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ORIGINAL ARTICLE

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

Geun-Young Park, MD, PhD,[a] Seong-Rim Kim, MD, PhD,[b] Young Woo Kim, MD, PhD,[b] Kwang Wook Jo, MD, PhD,[b] Eu Jeen Lee, MD,[a] Young Moon Kim, MD,[a] Sun Im, MD, PhD[a]

From the [a]Department of Rehabilitation Medicine, Bucheon St. Mary's Hospital, College of Medicine, The Catholic University of Korea, Bucheon-si; and [b]Department of Neurosurgery, Bucheon St. Mary's Hospital, College of Medicine, The Catholic University of Korea, Bucheon-si, Republic of Korea.

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 (cmH_2O) 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.

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The diaphragm is the primary respiratory muscle and accounts for approximately 75% of the airflow into the lungs.[1] It ensures sufficient precough insufflation, enabling the expiratory muscles to generate large positive intrathoracic pressures during cough.[2,3] Patients with stroke present with reduced diaphragm excursion,[4-6] which can result in restrictive lung dysfunction.[7] Previous studies[7-9] 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[5,6,10] and has been shown to be a reproducible method to assess hemidiaphragm movement.[11]

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

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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.

List of abbreviations:

DB	**deep breathing**
FEV_1	**forced expiratory volume in 1 second**
FVC	**forced vital capacity**
MBI	**Modified Barthel Index**
MEP	**maximum expiratory pressure**
MIP	**maximum inspiratory pressure**
NIHSS	**National Institutes of Health Stroke Scale**
PCF	**peak cough flow**
QB	**quiet breathing**
VC	**voluntary cough**

Diaphragm measurements using ultrasonography

Diaphragm excursion was assessed using ultrasound[a] in M-mode using a convex transducer (5−2MHz) with variable frequency depending on the depth. The images were obtained according to previous methods.[4-6] 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.[4,8] 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 craniocadual axis.[4-6] Ultrasonographic 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,[4-6] 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.[11] At least 3 attempts were recorded, and the average value was used for statistical analysis.[6] 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.[12] The clinician performing the sonography was blinded to the other spirometric and clinical variables of each participant.

Spirometric findings

Spirometry (VmaxTM Autobox V62J[b]) was performed in compliance with American Thoracic Society/European Respiratory Society standard guidelines.[13] 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 (FEV_1), and FEV_1/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[b]) with a standard flange