Review

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Achilles Tendon Injury Treatment: the History and Current State of the Art

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RELEVANCE The overall incidence of Achilles tendon rupture has been increasing in recent decades due to population aging, the growing prevalence of obesity and increased participation in sports. Achilles tendon ruptures are common injuries of the musculoskeletal system, and according to various authors, they account for 47% of all ruptures of human tendons and muscles, about 18 cases per 100 thousand people per year. Despite the abundance of various options of tendon suture in surgery, a wide choice of suture material and the use of precision techniques in tendon reconstruction, the proposed methods of macroscopic reconstruction of the tendon apparatus do not solve the problem of tendon suture failure.

CONCLUSION Despite the abundance of proposed accesses to the Achilles tendon, the optimal one for all types of injuries has not yet been developed. Currently, there are no clear recommendations for choosing a specific method of treating an Achilles tendon rupture.

Keywords: achilles tendon, achilles tendon plastic surgery, achilles tendon reconstruction

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EFD - external fixation device
AT - Achilles tendon
MRI - magnetic resonance imaging

RELEVANCE

The Achilles tendon (AT) is the strongest and largest tendon in the body, but it is also the most commonly torn tendon. For the first time the term "Achilles tendon" was used by the Flemish surgeon and anatomist Ph. Verheyen in 1693 [1]. The overall incidence of AT ruptures has been increasing in recent decades due to the aging of the population, rising prevalence of obesity, overweight and greater participation in sports [2, 3]. AT ruptures are among the most common injuries of the musculoskeletal system and, according to different authors, account for 47% of all human tendon and muscle ruptures, about 18 cases per 100,000 population per year [4–8].

At the outpatient stage, from 20 to 58% of AT disorders are not diagnosed (V.I. Karasev, 1960; T.S. Grigoryeva, 1961; S.I. Dvoynikov, 1994; N.A. Koryshkov, 2012). In most cases, AT ruptures occur during physical activity (up to 88%) [9]. Men are 2–12 times more likely to have an AT rupture than women [10]. The majority of patients with this pathology are people of working age from 30 to 45 years old who were injured during regular exercise, as well as 60–70 year old people. Patients of the older age group get injured, as a rule, during daily activities, patients of the middle age category – more often as a result of playing sports [11, 12]. Most often, AT ruptures occur in the middle third, as well as 3–6 cm proximal to the AT insertion onto the calcaneal tuberosity, which is due to the peculiarities of the blood supply [13].

The rupture of the left AT occurs more often, possibly due to the predominance of right-handers, whose left lower limb is dominant (jumping) [14–16].

The treatment of patients with ruptures, at first glance, seems quite simple, but researchers consistently record a high incidence of misdiagnosis of AT ruptures and complications after conservative and surgical treatment, which significantly worsen the quality of life in patients and often do not allow them to return to the level of physical activity that was before the injury. At the same time, different complications are characteristic of conservative and surgical treatment — the main disadvantage of surgical treatment is a high risk of infectious complications, and of conservative treatment — a high risk of recurrent ruptures (re-ruptures) [17].

Despite the abundance of various types of tendon suture in surgery, a wide choice of suture material, and the use of precision techniques in tendon repair, the proposed methods for macroscopic reconstruction of the tendon apparatus do not solve the problem of tendon suture failure.

In publications of recent years, surgeons continue to be dissatisfied with the results of reconstructive procedures using traditional techniques, and the search for less traumatic methods of AT repair while maintaining sufficient strength and accuracy of matching for tendon ends continues (Kornilov N.V., 2006).

The purpose of analyzing the special literature was to summarize the available information about modern methods of AT injury treatment.

Literature selection criteria. The search for sources was carried out in the open electronic academic databases PubMed and eLibray. Key words used for the search were: Achilles tendon injuries, allograft, autograft, chronic Achilles tendon rupture and their corresponding terms in Russian. Search depth was 20 years. To analyze and evaluate the literature data, criteria for including sources in the analytical study were determined.

The criterion for including sources in the study was the availability of the full text of an article or a report structured with specific quantitative data.

Exclusion criteria: clinical cases, abstracts, unpublished papers, studies with signs of duplication (similar study protocol, groups, number of patients, etc.). In case of detection of duplicate articles, more recent source by date of publication was chosen.

HISTORY

An AT rupture was first described by Hippocrates [17, 18]. Ambroise Pare was the first to describe AT re-rupture, and in 1736 Jean Louis Petit (1674–1750) described 3 AT rupture cases, one of which was bilateral. It is believed that surgical treatment for AT rupture was first proposed by the French surgeon Gustave Polaillon in 1888 [19].

In domestic medicine, information about AT was presented in the work of the famous Russian surgeon N.I. Pirogov: "On the transection of the Achilles tendon as an operative orthopedic means" (1840). In Russia,

successful outcomes of surgical treatment for this injury were first indicated by Smiryagin M. (1902) and Ostryansky A.M. (1907) [20, 21]. However, until the middle of the 20th century, the treatment remained predominantly conservative. In 1929, Qenu and Stoianovitch conducted the first study comparing conservative and surgical treatment outcomes, and published its results [22]. This work was the start of a long confrontation between surgical and conservative methods of AT injury treatment, which continues to this day.

In 1939, Kager described the local topographic anatomy of the AT [23].

From the middle of the 20th century, the incidence rate of this injury began to increase, which was associated with the influence of civilization, the mass enthusiasm for sports, changes in the nature of nutrition, and other factors [22–25]. In the 1950s, domestic authors also showed an active interest in the treatment of patients with AT ruptures: Chernavsky V.A., Nikitin G.D., Priorov N.N., Dobrovolsky V.D., Kurachenkova A.A., Kalnberz V.K., Yaunzime I.V., Putilin A.A., Amosova N. R. and others [26–29]. Later, their work was continued by Tkachenko S.S., Mironova Z.S., Lyskovets-Chernetskaya L.E. and many others.

The basis of the current trend in the surgical treatment for AT ruptures was created by the work of the Scandinavian surgeons Arner O. and Lindholm A., who in 1958-60s outlined the etiopathogenesis and mechanism of AT damage. Based on data on functional outcomes, the authors preferred surgical repair of the tendon [30, 31].

Subsequently, surgical treatment gained popularity among surgeons who offered various methods of tendon suturing [26, 30, 32–35], non-free autoplasty [36–41], free autoplasty [28, 42–45], alloplasty [19, 40, 43, 46] and prosthetic repair [36, 47–54].

At the same time, there was still a camp of conservative treatment advocates [55, 56]. In the 1970s and 1980s, the discussion between supporters of surgical and non-surgical treatment continued. Defenders of conservative treatment referred to the high rate of complications following surgical treatment, the cost-effectiveness and satisfactory outcomes of the non-operative technique.

Adherents of the surgical method pointed to a large number of repeated ruptures after conservative treatment. A logical compromise between surgical and conservative methods of treatment was found in minimally invasive surgical techniques. So, in 1977, American surgeons Ma G.W.C. and Griffith T.G. reported good results of percutaneous suturing repair of acute closed ruptures of the Achilles tendon [57]. Their idea was continued in the modifications of some domestic surgeons [58, 59].

By the end of the 80s, the accumulated experience, experimental and clinical data allowed the majority of surgeons to incline in favor of surgical treatment. As an alternative, in the treatment of elderly patients, as well as in the presence of contraindications to anesthesia and surgery, a conservative method of treatment was allowed [60, 61].

The improvement of surgical treatment was characterized by the search for the most sparing methods of anesthesia [63], low-traumatic and functionally beneficial incisions [23, 44], simple and reliable techniques for connecting the tendon ends and restoring the tendon sheath [63, 64].

ETIOLOGY

At present, various researchers have proposed several complementary theories about the origin of AT injuries. There are four main theories: degenerative, mechanical, hyperthermic and genetic [4, 5].

The main factors leading to AT rupture include: sudden forced dorsiflexion of a plantar-flexed foot, direct trauma, as well as long-term tendinopathy or internal degenerative changes, poor physical preparation before training, long-term use of corticosteroids, overexertion and antibiotics.

Sports that are often associated with AT rupture include diving, tennis, basketball, and running. AT rupture usually occurs about 2–4 cm above the AT insertion onto the calcaneal tuberosity. In right-handers, a rupture of the left AT is more common, and vice versa. Physiological aging of the tendon tissue is due to a regular decrease in blood flow in the AT with age. Most researchers note reduced blood flow after 30 years. Vessels passing longitudinally in the tendon tissue are especially susceptible to age-related changes - after the age of 40, the blood flow in the tendon is carried out mainly through the transversely directed vessels of the paratenon [65]. Despite the abundance of research papers, the exact etiology of AT rupture is still unclear [1, 6, 16], and there is also no consensus on the tactics of treating AT ruptures.

ANATOMY FEATURES

The Achilles (calcaneal) tendon is the common tendon of m.gastrocnemius and m.soleus. Proximally, the parts of the tendon are quite clearly distinguishable, the m.gastrocnemius tendon begins as a wide aponeurosis from the distal part of the muscle belly, and the m.soleus tendon is a strip located proximally along the posterior surface of the muscle. The length of the gastrocnemius component ranges from 11 to 26 cm, while that of the soleus is 3–11 cm. Distally, the AT becomes progressively rounder in transverse sections up to a level of 4 cm proximal to the AT insertion onto the calcaneal tuberosity, where it is at its thinnest (area about 0.8 -1.4 cm2), and then expands slightly and in a fanwise manner attaches to the calcaneus.

The underlying factor in the pathogenesis of AT rupture is the vascular theory [1, 2, 9]. Avascularity and hypoxia are considered important factors in the etiology of tendon degeneration [1, 2, 4, 5, 12]. The main perfusion of the tendon is carried out by the paratenon vessels, which in turn are branches of the posterior tibial and peroneal arteries. The intratendinous vasculature in the endotenon layer tightly anastomoses with the paratenon vasculature. [2, 13, 65]. The proximal third of the AT at the level of 7–9 cm above the calcaneus is nourished by the muscular branches of the posterior tibial artery [9] (Fig. 1).

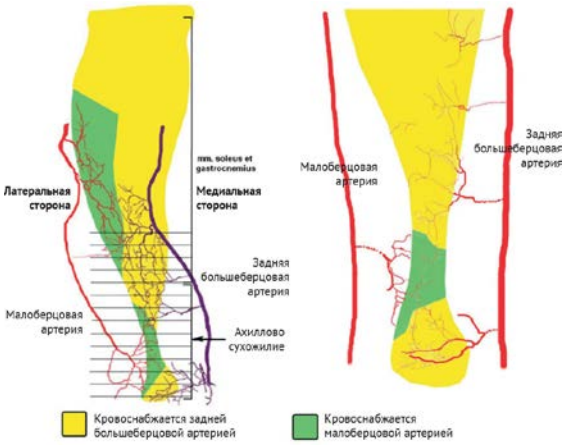

Fig. 1. Vascular distribution in the Achilles tendon. (Lagergren C., and Lindholm Â.: Vascular distribution in the Achilles tendon. An angiographic and microangiographic study. Acta Chir. Scandinavica, 116:491496,1958–1959)

The middle third of the tendon, 3-6 cm above the AT insertion onto the calcaneal tuberosity, is nourished by the branches of the peroneal artery. Accordingly, the AT in its middle third is hypovascular and is subject to the greatest risk of spontaneous rupture after repeated microtraumas [3, 4, 6] (Fig. 2).

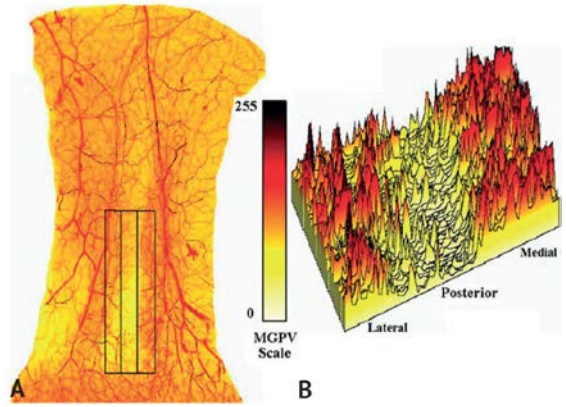

Fig. 2. Features of the blood supply to the Achilles tendon region (Masquelet AC, Romana MC, Wolf MD. Skin island flaps supplied by the vascular axis of the sensitive superficial nerves: anatomic study and clinical experience in the leg. Plast Reconstr Surg. 1992;89:1115–1121). A — Histological assessment of the density of the vascular bed in the Achilles tendon area; B — Perfusion of integumentary tissues around the Achilles tendon

DIAGNOSTICS

The diagnosis of acute AT rupture is primarily based on a thorough history and physical examination. As a rule, the diagnosis of subcutaneous damage to the AT is not difficult. Magnetic resonance imaging (MRI) or ultrasound is of great help in the diagnosis (Fig. 5). These examinations are effective for determining the location of the rupture, the gap between the torn ends of the tendon, and partial/complete rupture [13]. At the stage of pre-rupture (tendinopathy), MRI is of great help [66, 67].

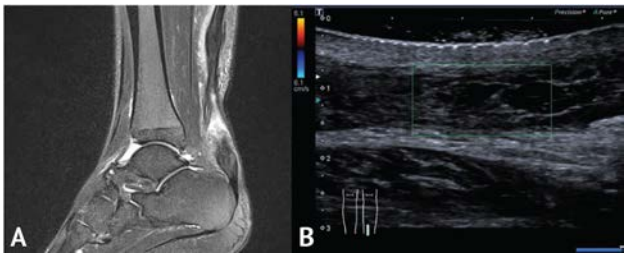

Fig. 3. Preoperative imaging showing chronic Achilles tendon rupture: (A) magnetic resonance imaging and (B) ultrasound. The green frame shows that the Achilles tendon has fused with the surrounding soft tissues, the proximal stump has contracted, the defect was about 60 mm, complete absence of joint movements of the distal and proximal stumps

TREATMENT

Surgical treatment of AT injuries requires careful and gentle handling of not only the tendon fibers but also the surrounding soft tissues to achieve optimal healing and function. Despite the superficial anatomical location, the main neurovascular bundles are located in close proximity to the AT. The blood supply of the AT consists of many small vessels (capillaries, precapillaries) and requires a very delicate surgical technique to prevent problems with surgical wound healing. On the other hand, damaged AT tissue is often flaky, making it difficult to stitch or repair. Finally, AT surgery significantly affects the further function of the ankle joint, where even small changes lead to statics and gait deviations.

Currently, there exists a large number of methods for the surgical treatment of acute and chronic AT injuries, but there is still no consensus as to which of them is easier to perform and universal [68, 69] (Fig. 3). All of them are divided depending on the timing of damage into conservative and operative, which in turn are halved into closed (the Girshin method) and open interventions. Treatment using external fixation devices (EFD) stands apart. All of them have their advantages and disadvantages. Some surgeons are in favor of surgery, while others believe that the risk of complications is not justified and prefer conservative treatment. Currently, the development of endoscopic techniques for AT suturing is underway.

Fig. 4. Treatment for Achilles tendon injuries

Conservative treatment is successful only in those cases when it is started within the first day after injury, since only in the early stages it is possible to re-establish ruptured ends' alignment. In this country, the conservative treatment was used by many surgeons: Tkachenko S.S. and Lyskovets-Chernetskaya L.E. (1974). At the same time, this method of treatment is also popular abroad, where it was studied by Fruensgaard S. et al. (1992) [68, 70]. The most common method of conservative treatment of acute AT ruptures is immobilization in equinus position for 6–8 weeks [68, 71].

The advantage of conservative treatment is the absence of surgical intervention (no suppuration, skin necrosis, suture sinuses, saphenous neuritis). However, a number of authors believe that conservative methods do not exclude a high risk of repeated ruptures. According to various reports, the incidence of re-ruptures in conservative treatment reaches 35% [14, 15, 69, 70]. European Union statistics show that re-rupture occurs in 3% of cases in operated patients, and in 13% of non-operated patients [66, 71]. The conservative method is more suitable for inactive and geriatric patients, among whom the risk of postoperative complications is higher, and the disadvantages are prolonged immobilization of the limb, the risk of relapse [72].

Most patients with acute AT rupture can be effectively treated with a closed percutaneous technique, and a satisfactory response can be achieved after rehabilitation. The Girshin (percutaneous) method has more advantages compared to other surgical procedures (minor invasiveness), but its use requires a highly qualified specialist.

There are various ways of percutaneous AT repair with minimal traumatization of the skin and sliding apparatus of the tendon, ensuring rapid uncomplicated healing of the skin and not disturbing the weak blood supply to the AT. The first example of their implementation was the work of American surgeons Ma G.W.C. and Griffith T.G. (1977) who developed and applied the technique of percutaneous buried tendon suture (Gritsyuk A.A., Sereda A.P., 2010).

Domestic surgeons Girshin S.G. and Tsypin I.S. (1981) suggested using the Cuneo suture in a similar way (Kornilov N.V., 2005) [63, 73, 74]. However, these methods do not guarantee accurate and durable connection of ruptured AT fragments, often the thread cuts through the dystrophically altered distal end of the Achilles tendon (Losev I.I. et al., 2010). Klein et al. (1991) noted the stitching of n. suralis in 13% of cases. Given a number of significant shortcomings, Bradley J.P. et al. (1990) report that with high sports demands of the patient, open tendon surgery will be the method of choice [74]. Despite the variety of proposed tendon sutures, not all of them have been widely used for many decades. In most cases, Cuneo or Krackow suture is used, followed by additional adaptation of the tendon ends. The more of the suture material is embedded in the tendon tissue, the stronger the suture. However, blood circulation is disturbed and the biomechanical properties of the tendon are reduced [21, 29, 42, 75, 76].

In most cases, open intervention on the tendon allows surgeons to achieve reliable adaptation of the AT ends and reduce the risk of repeated ruptures due to connective tissue formation. Along with the advantages of open surgical AT repair, there are also disadvantages: poor healing of the postoperative wound, infectious complications, and a rough postoperative scar that disrupts tendon gliding [50,77]. In the open method of surgical treatment, lateral peritendinous access is mainly used, which was first proposed by Abraham E. in 1975 [28]. In 1973 Goldwyn R.M. et al., and later in 2003 Green S.M. and Briggs P.J. [47, 48] performed surgeries with S- or Z-shaped accesses, respectively, which met the physiological requirements of wound healing in this area (Fig. 5).

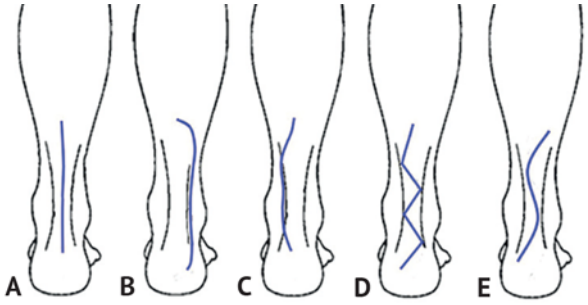

Fig. 5. Accesses used for the suture of the Achilles tendon: A — linear; B — lateral peritendinous; C — the E. Abraham and A. Pankovich curved medial parotendinous [17]; D — zigzag fashion; E — the Inglis and Sculco S-shaped [18]. (Khirurgicheskoye lecheniye razryvov akhillova sukhozhiliya : avtoreferat dis. ... doktora meditsinskikh nauk : / Sereda Andrey Petrovich; - Moskva, 2014. - 47 s)

Access to the tendon is best performed medially to reduce the likelihood of damage to the cutaneous nerve which supplies the lateral part of the foot and carries autonomic fibers [77].

These accesses are currently the main ones. Longitudinal access is not recommended according to the literature, although it is sometimes used in practice. Longitudinal accesses in most cases lead to tension of the wound edges and significantly increase the risk of marginal necrosis, according to Zulkarneev R.A. et al. (1989), a hypertrophic skin scar often forms [22, 30, 51, 59, 72].

After surgical access, the injured tendon is sutured end-to-end using one of the tendon sutures [72].

After the tendon stump is isolated and the hematoma is evacuated, the tendon integrity is being restored. Functionally complete restoration of the tendon provides for the preservation of its elasticity and resilience [21, 46]. There are certain requirements when suturing injured ends of the tendon: the AT ends must be connected with maximal reliability, and sufficient blood supply to the edges of the skin wound must be maintained [72].

Thus, significant tension of the tendon during suturing can subsequently lead (when the foot is brought into correct position) to the failure of the tendon sutures or to the preservation of the equinus position of the foot. Unfortunately, suture threads not only keep the tendon ends in contact, but can also compress intratendinous vessels, change interstitial pressure, disrupt the orientation of regenerating fibers, cause productive inflammation and enhance adhesion formation, as well as serve as a source of infection [11, 13, 20, 38, 49, 55].

A number of authors believe that after 3-4 weeks, the tendon suture becomes unnecessary, since the ends of the tendon are already held by young scar tissue [15, 19, 43, 49, 53], and the removal of the thread from the tendon during this period will only contribute to the correct distribution of tension force and, consequently, scar remodeling. Therefore, many surgeons prefer the Bunnell removable wire tendon suture technique [21, 29, 68].

In total, about a hundred types of tendon sutures are known, and almost all of them can be used for AT repair. Sereda A.P. proposes to classify tendon sutures as follows:

• By the number of threads crossing the rupture site: two-, four-, six-strand, pair-strand, etc., using block loops at the rupture site;

• By the number of knots (number of tied threads), when those threads are tied, the ruptured ends of the tendon are connected: one-, two-, three-, four-knot sutures;

• By the location of the tightening knots: outside the rupture site, at the rupture site, combined;

• By the location of the threads (direction of force vectors) relative to the axis of the tendon: predominantly parallel (non-deforming tendon fibers), cruciform or oblique passage of the threads (deforming tendon fibers), with the connection of the AT ends not end-to-end (the Pulvertaft, spiral repair technique);

• By the predominant location of the threads: on the surface of the tendon (twisted, mattress, zigzag), buried, peripheral (epitendinous), combined;

• By the location of the threads on the transverse section of the tendon: single-plane, multi-plane (located in different sectors of the transverse section);

• By the method of fixation: true tendon, with fixation to the bone (transosseous canal, anchor fixator), harpoon;

• By the variant of proximal and distal tendon stump suturing: mirror (stumps are sutured in the same way), asymmetric (stumps are sutured in different ways);

• By biomechanical purpose: load-bearing (shaft sutures) and adaptive (epitendinous, the Kleinert protocol).

Despite the variety of proposed tendon sutures, not all of them have been widely used for many decades. In most cases, the Cuneo or Krackow suture is used, followed by additional adaptation of the tendon ends. The more of the suture material is embedded in the tendon tissue, the stronger the suture. However, blood circulation is disturbed and the biomechanical properties of the tendon are reduced [21, 29, 42].

Operative treatment by open access according to Nyyssönen T. et al. consists in suturing the tendon end-to-end in various modifications (the Cuneo, Krackow, Kazakov, etc.) without grafting (2003). Leitner A. (1992) adheres to another point of view: in case of chronic ruptures with a large diastasis between damaged fragments of the tendon, grafting is the method of choice, which is confirmed by the work of Mayer L. et al. (1956).

In general, it should be noted that open surgical AT repair allows surgeons to achieve reliable adaptation of the tendon ends and ensures a low percentage of re-ruptures [37, 39, 58, 74].

However, making an access in an area with a weak blood supply predisposes to the occurrence of complications, primarily impaired skin wound healing. In this connection, Arner and Lindholm, 1959, in a series of 86 operated patients note 24% of complications, including 2 cases of deep vein thrombosis in the leg, one of which led to death as a result of pulmonary embolism; and 3 cases of deep wound infection; 11 cases of skin necrosis and 4 cases of repeated ruptures. Modern studies report a lower level of complications, but the problem of skin wound healing remains relevant [36, 38, 77].

The treatment of chronic AT rupture differs from that of acute AT rupture (Fig. 6). Chronic AT rupture is diagnosed if the rupture occurs within 4–6 weeks of injury (misdiagnosis or lack of effective treatment) [72] (Fig. 6). The cause of repeated ruptures of the calcaneal tendon is a degenerative change which leads to suture

eruption during the rehabilitation period (Klyuchevsky V.V., 1999; Cretnik A., 2000; Pajala A. 2007; Bertelli R. 2009; Rodomanova L.A. 2010; Kauwe M., 2017).

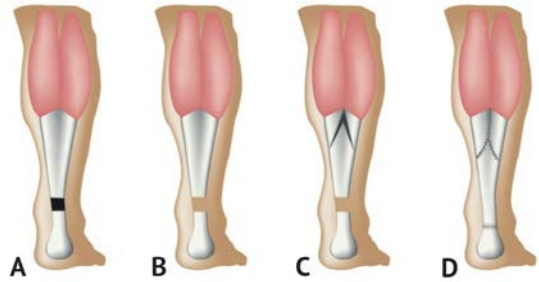

Fig. 6. Surgical diagrams of V-Y tendon plasty. A — chronic rupture of the Achilles tendon with scar tissue; B — excision of scar tissue between the fragments of the damaged tendon; C — V-shaped flap design; D — end-to-end anastomosis with "Y" suture

The clinical manifestations of chronic AT rupture include chronic pain, lameness, and weak or no hindfoot lifting. This seriously affects the daily life of those patients. In chronic AT rupture, tendon ends shorten, which results in scar tissue formation. Scar tissue is not a normal tendon fiber and can lead to limited function in the ankle joint and gait disturbances [35, 56, 78]; therefore, its complete excision is necessary. However, after excision of the scar tissue, a defect (more than 2 cm) is formed, which is difficult to eliminate by the percutaneous method [66, 78]. Restoring sufficient AT length and tension is vital to lower limb function. Reconstruction of chronic AT ruptures is very difficult. Consequently, the treatment of chronic AT ruptures is often a challenge for orthopedic surgeons.

Currently, there is no generally accepted strategy for the surgical treatment of chronic AT rupture. Sometimes, among many proposed methods, it is difficult to choose the most optimal one. Various repair techniques have been proposed to achieve the desired results in chronic ruptures, such as V-Y tendon repair (Fig. 8), Chernyavsky (Fig. 7), Krasnov, Nikitin, Lindholm, Bosworth, Mangini, Ducroquet and Lescoeur AT repair, FHL transfer, and others (Fig. 5), V-Y gastrocnemius muscle slide with turnover fascial flap, tendon transfer (flexor hallucis longus (FHL) tendon transfer and flexor digitorum longus tendon transfer), allograft reconstruction, autograft reconstruction (semitendinosus tendon autograft [10, 79], peroneus and longus peroneus) [11], synthetic graft (reinforced system) [80], bioabsorbable synthetic graft [62], and biological matrix augmentation [14]. Achilles tendon rupture reconstruction is difficult, so there is no standard treatment for chronic rupture, especially for large defects [15, 81].

One of the surgical treatment methods for chronic AT injuries is V-Y-lengthening with end-to-end suturing (Fig. 6). This technique was first proposed in 1975 and is still widely used abroad [10, 66]. In Russia, the popularity of this procedure is low. In this country, the V.A. Chernavsky AT repair is widespread. [31], despite a number of described negative parameters and proposed new methods [31, 33, 50, 76, 82].

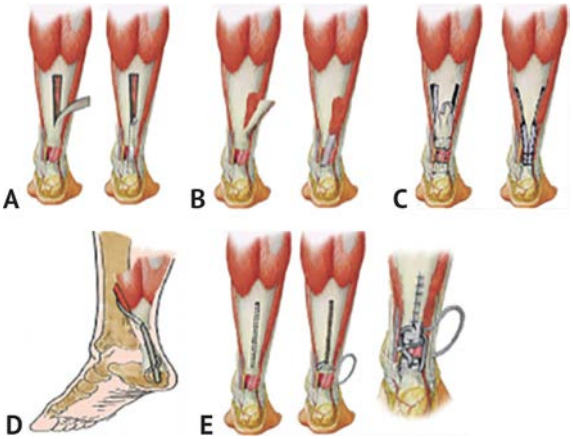

Fig. 7. Surgical treatment for the Achilles tendon ruptures, calcaneal tendon defect repair with a flap from the proximal fragment. A — the Krasnov surgical technique; B — the Nikitin surgical technique; C — the Lindholm surgical technique; D — FHL tendon transfer; E — the Bosworth surgical technique

The Chernyavsky technique for AT reconstruction is as follows: a distally based flap is cut out from the aponeurosis of the musculus triceps surae, moved to the distal end of the tendon and sutured superficially or inserting into the incised surface of the tendon (Fig. 7).

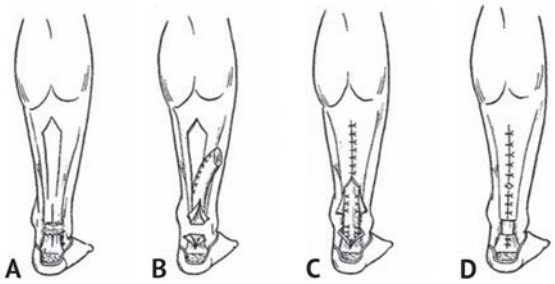

Fig. 8. The Chernyavsky technique for Achilles tendon reconstruction

The anterior surface of the AT can be further strengthened by the plantaris tendon. An extremely important point after plastic surgery is to assess the degree of blood circulation of the skin flap over the AT. If it is impossible to cover AT with local tissues, transplantation of a free revascularized fasciocutaneous flap into the defect area becomes the method of choice (Belousov et al.)

Along with the skin, two main options for AT reconstruction are available:

1. Non-vascularized tendon (fascial) grafts with closure of the skin defect with a skin-fascial flap.
2. Plastic repair of AT defects with a vascularized graft (Fig. 9).

Fig. 9. Reconstruction of Achilles region defects

The external fixation technique is characterized by low invasiveness, low incidence of repeated ruptures, and the presence of controlled immobilization with the possibility of eliminating AT diastasis. Disadvantages are the massiveness of the design and longer immobilization than in open surgical interventions.

Thus, among the shortcomings of surgical treatment, one can mainly single out the formation of extensive adhesions and scars in the area of surgical intervention, which, in turn, leads to prolonged immobilization and possible complications. Therefore, minimally invasive surgical techniques are a compromise between surgical and conservative methods of treatment.

In recent years, minimally invasive technologies in operative surgery for AT ruptures have become very popular. This more sparing to the patient approach, compared to the open surgery, significantly improves surgical outcomes, reduces the risk of postoperative complications, time spent in hospital and rehabilitation period. The method allows the patient to return to a normal lifestyle in a shorter time; early loading on the limb and early development of movements in the joint are also possible [64, 76].

Modern types of surgical treatment include such techniques for AT reconstruction as tendon suturing through separate skin punctures, percutaneous stapling technique, Achillon® Achilles Tendon Suture System, the use of reinforced superelastic titanium nickelide implants, endoscopic techniques, arthroscopy, etc. [34, 76].

Special guides for percutaneous sutures are used, and endoscopic techniques are being developed [33, 34, 49]. The minimally invasive open access technique was first developed by a group of Swiss surgeons led by Mathieu Assal to minimize complications such as postoperative wound infection in case of open access and damage of the sural nerve in case of percutaneous technique [34].

Surgical technique: A small skin incision is made above the rupture site, and the subcutaneous soft tissue is bluntly retracted. For a minimally invasive open technique, additional instruments are required (original AT percutaneous suture guide - Achillon® System™). The instrument is inserted through the incision under the paratenon and the suture is passed from the outer conductor through the skin into the tendon and out to the opposite side. Typically, three sutures are passed through the proximal and distal ends of the tendon. The device and suture are pulled out to connect the torn ends of the tendon, and the sutures are tied over the ankle with the foot plantar flexed (Fig. 10).

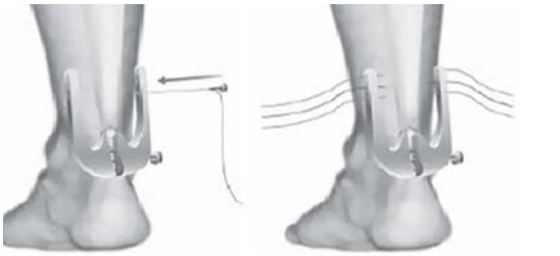

Fig. 10. Use of the Achillon device to treat Achilles tendon ruptures

Percutaneous and mini-open techniques compared with open reconstruction result in the reduction of wound complications and improve cosmetic appearance. However, the overall complication rate does not differ significantly between mini-open, percutaneous, and open surgical techniques. Against this background, literature data on the use of microsurgical techniques in the reconstruction of limb tendons remain scarce [65, 67].

It is generally accepted among modern surgeons to supplement the main tendon suture with a microsurgical adaptive epitendinous suture which improves the adaptation of the tendon ends and increases the strength of its fixation [32, 57]. Along with this, we did not find any works in which sutures inside the tendon shaft were performed using microsurgical techniques. This is largely due to the lack of microanatomical substantiation of one or another method of tendon suture, a differentiated approach depending on the level of damage to the tendon, the condition of the tendon tissue and its anatomical environment. The above problems of the traditional treatment for AT injuries determine the expediency of a deeper study of microsurgical anatomy and the search for new ways to restore the integrity of the damaged tendon apparatus. The use of microsurgical techniques would expand the surgeon's capabilities in this area, develop fundamentally new methods of tendon repair, prevent the development of complications, minimize socio-economic damage and the cost of providing specialized care to this category of victims [9, 17, 44, 49].

CONCLUSION

Based on the analysis of scientific and methodological literature, it can be concluded that in the treatment of patients with Achilles tendon ruptures, the main trend at the present stage is the increasingly widespread use of minimally invasive, sparing methods of surgical treatment in combination with active postoperative management of patients, providing early dosed loading on the limb and speedy recovery of function.

The use of traditional open suture and plastic interventions does not lose its relevance in cases of late rupture diagnosis. Despite the abundance of proposed accesses to the Achilles tendon, the optimal one for all types of injuries has not yet been developed.

Currently, there are no clear recommendations on the choice of a specific method for the treatment of Achilles tendon rupture. Although the understanding of Achilles tendon pathology is growing exponentially, much more research is still needed to more fully understand the multifaceted etiology, optimal treatment methods.

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