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Dual Peripheral Stimulation of Musculocutaneous and Radial Nerves for Refractory Upper Extremity Pain: Case Report

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Background: Peripheral nerve stimulation has been available for many years, yet there is relatively little information available regarding stimulation of many of the large sensory and mixed nerves.

Case Report: A 42-year-old woman presented to the clinic for a 10-year history of intractable left upper extremity and forearm pain following a motor vehicle accident requiring skin grafting. Based on the patient's failure of more conservative therapy, a shared decision was made to pursue opioid sparing interventional modalities. Implantable radial and musculocutaneous nerve stimulators were chosen for this patient for ease of use and high likelihood of favorable outcomes.

Conclusions: Sequential radial and musculocutaneous stimulation provided a 45% and 50% reduction in pain respectively, with the summative reduction of pain from original presentation being greater than 72% relief in total.

Key words: Peripheral nerve stimulation, neuromodulation, musculocutaneous nerve, radial nerve, regional anesthesia, upper extremity pain, pain medicine, implantable stimulation

BACKGROUND

Chronic pain can be classified into 3 broad categories: nociceptive (tissue related), neuropathic (somatosensory related), or mixed (from tissue and somatosensory stimuli) (1). Neuropathic pain is the abnormal function of a damaged nerve which results in continuous pain signal transmission in the absence of an extra-neuronal pain signal. Nociceptive pain by contrast, describes a normally functioning nerve which is receiving and transmitting pain signals following stimulation by a noxious stimulus to the nerve. Neuropathic pain is often classified into peripheral or central nervous system origin, it can be derived from virtually any nerve damage, such as nerve trauma, viral infection, autoimmune disease, diabetes, medication usage, and many other causes (1,2). The patient experiencing neuropathic pain typically presents with pain that is ongoing, radiating, and may have components of hyperalgesia or allodynia (2).

Peripheral nerve stimulation (PNS), like spinal cord stimulation (SCS), is a neuromodulation therapy thought to be effective via the "Gate Control Theory of Pain" mechanism discovered by Melzack and Wall in 1965 (3-5). This theory suggests the spinal cord dorsal horn laminae voltage gates regulate the nociceptive and non-nociceptive input which stimulates large-diameter sensory fibers to close voltage gates to nociceptive input traveling along small diameter fibers (6). Thus, when these gates are closed, pain

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is less intense, and pain is more intense when these gates are open (6). PNS is believed to work through the Gate Control Theory of Pain via central and peripheral mechanisms (5). Centrally, it has been shown to increase latency of pain signals to the brain under electroencephalogram, reduce postsynaptic potentials to the substantia gelatinosa, and inhibit neurons at the dorsal root ganglion (5). It also is believed to fatigue peripheral pain sensory fibers through repeat stimulation, decrease ectopic discharges, and cause downregulation or endorphins, neurotransmitters, and local inflammatory mediators that contribute to pain production.

When traditional neuropathic therapies fail to sufficiently relieve a patient's neuropathic symptoms, nerve stimulation can be considered in select patient populations (6). Common generalized criteria for PNS candidates includes pain that travels in a single peripheral nerve's sensory distribution, diagnostic peripheral nerve blockade that provides relief, and absence of psychological contraindications (6).

The effects of PNS have been recognized for many years, even predating SCS (7); however, there is still relatively little information available regarding stimulation of many of the large sensory and mixed nerves. This is in part due to the limitations regarding the feasibility of implantation, open surgical approaches and limited access to care for much of the neuropathic pain population. With the advent of the percutaneous PNS technique via Weiner and Reed, including subsequent modified electrode type, insertion procedures, etc. performed by Slavin and Burchiel, PNS has become more broadly available and considered by increasingly more physicians and patients alike (3). Subsequent research has shown efficacious relief with PNS for many neuropathic conditions, including trigeminal neuropathic pain, episodic cluster headache, chronic migraine/headache disorders, postherpetic neuralgia, complex regional pain syndrome Types 1 and 2, isolated peripheral neuropathy, ilioinguinal, iliohypogastric, lateral femoral cutaneous neuralgia, low back pain, and coccydynia (6). Despite these findings, there is still limited literature defining the safety and efficacy of peripheral and sequential implanted nerve stimulation for the treatment of isolated neuropathic pain. We present a case of sequentially implanted nerve stimulation of the musculocutaneous and radial nerves for the treatment of refractory upper extremity pain.

CASE PRESENTATION

A 42-year-old woman presented to the clinic for a 10-year history of left upper extremity and forearm traumatic/post-operative pain following a motor vehicle accident requiring extensive surgical repair and skin grafting. Her reported symptoms include constant sharp pain and burning in the left posterior upper extremity and medial forearm which are nonradiating and sensitive to touch. Prior to consultation, she tried pregabalin, meloxicam, nonsteroidal anti-inflammatory drugs, trazodone, various muscle relaxers, and physical therapy which did not adequately control symptoms. The physical exam was significant for multiple skin grafts over the posterior aspect of the left arm which exhibited hyperalgesia, but not frank allodynia. There was no tissue swelling, erythema, or signs of infection with full range of motion about the elbow joint.

Based on the patient's clinical findings, failure of more conservative therapy, and high risk for opioid abuse, a shared decision was made to pursue opioid sparing interventional modalities to control her pain. She reported that the majority of her pain was within cutaneous innervation of the radial nerve and musculocutaneous nerves. Single sequential peripheral blocks of the radial, then musculocutaneous nerves provided partial relief (Fig. 1). For diagnostic and potentially therapeutic value, the patient then elected to undergo simultaneous radial and musculocutaneous ultrasound guided nerve blocks. Following concomitant nerve blocks, the patient reported 90% pain relief which lasted for an approximate 8 hours. The radial and musculocutaneous nerve blocks were deemed successful in determining the source of the patient's pain and a shared decision was made to pursue PNS as a long-term therapy.

Implantable radial and musculocutaneous nerve stimulators were chosen for this patient for ease of use and potentially burdensome location of the axilla and forearm. Due to the proximity of the musculocutaneous nerve to the large axillary vessel and scarcity of publication regarding stimulation to this nerve, the decision was made to proceed first with the radial nerve implant. Implantation of radial nerve stimulators is well-documented and our implantation followed standard implantation reports (8). Radial nerve stimulation was successful in reduction of pain similar to the radial nerve block, with retention of pain of the lateral forearm along the distribution of the musculocutaneous nerve. For this reason, musculocutaneous nerve implantation was pursued.

After cleaning, prepping, and positioning the patient, the musculocutaneous nerve target was identified under ultrasound at the level of the axilla. The skin and PNS trocar path to the musculocutaneous nerve were anesthetized with 1% lidocaine. A 1 cm incision was made in the skin to accommodate the device trocar which was inserted to the musculocutaneous nerve. An electrical stimulation wire was introduced through the trocar and electrical current was passed through the wire to ensure accurate placement of the PNS in proximity of the nerve. Optimal proximity of the implantable device to the musculocutaneous nerve was determined and the peripheral nerve stimulator lead was introduced through the trocar where the device anchors were deployed (Fig. 2). A small pocket was created for the PNS receiver, the trocar was removed, and the receiver was placed into the surgical pocket. The patient tolerated the procedure well, only requiring conscious sedation.

CONCLUSIONS

Whenever nerve damage occurs, either peripheral or central, there is a potential that the patient will experience neuropathic pain (1). As seen above, our patient's history, symptomology, and exam is a classic example of peripheral post-traumatic neuropathy (1). Many mononeuropathic peripheral neuropathies, like ilioinguinal, iliohypogastric, lateral femoral cutaneous, and tibial neuralgia, are common indications for PNS (6). As a result, our patient's post-traumatic mono-neuropathic peripheral neuropathies fits both the exam and etiological findings proven to have successful PNS outcomes.

Our patient, following radial nerve implantation, had a significant reduction in left arm pain. She stated that she used the device 8 hours per day with an approximate 45% reduction in overall pain at the site with particular retention of pain within the distribution of the cutaneous branches of musculocutaneous. Subsequent PNS device implantation at the musculocutaneous nerve was well-tolerated, there were no adverse events with no complications at the incision site or with surrounding structures. The patient was educated on proper usage and maintenance of the device along with best practices. At 2-month follow-up, the patient reported an additional reduction of 50% of pain while wearing the second device. Thus, the patient experienced an initial 45% reduction from her baseline with only her radial PNS device engaged, followed by an additional 50% reduction with the musculocutaneous device engaged, resulting in a summative change of approximately 72.5%. This is suggestive of an additive effect when both devices were operating in conjunction with each other with either device providing less relief than both in combination. The etiology of this effect is not entirely understood; however, we hypothesize that it may be due to overlapping innervations and the persistence of pain fiber transmission via anastomosis of neighboring nerves. Contiguous cutaneous nerves frequently overlap with one another at their bordering

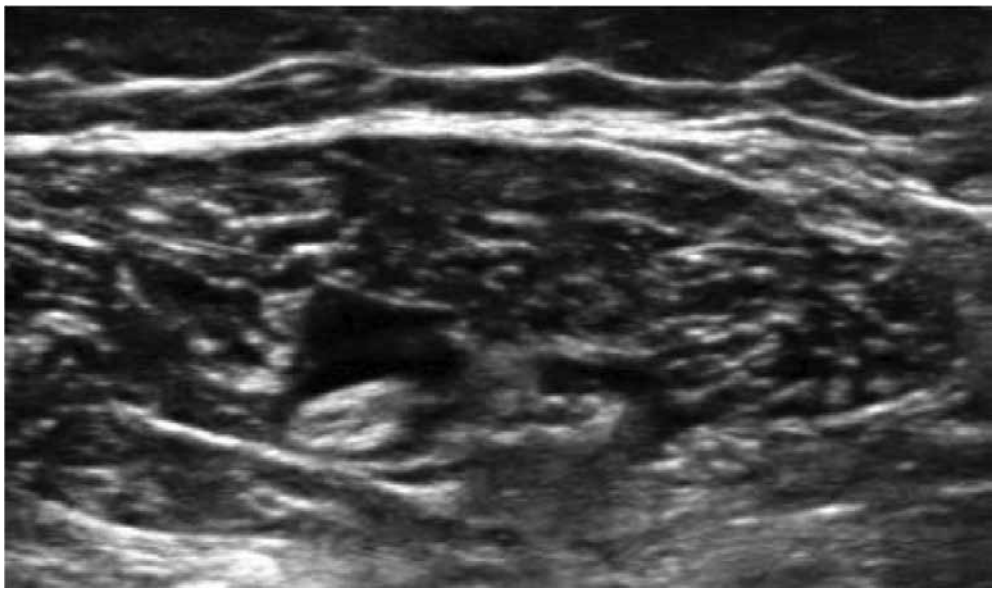

Fig. 1. "Halo sign" demonstrated following injection of local anesthetic onto musculocutaneous nerve

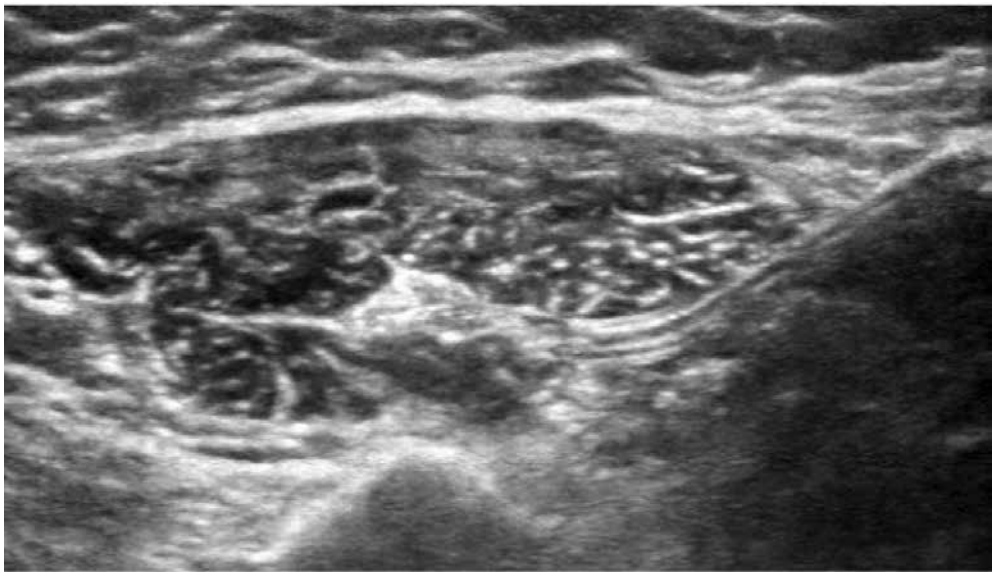

Fig. 2. Musculocutaneous nerve with PNS lead seen terminating directly adjacent to perineurium

innervations, with many locations likely receiving some level of sensory response from more than one sensory nerve. This has been demonstrated in cadaveric models, particularly with the certain cutaneous innervations of the forearm. Some authors suggest that cutaneous branches of radial and musculocutaneous nerves have either partial or completely overlapping innervations in as many as 75% of the cadavers examined (9). This would allow for either nerve branch to independently transmit pain signals unless both innervations were to experience a blockade simultaneously, as in the case of our patient. This concept of "watershed" innervation in the setting of nerve stimulation is not well understood and has uncertain clinical implications, warranting much more high-quality research.

To our knowledge, this is the first case reported of implanted nerve stimulation of the musculocutaneous nerve for the treatment of chronic forearm pain. Furthermore, this is the first case reported of implanted nerve stimulation to directly adjacent peripheral nerves to create a durable regional anesthesia effect by way of contiguous nerve innervation. Due to the uniqueness of the patient's medical history and presenting symptoms, a stepwise approach to PNS was preferred. Although radial nerve stimulation is frequently reported, implanted musculocutaneous stimulation is absent from the current medical literature. Implanted stimulation of the musculocutaneous nerve is a safe and effective method of analgesia for select patients. Dual implantation will require careful patient selection for successful therapy. Device pocket locations, accessibility for transcutaneous powering of the devices, implantation along muscular sheering planes, and many other considerations are very important to discuss with any patient receiving PNS, especially if one is considering implantation of 2 devices close to one another as in our case. We believe that stimulation of contiguous peripheral nerves can create an additive and durable regional anesthesia effect which may be highly successful in some carefully selected clinical scenarios. We recommend that this effect be more highly scrutinized and better defined with continued high-quality research and reports.

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