

# **COSTOCLAVICULAR APPROACH TO THE INFRACLAVICULAR BRACHIAL PLEXUS FOR PERIPHERAL NERVE STIMULATION IN TREATING REFRACTORY COMPLEX REGIONAL PAIN SYNDROME CASE REPORT**

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**Background:** In cases of complex regional pain syndrome (CRPS) that are refractory to conservative treatment, interventional therapies, such as neuromodulation, including peripheral nerve stimulation (PNS), may be considered as a treatment option. PNS has proven effective when applied to the brachial plexus. The anatomical positioning of the infraclavicular brachial plexus cords allows for targeting via either the conventional paracoracoid approach or the novel costoclavicular approach. The latter approach can be an excellent option to cover the plexus, as it clusters the brachial plexus cords at a more superficial level.

**Case Report:** We present the case of a 58-year-old woman who developed type 2 CRPS following a work-related wrist injury. Initially, she had ulnar nerve and tendon injury for which she received a series of surgeries. After failing conservative therapy, she underwent PNS with significant relief.

**Conclusions:** Our case demonstrates the successful use of PNS to the brachial plexus via the novel costoclavicular approach to the infraclavicular brachial plexus for the management of refractory CRPS.

**Key words:** Complex regional pain syndrome, peripheral nerve stimulation, infraclavicular brachial plexus, case report

## **BACKGROUND**

For intractable cases of complex regional pain syndrome (CRPS) that have failed conservative therapy, interventional therapies, such as neuromodulation, are viable treatment options. The choice between spinal cord stimulation (SCS), dorsal root ganglion (DRG) stimulation, and peripheral nerve stimulation (PNS) is dependent on pain location and nerve territories involved. These neuromodulators have been shown to significantly reduce pain and improve functionality in many patients.

PNS has shown efficacy in managing refractory pain syndromes affecting the shoulder and upper extremity (1-5) with documented success when applied to the

brachial plexus (6-8). The initial approach to percutaneous placement of electrodes to the brachial plexus was described using an interscalene approach, and there is limited literature on implementing this technology via an infraclavicular approach (7,9). The infraclavicular brachial plexus can be accessed using either the conventional paracoracoid approach or the costoclavicular approach, each with its own risks and benefits.

We present a case involving the novel use of the costoclavicular approach for PNS placement to the brachial plexus, with the receiver coil implanted in the lateral chest wall for treating refractory CRPS in a 58-year-old patient. With this approach, there is a reduced risk for neurostimu-

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lateral migration, as the systems do not cross the shoulder joint. Additionally, with this approach, it is possible to capture all 3 cords of the brachial plexus to provide pain coverage for the entire hand, forearm, and distal arm.

## **CASE PRESENTATION**

A 58-year-old right-handed woman who initially sustained a work injury to her wrist a year prior to her presentation in our clinic. She had sustained an ulnar nerve and tendon injury for which she received a series of surgeries with plastic surgery, including multiple carpal tunnel releases with neurolysis, neurectomies of the anterior interosseous nerve and posterior interosseous nerve, sympathectomies of the ulnar and radial nerves, and Guyon's canal release. Despite these interventions, she continued to have significant pain, edema, hair loss, and color changes in her right upper extremity, consistent with type 2 CRPS.

After failing conservative therapy and nerve blocks, neuromodulation was discussed, and she elected to proceed with a PNS trial to the brachial plexus. The novel costoclavicular approach to the infraclavicular brachial plexus using 2 electrode arrays resulted in > 75% pain relief and improved function of her arm during the PNS trial. Adjustments were made to avoid chest wall stimulation, and optimal results were achieved using both electrode arrays. Consequently, she proceeded with permanent PNS implantation.

Postoperatively, she reported a reduction in baseline pain from 9/10 to 6/10, which was significant for the patient, as she was able to have better sleep, function of her hand, and was able to return to work with reduced hours. She also noted improved color changes in her skin and absence of hyperalgesia. Following adjustments to the stimulation settings, her pain further decreased. At the 5-month follow-up, she reported that her pain had increased and was consistent at 6/10. Thus, ultrasound was used to ensure that the neurostimulators were in the correct tissue plane, and an x-ray was ordered to exclude migration, which confirmed correct placement of the neurostimulators. The stimulators were reprogrammed to an amplitude of 2 mA, a pulse rate of 1,499 Hz, and a pulse width of 30  $\mu$ s, which resulted in an overall experience of 50% to 60% pain relief and 70% improvement in function.

## **Technique**

### **Trial Technique**

Ultrasound was used to visualize the lateral, medial,

and posterior cords of the brachial plexus. They are found lateral to the proximal axillary artery, deep to the pectoralis major and subclavius muscles, superficial to the serratus anterior muscle, and superficial to the second and third rib (Fig. 1).

After the skin and subcutaneous tissue were infiltrated with local anesthetic, a 13G Coudé needle (Epimed, Dallas, TX) was advanced from the lateral chest wall in plane with the ultrasound toward the brachial plexus. Ultrasound was used to track the needle path far from the vessels and pleura; the tip of the needle was inserted superficial to the brachial plexus around the lateral cord. X-ray was used to direct the needle to the lateral aspect of the costoclavicular space, deep to the paraneural connective tissue around the posterior cord. An 8-contact nontined electrode array was advanced under ultrasound and x-ray. The electrode array was connected to a separate receiver. Ultrasound was used to track the electrode array deep to the clavicle. X-ray confirmed the location caudal to the midpoint of the clavicle. Subsequently, the needle was removed, and intraoperative testing was performed. The same procedure was repeated to insert the second electrode array.

Stimulation testing was performed utilizing low frequency, a pulse rate of 80 Hz, a pulse width of 320  $\mu$ s, and an amplitude of 2 mA. The patient felt a comfortable vibration in the distribution of pain in her arm and hand with minimal muscle contractions to confirm neurostimulator placement. The needle was removed with the stimulators in place. The systems were secured with 2-0 polydioxanone sutures and dermabonded. The transmitter assembly was placed on the anterolateral side of the chest wall and the trial lasted 7 days.

### **Permanent Implantation Technique**

The first incision was made near the axilla around the anterior axillary line (Fig. 2) after local infiltration at the needle entry site. The introducer was advanced in similar fashion to the trial technique, and two 2.0 nonabsorbable sutures were placed circumferentially around the introducer. The second introducer was inserted deep to the plexus around the medial and posterior cords. Proper placement was confirmed by the aid of fluoroscopy. Two 4-contact tined Freedom® (Curonix LLC, Pompano Beach, FL) electrode arrays were advanced through the introducers. Stimulation testing was performed as it was in the trial. Proper placement was confirmed by the aid of fluoroscopy in anteroposterior view (Fig. 3) and ultrasound.

A second incision was made for the implanted receiver

in the lower thoracic, midaxillary line (Fig. 2). The steering stylets were removed, and the electrode arrays were connected to the separate receivers. Subsequently, the needles were removed, intraoperative testing was performed, and positioning was confirmed. With the stylet in place, the introducer was advanced from the second incision receiver pocket to the first incision electrode array entry site. Then, the distal end of the neurostimulators was coiled and sutured to the deep fascia. After copious irrigation, the incisions were closed using absorbable sutures, skin closed with subcuticular continuous technique, and Steri-Strips™ (3M, St. Paul, MN) placed.

**DISCUSSION**

Diagnosis and management of CRPS is often challenging for providers and frustrating for patients.

Treatment typically involves a multidisciplinary approach, including physical therapy, adjuvant analgesics, and anesthetic blocks (10-11). For cases resistant to conventional therapies, neuromodulation can be considered (12,13). In one case series by Calvillo et al (13), 36 patients with CRPS for ≥ 2 years underwent SCS or PNS. Thirty-six months after implantation of the neurostimulator, pain decreased by a statistically significant amount, and analgesic consumption decreased. The authors stated that neurostimulation is a reasonable option when alternative therapies have failed (13). While systems, such as SCS and DRG stimulation, have been approved for management of CRPS for the lower extremities (14), we did not pursue a trial of these neuromodulation devices due to the increased risk of complications from pre-existing cervical stenosis in our patient.

Theories, which exist to explain the mechanism of PNS, include both mechanisms in the central nervous system and peripheral systems. The use of PNS for control of neuropathic pain is based on the original observation by Melzack et al (15) and Wall et al (16) and the gate-control hypothesis for its mechanism of action in pain modulation. Pain transmission to the brain can be diminished through use of nonpainful stimuli to A-beta

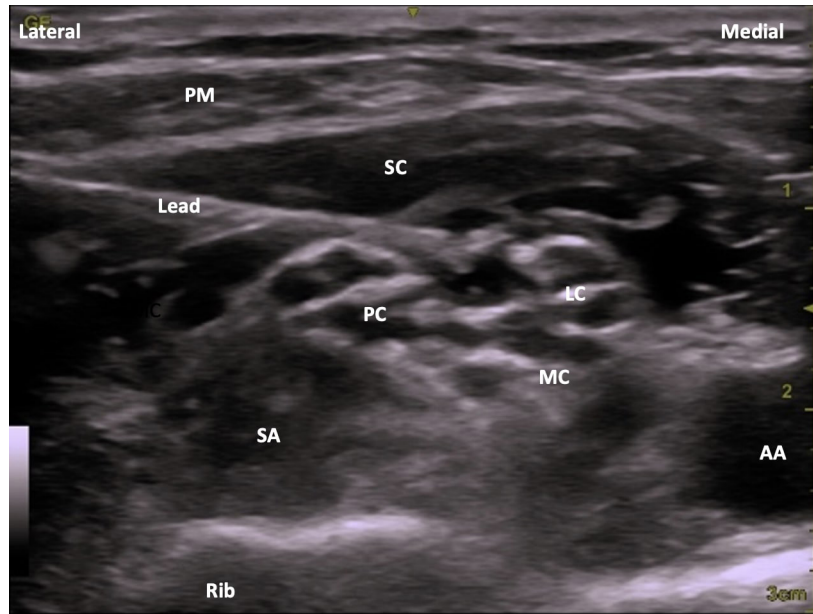


Fig. 1. Ultrasound image of the costoclavicular approach to the infraclavicular brachial plexus on our patient.

PM: pectoralis major, SC: subclavius muscle, SA: serratus anterior, AA: axillary artery, PC: posterior cord, MC: medial cord, LC: lateral cord.

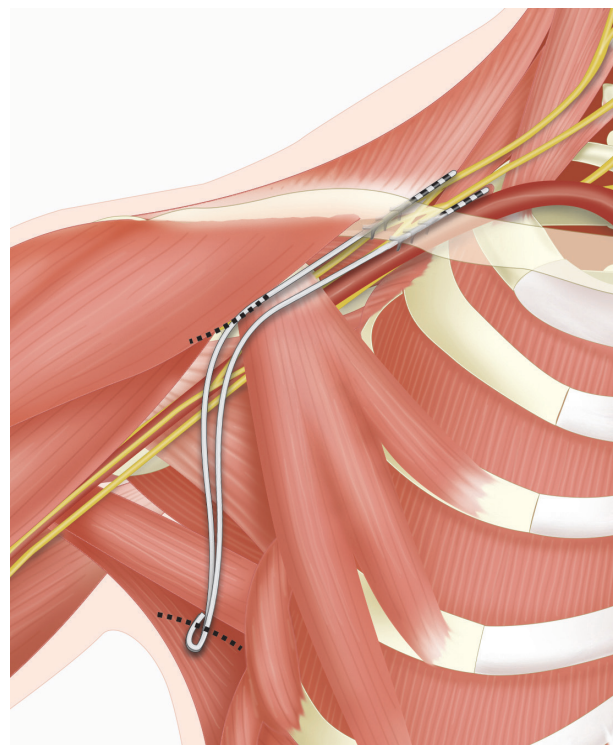


Fig. 2. Anatomy image of the location of the incisions (black dotted lines), the placement of the 2 stimulator leads, and generator site.

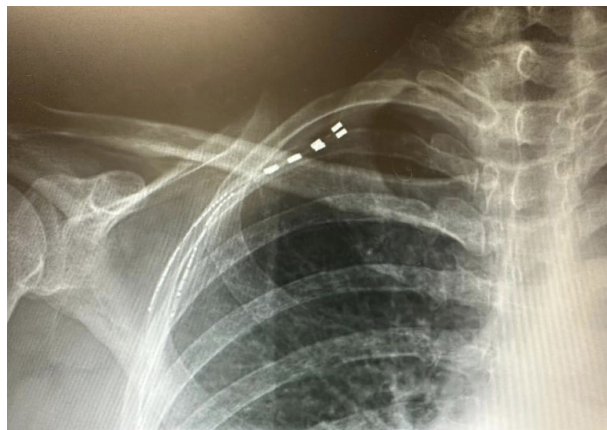


Fig. 3. X-ray of final placement of the two 4-contact tined Curonix peripheral stimulator leads.

fibers, which suppress the conduction of nociceptive A-delta and C fibers in the dorsal horn through activation of inhibitory interneurons (17). Other theories include depletion of excitatory amino acids, release of inhibitory neurotransmitters through long-term potentiation of dorsal horn neurons, and stimulation-induced block of cell membrane depolarization (17).

The advancements in PNS technology and implementation of percutaneous lead placement improved complications associated with the early surgically dependent systems (5,18-19). The first percutaneous PNS implant to the brachial plexus was described by Goroszeniuk et al (7) in 2007 using an interscalene approach, which showed satisfactory results. Subsequently, Bouche et al (8) reported a case series where 10 out of 17 of their patients experienced  $\geq 50\%$  improvement in pain relief using a similar technique. Another case series (20), including 18 patients with neuropathic pain due to brachial plexus partial avulsion, demonstrated that at 18 months postimplantation with brachial plexus PNS, the average Numeric Rating Scale decreased along with reductions in medication intake and improvements in quality of life.

Frederico et al (9) were the first to describe a percutaneous ultrasound-guided infraclavicular approach for lead placement. This method accesses the brachial plexus sheath so the electrode can be advanced into the supraclavicular region, where the trunks and divisions of the brachial plexus are densely grouped. With this single lead placement, broad stimulation of the upper limb could be achieved, and the generator was implanted in the subclavicular contralateral side to the electrode. Of the 14 patients that underwent a trial, 10 patients

had a permanent implant due to achieving  $\geq 50\%$  pain relief. Their patients reported improvements in quality of life and a reduction in pain at 12-month follow-up. The technique used in their study utilized an implantable pulse generator requiring a more extensive incision and tunneling of the electrode to reach the implanted generator, which increases risks of infection, bleeding, pneumothorax, and lead migration. Our technique employed a system without an implanted generator, allowing for a smaller incision. Further, our technique utilized tined electrode arrays, which reduces the risk for lead migration.

The infraclavicular brachial plexus can be accessed via either the traditional paracoracoid or the new costoclavicular approach (21). In the conventional paracoracoid approach for PNS lead placement, the ultrasound transducer is placed in the parasagittal plane below the clavicle, medial to the coracoid process. Disadvantages with this approach include a higher risk of lead migration, as the neurostimulators cross the shoulder joint, as well as difficulty in capturing all the cords of the brachial plexus due to anatomical variability between patients (21).

In the costoclavicular approach, the ultrasound transducer is placed parallel to and below the clavicle, which allows the cords to be clustered together at a more superficial level, as opposed to viewing the 3 cords separately as in the paracoracoid approach. This approach can be an excellent option to cover the plexus and could theoretically allow using one neurostimulator to provide comprehensive pain coverage for the entire hand, forearm, and distal arm pain conditions. Further, in patients with higher body mass indices, this technique could be an alternative compared to the paracoracoid approach, which can be a challenging technique to perform depending on body habitus.

Given these advantages, we trialed a PNS with the costoclavicular approach to the infraclavicular brachial plexus for a patient with refractory CRPS. Due to the trial's success, the patient chose permanent PNS implantation. For the permanent PNS implant, we utilized two 4-contact tined neurostimulators to help decrease the risk of lead migration. Since the system uses an external rechargeable transmitter assembly, this allows the location for the receiver coil implant to be more customizable than with an implantable pulse generator and allows for a smaller incision to be made.

Utilizing the costoclavicular approach for PNS of the brachial plexus enables more superficial targeting of

the clustered cords. Leurcharusmee et al (21) reported comparable performance times and success rates for surgical anesthesia between the traditional paracoracoid and newly described costoclavicular approaches to the infraclavicular block. A meta-analysis (22) found that the costoclavicular approach was neither superior nor inferior to the paracoracoid approach. Given that this technique is both practical and reproducible, it could be a viable option to consider for patients requiring PNS coverage at the infraclavicular brachial plexus. However, further comparative studies are necessary to better define the safety and efficacy of this approach, the anatomical variation (23), as well as to evaluate the effectiveness relative to the traditional paracoracoid method. If this approach can be shown to be reproduced

safely and effectively, exploration for outcomes in terms of pain, function, and quality of life, compared to DRG or SCS for CRPS in the upper extremities, should be analyzed.

## CONCLUSIONS

Neuromodulation offers a promising treatment option for CRPS, with PNS to the brachial plexus an excellent option for suitable patients. Our case report highlights a novel technique for brachial plexus PNS placement, employing ultrasound and fluoroscopic-guided costoclavicular approach to the infraclavicular brachial plexus and inserting the receiver coil in the lateral chest wall.

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