Findings of Videofluoroscopic Swallowing Studies Are Associated with Tube Feeding Dependency at Discharge in Stroke Patients with Dysphagia

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Abstract. The factors associated with tube feeding dependency in stroke patients with dysphagia have received little attention. This study aimed to identify factors independently associated with tube feeding dependency at discharge in stroke patients with dysphagia using videofluoroscopic swallowing studies (VSS) and clinical findings. One hundred eighty-one consecutive tube-fed inpatients with stroke-related dysphagia referred for VSS were enrolled in the study. Of them, 47 patients continued to require tube feeding at discharge. In the final logistic regression analysis model, advanced age, recurrent stroke, confinement to a wheelchair at discharge, long duration from stroke onset to VSS, and stasis in valleculae or pyriform sinuses and aspiration on VSS were independently associated with tube feeding dependency at discharge. This study confirms the association between findings of VSS and tube feeding dependency at discharge in stroke patients with dysphagia. Based on the final regression model, a preliminary equation was proposed to help clinicians better predict the tube feeding dependency at discharge in stroke patients with dysphagia.

Key words: Dysphagia — Deglutition disorders — Stroke — Videofluoroscopy — Tube feeding — Deglutition.

Dysphagia is a major complication of acute stroke with an incidence of 25%–54% at the onset of stroke, quickly resolving to around 11% at 6 months after stroke [1–10]. Although dysphagia resolves quickly, 31%–66% of patients residing in long-term-care facilities have been reported to have dysphagia [11–13]. Dysphagia results in various complications, such as aspiration pneumonia, dehydration, and malnutrition. Additionally, dysphagia is associated with increased mortality, longer hospital stay, and poor functional outcomes in stroke patients [4,7–9,14,15]. Tube feeding is frequently considered in patients with insufficient swallowing function to meet their fluid or nutritional needs. However, tube-fed patients have to face increased risk of aspiration pneumonia [16] and the high costs and discomfort associated with tube feeding.

The factors associated with tube feeding dependency in stroke patients with dysphagia have received little attention in the literature. Wojner et al. [17] reported that the clinical indicators, including wet voice after swallowing water, hypoglossal nerve dysfunction, high National Institutes of Health Stroke Scale score, and incomplete oral labial closure, were independently associated with tube feeding dependency in acute stroke patients. Wilkinson et al. [18] found that intolerance to grade 3 fluid (with thickness equivalent to instant pudding) at day 7 poststroke, or to puree at days 7 or 21, predicted percutaneous endoscopic gastrostomy (PEG) insertion one year after stroke [18]. Notably, previously reported prognostic indicators were all based on clinical findings and bedside swallowing assessments.

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Videofluoroscopic swallowing study (VSS) is an established objective method of assessing the swallowing process in real-time [19]. The presence of stasis in the valleculae or pyriform sinuses and aspiration during the VSS can be clearly observed with acceptable interjudge and intrajudge reliability [20–22]. During the acute phase of stroke, VSS-detected aspiration is associated with chest infections and malnutrition, but VSS adds little to the value of bedside swallowing assessment in mortality prediction [3,15,23]. Findings of VSS are associated with chest infection, swallowing impairment, and need for diet modification at 6 months poststroke [4]. However, the prognostic values of VSS on tube feeding dependency are not well understood in stroke patients with dysphagia. This study aimed to identify the factors independently associated with tube feeding dependency at discharge in stroke patients with dysphagia, using multivariate logistic regression analysis, considering VSS findings and clinical factors. Furthermore, a preliminary equation was proposed to help clinicians predict the tube feeding dependency at discharge in stroke patients with dysphagia.

Materials and Methods

Study Population

A cohort of patients with stroke-related dysphagia was constructed by identifying 237 consecutive tube-fed patients referred to the Department of Medical Imaging of a tertiary-care university hospital for VSS from July 1994 to April 1999. All study subjects were inpatients of the university hospital. The cohort included patients suffering from stroke-related dysphagia who had received a complete VSS evaluation. Stroke patients were referred for VSS if they had one or more of the following conditions: (1) difficulty swallowing or coughing associated with feeding, (2) persistent tube feeding, (3) prolonged feeding time, and (4) suspicion of aspiration by the primary care physician, for example, a history of pneumonia during the acute phase of stroke, severe dysphonia or dysarthria, abnormal gag reflex, or brainstem lesion. Forty-two patients were excluded for the following reasons: death during their hospital stay ($n = 2$), lack of brain imaging studies (computed tomogram or magnetic resonance study, $n = 17$), incomplete VSS ($n = 14$), or incomplete feeding condition information at discharge ($n = 9$). For patients who received multiple VSS tests, only the last test during the hospital stay for index stroke was recorded and analyzed. Fourteen patients, whose VSS were performed later than 6 months after index stroke, were excluded. Finally, the study group enrolled 181 tube-fed inpatients with stroke-related dysphagia. The medical charts of the entire study group were reviewed and abstracted. Moreover, the clinical data and imaging study results of each patient were recorded on a specially designed form. No coexisting neurological diseases besides stroke or structural disorders resulting in dysphagia were found in the study subjects. The

study was approved by the Human Research and Ethics Committee of the hospital.

Assessment of Clinical Features and Risk Factors

Stroke was diagnosed using the World Health Organization definition [24]. Stroke type (cerebral infarct or cerebral hemorrhage) was determined using brain imaging studies. According to the presenting clinical features and brain imaging studies, the brain lesions of each subject (including the index stroke and previous brain lesions if present) were classified into the following mutually exclusive categories: (1) supratentorium (unilateral), (2) infratentorium, and (3) multiple (combinations of two or three territories). Recurrent stroke existed when the index stroke was not the first stroke experienced by the patient. Additionally, a positive history of brain surgery was defined as the patient having undergone brain surgery for the index stroke. The following clinical variables were assessed upon discharge: (1) baseline characteristics, including age, gender, history of smoking, hypertension, diabetes, heart disease, blood chemistry studies, and socioeconomic status; (2) severe motor impairment, namely, a Brunnstrom staging of 4 or less [25] in the worst affected limb; (3) aphasia, defined as difficulty in verbal expression, auditory comprehension, repetition, or naming at discharge; (4) tube feeding; and (5) confinement to a wheelchair, defined as the inability to walk even with moderate support from a helper.

Assessment of Dysphagia by VSS

Standardized VSS was conducted using a remote-controlled fluoroscope (KOX-850, Toshiba Corp., Tokyo, Japan; RSZ2000, Shimadzu Corp., Kyoto, Japan) equipped with a high-resolution Super-VHS recorder (BR 1200, JVC, Japan). The videotape recorder had a frame rate of 33 frames per second and could display both real-time dynamic images and frame-by-frame static images. Patients were instructed to sit on a specially designed chair (VSS chair, Vess Chairs Inc., Milwaukee, WI, USA) while both true lateral and frontal anterior–posterior views were recorded. Each patient sequentially swallowed three standardized formula (5 ml each of thin, thick, and paste) of barium sulfate (E-Z-HD, E-Z-EM, Inc., Westbury, NY, USA) in sequence. The thin barium sulfate (suspension of 340 g of E-Z-HD and 65 ml of water) was the same as that used in routine gastrointestinal examinations. The thick barium was prepared by adding 7.5 ml of E-Z-HD powder to 15 ml of standard thin barium preparation, and the paste barium was prepared by adding 12 ml of E-Z-HD powder to 15 ml of standard thin barium preparation. The three consistencies were distinguishable physically. All VSS results were reviewed by an experienced radiologist (Chang) based on the previously published criteria [26]. Briefly, stasis in valleculae or pyriform sinus was defined as a visible barium fluid level (more than trace coating) within the valleculae or pyriform sinus after swallowing, and aspiration was defined as misdirection of barium below the vocal cords [19,27,28]. Based on the videotape review among 28 patients with stroke and dysphagia, the intrajudge reliability for VSS measures of stasis and aspiration in the current work was determined by comparing the ratings from two different viewings with two weeks apart at least. The judge was unaware of ratings from the previous viewing. Additionally, a psychiatrist, who is experienced in evaluating swallowing disorders and reading VSS, viewed the videotaped VSS of the 28 patients and independently recorded his ratings on a data sheet. The interjudge reliability for VSS measures of stasis and aspiration was determined by comparing the ratings from the two judges.

Assessment of Outcome

Primary outcome of this study was the tube feeding dependency at discharge. This information was obtained from the in-hospital medical records of each patient.

Statistical Analyses

All analyses were performed using the SAS System for Microsoft Windows (version 8.2, SAS Institute Inc., Gary, NC, USA) statistical software. A p value of <0.05 was considered statistically significant. Group comparisons were conducted using Fisher's exact tests for proportions and general linear models for continuous variables. The intrajudge and interjudge reliability for VSS measures was determined by calculation of kappa values [29]. The association between predictors and tube feeding dependency at discharge was analyzed using logistic regression models. First, univariate analyses were applied to assess the effects of age, gender, clinical features, risk factors, impairment and functional status at discharge, duration from stroke onset to VSS, and length of hospital stay on tube feeding dependency at discharge. Factors with $p < 0.10$ in univariate logistic regression analyses were further analyzed in the following multivariate model. Stepwise multivariate logistic regression analysis then was performed, with only variables with a significance level of $p < 0.05$ being retained in the model. The final model added the variables of VSS findings to the above multivariate logistic regression model. Possible interaction variables were also assessed for all regression models. Effect sizes were expressed in odds ratios (OR) with 95% confidence intervals (CI). A plot of the receiver operating characteristic (ROC) curve for the final logistic model was constructed by varying the cutoff point used for event prediction. The area under the ROC curve (AUC) was used to estimate the discrimination ability of the final multivariate model [30,31]. The Hosmer and Lemeshow goodness-of-fit test was used to assess adequacy for data of the final logistic model [30]. Furthermore, a predictive equation was developed to calculate the estimated probability level of tube feeding dependency at discharge by using the parameter estimates in the final model. To avoid bias in error-count estimate, the reduced-bias estimates of the predicted event probability for classification were calculated using the CTABLE option in the PROC/LOGISTIC procedure of the SAS system [30]. The optimum cutoff probability of the predictive equation was obtained by identifying the cutoff point most closely approaching 100% sensitivity and specificity.

Results

The median age of the 181 study subjects was 68 years (range = 32–87 years) and the median duration from stroke onset to VSS was 36 days (range = 2–174 days). Subjects were separated into four groups based on the VSS findings in the pharyngeal phase. Group A (no stasis or aspiration) contained subjects whose VSS findings revealed no stasis in valleculae or pyriform sinuses, and also no aspiration. Group B (stasis only) included subjects with stasis in valleculae or pyriform sinuses, but no aspiration. Group C (aspiration only) contained subjects with aspiration but no stasis in valleculae or pyriform sinuses. Group D (stasis and aspiration) included subjects with stasis in

valleculae or pyriform sinuses, as well as aspiration in VSS. The intrajudge kappa values for the VSS measures of valleculae stasis, pyriform sinus stasis, and aspiration were 0.837, 0.856, and 1.000 among 28 patients with stroke and dysphagia. The interjudge kappa values for valleculae stasis, pyriform sinus stasis, and aspiration were 0.761, 0.856, and 0.928. Table 1 lists the demographic characteristics and clinical features of the 181 patients. Notably, proportions of male gender, first-ever stroke, abnormal oral phase in VSS, and tube feeding dependency at discharge differed significantly among the four groups. Patients with no stasis or aspiration had the highest proportion of first-ever stroke and the lowest proportions of tube feeding dependency and confinement to a wheelchair at discharge. In contrast, patients with stasis and aspiration had the highest proportions of tube feeding dependency and confinement to a wheelchair at discharge. Duration from VSS to discharge was slightly longer for patients with stasis and aspiration than for other patients. The other demographic characteristics, clinical features, and functional status at discharge were similar among the four groups.

Of the 181 patients, 47 still required tube feeding after a median duration of 29 days from VSS to discharge. Most of these subjects were fed using nasogastric tube at discharge, and only two were fed by PEG. Subjects were further separated into two groups (oral feeding or tube feeding) based on the tube feeding dependency at discharge. Table 2 compares the demographic characteristics and clinical features of subjects in the two groups. Patients in the tube feeding group were significantly older than those in the oral feeding group. Additionally, duration from stroke onset to VSS and length of hospital stay were significantly longer in the tube feeding group than in the oral feeding group. However, the duration from VSS to discharge was similar for both groups. Significantly higher proportions of recurrent stroke, severe motor impairment, confinement to a wheelchair at discharge, stasis in valleculae or pyriform sinuses, and aspiration in VSS were observed in the tube feeding group. Other demographic characteristics and clinical features were similar between the two groups.

Univariate logistic regression analyses revealed that advanced age (OR = 1.07 per year, 95% CI 1.03–1.11, $p = 0.0008$), long duration from stroke onset to VSS (OR = 1.02 per day, 95% CI 1.01–1.03, $p = 0.0002$), recurrent stroke (OR = 2.12, 95% CI 1.08–4.16, $p = 0.0298$), severe motor impairment at discharge (OR = 2.72, 95% CI 1.18–6.29, $p = 0.0193$), confinement to a wheelchair at discharge (OR = 12.96, 95% CI 5.36–31.34, $p < 0.0001$), stasis

Table 1. Demographic and clinical characteristics of 181 stroke patients with dysphagia (grouped by the findings on VSS^a)

Variable	Group A ^b (<i>n</i> = 57) <i>n</i> (%)	Group B ^c (<i>n</i> = 47) <i>n</i> (%)	Group C ^d (<i>n</i> = 26) <i>n</i> (%)	Group D ^e (<i>n</i> = 51) <i>n</i> (%)	Total (<i>n</i> = 181) <i>n</i> (%)
Age (yr) ^f	68.3 ± 9.7	67.0 ± 10.6	67.7 ± 10.9	67.6 ± 11.6	67.7 ± 10.6
Duration from stroke onset to VSS (d) ^f	38.2 ± 28.7	34.3 ± 26.0	42.0 ± 27.7	29.1 ± 22.8	35.1 ± 26.5
Duration from VSS to discharge (d) ^f	44.7 ± 32.1	39.4 ± 29.8	49.0 ± 26.3	58.4 ± 36.7*	47.8 ± 32.7
Length of hospital stay (d) ^f	73.6 ± 41.3	65.1 ± 35.8	87.6 ± 44.9	76.6 ± 44.5	74.3 ± 41.7
Male in gender	24 (42.1)	37 (78.7)	11 (42.3)	36 (70.6)*	108 (59.7)
Smoking ever	14 (24.6)	22 (46.8)	7 (26.9)	18 (35.3)	61 (33.7)
Hypertension	42 (73.7)	36 (76.6)	15 (57.7)	39 (76.5)	132 (72.9)
Diabetes mellitus	21 (36.8)	18 (38.3)	13 (50.0)	20 (39.2)	72 (39.8)
Heart diseases	22 (38.6)	16 (34.0)	9 (34.6)	20 (39.2)	67 (37.0)
Atrial fibrillation	13 (22.8)	9 (15.2)	6 (23.1)	11 (21.6)	39 (21.5)
Ischemic heart disease	6 (10.5)	5 (10.6)	2 (7.7)	8 (15.7)	21 (11.6)
Heart failure	5 (8.8)	6 (12.8)	3 (11.5)	1 (2.0)	15 (8.3)
Valvular heart disease	5 (8.8)	3 (6.4)	4 (15.4)	5 (9.8)	17 (9.4)
Hypercholesterolemia	20 (35.1)	14 (29.8)	10 (38.5)	12 (23.5)	56 (30.9)
Hypertriglyceridemia	11 (19.3)	9 (19.2)	8 (30.8)	5 (9.8)	33 (18.2)
Hyperuricemia	20 (35.1)	11 (23.4)	7 (26.9)	8 (15.7)	46 (25.4)
Low socioeconomic status	35 (61.4)	24 (51.1)	13 (50.0)	26 (51.0)	98 (54.1)
First-ever stroke	40 (70.2)	26 (55.3)	10 (38.5)	22 (43.1)*	98 (54.1)
Type of stroke					
Infarct	42 (73.7)	38 (80.9)	23 (88.5)	36 (70.6)	139 (76.8)
Hemorrhage	15 (26.3)	9 (19.2)	3 (11.5)	15 (29.4)	42 (23.2)
Lesion of stroke					
Supratentorium (unilateral)	36 (63.2)	21 (24.7)	12 (46.2)	18 (35.3)	87 (48.1)
Infratentorium	1 (1.7)	3 (6.4)	0 (0.0)	5 (9.8)	9 (5.0)
Multiple	20 (35.1)	23 (48.9)	14 (53.9)	28 (54.9)	85 (47.0)
Brain surgery due to stroke	8 (14.0)	4 (8.5)	2 (7.7)	8 (15.7)	22 (12.2)
Severe motor impairment	37 (64.9)	35 (74.5)	18 (69.2)	35 (68.6)	125 (69.1)
Confinement to a wheelchair at discharge	22 (38.6)	19 (40.4)	13 (50.0)	27 (52.9)	81 (44.8)
Aphasia	21 (36.8)	15 (31.9)	7 (26.9)	19 (37.3)	62 (34.3)
VSS findings					
Abnormal oral phase	45 (79.0)	46 (97.9)	24 (92.3)	49 (96.1)*	164 (90.6)
No penetration or aspiration	31 (54.4)	22 (46.8)	0 (0.0)	0 (0.0)	53 (29.3)
Penetration but no aspiration	26 (45.6)	25 (53.2)	0 (0.0)	0 (0.0)	51 (28.2)
Aspiration	0 (0.0)	0 (0.0)	26 (100.0)	51 (100.0)	77 (42.5)
Tube feeding at discharge	7 (12.3)	13 (27.7)	8 (30.8)	19 (37.3)*	47 (26.0)

^aVSS: videofluoroscopic swallowing studies.
^bGroup A: Stasis in valleculae or pyriform sinuses (−), aspiration (−).
^cGroup B: Stasis in valleculae or pyriform sinuses (+), aspiration (−).
^dGroup C: Stasis in valleculae or pyriform sinuses (−), aspiration (+).
^eGroup D: Stasis in valleculae or pyriform sinuses (+), aspiration (+).
^fData are presented as mean ± standard deviation.
*Significant difference among groups (*p* < 0.05)

in valleculae or pyriform sinuses (OR = 2.20, 95% CI 1.09–4.43, *p* = 0.0276), and aspiration in VSS (OR = 2.27, 95% CI 1.15–4.46, *p* = 0.0176) were significantly associated with tube feeding dependency at discharge. In the final logistic regression analysis model, advanced age, recurrent stroke, confinement to a wheelchair at discharge, long duration from stroke

onset to VSS, and stasis in valleculae or pyriform sinuses and aspiration on VSS were independently associated with tube feeding dependency at discharge (Table 3). The final model displayed good discrimination ability, with an AUC of 0.87 (95% CI 0.83–0.91) (Fig. 1). Hosmer and Lemeshow goodness-of-fit test found no evidence of a lack of fit in the final model

$$P[\text{TUBE}] = \frac{\exp(-9.49 + 0.06 \times [\text{AGE}] + 1.05 \times [\text{CVA}] + 0.02 \times [\text{TIME}] + 2.14 \times [\text{WC}] + 1.30 \times [\text{V1}] + 0.98 \times [\text{V2}] + 1.18 \times [\text{V3}])}{1 + \exp(-9.49 + 0.06 \times [\text{AGE}] + 1.05 \times [\text{CVA}] + 0.02 \times [\text{TIME}] + 2.14 \times [\text{WC}] + 1.30 \times [\text{V1}] + 0.98 \times [\text{V2}] + 1.18 \times [\text{V3}])}$$

Table 2. Demographic and clinical characteristics of 181 stroke patients with dysphagia (grouped by tube feeding dependency at discharge)

Variable	Oral feeding at discharge (<i>n</i> = 134) <i>n</i> (%)	Tube feeding at discharge (<i>n</i> = 47) <i>n</i> (%)	Total (<i>n</i> = 181) <i>n</i> (%)
Age (yr) ^a	66.0 ± 10.8	72.3 ± 8.7*	67.7 ± 10.6
Duration from stroke onset to VSS (d) ^a	41.9 ± 29.1	64.6 ± 36.7*	47.8 ± 32.7
Duration from VSS to discharge (d) ^a	35.3 ± 27.4	34.8 ± 23.8	35.1 ± 26.5
Length of hospital stay (d) ^a	68.9 ± 38.9	89.4 ± 45.8*	74.2 ± 41.7
Male in gender	78 (58.2)	30 (63.8)	108 (59.7)
Smoking ever	42 (31.3)	19 (40.4)	61 (33.7)
Hypertension	98 (73.1)	34 (72.3)	132 (72.9)
Diabetes mellitus	55 (41.0)	17 (36.2)	72 (39.8)
Heart disease	52 (38.8)	15 (31.9)	67 (37.0)
Atrial fibrillation	29 (21.6)	10 (21.3)	39 (21.5)
Ischemic heart disease	17 (12.7)	4 (8.5)	21 (11.6)
Heart failure	11 (8.2)	4 (8.5)	15 (8.3)
Valvular heart disease	12 (9.0)	5 (10.6)	17 (9.4)
Hypercholesterolemia	46 (34.3)	10 (21.3)	56 (30.9)
Hypertriglyceridemia	26 (19.4)	7 (14.9)	33 (18.2)
Hyperuricemia	31 (23.1)	15 (31.9)	46 (25.4)
Low socioeconomic status	67 (50.0)	31 (66.0)	98 (54.1)
First-ever stroke	79 (59.0)	19 (40.4)*	98 (54.1)
Type of stroke			
Infarct	101 (75.4)	38 (80.9)	139 (76.8)
Hemorrhage	33 (24.6)	9 (19.1)	42 (23.2)
Lesion of stroke			
Supratentorium (unilateral)	67 (50.0)	20 (42.6)	87 (48.0)
Infratentorium	6 (4.5)	3 (6.4)	9 (5.0)
Multiple	61 (45.5)	24 (51.0)	85 (47.0)
Brain surgery due to stroke	20 (14.9)	2 (4.3)	22 (12.2)
Severe motor impairment	86 (64.2)	39 (83.0)*	125 (69.1)
Confinement to a wheelchair at discharge	41 (30.6)	40 (85.1)*	81 (44.8)
Aphasia	47 (35.1)	15 (31.9)	62 (34.3)
VSS ^b findings			
Abnormal oral phase	120 (89.6)	44 (93.6)	164 (90.6)
Stasis in valleculae or pyriform sinus	66 (49.3)	32 (68.1)*	98 (51.1)
Penetration/aspiration status			
No penetration or aspiration	43 (32.1)	10 (21.3)	53 (29.3)
Penetration but no aspiration	41 (30.6)	10 (21.3)	51 (28.2)
Aspiration	50 (37.3)	27 (57.4)*	77 (42.5)

^aData are presented as mean ± standard deviation.^bVSS: videofluoroscopic swallowing studies.*Significant difference between groups ($p < 0.05$).

($p = 0.8327$). Furthermore, the parameter estimates in the final model can be used to calculate the estimated probability level of tube feeding dependency at discharge ($P[\text{TUBE}]$) with the following equation involving exponential function (exp):

Table 4 defines each abbreviation in the above equation. The preceding coefficient of each parameter in the equation is the parameter estimate obtained in the final logistic regression model. The optimum $P[\text{TUBE}]$ cutoff point of 0.22 of the predictive equation is obtained by identifying the point that reduced-bias estimates of sensitivity and specificity most closely approaches 100% [30]. This $P[\text{TUBE}]$ cutoff point of the predictive equation yields sensi-

tivity of 83% and specificity of 75%. In the present study population, the positive predictive value of the equation, defined as the probability of a subject being tube feeding-dependent at discharge given $P[\text{TUBE}] > 0.22$, is 53%; meanwhile, the negative predictive value of the equation, defined as the probability of a subject oral feeding at discharge given $P[\text{TUBE}] \leq 0.22$, is 93%.

Discussion

This study demonstrates that findings on VSS are independently associated with tube feeding depen-

Table 3. Final multivariate logistic model for the associations of selected predictors with tube feeding dependency at discharge among 181 stroke patients with dysphagia

	OR ^a	95% CI ^b	<i>p</i> value
Age (per year)	1.07	1.02–1.12	0.0081*
Recurrent stroke vs. first-ever stroke	2.85	1.15–7.07	0.0240*
Wheelchair-confined at discharge	8.54	3.29–22.15	<0.0001*
Duration from stroke onset to VSS ^c (per day)	1.02	1.01–1.04	0.0017*
Stasis in valleculae or pyriform sinuses (–), aspiration (–)	1		
Stasis in valleculae or pyriform sinuses (+), aspiration (–)	3.67	1.05–12.84	0.0417*
Stasis in valleculae or pyriform sinuses (–), aspiration (+)	2.66	0.68–10.32	0.1582
Line missing

Fig. 1. Receiver operating characteristic (ROC) curve of the final multivariate logistic model. The area under the ROC curve (AUC) and its 95% confidence intervals (in parentheses) indicate the model’s discrimination ability.

dependency at discharge in stroke patients with dysphagia. Stasis in valleculae or pyriform sinuses on VSS, with or without aspiration, is independently associated with tube feeding dependency at discharge in stroke patients with dysphagia. In addition to providing information to guide swallowing training [32], the findings on VSS prove to be independently associated with dysphagia recovery among stroke patients in this study.

Our findings show that severe motor impairment and poor functional recovery (confinement to a wheelchair at discharge) are associated with tube feeding dependency at discharge among stroke pa-

tients who are referred for probable dysphagia in univariate analyses. A high National Institutes of Health Stroke Scale score, an indicator of severe stroke-related impairment, was reported to be associated with tube feeding dependency [17]. However, this study found that only poor functional recovery was independently associated with tube feeding dependency at discharge in the final model. Poor functional recovery at discharge might be a confounder in the study due to its associations with overall stroke severity and impaired cognitive function. Advanced age and recurrent stroke were also independently associated with the tube feeding dependency at discharge in this study. These associations have been reported in previous studies [4,33]. Besides, our findings demonstrate that the probability of tube feeding dependency at discharge increases with longer duration from stroke onset to VSS. Reduced consciousness, impaired cognitive function, and general weakness with poor trunk control were possible reasons for prolonged duration from stroke onset to VSS in the present study. The above factors actually reflect the severity of stroke, the extent of brain damage, and residual physical function in stroke patients.

The optimal nutritional route and timing for inserting a PEG remains uncertain in stroke patients with dysphagia [32,34]. A nasogastric tube is frequently inserted during the early stage of stroke to improve nutrition and hydration. Feeding via nasogastric tube has disadvantages such as nasal ulceration, laryngeal injury, pharyngeal discomfort, precipitated gastroesophageal reflux, impaired nutrition, dehydration, tube displacement, self-extubation, blockage, and unattractive appearance [35,36]. PEG is an alternative method of maintaining hydration and nutrition. The decision to use a PEG tube is often made when the patient and family members realize

Table 4. Definitions of the abbreviations in predictive equation for tube feeding dependency at discharge

Abbreviation	Response
<i>P</i> [TUBE]	Estimated probability level of tube feeding dependency at discharge
Age	Age of the patient (yr)
CVA	Recurrent stroke = 1 First-ever stroke = 0
Time	Duration from stroke onset to VSS (d)
WC	Confinement to a wheelchair at discharge = 1, else = 0
V1	VSS ^a finding: stasis in valleculae or pyriform sinuses, but no aspiration (Group B ^b) = 1, else = 0
V2	VSS finding: aspiration, but no stasis in valleculae or pyriform sinuses (Group C ^b) = 1, else = 0
V3	VSS finding: stasis in valleculae or pyriform sinuses, and aspiration (Group D ^b) = 1, else = 0

^aVSS: videofluoroscopic swallowing studies.
^bThe definitions of Groups B, C, and D are the same as listed in Table 1.

that recovery is unlikely and prolonged tube feeding is necessary. However, the benefits of tube feeding are questionable since some research claims that tube feeding may increase aspiration risk rather than reduce it [16]. Tube feeding is independently associated with increased 1-year mortality among nursing home residents during multivariate analysis [37]. Consequently, a method for predicting whether a stroke patient is tube feeding dependent at discharge is important in terms of clinical decision-making and outcome prediction.

The proposed equation may help clinicians predict tube feeding dependency at discharge, and consider the need for and timing of PEG feeding in stroke patients referred for probable dysphagia. This equation has high internal validity in the present study cohort but requires further validation in different populations. For example, take a tube-fed stroke patient with the following characteristics: 55 years of age, first-ever stroke, VSS performed on day 24 poststroke, and stasis in pyriform sinus and aspiration in VSS. Given [AGE] = 55, [CVA] = 0, [TIME] = 24, [WC] = 1 or 0, [V1] = 0, [V2] = 0, and [V3] = 1 in the predictive equation, *P*[TUBE] is below the cutoff point of 0.22. Thus, the probability that this patient will resume oral feeding at discharge is 93%. For another example, take a patient with the following characteristics: 85 years of age, recurrent stroke, VSS performed on day 46 poststroke, and stasis in valleculae and pyriform sinus but no aspiration in VSS. Given [AGE] = 85, [CVA] = 1, [TIME] = 46, [WC] = 1 or 0, [V1] = 1, [V2] = 0, and [V3] = 0 in the predictive equation, *P*[TUBE] exceeds the cutoff point of 0.22. This patient has a probability of 53% of being tube feeding dependent at discharge. The application of PEG may be considered in this case. However, the decision is difficult to make owing to the probability of resuming oral feeding at discharge being 47%. The relatively low positive

predictive value (53%) confines the applicability of the proposed equation under such circumstances. Until further data demonstrate the utility of such an equation, clinicians should be more concerned with the presence or absence of the individual factors of the equation than the equation itself. A previous study encountered similar difficulty in predicting tube feeding dependency [18]. Among patients unable to tolerate grade 3 thickened fluids or a puree diet 14 days after their stroke, half recovered sufficiently to manage oral feeding [18]. According to Bayes' theorem, this relatively low positive predictive value can be attributed to the low prevalence of tube feeding dependency in the study population [29].

The major limitation of this study is the referral bias owing to the exclusion of certain patients, namely, those whose dysphagia was too mild or whose general condition was too poor to undergo standard VSS. The study subjects thus represent stroke patients with moderate to severe dysphagia, and the proposed equation is valid only for individuals with similar characteristics. The second limitation is the retrospective design. Data were collected from medical records rather than gathered prospectively and selectively. This study failed to include information on nutritional condition and the bedside assessment of the swallowing function because of a lack of reliable data. The study also failed to consider the individual effect of different biomechanical problems on swallowing physiology of each study subject because the information obtained from VSS was simply abstracted to the existence of stasis or aspiration only [38]. Additionally, VSS is conducted in a controlled environment with suitable patient positioning and short filming time. This setting may not reflect real swallowing processes in a ward or at home, producing a high false negative rate in detecting abnormal findings [32]. Possible misclassifications resulting from this false negative rate will

reduce the effects of the VSS findings. The true effects of VSS findings for predicting tube feeding dependency at discharge may be higher than listed in Table 3.

Conclusion

Among stroke patients with dysphagia, stasis in valleculae or pyriform sinuses with or without aspiration on VSS are independently associated with tube feeding dependency at discharge. Considering the clinical factors and VSS findings, this study proposes a preliminary equation for predicting the tube feeding dependency at discharge for stroke patients. This equation is valid only for stroke patients referred for probable dysphagia. It may help clinicians predict which patients will resume oral feeding at discharge, and also help determine the need for and timing of PEG feeding. Further prospective studies are required to validate the clinical utility of this preliminary predictive equation in different populations.

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