Sonographically Guided Plantaris Tendon Release: A Cadaveric Validation Study

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Abstract

Background: The plantaris tendon (PT) has been implicated in the pathogenesis of symptoms in a subset of patients with Achilles region pain syndromes and traditionally has been managed via open surgical resection. Although the PT can be visualized on ultrasound, a minimally invasive technique for sonographically guided PT release has not been formally described.

Objective: To validate a technique to perform sonographically guided PT release in an unembalmed cadaveric model.

Setting: Procedural skills laboratory in a tertiary medical center.

Subjects: Twenty unembalmed cadaveric knee–ankle–foot specimens (10 right, 10 left; 6 male, 10 female) from 16 donors ages 55-96 years (mean 82.6 years) with body mass indexes of 14.1-33.2 kg/m² (mean 23.3 kg/m²).

Methods: After simulated local anesthesia and sonographically guided hydrodissection of the plantaris tendon–Achilles tendon interval, a single experienced operator performed sonographically guided PT release on each specimen using an in-plane, lateral-to-medial approach, a commercially available, disposable 3.0-mm hook knife, and either a 17-5 MHz or 15-7 MHz linear array transducer. Status of the PT, Achilles tendon, and regional neurovascular structures as determined by dissection.

Main Outcome: Status of the PT, Achilles tendon, and regional neurovascular structures as determined by dissection.

Results: All 20 PT releases were completed in a single attempt through a 3- to 5-mm incision. Dissection confirmed complete PT release in all specimens without damage to the adjacent Achilles tendon or regional neurovascular structures.

Conclusion: Sonographically guided PT release is technically feasible and can be performed while avoiding injury to the Achilles tendon and regional neurovascular structures. Additional research is warranted to further define the role of sonographically guided PT release in patients with suspected PT-mediated Achilles region pain syndromes.

Level of Evidence: ■ ■ ■

Introduction

The plantaris tendon (PT) increasingly has been implicated in the pathogenesis of symptoms in a subset of patients presenting with Achilles tendon (AT) pain syndromes, including Achilles tendinopathy [1-7]. The PT typically lies directly adjacent to the AT, and previous studies have confirmed that the PT and AT possess different biomechanical properties and exhibit differential motion during plantarflexion–dorsiflexion [1,8]. Consequently, repetitive compressive or shear forces at the PT-AT interface may pathologically alter the peritendinous tissues within the PT-AT interface as well as the tendons themselves [1,9]. Alfredson’s group [2,7] has reported that the fibrofatty tissue within the PT-AT interface of patients with Achilles tendinopathy typically exhibits neovascularity, hypercellularity, and somatic and sympathetic nerve fibers capable of mediating pain. Surgical removal of this pathologic tissue combined with PT resection has improved pain and function in patients with refractory symptoms after previous standard surgical AT debridement [3]. Alfredson et al also have reported degenerative changes within the PT consistent with tendinosis [3,7,10].

As clinicians increasingly have recognized the potential contribution of the PT to Achilles region pain syndromes, multiple therapeutic procedures have been developed to target the PT-AT interface, including PT release (or transection), PT removal (or resection), and...
removal/disruption of the presumably painful peritendinous tissues via surgical resection or hydrodissection [9-16]. Despite the reported clinical success of these procedures in patients with Achilles region pain syndromes, their precise mechanism of pain relief remains unknown. Nonetheless, the common goal of these procedures is to reduce the compressive and/or shear forces between the PT and AT within the PT-AT interface; PT release or removal also may provide the additional benefit of resolving pain arising from the PT itself [9,10,13]. Previously, PT release and PT removal have been performed in the context of a traditional open surgery [2,6,9-11,13,15-17]. However, the ability to identify the PT, the PT-AT interface, and the regional neurovascular structures using ultrasound (US) suggests that sonographically guided PT release and sonographically guided PT removal are technically feasible [8,9,17,18]. In theory, compared with sonographically guided PT removal, sonographically guided PT release would be easier to perform and should provide equivalent reduction in PT tension and compressive and shear forces within the PT-AT interface. Consequently, the primary purpose of this investigation was to describe and validate a technique for sonographically guided PT release using an unembalmed cadaveric model. Clinically, the results of this investigation would support clinical implementation of sonographically guided PT release in patients with suspected PT-mediated Achilles region pain syndromes.

Materials and Methods

General

A total of 20 unembalmed cadaveric knee–ankle—foot specimens (10 right, 10 left; 6 male, 10 female) obtained from 16 donors ages 55-96 years (mean 82.6 years) with body mass indexes of 14.1-33.2 kg/m² (mean 23.3 kg/m²) were used for this study. All specimens were free from trauma, deformity, and postsurgical change, and no specimen exhibited sonographic evidence of Achilles or plantaris tendinosis. All procedures and dissections were completed in the [removed for blinding] Procedural Skills Laboratory, and cadaveric specimens were obtained through the Department of Anatomy's [removed for blinding] Bequest Program. Fresh-frozen specimens were thawed at room temperature immediately before the study. A single, experienced examiner [removed for blinding] with more than 13 years of experience performing diagnostic and interventional musculoskeletal US performed sonographically guided PT release on each specimen using a commercially available, disposible 3.0-mm hook knife (ACUFEX; Smith & Nephew, Andover, MA) and a Philips iU22 US machine with either a 17-5 MHz or 15-7 MHz linear array transducer (Philips, Bothell, WA). Each specimen subsequently was dissected to assess for PT release and iatrogenic injury to adjacent structures. The project was approved by the Bio-Specimens Subcommittee of the [removed for blinding] Institutional Review Board (# 16-006838).

PT Release Technique

The leg was placed in a prone position with the ankle—foot hanging off the table and the transducer oriented transversely along the distal medial gastrocnemius muscle. The PT was identified at the junction of the distal musculotendinous junction of the medial gastrocnemius and soleus muscles as a small, ovoid structure with a tendinous echotexture and a cross-sectional area of 3-6 mm². As necessary, sonographic visualization of the PT was facilitated by (1) tilting the transducer to elicit differential anisotropy; (2) scanning the PT more proximally to increase the contrast between the hyperechoic, tendinous PT and the surrounding hypoechoic gastrocnemius and soleus muscles; and/or (3) detecting differential PT-AT motion during passive ankle dorsiflexion—plantarflexion (Figure 1) [8].

After identification of the PT, the anticipated working field was scanned and adjusted as necessary to avoid subcutaneous branches of the sural nerve and the saphenous vein. The sural nerve was easily identified on US as a small (1-3 mm) fascicular structure coursing along the lateral aspect of the AT and directly adjacent to the small saphenous vein [19]. Although the sural nerve and saphenous vein typically travel lateral to the PT, their position outside of the working field should be sonographically confirmed to avoid inadvertent injury. The transducer was then placed on the lateral border of the PT—AT junction, distal to the medial gastrocnemius muscle, and simulated anesthesia was delivered subcutaneously using 2 mL of water and a 27-gauge, 30-mm, stainless-steel needle. Thereafter, a 25-gauge, 38-mm stainless steel needle was used to hydrodissect the PT from the AT using 5-7 mL of water and a sonographically guided, in-plane, lateral to medial technique to guide the needle into the PT-AT interval tangential to the AT (Figure 2, Supplementary Video 1). This hydrodissection was used to create the plane between the PT and AT for the subsequent release. Under direct sonographic visualization, a #11 scalpel blade was used to make a 3- to 5-mm stab incision in the skin with the tip of the scalpel blade penetrating the paratenon and entering the hydrodissected PT-AT interval such that the blade was parallel to both the AT and PT within the interval. The scalpel is passed using the same technique as the hydrodissection needle, with the scalpel blade passing between the PT and AT and into the hydrodissected PT-AT interval.

The hook knife was then inserted in a similar manner and once the hook knife tip passed the PT, the hook was rotated so that the blade engaged the PT and the tip was located superficial to the tendon (Figures 3 and 4).
The operator then dorsiflexed the ankle to tension both the AT and PT and position of the hook knife with respect to the PT checked in 2 orthogonal planes. The working field was scanned again to ensure the absence of subcutaneous nerves that might be at risk during PT transection. While directly visualizing the PT and the hook knife, the operator applied a firm medial-to-lateral force while maintaining passive ankle dorsiflexion. In this manner, the hook knife transected the PT, the release being indicated by an abrupt loss of resistance and sonographic visualization of a hypoechoic space between the PT and AT. The transected region of the PT was consistently more conspicuous during passive ankle dorsiflexion–plantarflexion (Figure 5) [8,17]. The hook knife was then withdrawn under direct sonographic guidance. Given the cadaveric nature of the study, the wound was measured but not closed.

After completion of the sonographically guided PT release, each specimen was dissected to expose the operative region and assess the PT, AT, and regional subcutaneous nerves and veins. The status of the PT release was assessed not only statically but during passive ankle dorsiflexion. As the primary purpose of this study was to describe and validate a technique for sonographically guided PT release, no attempts were made to identify regional variations in PT anatomy as previously described [4,5,20].

Results

The PT was easily identified in all 20 cadaveric specimens using the US localization technique described in the Materials and Methods. After localization, the operator completed PT releases in all 20 specimens in a single attempt with procedure times ranging from 7 to 12 minutes (procedure time = time from simulated local anesthesia to hook knife removal) and wound sizes ranging from 3 to 5 mm. Dissection revealed complete PT transection in all 20 specimens (100% release rate) unaccompanied by injury to the adjacent AT or nearby sural nerve and small saphenous vein (Figure 6). Passive dorsiflexion–plantarflexion revealed the expected gapping between the 2 ends of the PT, indicating complete functional release (Figure 6B).

Discussion

The most important finding of the current investigation is that sonographically guided PT release is technically feasible and can be performed without injury to the AT or nearby neurovascular structures. Clinically, sonographically guided PT release may be considered in patients with suspected PT-related Achilles region pain syndromes, thereby potentially avoiding more invasive...
procedures that would require sutures and may result in prolonged recovery times.

Several technical aspects of sonographically guided PT release as performed in the current investigation warrant further discussion. First, although the PT was localized at the musculotendinous junctions of the medial gastrocnemius and soleus muscles, it was released more distally where it lay adjacent to the AT. This location was chosen to facilitate creation of the working plane between the PT and AT and avoid muscle injury and subsequent hematoma formation in clinical patients. Although all releases were performed just distal to the muscles, in theory the PT could be released at any point along the PT-AT interval. Second, an in-plane, lateral to medial approach was chosen to pass the scalpel and hook knife tangential to the AT, thereby minimizing the risk of injury to the AT and orienting the scalpel/hook knife parallel to the plane of the PT-AT interval. However, as long as the operator can create an adequate working plane between the PT and AT and avoid the sural nerve and lesser saphenous vein, an in-plane medial-to-lateral approach is also feasible.
The operator must maintain the position of the PT-AT interval exerts a rotational force on the knife. Tension, the resultant compressive force of the PT on the underlying PT-AT interval. Left, superior; right, inferior; top, medial; bottom, lateral.

Any knife rotation will increase the risk of the knife cutting through the PT but not completely transecting it (Figure 7). The distal aspect of the sural nerve provides sensory innervation to the lateral foot and fifth digit, and injury can result in sensory loss, paresthesias, and/or a painful neuroma [21]. Although the lesser saphenous vein only plays a minor role in venous return, injury may result in a local hematoma. Reassuringly, commonly available US transducers scanning at >10 MHz can typically identify both structures [19,22,23]. Third, it is important to extend the stab incision through the paratenon with the scalpel under direct US guidance before insertion of the blunt-tipped hook knife. The paratenon encases both the PT and the AT and, if not incised, will create a barrier to placing the hook knife within the PT-AT interval. As previously discussed in Fourth, the operator must maintain the position of the hook knife perpendicular to the PT to ensure optimal engagement of the PT (Figures 3 and 4). Although ankle dorsiflexion facilitates the release by increasing PT tension, the resultant compressive force of the PT on the PT-AT interval exerts a rotational force on the knife. Any knife rotation will increase the risk of the knife cutting through the PT but not completely transecting it (Figure 8, Supplementary Video 2). Knife rotation would be particularly problematic in the setting of a large PT, which can be up to 3.0 mm in diameter (ie, similar in size to the hook knife) [24]. Fifth, operators must use a high-force, low-amplitude motion to transect the PT, although considerable force is necessary to transect the PT, the tendon releases abruptly, and the operator may pull the hook knife out of the skin. Being aware of the likelihood of an abrupt release and stabilizing the hand holding the hook knife on the calf will assist in mitigating the risk of a high amplitude transection. Sixth, it is imperative to sonographically determine the position of the sural nerve and its branches within the working field to avoid iatrogenic injury, particularly considering its variable anatomy in the calf region [18].

Clinicians should consider several limitations when interpreting the results of the current investigation. First, all releases were performed by a single experienced examiner using a high-resolution US machine. Although this may potentially limit the generalizability of the results, the authors consider sonographically guided PT release to be an intermediate-level procedure and successfully have taught the procedure to multiple clinicians with foundational interventional US skills.
Second, the current study used cadavers to document the feasibility and safety of sonographically guided PT release, and none of the cadavers had sonographic evidence of Achilles tendinosis. The use of cadavers was necessary to allow direct assessment via dissection and in the authors’ opinion should not limit the generalizability of the results to clinical populations. Furthermore, although the presence of Achilles tendinosis may require modification of the technique, the operator should still be able to use US to precisely delineate the regional anatomy and locate an acceptable region within the PT-AT interval to perform the release. Of note, the corresponding author has successfully used the technique described herein in patients with Achilles tendinosis. Third, only a single technique was used to release the PT in the current investigation—the hook knife technique. Although this technique was successful, it is likely that additional techniques to release the PT are feasible. Fourth, since the role of the PT in a subset of Achilles region pain syndromes has only been recognized recently, optimal methods to diagnose and treat these patients have not been identified [9,10,15]. Clinicians should use appropriate caution when implicating the PT to avoid overtreatment. Furthermore, in cases in which there is a high clinical suspicion of PT-mediated pain, it is unclear whether the PT should be managed by simple hydrodissection of the PT-AT interval, PT release, or PT removal. It is also possible that certain patient subpopulations may be best managed by one of these 3 treatments. Clearly, further clinical experience is warranted and will add clarity to the decision-making process.

Conclusion

In conclusion, within the limitations of the current investigation, sonographically guided PT release is technically feasible and can be performed while avoiding injury to the AT and regional neurovascular structures. However, additional research is warranted to further define the role of sonographically guided PT release in patients with suspected PT-mediated Achilles region pain syndromes.

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Video Gallery: To view the online videos, use your smartphone camera QR Reader App to scan and capture this QR Code or visit www.pmrjournal.org to locate this video content.

References


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Disclosure

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