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Peripheral Nerve Stimulation for the Management of Chronic Pain Syndrome: A Case Study of Complex Regional Pain Syndrome Posttrauma and After Surgery in the Leg

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Background: Complex regional pain syndrome (CRPS) is a very challenging condition to treat. We present a case resistant to conservative management that was treated by peripheral nerve stimulation (PNS).

Case Report: Our case study highlights the efficacy of PNS in the management of chronic pain syndromes, specifically CRPS, following major trauma and surgical intervention. Our case report involves a patient experiencing debilitating postoperative pain who underwent PNS treatment targeting the right infrapatellar branch of the saphenous nerve and posterior tibial nerve. Remarkably, the patient demonstrated a significant improvement in subjective pain levels with a reduction of approximately 75%, as well as enhanced functional capacity, compared to before the intervention.

Conclusions: Our case underscores the potential of PNS as a viable therapeutic option for individuals suffering from CRPS and other postsurgical chronic pain syndromes.

Key words: Peripheral nerve stimulation, chronic pain syndrome, complex regional pain syndrome, trauma, postsurgical pain, tibial nerve, posterior tibial nerve

BACKGROUND

Chronic pain syndromes, such as complex regional pain syndrome (CRPS), often pose significant challenges in terms of management and treatment efficacy. While CRPS usually develops after some injury or trauma, the pain experienced by patients is out of proportion to the degree of tissue injury. Injuries may be accidental, such as fractures, or iatrogenic, such as surgery (often in the limbs).

The pathophysiology of CRPS is complex and multifactorial (e.g., inflammation, immune responses, central and peripheral sensitization, neuroplasticity, and autonomic changes), making it difficult to target and adequately treat (1). As a result, patients often struggle with chronically uncontrolled pain, which can be disabling. Some patients also experience significant weakness and dystonia, causing further debilitation (2). Outside of physical impairments, such as other chronic pain syndromes, CRPS is associated with a lowered quality of life and a higher incidence of mental health conditions, including depression and anxiety (2,4).

CRPS is a clinical diagnosis that clinicians make according to the Budapest Criteria, a set of accepted guidelines adopted by the International Association for the Study of Pain in 2004. For diagnosis, patients may have symptoms spanning 4 categories (e.g., sensory, vasomotor, sudomotor/edema, and motor/trophic) (3).

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In addition to CRPS being a clinical diagnosis, it is also a diagnosis of exclusion. The diagnosis can only be made if no other disease process explains the patient's symptoms and overall presentation.

A very popular management strategy for CRPS involves physical and occupational therapy. Manual therapy has been thought to increase range of motion, maintain functional capacity, and reduce overall disability (1). Aside from manual therapy, other techniques include hydrotherapy and guided exercises. The success of physical and occupational therapies in alleviating pain in CRPS patients is limited by the amount of effort and time that patients devote to keeping up with exercise recommendations and attending frequent appointments. This is not always feasible for all patients and is associated with high costs secondary to the frequency of appointments required to maintain relief. Even if patients stick with their physical or occupational therapy programs, certain patients may not experience symptom relief (2). Published literature (6,7), evaluating CRPS symptom changes with physiotherapy, often reports low-quality evidence or focuses on short-term rather than long-term exercise therapy.

Pharmacotherapy is another treatment used to mitigate CRPS symptoms. The agents prescribed most frequently are anticonvulsants, antidepressants, and opiates (8). Some of the most common medications include gabapentin, benzodiazepines, tricyclic antidepressants, steroids, bisphosphonates, N-methyl D-aspartate receptor antagonists, such as ketamine, and nonsteroidal anti-inflammatory drugs (NSAIDs) (9). Not only do each of these medications carry risks and side effects, they also contribute to increased health care costs for patients and health care systems, mainly if many appointments and medication trials are necessary.

There has been more attention on overprescription of opioids and a push for tighter physician-led opioid stewardship in recent years. In this regard, 70% of CRPS patients at an urban academic teaching hospital, between January 2010 and November 2022, were prescribed opioids (9). Because CRPS is somewhat abstract, multifactorial, and challenging to manage, the high proportion of patients receiving opioids is likely a result of a need to continue stepping up therapy after the failure of more conservative treatments, including both pharmacotherapy and physiotherapy. Furthermore, many studies have shown only low-quality evidence (10,11) to suggest that these pharmacologic agents effectively manage CRPS.

Other more invasive interventions studied to address CRPS include sympathetic blocks, spinal cord stimulation, and dorsal root ganglion stimulation. A 2016 study (12) could not confirm the efficacy of sympathetic blocks for treating CRPS related to insufficient evidence. Spinal cord stimulation has shown promising evidence in a 2022 study (13). Still, the procedure itself, which involves placement of electrodes in the epidural space, is associated with significant risks, including severe pain, central nervous system (CNS) infection, hemorrhage, spinal epidural hematoma, headache, and accidental puncture of the dura (13). Similar risks apply because the technique used in dorsal root ganglion stimulation also involves entry into the epidural space (14).

Although a more novel neuromodulation modality for the management of CRPS, some studies (15) have found it to be more effective than spinal cord stimulation in CRPS symptom relief.

Peripheral nerve stimulation (PNS) has therefore emerged as a promising minimally invasive intervention for individuals with refractory chronic pain. This intervention offers targeted pain relief, while minimizing systemic side effects and risks associated with proximity to the CNS. In a retrospective review (16) of 240 patient charts spanning ~30 years, pain scores in CRPS patients who received PNS intervention decreased from a baseline mean of 7.4 ± 1.6 to 5.5 ± 2.4 at the 12-month follow-up, with an estimated reduction of 1.87 (95% CI: [1.29, 2.46]; paired t test, $P < 0.001$). The use of PNS was also found to reduce opioid requirements in this population by 21%. PNS improved the functional status of 51% of the sample group (16). Our case study aims to further elucidate the role of PNS in the management of CRPS involving a patient with a history of significant trauma and postsurgical chronic pain syndrome.

CASE PRESENTATION

The patient is a 45-year-old man who initially presented to Colorado Pain Care in Denver, CO, in early 2020, for evaluation of CRPS affecting his right leg. This condition developed after a significant trauma sustained in a motor vehicle accident, which resulted in an open fracture of the tibia and fibula. The patient underwent open reduction and internal fixation approximately 16 months before his presentation. Despite following the prescribed postoperative care regimen, the patient continued to experience severe, chronic pain that remained largely intractable.

The patient consistently rated his pain through the Visual Analog Scale (VAS) at 9 out of 10, localized pri-

marily to the right knee and foot. Over the following 18 months, the patient underwent various conventional treatments, including multimodal analgesic pharmacotherapy (e.g., opioids, NSAIDs, and neuropathic pain medications), physical therapy to improve range of motion and strength, and additional surgical intervention, including hardware removal related to persistent discomfort. However, despite these efforts, the patient continued to suffer from debilitating pain, which significantly impaired his quality of life.

Upon clinical examination at Colorado Pain Care, the patient exhibited hallmark signs and symptoms of CRPS, such as allodynia (e.g., pain in response to normally nonpainful stimuli), hyperalgesia (e.g., heightened sensitivity to pain), and vasomotor instability, which included temperature changes, discoloration, and swelling in the affected limb. Imaging studies, including magnetic resonance imaging, revealed soft tissue injuries, regional edema, and evidence of nerve involvement consistent with neuropathic pain.

Intervention

Given the refractory nature of the patient's pain state, a multidisciplinary approach was adopted. PNS was incorporated, targeting both the right infrapatellar branch of the saphenous (IPS) and the posterior tibial (PT) nerves. Under fluoroscopic and ultrasound guidance, percutaneous electrode arrays were placed at the right IPS and PT nerves, followed by programming to optimize pain coverage and to minimize discomfort. Concurrently, the patient underwent tailored physical therapy sessions to improve range of motion, strength, and proprioception. Figures 1, 2, and 3 show the final location of the systems used. Figure 4 highlights the minimally invasive technique.

PNS Procedures

Trial Technique

The PNS trial was placed at the right IPS and PT nerves. The patient was selected for a PNS trial following successful diagnostic nerve blocks at the right IPS and PT nerves. Pain relief of approximately 95% was reported, exceeding the 50% threshold for a trial commitment on 2 separate occasions using low-volume diagnostic blocks targeting both nerves. Nerve conduction studies are generally less effective than low-volume targeted diagnostic blocks for evaluating candidates for PNS therapies and do not provide helpful information for PNS applications. The consensus among PNS implant specialists is

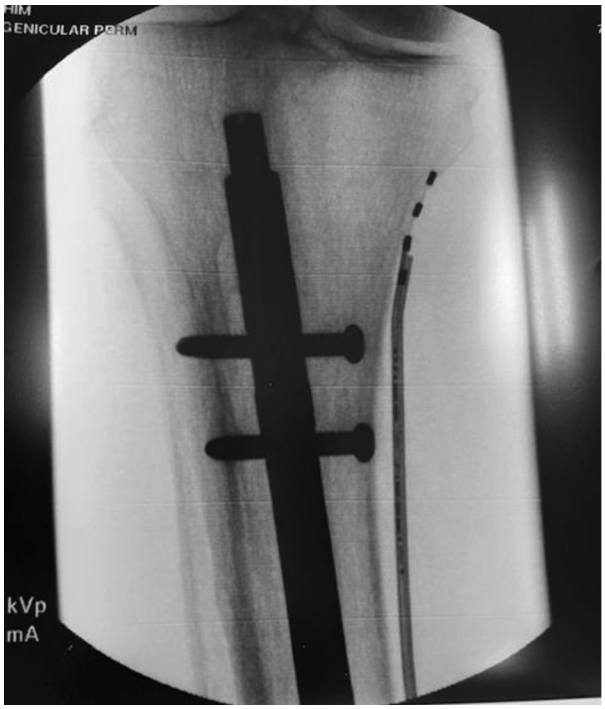

Fig. 1. The electrode array at the right IPS. IPS, infrapatellar branch of the saphenous nerve.

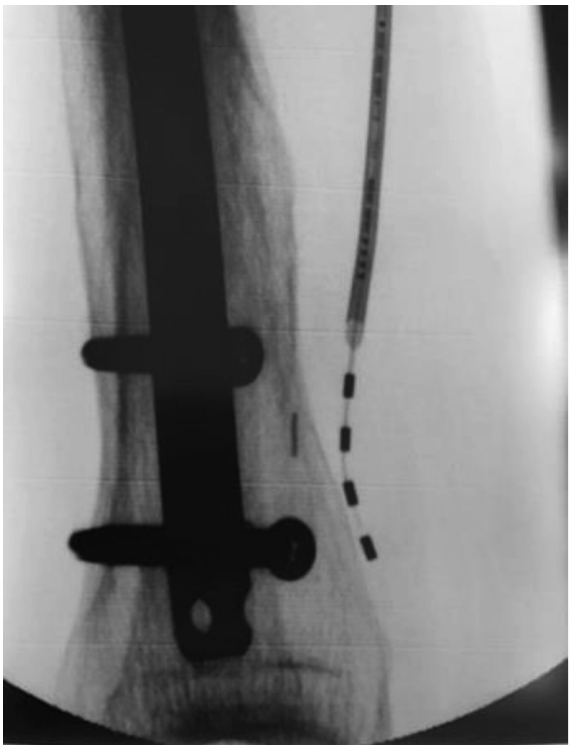

Fig. 2. Electrode array at the right PT nerve. PT, posterior tibial.

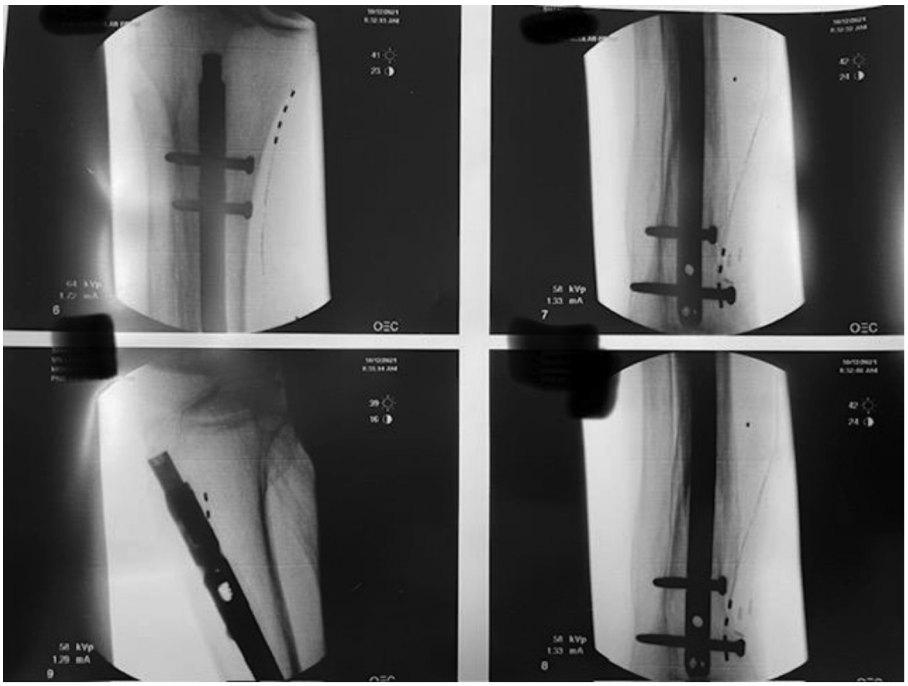

Fig. 3. Anterior and lateral views of the neurostimulators at the right IPS (left images) and right PT nerve (right images). IPS, infrapatellar branch of the saphenous nerve; PT, posterior tibial.

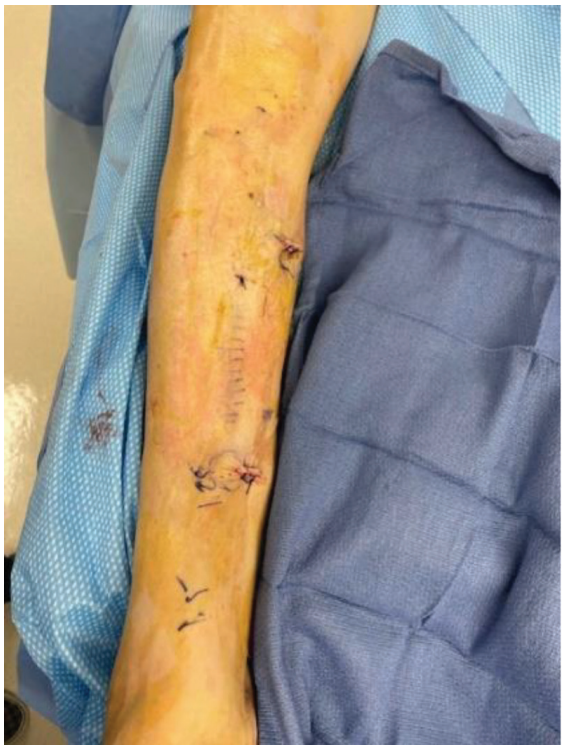

Fig. 4. Final image from the minimally invasive permanent placement of the PNS. PNS, peripheral nerve stimulator.

that electromyograms and nerve conduction studies have limited utility and do not play a significant role in the diagnostic process for PNS-based treatments. For example, in a survey by Abd-Elsayed et al (24), nerve conduction studies were not utilized, and only low-volume diagnostic blocks were used for identification purposes, with significant statistical findings in pain improvement and opioid reduction over 2 years.

Ancef 2 g intravenous (IV) was administered pre-operatively for infection prophylaxis. Moderate sedation was provided, allowing the patient to remain able to respond to verbal commands and to communicate sensations. Sedation details, including start and stop times and dosages, were documented in the Colorado Pain Care sedation record. The patient experienced no adverse effects from sedation and was instructed to avoid driving, operating heavy machinery, or making significant decisions for the remainder of the day. Emergency contact instructions were also provided.

The procedure began with preparing the right knee and ankle, which were prepped and draped under sterile conditions. The electrode array was unpackaged and maintained in the sterile field. Fluoroscopic guidance was used to identify the right IPS and PT nerve landmark targets at proximal and distal sites within the tibial flare. A 1 cm sagittal skin marker indicated the needle entry point, and the skin and deeper tissues were anesthetized using a mixture of 1% lidocaine with bicarbonate.

A small incision was made with a scalpel to facilitate blunt-tip introducer needle placement. The RX2 Coude® needle (Epimed, Dallas, TX) was advanced through subcutaneous tissues toward the IPS nerve under live fluoroscopy using the blunt tip. The introducer was positioned at a shallow angle (< 10°) with imaging confirmation (anteroposterior [AP] and lateral) before electrode array insertion. The electrode array was then advanced through the introducer to the target site, with

positioning confirmed via fluoroscopy. The separate receiver was connected to the electrode array, and the system was tested intraoperatively to confirm electrode placement concerning the targeted nerve and validate device functionality. The connection of the electrode array to the separate receiver was secured by tying a knot just after the channel marker.

The stimulator was then secured using Tegaderm® (3M Health Care, Maplewood, MN) to prevent migration, and negligible blood loss was noted during the procedure. The same procedure was repeated at the right PT nerve using both x-ray landmarks and ultrasound guidance to ensure proper placement of the neurostimulator(s) within 5 mm of the nerve.

The patient tolerated the procedure well with no complications. Instructions were provided to monitor adverse events or concerns, call with any issues, or seek emergency care if necessary. The final imaging confirmed proper stimulator placement, and verbal confirmation of electrode functionality was obtained intraoperatively.

The patient was monitored for response to the PNS trial over the next 7-10 days to evaluate pain relief and functional improvement. If successful, the patient would be scheduled for permanent lead implantation.

Permanent Placement Technique

The patient was selected for permanent PNS placement after a successful trial with > 95% pain relief at the targeted nerves. Ancef 2 g IV was administered preoperatively for infection prophylaxis. Moderate sedation was once again administered, during which the patient remained able to respond to verbal commands and to communicate sensations. The patient experienced no adverse effects from sedation and was instructed to avoid driving, operating heavy machinery, or making significant decisions for the remainder of the day. Emergency contact instructions were provided.

The procedure began with preparing the right knee and ankle, which were prepped and draped under sterile conditions. The stimulator kits were unpackaged and maintained in the sterile field. Fluoroscopic guidance was used to identify the inferior medial genicular nerve and PT nerve at proximal and distal target sites. A 1 cm sagittal skin marker indicated the needle entry points, and the skin and deeper tissues were anesthetized using a mixture of 1% lidocaine with bicarbonate.

A small first incision was made with a scalpel to facilitate introducer needle placement. Under live fluoroscopy, the RX2 Coude needles were advanced using the blunt tip application through subcutaneous tissues toward the right IPS and PT nerves. The introducers were positioned at shallow angles (< 10°) with imaging confirmation (AP and lateral) before electrode array insertion. Electrode arrays were advanced through the introducers to the target sites, with fluoroscopy confirming positioning. The receivers were connected to the electrode arrays, and the introducers were removed. The stimulators were tested intraoperatively to confirm electrode placement concerning the targeted nerve and validate device functionality.

Final positions were confirmed via x-ray imaging (AP and lateral). A second incision created a small subcutaneous pocket approximately 8-10 cm from each introducer needle entry point for the right IPS and PT nerve. Tunneling was performed from the pocket to the entry sites. The electrode arrays and connected receivers were coiled and anchored to the fascia with 2.0 silk sutures. To maintain the integrity of the coils, the tails were loosely tied with nonrestrictive ties to prevent unraveling.

The pockets and entry sites were closed in layers using absorbable sutures (Fig. 4). Steri-StripsTM (3M Health Care, St. Paul, MN) and Tegaderm were applied to secure the areas. The patient tolerated the procedure well with no complications. Instructions were provided to monitor adverse events or concerns, call with any issues, or seek emergency care if necessary. The patient was instructed on using the stimulator system and scheduled for follow-up to assess outcomes and device performance. Final imaging confirmed proper neurostimulator placement and functionality intraoperatively.

Outcome

The patient reported reduced pain intensity and improved functional capacity following PNS and subsequent physical therapy. At present, the patient has experienced a sustained 75% relief since the implantation on October 12, 2021. The patient typically uses the stimulator once a week and applies it only when pain recurs. Objective assessments, including VAS scores and functional outcome measures, demonstrated a remarkable improvement of nearly 75% compared to baseline pain and functional status. The patient reported decreased reliance on analgesic medications and enhanced participation in daily activities, indicating a significant enhancement in quality of life.

DISCUSSION

Our case highlights efficacy of PNS, mainly targeting

the IPS nerve, in managing chronic pain syndrome associated with CRPS posttrauma. In this regard, exceptional improvement in subjective pain and functional capacity emphasizes PNS as a valuable tool in the multimodal approach to CRPS treatment (4).

Similar techniques, involving PNS, have been described for the treatment of patients with limb pain secondary to CRPS. Some studies (17,18) have shown success by targeting one peripheral nerve for stimulation, while others, like this case, have reported successful pain management by targeting multiple nerves simultaneously. The combination of 2 nerve PNS targets addressed neuropathic, nociceptive, and functional aspects of pain. This broad approach led to substantial clinical improvement. A recent study (18), involving multiple nerve stimulation (e.g., tibial and common peroneal) for CRPS, has shown outstanding success with this technique, reporting sustained relief lasting 8-10 months in 2 patients and 34 months in the third patient.

Current alternative techniques for managing CRPS have many shortcomings. Notably, pharmacologic strategies have contributed to increased use of opioids in this vulnerable population, which raises risks of dependence, addiction, and death (9,21). As an independent management strategy, physiotherapy requires significant time commitment and potentially considerable monetary investment for long-term upkeep. Additionally, approximately 25% of CRPS patients have concurrent movement disorders, which can make movement and exercise less feasible in some instances (20). Physiotherapy may help increase strength, but data suggest limited pain relief (19). These drawbacks may be justifiable if they reliably and adequately address patients' symptoms, but they likely do not (6,7,10,11).

Previous studies (22-26) have demonstrated that a minimally invasive component of PNS and its potential for neuromodulation make it an attractive and practical option for individuals with refractory chronic pain syndromes. The possible long-term (months to years) benefit from this minor procedure should be considered when evaluating management options for treating CRPS (18,27). This technique has improved CRPS symptoms in the upper and lower limbs through various peripheral nerve targets (5,16-18,27). Improving pain with this minimally invasive technique is a valuable addition to the treatment plans for patients with CRPS. Since pain is the hallmark symptom of this syndrome, treating it effectively allows patients greater capacity for movement, strength building, and functional capacity improvement.

CONCLUSIONS

Our case demonstrates the effectiveness and sustainability of PNS as an innovative and minimally invasive medication-sparing treatment option for patients suffering from CRPS following trauma and surgery. After receiving PNS therapy targeting the right IPS and PT nerves, this patient experienced a significant reduction in pain intensity, improved functionality, and a reduced dependence on opioids. These outcomes emphasize the potential of PNS to provide long-term relief for patients with otherwise refractory pain syndromes, thus offering an alternative to more invasive surgical options. Future studies, including larger clinical trials and comparative effectiveness research, are warranted to further assess the role of PNS in the management of CRPS and other chronic pain syndromes. The promising results from this case warrant broader consideration of PNS in clinical practice as a viable treatment option for individuals struggling with chronic neuropathic pain.

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