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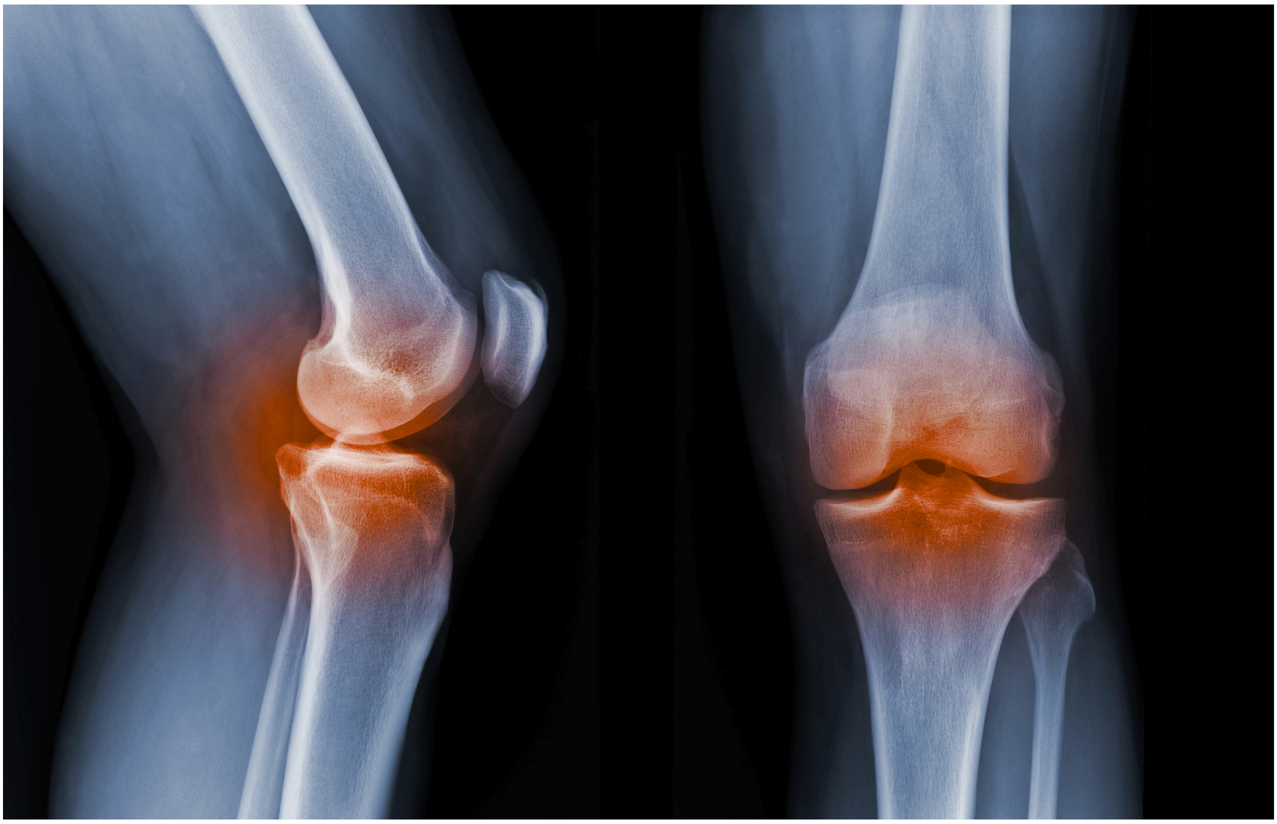
The Trauma Bulletin



What you knee-d to know

Knee injuries with associated vascular compromise

Issue twenty six

STATE ADULT TRAUMA SERVICE
WESTERN AUSTRALIA

Case summary

A patient arrives in the ED as a tier 1 trauma call. He is a front seat passenger, not wearing a seatbelt, and the car was so old that it didn't have airbags.

He is a true multi trauma patient with a significant head injury, with torso and lower limb injuries.

He required intubation for his head injury, therefore taking a history is impossible.

A thorough examination during the secondary survey reveals that **both knees are 'unstable'**, and so he progresses to a CT pan-scan including his knees.

This of course includes angiogram because the attending trauma team leader knows that associated popliteal artery injury is associated with knee dislocation (wildly different frequency quoted in the literature... somewhere between 5-65%!).

There is no evidence in the noted that a Brachial Ankle index was measured and it is also not clear that 'unstable' means dislocation.

The CT scan

The diagnosis

The angiogram is reported as normal by the registrar on the basis of 3 vessel runoff, but the next day the Consultant Radiologist revises the report and documents a popliteal artery injury.

Fortunately, there are no significant consequences because of the delayed diagnosis, but the literature is repleat with stories of amputation of a limb because of a delay in this diagnosis (85% amputation rate is arterial occlusion greater than 8 hours).

Discussion

Just recently a new patient group is emerging at special risk. Some morbidly obese middle-aged women are suffering a knee dislocation from a trivial injury, like stepping off a kerb (dislocation of this large joint is usually a high velocity injury, like coming off a motorcycle). They can arrive at the hospital post spontaneous reduction, lying flat on a bed and looking quite normal, and **unless** you actually examine the joint you can miss the injury.
You have to rupture at least three out of four stabilising ligaments to have a dislocation, and they are incredibly mobile joints. Unfortunately, if you miss the dislocation, you will also miss the arterial injury, with enormous consequences. We have a low threshold to do a CT angio, and it is also worth remembering that an intimal injury can progress to complete occlusion.

Remember, not every knee injury looks like this!

* No clinical photos are used in Trauma Bulletins *

The message

What are the learning points from this near disaster?

1. **Examine the knee joint**, looking for gross instability

2. Grossly unstable knees may have been dislocated at some point, the reduce pretty easily. A dislocation puts the popliteal artery at risk, and although that may produce a pulseless, cold, pale immobile leg, for some patients there may be no apparent problems.

3. It is always worth doing the **Ankle-Brachial Index (ABI)** comparing the injured limb with a normal limb. A minor intimal injury now might be an occluded vessel in 12 hours

4. **Good 3 vessel runoff does not exclude an injury** to the popliteal artery.

* No clinical photos are used in Trauma Bulletins *

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KNEE

Knee dislocation and associated injuries: an analysis of the American College of Surgeons National Trauma Data Bank

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Abstract

Purpose Knee dislocations (KDs) are potentially devastating injuries, leading to loss of function or limb in often young patients. This retrospective database review aims to determine the relative incidence and risk factors for KDs presenting to North American Level I and II trauma centers.

Methods The National Trauma Data Bank (NTDB) was retrospectively interrogated using ICD-9-CM codes to identify KDs between 2010 and 2014 to derive KD incidence. KDs were stratified by age, sex, Injury Severity Score (ISS), Glasgow Coma Scale (GCS), drug and alcohol use, injury mechanism, open vs. closed KD, vascular injury and fracture. Each co-variate was tested against different mechanisms of injury, using Chi-squared tests and risk adjusted analyses to derive risk factors for KD. The same calculations were done for secondary outcomes (vascular and neurological injuries, compartment syndrome, amputation, and mortality).

Results A total of 6454 KDs met the inclusion criteria (18/10,000 admissions). KDs occurred most commonly amongst men, aged 20–39, with an ISS score 1–14 and following motor vehicle collision (MVC). A vascular investigation was performed in 29%, with injury documented in 15% of KDs and 10.8% receiving a vascular procedure. Associated fractures were observed in 41.4% of KDs. Open injuries in 13.6%. Neurological injury documented in 6.2%, compartment syndrome in 2.7%, amputation in 3.8% (> 50% had vascular injury) and 2.8% died. MVC was the most common mechanism of injury ($p<0.001$), significantly more common in young, male patients, associated with higher ISS and lower GCS, especially when drugs or alcohol were involved ($p<0.0001$). Being male, having a vascular injury or open KD were all risk factors for compartment syndrome, amputation and neurological injuries.

Conclusions KDs are rare injuries, but their relative incidence may be increasing. Young, male patients involved in MVCs are risk factors for KDs and their associated injuries, such as neurological injuries, amputations and compartment syndrome. Vascular injury occurs at a frequency of around 15%. The findings of the current study may guide future research and help to inform clinicians on the expected rates of associated injuries in patients identified to have KD in a trauma center population. It informs regarding risk factors for KD, which may improve diagnosis rates of spontaneously reduced knee dislocations by increasing index of suspicion in high-risk patients and identifies specific links with impaired driving.

Level of evidence IV.

Keywords Knee dislocation · Vascular injury · Amputation · Incidence of knee dislocation · Neurological injury

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00167-019-05712-y) contains supplementary material, which is available to authorized users.

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Introduction

Several case series have attempted to identify the incidence of knee dislocations (KD) and their associated injuries [6, 23–25, 27, 32, 37, 46]. KDs are rare injuries and make up only 0.001–0.2% of all orthopedic trauma [6, 7, 25, 37]. KDs are important due to their potential to cause limb threatening associated neurovascular injuries, with catastrophic effect on young active patients [12, 21, 35, 37, 38]. Evaluating KDs and associated injuries can be difficult and may even be neglected as up to 20–80% may have spontaneously reduced before arrival in the Emergency Department [7, 25, 38]. The rates of vascular injury have been quoted to be between 3.3 and 64% [6, 12, 25, 27]. This large variation in reported values may reflect small sample sizes and variation in definition of a KD [12, 19, 40]. It may also represent referral and publication biases of research groups from major trauma units. Peroneal nerve injuries are thought to occur in up to 25% of KDs, but would be subject to the same difficulties in reporting [8, 21, 29, 31]. As KDs are potentially limb threatening injuries, oftentimes in young patients [35, 37], a more accurate understanding of their incidence and the incidence of associated injuries would be useful [35, 37].

Recent epidemiological studies that evaluate large national databases have been performed to better identify the incidence of KDs and potentially limb threatening associations such as vascular and neurological injuries [27, 37]. These studies identified substantially lower rates of vascular injury, between 1.6 and 3.3%. KDs with associated neurovascular injuries are known to have a poor prognosis, particularly when open [35, 44], making their accurate detection and earlier management essential [33]. Up to 20% of patients with vascular compromise have been quoted to eventually require amputation [20, 22, 33, 45], a figure that increases to more than 80% with an ischemic time of over 8 h [27, 33].

Examining the incidence rate of KD amongst trauma admissions, their associated injuries and risk factors in North America, particularly with increasing incidence of such injuries retains an inherent value [17]. Evaluation of epidemiological data provides a powerful tool to better identify trends and risk factors that could direct clinical care and inform further research of this rare injury, leading to improvements in care of an injury that can necessitate multiple surgeries and prolonged rehabilitation [12].

This present study aims to improve the accuracy and resolution of the epidemiological data through use of NTDB, giving access to data on a much larger group of KDs than most previous studies and negating some of the inherent biases of insurance based databases [15]. Although other valuable epidemiological studies have preceded the present study [27, 37], this study represents the largest group of KDs from a non-insurance based national database. Use of the NTDB allows us to include more baseline characteristics than previous studies [27, 37].

The aims of this study were to (1) identify the incidence of knee dislocation in a national trauma database (Level I/II trauma centers); (2) identify the proportion of KDs with an associated vascular injury requiring intervention; (3) identify the proportion of KDs with an associated neurological injury, amputation and compartment syndrome; and (4) identify risk factors associated with these injuries.

Materials and methods

Database

This study was a retrospective cohort study using data available through the National Trauma Data Bank (NTDB) [30]. This is the largest aggregation of trauma registry data in the world. Information is collected in accordance with the National Trauma Data Standard (NTDS). It is a data repository created by the American College of Surgeons intended for epidemiological research, containing data on more than six million cases from over 900 registered North American trauma centers. All the data in the NTDB is Health Insurance Portability and Accountability Act (HIPAA) compliant, with no patient-identifiable data. The coding from the NTDB has been published extensively [2, 4, 5, 10, 18].

Study design

International Classification for Diseases, Ninth revision, Clinical Modification (ICD-9-CM) codes (see Online Appendix 1) were available during the study period, and used to identify all relevant diagnoses and procedures. All KD codes (see Online Appendix 1) from patient encounters recorded in NTDB from North American Level I and II trauma centers between 1st January 2010 and 31st December 2015 were included. The relevant ICD-9-CM codes for KD defined each individual admission encounter and was taken as the index event (knee dislocation). Other specific ICD-9-CM codes for associated injuries (see Online Appendix 1) that were attributed to the same patient were also recorded. The observation window for each patient was terminated at the point of discharge or death (i.e., the index admission).

Demographic information collected from NTDB included age, sex, race and geographical region. Due to the nature of NTDB, neither previous, nor subsequent encounters by the same patients with the same institutions were available. External cause of injury codes (E-codes) were also available (see Online Appendix 2). Patients with only patella–femoral joint dislocation (ICD-9-CM codes 836.3 and 836.4) codes were then excluded.

The research protocol was approved by the Research Ethics board at Sunnybrook Health Sciences Centre (Project ID: 287-2019). Individual patient consent is not required for research using anonymized administrative health data.

Outcomes

The primary outcome for this study was the incidence of traumatic knee dislocations. The incidence of vascular injury was a secondary outcome measure. Various interventions and diagnoses were amongst the other secondary outcome measures evaluated in this review. The interventions included diagnostic vascular imaging (angiography, CT angiography) and vascular surgical procedures. Diagnostic codes were used for the identification of open or closed dislocations, open and closed fracture dislocations, neurological injuries, compartment syndrome, amputation and death. All relevant codes that were related to vascular injury, vascular procedure, open dislocations, open fracture dislocations, neurological injuries and amputation were initially combined to provide incidence values respectively (see Online Appendix 1 for relevant codes). Where possible a further breakdown of codes was performed to provide additional information.

Covariates

Patient factors Demographic data included patient age (1–19, 20–39, 40–59, ≥ 60 years), sex, geographical location of index hospital (Midwest, North-East, South and West United States), and race (White, Asian, Black, Other and Unknown).

Injury factors Mechanism of injury (falls, motor vehicle collision (MVC) and "other", see Online Appendix 2). Severity of injury at admission (Injury Severity Score (ISS): 1–14, 15–40, ≥ 41) and Glasgow Coma Scale (GCS): 3, 4–9 and 10–15). ISS groupings reflected conventional definitions of mild, moderate and severe [28].

Statistical analysis

Baseline characteristics were summarized using descriptive statistics. All continuous variables were analyzed using a 2-tailed t-test and categorical variables using the Chi-squared test. The annual incidence of KD amongst all trauma patients admitted was calculated as an average over the study period (2010–2014 inclusively).

The incidence of knee dislocation was tested against each of the above-mentioned covariates. This included year of study, age, race, geographical location, ISS, and GCS. Each co-variate baseline characteristic was then also tested against different mechanisms of injury (falls, MVC and other), using Chi-squared to determine their risk for knee dislocation.

Incidences of all secondary outcomes were described as a proportion within the KD cohort, with the outcome of interest being the numerator and the total number of KDs the denominator. Type of KD was divided into 5-groups; anterior, lateral, medial, posterior and tibiofibular dislocations as per ICD-9-CM coding. Arterial injuries were divided into popliteal and tibial artery injuries. Fractures associated with KD were divided into 5-groups; femoral condylar, femoral supracondylar, fibular, patellar and tibial fractures. Neurological injuries were divided into 5-groups; peroneal, tibial, tibial (foot and ankle), popliteal space and nerve entrapment. Orthopedic procedures were divided into 5-groups; temporizing external fixation, closed reduction, open reduction, open reduction and internal fixation (ORIF) and early repair. Incidence values were determined for each. Chi-squared analyses and risk adjusted evaluations were performed for these outcomes against each baseline characteristic and each of the other outcomes to determine estimates of standard error with 95% confidence intervals. Statistical significance was set a p value < 0.01 for these calculations. All calculations were made using the Statistical Analysis System (SAS) version 9.3 for UNIX (SAS Institute, Cary, North Carolina).

Results

Trauma admissions at participating Level I and Level II trauma centers from 2010 to 2014 inclusively amounted to 3,564,053 patients. Out of these, 6454 patients were recorded to have a KD on NTDB entry, equivalent to a relative incidence rate of 18 cases per 10,000 admissions or 0.18% of trauma admissions. KD was most common among male sex and those aged 20–39 years (Table 1). Most KD patients were not classified as major trauma admissions (ISS > 15). There appeared to be a possible trend to rising incidence of recording of KD; by 2014, an increase in the incidence of KDs of around 2 per 10,000 trauma admissions was observed.

Of the vascular injuries recorded, popliteal artery injuries made up 83.6% and tibial artery injuries 7.54% of the coded vascular injuries. Associated fractures around the knee were coded for in 41.5% (Table 2). Open injuries occurred in 13.6% of the cohort, of which half appear to be open dislocations with fracture. KD with vascular injury and same-admission amputation accounted for 2.11% (n = 136 of 6,454 KDs) of KD, but represented 55.3% of patients receiving an amputation. A vascular investigation was performed in 29.0% of the cohort with 37.3% of these subsequently also having a vascular procedure.

MVC as a mechanism for KD was the most common specified mechanism of injury ($p < 0.001$). It was

Table 1 Frequency and percentage of various demographics of KD population

Variable	Frequency	Percentage of KD cohort (%)	Relative incidence (per 10,000 trauma admissions)
	6454		
Year of admission			
2010	1144	17.7	17.4
2011	1244	19.4	17.8
2012	1328	20.6	18.1
2013	1255	19.5	17.0
2014	1478	22.9	19.7
Age			
0–19	720	11.3	11.5
20–39	2800	43.9	28.8
40–59	1990	31.2	23.4
≥ 60	872	13.7	9
Sex			
Male	4287	66.4	19.0
Race			
Asian	99	1.53	16.1
White	4153	64.4	16.9
Black/ African American	1299	20.1	24.7
Other	661	10.2	17.3
Unknown	242	3.75	15.7
Impairment			
Drug	972	15.1	–
Alcohol	1114	17.3	–
ISS			
1–14	4580	76.2	–
15–40	1249	20.8	–
≥ 41	184	3.06	–
GCS			
13–15	5449	88.0	–
9–12	151	2.43	–
3–8	593	9.59	–
Region			
Mid-West	923	24.9	16.0
North-East	620	16.7	17.9
South	1473	39.8	20.6
West	687	18.6	16.4
Mechanism			
Falls	1688	26.3	12.0
MVC	3931	60.9	31.2
Other	835	12.9	9.1

significantly more common in young patients, male patients, and was associated with higher ISS and lower GCS at presentation. For the patients that sustained a KD where either drugs or alcohol were involved, MVC was more likely than other mechanisms of injury (Table 3).

Risk adjusted sensitivity analysis showed that male patients, MVC, popliteal and tibial artery injuries were independent risk factors for compartment syndrome associated with KD. Risk factors for associated neurological injuries included male patients, falls and other mechanisms, posterior dislocations and vascular injuries. Risk factors for amputation included lower levels of GCS (3–9), male patients, open KDs and vascular injuries. Type of dislocation was poorly recorded in the NTDB making it difficult to determine which type was most common.

Table 2 Associated injuries observed as well as surgical interventions recorded on index admission

Diagnosis	Frequency (n)	Percentage of KD cohort (%)
Vascular injury	968	15.0
Popliteal artery injury	809	12.5
Tibial artery injury	73	1.1
Fracture	2675	41.4
Open fracture	443	6.9
Open dislocation	878	13.6
Mortality	182	2.8
Compartment syndrome	177	2.7
Neurological injury	400	6.2
Peroneal nerve	213	3.3
Amputation	246	3.8
Vascular injuries that led to amputation	136	2.1
Interventions		
Vascular investigation	1872	29.0
Vascular procedure	698	10.8
Operative procedure		
Temporizing external fixator	404	6.3
Closed reduction	2459	38.1
Open reduction	553	8.6
Open reduction and internal fixation	1516	23.5
Early ligament repair	868	13.5

Table 3 Statistically significant associations of baseline characteristics with MVC as the mechanism of injury for KD

Covariate	Mechanism			
	Falls (%)	MVC (%)	Other (%)	p value
Age (20–39)	34.3	47.9	43.9	< 0.0001
Gender (male)	48.5	71.8	78.2	< 0.0001
Alcohol	8.5	23.1	7.7	< 0.0001
Drugs	5.9	20.4	8.4	< 0.0001
GCS < 10	1.0	14.8	3.5	< 0.0001
ISS 15–40	4.8	31.0	7.7	< 0.0001

A closed reduction was more likely to be performed in higher GCS levels ($p=0.05$; less severe injuries) and where a popliteal artery injury ($p=0.03$) was involved. This was in fact less likely to be the case with each unit increment of the ISS, open dislocations and supracondylar or tibial fractures. An open reduction was likely to be required for MVC ($p<0.0001$), open dislocations ($p<0.0001$) and popliteal artery injuries ($p=0.008$). A temporizing fixator was more likely to be used each advancing year of admission in this study ($p=0.02$). Further analysis reveals that this effect is accentuated by a larger increase in external fixation rates between 2010 and 2011 (Fig. 1).

A temporizing external fixator was also more likely to be associated with MVC ($p<0.0001$), open dislocations ($p=0.001$) and popliteal artery injuries ($p<0.0001$). Risk factors for early repair included MVC ($p<0.0001$), open dislocations ($p<0.0001$). Open reduction and internal fixation of associated fractures were more likely with MVC ($p<0.0001$), open ($p=0.006$) and closed fractures ($p=0.008$), medial ($p=0.04$) and tibio-fibular dislocations ($p=0.009$), fibular ($p<0.0001$) and patellar fractures ($p=0.03$) and GCS category 10–15 ($p=0.01$; less severe injuries).

Discussion

The present study demonstrates a relative incidence of knee dislocation amongst admissions to North American Level I and Level II trauma center admissions, to be 18 KD per 10,000 admissions (0.18% of all trauma admissions). This is the first study to date to examine national database level data specific to the trauma center population. Patients with multiple injuries were included in this study, as opposed to just isolated KDs, reflecting the trauma center population. KDs are rare injuries and our results fit within previously quoted figures, 0.02–0.2% of all orthopedic injuries [12]. This is also in agreement with radiologically based studies, which at one point formed the most accurate indication of these injuries [6, 34]. A tendency toward increased rate of KDs was apparent over time. In 2014 an increase of 2/10,000 trauma admissions was observed relative to previous years. This may reflect a trend of increasing KD frequency, but further study to monitor subsequent years is required. Interestingly Arom et al. [1] using the same dataset as Natsuhara et al. [27] identified no rise in KD incidence during their study period from 2004 to 2009, though their counts of KD increased.

Vascular injuries were recorded in 15% of the cohort. These are of similar magnitude to those reported in some previous studies, including a recent systematic review by Medina et al. [26]. Sillanpää et al. reviewed Finland's National Hospital Discharge Registry to identify KDs and found that out of 4 million people their vascular injury rate was 1.6% ($n=837$ KDs) [37]. Natsuhara et al. have performed the largest epidemiological study to date, reviewing 11 million patients from the PearlDriver medical insurance (payer) database in the United States and found an overall vascular injury frequency of 3.3% ($n=8050$) [27]. This would not have included Medicare or uninsured patients

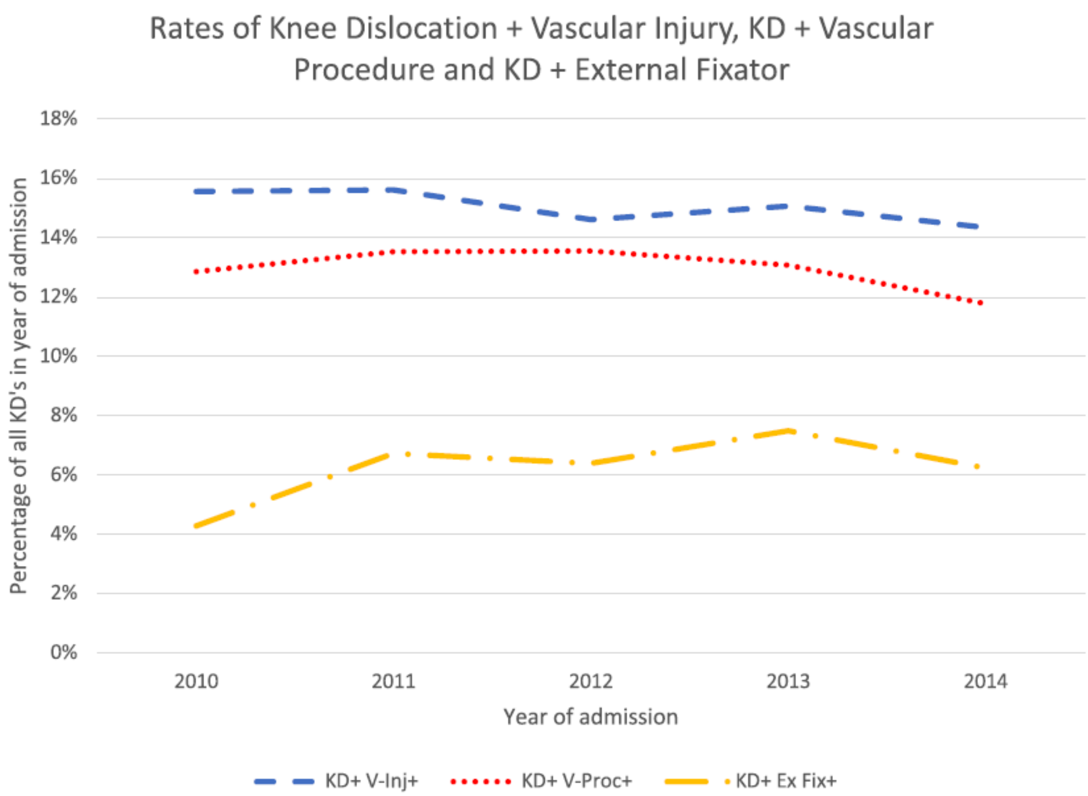

Fig. 1 Recorded rates of vascular injury, vascular procedure and use of external fixator by year of admission

receiving treatment for the same injury, and due to the nature of PearlDriver no reliable denominator can be established. The present study is the largest epidemiological study based on hospital level reporting, and noted a vascular injury rate that was substantially higher than other database research. This may be attributable to the defined population, of patients from Level I and II trauma centers, where KDs are more likely to be referred acutely and be associated with higher energy mechanisms of injury. A temporal trend towards slightly decreasing rates of vascular injury was noted (Fig. 1), though the actual count of vascular injuries identified increased throughout the study. It is possible therefore, that improved awareness of multi-ligament injuries and KD is leading to improving identification rates of KD without vascular injury. Notably the Finnish registry identified low-energy falls as the most likely cause (46%) of KD. This is representative of their population and may explain lower vascular injury (1.6%) rates [37].

A neurological injury diagnosis was found in 6.2% of the present cohort. This is a much greater rate of neurological injury than was quoted in a systematic review by Medina et al. with whom our vascular injury rate was more similar [26]. Neither Sillanpää or Natsuhara evaluated neurological injuries [27, 37]. Case series have tended to quote higher rates for neurological injury (17.8%) [8, 16, 21]. What most studies appear to agree on is that peroneal nerve injuries are the most common [3, 16, 21, 29, 42]. This was also found this to be the case (53.3% of neurological injuries) in the present study. Unusually, no correlation was observed between KD with associated fractures and neurological injuries. It may be that the resolution of the NTDB data is insufficient to distinguish major articular fractures from ligament avulsion fractures. This would explain our relatively high rate of associated fractures (41.45%) and potentially hide a true association between major articular fractures and neurological injury.

Typically, higher neurological injury rates have been seen in ultra-low velocity KDs among obese patients, in the order of 40% [3, 7, 13, 43]. From the data available it is not possible to comment on the proportion of low energy injuries in our cohort but based on the source population of trauma center admissions it may be biased towards high energy injuries.

MVC the most common mechanism of injury which correlates with the findings of several other studies, with the additional influence of drug/alcohol being of particular concern from a public health perspective [8, 12–14, 16]. It was apparent from our results that MVC patients with drug or alcohol on board lead to higher association with KD (see Table 3). Our data further supports published findings that driver impairment has a strong association with increased severity of injuries from motor vehicle accidents [36] and aligns with findings from the National Highway Safety Traffic Association demonstrating higher rates of speeding amongst alcohol impaired drivers involved in fatal MVCs [41]. MVC also appeared to be associated with KD patients more likely to have severe injuries, as evidence by higher ISS and lower GCS ($p < 0.001$; see Table 3).

Whilst MVCs were associated with younger patients, other mechanisms such as a fall were risk factors for KD in older patients. The presumption is that these are low energy injuries, perhaps from standing height, but other mechanisms such as sporting injuries may be included and indeed may account for a significant proportion of low energy dislocations [11, 12]. Overall KDs were more likely to occur in younger patients, aged between 20–39 and the large majority < 60 years of age. This is comparable to other epidemiological studies [27, 37].

The use of temporizing fixation suggests failure to obtain or maintain reduction with conservative measures, potentially the presence of a fracture or vascular injury. Risk factors for this type of treatment included open, posterior and MVC-associated KDs. Temporizing fixator use increased over the time period of the study, despite the prevalence of vascular injury not increasing, and potentially falling. This may be as a result of increased teaching of 'Span-scan-plan' philosophies. Consensus guidelines from knee dislocation experts regarding the appropriate indications of external fixation for KD may be needed, given inherent risks of the procedure.

Amputations occurred in 3.8% ($n = 246$) of all KDs identified. This is comparable to other smaller studies that evaluated amputations amongst their KD cohorts (2.5–3.7%) [26, 39], although interestingly one Level I trauma center evaluating amputation rates quoted a higher rate, at 9.2% [35]. The amputation rate in the present study was higher within the vascular injury cohort, 14% ($n = 136$), comparable to other similar studies (11.1–26.3%) [16, 20, 26, 44, 45], although those with vascular injury accounted for more than half of all amputations. Open dislocations are also associated with higher rates of amputation in the literature (14.3–15.8%) [20, 44]. This stands to reason, and matches the associated risk factors for amputation in the present study, which included male sex, lower GCS, open dislocations and vascular injuries.

Large registry-based studies such as this are inevitably retrospective and subject to coding errors. This study is dependent on the reliability and accuracy of ICD-9-CM diagnostic and procedural codes recorded on patient charts and transcribed by medical database professionals. A code validation study was not performed as part of the present study, however, the NTDB has been studied and published extensively [2, 4, 5, 10, 18]. In the absence of patient level identifiers and individual chart review, misclassified injuries could be introduced or left out. An assumption is also made that the codes all relate to the same injury, where bilateral injuries are plausible. Patients transferred between facilities cannot be identified and may lead to duplication. Previous epidemiological studies have been performed using the same codes [4, 10].

A database such as the NTDB lacks the detail that be offered by smaller scale studies [37]. Further in depth evaluation and radiographic confirmation of dislocation type and individual structures damaged are not as reliable in this setting [6, 26, 29]. For example, the direction of dislocation was poorly recorded. Finally, detailed analyses and outcomes relating to orthopedic and vascular surgery were not possible. The NTDB data set does not allow for patient identification, which prevents linking of admissions for longitudinal tracing of individual patient outcomes.

The ICD-9-CM codes regarding fractures do not adequately represent the complexity of fractures around the knee seen in knee dislocations. It is not possible, for example to distinguish amongst ICD-9-CM codes between femoral condyle or femoral epicondyle fractures; therefore encompassing both major intra-articular fractures (e.g. Hoffa's fracture), or extra-articular fractures (e.g. ligamentous avulsion). This may have contributed to the rate of fractures around the knee being higher than in other studies, and may have masked association between fractures and nerve injuries, which was not observed. Another study has previously observed even higher rates of fracture [9]; notably this paper also did not distinguish between fracture types.

Conclusion

Knee dislocations were identified in 18 cases per 10,000 trauma admissions (0.18%). Young, male patients involved in MVCs appear at highest risk for KD. The current study for the first time identifies the rate of neurological injury (6.2%) and mortality (2.82%) as recorded in a large registry based study and determines a greater rate of vascular injury (15%) than previous studies [27, 37]. Amputations (3.8%) can be the consequence of these injuries, particularly open KD and with vascular injury. While KDs are rare injuries, their incidence or identification may be increasing in Level I and II trauma centers in North America. Similarly, rising utilization of external fixation in the absence of increasing vascular injury rates is a finding that warrants further study and potentially expert consensus to establish practice guidelines.

The findings of the current study may aid future research will help to inform clinicians on the expected rates of associated injuries in patients identified to have KD in a trauma center population. It informs regarding risk factors for KD, which may improve diagnosis rates of spontaneously reduced knee dislocations by increasing index of suspicion in high risk patients and identifies specific links with impaired driving.

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Compliance with Ethical Standards

Conflict of Interest Avery Nathens: I am an employee of the American College of Surgeons and have oversight of the database that was used for this analysis. No other conflicts of interest were declared by any other authors.

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Ethical approval This study was reviewed by the Research Ethics Board of Sunnybrook Health Sciences Centre. The research ethics board determined that an Informed Consent Form (ICF) is not required for this study; consent requirements, if applicable, have been otherwise dealt with in accordance with Article 3.7 and/or 5.5 of TCPS2. Project Indetification Number 287-2019.

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