

Contemporary Practice Patterns for the Treatment of Anterior Cruciate Ligament Tears in the United States

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Background: There is a lack of research investigating current practice trends in the treatment of anterior cruciate ligament (ACL) tears as well as common concomitant procedures and reoperations associated with ACL reconstruction (ACLR).

Purpose: To analyze current practice patterns for ACLR as well as the frequency of concomitant and revision procedures with respect to patient characteristics in a cross-sectional population of the United States.

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

Methods: Patient data between 2010 and 2017 were queried using the Mariner PearlDiver database. International Classification of Diseases, Ninth Revision (in 2010–2014) and Tenth Revision (ICD-10; in 2015–2017), diagnosis codes were used to identify ACL tears, and Current Procedural Terminology codes were used to identify ACLR and concomitant surgical procedures. Patient characteristics were stratified by sex and age. Cases of subsequent knee surgery and conversion to total knee arthroplasty (TKA) within 2 years after ACLR were tracked using ICD-10 codes between 2015 and 2017 to ensure ipsilateral laterality.

Results: Of 229,295 patients identified with an ACL tear diagnosis during the study period, 75% underwent ACLR. In patients aged 10 to 39 years, 84% to 92% underwent ACLR, while patients aged 50 to 59 (50%) and 60 to 69 (28%) years were less likely to have surgery after an ACL tear. Female and male patients underwent ACLR at a similar rate (75%). Within the patients who underwent ACLR, 44% underwent concomitant meniscal debridement as compared with 11% with concomitant meniscal repair. Male patients were more likely to undergo meniscal debridement (48% vs 40%; $P < .0001$). The frequency of meniscal repair increased from 9% in 2010 to 14% in 2017, while the frequency of meniscal debridement decreased from 47% to 41% ($P < .0001$). Within 2 years of ACLR, 6% of patients underwent revision ACLR; 4%, subsequent meniscal debridement; 1%, meniscal repair; and 1%, conversion to TKA.

Conclusion: The frequency of ACLR for ACL tears has remained relatively stable in recent years and was similar between female and male patients in this cross-sectional population. The majority of patients aged 10 to 39 years underwent ACLR, while less than half of patients >50 years underwent surgery.

Keywords: ACL reconstruction; ACL tear; trend; characteristics; revision ACL

Anterior cruciate ligament (ACL) tears are one of the most common sports injuries in the United States. Although a high number of ACL reconstructions (ACLRs) are performed annually in the United States, literature regarding the characteristic trends, indications, and epidemiology of these procedures is sparse, and the true incidence of ACL tear and reconstruction in the United States is uncertain.¹⁶ This rate has been approximated to 200,000 cases per year, with nearly 150,000 patients undergoing ACLR according to recent studies.^{1,2,4,5,14,15} The use of administrative

claims databases analyzing Current Procedural Terminology (CPT) codes has helped to increase knowledge on this topic.^{7,10,19,20} For example, Herzog et al⁵ utilized the Truven Health claims database to identify 283,000 cases of ACLR between 2002 and 2014, estimating that the rate of reconstructions significantly increased $>20\%$ during this time. Mall et al¹⁵ used the PearlDiver patient record database to identify a 31% increase in ACLRs between 1994 and 2006, remarking that this increase was most notable among children, adolescents, and women. However, there is a lack of epidemiologic research analyzing contemporary trends for ACLR in the United States.

With the rising incidence of ACL injuries and surgical treatment, there is a need for research on the epidemiologic

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patterns of commonly associated injuries and concomitant procedures. For example, it has been hypothesized that long-term outcomes after ACLR may be correlated with need for surgical treatment of concomitant meniscal tears.^{17,18,23,24,29} In cohorts such as the Multicenter Orthopaedic Outcomes Network (MOON), Fetzer et al³ cited a high rate of meniscal pathology in the setting of ACL tears, with 36% and 44% of the 1014 studied ACLR cases exhibiting medial and lateral meniscal tears, respectively. This is reflected in the notably high rate of concomitant meniscal procedures in the database study conducted by Herzog et al,⁵ in which 37% of all patients undergoing ACLR received a concomitant meniscal debridement and 9% received a concomitant meniscal repair. Furthermore, Herzog et al and Fetzer et al demonstrated that meniscal debridement procedures in the setting ACLR increased by as much as 40% while meniscal repairs increased by as much as 70% between 2002 and 2014.^{3,5} Finally, in terms of subsequent operations after reconstruction, the MOON cohort reported a 2-year ACL revision risk of 2.9% after primary reconstruction,^{21,27} while the Multicenter ACL Revision Study group noted a 2-year meniscal reoperation rate of 8.6% after ACL revision surgery in 218 patients.²⁸

Despite data from these multicenter cohorts, a cross-sectional population of patients may contribute additional understanding to the clinical epidemiology of ACLR and the associated concomitant and subsequent operations. Therefore, the purpose of this study was to use a large contemporary database to perform a cross-sectional analysis of current practice trends in ACLR in addition to analyzing subsequent surgical procedures and complications after reconstruction.

METHODS

This study was exempt from institutional review board approval, as data were queried from the updated 2020 Mariner Patient Records Database (PearlDiver Technologies), a deidentified administrative database. The 2020 Mariner data set is a publicly available collection of orthopaedic patient records from multiple private insurance agencies throughout the United States as well as the Medicare, Medicaid, and self-pay populations. The database contains Health Insurance Portability and Accountability Act-compliant records between 2010 and 2019 and includes nearly 122 million patients. The Mariner data set contains CPT codes and International Classification of Diseases, Ninth Revision (ICD-9) and Tenth Revision (ICD-

10), codes. The database was utilized via subscription for academic orthopaedic research. ICD and CPT codes can be searched in combination or separately to yield the requested coding parameters and subsequent analyses of characteristic trends, such as patient sex, year of service, and 5-year age groups.

We queried the Mariner database for patients with ACL tear-related diagnoses between 2010 and 2017 using ICD-9 and ICD-10 codes (Appendix Table A1). New patient data from 2018 and 2019 were excluded from analysis, as patients from these years did not meet the minimum 2-year follow-up. The database was then queried for patients who underwent arthroscopic reconstruction of an ACL tear (CPT code 29888). Additionally, concomitant procedures were included by searching records for ACLR in combination with meniscal debridement, meniscal repair, chondroplasty, microfracture, and collateral ligament repair. All codes queried were distinctly identified using patient tracking to prevent counting multiple occurrences.

Patients between 2015 and 2017 were assigned ICD-10 codes that accounted for laterality of the injury. These patients could be tracked, and subsequent surgery could be verified, including revision ACLR, meniscal debridement or repair, and conversion to total knee arthroplasty (TKA; CPT code 27447) on the ipsilateral side. All patients with 24 months of follow-up and ICD-10 coding were included in this analysis.

Differences in frequency of ACLR based on patient sex and age group were analyzed using chi-square testing. Trends in incidence were assessed using the Cochran-Armitage independence testing with regard to ACLR and concomitant surgery. All statistical analysis was performed using Prism Statistics/Data Analysis software (GraphPad Software Inc), and statistical significance was set at $P < .05$.

RESULTS

We identified 229,296 patients with a diagnosis of ACL tear between 2010 and 2017. Of those patients, 172,083 (75%) underwent ACLR (Table 1). The percentage of patients with an ACL tear diagnosis who subsequently underwent ACLR varied slightly each year and ranged from 72% to 77% from 2011 to 2017. Patients in the 10- to 19-year age group demonstrated the highest frequency of ACLR after ACL tear (92%), followed by 20 to 29 years (88%), 30 to 39 (84%), 40 to 49 (72%), <10 (63%), 50 to 59 (50%), 60 to 69 (28%), and 70 to 79 (16%) ($P < .0001$) (Figure 1).

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Ethical approval was not sought for the present study.

Female and male patients with ACL tears underwent surgery 75% of the time (Table 1). When accounting for age, there was a significant difference based on patient sex in the percentage of patients with ACL tears who underwent ACLR: 91% of female patients in the 10- to 19-year age group versus 86% of male patients but 93% of male patients in the 20- to 29-year age group versus 91% of female patients ($P < .0001$) (Figure 2).

TABLE 1
Distribution of ACL Reconstruction by Year, Age Group, and Patient Sex^a

	Patients, No. (%) ^b	
	ACL Tear Diagnosis	ACL Reconstruction
Year		
2010	24,808	20,544 (82.8)
2011	29,646	22,230 (75.0)
2012	30,072	22,251 (74.0)
2013	30,921	22,303 (72.1)
2014	31,675	22,834 (72.1)
2015	30,484	22,127 (72.6)
2016	27,001	20,900 (77.4)
2017	24,689	18,894 (76.5)
Age group, y		
<10	168	106 (63.2)
10 to 19	49,778	45,636 (91.7)
20 to 29	41,897	36,751 (87.7)
30 to 39	42,172	35,415 (84.0)
40 to 49	47,161	33,827 (71.7)
50 to 59	32,327	16,272 (50.3)
60 to 69	12,488	3539 (28.3)
70 to 79	3305	537 (16.2)
Sex		
Female	115,961	86,946 (75.0)
Male	113,335	85,137 (75.1)

^aACL, anterior cruciate ligament.

^bPercentage of tear diagnoses.

Overall 44% of patients who underwent ACLR received concomitant meniscal debridement as compared with 11% with meniscal repair, 5% with microfracture procedure, 4% with chondroplasty, and 1% with collateral ligament repair (Figure 3A). Of the patients who underwent ACLR with meniscal debridement, 36% had debridement of 1 meniscus, while 11% had debridement of both menisci. The incidence of ACLR with meniscal repair increased from 9% in 2010 to 14% in 2017, while the frequency of concomitant meniscal debridement decreased from 47% to 41% during this same period ($P < .0001$) (Figure 3B). There was no difference in the sex distribution of patients receiving ACLR with meniscal repair (11% each; $P = .28$); however, male patients were more likely than were female patients to undergo meniscal debridement (48% vs 40%; $P < .0001$). Furthermore, as age increased, patients were more likely to undergo meniscal debridement and less likely to receive meniscal repair with ACLR ($P < .0001$) (Figure 3C).

ICD-10 laterality tracking of subsequent surgery within 2 years of ACLR (46,594 patients) showed that 6% of patients underwent revision ACLR; 4%, subsequent meniscal debridement; 1%, meniscal repair; and 1%, conversion to TKA (Figure 4A). There was a similar distribution between female and male patients across each type of subsequent surgery. As age increased, patients demonstrated a higher percentage of TKA conversions, with 13% in the group aged 70 to 79 years; 11%, 60 to 69; 5%, 50 to 59; 1%, 40 to 49; and 0%, <40 (Figure 4B). Younger patients were more likely to undergo revision arthroscopy, with the 10- to 19-year age group having the highest rates of revision ACLR (7%), meniscal debridement (5%), and meniscal repair (3%) (Figure 4B). The <10-year age group had nearly no subsequent procedures within 2 years after ACLR, while the 60- to 69-year age group showed the highest overall reoperation rate at 21% (11% TKA, 5% revision ACL, 5% meniscal debridement).

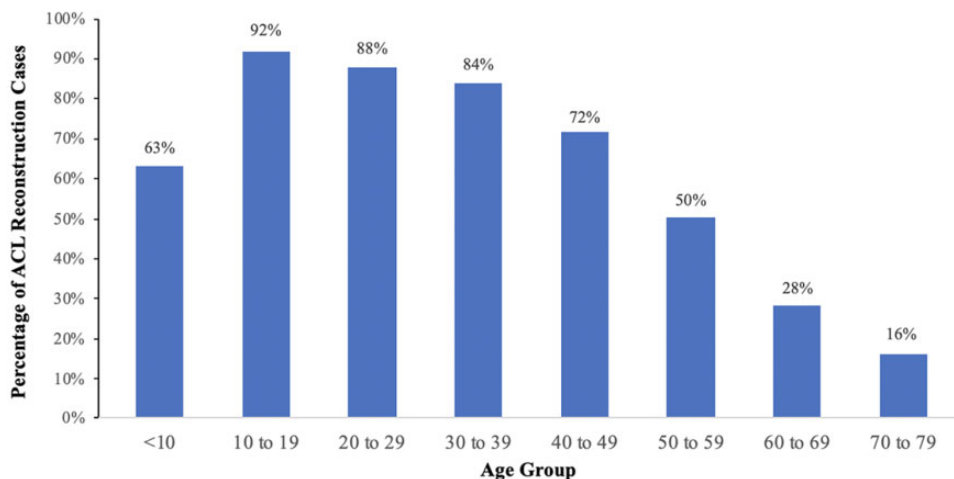


Figure 1. Percentage of patients with anterior cruciate ligament (ACL) tear diagnosis who underwent ACL reconstruction, stratified by age group.

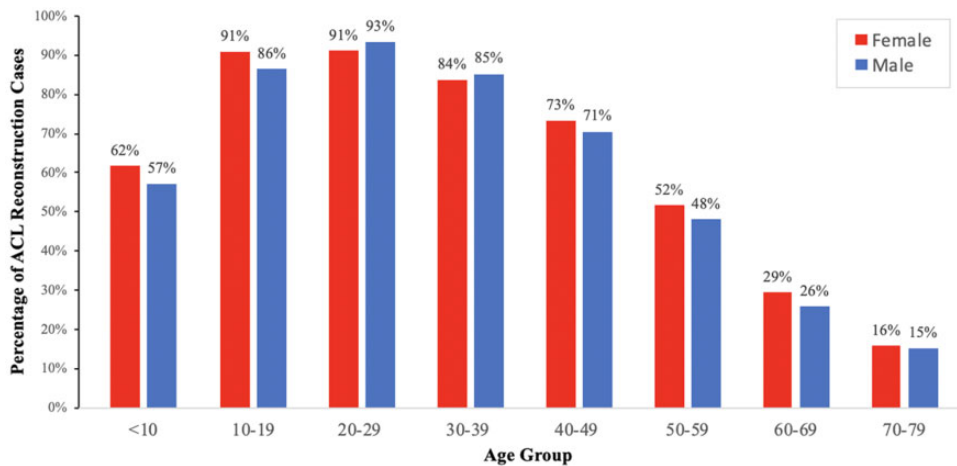


Figure 2. Percentage of patients with anterior cruciate ligament (ACL) tear diagnosis who underwent ACL reconstruction, stratified by age group and sex.

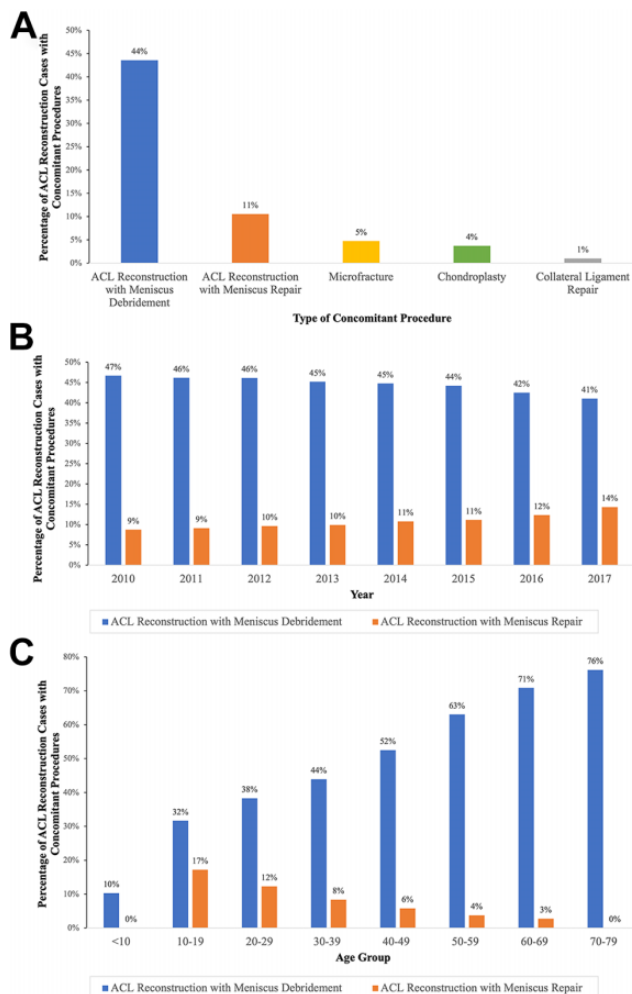


Figure 3. Percentage of anterior cruciate ligament (ACL) reconstruction cases with concomitant procedures by (A) procedure, (B) year, and (C) age group.

DISCUSSION

The purpose of this study was to investigate the current practice patterns for ACLR in the United States in a large cross-sectional population and assess concomitant injuries and subsequent procedures. In doing so, we analyzed data from nearly 230,000 patients with ACL tears and found a relatively stable 75% rate of ACLR among patients with ACL tears between 2010 and 2017. These findings differ from earlier epidemiologic studies, such as those by Mall et al,¹⁵ who reported an increase in incidence of ACLR from 32.9 per 100,000 person-years in 1994 to 43.5 in 2006, and Kim et al,¹¹ who noted a 77% increase in ACLRs between 1996 and 2006. Leathers et al¹² also showed an increased incidence of ACLR from 40.9 per 10,000 patients in 2004 to 47.8 in 2009. These previous studies included a general patient population from their respective databases as reference values for ACLR incidence, while in our study, we first queried for all patients with an ACL tear diagnosis before finding the proportion of these patients who underwent ACLR. The prior studies did not contain data past 2009; therefore, a more contemporary population assessing ACLR trends in patients with an ACL tear may provide a more accurate evaluation.

Our study stratified patients in 10-year age groups and found that a high frequency of patients aged 10 to 39 with ACL tears subsequently underwent ACLR (84%-92%). It was interesting that 50% of patients aged 50 to 59 and 28% of patients aged 60 to 69 had reconstruction after an ACL tear. ACLR has traditionally been advocated for younger patients, as they are more likely to be involved in high-intensity sports with pivoting activities, but contemporary trends of increasingly active patients in the older age groups may indicate benefit from ACLR.²⁵ To our knowledge, the frequency and outcomes for ACLR in a large population of patients aged >50 have not been reported previously. Further outcomes-related research for this cohort is warranted.

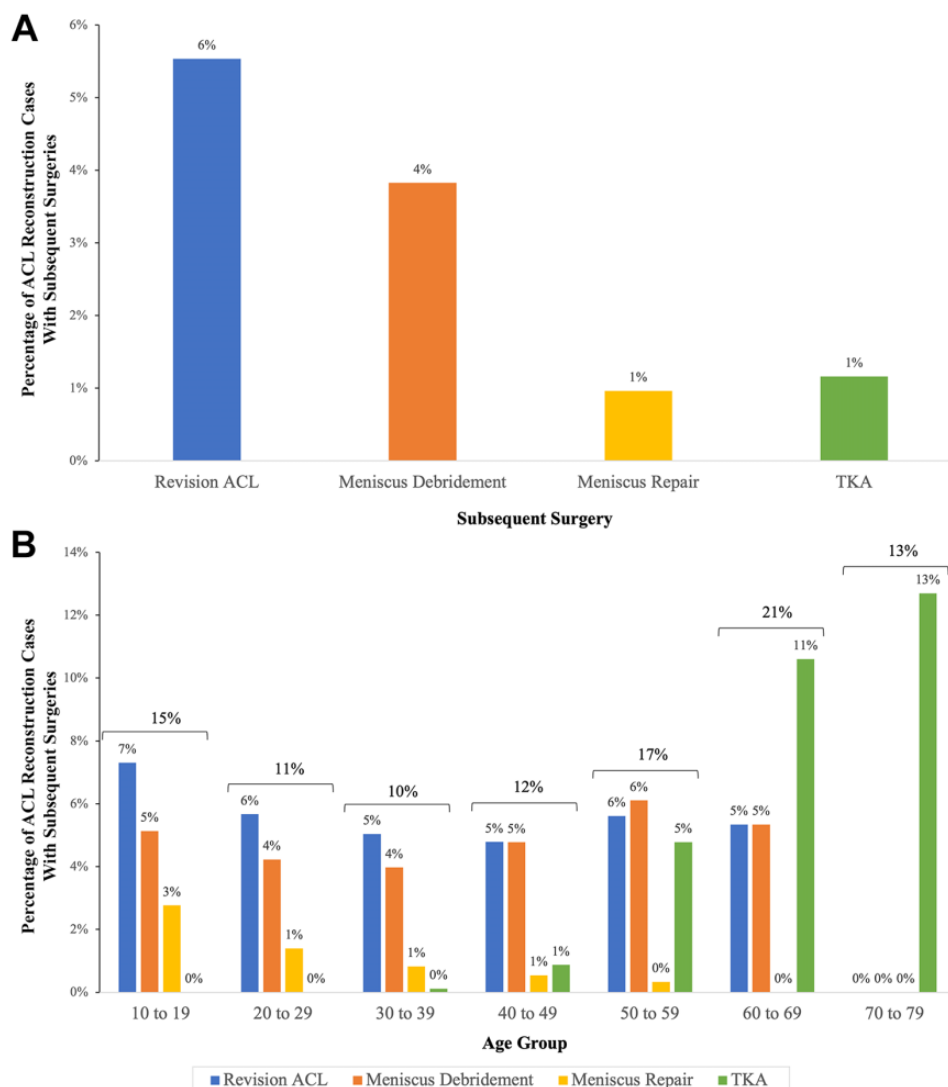


Figure 4. Percentage of patients who underwent subsequent surgery within 2 years of anterior cruciate ligament (ACL) reconstruction by (A) procedure and (B) age group. TKA, total knee arthroplasty.

Our data showed that female and male patients underwent ACLR at similar rates, while previous studies have revealed considerable differences in the epidemiologic trends for ACL surgery based on patient sex. For example, in a study of 70,547 ACL cases between 1997 and 2006 from a New York surgical database, Lyman et al¹³ found rates of 62.6% for male and 37.4% for female patients, while a population-based study in Sweden showed rates of 58.6% for male and 41.4% for female patients.¹⁸ Mall et al¹⁵ also reported a higher frequency of males (58%) to females (42%). Leathers et al¹² cited a higher male to female ratio (2.03) in their database. In the current study, the trends were from more recent years, and first selecting for patients with ACL tears before stratifying by sex may make our results more appropriate. In addition, we did observe greater differences in surgery frequency based on patient sex when stratified by age group, with the 20- to 29-year group favoring males and the 10- to 19-year

group favoring females. Depending on the age distribution of the prior database studies, this may have been an additional reason for the previously reported higher rate of surgery in male patients.

We reviewed concomitant procedures in patients who had ACLR and found that >55% also underwent a meniscal procedure. This is similar to results from Lyman et al,¹³ who noted that 50.6% of patients underwent a concomitant meniscal procedure. In addition, Herzog et al⁵ performed a database study on 283,000 ACLR cases between 2010 and 2014 and reported on the rate of concomitant meniscal debridement (50%) and meniscal repair (9%), with meniscal repair increasing over time. These findings were similar to those of our current analysis and help to substantiate the contemporary data set. Finally, our study revealed that male patients were more likely than were female patients to undergo concomitant meniscal debridement, which to our knowledge is a novel finding.

Analysis of subsequent surgery within 2 years of ACLR from our data showed an ACL revision rate of 6%, as well as a meniscal debridement rate of 4%, similar to the findings of Hettrich et al,⁶ who examined the MOON cohort of 980 cases and reported an ACL revision rate of 4.8% and a meniscal debridement rate of 5.0% at 2 years. Yabroudi et al³⁰ conducted a case-control study (n = 251 cases) and noted an ACL revision rate of 8.4% at mean 3-year follow-up. When reoperations in our data set were evaluated by age, the 10- to 19-year group was the most likely to undergo revision arthroscopy within 2 years of ACLR at a rate of 15%. This aligns with previous studies from Webster and Feller,²⁶ who cited a 29% subsequent ACL injury rate within a 3-year follow-up after primary ACLR in a cohort study of 354 patients <20 years old, and Sanders et al,²² who in a 20-year cohort study of 1355 patients found that those aged ≤22 years had a significantly higher graft failure rate as compared with older patients. In the MOON cohort, Kaeding et al⁸ showed that in 281 ACL cases, the 10- to 19-year age group had the highest frequency of graft failure and the odds of an ipsilateral ACL retear decreased by 0.09 for every yearly increase in age.⁹ Similarities of 2-year reoperations from our study to those of prospective cohorts help further validate the large population under study.

There are several limitations in this retrospective cross-sectional analysis. The database relies on accurate ICD-9, ICD-10, and CPT codes and proper coding during the clinical encounter. Before 2015, we were unable to track extremity laterality and therefore unable to conduct analysis of ACLR revision and TKA conversion rates in the full population. ICD-10 codes to ensure correct laterality of subsequent surgery were available in >46,000 patients for the 2-year follow-up analysis. In addition, given constraints with the database period, we were able to track patients for 2 years after surgery, which was a short interval. Longer follow-up, such as 5 or 10 years, is a goal for future studies, as this would better elucidate rates for revision surgery and conversion to TKA. Another limitation included the inability to assess the duration between ACL diagnosis and ACLR. Patients could also have changed insurance plans after ACLR and become lost to follow-up, but this limitation was somewhat mitigated via the Mariner database having multiple insurance systems. CPT coding did not allow us to ascertain the specific graft choice for ACLR with respect to allograft or autograft. Graft choice certainly may affect ACL revision rates. Finally, for subsequent procedures, we could not determine if secondary surgery for the ACL and/or meniscus was performed because of technical failure of the index surgery or if there was new trauma that necessitated the revision surgery.

CONCLUSION

The frequency of ACLR for ACL tears has remained relatively stable in recent years and was similar between female and male patients in this cross-sectional population. The majority of patients aged 10 to 39 years underwent

ACLR while less than half of patients aged >50 years underwent surgery.

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APPENDIX

TABLE A1
CPT/ICD Codes Queried^a

Description	CPT/ICD Code
Repair, primary, torn ligament and/or capsule, knee	CPT-27405
Arthroscopy, knee, surgical; debridement/shaving of articular cartilage (chondroplasty)	CPT-29877
Arthroscopy, knee, surgical; abrasion arthroplasty (microfracture)	CPT-29879
Arthroscopically aided anterior cruciate ligament repair/augmentation or reconstruction	CPT-29888
Arthroscopy, knee, surgical; with meniscectomy (medial AND lateral, including any meniscal shaving)	CPT-29880
Arthroscopy, knee, surgical; with meniscectomy (medial OR lateral, including any meniscal shaving)	CPT-29881
Arthroscopy, knee, surgical; with meniscus repair (medial OR lateral)	CPT-29882
Arthroscopy, knee, surgical; with meniscus repair (medial AND lateral)	CPT-29883
Anterior cruciate ligament-related diagnoses	ICD-9-D-8442, ICD-10-D-S83511A, ICD-10-D-S83511D, ICD-10-D-S83512A, ICD-10-D-S83512D

^aCPT, Current Procedural Terminology; ICD, International Classification of Diseases.