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Classification of Knee Ligament Instabilities Part I. The Medial Compartment and Cruciate Ligaments^{*}

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ABSTRACT: Based on the clinical and operative findings in sixty-eight knees with acute tears of the medial-compartment and cruciate ligaments, a standardized terminology and classification of knee ligament instability is presented. With an intact posterior cruciate ligament, anteromedial, anterolateral, or posterolateral rotatory instability may occur, but not true posteromedial rotatory instability. With the posterior cruciate ligament ruptured, straight anterior, posterior, medial, or lateral instability may be found.

After acute complete ligament tears the knee is relatively painless. There is usually no swelling, locking, or functional impairment for walking, but the patient is disabled for running, cutting, pivoting, and twisting. With an isolated medial-compartment tear. the abduction stress test is positive at 30 degrees of flexion and negative at zero degrees. With an associated acute tear of the posterior cruciate ligament, the posterior drawer test is often negative, and the most specific test for an acute tear of this ligament is a positive abduction stress test with the knee at zero degrees of flexion. Rupture of the anterior cruciate ligament is not the primary cause of a positive anterior drawer test. This test is most consistently positive with tears of the meniscotibial ligament and less so with meniscofemoral tears. An associated tear of the anterior cruciate ligament or posterior oblique ligament augments a positive anterior drawer test.

In 1941, Brantigan and Voshell were bewildered by the vast amount of literature concerned with the movements of the knee joint and the function of its ligaments. Today this bewilderment persists, despite their excellent anatomical studies and those subsequently reported by others. Only correlation of accurate clinical findings, operative observations, and data from functional studies of anatomical specimens can overcome this confusion. For such accurate observations to be made, however, there must be a universally accepted, standardized, and workable anatomical, clinical, and operative nomenclature.

It is our purpose in this report to describe our nomenclature, method of clinical evaluation, and classification of ligament instabilities. In addition, we will record and correlate the clinical and operative findings in sixty-eight patients with medial-compartment and cruciate ligament injuries (Part I) and in eighty-nine patients with lateral-compartment injuries (Part II) in order to document the evidence in support of our classification.

Anatomical Terminology

Over the years such terms as "medial collateral ligament" and "superficial and deep layers of the medial collateral ligament" have evolved. In 1950, O'Donoghue stated that the orthopaedist diagnosing and treating knee injuries needs more terms than have yet been provided. This statement is even truer today, when precise communication concerning anatomical structures not adequately described in standard textbooks is urgently needed.

The supporting structures of the knee are divided into two major groups: (1) the static stabilizers (ligaments), which are further divided into two layers, capsular and non-capsular ligaments, and (2) the dynamic stabilizers (musculotendinous units and their aponeuroses). The supporting structures are further divided into those of the medial compartment (Fig. 2), considered to extend medially from the patellar tendon to the posterior cruciate ligament, and those of the lateral compartment, considered to extend

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laterally to the posterior cruciate ligament. In each compartment there is a capsular ligament intimately attached to the meniscus and divided into meniscofemoral and meniscotibial portions (Fig. 3). The anterior and middle thirds of the capsular ligaments in the two compartments are similar. In the anterior one-third the ligaments are thin, loose, and covered superficially by the extensor retinaculum of the quadriceps mechanism, which functions as a dynamic stabilizing aponeurosis. In the middle one-third the capsular ligaments are strong and supported superficially by the tibial collateral ligament medially and the iliotibial band laterally. The middle one-third of the lateral capsular ligament is continuous with the fat pad and it is for this reason that it has been misinterpreted as being an insignificant structure anatomically and functionally.

In the posterior thirds of the two compartments the capsular ligaments differ. The thickened posterior onethird of the medial capsular ligament is termed the posterior oblique ligament⁹. Its supporting function is augmented by the dynamic stabilizing effect of the capsular arm of the semimembranosus tendon and its aponeurosis, the oblique popliteal ligament (Fig. 4). In a somewhat different arrangement, the posterior one-third of the lateral capsular ligament is composed of the fibular collateral ligament, the arcuate ligament, and the aponeurosis of the popliteus muscle. The supporting function of this arcuate complex is augmented by the dynamic effects of the biceps femoris and popliteus muscles. The medial and lateral heads of the gastrocnemius also support their respective compartments dynamically.

The central ligaments are the anterior and posterior cruciates. The anterior cruciate ligament extends from the lateral femoral condyle to the tibial surface in front of the medial tibial tubercle. When the knee is flexed 90 degrees this ligament is oriented almost parallel to the tibial plateau. The posterior cruciate ligament, attached posteriorly on the tibia, has a fan-shaped line of attachment on the medial femoral condyle which resembles the line of the plotted instant centers of rotation. When the knee is in full extension (in the standing position), the posterior cruciate ligament forms an angle of about 30 degrees with the horizontal. This angle changes minimally during the first 90 degrees of flexion, and throughout the full range of motion the posterior cruciate ligament remains taut. This ligament appears to be located in the center of the joint and to function as the axis about which the knee moves both in flexion-extension and in rotation. It, therefore, is the fundamental stabilizer of the knee.

For the purposes of standardizing evaluation and recording, in 1968 the Committee on the Medical Aspects of Sports of the American Medical Association published a handbook entitled "Standard Nomenclature of Athletic Injuries." In this book, a *sprain* is defined as an injury limited to ligament (connective tissue attaching bone to bone) and *strain*, as a stretching injury of muscle or its tendinous attachment to bone. In order to designate the degrees of severity in a standardized fashion, a mild (first degree) sprain of a knee ligament is defined as a tear of a minimum number of fibers of the ligament, with localized tenderness but no instability; a moderate (second degree) sprain, as a disruption of more fibers with more generalized tenderness but no instability; and a severe (third degree) sprain, as a complete disruption of the ligament with resultant instability.

Similarly, this publication³ proposed gradations of severity for evaluating the degree of instability demonstrated during stress testing. A mild (1+) instability indicates that the joint surfaces separate five millimeters or less; a moderate (2+) instability, that they separate between five and ten millimeters; and a severe (3+) instability, that they separate ten millimeters or more. Thus, a 3+ abduction stress test indicates more than ten millimeters of opening on the medial side of the joint and a 3 + anterior drawer test, anterior displacement of the tibia with respect to the femur in excess of ten millimeters. In the present study these measurements were established by measuring the displacement at the time of operation with the joint space exposed and by correlating this displacement with the clinical impression recorded before arthrotomy. Obviously, such measurements are not precise, but they provide a workable scale for clinical purposes. In the knees with a 3+ clinical abduction stress test or a 3+ clinical anterior drawer test, the displacements certainly seemed much greater than ten millimeters in most instances (and often were greater), but measurements at operation confirmed that the actual separation was not in excess of ten millimeters in many knees even though the severity had been graded 3+ preoperatively.

Clinical Examination

The clinical evaluation of an acutely injured knee should be carried out as soon after injury as possible, since the history and mechanism of the injury are important aids in diagnosis. The ideal situation is when an orthopaedic surgeon is present at the time of injury, as team physician, and witnesses the accident and examines the injured knee before muscle spasm commences.

It is important to know whether pain is present or not and whether the person can walk without pain. Information relative to intra-articular fluid accumulation is a vital part of the history. An accumulation of fluid noted within two hours of injury indicates hemarthrosis, whereas that which appears twelve to twenty-four hours after injury indicates a synovial effusion. Absence of swelling indicates a tear sufficiently severe that the fluid extravasates into the soft tissues surrounding the joint. The presence of a hemarthrosis suggests that there has been an anterior cruciate tear, osteochondral fracture, peripheral meniscal tear, or incomplete ligament sprain. A tear of the posterior cruciate ligament, however, is usually associated with such extensive capsular tears that extravasation prevents the accumulation of fluid within the joint. Tenderness, elicited by moderate or firm palpation, or localized edema may indicate the anatomical site of the tear. Neurovascular

KNEE Ligamentous Injuries

Pts. Name	Hist. No.	PR	PRE-OP		ANESTHESIA	
		Lt.	Rt.	Lt.	Rt.	
ANTERIOR DRAWER TEST *						
EXTERNAL TIBIAL ROTATION						
NEUTRAL TIBIAL ROTATION						
INTERNAL TIBIAL ROTATION						
POSTERIOR DRAWER TEST						
JERK TEST						
EXTERNAL ROTATION - RECURVATION TEST						
RANGE OF MOTION - DEGREES **						
ABDUCTION STRESS	TEST					
HYPEREXTENDED						
0 DEGREES						
30 DEGREES					_	
ADDUCTION STRESS TEST						
HYPEREXTENDED						
0 DEGREES						
30 DEGREES						

DIAGNOSIS

AGE	MECHANISM
COLOR	POSITION PLAYED
SEX	SWELLING
DATE OF INJURY	ECCHYMOSIS
DATE SEEN	PUFFINESS
DATE OF OPERATION	TENDER AREA
ETIOLOGY-SPORT	AMBULATORY

• This is recorded as +M if it appears to be a mild anteromedial rotatory instability; +L if anterolateral; and +M -L if it appears to be combined.

** This is primarily intended to show recurvatum or hyperextension, and when present is recorded as minus (-) degrees.

FIG. 1-A

Form used for evaluation of ligament stability in every acutely injured knee which requires surgical repair. In one column the preoperative examination is recorded at the time of the first evaluation, while in the column entitled "Anesthesia" the comparable findings after the patient has been anesthetized are listed.



FIG. 1-B

The line drawings on which the tears of the ligaments and other lesions found at operation are drawn. The list of anatomical structures at the top is used to check the ones involved.

structures may be damaged in any knee injury and it is important to establish and record the status of the pulses and the nerves promptly.

Once one has gathered this information, the next stage of the examination should determine whether instability is present by the following tests.

Abduction Stress Test

The most common mistake when performing this test is to attempt to abduct the leg forcibly with the knee fully extended and, on finding little or no valgus instability, to conclude that the test demonstrates adequate medial joint stability.

The abduction stress test should be performed first on the normal extremity. This is especially important in the acutely injured patient since it shows the patient what to expect and, therefore, gains his confidence by demonstrating that the test will not be rough and is likely not to be painful. Furthermore, testing the normal knee establishes a baseline for evaluating the stability of the injured knee.

Position the patient supine on the examining table (Fig. 5), head resting on a pillow, with the lower extremities free of drapes and clothing. Abduct the injured extremity slightly at the hip, and extend it so that the thigh is resting relaxed on the surface of the table. Flex the knee to 30 degrees over the side of the table, place one hand about the lateral aspect of the knee, and grasp the foot or ankle with the other hand. Then, gently apply abduction stress to the knee, while the hand at the ankle externally rotates the leg slightly. Generally this external rotation is produced unconsciously. Placing the hip in relative extension helps to relax the hamstrings. By performing this test in a consistent manner one can become adept at comparing the findings in any given case with those in previous cases. When doing the abduction stress test, always compare the involved knee with the normal knee and perform the test gently and repeatedly, gradually increasing the stress up to the point of pain. In this way, the maximum laxity can usually be demonstrated without evoking muscle spasm. If the initial test is positive but produces sufficient pain and muscle spasm to make subsequent tests negative, one must remember that the one positive test could not have occurred except in the presence of a ligament tear.

It is often stated that the examination for knee ligament stability should be carried out under general anesthesia when one strongly suspects that the medial ligaments are torn but cannot demonstrate a positive abduction stress test with the patient awake. Examination under anesthesia will rarely be necessary if the initial examination is performed by the technique described. If there is suspicion that a ligament tear is masked by muscle spasm, twentyfour hours of immobilization in a cylinder plaster cast will often relax the muscles and allow demonstration of looseness by the described test. Generally, the abduction stress test is more positive when the patient is under general anesthesia just prior to operation than it was previously. Once you have demonstrated that the abduction stress test



FIG. 2

Right tibia viewed from above showing the capsular ligament and its various thickenings or strong points: (1) medial capsular ligament, middle third; (2) lateral capsular ligament, middle third; (3) posterior oblique ligament; (4) arcuate ligament; (5) tibial collateral ligament; and (6) iliotibial band.

is sufficiently positive to require surgical repair, do not force the joint into severe abduction merely to demonstrate how far it will go.



FIG. 3

Coronal section in the plane indicated by the insert (left) shows the medial and lateral meniscofemoral and meniscotibial ligaments. In the past the medial ones were commonly called the deep layer of the medial collateral ligament or the coronary ligament. The tibial collateral ligament, like the fibular collateral ligament, is a separate anatomical entity even though it has commonly been termed the superficial layer of the medial collateral ligament. (1) Meniscofemoral ligament, medial and lateral; (2) meniscotibial ligament, medial and lateral; (3) anterior tendon of semimembranosus muscle; (4) tibial collateral ligament; and (5) fibular collateral ligament.

With severe ligament damage, abnormal medial opening can be demonstrated by almost any technique. However, for the astute evaluation of borderline and difficult cases the finesse gained by doing the abduction stress test on many patients, in a similar manner, is required. If the test is done in a different manner each time, the evaluation becomes inaccurate and the findings inconsistent.

The abduction stress test must also be performed with each knee in full extension (zero degrees), or in the amount of recurvatum present in the opposite, normal knee when it is fully extended. The technique of the abduction stress test at zero degrees is the same as that for this test at 30 degrees of flexion.

Adduction Stress Test

This test, the one most conveniently performed next, is also carried out with the knee both in full extension and in 30 degrees of flexion. Simply change hands: that is, if the right knee is being examined, move the left hand to the foot and the right hand to the medial aspect of the knee joint and apply adduction force.

Anterior Drawer Test (Fig. 6)

Place the patient supine on the examining table with the head resting on the pillow. If he actively raises his head to observe what you are doing, hamstring tightening often occurs. Flex the hip to 45 degrees, flex the knee to 80 to 90 degrees, and place the foot on the table top. Sit on the table with a portion of your buttocks on the dorsum of the fore part of the foot to fix it firmly. Place your hands about the upper part of the tibia with the forefingers palpating the hamstrings to make sure they are relaxed. Then, gently and repeatedly pull and push the proximal part of the leg in a to and fro manner, remembering that it is essential to be gentle. Perform the test first with the foot and leg externally rotated beyond the neutral position, then internally rotated as much as is comfortably possible, and finally in neutral rotation. Test each lower extremity and compare the findings. If the anterior drawer sign is negative for both knees, the result is described as such. If both knees show a positive anterior drawer test, the findings are, of course, normal for that patient, but they are still recorded (Fig. 1) indicating both the degree and the type of positive test for each knee.

Posterior Drawer Test

The "push" portion of the drawer test, used to demonstrate the presence or absence of a posterior drawer sign, may cause confusion. Even an experienced examiner may erroneously interpret such a positive sign as a positive anterior drawer sign. To avoid this error it is sometimes necessary to use additional gravity tests for clarification. One such test is to place the patient supine with the knees flexed to approximately 80 degrees and the feet planted together on the table. If the posterior drawer sign is positive, the tibial tuberosity can be seen to be displaced posteriorly on the affected side compared with the normal one. Swell-



FIG. 4

Medial-posterior aspect of the right knee showing the oblique popliteal ligament (1). This originates from the capsular arm of the semimembranosus muscle (2), which sends supporting fibers to the posterior oblique ligament (3). The tibial arm of the semimembranosus tendon has several branches, including the fibrous covering (5) which spreads out over the popliteus muscle (6). The popliteal recess in the posterolateral capsule (7) is bound laterally by the tendon of the plantaris (8) and medially by the posterior capsule. The medial (9) and lateral (10) heads of the gastrocnemius give further dynamic and fibrous-tissue support to the posterior aspect of the knee.

ing of the affected knee, either intra-articular or periarticular, can produce the illusion of posterior displacement when there is none. If in doubt, make a lateral roentgenogram of each knee in the aforementioned position with the cassette held between the knees. Posterior displacement of the tibia on the affected side may be evident on comparison of the two roentgenograms. Godfrey described another test, in which the patient is placed supine with the hips and knees flexed to 90 degrees and the heels supported by the examiner's hands so that the legs are parallel to the top of the table. If the test is positive, posterior sag of the proximal end of the tibia will be noted on the affected side.

The ''Jerk'' Test

With the patient supine, the examiner supports the



Fig. 5

The abduction stress test performed in the manner described in the text. (Reprinted by permission from Knee Ligament Injury in Athletes, by Jack C. Hughston. J. Med. Assn. State of Alabama, **36:** 1-8, Sept. 1966.)

lower extremity, flexing the hip to about 45 degrees and the knee to 90 degrees and internally rotating the tibia. If the right knee is being examined, grasp the foot with the right hand and internally rotate the tibia while the left hand is placed over the proximal end of the tibia and fibula and used to exert a valgus stress. Then extend the knee gradually, maintaining the internal rotation and valgus stress. If the test is positive, subluxation of the lateral femorotibial articulation becomes maximum at about 30 degrees of flexion and then, as the knee extends further, spontaneous relocation occurs. The relocation takes the form of a sudden change in the relative velocities of the tibia and the femur: that is, there is a sudden change in the rate of acceleration of the two surfaces which, in engineering terminology, is called a jerk.

Recurvatum Test

This is performed in two parts. First, observe the patient standing with the knees in full extension for evidence of recurvatum of the involved knee. Second, place the patient supine on the examining table, grasp the fore part of each foot, lift both extremities off the table, and compare and measure with a goniometer the amount of recurvatum in each knee.

External Rotation-Recurvatum Test

The external rotation-recurvatum test is carried out with the patient supine. Move the normal knee and then the injured one from about 10 degrees of flexion to maximum extension while observing and feeling the amount of external rotation of the proximal end of the tibia and the degree of recurvatum. In a positive test one observes excess rotation and recurvatum which appear as increased tibia vara. External rotation-recurvatum may also be demonstrated by simultaneously lifting each extremity by the great toe, thus causing each relaxed knee to fall into maximum recurvatum. Additionally, it is sometimes helpful to have the patient stand extending the knees maximally and then to compare the amount of rotationrecurvatum in each knee, or to have him walk barelegged and observe the external rotation-recurvatum that occurs as the involved knee goes into extension between heelstrike and take-off. The test is positive when there is excessive external rotation of the tibia on the femur and an apparent varus deformity. This sign may be very subtle and the test often must be performed repeatedly.

Classification of Instability

Based on the findings using the clinical tests described, the instabilities may be classified as straight (non-rotatory) or rotatory (either simple or combined).

Straight Instability

There are four types of instability which involve no rotation of the tibia with respect to the femur.

1. Medial instability. This is caused by a tear of the medial-compartment ligaments combined with a tear of the posterior cruciate ligament. It is demonstrated by a positive abduction stress test with the knee in full extension.

2. Lateral instability. This is the result of tears of the lateral-compartment ligaments and the posterior cruciate. It is demonstrated by a positive adduction stress test with the knee in full extension.

3. Posterior instability. This occurs when the posterior cruciate is torn and there is laxity or a tear of both the posterior oblique ligament and the arcuate complex. It is manifested by a positive posterior drawer test in which both tibial condyles subluxate posteriorly an equal amount with no rotation.

4. Anterior instability. This occurs when the posterior cruciate ligament is torn. It is demonstrated by a positive anterior drawer sign in which both tibial condyles subluxate anteriorly an equal amount with no rotation. When both anteromedial and anterolateral rotatory instability are present in combination, and sometimes when there is only anterolateral rotatory instability, there may be apparent, but not true, straight anterior instability.

Rotatory Instability

There are three types of simple rotatory instability: anterior rotation of the medial tibial condyle, and anterior or posterior rotation of the lateral tibial condyle.

1. Anteromedial rotatory instability. This is caused by a tear of the medial-compartment ligaments, including the posterior oblique, but may be accentuated by a tear of the anterior cruciate ligament. In this situation the abduction stress test with the knee at 30 degrees of flexion is positive, as is the anterior drawer test with the tibia externally rotated.

2. Anterolateral rotatory instability. This is caused by a tear of the middle one-third of the lateral capsular ligament and may be accentuated by a tear of the anterior cruciate. This type of instability is discussed in Part II of this report.

3. Posterolateral rotatory instability. This is caused by a tear of the arcuate complex and it, too, is discussed in Part II.

Combined rotatory instabilities: Various combinations of the rotatory instabilities just described may occur. The two most commonly encountered are combined anterolateral and posterolateral rotatory instability and combined anterolateral and anteromedial rotatory instability. These are described in Part II.

Nicholas, classifying instabilities of the knee, de-

scribed a posteromedial rotatory instability. We have not included this in our classification because we believe that posteromedial rotation does not occur if the posterior cruciate ligament is intact, since the tightening of the posterior cruciate ligament that accompanies internal rotation would prevent such instability. Furthermore, we have not observed any true rotational instability when the posterior cruciate ligament is disrupted.

Materials and Methods

Fifty consecutive patients with acute ruptures of the medial-compartment supporting structures of the knee and eighteen patients with acute medial-ligament lesions associated with rupture of the posterior cruciate ligament (some with anterior cruciate ligament tears as well) were studied. We also performed dissections of fifty fresh, unfixed amputation specimens to acquire a better knowledge of the various anatomical relationships.

The history, clinical examination, and operative findings were recorded on special forms (Figs. 1-A and 1-B). Most helpful in the follow-up studies were the printed diagrams on which were drawn the ligament ruptures observed at operation. These were also invaluable in the analysis of the operative reports and the correlation of the clinical findings with the ligament injury found at operation.

For further documentation, photographs were also made during each operation.

Correlation of Clinical and Operative Findings

The clinical findings were correlated with the operative findings to determine their diagnostic significance.

Pain

Pain sufficient to necessitate medication after the injury was relatively rare. Despite complete tears many patients were able to walk without aid and without acute pain. Athletes frequently stated that they had not taken as much as an aspirin for pain.

Thirty-eight (76 per cent) of the fifty patients with complete tears of the medial compartment walked into the clinic unaided, without a cane or crutches. Twelve (24 per cent) were using crutches or were carried on a stretcher; however, most of these were following instructions given by the referring doctor or trainer rather than limiting their walking because of pain or instability.

While complete tears of the medial-compartment ligaments rarely caused pain of a significant degree, incomplete tears (first-degree and second-degree sprains) were often quite painful and accompanied by much hamstring spasm and pseudolocking.

Disability

Although 76 per cent of our patients could walk without aid, none could spring or "cut," go up or down stairs and slopes with agility, or do full squats. They usually walked with a mild stiff-legged limp and reported that they had difficulty getting into and out of an automobile. They could only perform this maneuver deliberately and with care to avoid painful stress on the knee or giving-way when taking the first weight-bearing step after getting out of the vehicle.

Swelling

Effusion or hemarthrosis (intra-articular swelling) should not be confused with either mild periarticular swelling, often visible on inspection, or localized areas of edema noted on palpation.

Of our fifty patients with medial-compartment tears, twenty-seven had no clinically evident intra-articular swelling and at operation were found to have no excess fluid in the joint. Seven had mild swelling; fourteen, moderate; and two, severe. The patients with moderate and severe intra-articular swelling had only minimum tears of the synovium.

In the eighteen patients with tears of both the medial compartment and the posterior cruciate ligament, no intra-articular swelling was observed. This absence of swelling was explained by the extent of the tear of the ligaments, capsule, and synovium, which allowed extravasation of the fluid into the surrounding tissues.

Localized Edema

Twenty-two patients had localized edema over the medial aspect of the tibia, and at operation the tibial collateral ligament was found to be torn off the medial face of the tibia. Ten others had puffiness over the medial femoral epicondylar region, and a tear of the tibial collateral ligament from its femoral attachment was found at operation. Thus, thirty-two (64 per cent) of the fifty patients had localized edema at a site that corresponded to the location of the ligament tear found at operation.

Tenderness

In twenty-eight patients the tibial collateral ligament was torn only at its tibial attachment. Of these, twenty-one had tenderness only over the medial face of the tibia and at the joint line. In ten patients the tibial collateral ligament was torn only at its attachment on the femur and of these, eight had tenderness only over the medial aspect of the femur and at the medial joint line. In twelve patients there was either a z-shaped tear of the tibial collateral ligament (one-half torn from the tibia and one-half torn from the femur, with a connecting longitudinal tear), a complete transverse tear at the joint, or an interstitial tear. The location of tenderness did not indicate the site of the tear in these twelve patients. Therefore, the site of the tear in 76 per cent.

Tears of the medial capsular ligament and posterior oblique ligament were difficult to identify on the basis of tenderness and localized edema because of their deepseated position. The medial capsular ligament was avulsed from the tibia in twenty-one; from the femur, in twenty; and from both the tibia and the femur, in five. In three others there was a tear in the middle of the ligament and in one, an interstitial tear of the ligament near its femoral attachment.

The posterior oblique ligament was intact in seven patients, avulsed from the tibia in seventeen and from the femur in six, and torn in its mid-substance in seven. Four other patients had an interstitial tear. In the remaining nine patients there was a tear of the posterior capsule of the knee joint in addition to the tear of the posterior oblique ligament, and in all nine the posterior oblique ligament was avulsed from the femur.

Abduction Stress Test

Performed with the knee at zero degrees, this test was negative in thirty-three and 1 +or less in seventeen of the patients whose posterior cruciate ligament was intact. The opening of the joint space in the seventeen with a positive test was too mild to be confused with the 2 + or 3 + opening found in knees with associated posterior cruciate ligament tears. In the knees in which this test was negative, the posterior capsule was either torn or intact. The condition of the posterior capsule had no effect on this test.

When the abduction stress test was done with the knee at 30 degrees of flexion, it was 2 + in forty-seven patients, 1 + in two, and zero in one. Under anesthesia, however, it was 3 + in thirty-seven and 2 + in thirteen.

Seventeen of the eighteen patients with tears of the posterior cruciate ligament in association with medialcompartment tears had a 3+ abduction stress test at zero degrees. This finding was the most significant clinical difference between the patients with posterior cruciate ligament tears and those with tears limited to the medial compartment.

Therefore, one may conclude that if the abduction stress test on a patient with an acute knee injury is 2+ or 3+ at 30 degrees of flexion but negative at zero degrees, there is a tear of the medial-compartment ligaments but the posterior cruciate ligament is intact. A 3+ abduction stress test at zero degrees, on the other hand, indicates the presence of an associated rupture of the posterior cruciate ligament.

Anterior Drawer Test

Twenty-six of the fifty patients with medialcompartment tears were found at operation to have an intact anterior cruciate ligament. The results of the anterior drawer test with the tibia in external rotation in these twenty-six patients were negative in seven, 1 + in six, 2 + in seven, and inconclusive in six because of spasm of the hamstrings. Under anesthesia the test was negative in six, 1 + in seven, 2 + in twelve, and 3 + in one.

The operative findings in the six patients with a negative anterior drawer test under anesthesia were as follows: The anterior cruciate ligament was intact in all six, the posterior oblique ligament was intact in two, and the medial capsular ligament was torn in the meniscofemoral portion in five and in the meniscotibial portion in one. Only one patient had a negative anterior drawer test in the presence of a rupture of the meniscotibial portion of the medial capsular ligament and an intact anterior cruciate ligament.

The other twenty-four patients of the fifty with medial-compartment tears had associated tears of the anterior cruciate ligament. The results of the anterior drawer test with the tibia in external rotation in these patients were negative in four, 1 + in three, 2 + in nine, and 3 + in two, while in six patients there was so much hamstring spasm that the test could not be performed. Under anesthesia the same test was 1 + in two, 2 + in six, and 3 + in sixteen.

The anterior drawer test under anesthesia, therefore, was positive in twenty (77 per cent) of the twenty-six patients with a normal anterior cruciate ligament. This finding is strong evidence that a torn anterior cruciate ligament alone is not the cause of a positive anterior drawer test. However, the sixteen cases of a 3+ anterior drawer test under anesthesia when the anterior cruciate ligament was torn, compared with the one case of a 3+ test when the anterior cruciate ligament was intact, does demonstrate that a tear of the anterior cruciate ligament increases the anteromedial rotatory instability. On the basis of this clinical study, one would have to conclude that a positive anterior drawer test with the tibia externally rotated (anteromedial rotatory instability) is indicative of a tear of the medial capsular ligament, and that the severity of this instability is increased by an associated tear of the anterior cruciate ligament. The tear of the medial capsular ligament causing this instability may be interstitial, and not a clearcut transverse tear at the joint level.

In forty-nine of the fifty patients with a medialcompartment tear and an intact posterior cruciate ligament, the anterior drawer test with the tibia in internal rotation was negative both preoperatively and under anesthesia. In the remaining patient it was 1+ with the tibia both internally and externally rotated.

Posterior Drawer Test

This test was negative in fourteen and positive in four of the eighteen patients with acute posterior cruciate ligament ruptures. The four with a positive test had received their injury in a fall from a height in which they landed on their feet with the knees flexed, thereby incurring an initial direct posterior thrust of the tibia on the femur with resultant stretching of the arcuate complex at the same time that the medial-compartment and posterior cruciate ligaments were torn. An alternative mechanism is a direct blow to the proximal anterior aspect of the tibia with the knee extended, thus producing similar stretching of the arcuate complex. The patients with a negative posterior drawer test had incurred their injuries as a result of a block or clipping while playing football which disrupted the medial-compartment and the posterior cruciate ligaments but did not produce stress on the arcuate complex. Therefore, one restraint to posterior subluxation remained intact and prevented a positive posterior drawer sign. However,

we have never seen a patient with an old tear of the posterior cruciate ligament who did not have a positive drawer test. Even the mild stress of walking on an untreated or unsuccessfully treated tear of the medial-compartment and posterior cruciate ligaments will gradually stretch the arcuate complex so that posterior displacement is evident.

Recurvatum

Of the eighteen patients with a torn posterior cruciate ligament, seven had an intact and eleven, a torn anterior cruciate ligament. One of the seven with an intact anterior cruciate and six of the eleven with both cruciates torn had recurvatum.

Meniscal Injury

Of the fifty patients with medial-compartment tears, five had a torn medial meniscus within its substance necessitating removal; fourteen had a peripheral tear involving primarily the meniscotibial ligament that was sufficiently extensive to require excision of the meniscus; ten had a tear of the meniscotibial ligament which permitted suture of the meniscus to the capsular ligament; and twenty-one had a normal medial meniscus with the capsular ligament torn in its meniscofemoral portion. Therefore, in thirtyone of the fifty knees the medial meniscus was not removed.

Discussion

Knee stability in general is a function of ligament tautness, congruency of the joint surfaces, the effect of the menisci, and the synergistic action of all musculotendinous units acting across the knee joint. Static stability, that which is present when no muscle is active, is dependent only on the ligaments, joint surfaces, and menisci. The extent to which musculotendinous units can compensate for ligament incompetence varies greatly, depending on the status of the muscles and the severity of the static instability. The effectiveness of the muscles depends mainly on spinal reflex action, with afferent impulses originating in capsular and ligament nerve endings.

In this discussion we will limit our comments to the clinical signs of the medial-compartment instabilities and the ligaments involved.

Abduction Stress Test

In the presence of a tear limited to the medialcompartment ligaments, the abduction stress test at 30 degrees of knee flexion does not cause simple abduction but rather anterior rotatory subluxation of the medial tibial plateau. In the knees with a 3+ test, separation of the tibiofemoral condylar surfaces averaged 1.0 centimeter and anteromedial rotatory subluxation ranged from 2.5 to 3.0 centimeters. Comparable amounts of anterior and rotatory displacement were produced by abduction stress at 30 degrees of knee flexion in fresh amputation specimens after the soft tissues surrounding the medial compartment (including the posterior capsule) had been removed, leaving only the posterior cruciate ligament and the lateral-compartment ligaments intact. In both the clinical cases and the amputation specimens, the severity of this anteromedial rotatory subluxation during abduction stress was unrelated to whether the anterior cruciate ligament was intact or severed.

If there is a complete tear of all of the medialcompartment structures, including the medial one-half of the posterior capsule, as well as a tear of the anterior cruciate ligament, the abduction stress test at zero degrees of knee flexion demonstrates no medial looseness. Under these circumstances the intact posterior cruciate ligament (and possibly the arcuate complex) holds the joint surfaces in firm apposition and prevents rotational displacement.

An abduction stress test, negative at zero degrees and positive at 30 degrees of flexion, indicates a tear limited to the medial-compartment ligaments. Conversely, a positive abduction stress test at zero degrees (or at the normal amount of recurvatum that occurs with complete extension of the knee) indicates that there are tears of both the posterior cruciate and the medial-compartment ligaments. Again, an intact or torn anterior cruciate ligament has no effect on this abduction stress test at zero degrees. As long as the posterior cruciate ligament remains intact, other ligament injuries can cause only rotational instability. If the posterior cruciate ligament is ruptured as well as the ligaments of either the medial or the lateral compartment, the rotational element is eliminated and abduction or adduction stress causes simple opening of the joint with marked separation of the condylar surfaces: that is, straight medial or lateral instability. For all practical purposes, the knee has been dislocated.

The anterior one-third of the medial capsular ligament provides no clinically detectable medial-compartment static stability, and is torn infrequently. It is the disruption of the posterior two-thirds of the medial capsular ligament that produces instability. Some believe that the posterior capsule becomes taut in extension and causes the abduction stress test at zero degrees to be negative. If the posterior oblique ligament is considered to be part of the posterior capsule, this belief is correct, since this ligament is taut at zero degrees and therefore might make the abduction stress test negative in this position. However, only seven of the fifty patients with medial-compartment tears had an intact posterior oblique ligament and an intact posterior capsule, and neither these seven nor any of the other forty-three had a positive abduction stress test in extension. Had we assumed that the posterior capsule was intact because of the negative abduction stress test at full extension (zero degrees), our clinical evaluation would have been wrong in forty-three, or 86 per cent, of these fifty patients. Therefore, accepting our anatomical description of the posterior capsule, it has no relationship to medial or lateral stability of the knee at zero or 30 degrees of flexion.

Anterior Drawer Test

There are four types of positive anterior drawer sign,

each a manifestation of a different type of instability. Two types are truly rotatory, occurring when the posterior cruciate is intact and when any forward movement of either the medial or the lateral tibial plateau must be rotation about the posterior cruciate ligament acting as an axis. The third type is the apparent straight anterior instability, which actually indicates combined anteromedial and anterolateral rotatory instability, and the fourth type is true straight (non-rotatory) instability associated with a tear of the posterior cruciate ligament.

The first type of positive anterior drawer sign, described as indicative of rotatory instability by Slocum and Larson 18, we classify as anteromedial rotatory instability. With the tibia externally rotated, the medial tibial plateau subluxates anteriorly with respect to the medial femoral condyle, while the lateral tibial plateau retains a relatively normal relationship with the lateral femoral condyle. The vertical axis of rotation in this situation has shifted laterally. If the tibia is internally rotated, however, the posterior cruciate ligament tightens and prevents any external rotatory subluxation (forward displacement) of the medial tibial condyle, since the internally rotated tibia is held firmly against the femur. This action of the posterior cruciate ligament has been demonstrated in many patients with combined tears of both the medial-compartment ligaments (medial capsular, posterior oblique, and tibial collateral) and the anterior cruciate ligament. In these cases, with the patient anesthetized prior to operation, the anterior drawer test showed 3+ anteromedial rotatory instability with the tibia externally rotated but no instability with the tibia internally rotated.

The second type of positive anterior drawer sign demonstrates anterolateral rotatory instability. Performed with the tibia in neutral rotation, this test is positive when the lateral tibial plateau subluxates forward with respect to the lateral femoral condyle while the medial tibial and femoral condyles maintain a relatively normal relationship. In this type of instability, the rotation and prominence of the subluxating tibial condyle are less than they are in anteromedial rotatory instability because the tibia internally rotates as it subluxates forward, tightening the posterior cruciate ligament and limiting anterior subluxation. Occasionally, in pure anterolateral rotatory instability there appears to be 1 + to 2 + anterior subluxation of both the lateral and the medial tibial condyle.

The third type, a simultaneous forward subluxation of both tibial condyles with the tibia in neutral rotation, occurs when there are combined tears of the middle one-third of the medial and the lateral capsular ligament. In this type of instability the test becomes negative if the tibia is internally rotated because in this position the posterior cruciate ligament is taut. When the anterior drawer test with the tibia in neutral rotation appears to demonstrate equivalent displacement of both condyles, but this displacement is eliminated by internal rotation of the tibia, one should suspect that both anteromedial and anterolateral rotatory instability are present. This suspicion can be further confirmed by the jerk test.

The fourth type of positive anterior drawer sign is also demonstrable as simultaneous straight forward subluxation of both the medial and the lateral tibial condyle on their respective femoral condyles. Most importantly, however, the displacement in this type of instability is changed very little by external and internal rotation of the tibia, because when the posterior cruciate ligament is torn apposition of the joint surface is no longer produced by internal rotation.

With experience and attention to detail, these four types of anterior drawer test are not difficult to delineate. If the history indicates that the uninjured extremity is normal and has never been injured, the four types of test on the normal knee should be negative. However, the anterior drawer sign in external rotation may be 1 + if the patient has congenital recurvatum of 10 degrees or more, and may be 1 + or even 2 + in adolescent athletes. College basketball players often normally exhibit a bilateral 1 + anterior drawer sign. There may be other conditions or specific athletic endeavors which result in a normal 1 + test.

It has been common practice to interpret a positive anterior drawer test as indicative of a torn anterior cruciate ligament. The reason for this misinterpretation was the finding of a tear of the anterior cruciate ligament in association with a torn medial meniscus and anteromedial rotatory instability, while the associated tear of the medial capsular ligament was not apparent or not recognized. The instability was then blamed on the obvious anterior cruciate ligament tear. When the anterior cruciate ligament was repaired the anterior drawer test was rarely performed forcibly to check the immediate effect of the repair, for fear of disrupting the sutures. In the postoperative follow-up, if the anterior drawer test remained positive, and particularly if there was disabling anteromedial rotatory instability, the torn anterior cruciate ligament was blamed and it was assumed that the repair had failed. On the other hand, if stability was restored the anterior cruciate repair was credited. However, we believe that success here was due to healing of the medial capsular ligament during the period of immobilization.

In 1961 and 1962, one of us (J. C. H.) reported ^{7,8} that the anterior drawer sign was not consistently positive in the presence of a tear of the anterior cruciate ligament as seen during medial meniscectomy. In many cases, the anterior drawer sign preoperatively and at operation was negative in the presence of a torn anterior cruciate, while in other cases the anterior drawer test was positive in the presence of an intact anterior cruciate ligament. In 1963, Slocum¹⁷ observed an acutely injured knee with a positive anterior drawer sign and intact anterior cruciate ligament with a peripheral tear of the medial meniscus and a fresh tear of the thickened portion of the middle one-third of the medial capsular ligament at its tibial attachment. We would now term this a meniscotibial tear of the middle one-third of the medial capsular ligament. In 1968, Slocum and Larson ¹⁸ reported on their studies of the role

of this tear of the middle one-third of the medial capsular ligament in the causation of the positive anterior drawer sign, using the term rotatory instability. Further support for this concept was provided by Kennedy and Fowler, who produced an isolated tear of the middle one-third of the medial capsular ligament and resultant anterior rotatory instability in fresh amputation specimens by applying torque. With hindsight, it seems clear that prior to these three reports either a tear of the middle one-third of the capsular ligament hidden beneath the periphery of the meniscus or an unseen interstitial tear of the capsular ligament had been overlooked in the knees thought to be unstable because of anterior cruciate ligament tears.

The usual positive anterior drawer sign is a manifestation of anteromedial rotatory instability and is primarily the result of a tear of the meniscotibial portion of the middle one-third of the capsular ligament. However, a tear of the posterior oblique ligament also produces a positive anterior drawer sign, or increases the amount of anterior subluxation of the medial tibial plateau during testing. An associated tear of the anterior cruciate ligament definitely augments anteromedial instability, and removal of a torn medial meniscus may increase existing anteromedial instability considerably by removing the wedge effect of the meniscus interposed between the posterior femoral and tibial condylar surfaces. The anterior drawer test is almost invariably positive when the meniscotibial portion of the middle one-third of the capsular ligament is torn (with or without an associated tear of the anterior cruciate ligament), but is negative as a rule when the meniscofemoral portion is torn. In this study we found no knee with an isolated tear of the meniscofemoral ligament which showed a positive anterior drawer test, while all but one of the knees with a meniscotibial ligament tear had a positive anterior drawer test.

We urge that the anterior drawer test be performed with the patient supine and the tibia in external, internal, and neutral rotation while the foot is planted, and that the findings be reported in terms of anteromedial rotatory instability, anterolateral rotatory instability, and anterior instability. A review of the literature reveals that specific descriptions of other techniques of performing the anterior drawer test leave much to be desired. Palmer offered the most precise description, stating, "With the patient lying down or sitting up, the examiner should grasp the lower leg just beneath the knee joint and, with the foot between his knees or upper arm and trunk attempt to move the lower leg backwards and forwards." His illustrations showed the leg hanging over the edge of the examining table with the knee flexed 90 degrees. Subsequent descriptions in the literature were not precise but indicated a similar manner of performing the anterior drawer test ^{1,13,15}.

The assumption that a positive anterior drawer test indicates a tear of the anterior cruciate ligament seemed to be completely accepted after Palmer's treatise in 1938, although he himself noted that the significance of this sign was contested, many authors denying that it was specific for a lesion of the cruciate bands ^{4,16,19}. Palmer believed that the anterior cruciate ligament is under great stress only in extension and hyperextension, and that it is relaxed immediately as flexion begins. Brantigan and Voshell, however, stated that the anterior cruciate ligament is taut throughout flexion and extension, while Abbott and associates observed that the anterior cruciate ligament is relaxed in flexion. In more than 200 arthrotomies of knees in which the anterior cruciate ligament was shown to be normal, we have not seen one anterior cruciate ligament which was taut at 90 degrees of knee flexion with the foot resting on the operating table. Letting the leg hang over the side or end of the operating table, however, may produce sufficient distraction in a stable knee to render the anterior cruciate ligament taut at 90 degrees of flexion.

We know of three patients in whom the middle onethird of the medial capsular ligament was inadvertently severed during routine meniscectomy. In each case the knee was stable prior to the severance of this thickened ligament band, and immediately thereafter had a 2+ anterior drawer test with the tibia externally rotated and a 2+abduction stress test with the knee flexed 30 degrees. The tibial collateral ligament was not involved in any of these patients.

This observation further confirms our concept of the primary lesion in anteromedial rotatory instability.

From our clinical, anatomical, and operative evaluations of the anterior cruciate ligament, it is our impression that its major function is prevention of hyperextension or recurvatum. It could also function as a rotational guide during the screw-home mechanism of extension. We have found no evidence that the condition of the anterior cruciate ligament has any relation to a positive anterior drawer test performed with the patient supine, the knee at 90 degrees of flexion, and the foot fixed on the table in a weight-bearing position. The capsular ligament is the first line of defense preventing either type of anterior rotatory instability, while the anterior cruciate ligament is a second line of defense. Thus, a tear of the anterior cruciate ligament associated with a tear of the medial or lateral capsular ligament adds to the severity of the anteromedial or anterolateral rotatory instability. However, we must admit that the anterior cruciate ligament continues to be an enigma.

Posterior Instability

We have not seen a case of chronic posterior instability in which the posterior drawer sign or one of the gravity tests was not positive. However, after an acute tear of the posterior cruciate ligament the posterior drawer sign may not be positive even with the patient under anesthesia, a situation that we have seen repeatedly in athletes after a rotational injury or an injury involving abduction and rotation. Under these circumstances, all of the medialcompartment ligaments including the "posterior capsule" and the posterior cruciate ligament may be torn without stretching or tearing of the arcuate complex. If these pos-

a lesion of the cruciate bands ^{4,16,19}. Palmer believed that terolateral ligaments are intact, the posterior drawer sign the anterior cruciate ligament is under great stress only in remains negative.

On the other hand, if the injury is the result of a fall from a height with the patient landing on the feet with the knees flexed, a posteriorly directed force is exerted on the proximal end of each tibia. This force stretches all the ligaments that restrict posterior displacement, but invariably in such a fall one extremity receives the brunt of the force, since the patient falls to one side or the other. Most of the energy, therefore, is dissipated in the extremity on this side, and this extremity is rotated and abducted or adducted, so that a tear of the ligaments of the medial or lateral compartment is produced along with a tear of the posterior cruciate. The posterior drawer test in this situation is positive initially because both the posterior oblique ligament medially and the arcuate complex laterally are stretched before the force is dissipated as the patient falls to one side. We believe that in the acute stage a negative posterior drawer sign does not prove that the posterior cruciate ligament is intact. In fourteen of our eighteen cases of acute tears of the posterior cruciate ligament this test was negative. After an acute injury, a positive abduction or adduction stress test with the knee completely extended is the most reliable sign of a torn posterior cruciate ligament. Only when the posterior cruciate ligament is disrupted can this test be positive. An intact anterior cruciate ligament does not prevent this test from being positive.

In knees with chronic posterior cruciate ligament instability, the healed medial and lateral ligaments, even though lax, prevent sufficient abduction or adduction to make a diagnosis of a torn posterior cruciate ligament on the basis of opening of the joint at full extension. But in our series the posterior drawer test was positive in every case.

We believe that the positive posterior drawer test in chronic cases reflects the laxity of the posterior oblique ligament and arcuate complex caused by repeated microtears or the stretching produced by activity no more strenuous than walking.

When we severed only the posterior cruciate ligament in fresh amputation specimens, the posterior drawer sign was normal because the posterior oblique ligament medially and the arcuate ligament complex posterolaterally were intact.

The posterior drawer test, therefore, is consistently accurate for the evaluation of the posterior cruciate ligament in a chronically unstable knee, but not in one which is acutely injured. After an acute injury, a definitely positive abduction stress test with the knee at full extension (or in the normal amount of recurvatum) indicates a tear of the posterior cruciate ligament until surgical exploration proves otherwise. At surgery, the synovial covering of the posterior cruciate ligament must sometimes be opened to demonstrate the presence of a complete tear of this ligament.

We consider the posterior cruciate ligament to be the primary stabilizer of the knee in flexion, extension, and rotation. If it is intact only rotational instability can occur, since as the tibial plateaus move anteriorly and posteriorly they rotate about the axis of the posterior cruciate. Therefore, anteromedial, anterolateral, and posterolateral rotatory instability can occur but not posteromedial rotatory instability, since if the tibial plateau moves posteriorly during internal rotation the posterior cruciate tightens and locks the joint surfaces together. When the posterior cruciate is ruptured, on the other hand, there is no fixed axis about which the tibia rotates; therefore, all instabilities in the presence of the ruptured posterior cruciate are nonrotatory or straight.

Rarely, in the presence of a torn posterior cruciate associated with either medial or lateral ligament laxity, there may appear to be rotatory instability. However, in this situation the axis of rotation cannot be the torn posterior cruciate but instead is the intact medial or lateral structures, so that there is apparent posteromedial or posterolateral rotatory instability. One should not confuse this with true rotatory instability because: (1) other objective signs of posterior cruciate instability are present, and (2) posteromedial rotatory instability cannot occur in the presence of an intact posterior cruciate ligament.

Conclusions

1. Complete disruption of the medial compartment of the knee may occur without subsequent significant pain, effusion, or disability for walking. 2. Localized edema and tenderness after injury are good indicators of the site of disruption of the tibial collateral ligament.

3. The abduction stress test with the knee at 30 degrees of flexion is completely reliable as an indicator of a complete tear of the medial compartment.

4. A positive abduction stress test at full extension is the most reliable indication of an acute rupture of the posterior cruciate ligament in association with medialcompartment disruption. The posterior drawer sign is an unreliable test for an acute posterior cruciate rupture but is always positive in the presence of a chronic rupture of this ligament.

5. A strongly positive anterior drawer sign with the tibia in external rotation indicates that the medial capsular, posterior oblique, and anterior cruciate ligaments are ruptured. If the test is mildly or moderately positive it tells nothing about the anterior cruciate ligament, but indicates that the posterior oblique and medial capsular ligaments are disrupted.

6. Anteromedial rotatory instability can be recognized by the presence of a positive anterior drawer sign with the tibia externally rotated and a positive abduction stress test with the knee at 30 degrees of flexion.

7. In the acute stage, increased recurvatum is commonly associated with a rupture of the anterior cruciate ligament and not with disruption of the posterior cruciate ligament.

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