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SHORT REPORT

Posteroventrolateral pallidotomy through implanted DBS electrodes monitored by recording local field potentials

Angelo Franzini[1], Roberto Cordella[1], Federica Penner[1], Manuela Rosa[3], Giuseppe Messina[1], Michele Rizzi[1], Nardo Nardocci[2] & Alberto Priori[3]

[1]*Unit of Functional and Stereotactic Surgery, Fondazione IRCCS Istituto Neurologico "Carlo Besta", Milan, Italy,*
[2]*Department of Child Neurology, Fondazione IRCCS Istituto Neurologico "Carlo Besta", Milan, Italy, and*
[3]*Clinical Center for Neurostimulation, Neurotechnologies and Movement Disorders, Fondazione IRCCS Ca' Granda, Ospedale Maggiore Policlinico, Milan, Italy*

Abstract

This paper describes the use of globus pallidus internus (Gpi) local field potentials recorded through pre-implanted deep brain stimulation (DBS) electrodes on a patient affected by generalized dystonia. The recordings were made both before and after radiofrequency-induced posteroventrolateral bilateral stereotactic pallidotomy. LFP patterns and macroelectrode impedances were modified after the pallidotomy, along with the improvement of dystonic symptoms. After implantation, the DBS electrodes were used for subsequent bedside pallidotomies that were required by the evolution and/or persistence of symptoms. In our hands, LFPs were safe and effective in monitoring pallidotomy performed through DBS electrodes.

Keywords: dystonia; local field potentials; pallidotomy

Case report

A 15-year-old female patient affected by generalized dystonia secondary to perinatal hypoxia presented a clinical picture characterized by dystonic movements in both arms and legs and spasticity primarily involving the lower limbs. Frequent movements consisting of protrusion of the lips and opening of the mouth were also present. Pharmacological therapy included tetrabenazine (75 mg\die), lorazepam (3.5 mg\die), and valproate for concurrent seizures (850 mg\die), although it was ineffective in controlling the disease progression. Symptoms progressively worsened that required the patient to be admitted to our institute for evaluation to determine whether or not functional neurosurgical procedures were necessary. At the time of admission, the Burke–Fahn–Marsden Dystonia Rating Scale (BFMDRS) score was 56. Due to the patient's poor skin tropism, it was decided to implant only the intracerebral electrodes to perform bilateral pallidotomy instead of the full system (i.e., the connection cable and the internal pulse generator). The Leksell frame (Elekta, Stockholm, Sweden) was used for the procedure. The chosen target was the globus pallidus internus (Gpi), bilaterally, at a more anteromedial position than the usual one used for deep brain stimulation (DBS), in order to avoid possible lesional effects on the internal capsule. Final stereotactic coordinates were 4 mm anterior to the midpoint of the anterior commissure–posterior commissure or AC–PC line, $\pm$20 mm lateral to the midline, and 5 mm below the intercommissural plane. Two quadripolar DBS electrodes (DBS-3389; Medtronic, Inc., Minneapolis, MN) were inserted at the defined targets; then they were secured to the burr holes with titanium miniplates (Ethicon Bioplate Co., J&J, Raynham, MA, USA) and connected to the external extension, leaving the connector in a subgaleal location with the external lead emerging from the skin laterally to the vertex on both sides. A computerized tomography (CT) scan with the frame still in place was performed after the procedure to rule out complications and to verify the correct position of the electrodes. Implanted macroelectrodes consisted of four cylindrical contacts (diameter: 1.27 mm, length: 1.5 mm, placed 2 mm apart center-to-center) named 0-1-2-3, beginning from the most caudal contact.

Pallidotomies were performed by means of an external radiofrequency generator (RFG-1A, Cosman Medical Inc., Burlington, MA, USA) connected to contacts 1 and 2 of the external leads; a 30-second train of 40 V was delivered. These contacts were chosen because they were identified specifically as the contacts that were placed in the selected Gpi location and verified by post-operative anatomical reconstruction of the trajectory [merging between stereotactic pre-operative magnetic resonance imaging (MRI) and post-operative CT]. A total of three RF lesional procedures were performed after the implantation procedure. The first

Correspondence: Roberto Cordella, Unit of Functional and Stereotactic Surgery, Fondazione IRCCS Istituto Neurologico "Carlo Besta", Via Caloria 11, 20133 Milan, Italy. Tel: +39 0223 942421. E-mail: cordella.r@gmail.com

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pallidotomy was performed on the right Gpi 2 days after DBS. Local field potentials (LFPs) were recorded bilaterally from the external leads of the DBS electrode both before and 12 days after the right pallidotomy. The LFPs recording sessions lasted approximately 30 min and took place in the patient's hospital room. These sessions included the following steps: (1) evaluation of the impedance of each macroelectrodes' contact pair; (2) LFP recordings from the right DBS electrode for 10 min; and (3) LFP recordings from the left DBS electrode for 10 min. Macroelectrode impedance was evaluated on all contact pairs (0–1, 0–2, 0–3, 1–2, 1–3, and 2–3) through an impedance meter at 30 Hz (Model EZM 4, Grass, USA). LFPs were sampled using different contact pairs simultaneously (0–1, 1–2, and 2–3). An Ag/AgCl electrode placed on the right supraclavicular area was used as the recording reference. LFPs were pre-amplified, filtered (bandpass: 2–70 Hz), differentially amplified (100000×) and digitized with 1024-Hz sampling rate and 12-bit quantization with 5-V range through the BE Light EEG amplification system (EBNeuro Spa, Florence, Italy). Recorded signals were displayed online by monitor and stored for off-line analysis. Following the right posteroventral pallidotomy, the visual assessment of LFP from ipsilateral electrodes showed an amplitude reduction in all of the recorded traces, which was most noticeable in the contacts' pair 1–2, thus matching the effective RF lesion area. In addition, right macroelectrode impedance values were reduced for all recording contact pairs after the right posteroventral pallidotomy; the reduction was also greater for contacts' pair 1–2 (Fig. 1). Conversely, LFP amplitude and the related impedance values recorded from the left macroelectrode contact pairs did not change after right posteroventral pallidotomy. Subsequently, additional pallidotomies were performed 15 days apart, targeting the left Gpi in the first session and both nuclei in the second session.

The patient showed an improvement of symptoms a few weeks after lesions, especially with regard to orofacial dystonia and involuntary movements of the upper limbs. Such improvements were still present during the 12-months follow-up period, when the BFMDRS score was evaluated at 28.

Discussion

Posteroventral pallidotomy was initially introduced to treat primary and secondary severe dystonia. Recently, the same stereotactic coordinates have been widely used as the target for DBS to treat several forms of pathological conditions, including primary and secondary dystonia, cerebral palsy, and dopamine-induced dyskinesias in advanced Parkinson's disease.[1] The technique of DBS has led to the progressive abandonment of posteroventral pallidotomy. Nevertheless, it is our opinion that such a procedure may be performed to treat patients who are deemed unsuitable for DBS due to poor skin tropism, poor general condition, and recurrent infection of implanted neuroprostheses. The main disadvantages of pallidotomy are the lack of reversibility and the disappearance of the therapeutic effect over time.[2] Although the opportunity to perform RF lesions through implanted DBS

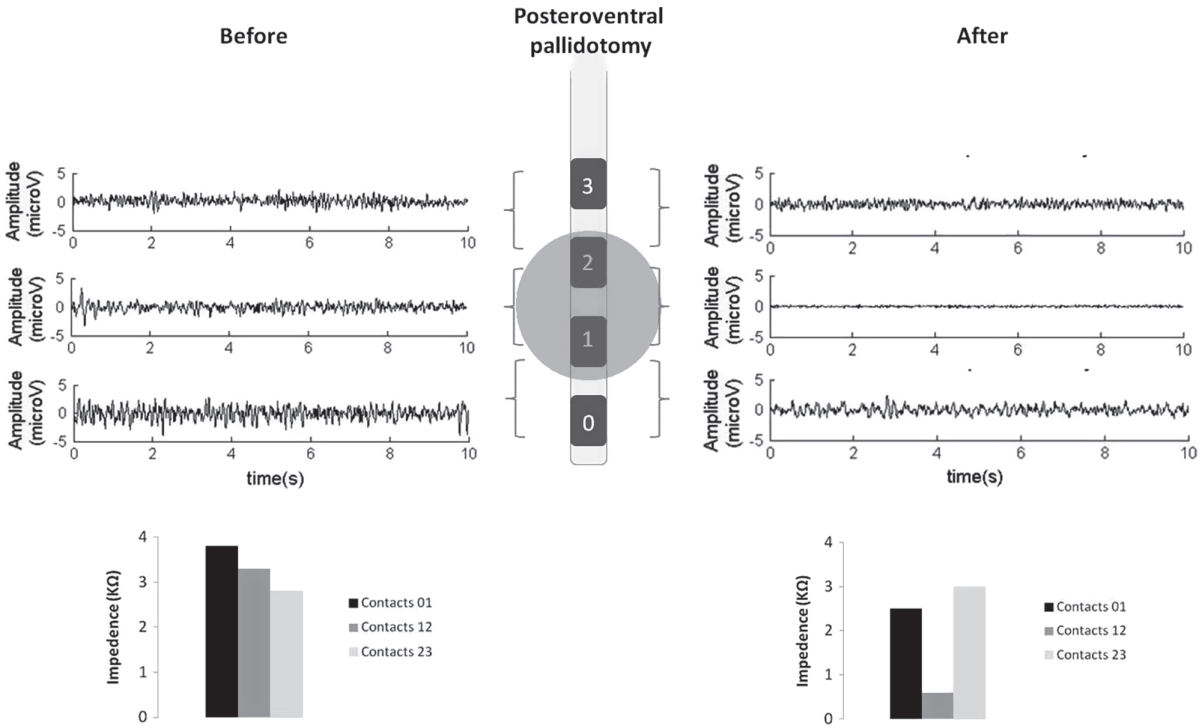

Fig. 1. Top panel: LFPs recorded from right DBS macroelectrode before (on the left) and after (on the right) posteroventral pallidotomy. The gray sphere represents the bipolar RF lesion area (contact 1–2). The recordings show LFP 10 s long, raw traces from different contact pairs: from bottom to top, respectively, 0–1, 1–2, 2–3. On the x-axis the time (s) and on the y-axis the signal amplitude (μV). Bottom panel: Histograms that represent impedance values on different contact pairs before (on the left) and after (on the right) posteroventral pallidotomy. On the x-axis the three recording contact pairs (0–1, 1–2, and 2–3) and on the y-axis the impedance values (KΩ) are represented. Note that the LFP amplitude and the macroelectrode impedance values were reduced after posteroventral pallidotomy in all recorded contact pairs with values strongly reduced for 1–2 contact pair.

leads has been previously reported,[3] this paper describes the effectiveness and use of the LFPs sampled through DBS electrodes as an electrophysiological demonstration of pallidotomy effects. This methodology has allowed us to monitor and optimize the effects of acute or staged RF lesions and has enhanced the study of the relationship between modifications of the LFP's at the target with the clinical responses. Additionally, it was determined that DBS electrodes could be left in place that would allow further lesions after months or years from the first procedure.[3]

LFP recordings from the DBS led to the following advantages: (1) the objective proof of the lesion at the target before clinical evidence; (2) the objective proof of the selectivity of the induced lesion which is limited to a discrete pool of neurons that was suggested by the marked flattening of electrical activity between the contacts that were used to perform the lesions versus the activity recorded from the adjacent ones (Fig. 1); and (3) the repeatability of the procedure, given that the intracerebral electrodes were left in place and were tunnelled through the skin of the vertex region, that eventually could be re-connected to the external cables for further lesions, depending on the clinical conditions of the patient. The decrease of impedance recorded from the contacts utilized for the bipolar RF coagulation confirms the safety of the procedure which thus appears to be self-limiting. In other words, when impedance between the anode and cathode falls near zero, no more current passes through the tissue and the thermal effect disappears. Thus, the selective decrease in both the amplitude and impedance in LFP contacts, along with knowledge from *in vitro* studies demonstrating how RF lesions by means of DBS electrode had a mean length extent of 5 mm at 40 V in egg white and brain cadavers,[3] assessed the magnitude of the lesion. It must be noted that the correct placement of the implanted DBS leads should be checked by merging the MR and post-operative CT images (as in our case) before performing the lesion. This may be an advantage for neurosurgeons who cannot perform intra-operative CT scans to check the target in real time before the pallidotomy is performed. Nevertheless, post-operative CT scans are not meaningful to show the entity of the lesion due to the artifacts caused by the presence of the DBS leads. Moreover, MRI cannot be performed in patients harboring an open electrical circuitry (intracranial leads with free subgaleal ending not connected to the implanted pulse generator or IPG). Thus, LFP recordings and clinical responses measured the extent of the lesion. In conclusion, the described technique appears to be safe, cost effective, and associated with favorable clinical outcomes. Thus, it renews interest in pallidotomy that is reserved for selected patients.

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