Overview of Treatment Methods for Anterior Cruciate Ligament (ACL) Injuries in the Knee Joint

Jialin Xu
School of Nursing, Inner Mongolia MinZu University, TongLiao, Mongolia, China

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Abstract: Anterior cruciate ligament (ACL) injuries are a significant clinical issue affecting joint function. This article systematically reviews the epidemiological background, diagnostic methods, treatment strategies, and rehabilitation approaches for ACL injuries. Epidemiological analysis shows that 70% of ACL injuries result from non-contact injuries in sports, primarily manifesting as sudden swelling, pain, and joint instability in the knee, along with secondary meniscal injuries. Diagnosis mainly relies on MRI (accuracy > 90%) combined with X-rays. Treatment strategies are divided into surgical reconstruction and conservative treatment. Surgical reconstruction is suitable for young, active patients and professional athletes, as it can effectively restore knee joint stability and prevent secondary meniscal injuries, but it carries risks of limited range of motion and complications such as infection. Conservative treatment is suitable for patients with low-intensity activities, but long-term follow-up shows that 40% require later reconstruction. Treatment decisions need to comprehensively Adjust training through a phased rehabilitation plan.

1 EPIDEMIOLOGICAL BACKGROUND OF ACL

The anterior cruciate ligament (ACL), as a core structure maintaining the dynamic stability of the knee joint, often leads to joint biomechanical disorders, loss of motor function, and increased risk of secondary osteoarthritis when injured. With the popularization of sports and the increase in traffic injuries, the incidence of ACL injuries has been rising year by year, becoming a key issue in the fields of orthopedics and sports medicine.

The knee joint is the most complex hinge joint in the human body, and its stability relies on the coordinated regulation of the anterior and posterior cruciate ligaments. Among them, the anterior cruciate ligament (ACL) serves as a key stabilizing structure, originating from the anterior intercondylar area of the tibia, connecting the femur and tibia, and inserting into the medial aspect of the lateral condyle of the femur. It extends obliquely upward and outward with an average length of 31-38mm and an average width of 10-12mm, it extends diagonally outward and upward, forming an oval cross-section (Ao et al, 2001). Its unique anatomical orientationprovides relative stability to the joint, preventing the tibia from moving forward relative to the femur, and it is also the structure most susceptible to injury during knee joint damage.

The mechanisms of ACL injury present two patterns: high-energy trauma (such as traffic accidents) accounts for about 27%, for example, ACL injuries caused by rapid twisting movements of the knee joint due to uneven ground. Low-energy non-contact injuries (such as in sports) dominate, accounting for about 70% (Ao et al, 2001; Waldén et al, 2022; Della Villa et al, 2020). These are also known as sports injuries and often occur in basketball and football during sudden deceleration, changes in direction, rotation, or jumping.

According to the progression of the condition, ACL injuries can be divided into three stages: the acute phase (less than 3 weeks), where patients often experience sudden joint swelling, severe pain, and restricted movement; the subacute phase (3 weeks to 3 months), where pain subsides but joint instability remains; and the chronic phase (more than 3 months), which is characterized by recurrent joint effusion, typically manifesting as the "giving way" phenomenon during movement and secondary meniscus injuries.

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2 ACL DIAGNOSIS

According to arthroscopy, ACL injuries can be classified into four grades. A normal ACL has a normal shape, represented by 0 degrees. Grade 1: The ACL shape is basically normal, with ligament damage; Grade 2: The ACL is slightly lax, with partial tearing; Grade 3: The ACL is lax, with most of the ligament torn; Grade 4: The normal shape disappears, the ligament is extremely lax, and the ligament is completely torn.

ACL (anterior cruciate ligament) injuries are usually first assessed through small tests such as stress tests, drawer tests, and pivot shift tests, but are generally confirmed through MRI (magnetic resonance imaging) and X-rays. The most commonly used diagnostic method is MRI diagnosis rate exceeds 90%, which utilizes nuclear magnetic resonance for comprehensive scanning. A torn anterior cruciate ligament will show specific signals, much like seeing a red flag (Liao, 2020). In addition, MRI can also assess whether there are any associated meniscus, cartilage, or other ligament injuries in the knee joint. Another advantage is that it does not involve any radiation, although sometimes MRI may miss parts of the ligaments, leading to missed diagnoses (Ao et al, 2022). X-rays are mainly used to rule out associated fractures, such as Segond fractures, which are very common, especially in small hospitals. This is because they are inexpensive and very suitable for observing bones. However, due to their radiation risks, they may cause adverse reactions in patients (Shea and Carey, 2015; Wang and Sun, 2023). Clinically, doctors usually combine MRI and X-ray results with the patient's clinical symptoms and signs to comprehensively assess the condition of ACL injuries and formulate the most appropriate treatment plan. In summary, MRI and X-ray examinations play an important role in the diagnosis of ACL injuries, but they still need to be combined with clinical manifestations for a comprehensive evaluation.

3 ACL TREATMENT

The treatment strategies for anterior cruciate ligament (ACL) tears in the knee joint are mainly divided into two categories: surgical reconstruction and conservative treatment. Surgical reconstruction, centered on minimally invasive techniques, restores the biomechanical stability of the knee joint through arthroscopically assisted ligament grafting, especially suitable for young, active patients with high athletic demands and secondary meniscus injuries. Non-surgical treatment is based on physical therapy protocols and is mainly suitable for individuals with incomplete tears, low activity demands, or those with surgical contraindications. Whether it is ACL reconstruction surgery or conservative treatment, the core of both therapies focuses on restoring joint functional stability, preventing post-traumatic osteoarthritis (OA), alleviating pain, and improving the patient's long-term quality of life (John et al, 2025).

3.1 Surgical Treatment

3.1.1 Surgical Method

The most common arthroscopic surgeries are anterior cruciate ligament (ACL) reconstruction and meniscus tear repair. There are two menisci inside the knee, which help protect the articular cartilage and allow the bones to glide smoothly over each other during movement. They also act as shock absorbers, distributing the load across the knee. Therefore, it is very common for the ACL and meniscus to be injured simultaneously, especially among athletes. Of course, elderly patients can also experience meniscus tears. Research shows that over 60% of patients with ACL tears also have meniscus tears. Depending on the sport, the likelihood of ACL tears in women is 2 to 6 times that in men (Toth et al, 2001). When the ACL is completely torn, surgeons must replace it with a graft. The graft can be obtained from the patient's own knee or from donated tissue. Generally speaking, autografts are used for adolescents and young athletes, while allografts are used for older patients (Paschos et al., 2018).

The core goal of ACL injury reconstruction treatment is to restore knee joint stability and function. The main surgical indications include: 1) young and middle-aged patients with knee joint dysfunction, 2) significant knee joint instability or abnormal internal and external rotation, and 3) cases with obvious anatomical displacement. In terms of reconstruction method selection, both single-bundle

and double-bundle reconstructions are clinically effective options. Studies have shown that there is no significant difference between the two techniques in restoring knee joint stability. However, it is noteworthy that the positive rate of the axial shift test after double-bundle reconstruction is significantly lower than that after single-bundle reconstruction (Zhu et al, 2013; Xiang et al, 2019). Nevertheless, clinical decisions should comprehensively consider various factors such as the patient's age, occupational characteristics, comorbidities, and activity demands.

3.1.2 Postoperative Complications

The spectrum of complications after ACL reconstruction is similar to those of conventional knee arthroscopy, mainly including limited joint mobility, poor wound healing, joint cavity infection, and deep vein thrombosis, among others (Sun et al, 2014). A stratified prevention and control strategy should be adopted for the aforementioned complications:

Regarding the limitation of knee joint mobility after surgery, it is recommended to strictly control the surgical indications before the operation, ensure precise anatomical positioning during the operation, implement early functional exercises after the operation, and it is suggested that passive mobility after 4 weeks and active mobility after 6 weeks should reach ≥90° (Ekhtiari et al, 2017). In response to the risks of poor incision healing and postoperative infections, a comprehensive preoperative assessment of the patient's skin condition and infection risk indicators is required to choose the appropriate timing for surgery. Additionally, strict adherence to aseptic principles during the operation is essential, with gentle handling and attention to protecting the soft tissues around the incision. Postoperative close monitoring of inflammatory indicators is essential. When adverse reactions such as poor wound healing and knee joint infections occur, early intervention measures such as antibiotics and joint clean -ing should be used for treatment. Postoperatively, simultaneously strengthen the prevention of thrombosis, and closely monitor the patient's coagulation function and lower limb circulation status throughout the perioperative period. For high-risk patients, it is recommended to use mechanical prevention, such as intermittent pneumatic compression devices, in conjunction with a comprehensive regimen of anticoagulant medication.

3.2 Non-Surgical Treatment

Conservative treatment for anterior cruciate ligament (ACL) injuries requires first assessing the patient's joint stability and its impact on motor function. Typical manifestations of joint instability include "giving way" of the legs while walking, and limitations in rapid running and sudden stop actions. If the patient can effectively avoid symptoms of joint instability through adjustments in exercise intensity or targeted functional training, conservative treatment is indicated.

Conservative treatment can include the use of topical traditional Chinese medicine, shortwave therapy, massage, local blockade, wearing a brace for 2-3 months, and systematic rehabilitation training. For example, chiropractic therapy requires a combination of mechanical and manual operations to diagnose and treat, and to enhance the body's natural self-healing abilities. The benefits of chiropractic therapy include: improving mobility and flexibility, enhancing balance, and strengthening supporting muscles. Chiropractors can also provide specific rehabilitation exercises and physical therapy tailored to individuals, focusing on the strength, flexibility, and stability of the knees and surrounding muscles. For cases of simple ACL partial tear or those not causing acute joint instability, a long leg cast can be used to fix the affected knee at a 30° flexion position for 6 weeks. After 3 days of casting, isometric contraction training of the quadriceps should begin to prevent disuse muscle atrophy.

3.3 Compare

Regarding the progression of osteoarthritis and the ability to return to sports after treatment, existing studies indicate that there is no significant difference in long-term prognosis between surgical and non-surgical treatments (Chalmers et al, 2014). ACL reconstruction itself cannot prevent the progression of osteoarthritis; meniscus removal or meniscus injury is the main cause of the progression of knee osteoarthritis. But during the non-surgical treatment of ACL injuries, many patients eventually experience meniscus damage (Smith et al, 2014). Long-term follow-up studies have shown that ACL reconstruction can prevent meniscus injuries. In terms of returning to sports, although there is no statistical difference in the overall effectiveness of the two treatment methods, clinical outcome analysis shows that surgery has more advantages. Frobell et al. (Frobell et al, 2010) conducted a controlled study that showed no significant difference in functional

recovery between the two groups after 2 and 5 years of follow-up. However, 40% of the non-surgical group required subsequent reconstruction, and 32% needed a second surgery due to meniscus injuries. In addition, the study by Bergerson et al. (Bergerson et al, 2022) indicates that the surgical group showed significantly better knee joint function scores, symptom improvement, and quality of life at 1, 2, 5, and 10 years of follow-up compared to the non-surgical group. Although non-surgical treatment has application value in specific cases, its use should be approached with caution from the perspective of preventing secondary injuries. For recurrent knee instability, high-intensity sports demands, and younger patients, ACL reconstruction remains the recommended option.

4 ACL REHABILITATION

4.1 Postoperative Rehabilitation Principles

Postoperative braces are not conventionally necessary, but they can be used short-term (1-2 weeks) for patients with psychological needs; long-term use may limit functional recovery. Theoret and Lamontagne's (Théoret and Lamontagne, 2006) study found that wearing a brace reduces the active range of motion in the knee joint and increases hamstring activity. Andersson et al. (Andersson, et al, 2009) reported that the use of functional knee braces postoperatively does not affect the prognosis of patients after ACL reconstruction. If a functional knee brace is to be prescribed after ACL reconstruction, a cheaper knee sleeve or hinged knee brace would be sufficient.

Neuromuscular training is being increasingly applied in rehabilitation and sports-specific training after anterior cruciate ligament reconstruction. At the same time, people have also recognized that to prevent sports-related knee injuries or re-injuries, knee joint stability can be improved through enhanced neuromuscular control (Hewett, et al, 1999). Risberg et al (Risberga, et al, 2004) designed a neuromuscular training program for patients after ACL reconstruction. In a 6-month follow-up, the overall knee joint function scores in the neuromuscular training group significantly improved compared to the conventional strength training group. But its effect is limited and should not replace strength and range of motion training.

Keays et al. (Keays et al, 2006) compared 12 subjects with chronic unilateral ACL deficiency who underwent a home exercise program with a control group. They found that after 6 weeks of the program, the exercise group showed significant improvements in muscle strength, agility, and flexibility. They recommended that all patients with ACL deficiency should participate in preoperative physical therapy before ACL reconstruction. Home rehabilitation is effective for patients with high compliance and requires the combination of visual and textual guidance, regular remote feedback, and emergency follow-up mechanisms. Its effectiveness is comparable to outpatient supervised rehabilitation (Saka, 2014; Risberga et al, 2004).

Enhancing confidence and rebuilding the "athlete role" in research has found that after ACL reconstruction, patients who engage in functional exercises simulating sports movements early in rehabilitation are more likely to return to sports. Functional training is more likely to improve patients' confidence and self-efficacy, and it helps them rebuild the "athlete role" more quickly during their targeted sports training. Additionally, shortening postoperative care can improve patients' function and reduce fear of movement (Brewer et al,1993; Langford et al,2009; Nyland et al,2005).

4.2 Postoperative Recovery Phase and Exercise Methods

Postoperative rehabilitation can be divided into six progressive stages, and the exercise plan should be scientifically arranged based on the postoperative timeline: the first 0-2 weeks post-surgery should focus on controlling acute inflammation, primarily using ice packs, elevating the affected limb, and performing ankle pump exercises. During weeks 3-5, the focus shifts to restoring basic muscle strength and joint mobility, with wall sits and glute bridges being introduced; during weeks 6-8, the emphasis moves to enhancing lower limb stability, with Bulgarian split squats being added. Swimming (freestyle or water jogging) can be resumed 8 weeks post-surgery. During the 9-12 week transition period, start low-intensity enhancement training, such as box jumps and progressive skipping (transitioning from both sides to one side); in the early 3-5 months of the return-to-sport phase, focus on rebuilding endurance and coordination by gradually adjusting intensity through intermittent walking/jogging training (e.g., transitioning from 5 minutes of walking + 1 minute of jogging to full jogging).After 6 months, enter the unrestricted exercise period, where multidirectional pivot jumps and non-contact competitive training are

required, ultimately achieving full-intensity specialized exercise adaptation (Kruse et al, 2012).

5 CONCLUSIONS

After an anterior cruciate ligament (ACL) injury, doctors and patients should comprehensively consider factors such as the extent of the injury and the patient's age when choosing a treatment method and jointly participating in a rehabilitation plan. Regardless of the treatment strategy adopted, it should address the injury, overcome psychological barriers to movement, restore knee joint function, minimize the occurrence of complications, and optimize long-term quality of life. Although surgical reconstruction remains the mainstream solution for severe ACL injuries, However, non-surgical rehabilitation has shown potential in some patients. Although both approaches have their own advantages and disadvantages, the author believes that post-ACL injury treatment should strengthen patient care, closely monitor the patient's temperature, breathing, and other conditions, pay close attention to the skin condition around the incision to prevent postoperative complications, and adhere to sterile procedures when changing medications. If unfortunately infected, timely treatment should be administered to reduce adverse reactions. At the same time, actively pay attention to the patient's psychological state, listen to their needs, and boost their confidence. In the future, it is also necessary to combine precision medicine with dynamic functional assessment to optimize treatment methods and improve joint health levels. If unfortunately infected, timely treatment should be administered to reduce adverse reactions. At the same time, actively pay attention to the patient's psychological state, listen to their needs, and boost their confidence. In the future, it is also necessary to combine precision medicine with dynamic functional assessment to optimize treatment methods and improve joint health levels.

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