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WHAT'S NEW IN ACHILLE'S TENDON RUPTURE, A LITERATURE REVIEW

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INTRODUCTION

The incidence of acute ruptures of the Achilles tendon appears to be increasing. The aim of this article is to summarize the different therapeutic approaches, discuss their merits, and present the latest developments regarding the management of this condition.

MATERIALS AND METHODS

After conducting a search on PUBMED regarding the management of acute Achilles tendon ruptures, the search was open to original manuscripts and review articles published between January 2006 and March 2023. A total of 623 articles were identified, and ultimately, 220 articles were selected for this study. Additionally, the experience of the Traumatology-Orthopedics department at the IBN SINA University Hospital in Rabat and images of treated cases from patients in the department were included.

RESULTS

The treatments for acute Achilles tendon rupture include surgical and conservative approaches. Surgical treatments mainly consist of open repair with or without augmentation, percutaneous repair, and minimally invasive repair. Traditional open repair has higher rates of secondary rupture and increased risks of complications. Percutaneous repair and minimally invasive repair show similar rates of re-rupture but lower overall complication rates compared to traditional repair. Percutaneous repair requires vigilance, particularly to avoid nerve injuries. Functional rehabilitation combining protected weight-bearing and early controlled mobilization can effectively reduce failure rates with satisfactory outcomes. Biological adjuncts help accelerate tendon healing by adhering to the rupture ends or releasing signaling and stimulation factors for healing.

CONCLUSION

The optimal treatment for acute Achilles tendon rupture remains controversial. Minimally invasive repair and functional treatment are attractive alternatives, while biotechnology holds promising developments for the future.

The Achilles tendon is the most powerful tendon in the body, transmitting forces from the gastrocnemius and soleus muscles to the calcaneus, enabling walking, jumping, and running. However, the incidence of Achilles tendon rupture has increased in recent years.[1,2] While most Achilles tendon ruptures occur during sports activities,[3] other factors such as gender,[4] medication,[5,6] intrinsic structural variations,[7] and biomechanical changes related to aging,[2] can all contribute. It is important to note that the tendon healing process occurs in three distinct phases: inflammation, proliferation, and remodeling.[8] The main goals of managing acute Achilles tendon rupture are to ensure a quick return to full function and prevent complications. The treatment of acute Achilles tendon rupture can be broadly classified as surgical and non-surgical. Clinical evaluation involves the use of objective rating scales9 and patient-reported outcome measures, such as the Achilles Tendon Total Rupture Score (ATRS).

Surgical Management: The surgical treatment of Achilles tendon rupture consists of two distinct elements, namely the surgical technique itself and post-operative rehabilitation and follow-up. The surgical management of an Achilles tendon rupture can be divided into four categories: open repair with or without augmentation, percutaneous repair, and minimally invasive techniques. Generally, surgical intervention is typically preferred for younger patients and those with high functional demands.[11,12]

Open Surgical Repair: The direct approach is a relatively simple procedure that involves a posterior-medial extended incision to expose the rupture site, followed by approximating the tendon edges using various suture techniques.[13-15] However, when the defect exceeds 3 cm, augmentation is necessary. Various techniques exist, such as tendon grafting, proximal

turnover flap, etc.[18] It is worth noting that two prospective randomized studies,[19,20] failed to demonstrate a clear advantage of using tendon grafts compared to simple end-to-end suturing.

Classic Achilles tendon surgery has a wound-related complication rate ranging from 8.2% to 34.1%,[21-23] with at least half of these complications attributed to infection.[24] Scar-related complications are classified as major or minor, based on their impact on the patient's quality of life.[21,24] The Achilles tendon is more susceptible to infection due to its relatively poor blood supply.[25] The soft tissue trauma during surgery further increases the risk of infection, and the use of tourniquets can also impair wound healing.[26] Corticosteroids, smoking, and diabetes are all factors that increase the risk of wound complications (tripled risk).[27] While there is no evidence supporting the use of prophylactic antibiotics,[28] many surgeons still administer prophylactic antibiotics such as cefazolin.[29]

Suturing Technique and Materials: All suture materials can cause local immunological and inflammatory reactions.[30] Different types of suture threads have varying effects on the surrounding tissues and, ultimately, the wound infection rate.[28,31] Many surgeons previously advocated for sutures using non-absorbable multifilament threads. However, it has been demonstrated that these sutures can lead to chronic inflammation,[32,33] and are susceptible to contamination and subsequent infection.[32,34] Yildirim et al.[35] showed that non-braided, absorbable sutures like polydioxanone (PDS, Ethicon, Somerville, New Jersey) have sufficient holding capacity and strength. Regarding technique, a systematic biomechanical review36 of 11 articles utilizing various different suture techniques, including Kessler, Bunnell, and Krackow sutures for open repair, the Achillon device (Wright Medical, Memphis, Tennessee), the Ma-Griffith repair technique, the triple bundle technique, and the "gift box" technique, found that the triple bundle technique, in combination with Ethibond sutures (Ethicon, Somerville, New Jersey), was the most effective. This conclusion was later confirmed by Bevoni et al.[37]

Percutaneous Technique: The percutaneous method involves suturing the Achilles tendon through multiple small incisions made under local anesthesia without directly exposing the rupture site. In 1977, Ma and Griffith described the percutaneous repair of an acute Achilles tendon rupture (.1a), which had the advantage of a relatively low re-rupture rate while reducing rates of infection and other soft tissue complications. In a prospective randomized controlled trial (RCT) of 33 patients comparing open and percutaneous methods, Lim et al. reported a postoperative infection rate of 21% in the open repair group and no wound infections in the percutaneous repair group. The re-rupture rates at a minimum follow-up of six months were 6% and 3%, respectively. Cretnik et al. conducted a comparative study involving 237 patients and reported that the percutaneous repair group had a lower number of complications (9.7% vs. 21%; p = 0.013). In another prospective RCT of 34 patients, Karabinas et al. found no statistically significant differences between the open and percutaneous groups regarding the time required to resume activities, the American Orthopedic Foot and Ankle Score (AOFAS), and patient satisfaction. Henríquez et al. retrospectively reviewed 32 patients, with 17 undergoing percutaneous repair and 15 undergoing open repair, and observed similar values in both groups in terms of muscle strength, range of motion (ROM) of the ankle, and single heel-rise tests. However, aesthetic appearance was better in the percutaneous group, with a shorter average scar length (2.9 cm vs. 9.5 cm). Furthermore, percutaneous repair may be a suitable option for elderly individuals, producing similar outcomes to those reported for percutaneous repair in younger patients. Percutaneous repair has also been reported as a viable option for elite athletes, allowing for a rapid return to sports activities.

Nerve Injuries: However, the two main risks of the percutaneous technique are sural nerve injury and reduced repair strength. Nerve injury can result in sensory disturbances, severe pain, or impaired function. The incidence of iatrogenic nerve injuries associated with the percutaneous method was reported to be 13% in early studies.[46] In cadaveric studies, high rates of sural nerve transfixion have been reported,[47,48] and anatomical variations can further exacerbate this rate.[49] In response to these complications, Webb and Bannister developed a percutaneous technique involving only three midline skin incisions, carefully avoiding the lateral side of the tendon to protect the sural nerve (.1b).[50] Subsequently, Wagnon and Akayi retrospectively reviewed the results of 57 patients who underwent this improved percutaneous technique, and no neurological injuries were reported.[51]

Low Repair Strength: The initial weakness.[48] and inadequate apposition of the tendon edges.[52] are likely responsible for the relatively high incidence of re-rupture in patients undergoing percutaneous repair. Using a modified approach (.1c), Cretnik et al.[53] tested 36 cadaver Achilles tendons to failure and found that their repair technique nearly doubled the tendon strength compared to the Ma-Griffith method. Furthermore, the Cretnik method showed a re-rupture rate comparable to open procedures (3.7% vs. 2.8%, p = 0.68)[40]. Carmont and Maffulli.[54] modified the percutaneous method by using eight strands of suture material with a combined strength likely exceeding 43 kg, and subsequently treated 73 patients with only one partial re-rupture during the first year.[55]

Endoscopy and Ultrasound: Endoscopically-assisted percutaneous repair allows for direct visualization of the tendon rupture and controlled suturing of the tendon ends without damaging the paratendon, thus preserving blood

supply and promoting biological recovery.[56] Re-rupture is minimized, and early ankle mobilization and weight-bearing can be performed after the surgery. The main advantages of real-time intraoperative ultrasound are accurate needle positioning and precise approximation of the tendon stumps.[57] It also eliminates the risk of sural nerve injury.[58]

Mini-Open Repair: The concept of "mini-open" repair is to combine the advantages of open and percutaneous techniques.[59] allowing for direct visualization of the tendon edges through a small incision. Several authors have further developed this technique (Table I).[60-63] Assal et al. published the results of a prospective multicenter study using a specially designed instrument called the Achillon device, which ensures that all sutures are guided outside the peritendinous region, theoretically avoiding nerve injury.[60] protecting the paratendon,[65] and promoting faster recovery.[66] Unlike the percutaneous technique, where repair must be performed early,[67] mini-open repair was performed up to three weeks after the rupture.[68] The small skin incision allows for the removal of any blood clots and interposed tissue and also reduces the risk of wound infection.[59,64] Visualization enables proper apposition of the tendon and increases the strength of the repair.[69] thus reducing the incidence of re-rupture.[70] Using a postero-medial vertical incision, the mini-open technique is superior to the percutaneous technique in reducing sural nerve injuries and is also better than the traditional open technique in reducing the risk of wound complications while providing a strong repair.

However, these techniques require skilled and experienced surgeons, as well as the availability of equipment.

Postoperative management: The postoperative protocol can influence the speed of rehabilitation, with the main goals being return to work and resumption of sports activities. Functional treatment is important. Several randomized controlled trials are listed in the supplementary table i. Kangas et al.[71] compared early ankle range of motion exercises without early weight-bearing to immobilization where weight-bearing was initiated three weeks after surgery. They reported somewhat better isokinetic calf muscle strength outcomes in the early movement group, with only one re-rupture among 25 patients. In a randomized controlled trial comparing two postoperative regimens in 110 patients, Suchak et al.[72] showed that two weeks after surgery, weight-bearing improves health-related quality of life in the early phase without adverse effects on recovery and no re-ruptures in both groups during six-month follow-up. Interestingly, in a randomized controlled trial comparing aggressive rehabilitation to conventional rehabilitation, De la Fuente et al.[73] demonstrated that the 20 patients who received aggressive therapy based on immediate controlled mobilization combined with weight-bearing from the first day after surgery had higher ATRS scores, lower verbal pain scores, earlier return to work, and greater Achilles tendon strength. The re-rupture rates in both groups were 5%, and the rates of other complications were 11% and 15% in the conventional and aggressive groups, respectively. Although aggressive rehabilitation begins immediately after surgery, a period of approximately two weeks of immobilization and unloading may be preferred to allow for soft tissue healing.

Conservative treatement: Conservative treatment involves immobilization and non-weight bearing for at least four weeks after the injury. Historically, non-surgical treatment was generally offered to older patients and those with reduced functional requirements or obvious surgical contraindications. Recently, the decision to treat an acute Achilles tendon rupture non-surgically has improved with dynamic ultrasound. Lawrence et al.[74] conducted a prospective cohort study of 38 patients and found that patients with a gap $\geq$ 10 mm, with the ankle in a neutral position after non-operative treatment, had a significantly higher strength deficit compared to those with gaps < 10 mm ($p = 0.023$), but there was no difference in ATRS scores ($p = 0.467$). Unfortunately, their treatment protocol did not include early mobilization. Using functional treatment, Hufner et al.[75] examined the long-term outcomes of 168 patients meeting the following inclusion criteria: a gap of less than 10 mm with the foot in a neutral position and complete apposition of the tendon stumps in 20° plantar flexion as demonstrated on ultrasound examination. The re-rupture rate was 6.4%, and 92 patients (73.5%) achieved good or excellent results on average 5 years after the injury. The authors suggested that a follow-up ultrasound examination be performed two to five days after the initial ultrasound to confirm the indications for non-operative treatment. Furthermore, all patients wore a 3 cm heel lift for eight weeks, followed by shoes with a 1 cm heel lift for an additional three months to provide prolonged tendon protection. Kotnis et al.[76] examined the role of ultrasound in a group of patients with a gap of 5 mm or more in their Achilles tendon, with the foot in equinus, who underwent surgical treatment and compared them to a group of patients with a gap of less than 5 mm, with the foot in equinus, who received orthopedic treatment. They reported no difference between surgical and non-surgical treatment in terms of re-rupture rates (1.5% vs 3.4%), nor in other complications such as chronic pain (1.5% vs 1.7%), numbness (3.0% vs 0%), wound infection (3.0% vs 0%), or deep vein thrombosis (0% vs 1.7%). Additionally, in a cohort study of 45 patients, Westin et al.[77] categorized the gap between the tendon ends as follows: 0 mm to 5 mm, > 5 mm to 10 mm, and > 10 mm. When comparing surgical and non-surgical treatments, they found that in the non-surgically treated group, three out of four patients with a gap of > 10 mm experienced re-rupture, and patients with a gap of > 5 mm had poorer outcomes in terms of ATRS scores ($p = 0.004$) and lower heel-rise

height (p = 0.048) at 12 months. Therefore, a gap of less than 5 mm is more reliable in confirming adequate apposition of the tendon ends and is recommended as the threshold for conservative treatment.

Functional Treatment: In many medical centers, functional rehabilitation after Achilles tendon rupture is similar, regardless of whether the treatment is surgical or non-surgical. The main difference lies in the fact that surgically treated patients start rehabilitation earlier.[78] The most widely used functional protocols combine protected weight-bearing and early controlled movements using an orthosis. This begins with a period of immobilization, gradually progressing from maximum equinus position to neutral position, using a heel lift to bring the tendon ends closer together.[79,80] There is considerable variation among these protocols regarding the strict immobilization period, the timing of initiating weight-bearing and early movements, as well as the progression of weight-bearing.

Immobilization vs Early Mobilization: Qureshi et al.[81] demonstrated that when the ankle's neutral position was replaced with maximum plantar flexion, the mean gap decreased from 12 mm to 5 mm. They reported that this gap distance would further decrease to 2 mm in maximum equinus position with the knee flexed from 0° to 90°. Therefore, immobilization with a below-knee plaster cast in plantar flexion position has been advocated. However, based on our experience, eight weeks of immobilization in this position can have major drawbacks, including soleus muscle atrophy, increased re-rupture rate, deep vein thrombosis, and loss of coordination and proprioception. On the other hand, ankle immobilization in equinus position for one to three weeks is important to allow hematoma consolidation and restore tendon continuity.[79] Aspenberg[8] suggested that early controlled movement of tendons promotes better healing through the release of growth factors, and animal studies have shown a threefold increase in the strength of the Achilles tendon with early mobilization[71] Applying tensile load to the healing tendon through mobilization leads to fundamental changes in the tendon's biological healing process, accelerating the restoration of load capacity until rupture[82] In a randomized clinical trial involving 35 patients, Schepull and Aspenberg.[83] demonstrated that early weight-bearing improves the elasticity of the human Achilles tendon and enhances healing after rupture. Arslan et al.[84] evaluated 22 patients following unilateral open repair and found that early postoperative mobilization appeared to have no complications. Majewski et al.[85] reviewed 103 patients who underwent percutaneous repair and different postoperative mobilization methods. They reported that early restricted movement shortened the time to return to work from 67 days to 37 days (p = 0.042) compared to plaster immobilization. Additionally, Nilsson-Helander et al.[22] randomized 97 patients to surgical and non-surgical treatment with early mobilization and suggested that early mobilization was beneficial for patients with acute Achilles tendon rupture, regardless of whether they were treated surgically or non-surgically. Although the current literature tends to favor early mobilization, a survey conducted among orthopedic surgeons in the UK found that the average immobilization period was eight to nine weeks. This indicates that a significant duration of immobilization was generally followed in clinical practice. Furthermore, the survey revealed that the use of functional bracing, which involves the use of devices or splints allowing controlled movement, was not as widespread as immobilization with a plaster cast.

Surgical or non-surgical treatment: Historically, non-surgical treatment has been associated with high rates of secondary ruptures (9.7% to 12.6%). One possible explanation for the difference in re-rupture rates between non-surgical and surgical methods may be related to the composition of the healed tendon. With primary repair, the gap is reduced, and consequently, the proportion of tendon composed of scar tissue is reduced. However, no significant difference was observed between the two treatments regarding tendon elongation (p = 0.31). Achilles tendon elongation has a negative effect on muscle strength, produces gait abnormalities, and reduces power generation around the ankle. As a result, many surgeons prefer surgical treatment due to greater ankle range of motion, improved quality of life, and shorter work absence periods.

However, when functional rehabilitation with early motion and early weight-bearing was adopted, Willits et al. found that re-rupture rates did not significantly differ between surgically and non-surgically treated patients (2.8% vs. 4.1%). Furthermore, complications other than secondary rupture, such as adhesions, sural nerve injuries, and infection, were all higher in the surgical group. From a biomechanical perspective, in an animal model, early functional activity associated with non-surgical treatment resulted in better fatigue properties. Non-surgical management may be more suitable for functional rehabilitation than primary repair. However, this remains to be proven in the context of a large randomized clinical trial.

A retrospective epidemiological study revealed that the best surgical outcomes were achieved in male patients under 40 years of age, while functional treatment was more beneficial in women over 40 years of age. Although high-quality randomized clinical trials and recent meta-analyses support the use of conservative treatment, significant variations still exist between different regions. In the United States, an analysis of 12,570 patients showed that the surgical-to-non-surgical treatment ratio increased from 1.41 to 1.65 between 2007 and 2011, whereas in Canada, a review of 29,531 patients from 2002 to 2014 reported a significant decrease in surgical treatment starting from 2009 (p <0.001).

In summary, controversies still exist regarding the optimal treatment strategy for acute Achilles tendon rupture. Open surgery can significantly reduce the incidence of re-rupture, but it carries higher risks of complications. While percutaneous repair may reduce complications associated with the surgical wound, there is still a risk of nerve injury. However, meta-analyses have clearly demonstrated the benefits of functional treatment. Additionally, bioactive agents have the potential to improve postoperative tendon healing. Furthermore, studying the role of mechanical and biological factors in Achilles tendon healing, particularly at the molecular level using genomics, epigenetics, proteomics, and metabolomics, would be highly valuable.

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