Knee Surgery, Sports Traumatology, Arthroscopy (2018) 26:2865–2871
https://doi.org/10.1007/s00167-017-4784-3

KNEE

Poly-traumatic multi-ligament knee injuries: is the knee the limiting factor?

Jarret M. Woodmass[1] · Nick R. Johnson[1] · Rohith Mohan[1] · Aaron J. Krych[1] · Bruce A. Levy[1] · Michael J. Stuart[1]

Received: 2 July 2017 / Accepted: 30 October 2017 / Published online: 29 November 2017

Abstract

Purpose Multi-ligament knee injuries (MLKI) from a high-velocity accident are rare but potentially devastating. This matched cohort analysis compares knee functional outcomes after multiple ligament reconstruction in poly-trauma patients to those that occurred in isolation.

Methods Sixty-two patients with MLKI that occurred either as a component of polytrauma or had occurred in isolation were matched according to age, sex, and knee dislocation grade. Functional outcomes and knee physical examination were assessed at a 2-year follow-up. New Injury Severity Score (NISS) was calculated based on the poly-traumatic injury pattern. Risk factors for worse outcomes in the poly-trauma cohort were analyzed.

Results The mean IKDC, Lysholm, and NISS scores in the polytrauma cohort were 57.2 ± 21.9, 62 ± 22, and 40.9 ± 20.4, respectively, at a mean of 67 months (range 24–220). The isolated knee injury group was followed for a mean of 74 months (range 24–266) with mean IKDC and Lysholm scores of 71.1 ± 26.5 and 78 ± 23, respectively. Patients in the control cohort had significantly higher IKDC ($p = 0.01$) and Lysholm scores, ($p = 0.003$). There were no major differences between the two groups in regards physical examination findings at final follow-up. None of the analyzed risk factors was predictive of poor outcome.

Conclusion When comparing knees with similar multi-ligament and neurovascular injury patterns, patients who sustained their injury as a result of poly-trauma demonstrated significantly lower functional scores following reconstruction. This is despite restoration of similar knee stability and range of motion. The functional outcomes following MLKI reconstruction in poly-traumatized patients are influenced by factors other than the knee including concomitant injuries and psychosocial factors.

Level of evidence Therapeutic Level III.

Keywords Multi-ligament knee injury (MLKI) · Knee dislocation · Poly-trauma · Multi-ligament reconstruction

✉ Bruce A. Levy
Levy.bruce@mayo.edu

Jarret M. Woodmass
woodmass.jarret@mayo.edu

Nick R. Johnson
Nicholas-Johnson@ouhsc.edu

Rohith Mohan
rohith@bu.edu

Aaron J. Krych
Krych.aaron@mayo.edu

Michael J. Stuart
Stuart.michael@mayo.edu

[1] Department of Orthopedic Surgery and Sports Medicine, Mayo Clinic, 200 First Street SW, Rochester, MN 55905, USA

Introduction

Multi-ligament knee injuries (MLKI) are rare but potentially devastating injuries that can result in considerable functional limitation [27]. These injuries can occur following a variety of mechanisms including high-velocity accidents, sport-related injuries, and ultra-low velocity ground level falls [23, 33, 39]. When MLKI occur as a result of a high-velocity mechanism, nearly, one-third of patients present with a life-threatening injury to the head, chest, or abdomen [5]. In addition, 60% of patients sustain an associated fracture and 41% have multiple fractures [38]. Poly-traumatized patients are commonly assessed at presentation using Trauma Scoring Systems which have demonstrated correlation with both short-term mortality and functional recovery [2, 14, 35].

Surgical reconstruction of MLKIs can provide substantial functional improvement [31]. However, significant variability in outcomes remains amongst individual patients [25]. Over the past decade, efforts have focused on identifying potential factors that can predict a poor outcome. Patient factors including age [25], sex [20] and body mass index (BMI) [7] as well as surgical factors including repair versus reconstruction [22] and timing [28] have all been correlated with outcome. However, despite recognizing that MLKIs commonly occur as a component of a more severe poly-traumatic injury, no study to date has assessed the impact that these associated injuries have on a patient's long-term function.

This study compares the post-reconstruction functional outcomes of knees with similar multi-ligament injury patterns that occurred as a component of poly-trauma to those that occurred in isolation. The cohorts were matched for age, sex, and KD classification score. The hypothesis was that poly-trauma patients would have lower functional scores despite restoration of similar knee range of motion and stability. This finding would highlight the influence concomitant injuries and psychosocial factors have on the functional outcomes of patients with MLKI sustained as a component of polytrauma.

Materials and methods

A prospective registry was created in 2007 dedicated to tracking patient outcomes after multi-ligament knee reconstruction. Patients who had injuries before 2007 were retrospectively added to the database. Three hundred and two consecutive patients who underwent surgical reconstruction for a multi-ligament knee injury between 1993 and 2014 were retrospectively reviewed. Injury patterns were evaluated using the new injury severity score (NISS). The NISS rating scale is from 0 to 75 points (most severe). A score of 16 or greater was classified as a poly-traumatic injury [9]. Forty-three (15.5%) patients reviewed met this criterion (Fig. 1).

All patients underwent surgical intervention for their multi-ligament knee injury by one of the two senior surgeons. Ligamentous reconstruction and/or repair were performed at the discretion of the operating surgeon. Consistent tunnel placement, graft preparation, and graft fixation were performed [23]. Neurovascular status was assessed using previously described methods [13, 30].

The patients meeting criteria for poly-trauma (NISS > 15) were matched against patients with isolated knee injuries from our multi-ligament database by age, sex, and modified Schenck classification [32]. There were no major differences in regards to group characteristics (Table 1). In the poly-trauma cohort, four patients (13%) suffered complete peroneal nerve injuries and four patients (13%) suffered vascular injuries. One patient (3%) suffered a combined peroneal nerve and vascular injury. All patients who suffered a vascular injury underwent popliteal artery bypass grafting. Of the four patients with complete peroneal nerve injuries, one patient underwent a nerve transfer procedure, one patient underwent a nerve transfer with a posterior tibial tendon transfer, and two patients were prescribed an ankle–foot orthosis (AFO). In the control group, three patients (10%) suffered complete peroneal nerve injuries and three patients (10%) suffered vascular injuries. One patient (3%) suffered a combined peroneal nerve and vascular injury. All patients who suffered a vascular injury underwent popliteal artery bypass grafting. Of the three patients with complete peroneal nerve injuries, two patients underwent a nerve transfer procedure and one patient was prescribed an ankle–foot orthosis (AFO).

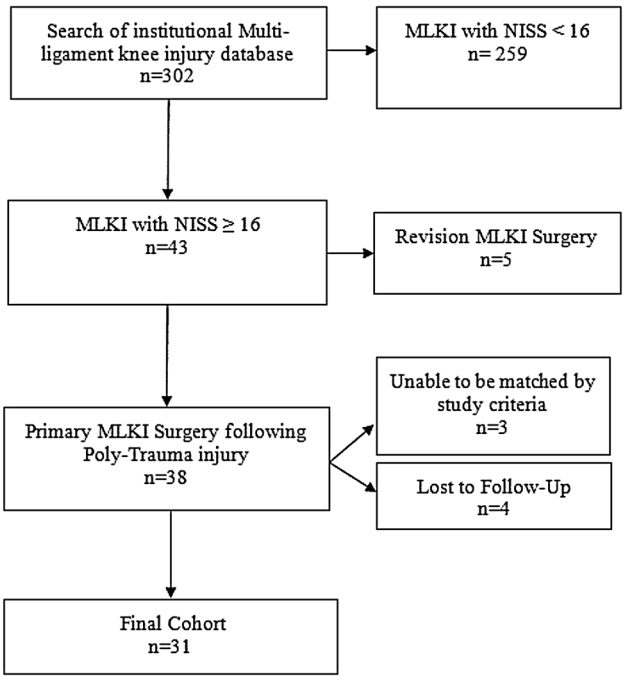

Fig. 1 Diagram detailing patient search and inclusion

The mechanism of injury in the poly-trauma group was variable: 25 (81%) motor vehicle collisions (MVC), 3 (9.5%) all-terrain vehicle (ATV) collisions, 1 (3.2%) industrial accident, 1 (3.2%) horse trampling, and 1 (3.2%) fall from a tree. Concomitant injuries ranged from tibial plafond fracture requiring amputation to aortic dissection requiring vascular repair. All patients were given a Glasgow Coma Score (GCS) upon admission to the emergency department (ED). Each patient's chart was assessed for the types of concomitant injuries, intensive care unit (ICU) admission, duration of stay, and endotracheal intubation. Patients were also classified by NISS score then stratified into severe (16–25) and

Table 1 Summary of poly-trauma and control cohorts

Patients	Poly-trauma knee injury ($n=31$)	Isolated knee injury ($n=31$)	p value
Age, mean (range)	34.0 (18–52)	33.0 (16–52)	n.s.
Sex			
Male	21	21	n.s.
Female	10	10	
KD class			
KD-I	12 (39%)	12 (39%)	n.s.
KD-II	0	0	
KD-IIIM	7 (23%)	7 (23%)	
KD-IIIL	5 (16%)	5 (16%)	
KD-IV	5 (16%)	5 (16%)	
KD-V	2 (6%)	2 (6%)	
BMI (mean ± standard deviation)	29.9 ± 5.2	31.5 ± 8.6	n.s.
Peroneal nerve injury			
Yes	4 (13%)	3 (10%)	n.s.
No	27 (87%)	29 (94%)	
Vascular injury			
Yes	4 (13%)	3 (10%)	n.s.
No	27 (87%)	28 (90%)	
Time to reconstruction			
Acute (< 3 weeks)	6	4	n.s.
Delayed (> 3 weeks)	25	27	
Staged MLKI surgery			
Yes	11	9	n.s.
No	20	22	

KD knee dislocation, *BMI* body mass index, *MLKI* multi-ligament knee injury

profound (> 25) [5]. Patient outcomes were assessed with physical exam by one of the two surgeons (MJS, BAL), International Knee Documentation Committee (IKDC) and Lysholm scores [4, 19]. This study was approved by the Mayo Clinic Institutional Review Board (IRB # 07-004018) prior to commencement.

Statistical analysis

Descriptive analyses of patient characteristics were performed using the mean and standard deviation for continuous variables along with the percentages and frequencies for dichotomous variables. Comparisons of patient characteristics between groups were conducted using the Wilcoxon-signed ranked sums for continuous variables and Chi-square or Fisher's exact test for categorical variables. Patients in the poly-trauma group were randomly matched by age, sex, and KD grade to non poly-trauma patients using the SPSS software (Version 18.0; SPSS, Chicago, IL, USA). Final patient outcome scores (Lysholm, IKDC) were assessed using a paired t test. Risk factors for worse outcomes in the poly-trauma group were analyzed using Wilcoxon-Signed Ranked sums test. All statistical tests were two sided with a p value of < 0.05 being considered significant. Statistical analyses were completed employing the JMP software (Version 7, SAS 135 Institute, Inc., Cary, NC, USA).

Results

Thirty-one patients in the poly-trauma group had a mean age of 34.0 years (range 18–52) and were followed for a mean of 67 months (range 24–220). Mean NISS score was 40.9 ± 20.4. Associated abdominal injuries were most common followed by lower extremity fractures. Eighteen patients (58%) had injuries that were categorized as profound by NISS scale (> 25). Fifteen patients required admission to the intensive care unit (ICU) with a mean duration of stay of 2.8 days (range 1–15 days). Median GCS on arrival was 12 (range 3–15), with 13 patients (42%) requiring intubation on arrival in the ED (Table 2).

The mean IKDC and Lysholm scores in the poly-trauma group were 57.2 ± 21.9 and 62 ± 22, respectively. In comparison, the control cohort measured 71.1 ± 26.5 and 78 ± 23, respectively. Patients in the poly-trauma cohort had significantly lower IKDC and Lysholm scores ($p = 0.01$

Table 2 Summary of associated injuries for poly-trauma group

Category	Poly-trauma knee injury ($n=31$)
NISS, mean ± standard deviation	40.9 ± 20.4
Severe (16–25) NISS	13 (42%)
Profound NISS (> 25)	18 (58%)
Mechanism of injury	
MVC	25 (81%)
ATV accident	3 (9.5%)
Other	3 (9.5%)
Head trauma	11 (35%)
Abdominal trauma	15 (48%)
Upper extremity fracture	10 (32%)
Spine fracture	8 (26%)
Pelvic ring injuries	9 (29%)
Lower extremity fracture	14 (45%)
Stay in the ICU	15 (48%)
Number of days in the ICU	2.8 (1–15)
Intubated during admission	13 (42%)
Glasgow Coma Scale on Arrival, median (range)	12 (3–15)

NISS New Injury Severity Score, *MVC* motor vehicle collision, *ATV* all-terrain vehicle, *ICU* intensive care unit

and $p=0.003$, respectively). On physical exam, there were no differences between final ROM between the two groups (Table 3). In addition, there were no major differences between the groups in objective tests of knee stability including: pivot shift, Lachman, posterior drawer test, varus stress at 0° and 30°, Valgus stress at 0° and 30°, or external rotation drawer test (Table 3).

Complications

Three patients (9.6%) in the poly-trauma cohort suffered post-operative infections requiring arthroscopic debridement and intravenous antibiotics. Four patients (12.9%) developed arthrofibrosis requiring manipulation under anesthesia, and one patient (3.2%) had a failed surgery requiring revision 15 months after primary surgery. Two patients (6.4%) in the control cohort developing arthrofibrosis requiring MUA and one patient (3.2%) had a wound infection that required revision surgery.

Risk factor analysis

Risk factors for worse outcomes were analyzed in the poly-trauma group. Age, sex, KD grade, body mass index (BMI), NISS category, associated injuries, ICU stay, intubation requirement, and GCS score on admission were assessed. No significant risk factors were found to be predictive of worse patient reported functional scores.

Discussion

The most important finding of the present study was that the post-reconstruction functional outcomes of patients who sustained a MLKI as a result of poly-trauma were significantly lower than those that occurred in isolation. This occurred despite controlling for age, gender, and pattern of ligament injury. Furthermore, the post-operative knee stability examination and range of motion were similar between the two cohorts. This information highlights the influence that concomitant injuries and psychosocial factors can have on the functional outcomes following MLKI reconstruction in poly-traumatized patients.

The two cohorts matched according to age, gender, and knee dislocation classification were compared using IKDC and Lysholm scores as measures for functional outcome. The mean IKDC score was 57.2 points in the poly-trauma injured cohort in comparison with 71.2 ($p=0.01$) for the isolated knee injury group. This difference is not only statistically significant, but more than doubles the minimal clinically important difference (MCID) for IKDC (6.3 points) [16].

Table 3 Functional outcomes of poly-trauma versus isolated knee injury cohort

Outcome	Poly-trauma	Isolated knee injury	*p* value
Mean IKDC Score ± SD	57.2 ± 21.9	71.1 ± 26.5	0.01
Mean Lysholm Score ± SD	62 ± 22	78 ± 23	0.003
Mean extension (range)	0° (0°–5°)	0° (−5°–10°)	n.s.
Mean flexion (range)	121.1° (80°–150°)	124.1° (90°–145°)	n.s.
Lachman	2, 2, 3	1, 2	n.s.
Pivot shift	1, 2	1	n.s.
Posterior drawer	1, 1, 1, 2, 2, 2, 3, 3	1, 1, 1, 3	n.s.
Quads active test	1, 1	1, 1, 1	n.s.
Valgus stress (30°)	1, 1, 2	1, 1, 1, 1	n.s.
Varus stress (30°)	1, 1, 1	1, 1, 1, 1	n.s.

IKDC International Knee Documentation Committee

A clinically and statistically significant difference was also found in regards to the Lysholm score with a 16-point difference (MCID = 10.1) [3] between the two cohorts (62 versus 78; $p = 0.003$).

It is well accepted that multi-ligament knee injuries commonly occur in conjunction with poly-trauma [10, 26]. Detailed treatment algorithms have been proposed to address both life-threatening and limb-threatening injuries [11, 18, 23, 36]. Poor outcomes in poly-trauma patients with a knee dislocation have been attributed to worse ligament injury patterns, the presence of a popliteal artery injury or increased rates neurologic injury [12, 37, 40]. However, the patients in this study were matched based on their ligament injury and there was no identifiable difference between the two groups regarding the rate of vascular or neurologic involvement. The absolute numbers demonstrated four patients in the poly-trauma cohort compared to three patients in the isolated knee injury cohort suffered complete common peroneal nerve palsy. Furthermore, it has previously been shown that common peroneal nerve palsy may not affect long-term functional outcomes following knee dislocation [21].

The timing of surgical reconstruction is an important consideration in multi-ligament reconstruction surgery. Acute single-stage reconstruction has been shown to lead to improved functional outcomes following multi-ligament knee injuries in comparison with delayed or staged procedures [10, 23, 24, 28]. The delay in knee ligament reconstruction because of associated life-threatening injuries has been blamed for poor outcomes in poly-trauma patients. In this study, there was no difference in the number of patients who underwent acute or staged reconstruction (Table 1) between the poly-trauma group (6 acute, 25 chronic) and the isolated knee injury group (4 acute, 27 chronic) (n.s.).

There was no difference in the pattern of ligament injury, the rate of neurologic injury, the rate of vascular injury, or the number of patients reconstructed on a chronic basis (> 3 weeks after injury). Physical examination demonstrated no difference in range of motion or ligament stability between the two groups. This information suggests that associated injuries unrelated to the knee influence functional outcomes in poly-trauma patients. This theory is supported by the trauma literature, where the Injury Severity Score or New Injury Severity Score is used to predict morbidity and mortality at the time of presentation to hospital [29].

The ISS was first described by Baker et al. [1] in 1974 and has since become a commonly used anatomic scoring method for assessing injury severity [2, 8, 15, 17]. This score is calculated using Abbreviated Injury Scale (AIS) scores in each of the three most critically injured body regions. This was later modified in 1997 by Osler et al. [29] to the New Injury Severity Score. This modification continues to use the AIS, but allows calculation using the three most critical injuries regardless of body region. As an example, if a patient sustained bilateral femur fractures and a knee dislocation, the ISS would only consider only the most severe of these three injuries when determining the lower extremity score. Alternatively, in the NISS, each of these injuries would be considered individually if they represent the three most severe injuries that the individual has sustained. The NISS was used for inclusion over the ISS as it allows extremity injuries to achieve greater influence when multiple severe injuries are preset. The NISS better predicts the functional outcomes in survivors of musculoskeletal trauma than the ISS [34, 35].

The current study demonstrated very severe injuries in the poly-trauma cohort. According to the NISS, 18 (58%) of patients had scores greater than 25 points representing profound injuries. In addition, 15 (48%) of patients required admission to the intensive care unit (ICU) and 13 (42%) required intubation during their admission. Associated injuries affected the head, chest wall, abdomen, solid organs, spine, pelvic ring, and upper and lower extremity fractures. Each of these factors was analyzed as a risk factor for a poor outcome; none reached statistical significance. This is likely the result of significant heterogeneity observed amongst the individual patients regarding injury location, patterns, and severity.

The following limitations should be considered when interpreting the results reported in this article. First, the reported data are a retrospective analysis of a prospectively collected database which introduces inherent bias and may limit the generalizability of the findings. Second, there is significant heterogeneity amongst the poly-trauma cohort regarding the location and severity of the injuries sustained. This did not allow determination if specific associated injuries were more likely to cause long-term functional deficits. Third, variability exists in all patients regarding associated meniscal injuries and cartilage damage. This was not assessed in either cohort of this study. Last, when time to reconstruction was assessed as a continuous variable, there was a significantly greater delay to reconstruction in the poly-trauma cohort when compared to the isolated knee injury cohort at 307.8 versus 107.8 days, respectively. The influence of surgical delay once a patient is being treated on a chronic basis is not clear. This is a potential bias influencing the difference in functional outcomes between the two groups. Last, this study did not assess for the influence of low self-efficacy, lower education level, poverty, or involvement in disability or compensation litigation that have been shown to affect outcomes [6].

This study also has several important strengths that should be noted. This is the first series to assess the influence of poly-trauma on long-term functional outcomes in patients with a knee dislocation. All patients in each of the matched cohorts were treated by a single surgical team

and subsequently underwent a standardized rehabilitation protocol. Minimum 2-year follow-up was obtained for all patients.

There is currently considerable variability in functional outcomes following MLKI reconstruction in the literature. The independent influence that poly-trauma can have on functional outcomes may account for some of this variability. Future research should identify poly-traumatized patients using a validated Trauma Scoring System such as the NISS. Poly-traumatized patients should be assessed independently from patients with isolated knee injuries. In the isolated knee injury population, unbiased and more predictable outcomes will be reported. However, more importantly, selective evaluation of poly-traumatized patients will allow determination of which concomitant injuries have the greatest influence on functional outcomes. In addition, psychosocial barriers can be more easily identified and resources can be selectively allocated to this population. Multi-center collaboration will likely be required due to the challenges encountered in the management of these rare and heterogeneous injuries.

Conclusion

When comparing knees with similar multi-ligament and neurovascular injury patterns, patients who sustained their injury as a result of poly-trauma demonstrated significantly lower functional scores following reconstruction. This is despite restoration of similar knee stability and range of motion. The functional outcomes following multiple knee ligament reconstruction in poly-traumatized patients are influenced by factors other than the knee including concomitant injuries and psychosocial factors.

Compliance with ethical standards

Conflict of interest No outside financial support was utilized for this study. Other potential conflicts of interest include: AJK is a consultant for Vericel and receives research support from Aesculap/B.Braun, Arthritis Foundation, Ceterix, and Histogenics. BAL is a consultant for Smith & Nephew and receives research support from Arthrex, Biomet, Smith & Nephew, and Stryker. MJS receives research support from Stryker. AJK, BAL, and MJS are consultants for and receive intellectual property royalties from Arthrex.

Funding No external funding sources were used for this study.

Ethical approval Ethical approval was obtained from the Institutional Review Board of the Mayo Clinic.

Informed consent Informed consent was obtained from all individuals who participated in the study.

References

1. Baker SP, O'Neill B, Haddon W Jr, Long WB (1974) The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 14:187–196
2. Bolorunduro OB, Villegas C, Oyetunji TA, Haut ER, Stevens KA, Chang DC et al (2011) Validating the Injury Severity Score (ISS) in different populations: ISS predicts mortality better among Hispanics and females. J Surg Res 166:40–44
3. Briggs KK, Kocher MS, Rodkey WG, Steadman JR (2006) Reliability, validity, and responsiveness of the Lysholm knee score and Tegner activity scale for patients with meniscal injury of the knee. J Bone Jt Surg Am 88:698–705
4. Briggs KK, Lysholm J, Tegner Y, Rodkey WG, Kocher MS, Steadman JR (2009) The reliability, validity, and responsiveness of the Lysholm score and Tegner activity scale for anterior cruciate ligament injuries of the knee: 25 years later. Am J Sports Med 37:890–897
5. Burrus MT, Werner BC, Cancienne JM, Miller MD (2015) Simultaneous bilateral multiligamentous knee injuries are associated with more severe multisystem trauma compared to unilateral injuries. Knee Surg Sports Traumatol Arthrosc 23:3038–3043
6. Cannada LK, Jones AL (2006) Demographic, social and economic variables that affect lower extremity injury outcomes. Injury 37:1109–1116
7. Carr JB, Werner BC, Miller MD, Gwathmey FW (2016) Knee dislocation in the morbidly obese patient. J Knee Surg 29:278–286
8. Collopy BT, Tulloh BR, Rennie GC, Fink RL, Rush JH, Trinca GW (1992) Correlation between injury severity scores and subjective ratings of injury severity: a basis for trauma audit. Injury 23:489–492
9. Copes WS, Champion HR, Sacco WJ, Lawnick MM, Keast SL, Bain LW (1988) The Injury Severity Score revisited. J Trauma 28:69–77
10. Darabos N, Gusic N, Vlahovic T, Darabos A, Popovic I, Vlahovic I (2013) Staged management of knee dislocation in polytrauma injured patients. Injury 44(Suppl 3):S40–S45
11. Fanelli GC, Stannard JP, Stuart MJ, MacDonald PB, Marx RG, Whelan DB et al (2010) Management of complex knee ligament injuries. J Bone Jt Surg Am 92:2235–2246
12. Georgiadis AG, Mohammad FH, Mizerik KT, Nypaver TJ, Shepard AD (2013) Changing presentation of knee dislocation and vascular injury from high-energy trauma to low-energy falls in the morbidly obese. J Vasc Surg 57:1196–1203
13. Giuseffi SA, Bishop AT, Shin AY, Dahm DL, Stuart MJ, Levy BA (2010) Surgical treatment of peroneal nerve palsy after knee dislocation. Knee Surg Sports Traumatol Arthrosc 18:1583–1586
14. Glancy KE, Glancy CJ, Lucke JF, Mahurin K, Rhodes M, Tinkoff GH (1992) A study of recovery in trauma patients. J Trauma 33:602–609
15. Goris RJ (1983) The injury severity score. World J Surg 7:12–18
16. Greco NJ, Anderson AF, Mann BJ, Cole BJ, Farr J, Nissen CW et al (2010) Responsiveness of the International Knee Documentation Committee Subjective Knee Form in comparison to the Western Ontario and McMaster Universities Osteoarthritis Index, modified Cincinnati Knee Rating System, and Short Form 36 in patients with focal articular cartilage defects. Am J Sports Med 38:891–902
17. Heath DF (1985) Morbidity and mortality of car occupants: uses of the injury severity score. Br Med J (Clin Res Ed) 290:319
18. Howells NR, Brunton LR, Robinson J, Porteus AJ, Eldridge JD, Murray JR (2011) Acute knee dislocation: an evidence based approach to the management of the multiligament injured knee. Injury 42:1198–1204

19. Irrgang JJ, Anderson AF, Boland AL, Harner CD, Kurosaka M, Neyret P et al (2001) Development and validation of the international knee documentation committee subjective knee form. Am J Sports Med 29:600–613
20. King AH, Krych AJ, Prince MR, Pareek A, Stuart MJ, Levy BA (2016) Surgical outcomes of medial versus lateral multiligament-injured, dislocated Knees. Arthroscopy 32(9):1814–1819
21. Krych AJ, Giuseffi SA, Kuzma SA, Stuart MJ, Levy BA (2014) Is peroneal nerve injury associated with worse function after knee dislocation? Clin Orthop Relat Res 472:2630–2636
22. Levy BA, Dajani KA, Morgan JA, Shah JP, Dahm DL, Stuart MJ (2010) Repair versus reconstruction of the fibular collateral ligament and posterolateral corner in the multiligament-injured knee. Am J Sports Med 38:804–809
23. Levy BA, Dajani KA, Whelan DB, Stannard JP, Fanelli GC, Stuart MJ et al (2009) Decision making in the multiligament-injured knee: an evidence-based systematic review. Arthroscopy 25:430–438
24. Levy BA, Krych AJ, Shah JP, Morgan JA, Stuart MJ (2010) Staged protocol for initial management of the dislocated knee. Knee Surg Sports Traumatol Arthrosc 18:1630–1637
25. Levy NM, Krych AJ, Hevesi M, Reardon PJ, Pareek A, Stuart MJ et al (2015) Does age predict outcome after multiligament knee reconstruction for the dislocated knee? 2- to 22-year follow-up. Knee Surg Sports Traumatol Arthrosc 23:3003–3007
26. Lustig S, Leray E, Boisrenoult P, Trojani C, Laffargue P, Saragaglia D et al (2009) Dislocation and bicruciate lesions of the knee: epidemiology and acute stage assessment in a prospective series. Orthop Traumatol Surg Res 95:614–620
27. Medina O, Arom GA, Yeranosian MG, Petrigliano FA, McAllister DR (2014) Vascular and nerve injury after knee dislocation: a systematic review. Clin Orthop Relat Res 472:2621–2629
28. Mook WR, Miller MD, Diduch DR, Hertel J, Boachie-Adjei Y, Hart JM (2009) Multiple-ligament knee injuries: a systematic review of the timing of operative intervention and postoperative rehabilitation. J Bone Jt Surg Am 91:2946–2957
29. Osler T, Baker SP, Long W (1997) A modification of the injury severity score that both improves accuracy and simplifies scoring. J Trauma 43:922–925 **(discussion 925–926)**
30. Redmond JM, Levy BA, Dajani KA, Cass JR, Cole PA (2008) Detecting vascular injury in lower-extremity orthopedic trauma: the role of CT angiography. Orthopedics 31:761–767
31. Schechinger SJ, Levy BA, Dajani KA, Shah JP, Herrera DA, Marx RG (2009) Achilles tendon allograft reconstruction of the fibular collateral ligament and posterolateral corner. Arthroscopy 25:232–242
32. Schenck RC Jr (1994) The dislocated knee. Instr Course Lect 43:127–136
33. Shelbourne KD, Porter DA, Clingman JA, McCarroll JR, Rettig AC (1991) Low-velocity knee dislocation. Orthop Rev 20:995–1004
34. Smith BP, Goldberg AJ, Gaughan JP, Seamon MJ (2015) A comparison of Injury Severity Score and New Injury Severity Score after penetrating trauma: a prospective analysis. J Trauma Acute Care Surg 79:269–274
35. Sutherland AG, Johnston AT, Hutchison JD (2006) The new injury severity score: better prediction of functional recovery after musculoskeletal injury. Value Health 9:24–27
36. Vinyard TR, Boyd J, MacDonald PB (2012) Initial evaluation of the acute and chronic multiple ligament injured knee. J Knee Surg 25:275–286
37. Wascher DC (2000) High-velocity knee dislocation with vascular injury. Treatment principles. Clin Sports Med 19:457–477
38. Wascher DC, Dvirnak PC, DeCoster TA (1997) Knee dislocation: initial assessment and implications for treatment. J Orthop Trauma 11:525–529
39. Werner BC, Gwathmey FW Jr, Higgins ST, Hart JM, Miller MD (2014) Ultra-low velocity knee dislocations: patient characteristics, complications, and outcomes. Am J Sports Med 42:358–363
40. Yeh WL, Tu YK, Su JY, Hsu RW (1999) Knee dislocation: treatment of high-velocity knee dislocation. J Trauma 46:693–701