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IDENTIFICATION OF A SIMPLE SCREENING TOOL FOR DYSPHAGIA IN PATIENTS WITH STROKE USING FACTOR ANALYSIS OF MULTIPLE DYSPHAGIA VARIABLES

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Objective: **To identify a most useful and simple clinical screening tool to predict videofluoroscopic aspiration in patients with stroke.**

Design: **Factor analysis of multiple dysphagia variables and sensitivity and specificity testing with chi-square test.**

Patients: **Sixty-one consecutive stroke patients with symptoms suggestive of dysphagia admitted to a university hospital and its 4 affiliated hospitals in Japan.**

Methods: **Factors were extracted from 6 oromotor examinations (lip closure, tongue movement, palatal elevation, gag reflex, voice quality and motor speech function), 2 swallow screen tests (saliva swallowing test and our modified water swallowing test using 30 ml of water) and 4 parameters evaluated with a videofluoroscopic swallow study. Sensitivity and specificity of each dysphagia-related variable was determined against aspiration in a videofluoroscopic swallow study.**

Results: **Factor analysis revealed that cough/voice change in the water swallowing test and aspiration on videofluoroscopic swallow study belonged to the same factor. Chi-square analysis showed that cough/voice change in the water swallowing test was the only variable that was significantly associated with aspiration on videofluoroscopic swallow study, with a sensitivity of 72% (95% CI: 61–83%) and a specificity of 67% (CI: 55–79%) as a predictor of aspiration ($p < 0.05$).**

Conclusion: **We recommend our modified 30 ml water-swallowing test as a useful single task-screening tool to detect aspiration.**

Key words: aspiration, screening test, cerebrovascular disease, videofluorography.

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INTRODUCTION

Dysphagia is one of the most common and life-threatening complications in patients with stroke; its reported prevalence, as detected radiographically, ranges from 40% (1) to 70% (2). Dysphagia after stroke can result in aspiration pneumonia (1, 3–5), malnutrition (6) and deleterious disability outcome (7, 8). Thus, it is important to have an efficient screening instrument to detect patients who are at risk of aspiration. Assessment sets for dysphagia usually comprise various clinical examinations such as the evaluation of consciousness, posture, oral function (lip seal, tongue movement and soft palate movement), gag reflex, voice quality, motor speech function, voluntary cough, laryngeal elevation on saliva swallowing, observation of eating and drinking and so on (9).

Recently, several authors have demonstrated that some of these variables are good predictors of dysphagia and aspiration. They include abnormal oral function, such as delayed oral transit and incomplete oral clearance (10), impaired voice quality (11–15), dysarthria (2, 13–15), abnormal gag reflex (2, 13–15), abnormal voluntary cough (13–15), reduced laryngeal elevation during saliva swallowing (15, 16), laryngeal sensory disturbance (17) and water swallowing (WST) test results (13, 14, 17, 18).

Although the performance of each of the above clinical features or tests as a predictor of aspiration has been described, it has not been determined which is the best standard dysphagia assessment tool. Our goal, therefore, was to identify a most useful and simple clinical screening tool to predict dysphagia in patients with stroke among the various clinical predictors of aspiration.

METHODS

Among patients with stroke admitted to Keio University Hospital and its 4 affiliated hospitals located in the Tokyo metropolitan area during the period from April 2000 to March 2003, we recruited 61 consecutive patients with stroke (40 men) who were referred for swallowing evaluations. Stroke was diagnosed either with computerized tomography (CT) scanning or magnetic resonance imaging (MRI). The patients presented with 1 or more of the following features suggestive of dysphagia (18, 19): (i) bilateral or brain stem stroke; (ii) history of aspiration pneumonia or increased sputum secretion; (iii) cough associated with feeding and/or drinking; (iv) weight loss, decreased oral intake or prolonged feeding times; (v) complaint of difficulty in swallowing; (vi) need for a therapeutic diet or non-oral feeding. We excluded patients who could not follow commands, who had a tracheostomy, who had a prior history of oropharyngeal impairments or who had active respiratory infection. The mean age at admission was 70.4 (30–93) years. There were 11 patients with cerebral haemorrhage, 47 with cerebral infarction and 3 with subarachnoid haemorrhage. Twenty-eight patients were within 1-month post-stroke, 11 were 1–3

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Table I. *Patient characteristics (mean (SD))*

Characteristics	Mean (SD)
SIAS motor items	
Knee mouth test	2.1 (1.8)
Finger function test	1.7 (1.9)
Hip flexion test	2.3 (1.8)
Knee extension test	2.2 (1.9)
Foot tap test	1.9 (2.0)
FIM™	
Motor score	39.3 (12.7)
Cognitive score	25.3 (7.3)

SIAS = Stroke Impairment Assessment Set; FIM™ = Functional Independent Measure. With the SIAS, the degree of motor impairment is rated from 0 to 5, where 0 means complete paralysis, 3 the ability to complete the task with clumsiness, 5 no paresis and 2 and 4 in between.

months and 22 were over 3 months post-stroke. Forty-seven patients had hemiparesis (21 on the right side and 26 on the left side), 5 had ataxia and the remaining 9 had bilateral hemiparesis. Table I illustrates the degree of limb paresis as assessed with the motor items of the Stroke Impairment Assessment Set (SIAS) (20, 21) and functional limitation in daily living as evaluated with the Functional Independence Measure (FIM™) (22).

Each hospital's Ethics Committee gave permission for this study. Before enrolment, the purposes and procedures were explained fully and a written informed consent was obtained from all subjects. The following parameters were evaluated by trained physicians and/or speech therapists.

Oromotor functions

For the screening of oromotor functions, we scored 6 items including lip closure, tongue movement, palatal elevation, gag reflex, voice quality and motor speech function with a binary normal/abnormal scoring. The functions of lip, tongue and soft palate were scored by assessing the symmetry, strength and agility of each isolated movement. Gag reflex elicited with a standard method was rated abnormal if the reflex was absent or diminished. Impaired voice quality was identified and classified as wet hoarseness, breathy, strained and non-specific hoarseness. Motor speech function was evaluated by its articulatory precision and agility in spontaneous speech and repetition of "pa-ta-ka" sounds. Details of the clinical screening protocol are given in the Appendix.

Clinical swallowing tests

The saliva swallowing test was performed as described by Oguchi et al. (16). Patients were asked to swallow their saliva, and they were classified as abnormal if they could not do so, i.e. the examiner could not confirm laryngeal elevation at all in a period of 30 seconds.

The WST is usually performed with 90 ml of clear liquid (18), but with such a large amount of the water in a screening test, especially for patients in the acute phase of stroke, risk of aspiration, choking and other complications cannot be overlooked. We therefore modified the WST by using a smaller amount (30 ml) of water. With the patient in an upright sitting position, the examiner gave a teaspoonful (5 ml) of water twice, after which the patient was asked to drink the rest of water from a beaker. This procedure was terminated if the patient coughed or voice change occurred. In this test, we evaluated oral-phase abnormality, absence of laryngeal elevation during swallow and cough or voice change after swallow. Oral-phase abnormality was defined as water dripping from lips or impaired oral transit. The examiner determined the absence of laryngeal elevation during swallow by observing and/or feeling laryngeal movement. Cough or voice change was assessed within 1 minute of swallowing.

Videofluoroscopic swallow study (VSS)

VSS was performed within 7 days of the above clinical screening at the latest and it was done within a day on acute phase patients. VSS evaluation consisted of a teaspoonful of thin liquid pudding, between a teaspoonful (5 ml) to 30 ml of liquid and some kind of food (rice, cookies) if necessary. All of the test foods contained a contrast medium (barium or iopamidol). Patients were seated upright and viewed in the lateral position. VSS was recorded with a videocassette recorder. The oral-phase abnormality (anterior bolus loss identified as spillage from the lips and slow or uncoordinated oral transfer) and pharyngeal-phase abnormalities (aspiration, delayed pharyngeal swallow and pharyngeal residue) were evaluated on VSS. Aspiration was defined as an entry of bolus inferior to the level of the true vocal folds. Following Daniels et al. (13), we defined delayed pharyngeal swallow as stage transition duration (STD) longer than 0.45 seconds on liquid swallowing. The STD was the duration from the time at which the bolus head reached the point where the ramus of the mandible bisects the base of the tongue to the time when the reflex was triggered (23). The pharyngeal residue was defined as coating or stasis of more than a trace of materials within the pharynx after swallowing.

Data analyses

To study the statistical structure of dysphagia, a total of 14 parameters (6 oromotor functions, 4 parameters obtained with 2 clinical tests and 4 VSS findings) were subjected to factor analysis (24). The number of components was determined by solution, which produced a simple structure to the factor loading, with a minimum number of factors needed to account for the majority of the variance in the 14 parameters.

Secondly, the sensitivity and specificity of the above variables, of 6 clinical features and 2 swallowing tests as an indicator of oral-pharyngeal abnormalities identified on VSS, were determined with chi-square analysis (24), setting the significance level at less than 5%.

The above analyses were performed using a StatView 5.0™ computer software package (Abacus Concepts Inc., California, USA) developed for Windows™ computers (Microsoft Corporation, Washington, USA).

RESULTS

A complete data set was obtained for all patients. Table II shows the percentages of abnormal findings for each test. They ranged from 56% to 72% for the 6 oromotor examinations. In the saliva swallowing test, 26% of the patients could not swallow at all in 30 seconds. In the modified WST, 34% of the patients presented

Table II. *Percentages of abnormal findings in clinical features and videofluoroscopic swallow study (VSS) findings* (n = *61)*

Clinical features	Abnormal findings (%)
Oromotor examinations	
Lip closure	56
Tongue movement	59
Palatal elevation	56
Gag reflex	72
Voice quality	67
Motor speech function	59
Swallow screen tests	
Saliva swallowing test	26
Oral-phase in the WST	34
Laryngeal elevation in the WST	25
Cough/voice change in the WST	44
VSS findings	
Oral-phase	59
Pharyngeal-phase	85
Delayed pharyngeal swallow	72
Aspiration	30
Pharyngeal residue	62

WST = water swallowing test.

Table III. *Factor loading matrix for the 14 variables after varimax rotation*

Factor	I	II	III	IV	V	VI
Subscale name	Pharyngeal function group I	Oral function group I	Oral function group II	Pharyngeal function groupII (aspiration)	Gag reflex	Pharyngeal function group III
Lip closure	−0.001	0.280	**0.693**	−0.010	0.172	−0.001
Tongue movement	−0.165	−0.093	**0.886**	0.101	−0.219	−0.028
Palatal elevation	0.189	0.017	**0.538**	−0.233	0.343	0.138
Gag reflex	−0.042	−0.007	0.019	0.056	**0.876**	0.022
Voice quality	**0.856**	−0.075	−0.009	−0.100	−0.002	0.072
Motor speech function	**0.708**	0.148	−0.209	0.158	0.091	−0.040
Saliva-swallowing test	−0.035	−0.059	−0.028	0.087	0.072	**0.855**
Oral-phase in the WST	0.040	**0.681**	0.239	−0.078	0.039	0.184
Laryngeal elevation in the WST	0.078	0.326	0.120	−0.001	−0.080	**0.609**
Cough/voice change in the WST	0.333	−0.024	−0.111	**0.607**	−0.024	0.296
Oral-phase on VSS	0.054	**0.704**	−0.107	−0.101	−0.181	0.120
Delayed pharyngeal swallow on VSS	**0.620**	0.085	0.147	0.162	−0.151	−0.026
Aspiration on VSS	0.004	0.005	0.035	**0.841**	0.031	−0.029
Pharyngeal residue on VSS	0.061	**0.750**	0.017	0.283	0.198	−0.217
Eigenvalue	4.099	1.931	1.600	1.200	1.014	0.835
% Variance	29.3	13.8	11.4	8.6	7.2	6.0
Cumulative % variance	29.3	43.1	54.5	63.1	70.3	76.0

VSS = videofluoroscopic swallow study; WST = water swallowing test.

with oral-phase abnormality, 44% with cough or voice change after swallow, and laryngeal elevation during swallow could not be identified in 25% of the patients. In the VSS evaluation, 59% presented with oral-phase abnormality and 85% with pharyngeal-phase abnormalities including delayed pharyngeal swallow (72%), pharyngeal residue after swallow (62%) and aspiration (30%).

The 6 factor solutions explained 76% of the total variance in the original 14 variables, and had a well-defined structure (Table III). Factor I included voice quality, motor speech function and delayed pharyngeal swallow on VSS. Factor II included the oral-phase in the WST, the oral-phase and pharyngeal residue on VSS. Factor III included lip closure, tongue movement and palatal elevation. Cough/voice change in the WST and aspiration on VSS belonged to Factor IV. Factor V included only the gag reflex. Factor VI included the saliva swallowing test and laryngeal elevation in the WST.

Table IV. *The sensitivity and specificity of 6 clinical features and 2 swallowing tests for aspiration on videofluoroscopic swallow study with chi-square analysis*

Variable	Sensitivity (%)	Specificity (%)
Lip closure	67	49
Tongue movement	72	47
Palatal elevation	67	49
Gag reflex	88	36
Voice quality	83	40
Motor speech function	78	44
Saliva swallowing test	28	76
Oral-phase in the WST	33	65
Laryngeal elevation in the WST	22	74
Cough/voice change in the WST	72	67*

WST = water swallowing test.
* $p < 0.01$.

Table IV depicts the sensitivity and specificity of the 6 clinical features and the 2 swallowing tests as an indicator of aspiration identified with VSS. Cough/voice change in the WST was the only variable that was significantly associated with aspiration on VSS. It had a sensitivity of 72% (95% confidence interval: CI, 61–83%) and a specificity of 67% (95% CI: 55–79%).

DISCUSSION

The present study is the first using factor analysis to compare several clinical screening tools simultaneously in order to prove which one could be a most useful predictor of aspiration on VSS. Factor analysis is a statistical tool used to analyse scores of a large number of variables and to determine whether there are any identifiable dimensions that can be used to describe many of the variables under study. It allows the researchers to summarize data by grouping variables that are inter-related (24). In our study, 14 variables including oromotor examinations, clinical tests and VSS findings were grouped into 6 factors, which could be interpreted in clinically meaningful ways.

Among the 6 oromotor examinations and the 2 swallow screen tests, it was only cough/voice change in the modified WST that belonged to the same factor group as aspiration on VSS. This indicates that the 2 variables have a close relationship with each other, and evaluation of cough/voice change in the WST is important in predicting aspiration. Delayed pharyngeal swallow on VSS belonged to another factor group that included voice quality and motor speech function.

In respect to oral functions, lip closure, tongue movement and palatal elevation formed one factor group, and oral-phase in the WST, oral-phase and pharyngeal residue on VSS made up

another factor. This indicates that clinical oromotor examinations do not reflect oral-phase abnormalities on VSS, and the oral-phase in the WST is required as a predictor.

Chi-square analysis supported the results of factor analysis. It demonstrated that cough/voice change in the WST was the only variable that was significantly associated with aspiration on VSS, with a sensitivity of 72% and specificity of 67% as a predictor of aspiration. Previous studies (13, 14, 17, 18) indicated that WST was associated with aspiration with a sensitivity of 57–76% and a specificity of 59–85%. The different sensitivity and specificity levels in different studies are probably due to different water volumes and different test protocol. Although we performed the WST with 30 ml of water, which is relatively a small amount, its sensitivity to detect aspiration on VSS was as high as in the study by Depippo et al. (18) where 90 ml of water was used. This might be due to our concurrent evaluation of voice change after swallowing in addition to coughing, which can detect pharyngeal residue or silent penetration on the vocal cord. The other reason might be that in our WST protocol, water loadings were repeated 3 times (5 ml of water twice and then the rest of water), and the chances were greater to detect aspiration.

Some previous studies have already declared the effectiveness of WST, and our study confirmed it by comparing clinical features and tests using factor analysis. We made some modification on the usual WST protocols, which helped improve the safety and accuracy of the test. But the sensitivity of our WST to predict aspiration on VSS is still limited, because not all silent aspiration could be identified. The prevalence of patients with silent aspiration has been reported as ranging from 20% (17) to 72% (25) among aspirators on VSS, which is too large to be overlooked. It might be difficult to detect all silent aspiration with clinical screening, but some more modification on the WST would be helpful. In this study, factor analysis implied that concurrent evaluation of voice quality or motor speech function could improve the accuracy of the WST because they belonged to the same factor as delayed pharyngeal swallow on VSS, which is a risk factor of aspiration. Further study of the "newly modified WST", including evaluation of voice quality and/or motor speech function, must be conducted to minimize false negatives for aspiration. The reliability and consistency of the test would be verified without fail. In the present study, the reliability of each clinical screening has not been assessed, but we are afraid that some inter-rater differences might be present, particularly in the evaluation of voice quality. If that is found to be the case, it would be necessary to assess the reliability in the advanced study and adopt a more precise design in the test.

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Appendix. *Clinical screening for dysphagia*

Patient's history	
Patient's name _____ Date of birth _____ Diagnosis/impairment _____ Date of onset _____ Sex _____ Age _____	
Test items	**Observations/results**
I. Oromotor examinations	
1. Lip closure	Symmetry at rest, during retraction, protrusion and speaking Strength in closure (dropping of saliva at rest or air leakage during lips pouting) *No abnormal findings → normal* *Any abnormal findings → abnormal*
2. Tongue movement	Fasciculation Symmetry at rest, during protrusion, lateralization and elevation Strength in protrusion, lateralization and elevation *No abnormal findings → normal* *Any abnormal findings → abnormal*
3. Palatal elevation	Symmetry at rest and during elevation *No abnormal findings → normal* *Any abnormal findings → abnormal*
4. Gag reflex	*Normal/abnormal (diminished/absent)*
5. Voice quality	Estimate during volitional speaking and/a-/on one voice *Normal/abnormal (hoarseness/breathy/strained/non-specific hoarseness)*
6. Motor speech function	Estimate during volitional speaking and repetitive speaking/pa-ta-ka/ Articulatory precision, agility, fluency and resonance *Completely understandable with appropriate speaking speed → normal* *Any abnormal findings → abnormal*
II. Clinical swallowing tests	
1. Saliva swallowing test	*Normal (___times in 30 seconds)* *Abnormal (cannot swallow in 30 seconds)*
2. Water swallowing test	
(i) oral-phase	*Normal* *Abnormal (water dripping from lips/impaired oral transit)*
(ii) laryngeal elevation during swallow	*Normal* *Abnormal (cannot observe or feel laryngeal elevation during swallow)*
(iii) cough/voice change after swallow	*Normal* *Abnormal (cough/voice change after swallow)*