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# Achilles tendon ruptures

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**Abstract** The incidence of acute Achilles tendon ruptures is on the rise. This is thought to be due to the increasing number of middle-aged persons participating in athletic and/or strenuous activity. Ruptures of the Achilles tendon can be severely debilitating, with deficits seen years after the initial incident. Also, these injuries can have substantial socioeconomic impacts regardless of the treatment selected. Debate continues over the optimal treatment of Achilles tendon ruptures, especially the argument whether to treat patients nonoperatively or surgically. Newer evidence shows that functional rehabilitation, including early weight-bearing, should be an integral part of successful treatment of acute Achilles ruptures. Further research is needed to further investigate the ideal treatment and rehabilitation protocols.

**Keywords** Achilles · Tendon · Ruptures · Achilles Tendon Total Rupture Score (ATRS) · Functional rehabilitation · Operative repair · Nonsurgical treatment · Functional braces · Weight-bearing

## Introduction

The Achilles tendon is the largest and strongest tendon in the human body [1]. Despite this fact, the Achilles tendon is the most commonly injured tendon in the lower extremity [2] with an incidence of roughly 18 per 100,000 [3]. The rise in number of acute ruptures is thought to be due to the increasing percentage of the population participating in sporting activities at an older age. The incidence rises rapidly after 25 years of age with males in their fourth or fifth decade accounting for the overwhelming majority of acute ruptures. Another peak is seen between the sixth and eighth decade, which predominantly occurs from a longstanding degenerative condition of the tendon. The male-to-female ratio has been estimated to range from 1.7:1 to 30:1 [4].

The inherent characteristics, function, and blood supply of the Achilles tendon predispose it to both acute and chronic rupture, as well as a wide spectrum of chronic overuse injuries stemming from inflammatory and degenerative changes within the tendon itself. In the situation of an acute rupture, patients are usually engaged in athletic activities, accounting for 68 % of injuries. The injury occurs during a strong dorsiflexion force that is applied to the ankle as the gastrocnemius-soleus complex simultaneously contracts to plantarflex the ankle: an eccentric contraction. Recently, a study investigating the general population of the United States population found that basketball was the most commonly involved sport, accounting for 48 % of all ruptures [5]. In Canada and Europe, soccer accounted for most of the traumatic tendon ruptures [6–9]. Prodromal symptoms are a common finding in the patient's history, especially the elite athlete [10, 11]. Older patients and patients with a body mass index greater than 30 were more likely to be injured in nonsporting activities, and were also more likely to have a missed diagnosis for their injury [5]. Furthermore, a study investigating Achilles tendon ruptures in women agreed with previous reports that acute Achilles rupture is more common in men. However, for acute ruptures, the mean age was not significantly different between men and women (43.8 vs 55.1) and there were similar rates of athletic activity as the causative factor in men (80.5 %) and women (71.4 %) [12].

Even as the incidence of acute traumatic Achilles tendon ruptures continues to rise, there is still considerable controversy as the most optimal treatment plan. Debate about nonoperative vs surgical repair for acute ruptures, minimally invasive vs traditional open repair, and early functional rehabilitation

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protocols instead of a more traditional rehabilitation program are only a few of the arguments that continue to exist in the realm of treatment.

## Anatomy

The tendon receives equal contributions from both the gastrocnemius and soleus muscle and tendinous fibers. These fibers converge approximately 15 cm from the insertion point. As the tendon courses inferiorly in the posterior aspect of the leg, the fibers twist approximatedly 120° internally (counterclockwise on the right leg) before its insertion point on the calcaneal tuberosity [13]. The Achilles tendon lacks a true synovial sheath. Rather, the tendon is enveloped within a paratenon. The paratenon permits gliding of the tendon between the skin and surrounding posterior soft tissues of the leg. In addition, the paratenon is responsible for a significant portion of the tendon's blood supply through a highly vascularized areolar tissue on its anterior aspect. A recent angiographic study showed that a dense net of small arteries inserts into the paratenon of the Achilles tendon in its lower 20 cm and seems to provide ample blood supply [14]. The Achilles' remaining blood supply is derived from the musculotendinous junction proximally, and from the osseous insertion, distally. The pattern of blood supply leaves the Achilles tendon vulnerable to injury in a watershed area approximately 2–6 cm from its insertion on the posterior calcaneus. Rupture occurs in this watershed area approximately 75 % of the time. Furthermore, ruptures can occur at the distal insertion (10 %–20 %) and the myotendinous junction (5 %–15 %) as well [15].

The Achilles' main purpose is to provide ankle plantarflexion. Other functions include acting as a checkrein during eccentric contraction to prevent excessive ankle dorsiflexion and forward lurching during ambulation. Unique viscoelastic properties of the Achilles allow the tendon to undergo plastic deformation as the gastrocnemius-soleus complex contracts. These viscoelastic properties also cause the tendon to become stiffer as rapidly increasing loading forces are applied [16, 17].

## Risk factors (Table 1)

Several different risk factors have been implicated as contributing to acute ruptures. Although a link might have been shown to exist between certain medications, medical conditions, or other entities, it must be emphasized that an acute rupture of the Achilles tendon is most likely multi-factorial. Local or systemic corticosteroids have been associated with partial and complete ruptures [18]. Mafulli et al presented 15 athletes that presented with Achilles tendon ruptures. All athletes reported prodromal symptoms along with multiple injections of different modalities, including corticosteroids, aprotinin, hypertonic glucose, prolotherapy agents, and mesotherapeutic agents in the peritendinous area [10]. Historically, fluoroquinolones were shown to cause Achilles tendon ruptures as well [19]. Degenerative changes within the tendon itself [20] or from vascular irregularities can cause a weakened tendon to rupture under normal physiological loads. Hyperthermia of the tendon caused by the generation of heat during strenuous activity compromises the integrity of the extracellular matrix and can also contribute to rupture [21, 22]. Finally, in the setting of a patient with a Haglund's deformity, mechanical irritation from the prominent calcaneal exostosis is thought to lead to an acute rupture in the setting of chronic Achilles tendinopathy .

**Table 1** Risk factors associated with acute Achilles tendon rupture

| | |
|---|---|
| Local corticosteroids | Vascular degeneration/irregularities |
| Systemic corticosteroids | Hyperthermia of tendon |
| Peritendinous injections | Training errors |
| Fluoroquinolones | Malalignment of foot and/or ankle |
| Degenerative changes in tendon | Chronic Tendinopathy (with Haglund's Deformity) |

In athletes, the most common cause of Achilles tendon injury is training errors, including a sudden increase in intensity, changes of terrain or surface, changes in training schedules, or use of inappropriate footwear [23, 24]. Malalignment of the foot and ankle, such as hyperpronation, cavus foot, and forefoot varus can also contribute to Achilles tendon injuries [25–27].

## Presentation, physical examination, and diagnosis

Acute Achilles tendon ruptures can mainly be diagnosed by history and physical examination alone. The typical patient will often describe sudden onset of pain in the posterior aspect of the foot and ankle, usually during activity that calls for maximum forceful plantar flexion. Patients will describe feeling a "pop" or a sensation of being kicked in the back of the leg. They will often lose the ability to bear weight and/or report weakness in plantar flexion of the ankle [23]. Interestingly enough, patients rarely present with significant pain. Rather, they present with bruising and a functional deficit.

Physical examination findings include increased passive ankle dorsiflexion, weak plantar flexion strength, and a palpable defect overlying the tear. There will also be a positive Thompson test. The test is performed by squeezing the musculature of the posterior calf and observing motion of the foot. A positive Thompson test reveals little or no plantar flexion of the foot relative to the contralateral leg. It should be noted that a very forceful calf squeeze may recruit the deep compartmental musculature and yield a false negative result. False positives can occur when the patient has an intact plantaris tendon [28].

In the authors' experience, this test can also yield a false positive in the setting of a chronic rupture, where scar tissue and fibrosis of the paratenon can mimic continuity between the gastroc-soleus muscle belly and the calcaneus. In addition to history and physical examination, imaging can be helpful in cases of suspected or partial ruptures. Magnetic resonance imaging (MRI) and ultrasound can aid in preoperative planning but are rarely necessary in making the diagnosis of acute Achilles ruptures [24]. Garras et al recently found there to be a 100 % sensitivity in diagnosing an acute rupture without MRI based on clinical findings alone [29].

## Management of acute ruptures

### Overview

The impact of Achilles tendon ruptures can be deeply felt across many aspects of patients' lives. High level athletes will undoubtedly miss long periods of playing time with the possibility of never returning to previous level of competition. Socio-economic costs can be grave, as treatment, physical therapy, rehabilitation, and absence from work pose a significant burden. Therefore, it is imperative that clinicians continue to strive for making an early diagnosis and choosing the best possible treatment and rehabilitation programs to optimize return to play/work, function, and patient satisfaction.

### Long-term deficits

In terms of function, sequelae of Achilles tendon ruptures can be felt for up to 10 years. Horstmann et al measured long-term changes in muscle strength, endurance, and muscle activity in 63 patients in whom surgical repair of the Achilles rupture was performed with subsequent 6-week immobilization. The morphology and function of the gastroc-soleus complex did not return to the values measured on the contralateral leg. Furthermore, objective measurement of ankle plantar flexion/dorsiflexion range of motion, heel height during heel-raise tests, and calf circumference showed smaller values in the injured leg [30]. This study confirms previous reports that muscle atrophy is a common long-term problem following repair of an acute tendon rupture [31, 32]. In addition, Rosso et al examined 52 patients at a mean of 91 months follow-up who underwent traditional open repair, percutaneous repair, or nonoperative treatment. The authors found that Achilles tendon length was greater across all groups compared with the contralateral leg, although no significant differences were found amongst the injured leg [33]. Silbernagel et al [34] showed similar results when examining heel-rise height and tendon length and concluded that minimizing tendon elongation appears to be an important treatment goal when maximizing function after repair. In regards to the running athlete, several studies have shown that deficits persist for up to 4 years after injury in both running biomechanics and functional muscle activity [35, 36].

### Patient outcomes

As research continues to investigate the optimal treatment regimens for acute Achilles tendon repairs, it is critical to have a solid, validated patient outcome system to complement clinical measurements for comparison to control groups or contralateral, uninjured extremeties. The SF-36 quality of life, the Hannover score [37], AOFAS Hindfoot score [38], the Foot and Ankle Outcome Score [39], and the Achilles tendon total rupture score (ATRS) [40] are just a few of the myriad patient outcome scores that have been used to evaluate function after Achilles tendon ruptures. The ATRS is the only validated questionnaire for the evaluation of Achilles tendon rupture to our knowledge.

### Operative vs nonoperative treatment

The fundamental goals of treatment of an acute Achilles tendon rupture are to restore length and tension of the tendon in order to optimize a patient's ability to return to their desired level of activity. Overall, management should be tailored to each patient according to many factors, such as age, functional demand, activity level, medical comorbidities, and expectations. The decision should also be dependent upon surgeon preference and skills. Treatment options include nonoperative regimens, traditional open repair (Fig. 1), and percutaneous or

**Fig. 1** Intraoperative photograph of traditional open repair of an acute Achilles tendon rupture

mini-open repairs. Despite a vast array of literature, consensus does still not exist at to the best choice. Furthermore, the advent of early, accelerated functional rehabilitation programs has further compounded decision-making and has created numerous pathways to choose in dealing with acute Achilles tendon ruptures.

Historically, many surgeons advocate early operative repair of acute ruptures, citing a lower re-rupture rate [41] of the tendon and improved functional outcomes, particularly with the amount plantar flexion and endurance, over nonsurgical treatment [42]. Conversely, proponents of nonoperative treatment argue that you avoid the increased risks of complications associated with surgical repair. In 2008, a review of the current options at the time by Metzl et al [43] reported that nonoperative treatment demonstrated a re-rupture rate of 10 %–30 % [44]. Some reports, however, displayed equivalent results between operative and nonoperative treatment [45–47]. Several studies showed favorable results with operative repair in younger, active patients in regards to return to pre-injury activity [48, 49].

More recently in 2010, Nilsson-Helander et al [50•] published the results of a randomized, controlled study comparing surgical and nonsurgical treatments using validated outcome measures. Their work demonstrated a re-rupture rate of 12 % in the nonsurgical group and 4 % in the surgical group. At 6 months, the surgical group had better results in muscle function tests. However, this difference was not present at follow-up of 12 months except for heel-rise work in favor of the surgical group. They concluded that treatment strategy for acute Achilles tendon ruptures remained debatable. In a similar study, Willits et al [51•] presented their results from a multicenter randomized trial in 2010 comparing outcomes of 144 patients treated either with operative repair ($n$=72) or nonoperatively ($n$=72). Patients followed identical functional, accelerated rehabilitation protocols. The results demonstrated re-rupture in 2 operative patients and 3 nonoperative patients. Furthermore, there was no difference between groups with regard to strength, range of motion, calf circumference, or patient outcome scores. They concluded support for nonoperative treatment and suggested that adding an accelerated rehabilitation program can yield equivalent results to surgical repair and avoid the complications of surgery.

Several meta-analyses have attempted to delineate the pros and cons of operative and nonoperative treatment of Achilles tendon ruptures. In 2012, Soroceanu et al [52•] published a meta-analysis of randomized trials studying surgical vs nonsurgical treatment of acute Achilles tendon ruptures. The authors compared the re-rupture rate, overall rate of other complications, return to work, calf circumference, and functional outcomes, as well as the effects of early range of motion on the re-rupture rate. If early range of motion was employed in a functional rehabilitation program, re-rupture rates were equal in both operative and nonoperative groups. Without early range of motion, the absolute risk reduction achieved by surgery was 8.8 %. In complications other than re-rupture (wound problems, skin and tendon necrosis, fistulas, nerve damage, adhesions, sural nerve damage, decrease range of motion, tendon over-lengthening, deep vein thrombosis, pulmonary embolus), surgery was associated with an absolute risk increase of 15.8 %. There was no significant difference between the 2 groups with regard to calf circumference measurements, strength, or functional outcomes.

Three other meta-analyses were published in 2012. Jones et al [53] analyzed studies from a Cochrane database studying nonsurgical and surgical methods and between different surgical techniques. Their data favored operative repair of the Achilles tendon. Operative repair was associated with a higher incidence of infections, but these were reduced when employing percutaneous techniques. No apparent advantage in outcomes existed with complex reconstruction methods. Furthermore, in disagreement with other studies, accelerated rehabilitation did not show an improvement over postoperative cast immobilization. Emphasis was made by the authors that in future research, more standardized and validated scoring systems should be used to better come to a consensus. Wilkins et al [54•] reported a reduced risk of re-rupture with surgical repair although surgery resulted in other complications, such as deep infections, scar complaints, and sural nerve injury, which were not seen with nonoperative treatment. Similarly, Jiang et al [55] concluded that operative treatment can effectively reduce the risk of re-rupture but increase complication risk with open repair. They emphasized that no sufficient evidence is available from current studies to support the theory that operative repair can lead to better functional outcomes.

Prior to 2012, 2 other meta-analyses had been published. In 2002, Bhandari et al [56] pooled the results of 448 patients and reported a relative risk of re-rupture of 0.32 in favor of surgical repair. In 2005 Khan et al [41] published the results of their meta-analysis and found that surgical repair also had a lower rate of re-rupture but that it came at a cost of higher rate of other complications, such as infections, adhesion, wound problems, and disturbed skin sensibility.

A recent questionnaire follow-up of 487 patients demonstrated that nonoperative management was a preferable option for most patients considering a relatively low rate of re-rupture and complications vs surgical management [57]. However, the study also suggested that the tendency for an overall lower re-rupture rate with surgery and a better performance on the heel-raise test made surgical repair an attractive option for selected patients. As evident in the conflicting literature, the optimum treatment of acute Achilles tendon ruptures remains in question. Further studies are certainly required if we are to provide narrow criteria for the treatment of large patient populations.

## Percutaneous techniques

As a way to decrease the complications associated with traditional open repair techniques, many new minimally invasive techniques have been described in the recent literature. Ma and Griffith first described percutaneous repair of acute Achilles tendon ruptures in 1977 [58]. Since then many modifications have been implemented. Basic principles of percutaneous techniques are lower wound complications, lower infections [59], lesser disruption to the paratenon and blood supply to the tendon and skin, lesser disruption to the hematoma in the zone of injury, and a lower overall complication rate. Also, percutaneous repair has an added benefit of occasionally being done without a tourniquet and under local anesthesia [60].

Some early studies showed neurovascular injuries, most notably to the sural nerve [61–64] and a higher rate of tendon re-rupture in percutaneous repair than after open tendon repair [65], attributed mostly to a weaker repair using percutaneous techniques. Aibinder et al [66] demonstrated that 5 of 18 cadaveric specimens had at least 1 suture passing through the sural nerve using a popular percutaneous device. As a way to improve upon the accuracy and strength of percutaneous techniques, endoscopically-assisted [67], and ultrasound-assisted [68], and mini-open operative techniques [69] have now been described.

In 2008, Metz et al [70] published the results of a randomized controlled trial of 83 patients who either underwent minimally invasive surgery vs nonoperative treatment with immediate full weight-bearing. In this study, the difference in the risk of complications between minimally invasive surgery and nonoperative treatment was not statistically significant. In 2012, Diao et al [71] reported favorable short-term clinical outcomes using the Achillon device (Integra, Plainsboro, NJ). Similar favorable findings were demonstrated in numerous other studies [72–75] with regard to functional outcome, better cosmetic appearance, less wound complications, patient satisfaction, and imaging results using percutaneous techniques (Fig. 2).

Recent literature published in 2013 echoes the equivocal or favorable results of minimally invasive techniques in treating acute Achilles tendon ruptures. Orr et al [76] reported outcomes and return to duty results in United States military personnel using the Achillon device. After a mean follow-up of 16 months, all 15 patients returned to full active duty without major complications, including wound problems, infection, or re-rupture. The authors concluded that the Achillon mini-open technique could be used successfully in higher-demand patients with minimal adverse outcomes. Ding et al [77] reported that minimally invasive percutaneous suturing could restore the original length and continuity of the Achilles tendon with fewer postoperative complications than other methods. A prospective randomized clinical study comparing efficacy and complications of open and minimally invasive

**Fig. 2** Intraoperative photograph utilizing percutaneous technique with the Achillon device (Integra, Plainsboro, NJ)

surgery in acute Achilles tendon ruptures showed no significant difference in clinical outcomes after a 2-year follow-up [78]. In terms of cost-effectiveness of open vs percutaneous repair, Carmont et al [79] suggested that percutaneous repair resulted in reduced costs with comparable outcomes and should be considered as the primary method of repair of Achilles tendon ruptures.

## Functional accelerated rehabilitation

Historically, after surgery patients were placed in nonweight-bearing casts for 6 to 8 weeks. Newer studies have shown excellent results when patients undergo functional rehabilitation [30] with early weight-bearing. This has been shown to be the case in both operative and nonoperative treatment of acute Achilles ruptures. Basic science and several animal models have shown that mechanical stimulation and range of motion improves tendon healing [80–82]. Recent trends in rehabilitation have focused on functional bracing with the goal of increasing patient satisfaction, lower re-rupture rates, and decrease postoperative complication with surgery. This is quickly becoming the standard of care at many orthopedic centers.

As early as 1999, Mortensen et al [83] compared acute Achilles repairs in 2 groups: patients who had conventional casting for 8 weeks vs patients who were placed in a below-the-knee brace and allowed to undergo early restricted motion. The early motion group returned to work and/or sports sooner than the immobilization group. Mafulli et al [84] in 2006 showed earlier independent ambulation, greater satisfaction levels, and no difference in tendon thickness or isometric

**Table 2** Principles of accelerated functional rehabilitation programs

| |
|---|
| Mechanical stimulation of tendon fibers |
| Early protected weight bearing |
| Functional bracing |
| Early restricted range of motion |

strength with immediate postoperative vs delayed weight-bearing. In 2 separate randomized trials, both Costa et al [85] in 2006 and Twaddle et al [86] in 2007 supported early motion and full weight-bearing postoperatively. Gwynne-Jones et al [15] demonstrated that functional bracing as part of nonoperative treatment can result in low re-rupture rates in patients over 40 years old, especially females. More recent studies have reiterated that accelerated rehabilitation is safe and effective, facilitates an early return to work and sports [87], improves muscle strength, functional level, and range of motion [88, 89].

In 2012 a systemic review of early rehabilitation methods concluded that the efficacy of different immediate weight bearing rehabilitation protocols remains unclear [90]. More recently in 2013, van der Eng et al published a meta-analysis reviewing re-rupture rate after early weight bearing in operative vs conservative treatment and found no difference in re-rupture rate between the 2 groups. The study also found a 2-fold greater complication rate in the surgical group [91]. Kearney and Costa [92] recently reported on the current concepts in rehabilitation of an acute Achilles tendon rupture. They concluded that current evidence points to the use of early functional rehabilitation, regardless of treatment. However, there is no consensus on which exact protocols should be used. Furthermore, certain questions remain such as which type of brace should be used, is movement or early loading more important, and what degree of plantar flexion provides the best balance between re-rupture and atrophy (Table 2).

## Summary

Treatment of acute Achilles tendon rupture remains a controversial subject. Recently, the American Academy of Orthopaedic Surgeons (AAOS) released 16 recommendations in a clinical practice guideline summary regarding treatment of acute Achilles tendon rupture. None of the recommendations made by the work group had a grade of “strong”, meaning that the recommendation was supported by available level 1 and 2 evidence. Only 2 recommendations were graded as “moderate-strength”. These included the suggestions for early post-operative protective weight bearing and for the use of protective devices that allow for postoperative mobilization [93••].

Patients should be counseled thoroughly on the inherent risks and benefits of each type of treatment. Many surgeons advocate surgical repair, quoting an historical decreased rate of re-rupture and improved function, especially with percutaneous techniques. Recent studies have shed light on nonoperative treatment as an equally acceptable alternative. Certainly, the advent of accelerated functional rehabilitation has made the decision-making process more complex. As the pendulum swings back-and-forth between operative and nonoperative treatment, surgeons must understand and tailor the treatments to each individual patient and his or her needs. Further research will certainly shed light on the most optimal treatment and the complement of an accelerated functional rehabilitation protocol.

In the senior author’s practice all patients are given a thorough explanation of both operative and nonoperative alternatives. If patients choose a nonoperative course, they are placed in a walking boot with three, 1.5-cm heel wedges (keeping them in plantarflexion). They are allowed unrestricted weight bearing in the boot and active plantarflexion out of the boot (no dorsiflexion) for 6 weeks. At the end of 6 weeks, they are sent to physical therapy. No passive dorsiflexion past neutral and no running or jumping is allowed until 12 weeks. If patients choose operative repair, they will undergo minimally invasive repair with a suture passing device. If they have a very large body habitus, patients are given a standard open repair; a decision which is based on surgeon comfort, not evidence based. Patients are nonweight bearing for 2 weeks in an equines splint then made weight bearing as tolerated in a walking boot with 3 wedges for the next 4 weeks. Patients are allowed to wean off of their crutches as they are comfortable. At 6 weeks, the protocol is the same as that for nonoperative treatment.

**Compliance with ethics Guidelines**

**Conflict of Interest** David Pedowitz declares that he has no conflicts of interest. Greg Kirwan declares that he has no conflicts of interest.

**Human and Animal Rights and Informed Consent** This article does not contain any studies with human or animal subjects performed by either of the authors.

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