Case Report

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Long-Term Chronic Stimulation of Internal Capsule in Poststroke Pain and Spasticity

Case Report, Long-Term Results and Review of the Literature

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Key Words
Deep brain stimulation · Internal capsule · Pain relief · Central pain · Spasticity

Abstract
This report describes the long-term follow-up of chronic stimulation of the posterior limb of the internal capsule (IC) adjacent to the sensory thalamus in an elderly patient who suffered pain and spasticity in the left leg due to stroke. Both pain and motor symptoms ameliorated during 5 years of deep brain stimulation. Our case report suggests the possibility to stimulate a more precise representation of the inferior limbs within the IC and thalamus. We propose that chronic stimulation of the IC might be an effective surgical option to motor cortex stimulation when the pain and spasticity are referred to the lower limbs.

Introduction

Stimulation of the posterior limb of the internal capsule (IC) has been employed to treat neuropathic pain [1–5] and movement disorders including spasticity due to trauma, tremor of the upper limb, cerebral palsy and dystonia [6, 7]. Chronic stimulation of IC has been proposed also to treat central pain, whether thalamic tissue is available or not [2–4, 8–12]. Good results were achieved in the treatment of central pain by Adams et al. [8], Hosobuchi et al. [2], Namba et al. [10], and Young et al. [12]. Encouraging results have been achieved also in pain syndromes not caused by thalamic strokes [12]. In addition, excellent outcomes were achieved in the treatment of movement disorders by Cooper et al. [6, 7].

Deep brain stimulation (DBS) has obtained poor long-term outcomes in chronic pain, leading to a dismission of this technique in the last decade [3, 4, 13–15]. However, in recent years new studies have shown that DBS may induce significant decrease of pain in selected facial pain syndromes [16–20], and may benefit neuropathic pain such as phantom limb pain [21, 22] and central pain [23]. Recently, motor cortex stimulation (MCS) has proven to be effective in relieving central pain, and motor-related disorders [24, 25], although the results are still controversial.

We describe the long-term results of the stimulation of the posterior limb of the IC for relieving both central pain and the associated spasticity in an elderly patient.

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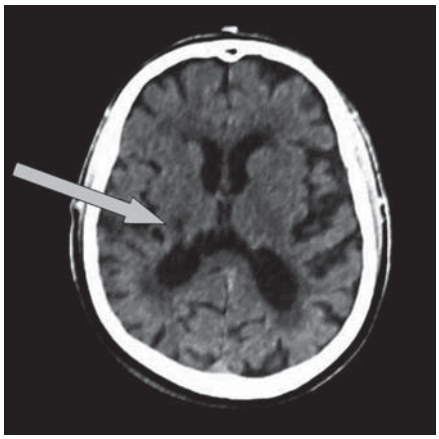

Fig. 1. Preoperative CT scan. Arrow displays the location of the stroke in the right thalamus.

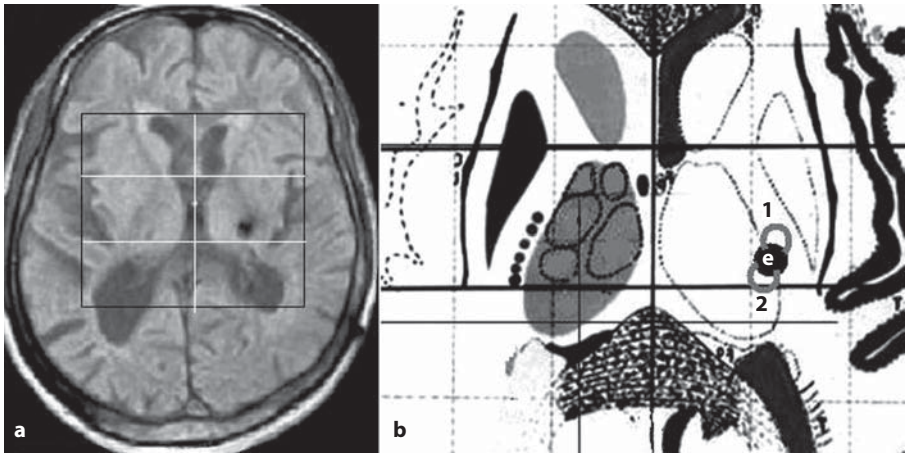

Fig. 2. a: Postoperative MRI. **b** Anatomical map showing the placement of the DBS lead. Adapted from Talairach and Tournoux's atlas [37]. Filled circle indicates the DBS lead position; empty circle 1 indicates intraoperative lead test where motor evoked responses were obtained in the contralateral inferior limb; empty circle 2 indicates test lead placement where paresthesias were evoked in the contralateral inferior limb.

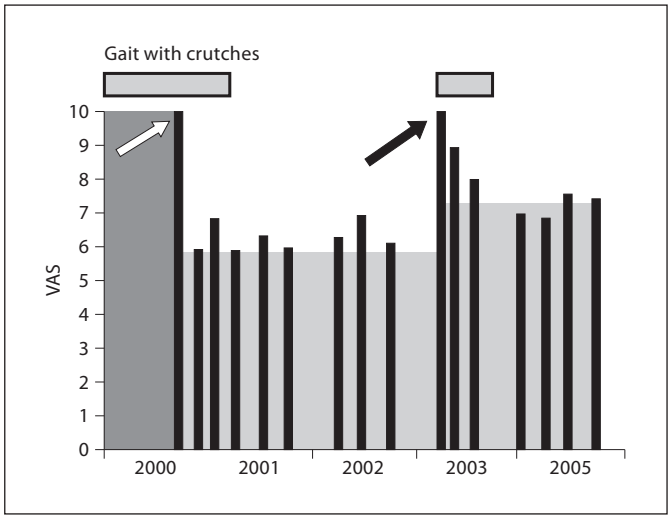

Fig. 3. Chart displaying the course of the subjective perception of pain, as indicated by VAS, and the gait difficulties, as indicated by the use of crutches (grey rectangle). White arrow indicates the time of the DBS implant. Black arrow indicates the time the pulse generator was exhausted and subsequently replaced. The pain and the gait clumsiness reappeared, and both were relieved by the replacement of the pulse generator.

Case Report

G.W. is a male patient who suffered a right thalamic stroke at the age of 72 (fig. 1). Central pain and left hemiparesis with leg spasticity developed a few weeks after the ictal event. Six years later, when he was admitted to our Institute, the pain was described as stabbing, and referred to in the posterior portion of the left thigh and ankle, but not in the foot. In addition, the patient had spasticity in the left leg causing difficulties in standing still and notably in his gait. Because of the left leg spasticity, he had to use crutches to walk independently. Drug treatment including nonsteroidal anti-inflammatory drugs, opioids and gabapentin was unsuccessful. After the treatment, no chronic drug treatment was tried.

In March 2001, at the age of 78, a DBS lead (DBS-3389; Medtronic, Inc., Minneapolis, Minn., USA) was implanted in the posterior limb of the right IC close to the boundaries of the ventrolateral thalamus. The operation was made in local anesthesia. Leksell frame, CT with fusion of MRI images through a Stealth Station (Medtronic Inc.) in stereotactic conditions, and intraoperative macrostimulations were used. Intraoperatively, several lead tests were performed: in the first, motor evoked responses in the contralateral inferior limb were obtained with the stimulating parameters of 0.6 V, 60 ms and 100 Hz (fig. 2); in the second, paresthesias in the contralateral inferior limb were evoked with the stimulating parameters of 1 V, 60 ms, and 100 Hz (fig. 2). The definitive stereotactic coordinates to the commissural system midpoint were: 17 mm lateral (X), 7 mm posterior (Y), and 2 mm over the commissural plane (Z) (fig. 2). At this site, the stimulation parameters required to evoke motor responses and paresthesias in the contralateral inferior limb were: amplitude 2 V, pulse width 60 ms, frequency 100 Hz, and amplitude 1.5 V, pulse width 60 ms, frequency 100 Hz, respectively.

The lead was connected to a subclavicular implanted pulse generator (Soletra 7426, Medtronic Inc., Minneapolis, Minn., USA) under general anesthesia.

Postoperative MRI showed the placement of the lead very close to the stroke area (fig. 2). Two days after the implant, the stimulation was turned on below the threshold of subjective motor and sensory responses (100 Hz, 60 ms, 1 V) and the patient reported a reduction of pain in the left leg. In parallel to the pain remission,

there was an improvement of the leg spasticity, although slower compared to the progress in pain score, and the patient was able to stand still and to walk without any external help (fig. 3).

Since the first dismissal, the patient was periodically checked, reporting a steady clinical situation with a 40% pain reduction (fig. 3). In March 2003, the patient was readmitted due to recurrence of pain and spasticity in the left leg. On this occasion, the impulse generator became exhausted and was replaced by a new one. The stimulation was turned on again, restoring the benefits induced by DBS on pain and spasticity. Decrease in pain occurred after a few weeks, while gait improvement occurred after 4 months (fig. 3). Fascinatingly, the benefit effect on gait clumsiness was more rapid than the one at the time of the implant. Indeed, the pain reduction after implantable pulse generator (IPG) replacement was slightly less impressive than before, possibly due to a sort of late tolerance [26] or psychological factors (subjective evaluation). Conversely, the motor improvement was the same as before the IPG replacement (objective evaluation). The patient was able to perform motor tasks impossible without DBS, like walking without crutches. In August 2006, the patient, who had until then a good return to a normal family environment with a good life quality, fell from a tree while picking fruits. The consequence was avulsion of the brachial plexus and a cervical spinal cord lesion, which has limited him to a wheel chair. The beneficial effect had lasted for more than 5 years.

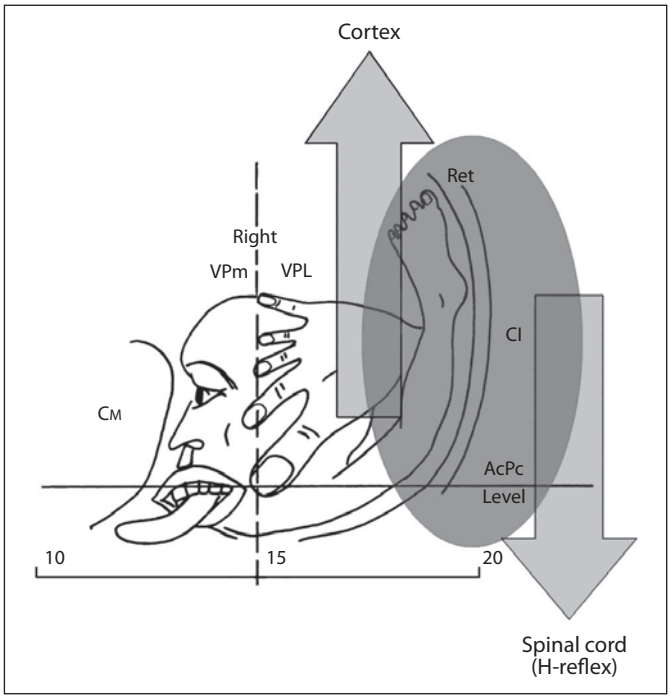

Fig. 4. Schematic diagram [modified from 38] showing the hypothesized neural circuit involved in chronic stimulation. The electrical field (indicated by the pale grey ellipse) generated by the DBS lead involves the sensory nuclei of the thalamus (VPL) where the inferior limb is somatotopically represented, and the descending IC fibers modulating the H-reflex at the spinal cord level. Reduction of pain and spasticity obtained in this case report matches this hypothesis.

Discussion

This report describes the case of an elderly patient affected by central pain, associated with leg spasticity, successfully treated by stimulation of the posterior limb of the IC. Beside pain reduction, the neurostimulation has allowed the patient to walk freely with no crutch support. The beneficial effects on both symptoms lasted for more than 5 years. An alternative stimulation site could have been the motor cortex; in fact, some reports [27–29] dealt with treatment of lower limb painful disease without the need to place the epidural electrode within the interhemispheric cistern where the lower limb representation lies. Our case report suggests the possibility to stimulate a more precise representation of the inferior limbs within the IC and thalamus (fig. 4), indeed the back portion of the posterior limb of IC has been targeted, where the corticobulbar fibers are compactly located [30]. It has been hypothesized that the DBS position in the back portion of the right posterior limb of the IC, adjacent to the sensory thalamus and passing through the thalamic reticular nucleus (fig. 2) recruited the motor fibers in IC and inhibited nociceptive neurons located in the sensory thalamus (fig. 4). In addition, the stimulation may have caused some influence to the thalamic reticular cells, probably inhibiting neuronal activity in ventral posterior lateral (VPL) nucleus relay cells, generating positive effects on pain, thus improving motor deficits. It is also possible that it stimulated fibers that reverberate from the thalamus to the cortex or different areas and increase the inhibition [31]. Furthermore, we cannot rule out that the patient's pain was secondary to the spasticity, and that when the spasticity improved, pain relief followed.

In a case described by Cooper et al. [6], pain and spasticity caused by a car accident have been relieved by implanting DBS leads in the pulvinar and in the posterior limb of IC. Other authors reported that electrical stimulation of this latter region in chronic pain patients induced motor responses accompanied by pain relief [11]. Beneficial effects achieved by IC stimulation on either pain symptoms, or motor-related disorders have been described in several studies [2–4, 6–12]. According to the literature, IC DBS relieved either completely or partially the symptoms in almost 60% of the treated patients (table 1). It is noteworthy that the discrepancy in outcomes between authors may be a consequence of the different

Table 1. Results of IC stimulation in pain and movement disorders

Authors	Year	Central pain		Other pain		Poststroke motor deficits		Other motor deficits	
		patients	success	patients	success	patients	success	patients	success
Adams et al. [8]	1974	2	2	3	3	–	–	–	–
Fields and Adams [9]	1974	0	–	1[1]	1	–	–	–	–
Hosobuchi et al. [2]	1975	4	4	3	1	–	–	–	–
Cooper et al. [6]	1980	–	–	–	–	–	–	4	4
Cooper et al. [7]	1982	–	–	–	–	9	6	40	21
Namba et al. [10]	1984	7	5	–	–	–	–	–	–
Young et al. [12]	1985	0	–	2	2[2]	–	–	–	–
Namba et al. [11]	1985	3[3]	2	1	0	–	–	–	–
Levy et al. [4]	1987	6	1	–	–	–	–	–	–
Kumar et al. [3]	1997	4	1	–	–	–	–	–	–

[1] This case is part of the series by Adams et al. [8].
[2] Two electrodes were implanted in both patients, 1 in PVG and 1 in IC.
[3] Seven out of 11 patients were already described by Namba et al. [10].

coordinates chosen to place the stimulating leads. In addition, these data should be evaluated with caution, due to the lack of satisfactory long-term follow-ups, and the impossibility to repeat the studies of Cooper et al. [6, 7]. The decrease in spasticity by IC DBS appeared to be the effect of the segmental reflex inhibition (H-reflex; fig. 4) since no increase in muscle strength has been objectively measured [25].

The mechanism of pain relief by IC stimulation is not clear. Unlike PVG, stimulation of either the thalamus or the IC is not correlated with an increase in endorphin levels [32]. IC stimulation should involve a pain-inhibiting pathway rather than the opiate-mediated system. Experimental models have been employed to identify the neural systems involved in IC stimulation [33]. In cats, train of electrical pulses delivered to IC elicited suppression of activity of nociceptive neurons in the thalamic sensory nucleus. Furthermore, IC stimulation has an inhibitory effect on deafferentation hyperactivity in neurons in cats' spinal trigeminal nucleus [34].

We have described the beneficial effects of neurostimulation of the motor fibers of the IC, and the adjacent sensory thalamus, in an elderly patient with central pain and spasticity. The aim was to suggest a valid option in the treatment of pain and spasticity of the lower limb as an alternative to MCS recently proposed for poststroke syndromes [35, 36]. IC chronic stimulation may interact with the same sensory-motor neural networks alleged to explain the mechanism of action of MCS but represents a better alternative, due to the cortical representation of the lower limbs, which lies in the interhemispheric fissure, thus not an easy target for the placement of epidural electrodes. In any case, our study provides a further evidence of the possibility to provoke both motor responses and pain relief by neurostimulation of deep cerebral areas. The peculiarity of the presented case is the long-term stability of pain control linked to the improvement of gait in an elderly patient. The 'drive' mechanism between motor and sensory symptoms is still poorly understood, but it is surely a main research topic to optimize the use of IC DBS and MCS in poststroke syndromes. To unveil this mechanism might be of great interest to plan investigations employing neuroradiological examinations, such as DTI and functional MRI, which could delineate the corticospinal tract with the lower limb fibers, and to detect potential changes in cortical and subcortical cerebral activity as a consequence of DBS.

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