Effect of Changes in Bolus Viscosity on Swallowing Muscles in Patients with Dysphagia after Stroke

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To the Editor: In the last recent years, significant progress has been achieved in research on dysphagia. This is important because approximately 50% of patients with dysphagia after acute stroke still have a slow functional recovery, and the duration of disease may last for several months or the whole life. The ultimate aim of dysphagia treatment is for patients to be able to eat again and to examine if the influence of eating conditions is inevitable in dysphagia research. Changes in the peripheral afferent nervous system related to eating, such as alimentary bolus characters and eating postures, can result in adjustments of swallowing by afferent pathways of the central nervous network, followed by corresponding changes in the time sequence, duration, and intensity of oropharyngeal muscle activities. Therapists often choose alimentary bolus according to their own experience with direct ingestion training, without quantitative evaluation of swallowing muscle group activities. To explore the influence of alimentary bolus viscosity changes on swallowing physiology, and study the relationship with swallowing muscle group activities and the role in the mechanism of dysphagia, the surface electromyographic (SEMG) technique was used in this study to observe the characteristics of muscle group activity real timely, dynamically, and synchronously.

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Affiliated Hospital of Guizhong Medical College. All participants provided informed written consent before their enrollment in this study. Forty patients with dysphagia were enrolled based on the following inclusion criteria: (1) diagnosed with primary cerebral infarction or cerebral hemorrhage confirmed by head computed tomography (CT) or magnetic resonance imaging (MRI); (2) stroke occurred within 1–3 months ago; (3) aged 45–70 years; (4) with stroke verified by videofluoroscopic swallowing study (VFSS).

Foods with different viscosities were prepared using Thickener (Ourdiet Swallow, Ourdiet Biotech Co. Ltd, Guangzhou, China) and water. A viscometer (NDJ-5S digital rotary viscometer from Fangrui Instrument Co. Ltd, Shanghai, China) was used to measure the viscosity at room temperature of 25°C. The boluses were water (viscosity = 1 mPa·s), nectar-like food (viscosity = 272–343 mPa·s), and pudding-like food (viscosity = 4750–5113 mPa·s).[1] During the test, the environment was kept quiet and the indoor temperature was stable at 25°C. Subjects lied flat on an adjustable angle test bed with their trunk and upper limbs at the same horizontal level. The forehead was fixed with a forehead hoop, and the neck was placed in an adjustable concave fixture to prevent subjects from turning left and right, flexing, and extending. The nose alar screen line was kept perpendicular to the test bed and the angle of the test bed was adjusted to 90°. Alcohol of 75% medical grade was used to clean the skin of the participants’ necks to reduce interference and increase conductivity. The electrodes were attached to the surface of the muscle belly of the submental muscles (SMs) (on both sides of the midline of the neck, between the submental border and the hyoid bone) and the infrahyoid muscles (IMs) (approximately 2 cm below the hyoid bone on both sides of the midline of the neck). The two recording electrodes were separated by 2 cm, and the reference electrode was placed 2 cm from the recording electrodes.[1] For ingestion, cups were used for drinking water, and spoons were used for feeding pudding-like foods. The participants completed the test of each 5 ml food (water, nectar-like, and pudding-like) in sequence. After the food was placed in their mouths, the participants were asked to keep it

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Table 1: Swallow durations of SMs or IMs of three viscosities in two groups

| Viscosity         | SMs Healthy controls (n = 40) | SMs Patients with dysphagia (n = 40) | IMs Healthy controls (n = 40) | IMs Patients with dysphagia (n = 40) | I   | P           |
|-------------------|-----------------------------|-----------------------------------|-------------------------------|-----------------------------------|-----|-------------|
| Water (s)         | 1.315 ± 0.211               | 1.423 ± 0.185                     | 2.422                         | 0.018                             | 1.241 ± 0.202 | 1.334 ± 0.137 | 4.003          | <0.001 |
| Nectar-like food (s) | 1.334 ± 0.197*               | 1.479 ± 0.206*                    | 3.212                         | 0.002                             | 1.274 ± 0.194* | 1.382 ± 0.202* | 2.422          | 0.017  |
| Pudding-like food (s) | 1.458 ± 0.212               | 1.685 ± 0.209*                    | 4.816                         | <0.001                            | 1.436 ± 0.233<1 | 1.555 ± 0.284<1 | 2.055          | 0.043  |
| F                 | 5.630                       | 19.688                            | 9.749                         | 11.544                            | 0.005         | <0.001       | <0.001         | <0.001 |
| P                 | 0.005                       | <0.001                            | <0.001                        | <0.001                            | <0.001        | <0.001       | <0.001         | <0.001 |

The data are shown as mean ± SD. *P<0.050, versus water in same group; †P<0.010, versus water in same group; ‡P<0.010, versus nectar in same group. SM: Submental muscle; IM: Infrapharyngeal muscle; SD: Standard deviation.

This study investigated the effect of bolus conditions on measurements of SEMG duration. Bolus conditions had significant effect on the swallow durations of SMs and IMs. Higher viscosity was associated with longer swallow duration. According to the rheological properties of the food bolus, the shear flow velocity decreased with the increase of the viscosity during swallowing.[2] Boluses with higher viscosities reduced the flow rate and increased the pharyngeal transit time.[3] When the tongue was placed upward, the bolus proceeded faster, and the swallowing process was open for longer periods of time, and therefore, the swallow duration was prolonged. The findings of this study were consistent with the results of previous studies.

The swallow durations of SMs and IMs in the patient group were longer than those in healthy group when subjects of the two groups swallowed the same viscosity, especially for the SMs in pudding condition. The damage to the swallowing center of the cortex or subcortex in stroke patients resulted in decreased coordination of swallowing muscles and prolonged muscle activity. The pharyngeal contraction time in patients was also significantly longer than that in healthy subjects, which might be important to promote laryngeal protection and upper esophageal sphincter (UES) dilatation in patients. An increase in bolus viscosity increased the duration needed for the tongue to push the bolus back.[4] The pudding bolus with a high viscosity, uniform tension, and looseness supports the patient’s swallowing muscle group which has a reduced coordination, to have enough time to successfully complete the swallowing, and at the same time increases the sensory afferent stimulation to the pharyngeal cavity, thereby effectively reducing leakage and aspiration. According to VFSS observation, Rofes et al.[5] have found that pudding bolus could reduce the leakage and aspiration rate to 98.9%, which was confirmed by electrophysiological activity.

There was a significant difference in the number of positive sequence values between the two groups. This indicated that SMs were activated before IMs in healthy volunteers and IMs were early activated in dysphagic patients. The SMs pull the hyoid bone up and forward while swallowing, which helps to close the nasopharyngeal area and prevent food from refluxing into the respiratory tract. The IMs pull the lifted and forwarded hyoid bone back to the starting position to prepare for the next swallow. Therefore, coordination between the IMs and SMs ensures the completion of hyoid bone movement and normal swallowing. Any dysfunction in the SMs or IMs might cause abnormal movements of the tongue or hyoid bone, thereby causing dysphagia.[6] The early onset of action of the IMs in dysphagic patients was associated with the abnormality of the temporal sequence of muscle activity between SMs and IMs. This might inhibit the hyoid bone elevation by SMs and be one of the causes of hyoid complex elevation insufficiency or insufficient UES opening.
In conclusion, changing the bolus consistency could significantly affect the activity duration of swallowing muscles. Especially the pudding bolus had the greatest effect on patients with dysphagia. The activating or intensifying training of the SMs might improve swallowing ability in the treatment of dysphagia.

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**Conflicts of interest**
There are no conflicts of interest.

**References**

1. Vaiman M, Eviatar E. Surface electromyography as a screening method for evaluation of dysphagia and odynophagia. Head Face Med 2009;5:9. doi: 10.1186/1746-160X-5-9.

2. Hwang J, Kim DK, Bae JH, Seo KM, Kim BK, et al. The effect of rheological properties of foods on bolus characteristics after mastication. Ann Rehabil Med 2012;36:776-84. doi: 10.5535/arm.2012.36.6.776.

3. Regueiro MR, Nascimento WV, Parreira LC, Dantas RO. Videofluoroscopic analysis of different volumes of liquid bolus swallowing in healthy individuals: Comparison between height and sex. Clinics (Sao Paulo) 2017;72:693-7. doi: 10.6061/clinics/2017(11)08.

4. Park JW, Sim GJ, Yang DC, Kang SH, Seo KM, Kim BK, et al. The effect of rheological properties of foods on bolus characteristics after mastication. Ann Rehabil Med 2012;36:776-84. doi: 10.5535/arm.2012.36.6.776.

5. Rofes L, Arreola V, Clave P. The volume-viscosity swallow test for clinical screening of dysphagia and aspiration. Nestle Nutr Inst Ser 2012;72:33-42. doi: 10.1159/000339979.

6. Park D, Lee HH, Lee ST, Oh Y, Lee JC, Nam KW, et al. Normal contractile algorithm of swallowing related muscles revealed by needle EMG and its comparison to videofluoroscopic swallowing study and high resolution manometry studies: A preliminary study. J Electromyogr Kinesiol 2017;36:81-9. doi: 10.1016/j.jelekin.2017.07.007.