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Subsequent Surgery after Revision Anterior Cruciate Ligament Reconstruction: Rates and Risk Factors from a Multicenter Cohort

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Abstract

Background—While revision ACL reconstruction (rACLR) can be performed to restore knee stability and improve patient activity level, outcomes after these surgeries are reported to be inferior to primary ACL reconstruction. Further reoperation after rACLR can have an even more profound effect on patient satisfaction and outcome. However, there is a current lack of information regarding the rate and risk factors for subsequent surgery after rACLR.

Purpose—To report the rate of reoperation, procedures performed, and risk factors for reoperation two years after rACLR.

Study Design—Cohort Study, Level of Evidence 2

Methods—1205 patients who underwent rACLR were enrolled in the Multicenter ACL Revision Study ("MARS") between 2006 and 2011, comprising the prospective cohort. Two-year questionnaire follow-up was obtained on 989 (82%), while telephone follow-up was obtained on 1112 (92%). If a patient reported having a subsequent surgery, operative reports detailing the subsequent procedure(s) were obtained and categorized. Multivariate regression analysis was performed to determine independent risk factors for reoperation.

Results—Of the 1112 patients included in the analysis, 122 patients (11%) underwent a total of 172 subsequent procedures on the ipsilateral knee at 2-year follow-up. Of the reoperation procedures, 27% were meniscus procedures (69% meniscectomy, 26% repair), 19% were subsequent rACLR, 17% were cartilage procedures (61% chondroplasty, 17% microfracture, and 13% mosaicplasty), 11% were hardware removal, and 9% were procedures for arthrofibrosis. Multivariate analysis revealed that patients under 20 years old had twice the odds of patients aged 20–29 to have a reoperation. Use of allograft at the time of rACLR (OR 1.79, p=0.007) was a significant predictor for reoperations at 2 years while staged revision (bone grafting of tunnels before rACLR) (OR 1.93, p=0.052) trended toward significance. Patients with grade IV cartilage damage seen during rACLR were 78% less likely to undergo subsequent operations within 2 years. Sex, BMI, smoking history, Marx activity score, technique for femoral tunnel placement and

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meniscal tear or meniscal treatment at the time of rACLR showed no significant effect on reoperation rate.

Conclusion—There is a significant reoperation rate following rACLR at two years (11%) with meniscal procedures most commonly involved. Independent risk factors for subsequent surgery on the ipsilateral knee include age<20 years old and use of allograft tissue at the time of rACLR.

Keywords

revision anterior cruciate ligament reconstruction; subsequent surgery; reoperation; risk factors; outcomes

Introduction

Anterior cruciate ligament (ACL) ruptures can be devastating injuries, leading to joint instability, meniscal tears[33], and subsequent osteoarthritis[16]. Primary ACL reconstruction provides increased stability to the knee and aids in returning patients to sports and activity[17]. Recent studies have further demonstrated a significant overall increase in the diagnosis of ACL injury and treatment with ACL reconstruction in both adult and pediatric populations[18, 19, 30, 32, 34]. As ACL reconstruction (ACLR) has become more widely utilized there has been a concomitant increase in failure of the surgery with estimated graft failure rates ranging from 1.8% to 10.4%[12–14, 37]. In fact, a recent meta-analysis by Wiggins et al. estimated an overall graft failure rate of 7% with failures upwards of 10% in a younger (age<25) population[34].

The increased number of ACLR has therefore amplified the need for revision ACL reconstruction (rACLR) which may present a challenging dilemma for both the surgeon and patient as several studies have shown inferior clinical outcomes after rACLR compared to primary ACLR[4, 15, 17, 26, 35, 36]. Studies by Wright et al.[35] and Spindler et al.[26] showed that Marx activity, International Knee Documentation Committee (IKDC), and median Knee injury and Osteoarthritis Outcome Score (KOOS) subscale Knee Related Quality of Life (KRQOL) scores were significantly decreased in rACLR compared to primary ACL reconstruction at 2-year follow-up.

Reoperation rates after primary ACLR are reported as high as 27.6% and have a profound effect on patient outcome and satisfaction[29]. Younger age at the index surgery, female sex, and the use of allografts have been reported as risk factors for subsequent surgery[12, 17, 24]. In fact, younger patients who undergo ACL reconstruction had significant increases in incidence of concomitant meniscal and cartilage procedures which can portend worse clinical outcomes[32]. Revision ACLR can be difficult and by definition involves a knee that already has had multiple traumatic episodes.

Currently, there is a lack of information concerning rates and risk factors for further reoperation after rACLR. The development of the Multicenter ACL Revision Study (MARS) group led to a prospective longitudinal cohort of patients to evaluate these factors as well as outcomes of reoperation after rACLR. This is the first multicenter, prospectively collected cohort study looking at rACLR and detailing the results and factors associated with

reoperations. The purpose of this study was to report the rate of reoperation in this cohort; the procedures performed, and identify potential risk factors for reoperation two years after rACLR. Our null hypothesis was that no variable was a risk factor for reoperation.

Methods

Setting and Study Population

The MARS Study is an academic and private practice multicenter consortium funded by the National Institutes of Health and sponsored by American Orthopaedic Society for Sports Medicine (AOSSM)[10]. This prospective cohort consisted of 1205 patients enrolled between 2006 and 2011 who had undergone rACLR following previously failed primary ACLR. All enrolled patients signed informed consent and were required to complete a series of previously validated patient-reported outcome questionnaires both prior to surgery and then again at 2-yearfollow-up. Exclusion criteria were inability or unwillingness to complete a 2-year follow-up survey, graft failure secondary to prior intra-articular infection, arthrofibrosis, or complex regional pain syndrome.

All participating sites obtained local institutional review board approval before enrolling subjects and complied with a standardized manual of operations. Participating surgeons were required to complete a training session that integrated articular cartilage and meniscus agreement studies, review of the study design, patient inclusion criteria, a practice intra-articular grading sheet, and a trial surgeon questionnaire. The surgeon questionnaire was completed at the time of surgery and included sections on history of knee injury and/or surgery on both knees, the results of the general knee examination done under anesthesia, recording of all previous and new intra-articular injuries and treatments to the meniscus and articular cartilage, and the surgical technique used for the revision ACL reconstruction.

Data Sources

Completed baseline data forms were mailed from the participating sites to the data-coordinating center. Data from both the patient and surgeon questionnaires were subsequently scanned and read with Teleform software (Cardiff Software Inc, Vista, California) using optical character recognition to avoid manual data entry, and the scanned data were then verified and exported to a master database. A series of logical error and quality control checks were subsequently performed prior to data analysis.

At 2-year follow-up, patients were mailed the same questionnaire, which they had completed at baseline and were asked to complete and send back. At the same time, patients were also contacted by telephone and asked if any subsequent surgeries had occurred on either knee since their rACLR. If they responded affirmatively, either on the questionnaire and/or by telephone, attempts were made to obtain the operative report. Operative reports were analyzed by a single MARS physician so as to ensure consistency, and all procedures were categorized and recorded along with the surgical date. If multiple procedures were performed during surgery, all procedures were recorded. Because one of our goals was to assess the impact of individual procedures on future outcomes in a multivariate analysis, all procedures were listed - not only whether the patient had any subsequent surgery.

Subsequent procedures encompassed hardware removal, arthroscopic scar debridement/ synovectomy/manipulation, loose body removal, debridement for infection, articular cartilage procedures (chondroplasty, microfracture, autologous chondrocyte implantation, osteochondral autograft transplantation, and/or osteochondral allografts), meniscal procedures (meniscectomy, repair, and/or meniscal transplants), revision ACL reconstruction, and total knee arthroplasty.

Statistical Analysis

Assuming normal distribution of the data on the basis of the large sample size (n=1112 with 2 year follow-up), we used the Pearson chi-squared test for analysis of categorical data and the independent-samples t-test for continuous data. Multivariable binary logistic regression analysis was performed to determine factors associated with reoperations. Results were reported as odds ratios (OR) with 95% confidence intervals (CI). A repeated measure ANOVA was used to assess for changes in patient-reported outcome scores comparing rACLR patients who had subsequent surgery and those who did not. Statistical significance was set for all analyses to $P < .05$. SAS version 9.3 software (SAS Institute Inc, Cary, NC, USA) was used for statistical analyses and data modeling.

Results

A total of 1205 patients who underwent rACLR were enrolled from 2006–2011. Two-year questionnaire follow-up was obtained on 989 (82%), while telephone follow-up was obtained on 1112 (92%) which comprised the study population (Table 1). One hundred and twenty-two patients (11% of the cohort) underwent a total of 172 subsequent procedures on the ipsilateral knee at 2-year follow-up. Of the reoperation procedures, 27% were meniscus procedures (69% meniscectomy, 26% repair, 5% meniscal transplant), 19% were subsequent rACLR, 17% were cartilage procedures (61% chondroplasty, 17% microfracture, 13% mosaicplasty, 9% cell based cartilage restoration), 11% were hardware removal, and 9% were procedures for arthrofibrosis such has lysis of adhesions and synovectomy (Figure 1).

Of the patients who underwent reoperations, there were 62 females (51%) and 60 males (49%). Reoperations occurred more frequently in patients aged 20 or younger compared with the overall cohort of patients over 20 years of age (35% reoperations vs. 24% in general cohort). The majority of the reoperation group had normal body mass index (BMI) levels (51%), with only 11% being defined as obese or morbidly obese. The overwhelming majority of the patients never smoked (99 patients, 81%) while only 8 (7%) of the patients were current smokers. Baseline surgical characteristics between the groups who underwent subsequent reoperations compared with the group who didn't also revealed some differences (Table 2). Staged revisions (bone grafting of tunnels before rACLR) occurred more frequently in the group who subsequently had a reoperation (13% vs. 8%). Allografts (59% vs. 49%) and meniscal repairs (25% vs 17%) were more common in the reoperation group, while Grade IV articular cartilage lesions were much less common (13% vs. 27%).

Multivariate analysis revealed that patients under 20 years old had an odds ratio of 2.1 (95% CI:1.2,3.7) for reoperation compared to patients aged 20–29 (Table 3). Use of allograft at the time of rACLR (OR 1.79 [95% CI: 1.17, 2.73], p=0.007) was a significant predictor for

reoperations at 2 years. Staged revision (bone grafting of tunnels before rACLR) (OR 1.93 [95% CI: 0.99, 3.75], p=0.052) and the use of a hybrid auto-allograft (OR 2.48 [95% CI: 0.92, 6.65], p=0.07) did not reach significance. Patients with grade IV cartilage damage seen during rACLR were 4.5 times (OR 0.22 [95% CI: 0.09, 0.53], p=0.018) less likely to undergo subsequent operations within 2 years. Sex, BMI, smoking history, Marx activity score, technique for femoral tunnel placement (anteromedial vs trans-tibial drilling), number of previous revision surgeries, and meniscal tear or meniscal treatment at the time of rACLR showed no significant effect on reoperation rate.

When analyzing the 989 patients who completed patient reported outcome surveys, while patients in both the reoperation and no reoperation group improved from baseline, patients who had not undergone reoperations showed significantly greater improvements in IKDC (p=0.005), KOOS Symptoms (p=0.001), and KOOS Pain (p=0.034) compared to the reoperation group (Table 4). In addition, WOMAC stiffness (p=0.02) scores improved more in the reoperation cohort as the baseline WOMAC stiffness scores (62 [95% CI:50, 87]) were lower in the reoperations cohort than the no reoperations cohort (75 [95% CI 50, 87]) (p=0.01).

Discussion

Our results showed that after rACLR, the rate of reoperation at a short-term follow-up of 2 years was 11% overall with 27% of reoperations consisting of meniscus operations, 19% undergoing another rACLR, and 17% having subsequent articular cartilage operations. These findings are consistent with previous studies reporting reoperations after primary ACLR. Lyman et al. reported a 6.5% reoperation rate on either knee after primary ACLR within one year using the New York SPARCS database[17]. Dunn et al.'s epidemiologic study on US Army personnel reported a 12.7% rate of reoperation following ACLR with 56% meniscal operations and 35% articular cartilage operations[6]. Hettrich and the MOON group reported an 18.9% rate of subsequent surgery on the ipsilateral knee at 6 years, of which there was a 7.7% rate of ACL revisions, a 13.3% rate of cartilage procedures, a 5.4% rate of arthrofibrosis procedures, and a 2.4% rate of procedures related to hardware[12].

Reoperations were associated with younger aged patients, as our under 20-year-old population had a 2.1 times higher risk of reoperation compared to the patients in their 20's. Paterno et al. showed an increased risk of repeat ACL tears after ACLR—up to six times more likely than a young, healthy cohort without ACLR[21]. Additionally, Hettrich et al. found that after ACLR, a 17-year-old patient had an over two-fold greater risk of reoperation compared to a 34-year-old patient[12]. This has been reiterated by literature showing the rate of subsequent surgery to the ACL to be age dependent, with the risk decreasing approximately 10% with each successive year[14, 24]. Similarly, Webster et al. found a 6-fold increase in ipsilateral ACL graft rupture in patients younger than 20 years at the age of surgery[31]. This was correlated with our study which showed that of the 32 rACLR in the reoperations cohort, 20 (62.5%) were performed in patients under 20 years old. Possible causes include younger patients who rupture their ACL may be likely to return to more aggressive cutting and pivoting sports, be less compliant with postoperative instructions, and/or have a genetic predisposition to collagen disruption impacting on their risk for ACL

retear as well as meniscal and cartilage damage[1, 24, 29]. Additionally, in older patients, further surgery, especially those with long recovery like revision-rACLR, may be discouraged by the surgeon.

In our analysis, use of allograft was shown to be a significant risk factor for reoperation at two years. The risk of ACL graft rupture with regards to graft choice has been extensively reported in the literature. Risk of rupture with allograft was seen to be up to 5 times greater compared to that of bone-tendon-bone autograft[14]. Other authors have noted that use of allograft significantly increases the risk for hardware removal reoperations[3]. In a previous MARS group manuscript, allograft was confirmed to have an increased incidence of re-rupture and lower outcome measures[9]. In addition to showing that patients undergoing rACLR using autograft tissue were 2.78 times less likely to sustain a subsequent graft rupture compared to allograft, the group showed that the use of autograft resulted in improved IKDC scores, KOOS sports and recreation and quality of life subscores, as well as increased Marx activity level scores[9]. While previous articles reported better outcomes with bone-tendon-bone autografts[18, 23], in our analysis, the choice of a specific type of allograft or autograft (hamstring, bone-tendon-bone, or quadriceps tendon) was not a significant risk factor for reoperations. When allografts were taken as a whole, they showed a 1.8-times increase in reoperations compared to autograft. Additionally, while using a hybrid auto-allograft did not reach significance (p=0.06), it showed a 2.5-times higher risk of reoperations compared to using autograft. This was likely due to the low numbers of hybrid grafts (39 total, 6 requiring reoperations) despite our large database.

A two-staged revision (bone grafting of tunnels before rACLR) had a OR of 1.93 (95% CI 0.99, 3.75 p=0.052) compared to a single stage revision for reoperation at 2 years. In our data collection, the 2nd stage of the revision itself is not counted as a reoperation. Shortcomings of two-staged revisions (increased costs, morbidity, and rehabilitation) notwithstanding, the increase in reoperations at 2 years may be due to increased Fairbanks changes that occur after a bone grafting procedure[7] and worsening meniscus pathology during the staged process. Typically, the time between bone grafting and the rACLR is between 4–5 months and during this time between surgeries, it is possible that the patient may sustain additional meniscal and chondral damage from ambulation on an unstable knee, or subtle microinstability. Additionally, various methods of bone grafting have been described[2, 7, 27, 28] and it is possible that despite our attempts to restore native bony anatomy to the knee, the previous tunnels remain a source of continued frailty for graft stability. While our numbers are low, 5 of the 95 two-staged patients (5%) sustained another ACL rupture compared to only 25 of the 1110 single-staged (2%) at 2 years. Further study is needed, however, as patients who underwent 2 stage revision might have done even worse with single stage revision surgery. Presumably these patients were bone grafted because one or both tunnels were very enlarged. Our findings emphasize the challenge of taking care of patients with failed ACL reconstruction and enlarged tunnels, and the importance of studying this issue further to better define the optimal treatment protocol.

At the time of the baseline rACLR, concomitant injuries such as meniscal tears and chondral damage were commonly present: 63% of the patients had meniscal tears noted during surgery and 39% of patients had concomitant cartilage procedures performed. This is similar

to Widener et al. who reported a 74% rate of concomitant meniscal pathology at the time of rACLR[33]. Our results demonstrated that grade 4 chondral damage noted at the time of initial surgery was associated with fewer reoperations within 2 years. This may be related to a decrease in activity with increasing chondral damage as patients develop more painful joints. These patients have lower IKDC knee scores and lower Marx activity level proportional to their Outerbridge classification[22]. Furthermore, there may also be the added impact of physician counseling to decrease activity with severe cartilage loss following rACLR and a decreased proclivity of surgeons to recommend further procedures in these patients.

Interestingly, meniscal pathology and meniscal surgery (either repair or meniscectomy) at the time of rACLR did not portend future reoperations. Previous studies have shown mixed results: some have demonstrated a correlation with meniscal surgery and future reoperations[3] while others studies have found no correlation[12]. This may be due in part to the philosophy of the operating surgeon with regards to meniscal pathology at the time of rACLR. Meniscal pathology, such as posterior lateral meniscal tears[5, 25] and small medial meniscal tears[5], can be left in situ with very low rates of reoperations at greater than 6 year follow-up following ACLR.

Female sex also was not an independent predictor for future reoperations, which at first seems contradictory to previous studies that suggest that females are more prone to arthrofibrosis and stiffness-related reoperations[3, 20]. However, our study focused on revision ACL surgeries. Patients who have already undergone previous ACL surgery may be more knowledgeable and compliant with the post-operative rehabilitation protocols. As a result, these patients may be more vigilant for prevention of arthrofibrosis compared to those undergoing primary ACLR. Alternatively, underlying biological differences that make patients more likely to undergo rACLR may make them less likely to develop scar tissue, arthrofibrosis and stiffness.

In our study, several knee function scores were relatively lower in the reoperations group. These included the IKDC, KOOS Symptoms, KOOS Pain, as well as their WOMAC stiffness scores. Similarly, Granan et al. found a correlation between lower KOOS scores and ACL graft failure[8]. The median IKDC score of our rACLR patients who did not undergo reoperations was 78 at 2 years, while the median IKDC score of patients who underwent reoperation was significantly lower at 66. While our study is the first to note decreasing patient-reported outcomes with reoperations after rACLR, van Dijck et al. reported significantly lower Lysholm scores in patients who underwent reoperation after primary ACLR in comparison with the patients who did not need additional surgery[29].

Our study has strengths as well as limitations. This is the largest prospective longitudinal cohort to analyze the outcomes of rACLRs. The 50:50 mix of academic and private practice surgeons makes the results generalizable to the sports medicine fellowship–trained community. The use of validated patient-reported outcome measures allowed us to compare this study with previous studies that have used these measures in other settings. The large number of patients enrolled allowed us to perform sophisticated statistical analyses controlling for a large number of variables to understand the predictors of inferior outcomes noted in rACLRs. Our study design is limited in that it currently precludes on-site follow-up

which may lead to recall bias and is limited to 2-year follow-up. It is also possible that important risk factors or confounders were not realized and not included in the multivariate regression. Long-term studies such as those by van Dijck et al.[29] and Hanypsiak et al.[11] show reoperation rates as high as 34% with greater than 7 year follow-up. Future follow-up studies, including continued follow-up of our current cohort, may show comparable incidence of reoperations.

Conclusion

There is a significant reoperation rate following rACLR at two years (11%). The most prevalent reoperations involved meniscal procedures. Independent risk factors for subsequent surgery on the ipsilateral knee include age<20 years old and use of allograft tissue at the time of rACLR. Knowledge of these facts will allow physicians to better council their patients appropriately before surgery.

Appendix

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What is known about the subject

Previous MARS studies have evaluated outcomes after primary ACL reconstruction including rates and risk factors for further reoperations. However, revision ACL reconstructions present a uniquely difficult problem for orthopedic surgeons.

What this study adds to existing knowledge

Currently, there is a lack of information concerning rates and risk factors for further reoperation after revision ACL reconstruction. This is the first multicenter, prospectively collected cohort study looking at rACLR and detailing the results and factors associated with reoperations.
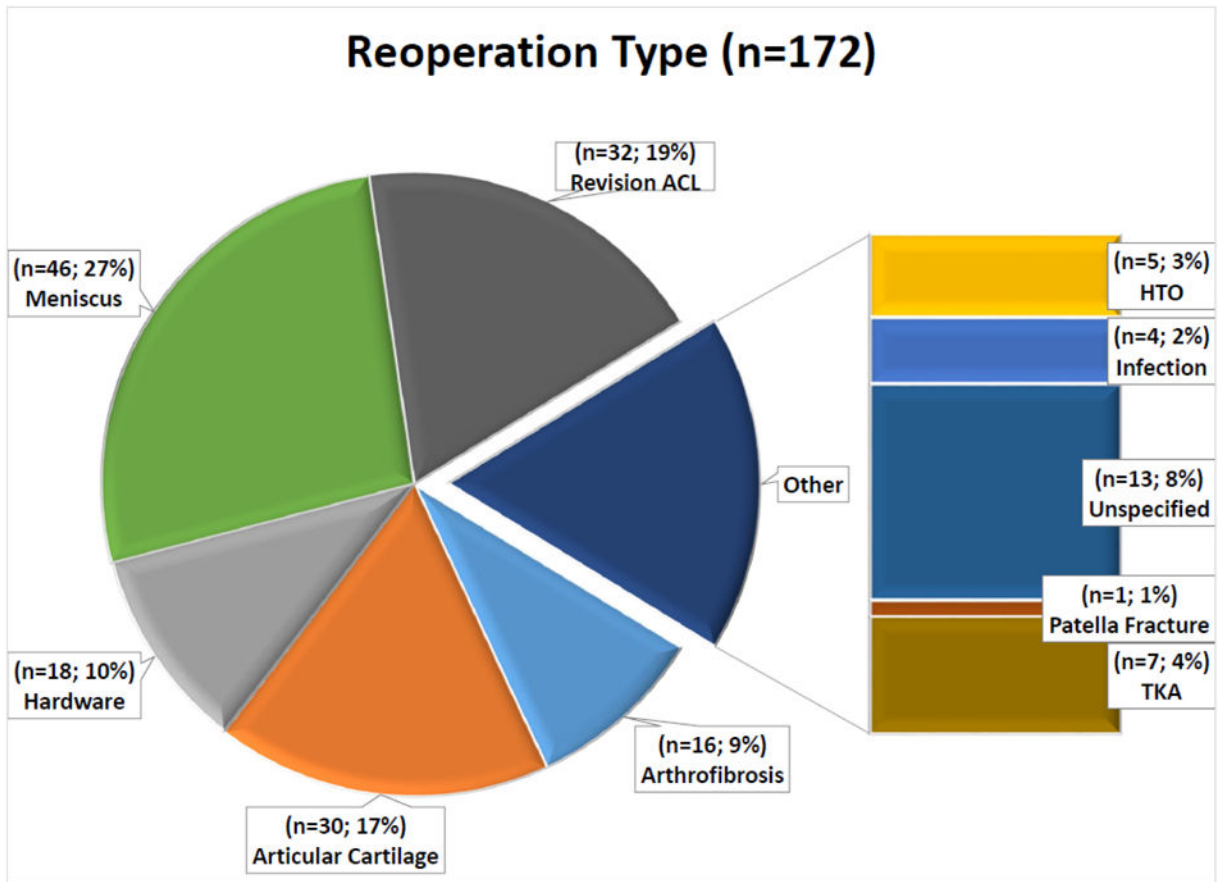
Figure 1.
Reoperation types that were performed within 2 years of rACLR

Table 1

Patient Characteristics of the Study Population

	NO Reoperations	Reoperations	Total
Total Patients	1083	122	1205
Sex			
Female	446 (41%)	62 (51%)	508 (42%)
Male	637 (58%)	60 (49%)	697 (58%)
Age Group (years)			
<20	249 (23%)	43 (35%)	292 (24%)
20–29	418 (39%)	33 (27%)	451 (37%)
30–39	254 (24%)	33 (27%)	287 (24%)
40–49	129 (12%)	9 (7%)	138 (12%)
>50	33 (3%)	4 (3%)	37 (3%)
Body Mass Index (BMI)			
Normal (18.5–24)	494 (46%)	62 (51%)	556 (46%)
Overweight (25–29)	385 (36%)	47 (39%)	432 (36%)
Obese (30–34)	151 (14%)	9 (7%)	160 (13%)
Morbidly Obese (>35)	53 (5%)	4 (3%)	57 (5%)
Smoking Status			
Never	824 (76%)	99 (81%)	923 (77%)
Quit	140 (13%)	14 (12%)	154 (13%)
Current	101 (9%)	8 (7%)	109 (9%)
Unknown	18 (2%)	1 (1%)	19 (2%)
Baseline Marx Activity Level (0–16)			
0–4	301 (28%)	35 (29%)	336 (28%)
5–8	131 (12%)	11 (9%)	142 (12%)
9–12	246 (23%)	24 (20%)	270 (22%)
13–16	398 (37%)	51 (42%)	449 (37%)

Table 2

Knee characteristics and types of procedures performed at the time of rACLR

	NO Reoperations	Reoperations	Total
Total Patients	1083	122	1205
REVISION #			
First	953 (88%)	102 (84%)	1055 (88%)
Multiple	130 (12%)	20 (16%)	150 (12%)
STAGING			
One-Stage	1004 (93%)	106 (87%)	1110 (92%)
Two-Stage	79 (7%)	16 (13%)	95 (8%)
Femoral Tunnel Technique			
Transtibial drilling	345 (32%)	43 (35%)	388 (32%)
Anteromedial portal drilling	442 (41%)	53 (43%)	495 (41%)
Two-incision outside-in drilling	155 (14%)	26 (21%)	181 (15%)
Revision ACL graft type			
Autograft BTB	308 (28%)	28 (23%)	336 (28%)
Autograft soft tissue	227 (21%)	17 (14%)	244 (20%)
Allograft BTB	252 (23%)	35 (29%)	287 (24%)
Allograft soft tissue	262 (24%)	36 (30%)	298 (25%)
Hybrid (autograft + allograft)	33 (3%)	6 (5%)	39 (3%)
Meniscus Tears			
Complete	489 (45%)	56 (46%)	545 (45%)
Partial	187 (17%)	25 (21%)	212 (18%)
None	407 (38%)	41 (34%)	448 (37%)
Meniscal Treatment			
Normal	404 (37%)	41 (34%)	445 (37%)
No treatment	44 (4%)	5 (4%)	49 (4%)
Repair	180 (17%)	30 (25%)	210 (17%)
Meniscectomy	436 (40%)	44 (36%)	480 (40%)
Other	19 (2%)	2 (2%)	21 (2%)
Concomitant Cartilage Operations			
None	660 (61%)	75 (62%)	735 (61%)
Chondroplasty	341 (32%)	37 (30%)	378 (31%)
Microfracture	74 (7%)	10 (8%)	84 (7%)
Other (e.g., OATS, ACI, osteochondral allograft)	8 (1%)	0 (0%)	8 (1%)
HIGHEST CARTILAGE GRADE			
Grade 1	307 (28%)	38 (31%)	345 (29%)
Grade 2	352 (33%)	48 (39%)	400 (33%)
Grade 3	110 (10%)	20 (16%)	130 (11%)
Grade 4	313 (29%)	16 (13%)	329 (27%)

Table 3

Multivariate Regression Predicting Reoperation after rACL

	OR (95% CI)	P
GENDER: Male vs. Female	1.30 (0.85, 1.99)	0.229
AGE: ref.=<20 yrs		
20–29 yrs	**0.47 (0.27, 0.81)**	**0.007**
30–39 yrs	0.87 (0.478, 1.57)	0.640
40–49 yrs	0.58 (0.25, 1.36)	0.212
50–59 yrs	0.99 (0.29, 3.40)	0.989
BMI: ref.= Normal (17–25)		
Overweight (25–29)	1.33 (0.85, 2.09)	0.211
Obese (30–34)	0.53 (0.25, 1.15)	0.107
Morbidly Obese (35–40)	0.68 (0.23, 2.04)	0.490
SMOKING HISTORY: ref = Never		
Current	0.72 (0.33, 1.59)	0.417
Quit	0.90 (0.48, 1.70)	0.752
MARX SCORE: ref = 0–4		
5–8	0.67 (0.32, 1.40)	0.285
9–12	0.86 (0.48, 1.54)	0.611
13–16	0.88 (0.52, 1.51)	0.649
STAGING: ref.=single stage revision		
Two-stage revision (bone grafting before revision)	**2.08 (1.12, 3.88)**	**0.021**
ACL GRAFT: ref.= Autograft		
Allograft	**1.83 (1.21, 2.78)**	**0.004**
Hybrid (auto-allograft)	2.53 (0.96, 6.65)	0.060
HIGHEST CARTILAGE GRADE: ref = Grade 1		
Grade 2	1.16 (0.72, 1.89)	0.539
Grade 3	1.59 (0.84, 3.02)	0.155
Grade 4	**0.45 (0.24, 0.87)**	**0.018**
FEMORAL TUNNEL TECHNIQUE: ref = Transtibial drilling		
Anteromedial portal drilling	0.97 (0.63, 1.51)	0.905
Two-incision outside-in drilling	1.38 (0.80, 2.38)	0.250
MENISCUS: ref.= No tear		
Partial tear	2.47 (0.12, 50.9)	0.559
Complete tear	2.13 (0.11, 42.8)	0.622
MENISCUS TREATMENT: ref.= normal meniscus		
No treatment for partial tear	0.51 (0.02, 11.6)	0.670
Meniscectomy	0.49 (0.02, 9.94)	0.642
Repair	0.81 (0.04, 16.6)	0.890
Other (Transplant)	0.72 (0.03, 15.8)	0.836

Table 4

Patient-Reported Median (25%, 75% quartile) Outcome Scores over Time

	Total		NO Reoperations		Reoperations		P-Value
	Baseline	**2-year**	**Baseline**	**2 Year**	**Baseline**	**2 Year**	
IKDC	51(37, 63)	77(60, 86)	51(37, 63)	78(63, 87)	50(38, 64)	66(48, 81)	**0.005**
KOOS							
Symptoms	67(53, 82)	78(64, 89)	67(53, 82)	82(67, 92)	64(50, 78)	71(57, 82)	**0.001**
Pain	75(58, 86)	88(75, 94)	75(58, 86)	91(77, 97)	72(58, 86)	83(69, 91)	**0.034**
ADL	86(69, 95)	97(88, 100)	86(69, 95)	97(89, 100)	83(64, 95)	94(83, 98)	0.157
Sports	45(25, 65)	75(55, 90)	45(25, 65)	75(55, 90)	45(25, 65)	65(37, 80)	0.063
Quality of Life	31(18, 43)	56(37, 75)	31(18, 43)	62(43, 75)	37(18, 50)	50(31, 68)	0.248
WOMAC							
Stiffness	75(50, 87)	75(62, 100)	75(50, 87)	75(62, 100)	62(50, 87)	75(62, 87)	**0.020**
Pain	85(70, 95)	95(80, 100)	85(70, 95)	95(80, 100)	80(70, 95)	90(75, 95)	0.089
ADL	86(69, 95)	97(88, 100)	86(69, 95)	97(89, 100)	83(64, 95)	94(83, 98)	0.157
Marx Activity Score	11(4, 16)	7(2, 12)	11(4, 16)	7(2, 12)	11(4, 16)	6(3, 12)	0.529