Decreased Diaphragm Excursion in Stroke Patients With Dysphagia as Assessed by M-Mode Sonography

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Abstract

Objective: To record diaphragm excursion via M-mode ultrasonography in stroke patients with dysphagia and determine whether they present reduced diaphragm excursion during voluntary cough compared with stroke patients without dysphagia and healthy subjects.

Design: Prospective cross-sectional study.

Setting: University rehabilitation hospital.

Participants: Acute stroke patients with dysphagia (n=23), acute stroke patients without dysphagia (n=24), and healthy control participants (n=27) (N=74).

Interventions: Not applicable.

Main Outcome Measures: Diaphragm motions during quiet breathing, deep breathing, and voluntary coughing were recorded via ultrasonography using M-mode tracing (mm). Maximum inspiratory and expiratory pressures (cmH2O) and peak cough flow (L/min) during voluntary coughing were measured.

Results: The mean diaphragm movement (mm) of the hemiplegic side for all groups during quiet breathing, deep breathing, and voluntary coughing was 14.8±4.3, 17.6±4.8, and 20.9±3.7 (P<.001); 23.8±7.1, 32.7±10.6, and 44.7±10.3 (P<.001); and 16.8±4.8, 28.5±4.9, and 36.0±8.2 (P<.001), respectively. The differences were statistically significant. Differences were observed in the maximum inspiratory (P<.001) and expiratory (P<.001) pressures and peak cough flow (P=.027) among the 3 groups. Forward selection stepwise regression analysis, which was performed to determine variables that help predict diaphragm excursion during voluntary coughing, showed that the presence of dysphagia explained up to 60% (P<.001) of the hemiplegic diaphragm movement during voluntary coughing in patients with stroke.

Conclusions: M-mode ultrasonography showed that stroke patients with dysphagia have decreased diaphragm excursion and compromised respiratory function during voluntary coughing.

Archives of Physical Medicine and Rehabilitation 2015;96:114-21
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The diaphragm is the primary respiratory muscle and accounts for approximately 75% of the airflow into the lungs. It ensures sufficient precough insufflation, enabling the expiratory muscles to generate large positive intrathoracic pressures during cough. Patients with stroke present with reduced diaphragm excursion, which can result in restrictive lung dysfunction. Previous studies have shown that patients with stroke exhibit asymmetric ventilation, with highly reduced diaphragm excursion and respiratory movement in the affected hemithorax. M-mode sonography is often used for evaluating diaphragm motion and has been shown to be a reproducible method to assess hemidiaphragm movement.

Ineffective diaphragm motion could limit the production of a sufficient cough and increase the risk of aspiration. Compromised cough production can result in grave consequences for stroke patients with dysphagia, who are known to be at increased risk of...
aspiration pneumonia. However, there are no studies to our knowledge that have assessed diaphragm function and its relation to cough in stroke patients with dysphagia with confirmed aspiration. Precise knowledge on the role of respiratory muscles, including the diaphragm, and their relation to dysphagia would help implement therapies that facilitate recovery and potentially prevent the development of aspiration pneumonia during the rehabilitation period.

The objective of this study was to record diaphragm excursion movement via M-mode sonography during quiet breathing (QB), deep breathing (DB), and voluntary cough (VC) in stroke patients with dysphagia and confirmed aspiration and to compare these results with those of stroke patients without dysphagia and a control group of healthy individuals. This study also sought to determine whether the presence of dysphagia with aspiration can affect diaphragm excursion in patients with stroke during VC. We hypothesized that stroke patients with dysphagia would present with severe impairment of diaphragm excursion during various respiratory maneuvers, including during VC.

Methods

Participants

This was a prospective cross-sectional study that assessed patients with stroke who were admitted to a rehabilitation unit of a university-affiliated hospital. The healthy controls were recruited via poster advertisements on local notice boards. The protocols of this study were approved by the Institutional Review Board of Bucheon St. Mary’s Hospital (no. IRB HC 12OISE0045), and formal written consent was obtained from all participants.

Subject recruitment

The healthy participants were selected based on the following criteria: no history of chronic respiratory (ie, asthma, chronic obstructive pulmonary disorder), endocrine, kidney, or rheumatologic disorder, and no history of any orthopedic or spinal lesions that could adversely affect the respiratory system and require admission or medical treatment. Additionally, individuals with past episodes of diaphragm weakness caused by unilateral phrenic nerve injury, past episodes of abdominal or thoracic surgery or rib fractures within 1 year of enrollment, or other neurologic conditions that may affect respiratory muscles were excluded.

In addition to the inclusion criteria, patients with stroke were eligible for enrollment if they showed unilateral hemiplegia caused by cerebrovascular disease with involvement of a single brain lesion confirmed by brain computed tomography or magnetic resonance imaging. For stroke patients with dysphagia (group A), subjects with evidence of aspiration that would require nasogastric tube feeding as confirmed by fiberoptic endoscopic evaluation of swallowing or video fluoroscopic swallowing findings were recruited. For stroke patients without dysphagia (group B), subjects who were on an oral diet without any clinical signs of dysphagia were recruited. To confirm the absence of dysphagia or aspiration, the participants in group B underwent formal instrumental evaluation (eg, video fluoroscopy) at the time of enrollment.

Individuals with multiple brain lesions, episodes of pulmonary embolism, or episodes of acute dyspnea and hypoxemia that would interfere with their physical therapy and require continuous oxygen supplementation were excluded. Also, those with congestive heart failure or cardiovascular disorders and individuals with a loss of consciousness or impaired cognitive function that could limit full participation were excluded. Only those with sufficient cognitive and language function (as determined by the admitting physiatrist) that would allow them to consent to this study were recruited.

Diaphragm measurements using ultrasonography

Diaphragm excursion was assessed using ultrasound in M-mode using a convex transducer (5–2MHz) with variable frequency depending on the depth. The images were obtained according to previous methods. To obtain the images, the transducer was positioned on the abdominal wall just below the ribs between the midaxillary line and the mammillary line, forming a 45° angle between the transducer and the surface of the abdominal wall in the cephalic direction. A single experienced physiatrist performed the sonography evaluations.

Both hemidiaphragms were examined in the supine position in the longitudinal semicoronal plane through a subcostal or intercostal approach. The movement of each side was measured (cm) in the craniocaudal axis. Ultrasonicographic measurements of the hemiplegic and nonaffected diaphragms were obtained during QB, DB, and VC. All images were recorded in the same position by M-mode ultrasonography during a few respiratory cycles (fig 1). As described by previous studies, the amplitudes were measured using one caliper placed at the baseline of the diaphragm echoic line and a second caliper placed at the apex or the maximum height of the line. At least 3 attempts were recorded, and the average value was used for statistical analysis. For the control group (group C), the left side was compared with the hemiplegic sides of groups A and B. The ratio of the nonaffected diaphragm to the hemiplegic side (right vs left in healthy controls) was obtained. In a healthy population, this ratio is known to be 1.1±0.2. The clinician performing the sonography was blinded to the other spirometric and clinical variables of each participant.

Spirometric findings

Spirometry (VmaxTM Autobox V62J) was performed in compliance with American Thoracic Society/European Respiratory Society standard guidelines. For the spirometry test, the subjects assumed a seated position and were instructed to breathe into a mouthpiece connected to a spirometer. The following parameters were assessed: predicted forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), and FEV1/FVC ratio.

Respiratory muscle strength evaluation

Static maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) were measured using a respiratory pressure meter (Micro-Plus Spirometer) with a standard flange
mouthpiece. The MIP indicates the inspiratory muscle strength, whereas the MEP indicates the expiratory muscle power. The assessments were compliant with the American Thoracic Society/European Respiratory Society standards. The highest recorded values were analyzed. The spirometric and respiratory pressure measurements were performed on the same day as the diaphragm excursion measurement.

Peak cough flow and MIP and MEP measurements

Peak cough flow (PCF) was used to measure VC (L/min). All subjects were assessed in a sitting posture with no arm rest and were asked to perform a quick, short, and explosive cough on the peak flow meter (Micropeak), in compliance with the American Thoracic Society/European Respiratory Society standard guidelines. The findings were assessed using SAS software for Windows (version 9.2); <.05 was considered to be significantly different.

Clinical variables

Stroke onset duration was calculated from the day the sonography and spirometric measurements were obtained. Stroke severity and functional status were assessed using the Modified Barthe Index (MBI), Trunk Control Test, Motricity Index, Mini-Mental State Examination, and National Institutes of Health Stroke Scale (NIHSS). The initial NIHSS score at the onset of stroke was used; the other parameters were assessed within 2 days after diaphragm assessment. Dysphagia severity was assessed using the Functional Oral Intake Scale. In individuals with dysphagia, aspiration severity was assessed using the Penetration Aspiration Scale. Incidence of aspiration pneumonia prior to admission to our department was also recorded.

Statistical analysis

A power analysis based on previous studies showed that a study with a minimum of 21 participants in each group could detect a mean difference of 1.28±1.45cm between groups, with a 5% significance level and a power of 80%.

The findings were assessed using SAS software for Windows (version 9.2); <.05 was considered to be significantly different. The spirometric findings and diaphragm excursion movement among the 3 groups were compared using an analysis of variance, and Duncan post hoc test was used to determine significance. Differences in clinical variables between groups A and B were analyzed using an independent samples t test for parametric variables and a chi-square test for nonparametric values. Correlation coefficients were calculated to determine factors correlated with the hemiplegic diaphragm excursion during VC and DB in groups A and B. Variables with significant positive correlations were included in the stepwise method of the variable selection in a multiple regression analyses at P=.005. In the second set of regression models (model 2), an extra variable, the presence of dysphagia with aspiration, was included.

Results

Participants

Participants were recruited from February to July in 2013. Of the 219 patients with stroke admitted to the department of rehabilitation medicine, 48 patients fulfilled the inclusion criteria and agreed to participate. All participants in groups A and B had a unilateral brain lesion with clinical contralateral hemiplegia. No statistically significant difference was observed between the 2 stroke groups in mean stroke onset days (group A, 34.5±36.9; group B, 38.9±53.3) and side of brain lesion. Although most participants underwent the procedure with no complications, 1 participant from group B showed cough apraxia and was therefore excluded from the final analysis. In total, data from 74 participants (group A: n = 23; group B: n = 24; group C: n = 27) who were able to complete the procedures were used for analysis. Between the 2 stroke groups, group A showed significantly higher functional impairment and neurologic deficit as assessed using the initial NIHSS, MBI, Mini-Mental State Examination, Motricity Index, and Trunk Control Test scores (table 1). Additionally, group A showed significantly higher Functional Oral Intake Scale and Penetration Aspiration Scale scores, indicating more severe dysphagia and aspiration. Also, group A included a significantly larger number of patients with aspiration pneumonia after their brain insult during their admission at the acute stroke department prior to their admission to the rehabilitation department than group B (see table 1). All these patients had undergone proper medical therapy, including antibiotics, at their stroke units, and none showed any clinical or radiologic evidence of acute aspiration pneumonia or signs of active infection at enrollment.

Diaphragm measurements using ultrasonography

Ultrasonography images for all 3 maneuvers were obtained from all subjects. The diaphragm movement of the hemiplegic side (left side for group C) was significantly different among the 3 groups as assessed by analysis of variance and post hoc analysis (P<.0001). Among these 3 groups, group A showed significantly lower movement of the hemiplegic diaphragm than the other 3 groups (fig 2). In addition to the weakness observed on the hemiplegic side, group A showed significantly reduced diaphragm excursion.
on the nonaffected side during DB (fig 3). Although both groups A and B showed significantly reduced diaphragm excursion during VC on the nonaffected side, the ratio of the nonaffected diaphragm to the hemiplegic side in group A was significantly increased compared with the other 2 groups during VC (fig 4).

**Spirometric findings, PCF, MIP, and MEP**

Group C showed a normative range of FVC and FEV₁ values with no evidence of either an obstructive or a restrictive type of lung dysfunction. Significant differences in the FVC were observed among the 3 groups, with group A showing a significant drop in FVC (percentage predicted) and FEV₁ (percentage predicted) relative to the other 2 groups. The MIP and PCF values were significantly different among the 3 groups, with group A showing the lowest values. However, both groups A and B showed reduced MEP values compared with the control group, but no significant differences were observed between these 2 groups (table 2).

**Multiple regression analysis**

For groups A and B, the variables that showed a positive correlation to the hemidiaphragm movement of the hemiplegic side during VC were analyzed using a stepwise method of variable selection in a multiple regression analysis. In model 1, initial NIHSS scores on admission explained up to 25% of the variance \( (P < .001) \) in the diaphragm excursion of the hemiplegic side during VC. However, when dysphagia with aspiration was taken into account in model 2, dysphagia became the single significant predictor that explained up to 60% of the variance \( (P < .001) \) (table 3). Similarly, the presence of dysphagia with aspiration became the single predictor that explained up to 20% of the variance for DB \( (P = .002) \) (table 4).

**Discussion**

The aim of this study was to determine whether stroke patients with dysphagia and confirmed aspiration present a significantly greater impairment of diaphragm function as assessed by M-mode sonography compared with patients without dysphagia or aspiration and patients without stroke. Group A showed significantly lower diaphragm excursion during QB, DB, and VC; greater impairment of cough flow force; and significantly weaker respiratory muscles than the other 2 groups. In this study, stroke patients with dysphagia and aspiration presented reduced diaphragm movement, especially during coughing with a restrictive type of

![Fig 2](image-url)  
Mean ± SD (mm) values of the hemiplegic diaphragm (left side in group C), during QB, DB, and VC as assessed by M-mode sonography. Significant differences were observed among the 3 groups.  

\*P < .0001.
respiratory dysfunction. Interestingly, our results showed that the nonaffected side may also manifest decreased diaphragm excursion to some extent.

Similar to the current results, reduced bilateral excursion of the diaphragm in patients with stroke has been reported in previous sonography studies. Reduced bilateral excursion has been observed within the first days after acute stroke, and decreased movement on the nonaffected sides has also been observed in patients with hemiplegia, which suggests that the diaphragm is both contralaterally and ipsilaterally innervated. The extent to which the bilateral uncrossed corticospinal connections contribute to diaphragm excursion needs to be studied further.

Some variability in movement between the right and left diaphragms has been reported in healthy subjects, and the normative range of the ratio between the 2 sides is known to be 1.1±0.2 with any ratio outside the range of 0.5 to 1.6 indicating unilateral diaphragm weakness. In group A, the ratios between the nonaffected and hemiplegic sides were all increased and outside the normative range during both DB and VC. The increase in the ratio was highest during VC, indicating pronounced asymmetry of diaphragm excursion during coughing. The weakness of the cough force in group A manifested as low PCF force. Based on these findings, it can be postulated that in addition to the bilateral involvement of the diaphragm, stroke patients with dysphagia present drastically reduced diaphragm excursion on the hemiplegic side, especially during VC.

In agreement with previous reports that hemiplegic stroke patients show decreased vital capacity and disturbances in respiratory function, the spirometric findings in this study showed restrictive lung dysfunction in the 2 stroke groups. However, group A showed greater lung dysfunction and weakness in other respiratory muscles and cough forces than group B. Patients with severe aspiration usually show more impairment of their VC compared with healthy participants and nonaspirating patients with stroke. This study is clinically significant in that it shows that diaphragm excursion is more impaired in stroke patients with dysphagia and aspiration than in healthy participants and nondysphagic, nonaspirating stroke patients during VC. Although group A had more severe stroke with more functional deficits, as shown in the multiple regression analysis, presence of dysphagia with aspiration was the single factor that explained the decreased diaphragm motion during both DB and VC, even when various
Clonal factors, including NIHSS scores, were taken into consideration.

Cough is an important protective mechanism, and its impairment can result in increased risk of aspiration. VC is defined as a cough that is produced voluntarily by command. Reflexive cough is involuntary and protects against aspiration. Reflexive cough may be tested by using tussigenic agents (eg, inhaled citric acid), and the test is known to be associated with aspiration as measured by instrumental assessments, such as videofluoroscopic swallowing study. Both coughs are important in protecting the airway, and both require adequate inspiration along with coordination of the expiratory muscles. This study shows that diaphragm excursion is markedly impaired during VC in stroke patients with dysphagia and aspiration. The role of the diaphragm during reflexive cough still needs to be determined.

Weakness of the diaphragm may limit the effectiveness of a cough and can contribute to the increased incidence of pneumonia observed on the hemiplegic side in patients with stroke. In accordance, group A showed a higher trend of aspiration pneumonia episodes after stroke prior to admission to our department. Reduced strength of VC may exacerbate pulmonary consequences resulting from aspiration by inadequately clearing aspirated material from the airway. It is possible that the increased incidence of aspiration pneumonia in group A during their admission at the acute stroke period may be related to the weak VC and weakened respiratory muscle dysfunction. Whether diaphragm dysfunction in the acute stages of stroke could help predict the development of aspiration pneumonia is a topic that warrants further future prospective studies, but considering that aspiration pneumonia is a common poststroke medical complication, stroke patients with aspiration could benefit from respiratory therapies that aid diaphragm excursion in the acute stages of stroke.

The role of respiratory muscle training, especially for the expiratory muscles, and their close relation to swallowing mechanisms has been well reported. For example, expiratory muscle training is reported to improve supramental muscle activation and improve hyolaryngeal excursion. Breathing and swallowing are known to be closely intertwined, and the diaphragm has been shown to be active during swallowing. Therefore, further studies are required to elucidate the mechanism by which the decreased diaphragm excursion during respiration contributes to swallowing dysfunction in stroke patients with dysphagia. As shown in previous studies with the expiratory muscles, the relation between the hyolaryngeal excursion and diaphragm excursion is a topic that warrants future studies. Although the presence of an adequate strong cough is important in stroke patients with dysphagia, there are no standardized protocols on how to approach these problems in

### Table 2 Pulmonary and respiratory pressure measurements

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory function *</td>
<td>26.6±15.3 z</td>
<td>40.5±19.3 z</td>
<td>62.0±23.7 z</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>MEP (cmH2O)</td>
<td>31.5±20.0 z</td>
<td>42.0±19.8 z</td>
<td>68.0±22.7 z</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>PCF (L/min)</td>
<td>127.6±83.8 z</td>
<td>195.3±67.1 z</td>
<td>256.2±90.8 z</td>
<td>.001</td>
</tr>
<tr>
<td>FVC (% predicted)</td>
<td>55.7±19.5 z</td>
<td>74.9±18.9 z</td>
<td>91.4±11.3 z</td>
<td>.0005</td>
</tr>
<tr>
<td>FEV1 (% predicted)</td>
<td>67.0±27.4 z</td>
<td>83.8±18.8 z</td>
<td>96.1±22.7 z</td>
<td>.002</td>
</tr>
<tr>
<td>FVC/FEV1</td>
<td>85.0±21.6</td>
<td>82.3±10.0</td>
<td>81.0±5.3</td>
<td>.575</td>
</tr>
</tbody>
</table>

NOTE. Data are presented as the mean ± SD or as otherwise indicated.
* P values for differences in group A versus group B versus group C, analyzed using the analysis of variance with post hoc Duncan analysis.
1 Statistically significant differences among all groups at P < .0001.
2 Mean values marked with symbol  were statistically different from those marked with § using post hoc Duncan analysis.
3 Mean values marked with symbol  were statistically different from those marked with § using post hoc Duncan analysis.

### Table 3 Multiple regression analysis showing variables related to the diaphragm excursion of the hemiplegic side during VC

<table>
<thead>
<tr>
<th>Clinical Variables</th>
<th>β (slope)</th>
<th>P</th>
<th>β (slope)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dysphagia</td>
<td>NA</td>
<td>NA</td>
<td>1.173</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>NIHSS</td>
<td>−0.053</td>
<td>&lt;.001</td>
<td>−0.039</td>
<td>.539</td>
</tr>
<tr>
<td>Trunk control</td>
<td>0.263</td>
<td>.053</td>
<td>−0.073</td>
<td>.166</td>
</tr>
<tr>
<td>MMSE</td>
<td>0.074</td>
<td>.616</td>
<td>−0.039</td>
<td>.711</td>
</tr>
<tr>
<td>MBI</td>
<td>0.234</td>
<td>.157</td>
<td>0.023</td>
<td>.847</td>
</tr>
<tr>
<td>PCF</td>
<td>0.171</td>
<td>.222</td>
<td>0.018</td>
<td>.866</td>
</tr>
</tbody>
</table>

R² = 0.252
R² = 0.601

Abbreviations: MMSE, Mini-Mental State Examination; NA, not applicable.
* Adjusted for the NIHSS, Trunk Control Test, MMSE, MBI, and PCF.
1 Adjusted for the NIHSS, Trunk Control Test, MMSE, MBI, PCF, and presence of dysphagia and aspiration.
2 Statistically significant differences at P < .05.

### Table 4 Multiple regression analysis showing variables related to the diaphragm excursion of the hemiplegic side during DB

<table>
<thead>
<tr>
<th>Clinical Variables</th>
<th>β (slope)</th>
<th>P</th>
<th>β (slope)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dysphagia</td>
<td>NA</td>
<td>NA</td>
<td>0.894</td>
<td>.002</td>
</tr>
<tr>
<td>MIP</td>
<td>0.02†</td>
<td>.011</td>
<td>0.234</td>
<td>.104</td>
</tr>
<tr>
<td>NIHSS</td>
<td>−2.3</td>
<td>.15</td>
<td>−0.081</td>
<td>.594</td>
</tr>
<tr>
<td>Motricity Index</td>
<td>0.126</td>
<td>.455</td>
<td>0.151</td>
<td>.294</td>
</tr>
<tr>
<td>MBI</td>
<td>0.2</td>
<td>.184</td>
<td>0.084</td>
<td>.607</td>
</tr>
</tbody>
</table>

R² = 0.137
R² = 0.201

Abbreviation: NA, not applicable.
* Adjusted for MIP, NIHSS, Motricity Index, and MBI scores.
† Adjusted for MIP, NIHSS, Motricity Index, and MBI scores and the presence of dysphagia with aspiration.
2 Statistically significant differences at P < .05.
patients with stroke. Further studies need to be performed to fully understand the direct influence of the respiratory muscles in dysphagic stroke patients and to find new therapies to enhance their diaphragm function to help improve their compromised coughing.

Study limitations

There are some limiting factors in this study that need to be considered. First, this study included a small number of patients with brainstem lesions. Although the proportion in the 2 groups was very small, there are no studies, to our knowledge, on whether patients with brainstem lesions manifest different diaphragm excursion when compared with those with cortical lesions, as assessed by ultrasonography. Second, the supine position is usually preferred for ultrasonography assessment because it allows greater freedom of movement than the sitting position by decreasing the effect of the crural diaphragm on postural control. Therefore, ultrasonography assessment was performed in the supine position, whereas the spirometric measurements were performed in the sitting position. Third, MIP does not solely reflect the strength of the diaphragm, but it also measures the effect of other inspiratory muscles combined. Other methods (eg, transdiaphragmatic pressure, sniff pressure measurement) can exclusively assess diaphragm strength; however, they are invasive and require the use of an esophageal electrode. Finally, data on the degree of hyolaryngeal excursion were not available in all patients because some participants had performed fiberoptic endoscopic evaluation of swallowing at the time of enrollment. However, future prospective studies that incorporate the use of hyolaryngeal excursion measures and detailed measurements of dysphagia would be helpful to elucidate the close relations between the diaphragm and swallowing muscles. Despite these limitations, the findings of this study are important because they highlight that stroke patients with dysphagia and confirmed aspiration have compromised bilateral diaphragm dysfunction, especially during VC. The impairment of respiratory function and cough, along with the preexisting swallowing dysfunction, may increase the risk of pulmonary complications (eg, aspiration pneumonia) in these patients.

Conclusions

The results of this study show that stroke patients with dysphagia have more pronounced weakness of the diaphragm as assessed by M-mode sonography, with a more restrictive lung dysfunction and weaker cough force compared with healthy controls and nondysphagic stroke patients.

Suppliers

a. HD11XE; Philips Healthcare, 3000 Minuteman Rd, Andover, MA 01810-1099.
b. Carefusion Corp, 3750 Torrey View Court, San Diego, CA 92130.
c. SAS Inc, 100 SAS Campus Dr, Cary, NC.

Keywords

Cough; Deglutition disorders; Diaphragm; Rehabilitation; Stroke; Ultrasonography

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Acknowledgments

We thank Hyeon-Woo Yim, MD, PhD, Seung-Hee Jung, PhD, and Hyun-Bin Kim, MPH, at the Catholic Medical Center Clinical Research Coordinating Center for their advice on statistics.

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