Demographics and Injuries Associated With Knee Dislocation

A Prospective Review of 303 Patients

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Background: Information on the incidence, injury mechanisms, ligament injury patterns, and associated injuries of knee dislocations is lacking in the literature. There is a need to characterize ligament injury patterns and associated injuries in knee dislocations to avoid missing common associated diagnoses and to plan surgical treatment.

Purpose: To evaluate patient demographics, ligament injury patterns and associated injury patterns, and associated injuries in patients with knee dislocation.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: A total of 303 patients with knee dislocations treated at a single level 1 trauma center were followed prospectively. Injury mechanism; ligament injury patterns; associated neurovascular, meniscal, and cartilage injuries; and surgical complications were recorded. The Schenck knee dislocation classification was used to classify the ligament injury patterns.

Results: The mean age at injury was 37.8 ± 15.3 years. Of the 303 patients included, 65% were male and 35% were female. There was an equal distribution of high-energy and low-energy injuries. Injury to 3 major ligaments was the most common, with Schenck classification type KD III-M constituting 52.4% of the injuries and KD III-L comprising 28.1%. Meniscal injuries and cartilage injuries occurred in 37.3% and 28.3% of patients, respectively. Patients with acute injuries had significantly lower odds of a cartilage injury than those with chronic injuries (odds ratio [OR], 0.28; 95% CI, 0.15-0.50; $P < .001$). Peroneal nerve injuries were recorded in 19.2% of patients (10.9% partial and 8.3% complete deficit), while vascular injuries were recorded in 5%. The odds of having a common peroneal nerve injury were 42 times greater ($P < .001$) among those with posterolateral corner injury (KD III-L) than those without. The odds for popliteal artery injury were 9 times greater ($P = .001$) among those with KD III-L injuries than other ligament injury types.

Conclusion: Medial-sided bicruciate injuries were the most common injury pattern in knee dislocations. Cartilage injuries were common in chronically treated patients. There was a significant risk of peroneal nerve injury with lateral-sided injuries.

Keywords: knee dislocation; knee; multiple ligament knee injury; ligament injury pattern

Few studies have reported on the incidence, injury mechanisms, ligament injury patterns, and associated injuries of knee dislocations.[3,4,28,29,33] Most studies are retrospective in nature, and few patients are included. The incidence of these injuries is reported to be between 0.02% and 0.2% of all orthopaedic injuries.[2,6,9,27,32,34] There is a general view that the incidence might be underestimated because some knees spontaneously reduce before presentation.[34]

Knee dislocations were historically defined as a complete loss of the tibiofemoral articulation that is confirmed radiographically.[15] In 1963, Kennedy[15] published a classification of knee dislocations based on the position of the tibia in relation to the femur. This classification system did not predict which structures were injured, and some of the knee dislocations that were reduced at presentation may have been misdiagnosed.[34] Good and Johnson[9] defined knee dislocation to include the grossly unstable knee, with a minimum of 2 of the 4 major knee ligaments injured, regardless of a reduced joint line. Currently, the Schenck classification of knee dislocations, based on injured ligaments, is the most widely used (Table 1).[30] Some authors have suggested that any combined anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) injury be considered a knee dislocation.[34] Therefore, the traditional definition of knee dislocation has been expanded to include bicruciate knee injuries, even when the knee is reduced on initial

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TABLE 1
Schenck Anatomic Knee Dislocation Classification[a]

KD I	Injury to single cruciate + collaterals
KD II	Injury to ACL and PCL with intact collaterals
KD III M	Injury to ACL, PCL, MCL
KD III L	Injury to ACL, PCL, LCL
KD IV	Injury to ACL, PCL, MCL, LCL
KD V	Dislocation + fracture

[a]Additional letters "C" and "N" are utilized for associated injuries. "C" indicates an arterial injury, such as open tibial fractures. "N" indicates a neural injury, such as the tibial or, more commonly, the peroneal nerve. ACL, anterior cruciate ligament; LCL, lateral collateral ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament.

presentation.[34] However, there have been reports of knee dislocations without cruciate ligament tears.[5,8,31] At this study's initiation in 1996, we defined knee dislocation as injury to both the ACL and PCL with or without concurrent injury to the posterolateral corner and/or posteromedial structures.

Understanding injury patterns and other concurrent knee injuries can aid surgeons in the diagnostic workup and planning of surgical procedures. Thus, the purpose of this study was to report on a large cohort of patients with knee dislocations, including the injury patterns, mechanisms of injury, patient demographics at time of injury, and the concurrent knee and limb injuries. The secondary aim was to report on risk factors for associated injuries.

METHODS

Participants

A total of 303 consecutive patients with traumatic knee dislocations were treated at a level 1 trauma center (Oslo University Hospital, Oslo, Norway) between May 1996 and December 2015. The hospital is an urban referral center that treats patients with road traffic accidents and sports injuries including ski injuries. These patients were entered into a prospective database and have been followed since the time of injury. In the present study, the inclusion criteria were injury to both the ACL and PCL with or without injury to the medial and/or lateral side, according to the classification of Schenck[30] (KD II, KD III, and KD IV) (Table 1). The exclusion criteria were severe intra-articular fractures of the ipsilateral knee and skeletal immaturity. In the early study years, the majority of patients had chronic knee dislocations because of a lack of surgical treatment offered prior to 1996. Prior to start of the study, institutional review board approval was obtained from the Regional Committee for Medical and Health Research Ethics Section South East C (REK Sør-Øst C; IRB00001870). All patients signed a written consent form.

Evaluation

At the time of admission, all patients had a thorough history and physical examination. The patients' vascular and peroneal nerve status and additional injuries to the damaged extremity were documented. In this cohort, only peroneal nerve injuries were recorded, and no tibial nerve injuries were recorded. Injuries besides those to the injured leg were not recorded, though these can affect the timing of treatment. All patients with an ankle-brachial index (ABI) less than 0.8[16] or other signs of reduced peripheral circulation were further evaluated using arteriography. Patients with vascular injury were treated urgently to address vascular injuries, and the knee was stabilized using an external fixator. All patients underwent standard radiographs of the injured knee and magnetic resonance imaging (MRI) examinations.

The injuries were classified according to energy: high energy versus low energy. The categorization of high and low energy is somewhat arbitrary in the literature. When classifying injuries according to the energy involved, the speed, energy, and presence of concomitant injuries were taken into account.[34] High-energy injuries resulted mostly from motor vehicle accidents, motorcycle accidents, pedestrians struck by moving vehicles, falls from great heights (>5 m), industrial injuries, skiing injuries involving high speeds such as downhill skiing and ski jumping, and tobogganing. Low-energy injuries involved most sports injuries, falls from lower heights (<5 m), trampoline injuries, and injury from other recreational activities.

An examination was performed, and the ligament status of the injured knee was compared with the uninjured knee using the American Medical Association subjective guidelines.[11,22] For patients undergoing surgery, the examination was repeated under anesthesia. During surgery, ligament injuries, meniscal injuries, and cartilage injuries were documented. From 2010 onward, stress radiographs were routinely used in the diagnostic workup for diagnosis

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of PCL, posterolateral corner, and posteromedial corner injuries in chronic injuries.[12,13,18,19] Additionally, alignment radiographs (hip to ankle radiographs) were obtained for patients with chronic injuries.

Statistical Analysis

Summary statistics including means, standard deviations, quartiles, counts, and percentages were computed and thoroughly reported for all variables. Questions about associations between injury variables were determined a priori and tested using Fisher exact tests. Odds ratios (ORs) with confidence intervals (CIs) were reported for these tests, and a P value < .05 indicated statistical significance. The statistical computing package R was used for all analyses (R Development Core Team).[25]

RESULTS

Patient Demographics

The mean age at injury was 37.8 ± 15.3 years (first quartile, 25.0 years; third quartile, 49.5 years). In this cohort, 65% were male and 35% female. Among those with a recorded date of injury, 58% were treated in the acute phase (<3 weeks). The majority of injuries were closed, accounting for 96.6%, while open injuries accounted for 3.4%.

Mechanism of Injury

Among those with a recorded mechanism of injury, there were equivalent rates of high- and low-energy trauma (50.3% and 49.7%, respectively). The majority of high-energy injuries were related to motor vehicle accidents (25.1%). Sporting activities accounted for 44.2% of all injuries, with skiing injuries contributing 29.4% of all injuries. Detailed information on injury mechanisms are reported in Table 2.

Ligament Injury Pattern According to Schenck Classification

The majority of patients (80.5%) had injury to 3 major ligaments, with injury to both cruciate ligaments and the medial side (KD III-M) being the most common (52.4%) (Table 3). Injuries to the ACL, PCL, and posterolateral corner (KD III-L) was recorded in 28.1% of patients. All ligaments torn (KD IV) in only 12.9% of patients, and bicruciate ligament injuries with intact collateral ligaments were found in 5.3% of patients (KD II). Four patients were not classified: 2 elderly patients with gross knee dislocation were reduced and treated nonoperatively, 1 patient with dislocation and vascular injury came late to the hospital and ended up with an above-knee amputation, and 1 patient with a dislocation was treated with an external fixator and transferred to his home country for definitive surgery (Table 3).

TABLE 2
Injury Mechanism Reported at Admission[a]

Mechanism	No. of Patients	Percentage
High energy		
Car accident	19	6.3
Motorcycle	39	12.9
Pedestrian	18	5.9
Skiing sports	27	8.9
Industrial	14	4.6
Falls >5 m	13	4.3
Other	18	5.9
Low energy		
Skiing sports	62	20.5
Fall <5 m	34	11.2
Ball sports	21	6.9
Other sports	24	7.9
Other	5	1.6
Not classified	9	3.0
Total	303	100

[a]Injury mechanism classified as "other" for high energy included tobogganing, snow scooter accidents, and snow avalanche. Injury mechanism classified as "other" under low energy included being kicked by a horse and direct trauma to the knee.

TABLE 3
Distribution of Patients According to Schenck Classification[a]

KD Class	No. of Patients	Percentage of Total
KD II	16	5.3
KD III-M	159	52.4
KD III-L	85	28.1
KD IV	39	12.9
NC	4	1.3
Total	303	100

[a]KD, knee dislocation; L, lateral; M, medial; NC, not classified.

Meniscal and Cartilage Injuries

Meniscal injuries were found in 37.3% of patients. Meniscus tears were equally distributed between the medial (16.5%) and lateral (15.8%) meniscus, while 5.0% of patients had injuries to both the medial and lateral menisci. Patients with high-energy injuries had nonsignificantly greater odds of a meniscus injury (OR, 1.36; 95% CI, 0.82-2.29; P = .219). There was no significant difference between the incidence of meniscal injuries in patients with acute versus chronic injuries.

Articular cartilage injuries were found in 28.3% of patients, with most cartilage injuries localized to the femoral condyles (12.5% of patients). Patients with meniscal injuries exhibited significantly greater odds of a cartilage injury (OR, 1.78; 95% CI, 1.03-3.09; P = .034). Patients with high-energy injuries had greater odds of a cartilage injury, but this was not significant (OR, 1.67; 95% CI, 0.97-2.92; P = .066). Articular cartilage injury was recorded in 20.1% and 47.7% of acute and chronic injuries, respectively.

Patients with acute injuries had significantly lesser odds of a cartilage injury than chronic patients (OR, 0.28; 95% CI, 0.15-0.50; $P < .001$).

Nerve Injuries and Degree of Injury (Motor, Sensory, Complete)

Peroneal nerve injuries were recorded in 19.2% of patients. Presenting findings were paralysis in 8.3%, paresis in 3.3%, reduced sensation in 2.6%, and a combination of reduced sensation and paresis in 5.0% of patients. The odds of having a peroneal nerve injury were 42 times greater among those with posterolateral corner injury than those without (OR, 42.0; 95% CI, 13.0-216.8; $P < .001$). Vascular injuries were recorded in 5.0% of patients. Lateral-sided injuries (KD III-L) were significantly associated with popliteal artery injuries (OR, 9.2; 95% CI, 2.0-85.9; $P = .001$). Additionally, peroneal nerve injury was significantly associated with vascular injury (OR, 20.6; 95% CI, 5.3-118.8; $P < .001$).

Other Injuries

Twenty-six patients (8.6%) had injuries to the extensor mechanism of the ipsilateral limb. Sixteen patients (5.3%) had a patella dislocation, 5 patients (1.7%) had a patellar tendon rupture, 1 patient (0.3%) had a patella dislocation with a partial tendon tear, and 4 patients (1.3%) had a patella fracture. Fifty patients (16.6%) had ipsilateral lower extremity fractures. Four patients (1.3%) had a femur fracture, 32 patients (10.6%) had a tibia fracture, 2 patients (0.7%) had fractures to both the femur and tibia, and 12 patients (4.0%) had a fibular fracture.

DISCUSSION

The most important finding in this study was that Schenck KD III-M was the most common injury type in knee dislocations. In addition, meniscus, cartilage, and nerve injuries were commonly associated with knee dislocations. Knee dislocations are unusual and therefore not an injury many orthopaedic surgeons will see often. Consequently, the ligament injury pattern and the extent of additional injuries can often be missed. Understanding the injury patterns and associated injuries can aid surgeons during their evaluation and in planning surgical management.

The mean age at the time of injury was higher (37.8 years) than in previous studies. Arom et al[2] reported a mean age of 35 years when using a large national insurance database with 8050 knee dislocations. Other studies with smaller cohorts reported a mean age of 28 to 32 years.[1,10,33] Meniscal injuries were found in 37.3% of patients in the current study, and cartilage injuries were found in 28.3%. Richter et al[26] reported a lower incidence (15%) of meniscal injuries in association with knee dislocation, while Krych et al[17] reported higher rates of meniscal and chondral lesions associated with knee dislocation in 121 patients (122 knees), with 76% of patients having a meniscal or chondral injury (55% with meniscal tears, 48% with chondral injury).

In our study, injuries with 3 torn ligaments were the most common, with medial-sided injuries (KD III-M) constituting 52.4% and lateral-sided injuries (KD III-L) 28.1%. Injuries with both cruciate ligaments torn and intact collaterals (KD II) were the least common (5.3%), and 12.9% had all the ligaments torn (KD IV). Robertson et al[28] reported rates of 41% and 28% for KD III-M and KD III-L, respectively, in a meta-analysis of previous studies. Our results are in contrast to those reported by Becker et al,[3] who reported KD III-L injuries to be the most common (43%) in a series of 106 patients.

Common peroneal nerve injuries were present in 19.2% and vascular injuries in 5% of patients in our study. There were significantly greater odds for both common peroneal nerve injuries and popliteal artery injuries with lateral-sided injuries (KD III-L). Additionally, peroneal nerve injury was significantly associated with vascular injury. Thus, one should have a higher level of suspicion for a concomitant vascular injury when a peroneal nerve injury is present. An arteriogram should be considered in patients with a concomitant nerve injury despite initial normal ABI. Medina et al[24] reported a frequency of 25% and 18% for nerve and vascular injuries, respectively, in a recent systematic review. Becker et al[3] reported peroneal nerve injury in 25% of knees and arterial injury in 21% in a series of 106 patients. Levy et al[21] recently reported a greater incidence of peroneal nerve injuries (22.4%) and vascular injuries (12.8%) in a cohort of 125 patients than those in the present study. Patients with severe intra-articular fractures and fracture dislocations were not included in our cohort, and this may explain the lower rates of peroneal nerve and vascular injuries recorded. Physical examination with the presence of a normal vascular examination (normal and symmetrical pulses, capillary refill, neurological examination) is reported to be reliable to screen patients with knee dislocations for "selective" arteriography.[14] The use of ABI has been reported to be useful as an adjunct to physical examination. There is still no consensus on the cutoff for ABI, with some protocols using ABI <0.8[16] and others recommending a cutoff of ABI <0.9 to perform arteriography.[14,20] A protocol for monitoring vascular injuries in knee dislocations developed by Stannard et al[32] can be a valuable tool in these patients. Early in the present study, an ABI <0.8 was used. The percentage of patients with ipsilateral fractures was consistent with data from other studies.[23,26,34] Lustig et al[23] reported that 17% of patients with knee dislocation had ipsilateral limb fracture; however, Becker et al[3] reported a greater incidence of fractures in the ipsilateral limb at 58%. Patients with bilateral multiligamentous knee injuries are reported to have a greater risk of concomitant head, chest, and abdominal injuries compared with unilateral multiligamentous knee injuries with similar mechanisms.[7]

There were some limitations in this study. Patients with severe intra-articular fractures were not included in this cohort because they were primarily treated by orthopaedic trauma surgeons in our hospital setting, and few ligament surgeries were performed in this group. There may be increased risk of neurovascular injuries associated with fractures around the knee, and our reported neurovascular injuries may be underestimated in these circumstances.

CONCLUSION

Medial-sided injuries were the most common injury patterns seen with knee dislocations. Cartilage injuries were common in chronically treated patients. There was a significant risk of peroneal neve injury with lateral-sided injuries.

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