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SYMPOSIUM: MANAGEMENT OF THE DISLOCATED KNEE

What Is the Frequency of Vascular Injury After Knee Dislocation?

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Abstract

Background Vascular injury secondary to an acute knee dislocation is a known complication. However, there exist wide discrepancies in the reported rate of vascular injury in this setting.

Questions/purposes Using a large private insurance database, we determined the frequency of vascular injury in knee dislocations across year of diagnosis, age, sex, and US geographic region and the proportion of these injuries requiring surgical repair.

Methods The PearlDiver database, which contains records from 11 million orthopaedic patients, was searched using ICD-9 diagnostic codes for all knee dislocation events from 2004 to 2009. Within this subset, we identified which knee dislocations had an associated vascular injury ICD-9 code. Patients were stratified by year of diagnosis, age, sex, and US geographic region, and Current Procedural Terminology codes were used to identify the subset of patients with vascular injury requiring surgical repair. Differences in frequency across demographic groups and over time were analyzed with Poisson regression analysis.

Results Among the 8050 limbs with knee dislocation identified over the study period, 267 had a concomitant vascular injury for an overall frequency of 3.3%. Males were found to have an increased risk of vascular injury compared to females (odds ratio = 2.59, $p < 0.001$). Additionally, patients aged 20 to 39 years had a higher risk of vascular injury when compared to those aged 0 to 19 years (odds ratio = 1.93, $p = 0.001$), 40 to 59 years (odds ratio = 1.57, $p = 0.014$), and 60 years or older (odds ratio = 2.81, $p = 0.036$). There were no differences in vascular injury frequency across US geographic regions or diagnosis year. Thirty-four of the 267 cases of vascular injury (13%) underwent surgical treatment.

Conclusions This is the largest study, to our knowledge, that analyzes the proportion of knee dislocations that result in vascular injury. Our data suggest that there is a lower frequency of vascular injury associated with knee

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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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dislocation and a lower proportion of vascular injuries undergoing surgical treatment than previously reported. These findings may support a more selective angiography protocol to screen for vascular injury, rather than performing this invasive diagnostic test on all knee dislocations, as has been done historically. Future large-scale and prospective studies should analyze factors that may predispose to vascular injuries after knee dislocation and determine which patients should be screened for vascular injury after knee dislocation.

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

Introduction

Tibiofemoral knee dislocation is a relatively uncommon injury, with a reported frequency of between 0.001% and 0.013% of all orthopaedic injuries [8, 15]. While rare, knee dislocation represents a substantial trauma that may result in multiple ligament injuries, meniscal injuries, fractures, or neurovascular injuries [7, 11]. The popliteal artery is particularly at risk for damage during knee dislocations [2, 15]. The artery is fixed proximally at the fibrous insertion of the adductor magnus onto the medial femoral epicondyle, and distally it is tethered by the tendinous arch of the soleus [2, 3, 6, 9, 15]. This restricted motion of the popliteal artery, especially during displacement of the tibia relative to the femur, can lead to a traction or blunt injury at its fixed segments [2, 15]. Anterior and posterior dislocations are injury mechanisms especially prone to result in a popliteal artery injury [9].

Knee dislocations associated with vascular injuries generally have a poor prognosis [2, 7, 9, 13, 15]. It has been reported that one in five patients who present to a Level 1 trauma center with a dysvascular limb associated with a knee dislocation will require amputation [13]. In addition, if the vascular repair is delayed past 8 hours of ischemia, there is a reported 86% amputation rate [5]. This can be attributed to the poor collateral circulation around the knee [6]. Despite the importance in recognition of vascular injuries in patients with knee dislocation, there is much controversy regarding its true frequency, thereby warranting further examination. The reported frequency of vascular injury associated with knee dislocation varies widely, ranging between 5% and 64% [1, 5, 7, 10, 14, 16–18, 20]. In addition, much of the literature is based on very small sample sizes since knee dislocations are uncommon [1, 5, 10, 14, 16–18, 20].

Using a large private insurer database, we therefore determined the frequency of vascular injuries after knee dislocation in the United States, analyzed frequency trends over time and across different age groups, sexes, and US geographic regions, and determined the proportion of vascular injuries that underwent surgical intervention.

Patients and Methods

The PearlDiver Patient Record Database (PearlDiver Technologies Inc, Warsaw, IN, USA; www.pearldiverinc.com) is a national insurance database, formed through record collections across all age groups from multiple private payer insurance agencies, with the largest contribution from the UnitedHealth Group (Minnetonka, MN, USA; www.unitedhealthgroup.com). The database contains patient records from 2004 to 2009, with more than 11 million patients who have orthopaedic ICD-9 and/or Current Procedural Terminology (CPT®) codes assigned to their diagnosis. Personal communication with PearlDiver Technologies Inc confirms that the database is continually internally validated for elimination of coding errors. The demographics of the PearlDiver database in regard to year of diagnosis, age group, sex, and US geographic region are shown (Table 1).

In this study, the database was used to query for patients who had a pertinent vascular injury ICD-9 and/or vascular

Table 1. Demographic distribution of patients in the PearlDiver database by year of diagnosis, age, sex, and US geographic region

Variable	Number of patients
Total	11,153,039
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%)
Age	
0–19 years	1,750,939 (16%)
20–39 years	2,901,122 (26%)
40–59 years	5,303,600 (47.5%)
≥ 60 years	1,197,378 (10.5%)
Sex	
Male	5,130,398 (46%)
Female	6,022,641 (54%)
US geographic region	
South	5,068,085 (45%)
Midwest	2,758,924 (25%)
West	1,853,870 (17%)
Northeast	1,472,160 (13%)

repair CPT® code that was entered within 30 days of a knee dislocation ICD-9 code. This database uses the Kennedy classification of knee dislocation based on the direction of tibial displacement relative to the femur. For a complete description of the ICD-9 and CPT® codes used, see Appendix 1 (supplemental materials are available with the online version of CORR®). The 30-day interval was chosen to account for delays in ICD-9 and CPT® coding and to capture vascular injuries that may have had a delayed manifestation such as progression of small intimal tears. The frequency of a vascular injury in knee dislocation events was calculated by dividing the number of vascular injuries identified within 30 days of all knee dislocation codes by the total number of knee dislocation events. The numerator in this equation, which is the number of vascular injuries, was equal to the total number of vascular injuries identified by ICD-9 coding. The number of vascular procedures identified by CPT® codes was not added to the total number of vascular injuries since all patients identified with CPT® codes for vascular procedure would presumably also have an ICD-9 code for vascular injury, and this would falsely increase the total number of vascular injury events.

For statistical analysis, patients were categorized by year of diagnosis (2004, 2005, 2006, 2007, 2008, 2009), age (0–19 years, 20–39 years, 40–59 years, 60 years or older), sex (male, female), and US geographic region (South, Midwest, West, Northeast). The frequency of vascular injury secondary to knee dislocation was compared between categories of year of diagnosis, age, sex, and US geographic region using a global Poisson regression analysis with Bonferroni correction. In the case of a significant difference, pairwise comparisons between the groups of the category were carried out using pairwise Poisson regression analysis with Bonferroni correction. Significance was set for all analyses to p values of less than 0.05. Odds ratios (ORs) and 95% CIs were generated from the pairwise Poisson statistical analyses for comparisons that had p values of less than 0.05. Stata® statistical software (StataCorp LP, College Station, TX, USA) was used to perform analyses.

Results

The overall frequency of vascular injury in patients identified to have had knee dislocations between 2004 and 2009 was 3.3% (95% CI, 2.9%–3.7%) (Table 2). There were no differences in frequency throughout the years between 2004 and 2009 ($p = 0.065$).

The frequency of vascular injury varied depending on the age of the patient ($p < 0.001$), with the highest frequency seen in patients aged 20 to 39 years (4.6%) (Table 2). Pairwise comparisons showed that the 20- to 39-year age group had a higher risk of vascular injury after knee dislocation than each of the other three age groups: 20 to 39 years versus 0 to 19 years ($p = 0.001$, OR = 1.93), 20 to 39 years versus 40 to 59 years ($p = 0.014$, OR = 1.57), and 20 to 39 years versus 60 years or older ($p = 0.036$, OR = 2.81) (Table 3). Males sustaining a knee dislocation had a higher likelihood of an associated vascular injury (4.8%) compared to females (1.9%) ($p < 0.001$, OR = 2.59) (Tables 2, 3). There were no differences in the likelihood of vascular injury after knee dislocation when compared across US geographic regions (Table 2).

Of the 267 cases of vascular injury secondary to knee dislocation, 34 required vascular repair, representing a frequency of 13% (95% CI, 9%–17%).

Discussion

Knee dislocations with associated vascular damage are serious, possibly limb-threatening injuries [8, 12]. Therefore, it is important to understand the epidemiology of these events. Previous studies vary widely on the reported frequency of vascular injuries in patients with knee dislocations, ranging from 5% to 64% [5, 11, 13–19]. This can most likely be attributed to the small sample sizes used in the majority of these studies, as knee dislocations are relatively rare. A study by Green and Allen [5], which reported a 32% frequency of vascular injuries secondary to knee dislocation, had the largest sample size (245) and is one of the only studies that reviewed patients from multiple sources (Duke University, Piedmont Orthopedic Society, and the English literature). Our study utilized the PearlDiver database to obtain a substantially larger sample size to more accurately estimate the frequency of vascular injuries associated with knee dislocation in the United States. We also analyzed frequency trends over time and across different age groups, sexes, and US geographic regions and determined the proportion of vascular injuries that underwent surgical intervention.

There are several limitations to our study. The study is naturally subject to errors in coding since it was a retrospective study of a large database searched by ICD-9 and CPT® codes. The database was searched for patients who had both vascular injuries codes and knee dislocation codes, assuming that the vascular injury was a result of the knee dislocation. However, the vascular injury could have also resulted from unrelated trauma, surgery, or other interventions to repair or reduce the knee dislocation. While it is unlikely that the same patient sustained a vascular injury unrelated to a knee dislocation that occurred 30 days before or after, it is nevertheless a possible source

Table 2. Incidence and number of cases of vascular injury associated with knee dislocation in the PearlDiver database by year of diagnosis, age, sex, and US geographic region

Variable	Number of knee dislocations	Number of cases of vascular injury associated with knee dislocation	Incidence of vascular injury secondary to knee dislocation (%)	p value*
Year				
2004	1121	35	3.1	
2005	1219	36	3.0	
2006	1417	63	4.4	
2007	1416	25	1.8	
2008	1457	58	4.0	
2009	1420	50	3.5	
Total	8050	267	3.3	0.065
Age				
0–19 years	2267	55	2.4	
20–39 years	2667	122	4.6	
40–59 years	2771	82	3.0	
≥ 60 years	477	8	1.7	
Total	8182	267	3.3	< 0.001
Sex				
Female	4172	80	1.9	
Male	3878	187	4.8	
Total	8050	267	3.3	< 0.001
US geographic region				
Midwest	2055	53	2.6	
Northeast	978	28	2.9	
South	3488	128	3.7	
West	1529	58	3.8	
Total	8050	267	3.3	0.099

* The p values determine whether the incidences across each of the stratifications (year, age, sex, US geographic region) varied significantly using a global Poisson regression analysis with Bonferroni correction.

Table 3. Odds ratios of the statistically significant ($p < 0.05$) comparisons by pairwise Poisson regression analysis

Comparison	Vascular injury secondary to knee dislocation		
	p value	Odds ratio	95% CI
Age: 20–39 years vs 0–19 years	0.001	1.93	1.40, 2.66
Age: 20–39 years vs 40–59 years	0.014	1.57	1.18, 2.09
Age: 20–39 years vs ≥ 60 years	0.036	2.81	1.37, 5.79
Sex: male vs female	< 0.001	2.59	1.99, 3.38

of error and may result in an overestimation of the frequency. On the other hand, vascular injuries may not have been coded properly, thus resulting in an underestimation of the frequency. The stated sources of error are presumed to be rare and would not alter the data significantly. There is an inherent selection bias of the PearlDiver database because it is not an exact cross section of the US population. The database is overly represented by the South, due to the large penetrance of the UnitedHealth Group in that region. Additionally, the PearlDiver database only includes patients with private insurance and does not include uninsured, Medicaid, or Medicare patients. This excludes lower socioeconomic groups and a large portion of the elderly population. Another population group that may be underrepresented in this study is the obese and obese elderly population. Low-energy knee dislocations have become increasingly recognized and these patients are more likely to have nerve and vascular injuries and more likely to undergo vascular repair [4]. Another limitation on use of the database for our purposes is the inability to obtain individual patient data and the availability of only limited information in terms of potentially confounding variables; these issues make multivariate analysis, a statistical approach that can help account for potentially confounding variables, inappropriate. A final limitation is that the study did not account for additional outcomes such as amputation or time of ischemia as a result of vascular injury related to knee dislocation.

Our data, which showed a lower frequency of vascular injury secondary to a knee dislocation than previously reported, can be attributable to several factors. There has been an increase in reported knee dislocation cases, especially of the low-velocity type, most noticeably because of more stringent documentation of and improved recognition of dislocations that have been spontaneously reduced before presentation [3, 9]. High-velocity knee dislocations are more likely to result in vascular injury [19], and therefore a higher incidence of low-velocity knee dislocations would presumably reduce the frequency of vascular injuries, which is what we observed. Additionally, many of the previous studies were able to identify minor vascular injuries that did not require operative intervention, such as intimal flap tears [17, 18]. These minor vascular injuries not requiring surgery were detected via angiography. It is unknown how often this diagnostic tool was used on the patients in the PearlDiver database.

It seems more likely that a younger demographic group might include patients more likely to be involved in high-velocity-type knee dislocation that occurs from mechanisms such as motor vehicle accidents and industrial injuries [19]. This would explain why the 20- to 39-year age group had the highest observed frequency of vascular injury. The same rationale can explain why we found the frequency of vascular injury to be higher in males than in females, since males may demonstrate more high-risk behavior (ie, motorcycle riding) or participate in sports that may predispose to high-velocity injury (ie, football).

Our data showed that 13% of patients with vascular injuries associated with knee dislocation underwent vascular repair. In previous studies, the percentage of vascular injuries diagnosed requiring surgical treatment ranged from 64% to 100% [1, 5, 10, 14, 16–18, 20]. The lower proportion of vascular injury undergoing surgery from our data is interesting since vascular injury secondary to knee dislocation may be severe with a high potential for limb loss [2, 7, 9, 13, 15]. Our findings are likely due to factors such as population bias, coding error, or increased reporting of minor vascular injuries not requiring surgical treatment.

To our knowledge, this study is the largest of its kind looking into the proportion of patients with vascular injury after knee dislocation. This study suggests that the frequency of vascular injury secondary to knee dislocation and the percentage of such injuries requiring a vascular repair procedure may be lower than has previously been reported. Our data may support the use of a more selective angiography protocol, which has been advocated for of late [8, 12]. Angiography is considered the gold standard to diagnose vascular injury and has historically been performed in all patients sustaining a knee dislocation [8, 12]. However, it is a costly and invasive test with associated risks [8, 12]. If there is a lower proportion of clinically significant vascular injury, as our data suggest, then angiography should be used more selectively. Additional large-scale studies should be carried out to validate the data presented here. Large prospective studies should also be performed to further analyze factors (mechanism of injury, comorbidities, BMI, etc) that predispose to vascular injury secondary to knee dislocation and to utilize other outcomes such as amputation or time of ischemia of the affected limb.

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References

1. Bui KL, Ilaslan H, Parker RD, Sundaram M. Knee dislocations: a magnetic resonance imaging study correlated with clinical and operative findings. *Skeletal Radiol*. 2008;37:653–661.
2. Dwyer T, Whelan D. Anatomical considerations in multiligament knee injury and surgery. *J Knee Surg*. 2012;25:263–274.
3. Fanelli GC, Orcutt DR, Edson CJ. The multiple ligament injured knee: evaluation, treatment, and results. *Arthroscopy*. 2005;21:471–486.
4. Georgiadis AG, Mohammed FH, Mizerik KT, Nypaver TJ, Shepard AD. Changing presentation of knee dislocation and vascular injury from high-energy to low-energy falls in the morbidly obese. *J Vasc Surg*. 2013;57:1196–1203.
5. Green NE, Allen BL. Vascular injuries associated with dislocation of the knee. *J Bone Joint Surg Am*. 1977;59:236–239.
6. Halvorson JJ, Anz A, Langfitt M, Deonanan JK, Scott A, Teasdall RD, Carroll EA. Vascular injury associated with extremity trauma: initial diagnosis and management. *J Am Acad Orthop Surg*. 2011;19:495–504.
7. Henrichs A. A review of knee dislocations. *J Athl Train*. 2004;39:365–369.
8. Howells NR, Brunton LR, Robinson J, Porteus AJ, Eldridge JD, Murray JR. Acute knee dislocation: an evidence based approach to the management of the multiligament injured knee. *Injury*. 2011;42:1198–1204.
9. Johnson ME, Foster L, DeLee JC. Neurologic and vascular injuries associated with knee ligament injuries. *Am J Sports Med*. 2008;36:2448–2462.
10. Kendall RW, Taylor DC, Salvian AJ, O'Brian PJ. The role of angiography in assessing vascular injuries associate with dislocation of the knee. *J Trauma*. 1993;35:875–878.
11. Merritt AL, Wahl C. Initial assessment of the acute and chronic multiple-ligament injured (dislocated) knee. *Sports Med Arthrosc*. 2011;19:93–103.
12. Nicandri GT, Chamberlain AM, Wahl CJ. Practical management of knee dislocations: a selective angiography protocol to detect limb-threatening vascular injuries. *Clin J Sport Med*. 2009;19:125–129.
13. Patterson BM, Agel J, Swiontkowski MF, Mackenzie EJ, Bosse MJ, LEAP Study Group. Knee dislocations with vascular injury: outcomes in the Lower Extremity Assessment Project (LEAP) study. *J Trauma*. 2007;63:855–858.
14. Rios A, Villa A, Fahandezh H, de Jose C, Vaquero J. Results after treatment of traumatic knee dislocation: a report of 26 cases. *J Trauma*. 2003;55:489–494.

15. Seroyer ST, Musahl V, Harner CD. Management of the acute knee dislocation: the Pittsburgh experience. *Injury.* 2008;39:710–718.
16. Stannard JP, Sheils TM, Lopez-Ben RR, McGwin G, Robinson JT, Volgas DA. Vascular injuries in knee dislocations: the role of physical examination in determining the need for angiography. *J Bone Joint Surg Am.* 2004;86:910–915.
17. Stayner LR, Coen MJ. Historic perspectives of treatment algorithms in knee dislocation. *Clin Sports Med.* 2000;19:399–413.
18. Treiman GS, Yellin AE, Weaver FA, Wang S, Ghalambor N, Barlow W, Snyder B, Pentecost MJ.. Examination of the patient with a knee dislocation: the case for selective angiography. *Arch Surg*. 1992;127:1056–1062.
19. Wascher DC. High-velocity knee dislocation with vascular injury: treatment principles. *Clin Sports Med.* 2000;19:457–477.
20. Wascher DC, Dvimak PC, DeCoster TA. Knee dislocation: initial assessment and implications for treatment. *J Orthop Trauma.* 1997;11:525–529.