Addressing ACL Injuries in Women

Diagnosis, management, prevention

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ABSTRACT: Female athletes are particularly susceptible to ACL injury. It is to be expected, then, that as female participation in athletics continues to grow, so too will the number of ACL injuries in women. To provide the best care, orthopedists need to be proficient at identifying ACL injuries, assessing their severity, and discussing treatment options. Among the most important advice to female athletes is how to prevent ACL injuries in the first place. History and physical examination are essential and often sufficient in establishing the diagnosis. A noncontact event associated with a "pop" and followed by significant swelling of the knee is more than 70% accurate for acute damage to the ACL. Reliable diagnostic evaluations are Lachman's test and the flexion-rotation drawer test. Imaging studies are crucial in identifying related injuries. (*Women Health Orthopedic Edition* 2001;4(3):100-107)

Female participation in athletics has increased dramatically during the past three decades and can be attributed to two key factors—a growing societal enthusiasm for sport and Title IX of the Educational Amendments Act of 1972, which required federally funded institutions to provide equal opportunities to men and women in all curricular and extracurricular activities. However, alongside this increase in participation by women has come an increased incidence of injuries.

Female athletes appear to be particularly susceptible to injuries of the anterior cruciate ligament (ACL). According to some estimates, young competitive female athletes have a twofold to tenfold higher risk of ACL injury than do their male counterparts.[1-8] The age distribution of ACL injuries also varies between men and women. Recent data provided by the American Board of Orthopaedic Surgery and based on CPT (current procedural terminology) codes for ACL surgery suggest that the incidence of ACL injury in women begins at age 14, peaks at age 18, and then declines dramatically. By contrast, the incidence of ACL injury in men starts to rise later, at age 16, peaks at age 20, and then, decreasing only slightly, plateaus through age 40 before it declines. These age-related differences in ACL injury and surgery correlate well with participation in competitive team athletics, which drops substantially among women (but not among men) after college.

It is alarming that, during a relatively short exposure to competitive athletics, women experience these devastating injuries earlier and with much greater frequency than do men. In this article, we begin with a discussion of why such disparities exist, but focus primarily on the clinical parameters most relevant to your practice: how to recognize, assess, and—most importantly—prevent ACL injuries in women. A short discussion entitled "ACL injury rates in the general population" (see page 102) highlights the magnitude of the problem and thus the essentialness of clinical know-how.

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SEX DIFFERENCES EXPLAINED

Several intrinsic and extrinsic factors account for the higher incidence of ACL injury in women compared with that in men. Proposed factors include anatomic differences in the ACL, femoral notch, and alignment of the lower extremities; differences in joint laxity; and differences in strength, training, and conditioning.[1,3,9-12] In women, the femoral notch is narrower, lower extremity alignment is more valgus, and joint laxity, pos-

sibly as a result of hormonal influences, is more common. Each of these variations puts the ACL at greater risk for injury.

More recently implicated, and arguably more promising in explanation, are differences in neuromuscular control strategies and movement patterns.[13-17] Kinematic studies using videographic motion analysis and surface electromyography have shown that female athletes perform stopping, cutting, and jumping maneuvers in ways that place strain on the ACL and thus increase the risk for injury. Compared with male athletes, female athletes tend to exhibit:

- A lesser degree of knee flexion.
- Greater valgus knee alignment.
- Higher quadriceps to hamstring muscle activation.
- Higher peak anterior shear forces at the knee.

DIAGNOSIS

Patient History

Oftentimes, the history of an ACL injury is of a noncontact event that occurred while changing direction or landing from a jump. The patient may report that she heard or felt a "pop" followed by acute swelling of the knee in the next few hours. Patients are usually unable to continue with their sporting activity and have difficulty bearing weight. This presentation is so characteristic of an acute injury to the ACL that the history alone, even without the assistance of any further tests or evaluations, will provide an accurate diagnosis more than 70% of the time.[18-20]

Physical Examination

When an acute ACL injury occurs and rapid swelling and pain develop, physical examination of the knee may be difficult. Serial examinations (and occasionally sterile aspiration and intra-articular injection with a local anesthetic) can be helpful but should be considered only if radiographs show no evi-

Figure 1. Lachman's test *is performed with the patient supine and the involved extremity on the side of the examiner. Holding the knee in slight flexion (10 to 15 degrees), the examiner stabilizes the femur with one hand while applying with the other an anteriorly directed force to the proximal posterior tibia. The degree of anterior translation suggests the extent of the injury. Ninety-degree counterclockwise rotation of the proximal hand and placement of the fingers across the patient's knee enable the examiner to simultaneously palpate the proximal medial tibial plateau, determine its relation to the medial femoral condyle, and better detect the amount of relative translation.*

Figure 2. The flexion-rotation drawer test *is performed with the patient and examiner in similar arrangement as Lachman's test but with the knee held in only slight flexion and supported instead at the proximal tibia. As the knee is brought from an extended position towards flexion, the absence of the ACL allows the tibia to roll on the femur without the simultaneous translation that is usually present. This results in an anteriorly subluxated tibia on the femur. Then, as a position of further flexion is reached, all of the translation occurs at once, with a dramatic reduction of the tibial subluxation. The flexion-rotation drawer test is usually less well tolerated than Lachman's test and is more difficult to perform without anesthesia.*

ACL injury rates in the general population

The annual incidence of anterior cruciate ligament (ACL) injury is about one in 3,000 persons, which translates to just over 100,000 ACL sprains per year.[35,56] The majority of these cases (more than 70%) are sports injuries in athletes of mean age 26 years.[1] Most ACL injuries occur during a three-decade period between the ages of 16 and 45. The adjusted incidence rate for this age-group is 1 in 1,750 persons. At least one half of the ACL injuries in this group, however, occur during the first decade between the ages of 16 and 25, raising the injury rate in the younger subset to an even higher 1 in 1,000.[13]

dence of fractures and the knee appears grossly stable. The usual recommendation of "rest, ice, compression, and elevation" for seven to ten days often successfully leads to reduced swelling and symptoms and thus can facilitate subsequent evaluations.

When the knee is less painful and the patient can relax, diagnostic maneuvers such as Lachman's test (Figure 1) and the flexion-rotation drawer test (a version of a pivot shift test; Figure 2) can be performed.[19,21] Lachman's test is positive for an ACL rupture when the side-to-side difference in anterior translation is greater than 3 mm.[20] Use of this test can also enable the detection of a "soft" end point—or, viewed another way, a lack of the expected "firm" end point. A firm end point is evidence of an intact ACL, which normally becomes taut with anterior translation of the tibia relative to the femur.[20,21] A soft end point is always present with ACL injury and is often easier to detect than an increase in translation.

Experienced physicians who use Lachman's test can accurately diagnose an acute ACL injury 80% to 90% of the time in the office setting and 100% of the time when the patient is under general anesthesia.[18,20,22] Similarly, the flexion-rotation test, which directly assesses the function of the ACL and its ability to control subluxation during flexion and extension, is particularly effective when it is performed with the patient under anesthesia.

Physical examination is also extremely important in guiding treatment choices and ruling out coexisting damage to other ligaments and the meniscus. Included in the differential diagnosis are acute patellar dislocation and meniscal, chondral, or osteochondral injuries.

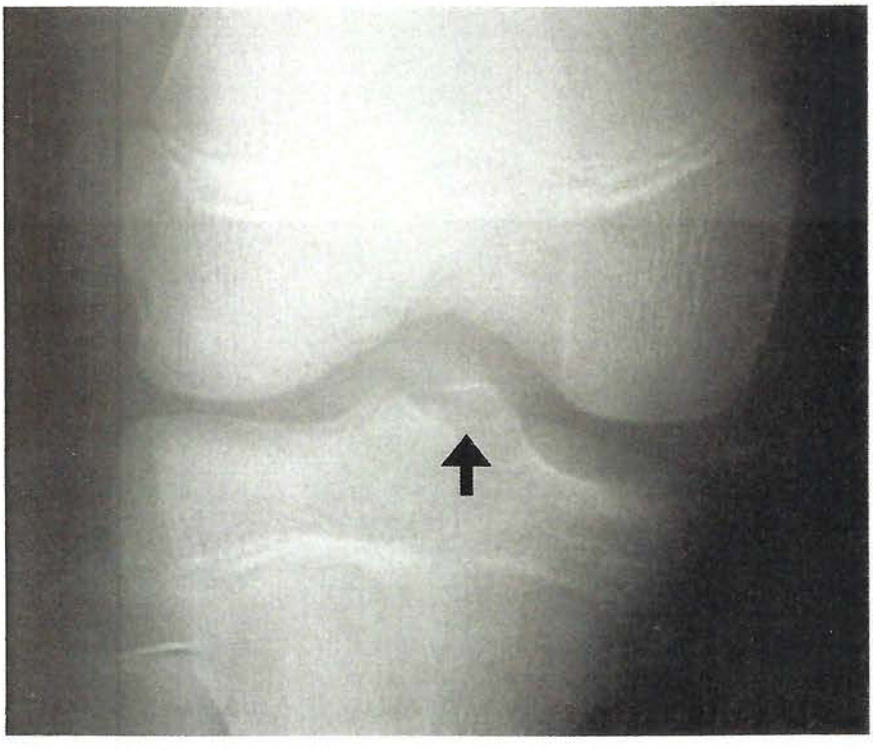

Figure 3. The presence of an avulsion fracture *at the medial tibial spine, the site of insertion of the ACL, indicates a loss of continuity of the ligament and (therefore) insufficiency.*

Imaging studies

Plain radiographs of the knee are rarely helpful in making the diagnosis but are necessary in ruling out other injuries, such as fractures and loose fragments of bone and cartilage. In addition, radiographs may reveal bony evidence of an ACL injury. Avulsion fractures of the medial tibial spine (Figure 3) and vertically oriented avulsion fractures of the lateral tibial plateau (Segond fracture, Figure 4) are commonly associated with damage to the ACL.

Magnetic resonance imaging (MRI) can be a valuable tool for visualizing damage to the ACL and associated structures when the clinical diagnosis is unclear (Figure 5). Preoperative MRI has been shown to be helpful in diagnosing multi-

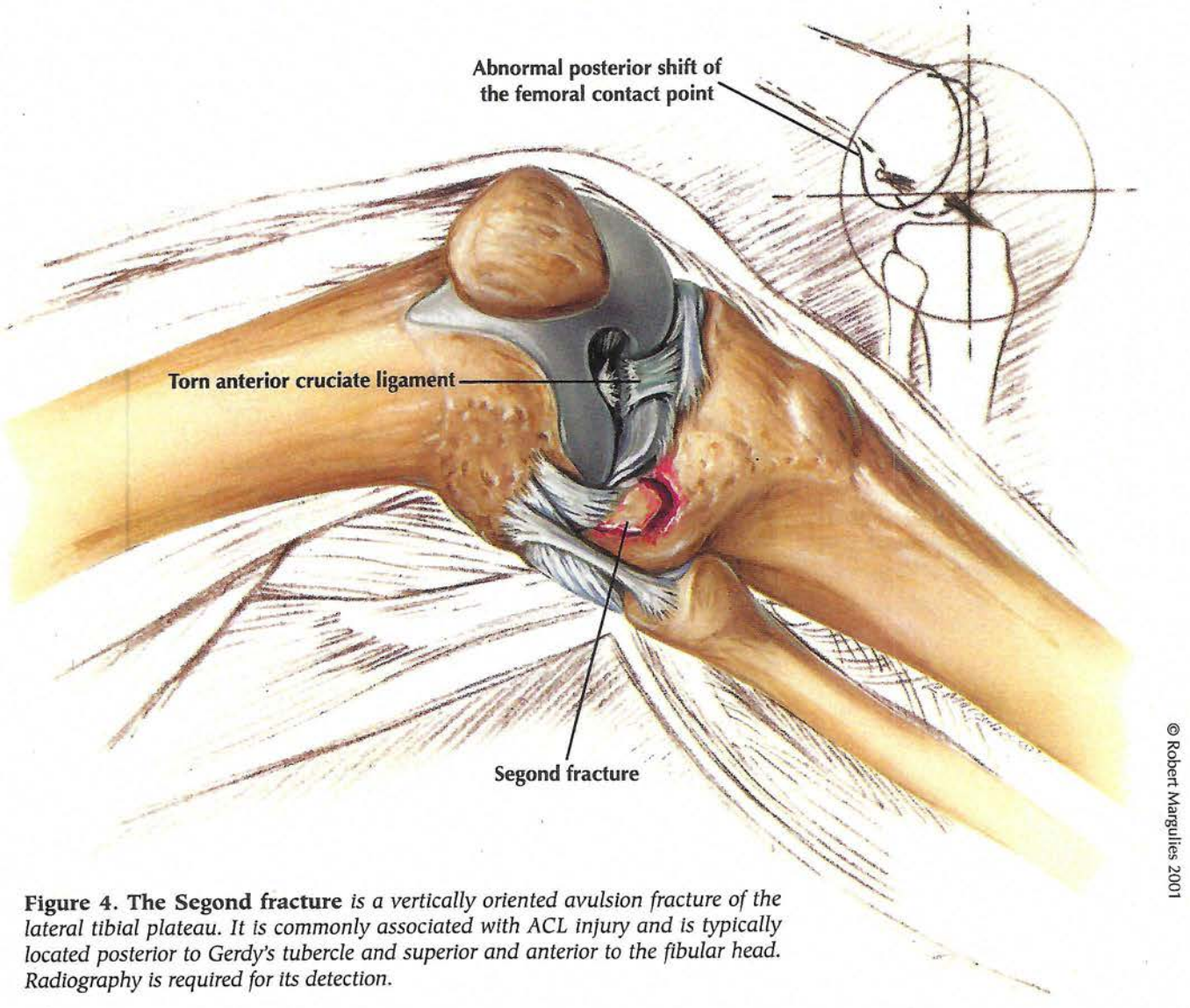

Figure 4. The Segond fracture *is a vertically oriented avulsion fracture of the lateral tibial plateau. It is commonly associated with ACL injury and is typically located posterior to Gerdy's tubercle and superior and anterior to the fibular head. Radiography is required for its detection.*

ligament injuries, osteochondral fractures, bone bruises, and (in particular) meniscal tears.[23,24] Identification of injuries to structures other than the ACL is crucial, as their existence can dramatically alter the plan of treatment and affect eventual outcome. A summary of the steps you should take in conducting a thorough diagnostic evaluation is found on page 108.

MANAGEMENT OPTIONS

Operative Treatment

Candidates: Operative treatment is generally recommended for any person who sustains combined ligament injuries and for athletic individuals who wish to maintain a level of activity above what the knee will allow without recurrent episodes of instability and injury. In practice, we commonly find that younger, active individuals who compete in activities requiring frequent deceleration, changes of direction, and jumping fare better with operative treatment. Surgery should also be considered when other injuries that can be repaired are present. Meniscal injuries corrected at the same time as ACL reconstruction have shown improved rates of healing.[25]

Key components: Operative treatment of ACL injuries includes two important aspects—a technically correct procedure and a sound and structured rehabilitation. The former requires proper graft selection, placement, and fixation, as well as proper treatment of other associated injuries. Because excellent results have been reported for both one-incision and two-incision arthroscopically assisted ACL reconstruction using a wide variety of autogenous and allogeneic graft materials, technique and graft selection is best left to the surgeon's familiarity and preference.[26-32] The most frequently used materials for ACL reconstruction (Figure 6) are bone-patellar tendon-

bone and hamstring tendon autografts.

Accelerated rehabilitation programs have allowed return to full athletic competition as early as four to six months after surgery and are associated with excellent long-term knee stability and minimal postoperative complications.[31,32] Many such programs are organized into distinct steps or phases of rehabilitation. *The first phase* begins preoperatively and its goals are to reduce swelling, regain range of motion of the knee, normalize gait, and mentally prepare the patient for the work to come. Attaining these goals preoperatively is especially important in decreasing the risk of postoperative arthrofibrosis, problematic scarring that significantly limits range of motion and function of the knee.[33] *The second phase* begins postoperatively and, while allowing for wound healing, centers on maintaining and further improving upon the goals achieved in phase 1. Phase 2 objectives are to maintain full knee extension, achieve knee flexion to 90 degrees, regain quadriceps control, and normalize gait. As these goals are met, *the third phase* begins. Patients are encouraged to work toward further knee flexion and to develop leg strengthening and endurance. Closed-chain exercises are useful in that they may protect the ACL graft from translation forces generated through cocontraction of the quadriceps and hamstring muscles.[34] *The last phase* focuses on return to sport. Further strengthening and endurance and proprioception, agility, and sports-specific drills are key to achieving the best outcome.

Rate of success: The outcome of ACL reconstruction is predictably good when measured by the restoration of stability. Most studies report that 85% to 92% of patients will achieve a less than 3-mm side-to-side difference in anterior translation, thereby eliminating instability and allowing return to sport.[35] However, some degree of knee pain and stiffness as well as other mild symptoms often persist after surgery.

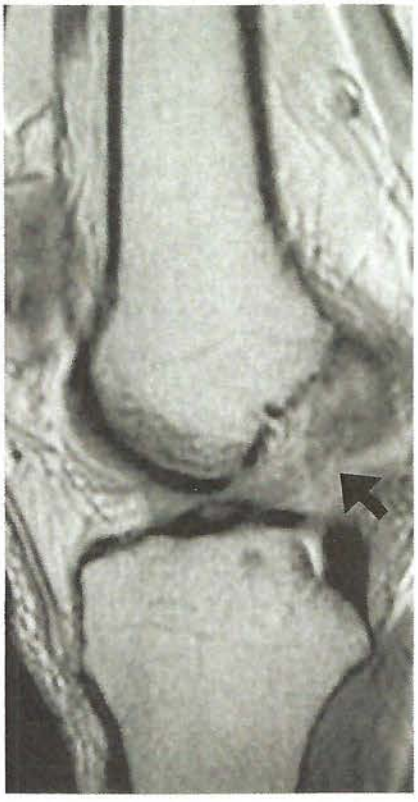

Figure 5. An acute tear of the ACL *is evident on this T2-weighted magnetic resonance image of the knee.*

The likelihood of experiencing postoperative symptoms correlates with the degree of damage encountered at the time of surgery and the extent of postoperative scarring and loss of motion. Despite their increased risk for ACL injury, women do as well as their male counterparts do after ACL reconstruction; outcomes and complications in the two sexes are similar.[36]

Nonoperative treatment

Candidates: Alternatives to surgery are generally recommended for older and less active individuals who are amenable to reducing or modifying their activity to a level that avoids episodes of knee instability and reinjury. Nonoperative treatment consists of an initial rehabilitation protocol similar to that of the postoperative ACL reconstruction program, but it differs by having a greater emphasis on dynamic stabilization of the knee and the development of protective motor patterns.[37]

Coping and its consequences: Prospective data suggest that most patients who initially elect not to undergo ACL reconstruction are able to cope by making functional adaptations and/or allowing their injury to dictate the limits of their activity.[1] Adaptations in motor pattern include a quadriceps-avoidance gait,[38] increased hip and knee flexion during cutting maneuvers,[39] and hamstring-enhanced knee stabilization.[37] All of these mechanisms prevent pathologic displacement of the anterior tibia, which is more likely to occur as a result of ACL deficiency.

However, of those patients who refuse surgical management and opt to compensate for their injury through behavioral and physical modifications, approximately 20% to 30% fail and later choose to undergo reconstruction. Failure to compensate correlates best with age, pre-injury level of participation, and degree of joint instability.[1] Only a limited number of persons who have an ACL injury are capable of making the necessary adaptations required to maintain a high level of athletic performance.

RISKS GUIDE PREVENTION

Recent investigations into the mechanisms, biomechanics, and kinematics of ACL injuries are providing needed information on the events surrounding ACL injury and are thus leading the way towards prevention. What has been established is that the majority of ACL injuries—up to 70% or 80%—are the result of a noncontact mechanism.[40,41] Collected video footage from an ad hoc study group of the American Orthopaedic Society for Sports Medicine–National Collegiate Athletic Association revealed

that most noncontact ACL injuries occur during sudden stops, landings, or changes in direction when the athlete appears off-balance.[13] In the off-balance position, the knees are usually in slight flexion and (sometimes) valgus alignment.

Biomechanical studies correlate well with these observations. Moreover, for the majority of knee positions that put the ACL at high risk of injury, the strain and stress measured in the ACL increases with simultaneous quadriceps activity and is dampened by simultaneous hamstring activity.[34,42-50]

As described earlier, human performance and kinematic studies have shown that women and men use different neuromuscular control strategies and movement patterns when they perform athletic activities; such studies may provide the strongest evidence yet for the disparity in ACL injury rates between the sexes.[13-17]

Together, these investigations are helping to explain the overall increased risk of ACL injury in women and are providing direction to other studies looking to establish a means of prevention. Already, neuromuscular training programs have shown some success. Many of them are designed to correct errors in neuromuscular control strategies and movement patterns and have led to documented decreases in the rate of ACL injury among women.[51-55] The completion of a six- to eight-week preseason jump-training program by female soccer, volleyball, and basketball players led to decreased peak landing forces, decreased varus/valgus moments at the knee, increased hamstring power and strength, increased hamstring-to-quadriceps peak torque ratios, increased vertical jump height, and—ultimately—significantly fewer ACL injuries.[53] Educating your female patients who regularly participate in athletics about this or a similar program should be considered.

Unfortunately, other studies have failed to document the success of training programs in preventing ACL injuries. Further investigation into the mechanism of ACL injury will certainly improve our understanding of why and how these injuries occur and by what means they can be prevented.

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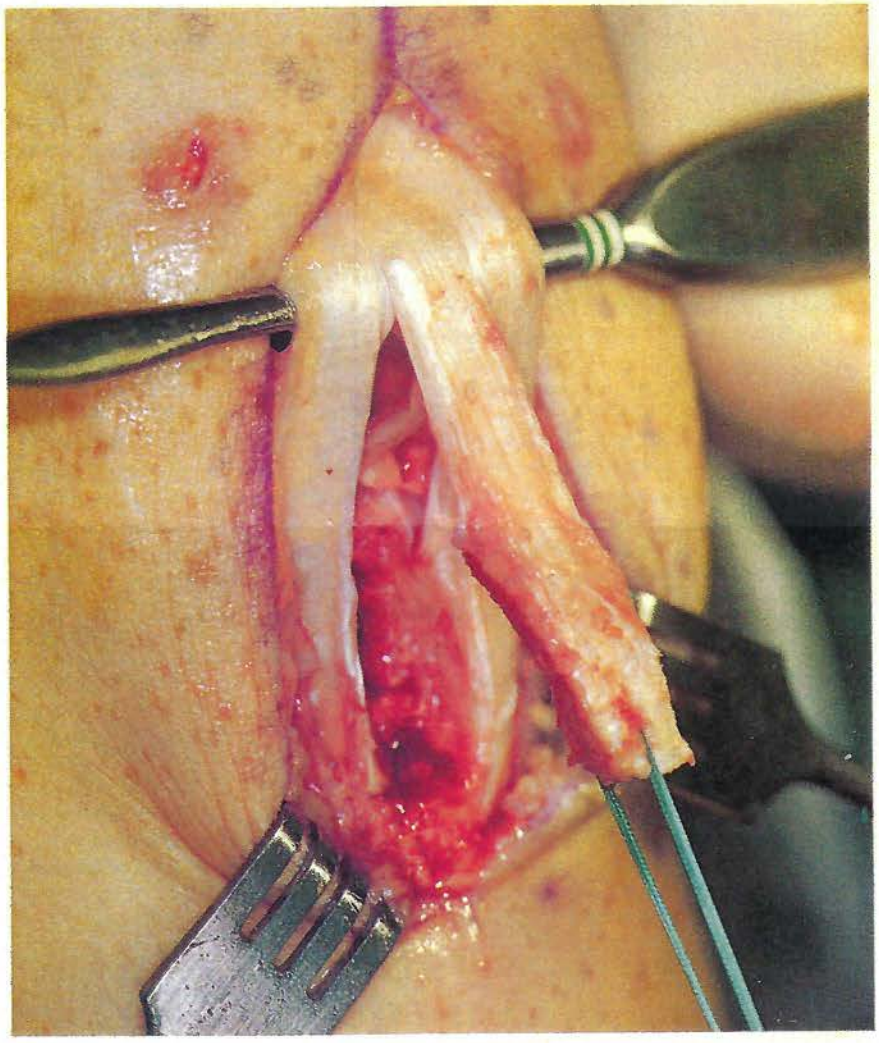

Figure 6. Bone plugs from the tibia and patella, *along with the central third of the patellar tendon, are harvested and prepared for a bone-patellar tendon-bone autograft, one of the most frequently used graft sources for ACL reconstruction.*

KEY POINTS

Addressing ACL Injuries in Women

- Due predominantly to differences in neuromuscular control strategies and movement patterns, female athletes are more susceptible than male athletes to injuries of the anterior cruciate ligament (ACL).
- Diagnosis of an ACL injury can usually be made from a thorough history and physical examination. ACL injuries often follow a stereotypical pattern that, when revealed by the patient, can help to confirm the diagnosis. Up to 80% result from a noncontact event such as occurs during sudden stops, landings, or changes in direction; in many instances, the patient will have been in an off-balance position.
- Physical examination of the knee may not be possible when acute swelling and pain are present. In such circumstances, serial examination is recommended. Sterile aspiration and intra-articular injection with a local anesthetic may also facilitate the evaluation.
- When physical examination is possible at the outset, two diagnostic assessments—Lachman's test and the flexion-rotation drawer test—are indicated. Both are easy to perform after appropriate training, are able to reveal the injury, and pose little risk to the patient. Lachman's test measures the extent of side-to-side anterior translation and thus the possibility of ACL rupture. The flexion-rotation drawer test measures the degree of control of subluxation and thus ACL function.
- In general, candidates for operative treatment fall into one of two groups: those with multiple ligament injuries and athletic individuals who wish to maintain a level of physical activity that only a reconstructed knee could support. Nonoperative treatment is typically reserved for older, nonathletic persons who are amenable to altering their physical activity level to avoid episodes of knee instability and reinjury.
- The office visit provides a key opportunity to inform all female athletes (young and old) about risk factors for ACL injury and current strategies for prevention.

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Establishing the Diagnosis of ACL Injury

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Among athletes, the circumstances of anterior cruciate ligament (ACL) injury are so characteristic that the history alone is often sufficient in establishing the diagnosis. Physical examination is important to support the clinical diagnosis and to rule out other possible injuries. Imaging tests are helpful in identifying associated injuries to bone, other ligaments, and meniscal and articular cartilage.

History

Patients with acute injury to the ACL are likely to report that:

- The injury was the result of a noncontact event that occurred while they were changing direction or landing from a jump. Patients will usually describe themselves as having been "off-balance" when the injury occurred.
- At the time of injury, they heard a "pop" that was followed by acute swelling of the knee during the next few hours.
- Immediately after the injury, they had to discontinue their sporting activity and had difficulty bearing weight.

It is also important to keep in mind that although injury to the ACL is quite common in athletes of both sexes, female athletes are at greater risk. Compared with male athletes, female athletes tend to exhibit less knee flexion, greater valgus alignment, and higher quadriceps to hamstring muscle use—factors that create substantially higher anterior shear forces at the knee and thus greater risk of ACL rupture or tear.

Physical examination

Inspect the injured area for swelling and assess the patient's pain level, both of which can influence the success and/or feasibility of physical examination. If thorough examination of the knee is not possible at initial presentation, serial examinations are recommended. Occasionally, sterile aspiration and intra-articular injection with a local anesthetic can be helpful. As part of a complete assessment, two diagnostic evaluations of the knee should be conducted:

- *Lachman's test* is positive for ACL rupture when the side-to-side difference in anterior translation is greater than 3 mm. It can also reveal the relative extent of soft-tissue damage. To perform this test, have the patient lie supine and position the involved extremity at your side. While holding the knee in slight flexion (10 to 15 degrees), stabilize the femur with one hand; with the other hand slowly apply an anteriorly directed force to the proximal posterior tibia.
- *The flexion-rotation drawer test* directly assesses the function of the ACL and its ability to control subluxation during flexion and extension. For this test, position the patient as she was in Lachman's test but with the knee held in only slight flexion and supported instead at the proximal tibia. Slowly flex the knee and note the degree of anterior tibial translation.

Coexisting injuries

During physical examination it is extremely important to rule out coexisting injuries. Often occurring at the same time as ACL injury are:

- Tearing of the meniscus.
- Tearing of other ligaments, most often the medial collateral ligament.
- Patellar dislocation.
- Chondral injury.
- Osteochondral injury.

Imaging tests

- Plain radiographs should always be ordered to rule out fractures and loose fragments of bone and cartilage. They may also reveal bony evidence of an ACL injury, such as an avulsion fracture of the medial tibial spine or the lateral tibial plateau.
- Magnetic resonance imaging is most useful preoperatively in identifying multi-ligament injuries, osteochondral fractures, bone bruises, and—especially—meniscal tears.