

Clinical Diagnosis, Treatment and Rehabilitation of Achilles Tendon Rupture

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Abstract. Achilles tendon rupture is a common global sports injury. It affects high-intensity players and middle-aged adults with degenerative changes, and harms patients' motor function and daily life. This makes standardized diagnosis, treatment and rehabilitation necessary. This study summarizes recent global advances in the diagnosis, treatment and rehabilitation methods of this injury. It also offers targeted guidance for Chinese patients to manage the disease and discusses the prevention and control system for it. The study systematically introduces the disease status and treatment strategies based on epidemiological data. It covers diagnostic techniques such as ultrasound and MRI, new treatment options including minimally invasive surgical and non-surgical approaches, post-surgical rehabilitation measures and key precautions. Additionally, it explores ways to integrate national standardization requirements with characteristics of Chinese clinical practice. Results show that the PARS system has a lower re-rupture rate (2.1% vs. 5.7%) and enables faster healing within 2 weeks. Platelet-rich plasma can boost muscle wound healing effectiveness by 37%. Smart socks and sensors used after surgery can reduce stress on the recovering tendons by 34%. Portable ultrasound aided by AI achieves a diagnostic accuracy of up to 96.3%. Four clinical rehabilitation stages, including protection, loading-adaptation, functional recovery and re-entry, can support the recovery of patients' motor function. The study aims to popularize small-incision surgical technology, ensure the implementation of effective rehabilitation measures and promote the standardization of Achilles tendon rupture management in China.

Keywords: Clinical diagnosis, clinical treatment, rehabilitation

1. Introduction

The Achilles tendon, which connects the gastrocnemius muscle of the leg to the calcaneus of the foot, is the largest and strongest tendon in the human body. After the Achilles tendon ruptures, not only is it difficult to run quickly, but in extreme situations, long-term activities can lead to mobility impairment and reduce quality of life. With the extensive development of various high-load sports activities and national fitness exercises in recent years, a rapid growth in the incidence rate has occurred.

In terms of high-risk populations and risk factors around the world, different groups have obvious features of Achilles tendon rupture. The main group at high risk of injury are sports personnel. In an

article, international scholars in The British Journal of Sports Medicine in 2021, it was stated that the annual incidence of Achilles tendon rupture among those who were engaged in high-intensity antagonistic sports, such as basketball, badminton and football, can reach up to 1.23 per 1000 people. "Landing suddenly," and "shifting speed suddenly," and other actions that damage the Achilles tendon happen in sports [1]. Individuals not belonging to athletics are mainly middle-aged people. Middle-aged people may also suffer spontaneous Achilles tendon rupture even without strenuous exercise. Zhang Changqing's team has reported an increasing incidence in a China Health Management Database. In recent years, there has been an 8.7% per year increase in the incidence of spontaneous Achilles tendon rupture in people aged between 45 and 60 years. Major risk factors for disease are diabetes, obesity ($BMI \geq 28 \text{ kg/m}^2$), long-term glucocorticoid use and other diseases. Middle-aged people might have torn their Achilles tendons even if they had no involvement with intense physical activity because their tendons had already decayed [2]. Different countries also have obvious regional differences. The occurrence rate of exercise-related Achilles tendon rupture in Europe and the United States is up to 0.8 per 1000 per year, higher than in Asia, where the occurrence of the disease is more frequent. However, due to the rising number of participating people in recent years, the incidence average growth rate of 11.3% in the past ten years has increased in China, which presents an increased disease load [3].

Although the diagnostic techniques and treatment methods for Achilles tendon rupture are still updated, there are still many difficulties in the process of clinical treatment. The misdiagnosis rate in the acute phase of the injury is more than 25%, which mainly refers to that hospitals lack advanced and accurate diagnostic equipment (particularly primary hospitals), and are prone to confusing "heel sprain" and "tendinitis". The rate of disability due to chronic injuries is as high as 40%, and may be related to poor postoperative rehabilitation, early weight bearing, etc. Now, dynamic ultrasound with image analysis by AI is gradually applied to clinical practice. The accuracy can reach more than 95%. In terms of treatment, the preferred method for European and American athletes is the minimally invasive channel technology (incision $\leq 3 \text{ cm}$). For these advantages, such as small trauma, low infection rates ($< 2\%$) and rapid recovery. However, China mostly still performs open surgeries to treat such injuries (68%), and the application of the minimally invasive technique is becoming popular in tertiary hospitals. Traditional treatments mainly involve 6 weeks of plaster cast fixation without personalization, and the return-to-sport time is 12-16 weeks. Therefore, this study will comprehensively discuss the diagnosis process, classification and related standards, treatment options, and the mechanism and effects of rehabilitation for Achilles rupture. It will also introduce the latest evidence-based findings and clinical experience from home and abroad, establish a "diagnosis-treatment-rehabilitation" systematic approach suitable for Chinese patients, and provide theoretical support and solutions to problems such as the low popularity of minimally invasive techniques, the lack of rehabilitation plans and the shortage of grassroots examination resources [4].

2. Exploration of Achilles tendon rupture

The diagnosis of Achilles tendon rupture is combined with medical history, physical examination and imaging. The innovation of imaging has largely improved the accuracy of diagnosis. The Thompson test is a classic sign in physical examination, which means that plantar flexion disappears when squeezing the back of the calf. However, acute pain leads to false negatives. The false negative rate was up to about 15% [4]. In terms of imaging, ultrasound is currently more and more preferred for its convenience, non-invasive features and the advantages of dynamic observation. Dynamic ultrasound can clearly show the location (proximal/middle/distal) and severity (partial/complete) of the rupture of the tendon. Combined with artificial intelligence image analysis technology, the

accuracy of ultrasound diagnosis can reach up to 96.3%, with only 88% accuracy as traditional ultrasound, and it can even detect small cracks in the tendons less than 2mm long [5]. Wang et al.'s research on diagnostic accuracy provides a basis for this. Magnetic resonance imaging (MRI) can be used in patients who need to distinguish whether there is a ruptured tendon after further confirmation by the clarity of the ultrasound image, which can also evaluate the degree of soft tissue swelling around the tendon and fat infiltration to provide a reference for surgical operation planning. But the cost is higher and the time needed is longer. It is not popularized in primary hospitals [5]. The problem of Achilles rupture in clinical diagnosis at present mainly comes from the lack of equipment and technical strength in primary hospitals. Gan et al. through their research found that only 32% of county hospitals in China were equipped with portable ultrasound devices and the percentage of operating physicians who had received specialized training in Achilles tendon ultrasound was less than 20%, which would lead to a misdiagnosis rate as high as 35%. To reduce the misdiagnosis rate, the promotion of equipment and technical training is urgent.

The treatment for Achilles rupture can be divided into surgical and non-surgical treatment. Should be selected on the basis of clinical practice according to the patient's age, time of injury, exercise needs and comorbidities. Minimally invasive surgery is suitable for < 50 years old with high demand, acute rupture (<2 weeks), such as athletes or dancers. This kind of operation has less trauma. The incision is only a few centimeters long. The infection rate and rupture rate are low. The time for returning to exercise is short. The international multicenter randomized controlled trial (RCT) study on the minimally invasive treatment (Minimally Invasive Technique) of ruptured Achilles tendon by Soroceanu et al., 1200 patients in total were included, the results showed that the incidence of re-rupture in the minimally invasive group was significantly lower than the open group 6 months after surgery at 2.1% and 5.7%, respectively. The postoperative pain score (VAS) is also lower. The scores of the minimally invasive group and open group were about 1.8 and 3.2 points, respectively. The time to return to work or exercise was shorter. The average of the minimally invasive group and the open group was 6.2 and 9.5 weeks, respectively [6]. Open surgery is more suitable for patients with chronic rupture (> 4 weeks) and combined with other deficiencies of the Achilles tendon or tendon defect exceeding 3 cm. The advantages include a clear view field, direct suturing repair of defects and easy to perform; but there is significant damage, the incision is 5 cm-8 cm in general, with a high infection rate and necrosis rate (about 5.7% and 3.2%, respectively). Research conducted by Gan and others supported this point [3]. Non-operative management is generally suitable for patients ≥ 60 years of age with low physical demand for exercise. It is not limited by age and avoids the risk and complications of surgery, saving medical costs, etc. However, high rupture rate (~12.5%) and higher probability for joint inflexibility are its deficiencies [1].

Commonly used minimally invasive techniques in the clinic are "PARS system" (percutaneous Achilles tendon repair system) and "endoscopic assisted Achilles tendon repair surgery", both of which can achieve tendon suturing through a small incision to reduce the damage of soft tissue around [6]. Non-surgical treatment mainly adopts the method of functional support fixing + progressive bearing, but strict follow-up is needed. Once tendinosis occurs (ultrasound shows that > 5mm), surgical treatment needs to be changed immediately [1]. The biologically enhanced technology and intelligence monitoring devices further improved Achilles tendon rupture treatment. In bio-revitalization therapy, using platelet-rich plasma (PRP) gel is the most mature. PRP rich in growth factors derived from blood (platelet-derived growth factors such as PDGF and transforming growth factor (TGF- β)) can promote the proliferation of tendon stem cells and synthesis of collagen. A meta-analysis involving 23 randomized controlled trials showed that intraoperative application of PRP can increase the healing rate of tendons by 37%, and speed up the muscle strength recovery rate

by 25% at 6 months after surgery, which belongs to level I evidence [7]. In addition, transplanting stem cells (such as bone marrow mesenchymal stem cells) is used for treatment in chronic rupture of the Achilles tendon, but it is still in clinical trials. Preliminary results show that it can improve the degeneration of the Achilles tendon, but its long-term effect needs more studies [7]. The intelligent monitoring device provides data to help with rehabilitation. The most commonly used intelligent device is smart sensing socks. Its inner side contains a pressure sensor that can detect and monitor the heel pressure of patients in real time and get weight-bearing data with a precision of less than 5%. This information can be fed back to the doctor through an app, in order to avoid improper weight bearing (the loading weight exceeding 30% of body weight), leading to another fracture or delayed bearing weight will cause stiff joints and limited motion range, the return to work and sports. Another research revealed that using smart sensor socks combined with a specific rehabilitation program could provide efficient and standardized guided physical therapy, and improve the return to exercise (work or activity level in a short time to regain full capabilities). In this experiment, 6 months later could raise the ratio from the traditional level (65%) to 82% [4].

3. Load management during the rehabilitation period

Load management in the rehabilitation period is an important part of Achilles tendon function recovery and is mainly based on moderate load stimulation to promote collagen remodeling, which can help restore normal function. Research has shown that the healing of the Achilles tendon can be divided into three periods (inflammatory period, proliferation period and remodeling period), and there are significant differences in load tolerance at different periods. The inflammatory period lasts from week 0–2 weeks, during which time the hematoma forms at the stump, the collagen fibers at the ends connect gradually, and the appropriate load intensity should be zero, i.e., non-load bearing. During the treatment of the inflammatory phase, the main aim is to reduce inflammation, protect the stump and prevent blood clotting [4]. Huang et al.'s studies clarified the features and rehabilitation goals of this period through biomechanical methods [8]. The proliferation period takes place from the 3rd to – 8th week, with the proliferation of fibroblasts and several collagen fibers arranged orderly. The appropriate weight-load intensity can be controlled at around 20% -50% body weight, and the main rehabilitation goal for this period is promoting collagen remodeling and keeping joint activities [4,8]. At this period of time, some sports training can begin, e.g., knee extension with sandbags around the ankle or swimming, and the patient's condition needs to be monitored closely. The remodeling period begins in the 9th-24th weeks with further connection and cross-linking of collagen fibers, and the strength increases slowly. In this period, the appropriate load can increase slowly to 50%-100% body weight, and the rehabilitation goal is muscle force, returning exercise coordination, as well as helping the patient to resume sports [8]. Based on the above mechanism of healing, individualized rehabilitation measures need to change dynamically, depending on people's differences in age and activity. For younger groups like athlete who often participates in sports, the recommended activity in the growth phase (from 3-5 weeks post-surgery) is an underwater treadmill, which uses buoyancy to reduce the weight intensity of limb movement, then shifting to slow jogging on land. Eight weeks after surgery, centrifugal exercises like "lifting heel up and down" can begin until muscle forces on the operation side reach over 80% level of the healthy side 12 weeks later, so that they can resume sports as per clinical requirement [4]. For elderly individuals with a non-exercise lifestyle, joint mobilization and restoration of daily living skills are the focuses of rehab, during which the time in a non-weight-bearing state is better extended up to 3 weeks; compared to athletes, increases in weight-loaded training are not too aggressive. Each time can

increase by 10% of the original weight per week, not causing the problems caused by overload and excessive load [8].

A 35-year-old male amateur badminton player experienced severe pain in his left heel while jumping to the ground, with a pronounced “popping” sound of “Pop” type, and was unable to walk and rushed to the hospital for medical attention after 2 hours of the injury occurring. Physical examination found that “the Thompson test was positive”. Dynamic ultrasound showed that the middle segment of the left Achilles tendon was completely broken (type III), and the broken ends are separated by approximately 1.5 cm. After discussion with him, since the patient is young and has specific needs for training and activity requirements, it is decided to adopt a treatment method of “PARS system minimally invasive suture+intraoperative PRP gel injection”. In order to monitor the rehabilitation post-operation, intelligent sensor socks have been used for tracking. Wear the braces 0-2 weeks, non load bearing walking, do passive ankle activities each day; increasing the weight from 0% of body weight to 40%, data from sensor socks given at time periods during 3-5 weeks, swim 30min each session of underwater treadmill, every three times once; allowed 6-8 weeks to put weight of up to 80% of the body weight, start eccentric training, raise and lower the foot heels 15 times per set, 3 sets a day. It can put on full weight bearing for 9 weeks, then perform some training for badminton, including step and jump movements. Six months after surgery, got ATR S of 94/100 was reached; Ultrasound also showed a good healing situation of the Achilles Tendon with no breakage again. After the successful recovery of the Achilles tendon with no pain and limited mobility at 9 weeks after surgery, returned to the field without any adverse factors. This case reflects great results obtained through the application of the “minimally invasive technology+biological enhancement+intelligent rehabilitation” mode in the athletic group [3,6,7].

4. Strategic recommendations for Achilles tendon rupture

In order to help the clinical doctors develop personal treatment pathways, we must determine according to the four elements "injury time age exercise needs comorbidities" of patients, acute rupture (≤ 2 weeks) under 50 years old, with high demand for sports or other exercise like athletes or fitness enthusiasts, can adopt minimally invasive surgery such as PARS system or endoscopic assisted surgery for surgery, combining intraoperative PRP injection if applicable. If ≥ 50 years old or low demand for sports or other exercise, like retired personnel, non-surgical treatment is suitable, i.e., function support combined with progressive weight bearing and ultrasound follow-up every 2 weeks. Non-surgical treatment is also needed in cases complicated with diabetes and glycosylated hemoglobin $> 7\%$ or peripheral vascular disease. In case of a greater displacement ($> 5\text{mm}$) of the broken end, open surgery is required. For patients with chronic rupture (> 4 weeks), no significant defect ($< 3\text{cm}$) in the tendon stump, we can stitch it directly with open surgery and coordinate the post-operation intelligent rehabilitation. Open surgery combined with self or allograft tendon transplantation is also needed if the tendon stump has a relatively large defect ($> 3\text{cm}$). After the operation need for PRP injection [3,6,7].

At the same time, this paper also refers to domestic clinical practice and evidence, attempts to further standardize the rehabilitation treatment process, and designs a four-stage follow-up rehabilitation plan for ankle plantar flexion. During the protection phase (0-2 weeks), the braking strategy is to use an adjustable Achilles tendon brace to fix the ankle joint in a 15° plantar flexion position and avoid active plantar flexion training. Rehabilitation training requires daily passive ankle joint movements from 0° dorsiflexion to 30° plantarflexion, 10 per group, 3 groups per day. At the same time, exercise the isometric contractions of muscles such as the quadriceps and gastrocnemius in the lower limbs, maintaining each contraction for 15 seconds, 20 times per group. Precautions

include raising the affected limb above the level of the heart and avoiding prolonged standing to prevent swelling [4,8].

Entering the load adaptation stage (3-5 weeks), weight load training should be carried out based on feedback from smart sensor socks. In the initial stage, the weight gradually increases from 20% of the body weight, and then increases by 10% of the body weight every week until the load reaches 50% of the body weight. Rehabilitation training involves walking on a water treadmill three times a week for half an hour each time, while conducting balance training. Each group of training requires standing on one foot with their eyes open for 30 seconds each time, with 10 sessions per group. Ultrasound examination should be performed every two weeks during follow-up to evaluate the healing of the Achilles tendon [4,8].

At the stage of functional recovery (6-12 weeks), patients can gradually increase the load weight to 100% of their body weight, at which point they can remove their braces and walk normally. Rehabilitation training includes 3 sets of eccentric heel lifting exercises per day, 15 times per group, as well as 3 sets of ankle active full range of motion exercises, 20 times per group, and walking gait training to correct limping. The functional outcome evaluation criteria are monthly testing of plantar flexion function of the ankle musculoskeletal system, which must reach 75% or more of the healthy side, and have an Achilles tendon rupture score scale (ATRS) of ≥ 80 points [4,8].

The three periods of returning to the exercise, training contents include running, jumping and changing direction. Gradually increase training content from 50% to 100%; specific sport simulation and function training content per sports type. For patients afraid of exercising, giving psychological therapy step-by-step progress training for reducing the fear and anxiety to recover to exercise. Final evaluation (include ultrasound examination before sports, confirming whether tendons healed, then check functional testing). As long as no pain, one can be back to exercise when one leg lifts the heel 10 times and achieves the standard required [4,8].

5. Conclusion

The diagnosis, treatment, and rehabilitation of Achilles tendon rupture is a systematic engineering involving multiple specialties and links. This study combines the latest evidence-based research at home and abroad with clinical practice in China to propose a comprehensive diagnosis and treatment strategy centered on minimally invasive technology, supplemented by biological enhancers and intelligent rehabilitation, and clarifies individualized plans suitable for different patients. By constructing a three-dimensional suggestion system of "graded diagnosis and treatment medical insurance payment community rehabilitation", this study aims to promote the popularization and specialized training of portable ultrasound in improving grassroots diagnosis and treatment capabilities. The goal is to achieve an accurate ultrasound diagnosis for more than 90% of grassroots medical personnel and shorten the diagnosis time to within 48 hours. In terms of promoting the promotion of minimally invasive technology, it is recommended to include relevant surgeries in the DRG payment directory and increase the payment ratio by 20%. At the same time, the reimbursement scope of innovative therapy medical insurance should be expanded, with the expectation of increasing the penetration rate of minimally invasive technology from 32% to over 60%. Building a digital rehabilitation follow-up platform to optimize rehabilitation management and achieve data sharing and personalized guidance is expected to reduce the recurrence follow-up rate caused by non-standard rehabilitation by 52% within 6 months and increase the patient's recovery rate by 80%. These strategies and suggestions not only provide practical solutions to the problems of weak grassroots capabilities, low penetration rate of minimally invasive techniques, and non-standard rehabilitation in the diagnosis and treatment of Achilles tendon rupture in China, but also

lay the foundation for subsequent research and practice in related fields. The limitations of this study lie in the insufficient consideration of the impact of differences in economic development levels in different regions on the configuration of grassroots ultrasound equipment and the implementation of medical insurance policies when proposing various recommendations, and the lack of long-term follow-up data to support the actual operational effectiveness of the digital rehabilitation follow-up platform. Future research can further refine the tiered diagnosis and treatment and medical insurance payment plans based on the actual situation in various regions, and develop special support measures for economically underdeveloped areas. Simultaneously, conducting multi-center long-term follow-up studies to verify the role of digital rehabilitation platforms in improving patients' long-term rehabilitation outcomes and reducing the incidence of complications. In addition, the deep application of AI technology in ultrasound diagnosis of Achilles tendon rupture can be explored to further improve the efficiency and accuracy of grassroots diagnosis, and promote the construction of a more complete "prevention diagnosis treatment rehabilitation follow-up" full-cycle digital health system to better meet the diagnosis and treatment needs of Chinese patients.

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