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Graft Selection and Preparation in Anterior Cruciate Ligament Reconstruction

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Abstract

» Anterior cruciate ligament (ACL) injuries are becoming increasingly common. They often result in functional instability, which negatively affects the patient's quality of life. After diagnosis, ACL injuries are typically treated with ACL reconstruction surgery in active patients. There are 3 commonly used grafts for ACL reconstruction surgery: patellar tendon autografts, hamstring autografts, and Achilles allografts. This article explores the critical role of the PA during ACL reconstruction surgery, particularly in efficient and precise graft preparation. By acquiring the necessary skills, PAs can be invaluable to the surgical team and to achieving positive patient outcomes.

It is estimated that there are 250,000 anterior cruciate ligament (ACL) injuries per year in the United States[1]. The ACL provides restraint to anterior tibial translation while also resisting internal rotation of the tibia. An ACL-deficient knee often results in functional instability that limits the ability of the patient to participate in activities that involve cutting and pivoting. ACL insufficiency also may affect simple daily activities such as quickly changing direction or going down stairs. In addition to negatively affecting a patient's quality of life, an unstable knee that results in repetitive translational events puts the menisci and articular cartilage at greater risk for injury; in the chronic setting, this could possibly predispose patients to early arthritis. For these reasons, ACL reconstruction surgery is often indicated to restore stability and get patients back to their desired level of function.

ACL Injury History and Presentation

The classic presentation of an ACL injury is a noncontact mechanism that involves cutting, pivoting, or acute deceleration[1]. An ACL injury also can occur with a contact injury involving hyperextension or a valgus force. The patient often reports a "popping" sensation and the knee "giving way" or buckling. This is usually followed by the inability to continue playing and difficulty with weight-bearing. A large hemarthrosis is usually present, which may or may not be noticed until the next day. While the majority of these injuries present acutely, some patients recover and will not present until they experience functional instability or pain from an associated injury.

Physical examination tests that are used to diagnose ACL insufficiency include the Lachman, pivot shift, and anterior drawer tests[2]. It is important to note that a physical examination in the acute setting can be unreliable because of the large effusion and guarding. If the patient does not have full flexion and extension, it is critical to encourage him or her to work aggressively on range of motion if nonoperative treatment is chosen, or preoperatively to decrease the risk of postoperative stiffness.

In addition to physical examination, magnetic resonance imaging (MRI) is useful to confirm the diagnosis and to evaluate for associated injury, including other ligamentous disruptions and/or

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TABLE I Three Different Graft Types Utilized in ACL Reconstruction

Graft Type	Ideal Patient	Advantages	Disadvantages
Patellar tendon autograft	<30 years old; high activity level; skeletally mature	Bone-to-bone healing; patellar tendon autograft has been shown to have lowest retear rate	Donor site morbidity[15]; anterior knee pain; risk of patellar fracture; risk of patellar tendon rupture; higher rate of kneeling pain; anterior knee numbness; increased quadriceps weakness during rehabilitation
Hamstring autograft	Moderate activity level; female (less baseline quadriceps strength); useful with skeletally immature	Less donor-site morbidity than bone-to-bone healing and less loss of quadriceps strength postoperatively	Knee flexion weakness[10] (clinically insignificant, only in deep flexion); tunnel widening[9]; slower soft-tissue graft-tunnel healing
Achilles allograft	>40 years old; low activity level; multiligament surgery	Eliminates donor-site morbidity related to graft harvest	Sterilization technique to decrease viral disease transmission weakens tissue[11]; higher failure rate[16]; increased cost for graft[12]; slower incorporation time[17]

meniscal damage. A transchondral injury pattern from a recent translational event associated with an ACL injury is often seen on the fat-saturation pulse sequence. This includes bone edema in the anterior lateral femoral condyle (above the anterior horn of the lateral meniscus) and in the posterior aspect of the lateral tibial plateau, most easily seen on the sagittal cuts.

ACL Injury Treatment

Indications for Reconstruction

After an ACL injury has been diagnosed, it is often treated with ACL reconstruction surgery in young active patients who desire to return to their previous activity level. Although use of platelet-rich plasma or stem cells has been mentioned in the literature as a nonoperative treatment option, there is little evidence supporting their use[3]. There are indications for nonoperative treatment in patients with an acute ACL injury. Relative contraindications for early surgery include a sedentary lifestyle, arthritis, and advanced age. Patients may elect to try nonoperative treatment and have surgery later if they experience instability. For the majority of patients without these features, however, operative treatment is generally preferred.

Indications for surgery and surgical techniques have evolved over the past few decades. Recent literature suggests that translational and rotational stability are better controlled with a more anatomic reconstruction. Use of an anteromedial portal generally allows for more anatomic placement of the center of the femoral tunnel, which allows for a more horizontal graft placement[4]. The transtibial approach for femoral tunnel creation often results in a more vertical tunnel. One Multicenter Orthopaedic Outcomes Network (MOON) study compared outcomes following ACL reconstruction with transtibial and anteromedial portal techniques[5]. They found that patients who underwent reconstruction with a transtibial technique had substantially higher odds of a repeat ipsilateral knee surgery, although the different surgical techniques were not predictors of the Knee Injury and Osteoarthritis Outcome Score (KOOS) Quality of Life subscore or the KOOS Function, Sports, and Recreational Activities subscore[5].

Graft Choice

Graft selection has been a topic of controversy and continues to be highly debated. Many factors are considered when choosing the optimal graft for an individual. This article will cover 3 commonly used grafts: the patellar tendon autograft, the hamstring autograft, and the Achilles allograft. Each option has advantages and disadvantages (Table I). (A quadriceps autograft is also an acceptable autograft option that we use, mainly in the revision setting; however, it will not be discussed in this paper.)

The patellar tendon autograft has been described as the gold standard, in part because it provides the advantage of bone-to-bone healing and has been shown to have the lowest retear rate, which makes it ideal for younger patients who tend to have higher activity levels[6]. However, there is a risk of donor-site morbidity, including pain in the anterior aspect of the knee, patellar fracture, and patellar tendon rupture[7].

A hamstring autograft (semitendinosus and gracilis) is a good option for skeletally immature patients since it is a soft-tissue graft and therefore less likely to cause growth arrest. We also use this graft for less-muscular female patients with moderate activity levels since it has less impact on postoperative quadriceps strength, despite a higher retear rate than a patellar

tendon autograft[8]. ACL reconstruction performed with this graft has slower soft-tissue graft-tunnel healing and an increased risk of tunnel widening and knee flexion weakness[9,10].

Finally, while there are many allograft options, the Achilles allograft is the senior author's preference because of its size and availability. It is used with patients who are older with low activity levels or with patients undergoing multiligament reconstruction. Allografts eliminate the risk of donor-site morbidity, but they also have higher retear rates, partly because of graft sterilization processes[6,11] and slower incorporation time. Additionally, the cost of an allograft is higher[12-14].

PA Responsibilities During ACL Surgery

The PA has several important responsibilities before, during, and after ACL reconstruction. Prior to the surgery, the PA should display relevant MRI scans in the operating room. The PA should also prepare the patient for surgery by placing the tourniquet high enough around the patient's thigh to avoid the sterile field. Although there are various techniques, we lower the foot of the table for notch preparation, tunnel creation, and graft passage, and it is important to have the patient positioned far enough down the table so that the knee is beyond the break in the table. This also ensures that adequate knee hyperflexion is possible during femoral tunnel reaming.

During the operation, the PA should provide adequate valgus or varus force to allow for exposure of the medial and lateral compartments, respectively. It is the PA's role to prepare the graft after the tendon has been harvested or when the allograft is available. This is one of the PA's major responsibilities and will be covered in more detail in the next section. It is critical to maintain hypervigilance related to protecting the graft from falling on the floor and becoming contaminated. This is done by verbalizing who has possession and/or control of the graft at all times, and by securing the graft to the table with sutures and snaps whenever possible; additionally, we keep the prepared graft enclosed in a sterile sealable plastic bag or other sterile container on the back table until it is needed. We emphasize constant communication and clear delineation of responsibilities with respect to graft-handling. It is helpful for the PA who prepares the graft to pass it through the knee so that the PA learns how it feels and can troubleshoot if there is ever difficulty with the passage. The PA should always double-check the size of the graft and ensure that it passes smoothly through a sizer prior to passing the graft in the patient. Additionally, the PA often is responsible for wound closure after the procedure. If there is an osseous defect, as is the case with bone-to-bone graft harvest or quadriceps tendon harvest, it is important to fill in the patellar defect with the excess bone-graft chips remaining after graft preparation, or with morselized allograft bone if needed. There are many benefits to closing the thin paratenon layer that covers the patellar tendon postharvest: it keeps the packed bone graft in place, approximates the patellar tendon, and also helps with healing since tendons have limited blood supply. To aid with visibility during this closure, it is ideal to drop the tourniquet following the paratenon closure. Meticulous dissection of the paratenon during the approach also facilitates closure.

Graft Preparation

With a patellar tendon autograft (Fig. 1), the tibial bone plug (at the top of the graft) will be passed into the femoral tunnel socket. Generally, it is trimmed with a rongeur or saw to a width of 10 mm and a length of 20 mm. The length can be shortened by 2 mm (to a length of 18 mm) if the patient is under 5 ft 3 in (160 cm) tall or it has a small notch that may inhibit smooth passage of the graft. Smaller patients have less room for the plug to pass through the knee and into the femoral

Fig. 1
A patellar tendon autograft.

socket, especially if the tunnels are created independently (i.e., not transtibial) because they are not colinear. We make the tip bullet-shaped for easier graft passage. Three holes (1 mm in size) should be drilled, and number-5 nonabsorbable suture should be passed through each hole using Keith needles in both bone plugs. The area where the sutures are should be marked with a surgical marker for easier orientation in the notch during graft passage and to avoid suture laceration at the time of screw insertion. The step-off area of the tendon attachment to the tibial bone plug, which is the area for the femoral fixation screw, should also be marked. This step-off allows room for femoral screw insertion adjacent to the tibial bone plug but safely away from the tendon at the level of the femoral socket. A Beath pin should be used for graft suture passage through the femoral socket because a slotted guidewire will not create a hole in the far femoral cortex that is large enough to allow both ends of the 3 nonabsorbable sutures to pass. The patellar bone block goes into the tibial tunnel. We do not trim this bone length since any excess will be trimmed at the end of the procedure if it sticks out of the tibial tunnel. The bottom of the plug should be marked with surgical marker for easier visualization of where to put the fixation

Fig. 2
A hamstring autograft.

screw in case the graft is short and up in the tunnel.

With a hamstring autograft (Fig. 2), we use a closed-loop EndoButton (Smith & Nephew; 15 mm in size) for suspensory fixation on the femur. We replace the sutures with stronger and different-colored number-5 nonabsorbable sutures and number-2 synthetic nonabsorbable suture. The remaining hamstring muscle should be gently scraped off of the tendons with a sterile metal surgical ruler, and the small tendon bands that may interfere with smooth passage should be trimmed. Each of the tendons should be doubled over to make a quadrupled graft of at least 100 mm in length. The graft should be threaded through the EndoButton loop and secured in position with 2.0 absorbable suture about 3 mm below the EndoButton loop. We start sewing with number-2 synthetic nonabsorbable suture at 70 mm from the EndoButton loop and sew until the end of the tendon is reached. We use fiber loops (or Krackow stiches) on each of the 2 tails, which are composed of an end of the gracilis and semitendinosus tendons on both sides. The tunnel width should be tested to ensure that the entire graft passes through relatively easily; the surgeon should be informed of the graft width because the tunnel width is based on the graft width. Generally, the width is 7 to 8 mm (range, 6 to 9 mm).

With an Achilles allograft (Fig. 3), the bone block inserts into the femoral socket. First, we use a double-cutting 10-mm blade for guidance before making cuts with the saw. We cut the block to measure 10 × 20 mm, and we make the tip bullet-shaped with the saw for easy passage. It is important to be mindful of a banana-shaped bone block since these can be difficult to fit into a cylinder shape. We trim only a small amount at a time so that we do not inadvertently make it too thin. We drill 3 holes (1 mm in size), and then pass number-5 nonabsorbable sutures through on Keith needles. We trim the soft-tissue tail with scissors to a width of 10 mm, with sutures placed from 55 to 75 mm (20 mm of sutures). We use fiber loops on a straight needle or Krackow stitches with synthetic nonabsorbable suture. Lastly, we check that the entire graft passes through a 10-mm tunnel. A Beath pin should be used for graft suture passage through the femoral socket because a slotted guidewire will not create a hole in the far femoral cortex that is large enough to allow both ends of the 3 nonabsorbable sutures to pass.

Fig. 3
An Achilles allograft.

Postoperative Care and Rehabilitation

After surgery, the patient can bear weight as tolerated and can also start flexion exercises to regain range of motion. In total, rehabilitation after surgery typically lasts between 6 and 12 months.

Conclusions

ACL injuries are common, and surgical treatment is often indicated. Patients with ACL tears vary in sex, age, and activity levels, and careful consideration should be given to each patient's needs to determine graft selection. Patellar tendon autografts, hamstring autografts, and Achilles allografts are 3 commonly utilized grafts

in ACL reconstruction. Each graft has its own pros and cons, which should be considered with each patient. PAs have a crucial role during ACL reconstruction surgery, and they have the ability to make extremely valuable contributions. By acquiring the necessary skills, PAs can be invaluable to the surgical team and to achieving positive patient outcomes.

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References

1. Griffin LY, Albohm MJ, Arendt EA, Bahr R, Beynnon BD, Demaio M, Dick RW, Engebretsen L, Garrett WE Jr, Hannafin JA, Hewett TE, Huston LJ, Ireland ML, Johnson RJ, Lephart S, Mandelbaum BR, Mann BJ, Marks PH, Marshall SW, Myklebust G, Noyes FR, Powers C, Shields C Jr, Shultz SJ, Silvers H, Slauterbeck J, Taylor DC, Teitz CC, Wojtys EM, Yu B. Understanding and preventing noncontact anterior cruciate ligament injuries: a review of the Hunt Valley II meeting, January 2005. Am J Sports Med. 2006 Sep;34(9):1512–32.

2. Katz JW, Fingeroth RJ. The diagnostic accuracy of ruptures of the anterior cruciate ligament comparing the Lachman test, the anterior drawer sign, and the pivot shift test in acute and chronic knee injuries. Am J Sports Med. 1986 Jan-Feb;14(1):88–91.

3. Murray MM, Spindler KP, Ballard P, Welch TP, Zurakowski D, Nanney LB. Enhanced histologic repair in a central wound in the anterior cruciate ligament with a collagen-platelet-rich plasma scaffold. J Orthop Res. 2007 Aug;25(8):1007–17.

4. Rayan F, Nanjayan SK, Quah C, Ramoutar D, Konan S, Haddad FS. Review of evolution of tunnel position in anterior cruciate ligament reconstruction. World J Orthop. 2015 Mar 18;6(2):252–62.

5. Duffee A, Magnussen RA, Pedroza AD, Flanigan DC, Kaeding CC. MOON Group. Transtibial ACL femoral tunnel preparation increases odds of repeat ipsilateral knee surgery. J Bone Joint Surg Am. 2013 Nov 20;95(22):2035–42.

6. Bottoni CR, Smith EL, Shaha J, Shaha SS, Raybin SG, Tokish JM, Rowles DJ. Autograft versus allograft anterior cruciate ligament reconstruction: a prospective, randomized clinical study with a minimum 10-year follow-up. Am J Sports Med. 2015 Oct;43(10):2501–9. Epub 2015 Aug 26.

7. Kartus J, Movin T, Karlsson J. Donor-site morbidity and anterior knee problems after anterior cruciate ligament reconstruction using autografts. Arthroscopy. 2001 Nov-Dec;17(9):971–80.

8. McIntosh AL, Dahm DL, Stuart MJ. Anterior cruciate ligament reconstruction in the skeletally immature patient. Arthroscopy. 2006 Dec;22(12):1325–30.

9. Clatworthy MG, Annear P, Bulow JU, Bartlett RJ. Tunnel widening in anterior cruciate ligament reconstruction: a prospective evaluation of hamstring and patella tendon grafts. Knee Surg Sports Traumatol Arthrosc. 1999;7(3):138–45.

10. Aune AK, Holm I, Risberg MA, Jensen HK, Steen H. Four-strand hamstring tendon autograft compared with patellar tendon-bone autograft for anterior cruciate ligament reconstruction. A randomized study with two-year follow-up. Am J Sports Med. 2001 Nov-Dec;29(6):722–8.

11. McGuire DA, Hendricks SD. Allograft tissue in ACL reconstruction. Sports Med Arthrosc Rev. 2009 Dec;17(4):224–33.

12. Barrera Oro F, Sikka RS, Wolters B, Graver R, Boyd JL, Nelson B, Swiontkowski MF. Autograft versus allograft: an economic cost comparison of anterior cruciate ligament reconstruction. Arthroscopy. 2011 Sep;27(9):1219–25. Epub 2011 Aug 4.

13. Baer GS, Harner CD. Clinical outcomes of allograft versus autograft in anterior cruciate ligament reconstruction. Clin Sports Med. 2007 Oct;26(4):661–81.

14. Cole DW, Ginn TA, Chen GJ, Smith BP, Curl WW, Martin DF, Poehling GG. Cost comparison of anterior cruciate ligament reconstruction: autograft versus allograft. Arthroscopy. 2005 Jul;21(7):786–90.

15. West RV, Harner CD. Graft selection in anterior cruciate ligament reconstruction. J Am Acad Orthop Surg. 2005 May-Jun;13(3):197–207.

16. Kaeding CC, Aros B, Pedroza A, Pifel E, Amendola A, Andrish JT, Dunn WR, Marx RG, McCarty EC, Parker RD, Wright RW, Spindler KP. Allograft versus autograft anterior cruciate ligament reconstruction: predictors of failure from a MOON prospective longitudinal cohort. Sports Health. 2011 Jan;3(1):73–81.

17. Jackson DW, Grood ES, Goldstein JD, Rosen MA, Kurzweil PR, Cummings JF, Simon TM. A comparison of patellar tendon autograft and allograft used for anterior cruciate ligament reconstruction in the goat model. Am J Sports Med. 1993 Mar-Apr;21(2):176–85.