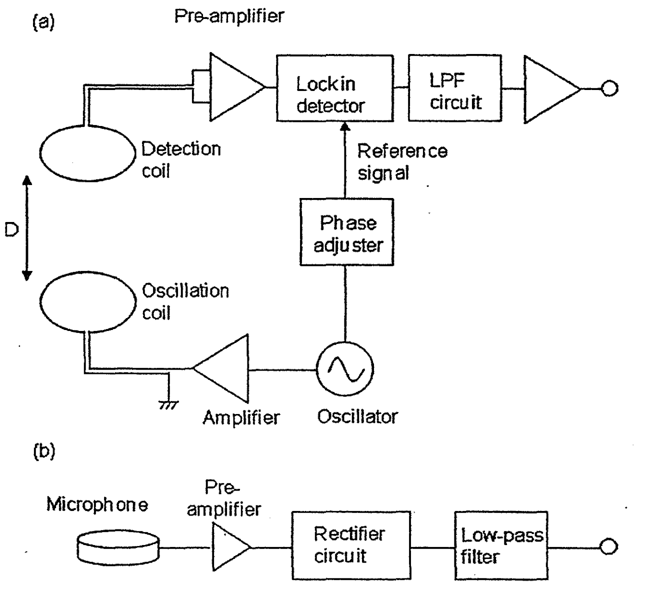

Fig. 1. Block diagram of the magnetic swallowing-detection system. (a) Distance D between two coils is estimated from magnetic-field magnitude. A magnetic field with 20-kHz frequency is generated by the oscillator, and the induced magnetic field is detected by a detection coil and demodulated by a lock-in amplifier. (b) The swallowing sound is detected by a piezoelectric microphone, and the output signal of the detected sound is rectified. The rectified sound passes through a low-pass filter.

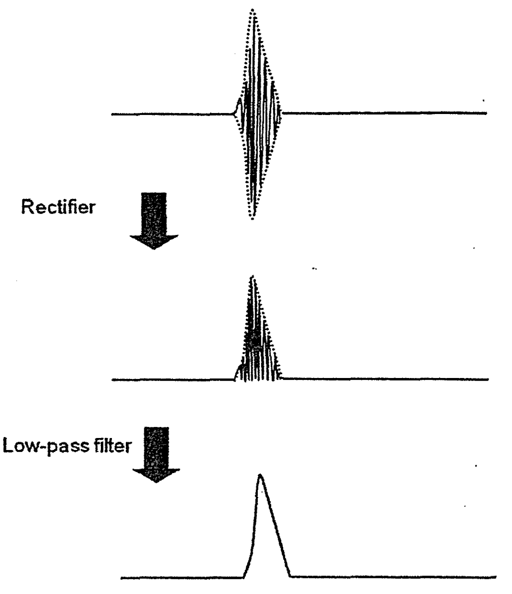

Fig. 2. Block diagram of rectified and low-pass-filtered sound.

B. Magnetic Swallowing-Detection System

The movement of the thyroid cartilage was measured by two coils, whose positions varied according to the rise and fall or the back-and-forth movements of the thyroid cartilage (or both). The swallowing sounds were detected by a piezoelectric microphone placed on the neck of the subject near the coils (Fig. 3).

A coil-length measurement system (Fig. 1(a)) detected the length (D) between the two coils (detection and oscillation), which were set on both ends of the thyroid cartilage (Fig. 1(a)). The principle of the measurement system is explained as follows. The oscillation coil produces a magnetic field with a frequency of 20 kHz, and the inductive voltage in the detection coil is detected in the same manner as a conventional finger-tapping measurement system [16]–[18]. The voltage is demodulated and passed through a low-pass filter (cutoff frequency < 30 Hz). The voltage is converted to D using calibration data measured by the relationship between D and the voltage.

The piezoelectric microphone in the swallowing-sound detection system (Fig. 1(b)) was used to detect only contacting sound without interference noise. The sound voltage detected by the microphone was rectified and passed through a low-pass filter to detect its envelope (as shown in Fig. 2). Detecting the envelope of the sound wave in this manner made it possible to acquire the swallowing sound data using a low sampling frequency (i.e., 100 Hz).

The swallowing-detection system is simply composed of three parts: a holder unit (containing the built-in coils and microphone), a detection-circuit unit, and a personal computer for controlling and recording the detected-sound signal and the measured coil-length voltage (Fig. 3(a)). The holder unit (Fig. 3(b)) is positioned at the front of the neck (Fig. 3(c)). It has two parts: one that maintains the holder shape, and another that holds the two coils against the subject's throat and follows the movement of the thyroid cartilage. This two-part structure makes it possible to attach the holder unit to subjects with different neck sizes.

The coil-length voltage and the swallowing-sound signals are converted from analog to digital format at a sampling rate of 100 Hz. The start time and length of the analog-to-digital sampling are controlled by the PC.

C. Simultaneous Measurements by Videofluorography and Magnetic Swallowing-Detection System

Videofluorography (Sonialvision Plus, Shimazdu Ltd.) was used to measure the swallowing movement of subjects positioned in the lateral position. VF images were recorded by a digital video recorder onto a DVD at 30 frames per second. The subjects drank diluted barium sulfates (10 ml) with water, which were injected into the mouth by a syringe on cue at the start of the VF measurement. Before starting the VF measurement, each subject fitted the holder unit of the magnetic swallowing-detection system themselves, and the holder unit was checked to verify that it did not hinder the recording of VF images.

The holder unit was tapped with a small metal bar, and the tapping sound was detected by the microphone in the magnetic swallowing-detection system. The movement of the metal bar was simultaneously recorded as a shadow in a VF image. These tapping recording data were used to adjust the start timing of the measurements by both the magnetic swallowing-detection system and VF. The tap timings recorded by both systems were detected, and the two measured times were compared.

D. Data Analysis

Two-dimensional positions of the hyoid bone in each VF image were detected, and the movement waveforms (back-and-forth direction (x-axis)) and the rise-and-fall direction (y-axis)) of the hyoid bone were produced by using tracking

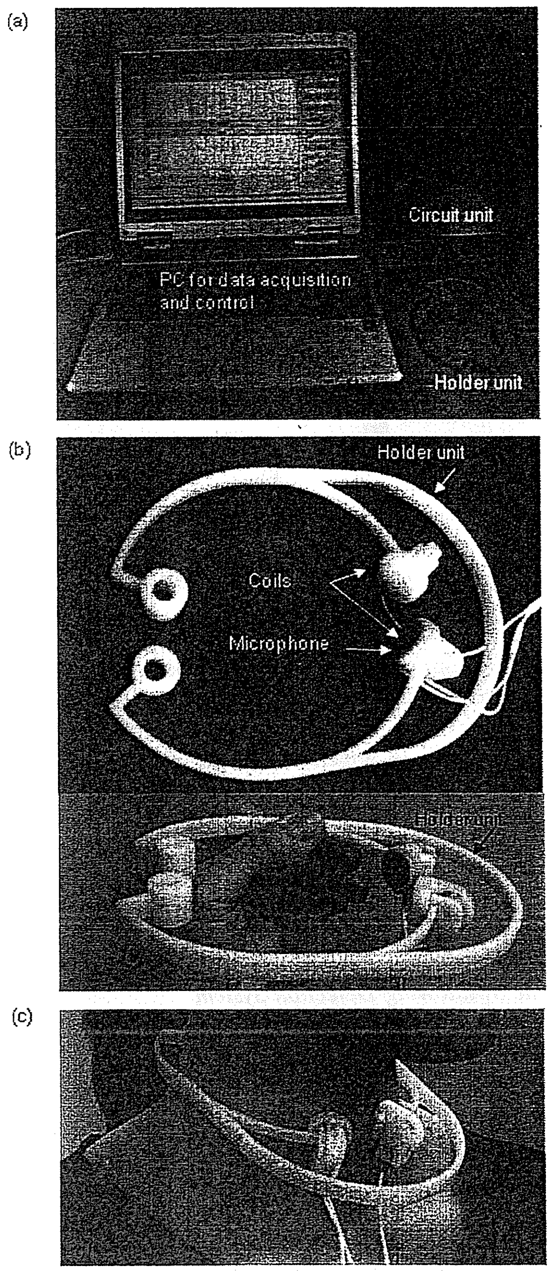

Fig. 3. (a) Photograph of the magnetic swallowing-detection system. The PC controls the circuit unit and collects the detection data. (b) Holder unit: the two coil parts (one contains the microphone) in the holder unit are pressed against the neck to establish good contact. To attain good sound transmission, the microphone is set in the top position in one coil part. (c) Holder unit attached to the neck of a subject.

software ("Move Tr 2D") (Fig. 4). The hyoid-bone-tracking waveforms were resampled at a sampling interval of 10 ms after spline interpolation to adjust the sampling time of the magnetic swallowing-detection system. To determine the position of diluted barium sulfates as they were swallowed, the starting and ending transit times of four fields (oral cavity (OC), upper oropharynx (UOP), valleculae (VAL), and hypopharynx (HYP); see Fig. 6, lower figure, by Saitoh *et al.* [19]) during the swallowing were determined from the VF images. On the other hand, the sound and coil-distance waveforms measured by the

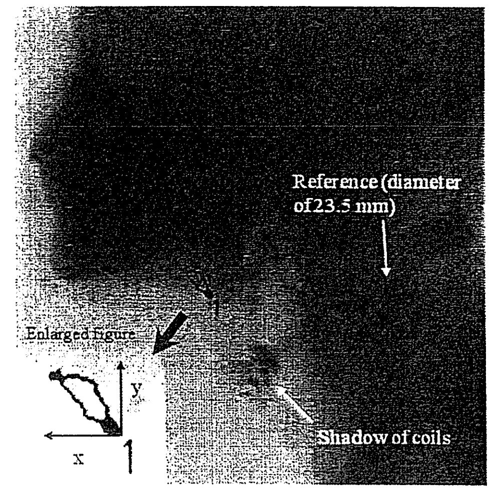

Fig. 4. Sample VF image. A copper coil (with a diameter of 25.5 mm) is positioned at the side of the neck as a reference. The coil shadow, along with the hyoid bone and the bolus, can be clearly seen. From the VF images, the tracking line of the hyoid bone can be detected during swallowing.

magnetic swallowing-detection system were not preprocessed because the sampling rate of the VF waveforms was adjusted to that of the magnetic swallowing-detection system (Fig. 5, upper graph).

After the VF waveforms were preprocessed, the characteristic times (P1, N2, P3, N4, P5, S1, Smax, S2, VF1, VF2, VF3, and VF4, in Fig. 5) in each VF waveform and in each magnetic swallowing-detection waveform were determined visually. To make it easier to understand the typical swallowing-detection waveforms, the amplitude of coil distance and the sound waveforms at times P1, N2, P3, N4, and P5 were also measured. Statistical differences between these times were tested by using the intraclass correlation coefficient (ICC).

III. Results

A. *Typical VF and Magnetic Swallowing-Detection System Waveforms*

The coil-distance waveform had a "W" shape, and the sound waveform had several peaks (Fig. 5). Five characteristic times (start time P1, three peaks in the W-waveform (N2, P3, and N4), and end time P5) could therefore be detected. Because several peaks appeared in the sound waveforms of each subject, only three times (start time S1, peak time Smax, and end time S3) were detected. In the VF waveform, an "x component" of the VF waveform indicated that the hyoid bone moved in a fourth direction and returned to its original position. A "y component" of the VF waveform indicated that the hyoid bone moved in the upper direction and returned to its original position. As for the characteristic times in these VF waveforms, only one time point (peak time VF1) was detected in the x-component, and only two time points (start time VF2 and end time VF3) were detected in the y-component because each subject had a variety of y-component waveforms. The absolute variance of the VF waveforms was calculated from the square root of the x- and

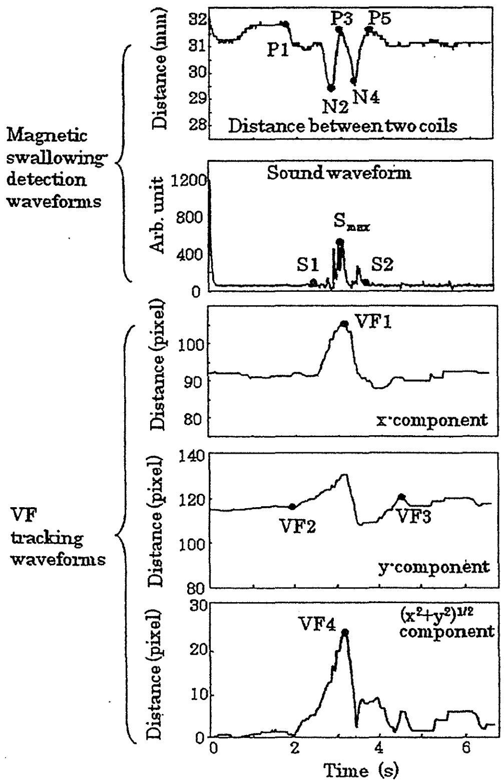

Fig. 5. Typical waveforms recorded by magnetic-swallowing detection and VF tracking. In the distance waveform (top one), five time points (P1, N2, P3, N4, and P5) are detected. Three time points are detected in the corresponding sound waveform. In the VF tracking waveform, a peak VF1 of the x-component, beginning at VF2 and ending at VF3 of the y-component are detected. In the absolute waveform recorded by the VF tracking, the peak time VF4 is detected.

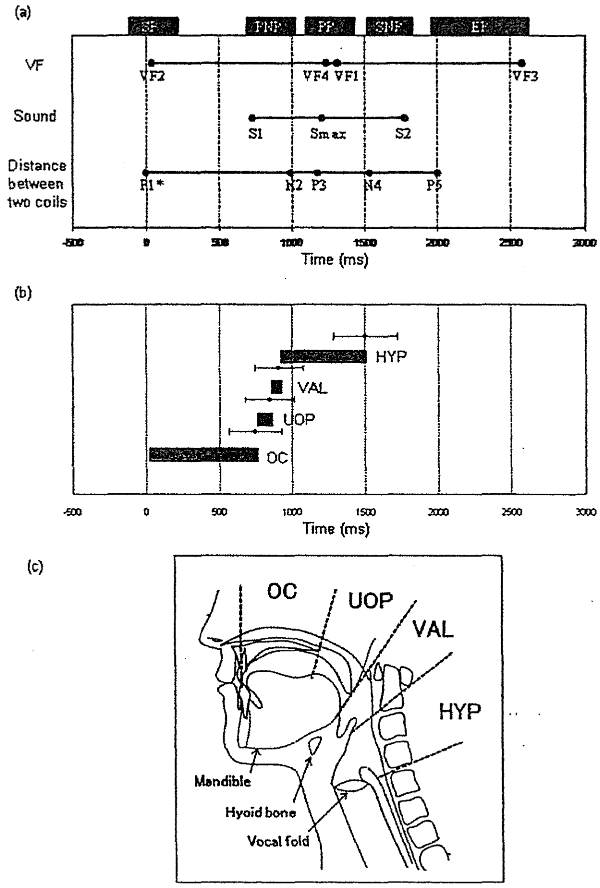

Fig. 6. (a) Characterized average time and standard deviation obtained from each waveform of nine normal controls. (b) Start and end times of swallowing 10 cc of liquid barium in the four fields (OC, UOP, VAL and HYP). The four-field time durations are also indicated as gray bars. (c) Four defined fields.

y-components of the VF waveform, so the peak time (VF4 in the bottom waveform in Fig. 5) could therefore be detected.

B. Time Variance of Swallowing

N2 and S1 at the primary negative peak (PNP) appear at the end of OC and the beginning of UOP and VAL (Fig. 6(a) and (b)). P3, Smax, VF1, and VF4 at the PP appear in the middle of HYP.

Although the ICC for P1 and VF2 in SP could not be calculated because P1 was defined as a standard time (0 s), the average VF2 was 38 ms (Fig. 6(a) and Table I). The four peak times P3, Smax, VF1, and VF4, which indicated the peak HYP time, were high, i.e., ICC > 0.9 (Table I). The ICC for N2 and S1 in PNP was 0.54, and that between N4 and S2 in SNP was 0.68. However, the ICC for P5 and VF3 in EP was 0.1.

C. Mean Coil Distance and Sound Waveforms

The mean coil distance appeared as a W-shaped waveform, and the mean sound waveform showed a one-peak waveform (Fig. 7). The W-shaped waveform means that the coil distance was shortened at N2, widened to the original distance at P3, shortened again at N4, and finally widened to the original distance. This shortening and widening produced the W shape in the detected magnetic-swallowing waveform. Although the swallowing sound appeared within the duration from N2 to N4

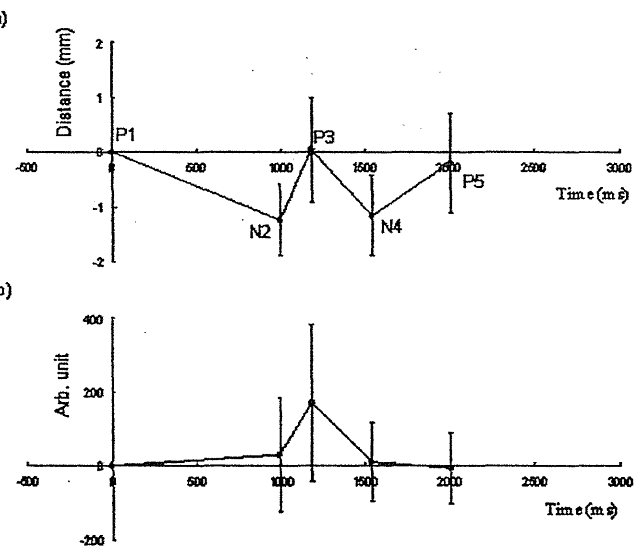

Fig. 7. (a) Mean coil distance at times (P1), (N2), (P3), (N4), and (P5) plotted with standard deviation (see Table I). Waveform shape is W-type. (b) Swallowing sound at times (P1), (N2), (P3), (N4), and (P5) plotted with standard deviation (see Table I). The sound waveform has one peak.

in the coil-distance timing, an individual variation with many peaks occurs in the waveform. Consequently, with the normal

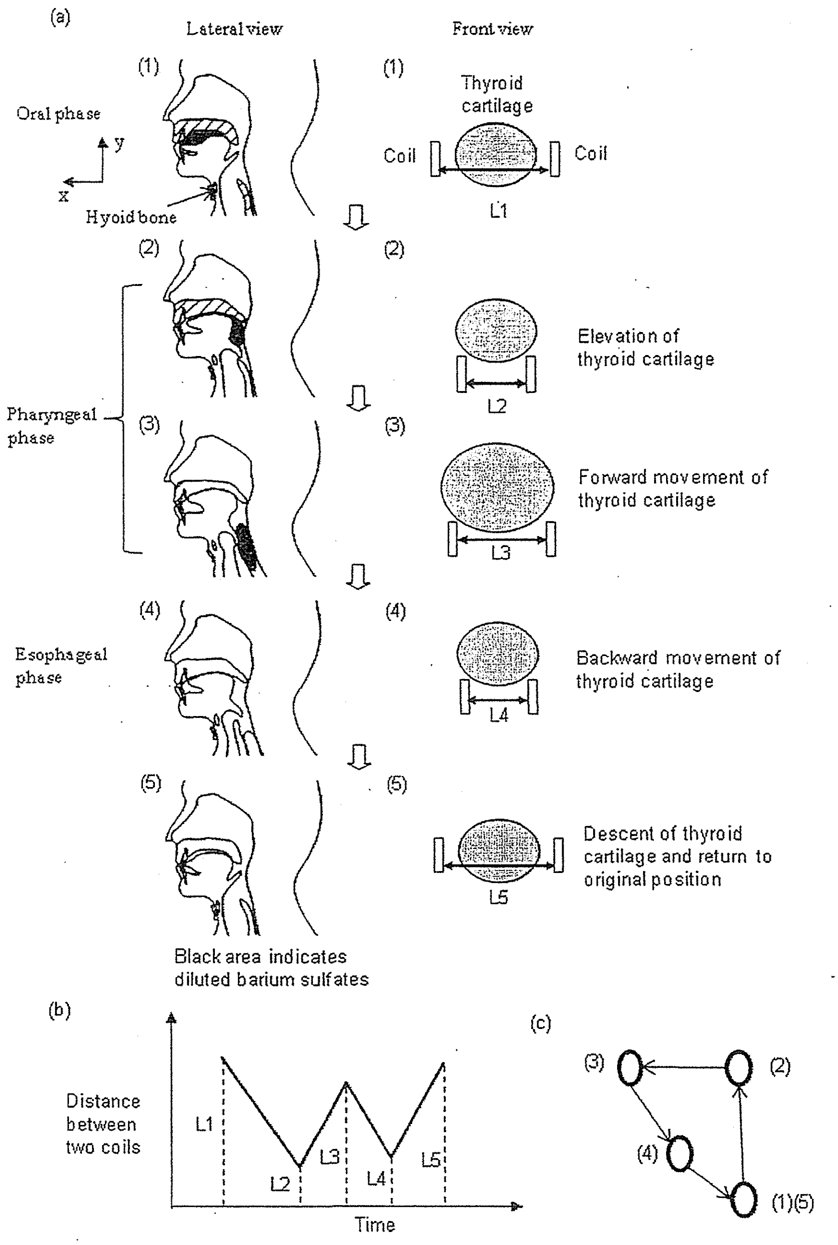

Fig. 8. (a) Relationship between liquid-barium position, coil distances (L1, L2, L3, L4, and L5), and thyroid cartilage site. (b) W-shaped waveform (Fig. 7(a)) reconstructed by using coil distance (L1, L2, L3, L4, and L5 of (a)). (c) Hyoid bone movement corresponding to (1) to (5) shown in (a).

controls, the coil distance showed a W-shaped waveform, and the swallowing sound had a one-peak waveform.

IV. Discussion

The relationship between the swallowing movement and magnetic swallowing-detection waveforms is explained as follows (see Fig. 8(a) and (b)). Coil distance L1 in the first oral phase hardly changes because the thyroid-cartilage movement changes very little. In the next pharyngeal phase, the deglutition reflex starts, and rapid laryngeal elevation occurs. The thyroid cartilage therefore goes between the two coils, and the coil distance is shortened to L2. The forward movement of the thyroid cartilage causes the coil distance to increase to L3. In the esophageal phase, the thyroid cartilage goes backward, and the coil distance is shortened to L4. After the swallowing movement, the distance decreases again to L5 (which is almost the same as L1). Therefore, it is apparent that the coil distance W-shaped waveform reflects the movement of the thyroid cartilage in the larynx, and the timing of the larynx movement can be detected based on this waveform. The correlation between the thyroid cartilage and the coil distance movements was also distinguishable by looking at their correlated movement in the VF images. Furthermore, the changes depending on the triangle movement of the hyoid bone (see Figs. 4 and 8(c)) could be seen in the coil distance waveforms because the main timings (P1 and P3) of the coil

TABLE I

SUMMARIZED TIME-VARIANCE LIST OF SWALLOWING. THE * INDICATES THE START TIME OF SWALLOWING. ITALICIZED NUMBERS INDICATE INTRACLASS CORRELATION COEFFICIENTS. FIVE TIMES ARE DEFINED: START POINT (SP), PRIMARY NEGATIVE PEAK (PNP), POSITIVE PEAK (PP), SECONDARY NEGATIVE PEAK (SNP), AND END POINT (EP)

Waveform	VF	Sound	Coils
SP	VF2 38±172 ms	–	P1* 0
PNP	–	S1 0.73±0.52 s	N2 0.99±0.30 s
		0.54	
PP	VF1 1.31±0.45 s	Smax 1.21±0.49 s	P3 1.18±0.32 s
	0.91		*0.89*
	VF4 1.24±0.35 s		
	0.93		
SNP	–	S2 1.77±0.52 s	N4 1.53±0.32 s
		0.68	
EP	VF3 2.58±0.40 s	–	P5 2.00±0.47 s
		0.10	

distance waveform were correlated with those (VF1, VF2, and VF4) of the VF waveforms.

When the magnetic swallowing-detection system measures the above-mentioned thyroid-cartilage movement, it might detect abnormalities in the swallowing movement as aspiration. If the time duration from N2 to P3 reflects a rapid laryngeal elevation after the deglutition reflex, the closure delay of the larynx causes the aspiration. It has been reported that the swallowing time is delayed [20] and the forward movement of the hyoid bone decreases [8] in accordance with the increasing age of the subjects. It can therefore be inferred that the long time from N2 to P3 is often seen in elderly people, and the insufficient forward movement of the thyroid cartilage (which depends on muscle weakness) produces an unclear P3 peak and monophasic wave shape (i.e., not a W-shape). Furthermore, the reduced time from N2 to N4 indicates the lack of elevation time of the larynx because it is thought that the bolus passes to the hypopharynx at time N4.

Although the mechanism that produces the swallowing sound is still not clear, the sound occurs when the bolus goes from the pharynx to the esophagus [21]. It is therefore thought that the peak Smax appears at the same time. The evaluation of the swallowing movement using both the coil length and the sound waveforms makes it possible to determine the correct deglutition reflex by using the coil-length changes when no swallowing sound occurs.

It has been reported that there is no correlation between the amplitudes of upward and forward displacements of the hyoid bone, and that the amplitude of the upward displacement is highly variable [7]. However, the magnetic swallowing-detection system obtained a W-shaped waveform of coil distance and a monophasic sound waveform, which were similar to the hyoid-bone tracking waveform determined by VF. These waveforms were invariable among healthy subjects. It can be concluded that the magnetic swallowing-detection system can detect swallowing movement more simply and non-invasively than a hyoid-movement detection system.

V. LIMITATIONS

There are several limitations to this study. One is that the magnetic swallowing-detection system cannot detect the position of the bolus or the degree of thyroid-cartilage elevation. Another is the small number of subjects used; further study with a larger sample is needed to confirm our findings. Finally, the measurement reliability of the magnetic swallowing-detection system was not evaluated. Therefore, further study for the reliability is needed. The system, however, can simply and noninvasively evaluate the swallowing movement.

ACKNOWLEDGMENT

The authors are grateful to T. Ono of Osaka University, Graduate School of Dentistry for discussing the swallowing mechanism with us. We also thank K. Morohoshi, K. Ishizuka, and N. Matsumoto of Hitachi Computer Peripherals Co., Ltd. for developing the magnetic swallowing-detection system.

REFERENCES

[1] M. A. Crary and M. E. Grother, *Butterworth Heinemann Elsevier 2003* (in Japanese), I. Fujishima, Ed. : Ishiyaku Publishers, Inc., 2007.

[2] J. A. Logemann, *Pro-ed.* Austin, TX: , 1998.

[3] T. Ono, K. Hori, Y. Masuda, and T. Hayashi, "Recent advancement in sensing oropharyngeal swallowing function in Japan," *Sensors. 10*, vol. 176, pp. 176–202, 2010.

[4] J. B. Saunders, C. Davis, and E. R. Miller, "The mechanism of deglutition (second stage) as revealed by cine-radiography," *Ann. Otol. Rhinol. Laryngol.*, vol. 60, no. 4, pp. 897–897, 1951.

[5] G. H. Ramsey, J. S. Watson, R. Gramiak, and S. A. Weinberg, "Cinefluorographic analysis of the mechanism of swallowing," *Radiology*, vol. 64, no. 4, pp. 498–498, 1955.

[6] R. I. Roberts, "A cineradiographic investigation of pharyngeal deglutition," *Br. J. Radiol.*, vol. 30, no. 357, pp. 449–449, 1957.

[7] R. Ishida, J. B. Palmer, and K. M. Hiiemae, "Hyoid motion during swallowing: Factors affecting forward and upward displacement," *Dysphagia*, vol. 17, no. 4, pp. 262–262, 2002.

[8] Y. Kim and G. H. McCullough, "Maximum hyoid displacement in normal swallowing," *Dysphagia.*, vol. 23, no. 3, pp. 274–274, 2008.

[9] K. A. Kendall, S. McKenzie, R. J. Leonard, M. I. Gonçalves, and A. Walker, "Timing of events in normal swallowing: A videofluoroscopic study," *Dysphagia.*, vol. 15, no. 2, pp. 74–74.

[10] A. R. Wintzen, U. A. Badrising, R. A. Roos, J. Vielvoye, and L. Liauw, "Influence of bolus volume on hyoid movements in normal individuals and patients with Parkinson's disease," *Can. J. Neurol. Sci.*, vol. 21, no. 1, pp. 57–57, 1994.

[11] R. L. Shelton Jr., J. F. Bosma, and B. V. Sheets, "Tongue, hyoid and larynx displacement in swallow and phonation," *J. Appl. Physiol.*, vol. 15, pp. 283–283, 1960.

[12] T. Ono, K. Hori, and T. Nokubi, "Pattern of tongue pressure on hard palate during swallowing," *Dysphagia.*, vol. 19, no. 4, pp. 259–264, 2004.

[13] A. Toyosato, K. Ueda, and S. Nomura, "Examination of swallowing evaluation method at the bedside," (in Japanese, English) *JADS*, vol. 26, pp. 42–46, 2007.

[14] Y. Yamamoto, T. Nakamura, Y. Seki, K. Utsuyama, K. Akashi, K. Jikuya, and Neck, "Electrical impedance for measurement of swallowing," (in Japanese, English) *T. IEE Jpn.*, vol. 118-A, no. 3, pp. 210–217, 1998.

[15] T. Hayashi, H. Kaneko, Y. Nakamura, T. Ishida, H. Takahashi, Y. Yamada, N. Michimi, and S. Nomura, "Relationship between Rice-Gruel properties and swallowing motion—Evaluation by simultaneous measurement of larynx movement, electromyogram and swallowing sound," (in Japanese, English) *Jpn. J. Dysphag. Rehabil.*, vol. 6, pp. 73–81, 2002.

[16] A. Kandori, M. Yokoe, S. Sakoda, K. Abe, T. Miyashita, H. Oe, H. Naritomi, K. Ogata, and K. Tsukada, "Quantitative magnetic detection of finger movements in patients with Parkinson's disease," *Neurosci Res.*, vol. 49, pp. 253–260, 2004.
[17] A. Kandori, T. Miyashita, N. Hosono, M. Yokoe, K. Ogata, K. Abe, and S. Sakoda, "Motion analysis of grip and release with fingers using simple magnetic detection system," *Rev. Sci. Instrum.*, vol. 78, pp. 034302–034302, 2007.
[18] A. Kandori, Y. Sano, T. Miyashita, Y. Okada, M. Irokawa, K. Shima, T. Tsuji, M. Yokoe, and S. Sakoda, "Estimation method of finger tapping dynamics using simple magnetic detection system," *Rev. Sci. Instrum.*, vol. 81, pp. 054303–054303, 2010.
[19] E. Saitoh, S. Shibata, K. Matsuo, M. Baba, W. Fujii, and J. B. Palmer, "Chewing and food consistency: Effects on bolus transport and swallow initiation," *Dysphagia*, vol. 22, no. 2, pp. 100–107, 2007.
[20] I. Kaneko, "A cinefluorographic study of hyoid bone movement during deglutition," *Nippon Jibiinkoka Gakkai Kaiho.*, vol. 95, no. 7, pp. 974–87, Jul. 1992.
[21] J. A. Y. Cichero and B. E. Murdoch, "The physiologic cause of swallowing sounds: Answers from heart sounds and vocal tract acoustics," *Dysphagia*, vol. 13, no. 1, pp. 39–52, 1998.

Akihiko Kandori was born in Hiroshima, Japan, on October 25, 1965. He received the B.S. and M.S. degrees in electrical engineering, and the Ph.D. degree in engineering from Sophia University, Tokyo, Japan, in 1988, 1990, and 1997, respectively, and the Ph.D. degree in medicine from Tsukuba University, Ibaraki, Japan, in 2003.

In 1990, he joined the Central Research Laboratory, Hitachi Ltd. From 1992 to 1994, he was with the Superconducting Sensor Laboratory of National Project. He has been interested in SQUID sensor and applications for many years. He is a Chief Researcher at the Central Research Laboratory, Hitachi Ltd. His current interests are in magnetic field measurement biomedical system, biomagnetic imaging, and SQUID sensor system.

Toshiyuki Yamamoto was born in Sapporo, Japan, on November 3, 1970. He received the M.D. degree from Sapporo Medical University, Sapporo, Japan, in 1996, and the Ph.D. degree from the Tokyo Medical and Dental University, Tokyo, Japan, in 2010.

He worked in the Department of Neurology, National Center Hospital of Neurology and Psychiatry (NCNP), Tokyo, Japan, from 1999 to 2004. He studied in the Department of Physical Medicine and Rehabilitation, Johns Hopkins University, from 2004 to 2005. He has been working as a Neurologist at the Department of Neurology, NCNP, since 2005. He has an interest in physiology and kinesiology of swallowing in neurodegenerative disease and psychiatric disease. He is now involved with a study using videofluorography and the simple magnetic swallowing detection system to evaluate the swallowing function in Parkinson's disease.

Yuko Sano was born in Tokyo, Japan, on July 7, 1982. She received the B.S. and M.S. degrees in mechano-infomatics from the University of Tokyo, Tokyo, in 2005 and 2007, respectively.

In 2007, she joined the Advanced Research Laboratory, Hitachi Ltd. In 2011, she joined the Central Research Laboratory, Hitachi Ltd. She has been interested in analysis of medical and biological data using multivariable analysis or machine learning techniques. Her main research topic is to quantify severity of diseases in finger tapping data.

Mitsuru Oonuma was born in Tokyo, Japan, on May 18, 1950. He graduated from Salesian Polytechnic in 1971.

He joined the Hitachi Design Research Institute in 1971, where he worked on the industrial design of home electrification apparatus, construction machinery, and medical equipment. Now, his research interests are in industrial design of the analysis equipment.

Tsuyoshi Miyashita was born in Kagoshima, Japan, on February 6, 1963. He received the B.S. degree in physics and the M.S. degree in engineering science from Kyushu University, Fukuoka, in 1987 and 1989, respectively.

In 1989, he joined the Advanced Research Laboratory, Hitachi Ltd., Tokyo, Japan. In 2011, he joined the Central Research Laboratory, Hitachi Ltd. He has been interested in analysis of bio-electric and bio-magnetic data such as EEG, MEG, ECG, MCG. His current interest is near-infrared spectroscopy system for measuring brain functions.

Miho Murata was born in Kofu, Japan. She received the M.D. degree from the University of Tsukuba, School of Medicine, Tsukuba, Japan, in 1984, and the Ph.D. degree from the Department of Neurology, University of Tsukuba, in 1992.

She worked at the University Hospital of Tsukuba and the University of Tokyo. She is currently the Director of the Department of Neurology, National Center of Neurology and Psychiatry, Japan. Her main focus is the therapy of Parkinson's disease and she found zonisamide effects on Parkinson's disease.

Saburo Sakoda was born in Hiroshima, Japan, in 1951. He received the M.D. degree in 1975 and the Ph.D. degree in 1984 from Osaka University, Faculty of Medicine, Osaka, Japan.

After postdoctoral training at the Osaka University Hospital (April 1975–May 1985), he moved to the Research Institute of Neurology, Department of Neurology, Osaka University, to begin additional postdoctoral studies and has been developing his research in neurology (December 1986–July 1994). From 2000 to 2010, he was a Professor at the Department of Neurology. He joined the National Organization Hospital, Toneyama Hospital, Osaka, Japan, as a Medical Center Director in April 2010.

Role of the External Oblique Muscle in Upper Camptocormia for Patients with Parkinson's Disease

Patients with Parkinson's disease (PD) often experience camptocormia, a postural disorder with unclear pathophysiology and unestablished treatments.[1] We clinically categorized camptocormia as upper and lower types based on the location of inflection points. We defined upper camptocormia as abnormal truncal flexion at a point between the lower thoracic and upper lumbar vertebrae whose flexion angle exceeded 40 degrees, whereas lower camptocormia was defined as abnormal truncal flexion at the hip joint. This study focused on upper camptocormia.

We performed lidocaine injections into the abdominal muscles of PD patients with upper camptocormia and evaluated their effects on posture to investigate its pathophysiology. Patients with fixed posture because of spinal disease or truncal muscle weakness were excluded. We included 5 patients (4 women and 1 man; mean age, 70.8 ± 4.4 years; PD duration, 8.2 ± 3.9 years; Hoehn & Yahr stage, 2.6 ± 0.8) treated with antiparkinson drugs in our hospital. Camptocormia did not respond to these drugs in any of the patients. Ultrasound guidance was used for lidocaine injections into the abdominal muscle (rectus abdomen [RA] and external oblique [EO] in all patients; internal oblique [IO] in 2 patients; 50 mg in each muscle bilaterally). Although the order of each injection was different in each patient, the following injection was performed on confirming that improvement diminished or if no improvement was observed after several days. Flexion angles were measured before and after each injection. The angle formed between a line perpendicular to the ground and a line linking the C7 vertebra with the inflection point of the trunk was defined as the flexion angle. This study was approved by the NCNP ethics committee. Informed consent was obtained from all patients.

The posture of all patients improved following injection into the EO. The average flexion angle decreased from 49 ± 6.0 degrees to 37 ± 10 degrees (truncal angle of age-matched PD patients without camptocormia was 29.4 ± 3.7 degrees; Fig. 1), Only 1 patient showed mild improvement after injection into the RA. No improvements were observed following injection into the IO.

The RA performs truncal anteflexion, whereas the EO and IO work bilaterally for truncal flexion. Azher et al previously reported improvement of camptocormia by botulinum toxin injection into the RA,[2] although they did not classify camptocormia by type. In the present study, forward flexion was reduced in all patients after injection into the EO, not RA nor IO. Our results may suggest that the EO is primarily associated with upper camptocormia pathogenesis. Considering that previous studies have speculated that lidocaine could suppress dystonic excitation,[3–5] dystonia of the EO may be a cause of upper camptocormia.

Although this study has some limitations, such as the small number of patients and not adjusting lidocaine dose for muscle size, this is the first report to investigate camptocormia pathophysiology by classification, and these findings may contribute to the treatment of upper camptocormia in patients with PD. To confirm our results, we have been carrying out a larger study.

Acknowledgment: We express our deepest gratitude to Dr. Atsuo Nakagawa, whose extensive support and insightful comments were invaluable during the course of our study.

Yoshihiko Furusawa, MD[1*], Yohei Mukai, MD[1], Yoko Kobayashi, PhD[2], Takashi Sakamoto, MD[1], Miho Murata, PhD[1]

[1]Department of Neurology, National Center Hospital of Neurology and Psychiatry Kodaira, Tokyo, Japan; [2]Department of Rehabilitation, National Center Hospital of Neurology and Psychiatry Kodaira, Tokyo, Japan

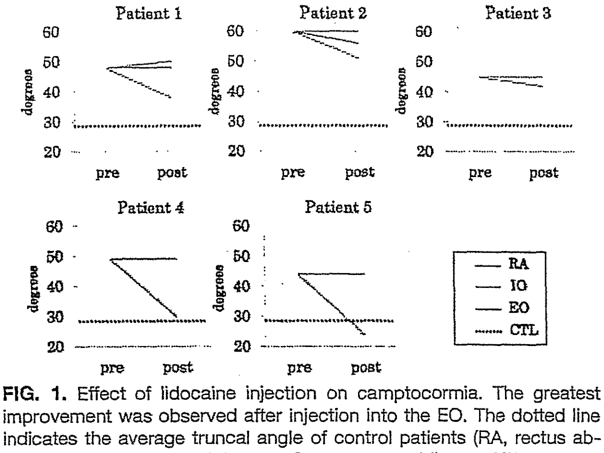

FIG. 1. Effect of lidocaine injection on camptocormia. The greatest improvement was observed after injection into the EO. The dotted line indicates the average truncal angle of control patients (RA, rectus abdomen; IO, internal oblique; EO, external oblique; CTL, control patients).

* **Correspondence to:** Yoshihiko Furusawa, Department of Neurology, National Center Hospital of Neurology and Psychiatry Kodaira, Tokyo, Japan; yfuru@ncnp.go.jp

Funding agencies: This work was supported in part by Grants-in-Aid from the Research Committee of CNS Degenerative Disease, the Ministry of Health, Labour and Welfare of Japan, and Intramural Research Grant (21B-4) for Neurological and Psychiatric Disorders of NCNP.

Relevant conflicts of interest/financial disclosures: Nothing to report. Full financial disclosures and author roles may be found in the online version of this article.

Published online in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/mds.24930

References

1. Melamed E, Djaldetti R. Camptocormia in Parkinson's disease. J Neurol 2006;253:VII14–VII16.
2. Azher SN, Jankovic J. Camptocormia: pathogenesis, classification, and response to therapy. Neurology 2005;65:355–359.
3. Kaji R, Rothwell JC, Katayama M, et al. Tonic vibration reflex and muscle afferent block in writer's cramp. Ann Neurol 1995;38:155–162.
4. Irwin D, Revuelta G, Lippa CF. Clinical improvement of secondary focal limb dystonia in neurodegenerative disease following a five-day lidocaine infusion: a case report. J Neurol Sci 2009;277: 164–166.
5. Yoshida K, Kaji R, Kubori T, Kohara N, Iizuka T, Kimura J. Muscle afferent block for the treatment of oromandibular dystonia. Mov Disord 1998;13:699–705.

Qual Life Res (2012) 21:1299–1303
DOI 10.1007/s11136-011-0041-2

BRIEF COMMUNICATION

Validation of the Japanese translation of the Swallowing Disturbance Questionnaire in Parkinson's disease patients

Toshiyuki Yamamoto · Kensuke Ikeda · Harumi Usui · Masako Miyamoto · Miho Murata

Accepted: 5 October 2011 / Published online: 16 October 2011

Abstract
Purpose The Swallowing Disturbance Questionnaire (SDQ) was developed as a self-rated screening tool for dysphagia in patients with Parkinson's disease (PD). We developed the Japanese version of this questionnaire (SDQ-J), according to the cross-cultural adaptation guidelines, and examined its reliability.
Methods Subjects were 61 Japanese patients with PD (mean age, 67.0 ± 9.2 years) who answered the SDQ-J before undergoing videofluoroscopic examination of swallowing (VF). We compared the findings of the questionnaire with the patients' aspiration status during VF.
Results Cronbach's alpha coefficient for the 15 questions of the SDQ-J was 0.84. According to the SDQ-J, 15 patients (24.6%) were diagnosed with dysphagia, while 9 patients (14.8%) aspirated liquid during VF. The sensitivity and specificity of the SDQ-J in predicting aspiration were 77.8 and 84.6%, respectively; therefore, the SDQ-J significantly predicted aspiration during VF ($P < 0.01$). The positive predictive value (PPV) and negative predictive value (NPV) for the SDQ-J were 0.46 and 0.96, respectively.
Conclusions The SDQ-J appears to be a reliable and useful screening tool for Japanese PD patients with aspiration. As the NPV was higher than the PPV in the SDQ-J, this questionnaire could potentially be used for early identification of severe dysphagia in patients with PD.

Keywords Parkinson's disease · Dysphagia · Questionnaires · Fluoroscopy

Abbreviations

PD	Parkinson's disease
VF	Videofluoroscopic examination of swallowing
SDQ	Swallowing Disturbance Questionnaire
SDQ-J	Japanese version of the SDQ
H&Y	Hoehn–Yahr
PPV	Positive predictive value
NPV	Negative predictive value
SLP	Speech and language pathologist
FEES	Fiberoptic endoscopic evaluation of swallowing

T. Yamamoto (✉) · K. Ikeda · M. Murata
Department of Neurology, National Center Hospital of Neurology and Psychiatry, 4-1-1 Ogawahigashi-cho, Kodaira, Tokyo 187-8551, Japan
e-mail: yamamoto@ncnp.go.jp

H. Usui
Department of Nursing, National Center Hospital of Neurology and Psychiatry, 4-1-1 Ogawahigashi-cho, Kodaira, Tokyo 187-8551, Japan

M. Miyamoto
Department of Rehabilitation Medicine, National Center Hospital of Neurology and Psychiatry, 4-1-1 Ogawahigashi-cho, Kodaira, Tokyo 187-8551, Japan

Introduction

Patients with Parkinson's disease (PD) who experienced dysphagia have reported greatly reduced quality of life (QOL) [1]; therefore, early diagnosis and treatment of the dysphagia of such patients is important. Videofluoroscopic examination of swallowing (VF) is the standard method used to diagnose dysphagia; however, it cannot be frequently used because it involves exposure to X-rays. The Swallowing Disturbance Questionnaire (SDQ), a self-rated scale comprising 15 questions regarding the frequency of the dysphagia symptoms of during every meal, was developed as a screening tool for dysphagia in PD patients ("Appendix"). The worst total score of SDQ has been 44.5 points, and dysphagia is diagnosed when the total score is 11 points or more [2]. The SDQ is not yet recommended for widespread use because it has only been tested on a relatively small number of patients in a single PD population. Its translation into other languages followed by further extensive testing of the questionnaire has, therefore, been advised [3]. Accordingly, we created a Japanese version of the SDQ (SDQ-J) and examined its reliability in relation to the patients' aspiration status during VF.

Patients and methods

Patients

The subjects of this study were 61 Japanese patients with PD who were able to consume food orally (mean age, 67.0 ± 9.2 years; 40 men, 21 women). These subjects were selected for inclusion in the study, irrespective of the subjective symptoms of dysphagia, from among 82 PD patients who were admitted for short periods to our hospital for evaluation or treatment of parkinsonism between April 6, 2010, and March 29, 2011.

All patients had been diagnosed with clinically definite PD [4] and were effectively treated with L-dopa. Cranial magnetic resonance imaging was performed on all subjects to exclude cerebral infarction and other neurodegenerative disorders. We excluded patients with other diseases that cause dysphagia and those who were being fed by tube or undergoing treatment for complications such as dehydration, pneumonia, delirium, or depression. Patients who had undergone VF within the previous year were also excluded to avoid overexposure to excessive radiation. Patients who could not fill out the questionnaire by themselves because of parkinsonism or dementia were also excluded.

This study was approved by the ethics committee of our institution (A2010-003), and written informed consent was obtained from all patients before beginning this study.

Japanese version of the Swallowing Disturbance Questionnaire

We created the SDQ-J according to the guidelines for the cross-cultural adaptation of self-reported measures [5]. With the permission of the original author, two translators translated the SDQ into Japanese and a native English language speaker reverse-translated it into English. We sent the back translation to the original author for proofreading, following which permission to use the complete SDQ-J was granted. Because of the difference in the meal cultures, we made certain revisions in the questionnaire like "a cracker" was changed to "a rice cracker" and "pureed food" to "mashed food." All patients answered the SDQ-J without being supervised by the assessors before VF.

Videofluoroscopy

During VF, the patients were seated in the same posture in which they ate their everyday meals, and fluoroscopy was performed from the side. The investigator used a syringe to inject a twofold dilution of 110% w/v liquid barium into the patient's oral cavity and gave the patient the signal to start swallowing. Patients who experienced wearing-off were tested during the "on" state. The patient's swallowing movements were recorded on DVD at 30 frames/s and evaluated for aspiration by an assessor after the test. In order to confirm the reliability of the evaluation of VF results, the same assessor re-evaluated thirty-five VF results and another evaluated same VF results independently. None of the assessors evaluating the VF results was notified of the findings of the SDQ-J.

Statistical analysis

We compared the Hoehn–Yahr (H&Y) stage, sex, and age of the patients with aspiration with that of the patients without aspiration using Mann–Whitney U test. The inter-rater and intra-rater reliability of the evaluation of VF were tested by κ coefficient. Receiver operating characteristic (ROC) analysis was used to determine the cutoff point for the total score of the SDQ-J [6]. We compared SDQ-J findings with aspiration status during VF using the Fisher's exact test. Values of $P < 0.05$ were regarded as significant, and IBM SPSS® (ver. 18.0) statistical software was used for all analyses.

Results

None of the subjects had difficulty comprehending the questionnaire or asked questions about its contents. Cronbach's alpha coefficient for the 15 questions of the SDQ-J was 0.84. With VF, 9 patients (14.8%) aspirated liquid and 52 patients did not aspirate (Table 1). The patients with aspiration had a significantly more severe H&Y stage than those who did not ($P = 0.01$). No significant differences were observed in terms of age and sex. Evaluation of aspiration during VF was highly consistent, with significant internal consistency (κ coefficient 1.00), and consistency between assessors (κ coefficient 0.91, 95% confidence interval (CI) 0.88–0.94).

Table 1 Results of videofluoroscopic examination of swallowing in patients with Parkinson's disease

	n (M:F)	Mean age	H&Y-I	H&Y-II	H&Y-III	H&Y-IV	H&Y-V
Aspiration (+)	9 (8:1)	69.6 ± 9.6	0	0	3	3	3
Aspiration (−)	52 (32:20)	66.5 ± 9.2	4	8	25	12	3
Total	61 (40:21)	67.0 ± 9.2	4	8	28	15	6

M male, *F* female, *H&Y* Hoehn–Yahr stage, aspiration (+), patient with aspiration during videofluoroscopic examination (VF); aspiration (−), patient without aspiration during VF

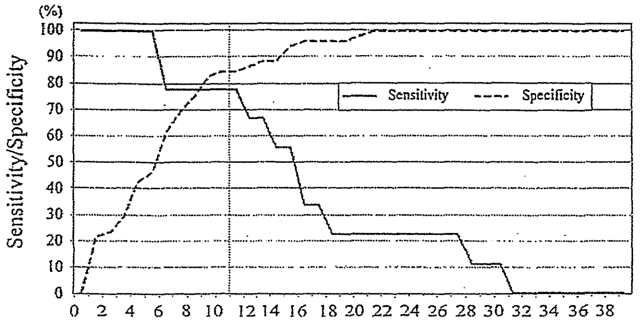

Fig. 1 The receiver operating characteristics curve. This graph enables us to visualize the sensitivity and specificity curves on a single axis. The *x-axis* represents the cutoff points for the SDQ-J score, and the *y-axis* represents the sensitivity and specificity. The sensitivity and specificity curves cross at 9 points, but the sensitivity curve is flat between 6.5 and 11.5 points. When the cutoff score of the SDQ-J is equal to 11 points, its sensitivity is 77.8% and its specificity is 84.6%

In ROC analysis, the sensitivity and specificity curves crossed at 9 points and the sensitivity curve became flat between 6.5 and 11.5 points (Fig. 1). We determined 11 points to be an appropriate cutoff point for the SDQ-J because in a screening tool, when sensitivity is same, higher specificity is better. Then, 15 patients (24.6%) who scored more than 11 points on the SDQ-J were assessed to have dysphagia. The sensitivity of the SDQ-J in predicting aspiration was 77.8%, and its specificity was 84.6%; therefore, the SDQ-J significantly predicted aspiration ($P < 0.01$) (Table 2). The positive predictive value (PPV) and negative predictive value (NPV) were 0.47 and 0.96, respectively. The pre- and post-test probabilities of aspiration were relatively low, at 14.7 and 46.7%, respectively.

Discussion

The original study for the SDQ reported that its Cronbach's alpha coefficient was 0.89 [2]. Cronbach's alpha coefficient was similar between the SDQ-J and the original scale, suggesting that the internal consistency of the SDQ-J was good and that this questionnaire would be reliable. According to the ROC analysis for the SDQ-J, 11 points was an appropriate

Table 2 Results of the Japanese version of the Swallowing Disturbance Questionnaire in comparison with those of videofluoroscopic examination while swallowing liquid

SDQ-J finding	Aspiration during VF		
	Positive	Negative	Total
Dysphagia (+)	7	8	15
Dysphagia (−)	2	44	46
Total	9	52	61
Sensitivity	77.8%		
Specificity	84.6%		
Positive predictive value	0.46		
Negative predictive value	0.96		
Pre-test probability	14.8%		
Post-test probability	46.7%		

SDQ-J The Japanese version of the Swallowing Disturbance Questionnaire, *VF* videofluoroscopic examination of swallowing

cutoff point for the SDQ-J, and this cutoff point was the same as that of original study. The SDQ comprised of questionnaire about the swallowing function, and there were few culture-related questions. Therefore, unlike subjective QOL assessment tools, physical assessment tool such as SDQ may be less influenced by culture.

In the original study, the subjects were PD patients who were referred to a speech and language pathologist (SLP), and the authors suggested that the subjects might have experienced speech, voice, or swallowing disturbances. Indeed, 41 of the 57 subjects (71.9%) were diagnosed with swallowing disturbance by the SLP and fiberoptic endoscopic evaluation of swallowing (FEES). The original study reported that the sensitivity of the SDQ was 80.5%, and its specificity was 81.3%. The pre- and post-test probabilities of aspiration in the original study were high, at 71.9 and 91.7%, respectively. We selected the present patients from our inpatient population, irrespective of subjective symptoms of dysphagia; moreover, we defined dysphagia as the presence of aspiration on VF. VF shows various abnormal findings in PD patients with dysphagia [7, 8], but the clinical importance of these findings has not been determined. However, aspiration during VF is a risk factor for the onset of pneumonia and the discontinuation of oral intake in patients with Lewy body disease, and the cumulative rate of pneumonia up to 24 months after VF is higher in PD patients with aspiration [9]. Our wide selection of subjects and strict definition of dysphagia may be the reasons of the sensitivity of the SDQ-J being lower than those of the original SDQ.

For the original SDQ, the PPV and NPV were calculated as 0.92 and 0.62, respectively. The relationships between the PPV and NPV in the original SDQ were opposite to those in the SDQ-J. The PPV was relatively low in the SDQ-J, so a potential use of the SDQ-J might be for the early identification of severe dysphagia in PD patients, and some type of further objective test, such as VF or FEES, would be required to diagnose the dysphagia.

A higher modified H&Y stage and lower body mass index are useful clinical parameters to screen for severe dysphagia in PD [10]. Anxiety and depression are also known to adversely affect the results of the SDQ [11]. Even though SDQ is a questionnaire for dysphagia in PD patients, there are no questions associated with parkinsonism. Hence, when the SDQ or SDQ-J is combined with other parameters that are related to parkinsonism, their diagnostic accuracy may change.

To conclude, this study shows the reliability of the SDQ-J and suggests its usefulness to screen for aspiration in PD patients; therefore, we recommend using the SDQ as a screening tool to diagnose dysphagia in PD patients. In the future, we intend to evaluate the SDQ-J and other clinical findings in a larger subject population and improve the diagnostic accuracy of dysphagia in PD patients.

Acknowledgments The authors thank Y. Manor (Tel-Aviv Sourasky Medical Center) for the permission to use the SDQ and proofreading the back translation. This work was supported by a TMC Young Investigator Fellowship from the National Center of Neurology and Psychiatry (NCNP), Japan, and by an Intramural Research Grant (22–Y2) for Neurological and Psychiatric Disorders that was also awarded by the NCNP.

Appendix

The questions of the original SDQ are enlisted below:

(1) Do you experience difficulty chewing solid food like an apple, cookie, or a cracker?
(2) Are there any food residues in your mouth, in your cheeks, under your tongue or stuck to your palate after swallowing?
(3) Does food or liquid come out of your nose when you eat or drink?
(4) Does chewed-up food dribble from your mouth?
(5) Do you feel you have too much saliva in your mouth; do you drool or have difficulty swallowing your saliva?
(6) Do you swallow chewed-up food several times before it goes down your throat?
(7) Do you experience difficulty in swallowing solid food (i.e., do apples or crackers get stuck in your throat)?
(8) Do you experience difficulty in swallowing pureed food?
(9) While eating, do you feel as if a lump of food is stuck in your throat?
(10) Do you cough while swallowing liquids?
(11) Do you cough while swallowing solid foods?
(12) Immediately after eating or drinking, do you experience a change in your voice, such as hoarseness or reduced?
(13) Other than during meals, do you experience coughing or difficulty breathing as a result of saliva entering your windpipe?
(14) Do you experience difficulty in breathing during meals?
(15) Have you suffered from a respiratory infection (pneumonia, bronchitis) during the past year?

Questions 1–14 have following options and scores; Never, 0 point; Seldom (once a month or less), 1 point; Frequently (1–7 times a week), 2 points; Very Frequently (more than 7 times a week), 3 points. For the 15th question, "Yes" is 2.5 points and "No" is 0.5 points.

References

1. Leow, L. P., Huckabee, M. L., Anderson, T., & Beckert, L. (2010). The impact of dysphagia on quality of life in ageing and Parkinson's disease as measured by the swallowing quality of life (SWAL-QOL) questionnaire. *Dysphagia, 25*(3), 216–220.
2. Manor, Y., Giladi, N., Cohen, A., Fliss, D. M., & Cohen, J. T. (2007). Validation of a swallowing disturbance questionnaire for detecting dysphagia in patients with Parkinson's disease. *Movement Disorders, 22*(13), 1917–1921.
3. Evatt, M. L., Chaudhuri, K. R., Chou, K. L., Cubo, E., Hinson, V., Kompoliti, K., et al. (2009). Dysautonomia rating scales in Parkinson's disease: Sialorrhea, dysphagia, and constipation—critique and recommendations by movement disorders task force on rating scales for Parkinson's disease. *Movement Disorders, 24*(5), 635–646.
4. Calne, D. B., Snow, B. J., & Lee, C. (1992). Criteria for diagnosing Parkinson's disease. *Annals of Neurology, 32*(Suppl), S125–S127.
5. Beaton, D. E., Bombardier, C., Guillemin, F., & Ferraz, M. B. (2000). Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine, 25*(24), 3186–3191.
6. Hanley, J. A., & McNeil, B. J. (1982). The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology, 143*(1), 29–36.
7. Leopold, N. A., & Kagel, M. C. (1997). Laryngeal deglutition movement in Parkinson's disease. *Neurology, 48*(2), 373–376.
8. Bushmann, M., Dobmeyer, S. M., Leeker, L., & Perlmutter, J. S. (1989). Swallowing abnormalities and their response to treatment in Parkinson's disease. *Neurology, 39*(10), 1309–1314.

9. Yamamoto, T., Kobayashi, Y., & Murata, M. (2010). Risk of pneumonia onset and discontinuation of oral intake following videofluorography in patients with Lewy body disease. *Parkinsonism & Related Disorders, 16*(8), 503–506.
10. Lam, K., Lam, F. K., Lau, K. K., Chan, Y. K., Kan, E. Y., Woo, J., et al. (2007). Simple clinical tests may predict severe oropharyngeal dysphagia in Parkinson's disease. *Movement Disorders, 22*(5), 640–644.
11. Manor, Y., Balas, M., Giladi, N., Mootanah, R., & Cohen, J. T. (2009). Anxiety, depression and swallowing disorders in patients with Parkinson's disease. *Parkinsonism & Related Disorders, 15*(6), 453–456.

嚥下医学：90-98，2012

原　著

問診によるパーキンソン病患者の誤嚥の評価

山本　敏之[*]，臼井　晴美[**]，新庄　孝子[**]，市川　直美[**]，
三好智佳子[**]，村田　美穂[*]

目的：問診からパーキンソン病（PD）患者の誤嚥の合併を評価することを目的とした．対象と方法：対象はPD患者69人（65.3±8.9歳）．嚥下障害とパーキンソニズムに関する20の質問で構成された問診票を使い，看護師，もしくは医師が対象に対面式聞き取り調査を行った．すべての対象に液体バリウム10 mLで嚥下造影検査（VF）を行い，問診の結果とVFでの誤嚥を比較した．結果：誤嚥した患者は18人，誤嚥しなかった患者は51人であった．誤嚥した患者と誤嚥しなかった患者の年齢，パーキンソニズムの重症度，体格指数に有意差はなかった．ロジスティック回帰分析から，VFで誤嚥した患者は「ここ1年でやせてきた」「薬を飲むときにむせる」「食事中の症状として動きの悪さがある」を有意に自覚した．予測式は，感度0.72，特異度0.90であった．結論：問診によるPD患者の誤嚥の診断には，嚥下障害の評価と食事中のパーキンソニズムの評価が有用であった．

嚥下医学　1：90-98，2012

Key words：パーキンソン病，誤嚥，問診，嚥下造影検査

はじめに

パーキンソン病（PD）は死因の22.1～44.1％が肺炎であり[1～3]，嚥下造影検査（VF）で誤嚥したPD患者は，検査から2年以内の肺炎発症率が有意に高い[4]．しかしながら，PDでは無症候性誤嚥が多く[4～6]，早期に誤嚥の合併を診断することは難しい．

問診から嚥下障害を評価する方法として，大熊ら[7]は摂食・嚥下障害スクリーニングのための質問紙を開発した．この質問紙は15問で構成され，重症度の高い回答をした患者は嚥下障害ありと判断される．この質問紙を使ってPD患者24人の嚥下機能を評価した報告[8]では16人が「嚥下障害あり」と判断された．しかしながら，この研究では嚥下障害を判定するための至適基準がなく，問診による嚥下障害の判定が妥当であるかは不明であった．また，Manorら[9]は，PD患者の嚥下障害を評価するための自己回答式質問票“Swallowing disturbance questionnaire (SDQ)”を開発した．この質問票は15問で構成され，嚥下障害であらわれる症状の頻度を質問したものである[10]．PD患者57人のうち言語聴覚士の臨床評価と嚥下内視鏡で嚥下障害ありと判定された41人と嚥下障害なしと判定された16人を，SDQは有意に判定した．Lamら[11]は，PD患者45人

* 国立精神・神経医療センター病院神経内科，** 同看護部
別刷請求：〒187-8551　東京都小平市小川東町4-1-1　国立精神・神経医療センター病院神経内科　山本敏之

を対象に，14問で構成された質問票による評価と50 mL水飲みテストを行い，VFで重度の嚥下障害を伴った6人の患者の特徴として，Hoehn-Yahr（H&Y）重症度が高い（p=0.04），体格指数（Body mass index：BMI）が低い（p=0.01），「口腔で食物や水分を保持するのが困難ですか？」の質問で肯定の答え（p=0.05）が有意とした．これまでの報告から，嚥下障害をきたすPD患者には臨床的な特徴があると推定された．

本研究は，問診から簡便に誤嚥しているPD患者を判定することを目的とした．日常の摂取場面での誤嚥の代用評価項目としてVFでの誤嚥を評価し，問診では嚥下障害であらわれる症状の自覚とパーキンソニズムに対する自覚の両方を評価した．

対象と方法

2007年10月から2008年2月，2010年5月から2010年9月までの10カ月間に当院に入院し，日常の食事を経口摂取していたPD患者のうち，検査同意が得られた患者69人（65.3±8.9歳，男40人，女29人）を対象とした．H&Y重症度は中央値3.0（H&Y I度0人，H&Y II度5人，H&Y III度43人，H&Y IV度16人，H&Y V度5人），BMIは20.6±3.2であった．すべての患者はprobable PDと診断[12]され，抗パーキンソン病薬で内服治療していた．すべての患者は頭部MRIで他の神経変性疾患を否定し，また，MIBG心筋シンチグラフィーで後期像の心筋/上縦隔集積比の低下[13]を確認した．幻覚や精神症状，認知症，脳血管障害の合併，向精神薬を内服している患者は除外した．

われわれは大熊ら[7]の開発した質問紙を参考にPD患者の嚥下障害を評価するための問診票（表1）を作成し，対面式聞き取り調査を行った．問診票の質問1，2，3は過去1年間の症状について，質問4以降は最近3カ月の症状についてとした．なお，質問14は薬の種類や剤型を問わなかった．また，質問15は食物形態について問わなかった．質問18では，誤嚥が飲んだものや食べたものが気管に入った状態であることを，適宜，患者に説明した．質問19，20は嚥下にかかわる器官の動きに限定せず，体全体のパーキンソニズムの自覚について自由回答させ，複数回答可とした．頻度の選択肢は，「まれに」は月1回以下，「しばしば」は週に1～7回，「よくある」は週に7回以上を基準とした．

すべての対象に研究概要を説明し，本人から文書同意を得て研究を行った．入院後5日以内に看護師，もしくは医師が問診票を使って患者から聞き取り調査した．質問の内容について回答者から質問があった場合は，質問者が理解できる内容で説明した．また，回答があいまいな場合は，質問者がもっとも適していると考えた回答を選択した．

VFはすべての対象に実施した．検査中，被検者は食事のときと同じ座位姿勢をとった．検者は2倍希釈した110 w/v%液体バリウム（液体）10 mLを被検者の口腔にシリンジで注入した．そして，検者は被検者に嚥下開始の指示を出した．被検者の口腔から上部食道までを側面から透視し，嚥下運動をDVDレコーダーに30フレーム毎秒で記録した．1施行目で嚥下できた場合は2施行目を行わず，口腔からの漏れや指示前に咽頭へ垂れこんだ場合は2施行目を行った．透視時間は5分以内とした．検査後，1人の解析者がフレームごとに動画を解析し，声帯を越える気道侵入を誤嚥として評価した．

統計では，VFで誤嚥したPD患者を誤嚥あり群，誤嚥しなかったPD患者を誤嚥なし群に分類し，年齢，H&Y重症度，BMI，問診票の質問について，Mann-Whitney U検定で2群を比較した．さらに2群の比較で有意だった質問について，尤度比による変数増加法によってロジスティック回帰分析を行い，有意に誤嚥に寄与する質問を同定した．なお，統計処理では，回答された選択肢を順位変数とし，「いいえ=1，あり=2」，「いいえ=1，まれに=2，しばしば=3，よく

表1　パーキンソン病患者の嚥下障害を評価するための問診表

過去1年間で	選択肢1	選択肢2	選択肢3	選択肢4
質問1. 肺炎と診断されたことはありますか？	いいえ	はい	-	-
質問2. 窒息したことはありますか？	いいえ	はい	-	-
質問3. やせてきましたか？	いいえ	3kg以内	3kg～5kg	5kg以上
この3カ月間で	選択肢1	選択肢2	選択肢3	選択肢4
質問4. 微熱はありますか？	いいえ	まれに	よくある	-
質問5. 食欲はありますか？	はい	いいえ	-	-
質問6. 座っているときに涎が出て困りますか？	いいえ	まれに	しばしば	よくある
質問7. 横になると咳こむことがありますか？	いいえ	まれに	しばしば	よくある
質問8. 食事中や食後に痰が絡んだ感じがありますか？	いいえ	まれに	しばしば	よくある
質問9. 食事以外のときに痰が絡んだ感じがありますか？	いいえ	まれに	しばしば	よくある
質問10. 食べ物を噛みにくいことがありますか？	いいえ	まれに	しばしば	よくある
質問11. 飲み込みにくいと感じることがありますか？	いいえ	まれに	しばしば	よくある
質問12. 食事中にむせることがありますか？	いいえ	まれに	しばしば	よくある
質問13. 水分を飲むときにむせることがありますか？	いいえ	まれに	しばしば	よくある
質問14. 薬を飲むときにむせることがありますか？	いいえ	まれに	しばしば	よくある
質問15. のどに食べ物が残る感じがありますか？	いいえ	まれに	しばしば	よくある
質問16. パサパサした食べ物が飲み込みにくいですか？	いいえ	まれに	しばしば	よくある
質問17. 食事形態を工夫していますか？	いいえ	はい	-	-
質問18. 自分は誤嚥していると思いますか？	いいえ	はい	-	-
質問19. 食事ではどのような症状が気になりますか？（複数回答可．該当した回答を記録）				
(a) 振戦	(b) ジスキネジー	(c) 動きが悪い	(d) 姿勢が悪い	
質問20. 食事に関係なく，困る症状は何ですか？（複数回答可．該当した回答を記録）				
(a) 振戦	(b) ジスキネジー	(c) 動きが悪い	(d) 姿勢が悪い	
(e) 会話	(f) 歩行	(g) すくみ	(h) オンオフ現象	

看護師，もしくは医師が対面聞き取り調査を行った．質問1，2，3は過去1年間について，質問4以降は最近3カ月の症状について質問した．頻度の選択肢は，「まれに」は月1回以下，「しばしば」は週に1～7回，「よくある」は週に7回以上を基準とした．

ある＝4」とした．質問19，20は選択肢ごとに症状のありなしを評価した．有意水準 $p<0.05$ を有意とした．統計ソフトはSPSS®(ver. 18) を使用した．本研究は当院倫理委員会で承認された．

結　果

69人中63人は1施行目で検査を終え，6人が2施行目で検査を終えた．誤嚥あり群は18人（年齢　67.6±6.9歳，男15人，女3人），誤嚥なし群は51人（年齢　64.5±9.5歳，男25人，女26人）であった．H&Y重症度は，誤嚥あり群と誤嚥なし群で有意差がなく，いずれも中央値3.0であったが，誤嚥あり群にはH&Y II度以下の患者はいなかった．BMIは，誤嚥あり群19.6±1.6，誤嚥なし群20.7±3.5で有意差はなかった（表2）．

問診票の回答では，「質問3. やせてきましたか？　p＝0.01)」「質問6. 座っているときに涎

表2 誤嚥あり群と誤嚥なし群のプロフィール

	n	年齢	性別(男：女)	BMI	H&Y I 度	H&Y II 度	H&Y III 度	H&Y IV 度	H&Y V 度
誤嚥あり	18	67.6±6.9	15：3	19.6±1.6	0 (0.0)	0 (0.0)	11 (61.1)	4 (22.2)	3 (16.7)
誤嚥なし	51	64.5±9.5	25：26	20.7±3.5	0 (0.0)	5 (9.8)	32 (62.7)	12 (23.5)	2 (3.9)
全体	69	65.3±8.9	40：29	20.6±3.2	0 (0.0)	5 (7.2)	43 (62.3)	16 (23.2)	5 (7.2)

年齢，BMI，H&Y 重症度に有意差はなかった．BMI；body mass index, H&Y 重症度；Hoehn-Yahr 重症度．

が出て困りますか？ ($p<0.01$)」「質問 7. 横になると咳こむことがありますか？ ($p<0.01$)」「質問 8. 食事中や食後に痰が絡んだ感じがありますか？ ($p=0.03$)」「質問 9. 食事以外のときに痰が絡んだ感じがありますか？ ($p=0.04$)」「質問 12. 食事中にむせることがありますか？ ($p<0.01$)」「質問 13. 水分を飲むときにむせることがありますか？ ($p<0.01$)」「質問 14. 薬を飲むときにむせることがありますか？ ($p<0.01$)」「質問 19(c). 食事ではどのような症状が気になりますか？ ―動きが悪い ($p<0.01$)」が2群の比較で有意差があった（表3）．なお，「質問 18. 自分は誤嚥していると思いますか？」の質問は誤嚥あり群の 55.6 %が「いいえ」と回答し，誤嚥なし群と有意差はなかった．

2群の比較で有意であった9項目についてロジスティック回帰分析を行った．「質問 3. やせてきましたか？ （オッズ比 1.85, $p=0.05$)」「質問 14. 薬を飲むときにむせることがありますか？（オッズ比 2.85, $p=0.01$)」「質問 19(c). 食事ではどのような症状が気になりますか？ ―動きが悪い（オッズ比 21.25, $p<0.01$)」が VF での誤嚥の予測に寄与する項目であった（表4）．

ロジスティック回帰モデルは以下となり，予測確率 $z>0.5$ のとき VF で誤嚥を合併している疑いありと判定された．

Logit(z) = − 8.99 + 0.62 × [質問 3] + 1.05 × [質問 14] + 3.06 × [質問 19(c)]

このロジスティック回帰モデルは，モデル χ^2 検定の結果が $p<0.01$ で有意で，ホスマー・レメショウの適合度検定の結果は $p=0.93$ であった．

問診での回答パターン別の予測確率と VF での誤嚥の比較を表5に示す．このロジスティック回帰モデルによる判別は感度 0.72, 特異度 0.90, 陽性適中率 0.72，陰性適中率 0.90，判別適中率 85.5 %であった．

考　察

PD 患者ではさまざまな嚥下障害が出現する[14]．本研究では VF での誤嚥を至適基準とし，嚥下障害についての自覚症状とパーキンソニズムの自覚症状を問診した．問診表による 20 問 30 項目の評価では9項目で誤嚥あり群と誤嚥なし群に有意差があったが，質問間の交絡を考慮し，ロジスティック回帰分析で有意な項目を検討した．VF で誤嚥した PD 患者は，以下の質問から評価できた：「この1年でやせてきましたか？」「薬を飲むときにむせることがありますか？」「食事ではどのような症状が気になりますか？―動きが悪い」．このロジスティック回帰式の適合度，判別的中率は高かった．

PD 患者の嚥下障害に対するこれまでの報告[9, 11]は嚥下機能の評価を目的とした質問で構成され，パーキンソニズムは H&Y 重症度で評価している．嚥下機能と H&Y 重症度については，H&Y 重症が高い PD 患者ほど嚥下障害のリスクは高いとする報告がある[10]一方で，PD 患者の H&Y 重症度と嚥下障害は必ずしも相関しないと

表3 パーキンソン病患者の問診結果

	誤嚥あり群				誤嚥なし群				
	選択肢1	選択肢2	選択肢3	選択肢4	選択肢1	選択肢2	選択肢3	選択肢4	有意水準
質問1	14(77.8)	4 (22.2)	-	-	44(86.3)	7 (13.7)	-	-	0.40
質問2	15(83.3)	3 (16.7)	-	-	44(86.3)	7 (13.7)	-	-	0.76
質問3	5 (27.8)	4 (22.2)	2 (11.1)	7 (38.9)	32(62.7)	7 (13.7)	2 (3.9)	0 (0.1)	0.01
質問4	14(77.8)	4 (22.2)	0 (0.0)	-	43(84.3)	6 (11.8)	2 (3.9)	-	0.59
質問5	16(88.9)	2 (11.1)	-	-	45(88.2)	6 (11.8)	-	-	0.60
質問6	4 (22.2)	4 (22.2)	6 (33.3)	4 (22.2)	31(60.8)	9 (17.6)	6 (11.8)	5 (9.8)	*<0.01*
質問7	8 (44.4)	4 (22.2)	5 (27.8)	1 (5.6)	42(82.4)	5 (9.8)	3 (5.9)	1 (2.0)	*<0.01*
質問8	10(55.6)	1 (5.6)	4 (22.2)	3 (16.7)	40(78.4)	7 (13.7)	2 (3.9)	2 (3.9)	0.03
質問9	11(61.1)	3 (16.7)	3 (16.7)	1 (5.6)	43(84.3)	4 (7.8)	3 (5.9)	1 (2.0)	0.04
質問10	8 (44.4)	4 (22.2)	4 (22.2)	2 (11.1)	37(72.5)	3 (55.9)	7 (13.7)	4 (7.8)	0.06
質問11	9 (50.0)	3 (16.7)	2 (11.1)	4 (22.2)	30(58.8)	8 (15.7)	9 (17.6)	4 (7.8)	0.37
質問12	4 (22.2)	4 (22.2)	7 (38.9)	3 (16.7)	35(68.6)	9 (17.6)	3 (5.9)	4 (7.8)	*<0.01*
質問13	5 (27.8)	3 (16.7)	5 (27.8)	5 (27.8)	35(68.6)	10(19.6)	4 (7.8)	2 (3.9)	*<0.01*
質問14	7 (38.9)	2 (11.1)	4 (22.2)	5 (27.8)	39(76.5)	7 (13.7)	4 (7.8)	1 (2.0)	*<0.01*
質問15	14(77.8)	0 (0.0)	2 (11.1)	2 (11.1)	40(78.4)	5 (9.8)	3 (5.9)	3 (5.9)	0.81
質問16	10(55.6)	2 (11.1)	2 (11.1)	4 (22.2)	38(74.5)	3 (5.9)	6 (11.8)	4 (7.8)	0.11
質問17	12(66.7)	6 (33.3)	-	-	40(78.4)	11(21.6)	-	-	0.32
質問18	10(55.6)	8 (44.4)	-	-	39(76.5)	12(23.5)	-	-	0.10
質問19 (a)	11(61.1)	7 (38.9)	-	-	40(78.4)	11(21.6)	-	-	0.15
質問19 (b)	18(100.0)	0 (0.0)	-	-	46(90.2)	5 (9.8)	-	-	0.17
質問19 (c)	3 (16.7)	15(83.3)	-	-	41(80.4)	10(19.6)	-	-	*<0.01*
質問19 (d)	7 (38.9)	11(61.1)	-	-	26(51.0)	25(49.0)	-	-	0.38
質問20 (a)	15(83.3)	3 (16.7)	-	-	38(74.5)	13(25.5)	-	-	0.45
質問20 (b)	18(100.0)	0 (0.0)	-	-	47(92.2)	4 (7.8)	-	-	0.22
質問20 (c)	9 (50.0)	9 (50.0)	-	-	31(60.8)	20(39.2)	-	-	0.43
質問24 (d)	10(55.6)	8 (44.4)	-	-	35(68.8)	16(31.4)	-	-	0.32
質問20 (e)	13(72.2)	5 (27.8)	-	-	38(74.5)	13(25.5)	-	-	0.85
質問20 (f)	9 (50.0)	9 (50.0)	-	-	28(54.9)	23(45.1)	-	-	0.72
質問20 (g)	14(77.8)	4 (22.2)	-	-	41(80.4)	10(19.6)	-	-	0.81
質問20 (h)	10(55.6)	8 (44.4)	-	-	35(68.6)	16(31.4)	-	-	0.32

数字は回答数，( )内は群別パーセンテージ．下線は回答の最頻値．有意水準0.05未満を有意とした（斜字）．

表4 問診結果のロジスティック回帰分析結果

	オッズ比	95％信頼区間	有意確率
質問3	1.85	1.00 − 3.42	0.05
質問14	2.85	1.30 − 6.26	0.01
質問19(c)	21.25	3.94 − 114.74	< 0.01

表５　問診の回答パターン別の誤嚥の合併の予測確率と嚥下造影検査結果の比較

問診の回答パターン				嚥下造影検査	
質問3	質問14	質問19(c)	予測確率	誤嚥あり	誤嚥なし
4	4	2	0.98	1 (5.6)	0 (0.0)
3	4	2	0.96	1 (5.6)	0 (0.0)
4	3	2	0.94	1 (5.6)	0 (0.0)
2	4	2	0.93	1 (5.6)	0 (0.0)
3	3	2	0.89	1 (5.6)	0 (0.0)
1	4	2	0.87	1 (5.6)	0 (0.0)
4	2	2	0.84	0 (0.0)	0 (0.0)
2	3	2	0.82	0 (0.0)	0 (0.0)
3	2	2	0.74	0 (0.0)	0 (0.0)
1	3	2	0.71	1 (5.6)	1 (2.0)
4	4	1	0.67	1 (5.6)	0 (0.0)
4	1	2	0.65	3 (16.7)	2 (3.9)
2	2	2	0.61	2 (11.1)	2 (3.9)
3	4	1	0.53	0 (0.0)	0 (0.0)
3	1	2	0.50	0 (0.0)	0 (0.0)
1	2	2	0.46	0 (0.0)	1 (2.0)
4	3	1	0.42	0 (0.0)	0 (0.0)
2	4	1	0.37	0 (0.0)	0 (0.0)
2	1	2	0.35	1 (5.6)	1 (2.0)
3	3	1	0.28	0 (0.0)	1 (2.0)
1	4	1	0.24	0 (0.0)	1 (2.0)
1	1	2	0.23	2 (11.1)	3 (5.9)
4	2	1	0.20	0 (0.0)	2 (3.9)
2	3	1	0.17	0 (0.0)	0 (0.0)
3	2	1	0.12	0 (0.0)	0 (0.0)
1	3	1	0.10	1 (5.6)	2 (3.9)
4	1	1	0.08	1 (5.6)	6 (11.8)
2	2	1	0.07	0 (0.0)	0 (0.0)
3	1	1	0.05	0 (0.0)	1 (2.0)
1	2	1	0.04	0 (0.0)	2 (3.9)
2	1	1	0.03	0 (0.0)	4 (7.8)
1	1	1	0.01	0 (0.0)	22 (43.1)
		誤嚥の合併ありの予測		13 (72.2)	5 (9.8)
		誤嚥の合併なしの予測		5 (27.8)	46 (90.2)
				18 (100)	51 (100)

予測確率はロジスティック回帰モデルから計算し，0.50 以上のとき，誤嚥の合併ありと判定した．（　）内は群別パーセンテージ．

する報告も多い[15~17]．本研究は誤嚥あり群と誤嚥なし群のH&Y重症に有意差がなく，後者を支持する結果になった．また，PD患者の嚥下障害は，動作緩慢が原因であることが指摘されている[18,19]．本研究から食事中のパーキンソニズムとして体の動きの悪さを自覚していたPD患者は有意にVFでの誤嚥が多く，これを問うことが嚥下障害の評価に有用であることが示唆された．食事場面以外では誤嚥あり群と誤嚥なし群で自覚的なパーキンソニズムに有意差がなかった．このことから，誤嚥あり群の食事中の動きの悪さの自覚は，食事中だから自覚できるパーキンソニズムである可能性があった．

PD患者のBMIの低下はVFで誤嚥した患者の特徴の1つである[10]．しかしながら，PD患者では嚥下障害以外にも味覚鈍麻，摂食動作の障害，抑うつ症状，筋強剛や不随意運動による必要エネルギーの増加など，さまざまな原因で体重が低下する[20]．本研究では誤嚥あり群と誤嚥なし群のBMIは有意差がなく，過去1年間の体重減少の自覚が誤嚥あり群で有意に多かった．VFで誤嚥した患者は，BMIが有意に低下する以前に体重減少を自覚している可能性があった．

誤嚥あり群で有意に自覚されていた，食事中のむせ（質問12），水分飲みでのむせ（質問13），内服時のむせ（質問14）は，日常の摂食場面での誤嚥を示唆する臨床所見である．PDではVFで誤嚥していない患者でも嚥下障害を自覚していることが多い[4]ことが知られている．本研究のロジスティック回帰解析から，食事や飲水でのむせよりも，内服時のむせの自覚がVFでの誤嚥の合併の予測に寄与することが示された．

結論として，VFで誤嚥するPD患者は，ここ1年でやせてきた，薬を飲むときにむせる，食事中の自覚症状として動きの悪さがある，という質問で判定できることを示した．レヴー小体病では，VFでの誤嚥が肺炎発症や経口摂取中止のリスク因子であり[4]，問診から早期に誤嚥の合併を疑うことは治療方針の決定において有用であると考えた．今後，本研究対象と異なるPD患者を対象に本研究の信頼性を検討する予定である．また，VFで誤嚥したPD患者において，パーキンソニズムの治療で食事中の動きの悪さの自覚がなくなった場合，誤嚥が改善するのか検討する予定である．

謝辞：本研究は精神・神経疾患研究開発費「レビー小体病関連疾患に関する研究」(21委－4)で行った．

文　献

1) Nakashima K, et al：Prognosis of Parkinson's disease in Japan. Tottori University Parkinson's Disease Epidemiology (TUPDE) Study Group. Eur Neurol 38S2：60-63, 1997.
2) Fall PA, et al：Survival time, mortality, and cause of death in elderly patients with Parkinson's disease：a 9-year follow-up. Mov Disord 18：1312-1316, 2003.
3) Wang X, et al：Clinical course and cause of death in elderly patients with idiopathic Parkinson's disease. Chin Med J 115：1409-1411, 2002.
4) Yamamoto T, et al：Risk of pneumonia onset and discontinuation of oral intake following videofluorography in patients with Lewy body disease. Parkinsonism Relat Disord 16：503-506, 2010.
5) Bird MR, et al：Asymptomatic swallowing disorders in elderly patients with Parkinson's disease：a description of findings on clinical examination and videofluoroscopy in sixteen patients. Age Ageing 23：251-254, 1994.
6) Fuh JL, et al：Swallowing difficulty in Parkinson's disease. Clin Neurol Neurosurg 99：106-112, 1997.
7) 大熊るり，他：摂食・嚥下障害スクリーニングのための質問紙の開発．日摂食嚥下リハ会誌 6：3-8, 2002.
8) 手塚淑恵，他：Parkinson病患者の嚥下障害 －質問紙による検討－．神経内科 68：488-490, 2008.
9) Manor Y, et al：Validation of a swallowing disturbance questionnaire for detecting dysphagia in patients with Parkinson's disease. Mov Disord 22：1917-1921, 2007.
10) 山本敏之：パーキンソン病の嚥下障害とその治療．MB Med Reha 135：37-44, 2011.
11) Lam K, et al：Simple clinical tests may predict severe oropharyngeal dysphagia in Parkinson's disease. Mov Disord 22：640-644, 2007.
12) Gibb WR, Lees AJ：The significance of the Lewy body in the diagnosis of idiopathic Parkinson's disease. Neuropathol Appl Neurobiol 15：27-44, 1989.
13) Yoshita M：Differentiation of idiopathic Parkinson's