Risk Factors Associated With Complications After Operative Treatment of Multiligament Knee Injury

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Background: Many factors can affect clinical outcomes and complications after a complex multiligament knee injury (MLKI). Certain aspects of the treatment algorithm for MLKI, such as the timing of surgery, remain controversial.

Purpose: To determine the risk factors for common complications after MLKI reconstruction.

Study Design: Case-control study; Level of evidence, 3.

Methods: A retrospective review was conducted on 134 patients with MLKI who underwent reconstruction between 2011 and 2018 at a single academic center. Patients included in the review had a planned surgical reconstruction of >1 ligament based on clinical examination and magnetic resonance imaging. Complications were categorized as (1) wound infection requiring irrigation and debridement, (2) arthrofibrosis requiring manipulation under anesthesia and/or lysis of adhesions, (3) deep venous thrombosis, (4) need for removal of hardware, and (5) revision ligament surgery. The potential risk factors for complications included patient characteristics, injury pattern categorized according to Schenck classification (knee dislocation [KD] I–KD IV), and timing of surgery. Significant risk factors for complications were analyzed by *t* test, chi-square test, and Fisher exact test.

Results: A total of 108 patients met the inclusion criteria; of these, 29.6% experienced at least 1 complication. Smoking (odds ratio [OR], 3.20 [95% CI, 1.28-8.02]; $P = .01$) and planned staged surgery (OR, 2.71 [95% CI, 1.04-7.04]; $P = .04$) significantly increased the overall risk of complication, while increased time from injury to surgery (OR, 0.99 [95% CI, 0.98-0.998]; $P < .01$) significantly decreased the risk. Increasing time from injury to surgery (OR, 0.99 [95% CI, 0.97-0.998]; $P = .02$) also led to a slightly but significantly decreased risk for arthrofibrosis.

Conclusion: The study findings suggest that smoking, decreased time from injury to initial surgery, and planned staged procedures may increase the rate of complications. Further studies are needed to determine which changes in the treatment algorithm are most effective to reduce the complication rate in patients.

Keywords: multiligament knee injury; knee dislocation; multiligament knee reconstruction; risk factors

A multiligament knee injury (MLKI) typically occurs after traumatic dislocation of the knee, in which at least 2 of the 4 major ligaments of the knee are disrupted.[3,14] These injuries are complex and, in up to 20% of cases, can be complicated by vascular injury, which leads to worse functional outcomes.[17,20,25] Surgical management of MLKIs is typically preferred and has shown to result in better patient-reported outcomes and functional outcomes as well as higher return to sport when compared with nonsurgical treatment.[2,21,22] However, there are many factors that influence decision-making after MLKIs, and further, there are many controversies with regard to type and timing of the surgical management.[8,15]

While surgical management of these injuries is usually the treatment of choice, it is important to consider the potential postoperative complications as well as the factors that influence the occurrence those complications. Commonly reported complications after multiligament knee (MLK) reconstruction include wound infection, deep venous thrombosis (DVT), and arthrofibrosis.[11,16] The rates of these complications are much higher than those seen with isolated anterior cruciate ligament (ACL) reconstruction (ACLR). For example, wound infection occurs in up to 12.5% of multiliagment injuries compared with less than 3% for ACL injuries, and the rate of arthrofibrosis requiring manipulation is up to 17% after multiligament injuries compared with less than 2% with an isolated ACL

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injury.[9,19,26] A previous study showed that higher body mass index (BMI) was a significant risk factor for complications, increasing the odds of complication by 9.2% for each unit increase in BMI.[24] Other studies have shown that age, tourniquet time, and history of prior knee surgery are all factors for wound complications.[16,31] Given that some studies have suggested that there are benefits to delayed reconstruction after MLKI, it is important for surgeons to be aware of risk factors, such as smoking and preoperative range of motion (ROM), that can be modified in the time before delayed reconstruction to potentially prevent the high morbidity associated with these injuries.

Thus, the purpose of this study was to determine the risk factors that affect the rate of common complications after reconstruction for an MLKI. This information will help to guide preoperative patient counseling and surgical decision-making within a treatment algorithm that has many variations. It was hypothesized that obesity, smoking, and diabetes would be risk factors for complications, while time to surgery and preoperative ROM would influence the risk of arthrofibrosis.

METHODS

Institutional review board approval was obtained prior to the start of this study. A retrospective review was conducted on 134 individuals who underwent reconstruction for an MLKI performed by 1 of 3 surgeons (V.M. and B.P.L.) between 2011 and 2018 at a single academic center. Patients included in the review had to have a planned surgical repair/reconstruction of more than 1 ligament based on clinical examination and magnetic resonance imaging (MRI) and not have had prior ligamentous reconstruction on the affected knee or an intra-articular fracture that required open reduction and internal fixation. Excluded were 12 patients who had had a prior ligamentous reconstruction on the affected knee, 10 patients who had had an intra-articular fracture that required open reduction and internal fixation, and 4 more who did not have accessible MRI scans to confirm injury pattern.

For the remaining 108 eligible patients, information was collected regarding patient demographics (age, sex), medical history (hypertension, diabetes, smoking status, etc), mechanism of injury (sports, trauma, ultra-low energy, other), injury pattern (categorized according to Schenck classification[27] as knee dislocation [KD] I–KD IV), intraoperative examination under anesthesia (passive ROM, Lachman, pivot shift, etc), reconstructive procedure, and postoperative complications. The potential risk factors for complications were age, BMI, smoking, diabetes, mechanism of injury (sports, trauma, ultra-low energy, other), injury pattern, cartilage injury classified as Outerbridge grade $\geq$2, meniscus injury, time from injury to surgery, staged surgery, and preoperative ROM.

Complications were assigned to 1 of the following categories: (1) wound infection requiring irrigation and debridement (I&D); (2) arthrofibrosis requiring manipulation under anesthesia (MUA) (and/or lysis of adhesions); (3) DVT; (4) need for removal of hardware (ROH); or (5) revision ligament surgery. The need for MUA was based on the surgeon's discretion and was not a predetermined criterion for knee ROM, and need for ROH was categorized as a complication only if the reason for removal was symptomatic hardware. A planned staged surgery was defined as 2 or more planned separate ligament repair/reconstructions regardless of completion of both surgeries. In all cases in which both stages of the surgery were not performed, only the initially planned repairs/reconstructions were completed at the first stage. Then, it was determined that the initially planned second stage repairs/reconstructions were not necessary based on clinical stability of the knee.

The number of overall complications were determined for patients with and without each risk factor. A 2-tailed *t* test (continuous variables) and chi-square or Fisher exact test (categorical variables) were used to determine significant differences in the presence of each risk factor in patients that did and did not have certain complications. Statistical significance was set at $P < .05$. Odds ratios (ORs) and 95% CIs were calculated for factors that were significantly related to each complication; the 95% CI was determined using logistic regression.

RESULTS

The mean age of the 108 included patients was 29.3 ± 12.0 years; baseline characteristics are outlined in Table 1. A majority of the patients had KD I injuries (52%) and KD III injuries (43%). Among the patients with KD I injuries, 29 had ACL/medial collateral ligament (MCL) injuries (ACLR and MCL repair performed for all but 5 patients, who had only an ACLR); 10 had ACL/lateral collateral ligament (LCL)/posterolateral corner (PLC) injuries (ACLR with LCL/PLC reconstruction was performed for all except 2 patients, 1 who did not have an ACLR and the other who did not have a LCL/PLC reconstruction); 8 had posterior cruciate ligament (PCL)/MCL injuries (PCL reconstruction

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Ethical approval for this study was obtained from the University of Pittsburgh (PRO17110230).

TABLE 1
Baseline Characteristics of the Study Patients (N = 108)[a]

Age, y	29.3 ± 11.9
BMI, kg/m^2	30.3 ± 7.9
Male sex	80 (74)
Smoker	27 (25)
Hypertension	12 (11)
Diabetes	4 (4)
Injury mechanism	
Sports	43 (40)
Trauma	54 (50)
ULV	7 (7)
Other	4 (4)
Injury pattern[b]	
KD I	56 (52)
KD II	2 (2)
KD III	46 (43)
KD IIIM	22 (20)
KD IIIL	24 (23)
KD IV	3 (3)
Other	1 (1)
Planned staged ligament repair	24 (22)
Completed both repair stages	17 (16)
Cartilage injury grade ≥2	35 (32)
Meniscal injury	56 (52)
Time from injury to first surgery, days	104.0 ± 189.2
Passive ROM, deg	
<90	15 (14)
90-110	8 (7)
>110	85 (79)

[a]Data are reported as n (%) or mean ± SD. ACL, anterior cruciate ligament; BMI, body mass index; KD, knee dislocation; LCL, lateral collateral ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament; ROM, range of motion; ULV, ultra-low energy.

[b]According to Schenck classification[27]: KD I = involvement of the ACL or PCL; KD II = injury to both ACL and PCL, with both collaterals intact; KD III = injury to both ACL and PCL, also MCL or LCL torn; KD IIIM = MCL torn, KD IIIL = LCL torn; KD IV: all 4 ligaments torn.

and MCL repair was performed for all except 2 patients, who had only a MCL repair); and 9 had PCL/LCL/PLC injuries (all treated with PCL and LCL/PLC reconstructions). One patient with an ACL/PLC/MCL tear, who was treated with ACL, PLC, and MCL reconstructions, was not categorized in the KD classification. The number of complications and staged procedures within each KD group is outlined in Table 2. The mean time to surgery was 128 days for KD I injuries, 155 days for KD II injuries, 77 days for KD III injuries, and 42 days for KD IV injuries.

Overall, 29.6% of the individuals undergoing reconstruction for an MLKI experienced at least 1 of the 5 complications, with 6 patients experiencing multiple. The rates for each complication were as follows: 16.7% had arthrofibrosis requiring MUA and/or arthroscopic lysis of adhesions; 6.5% had a wound infection requiring I&D; 5.6% had revision ligament surgery; 4.6% required ROH; and 1.8% had a DVT. Smoking, staged surgery, and time from injury to surgery were significant risk factors for any complication after reconstruction for an MLKI (Table 3). Smoking and planned staged surgery increased the risk of a complication (OR, 3.20 [95% CI, 1.28-8.02] and OR, 2.71 [95% CI, 1.04-7.04], respectively). On the other hand, increased time from injury to surgery slightly decreased the risk (OR, 0.99 [95% CI, 0.98-0.998]).

TABLE 2
Breakdown of Staged Surgeries and Complications by Injury Pattern[a]

Injury Pattern[b]	No. of Patients	Complications	Staged Procedures
KD I	56	10 arthrofibrosis, 2 wound infections, 2 revision ligament surgeries, 3 ROH	7 (5 completed)
KD II	2	None	0
KD IIIM	22	4 arthrofibrosis, 2 wound infections, 3 revision ligament surgeries, 1 ROH	7 (6 completed)
KD IIIL	24	3 arthrofibrosis, 3 wound infections, 1 revision ligament surgery, 1 ROH, 2 DVT	9 (5 completed)
KD IV	3	None	0

[a]DVT, deep venous thrombosis; KD, knee dislocation; ROH, removal of hardware.

[b]According to Schenck classification.[27]

The most common complication was arthrofibrosis requiring MUA, occurring in 18 (16.7%) of the 108 patients. Time from injury to surgery and completion of staged surgery were significant factors that decreased arthrofibrosis (Table 4), with ORs of 0.99 (95% CI, 0.97-0.998) and 0.11 (95% CI, 0.01-0.88), respectively.

DISCUSSION

The findings of this study showed that smoking, KD III injuries, and staged reconstruction procedures were significant risk factors for complications after reconstruction for MLKIs, while increased time from injury to surgery may be slightly protective. Additionally, increasing time from injury to surgery was slightly protective against arthrofibrosis requiring MUA. The rates of the common complications examined in this review were consistent with those previously reported. The rate of DVT, 1.8%, was similar to the rate reported at another single institution, which was 2%, and the rate of wound infection, 6.5%, was within the previously reported range of up to 12.5%.[1,16]

Smoking has been identified as a significant risk factor for postoperative complications across many surgical procedures, including elective orthopaedic procedures.[18,23,28] Thus, it is not surprising that it is also a significant risk factor for complications after MLK reconstructions. While this study did not look directly at smoking cessation, a previous review showed that longer periods of smoking cessation are more effective for reducing the risk of complications after surgical procedures but with no threshold of time established.[29] However, the timing of MLK

TABLE 3
Patient Characteristics According to Patients With and Without Complications[a]

	Any Complication (n = 32)	No Complication (n = 76)	*P* Value	OR (95% CI)
Age, y	27.1 ± 11.2	30.2 ± 12.3	.22	0.98 (0.94-1.01)
BMI, kg/m^2	28.8 ± 7.4	31.0 ± 8.15	.2	0.96 (0.91-1.02)
Male sex	21 (66)	59 (78)	.2	1.82 (0.73-4.5)
Smoker	13 (42)	14 (18)	**.01**	**3.20 (1.28-8.02)**
Hypertension	1 (3)	11 (14)	.13	0.20 (0.02-1.60)
Diabetes (n = 107)	2 (6)	2 (3)	.36	2.55 (0.34-19.98)
Injury mechanism (n = 107)				
Sports (set as indicator)	13 (41)	30 (40)		
Trauma	16 (50)	37 (49)	.99	1.00 (0.42-2.40)
ULV	3 (9)	4 (5)	.51	1.73 (0.34-8.85)
Other	0 (0)	4 (5)	.99	0.00 (0.00-no upper)
Injury pattern[b]				
KD I (set as indicator)	12 (38)	44 (57)		
KD II	0 (0)	2 (3)	>.99	0.00 (0.00-no upper)
KD IIIL	9 (28)	15 (18)	.19	1.99 (0.71-5.58)
KD IIIM	10 (31)	13 (17)	.08	2.54 (0.91-7.14)
KD IV	1 (3)	2 (3)	>.99	0.00 (0.00-no upper)
Other	0 (0)	1 (1)	>.99	0.00 (0.00-no upper)
Planned staged ligament repair (n = 106)	11 (34)	12 (16)	**.04**	**2.71 (1.04-7.04)**
Completed both repair stages (n = 23)	6 (55)	10 (83)	.15	0.24 (0.035-1.649)
Cartilage injury grade ≥2 (n = 84)	8 (31)	19 (33)	.86	0.912 (0.337-2.473)
Meniscal injury (n = 96)	12 (43)	38 (56)	.25	0.59 (0.24-1.44)
Time from injury to first surgery, days	48.1 ± 49.5	128.1 ± 22.2	<**.01**	**0.99 (0.98-0.998)**
Passive ROM, deg				
<90	5 (24)	5 (10)	.12	3.00 (0.75-11.92)
90-110	2 (10)	3 (6)	.47	2.00 (0.30-13.22)
>110 (set as indicator)	15 (67)	42 (84)		

[a]Data are reported as n (%) or mean ± SD unless otherwise indicated. Sample size = 108 patients unless otherwise indicated. Bolded values indicate statistically significant difference between groups. BMI, body mass index; KD, knee dislocation; OR, odds ratio; ROM, range of motion; ULV, ultra-low energy.

[b]According to Schenck classification.[27]

reconstruction remains controversial, with several previous retrospective and systematic reviews showing that early reconstruction results in better patient-reported outcomes and physical examination findings with the same postoperative knee ROM, while another systematic review showed that delayed reconstruction can produce the better knee stability and decreases the risk for arthrofibrosis (0% with treatment after 3 weeks vs 17% with treatment within 3 weeks).[10,12,19,30] The findings of this study, which has more patients than the previous retrospective reviews and avoids the bias of pooled data that is present with systematic reviews, support increasing the time to surgery to reduce the risk of complications. Further studies are needed to determine the threshold for timing that is best for MLK reconstructions, but based on the findings of this study and those of previous ones, it may be beneficial to counsel patients regarding smoking cessation, even if it requires delaying surgery.

Staged surgery is another point of debate in the treatment algorithm of MLKI, but there are several classifications that have been used to help guide the use of staged surgery based on the injury pattern.[4,5] For example, if a patient has a ACL/PCL/MCL injury in which the examination shows no endpoint to valgus stress, a staged procedure can be considered with early reconstruction/repair of the MCL within 1 week followed by the reconstruction of the ACL/PCL within 3 to 6 weeks later.[6] However, the results of our study suggest that, when possible, it may be better to avoid staging even in these injuries to protect against complications. While staged surgery is an independent risk factor for complication in this study, it is important to recognize that it may be confounded by the complexity of the injuries that are staged: Sixteen of the 23 cases staged in this study were KD III injuries, which in itself significantly increased the risk of complications compared with having a KD I injury. Additionally, completion of a staged procedure was found to be slightly protective against complication in this study, which is consistent with a systematic review that showed that staged procedures resulted in a slightly lower rate of arthrofibrosis requiring intervention compared with acute treatment (15% for staged vs 17% for acute treatment) and a retrospective review that showed a lower rate with staged management as well (5% for staged vs 10% for single procedure).[7,19] It is important to note that neither of the previous studies made direct comparisons between the groups with regard to arthrofibrosis as this study does, making the findings of this study unique. Still, further evidence with a larger cohort of patients is needed to truly determine the effect of staged surgery on complications.

TABLE 4
Patient Characteristics According to Patients With and Without Arthrofibrosis[a]

	Arthrofibrosis Requiring MUA (n = 18)	No Arthrofibrosis Requiring MUA (n = 89)	*P* Value	OR (95% CI)
Age, y (n = 107)	24.4 ± 9.28	30.1 ± 12.3	.08	0.95 (0.90-1.01)
BMI, kg/m^2 (n = 107)	27.2 ± 4.0	31.0 ± 8.5	.07	0.92 (0.85-1.01)
Male sex (n = 107)	15 (83)	64 (72)	.32	0.51 (0.14-1.92)
Smoker (n = 106)	5 (29)	22 (25)	.69	1.27 (0.40-4.00)
Hypertension (n = 106)	0 (0)	12 (13)	>.99	0.00 (0.00-no upper)
Diabetes (n = 106)	0 (0)	4 (4)	>.99	0.00 (0.00-no upper)
Injury mechanism (n = 106)				
Sports (set as indicator)	9 (50)	33 (34)		
Trauma	9 (50)	44 (50)	.58	0.75 (0.27-2.10)
ULV	0 (0)	7 (8)	.99	0.00 (0.00-no upper)
Other	0 (0)	4 (5)	.99	0.00 (0.00-no upper)
Injury pattern[b]				
KD I (set as indicator)	9 (50)	47 (53)		
KD II	0 (0)	2 (2)	.99	0.00 (0.00-no upper)
KD IIIL	4 (22)	19 (21)	.96	0.97 (0.27-3.47)
KD IIIM	4 (22)	19 (21)	.96	0.97 (0.27-3.47)
KD IV	1 (6)	2 (2)	.99	0.00 (0.00-no upper)
Other	0 (0)	1 (1)	>.99	0.00 (0.00-no upper)
Planned staged ligament repair (n = 105)	6 (33)	17 (20)	.2	2.06 (0.68-6.27)
Completed both repair stages (n = 23)	2 (33)	14 (82)	**.04**	**0.11 (0.01-0.88)**
Cartilage injury grade ≥2 (n = 83)	4 (29)	23 (33)	.73	0.80 (0.23-2.83)
Meniscal injury (n = 95)	7 (44)	43 (54)	.44	0.65 (0.22-1.92)
Time from injury to first surgery, days (n = 105)	37.4 ± 42.3	117.8 ± 205.4	**.02**	**0.99 (0.97-0.998)**
Passive ROM, deg (n = 70)				
<90	2 (15)	8 (14)	.78	1.28 (0.232-7.04)
90-110	2 (15)	3 (5)	.21	3.41 (0.50-23.40)
>110 (set as indicator)	9 (69)	46 (81)		

[a]Data are reported as mean ± SD or n (%) unless otherwise indicated. Sample size = 108 patients unless otherwise indicated. Bolded values indicate statistically significant difference between groups. BMI, body mass index; KD, knee dislocation; MUA, manipulation under anesthesia; OR, odds ratio; ROM, range of motion; ULV, ultra-low energy.
[b]According to Schenck classification.[27]

Arthrofibrosis was the most common complication after MLK reconstruction in this study, and a similar pattern as with overall complications was seen with regard to increased time from injury to surgery being protective. A retrospective review examining acute (<3 weeks after injury) versus delayed (>3 weeks after injury) treatment found that 4 of 19 patients treated acutely required MUA for arthrofibrosis, while none of the 12 patients in the delayed group required MUA.[10] While the statistical significance of this difference was not reported, it still supports the findings of this study with delayed surgery resulting in less arthrofibrosis. One possible explanation for this finding could be related to better preoperative physical therapy with more time until surgery, which could result in better postoperative ROM. Additionally, increased time from injury to surgery, which has been shown to reduce the risk for arthrofibrosis in patients undergoing ACLR, may allow for reduced inflammation and swelling in the knee.[13] In this study, the mean time to surgery in the group with arthrofibrosis was approximately 5 weeks compared with approximately 17 weeks in the group without arthrofibrosis. The reasons for delay in the cases that occurred more than 5 weeks from injury included planned delay in surgery, severity of overall injury complex from trauma, and initial trial of nonoperative management. A distinction between these factors was not made in the analysis conducted in this study. Of note, the mean time to surgery was 6 weeks or greater for all KD classifications, suggesting that the severity of injury did not affect the time to surgery.

The main strength of this study is the wide range of factors examined that could affect the rate of complications from patient factors and physical examination findings to surgical considerations. This allowed stronger interpretation of the results since the effect that possible confounding variables (other risk factors) had on complications was analyzed. This study does have some limitations. First, while it reports risk factors for complications associated with reconstruction for an MLKI, this may not necessarily reflect the outcomes associated with these factors. Another limitation is that total preoperative passive ROM was used as a risk factor instead of the terminal limits of preoperative flexion and extension resulting in an inability to identify preoperative contractures, which can significantly affect outcomes. Additionally, preexisting osteoarthritis in the knee and overall limb alignment were not included as part of the exclusion criteria, and this could influence the rate of complications such as arthrofibrosis. The number of patients in

this retrospective review is relatively small, and thus, the significance of certain risk factors may be due to chance. For example, given that a majority of the patients were either KD I or KD III, a separate regression within those groups to compare time with surgery may be able to determine if the classification or the time to surgery were statistically significant. Future prospective studies with a large sample size are needed to determine the effects of surgical timing and staged procedures on outcomes and complications after reconstruction for an MLKI.

CONCLUSION

The findings of this study suggest that smoking, decreased time from injury to initial surgery, and planned staged procedures may increase the rate of complications after operative treatment of MLKI. Further studies are needed to determine which changes in the treatment algorithm are most effective in reducing complication rates.

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