Published in final edited form as:

Knee Surg Sports Traumatol Arthrosc. 2016 September ; 24(9): 2778–2786. doi:10.1007/s00167-014-3478-3.

Characteristics of Inpatient Anterior Cruciate Ligament Reconstructions and Concomitant Injuries

Nathaniel A. Bates^{a,b,c}, April L. McPherson^{a,c}, Marepalli Rao^{a,d}, Gregory D. Myer^{a,c,e,f,g}, and Timothy E. Hewett^{a,b,c,e,h}

^aDepartment of Biomedical Engineering, University of Cincinnati, Cincinnati, OH, USA

^bThe Sports Health and Performance Institute, OSU Sports Medicine, The Ohio State University, Columbus, OH, USA

^cSports Medicine Biodynamics Center, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA

^dDepartment of Environmental Health-Genomics, University of Cincinnati, Cincinnati, OH, USA

^eDepartment of Pediatrics, College of Medicine, University of Cincinnati, Cincinnati, OH, USA

^fDepartment Orthopaedic Surgery, College of Medicine, University of Cincinnati, OH, USA

^gAthletic Training Division, School of Allied Medical Professions, The Ohio State University, Columbus, OH, USA

^hDepartments of Physiology and Cell Biology, Orthopaedic Surgery, Family Medicine and Biomedical Engineering, The Ohio State University, Columbus, OH, USA

Abstract

Purpose—The purpose of this epidemiologic study was to quantify the incidence, expense, and concomitant injuries for anterior cruciate ligament reconstruction (ACLR) procedures in the United States from 2003 to 2011 that required an inpatient stay. It was hypothesized that the relative reported rates of concomitant knee injuries would be greater with the MCL and menisci compared to all other concomitant knee injuries.

Methods—The National Inpatient Sample from 2003–2011 was retrospectively sampled using ICD-9-CM codes to identify ACLR patients and to extrapolate national averages.

Results—Between the years of 2003–2011, an average of $9,037 \pm 1,728$ inpatient hospitalization included ACLRs, of which $4,252 \pm 1,824$ were primarily due to the ACLR. Inpatient visits primarily due to ACLR involved an average hospitalization of 1.7 ± 0.2 days and cost $\$30,118 \pm 9,066$ per patient. Knee injuries that were commonly reported along with inpatient ACLRs included medial meniscus damage (18.1%), lateral meniscus damage (16.8%), collateral ligament

Corresponding: Timothy E. Hewett, Address: 2050 Kenny Road, Suite 3100, Columbus, OH, USA 43221, Phone: (614)-366-8215, Fax: (614)-293-4399, timothy.hewett@osumc.edu.

CONFLICT OF INTEREST

There were no conflicts of interest in the preparation of this manuscript.

repairs (12.3%), and medial collateral ligament strains (6.9%). Prevalence of meniscus injuries was consistent across years, but MCL related injuries increased over time.

Conclusions—ACLR related inpatient hospitalizations account for approximately 7.1% of the total ACLRs performed annually in the United States. Inpatient ACLR procedures continue to decrease in frequency; however, the mean cost per patient increased. Meniscus and collateral ligament injuries were the most commonly reported concomitant knee injuries. The clinical relevance of this investigation is that it informs, on a large clinical cohort of patients, the current state of incidence and expense for ACLR surgeries in an inpatient setting.

Level of Evidence—Prognostic, retrospective study, Level II.

Keywords

Anterior Cruciate Ligament Reconstruction; Inpatient; Incidence; Knee Injury; Expenditure; Patient Demographics

INTRODUCTION

Injuries to the anterior cruciate ligament (ACL) are highly prevalent, with an estimated 250,000 per year in the United States [13]. In the United States annually, there are 127,000 anterior cruciate ligament reconstructive (ACLR) procedures [15]. The estimated cost of per procedure and rehabilitation is \$17,000 [11], which results in approximately \$2 billion per year spent on ACLRs. ACL injuries commonly occur in an athletic setting during tasks that involve rapid deceleration and/or change of direction [21,4,9,20]. As many as one in fifty female athletes sustain a knee injury per year [22]. ACL ruptures are especially prevalent in high school and college level female athletes as they are four to six times more likely to experience injury than their male counterparts [3,4,30].

The ACL is the primary passive restraint to anterior tibial translation in the knee, as it resists up to 87% of this force [6]. The ACL also serves as a secondary restraint to knee abduction and internal tibial rotations [5]. Athletes with poor neuromuscular control exhibit motion patterns consistent with the kinematics that would directly load ACL [12,8]. These patterns can place abnormal loads on the ACL that lead to rupture as 70% of ACL injuries occur in non-contact scenarios [4,20]. Specifically, increased knee abduction during landing phase of a drop vertical jump has been prospectively identified as a leading predictive risk factor for ACL injury [12]. This abduction load at the knee may lead to abnormal loading in the medial and lateral compartments of the tibiofemoral joint. Accordingly, the MCL, which is the primary passive resistor to knee abduction [5,6,25], experienced concomitant failure in over 30% of ACL injuries [17,25].

Rupture of the ACL creates instability at the knee that can alter kinematics[28] and tibiofemoral contact [1,2]. The changes lead to abnormal loading of the knee and produce a long-term prognosis of increased risk for osteoarthritis patients [1,24]. To restore joint stability, ACLRs are the most common procedure performed in patients who wish to regain a physically active lifestyle [28,29]. Currently, the gold standard for ACLRs is an arthroscopic outpatient procedure that implants a bone-patellar-tendon-bone or hamstrings tendon autograft [19]. However, ACL ruptures are often accompanied by additional, concomitant,

catastrophic knee injuries [25,17,18]. These cases may require multiple surgical procedures and necessitate inpatient hospital admittance.

Prior to the mid 1990s, ACLR was an inpatient procedure with an average hospitalization of 2–3 days; however, surgical advancements allowed ACLRs to become less invasive and they have since shifted to outpatient operations [16,14]. Outpatient ACLRs have led to reduced cost and enhanced patient satisfaction as by 1995 inpatient ACLRs averaged approximately 300% of the cost of comparable outpatient procedures [14]. However, the current state of inpatient ACLRs has not been quantified by any recent investigation, which has left a gap in knowledge as to how prevalent and expensive this procedure is relative to modern medical treatment.

Though multiple investigations have tried to quantify the incidence rate [3], expenditure [11], and reconstruction incidence [15] for ACL injuries, to our knowledge, the incidence of ACL tears that result in inpatient hospitalization have not been reported. The purpose of this epidemiologic study is to quantify the incidence, expense, and concomitant injuries for ACLR procedures in the United States from 2003 to 2011 that required an inpatient stay. It was hypothesized that the relative reported rates of concomitant knee injuries would be greater with the MCL and menisci compared to all other concomitant knee injuries.

MATERIAL AND METHODS

The source of the data utilized in this investigation was the Nationwide Inpatient Sample (NIS), Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality (www.hcup-us.ahrq.gov/nisoverview.jsp). [10] The NIS was developed in 1988 to provide the largest all-payer inpatient care database in the United States. This database includes an annual survey of inpatient hospital visits accumulated from over 1500 medical centers across 45 US states that provides unidentified, patient-specific data relative to hospital admittance, diagnoses and procedures performed, patient expenditures, and patient demographics. The NIS provides a 20% stratified sample of United States community hospitals that can be extrapolated into national estimates. The present study analyzed the NIS database to determine the incidence of inpatient ACLR procedures from 2003 to 2011.

The NIS database was analyzed on a patient-by-patient basis for the eight years included in this study. Patients were included in this study if their NIS data exhibited *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) or procedure codes were relevant to ACL injury. Specifically, patients were included in the present study if their NIS data exhibited the diagnosis code for an old disruption of anterior cruciate ligament (717.83) or a sprain of cruciate ligament of the knee (844.2), or the procedure code for ACLR (81.45). All data was retrieved and analyzed using MATLAB code (version 2012a, The MathWorks, Inc., MA).

Once patients with ACLR diagnoses and procedures were isolated, the remaining patient population was statistically evaluated using custom MATLAB code. Annual means and standard deviations were calculated for all continuous variables (age, length of stay, number of procedures, and total charge). Relative frequencies were calculated for all categorical

variables (gender, and race). Additionally, a list of all additional ICD-9-CM and procedure codes that corresponded with ACL patients was compiled to evaluate injuries and operations that are frequently concomitant with ACLR. Due to the comprehensive nature of the coding database and multitude of corresponding codes reported for inpatient stays, additional codes were only incorporated if they occurred in greater than 1.0% of ACLR patients for a given year. Approval for the study was received by the Institutional Review Board of Cincinnati Children's Hospital Medical Center.

Though the NIS provides a comprehensive database, it is not inclusive of all medical center data in the United States. Annually the NIS reports on approximately 8 million inpatient hospitalizations from a diversity of medical centers. HCUP estimates that approximately 40 million inpatient hospitalizations occur each year in the United States. Software available on the HCUP website (<http://www.hcup-us.ahrq.gov/>) was used to extrapolate national averages for the entire inpatient ACLR population based on the stratified NIS database. HCUP software was also utilized to estimate national averages for the subset of patients whose primary reason for inpatient hospitalization was ACLR. Patient data within the NIS is stratified by hospital based on geographic region, urban/rural location, teaching status, bed size, and ownership. This stratification of data is used to create accurate estimates for geographic regions that are weighted relative to the number of hospitals from each stratum contained within a desired area.

Statistical Analysis

Analysis of variance (ANOVA) and Student's T-tests were used to determine differences between incidence percentages in categorical variables. All statistics were calculated in MATLAB using built-in functions. Statistical significance was determined at $\alpha < 0.05$.

RESULTS

Annually, the NIS database reported an average of $1,344 \pm 374$ ACLR procedures that required inpatient hospital admittance, with an average cost, as calculated from the annual means, of \$45,040 per patient (Table 1). With the exception of 2010, the annual number of inpatient ACLR procedures documented by the NIS declined between each year from 2003–2011. However, average expenditures per patient increased annually across all years. NIS patients had a mean hospital admittance of 4.0 days, with an average of 3.0 procedures were performed. From 2003–2011 the average number of procedures per patient increased by 0.7 and the average hospitalization increased by 2.7 days. Mean patient age, as calculated from annual NIS means, was 35.8 years. Inpatient ACLR procedures were more common among males ($61.3 \pm 1.7\%$) than females ($38.8 \pm 1.7\%$; $P < 0.01$). The breakdown of injuries by ethnicity is also displayed in Table 1.

Extrapolation of the NIS data to a national average indicated an average of $9,037 \pm 1,728$ inpatient ACLR procedures per year (Table 2), which accounts for approximately $7.1 \pm 1.4\%$ of the estimated 127,000 ACLR performed annually in the United States [15]. The extrapolated national average was also gender specific (males = $60.0 \pm 1.1\%$, females = $38.8 \pm 1.2\%$, $P < 0.01$). ACLRs were significantly more prevalent between the ages of 18–44 than in any other age group ($54.7 \pm 5.9\%$, $P < 0.01$).

Extrapolation of the NIS data into a national average for patients whose primary cause hospitalization was ACLR indicated a mean of $4,252 \pm 1,824$ annual procedures at a cost of $\$30,118 \pm 9,066$ per patient (Table 3). Annually, inpatient ACLRs where the ACLR is the primary reason for hospitalization generated a mean national expense of $\$115,631,936 \pm 26,288,717$ and accounted for approximately $3.4 \pm 1.4\%$ of all ACLR procedures in the United States [15]. The incidence of patients primarily admitted for ACLRs decreased by 5,523 patients from 2003–2011 whereas the cost per patient increased by $\$20,675$ (Figure 1). Annual aggregate national patient charges for inpatient hospitalization primarily due to ACLR fluctuated between years, but decreased overall by $\$90,134,894$ from 2003–2011. Patients admitted primarily due to ACLR had an average length of stay of 1.7 ± 0.2 days, which was consistent between years. This population subset again demonstrated a male gender bias ($58.1 \pm 2.3\%$, annual range = 55.2 – 61.8% , $P < 0.01$) and was again more prevalent in the 17–44 age range than any other group ($61.0 \pm 5.6\%$, annual range = 53.1 – 69.1% , $P < 0.01$).

According to the collected NIS subset, approximately $65.5 \pm 3.7\%$ of ACLR inpatient admittance involved primary ACL ruptures, while $34.7 \pm 3.5\%$ identified old disruptions of the ACL. The most commonly reported concomitant injury was “close fracture of C1–C4 with unspecified spinal cord injury”, as it appeared in $29.3 \pm 5.8\%$ of cases (Table 4). The most commonly reported concomitant knee-related injury was a “tear of the medial cartilage or meniscus of the knee” ($18.1 \pm 1.5\%$ of cases) followed by “tear of lateral cartilage or meniscus of knee” ($16.8 \pm 1.1\%$ of cases). The difference in the prevalence of meniscus injuries between the medial and lateral sides was statistically significant ($P = 0.04$). “Collateral ligament repairs” were less frequent ($P < 0.01$), documented in $12.3 \pm 2.3\%$ of cases. However, when combined with “sprain of medial collateral ligament of the knee”, collateral ligament damage significantly became the most commonly reported concomitant injury with inpatient ACLR procedures ($19.2 \pm 6.7\%$ of cases), though there was no statistical difference compared to the incidence of medial meniscus injuries ($P = 0.50$). Additional unspecified knee repairs and knee arthroscopy were performed in $14.6 \pm 0.7\%$ and $17.8 \pm 4.8\%$ of ACLR cases, respectively.

The incidence of meniscus injuries was consistent between years for both the medial (range 15.9 – 19.1%) and lateral (range 15.5 – 19.0%) sides (Figure 2). The combined incidence of collateral ligament repairs and strains increased by 18.4% between 2003 and 2011. Frequency of additional knee repairs was consistent between years (range 13.3 – 15.6%) while additional knee arthroscopies decreased by 16.8% from 2003–2011.

DISCUSSION

The most important finding of this study is that while the annual incidence of inpatient ACLRs has decreased, the cost of these hospitalizations has increased as inpatient cases more frequently involve complex, multi-ligament injuries. The purpose of this epidemiologic study was to quantify the incidence, expense, and concomitant injuries for ACLR procedures in the United States from 2003 to 2011 that required an inpatient stay. This investigation is clinically relevant as it informs, on a large clinical cohort of patients, the current state of incidence and expense for ACLR surgeries in an inpatient setting. It was found that inpatient

ACLRs comprise a minority of ACLR procedures as they account for only approximately 7.1% of procedures performed annually. However, as conservative estimates place surgical costs for outpatient, autograft ACLR procedures at \$4872 [23], as evidenced in the current dataset inpatient ACLRs are significantly more expensive. Between the years of 2003–2011, the average per patient charge of an inpatient stay that was primarily due to an ACLR was 618% greater than outpatient ACLRs. Previous studies have indicated that inpatient ACLRs have an average expense three times greater than the equivalent outpatient procedures [14]. The increased cost ratio in the present study is likely due to the combination of multiple procedures that accompany the majority of present-day inpatient ACLR treatments as well as rising costs of hospitalization, bed space, nursing, and more.

As hypothesized, the knee structures that were most commonly disrupted concomitantly with the ACL were the meniscus and MCL (which were both classified with multiple ICD-9 codes). 70% of sports-related ACL injuries occur in non-contact scenarios during rapid deceleration or change of direction movements [4,20]. Athletes with poor neuromuscular control have exhibited increased knee abduction during these athletic tasks [7,8]. Knee abduction has been shown to increase strain on the ACL [26,27] and has been prospectively associated with increased ACL injury risk [12]. These mechanics correlate well with the concomitant injuries recorded in the present study as the MCL is the primary ligamentous restraint to knee abduction rotation [5,6,25]. However, it is interesting to note that the rate of concomitant MCL injury for inpatient ACLRs reported in the present study was lower than MCL incidence reported for the overall population [17,25,21]. Similarly, meniscus injuries were less frequent in the present study than previously reported ACL-injury cohorts [21]. The current database identified concomitant injuries through ICD-9 codes. These codes indicate procedures performed; and therefore, track repairs. In many cases, the MCL can go unrepaired after injury and may not generate an ICD-9 code in these instances. As such it is possible that the incidence of concomitant MCL injuries presented in the NIS was lower than the actual rate of occurrence in the inpatient ACLR population.

In the present study, the incidence of inpatient ACLRs for all three cohorts consistently decreased between years from 2003–2011. This was mostly due to a decrease in the number of inpatient hospitalizations due primarily to ACLR, as the annual incidence of inpatient stays involving, but not primarily due to, ACLR was constantly between 4500–5000 cases. As inpatient ACLRs become less frequent, the cost disparity between inpatient and outpatient treatment has increased. That cost increase correlated with annual increases in number of procedures and length of hospitalization that were observed in the whole NIS cohort. These trends would seem indicate that the increasing inpatient expenses may be due to increased severity in injuries that require inpatient hospitalization. However, in the cohort admitted primarily for ACLR, the length of hospitalization only expressed a minor increase (0.4 days) over time, which implicates that rising costs in healthcare were also a driving force between the constantly increasing per patient charges.

Between 2003–2011, the extrapolated national average cost per patient for an inpatient visit primarily due to ACL reconstruction increased by 88.0%. Over this same time span, inflation would have accounted for a 22.0% increase in expenses according to the Bureau of Labor Statistics (<http://www.bls.gov>). Therefore, the rise in cost per patient was greater than

the rise in national inflation. As such, the additional expense per patient for inpatient ACLRs may be attributed to more complex repairs that may involve additional structures within the knee. This concept would seem to be supported as concomitant collateral ligament repairs increased by 7.0% of cases and concomitant MCL sprains increased by 3.9% of cases over the same time period (Table 4).

The significant presence of concomitant closed fractures of C1–C4 level with unspecified spinal cord injury in the current sample likely indicates that many inpatient ACLRs result from trauma rather than sports injuries. In athletic populations over 94% of ACL injuries occur as a result of sports injuries, but in non-athletic populations this drops to 75% as injuries from traffic and daily living accidents are more common [21]. Therefore, it is likely that a significant number of injuries documented in the present study occurred in traumatic events such as car accidents where large forces are applied across multiple areas of a patient's body and resulted in the need for multiple surgical procedures. The presented data would seem to support this theory as the mean charge and length of stay per patient for the whole NIS cohort were \$14,161 and 1.03 days greater than the subset of patients admitted primarily for ACLR. Also, the subset admitted primarily for ACLR had significantly lower variability in charge and length of stay, which indicated greater consistency in treatment than was present in the whole NIS cohort. Unfortunately, one of the limitations of the NIS dataset is that injury cause is not documented; and therefore, could not be reported.

The ethnic distribution of ACLRs in the present study was representative of the national diversity reported by the United States Census Bureau for 2012 (Caucasian = 63.0%, Hispanic = 16.9%, African = 13.1%, Asian = 5.1%; www.census.org). The gender distribution reported by all three cohorts examined in the present study also compared favorably with previous data on knee injuries where males accounted for greater than 60% and females accounted for less than 40% of the population [18,21]. Therefore, inpatient ACLRs do not exhibit ethnicity bias and maintain the same gender bias as seen in the overall ACL-injury population. Similarly, the age bias seen in previous ACL-injured populations was maintained in the present study as over 50% of inpatient ACLRs were performed 18–44 year old patients [18]. These statistics indicate that the cohort of inpatient ACLRs likely bears significant resemblance to the national ACL-injury patient population.

A limitation of the NIS database is that it does not document the mechanism or cause of injury. Therefore, in the present study, it was not possible to definitively distinguish sports-induced injuries from those caused by alternative sources of trauma such as traffic accidents. Similarly, the NIS does not itemize expenditures. As such it was not possible to partition out costs directly related to ACLR relative to those incurred from concomitant injuries. This inability to itemize expenses is likely what lead to the large standard deviations in annual treatment costs in the NIS database (Table 1). The authors acknowledge that a patient with concomitant spinal fractures, collateral ligament damage, and meniscus damage would most likely incur greater costs than an isolated ACLR. However, when isolated to inpatient stays where ACLR was the primary reason for hospitalization, the standard deviation for per patient was significantly reduced. Therefore, cases where ACLR was the primary cause of hospitalization were more likely to be representative of sports related ACL-injuries. Additionally, though the NIS database provides critical data regarding treatment, ICD-9

codes do not communicate specific details of treatment such as graft type used for ACLR, exact type of meniscal defect identified, or specific procedure used to repair cartilage damage. Accordingly, the authors were unable to further cross-examine the database in this manner.

CONCLUSION

In conclusion, although inpatient ACLRs continue to decrease in frequency, they still represent approximately 7.1% of the ACLRs performed annually in the United States. Inpatient operations represent significant financial burden and typically well exceed the reported costs of an average outpatient ACLRs. The per-patient cost for inpatient ACLRs is rising. This reflects inflation, but also, improved surgical methods that allow for greater outpatient admittance in isolated ACLRs and necessitate inpatient hospitalization for only the most severe injuries. Demographics indicate that the inpatient cohort is likely representative of the overall ACLR population. However, the inpatient ACLR population presented exhibited different concomitant injury patterns than previously published ACLR cohorts.

Acknowledgments

This work was supported by National Institutes of Health grants R01-AR049735, R01-AR055563, and R01-AR056259. The authors would also like to acknowledge the HCUP Data Partners listed on the HCUP-US website (www.hcup-us.ahrq.gov/hcupdatapartners.jsp).

References

1. Andriacchi TP, Briant PL, Bevell SL, Koo S. Rotational Changes at the Knee after ACL Injury Cause Cartilage Thinning. *Clin Orthop*. 2006; 442:39–44. [PubMed: 16394737]
2. Andriacchi TP, Dyrby CO. Interactions between kinematics and loading during walking for the normal and ACL deficient knee. *J Biomech*. 2005; 38(2):293–298. [PubMed: 15598456]
3. Arendt EA, Agel J, Dick R. Anterior Cruciate Ligament Injury Patterns Among Collegiate Men and Women. *J Athl Train*. 1999; 34:86–92. [PubMed: 16558564]
4. Boden BP, Dean GS, Feagin JA, Garrett WE. Mechanisms of anterior cruciate ligament injury. *Orthopedics*. 2000; 23(6):573–578. [PubMed: 10875418]
5. Boguszewski, DV. PhD dissertation. University of Cincinnati; Cincinnati, OH, USA: 2012. Characterizing the porcine knee as a biomechanical surrogate model of the human knee to study the anterior cruciate ligament.
6. Butler DL, Noyes FR, Grood ES. Ligamentous restraints to anterior-posterior drawer in the human knee. A biomechanical study. *J Bone Joint Surg Am*. 1980; 62(2):259–270. [PubMed: 7358757]
7. Ford KR, Myer GD, Hewett TE. Valgus knee motion during landing in high school female and male basketball players. *Med Sci Sports Exerc*. 2003; 35(10):1745–1750. [PubMed: 14523314]
8. Ford KR, Myer GD, Schmitt LC, Uhl TL, Hewett TE. Preferential quadriceps activation in female athletes with incremental increases in landing intensity. *J Appl Biomech*. 2011; 27(3):215–222. [PubMed: 21844610]
9. Griffin LY, Agel J, Albohm MJ, Arendt EA, Dick RW, Garrett WE, Garrick JG, Hewett TE, Huston L, Ireland ML, Johnson RJ, Kibler WB, Lephart S, Lewis JL, Lindenfeld TN, Mandelbaum BR, Marchak P, Teitz CC, Wojtyk EM. Noncontact anterior cruciate ligament injuries: risk factors and prevention strategies. *J Am Acad Orthop Surg*. 2000; 8(3):141–150. [PubMed: 10874221]
10. HCUP National Inpatient Sample (NIS). Agency for Healthcare Research and Quality; Rockville, MD: 2003–2011.

11. Hewett TE, Lindenfeld TN, Riccobene JV, Noyes FR. The effect of neuromuscular training on the incidence of knee injury in female athletes. A prospective study. *Am J Sports Med.* 1999; 27(6): 699–706. [PubMed: 10569353]
12. Hewett TE, Myer GD, Ford KR, Heidt RS Jr, Colosimo AJ, McLean SG, van den Bogert AJ, Paterno MV, Succop P. Biomechanical Measures of Neuromuscular Control and Valgus Loading of the Knee Predict Anterior Cruciate Ligament Injury Risk in Female Athletes: A Prospective Study. *Am J Sports Med.* 2005; 33(4):492–501. [PubMed: 15722287]
13. Johnson DL, Warner JJP. Diagnosis for anterior cruciate ligament surgery. *Clin Sports Med.* 1993; 12(4):671–684. [PubMed: 8261519]
14. Kao JT, Giangarra CE, Singer G, Martin S. A comparison of outpatient and inpatient anterior cruciate ligament reconstruction surgery. *Arthroscopy.* 1995; 11(2):151–156. [PubMed: 7794426]
15. Kim S, Bosque J, Meehan JP, Jamali A, Marder R. Increase in outpatient knee arthroscopy in the United States: a comparison of National Surveys of Ambulatory Surgery, 1996 and 2006. *J Bone Joint Surg Am.* 2011; 93(11):994–1000. [PubMed: 21531866]
16. Krywulak SA, Mohtadi NG, Russell ML, Sasyniuk TM. Patient satisfaction with inpatient versus outpatient reconstruction of the anterior cruciate ligament: a randomized clinical trial. *Can J Surg.* 2005; 48(3):201–206. [PubMed: 16013623]
17. LaPrade RF, Wentorf FA, Fritts H, Gundry C, Hightower CD. A prospective magnetic resonance imaging study of the incidence of posterolateral and multiple ligament injuries in acute knee injuries presenting with a hemarthrosis. *Arthroscopy.* 2007; 23(12):1341–1347. [PubMed: 18063179]
18. Majewski M, Susanne H, Klaus S. Epidemiology of athletic knee injuries: A 10-year study. *Knee.* 2006; 13(3):184–188. [PubMed: 16603363]
19. McCarty LP III, Bach BR Jr. Anatomy, biology and biomechanics of patellar tendon autograft anterior cruciate ligament reconstruction. *Tech Orthopaedics.* 2005; 20(4):342–352.
20. McNair PJ, Marshall RN, Matheson JA. Important features associated with acute anterior cruciate ligament injury. *N Z Med J.* 1990; 103(901):537–539. [PubMed: 2243642]
21. Mei Y, Ao YF, Wang J-Q, Ma Y, Zhang X, Wang J-N, Zhu J-X. Clinical characteristics of 4355 patients with anterior cruciate ligament injury. *Chin Med J (Engl).* 2013; 126(23):4487–4492. [PubMed: 24286412]
22. Myer GD, Ford KR, hewett tE. Preventing ACL injuries in Women. *J Musculoskel Med.* 2006; 23(1):12–38.
23. Nagda SH, Altobelli GG, Bowdry KA, Brewster CE, Lombardo SJ. Cost analysis of outpatient anterior cruciate ligament reconstruction: autograft versus allograft. *Clin Orthop Relat Res.* 2010; 468(5):1418–1422. [PubMed: 20020337]
24. Roos H, Adalberth T, Dahlberg L, Lohmander LS. Osteoarthritis of the knee after injury to the anterior cruciate ligament or meniscus: the influence of time and age. *Osteoarthritis Cartilage.* 1995; 3(4):261–267. [PubMed: 8689461]
25. Sankar WN, Wells L, Sennett BJ, Wiesel BB, Ganley TJ. Combined anterior cruciate ligament and medial collateral ligament injuries in adolescents. *J Pediatr Orthop.* 2006; 26(6):733–736. [PubMed: 17065935]
26. Shin CS, Chaudhari AM, Andriacchi TP. The effect of isolated valgus moments on ACL strain during single-leg landing: A simulation study. *J Biomech.* 2008; 42(3):280–285. [PubMed: 19100550]
27. Shin CS, Chaudhari AM, Andriacchi TP. Valgus plus internal rotation moments increase anterior cruciate ligament strain more than either alone. *Med Sci Sports Exerc.* 2011; 43(8):1484–1491. [PubMed: 21266934]
28. Tashman S. Abnormal Rotational Knee Motion During Running After Anterior Cruciate Ligament Reconstruction. *Am J Sports Med.* 2004; 32(4):975–983. [PubMed: 15150046]
29. Tashman S, Kolowich P, Collon D, Anderson K, Anderst W. Dynamic function of the ACL-reconstructed knee during running. *Clin Orthop Relat Res.* 2007; 454:66–73. [PubMed: 17091011]
30. Toth AP, Cordasco FA. Anterior cruciate ligament injuries in the female athlete. *J Gend Specif Med.* 2001; 4(4):25–34. [PubMed: 11727468]

Figure 1.

Incidence of inpatient ACLR and charges per patient across time. The change in per patient cost (dotted line) is inverse to the changes in incidence for the whole inpatient ACLR population (solid line) as well as for ACLRs that were the primary cause of hospitalization (dashed line). Inpatient hospitalization due primarily to ACLR accounted for $45.8 \pm 11.6\%$ of the whole inpatient ACLR population, but decreased from 62.1% in 2003 to 28.6% in 2011. Inpatient hospitalizations involving, but not primarily due to ACLRs, consistently accounted for approximately 5000 cases annually.

Figure 2.

Depiction of trends in the prevalence of additional knee procedures frequently documented with inpatient ACLRs. Prevalence is relative to inpatient ACLRs recorded in the NIS database. From 2003–2011 the percentage of collateral ligament injuries increased in prevalence, whereas meniscus injuries and other repairs remained constant, and knee arthroscopies decreased.

Table 1

Patient demographics calculated directly from the NIS data subset for all reported inpatient ACLR cases from 2003–2011.

	2003	2004	2005	2006	2007	2008	2009	2010	2011
Procedures	1963	1828	1435	1233	1223	1223	1038	1099	929
Age	32.5 ± 14.0	32.8 ± 14.2	34.4 ± 16.8	35.2 ± 16.6	35.1 ± 16.5	37.3 ± 17.5	37.0 ± 18.1	38.5 ± 18.4	39.6 ± 18.1
Length of Stay	2.6 ± 4.7	2.8 ± 4.2	3.6 ± 6.1	3.7 ± 5.3	3.7 ± 5.5	3.9 ± 5.7	4.4 ± 7.6	5.8 ± 10.3	5.3 ± 7.0
Operations per Patient	2.6 ± 1.6	2.6 ± 1.7	2.8 ± 2.4	2.9 ± 2.4	2.8 ± 2.3	3.1 ± 2.6	3.1 ± 2.6	3.5 ± 3.6	3.3 ± 3.0
Cost per Patient	\$27266 ± 31371	\$25629 ± 27167	\$32373 ± 60277	\$36394 ± 41988	\$38044 ± 43123	\$44897 ± 47463	\$55942 ± 74359	\$72259 ± 105678	\$72559 ± 89733
Gender									
Male	1197 (62.1%)	1062 (59.7%)	844 (60.5%)	767 (62.7%)	769 (63.8%)	709 (58.4%)	633 (62.2%)	657 (60.1%)	569 (61.9%)
Female	731 (37.9%)	718 (40.3%)	551 (39.5%)	456 (37.3%)	437 (36.2%)	505 (41.6%)	385 (37.8%)	437 (40.0%)	350 (38.1%)
Race									
Caucasian	1077 (74.2%)	929 (70.8%)	732 (69.9%)	619 (69.7%)	578 (66.2%)	623 (68.3%)	576 (67.1%)	581 (62.5%)	530 (64.5%)
African	163 (11.2%)	145 (11.1%)	117 (11.2%)	99 (11.2%)	121 (13.9%)	119 (13.2%)	125 (14.6%)	159 (17.1%)	124 (15.1%)
Hispanic	140 (9.7%)	161 (12.3%)	115 (11.0%)	123 (13.9%)	132 (15.1%)	101 (11.2%)	104 (12.1%)	119 (12.8%)	116 (14.1%)
Asian	32 (2.2%)	19 (1.5%)	14 (1.3%)	< 10 (0.9%)	< 10 (1.0%)	16 (1.8%)	19 (2.2%)	14 (1.5%)	17 (2.1%)
Other	39 (2.7%)	58 (4.4%)	69 (6.6%)	39 (4.4%)	33 (3.8%)	45 (5.0%)	35 (4.1%)	57 (6.1%)	35 (4.3%)

* Length of stay is reported in days hospitalized. Age is reported in years.

Table 2

National averages extrapolated from the NIS for all inpatient hospitalizations that involved ACLRs from 2003–2011.

	2003	2004	2005	2006	2007	2008	2009	2010	2011
Procedures	12,051	11,486	9,638	8,640	8,404	8,560	7,761	7,972	6,827
Age									
1–17	1,731 (14.4%)	1,598 (13.9%)	1,651 (17.1%)	1,075 (12.4%)	946 (11.3%)	967 (11.3%)	799 (10.3%)	897 (11.3%)	636 (9.3%)
18–44	7,693 (63.8%)	7,159 (62.3%)	4,987 (51.7%)	4,882 (56.5%)	4,885 (58.1%)	4,474 (52.3%)	4,059 (52.3%)	3,863 (48.5%)	3,194 (46.8%)
45–64	2,019 (16.8%)	2,157 (18.8%)	2,192 (22.7%)	1,919 (22.2%)	1,803 (21.5%)	2,270 (26.5%)	1,968 (25.4%)	2,280 (28.6%)	2,192 (32.1%)
65–84	459 (3.8%)	430 (3.7%)	582 (6.0%)	686 (7.9%)	595 (7.1%)	689 (8.1%)	651 (8.4%)	698 (8.8%)	626 (9.2%)
85+	82 (0.7%)	84 (0.7%)	150 (1.6%)	74 (0.9%)	143 (1.7%)	142 (1.7%)	174 (2.2%)	212 (2.7%)	149 (2.2%)
Gender									
Male	7,353 (61.0%)	6,748 (58.8%)	5,625 (58.4%)	5,280 (61.1%)	5,124 (61.0%)	5,061 (59.1%)	4,710 (60.7%)	4,706 (59.0%)	4,129 (60.5%)
Female	4,499 (37.3%)	4,502 (39.2%)	3,793 (39.4%)	3,294 (38.1%)	3,189 (37.9%)	3,456 (40.4%)	2,928 (37.7%)	3,242 (40.7%)	2,632 (38.6%)

Estimated national averages extrapolated from the NIS database for patients whose primary cause for inpatient hospital admittance was ACL injury or ACLR.

Table 3

	2003	2004	2005	2006	2007	2008	2009	2010	2011
Procedures	7,478	6,632	5,018	4,062	3,893	3,516	3,067	2,646	1,955
Length of Stay	1.5	1.6	1.7	1.8	1.7	1.7	1.8	2.0	1.9
Cost per Patient	\$23,501	\$20,080	\$21,392	\$24,684	\$25,465	\$32,408	\$39,642	\$39,716	\$44,176
National Charges	\$17,55,06,012	\$13,32,50,234	\$10,74,57,208	\$10,02,29,082	\$9,94,37,564	\$11,39,46,528	\$12,08,65,906	\$10,46,23,773	\$8,53,71,118
Age									
1–17	1,285 (17.2%)	1,211 (18.3%)	1,298 (25.9%)	731 (18.0%)	717 (18.4%)	605 (17.2%)	527 (17.2%)	603 (22.8%)	375 (19.2%)
18–44	5,164 (69.1%)	4,379 (66.0%)	2,666 (53.1%)	2,607 (64.2%)	2,531 (65.0%)	2,181 (62.0%)	1,812 (59.1%)	1,446 (54.6%)	1,093 (55.9%)
45–64	864 (11.6%)	878 (13.2%)	836 (16.7%)	599 (14.8%)	508 (13.1%)	634 (18.0%)	477 (15.6%)	460 (17.4%)	364 (18.6%)
65–84	79 (17.2%)	92 (1.4%)	126 (2.5%)	116 (2.9%)	97 (2.5%)	53 (1.5%)	129 (4.2%)	78 (2.9%)	77 (4.0%)
85+	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Gender									
Male	4,417 (59.1%)	3,716 (56.0%)	2,771 (55.2%)	2,437 (60.0%)	2,405 (61.8%)	1,995 (56.8%)	1,736 (56.6%)	1,599 (60.5%)	1,113 (57.0%)
Female	2,885 (38.6%)	2,689 (40.5%)	2,048 (40.8%)	1,586 (39.1%)	1,424 (36.6%)	1,483 (42.2%)	1,224 (39.9%)	1,022 (38.7%)	781 (40.0%)

* Length of stay is reported in days hospitalized. Age is reported in years.

Table 4

Annual percentages of ACL classifications and concomitant injuries documented within the NIS inpatient ACLR population.

ICD-9 CM	Description	2003	2004	2005	2006	2007	2008	2009	2010	2011
844.2	Sprain cruciate ligament of knee	61.4%	60.6%	65.2%	66.6%	61.7%	65.9%	70.5%	68.6%	69.4%
81.45	Cruciate leg repair	88.6%	86.9%	79.7%	75.6%	73.8%	71.9%	69.5%	59.1%	55.1%
717.83	Old disruption of anterior cruciate ligament	38.8%	39.6%	35.1%	33.6%	38.1%	34.3%	29.8%	31.7%	31.3%
806	Closed fracture of C1–C4 level with unspecified spinal cord injury	36.5%	37.6%	32.5%	31.1%	28.8%	26.6%	27.7%	21.2%	21.9%
401.9	Unspecified essential hypertension	8.3%	7.9%	12.1%	14.6%	14.4%	17.7%	19.0%	20.5%	19.4%
836	Tear of medial cartilage or meniscus of knee	20.6%	17.6%	19.1%	19.1%	15.9%	17.8%	18.4%	16.1%	18.5%
305.1	Nondependent tobacco use disorder	7.4%	7.4%	8.4%	10.4%	14.4%	13.6%	13.7%	19.3%	17.0%
836.1	Tear lateral cartilage or meniscus of knee	16.2%	16.7%	16.9%	16.8%	15.5%	17.7%	19.0%	15.8%	16.1%
8146	Collateral ligament repair	8.1%	11.1%	11.1%	13.3%	10.5%	13.6%	14.9%	13.5%	15.1%
8147	Other repair of the knee	14.8%	15.2%	13.3%	13.6%	14.6%	14.6%	15.6%	14.9%	14.3%
8026	Knee arthroscopy	29.0%	17.7%	15.5%	18.0%	16.1%	17.7%	20.1%	13.7%	12.3%
844.1	Sprain of medial collateral ligament of knee	>1%	8.1%	8.5%	10.8%	>1%	>1%	9.6%	11.7%	12.0%
793.6	Nonspecific (abnormal) findings on radiological and other examination of abdominal area, including retroperitoneum	>1%	>1%	8.2%	8.4%	>1%	>1%	10.7%	12.4%	>1%
823	Closed fracture of upper end of tibia alone	>1%	>1%	>1%	8.3%	>1%	>1%	10.6%	>1%	>1%
717.7	Chondromalacia of patella	6.7%	7.2%	10.0%	8.8%	>1%	>1%	>1%	>1%	>1%