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Risk Factors for Aspiration Pneumonia After Receiving Liquid-Thickening Recommendations

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Abstract

Objective. We examined the influence of liquid thickness levels on the frequency of liquid penetration-aspiration in patients with dysphagia and evaluated the clinical risk factors for penetration-aspiration and aspiration pneumonia development.

Study Design. A case series.

Setting. Single-institution academic center.

Methods. We reviewed medical charts from 2018 to 2019. First, we evaluated whether liquid thickness levels influence the frequency of liquid penetration-aspiration in patients with dysphagia. Penetration-aspiration occurrence in a videofluoroscopic swallowing study was defined as Penetration-Aspiration Scale (PAS) scores $\geq$3. Second, the association between liquid thickness level and penetration-aspiration was analyzed, and clinical risk factors were identified. Moreover, clinical risk factors for aspiration pneumonia development within 6 months were investigated.

Results. Of 483 patients, 159 showed penetration-aspiration. The thickening of liquids significantly decreased the incidence of penetration-aspiration ($P < .001$). Clinical risk factors for penetration-aspiration were vocal fold paralysis (odds ratio [OR], 1.99), impaired laryngeal sensation (OR, 5.01), and a history of pneumonia (OR, 2.90). Twenty-three patients developed aspiration pneumonia while undertaking advised dietary changes, including liquid thickening. Significant risk factors for aspiration pneumonia development were poor performance status (OR, 1.85), PAS score $\geq$3 (OR, 4.03), and a history of aspiration pneumonia (OR, 7.00).

Conclusion. Thickening of liquids can reduce the incidence of penetration-aspiration. Vocal fold paralysis, impaired laryngeal sensation, and history of aspiration pneumonia are significant risk factors of penetration-aspiration. Poor performance status, PAS score $\geq$3, and history of aspiration pneumonia are significantly associated with aspiration pneumonia development following recommendations on thickening liquids.

Level of Evidence. 3.

Keywords

dysphagia, penetration-aspiration, pneumonia, risk factors, thickened liquids

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Dysphagia has become an important health issue worldwide. The prevalence of dysphagia in older individuals is reported to range from 7% to 22%.[1] Patients with acute stroke have a higher prevalence of dysphagia (50%-80%) than those without stroke, and >80% of patients with Parkinson's disease have dysphagia.[2,3] It is associated with an increased risk of aspiration pneumonia and related mortality.[4]

Several factors increase the risk of aspiration, such as esophageal diseases, medications, alcohol consumption, reflux, tube feeding, dementia, and impaired consciousness.[5,6] In addition, laryngeal sensation is important for preventing aspiration pneumonia, as patients with laryngeal sensory deficits have a 6.8-fold higher risk of developing pneumonia than those with normal laryngeal sensation.[7] For patients with dysphagia, compensatory strategies, such as diet and liquid modification, can be crucial for increasing eating and swallowing efficiency and reducing the risk of aspiration.[8,9] Previous randomized and nonrandomized clinical trials suggested that bolus modification, such as controlling the volume and

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Table 1. Details of Performance Status Score[19] and the Penetration-Aspiration Scale.[20]

ECOG performance status scores	
Grade	ECOG performance status
0	Fully active, able to carry on all predisease performance without restriction
1	Restricted in physically strenuous activity but ambulatory and able to carry out work of a light or sedentary nature (eg, light housework, office work)
2	Ambulatory and capable of all self-care but unable to carry out any work activities; up and about >50% of waking hours
3	Capable of only limited self-care, confined to bed or chair >50% of waking hours
4	Completely disabled. Cannot carry on any self-care. Totally confined to bed or chair
5	Dead
Penetration-aspiration scale	
Score	Description
1	Material does not enter the airway
2	Material enters the airway, remains above the vocal folds, and is ejected from the airway
3	Material enters the airway, remains above the vocal folds, and is not ejected from the airway
4	Material enters the airway, contacts the vocal folds, and is ejected from the airway
5	Material enters the airway, contacts the vocal folds, and is not ejected from the airway
6	Material enters the airway, passes below the vocal folds, and is ejected into the larynx or out of the airway
7	Material enters the airway, passes below the vocal folds, and is not ejected from the trachea despite effort
8	Material enters the airway, passes below the vocal folds, and no effort is made to eject

Abbreviation: ECOG, Eastern Cooperative Oncology Group.

temperature of the bolus, may prevent aspiration pneumonia in patients with dysphagia.[10-12]

Thickening of liquids has become central to current dysphagia management approaches to reduce the risks of aspiration and subsequent pneumonia.[13-15] However, there is no strong evidence to conclusively state that the use of thickened liquids can reduce pneumonia in patients with dysphagia.[16] A systematic review and meta-analysis revealed no significant difference in the risk of pneumonia between aspirating patients who consumed thin liquids and those who consumed only thickened liquids.[17] Nevertheless, given that dysphagia is closely associated with age, physical function, frailty, polymedication, and multimorbidity,[18] these results may have been affected by the backgrounds of patients in these various study facilities.

In our institution, since 2014, we have been guiding patients with dysphagia on the appropriate viscosity of thickened liquids. In addition, liquid modification has been recommended according to patients' swallowing functions, as assessed by videofluoroscopic swallowing studies (VFSSs). We recommend a level of thickening that is as low in viscosity as possible without penetration-aspiration. In this study, we first examined whether the frequency of liquid penetration-aspiration varied with different levels of liquid thickness. We then assessed the clinical risk factors for penetration-aspiration in our patient group. Finally, we investigated the clinical risk factors for the development of aspiration pneumonia in patients with dysphagia despite adhering to advised dietary changes, including liquid thickening, based on VFSS-assessed swallowing functions.

Methods

Patients and Ethics

We included patients who had undergone swallowing function evaluation by VFSS at the University of Tokyo Hospital in 2018 and 2019. The exclusion criteria were as follows: age <18 years, a history of severe dementia, inability to hold liquids in the mouth, a history of laryngectomy or aspiration prevention surgery, a history of VFSS using only thin liquids, and inability to sit in a wheelchair or stand upright. If the same patient underwent multiple VFSSs, just the result of the first VFSS was included to avoid duplication.

This study was approved by the Human Ethics Committee of the University of Tokyo (No. 2487). Written informed consent was obtained from every patient, and patient anonymity was preserved.

Methodology

We conducted a retrospective single-center study using medical charts from the hospital database and the VFSS recording database of our institute. Clinical and demographic profiles were analyzed, such as age, sex, performance status (PS),[19] primary diseases, the patient's ability to follow commands, the presence of a tracheostomy, the presence of vocal fold paralysis (VFP), the condition of laryngeal sensation, and a history of aspiration pneumonia at the time of VFSS. PS was graded 0 to 5 (with grade 5 indicating the most severe condition; **Table 1**). In this study, the primary diseases that were considered etiologies of dysphagia were categorized into neurologic disorders, head and neck surgery, esophageal surgery,

other surgery, stroke, or other etiologies. Additionally, to understand the risks of penetration-aspiration for each disease, we performed subgroup analyses in patients with dysphagia due to neurologic disorders, which included a large number of patients, and in those with dysphagia due to surgery (head and neck surgery, esophageal surgery). Vocal fold movement was assessed by fiberoptic laryngeal examination. For laryngeal sensation, impaired sensation was defined as the absence of laryngeal adductor reflex, tested by touching the laryngeal mucosa with the distal end of a flexible laryngoscope.[7]

The Penetration-Aspiration Scale (PAS) score[20] was evaluated by VFSS and assigned to levels 1 to 8 (normal level, 1) for thin (10 mPa·s, 5 mL), mildly thickened (100 mPa·s, 5 mL), and moderately thickened (200 mPa·s, 5 mL) liquids (**Table 1**). A PAS score $\geq$3 was defined as penetration-aspiration and was used to assess the relationship between liquid thickness level and penetration-aspiration.[20] A PAS score of 8 was defined as silent aspiration.[21] The PAS scores were judged per a consensus between 2 otolaryngologists with at least 10 years of experience. In case of disagreement between the evaluators, the rating was determined from the recordings and by discussion between them.

Videofluorographic Study

Videofluorographic studies were performed and recorded in the lateral view. Iohexol (Omnipaque; Daiichi-Sankyo) was used as a contrast agent in VFSS since it has low pulmonary toxicity when aspirated into the lung.[22,23] To add viscosity to the contrast agent, a thickener (Toromeiku SP; Meiji) was used. First, 5 mL of a moderately thickened liquid (200 mPa·s) was administered, followed by 5 mL of mildly thickened liquid (100 mPa·s) and 5 mL of thin liquid (10 mPa·s). Penetration-aspiration at each swallowing was evaluated during VFSS. Subsequently, the PAS score of each swallow was evaluated. The occurrence of penetration and aspiration was defined as a PAS score $\geq$3, which is a clinically relevant classification for swallowing safety according to a previous study.[24] Given the PAS scores of each swallow for the 3 viscosities, we indicated the appropriate liquid-thickening stratification level to each patient that yielded PAS scores $\leq$2.

Statistical Analyses

We analyzed the data using BellCurve for Excel (version 3.20; Social Survey Research Information Co, Ltd). The association between the liquid thickness level and penetration-aspiration was analyzed by Cochran's Q test. A binomial logistic regression analysis was applied to identify the risk factors among the clinical and demographic profiles for penetration-aspiration. The inclusion of variables in the models was based on the existing knowledge of risk factors for penetration-aspiration. Analysis of the subgroups based on etiology was performed with binomial logistic regression, with the following parameters: age and sex and independent variables showing significant differences in univariable analysis. To compare clinical and demographic profiles between patients who developed aspiration pneumonia within 6 months after and those who did not, we used the Mann-Whitney test for continuous variables and Fisher's exact test for categorical variables. The parameters with significant differences in univariable analysis were evaluated by binomial logistic regression analysis, adjusted for age and sex, to calculate the odds ratio (OR) of developing aspiration pneumonia after VFSS evaluation. $P < .05$ was considered statistically significant.

Table 2. Patient Demographics (N = 483).

Characteristic	No. (%)
Age, y, median (IQR)	66 (55-74)
Male	317 (65.6)
Performance status	
0	230 (47.6)
1	115 (23.8)
2	81 (16.8)
3	44 (9.1)
4	13 (2.7)
Primary diseases	
Head and neck surgery	134 (27.7)
Neurologic disorders	107 (22.2)
Esophageal surgery	79 (16.4)
Other surgery	42 (8.7)
Stroke	34 (7.0)
Others	87 (18.0)
Insufficient ability to obey commands	11 (2.3)
Presence of tracheostomy	88 (18.2)
Presence of vocal fold paralysis	135 (28.0)
Impaired laryngeal sensation	193 (40.0)
History of aspiration pneumonia	85 (17.6)

Abbreviation: IQR, interquartile range.

Results

Patient Demographics

Table 2 lists the demographic data of the enrolled patients. We identified 483 eligible patients. The median age at the time of VFSS was 66 years (interquartile range [IQR], 55-74 years), and there was a male predominance (65.6%). Approximately half of the patients were assigned PS grade 0 and one-quarter PS grade 1. Regarding etiology, the most common cause of dysphagia was head and neck surgery (median days after surgery, 17.5 days [IQR, 8-63.8 days]), which accounted for approximately 30% of all cases, followed by neurologic disorders, excluding stroke, and esophageal surgery (median days after surgery, 15 days [IQR, 13-35 days]). Less than 2.5% of the patients could not respond to commands during the VFSSs. Approximately 20% of the patients had undergone a tracheostomy at the time of VFSS. Impaired laryngeal sensation was observed in 40% of the patients, and slightly under 20% of the patients had a history of aspiration pneumonia.

Association Between Liquid Thickness Level and Penetration-Aspiration

PAS score distribution by liquid viscosity levels is shown in **Table 3**. The rate of penetration-aspiration (PAS score $\geq$3)

Table 3. PAS Score Distribution With Various Liquid Viscosities.

	PAS score, No. (%)	
Liquid	≤2	≥3
Moderately thickened	414 (85.7)	69 (14.3)
Mildly thickened	381 (78.9)	102 (21.1)
Thin	324 (67.1)	159 (32.9)

Abbreviation: PAS, Penetration-Aspiration Scale.

decreased with increasing fluid concentration. Patients with a PAS score <2 for liquids did not show a PAS score ≥3 for thickened liquids. Cochran's Q test revealed a statistically significant difference in the frequency of penetration-aspiration (PAS ≥3) among the 3 graded thicknesses ($P < .001$).

Clinical Risk Factors for Penetration and Aspiration

To examine the clinical risk factors for penetration-aspiration, the patients were classified into 2 groups: those with penetration-aspiration (PAS ≥3) and those without penetration-aspiration (PAS ≤2) upon swallowing thin liquids. The variables listed in **Table 4** as clinical factors were evaluated. A binomial logistic regression analysis revealed that the presence of VFP (OR, 1.99; 95% CI, 1.24-3.19; $P = .0042$), impaired laryngeal sensation (OR, 5.01; 95% CI, 3.20-7.82; $P < .001$), and history of aspiration pneumonia (OR, 2.90; 95% CI, 1.62-5.19; $P < .001$) were significantly associated with penetration and aspiration, while no significant association was observed in age, sex, PS, limited ability to follow the commands during VFSS, and presence of a tracheostomy.

Based on the subgroup analysis, impaired laryngeal sensation (OR, 3.12; 95% CI, 1.24-7.84; $P = .015$) and a history of aspiration pneumonia (OR, 8.35; 95% CI, 2.47-28.3; $P < .001$) were significantly associated with penetration and aspiration in patients with dysphagia due to neurologic disorders (n = 107). In contrast, poor PS (OR, 2.00; 95% CI, 1.15-3.48; $P = .014$) and a history of aspiration pneumonia (OR, 5.83; 95% CI, 2.86-11.9; $P < .001$) were significantly associated with penetration and aspiration in those with dysphagia due to surgery (head-neck and esophageal, n = 213; **Table 5**).

Risk Factors for Developing Pneumonia Within 6 Months After VFSS While Following Proper Thickening Guidance

We identified patients who developed aspiration pneumonia within 6 months after receiving instructions on thickening liquids based on swallowing function determined by VFSS. Among all the patients, 23 (4.8%) developed aspiration-suspected pneumonia despite following the optimal diet and liquid recommendations. **Table 6** summarizes the characteristics of patients with and without aspiration pneumonia. Patients with aspiration pneumonia tended to be older (not statistically significant) and had poorer PS scores than those without pneumonia. Two (8.7%) patients found it difficult to follow commands during the VFSS.

To identify the potential risk factors for developing aspiration pneumonia within 6 months after instruction on proper liquid thickening, univariate analyses were performed: PS ($P < .001$), PAS score ≥3 ($P = .0012$), impaired laryngeal sensation ($P = .031$), and a history of aspiration pneumonia ($P < .001$) demonstrated a significant association with aspiration pneumonia development, whereas a PAS score of 8 was not identified as a potential risk factor ($P = .48$). A binomial logistic regression analysis adjusted for age and sex showed that poor PS (OR, 1.85; 95% CI, 1.32-2.58; $P < .001$), PAS score ≥3 (OR, 4.03; 95% CI, 1.67-9.74; $P = .0020$), and a history of aspiration pneumonia (OR, 7.00; 95% CI, 2.85-17.2; $P < .001$) were associated with the risk of developing aspiration pneumonia within 6 months after VFSS evaluation and instruction on proper liquid thickening (**Table 6**).

Discussion

The present study demonstrated that the thickening of liquids could reduce the frequency of liquid penetration-aspiration. Similarly, this study showed that the presence of VFP, impaired laryngeal sensation, and a history of aspiration pneumonia were significantly associated with an increased risk of penetration-aspiration. In addition, the clinical risk factors for developing aspiration pneumonia in patients with dysphagia, despite optimal diet and liquid recommendations, were poor PS, PAS score ≥3, and a history of aspiration pneumonia.

Our results suggest that the occurrence of aspiration pneumonia may be reduced by recommending optimal liquid thickness levels and instructing patients on the importance of thickening and that thickening could be effective in preventing penetration or aspiration. Moreover, to prevent pneumonia, thickening, as well as the patient's recognition of dysphagia or silent aspiration and management of general conditions, might be important. Dysphagia is an important factor for the occurrence of aspiration pneumonia.[25] A low incidence (4.8%) of aspiration pneumonia within 6 months after providing instructions regarding appropriate liquid thickness levels for patients with dysphagia suggests that recommending the appropriate degree of liquid thickness and explaining the dysphagic condition to patients based on VFSS findings might be important. However, guidelines for thickening liquids differ across facilities and nations. In Japan, the level of ''moderately thick'' liquid is 150 to 300 mPa·s per the Japanese Dysphagia Diet 2013 (thickened liquid).[26] In the United States, a ''nectar-like'' viscosity is defined as 51 to 350 mPa·s, as compared with a ''mildly thick'' level of 95 to 200 mPa·s in Australia.[26] The viscosity of the moderately thickened contrast agent used in this study was 200 mPa·s, which corresponds to the definition of the liquid thickness level as moderately thick in Japan, nectar-like in the United States, and mildly thick in Australia. The IDDSI framework (International Dysphagia Diet Standardisation Initiative)[27] is considered an appropriate classification system to overcome these issues.

Regarding the relationship between tracheostomy and penetration-aspiration, some previous studies reported that tracheostomy was associated with an increased incidence of

Table 4. Association Between Clinical Factors and Penetration-Aspiration (PAS ≥3).[a]

	PAS score, No. (%) or median (IQR)			
	≤2	≥3	OR (95% CI)	*P* value
Patients	324 (67.1)	159 (32.9)		
Age, y	66 (55-74)	67 (57-76)	1.00 (0.98-1.01)	.74
Male	209 (64.5)	108 (67.9)	1.17 (0.74-1.85)	.51
Performance status	0 (0-1)	1 (0-2)	1.13 (0.91-1.39)	.27
Insufficient ability to obey the commands	8 (2.5)	3 (1.9)	0.38 (0.084-1.74)	.21
Presence of a tracheostomy	52 (16.0)	36 (22.6)	1.36 (0.77-2.41)	.30
Presence of vocal fold paralysis	73 (22.5)	62 (39.0)	1.99 (1.24-3.19)	.0042[b]
Impaired laryngeal sensation	85 (26.2)	108 (67.9)	5.01 (3.20-7.82)	<.001[c]
History of aspiration pneumonia	36 (11.1)	49 (30.8)	2.90 (1.62-5.19)	<.001[c]

Abbreviations: IQR, interquartile range; OR: odds ratio; PAS, Penetration-Aspiration Scale.
[a]Blank cells indicate *not applicable*. $P < .05$ was considered statistically significant.
[b]$P < .01$.
[c]$P < .001$.

Table 5. Subgroup Analyses of Clinical Risk Factors for Penetration-Aspiration (PAS ≥3).[a]

	PAS score, No. (%) or median (IQR)				
	PAS ≤2	PAS ≥3	*P* value	OR (95% CI)	*P* value[b]
Neurologic disorders					
Patients	69 (64.5)	38 (35.5)			
Age, y	62 (52-70)	70 (55-78)	.059	1.00 (0.97-1.03)	.82
Male	35 (50.7)	21 (55.3)	.80	0.93 (0.37-2.29)	.87
Performance status	1 (0-2)	1.5 (1-3)	.11		
Insufficient ability to obey the commands	4 (5.8)	1 (2.6)	.41		
Presence of a tracheostomy	5 (7.2)	7 (18.4)	.078		
Presence of vocal fold paralysis	17 (24.6)	12 (31.6)	.59		
Impaired laryngeal sensation	28 (40.6)	25 (65.8)	.022[c]	3.12 (1.24-7.84)	.015[c]
Previous history of aspiration pneumonia	5 (7.2)	14 (36.8)	<.001[d]	8.35 (2.47-28.3)	<.001[d]
Head neck surgery and esophageal surgery					
Patients	143 (67.1)	70 (32.9)			
Age, y	66 (57-73)	65.5 (57-72)	.89	0.99 (0.96-1.01)	.3
Male	103 (72.0)	54 (77.1)	.53	1.72 (0.77-3.83)	.19
Performance status	0 (0-0)	0 (0-1)	<.001[d]	2.12 (1.23-3.65)	.0067[e]
Insufficient ability to obey the commands	0 (0.0)	0 (0.0)			
Presence of a tracheostomy	24 (16.8)	17 (24.3)	.26		
Presence of vocal fold paralysis	36 (25.2)	34 (48.6)	.0011[e]	1.67 (0.81-3.44)	.16
Impaired laryngeal sensation	24 (16.8)	43 (61.4)	<.001[d]	5.83 (2.86-11.9)	<.001[d]
History of aspiration pneumonia	3 (2.1)	11 (15.7)	<.001[d]	3.06 (0.68-13.8)	.15

Abbreviations: IQR, interquartile range; OR: odds ratio; PAS, Penetration-Aspiration Scale.
[a]Blank cells indicate *not applicable*. $P < .05$ was considered statistically significant.
[b]A binomial logistic regression aspiration scale.
[c]$P < .05$.
[d]$P < .001$.
[e]$P < .01$.

aspiration. The possible mechanisms underlying this phenomenon include a decreased laryngeal elevation due to the tethering of the larynx by the tracheostomy tube and obstruction of the esophageal pathway by the tube cuff.[28,29] However, the present study did not identify tracheostomy as a significant risk factor for penetration-aspiration. This may have been influenced by the fact that our study included many postoperative patients with head and neck cancer, those using

Table 6. Risk Factors for Developing Pneumonia, Even With Proper Liquid-Thickening Guidance After Videofluoroscopic Swallowing Study.[a]

	Pneumonia, No. (%) or median (IQR)				
	Positive	Negative	*P* value	Adjusted *P* value[b]	Adjusted OR (95% CI)
Patients	23	460			
Age, y	72 (60-77)	66 (55-74)	.13		
Male	15 (65.2)	302 (65.7)	.56		
Performance status	2 (1-3)	1 (0-2)	<.001[c]	<.001[c]	1.85 (1.32-2.58)
PAS score ≥3	15 (65.2)	144 (31.3)	.0012[d]	.002[d]	4.03 (1.67-9.74)
PAS score = 8	2 (9.7)	21 (4.6)	.48	.76	1.26 (0.28-5.66)
Insufficient ability to obey the commands	2 (8.7)	9 (2.0)	.092	.056	4.77 (0.96-23.7)
Presence of a tracheostomy	6 (26.1)	82 (17.8)	.23	.19	1.95 (0.72-5.23)
Presence of vocal fold paralysis	2 (8.7)	133 (28.9)	.023[e]	.053	0.24 (0.055-1.02)
Impaired laryngeal sensation	14 (60.9)	179 (38.9)	.031[e]	.056	2.32 (0.98-5.52)
History of aspiration pneumonia	13 (56.5)	72 (15.7)	<.001[c]	<.001[c]	7.00 (2.85-17.2)

Abbreviations: IQR, interquartile range; OR: odds ratio; PAS, Penetration-Aspiration Scale.
[a]Blank cells indicate *not applicable*. $P < .05$ was considered statistically significant.
[b]Binomial logistic regression analysis adjusted by age and sex.
[c]$P < .001$.
[d]$P < .01$.
[e]$P < .05$.

vocalizable uncuffed cannulas, and many patients with good PS. Regarding the association between VFP and dysphagia, a study reported that more than half of patients with unilateral VFP had associated dysphagia,[30] as supported by the present study. However, VFP was not identified as a clinical risk factor for the development of aspiration pneumonia in our patients after receiving instructions on the optimal level of liquid thickness based on their swallowing function. The reason might be that most VFPs in the present study were postoperative complications that could have been transient and on path to recovery, and many patients had a relatively good PS. In patients with neurologic disorders, VFP was not a risk factor for penetration-aspiration, suggesting that other factors (impaired laryngeal sensation or insufficient expectoration) might contribute more to the risk of penetration-aspiration than VFP.

The present study demonstrated that decreased laryngeal sensation was a risk factor for penetration-aspiration. Therefore, we should consider patients with this impairment as a pre–aspiration pneumonia population and monitor them carefully. In particular, attention should be paid to decreased laryngeal sensation in patients who undergo head and neck surgery or esophageal surgery, while those with neurologic disorders should be monitored for insufficient expectoration. A previous study revealed that the absence of a laryngeal adductor reflex, which is an airway protective reflex that manifests as a brief vocal fold closure in response to laryngeal stimulation, was related to pneumonia associated with swallowing disorders.[31] Furthermore, it has been reported that impaired pharyngeal squeeze, in addition to the absence of a laryngeal adductor reflex, could confer a high risk of penetration-aspiration.[32] The results of our current study indicated that although impaired laryngeal sensation was a risk factor for penetration-aspiration, it was not a significant factor for the development of aspiration pneumonia. Although silent aspiration is reported to pose a greater risk of pneumonia,[33] in the present study, a PAS score of 8 was not significantly associated with the risk pneumonia within 6 months after receiving instructions on thickening liquids. This finding suggests that the medical professionals may have fully explained the danger of silent aspiration to patients with a PAS score of 8, and accordingly, the patients may have strictly adhered to the diet and thickening instructions. Although the cough response to aspiration differed across bolus volumes and viscosities,[34] assessing the cough reflex and its strength in the event of aspiration might be important in the management of dysphagia. We believe that proper fluid-thickening instructions and patient recognition of the potential risks of silent aspiration could reduce the development of pneumonia within 6 months after VFSS, even in patients with decreased laryngeal sensation.

Patients with a history of aspiration pneumonia, particularly those with neurologic disorders, should be carefully monitored to prevent the recurrence of pneumonia. Once aspiration pneumonia occurs, respiratory and swallowing-related muscles and skeletal muscles can undergo atrophy.[35] Given these muscular atrophies, it is plausible that a history of pneumonia can be a risk factor for the recurrence of aspiration pneumonia, despite instructions on liquid thickness and modified diets. Thus, early induction of rehabilitation, such as expectoration training, trunk training, and chest physical therapy, is recommended to prevent aspiration and the recurrence of pneumonia. Since penetration-aspiration may further increase the risk of pneumonia recurrence, the conditions of patients with PAS scores ≥3 should similarly be carefully monitored.

While thickened liquids reduce the risk of penetration-aspiration, thickening has some disadvantages.[13,16] Extremely high viscosity may cause increased pharyngeal residue, insufficient bolus transfer, or difficulty to clear aspirated material. In addition, the polysaccharide-containing thickeners can change the taste of diets and liquids.[36] Besides, the risk of pulmonary inflammation caused by the polysaccharides contained in the liquid thickeners has been reported. Given these factors, patients should be instructed on the appropriate level of thickening and encouraged to adhere to the instructions as much as possible.

Several limitations of this study should be acknowledged. Retrospective chart review research is limited by incomplete or missing documentation, and VFSS was not periodically conducted to observe changes over time. The incidence of aspiration pneumonia treated at other hospitals was not included in this analysis, and the overall incidence may thus be underestimated. However, the impact thereof is expected to be minimal, as major events, such as hospitalization for aspiration pneumonia at other hospitals, would be expected to be documented in the medical records. Patients with difficulty responding to verbal commands and those with severe dysphagia were excluded from this study; however, this would not affect our results because these patients were very few. Under the supervision of medical professionals, patients followed recommended fluid-thickening level in all cases; however, even with our guidance, some patients may not have followed the instructions for liquid thickening in their daily lives. In addition, although VFSS is useful for diagnosing aspiration, it does not have absolute sensitivity or specificity for dysphagia.[37]

Conclusion

Liquid thickening can reduce the frequency of penetration-aspiration. VFP, impaired laryngeal sensation, and previous aspiration pneumonia were strong risk factors for aspiration. In addition, poor PS, PAS score $\geq$3, and a history of pneumonia were associated with the development of aspiration pneumonia despite instructions on proper liquid thickening. Our results indicate that in addition to providing instructions to patients with dysphagia on appropriate liquid thickening, those who have undergone head and neck or esophageal surgery should be carefully monitored for decreased laryngeal sensation, similar to those with stroke and neurologic disorders, to reduce the risk of penetration-aspiration and aspiration pneumonia.

Author Contributions

Hiroaki Masuda, collected and analyzed the data, and wrote the draft of the manuscript. **Rumi Ueha**, developed the concept, designed the study, collected and analyzed the data, and wrote the draft of the manuscript. **Taku Sato**, developed the concept, designed the study, collected the data, and reviewed the manuscript. **Takao Goto**, developed the concept, designed the study, collected the data, and reviewed the manuscript. **Misaki Koyama**, collected the data, analyzed the data, and reviewed the manuscript. **Akihito Yamauchi**, developed the concept and reviewed the manuscript. **Aasako Kaneoka**, designed the study, analyzed the data, and reviewed the manuscript. **Sayaka Suzuki**, designed the study, analyzed the data, and reviewed the manuscript. **Tatsuya Yamasoba**, developed the concept and reviewed the manuscript. All authors contributed to interpretation of the data and writing of the manuscript.

Disclosures

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Availability of Data and Materials

The data sets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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