Laryngeal Closure during Swallowing in Stroke Survivors with Cortical or Subcortical Lesion

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Background: One of the major, and most harmful, symptoms of dysphagia in stroke survivors is aspiration. Survivors of unilateral cortical strokes with dysphagia and resulting aspiration have been reported to have greater initiation delays in laryngeal closure than those who did not aspirate. Few studies have reported such data in survivors of subcortical stroke. *Methods:* This study measured initiation of laryngeal closure (ILC) and laryngeal closure duration (LCD) in 2 groups of subjects: 15 stroke survivors with cortical lesions and 15 stroke survivors with subcortical lesions. Means and standard deviations of ILC and LCD were analyzed on 5-mL thin liquid and 5-mL puree boluses using a 100-ms timer during subsequent analysis of videofluoroscopic swallowing examinations. Statistical comparisons were used by repeated measures analysis of variance. Significance level was set at $P < .05$. *Results:* ILC was significantly longer in stroke survivors with a subcortical lesion than in those with a cortical lesion for both bolus consistencies. However, there were no significant differences between the 2 groups in LCD. Stroke survivors with a subcortical lesion had a greater incidence of penetration or aspiration and silent aspiration than those with a cortical lesion and a longer delay in the ILC. *Conclusions:* Subcortical lesions may put these survivors at greater risk of aspiration due to delayed initial laryngeal closure and reduced oral and laryngeal sensation. The subcortical damage, which occurs at the basal ganglia, may interrupt the ILC. **Key Words:** Subcortex—stroke—laryngeal closure—aspiration—airway protection.
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Introduction

Laryngeal closure is critical for airway protection during the pharyngeal stage of swallowing. As the bolus enters the pharynx during the swallow, laryngeal closure occurs by approximation of the epiglottis to the arytenoid cartilages—as can be viewed in videofluoroscopic swallowing examination (VFSE). This event should occur in quick response to the bolus to protect the airway.[1] Delayed and incomplete laryngeal closure can allow aspiration to occur. Aspiration is defined as the entrance of food or liquid into the airway before, during, or after the swallow.[2] For example, aspiration that occurs before the swallow is likely to occur if the bolus passes into the pharynx before laryngeal closure. In healthy individuals, laryngeal closure begins when the bolus reaches the anterior faucial pillar or the ramus of mandible.[3-5] However, in stroke survivors with aspiration, laryngeal closure begins after the

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bolus reaches the ramus of the mandible.[6] Aspiration that occurs after the swallow results from inhalation of residue in the pharynx. In addition, 2 distinct patterns of aspiration have been identified by reflexive cough. For aspiration with reflexive cough, as the bolus enters into the airway, cough follows to expel the aspirated bolus from the airway. For aspiration without reflexive cough—silent aspiration—the aspirated bolus is inhaled without efforts through cough to expel it. Silent aspiration may be associated with reduced laryngeal sensation and impaired ability to produce a cough.[7]

Swallowing is often affected following stroke. More than 50% of stroke patients have difficulties in oral and pharyngeal swallowing.[8-10] Particularly, difficulties in airway protection are common.[11,12] Previous studies have reported problems with airway protection following cortical and brainstem lesions.[13-15] Park et al[6] reported that unilateral stroke survivors had reduced laryngeal closure regardless of incidence of aspiration. Several studies have attempted to establish a clear correlation between site of lesion and the occurrence of aspiration and clinical findings,[16,17] but these studies were limited mostly to cortical and brainstem lesions.

Airway protection has been investigated through the temporal measurements of VFSE, such as initiation of laryngeal closure (ILC) and laryngeal closure duration (LCD). ILC and LCD represent the efficiency and coordination of airway protection. ILC is the time between bolus arrival at the ramus of mandible and first contact of the arytenoids and epiglottis.[6,18] Previous research reported that subcortical stroke survivors had slower initiation of laryngeal elevation than normal individuals.[19] Park et al[6] reported that unilateral stroke survivors with aspiration had longer delayed ILC than unilateral stroke survivors without aspiration and normal participants. LCD is the duration of approximation of the arytenoid cartilages to the base of the epiglottis.[20-22] To better understand airway protection mechanisms following subcortical stroke, this study examined measures of ILC and LCD in stroke survivors with subcortical lesions compared with cortical lesions.

Method

Subjects

Our sample of stroke survivors consisted of 15 unilateral cortical stroke patients (mean age 71 years old, 11 men, 4 women) and 13 subcortical stroke patients (mean age 73 years old, 4 men, 9 women) admitted to the Seoul National University Hospital in Korea between January 2010 and July 2014. Stroke diagnoses were provided by neurologists and confirmed by computed tomography or magnetic resonance imaging. Fourteen unilateral cortical strokes occurred in the middle cerebral artery distribution and 1 in the precentral area of the left hemisphere. All subcortical stroke survivors suffered from infarction affecting the corona radiata, putamen, caudate nucleus, or internal capsule, without cortical involvement. The stroke survivors in this study who met the following inclusion criteria were included: (1) initial VFSE performed during the subacute stage within 35 days after stroke onset and (2) no history of previous stroke or some other disease that could affect swallowing function. All investigations were part of standardized routine diagnostic workup at Seoul National University Hospital (Table 1).

Videofluoroscopic Swallowing Examination (VFSE)

VFSEs were conducted on all stroke survivors. Each subject was seated upright in a wheelchair or stretcher chair for the examination. The fluoroscopic tube was focused in the lateral plane on the oral cavity (the lips anteriorly to the pharyngeal wall posteriorly) and the nasopharynx (superiorly) to below the upper esophageal sphincter area (inferiorly). Boluses were presented in 2-mL and 5-mL thin liquid and puree form. The thin liquid was a mixture of water and barium sulfate powder (35% w/v). Each subject swallowed the bolus after putting the liquid in his/her mouth after the clinician delivered it by spoon. A total of 120 swallows were submitted for analysis for this investigation. Frame-by-frame images were acquired to digital imaging files using a computer-based image processing system equipped with a digital computer frame grabber board (Pegasus HD/SD Board, Grass Valley Inc., Honorine, France) and image processing software (EDIUS 4.5, Grass Valley Inc.). The X-ray voltage was set at a 40-kV peak, which allowed the soft tissue of the pharynx to be visualized.

Procedures for Temporal Measurement

To accurately analyze the temporal sequence of events, slow motion and frame-by-frame analyses were performed using a 100-ms video timer. Adobe Element 14 (San Jose, CA) was used. First, each liquid swallow was analyzed for the following points of occurrence: (1) bolus passing the ramus of mandible, (2) first contact of arytenoids and epiglottis, and (3) final contact of arytenoids and epiglottis. Second, the times for each of the abovementioned markers were recorded and used to calculate the 2 measures of laryngeal closure. Laryngeal closure in this investigation referred to laryngeal vestibule closure rather than true vocal folds closure. However, laryngeal vestibule closure has been and continues to be the accepted and encouraged methodology for analyzing temporal measure of laryngeal closure.[4-6,12,20]

The occurrence of penetration and aspiration were verified. Aspiration was defined as entry of the bolus below the true vocal folds. As aspiration was identified, the occurrence of cough response was recorded. Penetration was defined as entry of the bolus in the vestibule, but not below the true vocal folds.