

Surgery for treatment of refractory chronic cluster headache: toward standard procedures

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Abstract The degree of disability due to chronic cluster headache refractory to conservative treatments justifies surgical procedures as second-line treatments. Many studies and reports nowadays confirm the efficacy of the two mostly used surgical techniques in such cases. Both deep brain stimulation and occipital nerve stimulation are in fact currently utilized for this purpose but the surgical technique has not yet been standardized. We describe the surgical steps of both procedures.

Keywords Chronic cluster headache · Occipital nerve stimulation · Deep brain Stimulation · Hypothalamus · Surgical technique

Introduction

Chronic cluster headache (CCH) is a pathological entity leading to a severe degree of disability; it is characterized by pain attacks occurring daily or spaced out by remission periods of <1 month, contrarily to the episodic form, in which attacks occur during a period (“cluster period”) of 6–12 weeks interrupted by remission periods lasting up to 12 months. When the condition results to be refractory to prophylactic treatments (verapamil, lithium, sodium valproate, methysergide, topiramate, gabapentin, indomethacin, and corticosteroids), when abortive therapy results unsatisfactory, and when such condition is present for at least 2 years [1, 2], surgical treatment is indicated

[occipital nerve stimulation (ONS) and deep brain stimulation (DBS)].

Since 2001, refractory cluster headaches have been shown to benefit from neuromodulation procedures. The first series of patients submitted to DBS of the posterior hypothalamus in Milan has been operated in Milan between 1998 and 2001 [3]. The rationale for neuromodulation in such cases was derived from neuroimaging and particularly position emission tomography and voxel-based morphometric brain MRI which pointed to the posterior hypothalamus as hyperactive node of the neuronal network responsible for autonomic trigeminal neuralgia [4, 5].

In 2003, Bartsch [6] demonstrated experimentally the role of the trigeminocervical complex in the etiology of autonomic cephalgia. This concept led to the introduction of occipital nerve electrical stimulation to modulate this system in patients affected by refractory cluster headaches. Due to its less invasiveness, ONS is usually performed as first choice procedure and posterior hypothalamic (pHyp) DBS is reserved only to ONS refractory patients as a second choice procedure.

ONS

The procedure described here has also been described in a previous report [7]. 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 to prevent post-operative skin and peripheral nerve lesions. The head is slightly flexed and positioned in line with the chest to avoid skin creases and curvatures. We then position the three-pin Mayfield headholder in the parietal region bilaterally.

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It is possible to implant two quadripolar bilateral electrodes or one longer octopolar one to obtain complete coverage of the suboccipital region, due to the frequent contralateral irradiation of the pain and to the frequent anastomoses among the main suboccipital nervous trunks [8].

After 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 [9]. Two symmetric vertical incisions are then made 4 cm lateral to the EOP on both sides.

A blunt dissection of subcutaneous tissue is then performed, thus exposing the cervical fascia located superficial to the trapezius and splenius capitis muscles.

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 electrode. The lead should be located at 4 cm lateral to the midline where the main trunk of the GON is located. Positioning the electrode tip too far laterally could prevent an optimal coverage of the electrical field (Fig. 1). The wires connected to the electrodes are then tunneled together in a caudal direction along the occipital and neck midline until about the middle dorsal level. At subcutaneous cervical level, we anchor both electrodes to the underlying fascia with non-resorbable stitches to prevent their caudal dislodgement, and relief loops are made at both this site and at more caudal sites along tunneling passages to prevent excessive tension, with possible discomfort to the patient, and fracture of the leads [10]. The age of the patient and his/her individual anatomy will determine the rostro-caudal level of the location of the lead connectors. We use 60- or 95-cm-length

connection wires to prevent, again, any excessive strain on the whole system. It is important at this point to create a little subcutaneous pocket at this level 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, Libra, St Jude) are used or may run on the same side if a dual-channel IPG is positioned on one side (Activa PC, Medtronic, Libra xp, St Jude) (Fig. 2).

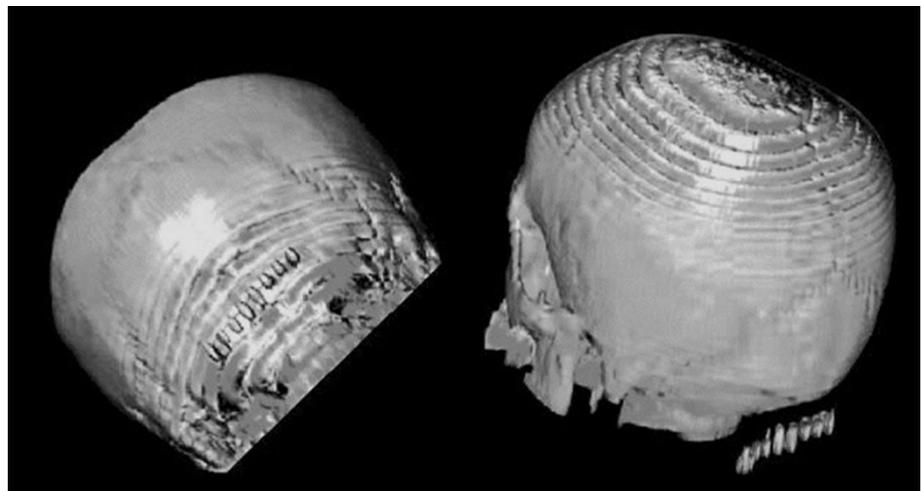
We consider the possibility of converting ONS into hypothalamic deep brain stimulation, thus leaving intact the implanted IPGs and lead extensions.

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 to prevent excessive bleeding and post-operative pain.

DBS

The planning procedure is performed with the aid of a stereotactic head frame (Leksell, Micromar, Maranello, CRW has been used in our Institute) with the patient under local anesthesia. A pre-operative set of MR images (generally axial, volumetric, fast spin echo inversion-recovery T1-weighted with Gd and T2-weighted sets) is obtained to acquire high-definition images for precisely defining the location of anterior and posterior commissures (AC, PC) and midbrain structures below the commissural plane (mammillary bodies and red nucleus). Magnetic resonance images are then merged with computerized tomography (CT) scans obtained under stereotactic conditions after

Fig. 1 3D CT reconstruction of correct suboccipital lead placement



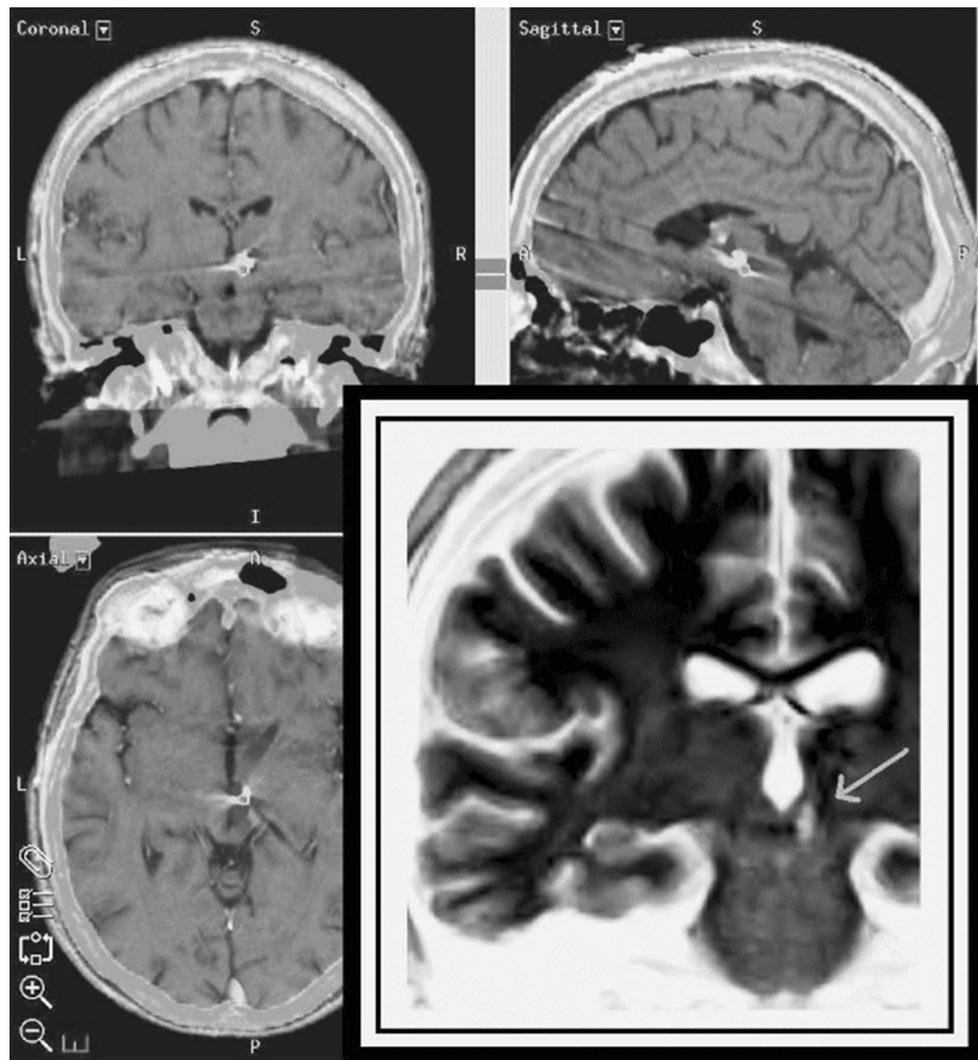


Fig. 2 Merging between pre-operative MRI and post-operative CT of a patient submitted to pHyp DBS in the three planes; *lower right* post-operative MRI showing the correct positioning of the DBS electrode (*arrow*)

positioning the head frame. The fusion of the 2 imaging sets is performed using an automated technique based on a mutual-information algorithm (Frame-link 5.0, Sofamor Danek Stealthstation, Medtronic). The merged images as well as every single slice of the imaging set are coregistered with the dedicated digital stereotactic atlas (available on internet at <http://www.angelofranzini.com>). Anyway midcommissural (MCP) point-related coordinates of the target are 2 mm lateral to MCP, 3 mm lateral and 5 mm inferior to it. It has to be remarked that targeting procedures based exclusively on the MCP or AC–PC plane may lead to slight electrode misplacement, due to the anatomical variability of the angle between the brainstem's major axis and the intercommissural plane. To overcome this problem, we took into account a new anatomical landmark that was incorporated into the final targeting procedure; we named this landmark the interpeduncular

point (IPP). It is localized in the apex of the interpeduncular cistern 8 mm below the AC–PC plane at the level of the maximum diameter of the mammillary bodies. With this correction point, target coordinates are individualized for every single patient. Under local anesthesia, two small incisions are made about 2 cm anterior to the coronal suture and 3 cm lateral to the midline. Through two small hand-driven burr holes, dura mater is coagulated and two blunted cannulas containing recording microelectrodes are inserted at about 5 mm above the target. Microrecordings within the pHyp are performed only in proximity to the target (starting at about 5 mm above it).

At the target, we record single-unit activity with the patients fully awake and in a pain-free state. All data sampled obtained by us in patients with TACs describe a low-frequency, tonic, and non-oscillatory discharge pattern. Anyway mean firing rates at the target differ among

different authors: Cordella et al. [11] described a mean discharge rate of 24 Hz in 3 patients; Bartsch et al. [12] a mean firing rate of 17 Hz and Sani et al. [13] a mean firing rate of 13 Hz. In our experience, the firing discharge did not change after tactile, motor, autonomic, and emotional tests performed during the surgical session.

Anyway Brittain [14] was able to record neural activity during a cluster headache attack: the pain attack was associated with an increase in the relative LFP power and specifically a distinct 16- to 22-Hz peak in neural activity. The presence of a specific neural rhythm was the first direct evidence of pHyp involvement during the cluster pain as indirectly described in neuroimaging studies. After this intraoperative evaluation, the definitive electrode (Medtronic, St Jude) is positioned at the target. Intraoperative macrostimulation with such electrodes is then performed, and the threshold for ipsilateral ocular deviation should be established at values higher than 3 Volts (130 Hz, 60 μ sec). If ocular movements are evoked by lower amplitude stimulation, the electrode should be positioned more laterally and the microrecording procedure should be repeated along the new trajectory.

Finally, to confirm the correct positioning of the electrode within the pHyp, we perform a second stimulation session increasing the amplitude over the threshold for ocular movements and we should evoke fear and unpleasant sensations lasting just few seconds. At the end of this intraoperative evaluation, the definitive electrode is secured to the burr hole by biological glue and by a titanium miniplate.

Then bilateral single IPGs (Medtronic Activa SC, St Jude Libra) or dual-channel monolateral IPGs (Medtronic Activa PC, St Jude Libra xp) are positioned into subclavicular subcutaneous pockets and connected to brain electrodes by tunneling connecting cables for chronic electrical stimulation. Post-operative brain CT or MR imaging constitutes a useful tool both for assessing the accuracy of electrode placement and correlating the extent of the clinical benefit or adverse effects. The two sets of images can be merged, taking advantage of the lower degree of image distortion with CT and the more precise defined gray–white matter boundaries provided by MR imaging [15].

Discussion and conclusions

Even if patients affected by refractory CCH are relatively few (<1 %) [16, 17], in our opinion, hypothalamic DBS and ONS should be available in neurosurgical units to treat these cases. Really these procedures have been utilized worldwide by different surgeons and their efficacy has been

confirmed by multicentric studies [18] and large series by single qualified authors [19–21].

The rate of complications is the same of all neuro-modulation procedures with implantable devices. The success rate of these procedures ranges between 50 and 80 % and should be considered highly significant in a pool of patients refractory to any other treatment. Due to neuromodulation, the limit of treatability of TACs has been overpassed in the last 10 years. The aim of this report was to describe the surgical steps of DBS and ONS to suggest neurosurgeons a standard procedure.

Conflict of interest The authors certify that there is no actual or potential conflict of interest in relation to this article.

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