Is there Still a Place for Achilles Tendon Lengthening?

Mark T Tagoe[1], FCPodS., Neil D Reeves[2], Ph.D., Frank L Bowling[3], DPM, Ph.D.

[1]West Middlesex University Hospital, Middlesex UK, University of Southampton; [2]School of Healthcare Science, Manchester Metropolitan University, UK; [3]Faculty of Medical & Human Sciences, University of Manchester, UK.

Correspondence to:
West Middlesex University Hospital,
Twickenham Road,
Isleworth
Middlesex
TW7 6AF
UK
Tel: +44 208 321 5369
Email: mark.tagoe@wmuh.nhs.uk

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Abstract

Diabetes patients with ankle equinus are at particularly high risk for forefoot ulceration due to the development of high forefoot pressures. High stiffness in the triceps surae muscles and tendons are thought to be largely responsible for equinus in diabetes patients and underpins the surgical rationale for Achilles tendon lengthening (ATL) procedures to alleviate this deformity and reduce ulcer risk. The established/ traditional surgical approach is the triple hemi-section along the length of the Achilles tendon. Although the percutaneous approach has been successful in achieving increases in ankle dorsiflexion >30 degrees, the tendon rupture risk has led to some surgeons looking at alternative approaches. The gastrocnemius aponeurosis may be considered as an alternative due to the Achilles tendon's poor blood supply. ATL procedures are a balance between achieving adequate tendon lengthening and minimizing tendon rupture risk during or after surgery. After ATL surgery the first seven days should involve reduced loading and protected range of motion to avoid rupture, after which gradual re-introduction to loading should be encouraged to increase tendon strength. In summary, there is a moderate level of evidence to support surgical intervention for ankle joint equinus in diabetes patients with forefoot ulceration that is non-responsive to other conservative treatments. Areas of caution for ATL procedures include the risk for overcorrection, tendon rupture and the tendon's poor blood supply. Further prospective randomized-control trials are required to confirm the benefits of ATL procedures over conservative care and the most optimal anatomical sites for surgical intervention.

Introduction

The plantar surface of the foot has a propensity for ulceration in people with diabetes mellitus and there are multiple factors involved in the breakdown of skin integrity. The characteristics of prolonged hyperglycaemia in patients with diabetes results in complications including neuropathy, ischaemia, immunopathy, collagen alterations and autonomic dysfunction. The combined effect on the integumentary system is an alteration in the structural integrity of the skin with clinical implications for the plantar surface of the foot when exposed to high vertical and shear pressures.

High forefoot plantar pressures were proposed by Boulton et al. (1987) as a mechanism for increased ulcer risk in people with diabetes. This was followed up with a single cohort study (1666 patients) published in 2002 by Lavery et al. They found that approximately 10% of those with diabetes also had ankle equinus and significantly higher forefoot plantar pressures compared to those with diabetes but no equinus deformity. Frykburg et al. (2012) reported that ankle equinus was present in 25% of their study population of 102 people, 43 of which had diabetes and 59 without diabetes. Ankle equinus was more prevalent in the diabetes group with 37% having this deformity, compared to only 15% of the non-diabetes group. The incidence of previous ulceration in the diabetes group with equinus was 50%, compared with 20% in the non-equinus diabetes patients. The presence of equinus in diabetes patients therefore was associated with a 4-fold increase in the risk of ulceration, which underlines the need for correction of this deformity in diabetes patients.

Pathophysiology of ankle joint equinus

Studies of cadavers with normal ankle morphology have demonstrated that the major limiting factor to ankle joint dorsiflexion is passive stiffness of the triceps surae muscles and tendons (Costa et al., 2006). The muscles of gastrocnemius and soleus combine to form the Achilles tendon, one of the largest tendons in the human body (O'Brien, 2005), which inserts into the posterior aspect of the calcaneum. The gastrocnemius muscle has two heads arising from the posterior surfaces of the medial and lateral femoral condyles,

forming a wide aponeurosis at the lower end of the muscle bellies. The soleus muscle originates from the posterior surfaces of the tibia and fibula along with the inter-osseous membrane. The muscle belly of the soleus is separated from the gastrocnemius by a sheet of connective tissue with the two tendons eventually combing to form the Achilles tendon 8-10cm above the calcaneal insertion (Benjamin et al., 2007).

All tendons stretch when a force is applied (tensile loading), but the degree to which a tendon stretches depends upon: 1) how much force is applied, 2) the tendon's cross-sectional area (CSA), and, 3) the tendon's tensile stiffness (Butler et al., 1978; Maganaris & Paul, 1999; Reeves et al., 2003; Reeves, 2006). Tendons will undergo greater stretch when: 1) higher forces are applied, 2) the tendon's CSA is smaller, and, 3) the tendon's stiffness is lower. Animal models of diabetes have shown that tendon stiffness is increased with diabetes, making the tendon more resistant to elongation (Reddy et al., 2002; Reddy 2004; 2006). Whilst this may be considered positive from the point of view of reducing the risk for tendon strain injuries in diabetes patients, increased stiffness in the Achilles and gastrocnemius tendons will reduce the degree to which these tendons can stretch, and may be a causal factor in restricting dorsiflexion of the ankle joint (Salsich et al., 2000) which underlines the need for strategies to lengthen the Achilles tendon.

The surgical management of ankle equinus

Traditionally surgery to address ankle equinus has been at the level of the Achilles tendon with a percutaneous hemi-section of the Achilles tendon. This was popularised by White et al., in the 1920's, although a tenotomy of the Achilles tendon is one of the oldest known surgical procedures. The Hoke triple hemisection is a common approach with a stab incision 2cm proximal to the insertion of the Achilles, here the medial half of the tendon is severed. This is repeated 3cm proximally and the lateral segment is cut and for a third time, 3cm above the second incision, but this time on the medial side. The knee is held in extension, the foot maintained in subtalar neutral and the ankle extended to give 10 degrees of dorsiflexion (Hoke, 1931). The advantages of this approach are the

ease and speed with which it can be undertaken. The superficial nature of the tendon facilitates its identification with relative ease, in comparison to surgery based more proximally. Lengthening the Achilles tendon provides the maximum amount of dorsiflexion, with in excess of 30 degrees available (Costa et al., 2006). However, the risk of tendon rupture, or over lengthening with the percutaneous approach has led some surgeons to transition to an open approach (Banks et al., 2001).

Addressing equinus proximally at the level of the gastrocnemius aponeurosis has advantages. The blood supply of the Achilles tendon is poorest within the watershed region between 2-6cm above its point of insertion (Benjamin et al., 2007). The watershed correlates with the site most prone to rupture, with the limited blood supply considered to be a key component of this injury (Ahmed et al., 1998; Langber et al., 1998; Lagergren & Lindholm, 1959; Zantop et al., 2003).

An open Z-plasty lengthening of the Achilles tendon allows direct visualization of the structure and measurable lengthening. Irrespective of the approach, these techniques are a balance between achieving adequate lengthening of the Achilles tendon sufficient for increasing the dorsiflexion range of motion, and minimising the risk for tendon rupture. During the procedure, transverse incisions to the Achilles tendon will reduce the effective CSA, markedly decreasing the magnitude of force and stress it can sustain before rupture.

Tendon healing after surgery is composed of three phases: 1) the inflammatory phase (typically 1-7 days), 2) the proliferative phase (typically 7-21 days), and, 3) the maturation/remodeling phase (typically 3 weeks to a year). The 'partial tendon ruptures', induced by the ATL procedure, are initially managed with a 7 day rest period with a "protected range of motion" to avoid disturbing the fragile tendon connections established during the inflammatory phase of healing (Curl & Martin, 1993). A supporting cast or other appropriate orthotic should be applied to stress shield the tendon from excessive loading whilst also maintaining the tendon at a length which optimises healing and function (Houglum, 1992).

The second part of the recovery phase involves cell proliferation (7-21 days post surgery and tissue maturation (3 weeks-one year) to promote tendon healing. During this phase, a gradual re-introduction to full range of ankle movement and weight bearing activities can be undertaken to increase collagen synthesis, and encourage longitudinal alignment of collagen fibrils (Kellett, 1986).

Appropriate re-loading of tendons is a key element of recovery and should be sustained throughout the periods associated with cell proliferation and tissue maturation. During these phases the tendons will adapt and increase their tensile stiffness as required for adequate recovery. In the absence of appropriate re-loading, tendon collagen fails to align longitudinally, resulting in an intrinsically weaker structure than collagen exposed to loading during recovery (Houglum, 1992). Studies have demonstrated that short and longer-term unloading of otherwise healthy tendons reduces tendon stiffness and the intrinsic 'strength' of the tendon (Reeves et al., 2005; Maganaris et al., 2006; de Boer et al., 2007). Therefore, a gradual re-loading of the Achilles tendon from seven days post-surgery is essential for adequate recovery of tendon strength. Protected weight bearing in an Aircast Walker, Total Contact Cast or short leg cast is advised for up to 6 weeks in the papers cited.

Firth (2013) examined the effects of lengthening the triceps surae at different levels in a cadaver study: the gastrocnemius muscle, conjoined gastrocnemius aponeurosis-soleus fascia and the Achilles's tendon. The force applied to the foot to lengthen the muscle or aponeurosis was 40kg whereas the double and triple hemi-section of the Achilles tendon both ruptured with just over 10kg of force applied. Adequate lengthening can be obtained at the level of the conjoined gastrocnemius aponeurosis-soleus fascia using the Baker and Vulpius procedures with in excess of 20 degrees of ankle joint dorsiflexion achieved. As part of their conclusion the authors considered that procedures performed at the level of the Achilles tendon in the form of a hemi and triple section were far less stable.

A proximal surgical approach to ankle equinus can also reduce the likelihood of Achilles tendon rupture and reduces the degree of calf weakening. Lengthening of the gastrocnemius or the conjoined gastrocnemius aponeurosis-soleus fascia is amenable to minimal invasive techniques thus reducing wound complications (Roukis & Schweinberger, 2010; DiDomenico et al; 2005).

The surgical management of equinus in the treatment of diabetic foot ulcers

The gold standard for managing the uncomplicated diabetic foot ulcer is debridement of non-viable tissues and bespoke dressings; a degree of offloading with total Contact Casting being the best model (International Working Group on the Diabetic Foot 2011). This is based on the evidence of a 90% success rate for ulcer healing and underpinned by several RCT's (e.g., Armstrong et al., 2001, Katz et al., 2005). However, in the presence of equinus this approach may not suffice, although there is limited data from which to draw conclusions. Mueller (2003) conducted a randomised controlled trial comparing prospective lengthening of the Achilles tendon (via the Hoke triple hemisection) in combination with a Total Contact Cast for 6 weeks, with a Total Contact Cast only. Surgery and casting combined achieved a 100% success rate in ulcer healing whilst those treated only with a total contact cast achieved 88%. Perhaps of greater interest, was a significant difference in the re-occurrence rates; 81% recurrence in the Total Contact Cast group compared to only 38% in the surgical cohort (p= 0.002). Four individuals within the surgical group did however develop heel ulcers. Case studies have also provided supportive evidence for surgical intervention to address ankle joint equinus. Laborde, (2008) reported positive outcomes after surgery in a study of 20 patients with diabetes related neuropathy. Ankle joint equinus, was addressed at the level of the gastrocnemius aponeurosis-soleus fascia (Vulpius procedure). In cases where the ulcer was situated beneath the 1st or 5th metatarsal head a peroneal longus or tibialis posterior tendon lengthening respectively, was undertaken in concert. Post-operative management was a short-leg walking cast with full weight bearing for 6 weeks. There were no instances of heel ulceration and of the 18

patients that completed the study all of the ulcers healed within 2 months. There were 3 re-occurrences, which subsequently healed after additional tendon procedures. Holstein et al. (2004) reported on 63 patients with 69 diabetic foot ulcers. This retrospective study recorded a 91% healing rate at a medium of review of 12 months. Holstein et al. concluded that Achilles tendon lengthening is an effective way of managing forefoot ulceration and minimising the risk of a recurrence. However, this research, and other studies, have demonstrated the potential for developing heel ulcerations due to excessive dorsiflexion (>15 degrees) post-surgery, with an incidence of 11% to 15% (Barry et al., 1993; Mueller et al., 2003). Conversely, Holstein et al. (2004) found that inadequate lengthening resulting in less than 10 degrees ankle dorsiflexion was associated with non-healing and reoccurrence rates of 33%. The rate of Achilles tendon rupture in this study, which incorporated periodic ultrasound examination, was 10%.

In a review of the literature, Lavery considered Achilles tendon lengthening as an acceptable adjunct in treating diabetic foot ulcers that are recalcitrant to conservative care in the presence of equinus (Lavery, 2012). However, Lavery also recommended that treating clinicians should give careful consideration to the risks of post-operative complications that may accompany surgery before embarking on invasive intervention.

Cadaveric studies indicate that lengthening of the gastrocnemius soleus at the level of the aponeurosis is potentially more stable than an ATL, and would provide adequate dorsiflexion. In addition performing the surgery proximally reduces muscle weakness and therefore the risk of a calcaneus gait. Whilst the advantages seem to outweigh the disadvantages the evidence in the literature is weak (Cychosz et al., 2015). Furthermore, there is considerable debate regarding the diagnostic criteria for ankle equinus, which influences the rationale for surgical intervention. Treating clinicians also need to be mindful of other causes of equinus including arthritis of the ankle joint, bone or joint abnormalities and the presence of a plantar flexed forefoot relative to the hindfoot. A detailed and

thorough clinical examination supported by appropriate investigations should rule out these potential complicating factors.

Conclusion

There is a moderate level of evidence to support addressing ankle joint equinus as an elective procedure in patients with diabetes who have forefoot ulceration that is non-responsive to conservative care. ATL is surgically convenient, it is not time consuming to perform, and anatomically the tendon is superficial and in the obese patient access is less challenging. However, it is not considered to be the procedure of choice when treating equinus in other reconstructive foot and ankle pathologies. The capacity for overcorrection leading to weakness of the lower limb, the increased risk of tendon rupture combined with the tendon's marginal blood supply, has caused some clinicians to reconsider the procedure. However, more evidence is needed in the form of prospective randomised trials to substantiate the perceived benefits of addressing ankle equinus and the benefits of intervening at the different anatomical sites.

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