

Western China Classification and Minimally Invasive Surgical Treatment Strategies of the Multiple Ligament Injury Knee

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Abstract: *Objective:* 1. Multiple ligament injuries of the knee (MLIK) often lead to severe injury, with high dysfunction but there is no special classification and corresponding minimally invasive surgical treatment strategy for MLIK, so according to the different degrees of the multiple ligament injury knee, summarize the different types of the multiple ligament injury knee, and develop a systematic classification method suitable for clinical surgeons to quickly understand and master; 2. According to the classification results of the multiple ligament injury knee, the corresponding minimally invasive surgical treatment strategies were developed to facilitate clinicians to make accurate judgment and treatment in a timely manner. *Methods:* 30 cases of the multiple ligament injury knee were summarized in our hospital, and the preliminary classification and minimally invasive surgical treatment strategies were proposed. A total of 50 cases of patients with the multiple ligament injury knee were collected in our hospital. Diagnosis and treatment were conducted according to the preliminary classification and surgical treatment strategies summarized in the early stage. The classification diagnosis and treatment effect were verified after the operation according to knee function score, etc., and the modification was carried out in stages. Finally, 80 cases of multiple ligament injuries of knee joint were summarized. *Results:* A systematic classification method and minimally invasive surgical treatment strategy were developed for the multiple ligament injury knee. *Conclusion:* The classification method and minimally invasive surgical treatment strategy for the multiple ligament injury knee are convenient for general clinical surgeons to quickly understand and master, make accurate judgment and treatment, and suitable for clinical popularization and application.

Keywords: Multiple Ligament Injury Knee, Classification, Minimally Invasive Surgical Treatment Strategies

1. Introduction

Multiple ligament injuries of the knee (MLIK) in China are defined as injuries of three or more major ligaments of the knee due to trauma. The damaged major ligaments include: anterior cruciate ligament, posterior cruciate ligament, lateral collateral ligament and medial collateral ligament, often appear the knee joint dislocation, this damage has the complexity and diversity [1-3], often with the popliteal vessels and tibial nerve and peroneal nerve injury, perioperative complications, postoperative limb often severe dysfunction, long-term prognosis is poorer, high morbidity [4, 5]. In typical knee dislocation, both anterior

and posterior cruciate ligaments are ruptured, accompanied by third-degree damage to the lateral collateral ligament structure and the corresponding joint capsule [6-7]. However, currently there is no classification and corresponding minimally invasive surgical treatment strategy for multiple ligament injuries of the knee joint. This study will summarize 80 cases of multiple ligament injuries of the knee joint treated in our hospital, and formulate the classification method and treatment strategy suitable for general clinical surgeons to understand and grasp.

2. Data and methods

2.1. General Information

2.1.1. Inclusion Criteria

- (1) Multiple ligament injuries of the knee, three or more main ligament injuries (anterior and posterior cruciate ligament, lateral and medial collateral ligament).
- (2) Multiple ligament damage merger or not (inside and outside structure after knee joint injuries, fractures around the knee joint, nerve damage, thrombosis, and vascular injury, in which one or more).

2.1.2. Exclusion Criteria

- (1) Not three or more of the four groups of knee ligament were damaged.
- (2) Severe osteoarthritis and joint dysfunction before knee ligament injury.

2.1.3. Outcome Indicators

- (1) Lysholm knee function score;
- (2) IKDC of knee function evaluation;
- (3) Postoperative knee motion;
- (4) Complication rate.

2.2. General Patient Condition

From January 2015 to January 2020, 80 patients with multiple ligament injuries of the knee were selected for treatment in our hospital. There were 55 males and 25 females with an average age of 52 ± 3.5 years. All patients were followed up for more than 1 year. Among them, 31 patients (38.75%) suffered simple multiple ligament injuries, and 49 patients (61.25%) suffered posterior medial and lateral knee

injuries, fractures, thrombosis and other problems. The operation was performed by the same surgeon and the rehabilitation exercise was performed by the same therapist.

3. The Implementation Steps

3.1. The First Stage

30 cases of multiple ligament injuries of knee joints in our hospital during the early period (January 2015-January 2017) were collected, and preliminary classification and minimally invasive surgical treatment strategies were proposed based on current domestic and foreign treatment plans and postoperative knee function scores.

3.2. The Second Stage

System overall collection (February 2017 - January 2020) to our frequent treatment knee ligament injury patients 50 cases, according to the preliminary summary of the preliminary classification and surgical treatment strategies for diagnosis and treatment, according to the postoperative knee function score to verify the classification diagnosis and minimally invasive surgical treatment effect, and every 3 month summary of classification and treatment plan, adjust or modify as appropriate.

3.3. The Third Stage

The 80 cases of multiple ligament injuries of the knee were summarized and formulate systematic classification methods and minimally invasive surgical treatment strategies for multiple ligament injuries of the knee.

4. The Results: General Treatment and the Classification of the MLIK

Table 1. The classification of the MLIK.

classification of multiple ligament injuries of the knee (MLIK)	
ML-I-A1	injury of three major ligaments
ML-I-A2	injury of three major ligaments + injury of other posterior medial and lateral structures
ML-II-A1	Injury of three major ligaments+ (F, N, B, T)
ML-II-A2	injury of three major ligaments + injury of other posterior medial and lateral structures + (F, N, B, T)
ML-III	Injury of four major ligaments + injury of other posterior medial and lateral structures
ML-IV	Injury of four major ligaments + injury of other posterior medial and lateral structures+ (F, N, B, T)

1. The main ligaments of the knee include: anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL) and lateral collateral ligament (LCL).
2. Other posterior-lateral structures include: Posterolateral joint capsule, popliteal tendon, popliteal fibular ligament, biceps tendon, iliotibial band, external Lateral patella femoral ligament.
3. Other posterior-medial structures include the posterior medial joint capsule, the posterior oblique ligament, and the medial patellofemoral ligament.
4. Fracture was represented by F, nerve injury was represented by N, vascular injury was represented by B, thrombosis (lower limb middle artery and large artery, deep vein thrombosis) are represented by T. (F, N, B, T) can occur separately or simultaneously.

In 80 patients with multiple ligament injuries of the knee joint, the active functional exercise of the quadriceps femoris muscle was instructed before surgery, and the surgery was performed about 10 days after injury on average (except emergency surgery). All the surgeries were completed in one stage, and the operation time was 2 hours and 35 minutes on average. On the first day after the operation, active straight

leg elevation exercise was started, 10 days after the operation, passive flexion and extension exercise, the average time of functional exercise was 15 days. None of the patients in this group had vascular and nerve injury after surgery (except those who had been injured before surgery) or deep venous thrombosis of lower limbs (except those who had formed thrombosis before surgery). Postoperative wound infection

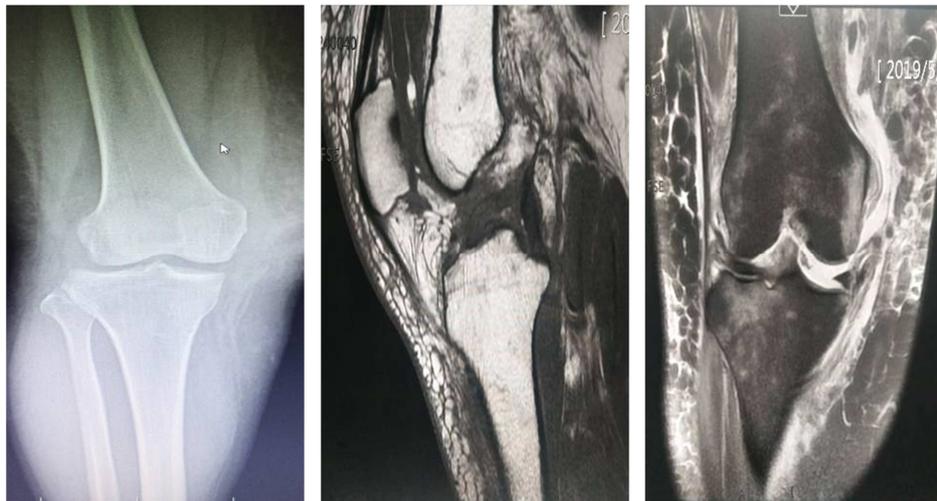
occurred in one case at the site of tendon removal, which healed after debridement, and the incidence of complications was 0.91%. All patients were followed up for 12-24 months, with an average of 16 months. The range of motion of the knee was $(122.8 \pm 12.5)^\circ$, the difference was statistically significant ($t=19.784, P=0.000$), and the Lysholm score was (86.3 ± 5.6) , the difference was statistically significant

($t=43.345, P=0.000$). IKDC score was (88.9 ± 6.8) , and the difference was statistically significant ($t=38.203, P=0.000$). By summarizing the 80 patients with multiple ligament injuries of the knee joint, the classification of MLIK was developed as shown in Table 1, and an example of the classification was shown in Figure 1.

Figure 1 Examples of MLIK classification.



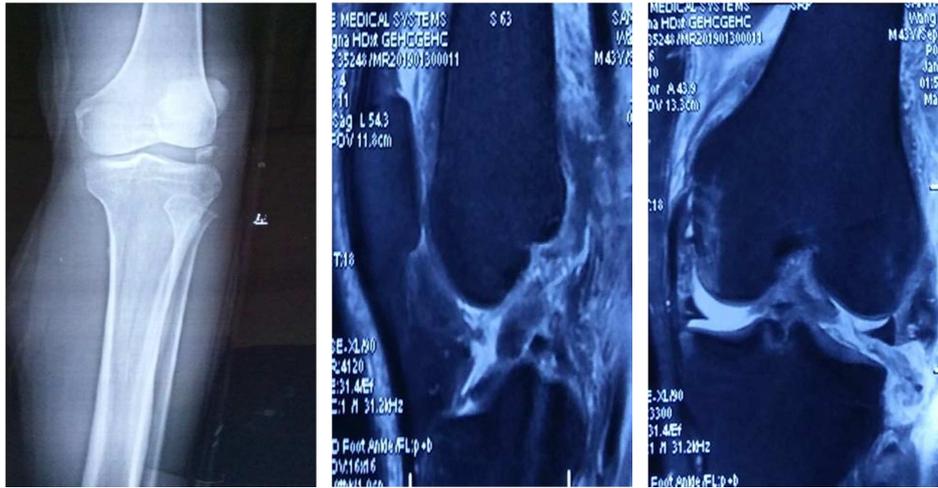
ML-I-A1 (ACL and PCL and MCL injury)



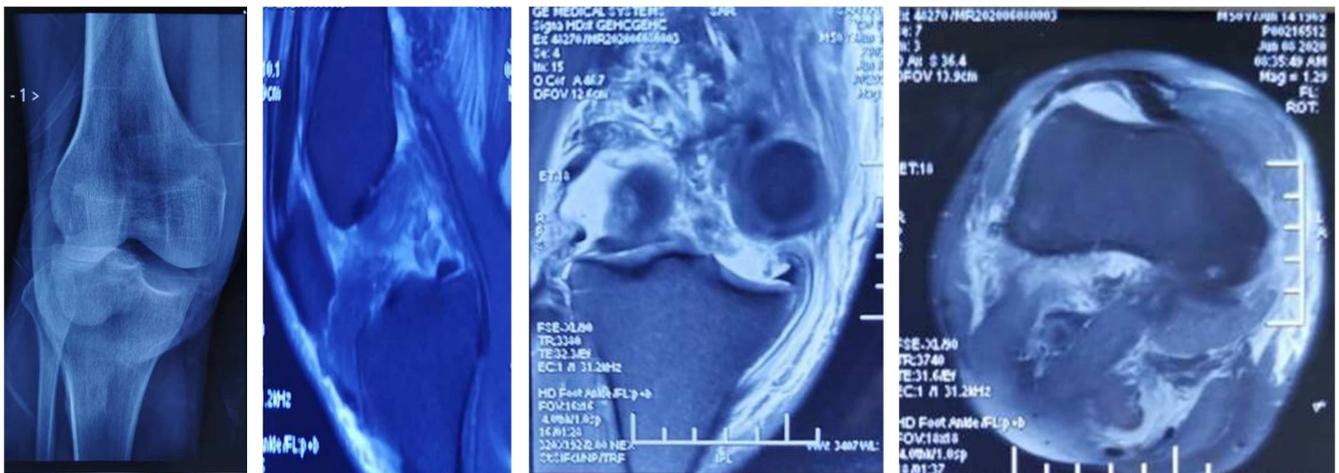
ML-I-A2 (ACL and PCL and MCL and posterior medial joint capsule and medial patellofemoral ligament injury)



ML-II-A1 (ACL and PCL and LCL and peroneal nerve injury)



ML-II-A2 (ACL and PCL and LCL and popliteal tendon injury, fibular head avulsion fracture, peroneal nerve injury)



ML-III (ACL and PCL and MCL and LCL injury, posterior medial joint capsule and medial patella femoral ligament)



ML-IV (ACL and PCL and MCL and LCL injury, posterior medial joint capsule, popliteal vascular injury)

Figure 1. MLIK classification is illustrated.

- (1) Initial screening according to MLIK, eligible entry into minimally invasive surgical treatment Strategies in table 2. From the table 2, the doctors can confirm which ligment injuries into the Minimally invasive surgical treatment strategy.
- (2) According to MLIK classification, the corresponding minimally invasive surgical treatment strategy was

- developed, In table 3. From the table 3, The doctors can easily master the treatment of the MLIK.
- (3) Emergency surgery is required in Table 3 is shown in Figure 2. From the Figure 2, The doctors can know the severe complication of the MLIK, which should be emergency surgery.



Figure 2. a: popliteal vascular injury b: compartment syndrome c: internal femoral condyle entrapment in the joint capsule d: popliteal artery thrombosis.

Table 2. Preliminary screening table of the MLIK.

Preliminary screening table of MLIK	
Open knee ligament injury	Debridement and suture tendon repair were performed in emergency, and tendon reconstruction surgery was considered in the second stage according to wound healing and joint stability
MRI, DR, CT and vascular color ultrasound examination of the knee showed multiple ligament injuries, but no vascular injury, thrombosis, fracture or nerve injury. Physical examination showed good joint stability, and the feeling of blood supply to the extremities was good	Non-operative treatment, knee brace fixation
MRI, DR, CT, and color doppler ultrasound examination of the knee revealed multiple ligament injuries with one or more of them	If one or more of the above conditions are met, one or more of the surgical treatments are selected to enter the minimally invasive surgical treatment strategy
1. Knee joint forward instability (ACL)	
2. Knee instability backward, and tibial plateau moved back >10mm, located behind the femoral condyle, with or without knee bend 90 degree external rotation test (+) (PCL)	
3. Eversion medial gap in straight knee position >10mm (MCL)	
4. varus lateral gap in straight knee position >10mm (LCL)	
MRI, DR, CT and color doppler ultrasound examination of the knee suggested multiple ligament injuries with one or more of them	If one of the above conditions is met, surgical treatment is selected and enter the minimally Invasive surgical treatment strategy
1. Fractures around the knee joint	
2. Nerve damage	
3. Vascular damage	
4. Thrombosis	
Previous MLIK of the knee joint, joint instability, limited flexion and extension function, flexion <90 degrees, extension difference >10 degrees	Rehabilitation exercise to knee flexion >110 degrees, 0-5 degrees of extension difference into minimally invasive surgical treatment strategy

Table 3. Minimally invasive surgical treatment strategy of the MLIK.

Minimally invasive surgical treatment strategy of MLIK	
ML-I-A1	Total arthroscopic anterior and posterior cruciate ligament reconstruction and limited incision repair or reconstruction of medial and lateral collateral ligaments were performed in one stage
ML-I-A2	Total arthroscopic anterior and posterior cruciate ligament reconstruction, limited open medial and lateral collateral ligament repair or reconstruction, and posterior medial and lateral structural repair were performed in one stage
ML-II-A1	Repair or reconstruction of vascular injury and external stent fixation were performed in the emergency department (within 6-8 hours), followed by arthroscopic ligament surgery 3-6 months later.
ML-II-A2	Thrombolectomy (arterial thrombosis) or placement of inferior vena cava filter (venous thrombosis) was performed in the emergency room (10-14 days), followed by arthroscopic ligament reconstruction, repair or reconstruction of the medial and lateral collateral ligaments, fracture reduction and fixation, and nerve exploration repair.
ML-III	Repair or reconstruction of vascular injury and external stent fixation were performed in the emergency department (within 6-8 hours), followed by arthroscopic ligament surgery 3-6 months later.
ML-IV	Thrombolectomy (arterial thrombosis) or placement of inferior vena cava filter (venous thrombosis) was performed in the emergency department (10-14 days), followed by arthroscopic ligament reconstruction, medial and lateral collateral ligament repair or reconstruction, posterior medial and lateral structural repair, fracture reduction and fixation, and nerve exploration repair.

Supplementary notes:

1. For patients with MLIK combined with compression of the femoral condyle into the medial joint capsule and unable to reduce, regardless of the above type, limited incision or arthroscopic joint reduction, medial joint capsule and lateral collateral ligament repair should be performed in emergency (within 6-8 hours), and anterior and posterior cruciate ligament reconstruction or repair should be performed 10-14 days later.
2. For multiple ligament injuries of the knee combined with the formation of compartment syndrome, regardless of the above type, compartment dissection and decompression were performed in emergency (within 30 minutes), followed by ligament surgery in the second stage (4-8 weeks later).

5. Case Examples

Ms. Yao, female, 50 years old, was admitted to the hospital due to "right knee joint pain and limited movement for 1+ hour caused by car accident". She immediately felt right knee joint dislocation accompanied by severe pain. For further diagnosis and treatment, she came to our hospital as "right knee joint dislocation accompanied by ligament injury". Physical examination: right knee valgus accompanying swelling, knee active and passive activities limited, knee joint rigidity in half buckling position of 35 degrees, patellar subluxation, Lachman test (+), turn over the stress test is positive, both inside and outside acromegaly blood supply, toes back stretch function exists, knee MRI tip: before and

after the cruciate ligament and lateral collateral ligament, patellofemoral ligament damage, etc. Preoperative diagnosis: 1. Multiple ligament injuries of the right knee joint, classification (ML-III): 1. (1) PCL injury (2) ACL injury (3) MCL injury (4) LCL injury (5) medial patella femoral ligament injury 2. Dislocation of right knee 3. Injury of medial and lateral meniscus of right knee 4. Dislocation of lateral patella of right knee. Ten days after the injury, arthroscopic anterior and posterior cruciate ligament reconstruction of the right knee, limited open medial and lateral collateral ligament repair, and medial patella femoral ligament repair were performed in one stage in Figure 3.



Figure 3. a: Preoperative anteroposterior radiograph of knee joint b: Preoperative lateral view of knee joint c: Postoperative anteroposterior radiograph of knee joint d: Anteroposterior image of postoperative knee injury e: Lateral image of postoperative knee injury.

6. Discussion

MLIK can lead to dislocation of the knee, which is a rare but severe injury [8]. The incidence of knee dislocation, once considered to be low, is significantly higher than in the past. The recognition of self-reduced knee dislocation makes physicians more aware that multiple ligament injuries of the knee must be regarded as the main treatment for knee dislocation [9]. Therefore, multiple ligament injuries are the first problem that clinicians need to recognize. However, there is no specific classification for multiple ligament injuries of the knee at present, but only for dislocation of the knee, namely, Shenck classification. This classification method does not systematically classify multiple ligament injuries, commonly associated fractures, vascular and nerve injuries, and thrombosis. Moreover, KD I and KD II are mostly reported as simple cruciate ligament injuries in clinical practice, which is not conducive to guiding clinicians to understand multiple ligament injuries and severe complications. Huaxi Professor Li Jian [10] developed huaxi classification method for knee dislocation with multiple ligament injuries, but this method was too complicated to be easily mastered by clinicians, and there was no specific explanation for the treatment of multiple ligament injuries of knee joints in the reported literature.

MLIK accompanied by serious ligament damage often leads to joint dislocation combined, but about 50% of the dislocation in the field has been reset by oneself, for the

clinical doctors early to judge the severity of the knee joint damage bring interference and misjudgment, influence the treatment effect, and the basic-level hospitals in the county and no special sports medicine doctor, most is judged by general surgeon or orthopedic surgeon, This further increases the misjudgment of doctors for MLIK and fails to make timely and correct diagnosis and treatment. In this study, the classification was named as "multiple ligament injuries of the knee", and the degree of MLIK was systematically classified for the first time. The classification included not only the injuries of "four major ligaments", but also the injuries of "other ligaments and structures of the posterior, internal and lateral sides", making the classification comprehensive and specific. classification of multiple ligament injury often merge "fracture, nerve damage, vascular injury [11, 12] and thrombosis" into the classification, in which more emphasis on "vascular injury, thrombosis", make the classification more clinical significance, because for the treatment of multiple ligament damage, ligament repair and reconstruction is not difficult, but the severe comorbidities associated with them are often not recognized early enough, resulting in a high disability rate.

As for the optimal timing of MLIK surgery, most scholars believe that early surgery (within 3 weeks after injury) is significantly better than delayed surgery in improving joint activity and function [13-14]. When combined with severe fracture, important vascular and nerve injury, compartment syndrome and other emergency surgical indications, immediate surgery is required. For MLIK without

indications of emergency surgery, symptomatic treatment can be performed first, and elective surgical treatment can be performed within 3 weeks after the patient's systemic and local conditions improve. In this study, treatment strategies were systematically formulated according to the degree of MLIK: It mainly treated multiple ligament injuries with minimally invasive knee arthroscopy and treated the lateral collateral ligament and other posterior medial and lateral ligaments with limited incision, it is important for anatomic repair and ligament bracing [15]. In the treatment strategy, emergency treatment plans were formulated for multiple ligament injuries combined with vascular injury, thrombosis, and femoral condyle compression. For example, microvascular repair treatment, minimally invasive artery thrombus removal, minimally invasive inferior vena cava mesh placement, arthroscopic reduction, etc., and second stage ligament surgery can facilitate the first-line doctors to timely select the plan and make the correct treatment. Minimally invasive concepts, such as arthroscopy and limited incision, are used throughout the strategy to strengthen the protection of blood supply to the ligament and surrounding tissues during treatment, which is conducive to ligament healing and reduces the occurrence of complications.

The deficiency of this study is that the number of cases is relatively small, the service population is mainly agricultural workers, and the follow-up time is relatively short. Under the guidance of the current classification and treatment plan, the number of cases, follow-up time and functional evaluation should be continuously increased to improve the classification and minimally invasive surgical treatment plan of MLIK.

7. Conclusion

Through 80 patients cases of the MLIK in our hospital, the classification and minimally invasive surgical treatment are effective and practical. This classification can enhance the understanding of early complications of multiple ligament injuries by first-line doctors, and make correct treatment as soon as possible to reduce the disability rate.

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