Prospective Evaluation of Range of Motion in Acute ACL Reconstruction Using Patellar Tendon Autograft

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Background: Optimal timing of anterior cruciate ligament (ACL) reconstruction has been a topic of controversy. Reconstruction has historically been delayed for at least 3 weeks, given previous studies reporting a high risk of postoperative arthrofibrosis and suboptimal clinical results.

Purpose: To prospectively evaluate postoperative range of motion following acutely reconstructed ACLs with patellar tendon autograft.

Study Design: Case series; Level of evidence, 4.

Methods: Patients (age >18 years) who had ACL reconstruction as soon as possible after injury, regardless of the condition or preoperative range of motion of the injured knee, underwent reconstruction with patellar tendon autograft. An identical standard surgical technique and postoperative rehabilitation were employed for all patients. Postoperative assessment included active range of motion measurements with a goniometer. Subjective outcomes were assessed with the Knee injury and Osteoarthritis Outcome Score (KOOS).

Results: A total of 25 consecutive patients who met the inclusion criteria were enrolled. The mean age was 27.9 years (range, 20-48 years), and 19 were men. The time from injury to surgery was a mean 4.5 days (range, 1-9 days). The mean objective follow-up was 10.9 months (range, 3 days–19.4 months), and range of motion was regained at a mean 4.4 months (range, 1-9 months). Three meniscal repairs and 3 microfractures were performed concomitantly. There was 1 graft failure at 3 years postoperatively, noted at 50 months of subjective follow-up. There was no loss of extension >3° as compared with the contralateral knee in any patient. There was no loss of flexion >5° as compared with the contralateral knee in any patient who completed objective follow-up. The mean KOOS at final subjective follow-up was 82.8 (range, 57.7-98.8) at a mean 56.6 months postoperative (n = 14/24; range, 48-58 months).

Conclusion: Excellent clinical results can be achieved following ACL reconstruction performed ≤9 days after injury with patellar tendon autograft. The authors found that early ACL reconstructions do not result in loss of motion or suboptimal clinical results as long as a rehabilitation protocol emphasizing extension and early range of motion is employed.

Keywords: ACL; reconstruction; acute; military; patellar tendon

Optimal timing for the reconstruction of an acute anterior cruciate ligament (ACL) tear has been a topic of controversy. Shelbourne et al[15,16] published a pair of landmark studies that reported an increased risk of arthrofibrosis in acutely reconstructed ACL tears; they concluded that it is best to wait until swelling resolves and range of motion returns before attempting ACL reconstruction. Multiple studies have sought to explore early versus delayed ACL reconstruction with regard to postoperative stiffness, and there have been 3 recent systematic reviews seeking to answer this question.[2,10,17] All 3 reviews commented on the difficulty of reaching any conclusions, given that there is no agreement among studies on what is the strict definition of early and delayed timing.

One of the authors (C.R.B.)[5] published a study comparing ACLs reconstructed approximately 1 week after injury with those approximately 12 weeks after injury and showed no loss of motion. One question regarding that study was whether it applied to patellar tendon grafts since all surgeries were performed with soft tissue grafts. In 1996, Hunter et al[8] published a prospective study of patellar tendon grafts with reconstructions performed as early as within the first 48 hours; they also found no increased risk of arthrofibrosis. However, they did acknowledge a select patient population with daily supervised therapy starting immediately after surgery, which may not be applicable to

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the general population. The purpose of this study was to prospectively evaluate a series of patients in whom acute ACL reconstructions were performed with patellar tendon autografts and to evaluate postoperative range of motion as compared with the contralateral extremity.

METHODS

The study protocol was approved by the human use committee at Tripler Army Medical Center. Investigators adhered to the policies for the protection of human participants as prescribed in 45 Code of Federal Regulation 46. This was an institutional review board–approved prospective consecutive study. Inclusion criteria consisted of patients aged >18 years who had surgery as soon as possible after an acute ACL tear that was diagnosed by history, examination, and magnetic resonance imaging. Patients who reported prior knee instability were excluded. Additionally, patients with multiligamentous knee injuries or any prior knee surgery were excluded. Meniscal and chondral pathology was not used as an exclusion criterion.

All surgical procedures were performed by 1 of 3 sports medicine fellowship–trained surgeons (D.J.R., J.M.T., C.R.B.) within 9 days of injury. The surgical techniques for the ACL reconstruction were identical, utilizing a bone–patellar tendon–bone autograft with metal interference screw fixation in both the tibia and the femur. Meniscal pathology was addressed at the attending physician's discretion; meniscal repairs were performed with either an inside-out technique or an all-inside technique. Patients were placed in a hinged knee brace and allowed full weightbearing and range of motion as tolerated immediately unless a meniscal repair had been performed. Meniscal repairs were restricted to weightbearing in full extension only and flexion to 90° for the first 4 weeks and then progression to full weightbearing and range of motion as tolerated. Full-thickness chondral defects were treated with microfracture at the same setting as the ACL reconstruction. These patients were kept nonweightbearing for 4 weeks but allowed immediate full motion.

Postoperative therapy was initiated within 2 weeks of surgery. Frequency of supervised appointments was determined by the physical therapist, with a mean 3.3 visits in the first 2 weeks (range, 0-6), and typically consisted of 1 or 2 visits a week after that until postoperative week 12. All patients used a standard accelerated ACL protocol, unless a concomitant procedure had been performed (ie, meniscal repair or microfracture).

Postoperative evaluations were performed monthly in a blinded fashion. Both knees were covered with a stocking prior to examination by the surgeon. A goniometer was used to measure the primary outcome of active range of motion on both knees. Patients were classified as having a flexion deficit if >5° was lost as compared with the contralateral side and an extension deficit if >3° was lost as compared with the contralateral side. Patients were followed with physical examinations until full range of motion was achieved and they had completed postoperative rehabilitation. Subjective outcomes were assessed using the Knee injury and Osteoarthritis Outcome Score (KOOS). Subjective outcome assessments were sent to patients every 6 months for a minimum of 2 years. Patients who left the practice service area were contacted by phone for follow-up.

Statistical Analysis

All statistical analyses and tests were conducted using SPSS (v 17 or higher) (PASW Statistics; IBM). The nonparametric Wilcoxon signed-rank test was used to analyze range of motion of each knee, side to side, at each time point and at follow-up. A 2-sided Fisher exact test was used to analyze the number of patients with flexion and extension motion loss as compared with historical controls. Thresholds for statistical significance were set to a minimum of $P < .05$. Power analysis indicated that 22 patients would be needed to detect a 3° difference between the normal and injured legs (power, 0.8; $\alpha = 0.05$). Statistical analyses were performed by a trained biostatistician.

RESULTS

Twenty-five consecutive patients who met the inclusion criteria were enrolled. The mean age was 27.9 years (range, 20-48 years), and 19 were men. The time from injury to surgery was a mean 4.5 days (range, 1-9 days). The mean objective follow-up duration was 10.9 months (range, 3 days–19.4 months). At the index procedure, 3 patients

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Ethical approval for this study was obtained from Tripler Army Medical Center Institutional Review Board.

TABLE 1
Flexion and Extension Deficits[a]

	Present Study	Historical Control	*P* Value
Lost >3° of extension	0/25 (0)	76/573 (13.3)	.060
Lost >5° of flexion	3/25 (12.0)	75/506 (14.8)	>.999

[a]Values are presented as n (%).

underwent concomitant meniscal repairs, and 3 underwent microfracture for full-thickness chondral lesions. One of the 3 patients with a microfracture had a meniscal tear, which was not repaired. There was 1 case requiring a return to the operating room at less than 1 year postoperatively for scar revision and resection of a symptomatic extra-articular tibial bone prominence.

There was no significant difference in flexion or extension of the operative knee as compared with the normal knee at final follow-up. All patients regained full extension, and there was no loss of flexion in any patient who completed objective follow-up (3 patients had flexion deficits >5° but were lost to final objective follow-up and thus were excluded). In the 22 patients who completed objective follow-up, all achieved full range of motion and reached it at a mean 4.4 months postoperatively (range, 1-9 months).

Three patients were lost to objective follow-up. These patients had flexion deficits of 20° to 45° at their last objective follow-up. Two of these 3 patients were last seen just 1 week postoperatively before permanently leaving the local practice area. The third patient sustained a medial collateral ligament injury postoperatively and failed to regain 20° of flexion in the operative knee; he did not complete objective follow-up and discontinued his physical therapy before regaining all of his motion.

In a review by Mohtadi et al[13] that evaluated the use of patellar tendon autograft for delayed ACL reconstruction, historical data indicated a loss of >3° of extension in 13.3% of patients and a loss of >5° of flexion in 14.8% of patients (Table 1). In our study, there was no significant loss of motion in the operative knee as compared with the normal knee. If we include the 3 patients with flexion deficits who did not complete objective follow-up into our analysis, we would still have only a 12% occurrence of flexion deficit, which is not significantly more than historical control ($P > .999$) (Table 1) and is not a significant difference as compared with the contralateral extremity in our group of patients ($P = .25$).

Patient-reported KOOS outcomes were significantly improved postoperatively as compared with preoperative evaluation ($P < .001$). The mean preoperative KOOS was 42.3 (range, 0-79). The mean postoperative KOOS at final subjective follow-up was 82.8 (range, 57.7-98.8) at a mean 56.6 months (n = 14/24; range, 48-58 months). One patient was excluded from final KOOS analysis owing to rerupture and subsequent revision 3 years after the index procedure (noted at 50-month subjective follow-up). All but 2 patients completed at least 1 subjective outcome evaluation at a minimum of 12 months postoperatively; 1 of these 2 patients refused to participate in the study after 6 months of follow-up, and the other could not be contacted.

TABLE 2
Mean Patient-Reported KOOS Subscale Scores[a]

		KOOS Subscale Score					
	n	Symptoms	Pain	ADL	Sports	QOL	Total
6 to 11 mo	2	80.0	82.0	92.0	65.0	53.5	74.5
12 to 23 mo	2	78.5	79.0	88.0	55.0	47.0	69.5
24 to 35 mo	5	86.4	84.6	94.8	76.0	71.4	82.6
36 to 47 mo	1	82.0	75.0	97.0	75.0	63.0	78.4
48 to 60 mo	14	78.8	86.3	92.3	75.7	63.4	82.8

[a]n = 24 patients (1 patient was excluded for rerupture 3 years postoperatively). ADL, Activities of Daily Living; KOOS, Knee injury and Osteoarthritis Outcome Score; QOL, Quality of Life.

Of 24 patients, 7 had a KOOS Quality of Life (QOL) or Sports subscale score <40 (Sports and QOL <40 at 12 months, n = 1; Sports <40 at 35 months, n = 1; QOL <40 at a mean 56 months [range, 48-58 months], n = 5) (Table 2). Of these 7 patients, 6 had meniscal tears, 2 required a meniscal repair, and 1 had a microfracture performed. Of the 7 patients, 2 were included in the group of 3 patients with incomplete objective follow-up and flexion deficits at their last objective follow-up visits. One of these patients, who had QOL and Sports scores <40, could not be contacted after 6 months of subjective follow-up.

DISCUSSION

The primary objective in this study was to examine postoperative knee range of motion and subjective outcomes after acute ACL reconstruction with patellar tendon autograft. Our data show that ACL reconstructions with a patellar tendon autograft can be performed within 9 days of injury with limited concern for loss of motion or arthrofibrosis. Our results were obtained with limited preoperative therapy and standard, minimally supervised postoperative physical therapy.

In 1991, Shelbourne et al[16] reviewed 169 ACL reconstructions that used ipsilateral patellar tendon (bone-tendon-bone) autografts, similar to our study. Since that landmark study, typical management of an acute ACL tear has been to delay reconstruction for a minimum of 3 weeks to decrease the risk of arthrofibrosis. In a later article, that recommendation was modified slightly with specific parameters regarding decreased swelling and normal range of motion.[15] Over the past 25 years, there has been a slowly growing trend to challenge the idea that early reconstruction results in more knee stiffness; it is thought that the difference likely lies in postoperative rehabilitation rather than the timing of the surgery itself.[10] One important difference between the study by Shelbourne et al[16] and our study is that they implemented early rehabilitation with an accelerated protocol and an emphasis on extension with early restoration of motion in some of their

patients. Those patients who were enrolled in early rehabilitation had more successful outcomes with less arthrofibrosis than those with delayed rehabilitation.

Multiple studies have been published regarding optimal timing of acute ACL reconstructions. These have included randomized controlled trials and prospective series.[1,2,4-9,12,14] There have been 3 systematic reviews or meta-analyses published in an attempt to answer the question of optimal timing for ACL reconstruction and the risk of arthrofibrosis.[2,10,17] All 3 conclude that there does not appear to be a significant difference between early and delayed reconstruction with regard to stiffness, particularly when modern, accelerated rehabilitation protocols are utilized. However, all 3 also comment on the substantial heterogeneity in defining "early" and "delayed." Andernord et al[2] noted that in the studies included in their review, "early" was defined as anywhere between <48 hours and <6 months from injury, while "delayed" could mean anywhere from >3 weeks to 13 years after injury. Smith et al[17] sought to limit this heterogeneity by focusing on articles in which "early" meant <3 weeks from injury and "delayed" was >6 weeks.

The senior author (C.R.B.) published a study comparing early (mean, 9 days from injury) versus delayed (mean, 12 weeks) reconstruction with hamstring tendon autograft via a single-incision arthroscopic technique and found no increased risk of stiffness in the acutely reconstructed hamstring tendon group.[5] Some questioned whether this would apply to patellar tendon (bone-tendon-bone) grafts. In 1996, Hunter et al[8] examined the question of motion with very acute reconstructions with patellar tendon grafts. They also did not see any loss of motion postoperatively in the acutely reconstructed ACL. However, the authors noted that this study was performed on a select population of downhill skiers who had 2 weeks of daily supervised therapy beginning immediately after surgery. They observed in their discussion that their results may not be generalizable to other patient populations who do not have access to daily supervised therapy.[8] The results of our study build on this report and perhaps increase the generalizability of the results, as our patients had a mean 3.3 supervised therapy sessions within the first 2 weeks.

This study has several strengths, one of which is the prospective design with a consecutive series, which removes selection bias, as no patient who was eligible refused to participate. The surgical technique and postoperative rehabilitation were uniform and consistent throughout, with modern graft fixation techniques and a standard accelerated rehabilitation protocol with early weightbearing and range of motion. However, 3 patients did have meniscal repairs requiring limitation of range of motion to <90° for 4 weeks. The physical therapy was not as highly supervised or structured as in the study by Hunter et al,[8] which may make the results more applicable to the general population. This study also had robust follow-up for subjective outcomes, with 100% of patients responding to at least 1 subjective survey ≥6 months postoperatively and 58% responding to the survey beyond 48 months postoperatively. The overall patient-reported outcomes for this series of patients were similar to the data reported by Antosh et al[3] for US Army cadets with ACL reconstructions, indicating that our athletic patients returned to an expected level of activity postoperatively.

The main weakness of this study is the lack of a prospective control group. However, we believed that performing patellar tendon ACL reconstructions in a delayed fashion is a well-established and reliable procedure. There are decades' worth of data showing that it has largely good outcomes; we chose to use the combined data of extension and flexion in a meta-analysis as a historical control (Table 1).[13] The residual flexion deficit seen in 12% of our cohort (3/25 patients) does approach the historical mean for delayed reconstruction but is not statistically different. We did not observe any extension deficits in our acutely reconstructed cases. We had short subjective follow-up (<2 years) in 16% (4/25) of patients, which is a weakness of this study but is not a major concern, as the primary outcome is return of range of motion. Finally, the short objective follow-up could also be a weakness; however, arthrofibrosis is a complication that occurs early in the postoperative course, and it would be rare for a patient to achieve full motion within 6 months of surgery and then regress to either a flexion contracture or significant loss of flexion.[11]

CONCLUSION

Acute ACL reconstructions can be performed within the first 9 days from injury without increased risk of postoperative stiffness or arthrofibrosis. With an accelerated rehabilitation protocol, even in the setting of a meniscal repair or microfracture, our study demonstrated a reliable return of function and return of active range of motion.

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