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Wireless Cervical Peripheral Nerve Stimulation for Treating Occipital Neuralgia-Induced Neuropathic Pain

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Background: Peripheral neuropathy is a leading cause of chronic pain and can result in cephalalgia when upper cervical nerves or their branches are injured. This condition often shows resistance to typical treatment methods used for long-term pain management. Peripheral nerve stimulation (PNS) is an effective way to treat neuropathic pain; however, there's limited literature available regarding the wireless modality at the cervical level.

Case Report: This was a retrospective case series involving 3 patients who received wireless PNS at the C2-C3 level for treating occipital neuralgia and/or axial neck pain. Average Visual Analog Scale scores decreased by 63.9% after trial ($P < 0.001$) and 78.3% ($P < 0.001$) at one-year postpermanent implantation.

Conclusions: Our study adds to the growing evidence supporting wireless PNS as an efficacious intervention at the cervical level for patients with occipital neuralgia-induced neuropathic pain who fail conventional management.

Key words: Peripheral nerve stimulation, headache, occipital neuralgia, chronic pain, case series

BACKGROUND

Chronic pain is considered a serious burden for patients, affecting daily activities. More than one in four Americans suffer from chronic pain. Mismanagement of this condition can result in opioid dependence and other psychological diseases, increasing both mortality and morbidity. Thus, the management of pain significantly impacts patients' long-term quality of life (1,2).

Neuropathic pain is a chronic pain condition caused by disease in the somatosensory nervous system (3). Common types include postherpetic and trigeminal neuralgia, polyneuropathy, and poststroke pain (4). Neuropathic pain impacts around 8% of the general population, comprising 20% to 25% of those experiencing chronic pain (5). Injury to the upper cervical nerves or their branches can result in cephalalgia (6).

Occipital neuralgia is a distinct type of headache characterized by sharp, stabbing pain in the distribution of the greater, lesser, and/or third occipital nerves (7,8). This condition can significantly impact a patient's quality of life, with symptoms ranging from intense paroxysmal pain to numbness in the affected areas (9). Occipital neuralgia can be difficult to diagnose as its symptoms often overlap with other headache disorders, requiring more imaging studies to rule out underlying causes.

The treatment of occipital neuralgia presents several challenges. First-line therapies include anticonvulsant and antidepressant medications, and physical therapy, followed by opioids as a second-line treatment (10,11). Anticonvulsants, such as gabapentinoids, can cause side effects like nausea, swelling, blurred vision, and drowsiness. Opioids, while potent pain relievers, increase the

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risk of substance abuse and can lead to side effects, such as nausea, constipation, drowsiness, and respiratory depression. Another drawback of pharmacological and nonpharmacological treatments is that they often provide only temporary relief (12). More invasive treatments, such as nerve blocks, radiofrequency ablation, or surgical decompression, carry their own potential risks and complications (13). There is also a variability in the treatment response amongst patients, necessitating a personalized approach to management.

Peripheral nerve stimulation (PNS) is used for treating peripheral neuropathies that are not responsive to other management (14). Its utility has received increased attention by researchers in the past 5 years (15). Recent advancements in technology have improved the safety and efficacy of PNS systems (16). Research has shown that PNS provides relief in patients with pain stemming from the upper extremities, lower extremities, and low back (17-19). This treatment modality can serve as an opioid replacement, eliminating the side effects of opioid misuse (20). Additionally, wireless PNS helps to address the challenges associated with treating occipital neuralgia by providing a minimally invasive approach, minimizing risk of infections, quicker recovery times, and lower costs compared to more invasive neurostimulation (21). There is also flexibility with treatment duration; the PNS system can be easily removed, offering a reversible treatment option for patients.

Occipital neuralgia and headaches are very challenging conditions to treat. The occipital nerve was the first nerve targeted by percutaneous lead placement of PNS and its efficacy has been widely examined (22,23). However, the wireless system is novel and lacks extensive literature at the cervical level. The only available literature on wireless PNS treating occipital neuralgia and headaches was a case report (24) previously published by the first author (AAE). The wireless system can be advantageous over a traditional system in the cervical region due to not having a pulse generator that is implanted.

This study shows a case series of 3 patients experiencing occipital neuralgia-induced neuropathic pain. These individuals received wireless PNS treatment due to the lack of response to alternative therapies like medications, steroid injections, and physical therapy.

Methods

This case series was eligible for institutional review board exemption. Data was collected retrospectively from electronic medical records on patients who had undergone implantation with the Freedom® PNS System (Curonix LLC, Distributor of Stimwave Freedom Products, Pompano Beach, FL) between September 24, 2020 and March 23, 2023. The Freedom PNS System was selected due to its ease of use in the cervical area with its wireless design that, unlike other systems, does not require an implantable pulse generator. Patients were included in this study if they were ≥ 18 years old and had been previously diagnosed with occipital neuralgia-induced neuropathic pain. The data was analyzed using SPSS Statistics Version 26 software (IBM Corporation, Armonk, NY), and a P value ≤ 0.05 was considered significant. Descriptive analysis was also performed to describe the cases and their outcomes. The outcomes of interest were changes in pain after the trial procedure and after one-year postpermanent implantation. The 11-point Visual Analog Scale (VAS) was utilized for the assessment of pain at baseline, posttrial, and one-year follow-up. All patients passed psychological evaluation and a one-week trial before proceeding with the permanent implant. The trial procedure involved implantation of temporary electrodes into the target location to assess if patients were responsive to PNS.

Permanent Implant Surgical Technique

Patients were placed in the prone position, and the site was aseptically prepared with chlorhexidine and covered with sterile drapes. The stimulation target was identified to be at the level of the C2 spinous process (25). As such, the planned site for needle entrance was caudal to C2. The site was anesthetized with lidocaine 1% and a ~1 cm incision was made. Then a 13G introducer needle was inserted approximately 1-2 cm lateral to the midline from caudal to cranial, along the articular pillar. A lateral projection was then obtained, and the introducer needle was advanced until the tip of the needle was at the level of the C2 spinous process on the lateral view. An anteroposterior (AP) view was then obtained, which confirmed the needle to be positioned over the articular pillar. The electrode was then inserted through the needle and the needle was removed leaving the tined lead in place. A second electrode was placed on the other side using the same technique.

A pocket in the upper back was created using a second incision, and the electrodes were tunneled subcutaneously from the first incision to the pocket. A

ligature was secured to establish a permanent connection between the distinct receivers and electrodes. The electrodes were coiled, and the coils were sutured to the fascia and secured within the pocket. The pocket was closed in 2 layers. All systems were programmed at 1,499 Hz.

RESULTS

Patient 1

Patient 1 was a 40-year-old woman. Her chronic pain stemmed from polytrauma in 2012 where she suffered traumatic brain injury and spinal cord injury, requiring fusion from C4 to occiput. Her chronic headache and neck pain remained poorly controlled and presented to the pain clinic where she was offered a PNS trial. At baseline, her VAS pain score was 8/10. Following the trial, this reduced to 4/10. With the success of the trial system, she underwent implantation of a permanent wireless PNS system (Fig. 1). At the one-year follow-up, her VAS pain score was reported to be 1/10.

Patient 2

Patient 2 was a 57-year-old woman with a long-standing history of neck and headache pain. She had tried many different management strategies, including physical therapy, cervical epidural steroid injection, medial branch nerve block/radiofrequency ablation, and oral medications. She also had cervical fusion from C4-C7. All were unsuccessful in managing her pain. Prior to PNS trial, she rated her pain as 8/10 on the VAS. After a successful trial where her pain reduced to 2/10, she proceeded to receive a permanent wireless PNS system (Fig. 2). After having the permanent system for one year, her VAS pain score reduced to 1.5/10.

Patient 3

Patient 3 was a 59-year-old woman with a history of C3-T1 fusion. Her primary complaint was chronic headache pain, but also experienced chronic neck pain. Epidural steroid injections failed to provide her relief. She had also previously undergone a suboccipital decompression procedure that initially provided 80%

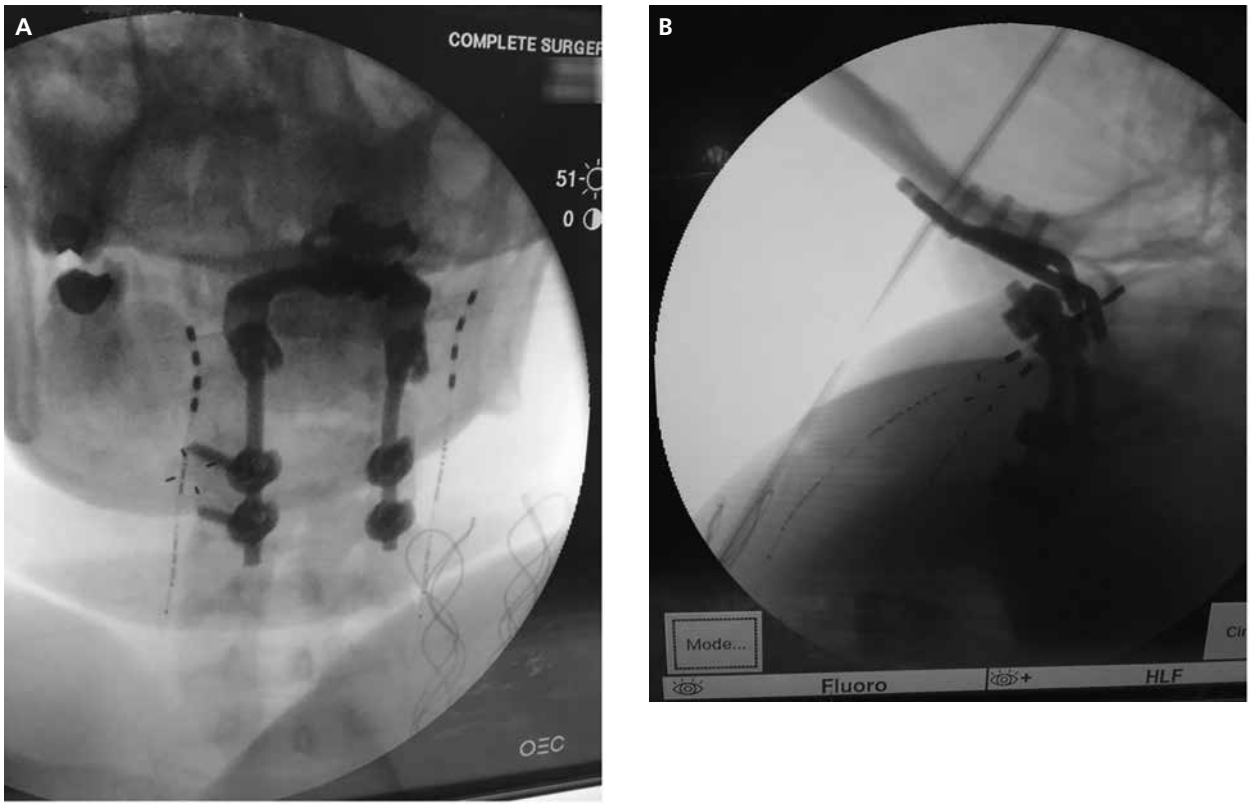

Fig. 1. The postoperative imaging results for Patient 1. A) Displays the AP view of the implanted occipital nerve stimulator. B) Displays the lateral view of the implanted occipital nerve stimulator. AP, anteroposterior.

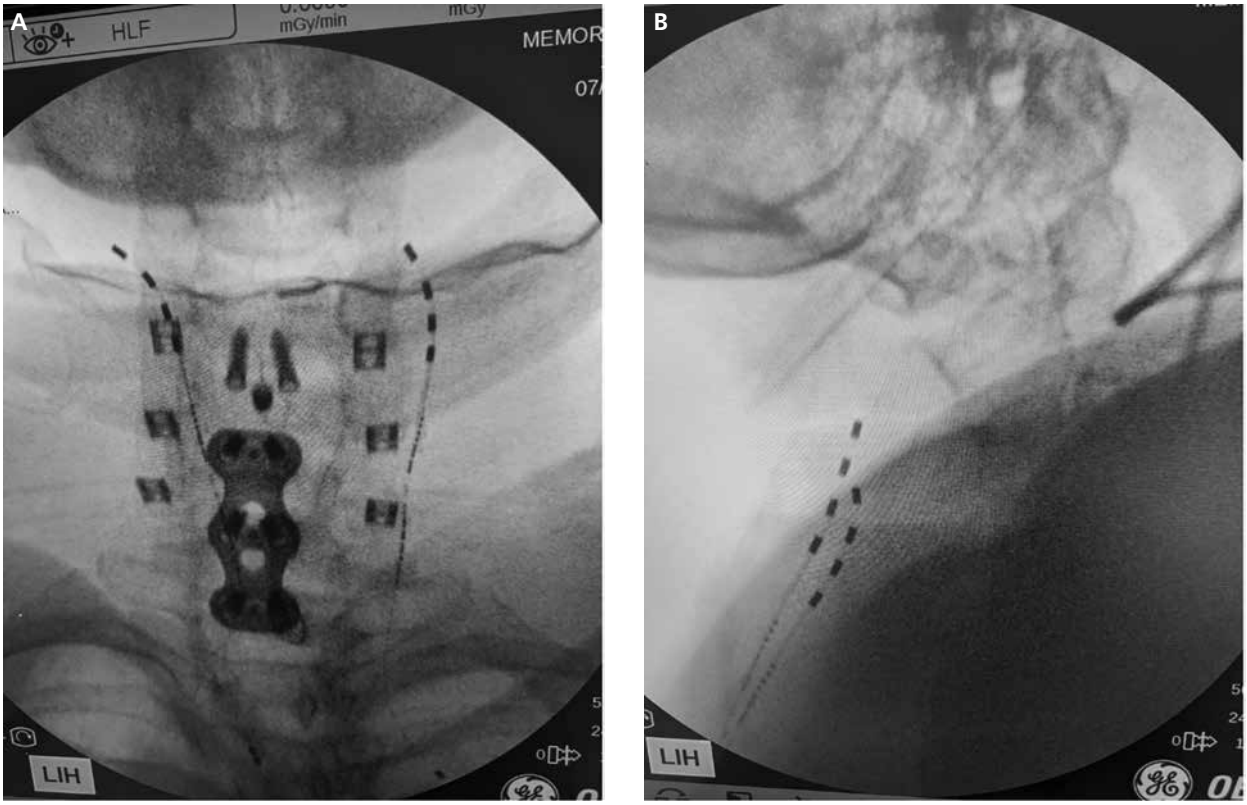

Fig. 2. The postoperative imaging results for Patient 2. A) Displays the AP view of the implanted occipital nerve stimulator. B) Displays the lateral view of the implanted occipital nerve stimulator. AP, anteroposterior.

relief, but the pain recurred. At baseline, her VAS pain score was rated as 9/10. After the one-week trial procedure, her pain reduced to 3/10. Following the successful trial, she was implanted with a permanent wireless PNS system (Fig. 3). At one-year postpermanent implantation, her VAS pain score was 3/10.

Summary of Cases

Our study included 3 patients with an average age of 52 years old (SD = 10.4). The patients from this case series underwent the implantation of wireless PNSs to treat occipital neuralgia and/or axial neck pain. Patients reported a notable reduction in their VAS pain scores, decreasing significantly ($P < 0.001$) from an average of 8.3 (SD = 0.58) at baseline to a score of 3 (SD = 1) after the trial procedure (Table 1). VAS scores were also measured at one-year postpermanent implantation, and patients reported an average score of 1.8 (SD = 1). A paired t test was conducted and the difference in pain scores was shown to be statistically significant ($P < 0.001$). No complications were reported.

DISCUSSION

The treatment of peripheral neuropathies can be quite challenging. Attempting to alleviate the pain through various approaches, including nonpharmacologic methods, medications, and interventional nerve blocks, may not yield the desired results (26). PNS has been previously described to treat chemotherapy-induced headaches, migraines, and cluster headaches (27,28). In our study, we focused on patients suffering from occipital neuralgia and/or axial neck pain. While an occipital nerve block is commonly regarded as the first-line minimally invasive intervention, it should be noted that its pain-relieving effects may have a relatively short duration with a failure rate of 16% (29). Our patients had already received alternative treatments, such as physical therapy, medications, steroid injections, and C2/C3 medial branch blocks, but none had provided satisfactory pain relief. Consequently, their overall well-being and ability to engage in physical activities were negatively impacted.

Recent studies (21,30-32) on wireless PNS have shown

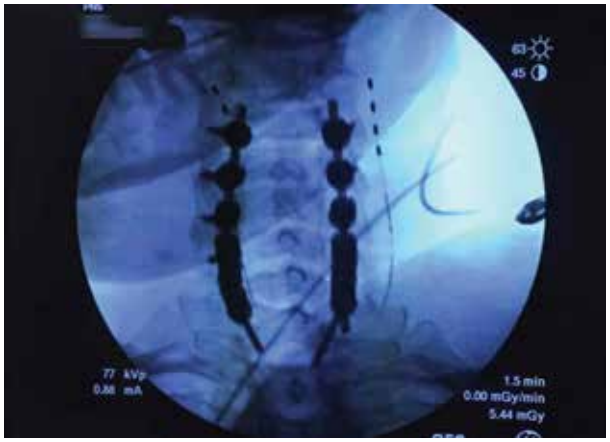

Fig. 3. The postoperative imaging result for Patient 3 and displays the AP view of the implanted occipital nerve stimulator. AP, anteroposterior.

Table 1. Summary of patient outcomes.

Patient	Gender	Age	Pretrial VAS	Posttrial VAS	1-Year VAS
1	Woman	40 y	8/10	4/10	1/10
2	Woman	57 y	8/10	2/10	1.5/10
3	Woman	59 y	9/10	3/10	3/10

Abbreviations: VAS, Visual Analog Scale; y, years.

promising results in treating various neuropathic pain conditions. It has been demonstrated to be successful in treating upper limb pain, foot pain, leg pain, low back pain, and pelvic pain (21,30-32). As previously mentioned, wireless PNS has also been described in successfully treating occipital neuralgia and headaches in a case report (24), which, to the authors' knowledge, is the only report of its usage at the cervical region. There is growing interest in wireless PNS for cervical-level neuropathic pain; however, more research is needed to establish its efficacy specifically for cervical-level applications.

Wireless PNS targeting the occipital nerves holds promise as a therapy for medically resistant occipital neuralgia. It is reversible, minimally invasive, with limited side effects, and exhibits sustained effectiveness during long-term follow-ups (33,34). Electrical stimulation is delivered to the occipital nerves by fixed electric discharges with a stimulation lead and an external easily wearable baseball cap antenna. The external antenna is able to send signals to the lead located near the nerve (30). While direct comparisons between wireless and traditional PNS are limited, initial studies (21,24,32) suggest that wireless PNS may offer similar pain relief with a more favorable safety profile due to its less invasive nature. The advantages of a wireless neuromodulation system include the absence of an implantable battery, which eliminates surgical complications and challenging placements (32). Wireless PNS should be strongly considered as an effective treatment option for peripheral neuropathies, especially in patients with occipital neuralgia. It may surpass other medical interventions in providing relief from chronic pain and can curb opioid misuse among patients (31).

The underlying mechanism for how wireless PNS can attenuate occipital neuralgia-induced neuropathic pain remains a subject of discussion. The peripheral component of the mechanism may be explained in part by the Gate Control Theory of Pain (35). PNS may also reduce the abundance of local proinflammatory molecules and neurotransmitters in the peripheral nervous system. Evidence of induced changes in neurotransmitter levels in the central nervous system has also been reported. Additional central mechanisms include alteration of activity in certain brain areas, such as the anterior cingulate cortex, dorsal lateral prefrontal cortex, and parahippocampal areas (36).

Limitations of this study include the small sample size and lack of a control group. Our study was also limited by the retrospective design. Future studies involving large sample sizes with a prospective or randomized controlled trial study design are warranted to increase the certainty of evidence surrounding wireless PNS. The use of wireless PNS for other chronic pain conditions should also be examined. Lastly, future studies should examine additional outcomes, such as quality of life, function, and sleep quality.

CONCLUSIONS

This case series adds to the growing evidence that wireless PNS is a safe and promising option for patients with various chronic pain conditions related to occipital neuralgia, particularly when previous treatments have not yielded success. Our results suggest that this modality should be offered to patients when other less invasive treatments have been exhausted. It is critical that the investigation of wireless PNS for the treatment of neuropathic pain continues so that the certainty of evidence for efficacy can be solidified and indications can be expanded.

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