2-1-2023

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Technical Note

Percutaneous Achilles Tendon Repair Using Ultrasound Guidance: An Intraoperative Ultrasound Technique

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Abstract: Rupture of the Achilles tendon is a common injury seen in patients of varying ages and activity levels. There are many considerations for treatment of these injuries, with both operative and nonoperative management providing satisfactory outcomes in the literature. The decision to proceed with surgical intervention should be individualized for each patient, including the patient's age, future athletic goals, and comorbidities. Recently, a minimally invasive percutaneous approach to repair the Achilles tendon has been proposed as an equivalent alternative to the traditional open repair, while avoiding wound complications associated with larger incisions. However, many surgeons have been hesitant to adopt these approaches due to poor visualization, concern that suture capture in the tendon is not as robust, and the potential for iatrogenic sural nerve injury. The purpose of this Technical Note is to describe a technique using high-resolution ultrasound guidance intraoperatively during minimally invasive repair of the Achilles tendon. This technique minimizes the drawbacks of poor visualization associated with percutaneous repair, while providing the benefit of a minimally invasive approach.

Introduction

Rupture of the Achilles tendon is a common injury among athletes, and the incidence of ruptures has increased over the past four decades.[1-6] A recent population study in Sweden found that over an 11-year time period, the increase of Achilles ruptures in men and women increased by 17% and 22%, respectively. The reported overall incidence for males and females was 55.2 per 100,000 person-years and 14.7 per 100,000 person-years, respectively.[2] These injuries are most commonly seen in older athletes in their fourth and fifth decades of life, possibly due to continuation of demanding athletic activity into older age.[7] Despite being the body's strongest and thickest tendon, the Achilles tendon is the most commonly ruptured tendon.[8-12] This is thought to occur because of cumulative, degenerative changes and/or mechanical forces that lead to eventual tendon failure.[3,7,13] Achilles tendon ruptures also occur in the young athletic population, most commonly in sports such as football, soccer and basketball. It is hypothesized that instead of chronic attenuation, these younger athletes sustain these injuries due to sudden eccentric contraction associated with a change of direction, such as in cutting sports.[14,15] These injuries can be devastating to young athletes, as numerous studies have shown that of all orthopaedic injuries, Achilles tendon ruptures are the most difficult to successfully return to play at a high level.[16-19]

The optimal treatment of Achilles tendon ruptures is still controversial, and the topic of much debate. Surgical repair of the Achilles tendon is reported to

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The authors report the following potential conflicts of interest or sources of funding: E.C.M. reports consulting fees from Smith & Nephew and publishing royalties and financial/material support from Springer, outside the submitted work. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received April 25, 2022; accepted October 12, 2022.

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2212-6287/22560

https://doi.org/10.1016/j.eats.2022.10.006

significantly reduce the risk of rerupture and promote earlier return to sport versus nonoperative management.[20-22] However, Achilles tendon repair is fraught with potential wound healing complications, surgical site infection, and nerve damage due to the tenuous soft tissue coverage and blood supply to the area.[21,23] Conservative management avoids potential complications of surgery, but patients must be counseled that their plantarflexion strength may remain decreased despite healing and therapy, while rates of tendon rerupture have been reported as high as 12% in some studies.[20,22,24] Although older patients or recreational athletes may elect for conservative treatment,[15,25-27] the gold standard for young patients and elite athletes remains surgical repair.[16,21,28-30] Ultimately, patient goals and functional demands must be weighed in a honest discussion of each treatment option, and ultimately, shared-decision making between patient and surgeon should determine a treatment plan.[31]

Minimally invasive surgical techniques have been developed to minimize the risk of wound complications with traditional open Achilles tendon repair.[32-34] One such technique, the Percutaneous Achilles Repair System (PARS), has demonstrated early success in the literature.[34] However, minimally invasive Achilles tendon repair is technically demanding and can involve "blind" suturing of the Achilles tendon,[13] which underscores the importance of describing the technique and continued monitoring of outcomes and results in the literature. The purpose of this Technical Note is to describe our preferred method of Achilles tendon repair using PARS under ultrasound guidance (Arthrex, Naples, FL). Our technique offers several advantages that improve the technical aspects of performing percutaneous Achilles tendon repair. Under ultrasound guidance, visibility and accuracy of suture placement in the Achilles tendon are improved, surgeon comfort with the technical difficulty of the procedure increases, and the risk of damaging nearby neurovascular structures is reduced.[35] This technique minimizes the associated risks and drawbacks of poor visualization during a minimally invasive procedure, while avoiding wound healing complications associated with open repair.

Surgical Technique

A detailed description of the ultrasound technique is provided in Video 1.

Diagnosis, Evaluation, and Imaging

Upon presentation in a clinical setting, a patient describing a history of a sudden "pop" or "snapping" sensation in the posterior heel, often feeling as if they were "kicked in the back of the heel," indicates a possible Achilles tendon injury. Most patients describe what action precipitated the injury, which is often associated with a sudden eccentric contraction of the plantar flexors of the ankle, such as landing from a jump or turning direction in a quick deceleration to acceleration maneuver. The injury quickly progresses to pain and swelling in the posterior ankle, often with bruising and a palpable gap at the Achilles tendon. Patients will state that they are unable to walk or push off during walking. After a complete history of the injury is described, a complete physical examination should be performed. This includes observation of the skin and surrounding soft tissues for ecchymosis, swelling, skin necrosis especially at the ankle and posterior heel, or skin tenting from associated boney injuries.[36,37] If the injury is the result of a high-impact mechanism, this should raise suspicion for other associated injuries; as such, a full examination of bilateral upper and lower extremities should be conducted to evaluate for bone, joint, tendon, or ligamentous injuries, which affect the patients' ability to bear weight through those extremities with crutches or other assistive devices. Palpation should include all joints, boney prominences, and at the site of the injured ankle, the medial and lateral ligamentous structures should also be palpated for tenderness. Palpation along the posterior aspect of the Achilles tendon should be performed with the patient lying prone on the examination table. Most often, the palpable defect is at the musculotendinous junction approximately 6 cm proximal to the calcaneus.[36] Occasionally, an avulsion of the tendon directly from the calcaneus presents as a palpable gap directly proximal to the bone.[37] Strength should be tested by first instructing the patient to perform a maximal plantarflexion of the ankle joint actively, followed by plantarflexion strength against resistance. Any preserved plantarflexion strength should be noted and may indicate a partial, rather than complete, Achilles tendon rupture. With the patient prone, the Thompson test may be performed by first making sure the patients' feet extend further than the end of the examination bed. The examiner manually squeezes the calf muscle proximal to the site of injury. A positive Thompson test results in a foot that does not move or respond to the calf squeeze, indicating a disruption of the musculotendinous unit from the calcaneus. The history and physical examination alone are sufficient to diagnose an Achilles tendon rupture.[37,38] However, a provider may determine that imaging is necessary if there is suspicion from the clinical examination that additional factors may be present, such as concomitant injury or bone prominences. Most notably, a lateral radiograph of the ankle may demonstrate a Haglund's deformity at the insertion of the Achilles tendon onto the calcaneus.[39] This bone prominence at the posterior calcaneus may be addressed with excision or debridement during operative repair.[39] In patients with a clinical presentation or physical examination consistent with a partial rupture,

an ultrasound or magnetic resonance imaging (MRI) can be ordered to evaluate the percent of tendon involvement. A partial Achilles tendon tear greater than 50% is often treated as a complete rupture with either surgical or nonsurgical management.[40]

Patient Positioning

Informed consent is gained in the preoperative area, and the operative site is confirmed and marked. The patient is taken into the operating room, and surgical time out is called. After induction of anesthesia, the patient is positioned prone on the operative table, and all bony prominences are well padded. The operative leg is prepped and draped in the standard sterile fashion. Examination under anesthesia is preformed, and an Esmarch bandage is used to exsanguinate the leg. High resolution ultrasound is used throughout the case.

Operative Technique

Prior to incision, ultrasound is used under sterile conditions to visualize the Achilles' tendon rupture location and proximity of the sural nerve. The calcaneal tuberosity at the insertion of the Achilles' tendon is a recognizable landmark, and thus, the first image obtained by ultrasound. The ultrasound transducer is then moved proximally in long axis of the tendon to visualize the site of the tear. The skin at this location is then marked with a marking pen to center the incision over the tear site. The transducer is then turned to short axis to visualize the proximal stump of the Achilles tendon, identifying the midportion, which is marked with a marking pen as a reference point when placing the jig. The Achilles tendon is then identified proximally and distally, as well in both short and long axis. The incision is then made in such a way that if the surgeon desired at any point to convert to a traditional open technique, this would be simple. The incision is primarily transverse; however, the lateral edge is slightly curved proximally, and the medial edge is curved distally, to easily facilitate an open approach if necessary (Fig 1). A 3-cm transverse incision is then made 1 cm proximal to the tear site, and dissection was taken down to the level of the peritenon. Care is taken to protect the sural nerve and pseudosheath. The peritenon was then divided in line with the incision, allowing visualization of the full-thickness Achilles tendon tear. An Allis clamp is then used to grasp the free edge of the proximal tendon, which will help avoid the proximal tendon further retracting with insertion of the PARS guide. Next, a freer elevator is used to define the planes between the peritenon and the Achilles tendon, both proximally and distally, creating a path for the PARS guide. The PARS guide is then placed proximally, and the first free needle is then passed through the #1 hole in the jig system,

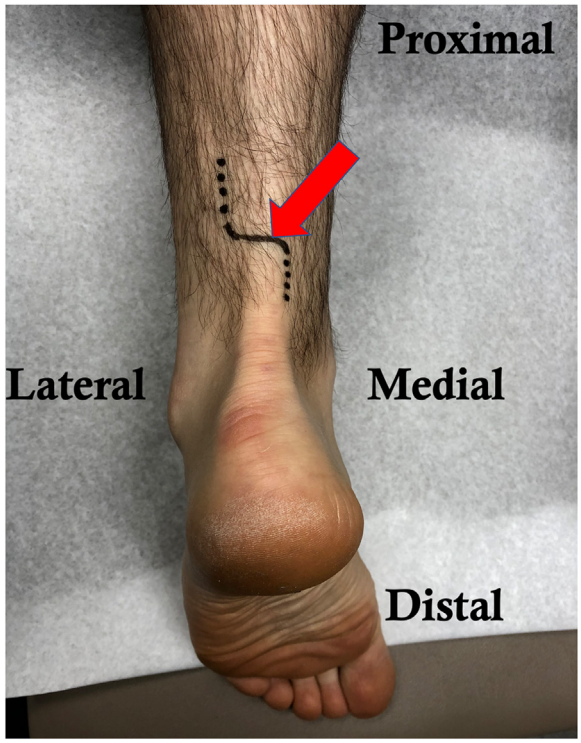

Fig 1. Viewing the posterior aspect of a left ankle, with the patient lying in the prone position. Outline of our preferred incision for minimally invasive Achilles repair using the Percutaneous Achilles Repair System (PARS) system. The incision (red arrow) is primarily transverse; however, the lateral edge is slightly curved proximally, and the medial edge is curved distally, to easily facilitate an open approach if necessary.

followed by the second free needle through hole #2 (Fig 2, A and B). During this process, each needle is placed and visualized on ultrasound in both short (Fig 3, A and B) and long axis (Fig 4, A and B) to confirm mid-substance placement. The ultrasound is also used to identify the location of the sural nerve and ensure that the needle placement does not disrupt the nerve (Video 1). The PARS jig was kept in position throughout the placement of the subsequent needles. Suture tape is then loaded onto the first needle and passed through the jig system and Achilles tendon, while the second needle stabilizes the jig system. The first needle is then placed into hole 3, and the second needle in hole 2 is loaded and passed with the blue striped suture (FiberWire), and then placed into hole #4. A looped suture is loaded onto the needle in hole #3, and the nonlooped end is passed through the jig system, and the needle is subsequently placed through hole #5. The looped sutures from holes #3 and #4 will be used to create a locking suture. Another looped suture is loaded onto the needle in hole #4, and the looped-end is passed through the jig system. There is now looped sutures passed through holes #3 and #4,

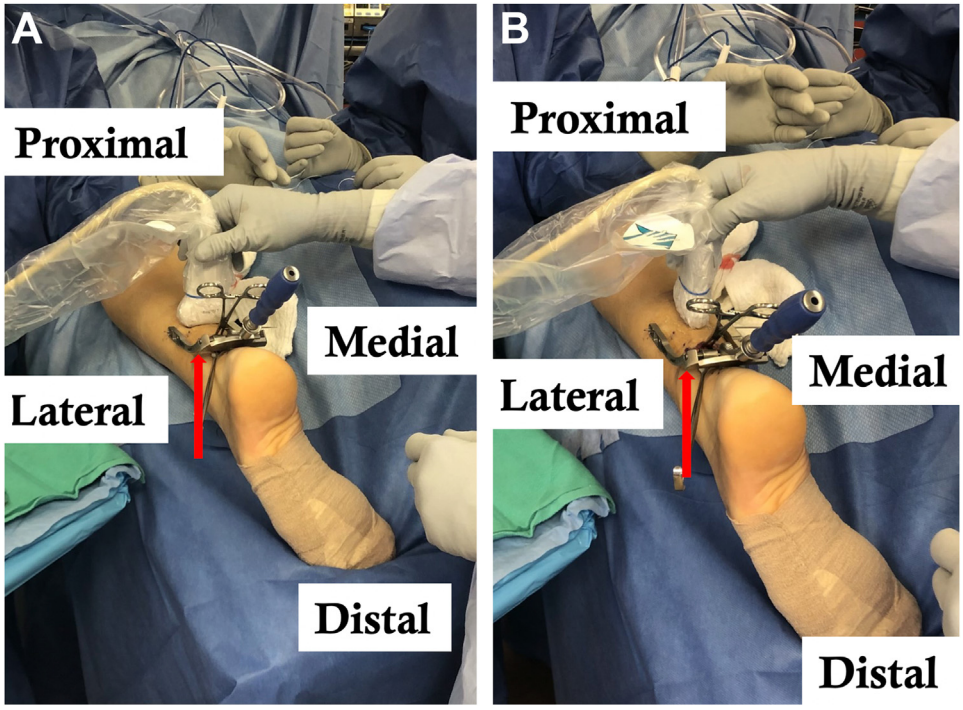

Fig 2. Viewing the posterior aspect of the left ankle and foot. The leg has been prepped and draped in the standard sterile fashion, and the patient is lying on the operative table in the prone position. The ultrasound probe is positioned over the posterior aspect of the ankle, overlying the Achilles tendon, at the level of the ankle surrounding the Achilles injury. This image demonstrates the intraoperative ultrasound visualization with the Percutaneous Achilles Repair System (PARS) jig system (red arrow). (A) Intraoperative ultrasound visualizing the Achilles tendon and nearby neurovascular structures in the short-axis view. (B) Intraoperative ultrasound visualizing the Achilles tendon and nearby neurovascular structures in the long-axis view.

with the looped ends on opposing sides relative to each other. The black and white suture (FiberWire) is loaded onto the needle in hole #5, and is passed through the jig system. Holes #6 and #7 may be used in elite athletes to create an additional locking suture, if necessary. The PARS guide is then withdrawn, and sutures were managed. To create the locking suture on each side of the tendon, the black and white suture on either side of the tendon is passed through the looped end of the looped sutures from holes #3 and #4. The

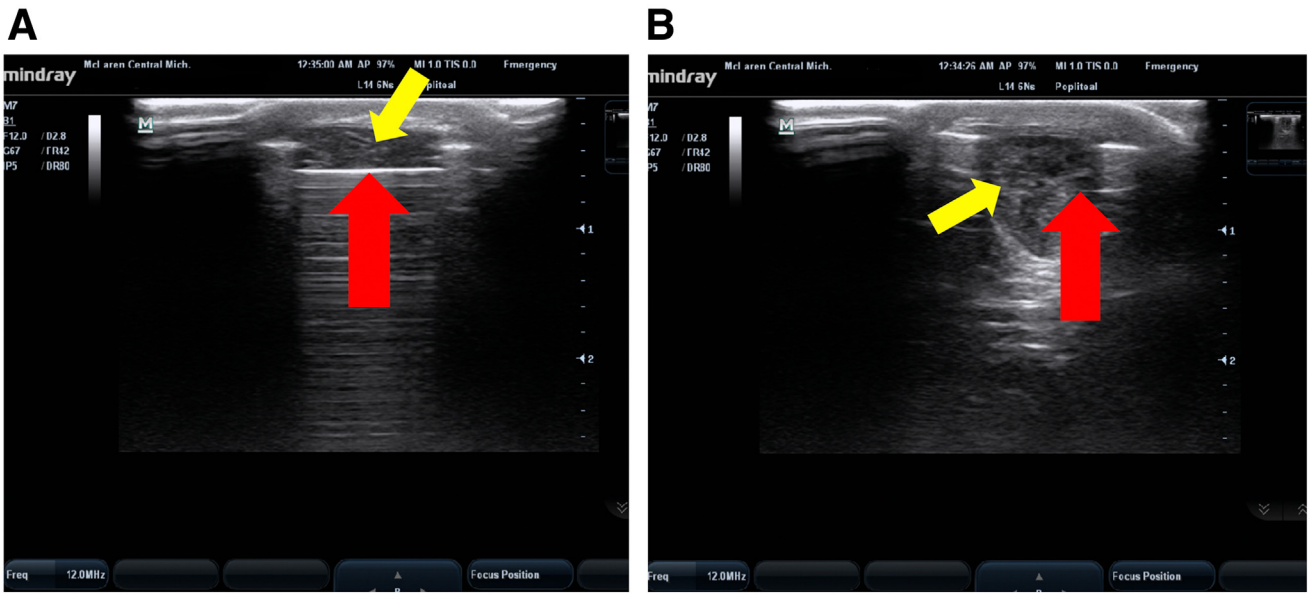

Fig 3. Short-axis intraoperative ultrasound imaging of Percutaneous Achilles Repair System (PARS) needle (red arrow) placement through the Achilles tendon (yellow arrow). The ultrasound probe is positioned over the posterior aspect of the ankle, overlying the Achilles tendon, at the level of the ankle surrounding the Achilles injury. (A) The PARS needle is visualized in appropriate position through the more proximal aspect of the Achilles tendon. (B) The PARS needle is visualized in appropriate position through the more distal aspect of the Achilles tendon.

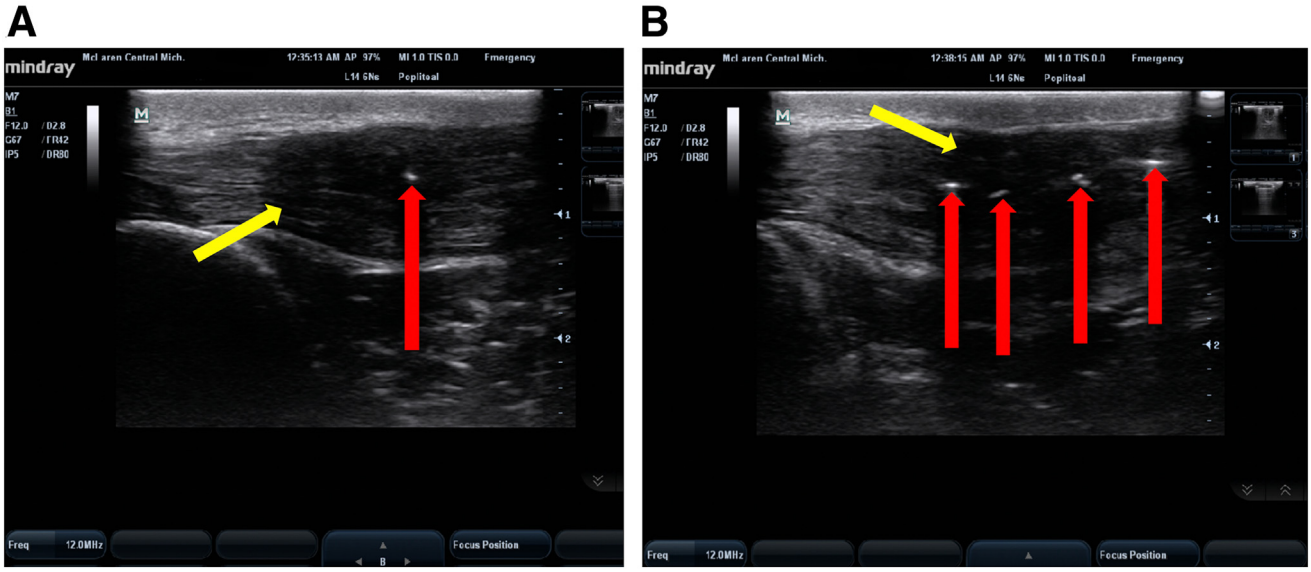

Fig 4. Long-axis ultrasound intraoperative ultrasound imaging of Percutaneous Achilles Repair System (PARS) needle (red arrows) placement through the Achilles tendon (yellow arrow). The ultrasound probe is positioned over the posterior aspect of the ankle, overlying the Achilles tendon, at the level of the ankle surrounding the Achilles injury. (A) One needle (red arrow) is visualized in the PARS jig system, passing through the Achilles tendon (yellow arrow). (B) Four needles (red arrows) are visualized in the PARS jig system passing through the Achilles tendon (yellow arrow).

nonlooped end of the sutures form holes #3 and #4 are pulled to finish the locking mechanism. The PARS guide is then placed on the distal stump and in similar fashion, the distal tendon is captured with the sutures in the same fashion, as described for the proximal tendon stump. The sutures are cycled, confirming good bite and allowing them to seat. The ankle is placed into full plantarflexion with an assistant manually holding this position. Sutures are tied in sequential fashion, according to the PARS technique: the black suture is tied on both sides first, then the white suture is tied on both sides, and finally the blue suture is tied on both sides.[34] The surgical site is then copiously irrigated with saline and antibiotics. 0 Vicryl is then used to repair the peritenon and fascial layer. 3-0 Monocryl is then used to close the subcutaneous tissues followed by 3-0 nylon in horizontal mattress fashion for the skin. The ankle is then placed into a sterile dressing and a posterior short leg splint in maximum plantarflexion was applied.

The described technique is not without its limitations. First, musculoskeletal sonography is a skill that requires significant training and may be associated with a steep learning curve. Orthopaedic surgeons may require additional training in order to obtain appropriate visualization to effectively utilize this technique. Additionally, there is a paucity of literature evaluating percutaneous Achilles tendon repair using ultrasound intraoperatively; therefore, the benefits of this technique are theoretical and should be subject to prospective studies evaluating its efficacy.

Discussion

The advantages of percutaneous Achilles tendon repair have clearly been demonstrated. A recent meta-analysis by Yang et al. investigated the outcomes and complications of a percutaneous versus traditional open approach to Achilles tendon repair.[41] The authors found similar outcome measures between the two groups and a significantly higher American Orthopedic Foot and Ankle Society (AOFAS) score in the percutaneous repair cohort. The percutaneous cohort also had decreased operation time and reduced deep infection rates compared with the open approach. These findings are in agreement with several studies that demonstrate equivalent, or even superior, outcomes of a percutaneous approach to Achilles tendon repair, as compared to traditional open approaches.[42-45] Karabinas et al. conducted a randomized controlled trial with 34 participants to compare outcomes between the percutaneous and open approaches to Achilles tendon repair, including wound healing, range of motion, return to work, and subjective assessment.[42] The authors found no significant differences between the two approaches in any of the metrics evaluated, but determined that the percutaneous approach had superior cosmetic appearance. Another randomized controlled trial by Lim et al. involved 66 patients who underwent either open or percutaneous repair of Achilles tendon rupture and were followed for 6 months postoperatively.[43] The investigators found a 0% infection rate in the percutaneous group versus 21% in the open repair, and there were no significant differences in

Table 1. Pearls and Pitfalls of Ultrasound-Guided Achilles Tendon Repair With the PARS Jig System

Pearls	Pitfalls
Scan the contralateral intact Achilles tendon beforehand to better familiarize oneself with each patient's unique anatomy.	Avoid introducing ultrasound gel into the wound.
Use a sterile ultrasound sleeve and gel.	Have the ultrasound appropriately positioned prior to draping.
Have an assistant hold the ultrasound transducer in short-axis view (SAX) while the surgeon passes the needles.	Avoid setting the ultrasound depth too deep.
The Achilles tendon is subcutaneous, so ensure the ultrasound depth is set at 3 cm and focus level of 2-3 cm.	Do not use the curvilinear transducer; instead, use the linear transducer.
Frequency level of 10 to 16 Hz with the linear transducer should be optimal.	Familiarize oneself with sonographic anatomy.
Sural nerve can be easily visualized if desired (small, honey-comb appearance in SAX view, usually running just posterior to sural vein).	

rerupture between the groups. A 2005 cohort study by Cretnik et al. also compared outcomes and complications of 132 consecutive patients treated with open and percutaneous tendon repair.[44] Significantly fewer major complications (4.5% vs 12.4%) and total complications (9.7% vs 21%) were found in the percutaneous versus open repair groups, respectively. No significant differences were found in the functional outcomes, rerupture rates and sural nerve disturbances between the two groups. Henriquez et al. conducted a retrospective review that found percutaneous repair to provide similar functional (ROM, strength) and superior cosmetic and complication rates compared with open repair.[45] Various other studies have also found equal or superior functional and cosmetic outcomes of the percutaneous approach versus open repair of Achilles tendon ruptures.[34,46]

Despite these findings, reluctance to adopt the percutaneous technique among surgeons is largely due to the technical considerations. A major area of hesitancy of the percutaneous approach is the inability to visualize tendon apposition and the anatomy of the sural nerve, potentially leading to complications of tendon healing and nerve disturbance.[47] The technique described herein alleviates these concerns through the use of preoperative and intraoperative high-resolution ultrasound guidance (Table 1). This allows the surgeon to adequately visualize the repair using ultrasound, providing the surgeon with confidence that the sutures are, in fact, capturing the critical portions of the Achilles' tendon to ensure solid construct.[48] The sural nerve, along with other important nearby neurovascular structures, can also easily be identified and protected throughout the entirety of the case. Additionally, the incision technique, as described earlier, allows for an easy transition to open approach if necessary. As percutaneous techniques continue to evolve and improve, intraoperative utilization of ultrasound can enhance the surgeon's ability to visualize the pertinent anatomy and gain confidence in the efficacy of this approach compared to traditional open repair.

In conclusion, our preferred technique for Achilles tendon repair in a young athletic patient is through the use of the PARS jig system. The use of preoperative and intraoperative high-resolution ultrasound guidance greatly enhances visualization of the surgical anatomy. This technique minimizes the associated risks and drawbacks of a minimally invasive procedure, while avoiding wound-healing complications associated with open repair.

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