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MINIREVIEWS

Progress in diagnosis and treatment of acute injury to the anterior talofibular ligament

Run-Peng Chen, Qing-Hua Wang, Ming-Yue Li, Xiao-Fang Su, Dong-Yang Wang, Xing-Hui Liu, Zhi-Li Li

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Abstract

Injury to the anterior talofibular ligament (ATFL) is a common acute injury of the lateral foot ligament. Untimely and improper treatment significantly affects the quality of life and rehabilitation progress of patients. The purpose of this paper is to review the anatomy and the current methods of diagnosis and treatment of acute injury to the ATFL. The clinical manifestations of acute injury to the ATFL include pain, swelling, and dysfunction. At present, non-surgical treatment is the first choice for acute injury of the ATFL. The standard treatment strategy involves the "peace and love" principle. After initial treatment in the acute phase, personalized rehabilitation training programs can be followed. These may involve proprioception training, muscle training, and functional exercise to restore limb coordination and muscle strength. Static stretching and other techniques to loosen joints, acupuncture, moxibustion massage, and other traditional medical treatments can relieve pain, restore range of motion, and prevent joint stiffness. If the non-surgical treatment is not ideal or fails, surgical treatment is feasible. Currently, arthroscopic anatomical repair or anatomical reconstruction surgery is commonly used in clinical practice. Although open Broström surgery provides good results, the modified arthroscopic Broström surgery has many advantages, such as less trauma, rapid pain relief, rapid postoperative recovery, and fewer complications, and is more popular with patients. In general, when treating acute injury to the ATFL, treatment management and methods should be timely and reasonably arranged according to the specific injury scenario and attention should be paid to the timely combination of multiple therapies to achieve the best treatment results.

Key Words: Anterior talofibular ligament; Acute injury; Diagnosis; Aetiology; Treatment

Core Tip: Anterior talofibular ligament injury is a common lateral ankle ligament sprain caused by mispositioning of the foot during landing and delayed gastrocnemius response time, resulting in pain, swelling, and impaired movement of the injury. It is necessary to diagnose and evaluate the injury degree of patients in a timely manner according to the imaging basis and develop individualized treatment and rehabilitation exercise programs to avoid delay in diagnosis and disease delay. After non-surgical treatment (conservative treatment, functional therapy, alternative therapy, and manual therapy) is ineffective, timely and reasonable surgical treatment should be selected for surgical treatment, so as to obtain positive therapeutic and rehabilitation effects.

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INTRODUCTION

The anterior talofibular ligament (ATFL) is one of the branches of the lateral ligament of the ankle. The lateral ligament of the ankle consists of three operative branches terminating anterolaterally to the talus (ATFL) and the calcaneus [posterior talofibular ligament (PTFL)], and posterolaterally to the calcaneus [calcaneofibular ligament (CFL)][1]. Among ankle sprains, lateral ligament sprain is the most common, accounting for about 77%[2]. In lateral ligament injury, the ATFL is the most vulnerable[3]. When ankle joint varus or metatarsal flexion occurs, the lateral joint capsule is torn. In this case, the fragile ATFL is very easy to sprain or even tear, accompanied by joint hematocele, swelling, or subcutaneous ecchymosis[4]. Acute injury to the ATFL can be treated by external fixation with braces or other conservative treatment measures. When the degree of injury is serious, surgical repair may be an option, *e.g.*, arthroscopic ligament repair or open anatomical repair. However, the current literature does not clearly indicate the best treatment approach for acute injury to the ATFL. If poorly managed, long-term migration of the injured site and serious complications occur, with serious repercussions on quality of life and increased economic burden[5]. Therefore, it is necessary to better understand and master prevention and treatment for this common disease. Therefore, this review aims to summarize the diagnosis and treatment progress of acute injury to the ATFL.

PREVALENCE AND ETIOLOGY

After an ATFL sprain, signs and symptoms such as local pain, swelling, ecchymosis, and dysfunction will manifest at the site of injury[6]. Research shows that the ATFL alone often accounts for the vast majority of injuries to the ankle[3]; the prevalence rate of ATFL-CFL combined injury is 20%-40%, whereas that for the CFL alone is only 2%[3]. About 50% of acute ATFL injuries occur in athletes who regularly engage in physical activities[7]. In addition, manual laborers and the elderly with osteoporosis are also at risk for acute ATFL injuries. Strenuous sports such as basketball and football are high-risk sports for ATFL sprain[5]. Acute ATFL injury can also occur when people walk on rough roads, exercise heavily, or walk downstairs.

The main causes of acute ATFL injury are mispositioning of the foot during landing and delayed reaction time of the gastrocnemius[8]. The position of the ATFL attachment is already more prone to tear than the talus attachment position. During jumping and landing, the foot overpronates or supposes, the calf supposes externally[9], and the tension on the ATFL increases, especially the elevated bone crest, making it susceptible to sprain or tear when the pressure is greater than its bearing capacity[8]. Risk factors for ATFL sprain are both internal and external. Internal factors include ankle sprain history, age, weight, height, foot posture when landing, postural balance, overall joint and ankle joint relaxation, anatomical order, muscle control, landing reaction force, ankle compression and shear force, muscle reaction time, and psychological factors[10]. Sex, general joint relaxation, and foot type are not risk factors for ankle sprain[11]. External factors include shoe type, ankle support, and exercise intensity and duration[12]. These risk factors are only related to ATFL injury and may not be the direct cause of injury. Additionally, an ankle sprain is closely related to a knee sprain and excessive reaction force during a fall may increase the risk of knee and ankle injury[13].

PATHOGENESIS

The ankle joint is composed of three parts: The talocalcular, the subtalar, and the distal tibiofibular joints. The talocalcular joint, which is composed of the talus dome, the tibial plateau, and the internal and external ankle joints, is relatively vulnerable to injury[8]. Its main purpose is metatarsal flexion and back flexion. The main supporting ligaments of the talocalcular joint are the ATFL, the PTFL, and the CFL. Among them, the ATFL is the weakest and smallest. In its neutral position, it is parallel to the long axis of the foot, perpendicular to the long axis of the leg, starting from the front edge of the lateral malleolus, and ending obliquely forward and downward at the lateral side of the talus neck, with a thickness of about 2-2.5 mm and a width of about 6-10 mm[14]. The main blood supply sources are the anterior artery of the lateral malleolus and the anterior branch of the peroneal artery[15]. The main role of the ATFL is to limit anterior displacement and internal rotation of the talus, which is essential to maintain ankle joint stability. The most common mechanism of acute injury to the ATFL is ankle varus. Because the fibula extends farther to the lateral ankle than to the medial ankle, the range of varus is larger than that of valgus. Therefore, varus sprain is more common[8], accounting for 73% of lateral ligament injuries to the entire ankle joint[2] and 85% of total ankle sprains[16]. When an acute injury to the ATFL occurs in varus, the ankle joint is in a state of excessive metatarsal flexion or back extension. In addition, when the ankle joint is in a supination injury, acute injury to the ATFL is also more likely[8].

CLASSIFICATION SYSTEM

Some studies have clearly distinguished ATFL injury based on ultrasonic examination, which is applicable to initial injury classification and treatment monitoring[17] (Table 1).

EVALUATION AND DIAGNOSIS (CLINICAL EVALUATION, IMAGING EVALUATION, AND LABORATORY DIAGNOSIS)

Clinical evaluation

In clinical practice, experienced doctors can judge the type and severity of acute injury to the ATFL through sprain history and physical examination[18]. Within 48 h after the occurrence of acute injury, pain, swelling, and muscle spasm at the ATFL may affect evaluation and examination results; therefore, the examiner should first palpate to rule out the possibility of fracture. Palpation should cover the following: (1) Bone structure; (2) Ligament structure; (3) Ankle range of motion (ROM) assessment; (4) Ankle muscle test; and (5) Special tests[19]. After excluding the absence of fracture, further evaluation should involve assessing whether ligament injury has occurred. At present, delayed physical examination is still a high-quality diagnostic mode for evaluating acute injury to the ATFL within about 4-5 d. This specifically manifests as hematoma at the damaged site and local pain and gives a positive front drawer test result. If there is no pain upon ATFL palpation, rupture may be ruled out. The front drawer and talus tilt tests[20] are common physical examination tests used to evaluate the acute injury to the ATFL. When performing the front drawer test, tibial displacement should be measured and the patient should lie on his back, bend the knee at a 90° angle and the hip at 45°, keep the back of the foot stable, and pull the proximal end of the tibia forward in the three positions of external rotation, neutral position, and internal rotation of the leg. A displacement > 6 mm compared with the normal side is considered abnormal. However, pain and hematoma or edema at the injured site decrease the reliability of the front drawer test results. A positive front drawer test, combined with tenderness and hematoma discoloration, has a sensitivity of 98% and specificity of 84% for the diagnosis of acute injury to the ATFL[7]. The talus tilt test is used to evaluate ATFL integrity. The ankle is pressed to apply varus force. If the absolute angle between the normal side and the injured side is > 23°, or the difference is > 10°, the test is deemed positive. In addition, the Ottawa ankle rules are often used to evaluate acute soft tissue injury within a week to rule out fractures and decide whether to use X-ray examination[20].

The diagnostic criteria and treatment methods for acute ATFL injury in children are different from those in adults; therefore, it is necessary to carefully select the treatment plan. Non-surgical treatment plans are preferred[21].

Special inspection and model

Many new techniques to assess the severity of acute injury to the ATFL and the need for auxiliary surgery have emerged in clinical practice. Some scholars have designed and developed a quick and simple single-leg-loading test[22], which can assess the severity of acute ankle sprain within 1 min. A novel micro-ligament performance probe system for ankle ligament tension measurement devices can establish effective limb position and ATFL strain relationships[23]. For mechanical and recurrent ATFL sprains, the non-invasive (closed) mechanical lateral ankle sprain model can simulate incomplete (mild to moderate) ligament injury caused by ankle sprains by controlling the inversion angle, speed, and

Table 1 Classification of anterior talofibular ligament sprains

Type	Clinical manifestations	ATFL structural integrity
Type I	No swelling and ecchymosis	Complete fiber structure
Type II	Organized swelling	Complete fiber structure
Type III	Tissue swelling, ligament elongation, and tear	Fiber structure failure
Type IV	Completely broken, "floating ligament" can always be found	Fiber structure failure
Type V	Avulsion fracture at the edge of the talus or distal end of the ankle joint	Fiber structure failure

ATFL: Anterior talofibular ligament.

time interval[24]. These new techniques can be used to measure surgical accuracy and assist ATFL injury repair and reconstruction, guiding the clinical investigation of ATFL injury patterns.

IMAGING EVALUATION

X-ray and ultrasonography

When an acute ATFL injury is suspected to be at risk for severe injury and fracture, history and physical examination alone are not sufficient; imaging examination is needed to assist evaluation and diagnosis.

An X-ray can diagnose mild ATFL injury and ankle effusion[25] but is unable to provide a detailed examination of the ligament injuries. Ultrasonography (US) has good diagnostic value for acute injury to the ATFL. Compared to surgery, the sensitivity, specificity, and accuracy of US in the diagnosis of ATFL acute injury were 98.9%, 96.2%, and 84.2%, respectively. The sensitivity for the diagnosis of complete interruption of ATFL was 87% (95%CI: 74%-95%) and the specificity was 69% (95%CI: 53%-82%)[26]. Like computed tomography (CT) and magnetic resonance imaging (MRI), US has fast imaging speed, and no radioactivity, and the results are comparable to those of an MRI examination at a lower price. When MRI examination is not available, US examination is a relatively good alternative. Ultrasound-mediated ATFL-enhanced repair can reduce ATFL relaxation without causing ankle instability[27]. Compared to conventional US, dynamic US has lower diagnostic value[28].

Several studies have compared the relationship between sex, generalized joint laxity (GJL), and the anterior drawer test for the ATFL ratio and found that the ATFL ratio is affected by the presence of GJL in males but not in females[29], providing an effective reference for evaluating and diagnosing the possibility of chronic ankle instability and ankle relaxation after acute injury to the ATFL.

In addition, many new US methods have been derived clinically. Ultrasonic shear wave elastography found that the shear wave velocity of normal lateral ankle ligament increased with the increase of applied force[30]. Non-invasive virtual touch tissue imaging quantification, a novel ultrasonic palpation method, can identify the hardness difference of acute type I ATFL injuries and evaluate ligament elasticity. These are all new methods for quantifying ankle ligament stiffness and diagnosing and monitoring ATFL injury[31]. According to the examination results, physicians can time the treatment plan appropriately, develop a more effective rehabilitation plan, further improve the outcomes, promote ATFL injury healing, accelerate ankle joint function recovery, and reduce the occurrence of complications.

Computed tomography

CT tests are more sensitive in detecting ATFL injury. CT is more sensitive in fracture detection than X-ray, US, stress radiography, and clinical diagnostics. Studies have confirmed that spiral CT and 3D imaging reconstruction technology have high uniqueness and sensitivity for the diagnosis of joint and ligament injuries, with an area under the curve of 0.954, which can make up for the shortage of X-rays in further assessment of ATFL acute injuries and soft tissues, with faster scanning speed and better patient coordination[32].

Magnetic resonance imaging

Due to its multi-parameter, multi-sequence, high-field intensity imaging, excellent imaging quality, short imaging time, and good soft tissue resolution[33], MRI has the most accurate and comprehensive observation of the characteristics of ligament injury, ligamentous joint injury, osteochondral lesion, and bone contusion, and provides a more direct display of the ligament morphology, signal, and pathological change process[5]. On MRI, a complete ATFL tear will show separation and shortening of the broken end, with bleeding, joint effusion, edema, and avulsion fracture. ATFL incomplete avulsions are characterized by low signal interruption, high signal, rough edges, and partial discontinuity. ATFL

interstitial tears are characterized by edema or bleeding and hyperintensities within the ligaments[34]. A meta-analysis showed that the sensitivity and specificity of MRI in diagnosing acute ATFL lesions were 1.0 (95%CI: 0.88-1) and 0.9 (95%CI: 0.79-0.96), respectively[18]. In addition, MRI can also be used for follow-up diagnosis of persistent pain and chronic ankle instability. Thus, regardless of injury type (acute or chronic) and the specific location and quantitative evaluation of the injury site, MRI has shown high diagnostic efficiency, providing a more accurate imaging basis for subsequent conservative or surgical treatment and the selection of specific surgical methods. With the continuous development of medical technologies, some emerging MRI techniques such as diffusion-weighted MRI, have achieved a sensitivity of 100% and specificity of 67%-100% for the diagnosis of the injured tendon[35]. However, MRI is not sensitive enough to rule out injuries and its use should therefore be cautious[36]. Moreover, the scanning effect varies with different locations and the optimal display effect is in the neutral position of the oblique section[37]. Owing to the high cost of MRI examination[26], relatively complex operation, and certain limitations in clinical application, it is not routinely used for acute ATFL injuries.

Arthroscopic examination

Arthroscopy is considered to be the gold standard for evaluating and diagnosing acute ATFL injury [18]. However, it is not the first choice as it is traumatic to the patient. Arthroscopic repair of the medial and lateral ligaments of the ankle joint may be an effective measure for the treatment of multidirectional ligament instability and can be used as a supplement MRI examination[38].

Each imaging examination method has its advantages and disadvantages, such as long examination time, insufficient accuracy, and differences in the examination. Diagnostic accuracy may not be achieved by a single examination method; multiple examinations are needed such as combined US and MRI or arthroscopy, combined CT and US[39], and multi-slice spiral CT combined with MRI, which can display the ATFL and the surrounding tissue damage more accurately, making up for the deficiency of a single examination method, and increasing diagnostic accuracy.

Laboratory diagnosis

So, what are the differences between acute injury and chronic disease? A study has shown that there are many biochemical and histological differences between acute ATFL injury and chronic ankle disease. Ligament tissues with chronic lateral ankle instability exhibit increased apoptosis and expression of apoptotic enzymes, potentially leading to further ligament degradation[40]. Other studies have indicated that women with high GJL scores may be more sensitive to the effect of estrogen on ATFL length changes during ovulation, which may explain why women are more prone to acute injury to the ATFL than men. However, it is not clear whether estrogen receptors are present in the ATFL. In future studies, hormone concentrations should be measured to examine the effect of menstrual cycle on acute injury to the ATFL[41]. In addition, some scholars claim that the lymphocyte-to-monocyte ratio can be used as a marker of systemic inflammation to predict the outcome of ATFL repair[42].

MANAGEMENT MEASURES

Given the large number of ATFL acute injury cases occurring at home and abroad, this appears to be a common injury, and related management and treatment methods are widely adopted. Based on current research, management methods can be divided into non-operative (conservative, functional, manual, and traditional medical) and surgical treatments.

Non-surgical treatment

Principle of non-surgical treatment: The rehabilitation process after acute injury of ligaments and soft tissues may be complex, and experts and scholars at home and abroad have explored many therapeutic measures to promote rapid recovery of acute injury to the ATFL. For early type I, type II, and mild type III acute ATFL injury, previous studies have mentioned the use of cryotherapy[43], the principle of PRICE (protection, rest, ice compress, compression, and elevation)[3], or conservative treatment options such as immobilization and plaster external fixation as the first treatment strategy to achieve pain relief, swelling reduction, and hemostasis. Even though, generally, the injury is properly treated in the acute stage, there is not enough attention to the subacute and chronic stages of recovery. Therefore, the current "peace and love" principle for acute injury to the ATFL, such as soft tissue injury[44], is slowly derived as the mainstream treatment strategy for conservative treatment. This principle constitutes the continuous whole of immediate care (PEACE) and follow-up management (LOVE). The acronym stands for the following: P = protect, E = elevate, A = avoid anti-inflammatory modalities, C = compress, E = educate; and L = load, O = optimism, V = vascularization, and E = exercise.

The PEACE part of this principle emphasizes that when acute injury to the ATFL occurs, it is necessary to limit exercise for 1-3 d to avoid aggravating injury to the damaged tissue and try avoiding excessive rest to avoid damaging tissue quality. The limb should be lifted higher than the heart to promote interstitial fluid outflow. Cryotherapy and anti-inflammatory drugs should be avoided as much as possible, because these may negatively affect the long-term tissue healing process. Elastic

bandages should be appropriately used to compress the injured area, reduce edema, and limit bleeding. Patients should be encouraged and educated to engage early in active exercise, but still rely on external forms of treatment for active recovery.

The LOVE part indicates that, after 24 h of injury, the following should be promptly achieved: Engaging in prompt contact with mechanical pressure; carrying out proper exercise with a suitable load; maintaining tissue, muscle, and tendon function; maintaining a positive and optimistic rehabilitation mood; actively carrying out painless aerobic exercise; promoting blood flow to the injured structure by aiding blood vessels healing and rebuilding in the damaged part; improving body function; actively exercising to recover related capabilities, proprioception, and muscle strength of the injured limb. The principles of PEACE and LOVE clearly emphasize that anti-inflammatory or analgesic drugs and blind cryotherapy should not be adopted when soft tissue injury occurs[44].

Studies have shown that a new type of bioelectric stimulation device can provide a small direct current and a direct current electric field. Electrical stimulation is applied close to the patient's inflamed or injured tissue using a percutaneous metal probe, which can relieve pain, prevent edema, and increase the rate of tissue regeneration. This novel treatment plan provides more possibilities for the conservative treatment of acute ATFL injury[45].

Functional treatment

Functional therapy combines external support with a rehabilitation program. External supports are important in the functional treatment of injury to the ATFL, which may involve limiting ankle activity and reducing the risk of injury, especially for athletes. Currently, the commonly used external supports in clinical practice are divided into rigid and flexible supports. Rigid supports (casts and braces) and orthotics are more commonly used. The flexible supports used include flexible plasters, silicone ankle covers, elastic bandages, elastic socks, and adhesive tapes[46]. There is no consensus on which rigid or flexible support is the best. For minor acute injuries, it takes about 3 wk for the body to repair after early treatment. To optimize injury repair, rehabilitation exercises should be carried out as soon as possible after the use of external support. The main rehabilitation objectives are to relieve the pain of the injured part, restore joint ROM, prevent joint stiffness, restore proprioception, help restore daily activities or sports as soon as possible, and reduce the occurrence of secondary injuries[44]. The main training methods include supervision training, muscle training, and functional training; additionally, joint mobilization can be included in the early treatment phase[47], followed by proprioception training. Proprioception training includes sensory balance training, coordination training, strength training, and limb stability training; it uses progressive somatosensory stimulation combined with passive and active movement and supplemented by intervention measures lasting for 6 wk or more. As a basic part of the rehabilitation process, proprioception training can effectively improve proprioception function and provide the basis for rehabilitation exercise and limb movement balance recovery of acute injury to the ATFL. It is also beneficial to relieve joint movement limitation and increase ankle joint stability[48]. The rehabilitation results and the appropriate time for resuming exercise need to be further determined through long-term follow-up assessing concrete patient recovery. Early changes in the conduction velocity of the peripheral nervous system and spinal cord are observed after injury. Although currently motor nerve conduction velocity cannot be accurately evaluated, it can be used as a potential modulatory therapy for acute injury to the ATFL[49].

Manipulation therapy

Physical manipulation treatment measures for acute injury to the ATFL, such as static stretching, should be undertaken in the early stage[50]. The joint should be manually loosened, and force to the joint should be applied through rotation, shearing, and traction to help mobilize the joint through a slow and passive movement. Gentle kneading and massage can reduce pain, improve foot dorsiflexion ROM, aid proprioception training, and promote foot function recovery.

Traditional medical therapy

Traditional medical treatment also plays an important role in the treatment of acute ATFL injuries. Although currently there are different opinions about the relevant laws and medical effectiveness of traditional medicine globally, some studies still suggest that traditional medical therapy provides obvious advantages. For example, in China, acupuncture and moxibustion[51] have been used for over 2000 years. By stimulating specific acupoints on the body surface, it elicits an analgesic effect, acting on central regulatory mechanisms, and inhibiting local and segmental pain. There are many types of acupuncture and moxibustion, including both traditional and Western acupuncture and moxibustion, and electroacupuncture. Traditional acupuncture and moxibustion include acupuncture at typical points. Western acupuncture and moxibustion select non-typical points for acupuncture, such as exercise and pain-stimulating points. Electroacupuncture uses electric current while moxibustion uses burned moxa cones, both in order to stimulate specific body points. In addition, Dangguixu-san, an herbal extract widely used to treat pain and swelling from ankle sprains, combined with acupuncture and moxibustion[52] was used as an additional treatment for acute grades I and II ligament sprains. Acupuncture and moxibustion can reduce the intensity and duration of pain, promote quick recovery of

the activities before the injury, and assist in the development of a suitable rehabilitation training regime while bearing almost no side effects. Ankle joint massage also has a long history in traditional Chinese medicine. The main techniques include rotation, traction, and poking; these act on the foot, rapidly improving acute sprain symptoms and ankle joint function and adjusting ligament imbalance with good analgesic and stable long-term effects[53]. At present, therapy involving traditional Chinese medicine is widely used in East Asia; however, in some countries, this type of medical approach has not been officially recognized by researchers and healthcare professionals. Therefore, it needs to be implemented in line with the specific legal requirements and diagnosis and treatment norms of different countries and regions.

For athletes, the incidence of re-injury and chronic ankle instability increases; this may lead to traumatic arthritis, bone necrosis[54], and other complications, which seriously affect the quality of life and sports activities. It is difficult to predict the time required for natural ligament healing after acute ATFL injury. Therefore, it is paramount to judge injury degree accurately and select appropriate treatment measures accordingly. After comparing the various factors influencing rehabilitation results and economic costs of conservative and surgical treatment, it was found that conservative treatment is not inferior to surgical treatment[55]; in fact, patients have higher satisfaction and can resume pre-injury work and sports activities earlier.

Surgical treatment

By understanding the etiology and pathogenesis of acute ATFL injury and implementing early diagnosis and treatment, the occurrence of complications can be effectively prevented. About 80%-85% of type I, type II, and some severe ATFL acute sprains can be cured through a rehabilitation treatment plan; however, 10%-30% of patients will suffer repeated pain, ankle instability, and re-injury. Around 20%-40% of patients will develop mechanical and functional chronic ankle instability[56]. For the third-degree injury of ATFL complete rupture, some scholars advocate functional conservative treatment first. Its failure and the occurrence of complications such as ankle instability, significant functional limitation, ankle arthritis, and bone lesions, indicate failure of conservative treatment, and surgical repair is warranted[57].

Surgical treatment includes anatomic repair, non-anatomic reconstruction, and anatomic reconstruction. Its purpose is to repair and reconstruct the lateral collateral ligament of the ankle joint, including the ATFL, and restore ankle joint stability.

Anatomical repair involves the *in situ* repair of the injured ATFL; the goal is to suture the ligament to adjacent tissues, or fix it to the bone surface without compromising other healthy structures[55], to enhance ligament strength and restore the normal anatomical structure and mechanical relationship, with minimum damage to the operative area. However, if the ligament quality is poor or the ligament itself is loose, and if the patient is too large, this operation will not be effective.

The anatomical repair can be either open (Broström surgery, Karlsson surgery, Duquennoy surgery, and Gould surgery) or arthroscopic (arthroscopy-assisted technique, total arthroscopic technique, and total medial suture technique).

The Broström procedure has a good effect in repairing ligament injury and restoring ankle stability. After Gould *et al*[58] improved it, Broström-Gould was called the "gold standard" of open surgery for anatomical repair of an injured ATFL. However, the disadvantages of this procedure include a large incision, severe local soft tissue injury, limited indications, and more complications, which are not conducive to early rehabilitation[59]. To ensure good outcomes and reduce surgical trauma, the modified Broström surgery is generally used for ATFL injury repair. Anatomical repair of the lateral ankle ligament supplemented by the modified Broström surgery has become the first choice for surgical treatment, consistent with the original ligament structure and function, with a success rate of 85%-95% [60]. For non-professional athletes or patients who do not participate in strenuous exercise, some of the modified Broström procedures are simple and convenient, and patients with high satisfaction have high follow-up rates. For athletes, soldiers, and other patients with demanding sports requirements, seeking simple and effective treatment with little trauma and a good prognosis is more urgent. After undergoing the modified surgery, some athletes did not recover to pre-injury levels. Most of the reasons were not due to the repair surgery method[61]. It might have been due to the damage to the internal brace on the ligament, resulting in complications[62]. Patients with good resilience have less postoperative pain burden. More attention should be paid to patients with proprioception disorders and neuromuscular control defects when performing postoperative recovery exercises[48].

Arthroscopic anatomic repair

With the rapid development of arthroscopic technology, minimally invasive surgical techniques for arthroscopic ATFL anatomical repair, ligament stability reconstruction, and assisted fracture fixation have progressively emerged and are now widely used. After comparing arthroscopic anatomical surgery with open anatomical repair, it was found that the two surgical methods have each their advantages and cannot be replaced by one other[62]. The suture technique used in arthroscopic surgery does not negatively affect surgical results, and patients usually experience faster postoperative pain relief, good ligament recovery and foot function, better ROM[63], and fewer complications.

At present, many new arthroscopy-based surgical methods and tools have been derived clinically, which are more ergonomic and flexible. For example, the total arthroscopic ATFL suture incremental repair technique can achieve similar tensile strength and better rigidity as a normal ATFL[64]. Minimally invasive needle arthroscopy technology has many advantages, such as less blood loss, fewer anesthesia complications, and faster return to sports activities, making it the preferred modality for many patients. More importantly, minimally invasive needle arthroscopy technology allows outpatient diagnosis and treatment, which saves operating room time, medical staff, anesthesia, and equipment costs, and achieves higher patient satisfaction[65]. Under arthroscopy, line anchors enhance ATFL repair, often with absorbable anchors[66], which retain the advantages of arthroscopic surgery, such as a small scar, low risk of postoperative adhesion, and the ability to deal with intraarticular lesions, while strengthening ankle stability in patients with high movement demands and poor ligament quality. Line anchors enhance ATFL repair and lays a solid foundation for postoperative healing and early high-intensity rehabilitation exercise programs. Arthroscopic arthro-Broström supported band enhancement using the all-medial lasso loop suture technique avoids nerve injury and does not interfere with subtalar joint stability[67]. With the rapid emergence of new technology, in the future, we may need to explore and utilize the advantages of various surgical techniques and treatment management tools[68].

For non-anatomical ligament reconstruction, the surgical method will replace reconstruction with grafts. Studies have shown that regardless of the grafts used (autograft or allograft), the Karlson-Peterson score is always over 80 with good or excellent outcomes[69]. Evans, Chrisman-Snook, and Watson-Jones surgeries are commonly used for non-anatomic reconstruction. The Evans surgery[70] has poor overall repair outcomes on lateral stability, damages the original structure of the ligament, has poor long-term efficacy, and is prone to complications. The Chrisman-snook surgery[71] elicits a postoperative overall vertical displacement of the ankle and subtalar joints similar to that of the normal lateral ankle. The surgical method is stable and firm with an obvious effect on ankle joint stability. The Watson-Jones surgery[72] is a complicated operation that has a great impact on dorsiflexion, valgus, and varus movement of the ankle joint, and is now rarely used. Non-anatomic reconstruction surgery is likely to lead to limited ankle movement and possibly degenerative ligament changes[73].

Anatomical reconstructive surgery not only repairs the ATFL, but it also sometimes involves repairing and reconstructing the anatomical positions of multiple ligaments and tendons; thus, it is necessary to accurately understand the anatomical positions of ligaments and tendons of the ankle joint and formulate detailed surgical plans. Anatomical reconstruction involves the reconstruction of the lateral collateral ligament of the foot and ankle using the peroneus brevis or semi-femoral peroneus brevis[74]. This has many disadvantages, such as a large surgical incision, influence on the function of other tendons, change of the normal structure of the lateral malleolus, and ankle joint ROM restriction. After ligament reconstruction with an autologous tendon[75], work and sports can be quickly resumed. However, due to the change in the normal anatomical structure of the ankle ligament, postoperative complications, such as ankle joint activity restriction and strain pattern change, are often observed[76]. Studies have shown that the density and stiffness of the ligament augmentation and reconstruction system (LARS) artificial ligaments are superior to those of natural ligaments[77], with unique advantages including no donor area damage, early postoperative recovery, and no risk of disease transmission. The surgical outcomes of total arthroscopic anatomical reconstruction are also better. However, autologous, allogeneic, and artificial LARS ligaments increase the risk of infection and rejection.

Studies have found that the early functional recovery of patients undergoing arthroscopic anatomic reconstruction is better than that of patients undergoing open surgery, albeit without any difference in long-term efficacy. With the development of arthroscopy, endoscopic Broström-Gould is now the widely accepted gold standard for ATFL repair for ankle instability; the American Orthopaedic Foot and Ankle Society (AOFAS) score, Visual Analog Scale pain score, and postoperative weight-bearing recovery time after arthroscopic Broström-Gould surgery were better than those after open Broström-Gould surgery[78]. Conversely, other studies reported no significant difference in pain, AOFAS, and Karlson-Peterson scores between arthroscopy and open surgery[79]. Therefore, more long-term clinical trials should be conducted for arthroscopy. Arthroscopic surgery has many advantages, such as early weight bearing, less damage to the joint capsule and surrounding soft tissue, accurate observation and treatment of the intraarticular ligament structure, fewer postoperative complications, and faster recovery. It can restore the anatomical stability of the ATFL along with the advantages of minimally invasive surgery. However, patients with high exercise requirements[3], excessive body mass, ligament relaxation, and poor quality are at risk of repair failure and may experience injury to foot tendons and nerves[80]. Ideal ligament function and stability cannot be achieved by Broström-Gould arthroscopic surgery alone. InternalBrace™ suture straps, which do not utilize autologous tendon tissue, involve little trauma and are simple and fast to apply. They provide long-term lateral stability and sufficient strength, and facilitate a faster return to ambulation and sports activities, making patients more receptive to this modality[81]. Some scholars have performed modified arthroscopic Broström surgery using soft anchors, suture anchors, and tape with excellent outcomes, safety, and reliability. Additionally, the stability of the reconstructed ATFL was improved with good functional scores and few complications[82].

Drug treatment and prevention

After acute sprain of the ATFL, athletes can try to use plasma rich in growth factors (PRGF) for treatment[83]. Injecting it into the injury site, along with early rehabilitation training, can promote rapid healing of the ligaments and aid prompt resumption of sports activities. Some studies have also used basic fibroblast growth factor, type 1 insulin growth factor, nerve growth factor, and other growth factors to help promote tissue regeneration and muscle healing[84]. It has been reported that gardenia extract and geniposide canaid for ligament injury treatment promoted fibroblast proliferation and collagen synthesis[85]. Related drug studies on acute sprain of the ATFL showed that ginsenoside Rg1 may regulate interleukin-1 through the PI3K/Akt/mitochondrial signal pathway. The induced apoptosis of human articular chondrocytes can be used as a drug target for the treatment of ankle traumatic arthritis[86]. Although various drugs and treatment methods are effective in promoting the growth of fibroblasts and tissue repair, the current mainstream research still favors a conservative treatment approach, functional exercise, and gradual recovery of damaged tissue integrity and motor function.

For acute injury of the ATFL, the biggest challenge is prevention. At present, what can be done is to increase the safety measures as much as possible when carrying out strenuous exercise or activities with a high-risk factor, wear appropriate shoes, carry out appropriate and effective management, guide functional exercise, promote tissue healing, encourage gradual resumption of daily activities and physical exercise, and prevent secondary injury occurrence[49]. In addition to treating the acute injury site of the ATFL, experts have also studied the impact of acute injury to the ATFL on the whole life function[87], stating that a severe ankle sprain may significantly reduce physical activity throughout the lifespan. This could pose a major public health problem, as an acute ATFL injury could lead to serious long-term health risks.

CONCLUSION

Acute ATFL injury is common. This ligament is small and weak, but its position is critical and improper treatment will greatly affect quality of life. Nowadays, people pay increasing attention to the rehabilitation treatment and management of ATFL, and the systematic treatment methods and measures are also becoming more systematic and detailed. After the occurrence of acute injury to the ATFL, it is crucial for clinicians to comprehensively evaluate, accurately diagnose, and ultimately find the most appropriate examination and treatment methods. X-ray, ultrasound, CT, MRI, conservative treatment, functional exercise, and proprioception training are all key assessment tools and treatment measures in the acute ATFL injury period. In the face of mild acute ATFL injury of type I, type II, and part of type III, adopting the treatment principle of "peace and love" is generally advocated; however, when the injury does not heal or is too severe, surgical treatment is required. Various surgical treatment methods exist; the more widely used is the modified Broström anatomical repair under arthroscopy. Postoperatively, it is still necessary to carry out sports rehabilitation exercises promptly to promote ankle stability and foot function recovery. The continuous development of clinical technologies requires our unremitting efforts. We will continue exploring a more systematic, complete, and high-quality acute ATFL injury management program according to the latest evidence measures and treatment means.

FOOTNOTES

Author contributions: Chen RP and Wang QH contribute equally to this work; Chen RP, Wang QH, and Wang DY performed most of the writing; Li MY, Su XF, Liu XH, and Li ZL performed data accusation and manuscript writing and prepared the figures and tables; Chen RP designed the outline and coordinated the writing of the paper; Chen RP and Wang DY contributed to the conception of the study.

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