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Feasibility of high-resolution manometry for decision of feeding methods in patients with amyotrophic lateral sclerosis

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Abstract

As amyotrophic lateral sclerosis (ALS) progresses, dysphagia gets worse due to the weakening of pharyngeal musculature. As oral feeding becomes more difficult or dangerous due to worsening dysphagia, tracheal aspiration, or undernutrition, the necessity for tube feeding becomes increasingly important. This study aims to establish a standard pressure point by applying pharyngeal pressure using high-resolution manometry (HRM) to start tube feeding in patients with ALS.

This study was designed as a retrospective analysis of prospectively collected data. Forty-one patients with ALS and 20 healthy subjects were participated. Both groups were evaluated using HRM, videofluoroscopic swallowing study (VFSS), and pulmonary function test. The swallowing pressure along the velopharynx (VP), tongue base (TB), pre-upper esophageal sphincter (UES), lower pharynx, and cricopharyngeus, as well as minimal UES pressure were measured using HRM.

There was significantly positive correlation between the pressure of cricopharyngeus and forced expiratory volume in 1 second (FEV1). And there were significant correlations between results of VFSS and FEV1, FEV1%, forced vital capacity (FVC), and FVC%. There was a significant difference in the pressure of TB and cricopharyngeus between the control group and the ALS patient group. The pressures of VP, TB, lower pharynx, and cricopharyngeus have a significant correlation with the recommended feeding type by VFSS.

Because it is possible to use HRM to quantitatively assess pharyngeal and respiratory weaknesses and it is more sensitive than other evaluation tools, the cutoff value of HRM parameters may be used to decide the feeding type in patients with ALS.

Abbreviations: ALS = amyotrophic lateral sclerosis, FEV1 = forced expiratory volume in 1 second, FOIS = Functional Oral Intake Scale, FVC = forced vital capacity, HRM = high-resolution manometry, PAS = penetration-aspiration score, PFT = pulmonary function test, TB = tongue base, UES = upper esophageal sphincter, VFSS = videofluoroscopic swallowing study, VP = velopharynx.

Keywords: amyotrophic lateral sclerosis, deglutition disorders, manometry

1. Introduction

Dysphagia is a critical problem in patients with amyotrophic lateral sclerosis (ALS). Dysphagia is reported to occur in 85% of patients with ALS at some point throughout the disease process.[1] Patients with dysphagia suffer not only from dehydration and malnutrition, but also from aspiration, which may result in pneumonia and death.[2] Safe swallowing requires sufficient strength of the pharyngeal musculature,[3,4] proper orosensory function,[5,6] and precise coordination of the neuromuscular events to successfully create pressure gradients that propel the bolus from the mouth to the esophagus.[7]

As disease progresses, dysphagia gets worse due to the weakening of pharyngeal musculature. As oral feeding becomes more difficult or dangerous due to worsening dysphagia, tracheal aspiration, or undernutrition, the necessity for enteral feeding becomes increasingly important.[8] Thus, the swallowing function of these patients should carefully be evaluated and followed-up during the course of disease progression to prevent aspiration pneumonia and to start enteral feeding appropriately.

Until now, there have been some attempts to determine the feeding types using pulmonary function test (PFT).[9] One clinically relevant prognostic factor in patients with ALS is the weakening of the respiratory muscles.[10] The algorithm for nutrition management in ALS patients published by American Academy of Neurology showed that the clinical symptom and forced vital capacity (FVC) are the evaluation items to determine the feeding type.[11]

Clinically, however, there were lots of patients who cannot conduct the spirometer due to weakness of respiratory muscles in the absence of tracheal aspiration. Thus, due to these pitfalls, PFT by a spirometer is not applicable to all patients with ALS with severe respiratory weakness and is impossible to be used as a

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method to evaluate dysphagia. Videofluoroscopic swallowing study (VFSS) is considered as the criterion standard method to evaluate swallowing function in patients with ALS. However, VFSS is not a quantitative study. It only evaluates the presence of pharyngeal residue or aspiration and cannot predict when the aspiration develops.[7] Therefore, new evaluation tool to predict aspiration with higher sensitivity and accuracy is required.

As high-resolution manometry (HRM) can measure the pharyngeal pressure quantitatively, HRM parameters can reflect the gradual weakening of the pharyngeal muscles in neuromuscular disease (NMD) patients. And it has sensitive sensors that are able to detect the pressure of 0.1 mm Hg.[12] Therefore, HRM might be used to predict dysphagia in NMD patients with severe respiratory weakness.

Our hypothesis is that the pharyngeal weakness evaluated by HRM could predict aspiration better than the PFT. And HRM parameters could be used as a guideline to determine appropriate feeding type in patients with ALS; therefore, the guideline using HRM parameters could reduce the development of aspiration pneumonia.

The first purpose of this study is to know the correlation between pulmonary function and pharyngeal pressure in patients with ALS. The second purpose is to find out the significant HRM parameters during pharyngeal swallowing between the ALS and the control groups. The third purpose is to establish feeding algorithm using HRM parameters to determine appropriate feeding type and to prevent aspiration in patients with ALS.

2. Methods

2.1. Subjects

This study was a retrospective analysis of prospectively collected data, which was carried out by examining the medical records of patients with ALS, including both inpatients and outpatients. Diagnosis of patients with ALS was conducted with Department of Neurology. The diagnosis was made according to "Revised El Escorial criteria for the diagnosis of amyotrophic lateral sclerosis."[13] Electrophysiological studies (electromyography and nerve conduction study) were performed to confirm lower motor neuron dysfunction and to exclude other pathophysiological processes. Brain and spine magnetic resonance imaging was performed for neuroimaging evidence of other disease processes. And several laboratory studies were performed to identify ALS with laboratory abnormalities of uncertain significance syndromes; complete blood count, admission panel, electrolyte, C-reactive protein, lipid panel, folate, vitamin B12, hepatitis, venereal disease research laboratory, acetylcholine receptor Ab, spinal muscular atrophy, survival motor neuron 1 (SMN1) and SMN2 deletion/duplication, spinal bulbar muscular atrophy (SBMA), electrocardiogram, creatine kinase, thyroid function test, alpha-fetoprotein, carcinoembryonic antigen, prostate-specific antigen, paraneoplastic Ab, anti-human T-lymphotropic virus, anti-Myelin-associated glycoprotein Ab, and protein electrophoresis (serum, urine).

ALS patients who had undergone VFSS, PFT, and HRM within 2 days between September 1, 2014 and September 5, 2018 were included in the ALS group. The data of the control group were obtained from previous prospective studies.[4,14] The inclusion criteria for the control group were as follows: subjects without swallowing, neurological, or gastrointestinal disorders, older than 20 years, and underwent VFSS and HRM simultaneously. This study was approved by the institutional review board at our institute (B-1603/338-103).

2.2. Equipment and procedure

A solid HRM (InSIGHT HRM; Sandhill Scientific, Highlands Ranch, CO) with the ability to measure rapidly changing pressures along the entire length of the pharynx was used in this study. In most areas of the manometric catheter, the intervals of the sensors were 1 cm apart; they were 2 cm apart in only 5 areas. Therefore, the capable length was 36 cm.[12]

To avoid any potential confounding effects of satiety, participants were instructed to not eat for 4 hours and to not drink liquids for 2 hours before the tests. Ten percent lidocaine spray was applied through the nasal passage. Once the catheter was positioned within the pharynx, participants rested for 5 to 10 minutes for adaptation before performing experimental swallows. In the neutral head position, participants swallowed 5 mL of water, twice.[12]

Pressure and timing data from HRM were extracted using a BioVIEW Analysis software version 5.6.3.0 (Sandhill Scientific). The swallowing pressure along the velopharynx (VP), tongue base (TB), preupper esophageal sphincter (UES), lower pharynx, cricopharyngeus, and minimal UES pressure were measured using HRM. Moreover, the area integral, rise time, duration of VP, TB, UES, and nadir UES were analyzed.[15] In addition, the maximal pressure, minimal pressure, area integral to the pressure peak, and timing intervals between the variables were measured (Fig. 1).[12] The inter- and intrarater reliabilities of HRM studies were well established in previous studies (coefficient of stability = 0.992 and 0.988, respectively).[3]

For VFSS, subjects were seated upright with neutral head position under a fluoroscopic machine. Each VFSS was performed using the following boluses: thick fluid (viscosity range >1750 cP); dysphagia I fluid (viscosity range, 351–1750 cP; a pureed diet); dysphagia II fluid (same viscosity; mechanically altered, but not pureed); dysphagia III fluid (same viscosity; regular texture); nectar-like fluid (viscosity range, 51–350 cP); and thin fluid (viscosity range, 1–50 cP).[16] We recorded the worst results during the tests.

Weight loss was defined as >5% weight loss in the previous month or >10% weight loss in the previous 6 months.[17] The tracheal aspiration was defined as the penetration-aspiration score (PAS) of 6 or more points.[18] We divided our patient cohort into 3 groups by clinical symptoms (weight loss, history of aspiration pneumonia) and VFSS findings: the fully oral feeding group, the limited oral feeding group, and the tube feeding group. The patients with tracheal aspiration, severe decreased laryngeal elevation, or severe oral phased delay (related to malnutrition) in VFSS were categorized into the tube feeding group [Functional Oral Intake Scale (FOIS): 1]. Patients with PAS of 5 or less points and weight loss were categorized into the limited oral feeding group (FOIS: 2–3). Lastly, patients without definite aspiration in VFSS, weight loss, and aspiration pneumonia were categorized into the fully oral feeding group (FOIS 4–7).[19]

PFT was conducted by assessing FVC, forced expiratory volume in 1 second (FEV1), and FEV1/FVC using a spirometer, Vmax29 (SensorMedics, Yorba Linda, CA).[20] Study participants inhaled and exhaled as long as they could, following the doctor's instructions. FVC and FEV1 were converted into predictive values in percentages, according to sex, age, stature, and weight.[21]

2.3. Statistical methods

SPSS 21.0 software (SPSS Inc, Chicago, IL) was used for statistical analyses. Mann-Whitney test was used to compare the different respects of background characteristics (age, pressure, values from

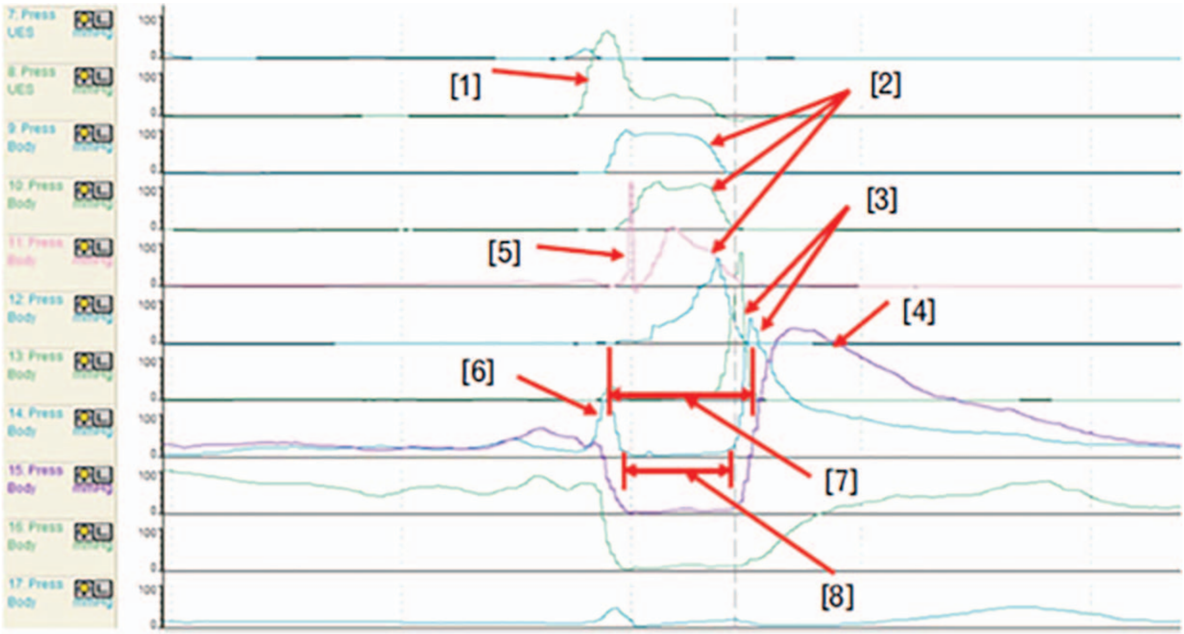

Figure 1. The individual peaks in the areas of interest. Each peak shows [1] velopharyngeal peak, [2] tongue base (TB) peaks, [3] low pharyngeal peak, [4] cricopharyngeal peak, [5] tilting of epiglottis, [6] pre-UES peak, [7] UES activity time, and [8] Nadir UES duration.

HRM) between the ALS group and the control group. In addition, this test was also used to compare the values of HRM in the ALS group and the control group. The chi-square test was used to compare the sex composition and VFSS findings between the ALS group and control group. The Kruskal-Wallis test was used to compare the different values from HRM between the control group and the other 3 subgroups of the ALS group—the fully oral feeding group, the limited oral feeding group, and the tube feeding group. A univariate logistic regression analysis with current feeding status was performed to identify the HRM parameters with positive prediction ($P<.05$). Moreover, the partial correlation coefficients were evaluated to discover the correlation between PFT and HRM in the ALS group. To obtain the cutoff value for each HRM parameter with positive prediction, a receiver operating characteristic analysis was performed for significant variables. We chose the cutoff value that maximized both sensitivity and specificity. All statistical tests were 2-tailed, and $P<.05$ was considered to be statistically significant.

3. Results

3.1. Participants

The clinical characteristics of participants are presented in Table 1. A total of 61 participants were included in this study. Forty-one participants were patients with ALS and 20 were healthy subjects. The average age of the NMD group was 65.14 ± 10.99 and that of the control group was 40.45 ± 15.08 (Table 1).

In the ALS group, there were 7 patients with tube-feeding status. Thirty-five patients with ALS (85.36%) had dysphagia symptom. Nineteen out of 41 patients with ALS could not complete PFT due to severe respiratory weakness.

3.2. Correlation between HRM variables and PFT variables

The partial correlation coefficients between the HRM variables and the possibility of PFT in the ALS group were determined after controlling for gender. The pressure of cricopharyngeus had a significant positive correlation with FEV1 (%) (Table 2, Fig. 2). And the result of VFSS had a significant correlation with FVC, FVC%, FEV1, and FEV1% in ALS group.

3.3. Significant HRM variables according to feeding types

The pressures of VP, TB, lower pharynx, and cricopharyngeus were significantly different between the control group and the other 3 subgroups of the ALS group. In a post-hoc analysis using Mann-Whiney *U* test, the pressures of VP and TB were significantly different between the fully oral group and the limited oral feeding group. The pressures of VP and low pharynx were significantly different between the fully oral feeding and tube feeding groups.

In comparison to healthy group, the pressures of TB and cricopharyngeus were significantly different between the healthy group and fully oral feeding group. The pressures of VP, TB, and cricopharyngeus were significantly different between the healthy group and the limited oral feeding group. And the pressures of TB, lower pharynx, and cricopharyngeus were significantly different between the healthy and tube feeding groups of patients with ALS (Table 3, Fig. 3).

Table 1

Demographic data of healthy group and amyotrophic lateral sclerosis group.

		ALS (n=41)	Healthy (n=20)
Sex	(Male: female)	21:20	12:8
Age	(years)	**65.14±10.99**[†]	40.45±15.08
Current tube feeding		7	0
Presence of dysphagia symptom		35	0

ALS = amyotrophic lateral sclerosis.
Values are mean±SD or n.
[†] $P<.01$.

Table 2

Partial correlation coefficients between current feeding type, high-resolution manometry variables, and parameters of pulmonary function test with gender controlled at patients with amyotrophic lateral sclerosis.

	FVC (L)	FVC (%)	FEV1 (L)	FEV1 (%)	FEV1/FVC
Current feeding type	−0.24	−0.22	−0.22	−0.21	0.11
Recommended feeding type by VFSS results	**−0.49**[*]	**−0.51**[*]	**−0.63**[†]	**−0.62**[†]	−0.21
Pressure of VP	0.19	0.14	0.32	0.27	0.23
Pressure of TB	−0.15	−0.14	−0.08	−0.10	0.15
Pressure of pre-UES	0.20	0.23	0.21	0.24	−0.19
Pressure of low pharynx	0.29	0.30	0.37	0.36	0.04
Pressure of cricopharyngeus	0.24	0.41	0.32	**0.47**[*]	−0.80
Pressure of minimal UES	−0.25	−0.30	−0.31	−0.40	−0.20

Cutoff value: pressure (mm Hg), area (mm Hg · s), time (s).
FEV1 = forced expiratory volume in 1 second, FVC = forced vital capacity, TB = tongue base, VFSS = videofluoroscopic swallowing study, VP = velopharynx.
[*] $P<.05$.
[†] $P<.01$.

3.4. Prediction of current feeding type using significant HRM variables

The pressure of lower pharynx negatively predicted the current feeding type according to a univariate logistic analysis. The regression coefficient in the pressures of lower pharynx was −0.017. The univariate logistic analysis showed that as the pressure of lower pharynx increased by 1 mm Hg, the possibility of tube feeding decreased by 1.7%. The equation is as follows (OR: odd ratio, exp: exponential).

$$OR_{\text{low pharynx}} = \exp[2.57 - 0.017^{*}(\text{pressure of low pharynx})]$$

Furthermore, the receiver operating characteristic analysis was performed to reveal the cutoff value for HRM parameters with reasonable sensitivity and specificity. The cutoff value of low pharyngeal pressure was 234.98 mm Hg, showing 85.71% sensitivity and 79.41% specificity for the current oral feeding.

3.5. Prediction of feeding type based on VFSS findings using significant HRM variables

The cutoff value of VP pressure was 162.56 mm Hg, which showed 72.0% sensitivity and 87.5% specificity for fully oral feeding in patients with ALS. The cutoff value of low pharynx pressure was 286.77 mm Hg, showing 72.0% sensitivity and 68.7% specificity for fully oral feeding. If the swallowing pressure was lower than the cutoff value, patients were unable to fully oral feed (Table 4). The pressures of low pharynx and minimal UES were significantly different between the tube feeding group and

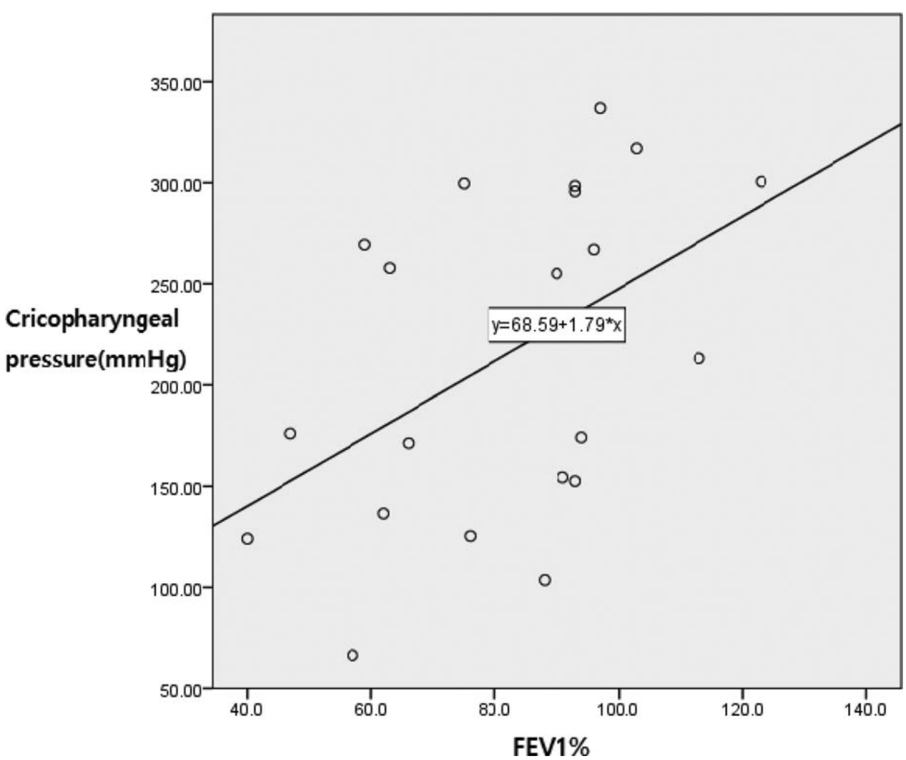

Figure 2. The linear correlation between FEV1 (%) and pressure of cricopharyngeus. FEV1 = forced expiratory volume in 1 second.

Table 3

The pressure and area variants of the high-resolution manometry sorted with recommended feeding types at patients with amyotrophic lateral sclerosis.

	ALS group			
HRM parameters	Tube feeding	Limited oral feeding	Fully oral feeding	Healthy group
Pressure of VP, mm Hg*	**137.74±34.31**	**146.13±35.75**	**213.46±62.29**	**208.88±94.40**
Pressure of TB, mm Hg*	**101.09±20.24**	**99.10±58.91**	**120.14±31.00**	**144.41±28.55**
Pressure of pre-UES, mm Hg	123.03±59.97	140.29±82.40	149.41±57.52	194.96±99.10
Pressure of low pharynx, mm Hg†	**177.01±97.69**	**280.45±98.03**	**351.89±174.74**	**372.83±164.12**
Pressure of cricopharyngeus, mm Hg*	**181.41±107.91**	**200.90±89.95**	**247.52±78.85**	**388.20±137.21**
Pressure of minimal UES, mm Hg	1.65±15.01	−7.33±5.47	−10.02±4.37	−7.97±5.64
Area integral of VP, mm Hg·s	35.55±19.10	39.30±35.01	52.39±26.60	54.99±35.37
Area integral of TB, mm Hg·s	45.70±12.30	45.85±33.28	48.56±24.20	54.67±18.65

ALS = amyotrophic lateral sclerosis, HRM = high-resolution manometry, TB = tongue base, VP = velopharynx.
* $P<.01$.
† $P<.05$.

the other groups in ALS. The cutoff value of low pharynx pressure was 183.10 mm Hg, which showed 60.0% sensitivity and 88.9% specificity for the fully oral and limited oral feeding (Table 4). And the cutoff value of minimal UES pressure was −5.65 mm Hg, which showed 80.0% sensitivity and 75.0% specificity. If the swallowing low pharynx pressure was lower than the cutoff value or the minimal UES pressure was higher than the cutoff value, patients required tube feeding.

4. Discussion

Safe swallowing in patients with ALS requires precise coordination of neuromuscular events to successfully generate pressure gradients that propel the bolus from the mouth to the esophagus.[3] It has been well established that weight loss and lower body mass index are negative prognostic factors for survival in ALS.[22] Therefore, safe swallowing and weight preservation are imperative for a good prognosis in patients with ALS.

Patients receiving enteral tube feeding generally have lower quality of life than those receiving oral feeding.[23] In accordance with the amount of oral feeding and presence of aspiration, we can divide patients with ALS into 3 feeding groups: the tube feeding, the limited oral feeding (oral feeding for pleasure but without sufficient amount), and the fully oral feeding group (with sufficient amount). However, there was no established guideline to determine appropriate feeding group in patients with ALS.

Recently, HRM has been considered as a good method to evaluate deglutition.[3,4,14] Deglutition is a pressure-driven process. In normal swallowing, VP, TB, and pharyngeal constrictors generate positive pressures behind the bolus in the

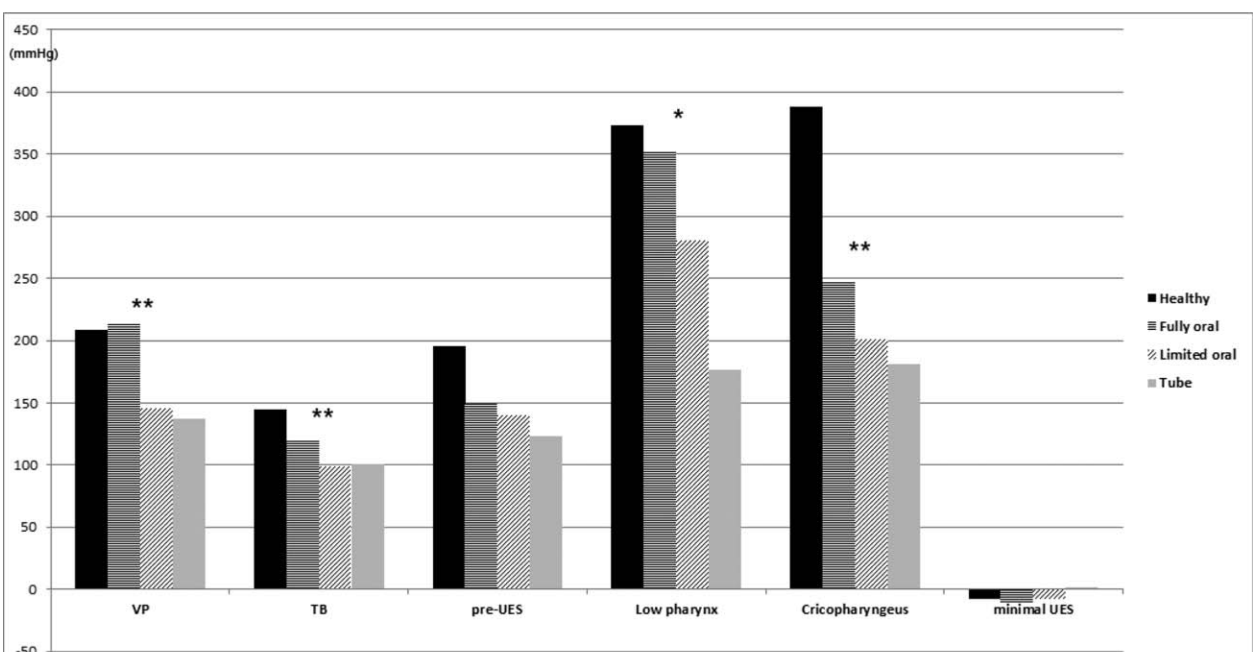

Figure 3. The pressure variants' comparison between 3 groups in amyotrophic lateral sclerosis (ALS) patient group (the fully oral feeding, the limited oral feeding, and the tube feeding group) and the healthy group using high-resolution manometry (HRM). TB = tongue base, UES = upper esophageal sphincter, VP = velopharynx. *$p<.05$, **$p<.01$.

Table 4

Sensitivity and specificity of the significant parameters of high-resolution manometry by current feeding type and videofluoroscopic swallowing study findings in amyotrophic lateral sclerosis group.

	Current feeding type (oral feeding and tube feeding)				Between the fully oral feeding and (the limited oral feeding, the tube feeding group)				Between (the fully oral feeding and the limited oral feeding) and the tube feeding group			
HRM parameters	AUC	Cutoff value	Sensitivity (%)	Specificity (%)	AUC	Cutoff value	Sensitivity (%)	Specificity (%)	AUC	Cutoff value	Sensitivity (%)	Specificity (%)
Pressure of VP, mm Hg*	0.76	158.60	85.7	61.8	**0.83**	**162.56**	**72.0**	**87.5**	0.71	137.23	60.0	77.8
Pressure of TB, mm Hg	0.63	102.02	71.4	50.0	0.74	106.27	72.0	75.0	0.53	103.72	60.0	52.8
Pressure of pre-UES, mm Hg	0.67	112.65	71.4	67.6	0.56	130.71	56.0	75.0	0.58	112.65	60.0	63.9
Pressure of low pharynx, mm Hg*,†,‡	**0.85**	**234.98**	**85.7**	**79.4**	**0.69**	**286.77**	**72.0**	**68.7**	**0.80**	**183.10**	**60.0**	**88.9**
Pressure of cricopharyngeus, mm Hg	0.62	192.21	57.1	55.9	0.65	248.45	64.0	56.3	0.61	182.19	60.0	63.9
Pressure of minimal UES, mm Hg‡	0.41	−7.40	71.4	58.8	0.71	−9.47	76.0	62.5	**0.81**	**−5.65**	**80.0**	**75.0**
Area integral of VP, mm Hg·s	0.31	31.50	71.4	73.5	0.74	35.75	72.0	75.0	0.62	25.75	60.0	88.9
Area integral of TB, mm Hg·s	0.66	42.00	71.4	58.8	0.60	40.00	60.0	62.5	0.41	38.75	80.0	52.8

Cutoff value: pressure (mm Hg), area (mm Hg·s).
HRM = high-resolution manometry, TB = tongue base, VP = velopharynx.
* $P < .05$ between the fully oral feeding and (the limited oral feeding, the tube feeding group).
† $P < .05$ between the oral feeding group and the tube feeding group.
‡ $P < .05$ between (the fully oral feeding and the limited oral feeding) and the tube feeding group.

pharynx and laryngeal elevator, whereas UES generates negative pressures in front of the bolus for peristaltic movement. Thus, detailed measurements and analysis of changes in the pressure during bolus transit can provide valuable information on the physiology of swallowing.[24]

This study aimed to find the relationship between HRM parameters and PFT by a spirometer. PFT can provide necessary information on the prognosis and help determine the timing for long-term mechanical ventilation and end-of-life planning.[10] Throughout the course of the disease, not only the respiratory muscles, but also the pharyngeal muscles, gradually weaken in patients with ALS. The concordant interactions between breathing and swallowing have been well established.[25,26] Shared anatomic and physiologic substrates allow for precise coordination of both events in tandem.[27] Shared commonalities include the location of neural control centers and anatomic structures. Then, theoretically, interruption in breathing has the potential to interfere with swallowing.[25]

Clinically, however, there were lots of patients who cannot conduct the spirometer due to weakness of respiratory muscles. Thus, due to these pitfalls, PFT is not applicable to patients with ALS with severe respiratory weakness and is impossible to be used as a method to evaluate dysphagia. HRM can overcome the limitation of PFT. HRM is more sensitive and permits the evaluation of weak pressure under the threshold of PFT. Thus, this study proposes that HRM can compensate for the shortcomings of PFT in measuring the respiratory and swallowing function of patients with ALS. In this study, 46.34% of patients with ALS failed to successfully complete the PFT. However, all patients with ALS completed the HRM. These results indicate that HRM could be applicable to most patients with ALS for the evaluation of not only the swallowing function but also the respiratory function. This study also revealed that the pressure of cricopharyngeus has a significant positive correlation with FEV1. Therefore, the parameters measured in patients with ALS, such as the pressure of cricopharyngeus, could also be used to predict respiratory function.

One of the other purposes of this study was to identify the standard pressure point in which to initiate tube feeding in patients with ALS by using HRM. We identified the significant HRM parameters including the cutoff values, sensitivity, and specificity using a receiver operating characteristic curve in accordance with the current feeding type, weight loss, and results of VFSS. To the best of our knowledge, this is the first study to use HRM parameters to find the sensitivity and specificity for the identification of ideal feeding type in patients with ALS.

In this study, the pressure of VP, TB, low pharynx, and cricopharyngeus were significantly different between the healthy group, the fully oral feeding group, the limited oral feeding, and the tube feeding group in the ALS patient group. The pressures of VP and TB were significantly different between the fully oral feeding group and the limited oral feeding group in ALS patient group. The pressures of VP and low pharynx were significantly different between the fully oral feeding and tube feeding groups in ALS patient group. It is noteworthy that the maximal pressure of VP could predict the fully oral feeding with a sensitivity of 72.0% and specificity of 87.5% in ALS. Other parameters showed higher sensitivity and specificity as well. Because HRM could be used to determine the quantitative measurements of pharyngeal weakness, the cutoff value of HRM parameters may be used to decide the feeding type in patients with ALS. In the present study, we established feeding algorithm using HRM parameters to determine appropriate feeding type and to prevent aspiration in patients with ALS (Fig. 4). This algorithm can be used to guide appropriate feeding type in patients with ALS. Follow-up studies are required.

The cutoff values in this present study were slightly lower than the reported values in a previous study using HRM.[3] The previous study included a heterogeneous population, and the major group included stroke patients. The main causes for varying cutoff values seem to be oropharyngeal sensory dysfunction and cognitive dysfunction, which are common in patients with stroke. Previous studies also supported the significance of oropharyngeal sensory and cognitive dysfunction in the development of aspiration.[6,28] Therefore, our findings suggest that the cutoff value of pharyngeal muscular pressure to develop tracheal aspiration is relatively lower in patients with intact oropharyngeal sensory and cognitive function. And the

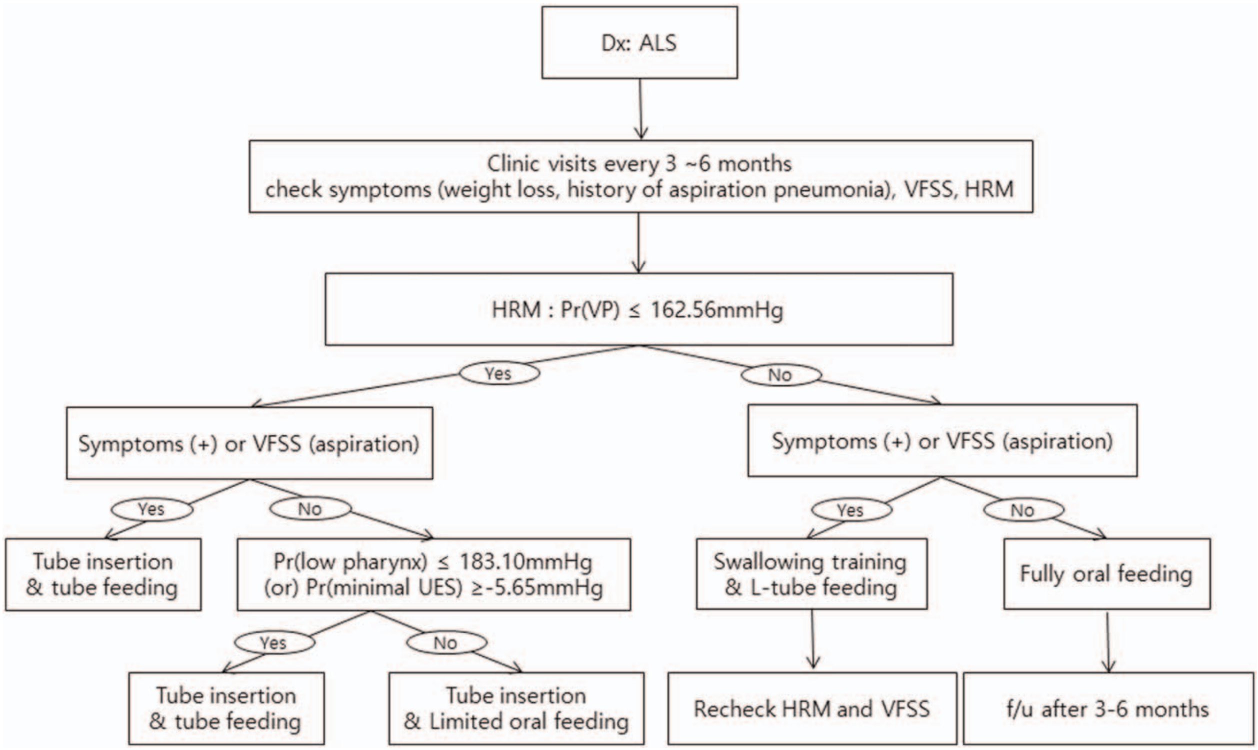

Figure 4. The algorithm for decision of feeding type in patients with ALS. ALS = amyotrophic lateral sclerosis, HRM = high-resolution manometry, UES = upper esophageal sphincter, VFSS = videofluoroscopic swallowing study, VP = velopharynx.

cutoff value of HRM parameters might be more reasonable as a predictor for aspiration, enabling the classification of the tube feeding, limited oral feeding, and fully oral feeding groups in patients with ALS.

Determination of the proper feeding type can prevent weight loss, aspiration pneumonia, and tracheostomy. Finally this can reduce social burden and improve the quality of life of patients with ALS.

5. Limitation

This study has some limitations. First, there was a significant difference in the mean age between the ALS group and the control group. Hence, it is necessary to conduct further studies regarding deglutition of patients with ALS, comparing them with an age-matched control group. Second, only a small number of subjects were included; therefore, we could not perform a multivariate logistic regression analysis. Third, the diagnosis of patient with ALS was made according to "Revised El Escorial criteria for the diagnosis of amyotrophic lateral sclerosis" in this study. This would reduce the sensitivity for diagnosis of patients with ALS compared with Awaji criteria. Fourth, this study was performed in a retrospective manner. However, HRM, PFT, and VFSS were performed prospectively, and only the results were analyzed retrospectively. Therefore, all patients in this study received 3 evaluations without any missing data. Fifth, this study focused on the weakness of the pharyngeal muscle, did not focus on spasticity of the pharyngeal muscle. Further studies with consideration of spasticity of oropharynx will be necessary.

6. Conclusions

This study identified the significant HRM parameters highly specific for the feeding type and the possibility of oral feeding in ALS. In addition, HRM can predict pulmonary function in patients with ALS. Because HRM could be used to determine the quantitative measurements of pharyngeal weakness, the cutoff value of HRM parameters may be used to decide the feeding type in patients with ALS.

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