Current Concepts Review: Comprehensive Physical Examination for Instability of the Knee
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Am. J. Sports Med. 2008; 36; 577 originally published online Jan 24, 2008;
DOI: 10.1177/0363546507312641

The online version of this article can be found at:
http://ajs.sagepub.com/cgi/content/abstract/36/3/577

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Effective physical examination is a cornerstone of successful diagnosis and subsequent treatment of complex knee injuries. As a matter of course, all clinical knee examinations should include assessment of range of motion, limb alignment, and neurovascular status, as well as comparison with the uninjured knee. Various physical examination tests have been developed that can assist in accurately diagnosing ligamentous and patellofemoral instabilities, although difficulty in performing or interpreting many of these tests merits their thorough description and discussion. Often, the information obtained from multiple tests may contribute to a final diagnosis.

This article reviews the various types of knee instability and the associated anatomic structures. Because injuries to more than one structure are common, it is important to conduct a thorough survey of the knee. We also describe physical examination tests that are based on both biomechanical analyses and clinical observations and useful accessory tests that may help confirm a diagnosis. One must also bear in mind the potential limitations of clinical testing, including the inability to produce sufficient magnitude of force to simulate physical activity; reflex resistance on the part of the patient because of anxiety, pain, or the recruitment of dynamic secondary knee stabilizers; and the presence or absence of static secondary stabilizers. Although we live in an age of advanced diagnostic imaging, a careful history and effective physical examination continue to serve as the foundation of orthopaedic sports medicine.

When approaching the patient with a knee injury, attention to the perceived direction of joint instability, mechanism of injury if known, and symptomatology may offer clues to the underlying structure or structures that have been damaged.

ANTERIOR INSTABILITY

The well-recognized primary function of the anterior cruciate ligament (ACL) is to prevent excessive anterior translation of the tibia relative to the femur. Anterior cruciate ligament rupture is epidemic, and as such, a brief consideration of ACL injury biomechanics is merited.

For contact injuries, the typical mechanism of injury is a blow to the lateral aspect of the knee when the foot is planted and is often associated with medial instability or anteromedial rotatory instability. Patients sometimes report feeling or hearing a “pop,” are generally unable to continue sporting activity, and often develop an acute hemarthrosis. With chronic ACL insufficiency, the knee is frequently perceived to be unstable, and patients may have activity-related pain or swelling, difficulty walking downhill or on ice, and trouble coming to a quick stop.

Abnormal anterior tibial translation is the basis for clinical diagnosis of an ACL-deficient knee using the Lachman and anterior drawer tests and KT-1000 or KT-2000 arthrometer (MEDmetric, San Diego, Calif). Butler et al. used cadaveric specimens to demonstrate that the ACL is
the primary restraint to anterior translation of the tibia, and the ligament's greatest contribution occurs at 30° of knee flexion. Specifically, the ACL was shown to provide an average restraint of 87.2% to an applied anterior load at 30° of flexion and 85.1% at 90°. In addition, Beynnon et al. established in vivo that the ACL experiences greater strain in response to an anterior load at 30° than at 90°. When the ACL is sectioned, the greatest anterior translation (mean value, 8.4 ± 1.9 mm) occurs at 30°. Secondary sectioning of the medial collateral ligament (MCL) increases anterior translation at 90°, but not at 30°, suggesting that the Lachman test at 30° (described below) carries diagnostic specificity for ACL deficiency.

In vitro and in vivo analyses thus indicate that the Lachman test is the clinical examination of choice for detection of ACL insufficiency and that the Lachman test places more strain on the ACL than the anterior drawer test (also described). Note that both tests, especially the anterior drawer, may be of less value in the acutely injured knee as a result of hemarthrosis and patient pain and guarding. After acute ACL rupture, DeHaven, found that the Lachman test result was positive (increased side-to-side laxity plus soft endpoint) in only 80% of patients examined without anesthesia but in almost 100% of patients examined under anesthesia. The anterior drawer test finding was positive in only 10% of patients without anesthesia and 50% of patients under anesthesia. Both tests have a higher diagnostic value (approaching 97%) in chronically injured patients.

The Lachman Test

Named for his mentor, John W. Lachman, MD, chairman and professor of orthopedic surgery at Temple University, this clinical test was originally described by Joseph S. Torg, professor of orthopedic surgery at Temple University, this clinical test was originally described by Joseph S. Torg, MD. When the test was first discussed, the recommendation was for the examiner to hold the knee “between full extension and 15° of flexion.” Now, however, it is common to place the knee in 30° of flexion. One must ensure that the tibia is not subluxated posteriorly to avoid a false-positive test result and misdiagnosis of ACL insufficiency in a posterior cruciate ligament (PCL)-deficient knee. The tibia must rest in neutral rotation because internal or external rotation will recruit secondary stabilizers, thereby confounding assessment of the ACL. The Lachman test offers high sensitivity and high specificity (approaching 95%). False-negative results have been attributed to concomitant bucket-handle meniscal tears that interfere with anterior tibial translation or scarring of a torn ACL to the PCL, although some data indicate that additional meniscal or ligamentous injuries generally do not alter test sensitivity.

Recommended Technique. With the patient supine and the knee positioned in 30° of flexion, the examiner stabilizes the anterolateral distal femur with one hand and uses the other hand to exert firm pressure on the posterior aspect of the proximal tibia in an attempt to induce anterior displacement. Proprioceptive and/or visible anterior translation of the tibia beyond the femur with a “mushy” or “soft” endpoint represents a positive test result. Qualitative and quantitative measures describe the results of the test, generally in comparison with the contralateral normal knee. Anterior translation of 1 mm to 5 mm is defined as grade I laxity, 6 mm to 10 mm as grade II, and >10 mm as grade III. The quality of the endpoint is also graded as firm, soft, or absent. Here, and below, this grading system and these qualities are relative to a normal, contralateral knee.

Difficulty performing the test in situations where clinician’s hands are small relative to the patient’s thigh girth can be a limitation of the Lachman test. In such cases, a variation on the Lachman test has been described in which the examiner cradles the patient’s leg in the axilla and places his hands behind the tibia. While pushing the tibia anterior, the examiner attempts to discern excessive anterior displacement of the tibia while observing any reduction in the contour of the patella and its tendon. The sensitivity of this alternative has not been well described. The Lachman test is illustrated in Figure 1 (all figures illustrate the right knee).

The Anterior Drawer Test

The origins of the anterior drawer test are obscure, although before the introduction of the Lachman test, the anterior drawer was the usual clinical examination for diagnosis of an ACL tear. Despite its historical importance, many authors have questioned its reliability and validity in the diagnosis of ACL injury. The posterior meniscal horns or the bony contour of the joint may interfere with the test. Additional limitations of the anterior drawer test are the impracticality of requiring 90° of flexion in an acutely injured or swollen knee, hamstring spasm that may restrict anterior translation at 90°, and secondary stabilization against anterior translation of the knee at 90° flexion by the MCL. Whereas test accuracy may improve in patients with chronic injury or loss of secondary restraints to anterior displacement, sensitivity in an alert patient is variably reported from 22% to 95%, although it is reported to improve to between 50% and 95% in the anesthetized patient.

Recommended Technique. The patient is placed in a supine position with the knee flexed to 90° and the tibia in neutral rotation. The femoral condyles should normally be palpable 1 cm posterior relative to the anteromedial tibial

Figure 1. Lachman test (for anterior instability). With the patient supine and the right knee flexed to 30°, an anterior force is applied to the proximal tibia (arrow). Tibial anterior translation and quality of the endpoint are evaluated.
plateau, and this relationship should be confirmed before performing the anterior drawer test to avoid misdiagnosis in a PCL-deficient knee. The patient must be encouraged to relax the hamstring muscles fully so as to minimize hamstring dynamic resistance to anterior tibial translation. When the patient is sufficiently relaxed, the examiner grasps the proximal tibia with both hands while placing both thumbs along the anterior joint line. A positive test result is indicated by increased anterior translation and a soft endpoint and graded similar to the Lachman test. The anterior drawer test is illustrated in Figure 2.

**KT-1000 and KT-2000 Arthrometry**

The KT-1000 and KT-2000 arthrometers (MEDmetric) are the devices most widely used to quantify anterior tibial translation. They provide an objective measure of anterior laxity and have been shown to be both accurate and reliable. As with the Lachman and particularly the anterior drawer test, patient relaxation, correct positioning, and application of an anteriorly directed force are required. At 30° of knee flexion and application of 20 lb (89 N) force, a maximum side-to-side difference of >3 mm, a maximum manual translation of >10 mm, or a compliance index (difference in translation between the 89- and 67-N tests) >2 mm were shown to correlate with ACL insufficiency. Others have reported that a side-to-side difference of <3 mm is a better indicator of an intact ACL than an absolute measurement.88

**Recommended Technique.** KT arthrometer testing is performed by first positioning the supine patient’s knees in 30° of flexion on the thigh support. With tall patients, it may be necessary to raise the thigh support to reach 30° of flexion. The patient’s thighs and heels are then placed against the lateral thigh and foot rests to ensure neutral rotation and standard stance distance. The device is placed against the knee to be tested (generally the normal knee is tested first), with the arrows of the arthrometer pointing directly at the joint line and the measurement pads secured against the tibial tubercle and patella using Velcro® straps. Malposition of the arthrometer by as little as 1 cm has been shown to influence results, with proximal malposition causing an increase in measured anterior translation and inferior malposition resulting in a decreased measurement. Before establishing the zero calibration point, the examiner places the thumb of the hand not used to apply the anterior force on the patellar pad and the remaining fingers of this hand to the patient’s lateral thigh. This stabilizes the measurement pad against the patella, engages the patella in the trochlear groove, and prevents rotation or changes in position of the patellar pad in relation to the joint line.

Once the arthrometer is secured, alternating anterior and posterior forces are applied a few times to the handle of the device to adjust the arthrometer to the zero point. After the reference point has been established, anterior translation measurements are recorded as 3 different forces are applied through the arthrometer handle. First, an anterior force of 15 lb (67 N) is applied, indicated by an initial audible tone. Second, a force of 20 lb (89 N) is applied, indicated by a different audible tone. Finally a manual maximum force is applied to the posterior aspect of the proximal tibia, as in the Lachman test. The KT-1000 arthrometer test is illustrated in Figure 3.

**The Pivot-Shift Test**

While the phenomenon was recognized by numerous authors, the term “pivot shift” was first coined and described by Galway and MacIntosh. This term is used to denote a specific sign that may be elicited during physical examination and to characterize a patient’s subjective description of their knee “going out” during an attempt to laterally pivot. The pivot shift does not actually represent a knee instability event itself but rather a reduction from a state of anterior tibial subluxation. Slocum et al. and Losee et al. have described
important variations of the pivot-shift test. In the original description of the pivot-shift maneuver, it was revealed that ACL sectioning alone caused the phenomenon in 89% of cadaveric knees tested. In contrast, sectioning of the iliotalibial band (ITB), biceps tendon, lateral collateral ligament (LCL), and popliteus was insufficient to produce a pivot shift.38 The pivot-shift test is particularly useful for confirming that anterior laxity is likely to be clinically significant65 and may thus represent a relative indication for ACL reconstructive surgery.

To perform the pivot-shift maneuver successfully, the examiner must appreciate subtle motions of the knee. As stated succinctly by Cummings and Pedowitz, “The goal is to observe a sudden shift of the tibia relative to the femur as the knee goes from an extended to a slightly flexed position.”18 Studies of the pivot-shift test have reported high sensitivities for detecting ACL injury ranging from 84% to 98.4%. The test’s specificity has been shown to vary more widely, with reported values from as low as 35% in the alert patient to as high as 98.4% in the anesthetized patient.23,62,77

The pivot-shift phenomenon may be explained as follows. In the ACL-deficient knee, anterior subluxation occurs in knee extension. When the PCL and posterior capsule are relaxed by initiation of knee flexion, a valgus stress will cause persistent anterior subluxation of the lateral tibial plateau due to tibial contact with the lesser curvature of the lateral femoral condyle. As the posterolateral tibial plateau shifts anteriorly, it impinges against the lateral femoral condyle at its greater curvature. This impingement prevents further anterolateral tibial subluxation and causes a hinging effect at the site of impingement. Continued flexion lever open the anterior aspect of the knee, generating a critical tension in the ITB acting at the anterior lateral tibial tubercle (Gerdy tubercle). At $30^\circ$ to $40^\circ$ of knee flexion, the ITB changes in relation to the axis of the knee, specifically changing from a knee extensor to a knee flexor. Tension in the ITB pulls the subluxated lateral tibial plateau posteriorly, the tibia no longer impinges on the femoral condyle, and the examiner perceives a sudden clunk as the joint reduces. This reduction phenomenon allows the examiner to appreciate a positive pivot-shift sign.76

Critical maneuvers in the pivot-shift test, in addition to internal tibial rotation and valgus stress mentioned above, may also include ranging the tibia through external rotation and positioning of the hip. Some authors have suggested that external rotation of the tibia can produce an equal or greater pivot-shift sign on physical examination.1,11,56,89 However, evaluation of the pivot shift using the externally rotated tibia must be distinguished from demonstrations of posterolateral laxity. Gollehon et al19 showed that the posterolateral structures of the knee resist external tibial rotation but can be differentiated from the pivot shift in external rotation by 2 methods. First, the pivot shift will remain positive when tested in internal rotation, whereas the laxity secondary to posterolateral damage will not. Second, careful palpation of the lateral tibial plateau in relation to the femoral condyle will allow the examiner to differentiate posterolateral versus anteromedial subluxation.59 (This is reiterated in the discussion of rotational instability below.)

A final and often overlooked factor is hip position. It has been shown that both hip position and tibial rotation independently and collectively affect the grade of the pivot shift. According to Bach et al,1 a combination of hip abduction and external tibial rotation produces statistically higher pivot-shift grades, whereas hip adduction combined with either internal or external tibial rotation lowers the grade. It has been shown that internal rotation of the tibia and adduction of the hip both tighten the ITB, causing earlier tibial reduction and a consequent decreased grade.20 The potential effect of hip and tibial positioning on locking and unlocking of the knee has been proposed as another explanation for these observations.72 In summary, whether by this mechanism or by the effect on the ITB or some combination thereof, abduction and slight flexion of the hip may be used to enhance the positive results of a pivot-shift test.1,56,89 It has been suggested that when performing the pivot-shift test, one should not rely on a “1 test, 1 position” evaluation of the pivot-shift phenomenon.72

The examiner should be aware of the possibility of false findings from a pivot-shift test.

- Ligamentous laxity in the face of an intact ACL may allow a subluxation to occur that mimics a positive pivot-shift test result. Therefore, both knees must always be tested.
- Rupture of the ITB prohibits the telltale reduction phenomenon. Losee14 reported that an insufficient ITB will permit continued subluxation through increased knee flexion (beyond $40^\circ$).
- Medial instability can prevent the necessary valgus forces from being applied to elicit a positive pivot shift.
- A locked bucket-handle tear of the meniscus may block a pivot-shift phenomenon from occurring.
- The posterior horn of the lateral meniscus may act as a buttress against anterior subluxation of the anterolateral tibial plateau. Thus, in the absence of an intact posterior horn lateral meniscus, there may be a blunting of the clinical test because the tibia can slip beneath the femur in a more subtle fashion, without the expected “sudden jump.”

**Recommended Technique.** In this test, the patient assumes a supine position and attempts to relax the leg muscles as much as possible. The examiner holds the affected leg in full extension and internal rotation while lifting the limb off of the table. The knee is flexed during application of concomitant valgus stress. In an ACL-deficient knee, the lateral tibial plateau will be anteriorly subluxated at the beginning of the test (knee flexion less than $30^\circ$ plus valgus stress). As flexion increases to $30^\circ$ to $40^\circ$, this anterolateral tibial subluxation will abruptly reduce (positive test result). This is palpable and sometimes audible.

The grading system for the pivot-shift test is based on the relocation event, specifically the difficulty and abruptness with which the tibia reduces. Grade 0 is considered normal, with no reduction or shift noted. Grade I represents a smooth glide with a slight shift; grade II is when the tibia is felt to “jump” back into a reduced position and

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Multiple cutting studies have shown that isolated sectioning of the PCL results in increased posterior translation of 15 mm to 20 mm, occurring maximally at 90° of knee flexion. The tensile strength of the PCL is almost twice that of the ACL, and the load-bearing capacity, stiffness, and size of the anterolateral (AL) bundle of the PCL are greater than that of both the posteromedial (PM) PCL bundle and the meniscofemoral ligaments, suggesting that the AL bundle is primarily responsible for the biomechanical properties of the PCL. Without additional damage to the PLC, isolated sectioning of the PCL has no effect on internal or external rotation, nor is there any increase in varus or valgus opening. Consequently, the most appropriate test for evaluating isolated PCL injury is a test that assesses posterior tibial translation alone.

**Posterior Drawer Test**

As with the anterior drawer test, the origins of this test are obscure. The posterior drawer test has been reported to be the most sensitive test in the evaluation of isolated PCL injury with a double-blind, randomized controlled study documenting 90% sensitivity. This test has also been shown to have 99% specificity for PCL injuries. In addition, the accuracy of this test is enhanced when its findings are combined with information from other tests of posterior instability.

The examiner must also be aware of the potential for false-negative results.

- If tested in internal rotation, intact meniscotibial ligaments, especially that of Wrisberg, may allow for an improvement of 1 grade. Clancy et al reported that the meniscofemoral ligaments (MFLs) are rarely injured with an isolated PCL tear and that they can actually eliminate the posterior drawer as they tighten in internal rotation.

**Recommended Technique.** Before dynamic evaluation of the affected knee, it is important to establish the normal relationship between the medial tibial plateau and the medial femoral condyle with the knee flexed to 90°. Pathologic posterior translation will be graded with this relationship in mind. As mentioned, the tibial plateau should normally be 1 cm anterior to the medial femoral condyle. Comparison with the contralateral, uninjured knee provides an additional measure of “normal.” The patient is placed supine with the affected knee flexed to 90° and the tibia in neutral rotation. The examiner then places both hands along the anterior aspect of the proximal tibia with the thumbs lying on the anterior joint line of both the medial and lateral compartments. A posteriorly directed force is applied equally with both hands and...
graded based on the amount of pathologic posterior tibial translation that occurs. Hughston et al suggested that a negative posterior drawer test finding with the tibia in neutral or internal rotation can help to rule out PCL injury and that performing the posterior drawer test with and without internal tibial rotation can be useful in distinguishing a positive result for posterolateral rotatory subluxation from a positive result for a PCL tear, as rotatory instability may sometimes be appreciated in the internally rotated knee.

As with many other tests, grade I PCL laxity is consistent with translation of 0 to 5 mm (and the tibial plateau remains anterior to the femoral condyle). Grade II is classified by posterior translation of 6 mm to 10 mm (which correlates with the tibial plateau being flush with the femoral condyle). Grade III injuries measure >10 mm of posterior translation (and allow the tibial plateau to translate posterior to the femoral condyle). The quality of the endpoint is also graded as “firm, soft, or absent.” Shelbourne et al pointed out that the endpoint may return to firm within the first 2 weeks after a PCL tear as a result of intact supporting structures. In these circumstances, or when evaluating chronic injuries, translation can be considered more reliable than the endpoint in the assessment of PCL status. The posterior drawer test is illustrated in Figure 5.

The Posterior Lachman Test

Although the PCL has been shown to provide all of the resistance to posterior tibial translation when the knee is flexed to 90°, the posterior drawer test can be difficult to perform in the acutely injured knee because of patient discomfort during knee flexion. In such situations, the posterior Lachman test may be useful in diagnosing suspected PCL injury because the knee is only required to flex to 30°. At this angle, the PCL is still responsible for providing 85% of the resistance to posterior translation.

**Recommended Technique.** With the patient’s knee flexed to 30°, the examiner should place his or her hands as in the posterior drawer test so that any variation in the normal relationship of the tibia and the femur can be appreciated; in the PCL-deficient knee, the tibia must be anatomically reduced at the start of this test. A posteriorly directed force is then exerted on the tibia. It is again important to maintain neutral rotation to avoid recruitment of secondary stabilizers. Grading is consistent with the systems used above. One caveat for the examiner is that a slight increase in posterior translation with the knee at 30° but not at 90° may indicate a PLC injury, whereas increased translation at both positions, with maximal translation at 90°, is consistent with PCL injury.

The Posterior Sag Test

As opposed to the posterior drawer, which is a dynamic clinical test, the posterior sag test is a static test. It has been shown to have 100% specificity for detecting PCL injuries. Its sensitivity has been reported at 79% by Rubenstein et al.

**Figure 5.** Posterior drawer test (for posterior instability). With the patient supine and the right knee flexed to 90°, a normal anatomical relationship between the tibia and femur is established. Next, a posterior force is applied to the proximal tibia (arrow). Tibial posterior translation and quality of the endpoint are evaluated.

**Figure 6.** Posterior sag test (for posterior instability). Patient lays supine with the knees flexed to 90° and the feet flat on examination table. The patient relaxes, and in comparison with the normal anatomical relationship between the tibia and femur (A), the PCL-deficient knee demonstrates a posterior sag of the tibial tubercle relative to the femur (B).

**Recommended Technique.** The patient is placed supine with knees flexed to 90°. The patient’s feet are allowed to rest flat on the examination table, and the patient is encouraged to relax completely, especially relaxing their quadriceps. The affected knee is then viewed from the side. A positive result is when the anterior aspect of the proximal tibia is found to “sag” posterior to the anterior aspect of the femoral condyles or in comparison with the normal, contralateral knee. The posterior sag test is illustrated in Figure 6.

The Quadriceps Active Test

As opposed to passive tests, which rely on externally imposed forces, this test uses the patient’s own quadriceps contraction as the displacement force. The test was originally described by Daniel et al who reported identifying confirmed PCL disruption in 41 of 42 knees, while pathologic anterior tibial translation did not occur in any patient’s contralateral, normal knee, nor in 25 other normal knees, nor in knees with...
documented ACL disruption. It should be noted that previous injury or surgery altering the native orientation of the patellar ligament may render the quadriceps active test useless.\textsuperscript{20} Although it is reported to be highly sensitive and specific in the original description of the test, the quadriceps active test was found by other researchers to be less sensitive (54\%) compared with other tests for PCL deficiency.\textsuperscript{28}

A second use of this maneuver is to determine the quadriceps neutral angle of the patient’s normal, contralateral knee—that is, the angle at which a quadriceps contraction produces no apparent tibial shift (usually around 60° to 70° of flexion). At the quadriceps neutral angle, the vector of force generated by the quadriceps is parallel to the tibial shaft, and contraction of the quadriceps at this angle will merely increase joint contact pressure if the foot is prevented from moving. By locating the quadriceps neutral angle in the patient’s normal knee, deviations from normal may be better understood in the injured knee for detection of both anterior and posterior laxity.

Recommended Technique. The patient is placed in the supine position with the knee flexed to 90°. The flexion angle of the knee at which the test is performed is critical and must exceed the quadriceps neutral angle described above. At 90° flexion, the quadriceps force vector angle includes a component of anterior drawer in relation to the shaft of the tibia. Thus, if a patient is asked to attempt to slide their fixed foot anteriorly (inducing a gentle quadriceps contraction), a saggard or posteriorly subluxated tibia will move in an anterior direction. This dynamic reduction of the tibia in relation to the femur represents a positive result for PCL deficiency if the tibia shifts anteriorly by at least 2 mm.\textsuperscript{20} The quadriceps active test is illustrated in Figure 7.

**ROTATORY INSTABILITIES**

Rotatory instabilities primarily affect knee function in flexion. Gait analysis indicates that during normal walking, the knee flexes between 0° and 20°, whereas during running, knee flexion increases in direct proportion to rate. In full extension and maximum weightbearing, no rotation is present (neutral rotation). External rotation of the tibia relative to the femur commences with knee flexion, with maximum rotation occurring between 60° and 90° of flexion.\textsuperscript{14} Isolated rotatory instabilities may manifest during cutting, pivoting, or rapid deceleration activity in a manner similar to combined ligamentous instability, and multiple directions of rotatory instability may also present.\textsuperscript{71}

**Anteromedial Rotatory Instability (AMRI)**

Slocum et al\textsuperscript{104} described excessive valgus motion coupled with external rotation of the knee as AMRI. This occurs when the anteromedial tibial plateau subluxates anterior to the corresponding femoral condyle. The postero medial corner (PMC) has been shown to serve as a restraint to AMRI throughout the normal range of motion. The PMC is functionally composed of 5 anatomic structures: the posterior horn of the medial meniscus, the posterior oblique ligament (POL), the semimembranosus expansions, the meniscotibial (coronary) ligaments, and the oblique popliteal ligament.\textsuperscript{102}

Anteromedial rotatory instability typically results from an abrupt external rotation-abduction force, such as occurs during a “clipping” injury in American football. Anteromedial rotatory instability may represent the most common form of knee instability in addition to the most frequent cause of ACL disruption; however, disability associated with AMRI may, at first, be minimal. Over time, this type of instability often progresses to associated anterolateral rotatory instability (ALRI), and when AMRI is combined with ALRI, the functional disability may be significantly more incapacitating.\textsuperscript{28}

**The Slocum Test**

The Slocum test\textsuperscript{104} is based on the premise that the PMC is a secondary stabilizer against anterior translation in the flexed ACL-deficient knee when the tibia is externally rotated. Thus a positive test result is represented by failure of tibial external rotation to diminish the anterior drawer in an ACL-deficient knee. A differential diagnosis for AMRI is posterolateral rotatory instability (PLRI) and vice versa. Posterolateral rotatory instability is diagnosed using the dial test (described in detail below). When a diagnosis of AMRI or PLRI is suggested based on the Slocum or dial test results, respectively, the examiner must carefully determine whether the anteromedial tibia is rotating anteriorly relative to the medial femoral condyle (AMRI) versus whether the posterolateral tibia lateral is rotating posteriorly relative to the lateral femoral condyle (PLRI). This is reviewed in the discussion of PLRI.

Recommended Technique. To evaluate the knee for AMRI, the anterior drawer test is performed as described above. Increased anterior translation of the tibia relative to the femur will be noted in an ACL-deficient knee. Next, the test is repeated with the foot fixed in approximately 15° of external rotation, tightening the PMC, and secondarily reducing

![Figure 7. Quadriceps active test (for posterior instability).](image-url)
the positive anterior drawer. Absence of this reduction of anterior translation during external rotation as a result of PMC deficiency is a positive test finding for AMRI. As some degree of physiologic anteromedial rotation is to be expected and the normal tissue laxity may vary, comparison with the uninjured contralateral knee is required.\(^{51}\)

**Anterolateral Rotatory Instability (ALRI)**

An important secondary function of the ACL is the prevention of rotational instability of the knee joint by prevention of excessive internal rotation of the tibia relative to the femur. Several clinical tests, including the pivot-shift test, the anterior drawer test with the tibia in neutral rotation, and various accessory tests, may be used to assess the presence and degree of ALRI. If all test results are negative, yet ALRI is still suspected, examination under anesthesia (EUA) may be of value. Anterior cruciate ligament injuries associated with ALRI are not uncommon. Norwood and Cross\(^{60}\) reported that EUA reveals unsuspected ALRI in 18% of patients treated operatively for ACL deficiency.

Anterolateral rotatory instability typically results when there is acute internal rotation and varus stress on the weight-bearing knee, such as when a basketball player loses his balance while landing from a jump.\(^{51}\) According to Hughston et al,\(^{51}\) injury to the middle one third of the lateral capsular ligament is implicated in this type of instability and may underlie ALRI in cases when the ACL is intact. Symptoms include a perception of instability as the knee approaches extension, and in cases of coexisting meniscal injuries, ALRI must be ruled out before a patient's symptoms should be ascribed to the meniscal tear alone.

Hsieh and Walker\(^{47}\) showed that at 30° of flexion, the axis of internal rotation in the transverse plane is located on the medial side of the knee. Therefore, the secondary structures anatomically most effective at reducing ALRI (internal rotational laxity in the presence of lateral capsular ligament) are the ACL and the MCL. The PCL is substantially less able to resist anterolateral rotation than the ACL because its insertion is in close proximity to the transverse axis of rotation and because it is more vertically oriented than the ACL.\(^{47}\) Fleming et al\(^{32}\) found that the application of an internal rotation force to the tibia produces an increase in ACL strain, and the additional application of valgus stress plus internal rotation increases ACL strain values significantly compared with internal rotation in isolation. The highest ACL strain values are found at knee flexion angles of 0° to 30°,\(^{32}\) whereas at flexion angles of greater than 30°, ACL strain decreases with the recruitment of secondary stabilizers.\(^{60,112}\) These findings are consistent with the observation that clinically significant anterolateral tibial subluxation in the context of ACL incompetence occurs at flexion angles from 0° to 30°.

As above, detection of anterior tibial translation in combination with tibial internal rotation by use of the pivot-shift test, the anterior drawer test in neutral rotation, and accessory tests serves as a basis for identifying ALRI. The pivot-shift and anterior drawer tests have been described above. According to Hughston et al,\(^{51}\) when the lateral tibial condyle becomes more prominent or both condyles become equally prominent during the anterior drawer test with the tibia in neutral rotation, this is suggestive of ALRI and should be followed by a confirmatory jerk test as described below.

**Accessory Tests for ALRI**

In addition to the pivot-shift and anterior drawer tests, the following clinical tests may confirm ALRI.

**The Jerk Test of Hughston**

This maneuver is a variation on the pivot-shift test and may be considered its opposite. It has been described as the most specific test for ALRI by its eponymous author.\(^{51}\)

**Recommended Technique.** The patient is placed supine with the affected knee in 90° of flexion and the tibia in moderate internal rotation. Valgus stress is applied to the knee, and the joint is slowly extended. In a positive test result, the tibia will be maximally displaced anteriorly and internally at approximately 30°, and the examiner will feel a sudden “jerk.” Continued extension of the limb will somewhat reduce the anterolateral tibial subluxation, although anterior subluxation will persist in the ACL-deficient knee.

A torn meniscus may generate a false-positive finding if the meniscus distracts the femorotibial joint through its interposition between the joint surfaces.\(^{51}\) Alternatively, the jerk that occurs during subluxation of the lateral tibial plateau and is sometimes associated with medial joint pain may be misinterpreted as a medial meniscal tear with an ensuing inappropriate intervention. Some critics believe that the jerk test may produce a substantial number of false-positive results\(^{76}\) because when a patient’s foot is internally rotated at the start of the test, there may be physiological anterolateral tibial subluxation. Next, when subsequent application of valgus stress compresses the lateral compartment, this compression may cause a sense of reduction obvious to the examiner and the patient even when ALRI does not exist. The jerk test is illustrated in Figure 8.

**The Losee Test**

This test was originally described in 1978 by Losee et al (who believed that this eponymous maneuver was more reliable than the jerk test).\(^{51}\) Dr Ronald Losee shared Hughston’s concern that beginning tests for ALRI with the knee in extension creates impingement between the lateral femoral condyle and the posterolateral tibia plateau, inducing pain, guarding, hamstring spasm, and damage to the lateral femoral condyle.

**Recommended Technique.** The Losee test begins with the knee held at 45° of flexion and the tibia in external rotation. This ensures that the knee begins in a reduced position. External rotation also accentuates the clunk, which represents a positive test result. The knee is slowly extended while valgus force is applied. The valgus stress is a key component of this maneuver because it applies a compressive load to the lateral compartment, which also accentuates a clunking subluxation episode. The leg and foot are allowed to drift into internal rotation. In a positive test finding,
when the knee reaches approximately 20° of flexion, the lateral tibial plateau shifts anteriorly, which will be perceived by the examiner and should also be recognized by the patient as a typical episode of joint instability.71,75 The Losee test is illustrated in Figure 9.

The Side-Lying Test of Slocum

Slocum was the first to suggest the term ALRI and developed a version of the pivot-shift test as a means of ascertaining this disorder.103 The side-lying test of Slocum may be especially useful in the acute setting and whenever a patient has hamstring spasm or guarding or when a patient’s leg is too heavy to easily manipulate.

Recommended Technique. The patient is placed in the lateral decubitus position with the affected side up, the pelvis in 30° of ipsilateral external rotation, and the knee in question fully extended. The medial aspect of the affected foot is placed on the examination table, permitting the affected knee to sag into varus. With the knee in this position, the tibia rotates internally, tension is applied to the MCL and medial capsule, and the lateral tibial plateau and lateral femoral condyle are compressed. This position minimizes the restricting effects of muscle tension, yet some authors recommend slight knee flexion (approximately 10°) so as to remove other stabilizing influences, such as that provided by tension of the PCL and posterior capsule as well as the bony architecture of the knee. Anterior subluxation of the lateral tibia may be appreciated at the joint line. The examiner then places both hands on the leg with the thumbs posterior and the fingers anterior and applies an anterior drawer while flexing the knee. A positive test result consists of audible and/or palpable reduction occurring as the knee is flexed and as the ITB changes from a knee extensor to a knee flexor between 25° and 45°. The side-lying test of Slocum is illustrated in Figure 10.

The Flexion Rotation Drawer Test

This test was originally described by Noyes et al,91 who suggested that it had the potential to detect ALRI in cases where a pivot-shift phenomenon has yet to develop. This test may also be easier to perform than other tibial translation tests. The flexion rotation drawer test builds on the Lachman test in that femoral rotation as well as tibial translation are observed.

Recommended Technique. The patient relaxes in the supine position, with the examiner holding the affected tibia in neutral rotation at 15° of knee flexion using one hand. In the ACL-deficient knee, the femur drops posteriorly and rotates externally. As the examiner flexes the knee using his other hand, reduction of the tibia with an internal rotation of the femur is appreciated as the knee approaches 40° flexion. Ranging the knee through gentle flexion and extension enables the examiner to note subluxation and rotation. The flexion rotation drawer test is illustrated in Figure 11.

Posteromedial Rotatory Instability (PMRI)

This is a least common form of rotatory instability, produced by concomitant valgus force and hyperextension of the knee, which lead to injury of the medial capsular ligament, tibial collateral ligament, POL, and ACL. When these structures are damaged, the proximal medial tibia sags posteriorly. This sag will only occur in the context of
Posterolateral Rotatory Instability (PLRI)

The PLC provides restraint to various types of pathologic knee motion: posterior tibial translation near full extension, external rotation of the tibia on the femur (where the PCL provides secondary restraint), and varus rotation all are affected by the structures of the PLC. The PLC is composed of both static and dynamic components. The static structures are the LCL, the arcuate ligament complex (deficiencies of which are particularly implicated in PLRI), \(^{1,17}\) the fabellofibular ligament, and the posterolateral capsule. The dynamic structures consist of the ITB, the biceps tendon, and the popliteus muscle-tendon complex, which includes the popliteofibular ligament and its fascicles. \(^{44}\)

Performing a reliable clinical examination of the PLC is an important but often underdeveloped skill. Failure to diagnose and treat PLC injury may be a major cause of failure of ACL reconstructive surgery. \(^{84}\) Without a thorough and competent examination, PLRI may be entirely overlooked as a cause of posterolateral joint pain, or symptoms may be mistakenly attributed to lateral meniscus tear. Chronic PLRI is also frequently misdiagnosed as a primary tibia vara deformity, with subsequent incorrect treatment by proximal tibial osteotomy. Posterolateral rotatory instability generally occurs as a consequence of a force directed posteriorly against the knee with resulting hyperextension, such as may occur during a block in American football. \(^{51}\) Symptoms include posterolateral pain, discomfort with standing, a perception of the knee giving out.

Multiple studies have been performed to establish the relative importance of the posterolateral structures. \(^{39,41,81}\) Gollehon et al \(^{59}\) performed selective cutting studies in fresh cadaveric specimens to establish the roles of the PCL, LCL, and the deep ligament complex, consisting of the popliteus tendon, arcuate ligament, fabellofibular ligament, and posterolateral capsule. These structures were sectioned in different sequences to establish their importance and contribution to static knee stability.

Anteroposterior translation, internal and external rotation, as well as varus and valgus motions were evaluated after sectioning of the various structures. Isolated sectioning of the PLC resulted in an increase in posterior translation (especially as the knee approached full extension), an increase in external tibial rotation, and an increase in varus instability (with the greatest increase in varus noted at 30°). Combined section of the PLC and the PCL resulted in further increases in external rotation and varus instability at 90°. By understanding these aspects of knee anatomy and biomechanics, such alterations can be tested clinically using corresponding physical examination tests.

Posterior translation may be assessed using tests described above. Tests for PLRI are mentioned in this paragraph and described below. Care must be taken to differentiate between PLC, PCL, and combined injuries because both the PLC and PCL may contribute to posterior tibial restraint depending on the degree of knee flexion. Negative posterior drawer testing results with the tibia in neutral and internal rotation can assist in ruling out PCL injury. \(^{51}\) Abnormal external tibial rotation can be evaluated with the dial test and the reverse pivot-shift test. Jakob et al \(^{55}\) have also used the reverse pivot-shift test to distinguish PLRI from ALRI. External rotation coupled with posterior translation is assessed with a posteriorly directed force using the posterolateral drawer test. Hughston and Norwood \(^{52}\) described confirmation of PLRI with the posterolateral drawer test and the external rotation recurvatum test. The posterolateral external rotation test may also detect posterolateral subluxation of the lateral tibial plateau: positive findings may also be consistent with an isolated PLC injury or combined injury to the PLC and the PCL, depending on the knee angle(s) at which subluxation occurs. These tests are clarified below. Finally, pathologic varus motion may be detected using the varus stress test at 0° and 30°, which is described below.

Dial Test at 30° and 90°

(Prone External Rotation Test)

Originally described by Cooper et al \(^{15}\) in 1991, this test assesses abnormal external tibial rotation and also helps differentiate between isolated PLC injury and combination PLC/PCL injury.

**Recommended Technique.** Although this test can be performed with the patient prone, supine, or sitting, the authors \(^{15}\) recommend the prone position. The patient’s knees are initially flexed to 30°. The examiner places both hands on the feet of the patient, cupping the heels and placing the fingers and thumb along either side of the talar-calcaneal bony contours. A maximal external rotation force is applied by the examiner, and the foot-thigh angle is measured and compared with the contralateral side. The knees are then flexed to 90°, and again an external rotation force is applied and the foot-thigh angle is measured. During application of the external rotation force, it may be useful to palpate the tibial condyles to determine their position in relation to the femoral condyles before measuring the foot-thigh angle. When comparing the...
degree of limb external rotation, a difference of 10° or more is significant.

Posterolateral subluxation of the lateral tibial plateau indicates PLRI; anteromedial subluxation of the medial tibial plateau is consistent with AMRI as noted in the section describing AMRI above. Once PLRI is confirmed and foot-thigh measurements have been taken, results of the test are interpreted. An isolated PLC injury is diagnosed if there is greater than 10° of external rotation versus the contralateral side at 30° of flexion but not at 90°. An important point is that, in this scenario, the external rotation of the involved knee actually diminishes when it is flexed to 90° because of restraint in the context of an intact PCL. In contrast, greater than 10° of increased external rotation in the affected knee at both 30° and 90° suggests a combination PLC and PCL injury. 14,15,39,41,73,108-110 The dial test is illustrated in Figure 12.

Reverse Pivot-Shift Test

The patient’s perception of the knee suddenly “giving out” may occur in the case of PLRI and in ALRI as the tibia shifts posteriorly on the femur. This is the “reverse pivot shift.”55

Recommended Technique. The patient is placed in the supine position with the knee flexed to 90° and the tibia in maximal external rotation. The examiner places a hand on the proximal lateral tibia, applying valgus force while maintaining external tibial rotation. An axial load is also applied. The examiner’s other hand is placed just distal to the first on the anteromedial tibia at midshaft so as to gain full control of the distal leg. The examiner then begins to extend the knee while maintaining external rotation, axial load, and valgus force on the tibia.

In a patient with PLRI, the lateral tibial plateau will be posteriorly subluxated at the onset of the test. As the knee is passively extended by the examiner, the lateral tibial plateau will reduce with a palpable shift or jerk when the knee is extended to about 30°. This occurs as the pull of the ITB changes from a flexion vector to an extension vector, thereby reducing the rotatory subluxation through its pull on the Gerdy tubercle. 55

The examiner should be alert to the potential for false-positive results. Generalized ligamentous laxity and mild varus alignment have been shown to yield positive test results in normal subjects. Furthermore, the test findings may be positive in up to 30% of normal knees, especially under anesthesia. A positive test finding is only considered to be clinically significant when there is a history of trauma, when the reduction phenomenon reproduces the patient’s symptoms, and when the finding is present only in the affected knee.15 The reverse pivot-shift test is illustrated in Figure 13.

Posterolateral Drawer Test

This test was originally described by Hughston and Norwood in 1980.52

Recommended Technique. The posterolateral drawer test essentially comprises the first stage of the reverse pivot-shift test. The patient is positioned supine with the hip flexed to 45° and the knee flexed to 90°, with the tibia placed in 15° of external rotation. The foot position is then fixed, and a posterior drawer test (described above) is performed with the examiner’s hands placed along the anteromedial and anterolateral joint line.

In its original description, a positive test result consisted of palpation of the lateral tibial plateau externally rotating in relation to the lateral femoral condyle; this finding was believed to be consistent with PLC injury. However, a grossly positive finding of increased external rotation that ensues with posterior tibial force application is more likely indicative of a combined PLC and PCL injury, as has been substantiated by biomechanical evaluation.39,50

False-negative findings may occur. In a combined PLC and PCL injury, the posterolateral drawer sign will be subtler and difficult to appreciate.72 In contrast, when the PLC is deficient and the PCL is intact, the medial compartment becomes the new center of joint rotation causing external

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**Figure 12.** Dial test (for posterolateral rotatory instability). With the patient prone or supine (illustrated), an external rotation force is applied with knees flexed to 30° and then flexed to 90° (illustrated). Side-to-side foot-thigh angle difference of greater than 10° of external rotation is considered positive (right knee illustrated as positive).

**Figure 13.** Reverse pivot shift (for posterolateral rotatory instability and in anterolateral rotatory instability). With the patient supine and the right knee flexed to 90° and the tibia externally rotated, the PLC-deficient knee exhibits posterolateral tibial subluxation (A). As the patient’s knee is extended while valgus force and axial load are applied, posterolateral tibial subluxation will palpably shift at approximately 30° as the tibia reduces with knee extension (B).
rotation during the test. The posterolateral drawer is illustrated in Figure 14.

External Rotation Recurvatum Test

Originally described by Hughston et al as the ultimate diagnostic test for PLRI, the external rotation recurvatum test has also been noted to be difficult to interpret. Thus, other tests, such as the posterior and posterolateral drawer tests, should be performed to obtain additional diagnostic evidence.

Recommended Technique. Traditionally, the patient is placed supine on the examination table with his or her legs together. With the patient’s knees in extension, the great toes of both feet are then grasped to lift the legs off the table. A positive result is when the knee falls into varus, hyperextension, and external rotation when compared with the uninvolved side. This finding was originally thought to indicate injury to the PLC; however, excessive varus and hyperextension during the test may indicate combined PLC plus ACL or PCL injury.

A variation on the external rotation recurvatum test requires the examiner to hold the heel of the affected limb while extending the knee from 30° of flexion to full extension. The examiner’s other hand grasps the posterolateral aspect of the knee to assess relative hyperextension and external rotation compared with the uninvolved side. This finding was originally thought to indicate injury to the PLC; however, excessive varus and hyperextension during the test may indicate combined PLC plus ACL or PCL injury. A variation on the external rotation recurvatum test requires the examiner to hold the heel of the affected limb while extending the knee from 30° of flexion to full extension. The examiner’s other hand grasps the posterolateral aspect of the knee to assess relative hyperextension and external rotation compared with the uninvolved side. According to Veltri and Warren, this test result may be mildly positive in the varus knee with isolated PLC injury; again, when there is substantial varus and hyperextension, ACL or PCL injury is also likely. The external rotation recurvatum test is illustrated in Figure 15.

Posterolateral External Rotation Test

This is a combination of the posterolateral drawer and dial tests, performed at both 30° and 90°.

Recommended Technique. With the patient supine, coupled posterior and external rotation forces are applied to the tibia of the involved leg in flexion of 30° and then 90°. The amount of posterolateral subluxation by the lateral tibial plateau is noted. Subluxation that occurs only at 30° is consistent with an isolated PLC, whereas subluxation at both 30° and 90° is indicative of combined injury to the PLC and the PCL. The posterolateral external rotation test is illustrated in Figure 16.

VARUS INSTABILITY

The LCL is the major restraint to varus instability at all flexion angles and is secondarily supported by the PLC. Injury to the LCL results from excessive varus stress and rarely occurs in isolation. Rather, injury to other ligaments usually accompanies an LCL tear. Symptoms vary, depending on the involvement of the PLC and the severity of the injury. Pain on weightbearing or lateral movement and/or the perception of knee instability during the stance phase of gait may be manifestations of varus instability.

Only small increases in varus rotation are seen with isolated LCL sectioning, with the greatest increase occurring at 30°. This amount, however, may be too subtle to be appreciated on clinical examination. When the LCL and the lateral deep ligament complex are sectioned together, there is a significant increase in varus rotation at all flexion angles, again with the maximum occurring at 30°. A large degree of varus instability at full extension may indicate a combination injury of LCL injury plus the PLC, ACL, or PCL insufficiency. Isolated cruciate injuries have been shown not to affect varus or valgus stability.
Varus Stress Test at 0° and 30°

The origins of using the varus stress test to detect LCL laxity are unclear. “Abduction and adduction rocking” of the knee as a means of examining collateral ligament integrity appears to be the antecedent of the current test. The varus stress test has undergone little assessment of sensitivity and specificity, although a small study suggested that in an emergency room setting, there may be fairly poor correlation between clinical examination and arthroscopic findings.

**Recommended Technique.** The patient is placed in the supine position with the tibia held in gentle internal rotation. The examiner places one hand on the medial aspect of the thigh and the other on the proximal tibia. The involved knee is flexed to 30°, and a varus force is applied across the joint line. The test is then repeated at full extension. The test finding is positive when the lateral joint line can be opened to a greater degree than the uninvolved side. The conventional grading system is based on the amount of lateral joint line opening compared with the contralateral joint. Grade I correlates with a lateral opening of 0 to 5 mm greater than the contralateral side, grade II is represented by an increased opening of 6 mm to 10 mm, and grade III is an opening of >10 mm versus the uninvolved side.

Other grading systems have since evolved, including those of Tria, Hughston, and O'Donohue. Tria believes that during testing, the examiner should record both the amount of opening in millimeters and the quality of the endpoint. In the Tria grading system, grade I corresponds to a stress test that allows minimal increased opening with varus stress, but the patient may experience pain with the test, usually at the site of the tear in the collateral ligament. Some opening of the joint line, with a distinct endpoint, yields a grade II score, whereas a grade III tear has no distinct endpoint to applied stress, and the knee opens to an almost unlimited degree. Hughston’s grading system scores a normal knee as grade 0, an increase in joint opening of 1 mm to 4 mm as grade I, an increase of 5 mm to 9 mm as grade II, and an increase in 10 mm to 15 mm as grade III. Point tenderness has been shown to identify the location of the tear in 78% of cases and localized edema in 67%. The O’Donohue grading system contextualizes positive test results using the degree of sprain assumed to be present. A mild sprain consists of few torn fibers with no loss of ligament integrity. A moderate sprain corresponds to incomplete tears with no pathologic laxity, and severe sprains have loss of integrity with a mushy or indefinite endpoint.

Certain anatomic correlates have been established with regard to positive test findings. When there is pathologic lateral joint line opening at both 0° and 30°, with the maximum at 30°, this indicates an injury to the LCL and the PCL, particularly the arcuate ligament. A combination injury to the LCL and PLC, the PCL, and perhaps also the ACL is suspected when there is significant lateral opening at 0°. The varus stress test is illustrated in Figure 17.

**VALGUS INSTABILITY**

Biomechanical research indicates that in addition to the role of the MCL as a rotational restraint, the anterior fibers of the superficial MCL act as the primary restraint.
to valgus load. In at least 1 study, no significant increase in valgus rotation occurred unless the anterior fibers of the superficial MCL fibers were sectioned. Sectioning of the deep MCL and POL resulted in minimal valgus rotation until the superficial fibers of the MCL were completely cut, at which point 7 mm of medial joint line opening occurred along with up to a 300% increase in valgus rotation. In a valgus-restricted model, Grood et al showed that the superficial MCL was the primary restraint to valgus stress, responsible for 78% of medial stability at 25° of flexion and 57% at 5° of flexion. Secondary supports against excessive valgus motion are the deep MCL and the POL. Research has shown the POL and the MCL to resist valgus force at 5° of flexion. The ACL has also been shown to withstand valgus stress under certain circumstances, such as when the knee approaches full extension in the case of superficial MCL deficiency. In the 5 degrees of freedom model, after the MCL and ACL are sectioned, there are large increases in valgus laxity, whereas if freedom of knee motion is not restricted, an applied valgus moment is not resisted solely by the MCL but is in fact shared by other ligaments and joint structures, particularly the ACL, and the ACL is recruited to provide restraint against pathologic valgus instability with as little as 5° of abnormal valgus rotation.

Valgus Stress Test at 0° and 30°

Although the accuracy of valgus stress testing is not well defined, the gold standard for evaluating the MCL is the valgus stress test performed at 30° of knee flexion with the tibia in external rotation. The valgus stress test in full extension evaluates the PMC and the POL as well as the MCL. The ACL is also an important secondary stabilizer at full extension, but only after the superficial MCL has been compromised. Because most patients with collateral ligament injury are treated without surgery, extensive correlation of clinical examination findings with arthroscopic data has not been performed. One study documented a valgus stress test sensitivity of 86% in 72 patients with arthroscopically confirmed MCL tears. Some studies have attempted to compare valgus stress testing on clinical examination with magnetic resonance imaging (MRI) findings; in general, agreement between the 2 diagnostic methods has appeared to be no better than fair to good.

Recommended Technique. The patient is placed supine with the hip of the affected limb slightly abducted and the knee flexed to 30° over the side of the table. The examiner positions one hand over the lateral aspect of the knee and grasps the ankle with the other hand. A valgus stress is applied. The test is then repeated in full extension.

Grading the valgus stress test incorporates both the amount of medial joint opening and the quality of the endpoint. Grade I is assigned to knees with 5 mm or less of joint opening and a solid endpoint, grade II corresponds to a 6 mm to 10 mm opening with a good endpoint, and grade III represents >10 mm of opening and a soft endpoint.

At 30° of flexion, the PMC and POL provide relatively little resistance to valgus stress, and the superficial MCL has a much more important role. Accordingly, maximum instability at 30° of flexion with relative stability at 0° signifies an isolated superficial MCL injury, with the severity of injury based on grade. According to Hughston et al, a valgus stress test positive in full extension denotes injury to both the MCL and the PCL. In their study, ACL integrity was not seen to affect the valgus stress test in extension. Marshall and Rubin, however, suggested that in addition to revealing incompetence of the PMC and MCL, a positive test result in extension indicates laxity of either cruciate ligament or both. The valgus stress test is illustrated in Figure 18.

PATELLOFEMORAL INSTABILITY

Anterior knee pain is among the most common orthopaedic complaints and may be a manifestation of instability at the patellofemoral joint. Other symptoms of patellofemoral instability can include crepitus, buckling, swelling, difficulty climbing or descending stairs or squatting, and “slipping” of the patella. There may be a history of trauma, although patellofemoral instability can also result from congenital factors. Unlike the aforementioned ligamentous instabilities, patellofemoral instability is multifactorial, and although recent focus has been on deficiency of the medial patellofemoral ligament (MPFL), patellofemoral instability cannot be attributed to the dysfunction of a single ligament or anatomic structure alone. Yet, because the symptoms and signs of a patient presenting with acute patellofemoral instability—“my knee buckled and swelled”—may be confused with other ligamentous injuries, consideration of patellofemoral instability within

Figure 18. Valgus stress test (for valgus instability). With the patient supine and the right knee at 0° and then flexed to 30°, the examiner applies valgus force across the joint line (arrows). Medial joint line opening and quality of the endpoint are evaluated.
the spectrum of ligamentous instability of the knee joint is warranted.

The anatomy and biomechanics of the entire lower extremity must be taken into account when evaluating a patient with patellofemoral instability. In addition to targeting the dynamics of the knee joint, gait and stance must be assessed, as must varus or valgus and rotational alignment of the limb. Although it is beyond the scope of this article to describe completely the biomechanics of patellofemoral instability, some common anatomic features and selected methods of evaluation will be considered. Notably, in addition, lateral facet compression syndrome and patellar tilt are not synonymous with patellofemoral instability; evaluation for signs of anterior knee pain not related to patellofemoral instability is not the purpose of this review.

Factors contributing to patellofemoral joint instability may include excessive quadriceps angle (Q-angle), femoral anteversion, external tibial torsion, patella alta, femoral trochlea or patellar dysplasia, generalized laxity, pes planus, vastus medialis obliquus (VMO) atrophy, MPFL insufficiency, and genu valgum. The VMO is a dynamic stabilizer of the patella and acts to balance laterally directed forces on the patella at the trochlea. The MPFL is a primary soft-tissue structure that checks lateral patellar motion and is often found to be injured in a traumatic lateral patellar dislocation. Sallay et al described the pathoanatomy of patellar dislocation and reported MRI evidence of medial patellofemoral ligament tears in 87% of 19 patients, with increased signal intensity adjacent to the adductor tubercle in 96% and within the VMO in 78%.

Bony configurations of the lateral patellar facet and the lateral femoral condyle also influence patellofemoral stability. Normally, in the axial plane, the anterior lateral condylar border lies 1 cm anterior to the border of the medial condyle. Furthermore, the lateral facet of the patella is usually longer and more acutely sloped than the medial facet. This contributes to static patellofemoral stability, and derangements of these features may cause patellofemoral pathology.

The spectrum of instability ranges from patellar maltracking to frank, typically lateral, dislocation. Patients with “miserable malalignment” syndrome have pathologic internal femoral rotation as a result of excessive femoral neck anteversion. Normally, femoral anteversion is defined as 11° with a standard deviation of 7°. Excessive femoral anteversion can cause the trochlea to rotate medially when the hip is placed in neutral rotation. These patients also have a large Q-angle (discussed below) produced by both associated external tibial torsion and pes planus, resulting in overpronation. Signs of this disorder include the “bayonet sign,” which refers to a sharp varus deformity of the proximal third tibia, and “squinting patellae,” in which the patellae face each other when the patient’s feet are held parallel.

Q-Angle Assessment

The Q-angle refers to the angle created by a line drawn from the anterior superior iliac spine (ASIS) to the center of the patella and from the center of the patella to the tibial tuberosity. A normal Q-angle is up to 15° in women and 10° in men. Greater angles increase laterally directed forces on the patella through the pull of the patellar tendon. The Q-angle is typically measured on the supine patient whose hips and knees are in neutral position. A Q-angle should also be assessed with the patient in a sitting position with knees flexed at 90°. If the Q-angle is measured in extension, the examiner must first reduce the patella in the trochlear groove. A laterally subluxated patella will result in measurement of a falsely low Q-angle. Especially in patients with rotationally lax knees, an apparently normal Q-angle in the supine position and knee extension may be abnormal in a more functional position of knee flexion with external rotation applied to the tibia. Furthermore, at 90° of flexion, the patella is engaged and centered in the trochlear groove, minimizing risk of a falsely low Q-angle measurement.

**Recommended Technique.** With the patient supine, the examiner marks the center of the tibial tuberosity. Next, while the patient relaxes, the examiner centers the patella in the trochlear groove and marks the center of the reduced patella. Finally, the examiner locates the ASIS and places the patient’s extended index finger as a marker of the ASIS. A goniometer is used to measure the angle...
The soft-tissue restraints of the patella.66

greater than 3 quadrants suggests a more global laxity of decreased patellar tilt, whereas medial displacement of dislocated. Medial displacement of 1 quadrant indicates a placement of 4 quadrants indicates a patella that can be within normal limits. Lateral displacement of no more than 2 quadrants is which the width of the patella is divided into quadrants. The J-sign suggests excessive lateral patellar tracking due to unbalanced and excessive lateral forces acting on the patella. Such pathologic changes may predispose the patella to subluxation or dislocation.

Recommended Technique. With the patient in a sitting position, the examiner simply observes patellar motion as the patient extends the leg from 90° of knee flexion to full extension or cyclically straightens and bends the knee. Abrupt or extreme lateral shift of the patella represents a positive J-sign.

Manual Translation Test

The manual translation test evaluates lateral patellar mobility. Reversal of this maneuver can be used to assess medial patellar displacement. Carson et al9 believe that the patella should not displace in either direction more than one half the width of the patella. Others have described a grading scheme for patellar translation in which the width of the patella is divided into quadrants. Lateral displacement of no more than 2 quadrants is within normal limits. Lateral displacement of 3 quadrants suggests an incompetent medial restraint, and lateral displacement of 4 quadrants indicates a patella that can be dislocated. Medial displacement of 1 quadrant indicates a tight lateral retinaculum and usually correlates with decreased patellar tilt, whereas medial displacement of greater than 3 quadrants suggests a more global laxity of the soft-tissue restraints of the patella.66

Recommended Technique. The patient is placed in the supine position, and the quadriceps is relaxed. The knee is fully extended (although Fairbank described that the test should be performed in 30° of knee flexion). The examiner places both thumbs on the medial border of the patella and slowly and gently attempts to displace the patella laterally. The patient’s reaction is noted. No pain is normal, but pain during the maneuver, while notable, does not represent a positive test finding. Rather, frank patient apprehension, or patient expression of fear that the patella will dislocate, represents a positive test result.

CONCLUSION

Accurate diagnosis is the hallmark of appropriate treatment, and by taking into consideration both structure and function, an orthopaedic surgeon’s ability to diagnose patterns of knee injury is enhanced.

ACKNOWLEDGMENT

The authors acknowledge Henry P. Hackett and Wylie Elson, MD, for their editorial support.

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