Lengthening of the Achilles Tendon in Diabetic Patients Who Are at High Risk for Ulceration of the Foot*

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Abstract

Background: **The purpose of this study was to determine the degree to which pressure on the plantar aspect of the forefoot is reduced following percutaneous lengthening of the Achilles tendon in diabetic patients who are at high risk for ulceration of the foot.**

Methods: **Ten diabetic patients who had a history of neuropathic plantar ulceration of the forefoot were enrolled in a laboratory gait trial. A repeated-measures design and a computer analysis of force-plate data were used to examine dynamic pressures on the forefoot, with the patient walking barefoot, immediately before percutaneous lengthening of the Achilles tendon and at eight weeks afterward. Although the wound in each patient had healed at least one month before the operation, we considered the patients to be at high risk for ulceration because they had had an ulcer previously.**

Results: **The mean peak pressure (and standard deviation) on the plantar aspect of the forefoot decreased significantly from 86 ± 9.4 newtons per square centimeter preoperatively to 63 ± 13.2 newtons per square centimeter at eight weeks postoperatively ($p < 0.001$). Commensurately, the mean dorsiflexion of the ankle joint increased significantly from 0 ± 3.1 degrees preoperatively to 9 ± 2.3 degrees at eight weeks postoperatively ($p < 0.001$).**

Conclusions: **The results of this study suggest that peak pressures on the plantar aspect of the forefoot are significantly reduced following percutaneous lengthening of the Achilles tendon in diabetic patients who are at high risk for ulceration of the foot. We are unaware of any other reports in the medical literature that describe such findings. These data may lend support to studies that have indicated that this procedure should be used as an adjunctive therapeutic or prophylactic measure to reduce the risk of neuropathic ulceration.**

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Ulceration of the foot is the most common precursor to amputation of a lower extremity among patients who have diabetes[26,27]. Ulceration is a pivotal event leading to the loss of a limb for two important reasons. First, ulcers are an avenue for infection. Second, they can cause progressive tissue necrosis, poor wound-healing, and the development of gangrene in the presence of advanced peripheral vascular disease[13]. Clearly, identification of patients who are at risk for ulceration, coupled with appropriate operative and nonoperative intervention, is of central importance in any plan for the avoidance of amputation of a lower extremity.

Structural deformities and limited joint mobility in an insensate foot have been associated with increased plantar pressures and a correspondingly increased risk of ulceration of the foot[13,26,27]. Boulton reported that 51 percent (twenty-one) of forty-one patients who had neuropathic ulcers had higher-than-normal peak plantar pressure on the forefoot[12]. Furthermore, Duckworth et al. noted that, in all of the patients in their study, abnormally high pressures were found at sites of previous ulceration[17]. One of us (D. G. A.) and colleagues subsequently confirmed these findings in patients who had active ulceration and also reported that high pressures on the foot were directly associated with prolonged wound-healing[5].

The focus of any treatment plan to reduce the risk of neuropathic ulceration of the foot should be to make accommodations for and to dissipate foci of increased pressure[20,30]. This may be accomplished in two ways. The first method is extrinsic accommodation through additions to and modifications of footwear. Complete off-loading of the focus of stress or an increase in the surface area under load, or both, can be accomplished with several methods of tailoring the outsole and the insole of the shoe and with bracing. If this type of therapy causes problems or leads to a less-than-ideal result (that is, if the deformity cannot be accommodated for over an extended period), the second method, intrinsic accommodation (a prophylactic operation), is considered[1,29].

It has been theorized that an equinus deformity of the ankle joint is a key component in the development of an ulcer of the forefoot in patients who have neuropathy[33]. The tethering action on the posterior aspect of the calcaneus from the unyielding and functionally short Achilles tendon places a plantar-flexion force on the arch of the foot during normal gait[19]. After repetitive footsteps and the loss of protective sensation due to sensory neuropathy, high plantar pressures on the forefoot and collapse of the arch are expected[9]. These biomechanical factors, among other physiological factors, create a risk for soft-tissue breakdown distally and osseous breakdown (Charcot arthropathy) in the midfoot[4,24].

We are unaware of any reports in the medical literature that quantify the effect of lengthening of the Achilles tendon on peak plantar pressures on the forefoot. Therefore, the purpose of this study was to determine the degree of reduction in plantar pressure on the forefoot following percutaneous lengthening of the Achilles tendon in diabetic patients who are at high risk for ulceration of the foot.

Materials and Methods

Informed consent was obtained from each patient, and the protocol was approved by the Institutional Review Board of The University of Texas Health Science Center at San Antonio. We enrolled ten patients (eight men and two women) with a mean age of 53 ± 5.1 years (range, forty-eight to sixty-three years) in this study. The mean duration (and standard deviation) of the diabetes was 11 ± 5.4 years (range, three to twenty years), and the mean body-mass index was 31 ± 2 kilograms per square meter (range, twenty-seven to thirty-three kilograms per square meter). All of the patients had neuropathy, a deformity, and a history of a diabetic neuropathic ulcer on the plantar aspect of the forefoot. Seven ulcers were beneath the first metatarsal, and three were beneath a lesser metatarsal. These feet were considered to be category 3 (at high risk for ulceration) according to The University of Texas system for the classification of diabetic feet[2,22]. Patients in this category are at approximately thirty-six times greater risk for an ulcer than are patients who have diabetes and no neuropathy[22]. In all of the patients, the neuropathic ulcer had healed at least one month before operative intervention. None of the patients had been managed with an amputation of the lower extremity or had Charcot arthropathy. The diagnosis of diabetes mellitus was verified for all of the patients with use of the criteria set forth by the World Health Organization[32]; these criteria include treatment with insulin or oral administration of a hypoglycemic agent, two random measurements of the glucose level of more than 200 milligrams per deciliter (11.1 millimoles per liter), or a level of fasting blood glucose of more than 140 milligrams per deciliter (7.8 millimoles per liter). Sensory neuropathy was evaluated with a biothesiometer (Bio-medical Instrument, Newbury, Ohio) with use of the method and the criteria described by one of us (D. G. A.) and colleagues[3,6,7]. These criteria include a vibration-perception threshold of more than twenty-five volts. All patients had profound clinical loss of protective sensation according to these criteria, with a mean vibration-perception threshold of 44 ± 5.1 volts (range, thirty-five to fifty volts).

The patients were managed with percutaneous lengthening of the Achilles tendon, which was performed under sterile conditions with the patient supine. Because of the profound peripheral sensory neuropathy in each patient, we used local anesthesia with parenteral sedation to perform the procedure. Three stab incisions were made with a number-11 blade. The first incision was in the medial aspect of the tendon, approximately one centimeter proximal to the calcaneal insertion of the Achilles tendon. The second incision was also placed medially, approximately one centimeter distal to the palpable myotendinous junction. The third incision was placed in the lateral aspect of the tendon, bisecting the two medial incisions. Subsequently, these incisions were carried to the level of the tendon. Approximately one-third of the tendon was transected through the medial incisions, and the same amount was transected through the lateral incision. A blunt nasal probe was used to ensure that the incisions were complete. The foot was dorsiflexed at the ankle until a readily appreciable attenuation was noted[14]. The small wounds were reapproximated with adhesive strips. The foot was immobilized in a below-the-knee weight-bearing cast for six weeks and then was transferred into a depth-inlay shoe. After the study, the patients were seen every two months at our high-risk diabetic foot clinic for care, in accordance with the clinical protocol for patients at high risk for ulceration.

We used the EMED pressure platform system (Novel, Dusseldorf, Germany) to evaluate dynamic pressures on the plantar aspect of the forefoot for all ten patients. Pressures were measured in newtons per square centimeter while the patients walked barefoot. A mean of the peak pressures from five mid-gait steps by each patient was used for analysis. The force-plate was embedded in the floor in the center of a twenty-meter-long corridor designed specifically for this system. The plate is connected to a base unit that is triggered by any pressure applied. The patients were allowed a period of as long as fifteen minutes to become comfortable with walking in the corridor and were instructed to walk at their own selected cadence. The gait of each patient was analyzed immediately preoperatively and at eight weeks postoperatively. We also assessed passive dorsiflexion of the ankle joint with use of the criteria described by Polley and Hunder[25], who bisected the lateral aspects of the leg and foot and then dorsiflexed the foot at the ankle to measure the degree of dorsiflexion with use of a tractograph.

A power analysis was performed before the patients were enrolled in the study. The analysis indicated that, with the repeated-measures design of the present investigation, a difference of 20 percent between the pre-

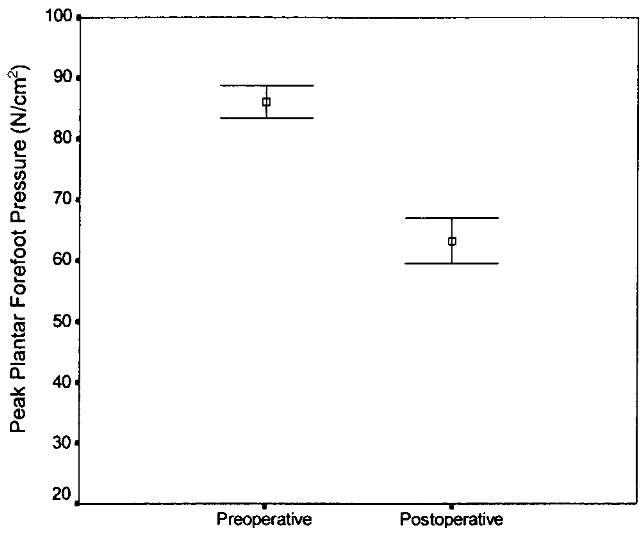

FIG. 1

Graph showing the mean peak pressures on the plantar aspect of the forefoot before and after lengthening of the Achilles tendon. The I-bars represent the standard deviation.

operative and postoperative pressures could be detected with a sample size of ten patients and approximately four repeated steps (four passes over the force-plate) with a power of 0.90. We therefore were confident in using a study design of five steps per patient, as described earlier. To assess potential differences between the peak preoperative and postoperative pressure on the plantar aspect of the forefoot, we used a general linear model with pairwise comparisons. To assess potential differences between preoperative and postoperative passive dorsiflexion of the ankle joint, we used a t test for paired samples. For all analyses, we used a significance (alpha) level[21] of 0.05.

Results

The mean peak pressure (and standard deviation) on the plantar aspect of the forefoot decreased significantly from 86 ± 9.4 newtons per square centimeter (range, sixty-nine to 101 newtons per square centimeter) preoperatively to 63 ± 13.2 newtons per square centimeter (range, thirty-nine to eighty-nine newtons per square centimeter) at eight weeks postoperatively ($p < 0.001$) (Fig. 1). Commensurately, the mean dorsiflexion of the ankle joint increased significantly from 0 ± 3.1 degrees (range, –5 to 5 degrees) preoperatively to 9 ± 2.3 degrees (range, 4 to 11 degrees) at eight weeks postoperatively ($p < 0.001$).

Discussion

The results of the present study suggest that peak pressures on the plantar aspect of the forefoot are significantly reduced (by approximately 27 percent) after percutaneous lengthening of the Achilles tendon in diabetic patients who are at high risk for ulceration of the foot. We are unaware of any other reports in the medical literature that describe such findings. These data may lend support to recommendations for percutaneous lengthening of the Achilles tendon as an adjunctive therapeutic or prophylactic measure[23,24].

As with many skeletal and soft-tissue structures, the Achilles tendon appears to be adversely affected by long-term hyperglycemia. Grant et al. noted marked increases in tendon-fibril packing density secondary to pervasive nonenzymatic cross-linking of fibrillar collagen[19], which has been identified in other anatomical structures as well[15,16,28]. It seems logical that this loss of natural extensibility and increased propensity for fibril adherence can precipitate tightening of the tendon and thus precipitate a soft-tissue deformity. This is clearly an area that calls for additional clinical and laboratory investigation.

There are three main factors that influence the development and possibly the duration of healing of neuropathic ulcers of the foot in diabetic patients. These include a deformity of the foot, limited mobility of the ankle joint, and repetitive stress. Both limited mobility of the ankle joint and frank deformity of the foot have been shown to increase plantar pressures[10,18,31]. Duckworth et al.[17] and Boulton et al.[11] suggested that there might be a pressure threshold at which an ulcer is more likely to develop in the presence of peripheral neuropathy in a patient who has diabetes. Lavery et al. found that peak pressures of more than sixty-five newtons per square centimeter were approximately six times more likely to be associated with ulceration than were pressures below this threshold[22]. Furthermore, as was discussed earlier, it has been suggested that ulcers at sites of higher-than-normal peak plantar pressures take considerably longer to heal than do ulcers at sites of lower peak pressures[5].

The described findings should come as little surprise because cyclic loading is the most widely recognized precipitating factor in the failure of a material. This phenomenon, also known as fatigue, stipulates that most catastrophic failures of a material are due to cyclic loading at a stress level that is lower than the strength of the material. Although we have noted that wounds can occur in areas of relatively normal pressure, when pressure is elevated the number of cycles of repetitive stress necessary to initiate breakdown of the skin decreases[5,8]. Again, this finding agrees with the concept of fatigue failure, which predicts that the higher the stress level, the smaller the number of cycles required for a material to fail. On the basis of the described findings, the data from the present study suggest that percutaneous lengthening of the Achilles tendon, in reducing peak pressure on the plantar aspect of the forefoot, may decrease the likelihood of breakdown of the skin or may increase the efficacy of pressure-reduction modalities such as casts and braces. Clearly, additional investigation is needed to determine the potential clinical utility of this adjunctive procedure.

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