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

Shuang Wu[1,2], Lan Chu[1,3,4], Chun-Feng Liu[1,4], Qian Zhang[2], Yi-Fan Zhang[3], Teng-Fei Zhou[2], Zhi-Tao Wang[2], Rui-Han Ni[3], Yuan Li[3]

[1]Department of Neurology, The Second Affiliated Hospital of Soochow University, Suzhou, Jiangsu 215004, China
[2]Department of Rehabilitation, The Affiliated Hospital of Guizhou Medical University, Guiyang, Guizhou 550004, China
[3]Department of Neurology, The Affiliated Hospital of Guizhou Medical University, Guiyang, Guizhou 550004, China
[4]Institute of Neuroscience of Soochow University, Suzhou, Jiangsu 215004, China

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 Guiyang 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 stable vital signs, abbreviated mental test scale score >7, and dysphagia outcome and severity scale grade 2–6; and (5) mild-to-moderate dysphagia, confirmed oral phase or pharyngeal dysphagia based on a videofluoroscopic swallowing study (VFSS) examination. Patients with true bulbar paralysis were excluded. Forty healthy volunteers were recruited with the following criteria: (1) aged 45–70 years; (2) without history of dysphagia, speech dysarthria, known ear-nose-throat diseases, pulmonary or nervous system diseases, gastroesophageal reflux disease, and head or neck surgery; and (3) without recent use of drugs that might affect the swallowing function and without existing dysphagia verified by 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 ear 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 the pudding- and nectar-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

Address for correspondence: Dr. Lan Chu, Department of Neurology, The Affiliated Hospital of Guizhou Medical University, Guiyang, Guizhou 550004, China
E-Mail: chulan8999@yeah.net

Access this article online

Quick Response Code:

Website: www.cmj.org

DOI: 10.4103/0366-6999.246071

Received: 09-08-2018 **Edited by:** Xin Chen
How to cite this article: Wu S, Chu L, Liu CF, Zhang Q, Zhang YF, Zhou TF, Wang ZT, Ni RH, Li Y. Effect of Changes in Bolus Viscosity on Swallowing Muscles in Patients with Dysphagia after Stroke. Chin Med J 2018;131:2868-70.

there. The myoelectric signals collected during the resting state for 5 s were taken as the baseline signal, and then, the participants swallowed the food all at once. Each viscosity bolus was repeated 3 times and averaged. When the EMG signal amplitude increased, and the amplitude exceeded the mean baseline value by +2 standard deviations (SDs), the muscle activity was recorded at the start of swallowing. The end of swallowing was defined as the decrease of the EMG signal amplitude by −2 SDs of the mean baseline value. The time from start of swallowing to end of swallowing was defined as the swallow duration. Sequence difference values were calculated as the duration from the baseline to start of swallowing of SMs (t1) or IMs (t2). If the value of t2–t1 was positive, SMs were activated before IMs. The SEMG (ME6000, MEGA Electronics Ltd., Kuopio, Finland) signals of hyoid muscles were collected from patients with dysphagia after stroke and healthy volunteers when subjects swallowed different viscous bolus. To examine the positive sequence difference value in the two groups, Software MegaWin 3.0 (MEGA Electronics Ltd., Kuopio, Finland) was used to perform a linear analysis of the collected SEMG signals of each muscle group. The differences in muscles activities between the two groups were compared and analyzed for clinical interpretation and implementation.

The data were analyzed using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). The data were shown as mean ± SD. The Chi-square test was used to evaluate the differences of the enumeration data, and an independent sample *t*-test was used to evaluate the differences of swallow duration between the two groups. The mean of multiple sets of data was compared by one-way analysis of variance. A $P < 0.05$ was considered as statistically significant.

There was no significant difference in gender, age, and body mass index between the two groups (all $P > 0.050$). There were significant differences in both swallow duration of the SMs and IMs among the three viscosities in the same group ($P < 0.010$, Table 1). Further comparison between viscosities showed that the swallow durations of SMs and IMs in the pudding bolus condition were significantly longer than those in water and nectar bolus conditions in the same group (healthy group: $P = 0.003$ and $P = 0.008$; patient group: all $P < 0.001$). Furthermore, the swallow durations of SMs and IMs in the patient group were significantly longer than those in the healthy group under the same viscosity condition (all $P < 0.05$), with a stronger significant finding for the pudding bolus of SMs and the water of IMs (all $P < 0.001$). Finally, the numbers of positive sequence different values for the healthy group were water 99 (82.5%), nectar-like 108 (90.0%), and pudding-like 105 (87.5%) and for the patient group were water 36 (30.0%), nectar-like 27 (22.5%) and pudding-like 18 (15.0%). These differences of each viscosity between two groups were statistically significant ($\chi^2 = 67.2$ for water, $\chi^2 = 111.1$ for nectar bolus, $\chi^2 = 126.2$ for pudding bolus, all $P < 0.001$).

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.

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

Viscosity	SMs				IMs			
	Healthy controls ($n = 40$)	Patients with dysphagia ($n = 40$)	*t*	*P*	Healthy controls ($n = 40$)	Patients with dysphagia ($n = 40$)	*t*	*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*	2.442	0.017
Pudding-like food (s)	1.458 ± 0.212†,‡	1.685 ± 0.209†,‡	4.816	<0.001	1.436 ± 0.233†,‡	1.555 ± 0.284†,‡	2.055	0.043
F	5.630	19.088			9.749	11.544		
P	0.005	<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: Infrahyoid muscle; SD: Standard deviation.

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.

Financial support and sponsorship

Nil.

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, 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.
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, Lee KH, Chang JH, Nam KY, *et al.* Increased bolus volume effect on delayed pharyngeal swallowing response in post-stroke oropharyngeal dysphagia: A Pilot study. Ann Rehabil Med 2016;40:1018-23. doi: 10.5535/arm.2016.40.6.1018.
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.