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KNEE

Does age predict outcome after multiligament knee reconstruction for the dislocated knee? 2- to 22-year follow-up

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Abstract
Purpose The purpose of this study is to determine whether age is a predictor of clinical and functional outcomes in patients who sustained a knee dislocation (KD) and underwent multiligament knee reconstruction. It was hypothesized that increasing age will negatively affect patient outcome.
Methods In total, 125 multiligament knee injuries (MLKI) associated with KD were surgically reconstructed between 1992 and 2013 and evaluated with IKDC and Lysholm scores at a median follow-up of 5 (range 2–22) years. Patient demographics including age were then analysed with respect to IKDC and Lysholm scores using rank sums and pair-wise rank sums analysis for continuous variables and Chi-square analysis for categorical variables.
Results In total, 125 patients (96 males and 29 females) with a median age of 31 (range 11–62) years at the time of surgery were included. At final follow-up, patients ≤30 years old compared to >30 years old obtained higher IKDC (73.3 vs. 61.9; $p = 0.01$) and Lysholm scores (76.9 vs. 68.5; $p = 0.04$). No confounding variables including gender, injury mechanism, injury pattern, injuries to the peroneal nerve, popliteal artery, meniscus, or cartilage accounted for differences in outcome scores between the two groups.
Conclusion Based on current available literature, this study represents the largest cohort with the longest follow-up reported on MLKI to date. At intermediate- to long-term follow-up, patients >30 years of age that undergo multiligament knee reconstruction for KD have inferior IKDC and Lysholm scores compared to those ≤30 years of age. However, successful multiligament knee reconstruction can still be obtained in this age group.
Level of evidence IV.

Keywords Multiligament knee injury · Knee dislocation · Age · Knee reconstruction

Introduction

Knee dislocation involves injury to multiple ligaments of the knee and is often associated with high-energy polytrauma. To date, there is a lack of high-level evidence studies on multiligament knee injury (MLKI) outcomes in the literature. This is likely due to the relative rarity of the presentation compounded with substantial variability in patient characteristics, knee injury patterns, surgical techniques, graft selection, and post-operative rehabilitation protocols. Therefore, optimal treatment protocols for knee dislocations remain controversial [19].

Achieving excellent clinical and functional outcomes in this population has been challenging, with reported complications and need for revision procedures [22]. These outcomes are also confounded by significant concomitant injuries sustained, such as peroneal nerve, popliteal artery, and meniscus or cartilage damage [13]. Therefore, it is difficult to obtain accurate functional measures without accounting for other concomitant injuries and makes interpretation of available literature difficult, with no universal standardized scoring [6, 8, 23].

Other factors in this setting may be equally important to outcome, including patient characteristics and their ability to recover and rehabilitate from this devastating injury.

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Though there have been data presented on ACL reconstruction outcomes in relation to age [4, 11], there are no prior studies that have reported outcomes of MLKI with assessment of age as a predictor of outcome. Therefore, the purpose of this study is to be the first to determine whether age is a predictor of intermediate- to long-term functional outcomes in patients who sustained knee dislocations and underwent multiligament knee reconstruction. It was hypothesized that increasing age at the time of surgery will negatively affect patient's knee rating and knee function.

Materials and methods

All patients diagnosed with knee dislocation or MLKI that underwent multiligament reconstruction from 1992 to 2013 were entered in a prospectively created database and were eligible for inclusion in this study.

In total, 184 potential patients were isolated from a prospective database. Patients were excluded if there was (1) isolated KD I injury involving only the ACL and MCL or (2) <2-year follow-up. This resulted in 125 knee dislocations in 123 patients. Patients were followed for a median of 5 (range 2–22) years.

All patients in this study underwent surgical intervention for their multiligament knee injury. Ligament reconstruction and/or repair was performed at the discretion of the operating surgeons (MJS, BAL). Soft tissue allografts and/or autografts were used when necessary to reconstruct combinations of anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), fibular collateral ligament (FCL), medial collateral ligament (MCL), and posterolateral corner (PLC) injuries. Standardized graft and tunnel preparation and graft fixation techniques were used based on surgeon preference with evolving surgical techniques during the study period. Damage to neurovascular structures was determined both pre-operatively and intraoperatively. Cartilage injury greater than Outerbridge Grade I and meniscal injury were evaluated and recorded intraoperatively. Knee dislocations were classified according to the modified Schenck criteria, as stated above, based on pre-operative and intraoperative findings [26, 29]. Postoperative recovery and rehabilitation were based on the Fanelli, Edson protocol [7], with minor variations tailored according to the pattern of ligament reconstruction.

After informed consent was obtained, all patients completed clinical and functional outcome forms, consisting of the IKDC subjective and Lysholm scores. These patient-reported outcome measures have been validated for the evaluation of ligamentous injury of the knee [12, 14]. All outcome scores were collected at a minimum 2-year follow-up, and if multiple outcome scores were available, the score at the time of last follow-up was utilized.

Indication for surgical intervention in this cohort included MLKI with clinical and/or functional instability. Clinical instability was detailed as (1) 1+ laxity to varus or valgus stress testing in extension and/or 3+ laxity to varus or valgus stress testing at 30° of flexion, (2) Grade III or higher anterior or posterior drawer test, (3) Grade III or higher external rotation drawer test, (4) Grade II or more Lachman and pivot shift test. Failure of repair or reconstruction was defined as recurrent clinical and/or functional instability requiring additional revision reconstruction. This study was granted IRB approval (Mayo Clinic IRB, study 07-004018).

Statistical analysis

Statistical analysis was carried out with study demographic data and injury descriptors such as popliteal artery and peroneal nerve injury. The data were summarized by means with standard deviations calculated for the appropriate respective distributions. Post-operative outcome scores were initially compared between subsets of pre-operative age demographics using the *t* test for continuous variables. Based on this, the cut-off age of ≤30 years was chosen as close to the mean age and also to equally distribute patients into two groups. In order to minimize potential confounding variables, Chi-square analysis was used to calculate significance in the distribution of categorical variables between the two groups (≤30 years of age and >30 years of age). All statistical tests were two-sided. p values <0.05 were considered statistically significant. Statistical analysis was conducted employing R 3.2.0 (R Development Core Team, Vienna, Austria) and JMP software (version 7, SAS 135 Institute, Inc., Cary, NC).

Results

Of the 125 knee dislocations analysed, there was a preponderance of left-sided injuries (62.4 %) and more male patients (76.8 %) than female patients ($p < 0.01$ for both; Table 1). The median age at surgery was 31 years (range 11–62). KD Grade III was the most frequent dislocation pattern, representing 57.6 % of the data set (Table 1).

The effect of age upon outcome scores was explored comparing 10-year age groups (Fig. 1). Statistical significance was noted when comparing the 21- to 30-year-old age group with the 31- to 40-year-old age group for IKDC and Lysholm scores ($p < 0.01$ for both), with mean difference of 17.9 points for IKDC and 15.4 points for Lysholm. There were no statistically significant differences in any other age-related pair-wise comparisons.

At the time of final follow-up, patients ≤30 years old at the time of surgery obtained superior knee outcomes

Table 1 Pre-operative patient demographics

Variable	Value
Mean age at surgery[a]	32.9 ± 10.6
Gender[b]	
Female	29 (23.2 %)
Male	96 (76.8 %)
Side[b]	
Left	78 (62.4 %)
Right	47 (37.6 %)
Revision status[b]	
Performed as primary surgery	104 (83.2 %)
Performed as revision	21 (16.8 %)
Mechanism of injury[b]	
Low energy	58 (46.4 %)
High energy	67 (53.6 %)
Meniscus injury[b]	
Not present	52 (41.6 %)
Present	73 (58.4 %)
Cartilage injury[b]	
Not present	75 (60.0 %)
Present	50 (40.0 %)
Peroneal nerve injury[b]	
Not present	97 (77.6 %)
Present	28 (22.4 %)
Vascular (popliteal artery) injury[b]	
Not present	109 (87.2 %)
Present	16 (12.8 %)
KD Grade[b]	
I	29 (23.2 %)
II	4 (3.2 %)
III	72 (57.6 %)
IV	18 (14.4 %)
V	2 (1.6 %)

[a] Values displayed as mean ± standard deviation

[b] Values displayed as number and per cent of total

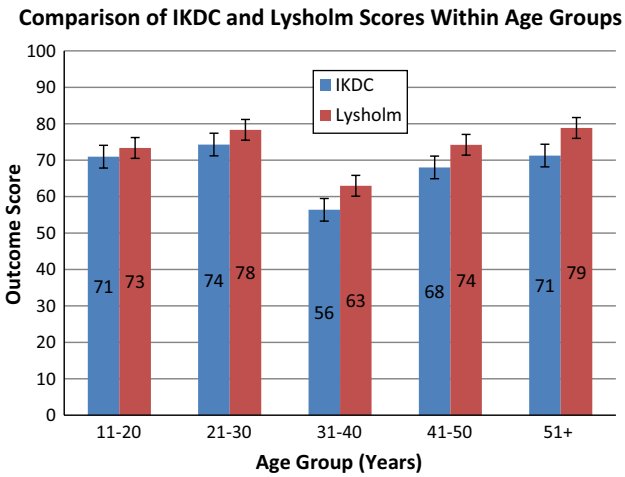

Fig. 1 Comparison of final IKDC and Lysholm scores for different groups according to age at surgery. Data presented as mean value within each group. *Error bars* represent standard error

compared to those >30 years old as evidenced by IKDC (73.3 vs. 61.9; $p = 0.01$) and Lysholm (76.9 vs. 68.5; $p = 0.04$) scores. Multivariable analysis revealed no significant difference in any other variables, including: side, gender, revision status, mechanism of injury, neurovascular, meniscus, or cartilage injury between patients ≤30 years of age and >30 years of age (Table 2).

Discussion

The most important finding of this study was that young patient age (≤30) was predictive of superior clinical and functional outcome scores after multiligament reconstructive surgery following knee dislocation. This information is helpful to determine prognosis and counsel patients on their expected outcome. Regardless of the current literature on MLKI management and clinical outcomes, there is no clear consensus on ideal treatment and prognosis. Several papers have shown correlations between concomitant injuries and outcomes for MLKI [5–7], but none have assessed patient age as a determinant of outcomes. Following ACL reconstruction, Spindler et al. reported that patient demographics including female gender, higher BMI, previous smokers, current smokers, lower education level, lower baseline activity level, and lower baseline IKDC score predicted significantly lower outcome scores [3]. However, they did not assess patient age as a variable. Patient age is likely a reflection of higher activity level and a higher baseline functional status, but that is difficult to demonstrate in a knee dislocation population where baseline functional scores are not available.

Another possible explanation is that older patients tend to have more articular degeneration than younger patients. Ahlden et al. [1] found that patients with ACL tears and associated meniscal or chondral injuries had inferior KOOSs at 1 year post-operatively, with inferior sport/recreation subscale scores at 5 years. King et al. [13] recently published that damage to either the articular cartilage or both medial and lateral menisci was associated with inferior IKDC scores at a mean follow-up of 6 years. Fanelli et al. [8] reported that approximately one-fourth of patients with knee dislocations were observed to have radiographic evidence of arthritis at 10-year status post-injury. In this study, 31 % of patients ≤30 years of age had cartilage injury versus 47 % of patients >30 years of age. This, however, did not reach a statistically significant difference.

Table 2 Distribution of pre-operative patient characteristics for age-defined cohorts

	Age ≤30 ($n = 61$)	Age >30 ($n = 64$)	p value
Side			
Left	39 (64 %)	39 (61 %)	n.s
Right	22 (36 %)	25 (39 %)	
Gender			
Female	13 (21 %)	16 (25 %)	n.s
Male	48 (79 %)	48 (75 %)	
Revision status			
Primary	48 (79 %)	56 (88 %)	n.s
Revision	13 (21 %)	8 (12 %)	
Mechanism of injury			
Low energy	29 (48 %)	28 (44 %)	n.s.
High energy	32 (52 %)	36 (56 %)	
Peroneal nerve injury			
Not present	48 (79 %)	48 (75 %)	n.s.
Present	13 (21 %)	16 (25 %)	
Vascular injury			
Not present	54 (89 %)	54 (84 %)	n.s.
Present	7 (11 %)	10 (16 %)	
Meniscus injury			
Not present	24 (39 %)	29 (45 %)	n.s.
Present	37 (61 %)	35 (55 %)	
Cartilage injury			
Not present	42 (69 %)	34 (53 %)	n.s.
Present	19 (31 %)	30 (47 %)	
KD Grade			
I	15 (25 %)	13 (20 %)	n.s.
II	2 (3 %)	2 (3 %)	
III	37 (60 %)	36 (59 %)	
IV	6 (10 %)	12 (19 %)	
V	1 (2 %)	1 (2 %)	

Moreover, King et al. [13] have previously reported that articular cartilage status can play a role in outcome following multiligament knee reconstruction.

The best approach to surgically repairing or reconstructing multiligamentous knee injuries is still not clear. A randomized control trial would potentially account for patient characteristics, such as age, that have an effect on outcome. However, the large association with concomitant injuries and other confounding factors makes randomized, controlled trials for treatment of MLKI exceedingly difficult to perform [18]. There are no randomized controlled trials comparing reconstruction to non-operative management, but several retrospective studies exist [23–25, 30]. Surgical reconstruction in these studies was associated with superior outcomes with respect to Tegner, Lysholm, and IKDC scores, as well as subjective patient function. Operative repair or reconstruction for MLKI is considered the gold standard for patient care [9]. The best approach for the type and timing of reconstruction is still a topic of debate. Stannard et al. [28] and Levy et al. [17] both reported improvement with reconstruction, compared to repair, and have since recommended a staged procedure for reconstructing MLKIs [27]. Staging procedures are preferred by many due to the significant concomitant injuries patients with MLKI incur [20].

In this study, vascular and nerve injuries had similar distributions within the age groups. Peroneal nerve injury is a common complication of knee dislocation, especially with a concomitant fibular head fracture [21]. Krych et al. published a study on peroneal nerve injury in knee dislocations and its effect on patient outcomes after surgery. No significant difference in IKDC or Lysholm scores was found in those with or without peroneal nerve injury [15]. Popliteal artery injury is also a deleterious consequence of knee dislocation [2]. Arterial injury can result in the loss of limb due to ischaemia, and it is important to urgently repair the artery in case of serious injury. Georgiadis et al. [10] showed that vascular injuries are increasingly associated with low-energy mechanism of knee dislocation and higher BMI. Up until now, Engebretsen et al. [6] published the largest cohort for MLKI outcomes in 2009. Their series includes 85 patients and showed no correlation between neurovascular injury and IKDC scores at 2–9 years.

There are several limitations to the current study. MLKIs are a relatively rare occurrence in the general population, and although this series is large, the study still may be underpowered when performing analysis of variables between groups. Another limitation is the difficulty in isolating symptoms only from the ligamentous injury and not from the plethora of other injuries associated with MLKI. MLKI is associated with a high rate of concomitant injury, including meniscal and cartilage injury [16], and isolating whether patients are doing poorly from ligamentous instability, or sequela of concomitant injury can be difficult. Better objective outcome measures are needed to help distinguish ligamentous problems from other concomitant injuries.

The data presented in this study are clinically relevant for surgeons who perform MLKI reconstructions and provide valuable information when counselling patients on what they can expect for long-term functional outcomes after their injury.

Conclusion

Based on current available literature, this study represents the largest cohort with the longest follow-up reported on MLKI to date. At intermediate- to long-term follow-up, patients >30 years of age that undergo multiligament knee

reconstruction for knee dislocation have inferior IKDC and Lysholm scores compared to those ≤30 years of age. However, successful multiligament knee reconstruction can still be obtained in this age group.

Compliance with ethical standards

Conflict of interest Nate M. Levy: None to disclose. Aaron J. Krych, MD: Arthrex, Inc: Paid consultant. Arthritis Foundation: Research support. Histogenics: Research support. Mario Hevesi, BS: None to disclose. Patrick J. Reardon, BS: None to disclose. Ayoosh Pareek, BS: None to disclose. Michael J. Stuart, MD: Consultant: Arthrex, Inc. Royalties: Arthrex, Inc. Research support: Stryker, USA Hockey Foundation. Bruce A. Levy, MD: Consultant: Arthrex, Inc. Royalties: Arthrex, Inc. Research support: Arthrex, Inc, Biomet, Stryker, NIH. Editorial Board: Arthroscopy [Board of Trustees], KSSTA, J Knee Surg., CORR [Deputy Editor].

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