The Changing Demographics of Knee Dislocation

A Retrospective Database Review

Gabriel A. Arom BS, Michael G. Yeraniosian MD,
Frank A. Petrigliano MD, Rodney D. Terrell MD,
David R. McAllister MD

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Abstract

Background Knee dislocations are uncommon but devastating orthopaedic injuries. Little is known about their frequency and the types of patients who are affected.

Questions/purposes Using a large national insurance database, we determined (1) the incidence of knee dislocation in patients with orthopaedic injuries and examined the incidence as a function of (2) year of diagnosis, (3) dislocation type (open versus closed, direction), and (4) patient demographic factors (sex, age).

Methods We searched the PearlDiver database, a national database of private insurance records consisting of 11 million patients with orthopaedic diagnoses, using diagnosis (ICD-9-CM) codes for knee dislocation between the years 2004 and 2009. The PearlDiver database does not include Medicare, Medicaid, or uninsured patients. Patients were stratified by age, sex, and year of diagnosis. Incidence was defined as the number of dislocation events per 100 patient-years.

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G. A. Arom (✉), M. G. Yeraniosian, F. A. Petrigliano,
R. D. Terrell, D. R. McAllister
UCLA Department of Orthopaedic Surgery, 10833 Le Conte
Avenue, Box 956902, Los Angeles, CA 90095-6902, USA
e-mail: Gabe.Arom@gmail.com; gabearom@gmail.com

Results We identified 8050 dislocations, representing an incidence of 0.072 events per 100 patient-years between 2004 and 2009. Annual dislocation incidence did not increase during the 6-year study period. Of the 8050 dislocations, 1333 (17%) were open and 6717 (83%) were closed, representing an incidence of 0.060 per 100 for closed dislocations and 0.012 per 100 for open dislocations. The most common direction of dislocation was unspecified or other (65%), followed by anterior (13%), lateral (11%), posterior (6%), and medial (5%). Of the patients sustaining dislocations, 4172 (52%) were female and 3878 (48%) were male. Males displayed an increased risk of knee dislocation compared to females (odds ratio = 1.09). The mean patient age was 35 years, and patient age was inversely correlated to the incidence of knee dislocation (10-year odds ratio = 0.77).

Conclusions Our data suggest that knee dislocation might represent a significantly larger burden among orthopaedic injuries than previously thought. The finding that males and females have a nearly equal risk of knee dislocation enhances the diagnosing physician's clinical suspicion of this injury. Future large prospective studies analyzing the various causes of knee dislocation could provide insight into the changing demographics of this injury.

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

Introduction

Knee dislocation is an uncommon yet severe orthopaedic injury typically resulting in multiligament injury of the knee. Knee dislocation is most commonly caused by high-velocity trauma or athletic injury and can be associated

with vascular and neurologic damage to the popliteal neurovascular bundle [13]. Due to the potential for limb loss, knee dislocation is appropriately considered an emergency. Despite the severity of the injury, few data are available regarding the national incidence and demographic distribution of knee dislocation [10, 16, 24].

The lack of reliable incidence reports for knee dislocation may be attributed to the rarity of the injury and the fact that dislocations often spontaneously reduce before presentation, resulting in missed diagnoses [9, 29]. While knee dislocation incidences of less than 0.001 events per 100 patient-years within the general population and of 0.0125 events per 100 patient-years within orthopaedic injuries are often reported in the literature, knee dislocation incidence has not been evaluated in a large patient population for more than half a century [14, 16, 22]. In addition, while some recent retrospective studies report the demographic distribution of patients with knee dislocation, these studies are limited by small sample sizes (< 250 patients) [3, 10, 17, 24]. Knee dislocations often reduce spontaneously, and so the diagnosis of knee dislocation depends largely on clinical suspicion and is often missed at initial presentation [15]. Accordingly, a better understanding of the true incidence of knee dislocation among different patient populations will assist the clinician in determining the likelihood of this injury. Incidence data also can help us better understand the burden on the healthcare system associated with repairing the dislocated, multiligament injured knee.

We therefore (1) determined the incidence of knee dislocation in a population from a large national database of insured patients with orthopaedic injuries and (2) examined yearly trends in knee dislocation frequency. To obtain a better understanding of this uncommon injury, we examined incidence as a function of (3) dislocation type (open versus closed, direction) and (4) patient demographic factors (sex, age).

Patients and Methods

This study was a retrospective database review of patients enrolled in the PearlDiver Patient Record Database (PearlDiver Technologies Inc, Warsaw, IN, USA; www.pearldiverinc.com), a commercially available searchable online database of data submitted by private insurance companies for patients with orthopaedic diagnoses. The database includes 11 million patients and 117 million records between the years 2004 and 2009 (Table 1). The PearlDiver database does not include Medicare, Medicaid, or uninsured patients.

The PearlDiver database has been used in a variety of incidence and demographic studies of orthopaedic injury [1, 18–20, 28, 31–33]. We chose this database for this

study because it is formed through record collections across all age groups from multiple private payer insurance agencies, the largest contribution of which is from the UnitedHealth Group® (Minnetonka, MN, USA; www.unitedhealthgroup.com). Personal communication with PearlDiver Technologies Inc confirms that the database is continually internally validated for elimination of coding errors.

We conducted a search using diagnosis (ICD-9-CM) codes for all known knee dislocation diagnoses between the years 2004 and 2009 (Table 2). This study used the Kennedy classification of knee dislocation based on the direction of tibial displacement relative to the femur [16]. Patients identified by the searched diagnosis codes were stratified by year of diagnosis, sex, and age. Patient age was divided into seven groups: 10 to 19 years, 20 to 29 years, 30 to 39 years, 40 to 49 years, 50 to 59 years, 60 to 69 years, and older than 70 years. Incidences are reported

Table 1. Demographic distribution of patients in PearlDiver database

Variable	Number of patients	Percentage
Year		
2004	1,561,066	14
2005	1,787,491	16
2006	1,914,721	17
2007	1,958,644	18
2008	2,003,157	18
2009	1,927,960	17
Total	11,153,039	100
Age		
< 10 years	577,849	5
10–19 years	1,173,090	11
20–29 years	1,062,649	10
30–39 years	1,838,473	16
40–49 years	2,583,040	23
50–59 years	2,720,560	24
60–69 years	1,146,114	10
> 70 years	51,264	0.5
Total	11,153,039	100
Sex		
Female	6,022,641	54
Male	5,130,398	46
Total	11,153,039	100
US region		
South	5,068,085	45
Midwest	2,758,924	25
West	1,853,870	17
Northeast	1,472,160	23
Total	11,153,039	100

Table 2. Diagnosis (ICD-9-CM) codes used to identify patients in the PearlDiver database

ICD-9-CM code	Diagnosis
836.50	Dislocation of knee, unspecified, closed
836.51	Anterior dislocation of tibia, closed
836.52	Posterior dislocation of tibia, closed
836.53	Medial dislocation of tibia, closed
836.54	Lateral dislocation of tibia, closed
836.59	Other dislocation of knee, closed
836.60	Dislocation of knee, unspecified, open
836.61	Anterior dislocation of tibia, open
836.62	Posterior dislocation of tibia, open
836.63	Medial dislocation of tibia, open
836.64	Lateral dislocation of tibia, open
836.69	Other dislocation of knee, open

Table 3. Odds ratios of study variables

Variable	Knee dislocation		
	p value	Odds ratio	95% CI
Age (years)	0.003	0.97	0.96, 0.99
Age (10 years)	0.003	0.77	0.74, 0.79
Sex (male)	< 0.001	1.09	1.04, 1.14
Study year	0.058	1.01	1.00, 1.02

as the number of dislocation events per 100 patient-years. Statistical significance ($p < 0.05$) for continuous independent variables (injury year and patient age) was calculated using univariate Poisson regression (GLM function in R software [R Project for Statistical Computing, Vienna, Austria]) with correction for overdispersion. Log-odds Poisson regression coefficients (β values) were converted to odds ratios (ORs) using the robust standard errors of the Poisson regression (deltamethod function in R software). Statistical significance ($p < 0.05$) for sex data was calculated using Pearson's chi-square test (Microsoft® Excel® Analysis ToolPak; Microsoft Corp, Redmond, WA, USA).

Results

We identified 8050 knee dislocations in the PearlDiver Patient Record Database between 2004 and 2009. This represents an overall incidence of 0.072 dislocation events per 100 patient-years.

While dislocation count increased during the study period from 1121 in 2004 to 1420 in 2009, dislocation incidence did not increase during the 6-year study period ($p = 0.058$, OR = 1.01) (Table 3). A total of 1121 (14%) knee dislocations were reported in the year 2004,

1219 (15%) in 2005, 1417 (18%) in 2006, 1416 (18%) in 2007, 1457 (18%) in 2008, and 1420 (18%) in 2009. The annual dislocation incidence was 0.071 per 100 in 2004, 0.068 per 100 in 2005, 0.074 per 100 in 2006, 0.072 per 100 in 2007, 0.073 per 100 in 2008, and 0.074 per 100 in 2009.

Most of these injuries were closed dislocations. Of the 8050 dislocations, 6717 (83%) were closed dislocations and 1333 (17%) were open dislocations, representing an incidence of 0.060 per 100 for closed dislocations and 0.012 per 100 for open dislocations (Table 4). Dislocations of unspecified direction (45%) and other direction (20%) were the most common, followed by anterior dislocations (13%), lateral dislocations (11%), posterior dislocations (6%), and medial dislocations (5%) (Fig. 1).

Males had a higher dislocation incidence than females (0.076 per 100 versus 0.069 per 100; $p < 0.001$, OR = 1.09) (Table 3). Of patients who sustained knee dislocations, 4172 (52%) were female and 3878 (48%) were male, representing an incidence of open dislocations of 0.011 per 100 for females and 0.013 per 100 for males and an incidence of closed dislocations of 0.058 per 100 for females and 0.063 per 100 for males (Table 4). The mean age of patients who sustained knee dislocations was 35 years. Patient age and incidence of dislocation were inversely correlated ($p = 0.003$, 10-year OR = 0.77) (Table 3). The dislocation incidence was 0.159 per 100 for patients aged 10 to 19 years, 0.101 per 100 for patients aged 20 to 29 years, 0.068 per 100 for patients aged 30 to 39 years, 0.050 per 100 for patients aged 40 to 49 years, 0.042 per 100 for patients aged 50 to 59 years, 0.036 per 100 for patients aged 60 to 69 years, and 0.017 per 100 for patients older than 70 years (Fig. 2).

Discussion

Knee dislocation is, in fact, a spectrum of injuries, rather than a discrete entity; depending on the direction of dislocation and which specific anatomic structures are disrupted, treatment and prognosis can vary widely. For this reason, we sought to elucidate patterns of injury among different demographics and dislocation types. Anterior and posterior dislocations, for example, are associated with a vascular injury rate of approximately 40%, while medial and lateral dislocations have a significantly lower risk of 25% and 3%, respectively [10]. Open dislocations exhibit significantly poorer outcomes than closed dislocations, with an open dislocation infection rate of 43% and an amputation rate of 17% in one series [17]. Despite the heterogeneity and severity of knee dislocations, little is known about their frequency and demographic distribution. We therefore determined (1) the incidence of knee dislocation in a population of patients in a large national

Table 4. Incidence of dislocation stratified by direction, type (open or closed), and sex

Variable	Incidence (number of dislocation events per 100 patient-years)						Total
	Anterior	Posterior	Medial	Lateral	Unspecified	Other	
Open	0.0018	0.0009	0.0011	0.0006	0.0059	0.0017	0.0120
Closed	0.0077	0.0033	0.0029	0.0072	0.0264	0.0128	0.0600
Male	0.0100	0.0050	0.0040	0.0070	0.0370	0.0130	0.0760
Female	0.0090	0.0040	0.0040	0.0080	0.0290	0.0160	0.0690

Fig. 1 A pie chart shows the incidence of knee dislocations as a function of direction of dislocation. Dislocations of unspecified direction and other direction were the most common. **Fig. 2** A graph shows the incidence of knee dislocation as a function of age group. The 10- to 19-year age group had the highest incidence.

database of insured patients with orthopaedic injuries and examined the incidence as a function of (2) year of diagnosis, (3) dislocation type (open versus closed, direction), and (4) patient demographic factors (sex, age).

Our study is limited by the quality and potential bias of the data extracted from the patient insurance database. If knee dislocations were miscoded or not coded at all, they would not be factored into our incidence calculations. Knee dislocation is typically defined as multiligament rupture and classified according to either anatomic direction or

ligaments ruptured [15, 16, 25, 26]. Our data are limited by the possibility that spontaneously reduced knee dislocations were miscoded or not coded as dislocations at all. It is also limited by the fact that ICD-9-CM coding does not indicate the specific ligaments ruptured. While the Pearl-Diver database conducts internal validation to ensure the accuracy of its records, we cannot quantify the extent of miscoding or bias in our incidence calculations. In addition, because the data were obtained from a private insurance database that does not include Medicare patients, Medicaid patients, or the uninsured, certain socioeconomic classes could have been excluded from the study. Another patient population that was potentially underrepresented in this study is the obese elderly patient with low- or ultralow-velocity knee dislocation. These obese elderly patients are being increasingly reported in the literature and represent a second demographic peak of knee dislocations after young patients with high-velocity injury [2, 7, 21]. Due to the exclusion of Medicare patients, our study potentially overlooked obese elderly patients. Accordingly, it is possible that we have underestimated the true incidence of knee dislocation. This study is also limited by the fact that the patient database surveyed only contained orthopaedic injuries. Thus, the incidences obtained in this study are the incidences within orthopaedic injuries, not within the population as a whole. Finally, this study is limited by the absence of a diagnosis code for rotatory dislocations, a widely recognized classification of dislocation direction [16]. We suspect, though, that patients with knee dislocations that would otherwise be categorized as rotatory may have been included in the unspecified or other group.

Our results indicated that the overall incidence of knee dislocation among orthopaedic injuries was higher than previously described. The most commonly cited incidences for knee dislocation are those of Hoover [14], Kennedy [16], and Quinlan and Sharrard [22], with reported incidences (in events per 100 patient-years) of less than 0.001 within the general population and of 0.0125 within orthopaedic injuries. In this study, we found an overall incidence of 0.072 events per 100 patient-years among 11.2 million patients with orthopaedic injuries sustained between 2004 and 2009. This knee dislocation incidence increase since

the mid-20th century could be attributed to the growing obese population that sustains low-velocity knee dislocation [5, 7, 8, 11]. Azar et al. [2] reported 17 clinically obese patients aged 16 to 59 years (mean, 29 years) who sustained knee dislocations while doing low- or ultralow-velocity activities of daily living (walking, stepping down stairs, etc).

Nonetheless, the most common cause of knee dislocation is currently motor vehicle accidents, followed by sports injuries [4]. Motor vehicle accidents are associated with dashboard injuries whereby the femur makes contact with the vehicle dashboard but the unrestrained tibia translates anterior to the femur with traumatic consequences. Thus, anterior dislocations are the most commonly reported dislocation direction [10, 23, 24, 30]. According to a retrospective review of case studies totaling 204 patients, the most common direction of dislocation is anterior (30%), followed by posterior (22%), lateral (15%), medial (4%), and rotatory (4.5%) [10]. Dislocations that spontaneously reduced were classified as unspecified and made up 24.5% of patients in that study. Of dislocations with a specified direction, we found that anterior dislocation was most common (13%), followed by lateral (11%), posterior (6%), and medial (5%) dislocations. In addition, we found a higher rate of unspecified and other dislocations (45%) and a lower rate of anterior dislocations (13%) than reported in previous studies. In fact, dislocations of unspecified direction made up the largest percentage of dislocations in our study, followed by dislocations of other direction. This large percentage of unspecified (45%) and other (20%) dislocations is likely attributed to knee dislocations that spontaneously reduced before presentation or to dislocations that were rotatory and could not be classified as such. While knee dislocation is a rare injury, open knee dislocations are exceedingly rare and represent approximately 4.8% to 17% of knee dislocations, according to previous reports [12, 17, 23, 27]. The rates of open (17%) and closed (83%) dislocations we found are similar to the rates previously reported.

Our data demonstrated that male patients were more likely to sustain a knee dislocation than female patients. This increased risk of dislocations in males has been previously reported, with most case studies exhibiting a male-to-female patient ratio of 4:1 or higher [6, 23, 27]. However, while our data demonstrated a statistically significant increase in knee dislocations in males, this increase was slight and we found a male-to-female patient ratio of nearly 1:1. Owing to the high-energy nature of knee dislocation injuries, they occur more frequently in younger and more active patient populations. The mean age of patients with knee dislocations typically reported in other studies ranges between 29 and 37 years [6, 23, 27]. We found a mean patient age of 35 years and a statistically significant inverse correlation between patient age and risk for dislocation. The patient group aged 10 to

19 years exhibited the highest incidence of dislocation, with each age group thereafter displaying a steadily decreasing incidence of dislocation.

Our study suggests that knee dislocation might represent a significantly larger burden among orthopaedic injuries than previously thought. Because the timely detection of knee dislocation relies largely on clinical suspicion of injury, the novel finding that males and females have a nearly equal risk of knee dislocation enhances the clinician's diagnostic abilities. Thus, our data represent an important step in understanding the demographics, incidence, and risk factors associated with knee dislocation. Future large prospective studies analyzing the various causes of knee dislocation could provide insight into the changing demographics of this injury.

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