

Occipital nerve stimulation (ONS). Surgical technique and prevention of late electrode migration

Angelo Franzini · Giuseppe Messina · Massimo Leone · Giovanni Broggi

Received: 13 December 2008 / Accepted: 8 April 2009
© Springer-Verlag 2009

Abstract Occipital nerve stimulation (ONS) is an emerging procedure for the treatment of cranio-facial pain syndromes and headaches refractory to conservative treatments. The aim of this report is to describe in detail the surgical intervention and to introduce some useful tricks that help to avoid late displacement and migration of the suboccipital leads. The careful description of the surgical steps may contribute to a standardization of the procedure and make the interpretation of results easier even if obtained in series of patients operated on by different authors.

Keywords Occipital nerve stimulation · Electrode migration

Introduction

A growing number of neurologists involved in headache treatment solicit the neurosurgeon for occipital nerve stimulation (ONS), which is an emerging procedure for the treatment of several cranio-facial pain syndromes and headaches refractory to conservative treatments. The most common painful conditions that have been treated with occipital nerve stimulation include chronic daily headaches [11], migraines [10], transformed migraines [8], cluster

headaches [4, 6], hemicrania continua [12], cervicogenic headaches [9] and occipital neuralgia [14].

The alleged neurophysiological bases are supported by the hypotheses that electrical stimulation of C2 C3 afferent fibers (the “occipital nerve complex”) modulates the trigeminal nucleus caudalis because of the anatomical relationships of C1, C2 and C3 sensory pathways to the trigeminal bulbo-pontine nucleus [7]. Clinical results are still in the research phase but seem to be promising in a selected series of headache patients [1, 2, 5, 17]. In our opinion, this is the moment to address and to clarify three points regarding the surgical procedure of occipital nerve stimulation:

1. The term ‘occipital nerve stimulation’ may be misleading because in most of the reported series the surgical methodology resembles a subcutaneous stimulation procedure [6] more than a true peripheral nerve stimulation (PNS) [13].
2. The main technical problem at long-term follow-up is the displacement or migration of the suboccipital leads, possibly due to movements of the neck.
3. The lack of a standard methodology makes both the interpretation of therapeutic results and the comparison among different authors and studies difficult.

In this report, we describe the surgical techniques of the ONS procedure we performed in 17 consecutive patients affected by chronic refractory headaches. Original technical procedural improvements are suggested to avoid electrode displacement and migration. Clinical results seem promising (overall 60% improvement), but careful long-term evaluation and double-blind studies are needed to reach any conclusive findings. The topic of this report is the description of the surgical methodology followed by suggestions for establishing a standard procedure.

A. Franzini · G. Messina (✉) · G. Broggi
Department of Neurosurgery,
Istituto Nazionale Neurologico “Carlo Besta”,
Via Celoria,
11 – 20133 Milan, Italy
e-mail: giusmex@gmail.com

M. Leone
Department of Neurology,
Istituto Nazionale Neurologico “Carlo Besta”,
Milan, Italy

Materials and methods

Since January 2004 we have performed 17 implants of occipital nerve stimulation systems for the treatment of occipital neuralgia (1 patient), chronic cluster headaches (14 patients) and transformed migraines (2 patients). The average age of the patients was 45 years. Eight of the patients were male and nine were female.

After administering general anesthesia and endotracheal intubation, the patient is placed on the operating table in a prone position with his/her head fixed in the Mayfield head holder system. Bony prominences, the chest wall and iliac crests must be adequately padded in order to prevent postoperative skin and peripheral nerve lesions (Fig. 1).

The head is slightly flexed and positioned in line with the chest to avoid skin creases and curvatures that could make the tunneling procedure more difficult and longer. We position the three-pin Mayfield headholder with the single pin placed above the auricle on one side and the two paired pins placed above the auricle and in the parietal region, contralaterally. Such pin placement prevents the headholder from being of hindrance in the course of the surgical procedure in the suboccipital region (Fig. 1). In the last 11 cases, we implanted the electrodes bilaterally (Fig. 2) to obtain complete coverage of the suboccipital

region, taking into account the following: (1) the frequent irradiation of the painful symptomatology from one side to the contralateral one in trigeminal autonomic cephalalgia and migraine and (2) the frequent anastomoses occurring among the main suboccipital nervous trunks [15]. Unilateral occipital nerve stimulation has been performed only in case of true unilateral occipital neuralgia.

Surgery

– Anatomic landmarks and skin incisions

After thorough shaving of the occipital hairline, a small vertical incision is made in the posterior cervical region in the midline from 1 cm above to 1 cm below the external occipital protuberance (EOP). The greater occipital nerve is usually present about 4 cm lateral to the midline turning in a slight medio-lateral direction before dividing into a medial and a lateral branch about 1 cm above the EOP [16]. Two symmetric vertical incisions are then made 4 cm lateral to the EOP on both sides (Fig. 1).

We then perform a blunt dissection of subcutaneous tissue exposing the cervical fascia located just superficial to the trapezius and splenius capitis muscles.

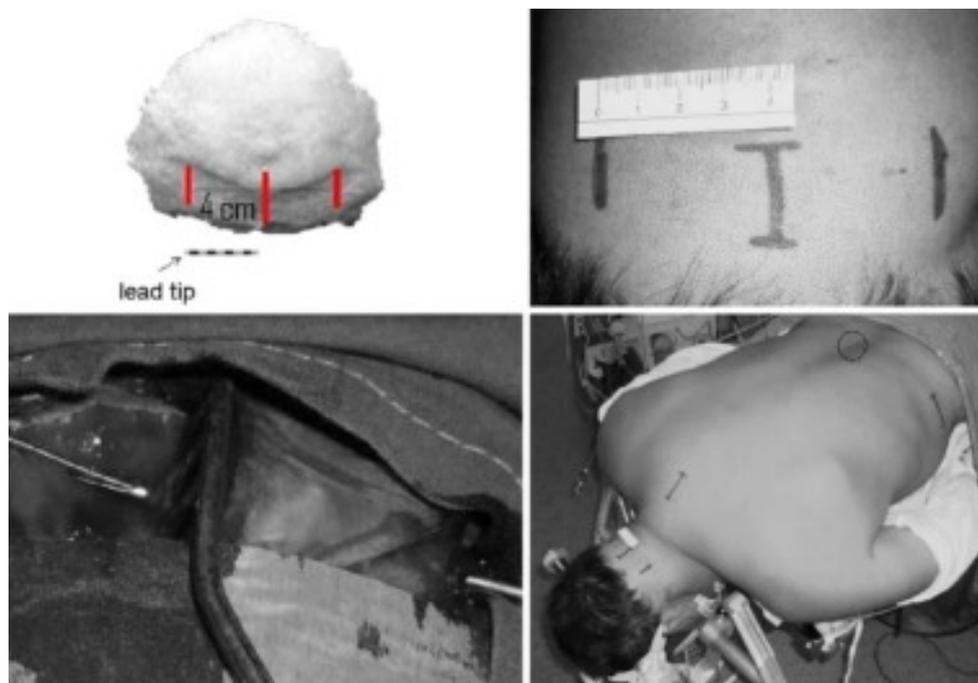
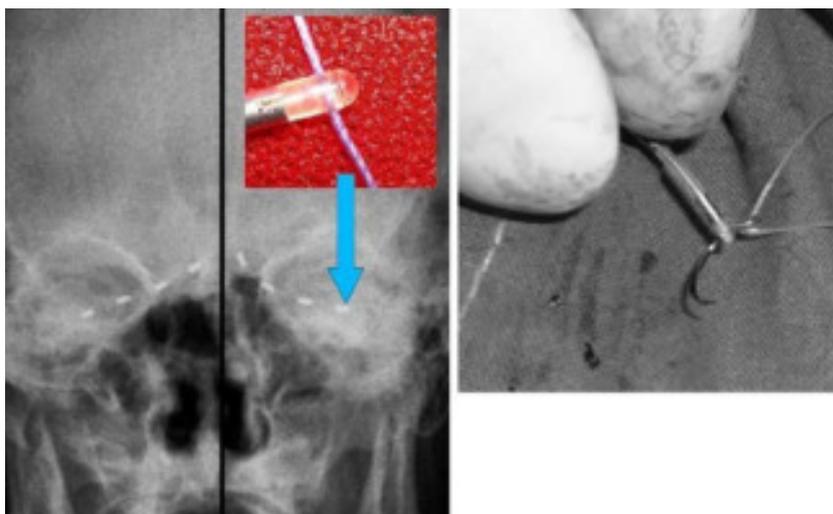


Fig. 1 *Upper left:* Schematic drawing of the occipital bone (posterior view), with the depiction of the anatomical landmarks for positioning of the Pisces Quad leads. The tip of the electrode should be located about 4 cm from the midline for optimal electric coverage of the greater occipital nerve. *Upper right:* Preoperative photograph (head vertex is at the bottom), showing the distance of the two lateral incisions from the midline (external occipital protuberance) incision.

Lower left: Intraoperative photo showing the Tuohy needle being utilized to tunnelize the lead from the lateral to the medial skin incisions *Lower right:* Preoperative photograph showing the position of the patient on the operating table and demonstrating the skin incisions required to perform the procedure (occipital midline and lateral incisions, dorsal and lumbar midline incisions, and subcostal lateral incision). The lumbar incision is surrounded by a black circle

Fig. 2 *Left*: Postoperative anteroposterior skull X-ray image showing the correct positioning of the suboccipital leads (the lead tip is indicated by a **blue arrow** in its definitive location secured to the fascia by the transfixing suture as indicated in the inset). *Right*: Intraoperative photo showing the plastic electrode tip being transfixied by the needle



– Lead placement and fixation

Then a Tuohy needle is inserted from each lateral incision to the midline incision in a lateral-to-medial direction, allowing the insertion of the Pisces Quad lead (Fig. 1). The plastic tip of each Pisces lead is then transfixied with the suture needle and secured to the lateral portion of the superficial cervical fascia situated superficial to the splenius capitis muscle. The plastic tip fixation is of great importance to avoid late lead migration (Fig. 2).

This maneuver must be performed while paying careful attention to the position of the lead tip at 4 cm lateral to the midline where the main trunk of the GON is located at 3–4 cm laterally from the EOP. Positioning the Pisces electrode tip too far laterally could prevent an optimal coverage of the electrical field (Fig. 3).

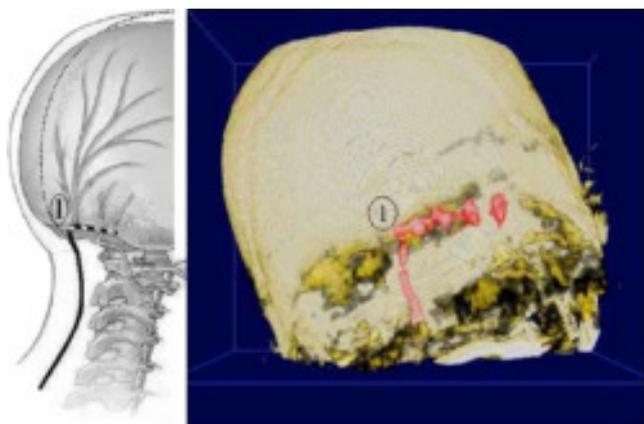


Fig. 3 *Left*: Schematic drawing of the correct position of the Pisces Quad lead with respect to the subcutaneous course of the great occipital nerve. *Right*: Postoperative three-dimensional reconstruction of the posterior occipital region of a patient during occipital nerve stimulation; the position of the lead contacts is evident with respect to the EOP (I). The **dotted line** on both figures represent the occipital bone's midline to make it easier to understand the picture. Note the right angle of the lead near the EOP (I) on both figures

– Lead connection and IPG positioning

The wires connected to the Pisces electrodes are then tunneled together in a caudal direction along the occipital and neck midline until about the middle dorsal level (Figs. 1 and 4). Of course, the age of the patient and their individual



Fig. 4 Postoperative X-ray image showing the posterior location of the lead wire (*inset: lateral view*) and the lateral location of the internal pulse generator in the subcostal region

anatomy will determine the rostro-caudal level of the location of the lead connectors. We use 66-cm or 95-cm length connection wires in order to prevent any excessive strain on the whole system. It is important at this point to create a little subcutaneous pocket at this level in order to allow enough room for both of the connectors and to avoid skin erosions. Another incision is then made in the midline at the lumbar level. Both dorsal and lumbar incisions serve as guides for midline tunneling of both wires. The two connection wires may then diverge with one on each side if two single-channel IPGs (Solettra, Medtronic, Minneapolis, MA) are used or may run on the same side if a dual-channel IPG is positioned on one side (Kinetra, Medtronic, Minneapolis, MA) (Fig. 4).

We use Kinetra and Solettra internal pulse generators because, in the event of loss of efficacy of occipital nerve stimulation, in chronic cluster headache patients (which constitute the majority of our patients), we consider the possibility of converting ONS into hypothalamic deep-brain stimulation, thus leaving intact the implanted IPGs and lead extensions.

Subcutaneous pockets for the pulse generators are made approximately 4 cm above the iliac crest at the level of the external oblique muscle, paying attention not to jeopardize the latter muscle in order to prevent excessive bleeding and postoperative pain. The average surgical time for the whole procedure is 40 min.

The stimulation parameters were: 30–50 Hz and 60–90 μ s; eight patients had unipolar configuration (case positive), and the rest had bipolar stimulation. In every case, the definitive stimulation amplitude (3–7 Volts) was set subthreshold with regard to the induction of paresthesias in the occipito-nuchal region.

Results

The mean follow-up was 1 year. None of the patients experienced lead migration, breakage of the wires or system failure; there were no cases of infections or subcutaneous hematomas in our series. None of the patients complained of pain or subjective perception of “tension” in any of the sites of surgery.

Discussion

The aim of this report was to describe the surgical technique of occipital nerve stimulation and to point out ways to avoid one of the main problems of the procedure, which is the late migration and late displacement of the electrodes due to movements of the neck. Trentman and

Zimmerman [15] have previously carried out a comprehensive review regarding the surgical techniques, the mechanisms of action of the occipital nerve stimulation and the most common postoperative surgical complications. We look forward to a proposal that will standardize surgical techniques. This standardization could lead to the reduction of complications in performing such operations.

The transfixion of the plastic tip of the Pisces Quad electrode and the suturing of it to the posterior portion of the superficial cervical fascia with non-absorbable suture are perhaps the most important aspects of the reported procedure as this has proven to be effective in preventing lead migration. An ideal electrode for ONS should have a ringed tip to make its application to the fascia easier. Another important point is the choice of the lead electrode versus the paddle electrodes suggested by other authors [3]. In our opinion, the cylindrical or spherical electrical field around the lead active contacts involves both deep and superficial branches of the occipital nerves, while the paddle electrical field is limited to one side either below or above the paddle according to the position of its active surface. The use of the prone position and subcostal IPG placement avoids tedious and time-consuming intraoperative repositioning of the patient for the placement of pulse generators. Tunneling the lead wires through the small occipital vertical incisions utilizing the Thuoy needle reduces intraoperative bleeding and the risks of lesions of the more superficial branches of the occipital nerve. Allocating the pulse generators at the level of the flanks allows for a less severe aesthetic impact, avoiding scars on the neck and breast, as may happen when IPG is implanted in the subclavicular pocket.

Finally, the extensive description and illustration of the procedure and postoperative neuroimaging may contribute to the development of a standard that can be referred to when reporting and discussing the clinical results of ONS.

References

1. Goadsby PJ, Bartsch T, Dodick DW (2008) Occipital nerve stimulation for headache: mechanisms and efficacy. *Headache* 48(2):313–318
2. Jasper J, Hayek S (2008) Implanted occipital nerve stimulators. *Pain Physician* 11:187–200
3. Jones RL (2003) Occipital nerve stimulation using a Medtronic resume II electrode array. *Pain Physician* 6(4):507–508
4. Leone M, Franzini A, Cecchini AP, Broggi G, Bussone G (2007) Stimulation of occipital nerve for drug-resistant chronic cluster headache. *Lancet Neurol* 6(4):289–291. doi:10.1016/S1474-4422(07)70061-3
5. Magis D, Allena M, Bolla M, De Pasqua V, Remacle JM, Schoenen J (2007) Occipital nerve stimulation for drug-resistant chronic cluster headache: a prospective pilot study. *Lancet Neurol* 6(4):314–321. doi:10.1016/S1474-4422(07)70058-3

6. Magis D, Schoenen J (2008) Neurostimulation in chronic cluster headache. *Curr Pain Headache Rep* 12(2):145–153. doi:10.1007/s11916-008-0027-0
7. Piovesan EJ, Kowacs PA, Oshinsky ML (2003) Convergence of cervical and trigeminal sensory afferents. *Curr Pain Headache Rep* 7(5):377–383. doi:10.1007/s11916-003-0037-x
8. Popeney CA, Alo KM (2003) Peripheral neurostimulation for the treatment of chronic, disabling transformed migraine. *Headache* 43:369–375. doi:10.1046/j.1526-4610.2003.03072.x
9. Rodrigo-Royo MD, Azcona JM, Quero J, Lorente MC, Acin P, Azcona J (2005) Peripheral neurostimulation in the management of cervicogenic headache: Four case reports. *Neuromodulation* 8:241–248. doi:10.1111/j.1525-1403.2005.00032.x
10. Rogers LL, Swidan S (2007) Stimulation of the occipital nerve for the treatment of migraine: current state and future prospects. *Acta Neurochir Suppl (Wien)* 97(Pt 1):121–128
11. Schwedt TJ (2008) Occipital nerve stimulation for medically intractable headache. *Curr Pain Headache Rep* 12(1):62–66. doi:10.1007/s11916-008-0012-7
12. Schwedt TJ, Dodick DW, Trentman TL, Zimmerman RS (2006) Occipital nerve stimulation for chronic cluster headache and hemicrania continua: Pain relief and persistence of autonomic features. *Cephalalgia* 6:1025–1027. doi:10.1111/j.1468-2982.2006.01142.x
13. Slavin KV (2008) Peripheral nerve stimulation for neuropathic pain. *Neurotherapeutics* 5(1):100–106. doi:10.1016/j.nurt.2007.11.005
14. Slavin KV, Nersesyan H, Wess C (2006) Peripheral neurostimulation for treatment of intractable occipital neuralgia. *Neurosurgery* 58:112–119. doi:10.1227/01.NEU.0000192163.55428.62
15. Trentman TL, Zimmerman RS (2008) Occipital nerve stimulation: technical and surgical aspects of implantation. *Headache* 48(2):319–327
16. Tubbs RS, Salter EG, Wellons JC, Blount JP, Oakes WJ (2007) Landmarks for identification of the cutaneous nerves of the occiput and nuchal regions. *Clin Anat* 20:235–238. doi:10.1002/ca.20297
17. Watkins L, Goadsby PJ (2007) Treatment of medically intractable cluster headache by occipital nerve stimulation: long-term follow-up of eight patients. *Lancet* 369(9567):1099–1106. doi:10.1016/S0140-6736(07)60328-6

Comment

This is an excellent paper that comes from an experienced team of pioneers in neuromodulation. It describes an interesting modification of surgical technique aimed at minimization of a frequent complica-

tion, an electrode migration, which has been a problem with most other occipital nerve stimulation system implantation techniques. The authors support their approach with a year-long follow-up in a group of 17 patients.

The main conclusion of this paper, in my opinion, is that each implanter should choose the approach that he or she is most comfortable with. I am convinced that there is no absolutely superior approach—as the matter of fact, we tried the midline approach recommended by the authors, and abandoned it—but not because of the migrations, but because of the high rate of electrode fractures, possibly as a result of the right angle of the electrode path with the curvature coinciding with the highly mobile cervical midline.

We routinely use the unilateral anchoring technique in the retromastoid area for both unilateral and bilateral occipital nerve stimulator implants. We place our generators in the infraclavicular area and enjoy the advantage of (1) very low mobility of the retromastoid area with thick fascia that holds the anchors well and (2) the short tunneling distance between the anchoring site and the generator pocket. Also, this makes our surgery much less involved with smaller incisions, no need for the prone surgical position and no need for invasive headholders (which also make intraoperative fluoroscopy all but impossible).

The authors use Soletra and Kinetra devices, and I do not have experience with these generators in the field of pain since we initially used Irel stimulators, then Synergy Versitrel devices, and currently the Eon Mini, Restore Ultra or Precision rechargeable generators, each of which is significantly smaller than the Kintera and is well tolerated by the patients in the infraclavicular location.

We recently analyzed our long-term cohort and found that the migration rate was relatively small (lower than we initially predicted). We also found that there were some late migrations and some patients who required system removal (for various reasons). In our series, all migrations were easily resolved by an outpatient procedure for electrode repositioning and/or replacement. Two issues with suturing the electrode tip are (1) the impossibility of using this maneuver with certain electrodes that either do not have a plastic tip or have a very small plastic tip and (2) difficulty with electrode removal when such removal is contemplated due to either infection/malfunction of the device or when the patient's condition improves to the point of not needing the system any more.

I tend to agree with the authors' preference in using percutaneous (cylindrical) electrodes rather than flat (paddle-type) leads, but would not discard the experience of those who routinely implant paddle leads with excellent long-term results.

Overall, however, I strongly support the authors' systematic approach in the long-term follow-up of this new category of implants and congratulate the authors for this excellent surgical series!

Konstantin Slavin, MD
Chicago, Illinois, USA