




Rate and Timing of Revision and Contralateral Anterior Cruciate Ligament Reconstruction Relative to Index Surgery

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Background: After anterior cruciate ligament (ACL) reconstruction (ACLR), ipsilateral ACL graft reinjury or contralateral ACL injury has been reported. The rate and predictors of such subsequent ACL injuries have not been reported in recent years and in large patient cohorts.

Purpose: The current study utilized a large, national, multi-insurance, administrative database to assess subsequent ACLR and factors associated with its occurrence.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: Using the PearlDiver M151 database, patients who underwent ACLR within the United States between 2015 and 2021 were abstracted. All included patients had ≥ 3 years of evaluation after initial ACLR. Patients who underwent a subsequent reconstruction (ipsilateral or contralateral) within 3 years were determined and the timing assessed. Using univariable and multivariable logistic regression, the factors associated with having a subsequent ACLR and the factors associated with returning for ipsilateral versus contralateral ACLR were examined.

Results: In total, 40,151 patients who underwent initial ACLR during the study period were identified. Of these, subsequent ACLR was performed for 1689 patients (4.2%). These included ipsilateral revision for 1018 (60.3%) and contralateral reconstruction for 671 (39.7%) patients. Patients returning for ipsilateral reconstruction did so sooner than patients needing a contralateral reconstruction. On multivariable analysis, the only factor independently associated with subsequent ACLR was younger age (odds ratio [OR] = 4.17 for 10-14 years relative to 25-29 years; $P < .0001$). Factors associated with returning for an ipsilateral revision ACLR as opposed to contralateral ACLR were earlier revision (OR = 1.49 within 1.5 years relative to after 1.5 years; $P = .0001$) and female sex (OR = 0.62 relative to male sex; $P < .0001$).

Conclusion: The overall rate of requiring a subsequent ACLR was found to be 4.2%, with 60.3% of these being to the ipsilateral ACL. This information may be helpful for evolving injury-prevention programs and patient counseling.

Keywords: knee ligaments; ACL; revision ACL reconstruction; contralateral ACL reconstruction; PearlDiver

With more than 200,000 anterior cruciate ligament (ACL) injuries per year in the United States and an incidence of 68.6 per 100,000 person-years,^{3,6,20} ACL reconstruction (ACLR) is the most common ligament reconstruction of the knee.^{4,8} Patients who undergo ACLR are at risk for subsequent ipsilateral ACL graft reinjury or a new injury of the contralateral knee. The rates of subsequent ACLR

are important to understand for both surgeons and patients.

Several studies have examined the rate of subsequent ACL injuries. Using the 1990 to 2000 Rochester Epidemiology Project database (a multidisciplinary database with >6.1 million health records), Schilaty et al²¹ tracked ACL tear patients and found that 6.0% of patients had a subsequent ACL tear with 66.7% of these tears on the contralateral side. In a later study using the same database from 2001 through 2010, Schilaty et al²² examined injury patients and found that 13.8% of patients had a subsequent ACL tear with about 50% on the contralateral knee.

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Separately, McMurray et al¹⁴ examined 743 ACL injury patients between 2011 and 2016 using a geographic database with approximately 150,000 patients and found the subsequent ACL tear rate to be 16.8%; of the second ACL tear patients, 66.4% of the tears were ipsilateral. Last, Paterno et al¹⁶ found that 23 of 114 (20%) of patients with an initial ACL injury sustained a subsequent ACL injury; of these 23 patients, 8 (35%) occurred on the ipsilateral knee. The number of patients in these studies is relatively low, from single centers/areas, and clearly variable in the reported rates of subsequent ACL injuries.

Beyond these database studies, Rahardja et al¹⁸ performed a systematic review of registry data including data from the Norwegian, Danish, Swedish, and Kaiser Permanente registries. These authors found that male sex, lower body mass index, and younger age were risk factors for revision ACLR.

In addition to rates of subsequent ACL injuries after an index injury, Paterno et al¹⁷ in 2014 examined a cohort of 78 ACLR patients and found that female patients were nearly 5 times more likely to have a subsequent ACL injury compared with male controls, and female patients were also more likely to sustain a contralateral ACL injury. Again, this study utilized a relatively small cohort of patients. Further, Kaeding et al¹⁰ found that higher activity levels were associated with a subsequent ACL injury.

In the current study, we aimed to utilize a large, national, multi-insurance, administrative database to assess subsequent ACLR and factors associated with its occurrence. Prior database and registry studies did not include a patient cohort as large as the cohort examined in the current study. Further, not all studies included laterality, so they did not examine subsequent revisions to the contralateral ACLR. Last, these studies did not examine patient comorbidity or adverse events associated with the index procedure.

METHODS

Study Cohort

The current study used the M151 PearlDiver database, which covers >151 million patients. PearlDiver is a large, national, multi-insurance, administrative claims dataset, and its use has been well-established in orthopaedic literature,^{5,9,11,12,15,19} including for examining ACLR.¹ As PearlDiver outputs aggregated and deidentified data, our institutional review board has found studies using PearlDiver to be exempt from review.

Patients who underwent ACLR in the first quarter of each year from 2015 to 2021 were identified based on the

Current Procedural Terminology code 29888. All patients were active in the dataset for 3 years and did not have bilateral ACLR on the same day. Patients without laterality were excluded. The laterality of the procedure was identified with International Classification of Diseases, Tenth Edition (ICD-10) codes (right side: ICD-10-D-M23611, ICD-10-D-S83511A, ICD-10-D-S83511D, ICD-10-D-S83511S; left side: ICD-10-D-M23612, ICD-10-D-S83512A, ICD-10-D-S83512D, ICD-10-D-S83512S).

The following patient variables were recorded: age, sex, Elixhauser Comorbidity Index (ECI; a marker of overall comorbidity burden²), 90-day adverse events after the index procedure (as previously defined⁵), laterality of surgery, and time to subsequent ACLR surgery. In addition to including mean age as a variable, age groups were also included: 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, and 65-69 years.

Subsequent Surgeries

Patients with a subsequent ACLR within 3 years were identified. The time to second surgery was determined as well as the laterality (ipsilateral or contralateral) of surgery.

Data Analysis

First, a 3-year survival analysis to subsequent ACLR was performed for patients who underwent a subsequent ipsilateral and contralateral ACLR and the total cohort.

Further, to understand the factors associated with a subsequent ACLR, univariable and multivariable logistic regression was performed to compare patients who returned for subsequent surgery with those who did not. Variables in the analysis included age, age group, sex, ECI, and having a 90-day adverse event after the index procedure. The significance on univariable analysis was set at $P = .05$, and using Bonferroni correction, the significance on multivariable logistic regression was set at $P = .01$.

Next, to further examine the cohort of patients who underwent a subsequent ACLR, patients who underwent ipsilateral versus contralateral reconstruction were compared. Using univariable logistic regression (Student t test and chi-square test as appropriate) and multivariable logistic regression, factors associated with returning for a revision ACLR were determined. Variables included in the analysis were age, age group, sex, ECI, returning to surgery within 1.5 years, and having a 90-day adverse

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Ethical approval was not sought for the present study.

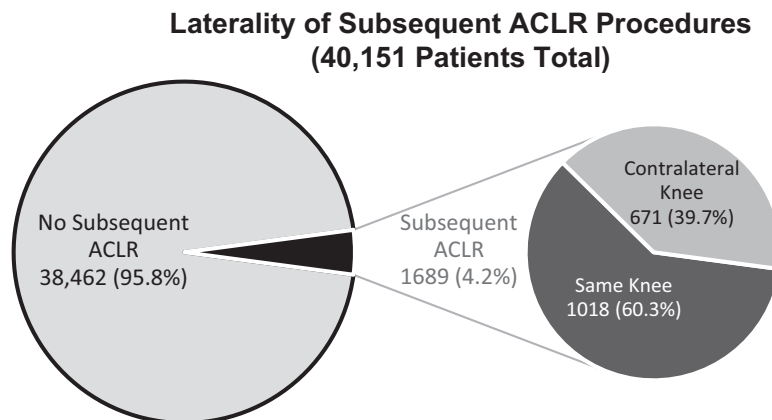


Figure 1. Chart showing the patients who returned for subsequent anterior cruciate ligament reconstruction (ACLR) and the laterality of the subsequent surgery.

event after the index procedure. Using Bonferroni correction, the significance was set at $P = .01$.

Statistical analysis and data collection were performed using PearlDiver Bellwether software (Version M151).

RESULTS

Study Cohort/Subsequent Surgeries

In total, 40,151 patients who underwent ACLR during the study period were identified. Of these, 1,689 (4.2%) underwent a subsequent ACLR within 3 years of the initial surgery: 671 (39.7%) contralateral and 1,018 (60.3%) ipsilateral (Figure 1). The timing of such subsequent surgeries is shown in Figure 2.

Variables Associated With Requiring Subsequent ACLR

Factors associated with requiring a subsequent ACLR by univariable and multivariable analyses are shown in Table 1. Positive findings on univariable analysis were related to age but not sex, ECI, or 90-day adverse events. On multivariable analysis, only age was identified as a significant factor (odds ratio [OR] = 4.17 for age group 10-14; 2.55 for 15-19; 0.64 for 40-44; 0.59 for 45-49; 0.54 for 50-54; 0.54 for 55-59 [relative to age group 25-29]).

Variables Associated With Requiring Ipsilateral Versus Contralateral ACLR

Factors associated with requiring ipsilateral relative to contralateral ACLR by univariable analysis are shown in the left columns of Table 2. Statistically significant findings were related to age, sex, comorbidity burden, and time from index surgery. The current study did not find a statistically significant difference between groups with

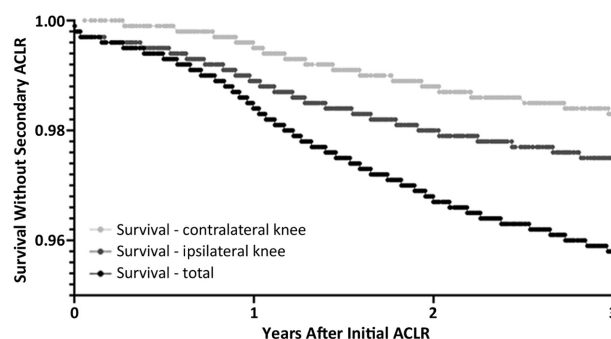


Figure 2. Graph showing the survival to subsequent anterior cruciate ligament reconstruction (ACLR) over a 3-year period for patients who returned for secondary ACLR on the contralateral and ipsilateral knee. The total group (black line) includes the whole patient cohort.

respect to having a 90-day adverse event after the index procedure.

Factors associated with requiring ipsilateral relative to contralateral ACLR by multivariable analysis are shown in the right columns of Table 2. Significant variables included whether patients returned for a subsequent ACLR within 1.5 years (OR = 1.49), age (15-19 years, OR = 0.56 [relative to age group 25-29]), and lower for female sex (OR = 0.62).

DISCUSSION

Of a total of 40,151 ACLR patients, 1,689 (4.2%) underwent a subsequent ACLR within 3 years. This is slightly below the previously reported range of 5% to 20%^{13,16,21,22} and could reflect an improvement in outcomes in the more recent years.

Of the 1,689 patients who returned for a subsequent ACLR, 1,018 (60.3%) underwent revision ACLR on the ipsilateral knee. This is slightly higher than prior studies, which found the ipsilateral ACLR rate to be about

TABLE 1
Results of Univariable and Multivariable Analyses of Subsequent ACLR^a

	Univariable Analysis			Multivariable Analysis	
	No Subsequent ACLR (n = 38,462)	Subsequent ACLR (n = 1689)	P	OR (95% CI) ^b	P
Age, y	31.7 ± 13.7	25.6 ± 11.9	<.0001		
Age group					
10-14 y	1172 (3.0)	35 (2.1)		4.17 (3.26-5.36)	<.0001
15-19 y	9611 (25.0)	785 (46.5)		2.55 (2.10-3.12)	<.0001
20-24 y	4463 (11.6)	269 (15.9)		1.29 (1.02-1.63)	.034
25-29 y	3600 (9.4)	131 (7.8)		Reference	—
30-34 y	3683 (9.6)	100 (5.9)		0.75 (0.57-0.99)	.0427
35-39 y	3949 (10.3)	97 (5.7)		0.82 (0.63-1.07)	.1372
40-44 y	3743 (9.7)	98 (5.8)		0.64 (0.48-0.85)	.0021
45-49 y	3524 (9.2)	66 (3.9)		0.59 (0.44-0.79)	.0006
50-54 y	2364 (6.1)	58 (3.4)		0.54 (0.37-0.76)	.0006
55-59 y	1455 (3.8)	26 (1.5)		0.54 (0.35-0.82)	.0047
60-64 y	556 (1.4)	16 (0.9)		0.47 (0.22-0.88)	.0315
65-69 y	227 (0.6)	<11 ^c		0.63 (0.22-1.40)	.3124
Sex			.6149		
Female	20,610 (53.6)	894 (52.9)		0.92 (0.83-1.01)	.0949
Male	17,852 (46.4)	795 (47.1)		Reference	—
ECI (per 2-point increase)	1.59 ± 1.93	1.60 ± 2.01	.7722	1.03 (1.00-1.06)	.0447
90-day adverse event after index procedure	1200 (3.1)	52 (3.1)	.9810	1.18 (0.88-1.56)	.2510

^aData are reported as mean ± SD or n (%) unless indicated otherwise. Boldface P values indicate statistical significance (set at P < .05 for univariable and P < .01 for multivariable analyses). ACLR, anterior cruciate ligament reconstruction; ECI, Elixhauser Comorbidity Index; OR, odds ratio. Dashes indicate no p value. Reference indicates the aspect of that variable that the other variables are compared to, e.g., in 'Sex' male is the reference, meaning females have a odds ratio of 0.92 relative to males.

^bOR of returning for a subsequent ACLR (compared with not).

^c<11 patients are reported as PearlDiver only delivers aggregated and deidentified patient data. As a result there are no percentages..

TABLE 2
Results of Univariable and Multivariable Analysis of Subsequent Ipsilateral Versus Contralateral ACLR^a

	Univariable Analysis			Multivariable Analysis	
	Ipsilateral Knee (n = 1018)	Contralateral Knee (n = 671)	P	OR (95% CI) ^b	P
Age, y	25.9 ± 11.9	24.9 ± 11.8	.0760		
Age group			.0105		
10-14 y	22 (2.2)	13 (1.9)		0.72 (0.33-1.63)	.4257
15-19 y	436 (42.8)	349 (52.0)		0.56 (0.37-0.84)	.0061
20-24 y	172 (16.9)	97 (14.5)		0.76 (0.48-1.19)	.2315
25-29 y	93 (9.1)	37 (5.5)		Reference	—
30-34 y	64 (6.3)	36 (5.4)		0.74 (0.42-1.30)	.2898
35-39 y	64 (6.3)	33 (4.9)		0.78 (0.44-1.39)	.3989
40-44 y	54 (5.3)	44 (6.6)		0.50 (0.28-0.87)	.0144
45-49 y	43 (4.2)	23 (3.4)		0.73 (0.38-1.41)	.3439
50-54 y	43 (4.2)	15 (2.2)		1.18 (0.59-2.44)	.6519
55-59 y	14 (1.4)	12 (1.8)		0.45 (0.19-1.09)	.0723
60-64 y	<11 ^c	<11		0.37 (0.12-1.09)	.0675
65-69 y	<11 ^c	<11		0.62 (0.10-4.93)	.6123
Sex			<.0001		
Female	488 (47.9)	406 (60.5)		0.62 (0.51-0.76)	<.0001
Male	530 (52.1)	265 (39.5)		Reference	—
ECI (per 2-point increase)	1.70 ± 2.09	1.46 ± 1.88	.0156	1.06 (1.00-1.12)	.0439
Return to surgery			<.0001		
<1.5 y	648 (63.7)	358 (53.4)		1.49 (1.22-1.83)	.0001
≥1.5 y	370 (36.3)	313 (46.6)		Reference	—
90-day adverse event after index procedure	33 (3.2)	19 (2.8)	.7388	1.01 (0.57-1.85)	.9737

^aData are reported as mean ± SD or n (%) unless indicated otherwise. Boldface P values indicate statistical significance (set at P < .05 for univariable and P < .01 for multivariable analyses). ACLR, anterior cruciate ligament reconstruction; ECI, Elixhauser Comorbidity Index; OR, odds ratio. Dashes indicate no p value. Reference indicates the aspect of that variable that the other variables are compared to.

^bOdds ratios of the second reconstruction being the ipsilateral knee (compared with contralateral).

^c<11 patients are reported as PearlDiver only delivers aggregated and deidentified patient data.

33.3%²¹ and 50%.²² This discrepancy may be due to the relatively short follow-up time, which would likely skew toward revision ACLR. Further reasons include sampling differences, including bias and sample size as well as other unknown confounding factors including the reason for subsequent ACLR.

In assessing predictors of requiring subsequent ACLR, the only variable identified by multivariable analysis was younger age. This finding is consistent with a prior study from Kaeding et al¹⁰ showing that younger patients were more likely to return for both ipsilateral and contralateral ACL tears. Although the current study did not examine patients' activity levels, Kaeding et al found that higher activity levels were associated with a subsequent ACL injury. It is likely that younger patients have higher activity levels, leading to an increased risk of ACL injury. Alternatively, younger patients could be more intolerant of knee instability and therefore more likely to return for a subsequent ACLR.

In assessing predictors of requiring ipsilateral relative to contralateral ACLR, several factors were identified by multivariable analysis, one being that patients who returned within 1.5 years for surgery were associated with an ipsilateral ACLR. This is consistent with a prior study that found that patients who returned within 24 months after ACLR are at increased risk of ipsilateral ACL injury.¹⁷ It is postulated that this may be related to incomplete healing or mechanical issues. Reinjury rates have also been found to be higher in patients with muscle atrophy and those returning to sport in <9.5 months.⁷

Further, the current study found that female patients were more likely to require contralateral ACLR relative to ipsilateral ACLR. Again, this finding is consistent with a prior study that found that male patients had a higher risk of revision ACLR and their female counterparts had a higher risk of contralateral ACLR.¹³

Strengths and Limitations

The strengths of the current study include its large and recent patient cohort. However, it is not without its limitations. Due to its retrospective nature, causality cannot be determined. Because of this, the context or reasoning for patients undergoing an ACLR was not able to be determined; the current study was only able to determine whether an ACLR occurred. Further, the current study was dependent on the accuracy of claims in the administrative database. Also, the current study was not able to assess levels of activity, mechanical and anatomic factors, associated procedures or diagnoses including meniscal tears, or timing from diagnosis to surgery. Last, the study examined outcomes for 3 years after the initial ACLR; further follow-up could show higher percentages of subsequent ACLR.


CONCLUSION


The current study included 40,151 patients who underwent ACLR. Of these, 1689 (4.2%) underwent a subsequent

ACLR within 3 years, with 60.3% being an ipsilateral revision ACLR. The current study, using the PearlDiver database, examines the largest cohort of ACLR patients in the literature. Younger patients were more likely to return for a subsequent ACLR. Patients who returned within 1.5 years to surgery were more likely to undergo ipsilateral ACLR, whereas female patients were more likely to undergo contralateral ACLR. The rate of ACL tears after an initial ACLR as well as the factors associated with it are important to patients and surgeons for postoperative planning to reduce subsequent injuries.

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