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Peripheral Nerve Stimulation: A New Horizon for Traumatic Brachial Plexus Injury, A Case Report

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Background: The management of traumatic brachial plexus injury is challenging. Treatment options consisting of physical therapy, pharmacologic therapy, and injection therapy often provide inadequate analgesia. Peripheral nerve stimulation (PNS) has emerged as a potential therapy for treatment of pain related to brachial plexus injury.

Case Report: We present a case of a 37-year-old man with painful ballistic trauma to multiple cords of the left brachial plexus refractory to medications and therapies. The patient was treated with a temporary 60-day PNS targeting the brachial plexus providing 90% improvement in pain intensity persisting 7 months postintervention.

Conclusions: The case supports the efficacy of a temporary PNS system as a minimally invasive treatment option for brachial plexus injuries resulting in refractory neuropathic pain. Extended lead implantation of the temporary PNS device beyond the US Food and Drug Administration-approved 60 days may be of benefit to patients, although the potential risk of infection should be assessed and monitored.

Key words: Traumatic brachial plexus injury, peripheral nerve stimulator, peripheral nerve stimulation, neuromodulation, neuropathic pain, case report

BACKGROUND

The brachial plexus is the collection of nerves from the C5 to T1 level of the spinal cord, which provides motor and sensory innervation to the upper extremities. Injury to the brachial plexus may result in a wide range of symptoms, including numbness, pain, paresthesia, weakness, and muscle atrophy. These symptoms may result in significant impairment in activities of daily living with associated psychosocial and socioeconomic impairment for both patients and their caregivers (1). Injury itself is most commonly caused by trauma, with the literature suggesting approximately 70% to 90% of injuries are due to motor vehicle collisions, followed by gunshot wounds, and then a variety of other etiologies, including knife trauma and obstetric complications (1,2). First-line treatment options for brachial plexus injuries include rehabilitation and physiotherapy. Surgical interventions consist of neurolysis, direct nerve repair, nerve grafts/transfer, tendon transfer, muscle transplantation, and arthrodesis (3). While these interventions can undoubtedly improve symptoms, they are not without risks, including surgical error in lesions surrounding neuromuscular structures, nerve injury, infection, scarring, and vascular damage.

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Over the past several decades, peripheral nerve stimulation (PNS) has emerged as a treatment option for a wide variety of acute and chronic pain disorders (4). Minimally invasive PNS devices have emerged, including fully implantable leads (e.g., StimRouter, Bioventus, Durham, NC) as well as temporary externalized leads (SPRINT, SPR Therapeutics Inc., Cleveland, OH). A 60-day temporary externalized lead PNS system is currently US Food and Drug Administration-approved for treatment of acute or chronic pain in the head, neck, torso, upper extremity, or lower extremity for up to 60 days. Although the temporary externalized PNS system is designed for short-term implantation for 60 days, pain relief can be persistent up to 12 months after removal (5). The temporary externalized PNS system (SPRINT, SPR Therapeutics Inc., Cleveland, OH) consists of fine wire leads implanted via a percutaneous introducer and connected to a miniature wearable stimulator that is programmed by the clinician and adjusted by the patient. Leads are placed in close proximity to the peripheral nerve innervating the location of pain (6). Furthermore, the coiled electrode structures of the system can promote tissue regrowth around them, helping to seal off the site where the leads exit the skin, thus minimizing the risk of infection and migration (6). Data is currently limited on the efficacy of this device for certain challenging neuropathic pain disorders, such as brachial plexus injury. We present a case of a primary brachial plexus injury secondary to ballistic trauma resulting in debilitating pain and functional deficits. The decision was made to pursue a 60-day temporary PNS resulting in 90% improvement in pain and function that persisted at the 7-month follow-up.

CASE DESCRIPTION

A 37-year-old man with a past medical history of multiple gunshot wounds to the left forehead, left collar bone, left arm, and left wrist presented to the pain management clinic in a tertiary referral center. The patient sustained these injuries through gang-related retaliation en route to his brother's funeral. The patient's injuries resulted in traumatic brain injury (TBI) with a subarachnoid hemorrhage, as well as upper and lower extremity pain and weakness. The patient reported mood and psychological disturbances from losing his brother, his own traumatic event, and debilitating pain. This pain was described as constant, severe, and 10/10 severity on the Numeric Rating Scale, and was located in the left arm, posterior shoulder, and scapula. Exacerbating factors included raising, bending, and rotating the shoulder. The pain quality was compared to a "wet fire" that radiated into his left forearm and all 5 fingers, mildly alleviated by ice and lidocaine cream. Physical exam was notable for impaired sensation in a left C4-T1 distribution, skin dryness in the left upper extremity, and a positive sulcus sign in the left humerus. He had globally limited left shoulder active range of motion. Motor strength in the left upper extremity was notable for shoulder abduction 0/5, elbow flexion 0/5, elbow extension 1/5, wrist extension 0/5, and finger abduction 3/5. Providers could not elicit reflexes in this extremity due to pain, though observed grossly 2+ right upper extremity and bilateral lower extremity reflexes.

On presentation, the patient was using gabapentin 900 mg 3 times daily, oxycodone 10 mg every 4 hours, lidocaine patches and creams, cyclobenzaprine 10 mg 3 times daily, and acetaminophen 1,000 mg 3 times daily with little to no effect on his pain intensity. Computed tomography of the cervical and thoracic spine revealed retained bullet fragments in the left cervical and supraclavicular region, right transverse process of T1, and right pedicle of T12 extending into the right facet joint. Furthermore, imaging showed a comminuted fracture of the right L1 superior articular facet and the right transverse process of L1, with fragments displaced into the central canal and an intramedullary hyperdense focus at approximately the level of L1-L2. Brachial plexus ultrasound revealed C7 nerve involvement distal to the plexus roots and rami with likely multilevel involvement and without root avulsion. An electromyogram and nerve conduction study (EMG/NCS) of the upper extremities showed a severe left brachial plexus injury involving all trunks, predominantly the middle and lower trunks. Sensory portions of the NCS displayed no responses in the left median, ulnar, or superficial radial nerves. An EMG of the left upper extremity revealed increased insertional activities, and abnormal spontaneous single muscle fiber discharges (i.e., positive waves, fibrillation potentials) in all muscles tested, except in the infraspinatus. No motor unit action potentials were observed in the deltoid, triceps, and extensor indicis proprius, and one motor unit action potential was observed in the pronator teres.

Despite medication adjustments and physical and occupational therapy, the patient continued to have unrelenting, debilitating pain. Eight months after his brachial plexus injury, the patient decided to pursue a temporary externalized PNS device (SPRINT, SPR

Therapeutics Inc., Cleveland, OH) to treat his left upper extremity pain.

Using ultrasound guidance, a PNS lead was implanted using an interscalene approach targeting the C5 and C6 nerve roots. A 15 Hz linear ultrasound transducer used to identify the common carotid artery and internal jugular vein along with the sternocleidomastoid, anterior scalene, and middle scalene muscles. The C5 and C6 nerve roots were visualized within the interscalene groove. The skin around the planned entry point and the subcutaneous tissues were injected with 1% lidocaine. A percutaneous sleeve and stimulating probe lead introduction system was inserted posteriorly in the trapezius muscle, and advanced through the middle scalene muscle. The introducer needle was delivered between the C5 and C6 nerve roots. Multiple stimulation parameters were used to deliver stimulation to the brachial plexus. Nerve target acquisition was confirmed, noting the generation of paresthesia specifically in the area of the patient's pain symptoms in the shoulder, arm, and forearm. Various electrical parameter combinations were tested, and the lead location was adjusted until the patient indicated paresthesia overlapping the distribution of the patient's typical region of pain. The stimulating probe was removed from the introducer, and a percutaneous lead was guided through the needle and delivered to a location close to the nerve. The introducer needle was removed, and the exposed end of the percutaneous lead was attached to an external stimulator unit. Various electrical parameter combinations were again tested until paresthesia overlapped the distribution of the patient's typical region of pain. After confirming that the lead impedance was in the normal range, the external stimulator unit was detached, the needle was removed, and the lead was anchored to the skin with surgical glue. The lead was threaded into the connector block, and electrical continuity and the desired patient response were confirmed.

Although the plan was to remove these temporary leads after 60 days of implantation, the patient was lost to follow-up because he lost his insurance. However, he presented to the emergency department after his daughter pulled out his leads 4½ months after the procedure. The patient was evaluated in the pain clinic 2 weeks after his leads were pulled. He reported that the procedure gave him 90% pain relief and dramatically improved the functional capacity of his left arm. He denied any pain, erythema, or discharge at the site of the lead entry, fever, or other systemic signs of infection. At the 7-month follow-up, the patient reported sustained 90% pain relief.

DISCUSSION

Our case highlights that temporary PNS may offer substantial pain relief in traumatic brachial plexus injury that persists long-term after lead removal. Further, due to loss of follow-up, our case highlights that temporary lead placement beyond the maximum recommendation of 60 days did not lead to any complications, namely site infection. Our findings are consistent with prior studies (6,7) highlighting the efficacy of PNS for a variety of acute and chronic pain conditions, such as low back pain, postamputation pain, shoulder pain, and postoperative pain. Different studies have shown benefits with lead implantation up to 60 days, but there are no prior studies assessing efficacy and safety profile from extending temporary lead implantation beyond 60 days. A study led by Gabriel et al (6) concluded that 60 days of PNS treatment may preclude the need for permanent implants in some patients. Another study (8) followed patients with hemiplegic shoulder pain for 12 months after having temporary PNS implanted for 6 weeks. The study showed maintained relief from pain for more than 12 months posttreatment (8).

Appraisal of the literature is limited on the use of temporary PNS for traumatic injuries or brachial plexus injuries. However, several case series described the use of temporary PNS for traumatic injuries of the lower limbs. One study (9) highlighted that at 12 weeks postimplantation, 90% of patients with traumatic lower extremity pain reported mild to no pain, although none of them had leads for longer than 51 days. Another study (10) assessed temporary PNS placement preoperatively to target the suprascapular nerve or the brachial plexus root or trunks. The study concluded that ultrasound-guided percutaneous PNS of the brachial plexus is feasible for ambulatory shoulder surgery and this modality may provide analgesia and decrease opioid requirements in the days following rotator cuff repair (10). A retrospective review of pain and quality-of-life outcomes (11) reported that 70% of patients who received an axillary or suprascapular temporary PNS reported more than 50% improvement of pain and quality of life.

The most crucial element of PNS therapy is patient selection. Recovery from traumatic injury is impacted by several factors, among them social, psychological, and physical. Social barriers resulted in delays in care from loss of insurance, incarceration, and an ongoing legal

case. This patient experienced undeniable psychological trauma with the loss of his brother and his own traumatic incident at the time of injury. Posttraumatic stress disorder and medical-reactive depression merited ongoing care that overlapped with pain management treatment. The patient was also treated for other physical ailments, including TBI amid his left upper extremity interventional pain treatment. These considerations warrant attention and may add to the complexity of brachial plexus injury cases in the pain management clinic.

CONCLUSIONS

Temporary PNS placement may be a viable, minimally invasive treatment option for people with refractory neuropathic pain from brachial plexus injury. Furthermore, the efficacy of prolonged lead placement time beyond the 60-day implantation window is yet to be determined. As the use of PNS expands, future powered and randomized control trials are needed to quantify efficacy in patients with brachial plexus injury.

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