Anterior Cruciate Ligament Reconstruction in Adolescents: A Survivorship Analysis

Wudbhav N. Sankar, MD, Robert B. Carrigan, MD, John R. Gregg, MD,† and Theodore J. Ganley, MD

Abstract

There are few reports on the longevity of anterior cruciate ligament (ACL) reconstruction in adolescents. In the study reported here, we performed a survivorship analysis of our experience with ACL reconstructions in adolescents. We retrospectively reviewed the cases of 276 consecutive patients (girls' bone age, >13 years; boys' bone age, >14 years; chronological age, <18 years) who underwent primary ACL reconstruction. All patients underwent transphyseal ACL reconstruction with Achilles tendon soft-tissue allograft using the same technique. Twenty-nine patients (10.5%) were excluded or lost to follow-up. Mean follow-up of the remaining 247 patients was 6.3 years (range, 2-10 years). Data were collected from charts and telephone interviews. Failure was defined as the report of symptomatic knee instability and/or revision ACL surgery. The Kaplan-Meier method showed that 1-year survivorship of ACL reconstruction was 96.4% and 5-year survivorship was 93.1%.

Dr. Sankar is Instructor, Department of Orthopaedic Surgery, University of Pennsylvania, Philadelphia, Pennsylvania.

Dr. Carrigan is Orthopaedic Surgeon, Premier Orthopaedics and Sports Medicie, Ridley Park, Philadelphia, Pennsylvania.

†Deceased. Dr. Gregg was Professor, Orthopaedic Surgery, Children's Hospital of Philadelphia, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania.

Dr. Ganley is Assistant Professor, Orthopaedic Surgery, Children's Hospital of Philadelphia, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania.

Requests for reprints: Theodore J. Ganley, MD, Children's Hospital of Philadelphia, Wood Building, 2nd Floor, 34th St & Civic Center Blvd, Philadelphia, PA 19104 (tel, 215-590-1527; fax, 215-590-1101; e-mail, ganley@email.chop.edu).

Am J Orthop. 2008;37(1):47-49.

Midsubstance anterior cruciate ligament (ACL) tears are rare injuries in adolescents with open physes. Increases in sports participation and improvements in imaging, however, have led to an increase in the reported incidence of ACL tears in adolescents.[1,2]

Conservative treatment options for skeletally immature patients with ACL tears have included bracing, quadriceps and hamstring rehabilitation, counseling, and activity modification.[2-5] Given the poor results of nonoperative treatment, several authors have advocated operative intervention to stabilize the ACL-deficient knee in skeletally immature patients.[1,2,6-9] Primary repair of midsubstance ACL tears has resulted in persistent instability and decreased activity level among patients.[10,11] Although extra-articular procedures may have a role in the treatment of skeletally immature patients, the results of such treatment have been mixed.[2,9] Intra-articular but extra-physeal techniques may be used with success in patients with wide-open physes.[12] Standard bone tunnels and fixation methods for ACL reconstruction, though common in adults, carry the potential risk for physeal damage in adolescents with open growth plates.[6,8,13,14] However, recent data suggest that drilling across the open proximal tibial or distal femoral physis, or both, can be a safe and effective technique for ACL reconstruction in patients approaching skeletal maturity.[1,7,14-19]

Regardless of the specific surgical technique, little is known about the longevity of ACL reconstruction in adolescents. In the study reported here, we used Kaplan-Meier methodology to evaluate the survivorship of our ACL reconstructions in a cohort of adolescents.

Materials and Methods

We retrospectively reviewed all 276 primary ACL reconstructions performed by a single surgeon (Dr. Gregg) between 1990 and 2000. Inclusion criteria for the cohort included chronological age less then 18 years and bone age more than 13 years for girls and 14 years for boys. Patients were excluded from the cohort if their follow-up was less than 2 years or if they had multiligament tears or associated fractures of the knee. Twenty-nine patients (10.5%) were lost to follow-up, leaving 247 for review. There were 156 boys (63.1%) and 91 girls (39.9%). Mean age at surgery was 15.4 years (range, 13-18 years). Mean follow-up was 6.3 years (range, 2-10 years).

All surgeries were performed with the same technique.[15] The ACL was reconstructed with Achilles tendon soft-tissue allograft. Holes of 9 to 10 mm in diameter are drilled across the distal femoral and proximal tibial physes. The graft is press-fit into the tibial tunnel, passed through the femoral tunnel, and secured to the lateral aspect of the femur with 2 staples (Smith & Nephew, Memphis, Tenn) (Figures 1A, 1B).

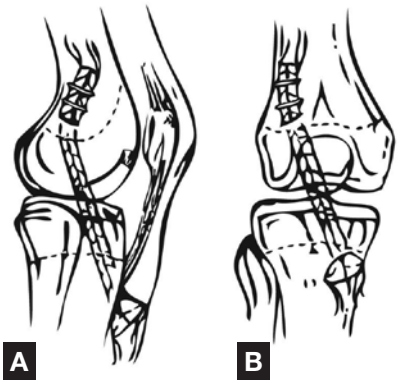

Figure 1. Lateral (A) and anteroposterior (B) view of the ACL reconstruction technique. An Achilles tendon allograft is passed through drill holes across the open physis of both the proximal tibia and distal femur. The graft is press-fitted on the tibial side before fixation with 2 staples on the femoral side.

After surgery, patients were enrolled in an accelerated physical therapy program. Early range-of-motion and stretching exercises were emphasized. After patients regained 75% of their quadriceps strength (tested by Cybex), they were cleared for jogging. At 85% strength, they started spinning and agility drills. No patients were braced after 3 months.

Follow-up information was obtained from charts and telephone interviews. We asked patients (a) whether their knee ever felt unstable and (b) if any revision surgery had been performed since the index procedure. Failure was defined as a "yes" answer to either question. Charts were reviewed for patient demographics, complications, and return to function. The Kaplan-Meier method was used to analyze the survivorship data.

Results

Of 17 failures (6.9%), 9 (3.6%) had occurred within 1 year after surgery, and the other 8 (3.3%) between 1 and 3 years after surgery. There were 6 failures among the boys and 3 among the girls, but there was no statistical difference in boys' and girls' failure rates. All failures occurred after return to competitive sports. In this series, 1-year survivorship of ACL reconstructions was 96.4%, and 5-year survivorship was 93.1% (Figure 2).

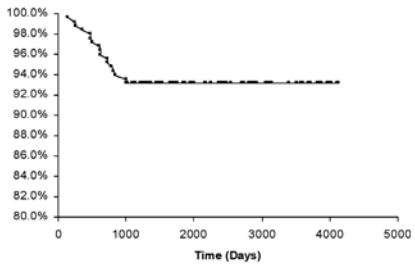

Figure 2. Kaplan-Meier survivorship curve for all anterior cruciate ligament reconstructions.

Discussion

Treatment of skeletally immature patients with midsubstance ACL tears has eluded a general consensus among treating physicians. Nonoperative treatment options include activity restriction, quadriceps and hamstring strengthening, and functional bracing. Although Woods and O'Connor[20] reported no increase in additional knee injuries in adolescents with ACL tears who had delayed treatment for 1 to 26 weeks, many authors believe that nonoperative treatment is unsuccessful and can lead to pathologic laxity, instability, and potential meniscal damage.[2-5]

Primary repair of the torn ACL in skeletally immature children has had equally poor results. DeLee and Curtis[10] and Engebretsen and colleagues[11] both reported continued laxity and episodes of giving way after primary repair of midsubstance ACL tears. Extra-articular surgical repair has had mixed results but perhaps is valuable in stabilizing skeletally immature patients until skeletal maturity is near and transphyseal procedures pose less risk to the physes.

Intra-articular reconstruction of midsubstance ACL tears is the most frequently used surgical technique in adults. However, drilling across open physes in skeletally immature patients theoretically can cause permanent damage to the growth plates and lead to leg-length discrepancy, angular deformity, and condylar dysplasia. Therefore, some authors have advocated techniques in which transphyseal drilling is avoided.[6,8,13,14] However, results from several animal studies suggest that, when up to 20% of the central physeal surface is drilled and filled with an inert substance, no alteration in growth-plate function occurs.[18,19] This finding led other authors to drill across the open proximal tibial or distal femoral physis, or both, in an effort to more closely approximate the anatomic position of the ACL.[1,7,14-17]

In 1999, Micheli and colleagues[12] described an intra-articular, extraphyseal technique in which a strip of iliotibial band is placed in the over-the-top position on the femur and passed deep to the intermeniscal ligament to the anterior aspect of the tibial metaphysis. The 8 patients in their series all had stable knees clinically and by KT1000 testing at a mean follow-up of 66.5 months. Mean Lysholm score was 97.4, and no leg-length discrepancies were reported. This technique avoids transphyseal drilling and was recommended for patients with wide-open physes.

In choosing a management protocol, we believe that growth-plate considerations should continue to shape the treating physician's decision. At our institution, treatment of midsubstance ACL tears in the pediatric population is based on skeletal age. Transphyseal ACL reconstruction is performed on female patients with a skeletal age of 13 years or more and on male patients with a skeletal age of 14 years of more.[15,21] For patients with an inadequately developed chondroepiphysis who do not meet the skeletal age requirements for transphyseal reconstruction, we prefer activity modification and bracing until these skeletal requirements are met.

We previously reported more detailed ACL reconstruction results[15] using the same transphyseal technique used in the present series. The previous cohort included 19 patients (mean age, 13 years) followed for a mean of 25 months. Sixteen of the 19 patients returned to the same sports after recon-

struction; the 3 who elected not to return to their previous sports stated that their decision was not based on symptoms in the reconstructed knee. At final follow-up, the mean side-to-side KT1000 arthrometer difference was 1.7 mm, and the mean Lysholm score was 97. Scanograms and long-leg plain films were obtained for all patients, and no significant leg-length discrepancies or angular deformities were reported.

Little has been written about the survivorship of ACL reconstruction in adolescents. In a series of 24 pediatric patients, Edwards and Grana[22] reported a 2-year failure rate of 19.1%—approximately a 4-fold increase over the adult 2-year failure rate of 2% to 5%.[23]

The Kaplan-Meier method, the most widely used statistical method for estimating time to event outcome, is best for data sets with precisely measured, timed events (eg, revision surgery). This method was previously used to evaluate outcomes after total joint arthroplasty in patients with degenerative osteoarthritis, congenital dislocation, and rheumatoid arthritis.[24,25] Other authors have used the Kaplan-Meier method to analyze survivorship after core decompression for nontraumatic osteonecrosis of the femoral head.[26]

In our study of adolescents, the Kaplan-Meier method showed that 1-year survivorship of primary ACL reconstruction using our technique was 96.4%, and 5-year survivorship was 93.1%. All failures occurred within the first 3 years after reconstruction. Our failure rate is higher than that of some adult series but lower than that of other pediatric ACL reconstruction studies.[10,15,23,27] Our series differs from other pediatric ACL series in that our sample size was larger (247 patients), the procedure was performed using a single technique by a single surgeon, and mean follow-up was more than 6 years.

Despite its large sample and long follow-up, our study has several limitations. A major shortcoming is the subjective nature of failure determination. Patients were asked if they had symptomatic instability after their reconstruction, but there was no quantitative measurement of anterior tibial translation. Patients could have reported instability that was in fact due to a patellofemoral disorder or other cause rather than a true failure of the ACL (this would actually improve our survivorship results). There was also a significant segment lost to follow-up (10.5%), which is a weakness in any survivorship analysis. At last report, none of the 29 patients lost to follow-up demonstrated symptomatic instability or had undergone revision surgery. However, we were not able to contact these patients to determine the long-term outcome of their ACL reconstruction. This study represents a single surgeon's experience with a single technique, and as such its ability to be generalized to other surgeons using other techniques can be questioned.

Regardless of its limitations, this study provides useful data about the survivorship of ACL reconstruction in adolescents—an area in need of data. This information is important for counseling families before surgery and for evaluating intermediate-term results of a given surgical technique.

Authors' Disclosure Statement and Acknowledgments

The authors report no actual or potential conflict of interest in relation to this article.

References

1. Andrews M, Noyes FR, Barber-Westin SD. Anterior cruciate ligament allograft reconstruction in the skeletally immature athlete. *Am J Sports Med.* 1994;22:48-54.
2. McCarroll JR, Shelbourne KD, Porter DA, Rettig AC, Murray S. Patellar tendon graft reconstruction for midsubstance anterior cruciate ligament rupture in junior high school athletes. An algorithm for management. *Am J Sports Med.* 1994;22:478-484.
3. Angel KR, Hall DJ. Anterior cruciate ligament injury in children and adolescents. *Arthroscopy.* 1989;5:197-200.
4. Graf BK, Lange RH, Fujisaki CK, Landry GL, Saluja RK. Anterior cruciate ligament tears in skeletally immature patients: meniscal pathology at presentation and after attempted conservative treatment. *Arthroscopy.* 1992;8:229-233.
5. Mizuta H, Kubota K, Shiraishi M, Otsuka Y, Nagamoto N, Takagi K. The conservative treatment of complete tears of the anterior cruciate ligament in skeletally immature patients. *J Bone Joint Surg Br.* 1995;77:890-894.
6. Brief LP. Anterior cruciate ligament reconstruction without drill holes. *Arthroscopy.* 1991;7:350-357.
7. Lipscomb AB, Anderson AF. Tears of the anterior cruciate ligament in adolescents. *J Bone Joint Surg Am.* 1986;68:19-28.
8. Nakhostine M, Bollen SR, Cross MJ. Reconstruction of mid-substance anterior cruciate rupture in adolescents with open physes. *J Pediatr Orthop.* 1995;15:286-287.
9. Parker AW, Drez D Jr, Cooper JL. Anterior cruciate ligament injuries in patients with open physes. *Am J Sports Med.* 1994;22:44-47.
10. DeLee JC, Curtis R. Anterior cruciate ligament insufficiency in children. *Clin Orthop.* 1983;172:112-118.
11. Engebretsen L, Svenningsen S, Benum P. Poor results of anterior cruciate ligament repair in adolescence. *Acta Orthop Scand.* 1988;59:684-686.
12. Micheli LJ, Rask B, Gerberg L. Anterior cruciate ligament reconstruction in patients who are prepubescent. *Clin Orthop*. 1999;364:40-47.
13. Janarv PM, Nystrom A, Werner S, Hirsch G. Anterior cruciate ligament injuries in skeletally immature patients. *J Pediatr Orthop.* 1996;16:673-677.
14. Matava MJ, Siegel MG. Arthroscopic reconstruction of the ACL with semitendinosus-gracilis autograft in skeletally immature adolescent patients. *Am J Knee Surg.* 1997;10:60-69.
15. Aronowitz ER, Ganley TJ, Goode JR, Gregg JR, Meyer JS. Anterior cruciate ligament reconstruction in adolescents with open physes. *Am J Sports Med.* 2002;28:168-175.
16. Bisson, LJ, Wickiewicz T, Levinson M, Warren R. ACL reconstruction in children with open physes. *Orthopedics.* 1998;21:659-663.
17. Lo IK, Kirkley A, Fowler PJ, Miniaci A. The outcome of operatively treated anterior cruciate ligament disruptions in the skeletally immature child. *Arthroscopy.* 1997;13:627-634.
18. Makela EA, Vainionpaa S, Vihtonen K, Mero M, Rokkanen P. The effect of trauma to the lower femoral epiphyseal plate. An experimental study in rabbits. *J Bone Joint Surg Br.* 1988;70:187-191.
19. Stadelmaier DM, Arnoczky SP, Dodds J, Ross H. The effect of drilling and soft tissue grafting across open growth plates. A histologic study. *Am J Sports Med.* 1995;23:431-435.
20. Woods GW, O'Connor DP. Delayed anterior cruciate ligament reconstruction in adolescents with open physes. *Am J Sports Med*. 2004;32:201-210.
21. Greulich WW. *Radiographic Atlas of Skeletal Development of the Hand and Wrist*. Stanford, Calif: Stanford University Press; 1950.
22. Edwards PH, Grana WA. Anterior cruciate ligament reconstruction in the immature athlete: long-term results of intra-articular reconstruction. *Am J Knee Surg.* 2001;14:232-237.
23. Millett PJ, Willis AA, Warren RF. Associated injuries in pediatric and adolescent anterior cruciate ligament tears: does a delay in treatment increase the risk of meniscal tear? *Arthroscopy*. 2002;18:955-959.
24. Finkelstein JA, Gross AE, Davis A. Varus osteotomy of the distal part of the femur. A survivorship analysis. *J Bone Joint Surg Am*. 1996;78:1348-1352.
25. Sochart DH, Porter ML. Long-term results of total hip replacement in young patients who had ankylosing spondylitis. Eighteen to thirty-year results with survivorship analysis. *J Bone Joint Surg Am*. 1997;79:1181-1189.
26. Bozic KJ, Zurakowski D, Thornhill TS. Survivorship analysis of hips treated with core decompression for nontraumatic osteonecrosis of the femoral head. *J Bone Joint Surg Am.* 1999;81:200-209.
27. Edwards TB, Greene CC, Baratta RV, Zieske A, Willis RB. The effect of placing a tensioned graft across open growth plates. A gross and histologic analysis. *J Bone Joint Surg Am.* 2001;83:725-734.