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Rotatory Instability of the Knee

ITS PATHOGENESIS AND A CLINICAL TEST TO DEMONSTRATE ITS PRESENCE*

BY DONALD B. SLOCUM, M.D.†, AND ROBERT L. LARSON, M.D.†, EUGENE, OREGON

In 1938, Palmer's monograph pointed out the essential pathological features of acute ligamentous injuries to the knee; and, since then, treatment of these conditions has undergone evolution from an almost completely conservative approach to one in which it is considered essential to undertake primary repair of major ruptures within the first ten to fourteen days at the latest. During the intervening years Brantigan and Voshell, Abbott and associates, Smillie, Kaplan, Hughston^{4,5}, and, especially, O'Donoghue, have further stressed the anatomical details of traumatic ligamentous rupture.

One of the most fascinating facets of the problem of knee ligament injuries is rotatory instability. In its most common form, such instability permits pathologically increased outward rotation of the tibia on the femur. Clinically, it manifests itself most frequently as instability in lateral movement: The runner is most vulnerable when he cuts or turns away from the side of the supporting foot; the walker, when he turns quickly to change direction or his leg is twisted by an uneven walking surface; and the individual with severe instability, when he turns medially on the supporting leg while standing. Although long recognized as a clinical entity, rotatory instability has too often been overlooked by inexperienced surgeons because standard testing methods stress valgus rocking and anteroposterior joint laxity rather than rotatory instability⁷. Interest has lagged because conservative therapy has been limited to muscle-strengthening exercises and surgical treatment has been directed more toward stabilizing the abnormal valgus than correcting the torsional laxity. It is the purpose of this paper to review the types of pathological change which we have encountered at operation when increased outward rotation of the tibia on the femur is present and to suggest a method of testing for rotatory instability.

Anatomy

The ligamentous structures of the medial side of the knee are composed of the capsular ligaments and an overlying tibial collateral ligament which reinforces the medial aspect of the joint. The capsular ligaments medially form a half-sleeve extending from the popliteal space behind to the patellar tendon in front. They have three distinct parts: anterior, middle, and posterior. The *anterior* portion is repre-

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† 750 East 11th Avenue, Eugene, Oregon 97401.

sented by the anterior capsule and its reinforcement from the vastus medialis retinaculum. This portion is tightened passively when the knee is flexed and is relaxed as the knee is extended; the tension varies with the state of contraction of the vastus medialis. If the anterior portion is torn and allowed to heal so that it is longer than normal, not only will ligamentous laxity be present but the action of the vastus medialis will be weakened. The *middle* portion of the capsular ligament is often called the deep layer of the medial ligament (or the short internal lateral ligament in the old anatomical terminology), but it is not presently designated by a special name¹⁰. This ligament is composed of a strong upper meniscomfemoral portion and a weak lower meniscotibial portion. The upper part is attached to the medial femoral condyle somewhat forward of the more superficial tibial collateral ligament and passes downward to become strongly fixed to the middle third of the medial

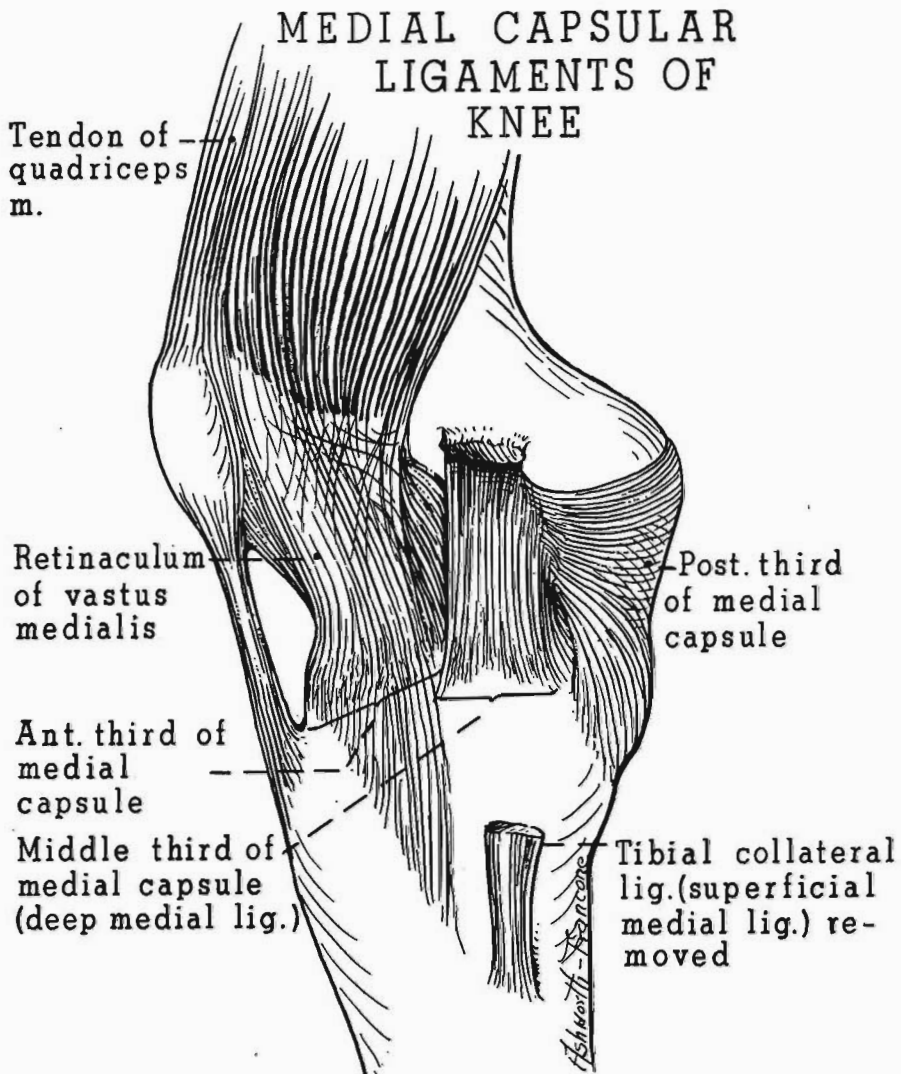


FIG. 1

The medial capsular ligaments of the knee. The overlying tibial collateral ligament has been removed; the cut ends of the anterior longitudinal portion of the ligament are shown at the medial femoral epicondyle and on the medial aspect of the tibia; the posterior triangular portion reinforces the posterior aspect of the mid-capsule and then continues backward to blend with the capsule at the back of the knee; it is not represented here. Note that the vastus medialis retinaculum blends with the anterior third of the capsule.

meniscus. Its function is to hold the meniscus to the femur. The lower portion of the ligament continues downward as the coronary ligament and is attached to the tibia just below its articular surface. This lax and relatively weak structure permits the meniscus to move on the tibia as the meniscus moves with the femur in flexion, extension, and rotation. The *posterior* part of the medial ligamentous sleeve is the posterior capsule. When the knee is extended this portion of the capsule embraces the rounded posterior aspect of the medial femoral condyle, forming a taut hemispherical pouch. When the knee is flexed, the pouch is slack. In our experience the posterior portion of the capsule varies greatly in strength in different individuals. In some, it is only a wispy membrane; in others, it is a strong, thick collagenous structure which is reinforced by the popliteal ligament. This variation in strength may be congenital or may develop in response to repetitive stresses.

The tibial collateral ligament overlies the medial portion of the capsule and is often referred to as the superficial portion of the medial ligament. Phylogenetically its anterior portion probably represents a vestigial remnant of the tendon of the adductor magnus muscle⁹. This ligament arises from the medial femoral epicondyle and inserts into the medial face of the tibia three to four inches below the joint line. This part of the ligament is separated from the underlying capsule by a bursa which provides for free movement between the two structures. When the knee is extended, the superficial ligament moves forward and tightens; when the knee is flexed the ligament drifts backward and becomes more relaxed. The posterior-superior and posterior-inferior fibers form a triangular membrane which swings obliquely backward to reinforce the posterior capsule and inserts into the posterior aspect of the tibia.

The longitudinal axis about which the tibia rotates in the horizontal plane during flexion and extension, according to one author⁶ is in the mid-lateral portion of the medial tibial articular facet, but other authors place it in the medial tubercle of the tibial plateau and the posterior cruciate ligament^{9,15}. It is our impression that the location of this pivot point varies with the position of the joint and that it moves posteriorly progressively as flexion takes place.

The amount of rotation varies greatly in different individuals depending on age, sex, body build, physical development, and general ligamentous laxity. In the same individual rotation varies with the position of the knee joint. It is practically nil when the knee is extended, for in this position the flattened surfaces of the femoral condyles are tightly cupped into the articular surfaces of the tibia by the taut capsular, collateral, and cruciate ligaments. As the knee is bent, these ligaments relax somewhat and the range of rotation in the horizontal plane gradually increases as the tibia moves on to the more ball-like posterior portion of the femoral condyles. The range of rotation reaches its maximum somewhere around 90 degrees of flexion and then gradually decreases. With the knee at right angles, the normal range of rotation has been stated to be between 6 and 30 degrees with outward rotation always being greater than inward rotation^{1,2,3,6}. It should not be assumed, however, that the usual functional range of rotation of the knee reaches these extremes for the protective action of the supportive muscles usually maintains the joint within these limits and protects the ligaments against rupture.

External rotation of the tibia is maintained within normal limits by the soft tissues about the knee.

Factors Controlling External Rotation

1. When the knee is twisted, the capsular sleeve shortens to the point where the pressure between the articular surfaces of the femur and tibia stops further outward rotation. If motion is forced beyond this point, the joint capsule will

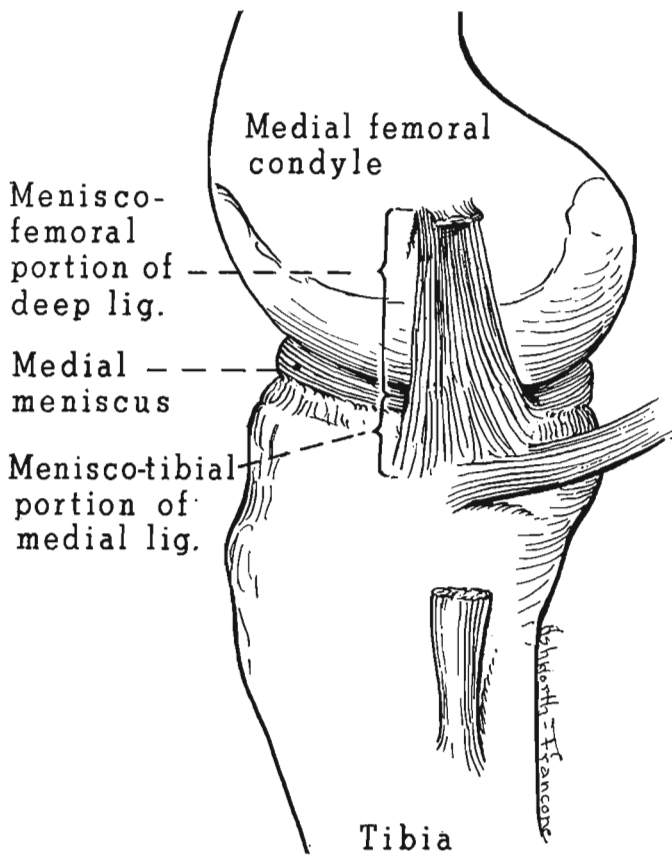


FIG. 2

The middle third of the medial capsular ligament is often called the deep layer of the medial ligament. It consists of a strong tough meniscofemoral portion and a lax and relatively weak meniscotibial portion. The upper part is attached to the medial femoral condyle somewhat forward and below the more superficial tibial collateral ligament and passes downward to be fixed to the middle third of the medial meniscus. The lower portion continues downward as the coronary ligament and is attached to the tibia just below its articular surface (modified from Last, R. J.: The Popliteus Muscle and the Lateral Meniscus, *J. Bone and Joint Surg.*, 32-B: 93, 1950).

rupture, especially if valgus stress is superimposed upon the twisting force. The position of the knee joint at the time of injury will govern the location of the tear: the anterior portion is most likely to be injured when the knee is flexed to 90 degrees or more; the posterior portion when the knee is nearly straight, and the mid-portion when the knee is flexed between 30 and 90 degrees and twisted or forced into the knock-knee position.

2. The fibers of the anterior portion of the tibial collateral ligament do not parallel the longitudinal axis of the limb but are inclined somewhat forward as they pass downward to insert on the tibia. This obliquity, together with the tension developed within it, tends to block rotation of the tibia when the knee is in the extended position. During flexion, the anterior margin of the ligament moves progressively backward so that the gap between it and the patellar tendon is widened, leaving only the capsular ligaments and their reinforcements to resist the initial stress of rotatory overpull.

3. The anterior cruciate ligament during the first 15 to 20 degrees of external rotation simply unwinds itself from the posterior cruciate ligament and does little to check this movement. With further outward rotation, the anterior cruciate ligament becomes progressively more taut until the extreme of normal rotation is

reached. At this point, it is wound tightly around the medial aspect of the lateral femoral condyle. Fortunately this seldom occurs unless the knee is flexed to 90 degrees or more.

4. The posterior third of the medial meniscus blocks external rotation of the tibia, particularly if weight is being borne on the extremity. When there is laxity of the ligaments which normally limit external rotation of the tibia, the presence of an intact posterior horn of the medial meniscus often may limit external rotation so effectively that the presence of a ligamentous tear is completely masked. However, with repetitive impingement of the meniscus against the back of the medial femoral condyle, the posterior horn will eventually give way, resulting in the syndrome of the late secondary tear of the posterior horn of the medial meniscus. When such a tear becomes evident and the meniscus is excised, the blocking effect is removed, and the rotatory instability becomes evident.

5. Whether the muscles react with the automaticity of repetitive motion or reflexly in response to tendon and ligament tension, they provide an effective companion to the ligaments in preventing excessive rotatory motion of the knee. The vastus medialis muscle effectively inhibits outward rotation of the tibia during the first 60 degrees of flexion of the knee. This is due to the anatomical arrangement of its lower fibers which derive from the distal portion of the intermuscular septum and from the epicondylar line and sweep downward and laterally to insert into the extensor aponeurosis and upper two-thirds of the medial aspect of the patella. Contraction of the vastus medialis results in upward and medial displacement of the patella, prevents lateral displacement of the patella and patellar tendon, and restrains external rotation of the tibia by tensing the medial extensor aponeurosis which inserts into the anterior-medial aspect of the upper end of the tibia through its capsular and deep fascial attachments. With further flexion of the knee this internal rotator action rapidly diminishes.

Kaplan has pointed out that the muscles in the medial side of the knee which stabilize, flex, and control its rotation in the horizontal plane are arranged into an anterior group consisting of the sartorius and gracilis and a posterior group composed of the semimembranosus and semitendinosus. These two groups of muscles are joined together by only a thin layer of fascia so that there is an area between them not reinforced by muscle where separation may occur. It is evident that, despite the powerful muscles which guard the medial side of the knee, they do not completely cover the medial aspect of the joint and hence do not afford complete protection against rotational and valgus stress.

Pathology

Rupture of the medial capsular ligament is the basic lesion which permits abnormal external rotation of the tibia. This may occur either as an isolated lesion or in association with adjacent capsular tears, rupture of the overlying tibial collateral ligament, or rupture of the anterior cruciate ligament. The lesion may involve either the strong, tough meniscofemoral portion of the ligament or the relatively weak meniscotibial portion, or both. The mechanical basis of the isolated lesion of the medial capsular ligament is abduction of the knee when it is flexed to 90 degrees, or thereabouts, combined with external rotation of the tibia. In this position the vertical anterior fibers of the tibial collateral ligament have moved backward, widening the gap between it and the patellar tendon and, thus, allowing the full stress to fall on the capsular ligaments. The combined ligamentous lesions occur with the knee in lesser degrees of flexion at the time the initial force is applied. It has been noted that the longitudinal axis about which the knee rotates in the horizontal plane lies at or near the medial tubercle of the tibial plateau. When the

restrictive action of the medial capsular ligaments has been released following rupture, this pivotal point shifts lateralward and permits abnormal forward and lateral movement of the tibia. The degree of shift progressively increases as the tibial collateral ligament gives way under further rotational stress so that when it is torn completely the center of rotation in the horizontal plane moves toward the lateral tibial plateau. As this is occurring, the anterior cruciate ligament unwinds itself from the posterior cruciate and relaxes. With further outward movement in the horizontal plane and especially if there is accompanying valgus stress, the anterior cruciate ligament tenses and finally ruptures as it is forced around the lateral femoral condyle. The sequence of injury is first rupture of the medial capsular ligament, second, rupture of the tibial collateral ligament, and third, rupture of the anterior cruciate ligament. These lesions will tend to overlap to some extent depending on the degree of valgus stress superimposed on external rotation.

Since the medial meniscus is intimately bound to the medial capsular ligament, it may remain attached either to the menisiofemoral portion or the meniscotibial portion of that ligament or be torn completely free from its ligamentous attachment at some point along its periphery. In fresh lesions, tears within the body of the meniscus are not usual for trauma opens the joint rather than squeezing it together. In lesions of long standing, meniscal impingement occurs and degenerative changes and lacerations are found with increasing frequency.

The Rotatory Instability Test

Traditionally, physical examination of the ligaments of the knee has been directed toward detection of pathologically increased anterior-posterior motion and valgus and varus relaxation. With our increasing appreciation of the clinical importance of torsional laxity and its surgical correction¹³, it became necessary to develop a reasonably sensitive testing method to detect defects in the meniscal-ligamentous system which permits external rotation of the tibia on the femur. The following factors were considered:

1. The knee must be flexed to the position of maximum normal rotational play.
2. The effect of gravity on ligamentous tension must be eliminated by support of the foot.
3. The integrity of the lateral and posterior-lateral ligaments must be tested to determine the extent to which they allow pathologically increased external rotation and to localize lesions permitting forward and lateral subluxation of the tibia. On the basis of surgical observation, it was determined that if the tibia were internally rotated about 30 degrees, intact lateral ligaments would tense sufficiently to prevent forward dislocation of the tibia on the femur even though complete rupture of the medial and anterior cruciate ligaments was present.
4. The position of 15 degrees of external rotation of the leg and foot appeared to be the position of greatest relaxation of the medial and cruciate ligaments in most instances and was, therefore, selected as the starting point for determining rotatory instability.
5. The rotatory instability test is said to be positive when pathologically increased forward and outward displacement of the tibia on the femur is possible when the tibia is pulled forward while externally rotated 15 degrees, with the knee flexed to right angles and the foot supported to eliminate gravitational tension. Arbitrary standards were established: The degree of relaxation of the normal knee is taken as zero. Forward dislocation up to one-half of an inch is rated one plus, between one-half and three-fourths of an inch is rated two plus, and more than three-fourths of an inch is rated three plus. Although the extent of displacement is estimated in routine examination, it may be measured accurately by lateral stress roentgenograms. The test is performed in the following manner:

The patient lies on his back in the dorsal recumbent position on the examining table. The affected knee is then flexed to a right angle to provide the position of greatest normal rotational laxity. The ankle is plantar flexed until the foot rests flat on the examining table. The examiner then sits on the dorsum of the patient's foot to stabilize it and places his hand behind the knee to ensure relaxation of the hamstring muscles. He then pulls the tibia forward as in testing for anterior cruciate instability. The test is carried out in two positions: first, with the foot and leg in 30 degrees of inward rotation and, second, with the foot and leg in 15 degrees external rotation. Necessary adjustments are made for torsional abnormalities of the tibia. The degree of rotational instability of the anteriorly displaced tibia in both positions is then recorded. It will be noted that the recumbent position eliminates the downward drag of gravity which in the sitting position often tightens the ligaments of

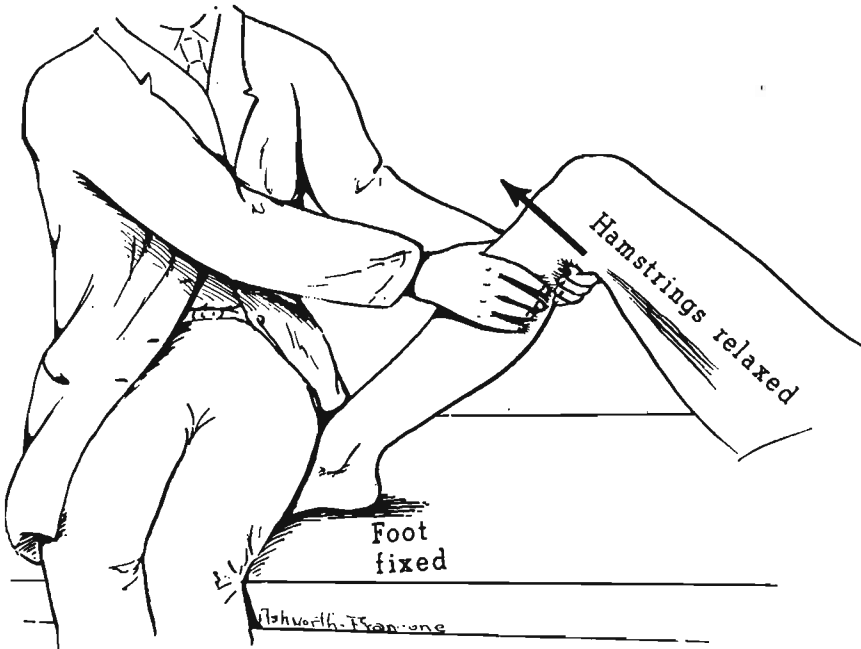


FIG. 3

The rotatory instability test: The patient is placed in the dorsal recumbent position with the knee flexed to 90 degrees and the foot fixed to the examining table by the physician. The tibia is now pulled forward on the femur as in testing for anterior cruciate instability. This is carried out in each of two positions: In the first position, the foot and leg are placed in 30 degrees of internal rotation to tighten the lateral and posterolateral ligamentous apparatus to a point where forward displacement will be prevented. In the second position, the foot and leg are placed in 15 degrees external rotation. In this position the anterior cruciate and lateral ligaments are relaxed and permit forward and outward movement of the medial side of the tibia if the medial capsular ligaments have been ruptured. Forward displacement is estimated at one-half inch or less, when laxity is rated, one plus, two plus between one-half and three-fourths inch, and three plus, over three-fourths of an inch.

the knee to a point where the increased tension minimizes forward displacement of the tibia. The opposite normal knee should always be tested for comparison. At operation, if the table is in the straight position, the test may be performed as described above with the assistant stabilizing the foot. When the knee is flexed to 90 degrees and the leg is hanging over the end of the table, the foot is supported on the sterile draped surgeon's lap and the test carried out in the usual manner.

The rotational instability test is a modification of the test for the anterior drawer sign, but the interpretation of findings is quite different. In the first position where the foot is placed in 30 degrees of internal rotation and the tibia drawn for-

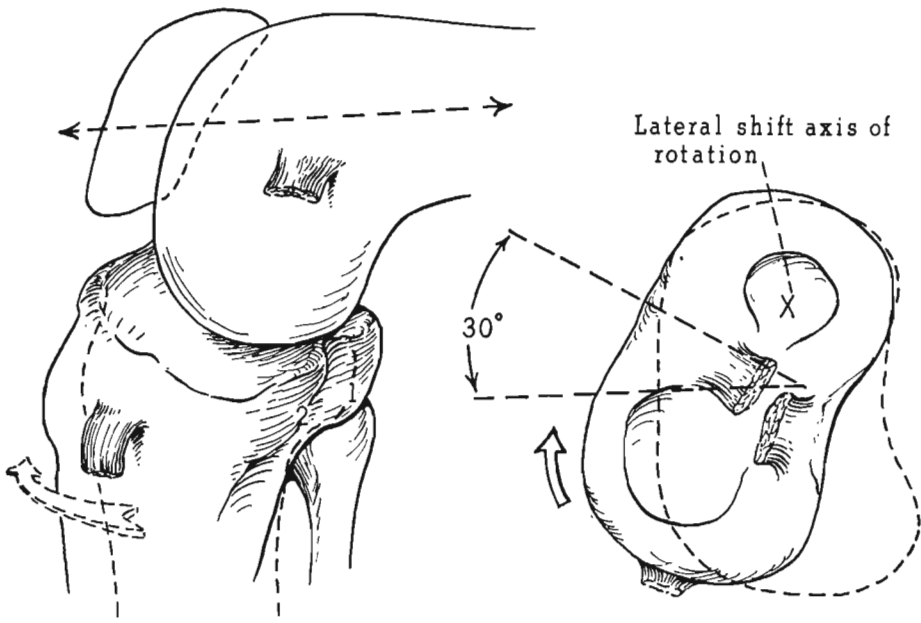


FIG. 4-A

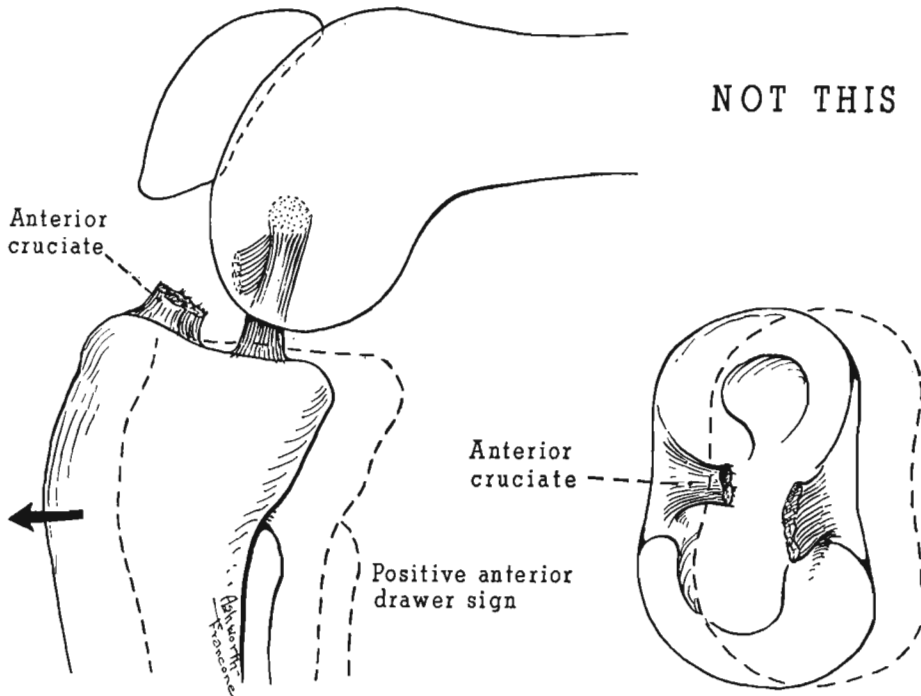


FIG. 4-B

Figs. 4-A and 4-B: Pathological external rotation of the tibia on the femur increases following successive rupture of the medial capsule, the tibial collateral ligament, and the anterior cruciate ligament and is demonstrated by the rotatory instability test.

Fig. 4-A: From above, the medial aspect of the tibia is seen to move forward and outward from its normal rest position represented by the dotted line. When this motion exceeds 30 degrees, it is usually considered to be pathological. Individual variations in normal rotation are determined by examination of the normal knee. When viewed from the inner side, the tibia does not subluxate, (1) but on the medial side of the joint it moves forward and outward on the femur, (2) an intact posterior horn of the medial meniscus can block this movement but repeated impingement will cause wear changes which result in the late posterior medial meniscal tear.

Fig. 4-B: The drawer sign evaluates straight forward movement of the tibia on the femur rather than rotatory movement. It is not an accurate test for the integrity of the anterior cruciate ligament.

ward, the posterolateral capsule, the posterior cruciate ligament, the popliteus tendon, the fibular collateral ligament, and the terminal portion of the tensor fasciae latae are placed under increased tension and forward dislocation of the tibia is prevented. If increased anterior instability is present in this position, it indicates damage to these structures as well and the subsequent test for medial rotatory instability is of less value.

In the second position where the foot is placed in 15 degrees of outward rotation, rotatory stress is placed on the ligamentous structures on the inner side of the knee joint, first on the medial joint capsule, then on the longitudinal anterior portion of the tibial collateral ligament, and finally on the anterior cruciate ligament as the tibia is pulled forward. It was noted previously that, with the successive rupture of each of these structures, the longitudinal axis of rotation in the horizontal plane moves progressively lateralward from its normal position at the medial tubercle of the tibial plateau so that in the more severe cases of abnormal external rotation the pivotal structures are the lateral and posterolateral ligaments of the knee. When the test was performed at operation, direct observation revealed that, in patients with intact lateral structures, what first appeared to be purely forward displacement of the tibia in the anterior-posterior plane was indeed a combination of this movement with outward tibial rotation as the medial tibial articular facet was subluxated forward and the lateral articular facet rotated on the lateral femoral condyle. Furthermore, when only moderate relaxation of the medial ligaments was present, forward and outward rotation could often be blocked by the presence of an intact posterior horn of the medial meniscus, resulting in a false negative test. In such instances, the test became positive immediately following medial meniscectomy.

While this test is not specific for any one ligament, certain inferences may be drawn from a positive result. Any significant abnormal external rotation of the knee in the horizontal plane, that is, forward and lateral drift of the medial aspect of the tibia as it pivots about the outer side of the joint, indicates that there is a major disruption of the medial capsular apparatus. This agrees with our clinical findings and with the experimental work of Kennedy who demonstrated that forced external rotation of the flexed knee results in consistent rupture of the deep capsular portion of the medial ligament. This rupture may exist without rupture of the anterior cruciate ligament or tearing of the superficial layer of the medial ligament. When the superficial portion of the medial ligament is intact, injury must have occurred with the knee in flexion since in this position the tibial collateral ligament moves posteriorly and offers little protection against external rotation stress. Greater degrees of instability suggest injury to the superficial layer of the tibial collateral ligament and anterior cruciate ligament.

The extent of ligamentous injury in the medial side of the knee cannot be determined by the rotatory instability test alone for it is primarily designed to reveal defective external rotational stability. Results of this test must be correlated with those found in other stress tests to evaluate accurately the size and location of rupture or relaxation of ligamentous support. When the forced valgus test is performed with the knee in full extension, the knee becomes locked against valgus stress as long as the posterior cruciate ligament and the posterior capsule are intact. This holds true despite rupture of the tibial collateral and anterior cruciate ligaments. When valgus stress in extension reveals mild valgus relaxation, extension of the ligamentous tear into the posterior capsule is anticipated; when moderate or marked relaxation is present, the lesion will usually be found to include the posterior cruciate ligament. When the valgus stress test is performed with the knee flexed to 30 degrees, the rotational factor must be taken into account. In this position the posterior capsule re-

laxes and no longer restricts valgus stress; the cruciate ligaments tense strongly if the tibia is internally rotated and relax somewhat if the tibia is mildly externally rotated. The leg naturally falls into mild external rotation when the patient is either sitting or recumbent. It is in either of these positions, with the leg falling into some external rotation, that the valgus stress test is usually performed. A positive result then indicates not only valgus instability but an element of rotational instability as well. The external rotation of the tibia is responsible for the correlation between the result of the forced valgus test with the knee flexed 30 degrees and that of the rotatory instability test. If the valgus stress test is repeated with the tibia held in internal rotation, the degree of valgus laxity will be sharply diminished.

Another important structural factor which is routinely evaluated is the degree of lateral subluxation of the patella which can be elicited in the sitting position as well as the extent of pathologically increased lateral mobility of the patella with the knee in the extended position. This indicates loss of the stabilizing action of the vastus medialis on the patella. When an increased degree of dislocation is found in combination with the rotatory instability test, the lesion is more likely to be placed anteriorly and to involve the extensor retinaculum.

Finally mention should be made of the anterior drawer sign. As the test for the anterior drawer sign is usually carried out with the patient sitting, the knee flexed to 90 degrees, the thigh supported on the examining table, and the leg hanging free, suspended by the ligaments of the knee, and the foot unsupported, it does not discriminate between lesions of single ligaments. Although the test was designed to determine the integrity of the anterior cruciate ligament, the fact that a lesion of the anterior cruciate probably never exists as an isolated entity does much to defeat the purpose of the test. The diagnosis of anterior cruciate rupture can only be predicted with fair reliability when forward dislocation of the tibia is three-quarters of an inch or more. With lesser degrees of dislocation, false positive results are usually due to the rotational element associated with ruptures of the medial capsule. False negative results may be attributed to ligamentous tension associated with gravitational pull of the unsupported leg, blockage of forward dislocation by an intact posterior horn of the meniscus, or by failure to place the tibia in neutral or slightly externally rotated position as forward displacement is attempted. Thus it may be said that a hierarchy of tests exists—the most sensitive one indicating ligamentous decompensation being the rotatory instability test, next the same test performed with the tibia at 0 degrees of tibial rotation, next the valgus stress test at 30 degrees of flexion, and the others (valgus stress test at 0 degrees flexion, the anterior drawer sign test with the foot unsupported, associated lateral patellar subluxation and so forth.)

Clinical-Pathological Correlation

This study of seventy-six patients personally examined and operated on represents our interpretation of the basic pathological features of rotatory instability and its related clinical findings. Rotatory instability is a functional deficit and is but a segment of a more general involvement of the meniscoligamentous system. As an isolated entity it is mainly found as a residuum where meniscectomy or other surgery has been done; this does not necessarily mean that other functional defects did not also exist; it may mean that they have been minimized through the natural healing process or with the aid of surgery. The case studies presented here represent those patients in whom clinically significant rotatory instability was present and for whom adequate data were available. Excluded were cases of lesser internal derangement requiring simple meniscectomy or excision of loose bodies, operations for dislocating patella or for degenerative conditions secondary to trauma, and for more extensive

traumatic conditions involving dislocation of the knee or rupture of the posterior cruciate ligament.

In each of the patients reported here, the medial, lateral, and posterior ligaments were tested for stability, and the rotatory instability test was performed. Patients who revealed more than mild laxity of the lateral or posterior lateral soft tissues or significant laxity of the posterior cruciate ligament were not included in this study. In each instance the pathological findings were verified by operation. A wide surgical exposure permitted examination of the medial capsule from the patellar tendon to at least the posterior medial angle of the joint and of the tibial collateral ligament from its epicondylar origin on the femur to its attachment on the medial face of the tibia. The anterior cruciate ligament was observed and tested for continuity by means of a blunt hook and by forward displacement of the tibia in all but the few patients in whom the joint was not opened. It is appreciated that a lesion of the anterior cruciate ligament may be easily overlooked, especially when the synovial membrane which normally covers it is intact. For this reason it has been our practice to open the synovial membrane and to observe the ligament directly to verify whether or not a tear is present when the ligament gives the appearance of being relaxed. When operation was performed soon after the injury, ligamentous tears could be identified by direct observation; later, ligamentous defects, relaxation, and scarring were taken as evidence of injury. The integrity of the medial meniscus and its ligamentous attachments was routinely noted.

For the purpose of analysis, the patients were grouped into four categories: Group I, rotatory instability associated with acute ligamentous injury; Group II, chronic rotatory instability; Group III, rotatory instability discovered at operation after meniscectomy; Group IV, chronic rotatory instability in patients with previous knee surgery.

The mechanism of injury was known for all but one patient; the usual history was one of violent external rotation of the knee when it was in the bent position. Significantly, the greater number of our patients were athletes, who were participating in sports at the time of injury. While running the athlete is particularly susceptible to external rotation injury, for the knee is flexed from the time the foot strikes the ground until the trailing leg is just about to leave it. There were sixty-five athletic injuries. Forty of these occurred in football: twenty-five injuries resulted from lateral or posterolateral blows to the weight-bearing leg while running (clipping), nine injuries occurred when the patient twisted a leg when suddenly changing direction while running (cutting), five injuries resulted from gang tackles; one result occurred when the patient received a lateral blow to the leg while standing. Seven basketball players were injured on descending from a jump or pivoting on the affected leg and two as the result of player collision. Nine skiing and two tobogganing injuries involved violent external rotation of the leg. In the remaining seven sports injuries, two were incurred in wrestling, two in gymnastics, one in rugby, one in running, and one in stream fishing. There were eight work injuries; one patient caught his foot in a hole while walking over rough terrain; three slipped and twisted a leg; three twisted a leg when they jumped from the tailgate of a truck; one was struck by a moving cable. There was one home and one auto-train accident.

Age, sex, and side of injury were reviewed. Ages ranged from fourteen to fifty-three years, with sixty-four of the patients falling in the fourteen to twenty-six-year-old age group. The greatest incidence (twenty-four) was in the seventeen and eighteen-year-old patients. This age distribution corresponded with the frequency of exposure to injury and to athletic and work experience. Sixty-eight of the injured patients were male and eight were female. This reflected the degree of exposure to injury in the sexes. No significance was attached to the fact that forty patients injured the right knee and thirty-six injured the left knee.

TABLE I

GROUP I: CORRELATION OF OPERATIVE FINDINGS WITH RESULTS OF ROTATORY INSTABILITY TEST
Acute Injuries

REFERENCE LINE	ROTATORY INSTABILITY TEST		MEDIAL CAPSULAR LIGAMENT	TIBIAL COLLATERAL LIGAMENT	CRUCIATE LIGAMENT	MEDIAL MENISCUS
	AT 30° IR	AT 15° ER				
1	0	0	△△△	○●○	○○○	□□■
2		+	△	○	○	□
3		++	△△△△△ △△△△	○●●●●○ ○●●○	○○○○○ ●○○○	■□□□□ □□□□
4		+++	△R△△△△	●R●●●●○	○○○○○○○	□□□□□□
5	+	+++	△△△△△	●●●●●●	○○●●○	■□□□□

△ = Segments of ligament: left is anterior, base is middle, right is posterior. Shaded where torn.

○ = An intact ligament. Shaded if torn or absent (◐ partial, ● complete).

□ = Avulsion of the meniscus. Shaded where torn.

R = A relaxed, lengthened ligament or attachment.

Acute injuries were operated on within two weeks of injury. At 0 degrees of rotation, forward mobility of the tibia was zero for patients in Lines 1 and 2, and was extensive (++) for those in Lines 4 and 5. Half of the patients in Line 3 had mild mobility (+) at 0 degrees of rotation and half had extensive (++) mobility. At complete extension, valgus stress revealed significant relaxation in two patients in Line 3, three in Line 4, and four in Line 5. Valgus stress revealed significant relaxation at 30 degrees of flexion in one patient in Line 1, one in Line 2, all in Lines 3 and 5, and all but one in Line 4.

The twenty-four patients in Group I, who were operated on soon after the initial injury, provided the clearest picture of the pathological changes responsible for rotatory instability. The mid-portion of the medial capsule (the deep layer of the medial ligament) was found to be torn in every patient, for it is attached to the femur above and the tibia below and tenses under rotational stress. Its posterior margin is reinforced by the oblique fibers of the tibial collateral ligament and is the strongest part of the mid-capsule. In contrast to those patients with long-standing disability, the incidence of anterior cruciate rupture was surprisingly small (five cases). The medial meniscus was injured in every patient. It was avulsed from its peripheral ligamentous moorings in all but one patient—completely in eight, anteriorly in three, and in the posterior two-thirds in twelve. Injuries to the body of the meniscus were infrequent since the joint surfaces on the inner side of the knee are forced apart rather than compressed in this type of injury. Three menisci had minor longitudinal splits. One was in the posterior horn and not associated with ligamentous avulsion, one was in the posterior horn and was associated with anterior avulsion, and one was in the anterior portion of the meniscal body and was associated with a posterior peripheral avulsion.

When the rotatory instability test was performed with the leg in 30 degrees of internal rotation, forward dislocation was absent in all but five patients in whom it was one plus. This was interpreted to indicate no lateral ligament laxity in the nineteen patients without forward dislocation and minimum relaxation in the

TABLE II

GROUP II: CORRELATION OF OPERATIVE FINDINGS WITH RESULTS OF ROTATORY INSTABILITY TEST
Subacute and Chronic Ligament Injuries without Previous Surgery
(Symbols same as in Table I)

REFERENCE LINE	ROTATORY INSTABILITY TEST		MEDIAL CAPSULAR LIGAMENT	TIBIAL COLLATERAL LIGAMENT	CRUCIATE LIGAMENT	MEDIAL MENISCUS
	AT 30° IR	AT 15° ER				
1	0	0				
2	+	+	RRRR	RRRR	00●●	0OR■
3	+	++	RRRRR RRRR	ROORO RRRR	00000 ORO●	□0■□■ R■R□
4	+	+++	RRRRR	RORRR	●0●R●	R■□R■
5	+	0 ++ +++	R R R	0 R R	● ● ●	R R ■
6	++	+	R R	R R	0 ●	0 □

Interval from injury to surgery, five weeks to eighteen years. At 0 degrees of rotation, forward mobility of the tibia was moderate for three patients in Line 3 and for all but one in Lines 4, 5, and 6. At extension, valgus stress showed no relaxation of the medial structures in any patient. At 30 degrees of flexion, valgus stress showed relaxation in four patients each in Lines 3 and 4 and one each in Lines 5 and 6.

remaining five patients. Clinically, when the tibia was placed in 15 degrees of external rotation, forward dislocation was always greater than that found with the knee in the neutral zero position of rotation.

With the knee in the 15-degree externally rotated position, four patients had forward dislocation of zero or one plus and two of these had lesions limited to the capsule alone; the remaining two patients presented partial tears of the tibial collateral ligament in addition. When forward dislocation was two plus, the capsular ligaments alone were involved in two patients, the capsular and tibial collateral ligaments in four patients, and the capsular tibial collateral and anterior cruciate ligaments in four patients. When three plus, the capsular and tibial collateral ligaments were torn in eight patients and the capsular, tibial collateral, and anterior cruciate ligaments in two patients. The rotatory instability test was felt to be a fairly accurate index of pathological external rotation of the tibia, but it did not reflect the integrity of the anterior cruciate ligament.

In Group II there were twenty-three patients with rotatory instability who had chronic unstable knees following old ligamentous injury. The relaxation of the joint on testing for the ligaments reflected the lengthening that had taken place after healing was complete. All patients showed a moderate to severe relaxation of the medial capsule. The tibial collateral ligament was intact in four patients, showed marked relaxation in five patients, and was mildly to moderately relaxed in the remainder. The rotatory instability test was positive in all patients: one plus in seven patients, two plus in twelve patients, and three plus in four patients. Forward dislocation of the tibia on the performance of the rotatory instability test was not an

accurate index of anterior cruciate ligament involvement. In the fourteen instances in which it was torn, three patients were rated one plus, six two plus, and five three plus. In the nine patients in whom the anterior cruciate ligament was intact, dislocation was one plus in four, two plus in four, and three plus in one. A review of the lesions of the meniscus revealed that there was either peripheral avulsion or ligamentous laxity in ten patients. In three of these the lesion was anterior, in four it was posterior, and in three it was complete. The meniscus was torn in eight patients: six of the lacerations were in the posterior horn and two were of the bucket-handle type. One patient had marked peripheral ligamentous laxity of the anterior two-thirds of the meniscus in combination with a tear of the anterior horn. Four patients had no meniscal involvement which could be demonstrated.

The results of the forced valgus test with the knee in 30 degrees of flexion showed a rough parallelism between the relaxation found on that test and the rotatory instability test. The explanation lies in the fact that in testing for valgus laxity with the knee partially flexed, the leg and foot naturally fall into some external rotation. Performed in this manner the test represents a combination of rotational laxity and true medial ligamentous relaxation. The degree of laxity may be sharply decreased if the tibia is consciously internally rotated and the test repeated.

In Group III there were twelve patients in whom rotatory instability could not be demonstrated until after the medial meniscus had been excised. In all of them instability was either absent or deemed inconsequential at the time of clinical examination. Once this syndrome was recognized, external rotation was checked routinely with the patient's knee flexed to 90 degrees over the end of the operating table both before and after medial meniscectomy. During this maneuver it was interesting to note that it was the posterior horn of the meniscus which blocked the forward and outward drift of the tibia. This movement occurred freely after meniscectomy. In the four patients in whom the anterior ligamentous attachments of the medial meniscus were markedly lax, we could not determine whether this was due to avulsion at the time of the initial injury or the result of repetitive rotational strain. The remaining eight patients had tears in the body of the meniscus which were anterior in one, posterior in three, and complete in four. Medial capsular ligament laxity was mild in two patients, moderate in four, and marked in six. In only five patients was there significant relaxation of the tibial collateral ligament: two had mild relaxation, two moderate relaxation, and one severe relaxation. The significance of the discovery of rotatory instability at the time of surgery is evident: if uncorrected, the patient will be relieved of symptoms of meniscal impingement as the result of his meniscectomy, but he will usually complain of increasing instability and the surgeon will be able to demonstrate that rotational and valgus laxity is greater than prior to operation. Furthermore, it is our impression that persistent unrecognized abnormal rotation is one of the important contributing factors to the narrowing of the medial joint space which often occurs several years after meniscectomy.

Group IV comprised seventeen patients who had had meniscectomy or ligament repair. They were classified as therapeutic failures since they were unable to engage in their usual sports and work activities and complained of continuing pain and instability; they presented signs of persistent synovial irritation. All had a markedly positive rotatory instability test: thirteen had a moderate to severe relaxation of the medial ligaments on valgus stress in 30 degrees of flexion but not in extension; fourteen had either a complete or partial rupture or marked relaxation of the anterior cruciate ligament. Eleven of these patients had had meniscectomies. Eight of these were medial; and, at the time of secondary surgery, two patients were found to have a lacerated posterior horn of the medial meniscus and a tear of the lateral meniscus.

Two patients had been operated on for tears of the lateral meniscus. One of these had both a tear in the anterior horn of the medial meniscus and a lacerated posterior horn of an incompletely removed lateral meniscus; the other did not leave a meniscal lesion. Fourteen of the seventeen patients in this group had tears of the anterior cruciate ligament. In most patients it was not possible to determine (1) if the lesion was present but not recognized at the time of the original surgery, (2) if the lesion was not thought to be reparable at the time of original surgery, (3) whether the lesion had been repaired and subsequently degenerated, (4) if the lesion was part of a more widespread ligamentous injury which had healed to a point where rotatory instability was the principle residuum, or, (5) if the lesion had been caused by trauma subsequent to the initial surgery. When questioned, all patients complained of repeated episodes of discomfort and occasional sprain of the knee, but none had a history of a secondary major ligamentous injury.

Summary

Rotatory instability of the knee permitting abnormal external rotation of the tibia on the femur is the result of forced abduction of the flexed knee and external rotation of the tibia. The basic lesion which is present in all patients is a tear in the medial capsular ligament. Occasionally, this may be present as an isolated lesion but more commonly there are associated lesions of the tibial collateral and anterior cruciate ligaments. A test for rotatory instability of the knee, based on the modification of the test for the anterior drawer sign has been presented. The essential feature of this test is the demonstration of a lateral shift of the longitudinal axis of rotation in the horizontal plane following rupture of the medial capsular ligament. It is stressed that rupture of the anterior cruciate ligament need not be present when the test is positive for rotatory instability, although it is most markedly positive when the anterior cruciate is torn.

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