Prediction of Patient-Reported Outcome After Single-Bundle ACL Reconstruction

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Abstract

Purpose—To identify pre-operative and intra-operative factors that predict patient-oriented outcome as measured by the IKDC Subjective Knee Form after ACL reconstruction.

Methods—We identified 402 subjects who had undergone primary single-bundle arthroscopic ACL reconstruction at a mean follow-up of 6.3 years (range 2-15 years). The International Knee Documentation Committee Subjective Knee Form (IKDC) was used to measure patient-reported outcome and was dichotomized as above or below the patient-specific age and gender matched population average. Potential predictor variables included subject demographics, activity level prior to surgery, previous meniscectomy, and surgical variables. Multivariate logistic regression analysis was performed to identify the best subset of predictors for determining the likelihood that the IKDC score was better than the age- and sex-matched population average.

Results—The dichotomized IKDC score was associated with BMI, smoking status, education, previous medial meniscectomy, and medial chondrosis at the time of ACL reconstruction. The multivariate model containing only factors known before surgery included BMI and smoking status. Subjects with a BMI > 30 had 0.35 times the odds of success than subjects with a normal BMI. Subjects who smoked had 0.36 times the odds of success as subjects who did not smoke. A model including medial chondrosis at the time of surgery had a slightly higher discriminatory power (area under the ROC curve 0.65 versus 0.61) and negative predictive value (71.4 versus 60.0), but similar positive predictive power (86.3 versus 85.9).

Conclusions—Lower patient-reported outcome following ACL reconstruction was strongly associated with obesity, smoking, and severe chondrosis at time of surgery.

Keywords

ACL Reconstruction; prognosis; patient-oriented outcome

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Level of Evidence: Level III, Retrospective Study

INTRODUCTION

Anterior cruciate ligament (ACL) rupture is a common knee injury with a recent estimated incidence of 81 per 100,000. (1) Many of these injuries require surgery and rehabilitation, however questions remain regarding which patient related factors have the greatest impact on the long-term prognosis of ACL reconstruction. The short-term goals of ACL reconstruction are to restore joint stability and eliminate symptoms. The long-term goals are to allow individuals to return to their prior level of activity and participation, and prevent future development of osteoarthritis (OA). Each of these goals may serve as an outcome measure after ACL reconstruction. Previous research has focused on analysis of joint structure and function, primarily measures of joint stability including the Lachman, KT-1000, and the pivot shift tests. However joint stability may not correlate with activities of daily living, sports participation, or patient satisfaction, which are of primary interest to the patient.(2)

Generally, ACL reconstruction is perceived to be a successful procedure, however critical analysis has shown that clinical outcomes are less than optimal. A recent meta-analyses has demonstrated that normal knee function is restored in only 37% of the patients undergoing ACL reconstruction.(3) Similarly, knee laxity is prevalent with 31.8% of patients exhibiting a positive Lachman test and 21.7% of patients exhibiting a positive pivot shift.(4) After ACL reconstruction, only 65 to 70% of individuals return to the pre-injury level of sports activity. (3,5) Finally, ACL reconstruction also fails to reduce the risk of OA after ACL injury.(6,7)

Given that not all patients have an optimal outcome, it is important to identify prognostic factors that maximize a successful outcome. The purpose of this present study was to identify the pre-operative and intra-operative factors that predict patient-oriented outcome as measured by the IKDC Subjective Knee Form at long-term follow-up after ACL reconstruction. We hypothesize that one or more pre-operative and intra-operative factors can reasonably predict patient-oriented outcome.

METHODS

We retrospectively identified subjects that underwent primary single-bundle arthroscopic ACL reconstruction between 1986 and 2002. We included all subjects who had a minimum two-year follow-up and had completed the IKDC Subjective Knee Form. Patients were excluded if they had incomplete survey data. Of the 422 subjects identified, 407 had a minimum follow-up of 2 years. A total of 402 subjects had complete survey data and were included in the analysis. Of the 402 subjects, 209 were male, 193 were female. The mean age at time of surgery was 28.4±11.59 years (range: 13.3 to 59.8 years). The mean length of follow-up was 6.3 years (range: 2.0 to 14.7 years).

The average time from injury to surgery was 22 months (median 3 months, range: 1 day to 328 months). All subjects had undergone arthroscopic intra-articular reconstruction regardless of physeal status. The 1-incision technique was used in 391(98%) subjects. Twenty-five subjects had concomitant ligamentous injuries. Three subjects had missing demographic or activity level data. There were eight subjects with incomplete operative data.

At follow-up, subjects completed the IKDC Subjective Knee Form. The IKDC Subjective Knee Form is a patient-oriented questionnaire, which contains 18 items evaluating symptoms, level of activity, ability to perform activities of daily living and sports, and knee function. It is scored on a scale of 0 to 100 with higher scores indicating higher levels of functioning and lower levels of symptoms. It has been found to be a reliable, responsive, and valid tool that measures symptoms, function, and sports activity in patients with a variety of knee disorders.(8,9) Normative data for individuals living within the United States with no current or past history of knee problems or surgery has been established.(10) We defined a successful outcome as an

IKDC Subjective Knee Form score greater than the subject-specific age- and gender-matched population mean and an unsuccessful outcome as a score less than the subject-specific age- and gender-matched population mean.

The potential predictors that were explored in this study included subject demographics, activity level prior to surgery, previous meniscectomy, and surgical variables. The subject characteristics that were assessed were patient age, weight, height, BMI, occupation, smoking, education level at surgery, and marital status. Mechanism of injury and activity level and frequency before injury and number episodes of giving way prior to surgery were also included as potential predictors of subject-oriented outcome. The surgical variables were obtained from operative notes and included concomitant ligamentous injuries, graft tissue (allograft vs. autograft), graft source (bone patellar tendon bone, hamstring or Achilles tendon), presence of meniscus tear and treatment, location and severity of chondrosis, method of tibial and femoral fixation and one versus two incision technique. Meniscus treatment was grouped as none, debridement or partial meniscectomy, and stable or repaired tear. Articular cartilage was graded according to the Outerbridge scale and recoded for data analysis as normal or mild (grade 0 to 2) and severe (grade 3 or 4).

Statistical Analysis

Data were summarized using descriptive statistics including frequency distributions for categorical data, and means and standard deviation for continuous variables. Student t-tests were used to compare continuous variables between patients with a score above the mean and patients with a score below the mean. Binomial test of proportions and chi-squared statistics were used to compare categorical variables. Univariate logistic regression analyses were performed to estimate the effect of each potential predictor on the odds of success (i.e. and IKDC Subjective Knee Score greater than the patient-specific age- and gender-matched population average.). Multivariate analyses were performed using stepwise logistic regression. Independent variables for the final model were selected based on previous research and the results of the univariate analyses. Each variable was added one at a time and tested for significance using the Wald and likelihood ratio tests. We decided a priori to include a maximum of 5 independent variables to prevent the model from becoming unstable.(11) Furthermore, we assessed for collinearity, interactions, and mediators (Sobel test for dichotomous outcomes) among the predictor variables. The Hosmer-Lemeshow-chi-squared statistic was calculated to measure the overall goodness-of fit. The final model was evaluated for all statistical assumptions. Results are presented using odds ratio (ORs) and 95% confidence intervals (CIs). All tests were two-sided with an α level of 0.05. The statistical analysis was performed using Stata software package (Release 10; Statacorp LP, College Station).

RESULTS

The median IKDC Subjective Knee Form score was 88.5 (Interquartile range 16.1). Fifty-nine subjects (14.7%) were classified as having an unsuccessful outcome, indicating that their IKDC Subjective Knee Form score was below their age- and sex-specific population average. The remaining 343 subjects (85.3%) were classified as having a successful patient-reported outcome. In the below average group, 17 (28.8%) subjects had surgery within 2 months of injury, 25 (42.4%) had surgery between 2 and 12 months, 11 (18.6%) had surgery between 12 and 60 months, and 6 (10.2%) had surgery after 60 months. In the above average group, 135 (39.4%) subjects had surgery within 2 months, 111 (32.3%) had surgery between 2 and 12 months, 60 (17.5%) had surgery between 12 and 60 months, and 37 (10.8%) had surgery after 60 months. Differences between the groups of subjects with above and below average patient-reported outcome are shown in Table 1 and 2.

The predictors independently associated with an IKDC Subjective Knee Form score below the subject-specific age and gender mean are presented in Table 3. The patient characteristics included BMI, smoking status, education, and previous medial meniscectomy. Lower activity levels were also significantly associated with a higher BMI. The only intra-operative characteristic that was associated with patient-reported outcome was severe medial chondrosis. Further testing indicated that prior medial meniscectomy was associated with severe chondrsis, however, the indirect effect of prior meniscectomy on the outcome through chondrosis was not significant.

The results of the step-wise forward logistic regression to predict the dichotomized IKDC Subjective Knee Form Score are summarized in Table 4. The most parsimonious model included BMI and smoking status. Obese (BMI 30 to 39) and morbidly obese (BMI > 40) subjects had 0.35 times the odds of success than subjects with a normal BMI. Smokers had 0.36 times the odds of success as nonsmokers. The goodness of fit statistic for the simple model was 0.25 (p-value 0.88). When surgical variables were included, only severe medial chondrosis was significant. Subjects with grade 3 or 4 chondrosis had 0.38 times the odds of success as subjects with grade 0 to 2 chondrosis. The goodness of fit statistic for the complex model was 0.05 (p-value 0.83). The more complex model had a slightly higher discriminatory power (area under the ROC curve 0.63 versus 0.61) and negative predictive value (71.4 versus 60.0), but similar positive predictive power (86.3 versus 85.9).

DISCUSSION

The principal finding of the present study was that lower patient-reported outcome following ACL reconstruction was strongly associated with obesity, smoking, and severe chondrosis at time of surgery. We used the IKDC Subjective Knee Form score and dichotomized the score based on the patient specific age- and sex-matched average to identify the determinants of patient-oriented outcome following ACL reconstruction. A simple model containing only variables known prior to surgery and the more complex model containing the degree of chondrosis had relatively high sensitivities (98.2-99.4) and positive predictive values (86.2-86.3). Both models accurately identify individuals who are likely to benefit from ACL reconstruction. However, neither reaches acceptable discriminatory power, indicating that additional factors not assessed in the current study and factors not yet identified may influence the subject's perception of the function of his or her knee.

Our study is unique for several reasons. First, we did not exclude subjects with previous injuries, concomitant injuries or who subsequently had a revision, thus our findings may be generalized to a larger population than previous findings. Second, our study contained a broad follow-up range, which allows for the evaluation of the effect of time on the outcome. Our analysis showed that the length of follow-up was not associated with patient-oriented outcome, suggesting that the subject's perception of his or her symptoms and knee function does not deteriorate over time. Finally, we utilized a validated patient-oriented outcome measure as our outcome and multiple regression. The advantage of multiple regression is the ability to assess multiple predictors at once and to explore the effects of confounding variables such as activity and BMI.

Many studies have reported good to excellent results following ACL reconstruction, however there are still a percentage of patients who are unable to return to their pre-injury level of activity.(15,17) Yet long-term studies have shown a significant number of patients develop osteoarthritis irrespective of surgery.(7) Thus, it is essential that determinants of long-term patient outcome and function are identified in order to counsel candidates for surgery and potentially modify risk factors for poor outcome. The present study identified obesity and smoking as modifiable risk factors for a poor outcome however, these risk factors alone were

unable to accurately discriminate patients who were likely to have a poor outcome. Previous studies have shown that a higher BMI at the time of reconstruction is predictive of osteoarthritis, damage to the menisci and medial chondrosis.(7,18,19) Additionally, Spindler et al. found that weight gain greater than 15 pounds resulted in worse IKDC and WOMAC scores.(20) These findings together suggest that the increased weight places excessive stress on the knee, accelerating the rate of degenerative changes. Another modifiable risk factor, smoking, is known to delay cell migration and decrease Type 1 collagen synthesis in wound healing, including ligamentous injuries.(21) The only other study to have looked at smoking in ACL reconstruction found that smokers have increased pain and laxity as well as decreased IKDC Subjective Knee Form scores.(22) Our results support these finding and indicate that the negative effects of smoking are significant after adjusting for other risk factors. This highlights the need for counseling of patients on smoking cessation prior to reconstruction to optimize patient-oriented outcome.

One interesting finding was that an education level beyond college was associated with an IKDC score above the age- and sex-matched population mean. Education level is often used as a correlate of socioeconomic status, however, there are many confounding factors associated with education. With ACL reconstruction, a large proportion of the patients are young athletes who have yet to complete their education. Indeed 40% of our population was less than 21 years and education was highly correlated with age. A more appropriate determinant may be advancement of education as used by Spindler et al., which showed that a lack of further education was associated with lower IKDC Subjective Knee Form and Knee Injury and Osteoarthritis Outcome Scores (20) However, future education is not known pre-operatively and individual plans may change, so this is not as useful in counseling patients prior to surgery.

Concomitant ligamentous and meniscus injuries as well as time from injury to surgery were not significant predictors of patient-oriented outcome. This is supported by previous studies, which have found no difference in strength, function, laxity, or patient-reported outcomes in regards to concomitant injuries or time from injury to surgery. (23-25) In contrast, Laxdal et al., in a study of 948 subjects, found that a longer time from injury to surgery, concomitant meniscal injuries, and chondral damage were poor prognostic factors for return to sports, patient-reported outcome, and function.(15) Karlsson et al. similarly found that a delay in surgery may decrease the desired activity level in competitive athletes.(17) The present study found severe chondrosis at the time of surgery was predictive of a poorer patient-reported outcome. It is important to note, however, that in the present study, a delay in surgery was associated with an increased the risk of medial chondrosis. This association between timing of surgery and chondrosis was previously shown by Vasara et al.(26) Thus, the timing of surgery and the development of chondrosis may predict the same variability in patient-reported outcome. The present study highlights the result of delaying surgery, chondrosis, as the key risk factor.

Many studies have analyzed the differences between graft tissue and graft source yet the significance of either variable on patient-oriented outcome is not clear. A recent meta-analysis of bone patellar tendon versus hamstring autograft by Goldblatt et al.(27) found no differences in IKDC overall knee ligament rating, Lysholm or Tegner scores. Several studies have also found that allografts are suitable replacements for autografts.(28,29) Ultimately the choice of graft tissue and source should be patient specific as there is lack of evidence to confirm the superiority of one graft over another.

One potential limitation of this study is that we were limited in our analysis of potential predictors including tunnel position, patient self-efficacy, motivation, compliance and expectations.(12-16) For example, Thomee et al. found that pre-operative self-efficacy of future knee function (K-SES, part D) was a significant predictor of patient-reported outcome

1 year after ACL reconstruction.(13) Gobbi et al. found that a psychological profile, which measure patient expectations and motivations, may be useful in predicting which patients undergoing ACL reconstruction are more likely to return to their pre-injury activity levels. (16) These psychosocial factors and patient expectations of surgery should be taken into consideration when attempting to predict patient-oriented outcome following ACL reconstruction. A second limitation is a relatively small sample size. Despite over 400 subjects, there were only 59 (14%) subjects with an IKDC Subjective Knee Form score less than their age- and sex-matched population average, limiting the number of potential predictors we could add to the model without creating an unstable model. The insufficient number of subjects also prevented internal validation of the model.

CONCLUSIONS

In conclusion, we found that few patient characteristics and intra-operative variables were associated with patient-oriented outcome as measured by the IKDC Subjective Knee Form score. The strongest predictors of lower patient-reported outcome following ACL reconstruction was obesity, smoking, and severe chondrosis at time of surgery. However, these factors only explained a small portion of the variation in patient-oriented outcome.

Acknowledgments

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Table 1

Demographic Characteristics of Sample

Characteristic[a]	Above Age and Gender Mean (n=343)	Below Age and Gender Mean (n=59)	P value
Age at Surgery, mean (SD), years	26.96 (0.06)	28.95 (1.45)	0.20
BMI, mean (SD), lbs/in ^{2}	25.12 (0.22)	27.17 (0.75)	0.01
Female	165 (48)	28 (47)	0.93
Chronicity, median (range), months	3.06 (0.03 - 308)	3.91 (0.20 - 328)	0.40
Currently Smoke (Y) %	22 (6)	10 (17)	0.01
Activity Level before surgery			0.05
No Sports	1 (<1)	2 (3)	
Light	4 (1)	1 (2)	
Strenuous or very strenuous	337 (99)	54 (95)	
Prior Lateral Meniscal Surgery (Y) (%)	10 (3)	3 (5)	0.39
Prior Medial Meniscal Surgery (Y) %	21 (06)	8 (14)	0.04
Episodes of Giving Way			0.63
< 1 episode	159 (47)	24 (41)	
2-5 episodes	74 (22)	13 (22)	
> 6 episodes	107 (31)	22 (37)	
Education			0.01
High school	45 (13)	3 (5)	
College	172 (50)	42 (71)	
Post-graduate	125 (37)	14 (24)	
Marital status			0.52
Single	157 (46)	24 (40)	
Married / Significant other	164 (48)	29 (49)	
Divorced / Separated	22 (06)	6 (10)	

Abbreviations: BMI, Body Mass Index.

[a] Data are presented as number (%) of patients unless otherwise indicated.

Table 2

Intraoperative Characteristics of sample

Characteristic[a]	Above Age and Gender Mean (n=343)	Below Age and Gender Mean (n=59)	P value
Concommitant injuries (Y) %	22 (6)	3 (5)	0.69[c]
Graft type and source			0.25
Patellar Tendon Allograft	79 (23)	12 (21)	
Patellar Tendon Autograft	118 (35)	14 (24)	
Hamstring Autograft	107 (31)	22 (38)	
Achilles Tendon Allograft	37 (11)	10 (17)	
Femoral fixation			0.92
Screw	255 (75)	43 (75)	
Sutures	1 (0.3)	0 (0)	
Endobutton	82 (24)	14 (25)	
Tibial Fixation			0.25
Aperture	285 (84)	52 (91)	
Peripheral	32 (9)	1 (2)	
Combination	19 (6)	4 (7)	
Other	1 (0.3)	0 (0)	
Lateral Meniscus			0.55
No tear	216 (63)	40 (68)	
Debride/Partial Meniscectomy	60 (17)	11 (19)	
Repaired/Stable	67 (20)	8 (13)	
Medial Meniscus			0.91
No tear	221 (64)	37 (63)	
Debride/Partial Meniscectomy	55 (16)	9 (15)	
Repaired/Stable	67 (20)	13 (22)	
Patellar Chondrosis			0.62
Normal or mild	314 (92)	53 (90)	
Severe	29 (8)	6 (10)	
Lateral Compartment Chondrosis			0.32
Normal or mild	348(91)	52 (88)	
Severe	5 (2)	3 (5)	
Medial Compartment Chondrosis			0.03
Normal or mild	321 (82)	50 (71)	
Severe	22 (11)	9 (14)	

[a] Data are presented as number (%) of patients unless otherwise indicated.

Table 3

Results of the Univariate Logistic Regression

Predictor	OR	SE	P value	95% CI
BMI [a]			0.02	
Overweight	0.92	0.31	0.82	0.47 – 1.80
Obese	0.35	0.13	<0.01	0.17 – 0.71
Currently smoke	0.34	0.14	0.01	0.15 – 0.76
Medial meniscal surgery	0.42	0.18	0.05	0.17 – 0.99
Severe medial compartment chondrosis	0.38	0.16	0.02	0.18 – 0.87

Abbreviations: BMI, Body Mass Index; OR, Odds Ratio; SE, Standard error; CI, Confidence Interval

[a] Odds ratios are presented in comparison to Normal BMI of < 24.9

[b] Odds ratios are presented in comparison to no activity

Table 4

Multivariate Regression Modeling

Predictor	OR	OR SE	P Value	95% CI
Simplest model				
BMI			0.02	
Overweight	0.87	0.30	0.70	0.46- 1.71
Obese	0.35	0.13	<0.01	0.17 - 0.71
Currently smoke	0.36	0.16	0.02	0.15 - 0.84
Complex model				
BMI			0.02	
Overweight	0.93	0.32	0.84	0.47 - 1.84
Obese	0.34	0.13	<0.01	0.16 - 0.70
Currently smoke	0.34	0.15	0.01	0.14 - 0.81
Medial compartment chondrosis	0.38	0.17	0.03	0.15 - 0.93

Abbreviations: BMI, Body Mass Index; OR, Odds Ratio; SE, Standard error; CI Confidence Interval