

Evaluation and Treatment of Medial Collateral Ligament and Medial-sided Injuries of the Knee

Kurt E. Jacobson, MD and Frederic S. Chi, MD

Abstract: Injuries to the medial side of the knee are not always isolated injuries of the superficial medial collateral ligament. Medial-sided injuries can also involve the deep medial collateral ligament, the posteromedial corner, or the medial meniscus. Magnetic resonance imaging is a useful adjunct to the physical examination; however, the extent of medial-sided injuries is frequently underappreciated on these images. An understanding of the anatomy and biomechanics of the medial side of the knee and a thorough physical examination aids the physician in determining the full extent of injury and helping the physician to treat each unique injury pattern.

Key Words: knee, anatomy, posteromedial corner, medial collateral ligament, anteromedial rotatory instability, posterior oblique ligament

(*Sports Med Arthrosc Rev* 2006;14:58–66)

The diagnosis and treatment of medial-sided knee injuries has evolved from an aggressive surgical approach for most injuries to a nonoperative phase to the present trend of nonoperative and operative management that is tailored to the specific nature and setting of the injury. The challenge of treating these injuries has been in defining the location and extent of the injury before deciding how best to manage it in a particular clinical setting. Accurate characterization of each component of the injury helps to define appropriate treatment guidelines.

ANATOMY

The medial meniscocapsular complex is a combination of static and dynamic structures. Static structures include the capsular and noncapsular ligaments, and the dynamic structures are the musculotendinous units and associated aponeuroses. Warren and Marshall¹ described this anatomy in layers, although a more simplified approach calls for dividing the medial aspect of the knee into thirds.

In terms of layers, Warren and Marshall¹ stratified the medial structures of the knee into 3 layers: superficial (I), intermediate (II), and deep (III). Layer I consists of the deep (crural) fascia, which invests the sartorius muscle and joins the periosteum of the tibia. Proximally, it is continuous with the fascia of the quadriceps; posteriorly, it becomes the deep fascia of the lower extremity, overlying the gastrocnemius muscles and popliteal fossa. Layer II comprises the superficial medial collateral ligament (SMCL) (which is also called the tibial collateral ligament, medial collateral ligament, internal lateral ligament, or superficial medial ligament), the medial patellofemoral ligament, and the ligaments of the posteromedial corner, where it merges with layer III into the tendon sheath of the semimembranosus with its 5 expansions. Layer III consists of the capsule of the knee joint and the deep medial collateral ligament (also called the deep medial ligament or middle capsular ligament). The deep MCL can be divided into 2 parts: the meniscotibial (coronary) ligament and meniscofemoral ligament, which attach to the tibia and femur, respectively.

Alternatively, the medial side of the knee can be divided into thirds: anterior third, middle third, and posterior third (Fig. 1). The anterior third consists of capsular ligaments covered by the extensor retinaculum of the quadriceps. The middle third contains the deep MCL and the superficial MCL. The posterior third, or “posteromedial corner,” contains the posterior oblique ligament, oblique popliteal ligament, semimembranosus attachments, and posteromedial meniscus. In our discussion, we will concentrate on the middle and posterior thirds.

In the middle third of the knee, the deep MCL originates from the medial epicondyle and inserts onto the tibia just below the joint line. Its attachment to the medial meniscus divides the deep MCL into its meniscofemoral and meniscotibial parts. This ligament tightens in knee flexion and is lax in full extension.² Slocum and Larson³ and Kennedy and Fowler⁴ report that injury to the deep MCL or capsular ligament is the basic lesion allowing abnormal external rotation of the tibia. However, isolated deep MCL tears are difficult to detect clinically. Others believe that the superficial MCL is the prime restraint to rotational instability.⁵ Hughston and Eilers⁶ state that the posterior oblique ligament (POL) and the posterior third are the most important determinants of anteromedial instability because “repair of the medial compartment

Received for publication September 8, 2005; accepted January 20, 2006. From the Hughston Sports Medicine Foundation, Columbus, GA. Reprints: Kurt E. Jacobson, MD, The Hughston Clinic, PC, 6262 Veterans Parkway, PO Box 9517, Columbus, GA 31909 (e-mail: kejacobson@hughston.com).

Copyright © 2006 by Lippincott Williams & Wilkins

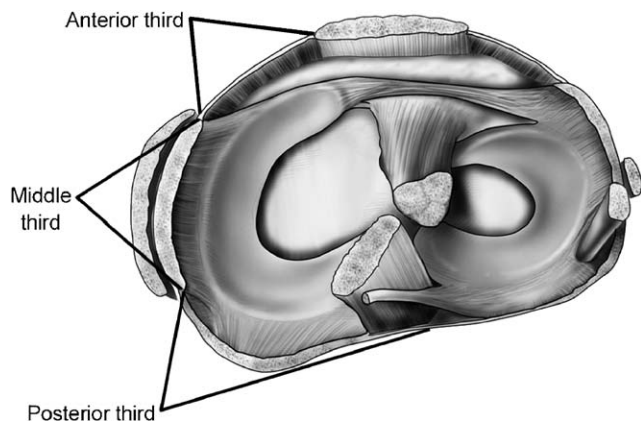


FIGURE 1. Anterior, middle, and posterior capsuloligamentous divisions of the medial-sided structures. (Reprinted with permission from Sims WF, Jacobson KE. The posteromedial corner of the knee. Medial-sided injury patterns revisited. *Am J Sports Med.* 2004;32:337–345.)

ligaments without repair of the posterior oblique ligament will often not reestablish static stability.”

The superficial MCL, or tibial collateral ligament, originates from the medial femoral epicondyle and has a broad, elongated insertion on the proximal medial tibia roughly 45 to 60 mm distal to the joint line (Fig. 2).^{7–9} It functions as the prime stabilizer of the medial aspect of the knee. Brantigan and Voshell⁷ describe 2 portions of

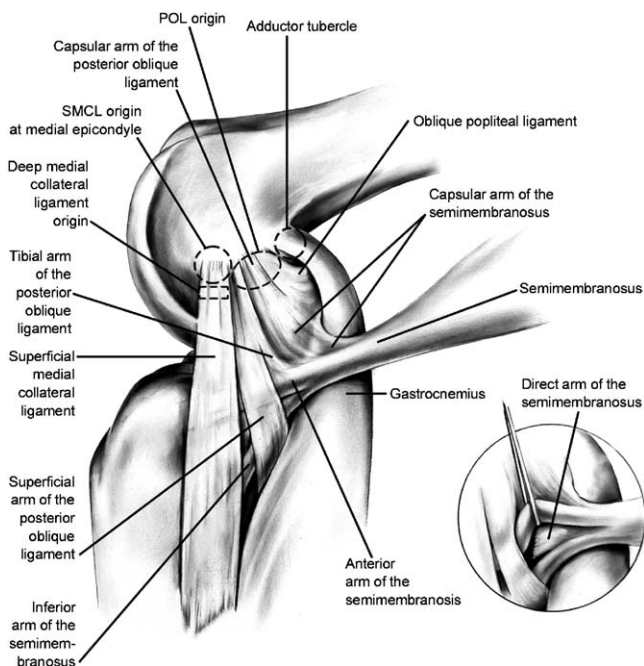


FIGURE 2. Anatomy of the middle and posterior thirds of the medial side of the knee. Origins of the SMCL, POL, deep medial collateral ligament, and adductor tubercle are indicated by circles. The 3 arms of the posterior oblique ligament are shown: (1) superior, or capsular, arm; (2) central, or tibial, arm; and (3) inferior, or superficial, arm.

the superficial MCL: an anterior parallel bundle of fibers and a more oblique posterior portion. The anterior bundle is 11 cm long and 1.5 cm wide.^{5,7} Brantigan and Voshell⁷ and Mains et al² believed that the superficial MCL fibers remain tensioned throughout the range of knee flexion, whereas Last⁹ and Slocum and Larson³ believed that the fibers relax in flexion. Horwitz¹⁰ and Warren et al⁵ found that both occur; the anterior border of the superficial MCL tightens in flexion, whereas the more posterior fibers slacken with knee flexion. The posterior oblique fibers are included in the posterior oblique ligament as defined by Hughston and Eilers⁶ and are in the posterior third of the medial side.

Müller¹¹ called the posterior third of the medial side of the knee, the “semimembranosus corner.” This posteromedial corner includes the structures from the posterior edge of the parallel fibers of the SMCL to the medial PCL, namely the POL, the 5 semimembranosus expansions, the oblique popliteal ligament (OPL), and the posteromedial meniscus.

The distinct fibers that Hughston and Eilers⁶ defined as the posterior oblique ligament have been confirmed anatomically by Fischer et al¹² and in a recent magnetic resonance imaging (MRI) study by Loredo et al,¹³ although others do not concur.^{1,14} Hughston and Eilers defined the POL as a “thickening of the capsular ligament attached proximally to the adductor tubercle of the femur and distally to the tibia and posterior aspect of the capsule.” These fibers fan out into 3 arms: superior, central, and inferior arms (Fig. 2). The superior or capsular arm blends with the posteromedial capsule (PMC) and proximal part of the OPL. The combination of the POL and PMC can be collectively referred to as the POL-PMC complex or the posteromedial corner. The prominent central, or tibial, arm attaches to the posterior edge of the tibia and the upper edge of the semimembranosus tendon. The less well-defined inferior, or distal, arm attaches distally to both the sheath of the semimembranosus and to the tibia distal to the insertion of the semimembranosus tendon.

The semimembranosus expansions are (1) the anterior arm or pars reflexa, which passes anteriorly beneath the TCL and inserts directly onto the tibia; (2) the direct arm, which has a posteromedial tibial insertion; (3) an OPL insertion arm; (4) a capsular arm with an expansion to the POL; and (5) an inferior arm with a popliteus aponeurosis expansion (Fig. 3). The OPL runs obliquely from the tibia proximally and laterally to its insertion on the lateral femoral condyle (Fig. 2). The posteromedial horn of the meniscus is attached to the semimembranosus via the POL and capsule.

POSTEROMEDIAL CORNER BIOMECHANICS

In a cadaveric study, Haimes et al¹⁵ demonstrated that the POL-PMC complex is an important secondary restraint to external tibial rotation, as well as to valgus stress in extension. Abduction rotation tripled when the POL-PMC complex was cut in anterior cruciate ligament

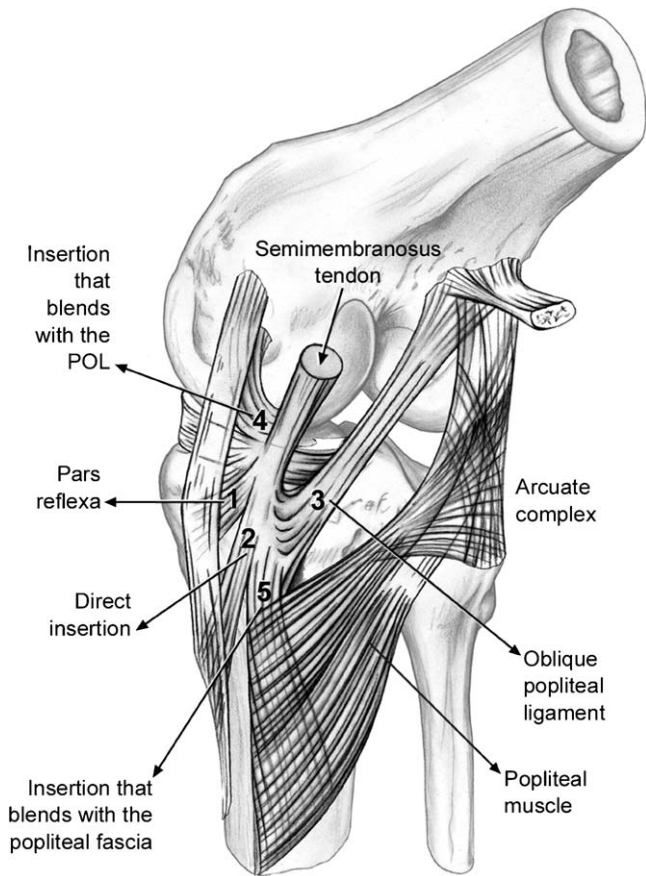


FIGURE 3. The semimembranosus expansions. The 5 insertions: (1) *pars reflexa*, (2) direct posteromedial tibial insertion, (3) oblique popliteal ligament insertion, (4) expansion to POL, and (5) popliteus aponeurosis expansion. Note the investment into the posterior oblique ligament. (Reprinted with permission from Sims WF, Jacobson KE. The posteromedial corner of the knee. Medial-sided injury patterns revisited. *Am J Sports Med.* 2004;32:337–345.)

(ACL)-deficient knees and was double that of combined ACL-MCL-deficient subjects. They also sectioned the MCL and found an increased external rotation limit that has been confirmed by other studies.^{5,16}

In another sectioning study, Shapiro et al¹⁷ sectioned the MCL while measuring strain in the ACL. They found that when the tibia was externally rotated and the MCL was cut, the load increases on the ACL during anterior tibial force. Although other investigators did not confirm this finding,^{16,18} these investigators did not measure load within the ACL, only displacement or laxity. However, these studies confirm the work of Mains et al² in which sectioning of the MCL and ACL increases anterior laxity greater than that which occurs with sectioning of the ACL alone.

Shapiro et al¹⁷ also found that a valgus force applied to the MCL-deficient knee increased force on the ACL, especially when flexed to 45 degrees. They further speculated that individuals with residual valgus laxity

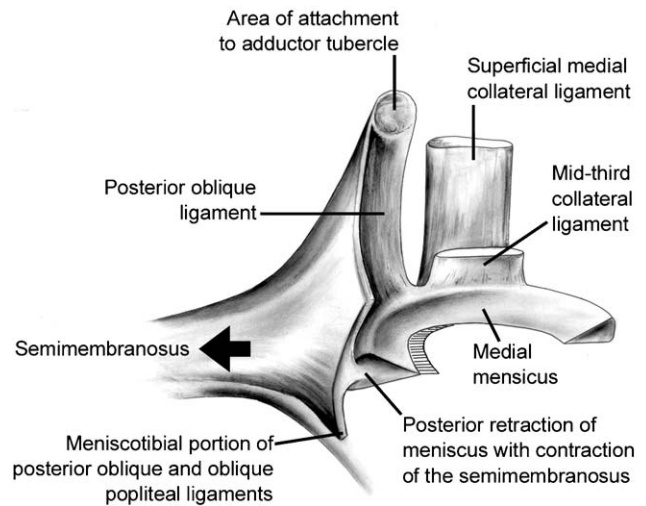


FIGURE 4. Intracapsular orientation of the posteromedial corner structures showing the proposed dynamizing action (arrow) of the semimembranosus. Note the relationship of the semimembranosus capsular expansion, the posterior oblique ligament, and the posteromedial meniscus.

because of an MCL injury might be at increased risk for ACL injury. Jaureguito and Paulos¹⁹ stated that for chronic ACL-MCL instability, ACL reconstruction alone would place undue stress on the ACL graft “resulting in stretching and eventual failure.”

The meniscocapsular complex, consisting of the posteromedial aspect of the meniscus, deep MCL capsular attachments, POL, and semimembranosus expansions, is critical for the dynamic stability of the medial side of the knee (Fig. 4).²⁰ As the knee flexes, the contraction of the semimembranosus muscle tenses the POL through the expansions and allows a dynamic stabilization of the meniscus. Injury at any level of this chain can cause anteromedial rotatory instability (AMRI). Tensioning the central arm of the POL can also retract the posteromedial horn of the meniscus, preventing its entrapment between the femur and the tibia during knee flexion (Fig 4).

MENISCAL BIOMECHANICS

Typically, the medial meniscus is firmly attached at its anterior and posterior ends to the intercondylar area of the tibia. The transverse intermeniscal ligament of the knee may provide additional anterior support. The fixed ends allow for hoop stresses to be generated, whereas the attachments to the capsule can modify this hoop stress. Disruption of the meniscotibial ligament not only destabilizes the meniscus from its tibial attachments, but it can also lessen appropriate hoop tension on the meniscus.

The superior surface of the medial meniscus is slightly concave to accommodate the femoral condyle; the inferior surface is flatter. When the meniscotibial ligament

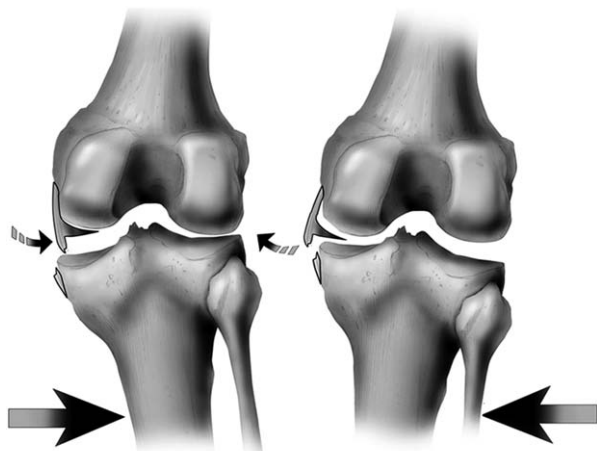


FIGURE 5. Disruption of the meniscotibial ligament. Abduction stress (left) results in lateral translation of the medial meniscus, whereas adduction stress (right) pushes the medial meniscus medially. (Large arrows indicate direction of stress. Small arrows indicate direction of meniscal translation.) (Reprinted with permission from Sims WF, Jacobson KE. The posteromedial corner of the knee. Medial-sided injury patterns revisited. *Am J Sports Med.* 2004;32:337–345.)

is torn, the shape of the meniscus causes lateral subluxation of the meniscus with abduction and medial subluxation of the meniscus with adduction (Fig. 5). The tibia can also rotate independently of the meniscus, causing AMRI (Fig. 6).²¹

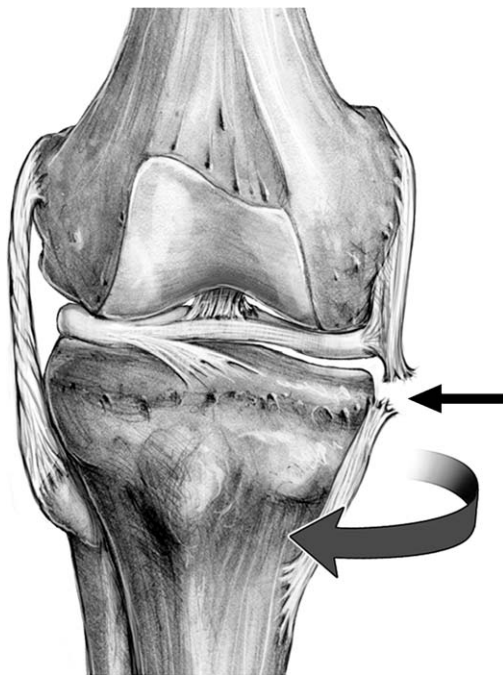


FIGURE 6. Disruption of the meniscotibial ligament (small arrow) results in anteromedial rotatory instability. (Large arrow shows rotatory element created.)

MECHANISM OF INJURY

Typically, the mechanism of a medial-sided injury is a valgus stress on the knee. This stress can be the result of a contact injury, such as a clipping injury in football, or a noncontact injury from cutting, pivoting, twisting, or a sudden change in direction. Skiing injuries are commonly the result of this mechanism.^{22–24} A pure valgus force can damage the superficial MCL primarily, and the addition of rotation can tear the posteromedial corner or ACL before the MCL is ruptured.²⁵

DIAGNOSIS

Physical Examination

The physical examination remains the best diagnostic tool for determining the location and extent of injuries to the medial compartment. A thorough knee examination consists of inspection of the skin, palpation of anatomic structures, assessment of the range of motion, and tests of stability.

On inspection of the skin, the examiner looks for ecchymosis, effusion, or edema to localize the site of injury, such as the femoral attachment of the superficial MCL. Hughston et al,²⁶ however, reported that sometimes a complete disruption of the medial compartment can occur “without subsequent significant pain, effusion, or disability for walking.” Although hemarthrosis is more frequently associated with ACL injury, capsular tears on the medial side may cause extravasation of blood with minimal hemarthrosis visible.²⁵

Careful palpation of the anatomic points of attachment allows localization of the site of injury. The examiner palpates the origin of the superficial MCL at the medial epicondyle and its broad-based insertion on the tibia several centimeters below the joint line. The POL-PMC complex originates just posterior and inferior to the medial epicondyle and then wraps around the condyle. The deep MCL originates inferior to the medial epicondyle. Next, the examiner palpates the body of the meniscus along the joint line and the meniscotibial ligament, which inserts below the joint. A positive McMurray test helps to confirm a meniscal tear. The semimembranosus can be felt within the soft tissue posterior and inferior to the medial femoral condyle (Fig. 3).

Stability Testing

Abduction Stress Test in External Rotation

Valgus stress testing at 30 degrees of knee flexion is the most sensitive test and is most indicative of the nature of the medial compartment injury (Fig. 7). The test is performed best by grasping the forefoot area and applying a valgus stress to observe and differentiate between an “open-book” injury pattern (superficial MCL injury) and one that causes AMRI (posteromedial corner injury). The amount of laxity can be measured in the acute stage of injury and at appropriate therapy intervals.

During the second phase of valgus stress testing, the examiner palpates over the medial meniscus to sense the

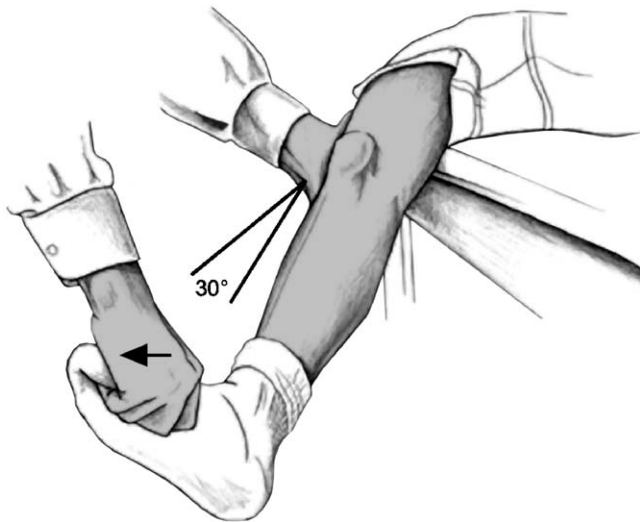


FIGURE 7. Abduction stress test in external rotation is performed at 30 degrees of knee flexion by grasping the patient's forefoot and applying a valgus stress (arrow).

peripheral detachment. The examiner will be aware of pathologic hypermobility of the meniscus as it subluxates in and out of the joint, a finding that is indicative of injury to the mensicotibial ligament.

Anterior drawer test in external rotation

The examiner applies a gentle anterior pull to the knee, which is flexed to 90 degrees (Fig. 8). This maneuver allows the examiner to observe abnormal motion—particularly in the medial compartment. With the tibia in 10 degrees of external rotation, application of the same force still allows the medial compartment to subluxate anteriorly in patients with anteromedial rotatory instability.

Imaging

Plain radiography is not usually helpful for acute ligamentous injury unless a bony avulsion is apparent. Kimori et al²⁷ found arthrography to be more useful in the diagnosis of tears of the meniscomfemoral and mensicotibial ligaments than arthroscopy. MRI with and without contrast is less invasive and especially helpful for lesions in the body of the medial meniscus and peripheral attachments, the superficial MCL, the POL-PMC complex, and semimembranosus tendon. Loredó et al¹³ demonstrated the value of intra-articular contrast to highlight and better define the structures of the PMC. The POL-PMC complex was best visualized on the coronal and axial plane images. The coronal oblique plane image was best for an overall perspective of the injuries.

Orthopaedists and radiologists must be able to analyze the injury characteristics. Medial compartment injuries are often underreported on MRI interpretations. One should observe for fluid or contrast tracking below the meniscus in patients with detachments of the mensicotibial ligament (Fig. 9).

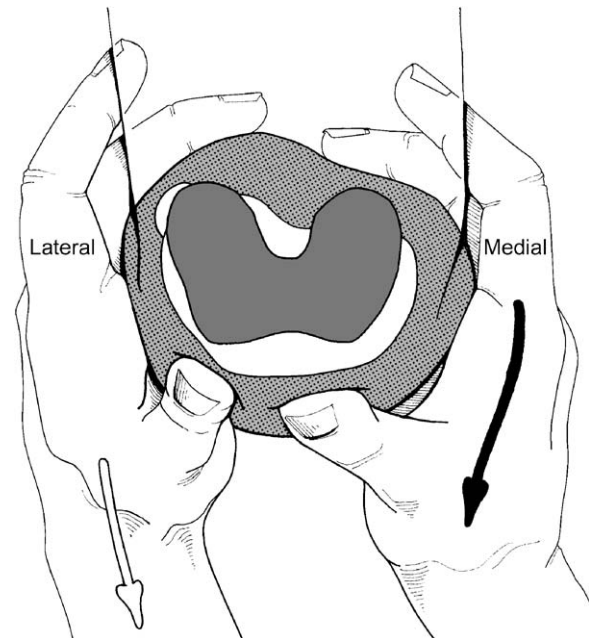


FIGURE 8. Anterior drawer test in external rotation is performed at 90 degrees of knee flexion. With anterior pull of the tibia (white and black arrows), the medial compartment may subluxate anteriorly (black arrow demonstrates rotation of the tibia in relation to the femur). (Reprinted with permission from Hughston JC. *Knee Ligaments: Injury and Repair*. Columbus, GA: The Hughston Sports Medicine Foundation; 2003.)

Injury patterns

Injury to the medial-sided structures can occur as an isolated injury or in combination with injury to the ACL or posterior cruciate ligament (PCL). Fetto and Marshall²⁸ found that the risk of concomitant ligament injury in the presence of a grade III MCL injury was almost 80%. With concomitant PCL tears, the medial compartment of the knee is unstable at 0 and 30 degrees of knee flexion. With an intact PCL, the medial compartment is stable when the knee is in 0 degree of flexion but will open at 30 degrees.²⁶

SMCL Injury at the Medial Epicondyle

A positive examination demonstrates medial-joint line opening that is more of an “open-book” type than occurs in patients with AMRI. Patients with this injury exhibit minimal abnormal motion on the anterior drawer test at 90 degrees.

Posteromedial corner injury

Sims and Jacobson²⁰ reported their results in a series of patients who had medial-sided knee injuries. Of these patients, 93 were treated operatively for clinical or functional AMRI. They found injury to the POL in 92 of the 93 knees, but not all of the knees had an injury to the semimembranosus and fewer still had peripheral meniscal detachment. From a functional standpoint, they found 3



FIGURE 9. MRI of extensive medial-sided injury with complete peripheral meniscal detachment (arrow), disruption of meniscotibial and meniscofemoral ligaments, deep medial one-third capsular ligament, and medial collateral ligament. Note orientation of medial meniscus. (Reprinted with permission from Sims WF, Jacobson KE. The posteromedial corner of the knee. Medial-sided injury patterns revisited. *Am J Sports Med.* 2004;32:337-345.)

basic patterns of posteromedial corner injury: (1) injury to the POL-PMC complex and the capsular arm of the semimembranosus (70%); (2) injury to the POL-PMC complex and peripheral meniscal detachment (30%); and (3) injury to the POL-PMC complex, peripheral meniscal detachment, and disruption of the capsular arm of the semimembranosus (19%). (The percentages did not total 100 because the third pattern is one in which the first 2 injury patterns occurred together.)

Careful examination of the knee allows the examiner to detect isolated ACL and PCL tears. With PCL tears, the medial compartment is unstable at 0 and 30 degrees of flexion. With an intact PCL, the medial compartment is stable when the knee is in 0 degree of flexion, but it will open at 30 degrees.

TREATMENT

The management of isolated superficial MCL tears is becoming less controversial. For a patient who has a superficial MCL injury, treatment in a brace with protected range of motion and rehabilitation allows most grade I and II lesions to heal in 2 to 6 weeks.²⁸⁻³² For treatment of grade III lesions, although many recommend operative treatment,^{11,21,28,32,33} nonoperative treatment also has a high success rate.^{28,34-36} In our experience,

nonoperative treatment can be used initially, and if the superficial MCL does not heal or tighten appropriately after 4-6 weeks of rehabilitation, consider either repair or reconstruction with allograft or autograft. If there is marked injury to the POL-PMC complex, operative intervention may also be necessary.

For individuals with combined MCL and ACL injuries, the ACL rehabilitation takes precedence, because early and full range of motion is the goal. Hughston³⁷ found good long-term results after medial-sided repair in 38 of 41 patients with grade III medial-sided injuries; 24 of these patients also had ACL injuries. Although none of the 24 patients with ACL injuries had formal ACL reconstruction, only 1 patient ever developed instability, suggesting the medial-sided injury should take precedence. Jokl et al³⁸ found good or excellent results in 20 of 28 patients treated conservatively, they recommended operative repair if the initial result was "unsatisfactory." Shelbourne and Porter³⁹ found good to excellent results in patients with combined MCL and ACL injuries who were treated with ACL reconstruction and conservatively for the MCL injury; however, they did not document the grade of MCL injury. Hillard-Sembell et al⁴⁰ compared 66 patients with ACL and MCL injuries and treated 11 with MCL repair and ACL reconstruction, 33 with only ACL reconstruction, and 22 with no surgery for both injuries. They found operative treatment of the ACL alone or with the MCL made no difference in late pure valgus instability; however, they did not address subtle rotatory instability.

At the time of the index cruciate procedure, a careful examination under anesthesia allows determination of the need for medial repair. Because the cruciate reconstruction can mask the need for medial repair, the decision to repair the medial side should not be changed after the cruciate is reconstructed. Even if medial instability decreases after ACL reconstruction, the medial compartment should be addressed as well to prevent possible ACL failure.^{17,19} If the repair is done anatomically with absorbable suture, there is little chance of over-tensioning the medial side.

With regard to posteromedial corner injuries with an intact superficial MCL, patients with grade I injuries typically do well with brace therapy and rehabilitation. Grade II or grade III injuries may require acute or subacute surgical treatment if there is significant disruption of anatomic structures. Many of these knees have meniscotibial ligament injuries that destabilize the meniscus. Knees in which meniscotibial ligament injuries are combined with an injury to the POL-PMC complex or semimembranosus expansions usually require surgical repair to restore normal anatomic attachments and tensioning. Each component of the meniscocapsular complex (meniscus, POL, and semimembranosus) must be intact for normal knee kinematics to be restored after injury. Because of the unique anatomy of the posteromedial corner, injuries have a potentially higher long-term morbidity due to instability and altered kinematics.

Surgical Treatment

Surgical treatment is reserved for patients who have persistent valgus laxity or rotatory instability despite brace treatment or subacute or chronic medial instability associated with cruciate injury. If the medial injury does not tighten during the 4- to 6-week brace treatment and rehabilitation before the planned cruciate reconstruction, open medial repair should be considered. Successful cruciate reconstruction and patient satisfaction depend on restoring medial compartment kinematics.

The surgical approach is through a medial incision centered on the joint line, between the medial epicondyle and the adductor tubercle (Fig. 10). This incision can be extended depending on the need for repair or reconstruction of the superficial MCL. The skin is retracted to expose the fascia of the sartorius muscle. Dissection continues through the fascia to locate the plane between the posterior aspect of the superficial MCL and the POL. Further dissection in this interval exposes the medial meniscus with its attachments to the deep MCL.

The repair should start with the deep structures, such as tears in the peripheral meniscus or injuries to the meniscotibial or menisiofemoral ligaments. Direct suture repair of the respective capsular ligament to its insertion stabilizes and re-tensions the meniscus. By developing a

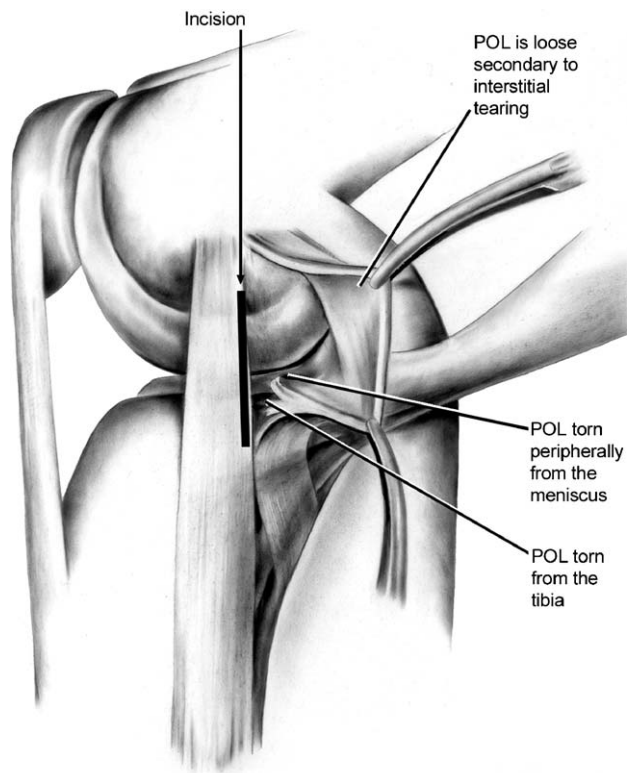


FIGURE 10. Dissection of the medial side of the knee showing the incision (dark line) in the interval between the superficial medial collateral ligament and the posterior oblique ligament (POL). By reflecting the POL and superficial medial collateral ligament, the medial meniscus and deep medial collateral ligament can be seen.

plane between the superficial MCL and deep MCL, the surgeon can expose the deep MCL and re-tension or repair the POL (Fig. 11). Staying deep to the superficial MCL, the superior attachment is attached first, followed by the inferior attachment, and, finally, a pants-over-vest suture technique to tension the central POL over the deep MCL. Next, palpate the capsular arm of the semimembranosus; any laxity can be repaired or advanced by suturing it to the POL. The superficial MCL can usually be repaired by direct suture to its attachments, or it may require reconstruction with a Bosworth, Umansky, or similar-type procedure.⁴¹⁻⁴³ Nicholas,⁴⁴ O'Donoghue,³³ and Slocum et al⁴⁵ also described repairs or transfers for capsular structures, pes anserine and semimembranosus tendons, and the MCL insertion. Allograft tendon has been shown to restore most of the biomechanical properties of the superficial MCL in a canine model.⁴⁶ Although their follow-up was short term, Yoshiya et al⁴⁷ recently demonstrated the success of using a triple-strand or quadruple-strand autogenous hamstring graft in reconstructing the superficial MCL.

Postoperatively, depending on the repair, the knee is protected with a hinged knee brace to allow carefully protected range of motion and partial weight bearing during the healing process of at least 6 weeks. After an isolated medial-sided repair, the knee is placed in a hinged brace at 45 degrees of flexion. Gentle range of motion is started, avoiding active extension with the goal of increasing passive extension by 15 degrees every 2 weeks. Touchdown weight bearing is allowed at 15 degrees of flexion and then the patient can advance as tolerated.

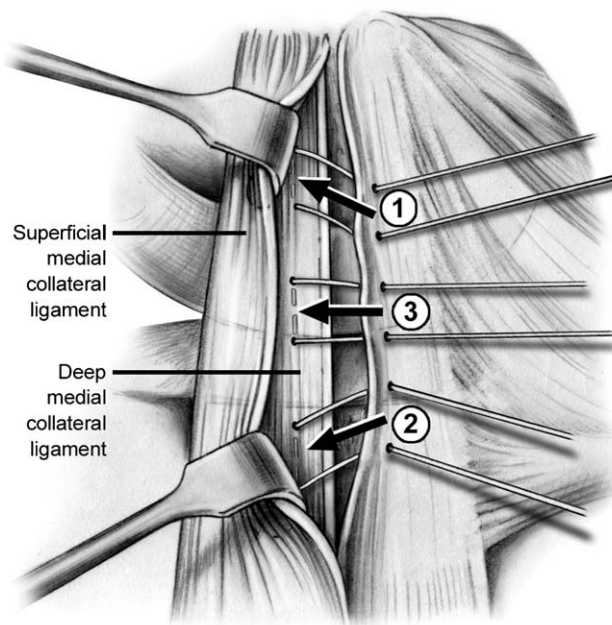


FIGURE 11. Re-tensioning of the POL should be done with pants-over-vest sutures with the POL over the deep medial collateral ligament first (1) in a superior direction, then in an inferior direction (2), and then directly anterior (3). (Arrows show direction of sutures.)

After a combined ACL and medial-sided repair, the knee is braced in full extension and a standard ACL protocol is followed. Again, the ACL rehabilitation takes precedence over the medial repair. A hinged knee brace is worn for 6 weeks and then rehabilitation is advanced as tolerated.

SUMMARY

The goal of treating medial compartment injuries is to accurately define the nature and extent of injury. Careful history taking and examination of the injury allows for a tailored approach that best addresses the anatomic basis of the therapy. The examiner should use a checklist to note the site or location of the injury, the degree of injury, and the presence of any laxity in the superficial MCL, the deep MCL, the POL-PMC complex, the semimembranosus capsular arm, and the body and capsular attachments of the medial meniscus. Both nonoperative and operative managements are appropriate depending on the specific injury pattern and clinical setting. Medial-sided injuries to the knee should not be simplified to isolated superficial MCL injuries. Many superficial MCL injuries heal with nonoperative measures, and those that fail to heal may have occult PMC injury. Failure to recognize and treat the posteromedial corner injury will prevent the restoration of normal kinematics to the medial side of the knee.

REFERENCES

- Warren LF, Marshall JL. The supporting structures and layers on the medial side of the knee: an anatomical analysis. *J Bone Joint Surg [Am]*. 1979;61:56–62.
- Mains DB, Andrews JG, Stonecipher T. Medial and anterior-posterior ligament stability of the human knee, measured with a stress apparatus. *Am J Sports Med*. 1977;5:144–153.
- Slocum DB, Larson RL. Rotatory instability of the knee: its pathogenesis and a clinical test to demonstrate its presence. *J Bone Joint Surg [Am]*. 1968;50:211–225.
- Kennedy JC, Fowler PJ. Medial and anterior instability of the knee: an anatomical and clinical study using stress machines. *J Bone Joint Surg [Am]*. 1971;53:1257–1270.
- Warren LF, Marshall JL, Girgis F. The prime static stabilizer of the medial side of the knee. *J Bone Joint Surg [Am]*. 1974;56:665–674.
- Hughston JC, Eilers AF. The role of the posterior oblique ligament in repairs of acute medial (collateral) ligament tears of the knee. *J Bone Joint Surg [Am]*. 1973;55:923–940.
- Brantigan OC, Voshell AF. The tibial collateral ligament: its function, its bursae, and its relation to the medial meniscus. *J Bone Joint Surg*. 1943;25:121–131.
- Palmer I. On the injuries to the ligaments of the knee joint. *Acta Orthop Scand Suppl*. 1938;5:282.
- Last RJ. Some anatomical details of the knee joint. *J Bone Joint Surg [Br]*. 1948;30:683–688.
- Horwitz MT. An investigation of the surgical anatomy of the ligaments of the knee joint. *Surg Gynecol Obstet*. 1938;67:287–292.
- Müller W. *The Knee. Form, Function, and Ligament Reconstruction*. Berlin: Springer-Verlag; 1983.
- Fischer RA, Arms SW, Johnson RJ, et al. The functional relationship of the posterior oblique ligament to the medial collateral ligament of the human knee. *Am J Sports Med*. 1985;13:390–397.
- Loredo R, Hodler J, Pedowitz R, et al. Posteromedial corner of the knee: MR imaging with gross anatomic correlation. *Skeletal Radiol*. 1999;28:305–311.
- Robinson JR, Sanchez-Ballester J, Bull AMJ, et al. The posteromedial corner revisited. An anatomical description of the passive restraining structures of the medial aspect of the human knee. *J Bone Joint Surg [Br]*. 2004;86:674–681.
- Haimes JL, Wroble RR, Grood ES, et al. Role of the medial structures in the intact and anterior cruciate ligament-deficient knee. Limits of motion in the human knee. *Am J Sports Med*. 1994;22:402–409.
- Shoemaker SC, Markolf KL. Effects of joint load on the stiffness and laxity of ligament-deficient knees: an in-vitro study of the anterior cruciate and medial collateral ligaments. *J Bone Joint Surg [Am]*. 1985;67:136–146.
- Shapiro MS, Markolf KL, Finerman GA, et al. The effect of section of the medial collateral ligament on force generated in the anterior cruciate ligament. *J Bone Joint Surg [Am]*. 1991;73:248–256.
- Sullivan D, Levy M, Sheskie S, et al. Medial restraints to anterior-posterior motion of the knee. *J Bone Joint Surg [Am]*. 1984;66:930–936.
- Jaureguito JW, Paulos LE. Why grafts fail. *Clin Orthop*. 1996;325:25–41.
- Sims WF, Jacobson KE. The posteromedial corner of the knee: medial-sided injury patterns revisited. *Am J Sports Med*. 2004;32:337–345.
- Hughston JC, Barrett GR. Acute anteromedial rotatory instability. Long-term results of surgical repair. *J Bone Joint Surg [Am]*. 1983;65:145–153.
- Hughston JC. *Knee Ligaments: Injury and Repair*. Columbus, Georgia: Hughston Sports Medicine Foundation; 2003.
- Jarvinen M, Natri A, Laurila S, et al. Mechanisms of anterior cruciate ligament ruptures in skiing. *Knee Surg Sports Traumatol Arthrosc*. 1994;2:224–228.
- Friden T, Erlandsson T, Zatterstrom R, et al. Compression or distraction of the anterior cruciate injured knee: variations in injury pattern in contact sports and downhill skiing. *Knee Surg Sports Traumatol Arthrosc*. 1995;3:144–147.
- Indelicato PA. Isolated medial collateral ligament injuries in the knee. *J Am Acad Orthop Surg*. 1995;3:9–14.
- Hughston JC, Andrews JR, Cross MJ, et al. Classification of knee ligament instabilities Part I. The medial compartment and cruciate ligaments. *J Bone Joint Surg [Am]*. 1976;58:159–171.
- Kimori K, Suzu F, Yamashita F, et al. Evaluation of arthrography and arthroscopy for lesions of the posteromedial corner of the knee. *Am J Sports Med*. 1989;17:638–643.
- Fetto FJ, Marshall JL. Medial collateral ligament injuries of the knee: a rationale for treatment. *Clin Orthop*. 1978;132:206–218.
- Bergfeld J. First-, second-, and third-degree sprains. *Am J Sports Med*. 1979;7:207–209.
- O'Connor GA. Collateral ligament injuries of the joint. *Am J Sports Med*. 1979;7:209–210.
- Cox JS. Injury nomenclature. *Am J Sports Med*. 1979;7:211–213.
- Kannus P. Long-term results of conservatively treated medial collateral ligament injuries of the knee joint. *Clin Orthop*. 1988;226:103–112.
- O'Donoghue DH. Reconstruction for medial instability of the knee: technique and results in sixty cases. *J Bone Joint Surg [Am]*. 1973;55:941–955.
- Indelicato PA. Non-operative treatment of complete tears of the medial collateral ligament of the knee. *J Bone Joint Surg [Am]*. 1983;65:323–329.
- Woo SLY, Inoue M, McGurk-Burleson E, et al. Treatment of the medial collateral ligament injury II: structure and function of canine knees in response to differing treatment regimens. *Am J Sports Med*. 1987;15:22–29.
- Woo SLY, Vogrin TM, Abramowitch SD. Healing and repair of ligament injuries in the knee. *J Am Acad Orthop Surg*. 2000;8:364–372.
- Hughston JC. The importance of the posterior oblique ligament in repairs of acute tears of the medial ligaments in knees with and without an associated rupture of the anterior cruciate ligament. *J Bone Joint Surg [Am]*. 1994;76:1328–1344.
- Joki P, Kaplan N, Stovell P, et al. Non-operative treatment of severe injuries to the medial and anterior cruciate ligaments of the knee. *J Bone Joint Surg [Am]*. 1984;66:741–744.

39. Shelbourne KD, Porter DA. Anterior cruciate ligament-medial collateral ligament injury; nonoperative management of medial collateral ligament tears with anterior cruciate ligament reconstruction. A preliminary report. *Am J Sports Med.* 1992;20:283-286.
40. Hillard-Sembell D, Daniel DM, Stone ML, et al. Combined injuries of the anterior cruciate and medial collateral ligament of the knee. Effect of treatment on stability and function of the joint article. *J Bone Joint Surg [Am].* 1996;78:169-176.
41. Bosworth DM. Transplantation of the semitendinosus for repair of laceration of medial collateral ligament of the knee. *J Bone Joint Surg [Am].* 1952;34:196-202.
42. Fenton RL. Surgical repair of a torn tibial collateral ligament of the knee by means of the semitendinosus tendon (Bosworth procedure); report of twenty-eight cases. *J Bone Joint Surg [Am].* 1957;39:304-308.
43. Umansky AL. The Milch fasciodesis for the reconstruction of the tibial collateral ligament. *J Bone Joint Surg [Am].* 1952;34:202-206.
44. Nicholas JA. The five-one reconstruction for anteromedial instability of the knee: indications, technique, and the results in fifty-two patients. *J Bone Joint Surg [Am].* 1973;55:899-922.
45. Slocum DB, Larson RL, James SL. Late reconstruction of ligamentous injuries of the medial compartment of the knee. *Clin Orthop.* 1974;100:23-55.
46. Horibe S, Shino K, Nagano H, et al. Replacing the medial collateral ligament with an allogeneic tendon graft: an experimental canine study. *J Bone Joint Surg [Br].* 1990;72:1044-1049.
47. Yoshiya S, Kuroda R, Mizuno K, et al. Medial collateral ligament reconstruction using autogenous hamstring tendons: technique and results in initial cases. *Am J Sports Med.* 2005;33:1380-1385.