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Videofluoroscopic Dysphagia Scale as an Additional Indicator of Gastrostomy in Patients with Amyotrophic Lateral Sclerosis with Dysphagia

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Pseudobulbar palsy and bulbar palsy cause dysphagia in patients with amyotrophic lateral sclerosis (ALS). Dysphagia in patients with ALS not only increases the risk of aspiration and pneumonia but also leads to malnutrition and weight loss, which are poor prognostic factors. Gastrostomy is the preferred route of feeding and nutritional support in patients with dysphagia. However, there are no established standards to determine the ideal timing of gastrostomy for patients with ALS. Therefore, we used the videofluoroscopic dysphagia scale (VDS), which objectively quantifies swallowing function, in videofluoroscopic swallowing study (VFSS) to investigate whether this scale at diagnosis can be a useful predictor for the timing of gastrostomy. We retrospectively evaluated 22 patients with ALS who were diagnosed at our hospital. We assessed the VDS scores in all patients within 3 months of diagnosis. A decline in the ALS functional rating scale revised (ALSFRS-R) scores was used as an indicator of disease progression. As a result, we found that the VDS score of the pharyngeal phase and the total VDS score were significantly correlated with the ΔALSFRS-R scores. These scores were also associated with the existing indicators for the timing of gastrostomy, i.e., decreased body weight and percent-predicted forced vital capacity. We demonstrated the noninferiority of the VDS scores relative to the existing indicators. In addition, the VDS score of the pharyngeal phase was significantly correlated with the time from diagnosis to gastrostomy. The VDS score could estimate the timing of gastrostomy in patients with ALS with dysphagia at diagnosis.

Keywords: amyotrophic lateral sclerosis; dysphagia; gastrostomy; videofluoroscopic dysphagia scale; videofluoroscopic swallowing study
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Introduction

Amyotrophic lateral sclerosis (ALS) is a rare, progressive, irreversible neurodegenerative disease characterized by the systematic and selective loss of upper and lower motor neurons (Tandan and Bradley 1985). In patients with ALS, dysphagia can be caused by both pseudobulbar palsy (reduced soft palate reflex caused by upper motor neuron damage from the cerebral cortex to the entorhinal, midbrain, and pons) and bulbar palsy (e.g., reduced swallowing reflex, tongue atrophy due to the degeneration of the IX, X, and XII neuronal nuclei in the medulla oblongata) (Kawai et al. 2003). Dysphagia in ALS not only increases the risk of aspiration, choking, and pneumonia but also leads to malnutrition and weight loss, which are poor prognostic factors (Nieves et al. 2016; Shimizu et al. 2019). Approximately 80% of patients with ALS develop dysphagia during the disease course (Muscaritoli et al. 2012).

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Surgery is a suitable option for preventing aspiration in patients with ALS with severe dysphagia (Soga et al. 2022). Several reports have shown that adequate caloric intake can attenuate ALS progression (Wills et al. 2014; Ludolph et al. 2020). Therefore, nutritional management is an essential issue affecting the prognosis of patients with ALS.

To ensure proper nutritional management and to secure medication routes, patients with ALS can undergo gastrostomy. Since gastrostomy is an invasive procedure, specific guidelines have been established to ensure its safety, e.g., the American Academy of Neurological Societies and the European Federation of Neurological Guidelines defined % forced vital capacity (%FVC) as > 50% based on the guidelines for safe gastrostomy placement (Miller et al. 2009; Kak et al. 2017). Another report revealed that the prognosis after gastrostomy is poor among patients with a %FVC of < 38% (Bokuda et al. 2016). However, there are no established standards for the appropriate timing of gastrostomy in patients with ALS, although gastrostomy is considered based on the following in clinical practice: presence of subjective symptoms (e.g., choking and prolonged mealtime), weight loss of ≥ 10% compared with the pre-morbid weight, body mass index (BMI) of < 18.5 kg/m^2, aspiration or saliva retention in the pisiform fossa based on the swallowing assessment, and indication before or at the time of noninvasive ventilation (NIV) induction (Shimizu 2013). Subjective symptoms are based on patient self-reporting only and are therefore narrative. BMI at diagnosis varies widely among individuals. NIV induction is considered on the basis of %FVC or arterial blood gas analysis results (Thakore et al. 2019). %FVC between 50% and 80% can be a good indicator for gastrostomy because the procedure should be considered before or at the time of NIV induction (Shimizu 2013). However, a disadvantage of %FVC is that it cannot be accurately measured in patients with weakness of the orbicularis oris muscle or in patients with strong complaints of fatigue. Direct and objective assessments, which can determine the degree of dysphagia accurately, are recommended to identify the appropriate timing for gastrostomy.

Videofluoroscopic swallowing study (VFSS) and flexible videoendoscopic examination of swallowing (FEES) are the current gold standards for the objective assessment of swallowing function (Aviv et al. 2000; Hiss and Postma 2003; Langmore 2003; Rugiu 2007). Compared with VFSS, FEES has several advantages, including low-cost, greater mobility, and repeatability without X-ray exposure. The Hyodo score, a scoring system developed to evaluate endoscopic swallowing using 3 mL of blue-dyed water, is a useful predictor of aspiration in FEES (Hyodo et al. 2010). A large retrospective study showed that the risk of aspiration increases in patients with a Hyodo score of > 6 (Chiba et al. 2018). Nevertheless, FEES also has a disadvantage; it cannot identify swallowing dynamics during the oral phase (Bastian 1993). Recently, a study assessed the appropriate timing of gastrostomy using FEES in patients with ALS. Although there was a correlation between disease progression and FEES findings, FEES was not a specific indicator for the timing of gastrostomy (Conde et al. 2018).

VFSS is a technique used to evaluate the oral and pharyngeal phases of swallowing. Further, it has been used to evaluate swallowing function in different neurological disorders (Han et al. 2008; Solazzo et al. 2014; Lee et al. 2015; Lee et al. 2021). Videofluoroscopic dysphagia scale (VDS), a VFSS rating scale, has been originally used for predicting the degree of dysphagia, which is a consequence of stroke (Han et al. 2008; Kim et al. 2014). However, in recent years, the use of VDS has been expanded to other diseases, such as spinal cord injury, peripheral neuropathy, neurodegenerative diseases, traumatic brain injury, brain tumors, poor general medical condition, and local structural lesions involving the head and neck (Han et al. 2008).

In patients with ALS, VDS has been found to be effective in detecting early asymptomatic dysphagia (Solazzo et al. 2014). Moreover, VDS score is significantly associated with food intake selection and the development of aspiration pneumonia (Lee et al. 2021). Therefore, this study examined whether VDS at diagnosis can be a useful predictor for the timing of gastrostomy.

Materials and Methods

Participants

We retrospectively evaluated 22 consecutive patients with sporadic ALS who were admitted for diagnosis at the Department of Neurology, Tohoku University Hospital, and underwent VFSS at the Department of Otolaryngology-Head and Neck Surgery, Tohoku University Hospital, from August 2015 to August 2020. Table 1 shows the clinical characteristics of the participants. All patients who met one of the revised El Escorial criteria (clinically definite, clinically probable, clinically probable laboratory-supported, or clinically possible) (Brooks et al. 2000) were diagnosed with ALS by at least two neurologists. The onset of ALS was defined as the month in which the patient developed initial motor symptoms, such as dysarthria, dysphagia, dyspnea, dropped neck, limb weakness, and muscle atrophy. The endpoint was set as the month in which the patient underwent gastrostomy or died. The timing of gastrostomy was discussed with the patients and their family members, physicians and nurses specializing in ALS, and other professionals, such as physical/occupational/speech therapists and social workers. Clinical findings, including decreased food intake, prolonged food intake time, weight loss of ≥ 10%, NIV induction, and %FVC ≤ 70, were used as guides. Patients were followed-up until September 2021. A written informed consent was obtained from all participants before gastrostomy.

All patients can refer to the public information document available in the hospital's website (https://www.med.tohoku.ac.jp/public/documents/index.html). The consent to participate was given via opt-out. This study was approved by the Ethics Committee of Tohoku University Hospital

Table 1. Clinical characteristics of the patients.

Parameters	Value	Range
Men: women, n	10:12	
Age at diagnosis (years)	67.5	57.9-77.5
Disease-onset region, bulbar: spinal, n	11:11	
Frontotemporal dementia, n	6	
Body weight at diagnosis (kg)	52.1	43.6-60.5
BMI at diagnosis (kg/m2)	20.8	18.2-23.4
⊿BW (%; n = 16)	6.6	1.0-12.1
ALSFRS-R (t)	37.9	29.1-46.8
ALSFRS-R (b)	8.3	5.4-11.3
%FVC	83.1	55.7-110.4
Disease duration (months)	12.4	4.9-19.8
Diagnosis to endpoints (months; n = 18)	11	0-26.8
Endpoints, gastrostomy: death (n = 18)	12:06	
Hyodo score (n = 20)	2.6	0.4-4.7
VDS of oral phase	10.4	3.6-17.3
VDS of pharyngeal phase	18.6	5.6-31.6
Total VDS	29.1	12.0-46.1

Clinical characteristics of the patients. Data are expressed as mean and range.
BMI, body mass index; BW, body weight; ALSFRS-R, amyotrophic lateral sclerosis functional rating scale revised; %FVC, % forced vital capacity; VDS, videofluoroscopic dysphagia scale.

(No. 2021-1-018). The consent for publication was given via opt-out.

Procedures

All patients underwent VFSS within 3 months of ALS diagnosis. The protocol was based on a previous report (Kuniyuki et al. 2022). Patients received 3 or 5 ml of diluted barium, jelly, rice porridge, or rice with standardized viscosity and quality orally. All examinations were recorded in audio video interleave (AVI) files (30 frames/s). VFSS was performed safely, with no apparent complications.

The AVI files were copied to digital versatile discs (DVDs), with each DVD containing all experiences in a different randomized order. All AVI files were analyzed by three physiatrists who were blinded to the study, and the conclusions were obtained based on the average score of the three physiatrists. Table 2 shows the details of each item of the VDS (Han et al. 2008).

In total, 20 patients underwent FEES, which was performed by one otolaryngologist within 3 months of ALS diagnosis. A nasopharyngeal laryngoscope with a diameter of 3.9 mm with up/down tip deflection capability (OLYMPUS ENF-VH, Tokyo, Japan) and a digital color video monitor were used. Table 3 depicts the details of each item in the Hyodo score.

Nutritional, bulbar, and respiratory status

We recorded the height (m), body weight (kg) before disease onset (B-BW) and at diagnosis (D-BW), and BMI (kg/m^2) at diagnosis. The BMI at diagnosis of all patients was assessed. ⊿BW (%) was defined as follows: [B-BW (kg) − D-BW (kg)] × 100/B-BW (kg). The ⊿BW (%) of 16 patients was assessed. However, the exact B-BW of six patients could not be obtained. The ALS functional rating scale revised (ALSFRS-R) was used to assess all patients at the time of diagnosis (Cedarbaum et al. 1999). The overall ALSFRS-R was defined as ALSFRS-R (t) (ALSFRS-R total score) that was rated on a 48-point scale. Swallowing, saliva, and dysarthria items in the ALSFRS-R, which were correlated with dysphagia or dysarthria, were referred to as ALSFRS-R (b) (ALSFRS-R bulbar subscore) and were evaluated on a 12-point scale. ⊿ALSFRS-R (t) (/month) and ⊿ALSFRS-R (b) (/month) were defined as follows: [48-at diagnosis ALSFRS-R (t)]/[time from onset to diagnosis (months)] and [12-ALSFRS-R (b)]/[time from onset to diagnosis (months)], respectively. When the ⊿ALSFRS-R (t) and ⊿ALSFRS-R (b) were greater, the progression of symptoms was faster. The %FVC at diagnosis, which is a measure of respiratory function, was assessed.

Statistical analysis

We used the Spearman's rank correlation coefficient to evaluate the association between the rate of ALS progression and the VDS and Hyodo scores at the time of diagnosis. ⊿ALSFRS-R (t) and ⊿ALSFRS-R (b) were used as progression markers. To confirm the consistency between the existing guidelines (Shimizu 2013) and the VDS and

Table 2. Videofluoroscopic dysphagia scale.

Parameters	Coded values		Parameters	Coded values	
Lip closure	Intact	0	Triggering of pharyngeal swallowing	Normal	0
	Inadequate	2		Delayed	4.5
	None	4	Vallecular residue	None	0
Bolus formation	Intact	0		< 10%	2
	Inadequate	3		10-50%	4
	None	6		> 50%	6
Mastication	Intact	0	Laryngeal elevation	Normal	0
	Inadequate	4		Impaired	9
	None	8	Pyriform sinus residue	None	0
Apraxia	None	0		< 10%	4.5
	Mild	1.5		10-50%	9
	Moderate	3		> 50%	13.5
	Severe	4.5	Coating on the pharyngeal wall	No	0
Tongue to palate contact	Intact	0		Yes	9
	Inadequate	5	Pharyngeal transit time	≤ 1.0 s	0
	None	10		> 1.0 s	6
Premature bolus loss	None	0	Aspiration	None	0
	< 10%	1.5		Supraglottic penetration	6
	10-50%	3			
	> 50%	4.5		Subglottic aspiration	12
Oral transmit time	≤ 1.5 s	0			
	> 1.5 s	3			
Oral phase		40	Pharyngeal phase		60
Total					100

Videofluoroscopic dysphagia scale (Han et al. 2008).

Table 3. Hyodo score.

Parameters	Coded values	
Salivary pooling degree at the vallecula and piriform sinuses	No pooling	0
	Pooling at the vallecular sinus only	1
	Pooling in the vallecula and piriform sinuses and no penetration in the larynx	2
	Pooling in the vallecula and piriform sinuses and penetration in the larynx	3
Glottal closure reflex induced by touching the epiglottis or arytenoid with the endoscope	Significant reflex with one touch	0
	Slow and/or weak reflex with one touch	1
	Reflex after one or three touches	2
	No reflex after three touches	3
Location of the bolus during the swallowing reflex initiation assessed using "white-out" timing	Pharyngeal	0
	Vallecula	1
	Piriform sinuses	2
	No swallowing	3
Extent of pharyngeal clearance after blue-dyed water is swallowed	No residue	0
	Pharyngeal residues remained. However, they were not observed after swallowing is attempted for two or three times.	1
	Pharyngeal residues remained. However, there was no penetration in the larynx.	2
	Pharyngeal residues remained, and there was penetration into the larynx.	3
Total		12

Hyodo score (Hyodo et al. 2010).

Hyodo scores in our study, linear regression analyses of ⊿BW, BMI, and %FVC at diagnosis and those scores were performed. In addition, the differences in correlation coefficients between the VDS scores and the existing indicators were tested. Finally, linear regression analyses were performed to evaluate the correlation between VDS or existing indicators for gastrostomy and the duration from diagnosis to gastrostomy. A P value of < 0.05 was considered statistically significant. Statistical analysis was performed using Prism9 for MacOS (version 9.2.0, GraphPad Software, San Diego, CA, USA).

Results

We found that the ALS progression rate was significantly correlated with the VDS scores at diagnosis. There was a significant correlation between ⊿ALSFRS-R (t), and the VDS score of the pharyngeal phase and the total VDS score (Table 4). Meanwhile, ⊿ALSFRS-R (b) was significantly correlated with the total VDS score alone (Table 4). The association between the Hyodo score and ALSFRS-R was not significant. Supplementary Tables S1 and S2 depict the correlations between each of items in the Hyodo score and VDS items as well as ALS progression rate.

Next, we found significant positive correlations between ⊿BW and the VDS score of the pharyngeal phase and the total VDS score at diagnosis (Fig. 1A, B). In addition, the VDS score of the pharyngeal phase and the total VDS score had a significant negative correlation with %FVC at diagnosis (Fig. 1C, D). We found that there were no significant correlations between VDS scores and BMI at diagnosis (Supplementary Fig. S1). Regarding the strength of correlation with ⊿ALSFRS-R (t) and ⊿ALSFRS-R (b), there were no significant differences in correlation coefficients between the VDS scores and either %FVC or ⊿BW (Table 5). In addition, we confirmed that Hyodo score had significant correlations with ⊿BW and %FVC

Table 4. Correlation between ⊿ALSFRS-R and swallowing functions.

	⊿ALSFRS-R(t)		⊿ALSFRS-R(b)	
	R	P value	R	P value
Hyodo score	0.421	0.065	0.100	0.675
VDS Oral	0.381	0.080	0.402	0.064
Pharyngeal	0.595	**0.004**	0.382	0.080
Total	0.590	**0.004**	0.468	**0.028**

Spearman's rank correlation coefficient (Hyodo score: n = 20; VDS: n = 22).
ALSFRS-R, amyotrophic lateral sclerosis functional rating scale revised; VDS, videofluoroscopic dysphagia scale.

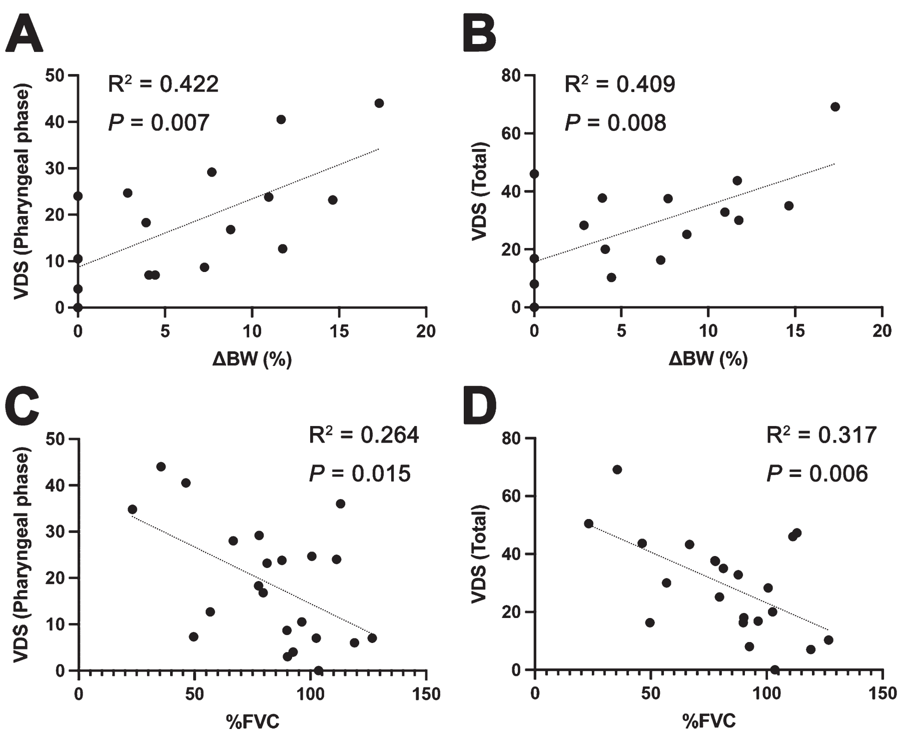

Fig. 1. Associations between the videofluoroscopic dysphagia scale (VDS) score and existing indicators for gastrostomy (n = 22).
(A) Correlations between the VDS score of the pharyngeal phase and ⊿BW. Y = 1.472 × X + 8.702, 95% confidence interval: 0.483-2.460, F value: 10.20. (B) Correlations between the total VDS score and ⊿BW. Y = 1.958 × X + 15.66, 95% confidence interval: 0.6072-3.309, F value: 9.665. (C) Correlations between the VDS score of the pharyngeal phase and %FVC. Y = −0.2445 × X + 38.93, 95% confidence interval: −0.4351 to −0.05393, F value: 7.162. (D) Correlations between the total VDS score and %FVC. Y = −0.3513 × X + 58.25, 95% confidence interval: −0.5919 to −0.1108, F value: 9.284. BW, body weight; %FVC, % forced vital capacity.

Table 5. The correlation coefficient difference test.

	from diagnosis to endpoint		⊿ALSFRS-R(t)		⊿ALSFRS-R(b)	
VDS	total	pharyngeal	total	pharyngeal	total	pharyngeal
%FVC	0.958	0.7725	0.4523	0.7005	0.8307	0.6777
⊿BW	0.218	0.3574	0.7581	0.5206	0.3735	0.2829

The correlation coefficient difference test. Each number indicates a *P* value. n = 22 for VDS, n = 22 for %FVC and n = 16 for ⊿BW. The specific correlation coefficients for %FVC and BW are listed in Supplementary Fig. 2.
VDS, videofluoroscopic dysphagia scale; %FVC, % forced vital capacity; BW, body weight; ALSFRS-R, amyotrophic lateral sclerosis functional rating scale revised.

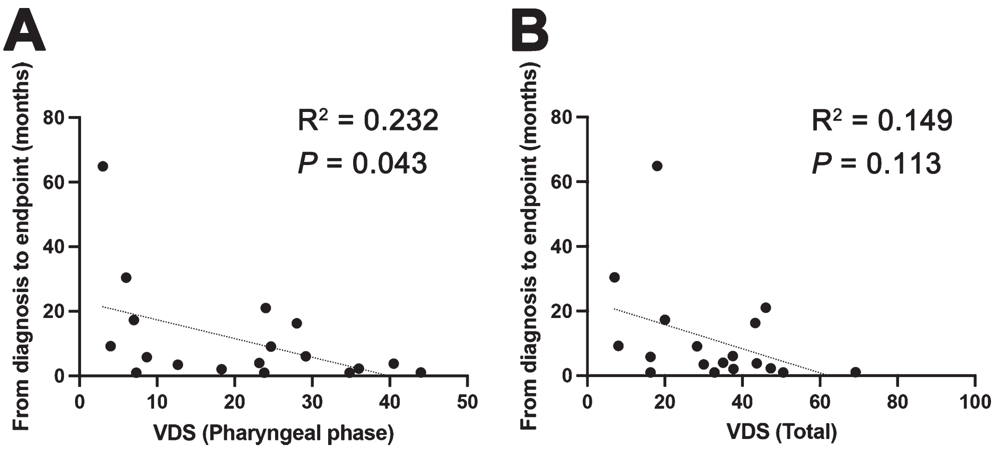

Fig. 2. Significant negative correlation between the videofluoroscopic dysphagia scale (VDS) score of the pharyngeal phase and time to endpoint (n = 18).
(A) Correlations between the duration from diagnosis to endpoint and the VDS score of the pharyngeal phase. Y = −0.5783 × X + 23.16, 95% confidence interval: −1.136 to −0.02067, F value: 4.833. (B) Correlations between the duration from diagnosis to endpoint and the total VDS score. Y = −0.3728 × X + 23.26, 95% confidence interval: −0.8442 to 0.09864, F value: 2.810.

(Supplementary Fig. S2).

Finally, we evaluated the relationship between VDS score and the duration from diagnosis to endpoint in 18 patients. Results showed a significant negative correlation between the VDS score of the pharyngeal phase and time to endpoint (Fig. 2A). However, the total VDS score was not significantly associated with the time to endpoint (Fig. 2B). We also found a significant correlation between ⊿BW and duration from diagnosis to endpoint (Supplementary Fig. S3); however, BMI, %FVC, and ⊿ALSFRS-R showed no significant correlation with the duration from diagnosis to endpoint (Supplementary Figs. S3 and S4).

Discussion

In this study, we confirmed that the VDS score could reflect disease progression in patients with ALS. We observed no significant correlation between the Hyodo score and ⊿ALSFRS-R. The mean Hyodo score was relatively low (2.6 ± 2.1) in the patient group (Table 1). ALS most rapidly progresses among all neurodegenerative diseases, and dysphagia in ALS can occur in both the oral and pharyngeal phases (Kawai et al. 2003). Therefore, it might be challenging to accurately assess the rate of disease progression in patients with ALS by evaluating the pharyngeal phase alone. VDS is advantageous as it can provide visual confirmation of the entire swallowing function itself and is an optimal and complementary swallowing assessment scale for ALS (Han et al. 2008).

In the present study, VDS scores in the pharyngeal phase were significantly correlated with the timing of gastrostomy compared with VDS scores in the oral phase and the VDS total score. Aspiration in elderly is associated with delayed swallowing reflexes, especially from the pharyngeal to the esophageal phase (Kurian et al. 2009). It has also been reported that patients with ALS have a delayed swallowing reflex in the pharyngeal phase (Watanabe et al. 2016). Furthermore, it has been reported that respiratory infections, such as bronchopneumonia and aspiration pneumonia, account for more than half of the deaths in patients with ALS (Kurian et al. 2009). Therefore, as the function of the pharyngeal stage declines in patients with ALS, the risk of developing pneumonia and choking increases, making it difficult for them to continue oral intake of sufficient calories and eventually leading to gastrostomy. This is supported by the fact that in our data, the Hyodo score, which mainly reflects pharyngeal function, was significantly correlated with ⊿BW and %FVC, which are indicators of gastrostomy timing.

In the present study, we showed that the VDS of the pharyngeal phase at diagnosis was significantly correlated with time to gastrostomy as well as ⊿BW. This significant correlation was not found for other indicators, such as BMI, %FVC, or ⊿ALSFRS-R. This result indicates that the VDS, especially the pharyngeal score, has the potential to be used as an additional indicator comparable to existing guidelines for gastrostomy. Even if the body weight and %FVC of a patient have not decreased, early gastrostomy should be considered if the VDS score of the pharyngeal phase is low at diagnosis.

The current study had several limitations. First, the number of patients was limited, and only patients who had been tested at diagnosis were selected. By conducting a large prospective study that includes patients who are suspected to have dysphagia during follow-up, the cutoff VDS score to predict the exact time of gastrostomy can be determined. In addition, more precise prognosis can be estimated by dividing patients by onset site and analyzing the correlation between VDS and time to gastrostomy in each group. Moreover, more precise sub-analyses could detect the item that can most significantly affect dysphagia in patients with ALS. Second, VFSS is an invasive procedure which is difficult to perform frequently due to the problem of radiation exposure. Therefore, we should take care in the timing of performing VFSS. VFSS should be performed at the time of diagnosis or when a patient shows signs of dysphagia or weight loss. Additionally, only limited facilities can perform this technique. Third, the progression of ALS significantly varies, and the progression rate is not always linear, with some patients experiencing a rapid worsening at a certain point and some experiencing a slight improvement. In these patients, the prognostic value of VDS at diagnosis alone is not accurate (Bedlack et al. 2016; Watanabe et al. 2016). Thus, repeated VFSS might be requested. In addition, we should not forget that gastrostomy is performed in patients with ALS to improve prognosis through nutritional therapy and support dysphagia nutritionally. Finally, VDS requires specialized evaluation by otolaryngologists, and accurate data collection is possible only via close communication between dysphagia specialists and neurologists.

In conclusion, VFSS is a useful examination tool for evaluating swallowing function in patients with ALS. The VDS score reflects ALS progression at diagnosis. In particular, the VDS score of the pharyngeal phase might be useful in identifying patients who should be considered for gastrostomy at diagnosis as an alternative to subjective dysphagia symptoms.

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Author Contributions

T.S., R.I., and N.S. designed the study. T.S. and R.I. analyzed and interpreted the data and made major contributors in writing the manuscript. N.S., H.W., and M.K. interpreted the data. J.O., J.S., A.H., and K.K. performed VFSS and FEES and evaluated the swallowing functions of patients. M.A. revised the manuscript for important intellectual content. Y.K. also revised the manuscript and finally approved the article. All authors read and approved the final version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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Supplementary Files

Please find supplementary file(s);
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