MCL is extra-capsular. The deep layer, or coronal ligaments, attaches to the joint margins and has an attachment from its deep layer to the medial meniscus. The MCL prevents excessive medial opening of the tibial–femoral joint.

The lateral collateral ligament (LCL) arises from the lateral epicondyle of the lateral border of the femur and passes downwards to attach to the head of the fibula. The LCL is a narrow strong cord with no attachment to the lateral meniscus. It serves to prevent lateral opening of the tibia on the femur during varus stress.

The two menisci, medial and lateral, are intra-articular and attach to the capsule layer at the level of the joint line. The menisci have an important role as a buffer absorbing some of the forces placed through the knee joint, thus protecting the otherwise exposed articular surfaces from damage. By increasing the concavity of the tibia, they play a role in stabilizing the knee. In addition, the menisci contribute to joint lubrication and nutrition. Thus, it is important to preserve as much of the menisci as possible after injury.

Clinical perspective

The acute knee injury of greatest concern to the athlete is the tear of the ACL. Meniscal injuries are common among sportspeople, either in isolation or combined with a ligament injury, for example, of the MCL or ACL. With the advent of arthroscopy and more sophisticated imaging techniques, it has become evident that the articular cartilage of the knee is often damaged in association with sports injuries including ligamentous or meniscal injuries. Cartilage damage, depending on the size and/or location, can have the most lasting negative consequence in regards to acute knee injuries. A list of acute knee injuries occurring in sport is shown in Table 27.1.

The main question the clinician needs to answer about the patient presenting with acute knee injury is, 'Does this patient have a significant knee injury?' A number of factors may help to provide the answer. These include:

- the mechanism of injury
- the amount of pain and disability at the time of injury
- the presence and timing of onset of swelling
- the degree of disability on presentation to the clinician.

Table 27.1 Causes of acute knee pain[a]

Common	Less common	Not to be missed
Medial meniscus tear	Patellar tendon rupture	Fracture of the tibial plateau
MCL sprain	Acute patellofemoral contusion	Avulsion fracture of tibial spine
ACL sprain (rupture)	LCL sprain	Osteochondritis dissecans (in adolescents)
Lateral meniscus tear	Bursal hematoma/bursitis	Complex regional pain syndrome type 1 (post injury)
Articular cartilage injury	Acute fat pad impingement	Quadriceps rupture
PCL sprain	Avulsion of biceps femoris tendon	
Patellar dislocation	Dislocated superior tibiofibular joint	

(*a*) All these conditions may occur in isolation or, commonly, in association with other conditions.

In the majority of cases, an acute knee injury can be diagnosed with an appropriate history and examination. The two main goals of assessment are:

1. to determine which structures have been damaged
2. to determine the extent of damage to each structure.

History

The first and most important step in taking the history is to invite the patient to tell his or her own story of the injury. Once the patient has had an unhurried opportunity to explain what happened, the practitioner may then wish to elicit additional aspects of the history.

Important components of the history include:

- a description of the precise mechanism of injury and the subsequent symptoms, for example, pain and giving way
- demonstration by the patient if possible, on the uninjured knee, of the stress applied at the time of injury
- the location of pain—pain associated with cruciate ligament injuries is often poorly localized (or emanates from the lateral tibial plateau); pain from injuries to the collateral ligaments is usually fairly well localized
- severity of pain—this does not always correlate with the severity of the injury, although most ACL injuries are usually painful immediately.

The degree and time of onset of swelling is an important diagnostic clue (Table 27.2). When a hemarthrosis is present, the swelling is usually considerable and develops within the first 1 or 2 hours following the injury. The causes of hemarthrosis are:

- major ligament rupture
  — ACL
  — PCL
- patellar dislocation
- osteochondral fracture
- peripheral tear of the meniscus, more common medially
- Hoffa's syndrome (acute fat pad impingement)
- bleeding diathesis (rare).

Note: Lipohemarthrosis (fat and blood in the knee) is caused by intra-articular fractures. Lipohemarthrosis will present in a similar manner to hemarthrosis.

An effusion that develops after a few hours or, more commonly, the following day is a feature of meniscal and chondral injuries. There is usually little effusion with collateral ligament injuries.

PRACTISE PEARL

If patients volunteer that they heard a 'pop', a 'snap' or a 'tear', the injury should be considered as an ACL tear until proven otherwise.

Patients presenting with a sensation of something having 'moved' or 'popped out' in the knee are usually thought to have a patellar dislocation. However, this symptom is more commonly associated with an ACL rupture. There may be associated 'clicking' or 'locking' and this is often seen with meniscal injuries. Locking is classically associated with a loose body or displaced meniscal tear. Locking does not mean locked in one knee position but is used when significant loss of passive range of motion is present, especially loss of full extension. It is helpful to ask the patient in what 'position' the knee locks. If the patient reports that the knee locks when it is straight, and does not bend, this usually is a manifestation of patellofemoral pain and injury—the kneecap is unable to engage in the groove secondary to pain.

The symptom of 'giving way' can occur with instability, such as in ACL deficiency. It may also occur with meniscal tears, articular cartilage damage, patellofemoral pain (Chapter 28) or severe knee pain. Patients with recurrent patellar dislocation and those with loose bodies in the knee can describe similar sensations. If a patient reports episodes of giving way on steps, this is most often a reflection of quadriceps weakness and/or pain, and rarely represents true kneecap instability.

The initial management of the injury and the degree of disability should be ascertained. A history of previous injury to either knee or any previous surgery should also be noted.

It is important to ascertain the patient's age, occupation, type of sport and leisure activities, and the level of sport played. All these factors may influence the type of treatment offered.

Table 27.2 Time relationship of swelling to diagnosis

Immediate (0–2 hours) (hemarthrosis)	Delayed (6–24) hours (effusion)	No swelling
ACL rupture Patellar dislocation	Meniscus	MCL sprain (superficial)

If the patient is a good historian, the diagnosis will be obvious in many cases. In the first two to three days following injury, examination can be difficult if the knee is painful and swollen.

Examination

The key feature of the knee examination is that each structure that may be injured must be examined. Clues to diagnosis are gleaned from the presence or absence of effusion, assessment of the state of the ligaments and menisci, and range of motion testing.

Examination includes:

A. Observation
   1. standing
   2. walking
   3. supine (Fig. 27.2a)

B. Active movements
   1. flexion
   2. extension
   3. straight leg raise

C. Passive movements
   1. flexion (Fig. 27.2b)
   2. extension (Fig. 27.2c)

D. Palpation
   1. patellofemoral joint (including patellar and quadriceps tendons)
   2. MCL
   3. LCL
   4. medial joint line (Fig. 27.2d)
   5. lateral joint line
   6. prone (e.g. hamstring tendons, Baker's cyst, gastrocnemius origins)

E. Special tests
   1. presence of effusion (Fig. 27.2e)
   2. stability tests
      (a) MCL (Fig. 27.2f)
      (b) LCL (Fig. 27.2g)
      (c) ACL
         (i) Lachman's test (Figs 27.2h–k)
         (ii) anterior drawer test (Fig. 27.2l)
         (iii) pivot shift test (Fig. 27.2m)
      (d) PCL
         (i) posterior sag (Fig. 27.2n)
         (ii) reverse Lachman's test
         (iii) posterior drawer test (Fig. 27.2o)
         (iv) external rotation test—active and passive
      (e) patella
         (i) medial and lateral patella translation (or mobility)
   3. flexion/rotation (McMurray's) test (Fig. 27.2p)

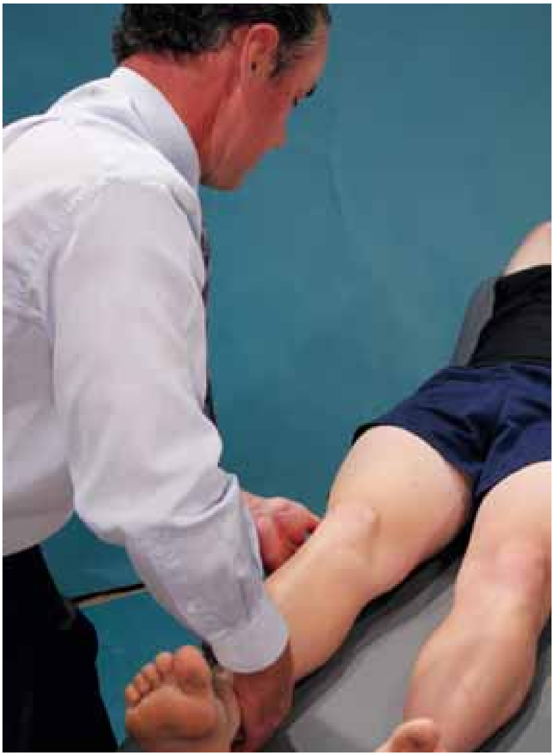


Figure 27.2 Examination of the patient with an acute knee injury

(a) Observation—supine. Look for swelling, deformity and bruising

(b) Passive movement—flexion. Assess range of motion, end feel and presence of pain

(c) Passive movement—extension. Hold both legs by the toes looking for fixed flexion deformity or hyperextension in the ACL, or PCL rupture. Overpressure may be applied to assess end range. This procedure may provoke pain in meniscal injuries

(d) Palpation—medial joint line. The knee should be palpated in 30° of flexion

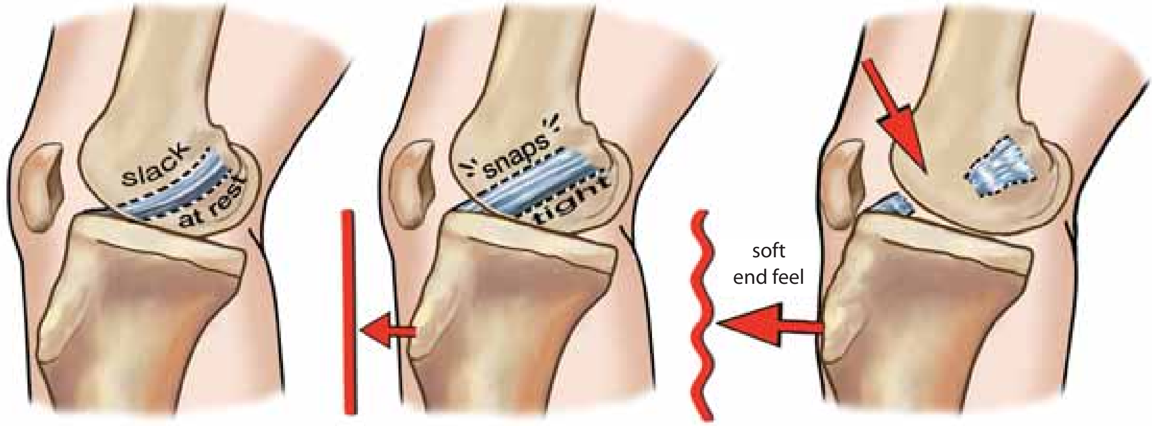
4. patellar apprehension test (Fig. 27.2q)
5. patellofemoral joint (Chapter 28)
6. functional tests
   (a) squat test
   (b) hop test

(e) Special tests—presence of effusion. Manually drain the medial subpatellar pouch by stroking the fluid in a superior direction. Then 'milk' the fluid back into the knee from above on the lateral side while observing the pouch for evidence that fluid is reaccumulating. This test is more sensitive than the 'patellar tap'. It is important to differentiate between an intra-articular effusion and an extra-articular hemorrhagic bursitis

(f) Stability test—MCL. This is tested with the knee in full extension and also at 30° of flexion (illustrated). The examiner applies a valgus force, being careful to eliminate any femoral rotation. Assess for onset of any pain, extent of valgus movement and feel for end point. If the knee 'gaps' at full extension, there must be associated posterior cruciate injury

(g) Stability test—LCL. The LCL is tested in a similar manner to the MCL except with varus stress applied

(h) Stability test—Lachman's test. Lachman's test is performed with the knee in 15° of flexion, ensuring the hamstrings are relaxed. The examiner draws the tibia forward, feeling for laxity and assessing the quality of the end point. Compare with the uninjured side



(i) **(j)** **(k)**

(i) The ACL is slightly slack in the start position
(j) When the ACL is intact, the ligament snaps tight and the examiner senses a 'firm'/'sudden' end feel
(k) When the ACL is ruptured, the Lachman's test results in a 'softer'/'gradual' end feel

(l) Stability test—anterior drawer test. This is performed with the knee in 90° of flexion and the patient's foot kept stable. Ensure the hamstrings are relaxed with the index finger on the femoral condyles. The tibia is drawn anteriorly and assessed for degree of movement and quality of end point. The test can be performed with the tibia in internal and external rotation to assess anterolateral and anteromedial instability respectively

(m) Special test—pivot shift test. With the tibia internally rotated and the knee in full extension, a valgus force is applied to the knee. In a knee with ACL deficiency, the condyles will be subluxated. The knee is then flexed, looking for a 'clunk' of reduction, which renders the pivot shift test positive. Maintaining this position, the knee is extended, looking for a click into subluxation, which is called a positive jerk test

(n) Stability test—posterior sag. With both knees flexed at 90° and the patient relaxed, the position of the tibia relative to the femur is observed. This will be relatively posterior in the knee with PCL deficiency

(o) Stability test—posterior drawer test. With the knee as for the anterior drawer test, the examiner grips the tibia firmly as shown and pushes it posteriorly. Feel for the extent of the posterior movement and quality of end point. The test can be repeated with the tibia in external rotation to assess posterolateral capsular integrity

(p) Flexion/rotation (McMurray's) test. The knee is flexed and, at various stages of flexion, internal and external rotation of the tibia are performed. The presence of pain and a palpable 'clunk' is a positive McMurray's test and is consistent with meniscal injury. If there is no 'clunk' but the patient's pain is reproduced, then the meniscus may be damaged or there may be a patellofemoral joint abnormality

(q) Special tests—patellar apprehension test. The knee may be placed on a pillow to maintain 20–30° of flexion. Gently push the patella laterally. The test is positive if the patient develops apprehension with a sensation of impending dislocation

Investigations

X-ray

Clinicians often wonder whether or not to perform an X-ray in cases of an acute knee injury. More than 90% of radiographs ordered to evaluate knee injuries are normal. A set of decision criteria known as the Ottawa knee rule was developed in an adult emergency medicine setting in the mid 1990s (Table 27.3).[1]

Also, surgeons always wish to see preoperative films so there are no intraoperative surprises.

The main aim of performing an X-ray in cases of moderately severe acute knee injuries is to detect an avulsion fracture associated with an ACL injury or a tibial plateau fracture following a high-speed injury. An osteochondral fracture may be evident after patellar dislocation.

Table 27.3 Criteria for the Ottawa knee rule

A knee radiograph is indicated after trauma only when at least one of the following is present:

- patient age more than 55 or less than 18 years
- tenderness at the fibular head
- tenderness over the patella
- inability to flex the knee to 90° (this captures most hemarthrosis, fractures)
- inability to weight-bear for four steps at the time of the injury and when examined.

To these, we suggest a high index of suspicion for:

- high-speed injuries
- children or adolescents (who may avulse a bony fragment instead of tearing a cruciate ligament)
- if there is clinical suspicion of loose bodies.

MRI

MRI may be used as an adjunct to clinical assessment in cases of uncertain diagnosis, especially if a meniscal abnormality is suspected. MRI is also a useful investigation in determining the extent of ACL injury, articular cartilage damage and patellar tendon injury.[2–4] MRI should never be ordered in the absence of a thorough history and physical examination.

With the advent of MRI it was noted that significant knee injuries were associated with the presence of edema in the subchondral region. This phenomenon is known as a bone bruise. Clinically, a bone bruise is associated with pain, tenderness, swelling and delayed recovery. The presence of a bone bruise indicates substantial articular cartilage damage.[5]

Ultrasound examination

High-quality ultrasound examination of the patellar tendon is an excellent means of demonstrating partial tears of this tendon. A complete rupture should be obvious clinically.

Ultrasound examination can also detect the size and location of bursal swelling, and identify intra- versus extra-articular swelling if necessary.

Arthroscopy

Arthroscopy may be used as an investigation, a treatment or both. In most cases when the diagnosis is evident from the clinical assessment, it is used as a treatment method, while also confirming the clinical diagnosis. However, on occasions when the clinical picture is unclear and the patient has persistent pain not responding to treatment, diagnostic arthroscopy is performed.

Immediately before arthroscopy, the surgeon performs an examination under anesthesia (EUA). The combination of EUA and arthroscopy provides the clinician with both an assessment of the stability of the knee and a view of the affected structures. Depending on the findings, it is usually possible to treat the abnormality during the same procedure.

Meniscal injuries

Acute meniscal tears occur when the shear stress generated within the knee in flexion and compression combined with femoral rotation exceeds the meniscal collagen's ability to resist these forces.[6] The medial meniscal attachment to the medial joint capsule decreases its mobility, thereby increasing its risk for injury compared with the more mobile lateral meniscus.[7]

Degenerative meniscal tears occur in the older population frequently without an inciting event.

The different types of meniscal tear are shown in Figure 27.3.

Clinical features

The history can provide a mechanism and a sense of the severity of meniscal tears. The clinical features are listed below.

- The most common mechanism of meniscal injury is a twisting injury with the foot anchored on the ground, often by another player's body.
- The twisting component may be of comparatively slow speed. This type of injury is commonly seen in football and basketball players.
- The degree of pain associated with an acute meniscal injury varies considerably. Some patients may describe a tearing sensation at the time of injury.

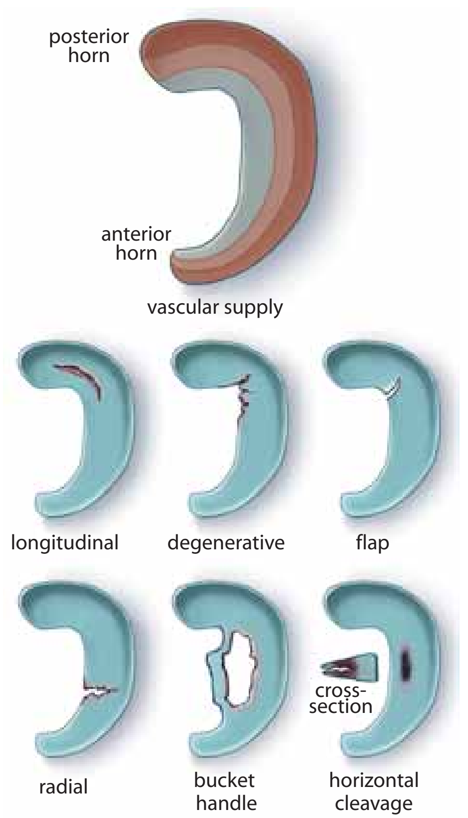


Figure 27.3 Meniscus tear orientation and zones of vascularity; these drawings are of a medial meniscal tear

- A small meniscal tear may cause no immediate symptoms; it may become painful and cause knee swelling over 24 hours.
- Small tears may also occur with minimal trauma in the older athlete as a result of degenerative change of the meniscus.
- Patients with more severe meniscal injuries, for example, a longitudinal ('bucket handle') tear, present with more severe symptoms. Pain and restriction of range of motion occur soon after injury. Intermittent locking may occur as a result of the torn flap, the 'bucket handle', impinging between the articular surfaces. This may unlock spontaneously with a clicking sensation. This often occurs in association with ACL tears. In these patients a history of locking may be due to either the ACL or the meniscal injury.

On examination, the signs of a meniscal tear include:

- joint line tenderness (palpated with the knee flexed at 45–90°)
- joint effusion—this is usually present, although absence of an effusion does not necessarily rule out meniscal damage
- pain—usually present on squatting, especially with posterior horn tears
- restricted range of motion of the knee joint—this may be due to the torn meniscal flap or the effusion.

The flexion/rotation (McMurray's) test (Fig. 27.2p) is positive when pain is produced by the test and a clunk is heard or felt that corresponds to the torn flap being impinged in the joint. However, it is not necessary to have a positive McMurray's test (i.e. a clunk) to make a diagnosis of a torn meniscus. The hyperflexion portion of the McMurray's test provokes pain in most meniscal injuries. Pain produced by flexion and external rotation is often indicative of medial meniscal damage, whereas pain on internal rotation indicates lateral meniscal pain. Asking patients where they feel pain during hyperflexion maneuvers gives a suggestion of the location of the tear, medial or lateral.

MRI examination is the investigation of choice. This can aid management if the MRI shows either a complex tear or minimal damage or, more rarely, a peripheral meniscus tear. If meniscal tearing is minimal and stable without displacement, clinical progress remains the best measure of non-operative management. Peripheral meniscus tears, depending on the length of the tear, may be surgically addressed. Diagnostic arthroscopy for meniscus injury is rarely performed in centers where MRI is available.

Treatment

The management of meniscal tears varies depending on the severity of the condition. At one end of the spectrum, a small tear or a degenerative meniscus should initially be treated conservatively. On the other hand, a large painful 'bucket handle' tear, causing a locked knee, requires immediate arthroscopic surgery. The majority of meniscal injuries fall somewhere between these two extremes and the decision on whether to proceed immediately to arthroscopy must be made on the basis of the severity of the symptoms and signs, as well as the demands of the athlete. Experienced clinicians use the clinical features shown in Table 27.4 as a guide for choosing either conservative or surgical treatment.

The aim of surgery is to preserve as much of the meniscus as possible. Some meniscal lesions are suitable for repair by meniscal suture, which can be performed with an arthroscope. The decision as to whether or not to attempt meniscal repair is based on several factors, including acuity of the tear, age

Table 27.4 Clinical features of meniscal injuries that may affect prognosis

Factors that may indicate that conservative treatment is likely to be successful	Factors that may indicate that surgery will be required
Symptoms develop over 24–48 hours after injury	Severe twisting injury, athlete is unable to continue playing
Injury minimal or no recall of specific injury	Locked knee or severely restricted range of motion
Able to weight-bear	Positive McMurray's test (palpable clunk)
Minimal swelling	Pain on McMurray's test with minimal knee flexion
Full range of movement with pain only at end of range of motion	Presence of associated ACL tear
Pain on McMurray's test only in inner range of flexion	Little improvement of clinical features after 3 weeks of conservative treatment
Previous history of rapid recovery from similar injury	
Early degenerative changes on plain radiographs	

of the patient, stability of the knee, and tear location and orientation. The outer one-third of the meniscus rim has a blood supply, and tears in this region can heal. The tear with the best chance of a successful repair is an acute longitudinal tear in the peripheral one-third of the meniscus in a young patient with a concomitant ACL reconstruction.[8] Degenerative, flap, horizontal cleavages and complex meniscal tears are poor candidates for repair.[7] Young patients have a higher success rate. Peripheral meniscus tears in otherwise stable knees without concomitant ligament damage have a reduced success rate.[9]

Partial tears may require removal of the damaged flap of the meniscus. Patients with degenerative tears with no or minimal cartilage wear will be less symptomatic than those patients with concomitant cartilage damage.

Rehabilitation after meniscal surgery

Rehabilitation should commence prior to surgery. In this period it is important to:

- reduce pain and swelling with the use of electrotherapeutic modalities and gentle range of motion exercises
- maintain strength of the quadriceps, hamstrings, and hip abductor and extensor muscles
- protect against further damage to the joint (patient may use crutches if necessary)
- explain the surgical procedure and the post-operative rehabilitation program to the patient.

The precise nature of the rehabilitation process will depend on the extent of the injury and the surgery performed. Arthroscopic partial menisectomy is usually a straightforward procedure followed by a fairly rapid return to activity. Some athletes with a small isolated medial meniscal tear are ready to return to sport after four weeks of rehabilitation. The rehabilitation process usually takes longer if there has been a more complicated tear of the meniscus, especially if the lateral meniscus is injured. The presence of associated abnormalities, such as articular cartilage damage or ligament (MCL, ACL) tears, will necessarily slow down the rehabilitation process.

If the athlete returns to play before the knee is properly rehabilitated, he or she may not experience difficulty during the first competition but may be prone to develop recurrent effusions and persistent pain. A successful return to sport after meniscal knee surgery should not be measured by the time to play the first match but rather the time to play the second!

Rehabilitation principles after arthroscopic partial menisectomy are:

- to control pain and swelling
- to regain pain-free active range of motion
- graduated weight-bearing
- progressive strengthening within the available range of motion
- progressive balance, proprioceptive, and coordination exercises
- return to functional activities.

A typical rehabilitation program following arthroscopic partial menisectomy is shown in Table 27.5. The suggested rehabilitation program may be varied depending on progress. It is important that this and other suggested rehabilitation programs contained in this chapter should only be considered as guidelines. Every patient is different and will differ in his or her response to injury, surgery and rehabilitation.

Close monitoring is essential during post-menisectomy rehabilitation as the remaining meniscus and underlying articular cartilage slowly increase their tolerance to weight-bearing. Constant reassessment after progressively more difficult activities should be performed by the therapist monitoring the rehabilitation program. The development of increased pain or swelling should result in the program being slowed or revised accordingly.

Conservative management of meniscal injuries

Conservative management of relatively minor meniscal injuries will often be successful, particularly in the athlete whose sporting activity does not involve twisting activities. The principles of conservative management are the same as those following partial menisectomy (Table 27.5), although the rate of progress may vary depending on the clinical features.

The criteria for return to sport following meniscal injury, treated surgically or conservatively, are shown below. If appropriate rehabilitation principles have been followed, then the criteria will usually all be satisfied:

- absence of effusion
- full range of movement
- normal quadriceps and hamstring function
- normal hip external rotator function
- good proprioception
- functional exercises performed without difficulty
- training performed without subsequent knee symptoms

Table 27.5 Rehabilitation program for conservative management of meniscal injury and following arthroscopic partial menisectomy

Phase	Goal of phase	Time post injury	Physiotherapy	Exercise program	Functional/sport-related activity
Phase 1	Control swelling Maintain knee extension Knee flexion to 100°+ 4/5 quadriceps strength 4+/5 hamstring strength	0–1 week	Cryotherapy Electrotherapy Compression Manual therapy Gait re-education Patient education	Gentle ROM (extension and flexion) Quadriceps/VMO setting Supported (bilateral) calf raises Hip abduction and extension Hamstring pulleys/rubbers Gait re-education drills Light exercise bike	Progress to FWB and normal gait pattern
Phase 2	Eliminate swelling Full ROM 4+/5 quadriceps strength 5/5 hamstring strength	1–2 weeks	Cryotherapy Electrotherapy Compression Manual therapy Gait re-education Exercise modification and supervision	ROM drills Quadriceps/VMO setting Mini squats and lunges Leg press (double, then single leg) Step-ups Bridges (double, then single leg) Hip abduction and extension with rubber tubing Single-leg calf raises Gait re-education drills Balance and proprioceptive drills (single leg)	Swimming (light kick) Exercise bike Walking
Phase 3	Full ROM Full strength Full squat Dynamic proprioceptive training Return to running and restricted sport-specific drills	2–3 weeks	Manual therapy Exercise/activity modification and supervision	As above—increase difficulty, repetitions and weight where appropriate Jump and land drills Agility drills	Running Swimming Road bike Sport-specific exercises (progressively sequenced) e.g. running forwards, sideways, backwards, sprinting, jumping, hopping, changing direction, kicking
Phase 4	Full strength, ROM and endurance of affected limb Return to sport-specific drills and restricted training and match play	3–5 weeks	As above	High level sport-specific strengthening as required	Return to sport-specific drills, restricted training and match play

FWB = full weight-bearing. ROM = range of motion. VMO = vastus medialis obliquus.

- simulated match situations undertaken without subsequent knee symptoms.

Medial collateral ligament injury

Injury to the MCL usually occurs as a result of a valgus stress to the partially flexed knee. This can occur in a non-contact mechanism such as downhill skiing, or in contact sports when an opponent falls across the knee from lateral to medial. MCL tears are classified on the basis of their severity into grade I (mild, first degree), grade II (moderate, second degree) or grade III (complete, third degree).

In patients with a grade I MCL sprain, there is local tenderness over the MCL on the medial femoral condyle or medial tibial plateau but usually no swelling. When a valgus stress is applied at 30° of flexion, there is pain but no laxity. Ligament integrity is intact.

A grade II MCL sprain is produced by a more severe valgus stress. Examination shows marked tenderness, sometimes with localized swelling. A valgus stress applied at 30° of knee flexion causes pain. Some laxity (typically <5 mm [<0.05 in.]) is present but there is a distinct end point. Ligament integrity is compromised but intact throughout its length.

A grade III sprain of the MCL results from a severe valgus stress that causes a complete tear of the ligament fibers. The patient often complains of a feeling of instability and a 'wobbly knee.' The amount of pain is variable and frequently not as severe as one would expect given the nature of the injury. On examination, there is tenderness over the ligament and valgus stress applied at 30° of flexion reveals gross laxity without a distinct end point. This test may not provoke as much pain as incomplete tears of the ligament due to complete disruption of the nociceptive fibers of the ligament.

Grade III MCL injuries are frequently associated with a torn ACL, but rarely associated with medial meniscus injury. The presentation of medial joint line tenderness and lack of full extension is more a reflection of MCL injury. The lateral meniscus is more at risk because the mechanism of injury typically opens the medial side and compresses the lateral side.

While swelling is uncommon in grade 1 sprains, it may occasionally be seen with grade 2 injuries. In grade 3 sprains there is associated capsular tearing (deep fibers and superficial) and fluid escapes so some degree of swelling is common although a tense effusion is not present.

Distal MCL injuries have a tendency to recover more slowly.[10]

Treatment

The treatment of MCL injuries involves a conservative rehabilitation program. Patients with grade III MCL injuries that have been treated conservatively have been shown to return to sport as well as those treated surgically.[11] The rehabilitation program following MCL injury varies depending on the severity. A typical rehabilitation program for milder MCL injuries (grade I and mild grade II) is shown in Table 27.6.

A hinged knee brace (Fig. 27.4a) provides support and protection to the injured MCL during the rehabilitation process.

The more severe MCL injury (the severe grade II or grade III tear) requires a longer period of rehabilitation. An example of a rehabilitation program following a moderate-to-severe MCL injury is shown in Table 27.7.

Anterior cruciate ligament tears

Tears of the ACL are relatively common among sportspeople. Over 100 000 ACL reconstructions are performed annually in the United States.[12] They occur most frequently in those who play sports involving pivoting (e.g. football, basketball, netball, soccer, European team handball, gymnastics, downhill skiing). The incidence rate of ACL tears is between 2.4 and 9.7 times higher in female athletes competing in similar activities.[13–17]

ACL tears may occur in isolation or in combination with associated injuries, particularly meniscal and articular cartilage injury, or injury to the MCL.[18] They are the most common cause of prolonged absence from sport.

Clinical features

The majority of ACL tears occur in a non-contact situation, when the athlete is landing from a jump, pivoting or decelerating suddenly. The jumping mechanism is more likely to be associated with an accompanying meniscal injury.[19] The mechanism of non-contact injury has come under intense scrutiny in recent years. It is common for it to result from an action that the injured athlete has performed repeatedly in their career, often a simple maneuver. Video analysis has shown that at times a trivial contact with another body part, such as a touch to the shoulder or hand, can precede the injury.

The typical features of the history include the following:

Table 27.6 Rehabilitation of a mild MCL injury (see Figs 27.5 and 27.6)

Phase	Goal of phase	Time post injury	Physiotherapy treatment	Exercise program	Functional/sport-related activity
Phase 1	Control swelling Knee flexion to 100°+ Allow +20° extension 4/5 quadriceps strength 4+/5 hamstring strength	0–1 week	Cryotherapy Electrotherapy Compression Manual therapy Gait re-education Patient education	Gentle ROM (flexion mainly) Quadriceps/VMO setting Supported (bilateral) calf raises Hip abduction and extension Hamstring pulleys/rubbers Gait re-education drills	Progress to FWB and normal gait pattern
Phase 2	Eliminate swelling Full flexion ROM Allow +10° extension 4+/5 quadriceps strength 5/5 hamstring strength Return to light jogging	1–2 weeks	Cryotherapy Electrotherapy Compression Manual therapy Gait re-education Exercise modification and supervision	ROM drills Quadriceps/VMO setting Mini squats and lunges Leg press (double, then single leg) Step-ups Bridges (double, then single leg) Hip abduction and extension with rubber tubing Single-leg calf raises Gait re-education drills Balance and proprioceptive drills (single leg)	Straight line jogging Swimming (light kick) Road bike With hinged knee brace
Phase 3	Full ROM Full strength Full squat Dynamic proprioceptive training Return to running and restricted sport-specific drills	2–4 weeks	Manual therapy Exercise/activity modification and supervision	As above—increase difficulty, repetitions and weight where appropriate Jump and land drills Agility drills	Progressive running Swimming Road bike Sport-specific exercises (progressively sequenced) e.g. running forwards, sideways, backwards, sprinting, jumping, hopping, changing direction, kicking
Phase 4	Full strength, ROM and endurance of affected limb Return to sport-specific drills and restricted training and match play	3–6 weeks	As above	High level sport-specific strengthening as required	Return to sport-specific drills, restricted training and match play With hinged knee brace

FWB = full weight-bearing. ROM = range of motion. VMO = vastus medialis obliquus.

Figure 27.4 Splints

(a) Hinged knee brace

(b) Limited motion knee brace

- The patient often describes an audible 'pop', 'crack' or feeling of 'something going out and then going back'.
- Most complete tears of the ACL are extremely painful, especially in the first few minutes after injury.
- Athletes are initially unable to continue their activity. Occasionally pain will limit further activity and this is usually associated with a large tense effusion. This is the clinical feature of a hemarthrosis. Occasionally, swelling is minimal or delayed. At times the athlete tries to recommence the sporting activity and feels instability or a lack of confidence in the knee. Occasionally the athlete may resume playing and suffer an acute episode of instability.

Most athletes with an ACL tear present to a sports medicine practitioner between 24 and 48 hours following the injury. At this stage it may be difficult to examine the knee. The best time to examine a patient with this condition is in the first hour following the injury before the development of a tense hemarthrosis, which limits the examination. After a few days when the swelling has started to settle and the pain is less intense the examination becomes easier to perform in most cases.

After ACL rupture the examination findings are typical:

- athletes have restricted movement, especially loss of extension
- they may have widespread mild tenderness
- lateral joint tenderness is often present, as the knee stretches the lateral joint capsule while subluxating
- medial joint line tenderness may be present if there is an associated medial meniscus injury.

PRACTISE PEARL

The Lachman's test[20] (Figs 27.2h–k) is positive in ACL disruption and is the most useful test for this condition. Students should learn to master this test.

A positive pivot shift (or jerk) test (Fig. 27.2m) is diagnostic of ACL deficiency but it requires the patient to have an intact MCL and iliotibial band. In cases of acute injuries, especially with associated injury (e.g. meniscal tear), the pivot shift test is difficult to perform as the patient is unable to relax sufficiently. The anterior drawer test (Fig. 27.2l) is usually positive in cases of ACL tears but is the least specific test. It should always be compared with the other side as often there is a degree of laxity present prior to injury.

Table 27.7 Rehabilitation of a moderate-to-severe MCL injury (see Figs 27.5 and 27.6)

Phase	Goal of phase	Time post injury	Physiotherapy treatment	Exercise program	Functional/sport-related activity
Phase 1	Control swelling Knee flexion to 90°+ Allow +30° extension 4/5 quadriceps strength 4+/5 hamstring strength	0–4 weeks	Limited motion knee brace (limited 0–30°) Cryotherapy Electrotherapy Compression Manual therapy Gait re-education Patient education	Exercises done in brace Gentle flexion ROM Extension ROM to 30° only Quadriceps/VMO setting Supported (bilateral) calf raises Hip abduction and extension Hamstring pulleys/rubbers Gait drills	Initially NWB/PWB Progress to FWB Walking (normal gait pattern)
Phase 2	FWB Eliminate swelling Full ROM 4+/5 quadriceps strength 5/5 hamstring strength	4–6 weeks	Removal of brace 4–6 weeks Cryotherapy Electrotherapy Compression Manual therapy Gait re-education Exercise modification and supervision	ROM drills Quadriceps/VMO setting Mini squats and lunges Leg press (double, then single leg) Step-ups Bridges (double, then single leg) Hip abduction and extension with rubber tubing Single-leg calf raises Gait re-education drills Balance and proprioceptive drills (single leg)	Swimming (light kick) Road bike Walking
Phase 3	Full ROM Full strength Full squat Dynamic proprioceptive training Return to light jogging Return to running and restricted sport-specific drills	6–10 weeks	Manual therapy Exercise/activity modification and supervision	As above—increase difficulty, repetitions and weight where appropriate Jump and land drills Agility drills	Straight line jogging with hinged knee brace (no earlier than 6 weeks) Running Swimming Road bike Sport-specific exercises (progressively sequenced) e.g. running forwards, sideways, backwards, sprinting, jumping, hopping, changing direction, kicking
Phase 4	Full strength, ROM and endurance of affected limb Return to sport-specific drills and restricted training and match play	8–10/12 weeks	As above	High level of sport-specific strengthening as required	Return to sport-specific drills, restricted training and match play With hinged knee brace for first 2–4 weeks

FWB = full weight-bearing. NWB = non-weight-bearing. PWB = partial weight-bearing. ROM = range of motion. VMO = vastus medialis obliquus.

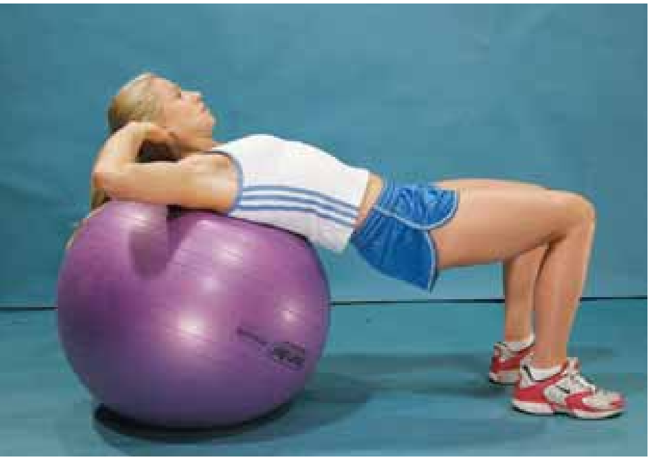
Figure 27.5 Knee rehabilitation

(a) Quadriceps drills—isometric contraction

(b) Assisted knee flexion. Place hands behind the thigh and pull the knee into flexion

(c) Double-leg calf raise. Progression of the double-leg calf raise should incorporate an increase in range, sets and repetition, and speed of movement. The eccentric component should be emphasized

(d) Bridging. This is used to develop both core muscular strength and proprioception



(e) Bridging with Swiss ball. A Swiss ball may be used to progress the exercise

(g) Hip abduction with rubber tubing

(f) Hip extension—with rubber tubing

(h) Rubber tubing eccentric stride catch—standing

(i) Lunge—performed as shown. Progression involves a combination of increasing the number of sets and repetitions, increasing the depth of the lunge, and finally by holding additional weight

(j) Double quarter squat

(k) Single-leg half squat. All squat exercises should be pain-free. The squat may be aided by the use of a Swiss ball. Particular attention must be given to technique, control of the pelvis, hip and knee. Progression of the squat is similar to that of progression of the leg press exercise

(l) Arabesque single-leg squat

(m) Rebounder—jogging. Jogging and bounding are common rebounder exercises

(n) Rebounder (not shown)—static proprioceptive hold/throwing ball. The rebounder can be used for a variety of proprioceptive and balance exercises. Ball throwing or 'eyes closed' exercises can provide an excellent functional challenge

(o) Wobble board

(p) Dura disk balance

Figure 27.6 Functional activities

(a) Jump and land from block. This exercise may be used to reciprocate functional movements in many sports. Begin the exercise from a small height and jump without rotation. This exercise can be progressed by increasing the height of the jump and rotating 90° during the jump

(b) Plyometric jumps over block—lateral. Plyometric exercises should only be included in the later stages of rehabilitation. Each plyometric exercise should be sport-specific

(c) Carioca exercises

(d) Figure of eight running

X-ray of the knee should be performed when an ACL tear is suspected. It may reveal an avulsion of the ligament from the tibia or a 'Segond' fracture (anterior–lateral capsular avulsion)[21] at the lateral margin of the tibial plateau (Fig. 27.7); this is pathognomonic of an ACL rupture. MRI may be useful in demonstrating an ACL tear (Fig. 27.8) when the diagnosis is uncertain clinically.

A bone bruise is usually (>80%)[17] present in conjunction with an ACL injury. The most common site is over the lateral femoral condyle (Fig. 27.9). The bone bruise is most likely caused by impaction between the posterior aspect of the lateral tibial plateau and the lateral femoral condyle during displacement of the joint at the time of the injury. The presence of a bone bruise indicates impaction trauma to the articular cartilage.[5]

The degree to which bone bruises result in permanent injury to the cartilage continues to be investigated. At present it is not clear whether the presence of a bone bruise is significant in the long term. It may be that those patients with a bone bruise are more prone to the development of osteoarthritis. It is also not clear at this time whether the presence of a bone bruise should result in a slower rehabilitation process with reduced loading of the knee in the first few months after injury. However, most clinicians would favor a conservative course of treatment in this regard, and limit pounding activities for three months post bone bruise.

Figure 27.8 MRI of anterior cruciate ligament (circled) showing the precise location of the tear (arrow)

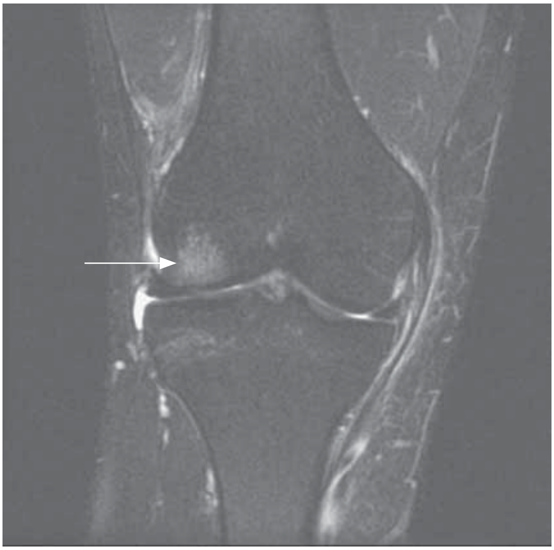


Figure 27.9 MRI showing a bone bruise of the lateral femoral condyle in association with an ACL tear

Figure 27.7 X-ray showing a Segond fracture

Conservative or surgical treatment?

There are several areas of controversy regarding the management of ACL injuries. These include the relative merits of conservative versus surgical management; the use of braces to prevent ACL injury or control ACL deficiency; whether surgery should be performed immediately after the injury or should be delayed; the relative merits of the various surgical techniques; and the different rehabilitation programs followed after surgery.

Once the diagnosis is made, the decision on whether to opt for initial conservative or surgical management is dependent on a number of factors:

- the age of the patient
- the degree of instability
- associated abnormalities (e.g. MCL tear, meniscal tear)
- whether or not the patient performs pivoting sports
- the patient's occupation (e.g. firefighter, police)
- social factors, such as cost of treatment or time off work.

The degree of instability may be assessed by a number of parameters. Clinical examination of the knee is not always a reliable indication of functional stability. If the patient is undergoing arthroscopy, then EUA will provide an opportunity to assess knee stability. A pivot shift test, difficult to perform in the conscious patient with a recent injury, should be performed at this time. A positive pivot shift test is indicative of a significant degree of knee instability. In the patient with longer term ACL deficiency, symptoms such as recurrent episodes of giving way indicate instability. For those patients whose knee shows appropriate strength on functional testing and whose knee gives way with activities of daily living despite adequate strength, an ACL reconstruction is recommended. Many surgeons would advocate ACL reconstruction in patients with concomitant meniscal injuries.

The decision is also influenced by the demands placed on the knee. In a young athlete who plays a pivoting sport, such as football or basketball, the demands placed on the knee will be considerable. However, an athlete who is prepared to confine activity to those sports that do not involve a large amount of twisting, turning and pivoting may be able to function adequately without an intact ACL. The patient must be reminded that repeated episodes of giving way greatly increase the development of osteoarthritis. Despite this, there is no scientific evidence that reconstruction reduces the incidence of long-term osteoarthritis.

Another important factor to assess is the likelihood of the patient adhering to a comprehensive, time-consuming rehabilitation program after surgery. If the patient indicates a lack of willingness to undertake appropriate rehabilitation, surgery may not be successful. Other factors to consider are the cost of surgery and the amount of time off work.

Surgery should be recommended for those athletes wishing to participate in a high-speed sport with constant change of direction and pivoting. Other cases are assessed on their merit, taking into account the factors previously mentioned. As with other conditions, a trial of conservative management does not rule out the possibility of eventual surgery.

Surgical treatment

There are numerous surgical techniques used in the treatment of ACL injuries. As ACL tears are usually in-substance tears and therefore not suitable for primary repair, reconstruction of the ACL is the surgical treatment of choice. Numerous methods of ACL reconstruction have been described. ACL reconstructions were originally performed via an arthrotomy (opening the knee capsule with a surgical incision). With the advance of arthroscopic techniques, ACL reconstructions are now performed 'arthroscopically aided' through a small incision with arthroscope. This utilizes small incisions to help visualize and make the tunnels for placement of the ACL graft. Depending on the type of graft, incisions to harvest the graft and secure the tunnels will be made as well.

The aim of an ACL reconstruction is to replace the torn ACL with a graft that reproduces the normal kinetic functions of the ligament. In most cases, an autogenous graft, taken from around the knee joint, is used. The most common grafts used are the bone–patellar tendon–bone (BTB) autograft involving the central third of the patellar tendon, or the hamstring (semitendinosus +/– gracilis tendons) graft. The decision on whether to perform a patellar tendon or hamstring reconstruction is dependent on a number of factors.

Among orthopedic surgeons there is considerable debate on the patellar tendon versus hamstring tendon subject. A systematic review published in 2004 showed no difference in failure rate, range of motion, or isokinetic strength of arthrometer testing of knee laxity between the two techniques.[22] Our view is that each case should be considered on its merit, taking into account some of the differences in potential post-operative problems. For example, after patellar tendon reconstruction, pain with kneeling is common and approximately 50% of patients develop anterior knee pain. Patients who have a hamstring graft ACL reconstruction have decreased end range knee flexion power. The potential problems need to be addressed in the rehabilitation program and for that reason we advocate slightly different rehabilitation regimens for the two types of surgery.

Other graft options include allografts (the transplantation of cadaver tissue such as ligaments or tendons). Allografts have been used successfully for many years and are associated with decreased morbidity and patients' return to their daily activities more quickly. It has been suggested that allografts may also be associated with earlier return to sport, however, there is little evidence to support this theory.[17] The incorporation of allograft tissue appears to take at least as long as autograft tissue and arguably longer; therefore, many consider delaying the return to full sporting activities for eight to nine months.

Patient information about what happens during ACL reconstruction surgery is provided in the box. This is also available as a downloadable PDF file at <www.clinicalsportsmedicine.com>.

The timing of ACL reconstruction after an acute injury has come under review. Traditionally, ACL reconstructions were performed as soon as practical after the injury. However, there is evidence that delaying the surgery may decrease the post-operative risk of arthrofibrosis (see below).[23] Initial reports suggested three weeks as the appropriate delay in surgery. More important than a specific time is the condition of the knee at the time of surgery. The injured knee should have little or no swelling, have near full range of motion, and the patient should have a normal gait. This period until surgery is a time for active rehabilitation ('prehabilitation').

Combined injuries

Injuries of the ACL rarely occur in isolation. The presence and extent of other injuries may affect the way in which the ACL injury is managed.

Associated injury to the MCL (grades I–III) poses a particular problem due to the tendency to develop stiffness after this injury. Most orthopedic surgeons would initially treat the MCL injury in a limited motion knee brace for a period of six weeks, during which time the athlete would undertake a comprehensive rehabilitation program (see above). Only then would the ACL reconstruction be performed.

Rehabilitation after ACL reconstruction

Traditional methods of management after ACL reconstruction included a lengthy period of non-weight-bearing and knee immobilization. Early muscle activity around the knee joint was discouraged due to concerns regarding the integrity of the graft and its fixation. This program led to weakness and stiffness around the knee joint with impaired proprioception and poor function. A fixed flexion deformity was common due to the prolonged extension block, while there was usually prolonged loss of full flexion. Patellofemoral joint problems were also common during the rehabilitation process.

Management principles have changed dramatically in recent years, resulting in greatly accelerated rehabilitation after ACL reconstruction.[24] These management principles have changed as surgical techniques have changed. There is now a better understanding of the strengths of grafts and the strength of fixation techniques. There is no difference in joint laxity or clinical outcome between those who underwent accelerated rehabilitation compared to those with a non-accelerated program at two years post surgery.[25]

Without an open arthrotomy the extensor mechanism has been better preserved. The principle of complete immobilization has been replaced with protected mobilization, with a resultant dramatic decrease in stiffness and increase in range of motion of the knee joint. This has allowed earlier commencement of a strengthening program and rapid progression to functional exercises. The average time for rehabilitation after ACL reconstruction to return to sport has been reduced from around 12 months to six to nine months.

Rehabilitation must commence from the time of injury, not from the time of surgery, which may be days, weeks or months later.[26] Pre-operative management aims to reduce pain, swelling and inflammation, thus reducing the amount of intra-articular fibrosis and resultant loss of range of motion, strength and function. Immediately after injury, treatment should commence, including interferential stimulation, ultrasound and TENS, as well as strengthening exercises for the quadriceps, hamstring, hip extensor, hip abductor and calf muscles. Pain-free range of motion exercises should also be performed.

This period is also an opportunity for explanation of the hospital protocol and the progression and goals of the rehabilitation program. The therapist should set a realistic goal, taking into consideration the individual patient and the type of surgery performed. It is helpful to provide a written explanation as well. If

What happens during ACL reconstruction surgery?

The surgical reconstruction technique involves harvesting the tendon (patellar or hamstring, Fig. 27.10a) through a small incision and threading the tendon through tunnels drilled in the bones. The most crucial part of the operation is the points of entry of the tibial and femoral tunnels, and then the fixation of the graft.

The tibial attachment should be in the center of the previous anterior cruciate attachment (at the level of the inner margin of the anterior portion of the lateral meniscus). The femoral attachment is to the so-called isometric point. This is a position in the intercondylar notch on the femur at which the graft is at a fixed tension throughout the range of knee movement.

Once the graft attachment areas have been delineated and prepared, the graft is fixed by one of a variety of different methods. These methods include interference screw fixation (Fig. 27.10b), staples or the tying of sutures around fixation posts. The better the quality of graft fixation, the more comfortable one is in advancing rehabilitation in the first weeks after surgery. Improvement in the quality of graft fixation is a major reason for advancement of rehabilitation in the first weeks after ACL surgery, as it is the weakest link in the first six to eight weeks after ACL reconstruction surgery.

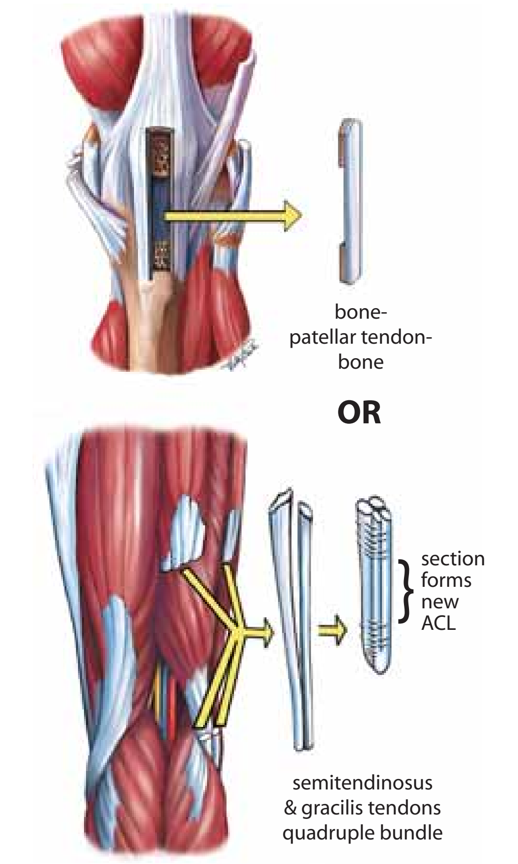


Figure 27.10 The key steps in the process of ACL reconstruction

(a) Harvesting graft tissue for the patellar tendon (top panel) or semimembranosus/gracilis tendon ('hamstring graft') ACL reconstruction

(b) Replacing the ruptured ACL with the graft tendon tissue; interference screw shown

(c) After surgery—the knee with the new graft or 'neoligament' in place necessary, the post-operative knee brace should be fitted and the use of crutches taught.

Immediately following surgery, weight-bearing status is largely determined by concomitant injuries (e.g. meniscal repair). Isolated ACL reconstructions are typically treated as weight-bearing as tolerated, using a brace and/or crutches until adequate quadriceps muscle strength is restored. Instructions should be given regarding the use of crutches as the patient will progress from limited weight-bearing to full weight-bearing for the first two weeks.

The rehabilitation programs for patellar tendon and hamstring tendon graft ACL reconstructions are slightly different due to the need to prevent the particular complications associated with each type of reconstruction. The main problem with the patellar tendon graft is anterior knee pain (see below). Therefore, attention must be paid to this area during the rehabilitation program with the use of soft tissue therapy to the patellar tendon, accompanied by a strengthening program for the tendon, and patellar taping (Chapter 28) to prevent patellofemoral and fat pad problems. The hamstring graft should be treated as though the patient has had a hamstring tear (Chapter 26), with an appropriate rehabilitation program to restore full range of motion and strength.

The major change in rehabilitation programs over the past few years is the incorporation of a core stability program along with increased emphasis on proprioceptive and balance exercises. These exercises have been used in successful ACL prevention programs (see below). Despite the widespread acceptance of these elements into rehabilitation programs, the two randomized trials have not shown convincing evidence of their efficacy.[27, 28]

The rehabilitation program is shown in Table 27.8. The time frames in the table are a guideline only and must be adjusted depending on the progress of the individual patient. It is essential to rehabilitate each patient individually, taking into consideration the extent of damage to the knee (e.g. articular cartilage damage), the patient's adherence to the exercise program, the amount of stiffness, which varies considerably between patients, and the eventual functional aims of the patient (e.g. daily activities, high level sport).

The patient must be taught to monitor the signs and symptoms around the knee following each work-out. Ice may need to be applied if pain, inflammation or swelling is present.

The timing of return to sport is dependent on several different factors, including the surgeon's assessment, the nature of the sport, the therapist's and coach's opinion and the confidence of the patient. Most surgeons support that ACL graft maturation takes up to six months, and advocate a six-month return to sport as an initial guideline. Beyond this temporal guideline, functional testing should be used to help assess readiness to return to sport.

Functional tests include agility tests, the standing vertical jump and the 'Heiden hop'. The patient performs the 'Heiden hop' by jumping as far as possible using the uninjured leg, landing on the injured leg. Athletes with good function are able to land solid with a single hop, to 'stick it'. Those with functional disability step further or take another small hop. Another way of testing function is by incorporating sport-specific drills. Isokinetic testing may be used to evaluate muscle strength. Quadriceps strength should be at least 90% of the uninjured leg and hamstring strength at least 100%. In the light of all these factors and the varying progress of different athletes and the sport to which they are returning, the time for return to sport after ACL reconstruction may vary from four to 12 months.

The use of a brace on return to sport is not necessary but may help the athlete's confidence. The use of a functional brace in the later stages of rehabilitation and on return to sport has not been shown to be helpful.[29, 30] There is some evidence that wearing a neoprene compression sleeve improves proprioception after ACL reconstruction.[31] Some sporting codes have restrictions on the type of brace and material used.

The research into the effectiveness of various rehabilitation techniques has generally been of poor quality and thus limited conclusions can be drawn. The research evidence is summarized in Table 27.9.

Problems encountered during ACL rehabilitation

Apart from surgical complications (e.g. infection, deep venous thrombosis), a number of secondary problems may occur during the rehabilitation process.

Patella problems

Patellofemoral pain may occur on the injured or the uninjured side. Patients may present with typical symptoms of patellofemoral pain (Chapter 28) but often will not comment on the presence of anterior knee pain as they assume that it is part of the normal process following surgery. The patient should always be asked about symptoms at the front of the knee and the patellofemoral joint should be examined at each visit.

Table 27.8 Rehabilitation following ACL reconstruction (see Figs 27.5 and 27.6)

Phase	Goal of phase	Time post surgery	Physiotherapy treatment	Exercise program	Functional/sport-related activity
Prehabilitation (preoperative rehabilitation)	No/minimal swelling Restore full ROM, particularly extension General 4+/5 lower limb strength or better Patient education—anatomy, surgical procedure, rehabilitation commitment, and goal setting	N/A	Cryotherapy Electrotherapy Compression Manual therapy Gait re-education Exercise modification and supervision	Dependent on ability of patient. In early stages, follow the exercise program from phase 1 and progress to phase 2. If patient has high level of function, start with exercise program from phase 2 and progress weights and repetitions as appropriate	Walking Bike riding Swimming (light kick and no breaststroke)
Phase 1	PWB–FWB Eliminate swelling 0–100° ROM 4+/5 quadriceps strength 5/5 hamstring strength	0–2 weeks	Cryotherapy Electrotherapy Compression Manual therapy Gait re-education Patient education	Gentle flexion ROM Extension ROM to 0° Quadriceps/VMO setting Supported (bilateral) calf raises Hip abduction and extension Hamstring pulleys/rubbers Gait drills	Nil
Phase 2	No swelling Full knee hyperextension Knee flexion to 130°+ Full squat Good balance and control Unrestricted walking	2–12 weeks	Cryotherapy Electrotherapy Compression Manual therapy Gait re-education Exercise modification	ROM drills Quadriceps/VMO setting Mini squats and lunges Leg press (double, then single leg) Step-ups Bridges (double, then single leg) Hip abduction and extension with rubber tubing Single-leg calf raises Gait re-education drills Balance and proprioceptive drills (single leg)	Walking Exercise bike

Table 27.8 Rehabilitation following ACL reconstruction (see Figs 27.5 and 27.6) *(continued)*

Phase	Goal of phase	Time post surgery	Physiotherapy treatment	Exercise program	Functional/sport-related activity
Phase 3	Full ROM Full strength and power Return to jogging, running, and agility Return to restricted sport-specific drills	3–6 months	Manual therapy Exercise/activity modification and supervision	As above—increase difficulty, repetitions and weight where appropriate Jump and land drills Agility drills	Straight line jogging Swimming (light kick) Road bike Straight line running at 3 months Progressing to sport-specific running and agility (progressively sequenced) e.g. running forwards, sideways, backwards, sprinting, jumping, hopping, changing directions, kicking
Phase 4	Return to sport	6–12 months	As above	High-level sport specific strengthening as required	Progressive return to sport, e.g. restricted training, unrestricted training, match play, competitive match play

FWB = full weight-bearing. PWB = partial weight-bearing. ROM = range of motion. VMO = vastus medialis obliquus.

Table 27.9 Rehabilitation techniques after anterior cruciate ligament reconstruction with evidence of effectiveness

- Immediate weight-bearing[32]
- Closed kinetic chain exercises selecting knee joint motions of less than 60°[33]
- Open kinetic chain exercises with knee angles greater than 40° of flexion[34, 35]
- High-intensity neuromuscular electrical stimulation (NMES) in addition to voluntary exercises for improving isometric quadriceps muscle strength[36]

A number of different factors may predispose to the development of patellofemoral pain. Commonly, the lateral structures around the patellofemoral joint, especially the lateral retinaculum and the iliotibial band, are tight. Weakness of the vastus medialis obliquus or proximal gluteal muscles may also be an important component, as may an altered gait pattern, typically associated with excessive subtalar pronation. An overemphasis on knee extension exercises and squats in the exercise program can cause patellofemoral problems. These patellofemoral problems occur not only with patellar tendon graft reconstructions but also with the hamstring tendon graft reconstructions.

The infrapatellar fat pad is frequently damaged by the arthroscope and may be the source of considerable discomfort after reconstruction. Taping techniques (Chapter 28) can be used to unload the fat pad.

Another complication seen after patellar tendon ACL reconstruction is inferior displacement of the patella (patella baja) due to traction on the patella by tight infrapatellar soft tissue structures. Patellar tendinopathy (Chapter 28) is also seen following ACL reconstruction, especially with patellar tendon grafts.

A common and as yet unexplained finding in cases of chronic ACL insufficiency and reconstruction is severe trochlea chondral damage.

Low back pain

Low back pain is not uncommon in the early stages of the rehabilitation program when it may be due to the use of crutches and to altered gait patterns. It usually occurs in patients who have a prior history of low back pain.

Lower limb stiffness

Stiffness in the foot and ankle commonly occurs as a result of a period of non-weight-bearing and the wearing of a brace. Tightness of the Achilles tendon is common. These problems typically present on return to running. Full range of motion of these joints should be maintained early in the rehabilitation program with mobilization and stretching in addition to active plantarflexion/dorsiflexion exercises.

Soft tissue stiffness (arthrofibrosis)

The rehabilitation program and its rate of progression will be influenced by the intrinsic tissue stiffness or laxity of the patient. This depends on the nature of the patient's collagen and appears to correlate with generalized ligamentous stiffness or laxity throughout the body. Patients with stiff soft tissues may develop a large bulky scar with adhesions after ACL reconstruction. These patients are usually slow to regain full flexion and extension, and the knee may require passive mobilization by the therapist. Patients tend to have tight lateral structures around a stiff patellofemoral joint. This is known as arthrofibrosis.[37]

Treatment involves encouraging active movement, early passive mobilization, massage and encouraging early activity. Efforts to control swelling are critical. It may be helpful to remove the brace earlier than usual in these patients. Severe cases may require arthroscopic scar resection as well as a vigorous rehabilitation program.

As mentioned previously, delaying the surgery until all signs of the hemarthrosis have disappeared and full range of motion has been regained appears to reduce the likelihood of arthrofibrosis developing.

Soft tissue laxity

The group of patients classified as having 'loose' soft tissue, are characterized by generalized increased ligamentous laxity. These patients tend to rapidly gain good range of motion in extension and flexion. They are treated by prolonging the time in the brace and restricting the range available. Range of motion exercises are discouraged, mobilization contraindicated and full extension work reduced to avoid stretching the graft. The rehabilitation program is slowed in these patients to allow time for the graft to develop as much scar tissue as possible.

Conservative management

When the clinical diagnosis of an ACL tear is made and the patient opts for initial conservative management, an arthroscopy should probably be performed. The aim of this arthroscopy is to assess stability of the knee under anesthesia, to wash out the hemarthrosis, and to assess and treat other injuries such as meniscal tears and articular cartilage damage. The presence of articular cartilage damage is indicative of a poor prognosis. These patients tend to have persistent problems with pain and swelling even after surgery. This is aggravated if a full or partial menisectomy is required, as the stresses placed on the articular cartilage are increased.

Derotation knee braces may be used as part of the conservative management of ACL tears to provide additional stability when playing sport (e.g. downhill skiing). The effectiveness of these braces varies depending on the degree of instability and the type of brace.

The rehabilitation program for the conservatively managed ACL injury is similar to management after reconstruction (Table 27.8). The principles of initial reduction of swelling and pain, restoration of full range of motion, increase of muscle strength and power, functional rehabilitation and, finally, return to sport all apply. Depending on the degree of instability and other associated abnormalities (e.g. articular cartilage damage), the rate of progress may be slower or faster than after a reconstruction. The final stages of the rehabilitation program, the agility work and sport-specific drills, may not be possible in the patient with ACL deficiency. Conservative treatment of ACL injuries is most successful in sports that are not dependent on jumping and pivoting motions.

Outcomes after ACL treatment

While the general consensus among the surgical and sporting communities is that those sustaining an ACL injury make a full recovery after ACL reconstructive surgery, research findings suggest that is not always the case. Three main outcome measures are used to determine the success or otherwise of ACL treatment:

1. return to sport
2. reinjury rate
3. prevalence of osteoarthritis.

Return to sport

The majority of those who have an ACL reconstruction have good to excellent knee function and most (65–88%) are able to return to sport within the first year.[38–41] Thus, surgery is effective in allowing injured athletes to resume their sports career.[42]

Among patients treated non-operatively, the return rate ranges from 19% to 82%.[43, 44] Athletes who successfully return to sport after non-operative treatment probably represent a selected group with functionally stable knees and a strong motivation to continue pivoting sport despite their injury.[42]

While most athletes return to their previous sport after ACL reconstruction, there is some evidence that they may stop playing earlier than their non-injured counterparts.[43, 45, 46] In the only study in which the reduction in sport participation can be related to a control group, Roos et al.[44] found that 30% of those who had ACL injury were active after three years compared with 80% of controls, and that after seven years none of the elite injured players were active regardless of the type of treatment.

Although the initial return to sport rate is high, previously injured athletes retire at a higher rate than athletes without previous ACL injury.[42] The reason for this may be that many of the athletes who return to sport experience significant knee problems such as instability, reduced range of motion and/or pain.[43]

Reinjury rate

The incidence of graft failure is generally of the order of 3–6% in most studies.[47] There is some evidence from a meta-analysis that the failure rate may be lower in patellar tendon autografts,[48] although another systematic review failed to show a difference.[22] There also appears to be an increased risk of rupturing the contralateral ACL in patients who have already had an ACL injury. There may also be an increased risk of other knee injuries (e.g. meniscal, articular cartilage injury) after ACL injury, particularly in those managed non-operatively. Reinjury appears to be most likely in the first 12 months after surgery.[22]

Osteoarthritis

ACL rupture is associated with a significant risk of development of osteoarthritis (OA); it may be that the initial injury itself may influence the development of OA irrespective of what treatment is used or how the knee is loaded during subsequent years. Whereas previously it was thought that an isolated ACL injury was quite common, we now know that bone bruising (as seen on MRI) occurs in more than 80% of cases of ACL tears. Bone bruising is highly associated with articular cartilage damage. Meniscal injury is found in 75% of cases of ACL tears and this also predisposes to the development of OA. Long-term follow-up studies of patients who have undergone ACL reconstruction with more modern techniques have shown that nearly all patients develop radiological signs of OA after 15–20 years.[43] Many of these patients are, however, asymptomatic.

Although it was recognized that ACL injuries treated non-operatively were associated with an increased risk of OA, it had been hoped that ACL reconstruction, by restoration of knee anatomy and reduction of instability, would eliminate, or substantially reduce, the incidence of OA. At this time, however, there is no evidence that ligament reconstruction prevents the future development of OA.[43, 46, 49–51] It seems that the important predictor of future OA is the damage to other structures, such as the menisci and articular cartilage, at the time of the injury.

A related, important sports medicine question is, 'Does returning to active sport increase the likelihood of developing OA, or does it bring this event on more quickly?' No studies have evaluated this phenomenon but it is reasonable to assume that intense weight-bearing activity involving pivoting would accelerate the degenerative process compared to in someone who remained sedentary or took up a non-weight-bearing sport (e.g. cycling, swimming). We and others[42, 52] propose that athletes who have undergone an ACL reconstruction should receive advice about the likelihood of developing OA, and the possibility that returning to active sports participation will accelerate its development. Many professional and dedicated athletes may decide to continue their sport in spite of that advice, but it is the duty of health professionals to enable them to make an informed decision.

Gender difference

In light of the increased prevalence of ACL injuries in female athletes discussed previously, attention has been to possible differences in outcome after ACL reconstruction between males and females. The majority of studies show increased post-surgical laxity in females but no difference in graft failure, activity level, or subjective or functional assessment.[38, 53–57]

Prevention of ACL injury

As 60–80% of ACL injuries occur in non-contact situations, it seems likely that the appropriate prevention efforts are warranted. In ball sports two common mechanisms cause ACL tears:

1. a cutting maneuver[58–60]
2. one leg landing.

Cutting or sidestep maneuvers are associated with dramatic increases in the varus–valgus and internal rotation moments. The ACL is placed at greater risk with both varus and internal rotation moments. The typical ACL injury occurs with the knee externally rotated and in 10–30° of flexion when the knee is placed in a valgus position as the athlete takes off from the planted foot and internally rotates with the aim of suddenly changing direction (Fig. 27.11a).[61, 62] The ground reaction force falls medial to the knee joint during a cutting maneuver and this added force may tax an already tensioned ACL and lead to failure. Similarly in the landing injuries, the knee is close to full extension.

High-speed activities such as cutting or landing maneuvers require eccentric muscle action of the quadriceps to resist further flexion. It may be hypothesized that vigorous eccentric quadriceps muscle action may play a role in disruption of the ACL. Although this normally may be insufficient to tear the ACL, it may be that the addition of a valgus knee position and/or rotation could trigger an ACL rupture.

One question that is often asked is why the ACL tears in situations and maneuvers that the athlete has performed many times in the past. Frequently,

Figure 27.11 Abnormal positions that may lead to ACL injury

(a) The typical position during the cutting maneuver which leads to ACL injury

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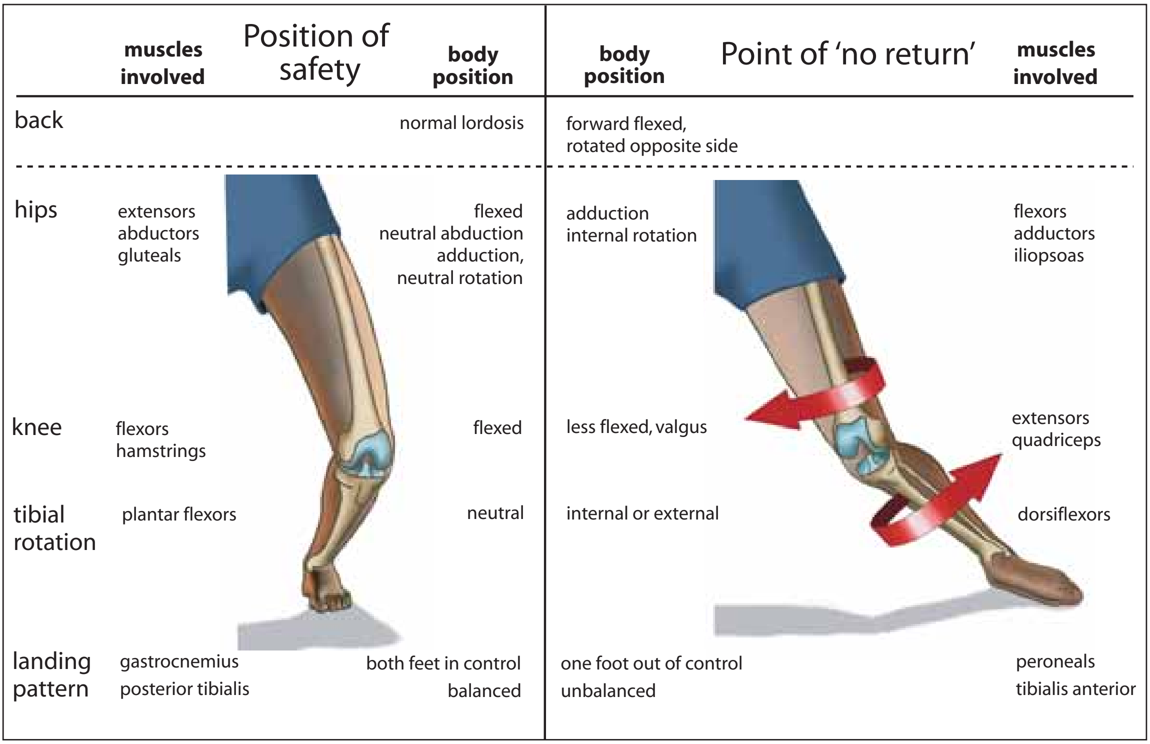


(b) The positions of safety and of 'no return'

there is some external factor that renders the athlete susceptible. The athlete could be off balance, be pushed or held by an opponent, be trying to avoid collision with an opponent, or have adopted an unusually wide foot position. These perturbations may contribute to the injury by causing the athlete to plant the foot so as to promote unfavorable lower extremity alignment; this may be compounded by inadequate muscle protection and poor neuromuscular control.[62] Fatigue and loss of concentration may also be a factor.

What has become recognized is that unfavorable body movements in landing and pivoting can occur, leading to what has become known as the 'functional valgus' or 'dynamic valgus' knee, a pattern of knee collapse where the knee falls medial to the hip and foot. This has been called by Ireland the 'position of no return', or perhaps it should be termed the 'injury prone position' since there is no proof that one cannot recover from this position (Fig. 27.11b).[63] Intervention programs aimed to reduce the risk of ACL injury are based on training safer neuromuscular patterns in simple maneuvers such as cutting and jump landing activities.

The mechanism of ACL injury in skiing is different from that in jumping, running and cutting sports such as football and basketball. In skiing, most ACL injuries result from internal rotation of the tibia with the knee flexed greater than 90°, a position that occurs when a skier who is falling backwards catches the inside edge of the tail of the ski.[64] Intervention programs in skiing are aimed at increasing the skier's awareness of patterns that are injurious to the knee, and giving alternative strategies in the hope of avoiding these patterns altogether.

Why do females tear their ACLs at three times the rate of males?

The rate of non-contact ACL injury among female athletes is considerably higher (×2–8) than that in males at comparable risk (exposure) and in comparable activities. At present, four main areas are being investigated to explain this discrepancy:

1. anatomical
2. hormonal
3. shoe surface interface
4. neuromuscular.

Anatomical differences

A number of anatomical differences between women and men have been proposed as contributing factors to the greater rupture rates of ACLs in females. These differents in females include:

- smaller size and different shape of the intercondylar notch[65, 66]
- wider pelvis and greater Q angle
- greater ligament laxity.[67]

Although anatomical differences may play a role in ACL injury risk, since there is little that one can change in one's anatomy, focus has turned to that which may be able to be changed.

Hormonal differences

Females have a unique hormonal cycle, and estrogen has long been implicated as a risk factor in the higher ACL injury rates in females. Estrogen receptors were detected in the human ACL[68] and more recently relaxin receptors were found on female but not male ACLs.[69] Research examining a possible relationship between phase of the menstrual cycle and ACL injury has shown conflicting results.[14, 70–74]

If estrogen level is a risk factor, it is not likely at the material level of ligament strength, as mechanical tests of ligament failure have not shown any difference in strength between ligaments in two studies of different animal models when levels of estrogen were modified.[75, 76]

If hormones have a role to play in ACL injury risk, most researchers believe they are mediated through the neuromuscular system and that a direct relationship is unlikely.[77]

Shoe–surface interface

The shoe–surface interface can be affected by a number of factors. In team handball a higher friction coefficient rate led to an increase in ACL tears.[78, 79] A higher rate of ACL injuries was found in footballers who wore cleats placed on the peripheral margin of the sole with a number of smaller pointed cleats positioned interiorly.[80] An uneven playing surface may also be a factor. A difference in rainfall or the type of grass may also contribute to alterations in the shoe–surface interface (Chapter 6).[81]

Neuromuscular factors

The balance of muscle power and recruitment pattern between the quadriceps and hamstring muscles is crucial to functional knee stability. Controlling the rotation of the limb under the pelvis in pivoting and landing is critical to controlling knee stability, and reducing or eliminating the functional valgus knee. Quadriceps contraction increases ACL strain between 10° and 30° of flexion. An eccentric quadriceps muscle contraction can produce forces beyond those required for ACL tensile failure.[82]

The hamstrings, in contrast, are ACL agonists, so any weakness, increased flexibility or delayed motor signal to the hamstrings may increase the susceptibility to ACL injury.[83] Female athletes rely more on their quadriceps muscles and respond to anterior tibial translation by activating their quadriceps first rather than their hamstrings.[84] Males, given a similar force, activate their hamstrings first to dynamically stabilize their knee, thus preventing displacement of the tibia on the femur.[85] This difference in the timing of muscle firing patterns has been thought to be related to the increased risk of injury in females. This study, along with Hewett et al.'s work,[86] which shows that females are more 'quadriceps dominant' than males, has led to the concept of a quadriceps dominant limb being a risk factor for serious knee injury, including injury to the ACL.

In addition to muscle strength and firing patterns, females land from a jump or pivot with less hip and knee flexion than do males.[86] This is what Hewett et al. refer to as 'ligament dominance'.[87] Training more flexion at the knee and hip in landing maneuvers has been shown to reduce valgus moments at the knee.

Risk equation

Uhorchak et al.[67] showed that a combination of female gender, decreased notch width, increased body mass index and generalized joint laxity were strong predictors of ACL injuries. This gives firm support to the notion of a 'risk equation', where no one factor predicts injury but, when combined, can increase injury risk with certain factors.

Prevention programs

Given the importance of neuromuscular factors in the etiology of ACL injuries, numerous programs have aimed to improve neuromuscular control during standing, cutting, jumping and landing.[86, 88–92] The components of the neuromuscular training programs are (Table 27.10):

1. balance training
2. landing with increased flexion at the knee and hip
3. controlling body motions, especially in deceleration and pivoting maneuvers

4. some form of feedback to the athlete during training of these activities.

A meta-analysis[93] of the six published prevention programs demonstrated an overall positive effect in reducing ACL injuries, with a total of 29 ACL injuries in the prevention group compared to 110 in the control group. Three of the six programs showed significant reduction, while two of the remaining three demonstrated positive trends and reduced odds ratios. The conclusion from this meta-analysis was that prevention programs may be effective provided that plyometrics, balance and strengthening exercises are incorporated into the training program, that the training be performed more than once a week, and that the program should continue for at least six weeks. The component of the programs which correlated best with ACL injury reduction was high-intensity plyometric movements that progressed beyond footwork and agility.[93]

Although, as mentioned above, the mechanism of ACL injury in skiing is different, neuromuscular conditioning also successfully prevented ACL injury.[64] Ski injury prevention programs teach skiers to recognize and respond with appropriate strategies to dangerous situations and to avoid potentially compromising positions.[83]

Factors not yet fully explored include the role of individual athlete compliance, failure to comply with neuromuscular training (i.e. how quickly do we forget what we learn?), and what is the ideal age to teach these techniques (i.e. does age matter?). Do all athletes benefit from these intervention techniques or can we identify the 'at-risk' athlete and train that athlete differently? These are the questions on which interventionists will be focusing future direction and research.

ACL rupture among children with open physes

ACL injuries are common in children and adolescents.[94] Traditionally, surgical reconstruction of the ACL in children with open physes has not been recommended due to the risk of growth abnormalities resulting from surgical violation of the physes. There are, however, concerns that non-operative or delayed operative management risk meniscal and/or cartilage injuries, leading to premature degenerative disease.

There is increasing clinical evidence that the risk of damage to the physes is minimal, especially with various surgical techniques currently available to minimize physeal trauma. Most surgeons currently

Table 27.10 ACL prevention program[77]

Week	Exercises
Floor exercises	
1	Running and planting, partner running backwards and giving feedback on the quality of the movement, change position after 20 s
2	Jumping exercise: right leg, right leg over to left leg, left leg and finishing with a two-foot landing with flexion in both hips and knees
3	Running and planting (as in week 1), now doing a full plant-and-cut movement with the ball, focusing on knee position (Fig. 27.12a)
4	Two players together, two-leg jump forward and backwards, 180° turn and the same movement backwards; partner tries to push the player out of control but still focusing on landing technique
5	Expanding the movement from week 3 to a full plant and cut, then a jump shot with two-legged landing
Mat exercises	
1	Two players each standing on one leg on the mat, throwing to each other (Fig. 27.12b)
2	Jump shot from a box (30–40 cm [~1 ft] high) with a two-foot landing with flexion in hip and knees
3	'Step' down from box with one-leg landing with flexion in hip and knee
4	Two players both standing on balance mats trying to push partner out of balance, first on two legs, then on one leg
5	The players jump on a mat, catching the ball, then take a 180° turn on the mat
Wobble board exercises	
1	Two players standing two-legged on the board, throwing to each other
2	Squats on two legs, then on one leg
3	Two players throwing to each other, one foot each on the board
4	One foot on the board, bouncing the ball with eyes shut
5	Two players, both standing on balance boards trying to push partner out of balance, first on two legs, then on one leg (Fig. 27.12c)

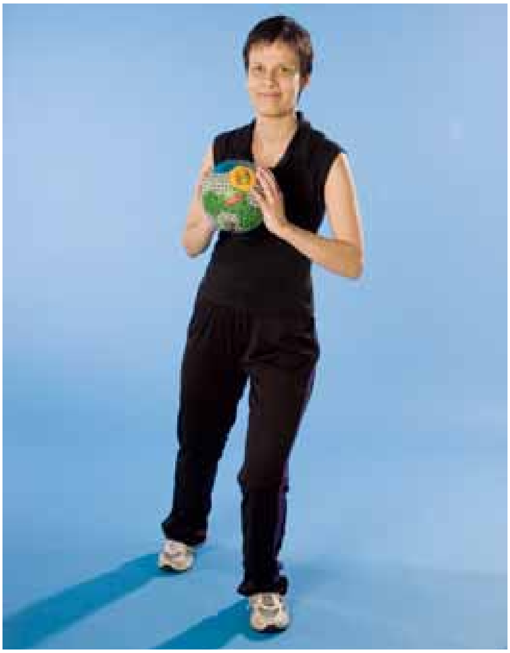
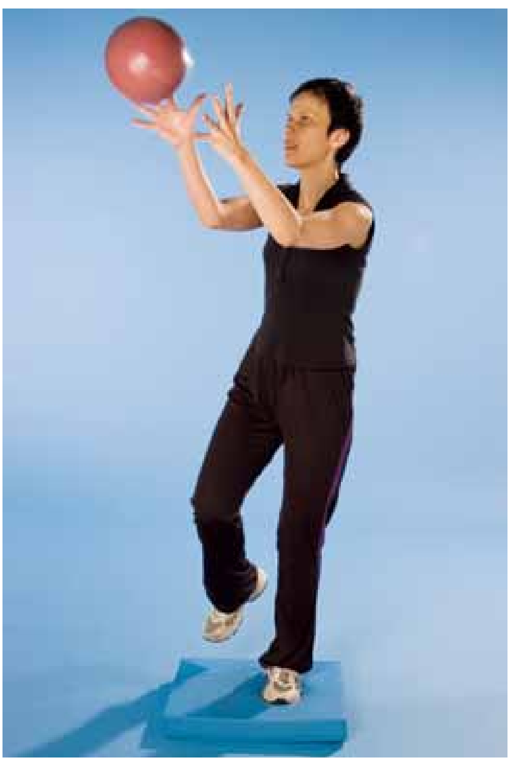
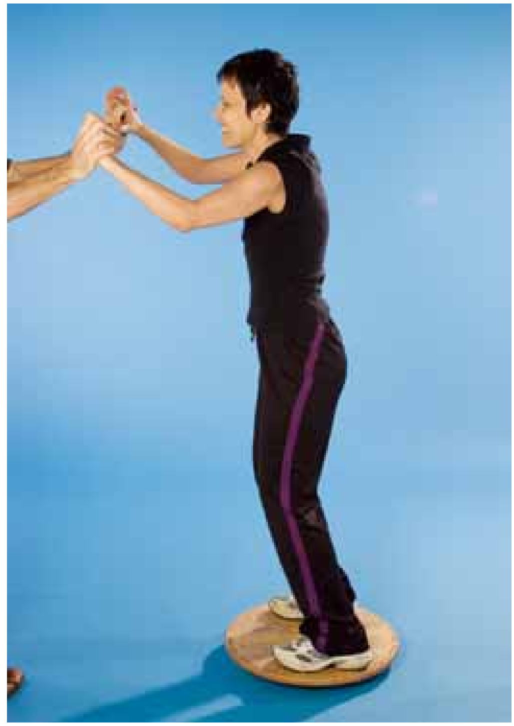


Figure 27.12 Examples of ACL prevention exercises

(a) Floor exercise



(b) Mat exercise



(c) Wobble board exercise

recommend ACL reconstruction in younger patients with open growth plates. In the adolescent patient approaching skeletal maturity, fixation of the ACL graft is performed in the same manner as in an adult, and graft choice is either the patella or hamstring tendons. In the younger patients, techniques are used to minimize the damage to the physes.[95] These include using only soft tissue for graft choice (such as hamstrings) to avoid a bone plug in the tunnel at the growth plate. Tunnels are made smaller in diameter and on the tibia they are slightly more vertical. On the femur one can avoid the growth plate altogether and use the 'over the top' technique of ACL graft placement. These techniques can be individualized to meet the needs of the surgeon and the patient, depending on the age and maturation of the patient.

Posterior cruciate ligament tear

The PCL is the primary restraint to posterior drawer, and secondary restraint to external rotation. Isolated sectioning of the PCL results in an increased posterior translation of the knee under a posterior tibial load. This increase in laxity is relatively small at full extension and most pronounced at 90° of flexion. Only small rotatory or valgus/varus laxity results from isolated PCL injury.

Up to 60% of PCL injuries involve disruption of the posterolateral structures. The primary stabilizers are the lateral collateral ligament (LCL) and the popliteus complex. They provide varus and external rotatory stability to the knee respectively. When both the PCL and posterolateral structures are cut, posterior laxity is significantly increased.[96]

Tears of the PCL do not appear to be as common as of the ACL, due partly to the greater strength of the PCL. However, the condition is under-diagnosed.

PCL injuries are often associated with meniscal and chondral injury. The incidence of associated meniscal tears varies from 16% to 28%. Longitudinal tears of the anterior horn of the lateral meniscus are the most common location. There is also a high incidence of radial tears in the middle or posterior lateral meniscus.[97]

The incidence of significant chondral damage with isolated PCL injury was not thought to be as high as with ACL injury, but a recent study showed chondral damage in 52% of those with PCL tears, with lesions of grade III or more found in 16%.[97]

Clinical features

The mechanism of PCL injury is usually a direct blow to the anterior tibia with the knee in a flexed position. This can be from contact with an opponent, equipment or falling onto the hyperflexed knee. Hyperextension may also result in an injury to the PCL and posterior capsule.

The patient complains of poorly defined pain, mainly posterior, sometimes involving the calf. On examination, there is usually minimal swelling as the PCL is an extrasynovial structure. The posterior drawer test (Fig. 27.2o) is the most sensitive test for PCL deficiency. This is performed in neutral, internal and external rotation. A posterior sag of the tibia (Fig. 27.2n), and pain and laxity on a reverse Lachman's test may be present. PCL rupture is particularly disabling for downhill skiers, who rely on this ligament for stability in the tucked up position adopted in racing.

PCL tears are graded I, II and III on the position of the medial tibial plateau relative to the medial femoral condyle at 90° of knee flexion (the posterior drawer position). The tibia normally lies approximately 1 cm (0.4 in.) anterior to the femoral condyles in the resting position. In grade I injuries the tibia continues to lie anteriorly to the femoral condyles but is slightly diminished (0–5 mm [0–0.2 in.] laxity). In grade II injuries the tibia is flush with the condyles (5–10 mm [0.2–0.4 in.] laxity). When the tibia no longer has a medial step and can be pushed beyond the medial femoral condyle (>10 mm [>0.4 in.] laxity), it is classified as a grade III injury.[98]

It is important to distinguish between isolated PCL injury and a combined PCL and posterolateral corner injury. In isolated PCL tears, there is a decrease in tibial translation in internal rotation due primarily to the influence of the MCL.[99]

X-ray should be performed to exclude a bony avulsion from the tibial insertion of the PCL (best seen on lateral tibia radiographs). If a fracture is present, acute surgical repair is undertaken. Stress radiographs provide a non-invasive measure of sagittal translation compared to the uninjured knee. It is considered that more than 7–8 mm (>0.3 in.) of posterior translation is indicative of a PCL tear.

MRI has a high predictive accuracy in the diagnosis of the acute PCL injury,[100] but a lesser accuracy in chronic injuries. If an injury to the posterolateral corner is suspected, MRI can be helpful but to view this region properly usually requires a specific imaging protocol. When the MRI requisition states that injury to the posterolateral corner is suspected, the radiologist can optimize the imaging protocol.

Treatment

PCL rupture can generally be managed conservatively with a comprehensive rehabilitation program. A suggested program emphasizing intensive quadriceps exercises is shown in Table 27.11. More severe injuries (grade III) should be immobilized in extension for the first two weeks.

Results show that patients with isolated PCL tears have a good functional result despite ongoing laxity after an appropriate rehabilitation program. Regardless of the amount of laxity, half of the patients in one large study returned to sport at the same or higher level, one-third at a lower level and one-sixth did not return to the same sport.[101]

Surgical reconstruction is indicated when the PCL injury occurs in combination with other posterolateral structures or where significant rotatory instability is present.

Table 27.11 Rehabilitation of a PCL tear (see Figs 27.5 and 27.6)

Phase	Goal of phase	Time post injury	Physiotherapy treatment	Exercise program	Functional/sport-related activity
Phase 1	PWB–FWB Eliminate swelling 0–100° ROM 4+/5 quadriceps strength 5/5 hamstring strength	0–2 weeks	Cryotherapy Electrotherapy Compression Manual therapy Gait re-education Patient education	Gentle flexion ROM Extension ROM to 0° Quadriceps/VMO setting Supported (bilateral) calf raises Hip abduction and extension Hamstring pulleys/rubbers Gait drills	Nil
Phase 2	No swelling Full ROM 4+/5 quadriceps strength 5/5 hamstring strength	2–4 weeks	Cryotherapy Electrotherapy Compression Manual therapy Gait re-education Exercise modification	ROM drills Quadriceps/VMO setting Mini squats and lunges Leg press (double, then single leg) Step-ups Bridges (double, then single leg) Hip abduction and extension with rubber tubing Single-leg calf raises Gait re-education drills Balance and proprioceptive drills (single leg)	Walking Exercise bike
Phase 3	Full ROM Full strength and power Return to jogging, running, and agility Return to restricted sport-specific drills	4–6 weeks	Manual therapy Exercise/activity modification and supervision	As above—increase difficulty, repetitions and weight where appropriate Jump and land drills Agility drills	Straight line jogging Swimming (light kick) Road bike Straight line running Progressing to sport-specific running and agility (progressively sequenced) e.g. running forwards, sideways, backwards, sprinting, jumping, hopping, changing directions, kicking
Phase 4	Return to sport	6–10 weeks	As above	High-level sport-specific strengthening as required	Progressive return to sport, e.g. restricted training, unrestricted training, match play, competitive match play

FWB = full weight-bearing. PWB = partial weight-bearing. ROM = range of motion. VMO = vastus medialis obliquus.

Lateral collateral ligament tears

LCL tears are much less common than MCL tears. They are usually due to a severe, high-energy, direct varus stress on the knee and are graded in a similar fashion to MCL sprains. Differential diagnosis may be an avulsion of the biceps femoris tendon. Clinicians should be aware that local tenderness on the posterolateral corner of the knee may also occur with ACL tears.

Complete tears of the LCL are usually associated with other instabilities, such as PCL rupture, and may result in posterolateral rotatory instability of the knee. These tears are best treated by acute surgical repair in conjunction with repair of other damaged ligaments. Chronic reconstruction of the LCL is difficult and results are poor. A varus knee with lateral and/or posterolateral instability appears to be associated with worse results. An osteotomy is necessary for treatment of this ligament injury, with or without a reconstruction of the ligament itself.

Articular cartilage damage

Since the introduction of arthroscopy and MRI, considerable insight has been gained into the role of articular cartilage (chondral) damage as a cause of symptoms and signs in the knee joint. Articular cartilage damage may occur as an isolated condition in which chondral or subchondral damage is the primary pathology, or in association with other injuries, such as ligamentous instability resulting from MCL, ACL or PCL injuries. ACL tears are associated with a high incidence of damage to the medial femoral condyle, lateral femoral condyle and lateral tibial plateau. Articular cartilage damage may also be seen in association with meniscal injury and patellar dislocation. Chondral injury is graded according to the Outerbridge classification and more recently the International Cartilage Repair Society (ICRS) grading system (Tables 27.12, 27.13). Articular cartilage damage varies from gross, macroscopically evident defects in which the underlying bone is exposed (grade IV), to microscopic damage that appears normal on arthroscopy but is soft when probed (grade I).

Articular cartilage damage in the knee has both short-term and long-term effects. In the short term, it causes recurrent pain and swelling. In the longer term, it accelerates the development of osteoarthritis. Various methods have been used to encourage healing of articular cartilage defects. These include microfracture (piercing the subchondral bone with an 'ice pick' to recruit pluripotential stem cells from the marrow), mosaic plasty (osteochondral plugs are taken from the trochlea margin and implanted within the injured area), and autologous chondrocyte implantation, where cultured chondrocytes (harvested from the patient and cultured in the laboratory) are reimplanted to the chondral defect. Gene therapy and bone morphogenetic proteins are currently in the experimental stage.

There is currently considerable debate as to the efficacy of the various treatments and as yet no consensus on optimal treatment has been reached. Although short-term reduction of symptoms has been shown with these treatments, long-term reduction of arthritic disability has not been shown. As yet, no method of treatment has been able to reproduce true hyaline cartilage with its complex layered structure.

An effective method of promoting scar tissue formation in damaged articular cartilage is by continuous passive motion. Continuous passive motion has been shown to stimulate formation of hyaline-like fibrocartilage in the chondral defect, especially in the immediate post-operative period. This should be supplemented by low load, non-weight-bearing exercise such as swimming and cycling. Following articular cartilage injury, the athlete may have to modify his or her training to reduce the amount of weight-bearing activity and substitute activities such as swimming and cycling.

When an injury (e.g. patellar dislocation, ACL or MCL tear) requires a lengthy period of partial or non-weight-bearing, particular attention must be paid

Table 27.12 ICRS classification of chondral defects

1. Superficial lesions
   A. Soft indentation
   B. Superficial fissures or cracks
2. Lesions < 50% cartilage depth
3. A. Lesions >50 % depth
   B. Down to calcified layer
   C. Down to but not through subchondral bone
   D. Blisters
4. Very abnormal into subchondral bone

Table 27.13 Outerbridge classification of chondral defects

1. Softening
2. <1 cm (<0.4 in.) partial thickness lesion
3. >1 cm (>0.4 in.) defect, deeper
4. Subchondral bone exposed

to preserving the integrity of the articular cartilage. This is done with continuous passive motion, a hydrotherapy program, swimming or cycling.

Other methods of reducing stress on the damaged articular cartilage include correction of biomechanical abnormalities, attention to ensure symmetry of gait and the use of a brace to control any instability. Pool running may also be helpful and the minitrampoline is used in the early stages of running and agility work to reduce load bearing. Proprioceptive exercises and strength exercises are also important.

Acute patellar trauma

Acute trauma to the patella (e.g. from a hockey stick or from a fall onto the kneecap) can cause a range of injuries from fracture of the patella to osteochondral damage of the patellofemoral joint with persisting patellofemoral joint pain. In some athletes, the pain settles without any long-term sequelae.

If there is suspicion of fracture, X-ray should be obtained. It is important to be able to differentiate between a fracture of the patella and a bipartite patella. A skyline view of the patella should be performed in addition to normal views.

If there is no evidence of fracture, the patient can be assumed to be suffering acute patellofemoral inflammation. This can be a difficult condition to treat. Treatment consists of NSAIDs, local electrotherapy (e.g. interferential stimulation, TENS) and avoidance of aggravating activities such as squatting or walking down stairs. Taping of the patella may alter the mechanics of patellar tracking and therefore reduce the irritation and pain (Chapter 28).

Fracture of the patella

Patellar fractures can occur either by direct trauma, in which case the surrounding retinaculum can be intact, or by indirect injury from quadriceps contraction, in which case the retinaculum and the vastus muscles are usually torn.

Undisplaced fractures of the patella with normal continuity of the extensor mechanism can be managed conservatively, initially with an extension splint. Over the next weeks as the fracture unites, the range of flexion can be gradually increased and the quadriceps strengthened in the inner range.

Fractures with significant displacement, where the extensor mechanism is not intact, require surgical treatment. This involves reduction of the patella and fixation, usually with a tension band wire technique. The vastus muscle on both sides also needs to be repaired. The rehabilitation following this procedure is as for undisplaced fracture.

Patella dislocation

Patella dislocation occurs when the patella moves out of its groove laterally onto the lateral femoral condyle. Acute patella dislocation may be either traumatic with a good history of trauma and development of a hemarthrosis following injury, or atraumatic, which usually occurs in young girls with associated ligamentous laxity, does not have a good history of trauma, and is accompanied by mild-to-moderate swelling.

Clinical features

Patients with traumatic patella dislocation usually complain that, on twisting or jumping, the knee suddenly gave way with the development of severe pain. Often the patient will describe a feeling of something 'popping out'. Swelling develops almost immediately. The dislocation usually reduces spontaneously with knee extension; however, in some cases this may require some assistance or regional anesthesia (e.g. femoral nerve block).

A number of factors predispose to dislocation of the patella:

- femoral anteversion
- shallow femoral groove
- genu valgum
- loose medial retinaculum
- tight lateral retinaculum
- vastus medialis dysplasia
- increased Q angle
- patellar alta
- excessive subtalar pronation
- patellar dysplasia
- general hypermobility.

The main differential diagnosis of patella dislocation is an ACL rupture. Both conditions have similar histories of twisting, an audible 'pop', a feeling of something 'going out' and subsequent development of hemarthrosis.

On examination, there is usually a gross effusion, marked tenderness over the medial border of the patella and a positive lateral apprehension test when attempts are made to push the patella in a lateral direction. Any attempt to contract the quadriceps muscle aggravates the pain. X-rays, including anteroposterior, lateral, skyline and intercondylar views, should be performed to rule out osteochondral fracture or a loose body.

Treatment

Treatment of traumatic patella dislocation depends on presentation. Relatively atraumatic dislocations are treated conservatively. Traumatic first- or second-time dislocations (hemarthrosis present) are treated with arthroscopic washout and debridement. Recurrent dislocation is treated with surgical stabilization.

The most important aim of rehabilitation after patellofemoral dislocation is to reduce the chances of a recurrence of the injury. As a result, the rehabilitation program is lengthy and emphasizes core stability, pelvic positioning, vastus medialis obliquus strength and stretching of the lateral structures when tight. A suggested rehabilitation program is shown in Table 27.14.

The most helpful addition to patellofemoral rehabilitation in the recent past is increased emphasis on core stability. Similar to ACL intervention exercises, rotational control of the limb under the pelvis is critical to knee and kneecap stability.

Less common causes

Patellar tendon rupture

The patellar tendon occasionally ruptures spontaneously. This is usually in association with a sudden severe eccentric contraction of the quadriceps muscle, which may occur when an athlete stumbles. There may have been a history of previous corticosteroid injection into the tendon. A previous history of patellar tendinopathy is uncommon.

Patients complain of a sudden acute onset of pain over the patellar tendon accompanied by a tearing sensation and are unable to stand. On examination, there is a visible loss of fullness at the front of the knee as the patella is retracted proximally. The knee extensor mechanism is no longer intact and knee extension cannot be initiated.

Surgical repair of the tendon must be followed by intensive rehabilitation. Full recovery takes six to nine months and there is often some residual disability.

Bursal hematoma

Occasionally, an acute bursal hematoma or acute pre-patellar bursitis occurs as a result of a fall onto the knee. This causes bleeding into the pre-patellar bursa and subsequent inflammation.

This usually settles spontaneously with firm compression bandaging. If not, the hematoma should be aspirated and the bloodstained fluid removed. Anti-inflammatory medication may also be appropriate. This injury is often associated with a skin wound (e.g. abrasion) and therefore may become infected. Adequate skin care is essential. If the bursa recurs, then aspiration followed by injection of a corticosteroid agent may be required. If conservative treatment fails, arthroscopic excision of the bursa is indicated.

Fat pad impingement

Acute fat pad impingement (often incorrectly referred to as 'Hoffa's syndrome') usually occurs as a result of a hyperextension injury. As the fat pad is the most sensitive part of the knee, this condition may be extremely painful.[102] There may be an inferiorly tilted lower pole of the patella predisposing to injury. On examination, tenderness is distal to the patella but beyond the margin of the patellar tendon. A hemarthrosis may be present.

This can be an extremely difficult condition to treat. The basic principles of treatment are a reduction of aggravating activities, electrotherapeutic modalities to settle inflammation and resumption of range of movement exercises as soon as possible. Taping of the patella may help in reducing the amount of tilt and impingement (Chapter 28). If conservative management is not successful, arthroscopic joint lavage and resection of the fat pad can be helpful.

Fracture of the tibial plateau

Tibial plateau fracture is seen in high-speed injuries such as falls while skiing, wave-jumping or horse-riding. This condition needs to be excluded when diagnosing collateral ligament damage with instability. The patient complains of severe pain and inability to weight-bear. Fractures are associated with a lipohemarthrosis, which can be detected on a horizontal lateral X-ray by the presence of a fat fluid level. CT scan is helpful in defining the fracture.

Minimally displaced fractures should be treated by six weeks of non-weight-bearing in a hinged knee brace (Fig. 27.4a). Displaced fractures (Fig. 27.13) or fractures with unstable fragment(s) require internal fixation. Displaced vertical split fractures may be fixed percutaneously during arthroscopy.

Tibial plateau fractures are commonly associated with meniscal or ACL injuries. In these cases arthroscopic assessment is required. Following recovery from a tibial plateau fracture, weight-bearing activity may need to be reduced as the irregular joint surface predisposes to the development of osteoarthritis.

Table 27.14 Rehabilitation program following patella dislocation (see Figs 27.5 and 27.6)

Phase	Goal of phase	Time post injury	Physiotherapy treatment	Exercise program	Functional/sport-related activity
Phase 1	Control swelling Maintain knee extension Isometric quadriceps strength	0–2 weeks	Extension splint (removal dependent on surgeon/ physician) Cryotherapy Electrotherapy PFJ taping Manual therapy	Quadriceps drills (supine) Bilateral calf raises Foot and ankle Hip abduction	Progress to FWB
Phase 2	No swelling Full extension Flexion to 100° 4+/5 quadriceps strength 5/5 hamstring strength	2–6 weeks	Cryotherapy Electrotherapy Compression Manual therapy Gait re-education Exercise modification	ROM drills Quadriceps/VMO setting Mini squats and lunges Bridges (double, then single leg) Hip abduction and extension with rubber tubing Single-leg calf raises Gait re-education drills Balance and proprioceptive drills (single leg)	Walking Exercise bike
Phase 3	Full ROM Full strength and power Return to jogging, running, and agility Return to restricted sport-specific drills	6–8 weeks	Manual therapy Exercise/activity modification and supervision	As above—increase difficulty, repetitions and weight where appropriate Single-leg squats Single-leg press Jump and land drills Agility drills	Straight line jogging Swimming (light kick) Road bike Straight line running Progressing to sport-specific running and agility (progressively sequenced) e.g. running forwards, sideways, backwards, sprinting, jumping, hopping, changing directions, kicking
Phase 4	Return to sport	8–12 weeks	As above	High-level sport-specific strengthening as required	Progressive return to sport, e.g. restricted training, unrestricted training, match play, competitive match play

FWB = full weight-bearing. PFJ = patellofemoral joint. ROM = range of motion. VMO = vastus medialis obliquus.

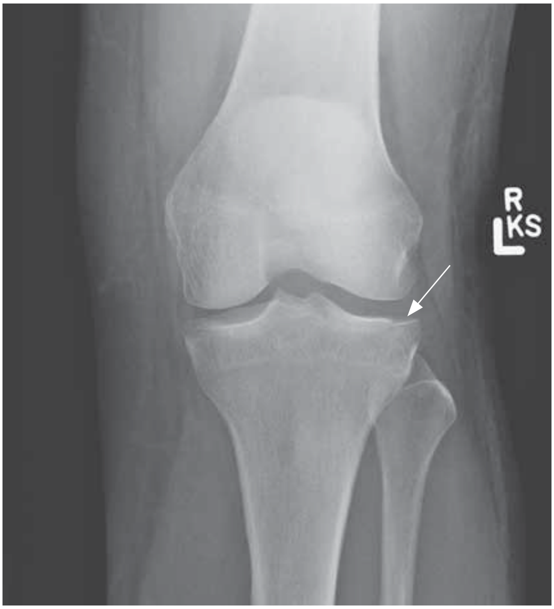


Figure 27.13 X-ray of a tibial plateau fracture

Superior tibiofibular joint injury

Acute dislocation of the superior tibiofibular joint occurs occasionally as a result of a direct blow. The patient complains of pain in the area of the joint and may be aware of obvious deformity. The lateral popliteal nerve may be damaged with this injury.

Sprain of the tibiofibular joint is more common. The patient complains of local pain aggravated by movement and, on examination, there is local tenderness and some anteroposterior instability. Treatment consists of rest and local electrotherapeutic modalities. Rarely, a chronic instability of the superior tibiofibular joint develops, which may need surgical stabilization.

Ruptured hamstring tendon

Spontaneous rupture of one of the distal hamstring tendons at the knee occurs occasionally during sprinting. Sudden onset of pain is localized to either the biceps femoris tendon or the semitendinosus tendon. Pain and weakness is present with resisted hamstring contraction. These injuries often require surgical exploration and repair, followed by protection in a limited motion brace.

Coronary ligament sprain

The coronary ligament is the name given to the deep portion of the fibrous joint capsule attached to the periphery of each meniscus and connected to the adjacent margin of the tibia.

A sprain of the coronary ligament may occur as a result of a twisting injury. These sprains may be difficult to differentiate from a meniscal injury. There is no joint effusion associated with this injury and usually minimal joint line swelling. There is, however, joint line tenderness and McMurray's test may be painful.

Arthroscopy may be required to differentiate coronary ligament sprains from meniscal tears. At arthroscopy, the only abnormality is occasional localized hemorrhage. Coronary ligament sprain is often associated with a grade I MCL sprain.

Recommended Reading

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Recommended Websites

The website of the University of Minnesota Orthopaedics' Sports Medicine Institute has useful videos of all aspects of the acute knee examination. See: <http://www.sportsdoc.umn.edu>.

The important information websites for ACL prevention are:

- www.med.uio.no
- www.cincinnatichildrens.org/svc/prog/sports-med/human
- www.aclprevent.com/aclprevention.htm
- www.vermontskisafety.com
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