Peripheral Nerve Stimulation (PNS) is a term generally used to describe techniques for the treatment of neuropathic pain utilizing various types of leads containing electrodes that are positioned around the affected peripheral nerves. Such approaches can be used in the treatment of neuropathic pain of different origins, located in areas that are difficult to reach using spinal cord stimulation (SCS), including the skull, face and occiput. As a rule, the painful area should be limited, pain severe, and the patient should fail other less-invasive therapies and interventions. As new approaches have been developed to more selectively target areas of pain and provide more efficient paresthesia coverage, the list of indications and new modalities of neurostimulation emerged [1].

Peripheral Nerve Stimulation for Occipital Neuralgia: Surgical Leads

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Abstract

Peripheral nerve stimulation (PNS) has been used for the treatment of various neuropathic pain disorders, including occipital neuralgia, for the patients who failed less-invasive therapeutic approaches. Several different mechanisms of pain relief were proposed when PNS is used to treat occipital neuralgia and clinical studies using various types of electrical leads suggested largely positive clinical responses in patients with mostly refractory, severe neuropathic pain. With advancements in cylindrical lead design for PNS and placement/implantation techniques, there are very few clear indications where ‘paddle’ (surgical) leads could be advantageous. Those include patients who experienced repeated migration of cylindrical lead as paddle lead may provide greater stability, who are experiencing unpleasant recruitment of surrounding muscle and/or motor nerve stimulation and for cases where skin erosions were caused by a cylindrical lead. However, disregarding the type of lead used, multiple clinical advantages of this minimally invasive, easily reversible approach include relatively low morbidity and a high treatment efficacy.

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Classification and Terminology

Classically, ‘PNS is a procedure that targets a single nerve and attempts to produce a paresthesia that spreads along the territory innervated by the stimulated nerve’ [2]. Recently, another clinical application of minimally invasive PNS was described [3] where significant open dissection near the peripheral nerve is avoided and near nerve electrode placement achieved. Subsequently in use now are two types of PNS: one minimally invasive approach using cylindrical leads and imaging guidance (ultrasound or CT), and classical nerve dissection where the nerve is exposed and lead placed directly to the nerve stimulated.

Peripheral nerve field stimulation (PNfS) is a somewhat different technique where the goal is to ‘produce a field of paresthesia within the peripheral distribution of pain by creating an electrical field around the activated bipoles’ [2]. In PNfS, the leads are placed subcutaneously in the area of pain to stimulate the region of the affected nerves or the dermatomal distribution of these nerves (fig. 1, 2). Recently, initial successes of PNfS using cylindrical and paddle leads have been reported in a growing list of clinical settings, primarily in the head and cervical regions [4–8].

Mechanism of Action and History of PNS

Like in SCS, the mechanism of pain suppression provided by PNS is thought to be based on the gate control theory of pain [1]. Chronic and spontaneous afferent
activity can be inhibited by electrical stimulation of the proximal portion of the affected nerve, suggesting another mechanism through which peripheral nerve stimulation may decrease at least neuropathic pain [9]. Other proposed mechanisms of pain relief include subcutaneous electrical conduction, dermatomal and myotomal electrical stimulation, partial sympathetic blockade and local blood flow alteration [9–11]. Occipital nerve stimulation (ONS) is directed to distal branches of the C2 and C3, which form greater and lesser occipital nerves. As the occipital nerve is a functional part of trigeminocervical complex (TCC), its stimulation may inhibit central nociceptive transmission and provide pain relief from various types of headaches [10, 11].

Over the years, PNS has had lesser therapeutic importance than SCS, for several reasons: lack of scientific investigation, lack of complex trialing, and implantation via surgical exploration of the peripheral nerve with placement of a flat plate multicontact electrode (a paddle electrode) immediately next to it. Such traditional methods of surgically placing the lead continued to be time consuming and reports of nerve injury from electrode insertion or stimulation-related fibrosis made PNS less attractive as a pain-relieving modality [1]. The current FDA-approved electrode for PNS is a homologue of the electrode used for SCS to which a Gortex mesh has been added to allow its fixation to adjacent tissues. Unfortunately, such design does not allow

![Fig. 2. Schematic of the paddle leads final position when used for the bilateral occipital neuralgia. (Used with permission from [24]).](image-url)
multiple contacts to provide uniform stimulation to a nerve trunk, the diameter of which may vary in size [1]. The PNS technique of lead insertion in the vicinity of the occipital nerves to treat occipital neuralgia renewed interest in the effectiveness of PNS in general [4–8].

**Occipital Neuralgia**

Occipital neuralgia is described as 'pain, usually deep and aching, in the distribution of the second cervical dorsal root' according to the International Association for the Study of Pain (IASP) [12]. Symptomatology commonly manifests itself as pain that is lancinating in character, with paroxysmal exacerbations, and is distributed from the inter-nuchal line (between occipital protuberance and mastoid process) with radiations around the hemicranium up to the supraorbital ridge.

The anterior rami of the upper four cervical nerves unite to form the cervical plexus, which supplies the skin and muscles of the neck. The posterior primary ramus of C1 is a motor nerve and supplies multiple muscles. The posterior primary ramus of C2 emerges between the posterior arch of the atlas and the lamina of the axis, curves around the inferior border of the inferior oblique muscle, to which it sends a branch and then divides into a large medial and a small lateral branch. The medial branch is the greater occipital nerve. This pierces semispinalis capitis and then trapezius. This may have profound implications for ONS as closeness of the muscles at the height (and depth) where the leads are positioned may produce unwanted muscle stimulation. The lesser occipital nerve (C2) hooks around the spinal accessory nerve (XI) then ascends along the posterior border of the sternocleidomastoid. It pierces the deep fascia in the upper part of the medial aspect of the posterior triangle. It then splits up into the auricular, mastoid, and occipital branches. The occipital branch is sensory to the skin in the occipital area immediately above and behind the mastoid [13, 14].

The possible sources of cervical spinal pain that might be referred to the head are dictated by the distribution of the upper three cervical spinal nerves. Through their various branches these nerves innervate the joints and ligaments of the median atlanto-axial joint, the atlanto-occipital joint, and lateral atlanto-axial joints, the C2-C3 zygapophyseal joint, the suboccipital and upper posterior neck muscles, the upper prevertebral muscles, the spinal dura mater of the posterior cranial fossa, the vertebral artery, the C2-C3 intervertebral disc, and the trapezius and sternocleidomastoid muscles. All of these structures can be sources of pain and should be considered in the differential diagnosis of cervicogenic headache. In most cases, the cause of the neuralgia is not found. However, there are examples of occipital neuralgia caused by lesions to the nerves [13–15].

Patients with occipital neuralgia usually present with an associated cervicogenic headache. The IASP [12] defines this as 'attacks of moderate or moderately severe unilateral head pain without change of side, ordinarily involving the whole hemicranium,
usually starting in the neck or occipital area, and eventually involving the forehead and temporal areas, where the maximal pain is frequently located. The headache usually appears in episodes of varying duration in the early phase, but with time the headache frequently becomes more continuous with exacerbations and remissions. Symptoms and signs such as mechanical precipitation of attacks imply involvement of the neck.

The reason for globalized pain in occipital neuralgia is explained by convergence between cervical and trigeminal afferents in the spinal cord [16]. Afferents of the trigeminal nerve descend through the spinal tract of the trigeminal nerve. Their collaterals terminate in the pars caudalis of the spinal nucleus of the trigeminal nerve and in the dorsal horns of their respective segment, and send ascending and descending collaterals to adjacent segments. Therefore, at any given cervical segment, second-order neurons that project to higher centers can receive a convergent input from afferents of the trigeminal nerve and the C1, C2, and C3 spinal nerves [13–16].

**Indications and Technique for the Implantation of Paddle Leads**

The usual indications for PNS using paddle leads are similar to those for SCS procedures. The pain has to be chronic, severe, negatively affecting patient’s functionality, and refractory to usual medical treatments. With advancements in cylindrical lead design and placement/implantation techniques, there are very few clear indications where ‘paddle’ leads could be advantageous when compared to cylindrical. The argument could be made that the placement of paddle leads is associated with less scar tissue formation around the electrode, better field of stimulation, and less of lead migration. Therefore, patients considered for ONS using paddle leads are frequently those who have already had implanted cylindrical leads that migrated and required revisions, sometimes several (fig. 3). The main advantage of plate electrodes is their greater inherent stability, as they are believed to have less propensity to migrate [5, 9, 14]. The lead migration rate for cylindrical leads implanted for ONS can vary between 9 and 33% [17, 18]. Such migration rates are believed to persist over long-term use, and may happen later during its therapeutic use [18]. Although prospective comparison studies related to lead migration are lacking, a large overview of paddle lead use for various indications in the epidural space in the hands of experienced neurosurgeon suggested a significantly lower rate of migration, only 1.1% [19].

Plate electrodes are also more energy efficient. Multiple arrays or different electrode configurations can be constructed with plate electrodes. The insulating side of the plate electrode isolates the contacts from dorsal structures and, using much larger cross-sectional area then a cylindrical electrode, brings the entire contact surface ventrally, closer to the stimulated nerve [20]. Therefore, another indication for the implantation of paddle leads may include patients who are experiencing unpleasant recruitment of surrounding muscle and/or motor nerve stimulation when cylindrical lead is used [21].
Finally, another likely indication for the implantation of paddle leads is the presence of repeated skin erosions caused by a cylindrical lead within the delicate area of the posterior neck, which contains minimal subcutaneous fat. During cylindrical lead implantation a Tuohy needle is used to position the lead in the occipital region. As the curve of the occipital region does not perfectly match the curve of a bent Tuohy needle, the needle itself and eventually the lead can terminate at a point much more superficial to the skin at its distal aspect, increasing the risk for skin erosion [22]. Although deeper needle placement may decrease the risk of erosion, it can in turn increase the risk of direct muscle stimulation [21].

Lateral and medial approach to both ‘paddle’ and cylindrical leads placement have been described (table 1). The technique originally described by Weiner et al. [8], later continued by Slavin et al. [6] and recently detailed by Trentman et al. [23] involved lateral incision close to the mastoid process. Later, midline placement was described and it has been the approach that we use in our institution. Arguments can be made that the midline incision is better due to presence of more subcutaneous fat in the midline of the neck, leaving enough space for anchoring and loop placement (fig. 2) without adding more discomfort to the patient. In addition, if bilateral leads are required, only one small midline incision over the upper neck is used to achieve stimulation of both greater and other occipital nerves. Still, it seems that the frequency of lead migration was higher when midline approach was used with cylindrical leads [18]. It is not clear if the same applies when paddle leads are used via the midline approach [24].

Fig. 3. a, b Same female patient after percutaneous (a) and surgical (b) permanent lead implantation. Here illustrated indication is currently one of the most common for the implantation of surgical paddle leads. Patient lost adequate stimulation after the cylindrical leads migrated and, in addition, produced localized discomfort in the left occipital area when stimulation turned on. Replacement with surgical paddle leads resulted in restored occipital coverage with more even, stable stimulation.
Table 1. Outcomes of the studies where ONS was used for the treatment of various headaches, mainly occipital neuralgia

<table>
<thead>
<tr>
<th>Study</th>
<th>Technique</th>
<th>Number of patients</th>
<th>Type of lead</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oh et al., 2004 [5]</td>
<td>below mastoid</td>
<td>20</td>
<td>paddle</td>
<td>14 patients &gt;90% pain reduction at 6 months’ follow-up, 95% improved QoL</td>
</tr>
<tr>
<td>Kapural et al., 2005 [25]</td>
<td>midline</td>
<td>6</td>
<td>paddle</td>
<td>VAS decreased at 6 months from 8.66 to 2.5, PDI improvement 49.8 to 14</td>
</tr>
<tr>
<td>Johnstone and Sundaraj, 2006 [26]</td>
<td>midline</td>
<td>8</td>
<td>paddle</td>
<td>5/7 with improvement in VAS, 7/8 reduction in opioid use</td>
</tr>
<tr>
<td>Magis et al., 2007 [27]</td>
<td>below mastoid</td>
<td>8</td>
<td>paddle</td>
<td>5/8 &gt;90% reduction in pain, 2/8 with 40% improvement in pain</td>
</tr>
<tr>
<td>Jones, 2003 [28]</td>
<td>midline</td>
<td>3</td>
<td>paddle</td>
<td>all 3 ‘excellent’ outcome</td>
</tr>
<tr>
<td>Weiner, 2006 [29]</td>
<td>various</td>
<td>150</td>
<td>paddle and cylindrical</td>
<td>70–75% &gt;50% improvement (VAS and medication usage)</td>
</tr>
<tr>
<td>Weiner et al., 1999 [4]</td>
<td>below mastoid</td>
<td>13</td>
<td>cylindrical</td>
<td>2/3 of patients with &gt;75% pain relief and 1/3 with &gt;50% relief</td>
</tr>
<tr>
<td>Hammer and Doleys, 2001 [30]</td>
<td>midline</td>
<td>1</td>
<td>cylindrical</td>
<td>90% improvement in pain 9 months’ follow-up</td>
</tr>
<tr>
<td>Nörenberg and Winkelmüller, 2001 [31]</td>
<td>below mastoid</td>
<td>3</td>
<td>cylindrical</td>
<td>all three &gt;50% improvement in pain</td>
</tr>
<tr>
<td>Popeney and Aló, 2003 [32]</td>
<td>below mastoid</td>
<td>25</td>
<td>cylindrical</td>
<td>100% satisfied at 18 months, 88.7% improvement in MIDAS scores</td>
</tr>
<tr>
<td>Rodrigo-Royo et al., 2005 [33]</td>
<td>below mastoid</td>
<td>4</td>
<td>cylindrical</td>
<td>VAS scores to 0 in all patients, global symptom improvement &gt;50% ×4</td>
</tr>
<tr>
<td>Slavin et al., 2006 [7]</td>
<td>below mastoid</td>
<td>14</td>
<td>cylindrical</td>
<td>70% adequate pain control, continued employing, decrease in opioid (22 months)</td>
</tr>
<tr>
<td>Slavin et al., 2006 [6]</td>
<td>below mastoid</td>
<td>30</td>
<td>cylindrical</td>
<td>22/30 &gt;50% pain reduction trial, 16/22 implants &gt;50% pain reduction</td>
</tr>
<tr>
<td>Schwedt et al., 2007 [18]</td>
<td>midline</td>
<td>15</td>
<td>cylindrical</td>
<td>improvement in HIT-6 by 11 and BDI by 20</td>
</tr>
<tr>
<td>Burns et al., 2007 [34]</td>
<td>midline</td>
<td>8</td>
<td>cylindrical</td>
<td>20 months’ follow-up, 5/8 with &gt;40% improvement in pain</td>
</tr>
<tr>
<td>Melvin et al., 2007 [17]</td>
<td>midline</td>
<td>11</td>
<td>cylindrical</td>
<td>VAS, PPI, medication use and number of attacks reduced in &gt;64%</td>
</tr>
<tr>
<td>Trentman et al., 2008 [35]</td>
<td>below mastoid</td>
<td>10</td>
<td>cylindrical</td>
<td>all improved, 20 months’ follow-up</td>
</tr>
</tbody>
</table>

Described are outcomes of the patients who had paddle lead implants (first 5 rows) and cylindrical lead implants. Please note that descriptive outcomes did not allow comparison between the groups. QoL = Quality of life; PDI = Pain Disability Index.
Similar to the placement of cylindrical lead, patients are positioned prone with support under the chest and forehead, and prepared and draped over the occipital area, neck, and parts of the upper and lower back and left or right upper buttock. Initial incision is made in the nuchal region about 3 cm in length, positioned cranio-caudal for either bilateral or unilateral lead implants. Subcutaneous blunt dissection is then completed from the midline bilaterally at the level of C1-C2 and a pocket created using a ‘hockey stick-like’ plastic introducer in the shape of the surgical lead. Leads are then positioned and the patient awakened for the intraoperative trial of stimulation. After complete coverage in the painful occipital area has been confirmed by the patient, leads are anchored in position subcutaneously. We usually place a ‘strain relief’ loop at the implant site (fig. 2). This is loosely sutured at three points to the subcutaneous tissue, the intention being to reduce tension on the lead during flexion. Later, the pulse generator is connected to the two leads by extension cables that were drawn through a subcutaneous tunnel and placed in a pocket in the buttock. We speculated earlier that such a midline approach using ‘paddle’ leads and extensive anchoring may provide less strain on the lead extension as it occurs only with flexion and is minimal with lateral flexion and rotation of the neck [25].

Clinical Outcomes and Peer-Reviewed Evidence

It needs to be emphasized that the patient group treated using this invasive approach are those patients who were unresponsive to all prior conservative and interventional procedures and uniformly had had uncontrolled occipital headaches despite increasing dosages of membrane stabilizers, antidepressants, and opioids. Clinical outcomes of patient groups receiving paddle leads were illustrated in table 1 and descriptively compared to those patient groups receiving cylindrical leads. Either group of the patients achieved very good outcomes and it is impossible to speculate if the use of either type of electrodes provides better long-term improvements in pain, function or frequency of various headaches, including occipital neuralgia. As the implantation of surgical (paddle) leads causes more tissue injury, it should be reserved for patients with the indications listed above.

Complications

The complication rate for PNS when paddle (surgical) leads are used is generally low, but both minor and major complications have been reported, including local infections, hardware erosions, component disconnections, electrode fractures and displacements, and even sepsis. Perineural fibrosis, described in the past with the use of plate or wraparound electrodes with so-called ‘On-Point’ PNS electrodes (Medtronic, Minneapolis, Minn., USA) is much less likely with the current ONS application of the
paddle leads which essentially serve as PNfS. Still, the most frequent complication of any subcutaneous techniques for ONS is lead migration necessitating electrodes revision [17–19]. Paddle lead implantation may improve lead stability [19], as suggested in multiple reviews and study discussion, although there is no clear evidence in the form of a prospective study to confirm such a claim (please see section on indications for paddle lead implantation).

When clinically compared to spinal cord stimulation, wound dehiscence and infection are associated with lower overall morbidity; however, these complications usually require total system explantation. Another complication that can lead to failure of the system is unpleasant muscle recruitment causing spasm in the neck or occipital region. Recently, a report of a case series suggested that such problem may be less frequent when paddle leads are used [21].

**Conclusions**

PNS and especially ONS as a treatment modality is seeing a resurgence, with new evidence and widespread use demonstrating effectiveness in attenuating pain and improving function in patients not only with neuralgia that is not controlled with medications, but also in the treatment of migraine and cluster headaches. More research is needed to clearly assess the long-term effectiveness of this treatment. Such use of PNfS does provide multiple clinical advantages, namely, it is easily reversible, minimally invasive, and has relatively low morbidity.

**References**

2 Abejon D, Krames ES: Peripheral nerve stimulation or is it peripheral subcutaneous field stimulation; what is in a moniker? Neuromodulation 2009;12:1–4.


