Simplified Cough Test for Screening Silent Aspiration

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Objective: To simplify the cough test to screen silent aspiration without sacrificing accuracy.

Design: Criteria standard.

Setting: University dental hospital.

Participants: Consecutive patients (N=141; 92 men, 49 women; mean age 71±14y, range 23–94y) who had complained of some dysphagic symptoms between June 2008 and February 2010.

Interventions: All patients were administrated a simplified cough test and underwent the fiberoptic endoscopic evaluation of swallowing. Citric acid inhalation was terminated when the first cough occurred, and the time between the start of inhalation and the first cough was measured.

Main Outcome Measures: The time when the first cough was observed by the simplified cough test was compared with the results of the fiberoptic endoscopic evaluation of swallowing, which was used as a criterion standard.

Results: Receiver operating characteristic curve analysis was performed for 53 patients evaluated as having aspiration by fiberoptic endoscopic evaluation of swallowing. We found that 30 seconds or less was an appropriate cutoff value for detecting patients without silent aspiration, where the sensitivity was .92 and the specificity was .94. From the receiver operating characteristic curve analyses for all patients, 60 seconds or less was determined to be an appropriate cutoff, and the sensitivity and specificity were .81 and .65, respectively.

Conclusion: The simplified cough test is a useful screening tool for silent aspiration in patients with aspiration.

Key Words: Cough; Deglutition disorders; Diagnosis; Rehabilitation; Respiratory aspiration.

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The videofluoroscopic swallowing study and the fiberoptic endoscopic evaluation of swallowing (FEES) are considered ideal methods to assess dysphagia. However, given that many facilities lack the equipment required for these tests, numerous alternative screening tests that can be readily performed at the patient’s bedside have been developed. These tests use coughing as an indicator to determine the presence of aspiration. For this reason, silent aspiration may be overlooked during screening. Consistent with this, there are reports that almost 40% of the silent aspiration cases are overlooked in bedside evaluations of dysphagia.

We previously reported the usefulness of a cough test for screening silent aspiration. Among 204 patients with dysphagia who were administered the cough test, the sensitivity and specificity for the detection of silent aspiration were .87 and .89, respectively. In a different study in which patients were examined by condition, silent aspiration could be satisfactorily screened not only for patients with cerebrovascular disorders, which are the most frequent primary diseases underlying eating disorders and dysphagia, but also for patients with various other underlying etiologies. These included neuromuscular disorders, respiratory disorders, and those following head and neck tumor surgery. These studies indicate that cough tests can be useful for screening silent aspiration. However, given that these methods assessed 5 coughs within a minute as negative, the strain on patients was high. That is, even if 1 cough occurred immediately after inhalation, it was necessary for patients in which the cough reflex did not subsequently occur to continue inhaling the irritant. Furthermore, because these studies used a nonportable nebulizer, it was difficult to use the cough test in home visits. Given the above, we sought to reduce the physical stress on patients and simplify the cough test without reducing accuracy while also using more portable equipment.

METHODS

Subjects
Subjects were 141 consecutive patients (92 men, 49 women; mean age 71±14y, range 23–94y) who had complained of some dysphagic symptoms between June 2008 and February 2010 and were evaluated by FEES. The underlying disorders were cerebrovascular for 89 patients, disuse syndrome for 22 patients, neuromuscular for 8 patients, respiratory for 14 patients, cancer for 3 patients, cervical spine injury for 2 patients, and miscellaneous for 3 patients. Neuromuscular disorders included the following: Parkinson’s disease (n=5), corticobasal degeneration (n=1), multiple system atrophy (n=1), and spinocerebellar degeneration (n=1).

Inclusion and Exclusion Criteria
This study compared the results of the simplified cough test (SCT) with those of FEES. All consenting subjects were able to

List of Abbreviations

| AUC | area under the receiver operating characteristic curve |
| FEES | fiberoptic endoscopic evaluation of swallowing |
| NPV | negative predictive value |
| RAR | rapidly adapting receptor |
| ROC | receiver operating characteristic |
| SCT | simplified cough test |
was blinded to the SCT results. A small amount of nasal inhalation, the result was considered “no coughing.”

Data Analysis

FEES was conducted as a criterion standard either on the same day or within 2 days after the SCT. A FEES evaluator was blinded to the SCT results. A small amount of nasal anesthesia jelly was used during FEES, but the SCT was always conducted before the FEES to avoid confounding effects of the nasal anesthesia. Test foods with different consistencies, such as thin liquid, thick liquid, semisolid material, and solid material, were used, and the bolus size was 3 to 5mL. The number of presented foods was modified depending on the patient’s severity of dysphagia. For example, if a patient had aspirated thick liquid, then thin liquid was not presented. In the absence of coughing, if the patient aspirated any amount of liquid or food, the patient was considered to have silent aspiration. Patients with laryngeal penetration were judged to have no aspiration. From the results of the SCT and the diagnoses of silent aspiration on the basis of FEES, we constructed a 2-by-2 contingency table for each 5-second interval cutoff point. If there was no cough within a given interval, the result was recorded as “negative.” The occurrence of the first cough within each interval was recorded as “positive.” We then calculated the sensitivity, specificity, positive predictive value, negative predictive value (NPV), and efficiency from each table. In addition, a receiver operating characteristic (ROC) curve analysis was used to determine the desirable cutoff value. The study was carried out with approval of the ethics committee of Nihon University School of Dentistry. Statistical analyses were performed using SPSS Statistics 17.0 (SPSS Inc).

RESULTS

Table 1 outlines patient characteristics for the 141 subjects suspected to have dysphagia and recruited for the present study.

Based on FEES, aspiration was confirmed in 53 patients (46 men, 7 women; mean age 72±16y, range 24–93y). The underlying disorders were cerebrovascular for 35 patients, neuromuscular for 3 patients, respiratory for 5 patients, and miscellaneous for 10 patients. Thirty-seven patients (35 men, 2 women; mean age 68±17y; range 24–87y) had silent aspiration. Underlying disorders were cerebrovascular (n=23), neuromuscular (n=3), respiratory (n=4), and miscellaneous (n=7).

Given that the SCT evaluates a cough reflex related to aspiration, we first obtained a desirable cutoff value on the basis of the ROC curve of subjects evaluated to have aspiration by FEES. Area under the ROC curve (AUC) was .94, indicative of excellent diagnostic efficiency for silent aspiration. The desirable cutoff was the closest point to the upper-left corner of the graph, which was when the first cough occurred within 30 seconds after citric acid inhalation (fig 2). Using this cutoff, the sensitivity, specificity, efficiency, positive predictive value, and NPV were .92, .94, .92, .97, and .83, respectively (table 2).

The ROC curve graphed for all patients revealed an AUC value of .77. The desirable cutoff was when the first cough occurred within 60 seconds after citric acid inhalation (fig 3). At this established cutoff point, the sensitivity, specificity, efficiency, positive predictive value, and NPV were .81, .65, .70, .45, and .91, respectively (table 3).

Table 1: Characteristics of All Patients With and Without Aspiration

<table>
<thead>
<tr>
<th>Feature</th>
<th>All Patients</th>
<th>Patients Without Aspiration</th>
<th>Patients With Aspiration</th>
<th>Patients With Silent Aspiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>141</td>
<td>88</td>
<td>53</td>
<td>37</td>
</tr>
<tr>
<td>Age (y), mean ± SD</td>
<td>71±14</td>
<td>71±14</td>
<td>72±16</td>
<td>68±17</td>
</tr>
<tr>
<td>Men</td>
<td>92</td>
<td>46</td>
<td>46</td>
<td>35</td>
</tr>
<tr>
<td>Women</td>
<td>49</td>
<td>42</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Penetration Aspiration Scale</td>
<td>3.4±2.7</td>
<td>1.7±1.0</td>
<td>7.0±1.0</td>
<td>7.5±0.6</td>
</tr>
</tbody>
</table>

NOTE: Values are mean ± SD or n.
The water swallowing test, which is widely used in clinical practice for screening aspirators, has several variations. The subject is typically asked to drink water in the volume range of 0.4 to 100mL, and the response is observed.2,5,11-13 The simple subject is typically asked to drink water in the volume range of practice for screening aspirators, has several variations. The

Screening Tests for Dysphagia

The water swallowing test, which is widely used in clinical practice for screening aspirators, has several variations. The subject is typically asked to drink water in the volume range of 0.4 to 100mL, and the response is observed.2,5,11-13 The simple swallowing provocation test evaluates latent time for swallowing after a bolus injection of distilled water at the suprapharynx from the nostril via a narrow tube, using 0.4mL of water for the first step and 2mL for the second step.11 If it takes 3 or more seconds to swallow after the bolus injection, the test result is to be judged abnormal. Excellent results have been shown, with the sensitivity and specificity of 1.0 and .84 for the first step and .76 and 1.0 for the second step, respectively. However, because the test requires the patient to be in the supine position, it is not suitable for the evaluation of eating.

Modified water swallowing test uses 3mL of water to swallow and evaluates whether the subject is unable to swallow, or experiences dyspnea, coughing, or wet-hoarse dysphonia after swallowing in the normal sitting position.3 The results are passable, with the sensitivity and specificity of .70 and .88, respectively. The 85mL of water test and 100mL of water test have been used to evaluate cough and wet hoarseness after swallowing.2,12 The results were unsatisfactory, with the sensitivity and specificity of .76 and .59 for the former and .36 and .21 for the latter, respectively.

To summarize, although water swallowing tests are easy to perform clinically and some even show statistical usefulness, silent aspiration may be overlooked during screening because these tests take coughing as an indicator to determine the presence of aspiration.

Pulse oximetry is a noninvasive bedside swallowing test13-15; however, several studies have shown that there is no relation between aspiration and desaturation,16,17 which occurs easily during a postural change, cough, or swallow, as well as aspiration.18 Thus, the usefulness of pulse oximeter oxygen saturation for diagnosing aspiration is now deemed controversial.

Cervical auscultation is a noninvasive test in which an examiner listens to the sounds of swallowing by applying a stethoscope to the lateral aspect of the neck.19 The sensitivity and specificity for detecting aspiration were reported to be .84 and .71, respectively, but the test requires a highly trained examiner.19 Bronchial auscultation for screening aspiration has also been reported, but with low sensitivity and specificity of .45 and .88, respectively.20

A number of studies have reported screening tests for dysphagia with various advantages and disadvantages. Generally, most of these tests are for aspiration, rather than for silent aspiration. Therefore, a screening test aimed specifically at detecting silent aspiration is indispensable.

Table 2: Results of the SCT for Patients With Aspiration Using the Occurrence of the First Cough Within 30 Seconds as the Cutoff

<table>
<thead>
<tr>
<th>VFSS/FEES</th>
<th>SCT</th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silent aspiration (+)</td>
<td>34</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Silent aspiration (−)</td>
<td>1</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

NOTE. Sensitivity=.92, specificity=.94, efficiency=.92, PPV=.97, NPV=.83; n=53.

Abbreviations: PPV, positive predictive value; VFSS, videofluoroscopic swallowing study.

Table 3: Results of the SCT for All Patients Using the Occurrence of the First Cough Within 60 Seconds as the Cutoff

<table>
<thead>
<tr>
<th>VFSS/FEES</th>
<th>SCT</th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silent aspiration (+)</td>
<td>30</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Silent aspiration (−)</td>
<td>36</td>
<td>68</td>
<td></td>
</tr>
</tbody>
</table>

NOTE. Sensitivity=.81, specificity=.65, efficiency=.70, PPV=.45, NPV=.91; n=141.

Abbreviations: PPV, positive predictive value; VFSS, videofluoroscopic swallowing study.
Utility of SCT as a Tool to Detect Silent Aspiration

As requirements, Logemann suggested that a screening test should be of short duration, minimally invasive, inexpensive, and simple to perform. Using the approach described here, we shortened the inhalation time from 1 minute to 30 seconds. In addition, because the SCT was terminated on confirmation of the first cough, we could also reduce invasiveness.

In our previous studies, many patients complained of discomfort after the first cough occurred and stopped inhaling citric acid. As such, continued inhalation of citric acid until the 5 coughs had occurred was difficult. However, the present study noted that all patients were able to continue inhalation of citric acid until the SCT concluded. We would therefore surmise that patient’s physical stress during the cough test was reduced and that the SCT can detect silent aspiration in a more suitable manner.

The nebulizer we used in previous reports was an ultrasonic model (NE-U17, Omron) that weighed approximately 4kg and cost about 80,000 yen (approximately $970 US).

In contrast, the model used here weighed about 100g and cost about 30,000 yen (approximately $360 US), thus being considerably smaller and less expensive. Hence, the method presented here may be superior for the conditions mentioned above.

Regarding the ability to detect silent aspiration, favorable results of the SCT were obtained for sensitivity (.92) and specificity (.94) in patients with aspiration. In addition, the efficiency (overall accuracy) and AUC (measure of concordance between the result of a screening test and the disease status indicator) were .92 and .94, respectively. In our previous studies of patients with aspiration, the ability to detect silent aspiration was .87 in terms of sensitivity and .95 in terms of specificity. The present method did not decrease our ability to detect silent aspiration in patients with aspiration. Thus, the SCT can effectively detect silent aspiration at a high rate in patients with aspiration.

Regardless of the presence or absence of aspiration, the ability to detect silent aspiration in patients with dysphagia was .81 in terms of sensitivity and .65 in terms of specificity, thus showing a high rate of false positives. The ROC curve for all patients revealed a low efficiency (.70) and an AUC value of .77. Perhaps the reason for the high number of false positives was that patients without aspiration included those with abnormal cough responses (weak or absent). From another point of view, the NPV was very high at .91, and the false-negative error rate was low at .19. Therefore, performing SCT with all patients would help to exclude patients with nonsilent aspiration.

The present study demonstrated the utility of SCT to detect silent aspiration, but this does not reveal the depth or amount of aspiration, the mechanism of aspiration, pharyngeal or laryngeal movement, or the way to prevent aspiration. Therefore, videofluoroscopic swallowing study or FEES is still required to evaluate the nature of swallowing disorders and help determine adequate dysphagia rehabilitation.

About the SCT Method

Particles most frequently deposited on the peripheral bronchi up to the bronchial tubes are believed to be 1 to 5 μm in diameter, whereas those on the larynx are 10 to 20 μm in diameter. The size of the particles sprayed by an ultrasonic nebulizer is uniform and stable, being 0.5 to 5μm in diameter. In contrast, particle sizes from jet nebulizers are more variable than those from ultrasonic nebulizers with fewer microparticles being formed. In addition, although many of the particles from jet nebulizers are deposited in the nasal and oral cavities, those from ultrasonic nebulizers are deposited in the nasopharynx, oropharynx, and hypopharynx and reach deeper areas when inhaled orally rather than nasally. This, together with the fact that the particle sizes of the mesh nebulizer used here were approximately 5μm and thus similar in size to those of ultrasonic nebulizers, suggests that the method used here was appropriate for efficiently stimulating the airway.

Of the various concentrations (1%–9%) of inhaled citric acid-physiological saline previously used, the 1% w/v used here was based on a report that this concentration of irritant is appropriate. In our previous reports, we have also used solutions of the same 1% w/v concentration, and in both cases we obtained favorable results. This suggests that both the equipment and the concentration of citric acid-physiological saline used in this study were appropriate.

Difference Between Stimulation of Airway by Food Aspiration and by Citric Acid Particles

Both the bronchial tubes and peripheral bronchi are controlled by the vagus nerve. In addition, the airway contains rapidly adapting receptors (RARs) (Aδ fibers), which are myelinated nerves, and C-fiber receptors, which are unmyelinated nerves. It is believed that the former are stimulated by mechanical and chemical stimuli, whereas the latter are stimulated by chemical stimuli. RARs and C-fiber receptors show different responses depending on region. In the nasolarynx, they are sensitive to mechanical stimulation but respond little to chemical stimulation. In contrast, RARs in the larynx are sensitive to mechanical and chemical stimulation, and RARs in the bronchial tubes are sensitive to nonisotonic solutions. For RARs and C-fiber receptors, the chemical substances to which they can respond differ because the receptors on their membrane surfaces vary. Moreover, it is believed that the cough control system differs between the lower airway and the larynx. The SCT causes a single chemical stimulation due to citric acid as well as a light mechanical stimulation due to the deposition of microparticles in the lower airway and/or the larynx. Therefore, the present results do not permit definitive discussions on the degree to which this reflects the coughing during food aspiration evoked by various chemical and mechanical stimuli.

Study Limitations

Our results indicate that the SCT can be used independently to screen for silent aspiration. However, it is important to note that the SCT was designed to screen for silent aspiration, not aspiration in a clinical setting. Therefore, an evaluation of patient condition by combining SCT with other screening tests for aspiration (not videofluoroscopic swallowing study or FEES), as reported previously, would be optimal.

Strictly speaking, airway stimulation by food aspiration and that by citric acid are different. The cough control system differs between the lower airway and the larynx. Therefore, the next step of this study should examine differences in the type and location of stimulation required to elicit cough (ie, mechanical vs. chemical stimulation and supraglottic vs. infraglottic stimulation).

CONCLUSIONS

By spraying citric acid using a nebulizer and designating a first cough reflex within 30 seconds as an indicator, we were
able to evaluate silent aspiration especially in patients with aspiration. Hence, we have successfully simplified the preexisting cough test. However, as the SCT yields a high rate of false positives when patients, with or without aspiration, are included in the statistical analysis, it is desirable to use the SCT in combination with a screening test for aspiration.

References

Suppliers
b. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.