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Case Report

A Case Report of Multitrack Recording of Posterior Subthalamic Nucleus, Caudal Zona Incerta, and Prelemniscal Radiation: Which Is Most Effective for Bradykinesia?

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Deep brain stimulation (DBS) of the posterior subthalamic nucleus (pSTN), caudal zona incerta (cZI), and prelemniscal radiation (Raprl) has been shown to improve Parkinsonian motor symptoms. We herein report neurophysiological and functional differences among the cZI, Raprl, and pSTN in a 68-year-old male patient with Parkinson's disease (PD). The stereotactic implantation of DBS electrodes in the right STN was performed. Thereafter, a transfrontal trajectory for the left cZI was planned for left side implantation, with the expectation that the electrode entered the pSTN in the case of a posterior brain shift. In the implantation of the DBS lead in the cZI, three microelectrodes were simultaneously placed in an array with the central, medial, and anterior positions placed 2 mm apart to delineate the cZI, Raprl, and pSTN, respectively. A maximal reduction in bradykinesia was obtained from the stimulation of the pSTN at the lowest voltage thresholds, and the voltage threshold for abolishing tremors was lower in the Raprl and cZI than in the pSTN. The left DBS lead was implanted in the pSTN because right-sided bradykinesia was more severe than tremor. The multitrack recording of cZI, Raprl, and pSTN might broaden target selection depending on patients' symptoms.

Keywords: deep brain stimulation, caudal zona incerta, Parkinson's disease, micro-recording

Introduction

Previous study reported that posterior portion of the subthalamic nucleus (pSTN) is the useful target of deep brain stimulation (DBS) for the treatment of Parkinson's disease (PD).[1)] Recently, caudal zona incerta (cZI)–DBS and prelemniscal radiation (Raprl)–DBS have also been shown to improve Parkinsonian motor symptoms.[2–5)] Anatomically, cZI is located behind STN,[3,4)] while Raprl is located 2 mm medial to cZI.[2,5)] We herein report functional differences among cZI, Raprl, and pSTN in a patient with PD, using multitrack recording of each region.

Case Report

A 68-year-old right-handed man with a 9-year history of PD requested bilateral STN–DBS before the age of 70 years. He had been treated with L-dopa/carbidopa, entacapone, cabergoline, amantadine, and zonisamide, and the levodopa equivalent daily dose (LEDD) was 612 mg. Preoperatively, the Movement Disorder Society Unified Parkinson's Disease Rating Scale (MDS-UPDRS) during OFF-medication was as follows: IA, 3; IB, 8; II, 22; III, 39; IV, 0. MRI revealed mild brain atrophy (Fig. 1a).

Bilateral STN–DBS was planned using the MRI/CT imaging fusion software BrainLAB system (Brainlab, Feldkirchen, Germany). The surgery was performed in the position of 10° head elevation. After right side implantation of the DBS electrodes 3389 (Medtronic, Minneapolis, MN, USA), the risk of posterior brain shift needed to be considered due to leakage of cerebrospinal fluid. In addition, the patient mainly suffered from bradykinesia and tremor, which can be improved by cZI–DBS.[3)] Therefore, the left-side target was changed to cZI (13 mm lateral, 6 mm posterior, and 4 mm inferior to the mid-commissure point, 30° relative to the midline plane, 60° relative to the AC–PC plane) with the expectation that the electrode entered pSTN in the case of a posterior brain shift. Three microelectrodes were simultaneously placed in an array with central, medial, and anterior positions placed 2 mm apart to delineate the cZI, Raprl, and pSTN, respectively (Fig. 1b). Right hand tremors stopped immediately after the microelectrode passed 10 mm above the target, suggesting that the microelectrodes passed through the ventral intermediate nucleus. At 7–9 mm above the target, thalamic activity was recorded from the central electrodes. At 5 mm above the target, typical STN activity was recorded from the anterior electrode. At the same level, a "rhythmic" firing pattern, which has been reported to be one of the firing characteristics of ZI,[6)] was recorded from the central electrode. The medial electrode passed through a relatively quiet region of typical Raprl.[5)] A stimulation through each microelectrode was performed at 1 mm below the level of the superior border of STN. The stimulus parameters were a pulse duration of 60 μs, frequency

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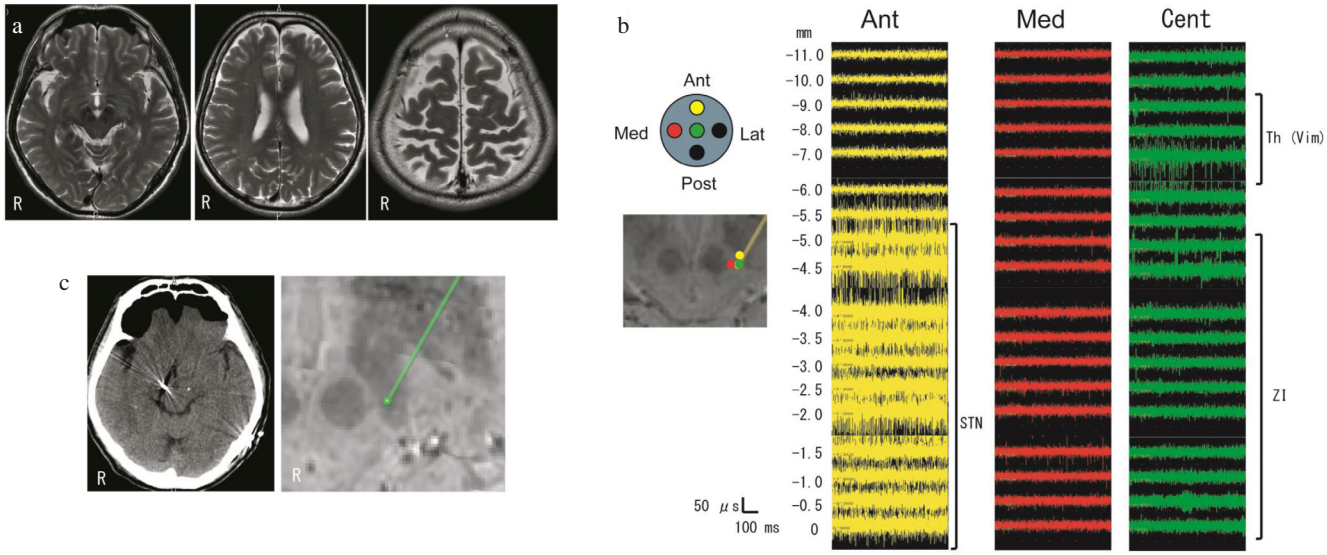

Fig. 1 (a) Preoperative MRI revealed mild brain atrophy. (b) The location of tips of central, anterior, and medial electrodes. The central, anterior, and medial electrodes are supposed to be inserted within cZI, pSTN, and Raprl respectively. The microelectrode recording of each electrode. At 7–9 mm above the target, thalamic activity was recorded from the central electrodes. At 5 mm above the target, STN activity was recorded from the anterior electrode. (c) Postoperative CT and preoperative MRI fused with postoperative CT. Postoperative CT showed pneumocepahlus. Preoperative MRI fused with postoperative CT revealed that the left electrode was placed in the posterior STN. Ant: anterior, Cent: central, Lat: lateral, Med: medial, Post: posterior, STN: subthalamic nucleus, Th: thalamus, Vim: ventral intermediate nucleus, ZI: zona incerta.

of 130 Hz, and stimulus amplitude ranging between 0.1 and 5 mA. A stimulation through all three electrodes decreased tremors, rigidity, and bradykinesia with a stimulus amplitude of ≤2 mA. No adverse effect was observed with stimulation of ≤4 mA. A maximal reduction in bradykinesia was obtained from pSTN stimulation at the lowest voltage thresholds (1 mA). In contrast, the threshold for abolishing tremors was lower (1 mA) in Raprl and cZI than in pSTN (2 mA). We decided to implant the DBS electrodes 3389 in left pSTN because right-sided bradykinesia was more severe than tremor. Postoperative CT showed pneumocepahlus, and preoperative MRI fused with postoperative CT revealed that the left electrode was placed in the posterior STN (Fig. 1c). Three months after surgery, the stimulation parameters of both STN–DBS were 130 Hz, 60 μs, and 1.5 V. The LEDD was 390 mg. Bilateral STN–DBS improved Parkinsonian symptoms, but right hand tremor slightly persisted. MDS-UPDRS scores during OFF-medication/ON-DBS were as follows: IA, 1; 1B, 4; II, 11; III, 11; IV, 0.

Discussion

In this case, the effects of stimulating pSTN, cZI, and Raprl on Parkinsonian motor symptoms differed. The threshold for ameliorating tremors was lower in cZI and Raprl than in pSTN, while the threshold for bradykinesia was the lowest in pSTN. The stimulation of cZI and Raprl exerted greater effects on tremor than pSTN, which may have been due to stimulation to the dentato-rubro-thalamic tract. Although Plaha et al. reported that cZI–DBS improved bradykinesia more than STN–DBS, the efficacy of cZI stimulation was not compared with STN stimulation in individual patients. In addition, it is important to note that previous studies identified cZI on T_2-weighted MRI images.[3,4] Dormont et al.[7] reported that the posterior tail of the STN was not visible on T_2-weighted MRI images in most cases, and intraoperative physiological mapping is necessary to distinguish cZI from pSTN. Our method enable to identify pSTN, cZI, and Raprl, and also select the best target for an individual patient.

Furthermore, this approach may be useful especially in elderly patients with atrophic brains because cerebrospinal fluid loss during DBS surgery could cause a posterior brain shift.[8] Since the most common approach targets the center of STN, a posterior brain shift may result in the inappropriate placement of an electrode in the anterior STN. Therefore, trajectory to cZI could lead the electrode to pSTN in the case of a posterior brain shift. This approach with an additional lateral or medial electrode could deal with wide range of brain shift, and may be a versatile method to treat PD patients with atrophic brain. Though we need to accumulate more cases to confirm the conclusion, our method might be a useful approach for choosing the appropriate target and dealing with the brain shift.

Conflicts of Interest Disclosure

The authors have no disclosures to declare.

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