

## ORIGINAL ARTICLE

# Can Postural Instability Respond to Galvanic Vestibular Stimulation in Patients with Parkinson's Disease?

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## ABSTRACT

**Objective** Galvanic vestibular stimulation (GVS) activates the vestibular afferents, and these changes in vestibular input exert a strong influence on the subject's posture or standing balance. In patients with Parkinson's disease (PD), vestibular dysfunction might contribute to postural instability and gait disorders.

**Methods** Current intensity was increased to 0.7 mA, and the current was applied to the patients for 20 minutes. To perform a sham stimulation, the current intensity was increased as described and then decreased to 0 mA over the course of 10 seconds. The patient's status was recorded continuously for 20 minutes with the patient in the supine position.

**Results** Three out of 5 patients diagnosed with PD with postural instability and/or abnormal axial posture showed a reduction in postural instability after GVS. The score for item 12 of the revised Unified Parkinson's Disease Rating Scale part 3 was decreased in these patients.

**Conclusions** The mechanism of postural instability is complex and not completely understood. In 2 out of the 5 patients, postural instability was not changed in response to GVS. Nonetheless, the GVS-induced change in postural instability for 3 patients in our study suggests that GVS might be a therapeutic option for postural instability.

**Key Words** Parkinson; Galvanic vestibular stimulation; Vestibular stimulation; Postural instability; Vestibular dysfunction; Posture.

Galvanic vestibular stimulation (GVS) involves transcranial direct current stimulation, which stimulates and inhibits the vestibular afferents on the side of the negative (cathode) and positive (anode) electrodes.<sup>1,2</sup> These changes in vestibular input exert a strong influence on the subject's posture<sup>3-5</sup> and standing balance.<sup>6</sup> More recently, we reported that the severity of a bending posture was diminished by GVS.<sup>3</sup> Here, to determine whether the postural instability improves after GVS, we studied 5 patients with Parkinson's disease (PD) that presented with a lateral trunk flexion or a camptocormia and that had postural instabil-

ity, as defined by a score of 3 on item 12 of the revised Unified Parkinson's Disease Rating Scale (UPDRS) part 3.<sup>7</sup>

## MATERIALS & METHODS

All 5 patients fulfilled the UK Parkinson's Disease Society Brain Bank criteria.<sup>8</sup> Two patients had mild lateral trunk flexion, and the other three patients had camptocormia. No patient had a history of neurosurgery or otorhinolaryngeal illness.

Binaural monopolar GVS was performed using devices de-

Received: July 30, 2015 Revised: September 5, 2015 Accepted: September 25, 2015

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scribed previously (Chattanooga Intellect Advanced Combo, DJO Global, Vista, CA, USA).<sup>3,4</sup> In patients with a lateral trunk flexion, binaural bipolar GVS was used, i.e., a 10.2-cm<sup>2</sup> cathode electrode was located ipsilateral to the lateral trunk flexion, and a 10.2-cm<sup>2</sup> anode electrode was located on the contralateral side. In the patient with a camptocormia, pairs of 10.2-cm<sup>2</sup> cathode and anode electrodes were placed over both mastoid processes and trapezius muscles. The current intensity was increased to 0.7 mA, and the current was applied for 20 minutes with the patient in the supine position. For the sham stimulation, the first procedure was same, but the current intensity was subsequently ramped down to 0 mA over the course of 10 seconds, and this status was continued for 20 minutes. Either one of these procedures was randomly assigned to each

patient. At the same time, 1 week after the initial procedure the other procedure was performed again in the same patient. Neurologists who were blind to all clinical information and the status of GVS performed a pull test according to item 12 of the revised UPDRS part 3.<sup>7</sup> Briefly, the examiner instructed the patient to stand erect with eyes open and feet comfortably apart and parallel to each other. There was a solid wall at least 1 to 2 meters behind the examiner. The examiner informed the patient of testing process and explained that the patient was allowed to take a step backwards to avoid falling. First, the examiner then delivered a quick, forceful pull on the shoulders of the patient. The pull is purposely mild and not rated. Second, the shoulders were pulled briskly and forcefully towards the examiner. The pull test was performed approximately

**Table 1.** Clinical features of 5 patients with Parkinson's disease

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
Age/sex	69/F	73/F	66/F	63/M	72/F
Disease duration (years)	4.5	7	14	10.5	20
Hoehn-Yahr stage	3	4	4	3	3
UPDRS part 3	34	32	13	18	30
Onset's feature	Left tremor	Right tremor	Gait difficulty	Akinesia	Right tremor
History of hallucinations	-	+	-	-	+
History of falls	-	+	+	+	+
Wearing-off	-	+	+	-	+
Dyskinesia	-	-	-	-	-
Lumbago pain	-	-	+	+	+
Abnormal posture	LTF	LTF	Cam	Cam	LTF
Duration of the abnormal posture (m)	11	9	6.9 years	2 years	4 years
Daily treatment during the study (dose/d)					
Levodopa	300 mg	200 mg	550 mg	300 mg	200 mg
Pramipexole	1.5 mg	1.5 mg	3 mg	-	1.5 mg
Ropinirole	-	-	-	6 mg	-
Bromocriptine	-	-	5 mg	-	-
Selegiline	-	-	-	2.5 mg	-
Trihexyphenidyl	-	6 mg	2 mg	-	6 mg
Amantadine	-	150 mg	-	-	150 mg
Entacapone	-	200 mg	-	100 mg	200 mg
Zonisamide	-	-	-	25 mg	-
Istradefylline	-	40 mg	-	-	40 mg
Neuroleptics	-	Rivastigmine (18 mg/d), quetiapine (12.5 mg/d)	-	-	-
First stimulation	Sham	GVS	GVS	GVS	Sham
UPDRS part 3, item 12					
Before GVS stimulation	3	3	3	3	3
After GVS stimulation	0	1	0	3	3
Postural abnormality					
Before GVS stimulation (degree)	5.94	2.31	49.70	57.49	5.82
After GVS stimulation (degree)	6.18	3.01	46.90	55.25	3.86

UPDRS: Unified Parkinson's Disease Rating Scale, LTF: lateral trunk flexion, Cam: camptocormia, GVS: galvanic vestibular stimulation, Sham: sham stimulation, m: months, d: day.

10 minutes after the stimulation. All of the patients were completely aware and understood the proceedings, as confirmed by personal interviews. The score for item 12 of the revised UPDRS part 3<sup>7</sup> was determined before and after GVS. The average anterior and lateral bending angles while the patient was standing with their eyes open for 30 s were measured as described previously.<sup>3</sup> For the postural evaluation, the patients were instructed to stand comfortably with their feet 10 cm apart and with their arms along their trunk. To evaluate the anterior and lateral bending angles, we captured the patients' sagittal and frontal posture using two digital video cameras and conducted a frame-by-frame video analysis. The anterior and lateral bending angles were calculated as the angles formed between the line joining the marker positioned on the C7 spinous process and the mid-points of the right and left posterior superior iliac spine, and the vertical reference lines in the sagittal and frontal planes. The values were calculated every 30 frames and then averaged. The protocol of this study was approved by the Medical Ethics Committee of Nara Medical University and Kio University, and written informed consent was obtained from all subjects.

## RESULTS

Postural instability retropulsion was evident both before and after sham stimulation in patient 1, 2, and 3. After true GVS, the frequency of the retropulsion decreased in patient 1, 2, and 3, and the score for item 12 of the revised UPDRS part 3<sup>7</sup> at the time of the highest postural instability changed from 3 to 0 in patient 1, 3 to 1 in patient 2, and 3 to 0 in patient 3 (Supplementary Video in the online-only Data Supplement). Detailed clinical information on the patients is shown in Table 1. In the other 2 patients, the severity of postural instability was unchanged after true GVS. The average lateral bending angles in patients 1 and 2 did not decrease, and the average anterior bending angle in patient 3 was mildly decreased. The other 2 patients showed mildly decreased lateral bending angles.

## DISCUSSION

Our three patients showed a reduction in postural instability after GVS. Patients with PD have pro-

cessing abnormalities in sensorimotor integration and organization that affect postural stability.<sup>9</sup> Postural stability depends on the appropriate integration of not only visual and somatosensory input but also vestibular information.<sup>10</sup> In patients with PD, vestibular disorders have been reported.<sup>4,11</sup> Several studies have investigated the relationship between vestibular dysfunction and postural instability and found that vestibular dysfunction was unrelated to postural deficits in patients with mild or moderate PD.<sup>12</sup> However, patients with PD have an abnormal vestibulocolic reflex and an impaired vestibulo-ocular reflex, which suggests that vestibular dysfunction contributes to postural instability and gait disorders.<sup>10</sup> Yamamoto et al.<sup>13</sup> reported that axial motor function was improved after stimulation of vestibular nerves by GVS in patients with parkinsonism. The vestibular dysfunction was ipsilateral to the lateral trunk flexion with PD, and dysfunction of vestibular control related to posture might be responsible for postural instability in PD,<sup>4</sup> but the severity of the lateral trunk flexion or camptocormia in our patients was apparently not reduced after GVS.

The vestibular afferent fibers send axons to the cerebellar vermis via the vestibular nuclei,<sup>14,15</sup> which exerts a strong effect on the turnover of dopamine in the caudate and nucleus accumbens through the ventral tegmental area.<sup>16,17</sup> GVS activates the vestibular afferents, and the vestibular nerves influence the basal ganglia and limbic system<sup>16,17</sup> via the cerebellar vermis.<sup>14,15</sup> Positron emission tomographic studies in humans have shown activation in the putamen in response to vestibular stimulation.<sup>18,19</sup> In addition, vestibular afferents project to the basal ganglia, and outputs from the basal ganglia are directed to the brain stem, including the pedunculopontine nucleus and spinal cord.<sup>20</sup> GVS may activate these extrapyramidal connections through the vestibular nerves, leading to increased axial motor function and improving postural instability.

One limitation of this study is that part 3 alone of the pull test of the revised UPDRS is not enough to objectively quantify the magnitude of improvement in postural instability because of its poor test-retest reliability. A second limitation was the small sample size.

The mechanism of postural instability is complex and not completely understood. In fact, although 3 patients did respond to GVS, the postural instability

of 2 other patients did not respond. However, the positive responses of those 3 patients suggest that GVS might be a therapeutic option for postural instability.

### Supplementary Materials

The online-only Data Supplement is available with this article at <http://dx.doi.org/10.14802/jmd.15030>.

### Conflicts of Interest

The authors have no financial conflicts of interest.

### Acknowledgments

We are extremely grateful to Dr. Kazuma Sugie and Dr. Mari Terashima (Department of Neurology, Nara Medical University) for providing the subjects for the present study.

This research was supported by the Grant-in-Aid for Young Scientists B (25750246).

### REFERENCES

- Minor LB, Goldberg JM. Vestibular-nerve inputs to the vestibulo-ocular reflex: a functional-ablation study in the squirrel monkey. *J Neurosci* 1991;11:1636-1648.
- Goldberg JM, Smith CE, Fernández C. Relation between discharge regularity and responses to externally applied galvanic currents in vestibular nerve afferents of the squirrel monkey. *J Neurophysiol* 1984;51:1236-1256.
- Okada Y, Kita Y, Nakamura J, Kataoka H, Kiriya T, Ueno S, et al. Galvanic vestibular stimulation may improve anterior bending posture in Parkinson's disease. *Neuroreport* 2015;26:405-410.
- Vitale C, Marcelli V, Furia T, Santangelo G, Cozzolino A, Longo K, et al. Vestibular impairment and adaptive postural imbalance in parkinsonian patients with lateral trunk flexion. *Mov Disord* 2011;26:1458-1463.
- Okada Y, Kita Y, Nakamura J, Tanizawa M, Morimoto S, Shomoto K. Galvanic vestibular stimulation for camptocormia in Parkinson's disease: a case report. *J Nov Physiother* 2012;S1-001.
- Tax CM, Bom AP, Taylor RL, Todd N, Cho KK, Fitzpatrick RC, et al. The galvanic whole-body sway response in health and disease. *Clin Neurophysiol* 2013;124:2036-2045.
- Goetz CG, Tilley BC, Shaftman SR, Stebbins GT, Fahn S, Martinez-Martin P, et al. Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS): scale presentation and clinimetric testing results. *Mov Disord* 2008;23:2129-2170.
- Hughes AJ, Daniel SE, Kilford L, Lees AJ. Accuracy of clinical diagnosis of idiopathic Parkinson's disease: a clinicopathological study of 100 cases. *J Neurol Neurosurg Psychiatry* 1992;55:181-184.
- Benatru I, Vaugoyeau M, Azulay JP. Postural disorders in Parkinson's disease. *Neurophysiol Clin* 2008;38:459-465.
- Vaugoyeau M, Viel S, Assaiante C, Amblard B, Azulay JP. Impaired vertical postural control and proprioceptive integration deficits in Parkinson's disease. *Neuroscience* 2007;146:852-863.
- Pollak L, Prohorov T, Kushnir M, Rabey M. Vestibulocervical reflexes in idiopathic Parkinson disease. *Neurophysiol Clin* 2009;39:235-240.
- Pastor MA, Day BL, Marsden CD. Vestibular induced postural responses in Parkinson's disease. *Brain* 1993;116(Pt 5):1177-1190.
- Yamamoto Y, Struzik ZR, Soma R, Ohashi K, Kwak S. Noisy vestibular stimulation improves autonomic and motor responsiveness in central neurodegenerative disorders. *Ann Neurol* 2005;58:175-181.
- Barmack NH. Central vestibular system: vestibular nuclei and posterior cerebellum. *Brain Res Bull* 2003;60:511-541.
- Newlands SD, Perachio AA. Central projections of the vestibular nerve: a review and single fiber study in the Mongolian gerbil. *Brain Res Bull* 2003;60:475-495.
- Albert TJ, Dempsey CW, Sorenson CA. Anterior cerebellar vermal stimulation: effect on behavior and basal forebrain neurochemistry in rat. *Biol Psychiatry* 1985;20:1267-1276.
- Anderson CM, Polcari A, Lowen SB, Renshaw PF, Teicher MH. Effects of methylphenidate on functional magnetic resonance relaxometry of the cerebellar vermis in boys with ADHD. *Am J Psychiatry* 2002;159:1322-1328.
- Bottini G, Paulesu E, Sterzi R, Warburton E, Wise RJ, Vallar G, et al. Modulation of conscious experience by peripheral sensory stimuli. *Nature* 1995;376:778-781.
- Bottini G, Sterzi R, Paulesu E, Vallar G, Cappa SF, Erminio F, et al. Identification of the central vestibular projections in man: a positron emission tomography activation study. *Exp Brain Res* 1994;99:164-169.
- Visser JE, Bloem BR. Role of the basal ganglia in balance control. *Neural Plast* 2005;12:161-174; discussion 263-272.

## **Supplementary Video Legends**

Videos A and B were obtained before and after true galvanic vestibular stimulation, and videos C and D were obtained before and after sham stimulation. The severity of the postural instability was reduced after true galvanic vestibular stimulation (B), but not after sham stimulation (D).