The Anterior Cruciate Ligament: A Review of Recent Concepts
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The anterior cruciate ligament (ACL) consists of a small anteromedial band and a larger posterolateral band. Recent findings have shown the ACL to play a major role in the function of the knee joint. The ACL prevents anterior luxation of the tibia, limits tibial rotation, and resists valgus and varus stress to the knee. The most common mechanism of ACL injury involves hyperextension of the knee with a rotational component. Diagnosis of an ACL lesion consists of an accurate history, clinical tests and often, arthroscopic investigation. Treatment of an ACL injury may consist solely of a rehabilitation program, may involve surgical intervention, or a combination of the two. Many surgical procedures both intra-articular and extra-articular, have been used in the past. The most successful approach at this time appears to be a combination of intra-articular and extra-articular procedures. A contemporary trend in rehabilitation following surgery is the use of graduated stages of treatment beginning immediately postsurgery and continuing through to full return to activity.

Recent findings in the field of medical research have led to considerable advancements in the diagnosis and treatment of various pathological conditions. The area of sportsmedicine is by no means an exception. Injuries or conditions which may once have jeopardized the future of an aspiring athlete are now being understood and treated with consistent success. One example of this is the management of lesions to the anterior cruciate ligament (ACL).

Until recently, injury to this structure may well have eluded proper diagnosis and treatment. However, the development of sophisticated forms of diagnosis, surgical repair, and rehabilitation routines have brought a new outlook to this problem.

The following is a review of the philosophies and concepts of management of ACL pathology as it has been presented in the literature over the past 10 years. A focus will be placed on contemporary modes of treatment in the area of sportsmedicine. As a basis for understanding mechanisms of injury, techniques of diagnosis, and forms of treatment, a background in the anatomy and function of this ligament will be presented.

ANATOMY OF THE ANTERIOR CRUCIATE LIGAMENT (Fig. 1)

Osseous Attachments

The ACL begins to develop along with the femoral and tibial condyles between the seventh and eighth week of fetal life, and is well defined by the ninth week.24,27

The ligament arises from the nonarticular aspect of the tibia, passing superiorly, laterally, and posteriorly to attach to the posterior portion of the intercondylar notch.9,57 The tibial attachment in the intercondylar groove is long and firm. Some fibers arise from the medial and anterior aspect of the tibial spine, but most attach to its tip. Marshall et al.52 reported from a study of 50 cadaver knees that 100% of the ACLs attached to the anterior tibial origin of the lateral meniscus and 20% reached posteriorly as far as the posterior tibial origin of the lateral meniscus. The femoral attachment is to the posterior aspect of the medial surface of the posterior condyle. This is well posterior to the longitudinal axis of the femoral shaft. It is interesting, though, to note that various researchers have reported congenital absence of the cruciate ligaments associated with normal knee function.40,53,64

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Fiber Arrangements

The ACL is composed of two portions: one being a small anteromedial band (AMB), and the other a larger, bulky posterolateral band (PLB). Girgis et al. suggested the best way to visualize these two components is to think of them as a narrow medial band and a broad lateral part joined together along their length by soft material which permits them to move differently. This geometric configuration is responsible for the tightening and loosening of the different portions throughout the range of motion of the knee. It must, however, be remembered that part of the ligament is tight at all times.

Vascular Supply

The blood supply to the ACL is classically attributed to the inferior and superior middle geniculate arteries which enter the knee anteriorly and posteriorly, respectively. The largest branch enters in the upper portion of the ligament, descending along the dorsal surface to a point just proximal to the tibial spine. Most of the recent literature reports the important contribution of vessels arising from the soft tissue and synovium in the region of the retropatellar fat pad. These vessels surround the ligament and give rise to small connecting branches that penetrate it transversely and intercommunicate with the longitudinal network of endoligamentous vessels. The ligamentous-osseous junction of the ACL does not
FUNCTION OF THE ANTERIOR CRUCIATE LIGAMENT

The relative importance of the ACL in the function of the human knee joint has long been a point of controversy in medical circles. There are some who would play down the major importance of this structure; but recent research in orthopaedics and sports medicine indicates the important contribution it provides in knee stability. Feagin and Walton \(^{23}\) stated: "the anterior cruciate ligament is an essential stabilizer of the knee," and that it "is critical to the function of the knee in the young athlete." Most of the evidence supporting this view comes from the observation of joint structures and mechanics in patients with deficient or functionally absent ACLs. The observation of joint function when the ligament is absent, degeneration of articular cartilage, abnormalities in the quadriceps extensor mechanism, and lesions to the menisci points to the importance of this structure in proper knee function.\(^{10,23,36,56,52}\)

Researchers do, however, agree on the specific functions of the ACL. These are: the prevention of anterior luxation of the tibia on the femur, limitation of tibial rotation, and resistance to varus and valgus stress of the knee.

Prevention of Anterior Luxation

The major function of the ACL is the prevention of anterior tibial luxation when the knee is in extension as well as in flexion.\(^{10,14,26,33,41,46,48,52,61,66,69}\) Only certain parts of the ligament are involved throughout the range of motion of the articulation. As was mentioned previously, there are two components of the ligament and each plays the role of primary stabilizer at different joint angles.

The AMB is taut and provides resistance from about 70° of flexion to full flexion.\(^{10,26,33,41,46,48,52,61}\) Eighty-five percent of the resistance counteracting anterior luxation of the tibia is provided by the AMB at 90° of knee flexion.\(^{53}\) Studies using sequential sectioning of knee structures demonstrated marked increases in anterior movement of the tibia in 45° and 90° of flexion when the AMB was the only structure sectioned.\(^{26,52}\)

The PLB is taut in extension and up to 20° of flexion.\(^{10,26,33,46,52,61}\) This component of the ACL is the principle structure resisting hyperextension of the knee.\(^{49,61}\) As flexion increases to the point of 40°–50°, neither component is tight and a general laxity exists in the fibers.\(^{48}\) Furman et al.\(^{46}\) reported the greatest amount of anterior tibial luxation found in healthy, intact ACLs occurred at 45° of flexion.

Limitation of Tibial Rotation

A secondary function of this ligament is the limitation of tibial rotation.\(^{16,41,48,49,61}\) Internal rotation in knee extension and slight flexion is prevented by both the AMB and the PLB.\(^{48}\) Lipke et al.\(^{48}\) stated that the ACL provides the primary restraint of excessive internal rotation of the tibia.

Although it is beyond the scope of this paper to discuss rotatory instability in depth, a very brief consideration is appropriate at this time. Anteromedial rotatory instability occurs when the axis of rotation of the knee joint is allowed to shift into the lateral compartment causing subluxation of the medial tibial plateau. The reverse is true for anterolateral rotatory instability. This can only occur as the result of a lesion to certain structures of the knee. The type of instability depends on which structure(s) have been injured.\(^{41}\) Lipke et al.\(^{48}\) feel that anterolateral rotatory instability can only occur in the presence of a deficient ACL. Clancy et al.\(^{16}\) stated that anterolateral instability was the more significant functional problem produced by an insufficient ACL.

It must be emphasized that although the AMB and PLB perform different functions at times, the two components are so closely related that they serve as "back-up" units for one another. Therefore, a deficiency in one of the bands will result in the "coming into play" of the other in order to prevent total dysfunction of the ligament's contribution to knee stability.
Resistance to Valgus and Varus Stress

Sectioning studies have demonstrated the secondary role of the ACL in resisting both valgus and varus stress in the case of deficiency or functional absence of the collateral ligaments.\textsuperscript{49,61}

MECHANISMS OF INJURY TO THE ANTERIOR CRUCIATE LIGAMENT

The mechanisms of injury to the ACL can be classified into three major categories. These are: 1) forced hyperextension of the knee, 2) forced flexion and external rotation of the tibia on the femur, and 3) forced hyperflexion of the knee.

Hyperextension

The most common mechanism includes some component of knee hyperextension (Fig. 2). This may occur with or without rotation of the tibia.\textsuperscript{4,9,23,25,26,34,46,61,68,72} One situation which seems to account for a large number of ACL lesions is a deceleration activity with the foot planted and the knee in slight flexion.\textsuperscript{23,34,72} It may occur without a rotational component, but is most often seen with internal rotation of the tibia.\textsuperscript{3,9,23,25,26,34,46,69,72} This particular mechanism is often described as the cause of isolated ruptures of the ACL.\textsuperscript{9,25,26} A posteriorly directed force applied to the anterior aspect of the femur is a mechanism seen frequently in contact sports such as football and hockey. This usually occurs with the foot planted. Lesions caused by a forceful contraction of the quadriceps muscle group with the knee in extension have also been cited.\textsuperscript{4} Beauchamp\textsuperscript{8} reported injuries involving hyperextension of the knee while the athlete was non-weightbearing. This could occur in jumping events such as basketball, handball, and gymnastics. In general, it would seem that the majority of hyperextension injuries do not involve direct contact from an external force.

Flexion

A mechanism which occurs less often is that of knee flexion accompanied by external rotation of the tibia on the femur.\textsuperscript{15,25,46,72} The addition of a valgus stress applied from the lateral aspect of the knee is also reported in many of these incidences.\textsuperscript{25,46} Kennedy et al.\textsuperscript{46} stated that the ACL can often be stretched over the medial border of the lateral femoral condyle causing disruption of the ligament, but only when external rotation of the tibia is accompanied by an abduction force.
Another mechanism leading to disruption of the ACL is an anteriorly directed force applied to the posterior aspect of the proximal tibia. This may occur while the knee is in flexion or complete extension. It may result from a clipping type force commonly witnessed in football.

Hyperflexion

A rare mechanism reported by Fetto and Marshall is that of forced hyperflexion of the knee. Sports involving jumping and landing activities are possible situations leading to such an injury.

DIAGNOSIS OF THE ANTERIOR CRUCIATE LIGAMENT INJURY

The diagnosis of an ACL lesion has for many years posed a problem to health care professionals. In general, an accurate and consistent assessment of this type of injury has been nonexistent, at least until fairly recently. Sisk stated: "acute disruptions of the anterior cruciate ligament are probably the most undetected lesion in acute knee injuries." This has been due in part to the lack of a precise regimented routine in the area of diagnosis. Recent advances in the use of sophisticated medical technology for diagnosis, and a better understanding of the function of this structure have shed new light on this subject. The once somewhat mysterious lesion no longer defies proper diagnosis.

The purpose of this section is not to elaborate on the multitude of tests and methods of diagnosis which are presently in use. It is, rather, to present a general outline of the various areas involved in assessing the existence and extent of injury to the ACL.

History

The first area involves compiling an accurate history of the injury. There are a few "classic" mechanisms, signs, and symptoms presented in the literature which may aid the examiner in identifying injuries to the ligament.

The most common mechanism involves a rotational component while decelerating on an extended knee. An audible "pop" can often be heard in the case of an acute injury and if there is a significant tear of the ligament, the acute injury is usually accompanied by measurable swelling. Finally, a hemarthrosis that presents itself within the first 12 hours after injury is often representative of an ACL lesion.

Clinical Tests

The second area of diagnosis is the use of clinical stress tests. Through the use of such tests, insufficiency in the ligament can usually be detected. There are numerous tests for evaluating the integrity of this structure. The following are only a few: Anterior Drawer Test, Lachman's Test, Pivot-Shift Test, Cross-Over Test, Slocum Test, and MacIntosh Test. Although rotational tests may give reliable results in some cases, the Anterior Drawer Test and the Lachman's Test seem to be the most conclusive and reliable in detecting ACL lesions. For this reason they will be the only ones dealt with in this section.

The Anterior Drawer Test has until recently been the most widely used test for the ACL. Because of the various inherent difficulties in the protocol, it has recently lost some status in many medical circles. A brief description of the test will help in understanding these difficulties. The patient is situated in the supine position with the knee in approximately 90° of flexion. The examiner sits on the foot to stabilize the extremity in the position of neutral rotation. The examiner's thumbs are placed parallel to the infrapatella tendon crossing the joint line to detect anterior subluxation of the tibia on the femur. The fingers palpate the hamstring tendons at the back of the knee in order to check for tightness or spasm. An anterior stress is then applied causing theibia to translate forward. It becomes obvious, in recalling the anatomy and function of the ligament, that the integrity of the AMB is the only component in question in this position of knee flexion. Therefore, one can at best make a statement concerning the condition of this component of the ligament following the Anterior Drawer Test. A common fault in the past has been the conclusion that the total ligament is intact if a negative response is exhibited from this maneuver. However, this test overlooks totally the largest component of the ligament, the PLB. As was mentioned previously, this portion only becomes tight in or near full extension and therefore can only be properly assessed in this position. Recent studies have demonstrated three common factors which may cause a false negative Drawer sign. The first is that a joint containing considerable effusion or a hernar-
throsis will not allow a proper test at 90° of knee flexion.\textsuperscript{51,65} Second, protective hamstring spasm which often accompanies acute injury may be sufficient to restrain anterior subluxation of the tibia when the knee is flexed at 90°.\textsuperscript{51,65} Finally, because of the curvature of the femoral condyles, it is possible for an impingement to occur on the posterior aspect of the medial meniscus, especially if there is an associated tear of the meniscus. This may block forward translocation of the tibia.\textsuperscript{51,65}

Because of problems associated with the Anterior Drawer Test, its popularity has dwindled in the recent past and an examiner must be cautious not only of the procedural mechanics but also of its results.

A contemporary test that has received much attention is the Lachman’s Test. In this procedure, the patient is lying in the supine position with the tibia in neutral or slight external rotation. The examiner places the knee in slight flexion (10–20°) with one hand on the posterior aspect of the proximal tibia. Once again, an anterior stress is applied to the tibia in an effort to translate it forward on the femur.

This particular test has been reported to be highly reliable in the detection of ligamentous injury.\textsuperscript{9} It must be remembered, however, that the PLB is the only component of the ACL that is taut in this position. A statement can, therefore, only be made concerning the integrity of this part of the ligament.

Keeping in mind their limitations, the accurate conclusions drawn from these two procedures can be of major importance in the diagnostic process. The various other tests have to be viewed as secondary or supportive in nature.

**Technological Apparatus**

The final area of diagnosis belongs to the orthopaedic specialist. This involves the use of arthroscopy.\textsuperscript{58,63} This procedure has become an increasingly popular technique in the diagnosis of ACL injuries. In the context of this paper, it will suffice to point out the need for careful investigation, observation, and palpation in the utilization of these modes of diagnosis. An observation reported by Kennedy et al.\textsuperscript{44} demonstrates how difficult an accurate diagnosis of ligamentous insufficiency can be even with the aid of sophisticated equipment. In reference to ACLs, they stated: “ligaments may be stressed to ultimate failure in the absence of macroscopic disruption.”

A high index of suspicion must be present on diagnosis in order to rule out ACL injury.

**TREATMENT**

Treatment of the acute or chronic lesion to the ACL may be the most controversial area in sports medicine at the present time. Once an accurate diagnosis of the condition has been established, there are a number of routes that may be followed. These may be classified as: 1) a “trial of function” period, 2) nonsurgical treatment, and 3) surgical intervention followed by rehabilitation.

**Trial Period**

The trial of function approach involves a period of observation and evaluation of the functional ability of the knee joint.\textsuperscript{6,25,47,56} Although this procedure is really a further aspect in the diagnosis of ACL insufficiency, it has been included in this section because of its direct relationship with nonsurgical treatment. This approach to treatment is most often taken in the case of an acute injury. During this period, secondary complications such as pain, swelling, and decreased range of motion are treated. The patient is introduced to increasingly more challenging activities until an objective opinion can be made as to whether further treatment, surgical or nonsurgical, is indicated.

Although a conservative trial of function routine may prove valuable in certain cases where a less severe injury has occurred, this approach can be a disadvantage when surgical intervention is ultimately required. It has been shown that the success of ACL surgery may be directly related to the length of time which elapses between the injury and the surgical repair.\textsuperscript{26}

**Nonsurgical**

Nonsurgical treatment of ACL lesions often works hand-in-hand with the trial period approach. If the patient appears to be progressing well, without signs of knee instability, a more vigorous program of rehabilitation exercises may be embarked upon. Since a detailed routine of rehabilitation exercises will be introduced later, only the basic concepts of rehabilitation will be presented at this time.

The secondary complications of pain, swelling, and decreased range of motion are the first obstacles to be overcome. Once these have been
dealt with successfully, the strength, power, and endurance of the musculature involved in knee stability and function are then augmented. At the end of the rehabilitation program, some form of knee orthosis may be used to aid the stability of the knee during participation in athletic activities.

The choice of nonsurgical treatment is made on the basis of several factors. The principal ones are the age of the patient, the level of demand that will be placed upon the knee, the degree of laxity of the ligament and finally, the desire, commitment, and motivation displayed by the patient to go through the necessary steps involved with surgery. In certain situations, especially in the case of older patients, the nonsurgical approach may be the wisest decision. This is only true, however, if the patient is aware of the possible progressions of the injury and is willing to adapt his/her lifestyle to possible restraints in physical activity.

In the case of a younger, active individual, with a significant lesion of the ACL, the nonsurgical approach may lead to future complication.

The potential for progressive deterioration of the ligament and the development of further intra-articular complications is great. Cabaud et al. stated: "the anterior cruciate deficient knee is a handicap which is never compensated satisfactorily by bracing or rehabilitation." It has been clearly proven that anterior instability only increases with time. Continued activity may also lead to damage of the meniscus. Perhaps even more serious than these is the frequency of progressive damage to the articular cartilage. This can be the result of numerous repeated major or minor traumas caused by subluxation in the unstable knee. Significant osteoarthritis can occur within 2 years of an injury. Finally, increased rotatory instability has also been demonstrated in long-term ACL deficient knees.

The results of a study by Fetto and Marshall are perhaps indicative of what the future holds for an unstable knee. It was found in a follow-up study on nonsurgically treated ACL lesions, that after 3 years not one knee was rated in a “good-to-excellent” category. After 5 years, it was very uncommon for any knee to be rated better than “poor.” In the past, one common reason for not performing surgery when faced with significant injury of the ACL had been the apparent lack of success of the surgical approach. This concept has currently been proven inaccurate, as we shall now see.

Surgical

An increased understanding of the function of the ACL and the possible implications of long-term instability, have led to a definite increase in the popularity of surgical intervention. A vast repertoire of surgical procedures has been used in the last decade. These procedures may be classified as intra-articular or extra-articular repairs. A brief description of a few common procedures in each category will be presented. This will be followed by a discussion of the advantages or disadvantages of these surgical approaches.

Intra-articular

The intra-articular approach can be further divided into three categories: primary repair, the substitution of inert structures, and the use of prosthetic materials.

The primary repair approach involves the use of sutures to reapproximate the severed ends of the ligament in a attempt to re-establish function of the ligament. This may be done by simply suturing within the body of the ligament itself or passing sutures through the entire length and anchoring them to structures such as the tibia, the femur, and the iliotibial band.

The primary repair approach seems to be the procedure with the least amount of success. The major reason for this may be the lack of revascularization of the damaged ligament. Those procedures using the augmentation of the infrapatellar fat pad as a source of vascular supply appear to remedy this situation to some degree. The stress put on the ligament in the early stages of rehabilitation often proves to be too great in the case of the primary repair. Incorrect placement of the femoral attachment may lead to insufficiency in re-establishing the proper function of the ACL. In the case of serious disruption of the midsubstance of the ligament, it is often difficult to properly reapproximate the torn ends.

Another approach to intra-articular repair involves the use of certain inert structures to simulate the function of the ACL. The most common structures are the patellar tendon, the iliotibial
In the patellar tendon procedure, the medial one-third of the tendon is often excised near the proximal end and rerouted from its distal insertion through the joint cavity and anchored to the lateral condyle of the femur. The use of the iliotibial band displays an almost reversed pathway. A section of the distal portion is excised and routed over the posterior aspect of the lateral femoral condyle, through the joint cavity, and inserted onto the tibia. In the case of the menisci, a totally resected meniscus (usually medial) is used to simulate the structure and function of the ACL. Sutures are placed in each end of the meniscus and the structure is then attached to the lateral femoral condyle and the anterior aspect of the tibial plateau. The semitendinosus tendon is detached distally, fed through a drill hole on the anterior medial aspect of the tibia, and then through another hole in the lateral femoral condyle and sutured to the iliotibial band. It is important to emphasize that all of these procedures attempt to simulate the function of the ACL by duplicating the anatomical position, e.g., tibial and femoral attachments.

The use of inert structures for intra-articular repair has become a very popular technique. These procedures appear to better survive the stress placed on the repair in early rehabilitation. This is perhaps because less time is required for tissue healing when an intact structure is involved. Proper revascularization and correct anatomical placement of the structures once again dictate the eventual outcome of the surgery.

The final type of intra-articular approach to be discussed is the use of prosthetic ligaments. Materials such as polyethylene, polyglycolic acid sutures, and carbon fiber implants have been used in recent years as replacement structures. These prosthetic ligaments are positioned along the same anatomical pathway that the ACL would normally follow. Some of these structures are designed to be biodegradable while others serve as permanent fixtures.

The general success of repairs involving the use of prosthetic ligaments has been unfavorable. This has been due in part to the inferior tensile strength of some materials in comparison to an intact ACL. The forces exerted on these structures during normal physical activity have, in some cases, proven to be too great. Kennedy has described a procedure of combining a primary type procedure with a prosthetic ligament. Preliminary indications demonstrate favorable results with this approach.

**Extra-articular**

Extra-articular repairs also involve the use of inert structures to provide stability to the knee joint. The iliotibial band, biceps femoris, and the pes anserinus group are most commonly used in this approach. In the case of the iliotibial band, the distal attachment is removed and the distal portion is passed under the lateral collateral ligament and inserted on the tibia, anterior to Gerdy's tubercle. A similar procedure may be performed using the distal portion of the biceps femoris tendon. For the pes anserinus group, the distal insertion is transferred superiorly and anteriorly on the tibia.

Extra-articular repair procedures have met with reasonable success. The most common problem is that the primary structures used in this type of surgery often stretch out during rehabilitation and ensuing activity, leaving the patient with residual instability. Consequently, the extra-articular approach has become popular as an augmentation to intra-articular type repairs. This dual procedure holds the advantage of early reinforcement of the intra-articular structure during the rehabilitation process, thus increasing the chances of long-term stability.

No single approach to the repair of the ACL deficient knee has met with consistently favorable results. The popular trend at present would appear to be the combination of two or more repair procedures, in the attempt to maximize the advantages of the different methods. The results reported by Clancy et al. may lend hope to the future of such procedures. Ninety-two percent of their patients were able to return to normal athletic activities without the recurrence of instability.

Warren and Marshall reported an interesting adjunct to the surgical repair approach. It was reported that 13 of 15 knees, which were rated as poor following surgical repair of the ACL, had been operated on later than 8 weeks postinjury.

The long-term success of ACL repairs is only beginning to be realized. It will be the results in this area that will eventually determine the success or failure of the various surgical repair procedures.

**REHABILITATION**

The focus of this section will be placed upon the philosophies and goals of rehabilitation follow-
ing surgical repair of an ACL injury. Although each type of repair will dictate specific exercises in accordance with the structures implicated in the repair procedure(s), only general principles for rehabilitation will be dealt with.

The basic philosophy of rehabilitation is the same following nonsurgical and surgical treatment. This involves the prevention of progressive instability, postponement of the onset of degenerative changes, reinstatement of the preinjury level of performance, and protection from reinjury.41

An aspect of the total rehabilitation program which has come into vogue in some medical circles is the use of presurgical conditioning. This concept is most often used in the case of chronic lesions. The patient with chronic instability often has marked atrophy of the quadriceps muscle group as well as other muscles involved in knee mechanics. For this reason, a strengthening program is embarked upon in order to increase the strength, power, and endurance of the affected muscles. Strengthening of the muscles before surgery leads to a decrease in time and an increase in efficiency of the postsurgery rehabilitation procedure.

Another recent trend in the area of ACL rehabilitation is the use of postsurgery treatment schemes that are broken down into specific steps or stages.11,41,57,71 These stages begin the first few days following surgery and continue until total function of the knee has been regained and the patient is ready to meet all the challenges that will be faced during physical activity. O'Donoghue57 reinforced the importance of this concept stating: "one needs to have a distinct pattern for rehabilitation." Each of the particular stages have specific goals or objectives. Once the patient has met these criteria, they are ready to advance to the next phase. Most programs indicate basic time intervals for each stage, but it is understood that an individual may progress at a slower or faster rate depending on goal attainment.

In this section, an attempt has been made to present an overview of some such programs. The result is by no means an ideal model. It will, however, represent the principal concepts of rehabilitation as they presently exist.

Stage One

The first stage begins within 48 hours of the surgery.57 At this time, the patient is instructed to carry out a routine of isometric quadriceps tightening exercises. Active movements of the ankle and hip are often included. The objectives of these exercises are to enhance circulation, minimize atrophy, and stimulate nervous activity in the lower limb.11 Other exercises performed during this stage depend on the type of immobilization technique being used. It would therefore seem appropriate at this point to briefly discuss these procedures.

Perhaps the most common method is the application of a full leg cast with the knee fixed in 30–40° of flexion. This technique allows the structures involved in the surgical procedure to heal in a shortened position, disallowing early compromise of their functional integrity. One disadvantage of this method is that the contraction of the quadriceps group may cause anterior displacement of the tibia, causing stress on the repaired structures. This may be accentuated as the cast begins to loosen due to decrease in swelling and atrophy of the surrounding musculature.71

A similar procedure may be used with the knee fixed in 5–10° of flexion. An advantage of this technique is that the patient may begin partial weightbearing earlier in the rehabilitation program. Anterior displacement of the tibia is virtually eliminated during quadriceps contractions with this method. A possible concern, though, is that early return to complete extension of the knee is often associated with failure to provide long-term stability and function of the joint.71

A third method of immobilization involves the use of hinge casting. This technique may be applied immediately following surgery or after a period of full leg casting. Exercises may be performed through a safe range of motion in this case. Although this may be a definite advantage in some ways, the problem of anterior tibial displacement must be taken into account. Hinge casting also tends to loosen more quickly than the other methods. This may be compounded if windows are cut in the cast to allow electrical stimulation of the muscles.

Eriksson21 has suggested two further forms of treatment for the first stage. In the case of a partially mobile hinge cast, light isokinetic activities may be performed. This would obviously depend on the type of repair and the amount of pain and swelling in the knee joint. The second form of treatment is the use of electrical muscle stimulation. A study of the effects of immobilization on muscle tissue by Eriksson demonstrated that it is primarily type I, slow twitch, oxidative fibers
that atrophy during immobilization and that this is combined with a drop in their succinic dehydrogenase (SDH) enzyme activity. Electrical muscle stimulation seemed to prevent some of this drop in SDH activity as well as to hypertrophy the type I fibers.

Stage Two

This stage of rehabilitation begins when the cast is removed. This may occur between the fifth and eighth week postsurgery. The objectives at this point are to increase the range of knee flexion, begin selected active and progressive resistance exercises, and to decrease edema and joint effusion.

The range of motion of knee flexion may be initiated as a gravity-assisted movement. It would then progress to an active movement on the part of the patient. A goal during this stage is to increase the movement to at least 90° of knee flexion.

Active and resisted exercises may involve isometric, isotonic, isokinetic, or eccentric activities. Hip and ankle movements should be possible with only minor limitations. An emphasis must be placed on strengthening the hamstring group, which will serve as a dynamic stabilizer to anterior tibial displacement. For this reason, the rehabilitation program rests more in the area of hamstring reconditioning than in any other muscle group. The quadriceps group should be limited to active or light resisted exercise at this point. One important consideration pertaining to knee extension is the creation of anterior shearing forces that are possible with active knee extension. The therapist must be careful especially in the first three stages of rehabilitation to ensure that extension exercises do not compromise the surgical repair.

In dealing with joint discomfort, edema, and effusion, the therapist will involve various modalities. The choice of specific modalities will depend largely on the preference of the individual therapist.

Stage Three

The next stage takes place in the third and fourth month postsurgery. The range of motion of the knee is an important factor at this time. Resisted exercises for both the hamstring and quadriceps groups are increased.

An objective for range of motion in this phase is to reach 120° of knee flexion. The use of more aggressive passive exercises is indicated in an effort to attain this goal. Both active and passive knee extension are begun, with the target of finishing 5–10° short of complete extension. The use of 3-S (Scientific Stretching for Sport) stretching program may prove valuable for increasing range of motion and muscular strength during this stage.

Various forms of muscle strengthening exercises can be used to hypertrophy the hamstring and quadriceps groups. The advantages of isokinetic resistance become evident at this point. Routines at slow speeds for the hamstring group can now be augmented with faster speed movements. Also, submaximal contractions may be increased to maximal efforts. End of range of motion exercises beginning with submaximal efforts can now be performed for extension. Once the patient has attained 110° of knee flexion, a routine of progressive resistance stationary cycling may begin. Swimming activities using the lower limb are encouraged in this stage with a restriction to the flutter style kick. The use of a swimming pool in the rehabilitation program can be a valuable asset, remembering that exercise performed in water is isokinetic in nature. The initiation of a general fitness program is advocated at this time, respecting the necessary limitations placed on lower body involvement.

Stage Four

This stage of rehabilitation contains relatively few restraints on activity. From the fourth month postsurgery onward, the goals of rehabilitation are to regain complete range of motion of the knee and to maximize muscular functions.

Active and passive range of motion exercises are performed until full knee flexion is present. Work on extension ceases at 5–10° short of complete extension.

Progressive resistance exercises are continued in this phase. Maximal efforts at slow, medium, and fast speed movements are emphasized. The component of muscular endurance is now introduced. Full weightbearing should be attained early in this stage and running in chest-deep water may begin 5–6 weeks later. An increase in the duration and intensity of stationary cycling is encouraged. A progressive running program, beginning with light jogging, may be initiated around the sixth month postsurgery. Perhaps a more accurate criterion for the introduction of such a program is...
when the strength level of the hamstring group has reached 80% of the uninjured leg.

Stage Five

The final phase of the rehabilitation routine involves the return to participation in physical activities. This stage may only begin when the criteria from the previous stages have been fully realized. At this time, a decision is made as to which activities may be started and at what levels of intensity and duration. The type of activities and the time at which they are begun may vary to a large extent from one individual to another.

Some form of bracing is usually worn during this period, lending both physiological and psychological support. The latter aspect may play a greater role in complete and safe return to participation than has been thought in the past. The most popular form of bracing has been the Lennox-Hill brace.41,46,47,57 This orthosis is designed not only to provide functional support to the knee in an anterior-posterior plane, but also to prevent rotatory instability.

Throughout the entire rehabilitation program, the skills of the therapist will be constantly tested. The decisions as to when and how much to progress are compounded by the need for fresh and innovative exercises that will keep both the patient and the therapist motivated. Regular intensive rehabilitation will continue for up to 1 year and often longer. However, the importance of rehabilitation in the treatment of ACL lesions cannot be overemphasized. At least 50% of the ultimate success of the surgical procedure depends upon the rehabilitation effort.31

SUMMARY

The ACL consists of two functionally different, yet anatomically associated portions. The ligament originates in the intercondylar groove on the tibial plateau. Its proximal attachment is to the medial aspect of the lateral femoral condyle. The ligament consists of a thin AMB and a bulky PLB which are connected throughout their entire lengths. The vascular supply, once thought to be inadequate for repair, has recently been proven extensive. The surrounding soft tissue and synovium seem to provide the largest source of vascularity, with minor augmentations from the ligamentous-osseous junctions.

The primary function of this structure is the prevention of anterior tibial luxations on the femur. The ligament plays a role in preventing excessive tibial rotation and aids in valgus and varus stability.

There have been several reported mechanisms of ACL injury. Forced hyperextension of the knee appears to be the most common. Flexion and external rotation of the tibia and forced hyperflexion of the knee are also often implicated in trauma to this structure.

Diagnosis of ligamentous insufficiency has become much more efficient in recent years. An accurate and precise history of the injury must first be made. The use of clinical stress tests then provided strong indication of the location and severity of the lesion. The availability of advanced forms of diagnostic aids such as arthrography and arthroscopy have become invaluable in providing accurate and consistent diagnosis.

The treatment of ACL injuries may consist of a trial of function period followed by extensive rehabilitation in the case of mild injuries. Significant insufficiency is most often treated by surgical repair. Intra-articular repairs may involve primary repair of the ligamentous substance, augmentation using inert structures, or prosthetic replacements. Extra-articular repairs involve the anatomical transfer of inert structures to provide functional stability of the knee joint. A combination of the intra-articular and extra-articular repairs is a contemporary approach meeting with considerable success.

Rehabilitation is an essential adjunct to the treatment process. Specific goal oriented phases for rehabilitation have become popular in many medical circles. Gradual progressions in joint range of motion exercises and muscle developing routines evolve into total body conditioning and eventual return to physical activity.

The continual improvements of diagnostic techniques, treatment procedures, and rehabilitation programs indicate a bright future in this area. A pathology that once implied definite physical restrictions and possible disability can now be handled with expertise and precision.

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REFERENCES

3. Amoczky SP, Torvin GB, Marshall JL: Anterior cruciate ligament
42. Kennedy JC: The Injured Adolescent Knee. Baltimore: Williams & Wilkins, 1979