Proceedings of ICBioMed 2024 Workshop: Computational Proteomics in Drug Discovery and Development from Medicinal Plants
DOI: 10.54254/2753-8818/65/2024.LA18202

Overview of Anterior Cruciate Ligament Injury Diagnosis and Treatment

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Abstract. The anterior cruciate ligament (ACL) is crucial for maintaining knee joint stability and is a common site of injury, especially among professional athletes engaged in high-intensity sports. Treatment of ACL injuries ranges from conservative approaches to surgical interventions, with severe injuries typically necessitating surgical reconstruction. ACL reconstruction (ACLR) is considered the gold standard for treating ACL injuries. ACL repair techniques have been increasingly applied in clinical settings, aiming to preserve ACL remnants and minimize tissue trauma. Dynamic intraligamentary stabilization (DIS) and bridge-enhanced ACL repair (BEAR) are two emerging repair techniques. DIS uses a spring device to maintain knee stability and promote biological healing of the ACL. BEAR involves using an implant and the patient's blood to stimulate ligament healing, showing promising postoperative recovery. Biological enhancement repair techniques employ stem cells and growth factors to promote ligament recovery, offering potential clinical applications.

Keywords: ACL, Injury, Diagnosis.

1. Introduction

The anterior cruciate ligament (ACL) is one of a pair of cruciate ligaments. It is composed of two crossed cruciform ligaments. The most common injury of ACL is the ACL tear. ACL tear is familiar among people especially athletes. It will occur when the ACL gets stretched, torn totally or partly on account of the sudden change in direction of the knee making the knee to rotate inwards. Patient will feel acute pain and hear the sound of tearing when they are torn. Also, they cannot balance themselves when walking or moving which they lose the stability. This symptom may last even the swelling and pain is reduced. The knee will be swelling as well, due to the hematocele of the joint. Sometimes, if the injury is really crippling, there might be additional damage to other part of the knee like meniscus, cartilage articularis and other ligaments. Doctors have classified the level of the ACL injury based on the severity of the tear. There are three sorts of tear which are respectively called grade1, grade2 and grade3. The grade1 is the least severe one injury and grade3 is the most severe injury. The grade1 involves the partial overstretch of the ACL that the ligament is still intacted in structure so that does not require the surgery essentially in general. The grade2 injury is the partially tearing of the ACL. Patients can either choose to have a surgery or conservative treatment. The grade3 injury, the most serious one, under most circumstance, doctor will have a surgery as measure in order to make the patients recover better. A surgery is like rebuilding of the ligament and the non-surgical intervention uses physical therapy to tackle with pain, mobility, and strength. As it is very popular among the people, over all ages and genders,

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there will be 68.6 people suffer from ACL injuries in every 100,000 people. For male, it is much more easily to get ACL injury compare to female for the ratio of 81.7: 100,000 for male and 55.3: 100,000 for female. What is more, age is a significant factor of getting ACL tearing. The peaks of the age of the ACL tearing occur at age between 19 and 25 (with the ratio 241 per 100,000) for male and between 14 to 18 (with the ratio 227.6 per 100,000) for female. Also, as for a great contributor to the number of the patients who suffer from the knee injuries, about half of the people who have knee injuries are the sufferers of the ACL injuries [1]. Football is one of the sports that has the most ratio of athletes suffering from the ACL injuries. Some famous football players like Neymar JR, Ronaldo, Wirtz, Baggio and so on. It is reported that 336 players have diagnosed from more than seventeen thousand footballers in a football league of Brazil. And what is interesting, the amateurs will have a higher chance to get tearing in ACL in common. That is contribute to the unprofessional of the amateurs. For the professional player, they obtain the tearing in ACL mainly because the professional games are highly competitive so the players will play at a highly intensive condition which means they are required with more movement and turning. For instance, the player called Gavi, a footballer from Barcelona football club, suffered from a serious ACL injury on his right knee in the game against Georgia. It is reported that Gavi also hurled his lateral meniscus and he has been absent for about 10 months so far. He got a complete tear in anterior cruciate ligament when he landed after he jumped for the possession of the ball without confronting. He took about 2 months to get back to the gym and approximately 11 months to go back on the field again [2]. This experience will bring plenty of negative effects to this 20-year-old up-rising star. Comparing with another player from Barcelona as well, Bernal, he ruptured his anterior cruciate ligament on his left knee. His situation is really similar to Gavi that they both got external meniscus. But as for Bernal, he got additional swelling for his knee due to the congestion of the blood in the knee. In order to take the surgery, he has to wait until the left knee is not swelling anymore and before the surgery it is not suggested to have a full range of movement.

2. Diagnosis

2.1. Ultrasound

Ultrasound has the advantages of being economical, flexible, and having good repeatability. With the development of joint surface probes and ultrasound technology, ultrasound has gradually been applied in the screening and assessment of ACL injuries. The normal ACL longitudinal section appears as a continuous, clear, uniform, and well-tensioned oblique low-echo band; when the ACL is injured, it appears as a thickened or thinned ligament, with increased and enhanced echo, and when ruptured, the echo is discontinuous, floating, or disappears. Some scholars have analyzed the correlation between the diameter of the semitendinosus tendon and the gracilis tendon measured by ultrasound before surgery and the actual diameter measured during the grafting process, and the results show that preoperative ultrasound measurement of the hamstring tendon is an effective method to predict its surgical diameter. However, due to different probe frequencies and knee joint positions, the display of the ACL also varies; ultrasound imaging is two-dimensional, while the ACL has a three-dimensional course, and ACL injuries are often accompanied by injuries to surrounding structures such as the meniscus, making some structures poorly displayed by ultrasound. More research is needed to further explore the overall assessment of ACL injuries [3,4].

2.2. CT

DECT can display ACL injuries through color coding, specifically manifesting as "reduced dual-energy staining," where the injured ACL shows lower staining intensity or even no staining. Fickert et al. demonstrated in ex vivo animal experiments that DECT is superior to MRI in terms of specificity for displaying the anterior medial bundle and sensitivity for the posterior lateral bundle of partial ACL tears [5]. The bone marrow edema associated with acute ACL injuries can also be displayed using the same principle. Additionally, CT three-dimensional imaging aids in the assessment of bone tunnels before and after ACL injury reconstruction; CT scan images can also provide original image data for three-

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dimensional finite element analysis to evaluate the size of ACLR grafts, pre-tension of grafts, and biomechanical analysis [6].

2.3. MRI

The high soft tissue resolution of MRI makes it widely used in the imaging diagnosis of knee joint injuries. A normal ACL appears as a continuous, relatively uniform band of low signal on magnetic resonance fat-suppressed images; after ACL injury, the ligament thickens, and focal or diffuse high signals can be seen within the ligament, with complete ACL tears showing discontinuity and retraction of the torn ends [7]. However, the sensitivity and specificity of MRI diagnosis for partial ACL tears are still relatively low, due to several factors: (1) high signals similar to tear edema can appear when the ACL undergoes mucoid degeneration; (2) partial volume effects or pulsation artifacts can cause varying degrees of high signals in the ACL; (3) water-containing connective tissue enveloping the double-bundle structure of the ACL can produce high signals similar to ligament tears [8]; (4) the scanning direction of the oblique sagittal position is usually externally rotated by 15°, and when the scanning plane is not parallel to the course of the ligament, it may not display the entire length of the ACL, leading to a missed diagnosis of partial ACL tears. Although studies have found that different knee flexion positions can better display the ACL structure than the extended position, currently, the conventional position for knee MRI scanning in clinical practice is mainly the supine extended position, and flexion position scanning is not widely used in clinical practice, and there is no consensus on the optimal flexion angle for scanning [9]. Therefore, when direct signs are not sufficient for diagnosis or are in doubt, indirect signs such as the notch sign (deepening of the depression or local bone contusion of the lateral femoral condyle), kissing contusion (bone contusion of the lateral femoral condyle and posterior lateral tibial plateau), posterior horn of the meniscus exposed sign (the posterior edge of the posterior horn of the lateral meniscus is located behind the posterior cortical line of the tibia), and anterior tibial translation (in the sagittal plane at the midpoint of the lateral femoral condyle, the vertical line of the tibial rear edge is located 5 mm in front of the vertical line of the posterior edge of the femoral condyle) can be used to improve the accuracy of the diagnosis[10,11].

In addition to conventional MRI imaging, functional MRI imaging and machine learning are also gradually emerging in the auxiliary diagnosis of ACL injuries. Li Pei et al. found that magnetic resonance diffusion tensor imaging can reflect the degree of ACL injury, providing imaging diagnostic evidence for microscopic structural changes in ACL injuries. Machine learning establishes decision support models for ACL injuries, providing references for doctors in the diagnosis of ACL injuries. MRI also plays an important role before and after ACLR surgery. The assessment of bone tunnels, graft sizes, and graft maturity in reconstruction surgery can be completed through MRI. Grasso et al. used high-resolution MRI for digital processing of bone tunnels during surgery and compared the results with three-dimensional CT, with no significant differences, demonstrating the reliability of high-resolution MRI in assessing the position of reconstruction surgery bone tunnels [11,12]. Zakko et al. used MRI for preoperative measurement of the diameter of the hamstring tendon cross-section, and the results were highly correlated with the graft diameter during surgery [13.14], indicating that MRI accurate measurement can assist patients in making appropriate graft choices before surgery. The signal-to-noise ratio of the MRI graft is considered an indicator for evaluating graft maturity. However, despite the clinical significance of these studies, they have not been widely applied in clinical practice [15].

3. Conclusion

ACLR is the main treatment method for severe ACL injuries. Due to the anatomical relationship of the ACL, which is different from other ligaments in the knee joint, its healing conditions are more difficult, and the selection of grafts is more demanding. Autografts have good stability and the ability to return to high-intensity sports, but they also come with varying degrees of donor site complications. Allografts can well avoid donor site complications and reduce surgical invasiveness, but there are risks of disease transmission and high costs. Synthetic ligaments are convenient to obtain, have short surgery times, and especially have fast early stability recovery, which is beneficial for professional athletes to return to the

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field as soon as possible, but their clinical effects still need further research. At present, with the development of minimally invasive surgical concepts and the deepening understanding of the anatomical reduction of the ACL, ACL repair techniques in clinical practice are expected to replace ACLR as a more ideal solution for ACL injuries. However, the current data on ligament repair techniques are limited, and more clinical studies are needed to confirm their clinical effects and potential advantages.

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