Book Chapter: Occipital Neurostimulation (ONS) for Treatment of Intractable Headache Syndromes

Richard L. Weiner, MD
Kenneth M. Alo MD*

^Chair, Department of Neurosurgery
Presbyterian Hospital of Dallas
Clinical Associate Professor of Neurosurgery
University of Texas Southwestern Medical School
Dallas, Texas USA

*President, Kenneth Alo MDPA
Houston Texas Pain Management, PA
TOPS Surgical Specialty Hospital
Palladium for Surgery-Houston
Houston, Texas USA

Correspondence:
8230 Walnut Hill Lane
Suite 220
Dallas, Texas 75231
USA
TEL: 214-750-3646
FAX: 214-987-4865
Email: RLW1@ix.netcom.com
Introduction
Primary headache disorders are a dominant presentation in many neurology, pain management and primary care practices worldwide. A greater understanding of the various headache types has been facilitated by the recent reclassification scheme developed by the International Headache Society (IHS) in 2004 (1). Clarification of the diagnosis criteria for various migraine and tension headache syndromes, as well as, the addition of previously unrecognized conditions such as hemicrania continua, and a more precise definition of secondary headaches such as occipital neuralgia are extremely important in the formulation of successful treatment strategies by the clinician.

Intractable Migraine, Chronic Daily Headache, Cervicogenic, and secondary headache syndromes such as occipital neuralgia, affect almost 40 million Americans and many more millions worldwide (2). It is estimated that up to 5% of these headache sufferers experience daily or near daily headaches (transformed migraine, chronic daily headaches) and 1 to 2% are so poorly responsive to medication paradigms that this failure can lead to narcotic dependence, severe restrictions in daily activities, failed personal and career objectives and an overwhelming sense of hopelessness and despair.

Specifically, Chronic daily headache refers to a group of non paroxysmal headaches, including those associated with overuse of symptomatic medications, that present on a daily or near daily basis with a duration greater than four hours a day and lasting longer than six months (3). Its prevalence in the general population varies from 0.5 to 6% approximating 2.2 million patients (4,5). Due to episodic migraines, annual direct costs are over $1 billion, costing American employees $13 billion/year due to absenteeism (6).

Seventy-eight percent of patients with chronic daily headache have had episodic migraine in the past. Episodic migraine sufferers tend to range in the age from 25 to 45 years with peak prevalence at age 40. Women are five times more likely to experience migraines than men. Females tend to have more frequent occurrences of migraine. There is an estimated 28,000,000 migraineurs in the United States. Only 15% have migraine with aura and 85% have migraine without aura (7). With increased frequency of episodic migraine and time, migraine patients show a progressive change or loss of specific migraine characteristics, and present with a daily or near daily headache, with mixed clinical features of migraine and tension type headache (8). These patients typically have an 80% chance of symptomatic overuse of medicines including simple analgesics, narcotics, and other symptomatic medications (9). Interestingly, these patients with transformed migraine that only make up approximately 5% of the headache prevalence are responsible for the vast majority of treatment costs. These patients commonly present with episodic migraine early in life which later becomes chronic and progressive. The natural progression of disease is that of relapsing progressive disease. Migraine transformation is a critical aspect of patient treatment. Physicians play a pivotal role in preventing chronic daily headache. It is important to control acute medications as well as to insure that acute migraine attacks are controlled properly. Symptomatic overuse should also be addressed.
Treatment of Migraine Headaches

Treatment options for almost all headache syndromes have centered around a variety of medication management paradigms including acute pain relieving as well as preventative measures. Pain medication options fall into categories including NSAIDS, Tryptans, opioids, ergot compounds and sedatives. Preventative medications include anticonvulsants, antidepressants, beta blockers and serotonin antagonists. Additionally, efforts to identify and treat any underlying migraine triggers, whether physical or emotional in nature, can produce significant relief. Acupuncture and other alternative treatment options including biofeedback, massage and diet control are commonly employed. Migraines continue to be under-diagnosed and under-treated (43). Therefore, the true nature of the degree of disability and suffering with these headache conditions, despite a variety of conservative management schemes, may, indeed, be under-reported and under-appreciated.

Neuromodulation for treatment of chronic pain disorders over the past 35 years has centered on spinal cord stimulation (SCS) and peripheral nerve stimulation (PNS) using implanted electrode and generator devices to modulate perception of abnormal pain signals to the brain. Examples are SCS for FBSS (40), SCS for CRPS (41), and PNS or sacral nerve stimulation for bladder pain and dysfunction (42). More recently multiple authors (12,25,26,27) have reported that successful neuromodulation for occipital headache syndromes can be accomplished with subcutaneous regional electrode placement at or near the level of C1 without direct contact with a specific peripheral nerve. It is been postulated that nociceptive transmission and pain modulation at this level can both prevent central sensitization and modulate the dorsal horn-brainstem by altering the trigeminocervical pathway (10,11,22).

Literature Review:
Occipital nerve neurolysis and/or neurectomy have been part of the neurosurgical armamentarium in treating intractable occipital headaches for many years. Though occasionally very effective, the not infrequent development of delayed deafferentation pain in the distribution of the affected occipital nerve limits the long-term usefulness of the procedure. C2 gangliectomy (Lozano, 1998) (13) for posttraumatic C2 pain syndromes has resulted in an 80% good to excellent outcome with a 3-year follow-up. Patients with non-traumatic C2 pain did not fair nearly as well as those with traumatic C2 pain and subtle but significant morbidity, including postoperative dizziness or gait disturbances may be a persistent problem.

C2 nerve decompression (Pikus, et al, 1997) (14) can achieve up to a 79% success rate with 33% complete pain relief and 46% adequate pain relief over 2 years. C1, 2 fusion (Joseph, 1994) (15) can correct focal instability and may be indicated on occasion. C1-3 posterior rhizotomy (Dubuisson, 1995) (16) via ventrolateral DREZ lesioning at C1-3 can be an effective but highly invasive surgical technique. Neurolysis of the greater occipital nerve (Bovim, et al, 1992) (17) can be effective in the short term but most patients tend to
have significant recurrences within one to two years. Picaza et al (1977) (18) reported pain suppression by peripheral nerve stimulation on six patients with occipital neuralgia using a cuff electrode technique with 50% of patients reporting a good outcome. Waisbrod et al. (1985) (19) reported a very good result from stimulation of the greater occipital nerve for painful peripheral neuropathy.

Experience with peripheral nerve electrical stimulation for painful mononeuropathies and complex regional pain syndromes involving major peripheral nerves led to the sentinel observation (39) that subcutaneous tissue can conduct and propagate electrical impulses in a dermatomal and/or myotomal distribution of one or more peripheral nerves without direct nerve contact producing pain relief in the region of the electrically induced local paresthesias. This has led to the development and refinement of a percutaneous neurostimulation procedure implanted transversely into the subcutaneous space nominally at or just above the level of C1 (10,11,12, 20,21,25,26,27) as a minimally invasive treatment alternative for intractable occipital headache syndromes.

Surgical Technique
Using local anesthesia at the incision site only, a vertical 2cm incision is made at the level of the C1 lamina either medial and inferior to the mastoid process or in the midline posteriorly under fluoroscopic control extending to but not into the cervicodorsal fascia. The patient may be positioned laterally or prone depending on the incision entry point. The subcutaneous tissues immediately lateral to the incision are undermined sharply to accept a loop of electrode created after placement and tunneling to prevent electrode migration. A Tuohy needle is gently curved to conform to the transverse posterior cervical curvature (bevel concave) and without further dissection is passed transversely in the subcutaneous space across the base of the affected greater and/or lesser occipital nerves which at the level of C1 are located within the cervical musculature and overlying fascia (See fig 1 and fig 2). Single or dual quadripolar or octapolar electrodes may be passed from a midline incision to either affected side or alternatively placed to traverse the entire cervical curvature bilaterally from a single side or via two opposing incisions. Surgical paddle electrodes can also be implanted subcutaneously, though somewhat more invasively, using sharp dissection techniques with the electrode contacts oriented towards the fascia (12,21).

Rapid needle insertion usually obviates the need for even a short acting general anesthetic once the surgeon becomes facile with the technique. Following placement of the electrode into the Tuohy needle, the needle is withdrawn and the electrode connected to an extender cable for intraoperative testing.
Intra-operative stimulation testing
After lead placement, stimulation is applied using a temporary RF transmitter to various select electrode combinations enabling the patient to report on the table the stimulation location, intensity and overall sensation. Most patients have reported an immediate stimulation in the selected occipital nerve distribution with voltage settings from 1 to 4 volts with midrange pulse widths and frequencies. A report of burning pain or muscle pulling should alert the surgeon the electrode is probably placed either too close to the fascia, intramuscularly, or too far above or below the C1 level and should be repositioned. Repeated needle passage for electrode placement can lead to subcutaneous edema and/or hematoma formation with loss of electrode conductivity thereby blocking evaluation for permanent lead positioning.
Electrode Fixation and Tunneling
Probably the most important aspect of the procedure involves techniques to prevent electrode migration (pullback) from its transverse subcutaneous position in the highly mobile upper cervical region. Following successful stimulation, the electrode is sutured to the underlying fascia with the supplied silicone fastener and 2-0 silk sutures. A small dab of medical grade silicone glue is placed between the fastener and electrode using a small angiocath to ensure fixation. A loop of electrode (fig 3) is also sutured loosely in the previously prepared subcutaneous pocket to reduce migration risk as well. This allows for strain relief to mitigate the stress of cervical motion. A short acting general anesthetic is used to tunnel the electrode(s) or extender wire to the distal site for connection and implantation of the receiver or generator.
Pulse Generator Implantation
There are three options available for the system power source: an external RF transmitter/receiver system, a primary cell implantable pulse generator, and a rechargeable implantable pulse generator. The RF and rechargeable systems generally allow for more continuous higher voltage outputs, while the primary cell requires less programming interaction. Most patients currently opt for the implantable pulse generator system, which is currently an off-labeled application for peripheral use. With the voltage settings usually required for occipital stimulation, the primary cell lithium ion battery can last 3 to 5 years while the rechargeable may last 7-9 years before replacement.

Generator placement appears to influence both patients positioning during the procedure and the risk of postoperative migration, particularly if strain relief is not generously applied. Typical implant locations are:
1. Upper buttock – facilitates single stage electrode and generator placement in the prone position.
2. Abdomen – usually done with the patient in the lateral position.
3. Upper chest – lateral or supine positions favor this location.

There is significant extension wire stretching with upper buttock generator placement when a patient bends forward creating excessive tugging on the cervically placed electrodes. This could be one of the major factors, along with anchoring technique, mitigating electrode migration. Thus, abdominal or anterior chest placement might reduce migration potential.

Results
The authors combined implant experience from 1993 through 2005 has consistently shown an approximately 75% good and excellent long term pain relief with a 15% fair and 10% poor response in over 150 implanted patients with long term follow-up. The total headache years in this population was approximately 1200 years with mean headache duration of 8 years in 77% females and 23% males. Most of the patient population exhibited some degree of bilateral pain with one side typically dominant. Preoperative VAS scores ranged from 5 to 10 with a mean of 9. Postoperative VAS ranged 0 to 6 with a mean of 3.

A review of published ONS outcomes to date lends significant support for consideration of neuromodulation implant techniques for intractable headache syndromes. Though all of the studies report small numbers, the overall success rate of 70 to 100% in short term follow-ups with 70 to 75% long term followup (W) appears to be meaningful and reproducible (12,21,28-39).

<table>
<thead>
<tr>
<th>Authors</th>
<th>Patient #/Method</th>
<th>Results</th>
<th>Followup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weiner R, Reed K</td>
<td>13 pts/perc leads</td>
<td>All good to excellent</td>
<td>1 to 6 years</td>
</tr>
<tr>
<td>Hammer M, Dolan D</td>
<td>1 pt/perc lead</td>
<td>90% improvement</td>
<td>9 months</td>
</tr>
<tr>
<td>Popeney C, Alo K</td>
<td>25 pts/perc lead</td>
<td>100% satisfied</td>
<td>18 months</td>
</tr>
<tr>
<td>Jones R</td>
<td>3 pts/perc and paddle leads</td>
<td>excellent</td>
<td>Not specified</td>
</tr>
<tr>
<td>Oh M, et al</td>
<td>20 pts/paddle leads</td>
<td>16 exc. 2 worse</td>
<td>6 mo to 5 yrs</td>
</tr>
<tr>
<td>Kapural, et al</td>
<td>6 pts/perc trial, paddle perm</td>
<td>100% improved</td>
<td>6 mo</td>
</tr>
<tr>
<td>Rodrigo-Royo M, et al</td>
<td>4 pts/perc</td>
<td>All good or very good</td>
<td>4 to 16 mo</td>
</tr>
<tr>
<td>Weiner R with Alo K</td>
<td>150 pts/perc and paddle leads</td>
<td>70 to 75% &gt;50% success</td>
<td>12 years</td>
</tr>
<tr>
<td>Schwedt TJ, Dodick DW, Trenntman TL, Zimmerman RS</td>
<td>2 pts/ Bion implant Cluster headaches</td>
<td>70% improvement</td>
<td>Short term</td>
</tr>
<tr>
<td>Slavin N, et al</td>
<td>10/14 pts implanted/perc</td>
<td>70% had 60 to 90% relief</td>
<td>22 mo mean f/u</td>
</tr>
<tr>
<td>Burns B, Watkins L, Goddsby P</td>
<td>9pts/perc leads. Cluster headaches</td>
<td>Two 90-95% improve Three 40% improve One 25% improve</td>
<td>20 mo median f/u</td>
</tr>
<tr>
<td>Magis, et al</td>
<td>8pts/paddle leads</td>
<td>Overall 50% decreased</td>
<td>16-22 mo</td>
</tr>
<tr>
<td>Schwedt TJ, et al</td>
<td>15 pts/perc leads</td>
<td>52% overall pain reduction</td>
<td>5-42 mo</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------</td>
<td>---------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Melvin, et al</td>
<td>1 pts/perc leads</td>
<td>82% excellent and good</td>
<td>12 weeks</td>
</tr>
<tr>
<td>Trentman TL, et al</td>
<td>10 pts/perc leads</td>
<td>All improved</td>
<td>20 months mean</td>
</tr>
<tr>
<td>Johnstone, et al</td>
<td>7pts/paddle leads</td>
<td>5/7 reduced VAS</td>
<td>25 mo mean</td>
</tr>
</tbody>
</table>

Stimulation Usage
Patients report using the devices in a variety of scenarios including intermittent stimulation for migraine with aura, cervicogenic headache, occipital neuralgia, post herpetic neuralgia, tension headache and cluster headaches. Continuous use with chronic daily headaches (transformed migraine) and even deafferentation posttraumatic pain is common as well. Objective PET scan changes have also been shown to correlate with patient activation/deactivation of the device (22). Common stimulation parameters and use patterns have been described (10,12,20,21).

Complications
Most complications have revolved around lead migration (15%) skewed more towards the early years of implant technique development. Improved anchors and anchoring techniques as well as continuing education opportunities for implanters should minimize this concern. Generator placement and future development of localized leads and mini-generators should also have a positive impact on reducing or even eliminating migration problems. Lead breakage or disconnection (8%) is probably a function of the lead implant location in a highly mobile area. Infection was relatively uncommon (3%), however, attention to meticulous surgical technique is essential to avoid primary contamination of the implanted equipment even from skin contaminants such as staphylococcus epidermidis. Subsequent wound dehiscence with external exposure of any of the implant requires explantation of the total device. In our experience, a previously infected area can be successfully re-implanted after suitable treatment (10,11,12,20,21,22,25,26,27).

Positioning and Sedation
Most electrode implants can be performed in the lateral position utilizing a midline incision for bilateral electrode placement with lead tunneling and generator pocketing either in the chest, upper buttck or abdomen. This allows greater access to the airway during short-acting sedation. Surgical paddle placement, especially bilaterally, is facilitated in the prone position on a horseshoe or similar frame; however, airway access is limited and sedation agents should be chosen that do not significantly alter respiration (i.e. Ketamine, etc).
Mechanisms of Action
The mechanisms of action for the paresthesia patterns and pain relief obtained from this therapy are incompletely understood but would appear to involve the following elements:

- Subcutaneous electrical conduction
- Dermatomal stimulation
- Myotomal stimulation
- Sympathetic stimulation
- Local blood flow alteration
- Peripheral nerve stimulation
- Peripheral and Central Neurochemical mechanisms
- Trigeminovascular System
- Trigeminocephalic Tract

The most important of these mechanisms appear to be the involvement of the Trigeminovascular and Trigeminocephalic systems (10,11,22,23,24). For example, direct electrical stimulation of the greater occipital nerve (Goadsby, et al, 1997) (22) has shown an increase in metabolic activity in the trigeminal nucleus caudalis and cervical dorsal horn cells in the cat by 220% ipsilaterally to the stimulation and by a lesser amount contralaterally. The dorsal horn activity was at the level of C1, C2 and interaction with the trigeminal innervated structures suggests that the frontally radiating occipital headaches occur as a consequence of overlap of nociceptive information processing at the level of the second order neurons. PET scan studies in episodic migraine headache patients (Bahra, et al., 2001) (23) further demonstrate specific areas of brainstem activation in the dorsal rostral pons. In fact, a PET study of 8 patients with chronic migraine headaches (Matharu et al., 2004) (24) showed excellent responses to implanted bilateral suboccipital stimulators demonstrating activation of the dorsal rostral pons that persisted after alleviation of headache pain. These combined observations suggest the presence of a central trigger mechanism for a variety of headache pain conditions (10,11,22,23,24). Finally, peripheral, subcutaneous electrical stimulation may influence blood flow within these activated regions or be involved in descending pathways that control pain via stimulation of the trigeminovascular and trigeminocephalic systems at the level of the upper cervical spine. This may occur by electromodulation reducing abnormal excitation of these peripheral nociceptive afferent fibers, and preventing central sensitization of trigeminal nociceptive pathways, potentially reducing on-cell activity, and positively modulates the descending modulatory system at the level of the dorsal horn (10,11,22,23,24).

Conclusions
Medical management is the mainstay of treatment for the spectrum of chronic headache syndromes listed in the International Headache Society ICHD-II Compendium (1). These
include but are not limited to primary headache disorders such as migraine syndromes
tension headaches and cluster headaches, secondary headache disorders such as
medication overuse migraines or increased intracranial pressure, and the third main
category of cranial neuralgias and face pain including occipital neuralgia and trigeminal
neuralgia. Clinicians are increasingly faced with growing numbers of patients refractory
to current multimodality approaches to chronic headache control with estimates of
between one half to one million marginally controlled headache sufferers in the US alone.
Peripheral occipital subcutaneous field neurostimulation for a variety of intractable
headache syndromes is a safe, reasonably effective, and uncomplicated treatment
modality to be considered when dealing with patients refractory to conventional therapy.
Multicenter studies are underway to further define the safety and efficacy of this
treatment modality while further defining the mechanism and pathophysiology effects
described to date. Recent advances in commercially available neurostimulator products
in terms of electrode design and generator rechargability and miniaturization hold
promise for more focused use of neuromodulation for the headache indications.
Bibliography


