Outcomes and Predictors of Revision Anterior Cruciate Ligament Reconstruction: An evaluation of the Norwegian Knee Ligament Registry

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Abstract

Background: A subset of patient population undergoing anterior cruciate ligament reconstruction (ACLR) will require revision ACLR. Intraoperative findings at the time of revision ACLR and patient related risk factors associated with re-revision ACLR have not been fully delineated.

Purpose: There were two purposes of this study; 1) to identify the rate of re-revision ACLR and to estimate the influence of patient related factors on the risk of re-revision ACLR, and 2) to report the intraarticular findings and patient related factors at the time of revision ACLR and to compare these to the findings in a matched controlled group of primary ACLR.

Study Design: Cohort study; Level of evidence 2

Methods: All patients with both primary and revision ACLR identified in the Norwegian National Knee Ligament Registry (NKLR) from June 1, 2004 until September 30, 2016 that had not undergone cartilage restoration surgery, meniscal transplant or with a fracture at the revision reconstruction were included in the study. Using age at operation, sex, activity at injury and year of ACL reconstruction as covariates, a propensity score matched control group of primary ACLR patients for the revision ACLR patients was identified with a ratio of 5:1. For the revision ACLR patients, re-revision ACLR rates at 1, 2, 5, and 8 years were estimated with Kaplan-Meier
analysis, and the hazard ratio for a re-revision ACLR were estimated using a
multivariable Cox regression model.

Results: A total cohort of 4704 patients were included in the study, consisting of 784
patients registered with a revision ACLR and 3920 matched controls registered with a
primary ACLR. The cumulative estimated proportion of patients undergoing a re-revision
ACLR at 1, 2, 5, and 8 years after the original revision ACLR was 0.4%, 3.0%, 6.5%, and
9.0 % respectively.
Comparing the control group with the revision ACLR patients, there was no difference
between the groups in cartilage injury (p=0.72) or associated ligament injury (p=0.17) at
the time of ACLR. In the revision ACLR patients, there were less meniscal injuries
(p<0.001) and a longer surgery time (p<0.001) compared with the control group. There
were no intraoperative findings or surgical techniques identified as a predictor for a
higher risk of re-revision ACLR. Patients who participated in a pivoting sport had a
lower rate of re-revision ACLR in comparison to those that did not.

Conclusions:
Based upon a review of a large ligament reconstruction registry, one can expect 9% of
patients to undergo a re-revision ACLR within 8-years of their revision ACLR. Revision
ACLR did not result in an increase in cartilage injuries or associated ligament injuries
and patients with a revision ACLR had significantly less meniscal injuries when
compared with a primary ACLR control group. These results highlight the importance
of the continued need to improve the success of primary ACLR.
Keywords: anterior cruciate ligament; revision anterior cruciate ligament; meniscal tear; re-revision anterior cruciate ligament reconstruction, ligament registry

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What is known about this subject: The outcomes for primary and revision ACLR have been reported in the literature to be independently effected by meniscal tears and cartilage lesions. However, there has yet to be a comprehensive look at how collectively these injuries and other patient specific factors (age, gender, BMI, graft choice) serve as predictors for revision ACLR patient outcomes.

What does this study add to the literature: This study provides important demographic information regarding the outcomes and predictors for revision anterior cruciate ligament reconstruction from a large national registry. It provides survivorship expectations for patients who decide to undergo revision ACLR and allows the providing surgeon to better council their patient regarding their expected outcomes. This is the first study according to the authors’ knowledge where propensity score matching has been used to identify a control group for comparison in ACL registry settings. It sets an important example of how comparing groups with equal baseline covariates can be done to reduce bias.
Introduction

Anterior cruciate ligament reconstruction (ACLR) is one of the most common orthopaedic procedures performed in the United States and Scandinavia.\textsuperscript{12, 13, 28, 30, 31} Despite improved biomechanics with anatomically based ACLR techniques\textsuperscript{24, 40} graft re-rupture rates have been reported up to 25\% with cumulative re-rupture and objective clinical failure rate as high as 85\%.\textsuperscript{15, 21, 22, 31} Subsequently a significant patient population who undergo ACLR will require a revision ACLR.\textsuperscript{21, 25}

In patients undergoing a revision ACLR, a higher prevalence of chondral injuries, and lower patient reported outcome scores at the time of surgery compared to primary ACLR have been reported.\textsuperscript{2, 7, 8, 14, 17, 20, 27, 38} Patient expectations regarding primary ACLR and revision ACLR are generally high and can subsequently contribute to postoperative dissatisfaction if patients are not appropriately counseled.\textsuperscript{10} Although there has been an expansion in the literature regarding primary ACLR and first time revision ACLR\textsuperscript{6, 17}, in particular with data from large multicenter and national cohorts, there still remains an incomplete understanding of the risk factors for failures of revision ACLR.\textsuperscript{4, 19} Defining the risk of and outlining the patient related and intraoperative factors associated with revision ACLR failure are important. Therefore, there were two purposes of this study. First, we desired to estimate the rate of re-revision ACLR and to estimate the influence of patient related factors on the risk of re-revision ACLR. Second, we desired to report the intraarticular findings and patient related factors at the time of revision ACLR and to compare these to the findings in a matched controlled group of primary ACLR.
Methods:
The Norwegian National Knee Ligament Registry (NKLR) was established in June 2004 to prospectively collect data on all cases of cruciate ligament reconstruction surgery in Norway. Data from the start of the registry until September 30th, 2016 was used to identify both a case and a control group of patients. The case group had undergone at least one revision ACLR of the index knee following their primary ACLR. Patients were excluded if they had undergone cartilage restoration surgery (osteochondral autograft transplantation, autologous chondrocyte implantation or microfracture treatment), meniscal transplant, or if there had been an ipsilateral intra-articular fracture either at the time of primary ACLR or at the time of revision ACLR surgery. Revision ACLR was defined as either the first stage of a planned 2-stage revision or as single staged revision ACLR. The control group of patients had undergone a primary ACLR without a subsequent revision ACLR and was identified through propensity score matching.

The following data was reviewed for this study: date of primary surgery, revision ACLR and date of any subsequent revision ACLR, surgery time, graft choice, activity at the time of injury, cause of revision of an ACLR, demographic profile (sex, age, body mass index) and associated pathology; cartilage injuries (International Cartilage Repair Society (ICRS) grade 1-2 or 3-4), meniscal tears (medial, lateral or both menisci) and other concomitant ligament injuries (posterior cruciate ligament, medial collateral ligament, fibular (lateral) collateral ligament or injury to the posterolateral corner).
Propensity score matching

The propensity score is the conditional probability of receiving a certain treatment given a specific set of covariates. We matched those considered treated and those untreated on their estimated probability of being treated. In our study the treated were the revised patients and the untreated were the primary controls. To estimate the propensity scores, we used logistic regression including the covariates; age at operation, sex, activity at injury and year of primary ACL reconstruction. We matched the data using a 1:5 ratio and set the scale parameter to 0.2 (default value). Based on the calculated propensity scores, we identified five controls for each case giving us a full dataset of 4704 patients.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics Version 23.0 (IBM Corporation, Armonk, NY, USA) and the R computing environment R 3.4.1 (The R Foundation, Vienna, Austria) using algorithms of the R ‘survival’ and ‘nonrandom’ packages to perform the survival analysis and propensity score matching (PSM). All tests were 2-sided with a significance level set to 0.05. We used the Chi-square test for categorical variables and Student’s T-test for continuous variables to test for group differences.

Estimated 1, 2, 5 and 8-year re-revision rates with 95% confidence interval (CI) were calculated with Kaplan-Meier analysis. The hazard ratio for re-revision ACLR for the case group was analyzed with the second revision defined as the
endpoint in the Cox multiple regression model. The proportional hazards assumption of the Cox regression models was evaluated by tests and inspection of Schoenfeld residuals and found suitable. Revision surgeries where no new graft was recorded (n=60) were excluded from analysis calculating survivorship and risk estimates for re-revision because they were most likely the first stage in a staged revision surgery. Patients were followed and presumed at risk until the end of the study or until emigration (n=10) or death (n=4).

Confounding factors

The following variables were considered as possible confounding factors and tested in the Cox regression models: age group (<20y, 20-30y, >30y), graft choice, activity at injury (pivoting activities [soccer, handball, basketball] or non-pivoting activities), concomitant ligament injuries, cartilage injury, BMI, meniscal injuries, and sex. Multivariable analysis was tested with associated pathology and patient demographics as covariates (age at surgery, sex, activity at injury (pivoting/non-pivoting), chondral injuries (ICRS 1-2 or ICRS 3-4 and meniscal injury (medial, lateral, both menisci or no injury).

Results

Patient demographics

A total of 812 patients were identified in the study period to have undergone at least one revision ACLR, of whom 24 patients had undergone cartilage restoration
surgery and 4 had a meniscal allograft transplant and were therefore excluded. Based on the calculated propensity scores we found five controls for each case, giving us a full dataset of 4704 patients; 784 in the case group and 3,920 in the control group. (Figure 1)

Patient characteristics, intraoperative findings and associated injuries are presented in Table 1. The average patient age was 25.5 and 25.6 years for the case and control group respectively, with 53% males in both groups. There was a significant difference in graft choice between the two groups, with a predominance of BPTB in the case group (62.1%) and hamstring tendon autografts in the control group (64.9%) (p<0.001).
Revision ACLR patients had significantly less new meniscal pathology at time of surgery compared to the control group (p<0.001). Surgery time was reported to
be 11.7 minutes longer for the case group compared with the control group (p<0.001).

**Revision ACLR failure and re-revision ACLR**

At a mean follow-up of 4.6 years (median 4.3 years) the rate of re-revision ACLR was 5.5%. Of those patients who underwent re-revision, 28 (3.9%) required a second re-revision ACLR and 12 patients (1.7%) required a third re-revision ACLR during the study period. New trauma (290) and graft failure (208) were the most common causes of revision ACLR (Table 2). The 1, 2, 5 and 8-year re-revision ACLR rates were 0.4% (95% CI 0.0-0.8), 3.0% (95% CI 1.6-4.4), 6.5% (95% CI 4.3-8.7), and 9.0% (95% CI 5.8-12.2) respectively (Figure 2). In a multivariable Cox regression analysis adjusted for sex, meniscal injury, age at revision surgery, graft choice, activity at time of injury and cartilage injury, the hazard ratio for re-revision was 0.3 (95% CI 0.2-0.7, p=0.002) for patients reported to have participated in pivoting activity at the time of injury compared with non-pivoting activity.
Table 2: Cause of revision Anterior Cruciate Ligament Reconstruction

<table>
<thead>
<tr>
<th>Cause of Revision</th>
<th>N (%)</th>
</tr>
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<tbody>
<tr>
<td>New Trauma</td>
<td>290 (37.0 %)</td>
</tr>
<tr>
<td>Graft Failure</td>
<td>208 (26.5%)</td>
</tr>
<tr>
<td>Unknown</td>
<td>141 (18.0 %)</td>
</tr>
<tr>
<td>Graft Failure &amp; New Trauma</td>
<td>73 (9.3%)</td>
</tr>
<tr>
<td>Fixation Failure</td>
<td>28 (3.6%)</td>
</tr>
<tr>
<td>Other combinations</td>
<td>17 (2.2%)</td>
</tr>
<tr>
<td>Tunnel Position</td>
<td>14 (1.8%)</td>
</tr>
<tr>
<td>Infection</td>
<td>8 (1.0%)</td>
</tr>
<tr>
<td>Pain</td>
<td>3 (0.4%)</td>
</tr>
<tr>
<td>Untreated other ligament laxity</td>
<td>2 (0.3%)</td>
</tr>
</tbody>
</table>
The most important finding of this study was that the predicted rate of a subsequent re-revision for revision ACLR patients was 6.5% at 5 years and 9.0% at 8 years. Failure rates (re-revision ACLR) after revision ACLR are higher than after primary ACLR, highlighting that this group of patients are at a higher risk of failure than a primary ACLR. Furthermore, there was a three times increase in failures between year 2 and year 8 of follow-up, with 3% failure rates at 2 years and 9% at 8 years’ follow-up, indicating that most failures occur after the 2-year mark. It is important to understand factors that increase this risk of failure in order to address them and also to counsel patients accordingly about their anticipated outcomes. In the present study, we did not find any concomitant pathology (cartilage lesions,
knee ligament tears) or demographic factors (age, gender, BMI, activity at time of injury) associated with the risk of a revision ACL. This demonstrates the difficulty in predicting failures of revision ACLR, and future studies should delve into other factors including tibial slope, alignment, ligament laxity and rehabilitation protocols.

The 5-year re-revision ACLR rate of 6.5% in our study was higher than the 2.0% to 5.4% reported in previous database and registry studies. Lind et al reported a revision ACLR rate of 4.1% from the Danish registry at 5 years. The time from a revision ACLR to a re-revision ACLR has previously been reported to range from 2.8-4.4 years. A systematic review of the literature on revision ACLR by Liechti et al found that although re-revision ACLR could restore stability and improve functional outcomes compared with the preoperative state, outcomes were inferior when compared with primary ACLR regarding a patient’s ability to return to his or her pre-injury level of activity. Therefore, identifying patients who are at risk of re-revision ACLR, and adequate preoperative counseling are important.

Patient demographics in our study for patient age, gender, and BMI were similar to those reported for other large revision ACLR registry database studies. Schlumberger et al. reported that age (<25 years) was a risk for graft rupture after primary ACLR and revision ACLR; however, our results did not find that correlation. Just over one third of our patients had meniscal injury at the time of revision ACLR, which was lower than previously reported by Arianjam et al (more than half), and the Multicenter Orthopaedic Outcomes Network (MOON) and the
Multicenter ACL Revision Study (MARS) (close to 40% of new medial meniscal tears and 34% of new lateral meniscal tears). Close to one quarter of patients in our study had cartilage injuries at time of revision ACLR, with two thirds having ICRS Grade 1 and 2 cartilage changes, and one third Grade 3 and 4. This is similar to the findings of Lind et al (20%) but lower than those reported by Arianjam et al (42%). The MARS and MOON studies only reported on Grade 3 and 4 lesions with the medial femoral condyle the most common location approximately 22% of the time.

Autograft BPTB or hamstrings were the predominant grafts used with allografts employed only 1.1% of the time. In regards to a difference between the type of autograft used, our results demonstrated no significant difference in survivorship based upon the type of autograft used. This lack of difference between autografts is in line with previous work. However, some studies on primary ACLR have reported higher risk of revision with hamstring tendon autograft than bone-patella tendon-bone autograft. Previous revision ACLR studies have reported a higher use of allografts ranging from 21% – 76.7% of the time. A recent systematic review of graft type and the outcomes of revision ACLR reported autografts to have better results than allografts with lower postoperative laxity, and lower rates of re-operation and complications.

Patients reported to have participated in pivoting activities at the time of injury prior to their first revision had a lower risk of re-revision compared to patients participating in non-pivoting activities. An ongoing study validating the
data in the NKLR has found that surgeons sometimes report the activity at the time of injury for the primary reconstruction on the form for the revision surgery (unpublished data). The results for this category might therefore be caused by a reporting bias. Other explanations may be that these patients were able to regain a high level of quadriceps and hamstring strength which have been reported to be indicative of those able to cope with an ACL deficient knee.\textsuperscript{9,11,23}

\textbf{Limitations}

We recognize some limitations to this study. Although the expected re-revision ACLR rate determined by this study is important, the unavailability of patient-reported outcomes measures limits the clinical insight of this study. Subsequently, it is possible that there would be a difference in regards to the subjective outcome scores for different groups of revised patients had those been available. A second limitation was no information regarding surgical technique of whether a trans-tibial, or accessory medial portal was used for the femoral tunnel reaming was available for review. Additionally, we do not have the data on the postoperative rehabilitation protocol used for the different groups of patients, surgeons experience or patients’ activity levels which could affect the results.

\textbf{Conclusion}

Based upon a review of a large ligament reconstruction registry, one can expect 9\% of patients to undergo a re-revision ALCR at 8-years of follow-up. Revision ACLR did not have an increase in cartilage injuries or associated ligament injuries and had
significantly less meniscal injuries when compared with a primary ACLR control group. Despite a high percentage of revision ACLR performed with autografts, graft type was not predictive for a revision-ACLR failure. These results highlight the importance of the continued need to improve the success of primary ACLR.

References


management and outcome of 10 patients with an average 3-year follow-up.  

