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ORIGINAL ARTICLE

Impaired Food Transportation in Parkinson's Disease Related to Lingual Bradykinesia

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Abstract This study aimed to analyze quantitatively videofluoroscopic (VF) images of patients with Parkinson's disease (PD), to evaluate if the predicted factors of the oral phase of swallowing deteriorated with PD progression, and to demonstrate a relationship between the abnormal movements of the tongue and food transportation. Thirty PD patients were recruited and divided into mild/moderate (Hoehn & Yahr stages II and III) and advanced (stages IV and V) groups. They underwent measurement of tongue strength and VF using 5 ml of barium gelatin jelly as a test food. We measured the speed of bolus movement and the range of tongue and mandible movements during oropharyngeal transit time. The maximum tongue pressure of the mild/moderate group was significantly larger than that of advanced group ($p = 0.047$). The oropharyngeal transit time of the mild/moderate group was significantly shorter than that of the advanced group ($p = 0.045$). There was a significant negative correlation between the speed of tongue movement and the oropharyngeal transit time ($p = 0.003$, $R = -0.527$). Prolonged mealtimes and the ejection of insufficiently masticated food from the oral cavity into oropharynx were associated with PD progression. These results indicate the importance of the oral phase of swallowing in PD patients.

Keywords Parkinson's disease · Oropharyngeal transit time · Speed of tongue movement · Tongue bradykinesia · Deglutition · Deglutition disorders

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Parkinson's disease (PD) is one of the most common neurodegenerative disorders. It is characterized by bradykinesia, rigidity, resting tremor, and postural instability. Muscle rigidity and bradykinesia seen in PD are recognized causes of swallowing dysfunction and may lead to aspiration and chest infection. In most PD patients, dysphagia is related to abnormal movements with respect to oropharyngeal dysfunction. In the oral stage in PD patients, related movement abnormalities include labial bolus leakage, deficient or hesitant mastication, lingual tremor, lingual pumping, prolonged lingual elevation, and slowed and limited mandibular excursion [1–4]. Troche et al. [5] assessed the oral function of PD patients using bolus transit time and the number of tongue thrusts using videofluoroscopic (VF) images, but very few studies have quantitatively evaluated tongue and mandibular movements in PD patients.

In 1996, Leopold et al. [1] divided PD patients into mild/moderate and advanced groups using the Hoehn & Yahr disease severity scale. This study indicated that the advanced group had more prepharyngeal abnormalities of ingestion such as jaw rigidity and impaired lingual transfer movements [1]. Ali et al. [2] suggested that neither the presence nor severity of dysphagia correlated with overall disease severity. Oropharyngeal dysphagia in PD is multifactorial and difficult to evaluate, and the relationship between dysphagia and PD progression is obscure.

The aims of the present study were to analyze quantitatively VF images of PD patients, to evaluate if predicted factors in the oral phase deteriorated with PD progression, and to demonstrate a relationship between abnormal movements of the tongue and mandible and food transportation.

Patients and Methods

Participants

We studied 30 patients with idiopathic PD (13 males and 17 females; mean age = 70.4 ± 7.5 years; range = 56–83 years) recruited from the Department of Neurology, Faculty of Medicine, Fukuoka University, and the Department of Neurology, Neuro-Muscular Center, National Omuta Hospital. Clinical assessment of PD severity for each participant was conducted by neurologists in these two hospitals before inclusion in the study. Patients were treated with levodopa, and their medication states were stable through the study period. The measurement of tongue strength and VF examination were done in about 10 min in the on state to avoid the effect of the medications. Patients with other neurologic disorders, neuropsychological dysfunction, head and neck cancer, and those undergoing tube feeding were excluded. The study was approved by the ethics committees of Fukuoka University and National Omuta Hospital and informed consent was obtained from all participants.

Participants were divided into a mild/moderate group (Hoehn & Yahr stages II and III; 6 males and 9 females; mean age = 70.3 ± 7.5 years; range = 56–83 years) and an advanced group (Hoehn & Yahr stages IV and V; 7 males and 8 females; mean age = 70.6 ± 7.6 years; range = 56–83 years). There was no significant difference in the total levodopa equivalent daily dose (LED) between these two groups ($p = 0.578$) (mild/moderate group: mean dose, 370.4 ± 210.4 mg/day; advanced group: mean dose, 330.3 ± 177.1 mg/day) and two patients had used anticholinergics.

Measurement of Tongue Strength

Tongue pressure was measured using a handy probe [6] consisting of a small balloon and pressurized with air at 19.6 kPa. Participants were asked to compress the balloon onto the palate for approximately 7 s using maximum voluntary effort of the tongue. Increase in the inner pressure of the balloon was measured as tongue pressure. This test was repeated three times and mean values were obtained.

VF Examination

Swallowing function was evaluated using a modified barium swallow procedure with VF imaging [7]. It was videotaped on a SVHS tape recorder that ran at 30 frames/s. Each participant swallowed 5 ml each of barium and barium gelatinous jelly while in the lateral upright position. Recordings were analyzed frame-by-frame and scored based on the VF dysphagia scale with a sum of 100 (Table 1) [8]. Oropharyngeal transit time and the tongue and mandible movements were studied.

Measurements of bolus transit and movements of the tongue and mandible were completed by analyzing recordings of swallow trials frame-by-frame or in slow motion using movement analysis software in two dimensions (Dipp-Motion Pro, Ditect, Tokyo, Japan).

To evaluate tongue movement, the movement of the point where the tongue line and the mandible line intersected was calculated on the Y axis based on two optional points on cervical vertebrae (Fig. 1). To evaluate mandibular movement, the movement of the most inferior point of the mandible on the X axis was measured. Values of the evaluation were divided by the values of oropharyngeal transit time, which was taken as a measure of the speed of tongue and mandibular movements.

Data Analysis

Unpaired t tests were used to compare data of the two groups with regard to maximum tongue pressure, oropharyngeal transit time, and the speed of tongue and mandibular movements. The Mann–Whitney U test was used for data of the total oral and pharyngeal phase scores. Pearson's correlation coefficient was used to measure linear relationships between maximum tongue pressure, oropharyngeal transit time, and the speed of tongue and mandibular movements. Spearman's rank correlation coefficient was used to measure linear relationships between the total oral phase score and other data. Statistical data were analyzed using the Statistic Package for Social Science (SPSS) for Windows (SPSS, Inc., Chicago, IL) and $p < 0.05$ was considered significant.

Results

The maximum tongue pressure of the mild/moderate group was significantly larger than that of the advanced group ($p = 0.047$) (Fig. 2). The oropharyngeal transit time of the mild/moderate group was significantly shorter than that of the advanced group ($p = 0.045$) (Fig. 3). The speed of mandibular movement of the mild/moderate group was significantly faster than that of advanced group ($p = 0.047$) (Fig. 4). There was no significant difference between the mild/moderate group and the advanced group with respect to the total oral and pharyngeal phase scores and the speed of tongue movement (Table 2). The tongue

Table 1 Videofluoroscopic dysphagia scale

Parameter	Coded value	Score
Oral phase score		
Lip closure		
Intact	0	4
Inadequate	2	
None	4	
Bolus formation		
Intact	0	6
Inadequate	3	
None	6	
Mastication		
Intact	0	8
Inadequate	4	
None	8	
Apraxia		
None	0	4.5
Mild	1.5	
Moderate	3	
Severe	4.5	
Tongue-to-palate contact		
Intact	0	10
Inadequate	5	
None	10	
Premature bolus loss		
None	0	4.5
<10%	1.5	
10–50%	3	
>50%	4.5	
Oral transit time		
<1.5	0	3
>1.5	3	
Pharyngeal phase score		
Triggering of pharyngeal swallow		
Normal	0	4.5
Delayed	4.5	
Vallecular residue		
None	0	6
<10%	2	
10–50%	4	
>50%	6	
Laryngeal elevation		
Normal	0	9
Impaired	9	
Pyriform sinus residue		
None	0	13.5
<10%	4.5	
10–50%	9	
>50%	13.5	
Coating of pharyngeal wall		
No	0	9
Yes	9	
Pharyngeal transit time		
<1.0 s	0	6
>1.0 s	6	
Aspiration		
None	0	12
Supraglottic penetration	6	
Subglottic aspiration	12	
Total		100

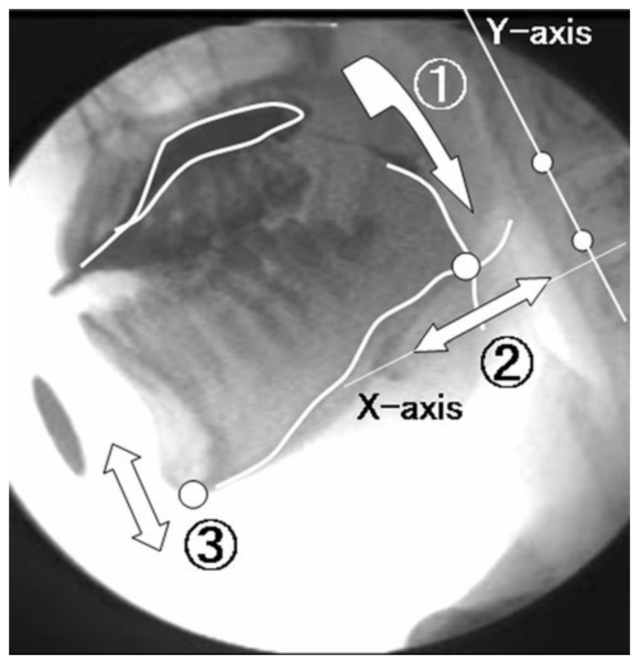

Fig. 1 Analysis of videofluoroscopic images:(*1*) oropharyngeal transit time, (*2*) distance of tongue movement in the *X* axis, (*3*) distance of mandibular movement in the *Y* axis

and chin tremor and drooling were detected in one patient of the mild/moderate group and in five patients of advanced group in these examinations.

There was a significant negative correlation between the speed of tongue movement and the oropharyngeal transit time ($p = 0.003$, $R = -0.527$) (Fig. 5), but there was no significant correlation between the speed of the mandible and the oropharyngeal transit time ($p = 0.137$, $R = -0.278$). There was no significant correlation between maximum tongue pressure and oropharyngeal transit time ($p = 0.305$, $R = -0.214$). There was a significant negative

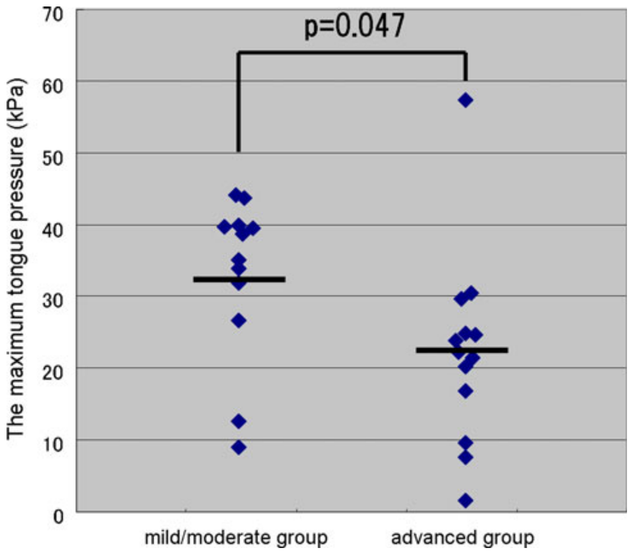

Fig. 2 Comparison of the maximum tongue pressure between the two groups

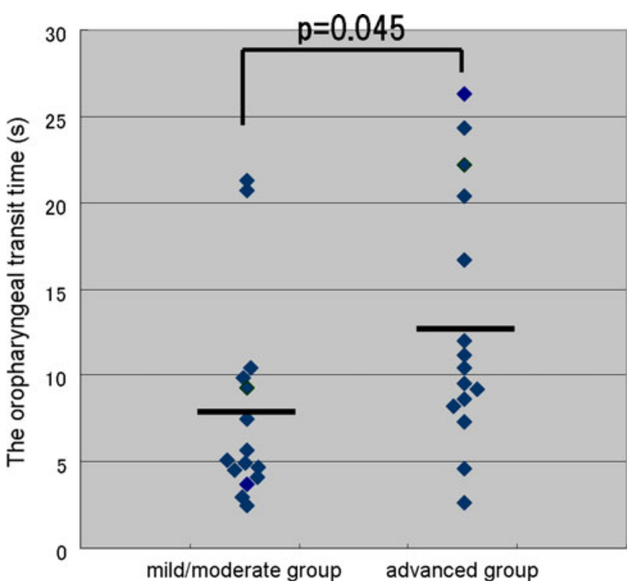

Fig. 3 Comparison of the oropharyngeal transit time between the two groups

correlation between the speed of mandibular movement and total oral phase score ($p = 0.011$, $R = -0.471$) (Fig. 6), but there was no significant correlation between the speed of tongue movement and total oral phase score ($p = 0.124$, $R = -0.286$).

Discussion

The results of Table 2 indicate a tendency for oral functions, especially for the maximum tongue pressure, the oropharyngeal transit time, and the speed of mandibular

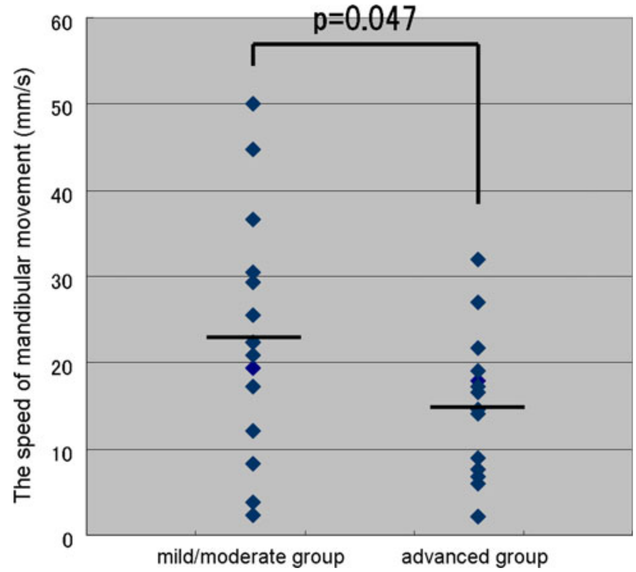

Fig. 4 Comparison of the speed of mandibular movement between the two groups

movement, to deteriorate with the severity of PD. Progression of PD may slow down most mandibular movements, but some patients in the mild/moderate group moved the mandible slowly. Conversely, some patients in the advanced group had fast mandibular movement. The relationship between impairment of oral function and PD progression is obscure, but impairment of oral function is thought to relate restrictively to deterioration caused by PD. The results of the present study are similar to the results of Leopold et al. [1], i.e., the advanced group had more prepharyngeal abnormalities of ingestion, but different from the suggestion of other studies that swallowing variables are not related to PD severity [2, 9]. Statistical differences between the groups with respect to tongue movement may be seen in a larger study population.

The oropharyngeal transit time did not correlate with maximum tongue pressure but did correlate with the speed of tongue movement. A phenomenon that patients with PD cannot gain strength is often noted because of their slow movement, but the slow speed of tongue movement (tongue bradykinesia) in PD patients may impair food transportation in the oral cavity and oropharynx more severely than the low tongue strength in this study. Drooling in patients with PD is caused by swallowing disorder [10], especially impaired transportation or low swallow frequency, but the relationship between drooling and impaired transportation has not been made clear yet. Actually, one third of the patients in the advanced group, which has a longer oropharyngeal transit time, showed tongue and chin tremor and drooling. The tongue and chin tremor might cause the longer oropharyngeal transit time in the advanced group in spite of no significant difference in the speed of tongue movement.

Table 2 Comparison between the mild/moderate group and the advanced group

	Mild/moderate group	Advanced group	*p*
Total oral phase score	8.7 ± 4.6	13.0 ± 6.8	0.053
Total pharyngeal phase score	4.9 ± 4.5	12.5 ± 14.4	0.058
Maximum tongue pressure (kPa)	32.9 ± 11.5	22.3 ± 13.6	0.047*
Oropharyngeal transit time (s)	7.8 ± 5.9	12.9 ± 7.3	0.045*
Speed of tongue movement (mm/s)	15.4 ± 9.2	11.0 ± 7.2	0.156
Speed of mandibular movement (mm/s)	23.0 ± 13.8	14.3 ± 8.8	0.047*

* $p \leq 0.05$

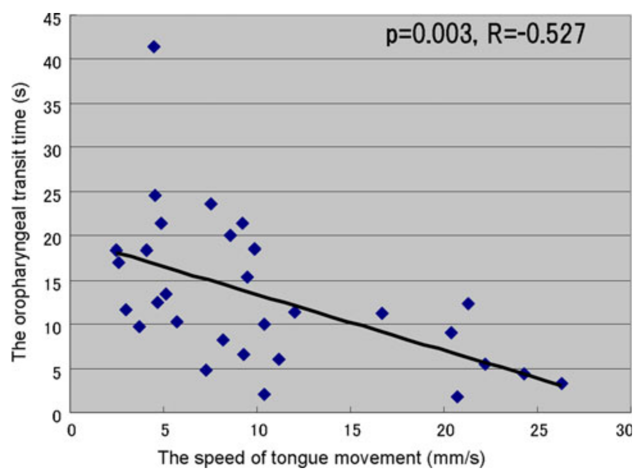

Fig. 5 Distribution and relationship between the oropharyngeal transit time and the speed of tongue movement

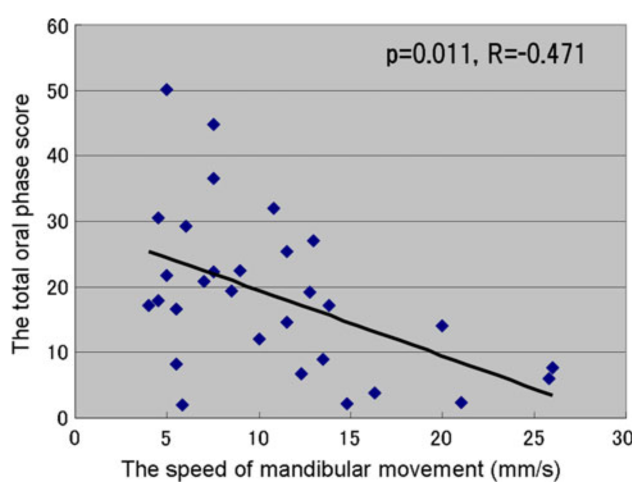

Fig. 6 Distribution and relationship between the total oral phase score and the speed of mandibular movement

The total oral phase score did not correlate with speed of tongue movement but did correlate with the speed of mandibular movement. These findings may result from a trait of the VF dysphagia scale whose many parameters (e.g., bolus formation, mastication, and apraxia) can elicit greater differences from mandibular movement than from tongue movement.

The results of the present study require further investigation because of the small sample size, the intrinsic heterogeneity among PD patients, and the method of analyzing tongue movement, for there are some potential or obvious midline symptoms to greater or lesser degrees, even in patients with the first stage of PD. Although there are some complicated methods for analyzing tongue movement, we analyzed the movement of a point at the back of the tongue using a simple method. Despite the limited analysis of tongue movement, this method was able to evaluate efficiently the ability of the tongue to transfer food from the oral cavity to the oropharynx.

Because there was no significant difference in the total levodopa equivalent daily dose (LED) between the mild/moderate group and the advanced group in this study, we could eliminate the influence from dopaminergic stimulation to discriminate the two groups. Furthermore, the examinations were conducted in about 10 min at the on state to avoid the effect of the medication. Sueli Monte et al. [11] suggested that the oral phase may be more responsive to dopaminergic stimulation, because the oral phase of deglutition is under voluntary control [12] and its alterations are related to rigidity and bradykinesia [3]. However, there is a diversity of views on the effect of dopaminergic agents on the swallowing abnormalities of PD [11, 13].

Nilsson et al. [14] concluded that prolongation of the oropharyngeal transit time is likely to reflect dysfunction caused by rigidity and hypokinesia and that bradykinesia and rigidity affect the motor function of the tongue [15]. VF images in PD patients show residues on the tongue or the anterior and lateral sulci, repeated pumping tongue movement, uncontrolled bolus or premature loss of liquid, and piecemeal deglutition [3]. These findings could be simplified quantitatively by the method used in the present study, which analyzes movement of a point at the back of the tongue.

Oropharyngeal dysphagia in PD is difficult to evaluate because the oral phase of deglutition is under voluntary control [12] and multifactorial. In PD patients, alterations in the oral phase are related to rigidity and bradykinesia [3]. A prolonged mealtime and ejection of insufficiently masticated food from the oral cavity into the oropharynx are associated with PD progression. Therefore, evaluation of the swallowing function during the oral phase of PD and adjusting the diet is important for prevention of aspiration and chest infection.

Conclusion

The maximum tongue pressure, the oropharyngeal transit time, and the speed of mandibular movement in the mild/moderate group were significantly better than those in the advanced group, and there was a significant positive correlation between the speeds of movement of bolus and tongue.

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References

1. Leopold NA, Kagel MC. Prepharyngeal dysphagia in Parkinson's disease. Dysphagia. 1996;11:14–22.
2. Ali GN, Wallace KL, Schwartz R, DeCarle DJ, Zagami AS, Cook IJ. Mechanisms of oral-pharyngeal dysphagia in patients with Parkinson's disease. Gastroenterology. 1996;110:383–92.
3. Nagaya M, Kachi T, Yamada T, Igata A. Videofluorographic study of swallowing in Parkinson's disease. Dysphagia. 1998;13: 95–100.
4. Ertekin C, Tarlaci S, Ayodogdu I, Kiylioglu N, Yuceyar N, Turman AB, Secil Y, Esmeli F. Electrophysiological evaluation of pharyngeal phase of swallowing patients in patients with Parkinson's disease. Mov Disord. 2002;17:942–9.
5. Troche MS, Sapienza CM, Rosenbek JC. Effects of bolus consistency on timing and safety of swallow in patients with Parkinson's disease. Dysphagia. 2008;23:26–32.
6. Hayashi R, Tsuga K, Hosokawa R, Yoshida M, Sato Y, Akagawa Y. A novel handy probe for tongue pressure measurement. Int J Prosthodont. 2002;15:385–8.
7. Logemann JA. Measurement of swallow from videofluorographic studies. In: Logemann JA, editor. Manual for the videofluorographic study of swallowing. 2nd ed. Austin, TX: Pro-Ed; 1993. p. 115–26.
8. Han TR, Paik NJ, Park JW, Kwon BS. The prediction of persistent dysphagia beyond six months after stroke. Dysphagia. 2008;23:59–64.
9. Fuh JL, Lee RC, Wang SJ, Lin CH, Wang PN, Chiang JH, Liu HC. Swallowing difficulty in Parkinson's disease. Clin Neurol Neurosurg. 1997;99:106–12.
10. Nobrega AC, Rodrigues B, Torres AC, Scarper RD, Neves CA, Melo A. Is drooling secondary to a swallowing disorder in patients with Parkinson's disease? Parkinsonism Relat Disord. 2008;14:243–5.
11. Sueli Monte F, da Silva-Junior FP, Braga-Neto P, de Souza MA, de Broin VM. Swallowing abnormalities and dyskinesia in Parkinson's disease. Mov Disord. 2005;20:457–62.
12. Johnston BT, Li Q, Castell JA, Castell DO. Swallowing and esophageal function in Parkinson's disease. Am J Gastroenterol. 1995;90:1741–6.
13. Lim A, Leow L, Huckabee ML, Frampton C, Anderson T. A pilot study of respiration and swallowing integration in Parkinson's disease: "On" and "Off" levodopa. Dysphasia. 2008;23:76–81.
14. Nilsson H, Erberg O, Olsson R, Hindfelt B. Quantitative assessment of oral and pharyngeal function in Parkinson's disease. Dysphagia. 1996;11:144–50.
15. Bushmann M, Dobmeyer SM, Leeker L, Perlmutter JS. Swallowing abnormalities and their response to treatment in Parkinson's disease. Neurology. 1989;39:1309–14.

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