Treatment of medically intractable cluster headache by occipital nerve stimulation: long-term follow-up of eight patients

Brian Burns, Laurence Watkins, Peter J Goadsby

Summary

Background Cluster headache is a form of primary headache that features repeated attacks of excruciatingly severe headache usually occurring several times a day. Patients with chronic cluster headache have unremitting illness that necessitates daily preventive medical treatment for years. When medically intractable, the condition has previously been treatable only with cranially invasive or neurally destructive methods.

Methods Eight patients with medically intractable chronic cluster headache were implanted in the suboccipital region with electrodes for occipital nerve stimulation. Other than the first patient, who was initially stimulated unilaterally before being stimulated bilaterally, all patients were stimulated bilaterally during treatment.

Findings At a median follow-up of 20 months (range 6–27 months for bilateral stimulation), six of eight patients reported responses that were sufficiently meaningful for them to recommend the treatment to similarly affected patients with chronic cluster headache. Two patients noticed a substantial improvement (90% and 95%) in their attacks; three patients noticed a moderate improvement (40%, 60%, and 20–30%) and one reported mild improvement (25%). Improvements occurred in both frequency and severity of attacks. These changes took place over weeks or months, although attacks returned in days when the device malfunctioned (eg, with battery depletion). Adverse events of concern were lead migrations in one patient and battery depletion requiring replacement in four.

Interpretation Occipital nerve stimulation in cluster headache seems to offer a safe, effective treatment option that could begin a new era of neurostimulation therapy for primary headache syndromes.

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Headache Group (B Burns MRCP, Prof P J Goadsby MD) and Division of Neurosurgery (L Watkins FRCS), Institute of Neurology, National Hospital for Neurology and Neurosurgery, London WC1N 3BG, UK; and Department of Neurology, University of California, San Francisco, CA, USA (P J Goadsby)

Correspondence to: Professor P J Goadsby peterg@ion.ucl.ac.uk

Introduction

Cluster headache is a form of primary headache characterised by bouts during which patients experience many attacks of very severe headache, considered by some to be the worst pain experience. The chronic form of cluster headache is defined as having a break of no more than a month in every 12 months, unless treatment is given. The 1-year prevalence of cluster headache is about 0·1%; about 10% of this group have chronic cluster headache. Chronic cluster headache is probably over-represented in headache clinic populations, although the definition itself is probably too restrictive in terms of the length of a meaningful gap between bouts for an individual. The devastating nature of intractable chronic cluster headache has encouraged us to explore novel approaches to its management.

Both episodic and chronic cluster headache can be successfully treated with a range of oral and parenteral medications that can be divided into abortive, transitional, and preventive treatment, all of which have been extensively reviewed. Although many patients are treated effectively, a proportion, particularly with chronic cluster headache, present an ongoing challenge. Treatment of episodic and chronic cluster headache by injection of local anaesthetic and steroid into the greater occipital nerve is generally reported to be useful. Adverse events are modest, and further studies are warranted. Because the effect of greater occipital nerve injections is limited to weeks, this approach is less useful in chronic cluster headache, where repeated injections are impractical or cease to be effective.

A proportion of patients with chronic cluster headache are refractory to medical management, although the extent of this problem is unclear, since guidelines to define such patients have only recently evolved. That such refractory patients exist is clear from reports of surgical interventions in cluster headache aimed at the trigeminal nerve or cranial parasympathetic outflow. Destructive or invasive surgical interventions reported include application of glycerol to the trigeminal ganglion, radiofrequency rhizotomy of the trigeminal ganglion, gamma knife surgery to the trigeminal nerve, trigeminal rhizotomy, trigeminal sensory nerve root section, surgical section of the nervus intermedius, radiofrequency rhizotomy of the nervus intermedius, combinations of nerve section, decompression of the facial nerve, endoscopic spheno-palatine ganglion blockade with lignocaine and corticosteroids, and radiofrequency lesions of the pterygopalatine ganglion. The reported complications from such procedures include death, permanent neurological impairment, including corneal anaesthesia, which can lead to visual loss, anaesthesia dolorosa, jaw deviation, and cluster attacks switching sides after a unilateral lesion has been made. In addition to these complications, a case has also been reported of attacks that persisted on the same side despite trigeminal nerve root section.[3] A 79% success rate was reported for microvascular decompression combined with sectioning of the nervus intermedius without producing a neurological deficit in 28 patients who underwent 39 procedures.[4] Many of these procedures bear the risks of a craniotomy or the real problem that the attacks may swap sides. With such potential side-effects for destructive procedures, non-destructive ways of pain control would be an important advance.

See Online for webappendix

Neurostimulation therapy approaches that entail central or peripheral nervous system targets might offer a direction for the development of treatments for medically intractable headache disorders. The approach has been used in other pain indications, including neuropathic pain,[5] and was pioneered by Weiner and Reed[6] in head pain. Identification of an area of activation[7] and structural change[8] in the region of the posterior hypothalamus in cluster headache led to deep brain stimulation of that region being trialled successfully.[9,10] This procedure is associated with a small risk of fatal haemorrhage.[11] Peripheral stimulation of the occipital nerve for medically refractory headache has been used in several open label trials and series for migraine,[12,13] occipital neuralgia,[14–16] and other primary headaches.[17] On the basis of our experience with greater occipital nerve injections,[18] our neuroimaging studies of the effects of occipital nerve stimulation,[19] and our concerns about morbidity and mortality of deep brain stimulation for cluster headache, we began to give occipital nerve stimulator implantations to patients with medically intractable chronic cluster headache. We report the systematic long-term follow-up of these patients.

Methods

Selection of patients

Patients with medically refractory chronic cluster headache from the outpatient department at the National Hospital, London, UK, were offered an occipital nerve stimulator. Patients seen at this hospital are referred by neurologists throughout the UK and represent a wide geographical catchment. These patients were offered the choice of a destructive trigeminal nerve procedure or deep brain stimulation; all eight individuals opted for occipital nerve stimulation. All patients were diagnosed with chronic cluster headache and fulfilled the standard criteria,[2] with the exception that one patient had long attacks (patient 1, webappendix).

Some hospitals use a temporary percutaneous wire electrode connected to an external generator, to stimulate the occipital nerve for a trial period of several days before implantation of a permanent device.[20,21] This practice is not used at our unit and therefore it was not a selection criterion. Additionally, although we were aware of each patient's response to occipital nerve block using lidocaine and steroid, this response was not a selection criterion.

The patients were given implants on compassionate grounds and the study was an audit of outcome, and as such under UK guidelines did not require ethics committee approval.

Surgical technique

Occipital nerve stimulator electrodes, leads, and battery were implanted by use of a technique similar to that previously described.[15] Implants were bilateral in all patients except the first, who initially had a unilateral left-sided implant followed 9 months later by the addition of a right-sided electrode. In brief, a single-stage procedure was used with two parts to allow an intraoperative trial of stimulation. The first part was done under local anaesthetic and gentle sedation, with care taken to avoid anaesthetising the occipital nerves. The patient was placed in the lateral position and a sterile field was established. A midline posterior cervical incision was made and bilateral cylindrical eight-quad electrodes (Medtronic, MN, USA) were introduced with curved Tuohy needles using an image intensifier to aid position. A dual programmable pulse generator (Medtronic Synergy, Medtronic) was then used to test stimulation and confirm that paraesthesia was felt bilaterally. The second part of the insertion was done under a general anaesthetic. The electrodes were looped and anchored to the cervical fascia, then tunnelled to a lateral cervical or subclavicular skin crease intermediate incision. A left subclavicular or abdominal incision was made (according to the patient's preference) to form a pocket to implant the pulse generator. Electrodes were tunnelled to the intermediate incision and a pair of extension leads (Medtronic) attached. Silicone sheaths were used to protect the lead connections. Topical antibiotic cover with gentamicin was introduced around the pocket and the incisions were closed.

Patients were provided with remote controls and instructed how to use them to communicate with the implanted pulse generators. Patients could adjust their stimulator settings with the remote control, although the pulse generators were programmed to provide continuous

	Age (years) at time of implant/sex	Type of chronic cluster headache	Years since first cluster attack at time of implant	Years since chronic cluster onset at time of implant
1	[illegible]	Primary	[illegible]	[illegible]
2	[illegible]	Primary	[illegible]	[illegible]
3	32/M	Secondary	[illegible]	3
4	40/M	Secondary	13	[illegible]
5	55/M	Secondary	[illegible]	[illegible]
6	38/M	Secondary	[illegible]	6
7	[illegible]	Primary	[illegible]	[illegible]
8*	[illegible]	Secondary	[illegible]	[illegible]
Median (range)	46 (32–58)	..	13 (5–52)	6 (2–12)

[illegible]

Table 1: Patients' demographics

stimulation. Patients could turn the stimulator on or off, and vary the pulse width, frequency, or amplitude, although most patients tended only to vary the amplitude. The polarity of the electrodes was adjusted during follow up visits to achieve comfortable bilateral paraesthesia in the occipital region. Patients remained in hospital for several days after implantation before discharge.

Follow up and data collection

The data for this report were obtained from the patients' records, from outpatient visits, and by postal and telephone by one investigator (TM). At the follow-up interview, patients were asked to compare retrospectively their attacks before and after the procedure, to gain an overall impression of effectiveness. They were also asked whether their use of triptans had altered, and to provide an overall response to the question "would you recommend the procedure to a fellow cluster headache sufferer?" Data on frequency, severity, and duration of headaches were obtained from contemporaneous medical records and then by direct follow-up with the patients. All patients were presented with their own case history and the data, and asked to confirm to the best of their knowledge that the information was accurate.

Results

Seven men and one woman with a median age at operation of 46 years (range 32–57 years) were given implants (table 1). Full case histories are shown in the webappendix. Median duration of chronic cluster headache at the time of the operation was 6 years, although for the patients with secondary chronic cluster headache the number of years spent with episodic cluster headache was much longer. Five patients had secondary chronic cluster headache (ie, the chronic form had evolved from an episodic form), and three had primary chronic cluster headache (ie, chronic since the beginning). Patients all fulfilled new criteria for intractability[6] and would have been suitable for deep brain stimulation by current criteria.[6]

Before stimulation, frequency of attacks ranged from one to eight per day, peak severity was rated as 10/10 on a verbal rating scale for seven of eight patients, and the duration of attacks was in the range 15–240 min.

These patients had not had sustained benefit from a range of preventive drugs used as monotherapy (table 2) and transitional treatments (table 3). Some patients also tried combination therapy (data not shown), which was also ineffective. Two patients had undergone trigeminal

	Verapamil	Lithium	Methysergide	Topiramate	Melatonin	Gabapentin	Sodium valproate	Other drugs
1	960	1200	12	200	6	2400	1000	Antiinflammatory preparations
2	960	1500	12	200	6	3600		Amitriptyline, pizotifen
3	480	400	NK	NK	NK	..	..	Antiinflammatory preparations
4	720	1500	12	12	9	2400	1000	Pizotifen, clonidine, carbamazepine, phenytoin
5	1200	1200	12	300	9	3600	2000	[illegible]
6	960	1200	12	100	6	900	..	..
7	720	NK	6	100	10	..	NK	Indometacin
8	960	1200	12	400	9	NK	NK	Antiinflammatory preparations, pizotifen

[illegible] NK=not known.

Table 2: Preventive treatments tried without sustained improvement and doses (total mg per day)

	DHE infusion (given over 3–4 days)			Prednisolone (oral, total course)		GON injection (lidocaine and steroid)		
	Cluster headache improved?	Number given	Duration of response (days)	Cluster headache improved?	Dose (mg/day)	Cluster headache improved?	Side of injection	Duration of response
1	Yes	1	2–4	No	60	Yes	L	Few hours
2	NT	0		Yes	60	No	L	
3	..	..	..	Yes	60	Yes	L+R	3 months; [illegible] no response
4	..	..		Yes	60	Yes	L×2	2 weeks; [illegible]
5	Yes	1	7	Yes	60	No	R	
6	Yes	1	14	Yes	60	No	L	
7	Yes	1	3	No	40	No	L	
8	Yes	1	3	Yes	60	No	L	

[illegible] NT=not tried. L=left. R=right.

Table 3: Transitional treatments tried for cluster headache and responses

	Sumatriptan		Oxygen
	Response	Response time (min)	Response?
1	No	–	No
2	Yes	10	Yes
3	Yes	[illegible]	Yes
4	Yes	10	Yes
5	Yes	[illegible]	Yes
6	Yes	[illegible]	Yes
7	Yes	60	Yes
8	Yes	10	Yes
Summary	88%	10 (10–60)*	88%

*Median (range).

Table 4: Responses to short-lived drugs before implantation

or stellate ganglion injections of local anaesthetic without long-term success. The patients' responses to sumatriptan (6 mg subcutaneous) and inhaled high-flow oxygen are shown in table 4. Three patients had single-blinded placebo-controlled indomethacin tests; all were negative. Four patients had oral indomethacin at doses from 75 mg to 150 mg daily without useful effect, whereas one patient had never had indomethacin (patient 6); his history was most untypical for an indomethacin-sensitive headache.

Before stimulation, only three of the eight patients were taking a preventive (verapamil in all cases). After implantation, two of these three patients continued to use verapamil and one stopped because of side effects. None of the five patients who were not taking a preventive drug before implantation started taking one afterwards.

The median follow-up for bilateral electrode use was 20 months (range 8–27; table 5). Six of eight (75%) patients noted improvement in their condition and said that they would recommend an occipital nerve stimulator to other patients with chronic cluster headache in similar circumstances. One patient's headache was about the same before and after use of the stimulator, but she said that she would still recommend another patient try using the stimulator if they were in a similar situation. One patient who had used the stimulator only for [illegible] did not find it helpful, and said that he would not recommend it to another patient. None of the patients became pain

	Years since disease onset	Months since implantation at follow-up	Patients' overall view of cluster headache outcome since implantation	Patients' estimate of % change in cluster headache since implantation	Triptan use before vs after implantation	Would patient recommend use of stimulator?
1	[illegible]	[illegible]	Same	–	Same	No
2	[illegible]	[illegible]	Same	–	Same	Yes
3	[illegible]	[illegible]	Improved	[illegible]	Less (stopped)	Yes
4	[illegible]	[illegible]	Improved	[illegible]	Less	Yes
5	[illegible]	[illegible]	Improved	[illegible]	Same	Yes
6	[illegible]	[illegible]	Improved	[illegible]	Less	Yes
7	[illegible]	[illegible]	Improved	[illegible]	Same ([illegible])	Yes
8	[illegible]	[illegible]*	Improved	[illegible]	Same	Yes
Summary	[illegible]	20 (8–27)	75% improved	[illegible]	[illegible]	[illegible] recommended use

[illegible]

Table 5: Follow-up for each patient

	Frequency		Severity (peak/average)*		Duration (min)			
	Before	After	Before	After	Before		After	
					Without treatment	After triptan	Without treatment	After triptan
1	[illegible]	[illegible]	[illegible]	Same	[illegible]	No data	[illegible]	[illegible]
2	[illegible]	Same	[illegible]	Same	120	10	No data	Same
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Same
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30	[illegible]	Same
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Same
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	[illegible]	Same

[illegible]

Table 6: Patients' estimates of cluster frequency, severity, and duration of attacks before and after use of stimulator

free, although in one patient, severity of pain was reduced so much that he stopped using triptans.

Of the six patients who improved, two noticed a marked improvement of 90% or better in their attacks (table 6). Three patients noticed a moderate improvement in their attacks of 40% or more, and one patient recorded a mild improvement of 25%. The meaning of the term improvement differed between individuals and typically meant a change in frequency or severity rather than duration (table 6). Patients who felt that they improved did so without a change in the dose or type of preventive treatment. After stimulator implantation, one patient stopped using triptans completely, three patients reduced triptan use, and four patients had no alteration in triptan use (table 5).

The benefit from the stimulator was not immediate and was never clearly reported in less than weeks. Indeed, the useful effect built up over months. By contrast, when a technical fault in the implanted device developed for one of the patients who reported a 90% benefit from the stimulator, there was an almost immediate worsening in their headache pattern (over hours or days). A similar rapid decline was also noticed by two other patients when the batteries in their devices failed.

The first patient to undergo implantation had a unilateral left-sided electrode, because 95% of their attacks had been left-sided. After implantation the attacks changed; 40% were right-sided or left-sided, whereas 20% of attacks started on the right and merged into a left-sided attack. After the addition of the right-sided electrode to complete bilateral stimulation, the attacks became 70% left-sided and 30% right-sided with an overall 40% improvement compared with attacks before any stimulation. On the basis of this event, we chose to give all subsequent patients bilateral implants.

The paraesthesia produced by stimulating the occipital nerves can be maintained and adjusted by altering the stimulation amplitude, frequency, or pulse width of the device. A wide range of settings were used for each patient (table 7). We do not know the optimum values for efficacy; so far, the most crucial variable seems to be the presence of paraesthesia itself.

Complications are listed in table 8. Eight subsequent surgical interventions (nine individual events) needed to be done in these patients. Three were due to electrode migration (all three occurred in the same patient), one was due to electrode failure, and five were related to battery malfunction or depletion (with two battery depletions in the same patient). Because of these complications, the patients had to be seen at the hospital for a diagnostic check by a neurosurgeon followed by a booked admission to the operating theatre. One patient elected not to have a battery replaced after 23 months of bilateral stimulation because they did not want another operation at that time and wanted to see how their attacks altered without use of the stimulator. Lead replacement was done in one patient and battery replacement in four.

	Ranges of values set during clinic visits*			Patterns of use indicated (number of hours of use)
	Amplitude (V)	Rate frequency (Hz)	Pulse width (μs)	
1	0·6–2·4	10–100	210–360	Intermittent
2	0·6–7·0	10–80	210–450	Continuous
3	[illegible]	[illegible]	[illegible]	Continuous
4	0·6–2·0	[illegible]	210–450	Continuous
5	[illegible]	[illegible]	[illegible]	Continuous
6	[illegible]	[illegible]	[illegible]	Continuous
7	1·5–10·0	10–80	210–450	Intermittent
8	[illegible]	[illegible]	180–200	Continuous

*Individual settings were frequently adjusted by the patients; the implanted device generally permitted the following ranges of values: amplitude 0–10·5 V, rate frequency 2–130 Hz, pulse width 60–450 μs.

Table 7: Settings used for occipital nerve stimulation

Table 8 also includes one patient who had postoperative pain and another whose device needed to be reprogrammed when a suspected electrode complication developed. In addition to these events, some patients reported neck stiffness or limited neck movements after implantation, and one patient had muscle recruitment from migrated electrodes.

Paraesthesia in the occipital region occurred in all patients and was more evident at times for some patients than for others, but since all patients generally considered this effect to be a reassuring or even a pleasant sensation and a marker of stimulator activity rather than an adverse effect, we have not listed it as a complication in table 8.

Discussion

Our case series provides long-term, albeit open-label evidence, that occipital nerve stimulation might have a role in the management of medically refractory chronic cluster headache. That the patients did not respond to medical treatment and had long histories of cluster headache, and that attacks returned when technical problems occurred, all suggest that the stimulator had more than a placebo effect. A further strength of the findings is the relatively long duration of follow-up, which suggests that the effect is robust and long-lasting. In selected patients whose lives are otherwise completely wrecked by a devastating illness, even a modest response rate would seem to be worthwhile, particularly in view of the very minimal side-effect profile for the procedure.[1] Since the alternative for such patients is either destructive, irreversible procedures, with substantial morbidity or even mortality, or deep brain stimulation, which also has complications, this treatment seems to be an attractive next step. The time to onset of effect suggests an interesting neurobiology in terms of brain plasticity. Further studies are warranted, with even longer term follow-up, to understand the place of this potentially important development in clinical practice.

Neurostimulation therapy for chronic cluster headache has thus far focused on deep brain stimulation.[2–4] Two

	Months since implantation at review	Complications	Action taken
1	20	(1) Excessive [illegible]	(1) [illegible] wound [illegible]
2	27	(1) [illegible]; (2) Battery [illegible]; (3) [illegible]	(1) New [illegible] (5 months); (2) New battery, electrodes, and leads ([illegible]); (3) New electrodes (1[illegible] months)
3	11	None	
4	17	(1) Battery depletion	(1) Waiting for new battery ([illegible])
5	27	(1) Electrode failure (lead [illegible] malfunction); (2) Battery depletion	(1) New electrodes and leads (9 months); (2) Waiting list for new battery (25 months)
6	18	(1) [illegible] sensation [illegible]	(1) [illegible] electrodes (7 months)
7	11	None	..
8	32 (28)	(1) Battery depletion; (2) [illegible]	(1) New battery (18 months [illegible]); (2) [illegible]

[illegible]

Table 5: Complications

cases have been abstracted in which occipital nerve stimulation was used in patients with chronic cluster headache who had had "every conceivable medication", and this approach was said to be helpful.[illegible] A patient implanted with a smaller unilateral device (Bion) reported a 70% improvement in frequency and severity of attacks.[illegible] By contrast, no benefit was noted in another series of six patients.[illegible] Unilateral implants were used in this series and follow-up was short (3 months). Longer-term findings (8 months) reported at a meeting[illegible] suggest that four of five patients noted an improvement, the timing of which is consistent with our results. Deep brain stimulation for cluster headache was developed after identification of an area of activation[illegible] and structural change[illegible] in the region of the posterior hypothalamus. Deep brain stimulation of the posterior hypothalamic region has been used successfully,[illegible] but has a small risk of fatal haemorrhage,[illegible] which has led us to investigate occipital nerve stimulation as an initial, perhaps screening, option before deep brain stimulation. One might conclude that occipital nerve stimulation should be tried first, since its side-effect profile is so modest, although response rates seem to be better for deep brain stimulation, with [illegible] of treated patients reported to be completely pain free.[illegible]

Peripheral nerve stimulation has been used in neuropathic pain with mixed success.[illegible] Its translation to head pain was first focused on cases described as occipital neuralgia, because of pain in the distribution in the occipital region.[illegible] Our experience with such patients is that most have another underlying primary headache, typically migraine.[illegible] Remarkably, the effect of occipital nerve stimulation is not restricted to the peripheral distribution of the greater occipital nerve, although the paraesthesiae patients report does. Pain syndromes clearly involving extra-occipital territory, such as migraine,[illegible] and hemicrania continua (unpublished data[illegible]), are also effectively treated with occipital nerve stimulation. This extra-occipital effect is also seen with greater occipital nerve injection in migraine,[illegible] although response to greater occipital nerve blockade was not a useful predictor of outcome to occipital nerve stimulation. The probable explanation for the effect is a central modulatory change at least involving the trigeminocervical complex of neurons where second order neurons have input from both trigeminal and cervical afferents.[illegible] Indeed, since functional brain imaging has shown that patients with chronic migraine with occipital nerve stimulation have modulation of [illegible] rather than the recurrent migraine areas,[illegible] the effect in cluster headache might be much more central than the trigeminocervical complex.

In other reports of occipital nerve stimulation for headache common complications have included electrode migration, infection, cervical pain, allergy to metal, and muscle recruitment or spasms of the neck.[illegible] In this series with a median follow-up of 20 months for bilateral electrodes we have seen a range of complications, although no infection or allergy. Four of eight patients needed a new battery, and two patients needed new electrodes. Muscle recruitment, pain, and electric shock sensations were also noted. Battery depletion is not strictly a complication but it does mean that the patient is required to have an operation, should they choose to have the battery replaced. In previous reported series, battery depletion seems to have been less common, possibly because of shorter follow-up, lower voltage use, intermittent use of the stimulator, or different electrode contacts. Several issues need to be explored, such as selection of patients and predictors of successful outcome. Occipital nerve block did not seem to predict the outcome of successful occipital nerve stimulation (see table 3) but the numbers here are small and more data are needed. Other than selection of patients and predictors of outcome, operative technique and equipment improvements are important; electrode migration needs to be minimised, and battery consumption, or the possibility of a rechargeable battery system, needs to be explored.

In these patients a range of different stimulation frequencies, pulse widths, and voltages were used. The reason for changing the variables was to achieve a comfortable degree of paraesthesia in the distribution of the occipital nerves by adjustment of the parameters. We have not been able to identify a trend or pattern for the settings, and this point should be carefully researched in the future.

Although our results are promising, with six of eight patients reporting that they noticed an improvement in their headache, the study did not have a placebo control. This issue is among the most challenging for trials of device-based treatments, since paraesthesia seems to be a requirement for effective therapy. Little doubt exists that placebo effects are seen in cluster headache, but they seem an unlikely basis for the substantial effects that we observed: alleviation of medically intractable symptoms, stable results on long-term follow-up, and return of attacks with electrode migration or battery failure. For the mid-range effects, we cannot be sure, although the observation that patients reduced use of triptans and did not start to take another preventive drug suggests a positive outcome. For a condition such as medically intractable chronic cluster headache, where the options are so limited and stark, a new treatment to control the problem in just a fifth of patients would be a wonderful advance. These results open up a more complex question, which our study cannot address: should patients with medically treated chronic cluster headache, whose symptoms are controlled but who also have side-effects, be offered this approach? The mainstay treatments of chronic cluster headache have important and substantial side-effects; patients should be involved in decisions about how to advance this potential option.

In summary, six out of eight patients with stable medically intractable chronic cluster headache had, for them, important and worthwhile improvements in their condition such that they would recommend the procedure to similarly troubled patients. The effects we noted persisted over a median follow-up of 20 months, do not seem to be predicted by greater occipital nerve blockade with local anaesthetic and steroid, and are reversible when the device malfunctions. The procedure itself is relatively straightforward, without substantial morbidity over the time we have observed this group. The fact that syndromes in which the pain is mainly felt in the ophthalmic division of the trigeminal nerve can be modified by stimulation in a connected dermatome suggests that the underlying principle of this treatment is one of alteration of brain function, while the time to onset of the therapeutic effect has all the hallmarks of the implication of brain plasticity. The outcome provides hope for patients, and a rich opportunity to understand the biology of primary headache syndromes by careful follow-up of these and further cases.

Contributors

B Burns was involved in initial design of the study, recruited patients, collected and compiled results, and contributed substantially to the writing of the paper. L Watkins was involved in initial design of the study, was involved in clinical management, did most surgical procedures and reviewed results, and contributed to the writing of the paper. P J Goadsby conceived the idea of occipital nerve stimulation for cluster headache, designed the initial study, recruited patients, did some surgical procedures, reviewed results, and wrote the first draft of the manuscript. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Conflict of interest statement

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