NEUROSURGICAL DECOMPRESSION FOR PAINFUL DIABETIC NEUROPATHY

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Diabetic neuropathy remains a national health concern, affecting 10-25% of six million diabetics in the US in 1987.[1] The number of diabetics in the United States rose to 15 million in 1998. Conventional teaching states that diabetic neuropathy is progressive and irreversible.[2] Traditional treatment for diabetic neuropathy has been prophylactic control of hyperglycemia and palliative care of foot problems. Despite our best efforts, approximately 15% of patients with diabetic neuropathy will develop a foot ulcer.[3] In 1996, 67,000 amputations were performed and the amputation rate remains at 8.6 per 1000 patients.[4,5] A review of clinical trials for the treatment of diabetic neuropathy has concluded that reversing the development of peripheral neuropathy is the best approach to its treatment.[6]

Figure 1.

Our understanding of the pathogenesis of symptomatic neuropathy, on the other hand, has been nonprogressive. A theoretical model termed double crush syndrome was proposed in 1973 to describe the development of peripheral neuropathic entrapment[7] (Figure 1). This hypothesis is based upon metabolic derangement (crush one) plus nerve compression (crush two), which together set the stage for compression neuropathy. Thirty years have since passed since our initial understandings of this process, and we still have no viable treatment options available. Recent literature has reported some success with nerve decompression,[8-11] and from these minimal yet positive results has stemmed a growing belief in neurosurgical decompression for treatment of peripheral neuropathy.

The causes of painful sensory neuropathy are diverse, and they are most easily clarified through categorization into subtypes. One subtype is referred to as the small-fiber painful sensory neuropathy, and this subtype has only the A-(delta) (small myelinated) and nociceptive C (unmyelinated) nerve fibers affected. Reports have indicated that this subtype is the most common type of painful sensory neuropathy in patients older than 50 years of age. This small-fiber subtype remains vastly under-diagnosed, and in most cases, no cause can be found.[12-14] A second subtype of painful neuropathy is associated with additional damage to the larger nerve fibers A-(beta) and A-(alpha). These large fibers are responsible for proprioception, vibratory sensation, muscle-stretch reflexes, and muscle strength. These two subtypes share the pain associated with damage to small nerve fibers. For these patients, the pain is life-altering and does not respond well to conservative treatments.

Clinically, painful sensory neuropathy can perplex and frustrate even the most accomplished physician. A firm comprehension of neurological terminology as it relates to the lower limb provides a sturdy foundation upon which to proceed. Although pain is a normal protective response,
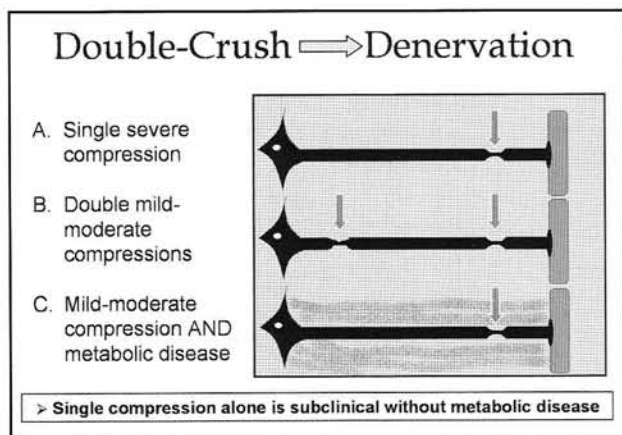
persistent pain will significantly alter patient livelihood. The pain associated with neuropathic pain can occur without provocation, such as pain associated with burning and paresthesias. Also, the pain can be stimulus-provoked, such as the pain of hyperalgesia or allodynia. Typical symptoms associated with neuropathic pain include burning, sharp, shooting, or aching pain. Symptoms are associated with subjective descriptions such as tingling, pins-and-needles, numbness, feeling tight, wooden, or dead feet. These symptoms are most prevalent at night, however some patients will describe pain with standing or walking, which may obscure the diagnosis. A thorough patient history will assist distinction from plantar fasciitis, arthritis, bursitis, tendonitis, etc. Lumbosacral radiculopathy is often associated with paraspinal muscle spasm and is aggravated by lifting activities. Entrapment of the posterior tibial nerve at the tarsal tunnel (tarsal tunnel syndrome) may cause pain in the toes, thereby presenting as painful sensory neuropathy.[15]

Once diagnosed, elucidating the subtype of painful sensory neuropathy involves closer inspection. An abnormal loss of pinprick sensation in the feet is seen in the typical small fiber sensory neuropathy affecting patients older than 50 years of age.[14] The sensation of touch may be diminished although other types of sensation are preserved. Conversely, pain associated with both small and large nerve fibers involves additional loss of proprioception, muscle-stretch reflexes, and muscle strength.

Specific clinical signs may help clarify a diagnosis in the scene of peripheral neuropathy. Traditionally, the Semmes-Weinstein monofilament (n 5.07) has been commonly employed in identifying an individual with diabetes who has lost protective sensation. However, this method presents many shortcomings. The monofilament represents a cutaneous pressure threshold of greater than 90 gm per mm. If a patient fails to have sensation to this monofilament, then the degree of diabetic neuropathy is often irreversible. A positive Tinel sign (tingling in the region served by a percussed nerve) indicates the progress of nerve regeneration. This test is commonly misinterpreted as a positive Tinel as a prelude to complete regenerative potential of a damaged nerve.[16] This test has varied objectivity in that the force of percussion will vary, and the subjective perception of radiating tingling will also fluctuate. However, a positive Tinel sign is believed to be the single most valid prognostic sign indicating a positive outcome with peripheral nerve decompression.[17-19] Percussing areas of known anatomic narrowing will offer evidence of possible restoration of sensibility. Recently, the Pressure-Specified Sensory Device™ (PSSD) has been developed as a noninvasive test to identify nerve compression by measuring the pressure required to distinguish one from two points touching the skin. This test quantifies axonal degeneration at subclinical levels, but is not without its weaknesses. With PSSD, there is a high learning curve for the clinician, the clinician must instruct the subject correctly, and the test requires a communicating patient who understands the procedure. More recently, high resolution ultrasonography has shown a sensitivity of 80% and a specificity of 91% in diagnosing peripheral neuropathy.[20] However, the literature has yet to clarify the use of diagnostic ultrasound with painful sensory neuropathy in the lower extremity.

The initial diagnostic evaluation must include electromyography (EMG) and nerve-conduction studies (NCS). These electrodiagnostic studies are useful for identifying a mononeuropathy (e.g. tarsal tunnel syndrome or focal nerve entrapment at the tarsal tunnel), differentiating multiple mononeuropathy from polyneuropathy (symmetric), and distinguishing axonal neuropathy (e.g. diabetic neuropathy) from demyelinating neuropathies.[21] When clarifying the diagnosis of painful sensory neuropathy, a normal set of neurodiagnostic studies directs the physician toward pure small-fiber neuropathy, and further testing is warranted. The sudomotor-axon reflex test (which quantitates sweating) is a practical, highly specific, and approximately 80% sensitive test for documenting small nerve fiber damage.[22] A skin biopsy will offer higher sensitivity with demonstration of loss of intraepidermal nerve fibers.[12,14] Quantitative sensory testing is less sensitive and less specific than skin biopsy or sudomotor testing.[13,14] The aim of quantitative testing is to measure pain and temperature thresholds in the skin.[13] Performance, however, is entirely dependent upon patient cooperation and attention.[23]

Conservative management of painful sensory neuropathy is initially guided by treatment of any underlying condition, which is beyond the scope of this article. Painful neuropathy, irrespective of the cause, is managed through different pharmacologic

strategies. The tricyclic antidepressants are the most thoroughly studied medication for the relief of neuropathic pain.[24] Blockage of serotonin and noradrenaline reuptake presumably leads to pain relief through inhibition of the sodium channel. Approximately one third of patients achieve a 50 percent reduction in neuropathic pain.[25-27] Responses to tricyclic antidepressants, however, are clinically insufficient, and the side effects associated with high dosage levels often lead to discontinuation of the medication, especially among the elderly.

Selective serotonin-reuptake inhibitors have a lower efficacy than that of tricyclic antidepressants.[28-30] Venlafaxine (Effexor), a reduced-binding antidepressant, has fewer side effects than tricyclic antidepressants, and it has been found beneficial for patients with cancer-related painful sensory neuropathy.[31] Bupropion (Wellbutrin, Zyban), a second-generation, specific inhibitor of norepinephrine reuptake, has been shown to diminish neuropathic pain by 30 percent in a six-week study of 41 subjects with painful neuropathy.[32] Carbamazepine (Tegretol), which stabilizes membranes by inhibiting sodium channels, has a benefit in diabetic neuropathy similar to tricyclic antidepressants, although intolerance to its side effects has limited its use.[33] Phenytoin, another sodium channel blocking medication, is rarely used as first-line therapy for neuropathic pain. A recent small study, however, has reported reduction in pain due to neuropathy after a single intravenous infusion of phenytoin[34] Gabapentin (Neurontin) has been found to have efficacy equal to that of amitriptyline (Elavil).[35] Reduction in neuropathic pain requires doses higher than 1600 mg per day. Gabapentin has a favorable side effect profile over other agents, although nearly 25 percent report dizziness, and 30 percent report sedation. Lamotrigine (Lamictal) has been reported to provide moderate pain relief with minimal side effects in a single small trial of subjects with diabetic or HIV-associated neuropathy.[36] Mexiletine (Mexitil), the oral analogue of lidocaine, has been studied with contrasting results, and further testing is indicated to provide clarification.[37-43] Dextromethorphan has even been found beneficial for treatment of painful diabetic neuropathy in a few controlled studies.[44,45] However, patients must tolerate the side effects of sedation, memory impairment, ataxia, and motor in-coordination. A single small study of levodopa, a dopamine agonist, has demonstrated a reduction of pain in diabetic neuropathy.[46]

Data is sparse regarding the effects of opioid analgesics on painful sensory neuropathy. Oxycodone (OxyContin) has been reported beneficial for painful post-herpetic neuralgia.[47] Levorphanol (Levo-Dromoran) has been demonstrated to reduce neuropathic pain by 36 percent, however the higher doses required for effective pain relief were associated with frequent side effects (itching, mood changes, weakness, confusion). Tramadol (Ultram) is a non-narcotic analgesic that is well tolerated and less likely to cause dependence and lead to abuse. The efficacy of tramadol has been reported similar to that of tricyclic antidepressants and levorphanol.[48,49] Side effects of tramadol include nausea and constipation in 20 percent, and headache or somnolence in 15 percent.

Topical medications have found limited use in the treatment of painful neuropathy. Capsaicin, which depletes substance P from sensory nerves in the skin, has proven inconsistent in different studies.[50,51] At least three studies have shown moderate efficacy in diabetic neuropathy.[52-54] One consequence to its discontinuance is the exacerbation of pain with initial applications. Lidocaine patches reduce ectopic neural discharges in superficial nerves, and some patients may benefit from patches trimmed to match a particular geographic area of excessive pain.

Current therapeutic strategies of painful sensory neuropathy result in a dismal 30 to 50 percent reduction in pain. This reduction is rarely sufficient for pain relief. Additional studies, including randomized trials, are warranted to measure the pain-relief efficacy of many of the aforementioned medications. With current efforts aimed at varied targets along the pain pathway, it remains uncertain whether adequate pain relief can be garnered from multidrug therapy. Furthermore, no guidelines currently exist for the pharmacologic approach to painful sensory neuropathy. Mendell and Sahenk have suggested the use of gabapentin 900mg per day increasing to 3600mg per day if needed. If pain persists or if the patient cannot tolerate the side effects of gabapentin, then tramadol may be added. Many choices exist for the addition of a third medication, if needed. If a three-drug regimen does not provide adequate pain relief, then substitution with a narcotic medication is advised. Despite exhaustive efforts on the part of many physicians, the patient is often undermedicated and their pain is left untreated. Patients must understand

that complete relief of neuropathic pain is uncommon with current medications, and alternative therapies are available albeit unproven in the search for relief of painful neuropathy.

Several surgical techniques address the damaged nerve, including neurolysis,[55] transection,[56-75] containment procedures,[56,63,71,72,76-78] barrier procedures,[59,79-83] and peripheral nerve stimulation.[80,84-89] The procedure of choice varies per patient and is dependent upon many factors. Vein wrapping and peripheral nerve stimulation procedures have been shown beneficial in reducing chronic intractable nerve pain that has been unresponsive to non-operative and operative treatment efforts.[90]

One treatment for painful diabetic neuropathy, which has been gaining momentum in recent literature, is neurosurgical decompression of peripheral nerves. The underlying premise in neuro-surgical decompression involves improvement of sensory function in diabetic individuals with peripheral sensorimotor polyneuropathy. By comparing the symptoms of diabetic neuropathy with those of chronic nerve compression, the belief is that alleviating compression at a specific location(s) will lead to reduction of patient symptomatology. This approach was first reported clinically in 1992 and has been steadily increasing in popularity. The treatment aims to directly address a main component of the previously mentioned double crush hypothesis, that of specific sites of anatomic nerve compression. In the lower extremity, there are three known sites of anatomic narrowing:

1. on the lateral calf distal to the head of the fibula[91-94]
2. within the tarsal tunnel[95-97]
3. on the dorsum of the foot at the bases of the first and second metatarsals, where the extensor hallucis brevis tendon crosses obliquely over the deep peroneal nerve branch[98,99]

The procedure for neurosurgical decompression of peripheral nerves is performed using spinal or general anesthesia, loupe magnification, and a pneumatic thigh tourniquet.

1. The common peroneal nerve is identified distal to the fibular neck on the lateral calf through an incision involving the peroneus longus muscle, which is a documented site of peroneal nerve compression.[100] The superficial fascia of the superficial head of the peroneus longus muscle is released through a transverse as well as a proximal and distal transection of this fascia. Once the deep fascia of this muscle is incised and the peroneus longus muscle is retracted anteriorly, the common peroneal nerve is exposed into the wound. Gentle retraction of the nerve superiorly offers deep visualization of any fibrous band or fascial sheath on the surface of the deep head of the peroneus longus muscle, which is then divided. The final site of common peroneal nerve compression is found at a fibrous connection between the peroneus longus and the soleus origin from the fibula. This connection is released as well as any fibrous adhesions deep to the muscle.[101] When the surgeon's finger can pass along the nerve and into the anterolateral compartment of the leg, decompression of the common peroneal nerve is complete. Particular care must be made to preserve any nerve branches innervating muscle in this region.

2. The posterior tibial nerve and its branches are decompressed by a technique releasing four medial ankle tunnels: the tarsal tunnel, the medial plantar tunnel, the lateral plantar tunnel, and the medial calcaneal tunnel.[89,102-105] An approximately 10cm curvilinear incision is made posterior to the medial malleolus extending distally along the abductor hallucis muscle. Blunt dissection is then performed to gain access to the posterior tibial neurovascular bundle. Metzenbaum scissors are utilized to incise the third compartment of the flexor retinaculum, and red and yellow vessel loops are placed around the artery and nerve, respectively. Suction peanuts are of benefit at this level for visualization. The tibial nerve will be located deep and posterior to the posterior tibial artery. The nerve is gently freed along the length of the incision. The fascia overlying the abductor hallucis muscle is released, and a freer elevator assists the gentle gleaning of the muscle fibers from the deep fascia. The thicker fascia deep to the abductor muscle

belly is incised with metzenbaum scissors, being careful of the immediate nature of the underlying nerve pathway. At this time, a septum is apparent between the medial and lateral plantar nerves as they descend into the plantar vault via the porta pedis. This intraneural septum is transected with metzenbaum scissors. The porta pedis is then decompressed by insertion of the surgeon's finger into the plantar vault. Venous branches or varicosities, which may be pressing on the nerve, are resected after ligating with 3-0 vicryl hand-ties. At this point, the decompression of the posterior tibial nerve is surgically complete.

3. The deep peroneal nerve is decompressed through a longitudinal incision over the bases of the first and second metatarsals. Resection of the extensor hallucis brevis tendon as it crosses obliquely confers decompression to the deep peroneal nerve. Resection of any osseous prominences or cystic lesions is also performed at this time.[106]

Nominal closure of the deep fascia is performed with a 3-0 absorbable suture, and the superficial fascia is closed with a 4-0 absorbable suture. Care is made to minimize suture pressure onto any neural structures. The skin is then closed with the surgeon's suture of choice. Placement of a Penrose drain into the tarsal tunnel incision may help alleviate wound dehiscence. The patient is then placed, prior to awakening from anesthesia, into a Jones-type cast. Immediate ambulation in a postoperative shoe is permitted, and the administration of oral antibiotics is at the discretion of the surgeon. The drain is removed 48-72 hours after surgery, sutures are removed at 2-3 weeks, and return to regular shoegear is attempted at three weeks.

Recent publications have demonstrated positive results regarding the sensory benefits of peripheral nerve decompression in diabetic patients.[8-11,107] However, evidence supporting surgical decompression of peripheral nerves has not been sufficiently demonstrated. Although some articles suggest a causal relationship between decompression and improved sensibility, the evidence-based support is sparse and incomplete. The clinical significance of these early reports has yet to be determined, and the decompression of peripheral nerves for diabetic neuropathy should be limited to closed trials until controlled and validated evidence has been ascertained. The current body of literature certainly provides a sound foundation for the design of a comprehensive and definitive study. Until the completion of such research, surgical decompression of peripheral nerves for treatment of diabetic peripheral neuropathy must be approached with caution. Further investigation has the potential to dramatically alter the course of diabetic foot care.

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