# Cost of Outpatient Arthroscopic Anterior Cruciate Ligament Reconstruction Among Commercially Insured Patients in the United States, 2005-2013

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**Background:** Despite the significance of anterior cruciate ligament (ACL) injuries, these conditions have been under-researched from a population-level perspective. It is important to determine the economic effect of these injuries in order to document the public health burden in the United States.

**Purpose:** To describe the cost of outpatient arthroscopic ACL reconstruction and health care utilization among commercially insured beneficiaries in the United States.

**Study Design:** Economic and decision analysis; Level of evidence, 3.

**Methods:** The study used the Truven Health Analytics MarketScan Commercial Claims and Encounters database, an administrative claims database that contains a large sample (approximately 148 million) of privately insured individuals aged <65 years and enrolled in employer-sponsored plans. All claims with Current Procedural Terminology (CPT) code 29888 (arthroscopically aided ACL reconstruction or augmentation) from 2005 to 2013 were included. "Immediate procedure" cost was computed assuming a 3-day window of care centered on date of surgery. "Total health care utilization" cost was computed using a 9-month window of care (3 months preoperative and 6 months postoperative).

**Results:** There were 229,446 outpatient arthroscopic ACL reconstructions performed over the 9-year study period. Median immediate procedure cost was $9399.49. Median total health care utilization cost was $13,403.38. Patients who underwent concomitant collateral ligament (medial [MCL], lateral [LCL]) repair or reconstruction had the highest costs for both immediate procedure ($12,473.24) and health care utilization ($17,006.34). For patients who had more than 1 reconstruction captured in the database, total health care utilization costs were higher for the second procedure than the first procedure ($16,238.43 vs $15,000.36), despite the fact that immediate procedure costs were lower for second procedures ($8685.73 vs $9445.26).

**Conclusion:** These results provide a foundation for understanding the public health burden of ACL injuries in the United States. Our findings suggest that further research on the prevention and treatment of ACL injuries is necessary to reduce this burden.

**Keywords:** anterior cruciate ligament; ACL reconstruction; cost; claims data

Musculoskeletal conditions affect up to 1.7 billion people worldwide and contribute to approximately 166 million years lived with disability (YLDs), which was an increase of 44.7% from 1990.[22,23] Roughly 1 in 7 people in the United States report musculoskeletal conditions.[5] Anterior cruciate ligament (ACL) ruptures are one of the most common,[11] and the incidence of these injuries among younger age groups, in particular, is high and has increased in recent years.[4,13,14]

Despite the significance of ACL and other musculoskeletal injuries, these conditions have been under-researched from a population-level perspective.[3,10] Jacobs et al[10] reported that musculoskeletal research represented only <2% of the National Institutes of Health (NIH) budget in 2013. The United States Bone and Joint Initiative also produced "The Burden of Musculoskeletal Diseases in the United States: Prevalence, Societal and Economic Costs, 3rd edition," which advocates for research that provides support for future investment in musculoskeletal conditions.[20] Furthermore, the United States Centers for Disease Control and Prevention (CDC) highlighted the importance of determining the economic costs of sports

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injuries, such as ACL injury, to document the public health burden of these conditions in the United States in the 2009-2018 CDC Injury Research Agenda.[9]

Because of the debilitating nature of ACL tears, many people with ACL disruption undergo surgical intervention to reconstruct the ligament and stabilize the knee.[11,15,24] The incidence of ACL reconstruction has increased steadily over the past decade, which may be due to an increase in injuries and/or increased recognition of benefits of reconstruction.[14,15] Apart from the costs of surgery, patients face a long course of rehabilitation after reconstruction, typically for approximately 6 months, along with other associated health care utilization.[11,17] Surprisingly, limited information is available in the literature on the surgery-specific costs and other health care utilization related to treatment of these injuries.

Large, administrative health care databases provide a unique opportunity to quantify the economic effect of musculoskeletal injuries. Compared with hospital- or health care system–specific cost estimates, these data sources can provide important information regarding cost to the health care system with a broad, population perspective. The purpose of this study was to provide a current description of cost of ACL reconstruction by detailing costs of outpatient arthroscopic ACL reconstruction and associated health care utilization among commercially insured individuals <65 years of age in the United States. We hypothesize that the results of this study will highlight the cost burden of these injuries and illustrate the population effect of these injuries.

## METHODS

### Study Population

This descriptive cost analysis of outpatient arthroscopic ACL reconstruction in the United States was conducted using the Truven Health Analytics MarketScan Commercial Claims and Encounters database from 2005 to 2013. The Truven Health Analytics MarketScan Commercial Claims and Encounters database is an administrative database that contains claims data related to insurance enrollment, clinical utilization, and health care expenses for a large sample of privately insured patients.[6] Patients included in this database are insured through approximately 100 payers from employer-sponsored plans and include active employees, early retirees, Consolidated Omnibus Budget Reconciliation Act (COBRA) beneficiaries, and dependents.[6] All patients included in the database are <65 years old. To date, there are more than 20 billion claims for approximately 148 million unique individuals included in the database, and individuals in the database can be followed for the duration of their insurance coverage.[6]

### Inclusion Criteria

Patients were identified using physician claims from the Outpatient Services file, and ACL reconstruction was identified using Current Procedural Terminology (CPT) codes. The inclusion criterion was CPT code 29888 for arthroscopically aided ACL reconstruction or augmentation between January 1, 2005, and December 31, 2013. Both primary and revision ACL reconstruction procedures were included. Inpatient ACL reconstruction and open ACL reconstruction (CPT 27428) were not included in the sample because the majority of ACL reconstructions performed over this time period were outpatient, arthroscopic reconstructions.[2,14] Outpatient procedures were abstracted from the "Outpatient Services Table" of the database, which includes services performed in a hospital outpatient facility or other outpatient facility such as an ambulatory surgical center.[6] In addition, services that were performed in a hospital setting but did not result in admission to the hospital were included.[6] All patients who met these criteria were included in the analysis of the "immediate procedure" costs.

For the analysis of "overall health care utilization" costs related to the reconstruction, there were additional exclusion criteria. In order to determine cost, patients were required to have a period of continuous enrollment in the database for 3 months prior to the surgical procedure and 6 months after the surgical procedure. Continuous enrollment was necessary to ensure that health care utilization was captured in the database and cost could be correctly estimated for a utilization period. A grace period including a maximum 8-day lapse in coverage was used for continuous enrollment identification. Patients who were not continuously enrolled in the database for the 9-month utilization period were excluded from the analysis of overall health care utilization costs but were included in immediate procedure cost analysis.

### Cost Analysis

*Immediate Procedure Cost.* For the purposes of identifying the immediate procedure cost, including associated costs for the facility, physician, anesthesia, and other care,

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all codes billed for a 3-day window surrounding the day of the procedure were identified (day of procedure ± 1 day). The 3-day window was used because some procedural costs might be billed on days adjacent to the day of surgery. The cost of all codes billed during the 3-day period were summed by individual beneficiary and date of surgery. Total cost was calculated using the variable for gross payments to a provider for a service. This variable indicates the total eligible payment under the terms of the medical plan prior to applying coordination of benefits, copayment, coinsurance, or deductible.[6]

*Total Health Care Utilization Costs.* To compute total health care utilization costs related to the surgical procedure, claims from a 9-month time window comprising 3 months preoperative through 6 months postoperative were considered. This period was chosen based on clinical experience and previous literature on typical preoperative and postoperative duration of care related to an ACL reconstruction.[7,12] We included all claims billed for the patient during the 9-month window of care that included any knee-related diagnosis code or a CPT code of 29888, where a knee-related diagnosis code was defined as International Classification of Diseases, 9th revision (ICD-9) diagnosis codes 717.XX, 836.XX, 844.X, 959.7, 719.X, 719.X0, 719.X6, 719.X8, and 719.X9 (except ICD-9 719.3X). This method is hereafter referred to as "any knee-related diagnosis in a 9-month window." The working assumptions of this method are that (1) all care is completed within the 3-month preoperative and 6-month postoperative window, (2) all care pertaining to the reconstruction receives one of the knee-related diagnosis codes listed above, and (3) all care for knee diagnosis during this 9-month window pertains to the index ACL reconstruction. We examined the robustness of our cost estimates to these assumptions by comparing the results with those obtained under 2 alternate methods. The first alternative method implemented a "lower bound" conservative approach by using diagnosis codes billed with the 29888 CPT for the patient during the 9-month period. The second alternative method represented an "upper bound" liberal approach by simply including all claims during the 9-month window, irrespective of diagnosis.

In addition, because the immediate procedure costs are included in the total health care utilization costs, we computed the difference between the costs. This calculation allows for better assessment of whether certain procedures are more or less costly during the perioperative period.

*Concomitant and Multiple Injuries.* To compare costs associated with isolated ACL reconstruction to costs associated with ACL reconstruction performed with other procedures, the following concomitant procedures were identified: medial and/or lateral meniscectomy (CPT: 29880, 29881, 27332), medial and/or lateral meniscal repair (CPT: 29882, 29883, 27403), chondroplasty (CPT: 29877), microfracture (CPT: 29879), collateral ligament (MCL, LCL) repair or reconstruction (CPT: 27405, 27409, 27427), and posterior cruciate ligament (PCL) repair or reconstruction (CPT: 29889). Total cost for patients who underwent isolated ACL reconstruction were compared with costs for patients who underwent these concomitant procedures for both immediate procedure and total health care utilization costs.

Finally, in order to assess the cost difference for reconstruction between patients who have 1 ACL injury versus patients who have bilateral or revision ACL injuries, first and subsequent ACL reconstructions were identified in the database. The first ACL reconstruction identified in the database per patient was considered the index reconstruction. Any ACL reconstruction captured in the database after the index procedure per patient was considered a subsequent ACL reconstruction, which could either represent a revision ACL reconstruction or an ACL reconstruction of the contralateral knee.

### Statistical Analysis

Descriptive statistics, including mean, median, and range, were calculated for all cost variables. Costs were also adjusted to 2013 values to account for inflation over the time period. Each annual cost was calculated in 2013 dollars using United States Government Consumer Product Index (CPI) data.[21] Comparative cost analyses were not performed to assess statistical significance of results or cost-effectiveness of procedures.

## RESULTS

There were 229,446 unique outpatient arthroscopic ACL reconstructions performed between January 1, 2005, and December 31, 2013. More males (57%) underwent ACL reconstruction than females (43%) (Table 1). The mean patient age at the time of arthroscopy was 29 years, with 25% younger than 18 years and 25% older than 39 years. Sixty-five percent of ACL reconstructions had concomitant procedures, with a mean 0.82 ± 0.72 concomitant procedures performed in addition to the ACL reconstruction overall.

The total immediate procedure cost for the 229,446 ACL surgeries identified in the database was $2,622,928,663.00 for ACL reconstructions occurring between 2005 and 2013. The mean immediate procedure cost was $11,431.57, and the median was $9399.49 (Table 2). The median immediate procedure cost for ACL surgery increased over the study period from $7634.19 in 2005 to $10,780.03 in 2013 (Figure 1). When adjusted to 2013 value, an increase in cost over the study period was still appreciated (Figure 1). The total cost median was lowest among patients who underwent isolated ACL reconstruction, whereas patients who underwent concomitant collateral ligament (MCL, LCL) repair or reconstruction had the highest total cost for the immediate procedure.

Of the patients who met the initial inclusion criteria for the study, 159,201 (69.4%) had continuous enrollment in the database for the 9-month period of care. Median total cost of related care for all ACL patients was $13,403.38 (Table 3). The median total health care costs for ACL surgery also increased over the study period from $10,891.41 in 2005 to

TABLE 1
Demographic Information for Patients Who Underwent Outpatient Arthroscopic ACL Reconstruction Identified in the Truven Health Analytics MarketScan Commercial Claims and Encounters Database, 2005-2013[a]

| | Total Population (N = 229,446) | | Included in 9-Month Period (N = 159,201) | |
|---|---|---|---|---|
| | n | % | n | % |
| Sex | | | | |
| Male | 130,284 | 57 | 89,282 | 56 |
| Female | 97,857 | 43 | 27,938 | 44 |
| Missing | 1305 | | | |
| Region | | | | |
| Northeast | 31,558 | 14 | 21,213 | 13 |
| North Central | 54,604 | 24 | 38,658 | 24 |
| South | 91,577 | 40 | 63,688 | 40 |
| West | 48,642 | 21 | 33,847 | 21 |
| Unknown | 3065 | | 1795 | |
| Concomitant procedures[b] | | | | |
| Meniscectomy | 115,947 | 51 | 80,859 | 50 |
| Meniscal repair | 37,927 | 17 | 26,086 | 16 |
| Chondroplasty | 17,606 | 8 | 12,714 | 8 |
| Microfracture | 11,646 | 5 | 8082 | 5 |
| Collateral ligament (MCL, LCL) | 4021 | 2 | 2713 | 2 |
| PCL | 1831 | 0.8 | 1242 | 0.8 |

[a]ACL, anterior cruciate ligament; LCL, lateral collateral ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament.
[b]Categories of concomitant procedures are not mutually exclusive. A patient who had 2 concomitant procedures would have his or her costs included in both procedure calculations.

TABLE 2
Immediate Procedure Cost for Outpatient Arthroscopic ACL Reconstruction Among Patients Included in the Truven Health Analytics MarketScan Commercial Claims and Encounters Database, 2005-2013 (N = 229,446)[a]

| Procedure | N | Mean, $ | Median, $ | 25th Percentile, $ | 75th Percentile, $ |
|---|---|---|---|---|---|
| All ACL | 229,446 | 11,431.57 | 9399.49 | 6491.36 | 14,157.30 |
| ACL only | 78,676 | 10,144.91 | 8276.88 | 5648.44 | 12,692.43 |
| ACL + meniscectomy | 115,947 | 11,987.17 | 9945.01 | 7011.33 | 14,689.55 |
| ACL + meniscal repair | 37,927 | 13,134.13 | 10,853.55 | 7613.02 | 16,211.42 |
| ACL + chondroplasty | 17,606 | 11,677.91 | 9520.17 | 6685.71 | 14,201.22 |
| ACL + microfracture | 11,646 | 13,027.16 | 10,599.60 | 7338.18 | 15,848.79 |
| ACL + collateral ligament | 4021 | 15,338.88 | 12,473.24 | 7952.15 | 19,385.88 |
| ACL + PCL | 1831 | 15,666.83 | 11,776.85 | 6984.00 | 20,193.37 |

[a]ACL, anterior cruciate ligament; PCL, posterior cruciate ligament.

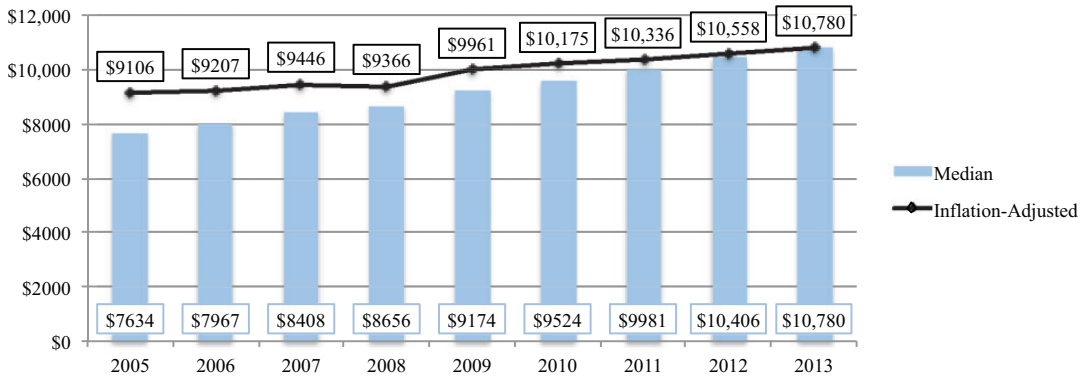


**Figure 1.** Annual trends for median immediate procedure cost for outpatient arthroscopic anterior cruciate ligament reconstruction among patients included in the Truven Health Analytics MarketScan Commercial Claims and Encounters database, 2005-2013 (N = 229,446).

TABLE 3
Total Cost of Health Care Utilization Related to the Outpatient Arthroscopic ACL Reconstruction, Identified Using Any Knee-Related Diagnosis Code Billed for the Patient During the 9-Month Period of Care, Among Patients Included in the Truven Health Analytics MarketScan Commercial Claims and Encounters Database, 2005-2013 (N = 159,201)[a]

| Procedure | N | Mean, $ | Median, $ | 25th Percentile, $ | 75th Percentile, $ | Median, Excluding Immediate Procedure Costs, $ |
|---|---|---|---|---|---|---|
| All ACL | 159,201 | 15,457.06 | 13,403.38 | 9776.07 | 18,821.63 | 4003.89 |
| ACL only | 54,965 | 14,230.05 | 12,348.86 | 8978.30 | 17,462.48 | 4071.98 |
| ACL + meniscectomy | 80,059 | 15,880.37 | 13,806.30 | 10,173.54 | 19,233.23 | 3861.29 |
| ACL + meniscal repair | 26,086 | 17,569.88 | 15,248.86 | 11,307.40 | 21,317.68 | 4395.31 |
| ACL + chondroplasty | 12,714 | 15,485.28 | 13,298.28 | 9667.70 | 18,764.00 | 3778.11 |
| ACL + microfracture | 8082 | 16,642.17 | 14,091.64 | 10,059.17 | 20,050.77 | 3492.04 |
| ACL + collateral ligament | 2713 | 20,101.06 | 17,006.34 | 12,212.57 | 24,567.22 | 4533.10 |
| ACL + PCL | 1242 | 20,435.81 | 16,358.12 | 10,460.48 | 26,590.69 | 4581.27 |

[a]ACL, anterior cruciate ligament; PCL, posterior cruciate ligament.

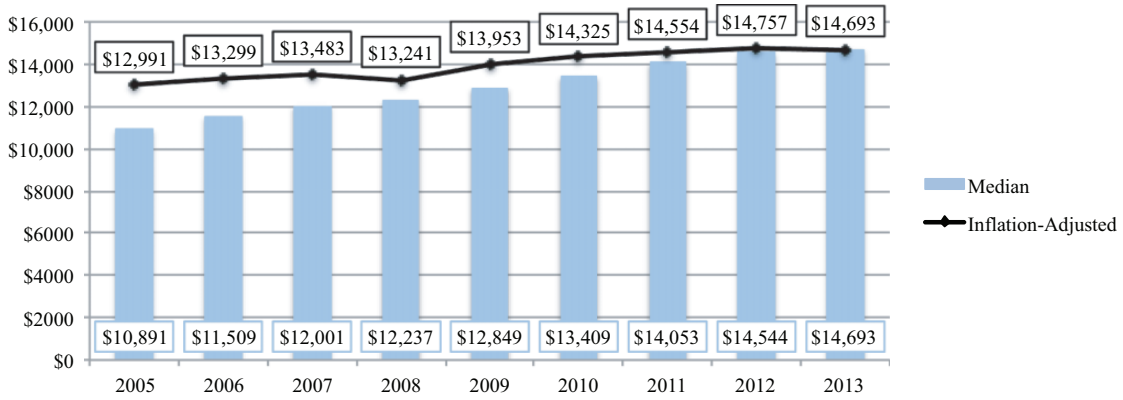


**Figure 2.** Annual trends for median total cost of health care utilization related to the outpatient arthroscopic anterior cruciate ligament reconstruction, identified using any knee-related diagnosis code billed for the patient during the 9-month period of care, among patients included in the Truven Health Analytics MarketScan Commercial Claims and Encounters database, 2005-2013 (N = 159,201).

$14,692.65 in 2013, although the relative increase was reduced when the costs were adjusted to 2013 value (Figure 2). Patients who underwent concomitant collateral ligament (MCL, LCL) repair or reconstruction had the highest total cost as well as the greatest difference in median costs between the immediate procedure and total health care utilization. Patients who underwent isolated ACL repair or reconstruction had the lowest total cost; however, patients who underwent ACL repair or reconstruction with concomitant microfracture had the smallest difference in median costs between the immediate procedure and total health care utilization.

An analysis of patients who underwent 1 ACL reconstruction observed in the database compared with patients who underwent 2 or more ACL reconstructions observed in the database showed that total immediate procedure cost for the subsequent reconstruction was slightly lower than the total immediate procedure cost for the index reconstruction (Table 4). However, the total cost for health care utilization during the 9-month period of care surrounding the reconstruction was greater for the subsequent reconstruction than for the index reconstruction. On average, there were 0.77 ± 0.71 (SD) concomitant procedures performed during a subsequent reconstruction, compared with 0.83 ± 0.72 during the index reconstruction (2-sample $t$ test, $P <$ .0001).

To determine the sensitivity of our findings for total health care costs to the choice of method used to determine claims related to the reconstruction, we compared the method used to produce the results presented above ("any knee-related diagnosis in 9-month window") to 2 alternate methods ("diagnosis match in 9-month window" and "all claims in 9-month window") (Table 5).

The "diagnosis match in 9-month window" method resulted in mean and median total costs that were 13% lower than those obtained using the "any knee-related diagnosis in 9-month window" assumption, while the "all claims in 9-month window" costs were 23% higher.

## DISCUSSION

This study provides a descriptive analysis of the cost of ACL reconstruction among commercially insured patients in the United States that can be used to better understand the

TABLE 4
Immediate Procedure and Total Health Care Utilization Costs of Outpatient Arthroscopic ACL Reconstruction Comparing the Cost of the First ACL Reconstruction to the Cost of Subsequent ACL Reconstructions Among Patients Included in the Truven Health Analytics MarketScan Commercial Claims and Encounters Database, 2005-2013[a]

| | N | Mean, $ | Median, $ | 25th Percentile, $ | 75th Percentile, $ |
|---|---|---|---|---|---|
| Immediate procedure | | | | | |
| First[b] ACL reconstruction | 213,732 | 11,482.10 | 9445.26 | 6564.46 | 14,179.49 |
| Subsequent ACL reconstruction | 15,714 | 10,744.29 | 8685.73 | 5060.74 | 13,866.92 |
| Total health care utilization | | | | | |
| First[b] ACL reconstruction | 147,827 | 17,353.97 | 15,000.36 | 11,017.87 | 20,977.58 |
| Subsequent ACL reconstruction | 11,374 | 19,016.54 | 16,238.43 | 11,775.91 | 23,100.62 |

[a]ACL, anterior cruciate ligament.
[b]Defined as first ACL reconstruction during period of coverage on MarketScan Commercial Claims database, 2005-2013. Excludes ACL reconstructions prior to period of coverage.

TABLE 5
Comparison of Methods for Determining Cost of Total Health Care Utilization Costs Related to the Outpatient Arthroscopic ACL Reconstruction Among Patients Included in the Truven Health Analytics MarketScan Commercial Claims and Encounters Database, 2005-2013 (N = 159,201)[a]

| Method | | Mean, $ | Median, $ | 25th Percentile, $ | 75th Percentile, $ |
|---|---|---|---|---|---|
| Preferred | Any knee diagnosis[b] | 15,457.06 | 13,403.38 | 9776.07 | 18,821.63 |
| Alternate 1 | Any diagnosis[c] | 17,472.75 | 15,083.72 | 11,068.38 | 21,127.35 |
| Alternate 2 | Diagnosis match[d] | 12,144.00 | 10,319.91 | 6738.98 | 15,441.70 |

[a]ACL, anterior cruciate ligament.
[b]Any knee-related diagnosis code, or the presence of the 29888 code, billed for the patient during 3 months preoperative and 6 months postoperative. This method was used to generate the results presented in Tables 1-4.
[c]All claims during 3 months preoperative and 6 months postoperative.
[d]This method used a match in diagnosis code billed on the date of surgery to any diagnosis code, or the presence of a 29888 code, for billed charges for the patient during 3 months preoperative and 6 months postoperative.

effect of these injuries on the health care system. These results provide a glimpse into the injuries that lead to the burden of musculoskeletal problems in the United States. In 2010, musculoskeletal problems resulted in an estimated $170 billion in health care spending in the United States, ranking third behind circulatory conditions ($234 billion) and prevention, colds, and other basic care ($207 billion).[1] The results clearly justify the need for increased population-based musculoskeletal research.

The incidence of ACL injuries[14,15] and the high costs identified for the health care system provide additional support for implementation of injury prevention initiatives and other cost-saving programs. The documentation of cost of surgical intervention can be used to refine cost-benefit analyses of injury prevention programs. Additionally, the increased cost of health care utilization associated with subsequent reconstructions, in addition to the evidence that patients who sustain 1 ACL injury are at risk for a second injury,[16,18,19] suggests that injury prevention programs should be developed and validated in order to incorporate them into the rehabilitation protocol for patients recovering from ACL reconstruction. In particular, it should be noted that 25% of the patients in this study were younger than 18 years, and this group is more likely to have a revision or contralateral ACL reconstruction.[8,18] Future research should use the information provided from this study to perform cost-benefit and cost-effectiveness analyses for ACL injury prevention and other cost-saving programs.

## Concomitant Procedures and Multiple Injuries

An analysis comparing cost of an isolated ACL reconstruction to cost of ACL reconstruction with various concomitant procedures suggested that both immediate procedure and total health care costs were greatest among patients who underwent concomitant collateral ligament (MCL, LCL) repair or reconstruction, followed by concomitant PCL reconstruction and concomitant meniscal repair. These procedures also had the highest difference in median costs between the immediate procedure and total health care utilization, which suggests higher health care costs during the perioperative period. These additional procedures likely reflect more severe injuries that require additional surgical supplies, increased surgical time, and additional physical therapy and other rehabilitation costs. It is important to note that the categories of concomitant procedures are not mutually exclusive. Therefore, a patient who had multiple concomitant procedures (eg, ACL reconstruction, collateral ligament repair, and meniscal repair) would have his or her costs included in each procedure calculation (eg, collateral ligament and meniscal repair).

Our expectation was that subsequent reconstructions would be more costly than initial reconstructions due to the potential for increased intra-articular damage at the time of the second reconstruction. However, the data suggest that patients who had more than 1 ACL reconstruction observed in the database have a slightly lower mean immediate procedure cost for the subsequent reconstructions ($8685.73 vs $9445.26). Contrary to our expectations, patients who had a subsequent ACL reconstruction had fewer concomitant procedures performed at the subsequent procedure compared with the initial procedure ($0.76 \pm 0.70$ vs $0.82 \pm 0.71$, respectively). These results may be due to the inability to distinguish between revision and contralateral reconstructions in the second reconstruction category.

Although the immediate procedure cost was similar between the first and subsequent reconstructions, the cost of health care utilization was slightly greater for the 9-month period of care around subsequent reconstruction compared with the first ($16,238.43 vs $15,000.36). This suggests that patients may require more health care utilization, such as physical therapy or imaging, after a second reconstruction. Consequently, patients who undergo more than 1 ACL reconstruction should be a priority when identifying strategies to reduce the burden of health care costs in orthopaedics.

### Limitations

There are limitations to this descriptive analysis of cost of ACL reconstruction. First, this study only includes ACL reconstructions that were performed arthroscopically in the outpatient setting. While outpatient arthroscopic reconstruction currently represents the majority of ACL reconstructions performed in the United States,[2,14] the results are not generalizable to open or inpatient ACL reconstructions. Similarly, our methodology specifically utilized a database created out of records for patients who have commercial insurance, and thus, the results are only generalizable to that population. Specifically, this database only contains individuals who are <65 years old who are commercially insured. It is expected that the incidence and presentation of ACL rupture may be very different among individuals $\geq$65 years old, which could influence the costs associated with ACL reconstruction. This database also does not contain individuals who are insured by Medicaid, which insures low-income patients, or uninsured patients, and costs associated with ACL reconstruction may also be quite different among those subsets of the population. Also, the immediate procedure cost was determined by summing payments for a 3-day window surrounding the procedure. This decision was made in order to account for aggregate costs of the procedure, including associated costs for the facility, physician, anesthesia, and other care. Although this choice may result in small misclassification of other claims into the immediate procedure costs, the nature of this type of procedure, including the typical acute presentation, mean that this window is appropriate for calculating the immediate procedure costs. Unfortunately, we were not able to assess procedure costs more granularly, such as specific equipment or facility expenses. Therefore, we cannot comment on whether a specific area contributed most to rising procedure costs. In the analysis of subsequent injuries, we were unable to distinguish between revision ACL reconstruction and contralateral ACL reconstruction due to lack of laterality information in this database. The ability to identify true revision ACL reconstruction would be potentially valuable in understanding health care system costs, particularly health care utilization surrounding the procedure. However, we believe the information is still valuable for understanding the health care costs associated with multiple reconstructions versus a single reconstruction. In addition, it is possible that some patients had a prior ACL reconstruction that was not captured in the database or in the study. We required that patients have only 3 months of continuous enrollment in the database prior to the reconstruction. This likely results in some misclassification of prior injuries as first injuries and may have attenuated the difference in cost between first and subsequent injuries.

For the purposes of this study, we used a 9-month period for determining health care utilization, based on previous literature about the typical period of care[7,12]; however, costs of complex injuries or those who sustain complications related to the procedure may not be adequately represented in this analysis due to the cutoff at 6 months postoperative for reporting cost. The method used (any knee-related diagnosis code) could include charges from a knee injury that were unrelated to the ACL surgery, but could also potentially miss charges that were related to the ACL surgery but were not knee related, such as postoperative infection or complications from anesthesia. This approach has to be weighed against the limitations of the 2 other methods. Using a 9-month period of care and considering all charges to be related to the ACL surgery likely overestimates the cost of the procedure by including incurred charges that were unrelated. On the other hand, the method using a diagnosis code match of the procedure to other charges billed likely underestimates the cost of the procedure by excluding incurred charges that were related, since some episodes of care may not be linked by diagnosis code due to nuances of billing methods.

Finally, this study did not compare the costs of the procedure to other ACL treatment options, as this was a descriptive analysis using an insurance claims database. We also did not perform statistical analyses to assess the significance of the trend over time; however, the results were adjusted to 2013 values to account for inflation, allowing for visual comparison over time. Finally, we were not able to include other measures of economic burden, including lost wages or disability-adjusted life years (DALYs).

## CONCLUSION

These results provide a foundation for understanding the public health burden of ACL injuries in the United States. Our findings suggest that further research on the prevention and treatment of ACL injuries is necessary to reduce this burden.

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