# Pharyngeal Swallowing Mechanics Secondary to Hemispheric Stroke

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*Background:* Computational analysis of swallowing mechanics (CASM) is a method that utilizes multivariate shape change analysis to uncover covariant elements of pharyngeal swallowing mechanics associated with impairment using videofluoroscopic swallowing studies. The goals of this preliminary study were to (1) characterize swallowing mechanics underlying stroke-related dysphagia, (2) decipher the impact of left and right hemispheric strokes on pharyngeal swallowing mechanics, and (3) determine pharyngeal swallowing mechanics associated with penetration–aspiration status. *Methods:* Videofluoroscopic swallowing studies of 18 dysphagic patients with hemispheric infarcts and age- and gender-matched controls were selected from well-controlled data sets. Patient data including laterality and penetration–aspiration status were collected. Coordinates mapping muscle group action during swallowing were collected from videos. Multivariate morphometric analyses of coordinates associated with stroke, affected hemisphere, and penetration–aspiration status were performed. *Results:* Pharyngeal swallowing mechanics differed significantly in the following comparisons: stroke versus controls ($D = 2.19$, $P < .0001$), right hemispheric stroke versus controls ($D = 3.64$, $P < .0001$), left hemispheric stroke versus controls ($D = 2.06$, $P < .0001$), right hemispheric stroke versus left hemispheric stroke ($D = 2.89$, $P < .0001$), and penetration–aspiration versus within normal limits ($D = 2.25$, $P < .0001$). Differences in pharyngeal swallowing mechanics associated with each comparison were visualized using eigenvectors. *Conclusions:* Whereas current literature focuses on timing changes in stroke-related dysphagia, these data suggest that mechanical changes are also functionally important. Pharyngeal swallowing mechanics differed by the affected hemisphere and the penetration–aspiration status. CASM can be used to identify

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patient-specific swallowing impairment associated with stroke injury that could help guide rehabilitation strategies to improve swallowing outcomes. **Key Words:** Ischemic hemispheric stroke—dysphagia—swallowing mechanics—aspiration.


## Introduction

Dysphagia commonly follows stroke and is a predictor of poor outcomes including aspiration, lengthened hospital stay, need for institutional care, pneumonia, and even mortality.[1-5] During pharyngeal swallowing, the pharynx is transformed from a respiratory channel into an alimentary conduit. In the current study, pharyngeal swallowing mechanics of dysphagic ischemic stroke patients are compared to those of healthy controls to better appreciate the impact of stroke on swallowing. We compared left and right hemispheric stroke groups to understand the impact of each on swallowing mechanics. Furthermore, we investigated the sample's pharyngeal mechanics associated with penetration and aspiration.

Current literature of the functional changes in stroke-related dysphagia emphasizes delays in timing,[6-8] aspiration risk associated with timing,[9-11] and related sensorineural deficits[12-14] with mechanistic deficits receiving less attention. Reports suggest differences in hyoid and laryngeal displacements but are mixed (Table 1).[11,15-18] A more comprehensive understanding of covariant swallowing mechanics including hyoid and laryngeal movements, tongue base retraction, pharyngeal shortening, and head and neck extensions could not only highlight the dysfunction underlying stroke-associated penetration and aspiration but also suggest which treatment goals would be more salient.[19,20]

Another important factor that could be contributing to dysfunction of swallowing mechanics is the impact of left versus right hemispheric lesions. Although the consensus in the literature supports the idea that swallowing is bilaterally innervated,[21-24] some studies suggest that 1 hemisphere is more dominant, varying by person.[25-29] Increasingly, recent studies indicate that right hemisphere lesion is associated with deficits in the pharyngeal stage of swallowing.[30-32] Teismann et al and Mihai et al showed a shift of neural activity to the right hemisphere during the pharyngeal stage of swallowing in healthy subjects.[33,34] Other authors support the notion that the 2 hemispheres do, in fact, control different aspects of swallowing.[35] Support for this theory dates back to 1993 when Robbins et al found right hemispheric strokes to be associated with longer pharyngeal transit and response times as well as increased risk of penetration and aspiration when compared to left hemispheric strokes.[36] However, consensus on whether there is a dominant hemisphere, varying by person, or whether there are instead distinct roles assigned to each hemisphere remains unclear. Furthermore, the specific impact of hemispheric stroke on the multiple muscle group actions underlying pharyngeal swallowing mechanics is unreported.

Conventional univariate displacement measurements from videofluoroscopic swallowing studies are helpful to quantify stroke impact, for example, on hyoid movement. The impact of multiple stroke variables, however, on multiple interacting elements of swallowing mechanics requires a different approach. Pharyngeal swallowing is complex. Computational analysis of swallowing mechanics (CASM) utilizes geometric morphometrics to quantify overall shape differences associated with variables of interest. Once these overall differences are determined, eigenvectors are used to visualize the impact of variables on covariant pharyngeal swallowing mechanics. As such, the traditional outcome of distance measurements is replaced by eigenvectors that provide

**Table 1.** *Previous literature reporting differences in swallowing mechanics associated with stroke*

| Landmark | Authors | Relevant finding |
|---|---|---|
| Hyoid | Bingjie et al[11] | *Reduced* **vertical** movement in aspirating versus nonaspirating stroke patients<br>**Horizontal** movement showed *no significant difference* between groups—stroke or healthy |
| | Paik et al[15] | *No significant difference* for **vertical** movement<br>*Decreased* **anterior** movement in dysphagic stroke patients as compared to normal |
| | Kim et al[16] | Slightly *decreased* but *nonsignificant* difference in aspirating versus nonaspirating stroke patients in **vertical** and **horizontal** directions |
| | Seo et al[17] | *Nonsignificant decreases* in movement for nonrecovered stroke aspirators compared to recovered |
| Larynx | Bingjie et al[11] | *Reduced* **vertical** displacement in aspirating versus nonaspirating stroke patients |
| Hyolaryngeal complex | Han et al[18] | Penetration–aspiration status predicted *reduced* hyolaryngeal **elevation** in stroke survivors |