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A Citric-Acid-Solution Swallowing Test is Useful as a Screening Test for Aspiration at Bedside and for the Early Detection of Swallowing Dysfunction

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Abstract

We developed a citric-acid-solution swallowing test (CST) as a screening test for dysphagia with laryngopharyngeal sensory dysfunction. In this report, we evaluated the usefulness of CST in detecting aspiration and in evaluating swallowing dysfunction. The study subjects were 51 patients suspected of dysphagia. Video-endoscopy (VE), the modified water swallowing test (MWST) and the CST were performed on each patient. Swallowing dysfunction and aspiration were diagnosed by VE. On the basis of the diagnosis by VE, the sensitivity and specificity were each calculated for the MWST and CST, respectively. The sensitivity and specificity of CST for detection of aspiration was 94.4% and 69.7%. The sensitivity of MWST decreased to 57.9%, with a slight increase to 75 percent in specificity. The sensitivity and specificity of CST for evaluation of swallowing dysfunction was 96.3% and 95.8%. The sensitivity of MWST decreased to 66.7%, with no decrease in specificity. CST had a higher positive likelihood ratio and a lower negative likelihood ratio than MWST for both detection of aspiration and evaluation of swallowing dysfunction. The results suggest that the CST is more sensitive in the detection of dysphagia with laryngopharyngeal sensory dysfunction than the MWST, and that coughing could be induced by acid stimulation with citric acid. We conclude that the CST might be useful as a screening test for the detection of aspiration and swallowing dysfunction.

Introduction

Swallowing function declines due to anatomical and physiological changes that accompany aging. In addition, dysphagia can be caused by numerous disorders. In patients with acute stroke, deglutition disorders are observed at a frequency of 37-78% [1], and can be fatal if aspiration pneumonia or suffocation occurs. More than 90% of patients who die of pneumonia are elderly, aged 65 years or older, and the most common cause is aspiration pneumonia due to dysphagia.

Silent aspiration (SA), which has no signs or symptoms, such as coughing, when saliva or food enter the subglottis, oropharyngeal aspiration is an important etiologic factor leading to pneumonia in the elderly [2]. Video-fluorography (VF) or video-endoscopy (VE), which can indicate SA, are useful in diagnosing dysphagia and are performed routinely in facilities specializing in dysphagia rehabilitation. In facilities that do not have the necessary equipment for VF or VE, or under circumstances where the patients cannot be referred to a testing facility, the evaluation of dysphagia is performed using a variety of screening tests that can be performed at the bedside. These screening tests include the water swallowing test and the food test [3-7], and many of these tests assess the presence or absence of coughing to diagnose aspiration and swallowing dysfunction. Unfortunately, dysphagia with laryngopharyngeal sensory dysfunction is difficult to detect using these tests. Therefore, an accurate screening test for silent aspiration and dysphagia with laryngopharyngeal sensory dysfunction is needed.

We developed a citric-acid-solution swallowing test (CST) as a screening test for silent aspiration and dysphagia with laryngopharyngeal sensory dysfunction. In this report, we evaluated the usefulness of CST in detecting aspiration and in evaluating swallowing dysfunction.

Materials and Methods

Study subjects

Of inpatients to our hospital during the period from July 2009 to April 2010, we recruited 51 patients who were referred for swallowing evaluations. The patients presented with 1 or more of the following features suggestive of dysphagia:

- A history of aspiration pneumonia or increased sputum secretion
- Coughing during eating or drinking
- Weight loss, decreased oral intake, prolonged feeding time
- Complaint of difficulty in swallowing
- Need for a therapeutic diet for dysphagia or non-oral feeding.

The patients included 31 males and 20 females, with a mean age of 80.5 ± 11.2 years (range: 38-97 years). The patients were 37 cases of pneumonia, 8 cases of stroke, and 6 cases of other diseases in acute phase. This study was approved by the Tokyo Metropolitan Otsuka Hospital Ethics Committee (2009-10). Subjects were informed of the research procedures and privacy protection, and written consent was obtained.

Study protocol

All patients underwent VE (PENTAX, FNL-10RBS) in a 60° supine position with anterior flexion of the neck while the MWST and CST were performed. Water and the 2.0% w/v citric acid solution were colored with indigo carmine for visualization. Dysphagia was evaluated using a penetration-aspiration scale (Table 1) [8]. Each behavior

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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

Table 1: Penetration-aspiration scale [8].

Score	Description
1	No swallow
2	Swallow/dyspnea
3	Swallow/cough or wet-hoarseness
4	Swallow/no dyspnea/no cough no wet-hoarseness/no two dry swallows
5	Swallow/no dyspnea/no cough no wet-hoarseness/two dry swallows

Table 2: MWST and CST assessment criteria.

identified by scores 2 through 8 was assumed to be a sign of swallowing dysfunction. Scores of 6-8 were diagnosed as "aspiration is present".

Modified water swallowing test (MWST)

The MWST is a method for evaluating swallowing function based on swallowing reflex, choking, and changes in breathing by pouring 3 ml of cold water onto the floor of the mouth by syringe and instructing the subject to swallow[5,7]. The assessment criteria are shown in Table 2. If the subject was unable to swallow, or experienced dyspnea, coughing, or wet-hoarse dysphonia after swallowing, a score was recorded (1 for inability to swallow, 2 for dyspnea, and 3 for cough or dysphonia) and the test was terminated. Dyspnea was defined as any complaint or observation of difficulty breathing in association with the swallowing test. Otherwise, the subject was asked to perform two dry (saliva) swallows. If the subject was able to swallow the water, but was unable to perform either of the two dry swallows, a score of 4 was recorded. If the patient was able to complete the water and two dry swallows, a score of 5 was recorded. The entire procedure was performed 3 times. The final score was defined as the lowest score on any trial. Scores of 1-3 were diagnosed as "dysphagia is present" [7].

Citric-acid-solution swallowing test (CST)

The Food and Agriculture Organization (FAO) and World Health Organization (WHO) established the FAO/WHO Joint Expert Committee on Food Additives (JECFA). The JECFA evaluates the results of safety tests on additives carried out in each country, and determines the acceptable daily intake (ADI). The ADI of citric acid is evaluated as "no limit" with no definite value. This evaluation is applied for extremely low toxicity substances such as constituents existing universally in food, and those that can be regarded as food or regular metabolites of humans.

We conducted a preliminary study in which the pH of the citric acid solution was measured as an indicator of the strength of the acid stimulation, and we determined the appropriate concentration to use for the acid stimulation. When citric acid is used for acid stimulation, the pH should be greater than the pH of gastric acid (pH 1.6-2.0) in order to reduce the risk of aspiration pneumonia. Therefore, the citric acid concentration was maintained below 2.4% w/v, which corresponds to pH 2.0. We determined that 2.0% w/v was an optimum concentration of citric acid for use in the CST, since it is easy to adjust and provides strong acid stimulation.

For the CST, 3 ml of 2.0% w/v of a citric acid solution is poured onto the front floor of the mouth, and the subject is instructed to swallow, similar to the MWST. The pH of the citric acid solution changes due to the buffering capacity of bicarbonate contained in the saliva of the mouth [9]. Therefore, scores of criteria 2-5 (Table 2) were assessed in the CST only when the swallowing reflex was induced within 10 seconds of pouring the citric acid solution onto the floor of the mouth. Scores of 1-3 were diagnosed as "dysphagia is present", similar to the MWST.

Statistical analysis

Using the results of VE as reference, the sensitivity, specificity, positive likelihood ratio and negative likelihood ratio were determined for swallowing dysfunction during the MWST or CST. The chi-squared statistic method was used for data analysis. Confidence intervals for the estimated parameters were computed by a general method (based on constant χ^2 boundaries).

Results

The distribution of the results of MWST and CST for detection of aspiration is shown in Table 3. Table 4 compares the test characteristics of MWST and CST with aspiration on VE. For CST, the sensitivity was 94.4% (95% confidence interval, 78.3% to 99%) and the specificity was 69.7% (95% confidence interval, 60.9 to 72.2%), as compared with 57.9% (95% confidence interval, 40.6 to 72.6%) and 75% (95% confidence interval, 64.7 to 83.7%), respectively, for MWST. The positive and negative likelihood ratios for MWST were 2.32 and 0.56, respectively. CST had a positive likelihood ratio of 3.12 and a negative likelihood ratio of 0.08. CST was more sensitive (36.5% difference) and only 5.3% less specific than MWST.

The distribution of the results of MWST and CST for evaluation of swallowing dysfunction is shown in Table 5. Table 6 compares the test characteristics of MWST and CST with swallowing dysfunction on VE. For CST, the sensitivity was 96.3% (95% confidence interval, 87.5 to 99%) and the specificity was 95.8% (95% confidence interval,

Screening test	Aspiration on VE		Total
	Present	Absent	
MWST			
1-3	11	8	19
4,5	8	24	32
Total	19	32	51
CST			
1-3	17	10	27
4,5	1	23	24
Total	18	33	51

Table 3: MWST and CST as screening test of aspiration.

Test	Sensitivity	Specificity	+LR	-LR
	Percent (95 percent confidence interval)			
MWST	57.9 (40.6-72.6)	75 (64.7-83.7)	2.32 (1.15-4.46)	0.56 (0.33-0.92)
CST	94.4 (78.3-99)	69.7 (60.9-72.2)	3.12 (2-3.56)	0.08 (0.01-0.36)
+LR: positive likelihood ratio; -LR: negative likelihood ratio				

Table 4: Comparison of test characteristics for MWST and CST as screening test for aspiration.

Screening test	Swallowing dysfunction on VE		Total
	Present	Absent	
MWST			
1-3	18	1	19
4,5	9	23	32
Total	27	24	51
CST			
1-3	26	1	27
4,5	1	23	24
Total	27	24	51

Table 5: MWST and CST as screening test of swallowing dysfunction.

Test	Sensitivity	Specificity	+LR	-LR
	Percent (95 percent confidence interval)			
MWST	66.7 (55.9-69.7)	95.8 (83.7-99.2)	16 (3.4-92.2)	0.35 (0.31-0.53)
CST	96.3 (87.5-99)	95.8 (86-98.9)	23.1 (6.2-86.1)	0.04 (0.01-0.15)
+LR: positive likelihood ratio, -LR: negative likelihood ratio				

Table 6: Comparison of test characteristics for MWST and CST as screening test for swallowing dysfunction.

86 to 98.9%), as compared with 66.7% (95% confidence interval, 55.9 to 69.7%) and 95.8% (95% confidence interval, 83.7 to 99.2%), respectively, for MWST. The positive and negative likelihood ratios for MWST were 16 and 0.35, respectively. CST had a positive likelihood ratio of 23.1 and a negative likelihood ratio of 0.04. The difference in sensitivity between the two tests was 29.6 percentage points, and no difference in specificity.

Discussion

We designed the present study to determine whether the detection power for dysphagia with laryngopharyngeal sensory dysfunction, which is difficult in the bedside screening tests, can be increased by using a citric acid solution instead of water. CST was more sensitive (36.5% difference) and only 5.3% less specific than MWST for detection of aspiration. The difference in sensitivity between the two tests was 29.6 percentage points, and no difference in specificity for evaluation of swallowing dysfunction.

Among patients in whom aspiration was present by VE, aspiration could be detected by screening with the MWST in 11 patients, whereas it could be detected by the CST in 17 patients. These additional 6 patients were negative for the MWST and aspiration was observed by VE, indicating patients with SA, and the CST was able to detect the aspiration.

Among patients in whom aspiration was absent by VE, the MWST was positive in 8 patients, whereas the CST was positive in 10 patients. 2 of the patients with laryngeal penetration observed by VE were detected as positive by the CST. Choking is caused by the cough reflex. The primary cough reflex receptors include rapidly adapting stretch receptors (RARs) distributed in the submucosa of the airway and C-fibers distributed in alveolar walls and airway walls. When signals from these receptors are transmitted to the cough center in the dorsal medulla, a deep inhalation is induced. Then, the glottis closes and the abdominal muscle groups contract, increasing the intrathoracic pressure. When the intrathoracic pressure reaches the limit, the glottis opens, and, at the same time, an explosive exhalation occurs as a cough. Acid stimulation by citric acid causes a stronger sensory input through RARs and C-fibers than water, and induces a cough reflex. Therefore, it seems that not only aspiration with a negative MWST, but also cases with laryngeal penetration were detected by the CST.

Twenty-one patients were found to have aspiration by the MWST, whereas 20 patients with aspiration were identified by the CST. One patient showed aspiration with water, but not with the citric acid solution. A few studies have reported the relation between acid stimulation and swallowing. The swallow onset time, oral transit time, and pharyngeal transit time were shortened, and the aspiration and penetration were decreased when acid stimulation was added [10-12]. A shortened onset time of contraction, tighter approximation of onsets and increased amplitudes of suprahyoid muscles were observed during swallowing of acidic water [13,14]. So, stronger and faster swallowing is elicited in healthy volunteers and dysphagia patients when sensory input is enhanced by acid stimulation. When sensory input is enhanced by acid stimulation, the excitability of sensory fibers in the nucleus tractus solitarius in the medulla, which form a central pattern generator of swallowing, increase resulting in activation of the nucleus ambiguous and stronger and more rapid swallowing is induced. Therefore, aspiration did not occur with the citric acid solution even if it occurred with water.

The CST successfully validated the accuracy for detecting aspiration, revealing a sensitivity of 0.96, which exceeded a sensitivity of 0.58 in the MWST. By contrast, the specificity of 0.67 in the CST was slightly lower than the specificity of 0.75 in the MWST. The screening test with a high sensitivity and a high specificity is the most useful and ideal. CST had a higher positive likelihood ratio and a lower negative likelihood ratio than MWST. Comprehensively, CST is more useful as a screening test for aspiration than MWST.

Another feature of this study was to determine the role of the CST in evaluating swallowing dysfunction. The diagnosis of swallowing dysfunction by the MWST with respect to VE showed a sensitivity of 0.67 and a specificity of 0.96. On the other hand, the diagnosis of aspiration and penetration by the CST with respect to VE showed a sensitivity of 0.96 and a specificity of 0.96. Based on its high sensitivity and specificity, the CST is a useful screening test for the early detection of swallowing dysfunction.

There have been several reports about cough test that focused on cough reflex after aspiration [15-17]. Sato et al. compared the simplified cough test with the results of the fiberoptic endoscopic evaluation of swallowing, which used any amount of liquid or food [17]. We compared MWST and CST with the results of VE, which used only liquid and the bolus size, was 3 ml. It is difference that CST defines the bolus and size in comparison with SCT.

Conclusion

In this study, we developed the CST and compared it with the MWST for diagnosing aspiration with respect to VE. The results suggest that the CST is more sensitive in the detection of dysphagia with laryngopharyngeal sensory dysfunction than the MWST, and that coughing could be induced by acid stimulation with citric acid. We conclude that the CST might be useful as a screening test for the detection of aspiration and swallowing dysfunction.

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