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SYMPOSIUM: MANAGEMENT OF THE DISLOCATED KNEE

Epidemiology of Multiligament Knee Reconstruction

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Abstract

Background The multiple-ligament-injured knee represents a special challenge, being an uncommon injury that is both severe and complicated to treat. Many studies have evaluated patients treated for this injury, but most are limited in their scope. The evaluation of this injury and its treatment using an administrative database might provide a different perspective.

Questions/purposes Using a large administrative database, we determined (1) the number of multiligament knee reconstructions in New York State, (2) the rate of 90-day hospital readmission, and (3) the frequency of subsequent knee surgery. We examined the rates of these outcomes as a function of diagnosis, admission type, discharge status, comorbidity burden, and patient demographic factors.

Methods We used the New York Department of Health Statewide Planning and Research Cooperative System (SPARCS), a database with information on patient characteristics, diagnoses, and treatments, to identify patients who underwent a multiligament procedure in a nonfederal facility from 1997 to 2005 using ICD-9-CM and Current Procedural Terminology codes. SPARCS collects data from all nonfederal acute care facilities, with an estimated reporting completeness of almost 99% for the years in this study. We evaluated data on patient age, sex, admission type, discharge status, and comorbidity burden (using Elixhauser comorbidities) and developed a multivariable logistic regression model to assess the influence of confounding variables.

Results We identified 1032 patients in this database who underwent multiligament knee reconstruction in New York State from 1997 to 2005. The frequency of readmission within 90 days was 4.8% (n = 49). Readmission was more likely for patients who underwent inpatient multiligament reconstruction (odds ratio [OR] = 2.3; 95% CI: 1.2–4.4; p = 0.014), had a diagnosis of dislocation (OR = 2.2; 95% CI: 1.2–3.9; p = 0.011), or had various Elixhauser comorbidities, including chronic lung disease (OR = 6.4; 95% CI: 1.5–27.2; p = 0.013), fluid and electrolyte disorders (OR = 19.7; 95% CI: 2.5–155.7; p = 0.005), and anemia deficiency (OR = 5.6; 95% CI: 1.05–29.4; p = 0.044). Two hundred eighty-seven patients (28%) underwent subsequent knee surgery between their index

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Each author certifies that his or her institution approved or waived approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.
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procedure and 2006. Subsequent surgery was more likely for patients who underwent inpatient multiligament reconstruction (OR = 1.4; 95% CI: 1.1–1.9; p = 0.011) or were readmitted within 90 days of the index surgery (OR = 4.2; 95% CI: 2.3–7.6; p < 0.001).

Conclusions Our findings have the potential to aid clinicians in identifying their patients with multiligament reconstruction at highest risk for 90-day readmission and subsequent knee surgery. Future research, particularly large prospective studies evaluating surgical approaches and timing, will be critical in advancing the treatment of multiligament knee injuries.

Level of Evidence Level IV, therapeutic study. See Instructions for Authors for a complete description of levels of evidence.

Introduction

The multiple-ligament-injured knee is somewhat unique in orthopaedic surgery in that it is both an uncommon injury and also a difficult one to treat. In addition to joint instability, vascular and neurologic injuries are commonly present, further complicating management [3, 9]. Case series suggest that popliteal artery damage is present in 20% to 40% of all multiligament injuries and that the incidence of neurologic injury ranges from 16% to 40%, depending on the direction of dislocation [3, 10, 12].

A paucity of high-quality evidence on which to base treatment decisions further complicates the management of the multiligament-injured knee. The evidence supporting management of the multiligament-injured knee is limited mostly to case series [9, 18, 24, 25]. This is primarily because its low incidence makes it inherently difficult to evaluate treatments with large, prospective clinical trials. Recent evidence suggests an incidence of 0.072 events per 100 patient-years [2]. Although this is substantially higher than the previously reported incidence of 0.001 events per 100 patient-years in the general population and 0.0125 events per 100 patient-years within orthopaedic injuries, it is still very low [14, 18]. Because multiligament injuries often reduce spontaneously, the actual incidence may be slightly higher as a result of missed diagnoses [1–4, 9]. The low incidence of this injury also presents barriers to epidemiologic investigation [3]. As a result, the current epidemiologic profile of multiligament knee injuries relies predominantly on merging data from various case series [3, 5, 6, 16, 20, 23]. While this approach has yielded valuable information on patterns of patient presentation and injury mechanisms, it is handicapped by the intrinsic limitations of the constituent studies. As a result, the epidemiologic profile of multiligament knee injuries remains conspicuously incomplete. A recent study on the demographics of knee dislocations, the first population-based study on the topic in more than five decades, has provided essential data on the incidence of this injury [2]. However, to our knowledge, there still are no population-based data on the outcomes of multiligament knee reconstruction.

We analyzed a statewide administrative database to determine (1) the number of multiligament knee reconstructions in New York State, (2) the rate of 90-day hospital readmission, and (3) the frequency of subsequent knee surgery. We examined the rates of these outcomes as a function of diagnosis, admission type, discharge status, comorbidity burden, and patient demographic factors.

Patients and Methods

The data for this study were provided by the New York Department of Health Statewide Planning and Research Cooperative System (SPARCS) database, which was established in 1979. This administrative database collects patient-level information on demographics, diagnoses, treatments, services, and charges for every hospital discharge, ambulatory surgery procedure, and emergency department admission in nonfederal facilities in New York State. SPARCS' annual reports indicate that the completeness of reporting for the years in this study was between 95% and 99%, with a median of 99% [21]. SPARCS derives this estimate from a comparison with institutional cost reports submitted to the New York Department of Health.

The available data years for this study were 1997 to 2006, so we identified patients who underwent a multiligament procedure from 1997 to 2005 and used 2006 data only to select subsequent episodes of care for these patients. A multiligament procedure was defined as an inpatient admission having ICD-9-CM procedure codes 81.45 and 81.46 recorded with the same procedure date or an outpatient admission having these same two ICD-9-CM procedure codes or Current Procedural Terminology (CPT®) codes for both a cruciate ligament procedure and collateral ligament procedure (cruciate codes: 29888, 29889, 27407, 27428; collateral codes: 27405, 27427; cruciate plus collateral codes: 27409, 27429) (Table 1). Patients younger than 12 years and older than 70 years or those with a diagnosis of malignant neoplasm of the bone and articular cartilage of the long bones of the lower limb (ICD-9-CM 170.7) were excluded.

The main outcome measures were rate of readmission within 90 days and rate of subsequent surgery. We used unique patient identifiers in the database to determine whether the patient had another inpatient admission within 90 days of the multiligament admission for any reason and whether the patient had an inpatient or outpatient

Table 1. Procedure codes used to identify patients in the New York Department of Health Statewide Planning and Research Cooperative System database

Code	Procedure
ICD-9-CM	
81.45	Other repair of the cruciate ligaments
81.46	Other repair of the collateral ligaments
Current Procedural Terminology	
29888	Arthroscopically aided ACL repair/augmentation or reconstruction
29889	Arthroscopically aided PCL repair/augmentation or reconstruction
27407	Repair, primary, torn ligament and/or capsule, knee; cruciate
27428	Ligamentous reconstruction (augmentation), knee; intraarticular (open)
27405	Repair, primary, torn ligament and/or capsule, knee; collateral
27427	Ligamentous reconstruction (augmentation), knee; extraarticular
27409	Repair, primary, torn ligament and/or capsule, knee; collateral and cruciate ligaments
27429	Ligamentous reconstruction (augmentation), knee; intraarticular (open) and extraarticular

admission with an ICD-9-CM procedure code or CPT® code for a knee procedure through 2006. We evaluated data on patient age, sex, year of surgery, admission type (inpatient versus outpatient), discharge status (home, inpatient transfer, transfer to another healthcare facility), and comorbidity burden. We used the Elixhauser comorbidity algorithm to identify in-hospital comorbidities using ICD-9-CM codes [8]. The Elixhauser method includes 30 unweighted comorbidity measures that are associated with outcome measures commonly available in administrative data (including substantial increases in length of stay, hospital charges, and mortality).

Information about the mechanism of injury, physical examination, operative details, complexity of procedure, and rehabilitation protocol was unavailable as a result of the administrative nature of the database.

Descriptive statistics calculated were means and SDs for continuous variables and frequency counts and percentages for discrete variables. Univariate analyses were performed using the Wilcoxon rank-sum test for continuous variables and Fisher's exact test or the chi-square test for categorical variables. Covariates of interest were included in the development of multivariable logistic regression models to determine patient-level predictors of readmission within 90 days and subsequent knee surgery. These covariates included age, sex, surgery type (inpatient and outpatient), dislocation diagnosis, various Elixhauser comorbidities (alcohol abuse, anemia deficiency, arrhythmias, chronic lung disease, depression, fluid and electrolyte disorders, hypothyroidism, and valvular disease), and disposition (home, transfer inpatient, transfer other). Odds ratios (ORs) and 95% CIs are reported for covariates included in the final multivariable logistic regression models adjusted for age and sex.

Results

We identified 1032 patients who underwent multiligament knee reconstruction in New York State from 1997 to 2005 (Table 2). The mean age of patients was 32 ± 12 years (range, 13–69 years). A total of 365 surgeons performed the 1032 surgeries at 180 distinct hospital facilities. Over the course of the study, 53% of surgeons (195 of 365) performed only one multiligament reconstruction and only 1.4% of surgeons (five of 365) performed more than 20 reconstructions. The mean for all surgeons was 2.8 reconstructions, with a maximum of 48. Males accounted for 72% of patients (739 of 1032). Of the 1032 surgeries, 526 (51%) were outpatient procedures and 506 (49%) were inpatient. At least one Elixhauser comorbidity was present in 11% of patients (111 of 1032); 3.8% of outpatients (20 of 526) had at least one comorbidity compared to 18% of inpatients (91 of 506) (OR = 5.47; 95% CI: 3.31–9.04; $p < 0.001$).

The rate of readmission within 90 days was 4.8% (49 of 1032). The 90-day readmission rates for inpatient and outpatient surgeries were 6.9% (35 of 506) and 2.7% (14 of 526), respectively. Postoperative infection was the most common diagnosis at readmission and accounted for 27% of patients readmitted within 90 days (13 of 49). Readmission of patients for infection occurred within 5 to 55 days after the index surgery (mean 27 days). The majority of these patients (62%, eight of 13) had knee surgery during this readmission. According to our multivariable logistic regression model, variables contributing to readmission within 90 days included inpatient multiligament reconstruction, a diagnosis of dislocation, and various Elixhauser comorbidities, specifically chronic lung disease, fluid and electrolyte disorders, and anemia deficiency (Table 3).

The rate of subsequent knee surgery between the index procedure and 2006 was 28% (287 of 1032). The subsequent knee surgery rates for inpatients and outpatients were 32% (163 of 506) and 24% (124 of 526), respectively. Of the 287 patients with subsequent surgery, 62 (22%) had multiple subsequent knee surgeries. The total number of subsequent knee surgeries was 369. The mean time to subsequent surgery was 467 days (range, 1–3240 days). Common procedures included removal of an implanted device (49%, 180 of 369 total procedures), cruciate ligament reconstruction (25%, 91 of 369), collateral ligament

reconstruction (4.9%, 18 of 369), and additional multiligament surgery (1.4%, five of 369). Sixteen of the 287 patients with subsequent surgery (5.6%) had a TKA. The mean time to TKA was 1081 days and the frequency of revision TKA was 13% (two of 16). Subsequent knee surgery was more likely for patients who underwent inpatient multiligament reconstruction or were readmitted within 90 days of the index surgery (Table 3). Twenty of the 49 patients readmitted within 90 days (41%) underwent a subsequent knee procedure during their readmission. Eleven of the 49 readmitted patients (23%) underwent more than one knee procedure during readmission and one patient had four procedures. The most common procedure performed in these patients was local excision of a knee lesion (40%, eight of 20). Other common procedures were knee arthroscopy (25%, five of 20) and cruciate ligament repair (20%, four of 20).

Discussion

Because knee dislocations are uncommon, epidemiologic studies of the multiple-ligament-injured knee have relied heavily on case series. These studies have provided useful information on patterns of patient presentation, injury mechanisms, and treatment approaches, but without population-based studies, the epidemiologic profile of the multiligament-injured knee remains conspicuously incomplete. We therefore analyzed a statewide administrative database to determine (1) the volume of multiligament knee reconstructions in New York State, (2) the rate of 90-day hospital readmission, and (3) the frequency of subsequent knee surgery. We examined the rates of these outcomes as a function of diagnosis, admission type, discharge status, comorbidity burden, and patient demographic factors.

There are numerous limitations to our study, many intrinsically related to the nature of the data. Because this is a health outcome study based on an administrative database, pertinent clinical information (eg, mechanism of injury, physical examination, operative details, complexity of procedure, and rehabilitation protocol) is unavailable. Moreover, the relationship between the index procedure and objective outcome measures (eg, 90-day readmission and subsequent knee surgery) is not always clear. Because of this, it is difficult to determine whether readmission or subsequent surgeries were associated with the index procedure. Although it would be useful to know whether subsequent surgeries represented reinjury or technical failure or were unrelated to the index procedure, our data do not provide this information. Since ICD-9-CM codes do not indicate laterality, we cannot determine whether subsequent operations were on the same knee. In addition, nonfederal facilities within New York State are not necessarily representative of the US population in terms of patient-, surgeon-, and hospital-related factors. Geographic variation limits our ability to extrapolate these data to the US population as a whole.

Another limitation inherent in our dataset is the possibility of underreporting subsequent knee surgeries. Since the database is limited to New York State, subsequent knee surgeries performed out of state are not reported in our analysis. This could lead to a systematic underestimation of the frequency of subsequent surgeries. In addition, because we included patients with an index procedure between

Table 2. Patient demographics

Variable	Value
Number of index procedures	1032
Number of outpatient procedures	526 (51%)
Number of inpatient procedures	506 (49%)
Number of hospitals	180
Number of surgeons	365
Age (years)*	32 ± 12
Sex (number of patients)	
Male	739 (72%)
Female	293 (28%)

* Value is expressed as mean ± SD.

Table 3. Variables contributing to readmission and subsequent surgery*

Variable	Readmission within 90 days (n = 49)			Subsequent knee surgery (n = 287)		
	Odds ratio	95% CI	p value	Odds ratio	95% CI	p value
Inpatient multiligament surgery admission	2.3	1.2–4.4	0.014	1.4	1.1–1.9	0.011
Dislocation diagnosis (ICD-9-CM 836.XX)	2.2	1.2–3.9	0.011			
Elixhauser comorbidities						
Chronic lung disease	6.4	1.5–27.2	0.013			
Fluid and electrolyte disorders	19.7	2.5–155.7	0.005			
Anemia deficiency	5.6	1.05–29.4	0.044			
Readmission within 90 days				4.2	2.3–7.6	< 0.001

* Both logistic regression models also adjusted for age and sex.

1997 and 2005 but only identified subsequent knee surgeries performed through 2006, the followup time for our patients is variable. With a mean time to first subsequent knee injury of 467 days (with an SD of 623 days), it is likely that the abbreviated followup of patients in the latter years of the study artificially deflated the reported frequency of subsequent surgery.

An underreporting of index multiligament reconstructions is also likely. Although some cases may have gone unreported to SPARCS, this is likely a small number, as SPARCS claims a completeness of reporting of almost 99%. The more likely cause of underreporting is the administrative nature of the data, which necessitated the use of ICD-9-CM and CPT® codes to identify multiligament reconstructions. Because it is difficult to generate an ideal definition of multiligament reconstruction using these coding systems, our choice of codes likely resulted in a systematic underestimation of index surgeries. There is also the possibility of coding errors. Finally, it is important to recognize that the term multiligament knee injury refers to a variety of distinct injuries involving an array of anatomic structures. The subcategories of multiligament knee injuries (eg, anterior, posterior, medial, and lateral dislocations) are associated with different patient presentations, treatments, and prognoses. Our study does not identify these distinctions, and there is need for future research to elucidate these important nuances.

We determined that, between 1997 and 2005, 365 surgeons performed a total of 1032 multiligament knee reconstructions in New York State. Since there are only limited data on the incidence of knee dislocations and effectively no information on the frequency of multiligament knee surgeries, it is difficult to situate this within the existing literature. For a point of reference, another study using the same database and similar methods reported 63,040 ACL reconstructions during the same time period, representing an annual frequency of 7004 [19]. This suggests that ACL reconstruction is approximately 60 times more common than multiligament reconstruction. The mean patient age in our sample was 32 years. The mean age typically reported in the literature for patients with multiligament knee injuries is between 29 and 37 years [2, 22, 26]. Because the mechanism of injury is often associated with high-energy trauma or sports, it is not surprising that this patient population is relatively young. Indeed, case series have established young athletes as a common patient population and there is evidence of an inverse relationship between patient age and risk for injury [2, 3]. The data demonstrated that males were more likely to undergo multiligament reconstruction, as 72% of the population was male. This is close to the 4:1 male-to-female ratio reported in most case series of multiligament knee injuries [2, 22, 26]. One possible explanation is the difference in sport participation. Although several studies have established that female athletes have a higher prevalence of knee injuries than their male counterparts, male participation in sports with higher collision forces (eg, football) may put them at greater risk for serious knee injuries, including multiligament and other knee dislocation injuries [3, 7, 13, 15]. Since this dataset does not include the mechanism of injury, the number of patients who sustained their injury in sports is unknown.

The results showed a 90-day readmission rate of 4.8%. Predictors of readmission within 90 days included an index inpatient surgery, a diagnosis of dislocation, and various comorbidities, including chronic lung disease, fluid and electrolyte disorders, and anemia deficiency. According to previous studies, comorbidity burden is a predictor of adverse outcome after total joint arthroplasty and shoulder surgery [11, 27].

The frequency of subsequent knee surgery between the index procedure and the end of the study period was 28%. Predictors of subsequent knee surgery included an index inpatient surgery and readmission within 90 days of the index surgery. The interaction term between index inpatient surgery and readmission within 90 days was not significant and was not included in the final regression model. This suggests that readmission within 90 days has an independent effect on the risk for subsequent surgery. Although hospital identification numbers and physician license numbers are available in the database we used, the small overall sample size and small number of high-volume surgeons and hospitals (only 1.4% of surgeons and 3.9% of hospitals performed more than 20 reconstructions over the study period) precluded an analysis of the effects of hospital and surgeon volume on readmission or reoperation frequencies. However, previous studies suggest an association between surgeon and hospital case volume and perioperative mortality and morbidity and patient-reported outcomes for other orthopaedic procedures [17, 28]. Considering the complexity of multiligament reconstruction, a similar association between volume and outcomes seems likely and is an important question for future research.

Our findings have the potential to aid clinicians in identifying multiligament reconstruction patients at highest risk for 90-day readmission and subsequent knee surgery. Future research, particularly large prospective studies evaluating surgical approaches and timing, will be critical in advancing the treatment of multiligament knee injuries.

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