Morphological and Functional Changes in the Diabetic Peripheral Nerve

Using Diagnostic Ultrasound and Neurosensory Testing to Select Candidates for Nerve Decompression

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It has been hypothesized that in individuals with diabetes mellitus the peripheral nerve is swollen owing to increased water content related to increased aldose reductase conversion of glucose to sorbitol. It has further been hypothesized that the tibial nerve in the tarsal tunnel is at risk for chronic nerve compression related to this swelling. We used diagnostic ultrasound to evaluate this hypothesis. Cross-sectional areas of the tibial nerve were measured in diabetic patients with neuropathy and compared with previously reported measurements in nondiabetic patients and diabetic patients without neuropathy. We used the Pressure-Specified Sensory Device (Sensory Management Services LLC, Baltimore, Maryland) to document the presence of neuropathy in 24 diabetic patients (48 limbs). Previous studies have found that the cross-sectional area of the tibial nerve in nondiabetic patients and in diabetic patients without neuropathy is not significantly different. We found that the mean cross-sectional area of the tibial nerve in diabetic patients with neuropathy is significantly greater than that in diabetic patients without neuropathy (24.0 *versus* 12.0 mm^2). Our study highlights the value of newer ultrasound imaging techniques in identifying morphological change in the tibial nerve and confirms that the tibial nerve in the tarsal tunnel is swollen, consistent with chronic compression, in diabetic patients with neuropathy. (J Am Podiatr Med Assoc 95(5): 433-437, 2005)

Entrapment neuropathies are common in people with diabetes mellitus, affecting one in three diabetic patients.[1] These nerve injuries begin slowly but can progress to cause permanent damage if not addressed appropriately. The damage should be analyzed early to allow potential therapies (which may include surgical intervention) to help change the natural progression of the disease, which may involve permanent anesthesia.[2]

Interest in the surgical treatment of diabetic neuropathy has increased in the past several years. The articles by Wood and Wood[3] in 2003 and Biddinger and Amend[4] in 2004 from the podiatric surgery and orthopedic literature, respectively, described small diabetic patient cohorts selected for surgical decompression of multiple nerves. Both of these studies describe a protocol using the Pressure-Specified Sen-

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sory Device (Sensory Management Services LLC, Baltimore, Maryland) to help select patients with axonal degeneration. These studies add to those from the plastic surgery,[5-7] microsurgery,[8] and general surgery[9] literature that suggest hope for restoration of sensation and relief of pain in the lower extremity in patients with diabetic neuropathy with an overlying nerve compression injury.

In addition, newer diagnostic ultrasound techniques allow clear visualization of the peripheral nerves. Ultrasound has already been established as an effective tool in the diagnosis and evaluation of peripheral nerve diseases, including carpal tunnel syndrome.[10-13] We sought to determine whether neurosensory changes at the medial plantar and medial calcaneal nerves, identified by the Pressure-Specified Sensory Device, correlate with the cross-sectional area measurements of the tibial nerve in diabetic patients with neuropathy.

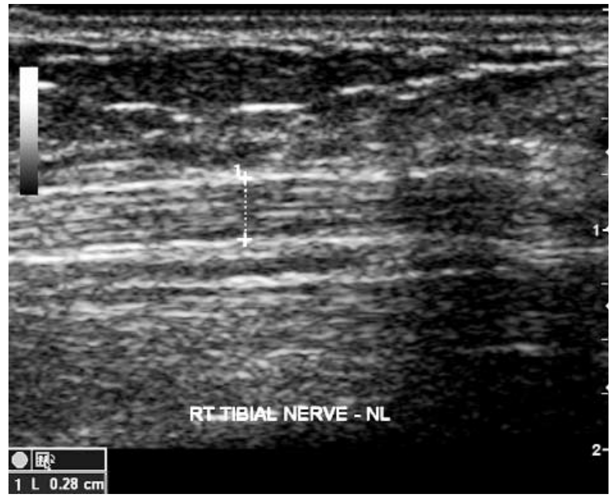

Figure 1. Longitudinal ultrasound view of a normal tibial nerve. Note the easily identifiable striations and linearity.

Materials and Methods

A consecutive series of 24 patients with type 2 diabetes mellitus who had numbness, burning, tingling, or pain in both feet, with clinically adequate circulation, was evaluated for neurosensory changes. The Pressure-Specified Sensory Device was used to study the distribution of the medial calcaneal nerve, medial plantar nerve, and peroneal sensory nerves according to the technique described by Dellon[14] in 2000. These patients were then studied using diagnostic ultrasound of the tarsal tunnel. The longitudinal course (Fig. 1) and the cross-sectional area (Fig. 2) of the tibial nerve were measured using high-frequency linear array ultrasound transducers (10–12 MHz) (Acuson-Siemens, Malvern, Pennsylvania, and GE Ultrasound, Milwaukee, Wisconsin). The transducer focuses electronically in the long and short axes, which results in improved near- and far-field image quality, allowing better differentiation among types of tissue.

The frequency of the transducer can be adjusted between 9 and 14 MHz. It is imperative that the focal zone, depth, and dynamic range are adjusted appropriately. This will allow better differentiation of the ligaments, tendons, nerves, and muscles in the ankle area. A high-viscosity couplet is applied to the transducer, and images are obtained by placing the transducer on the medial aspect of the ankle. Images and measurements are taken from proximal (before the tarsal tunnel) to distal (after the tarsal tunnel) in the transverse and sagittal planes of the tibial nerve. The tibial nerve lies just posterior to the posterior tibial artery and veins and is followed until it tapers or bifurcates.

The cross-sectional areas were calculated by multiplying the lengths of the short and long axes of the tibial nerve throughout the tarsal tunnel. At least three separate measurements were obtained, and the mean value was calculated. The longitudinal course and contour of the tibial nerve was also evaluated for focal compressions and deformities (Figs. 3 and 4). Local contributing factors, such as ganglion cysts and tenosynovitis, were also documented. The exam-

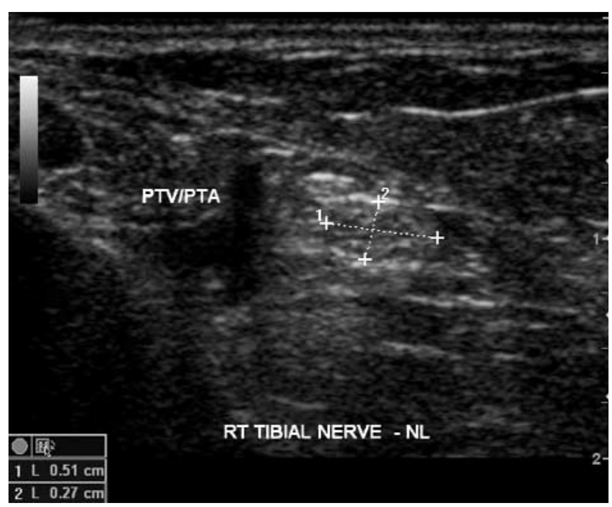

Figure 2. Cross-sectional ultrasound view of a normal tibial nerve measuring approximately 13.5 mm^2. The posterior tibial artery and accompanying veins are labeled PTV/PTA.

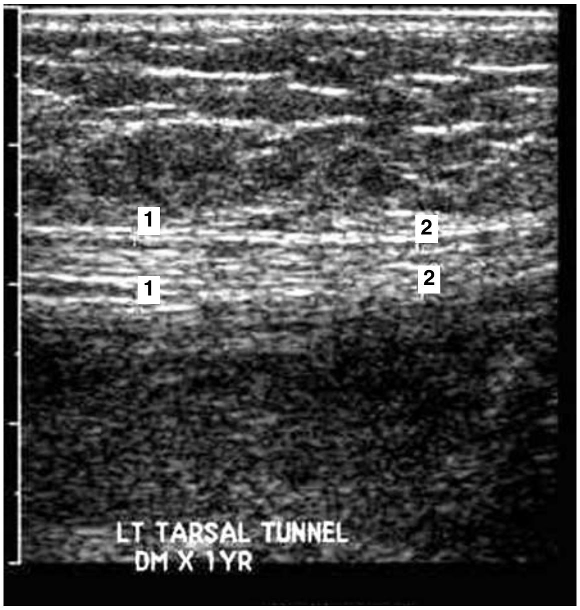

Figure 3. Example of a marked longitudinal compression of the distal portion of the tibial nerve.

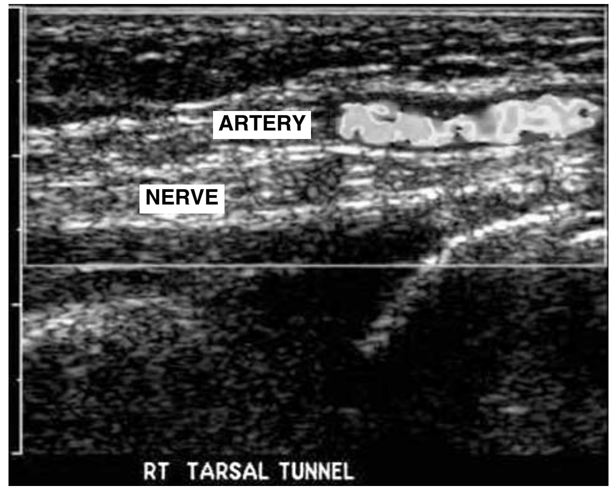

Figure 4. Longitudinal view of a focal compression of the tibial nerve by the posterior tibial artery resulting in an "hourglass" deformation of the nerve.

inations were performed with the patient in the recumbent position, turned to either the right or the left, depending on the ankle being imaged. A small rolled-up towel was placed under the ankle to slightly open the medial side of the ankle. A single examiner (D.L.) performed all of the examinations.

Our patient cohort comprised 16 men and 8 women aged 49 to 74 years (mean, 57.4 years). Patients were not included in the cohort if they had previous diagnoses of back problems, such as radiculopathy, herniated discs, or spinal fusions. Patients with other potential causes of their neuropathic complaints (eg, human immunodeficiency virus, alcoholism) were also excluded. Normative data and measurements in diabetic patients without neuropathy were reported previously and are referred to for comparison in the present study.[15]

Results

Results of neurosensory testing using the Pressure-Specified Sensory Device were markedly abnormal in patients with symptoms of diabetic neuropathy. These results were noted in all of the patients included in this study, resulting in 100% correlation between the Pressure-Specified Sensory Device findings and ultrasound measurements of abnormal tibial nerve dimensions.

The mean cross-sectional area of a normal tibial nerve is 12 mm^2 in nondiabetic patients and in diabetic patients without neuropathic complaints (Figs. 1 and 2).[15] The mean tibial nerve cross-sectional area in our cohort of patients with diabetic neuropathy was 24 mm^2 (Figs. 5 and 6), twice the normal cross-sectional area found in nondiabetic patients and in diabetic patients without symptoms of neuropathy ($P < .001$). Distal compression was the most common factor contributing to symptoms of neuropathy (Fig. 3). A prominent or tortuous posterior tibial artery was a frequent exacerbating etiology (Fig. 4).

Discussion

The use of diagnostic ultrasound for musculoskeletal and soft-tissue injuries is becoming more prevalent as the related hardware, software, and techniques improve. Several recent articles[10-13, 16-19] focus on the use of ultrasound in diagnosing or mapping peripheral nerve injury. Even in animal studies, the correlation between anatomical measurements and ultrasound measurements has been established.[20] No previous studies were found focusing on monitoring or documenting peripheral nerve changes in diabetic peripheral neuropathy.

From the surgical perspective, Pressure-Specified Sensory Device testing provides a clinical measurement of loss of sensory discrimination with chronic tibial neuropathy. This test, however, is limited when used alone in that it does not discriminate focal disease from diffuse abnormality of the tibial nerve. In other words, an abnormality of the tibial nerve anywhere along its path can result in symptoms of neu-

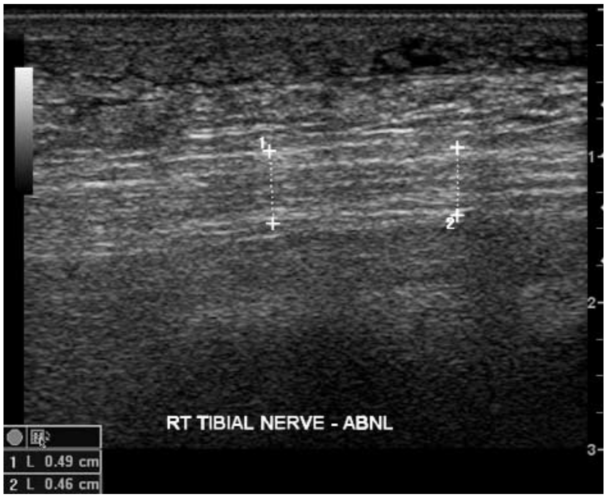

Figure 5. Longitudinal ultrasound view of an abnormal, edematous tibial nerve in a diabetic patient. Note the comparative loss of easily identifiable linearity.

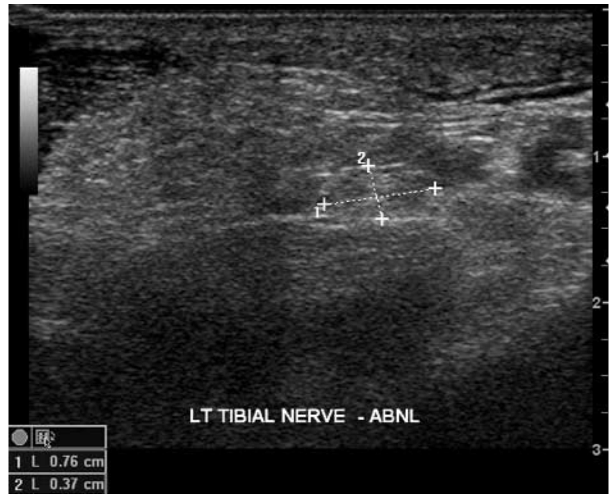

Figure 6. Cross-sectional ultrasound view of an abnormal, edematous tibial nerve measuring approximately 28 mm^2.

ropathy. The effectiveness of the Pressure-Specified Sensory Device increases dramatically, however, when combined with ultrasound by confirming the tibial neuropathy in the tarsal tunnel region. This allows treatment plans to be developed, including the possibility of surgical decompression, leading to improvement in symptoms.[1-3]

When the ultrasound values are compared with values from Pressure-Specified Sensory Device testing, the surgeon has abundant data with which to make an educated decision regarding whether to proceed with surgical decompression. This study demonstrates that ultrasound measurements of the tibial nerve in the tarsal tunnel area correlate well with neurosensory changes in the distribution of the tibial nerve as measured using the Pressure-Specified Sensory Device. These results indicate that diabetic neuropathy is strongly affected by tibial neuropathy from compression within the tarsal tunnel and that surgical decompression has a significant role in the relief of symptoms, thereby avoiding the long-term sequelae of untreated tibial neuropathy.

Sonography is a valuable tool in the diagnosis of pathologic abnormalities in the tarsal tunnel. Diagnostic ultrasound, when combined with Pressure-Specified Sensory Device testing, offers a noninvasive and cost-effective way to monitor the morphological changes in the peripheral nerves of diabetic patients with neuropathy. We recognize several limitations of this study: the relatively small patient cohort; the lack of normative data for the common peroneal nerve size in nondiabetic and diabetic patients; and the inability to image the medial calcaneal, medial plantar, and lateral plantar nerves in the porta pedis.

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