Influence of Thermal and Gustatory Stimulus in the Initiation of the Pharyngeal Swallow and Bolus Location Instroke

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Introduction/Objective: The aim of this study is to analyze the influence of sour taste and cold temperature in the initiation of the pharyngeal swallow (IPS) and bolus location at pharyngeal swallow onset in individuals after stroke. *Methods:* Cross-sectional prospective study. The study included 52 individuals with unilateral ischemic stroke. Each individual was assessed by videofluoroscopic swallowing study with 5ml of paste bolus offering four different stimuli (natural, cold, sour, and sour-cold). The individuals were divided into two groups according to the offer sequence. Group 1 (G1) – received a randomized sequence of stimuli (24 individuals), and Group 2 (G2) –the stimuli were offered in the following order: natural, cold, sour, and sour-cold(28 individuals). The IPS time and bolus location at pharyngeal swallow onset were analyzed. The bolus location at pharyngeal swallow onset was defined using six different levels. *Results:* Individuals in G1 did not show a significant difference in IPS time between stimuli. However, individuals in G2 presented a significantly shorter IPS time with the sour and sour-cold stimuli than with natural or cold stimuli. The bolus location at pharyngeal swallow onset did not show significant difference between stimuli in both groups. On the other hand, in the G2 it was observed higher frequency of swallowing with sour-cold stimulus at level 1 (the bolus head was located in any region between the fauces pillar and the point where the tongue crosses the inferior border of the mandible). *Conclusion:* The sour and sour-cold stimuli influenced the IPS time when they were offered in a sequential order. Moreover, both the IPS time and bolus location at pharyngeal swallow onset were not influenced by the sour and sour cold-bolus when offered in a random sequence.

Key Words: Sour taste—Cold temperature—Deglutition disorders—Deglutition—Stroke

Introduction

The quantitative analysis of the swallowing videofluoroscopic study has been used since the early 80`s. Through this evaluation, it is possible to understand the normal temporal measures of swallowing events and the impact of these disorders to predictive risk in different swallowing abnormalities.[1–10]

The temporal measurement of the swallowing events is an important parameter for the clinician in assessing swallowing. The pharyngeal transit time, initiation of the pharyngeal swallow and laryngeal closure duration are predictive features of aspiration.[7] Studies postulate that remediation of these features should help reduce post stroke aspiration and, consequently, reduce broncho pulmonary complications.[7]

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Thus, in order to verify if the taste or thermal stimuli influences the time of oral and pharyngeal swallowing transit, some studies investigated the impact of these stimuli in the times of the oropharyngeal swallowing events in post-stroke population with dysphagia.[8,11–13] The intense taste, such as, sour taste, was used based on the hypothesis that it increases activation of different sensory receptors. Thus, it would be able to provide significant inputs to the nucleus of the solitary tract and higher centers in activity regulation of swallowing, resulting in a more coordinated swallowing.[11,14–16]

Therefore, the aim of this study is to analyze the influence of sour taste and cold temperature in the initiation of the pharyngeal swallow (IPS) and bolus location at pharyngeal swallow onset in individuals after stroke.

Methods

Participants

Fifty-two (52) individuals participated in this study, right handed adults, post unilateral ischemic stroke with right and left lesions, 28 males and 24 females aged 50-80 years (mean age: 66 years), and the time of stroke to the inclusion in the study ranged from 1 to 30 days (median 6 days). The individuals presented mild or moderate oropharyngeal dysphagia.[17]

Neurological diagnosis of ischemic stroke and cortical involvement were made by neurological clinical assessment and confirmed by neuroimaging studies, such as computed tomography and / or magnetic resonance imaging.

The study protocol was approved by the Research Ethics Committee (OF. 284/2007). All individuals or their legal representative gave written consent before the study was initiated. Individuals with hemorrhagic stroke, who were taking medication that could interfere with the dynamics of swallowing, those with history of previous stroke, with decreased level of consciousness, and clinical unstable patients, as confirmed by medical evaluation, were excluded from the study.

Methods

The videofluoroscopic swallowing study was performed to analyze the IPS time and bolus location at pharyngeal swallow onset. The Prestilix seriographer, model 1600X (1000 MA, 130 KV – GE), operated by remote control was used. The images were transmitted to a video monitor (Sony, model PVM-95E)with 29.97 frames per second.

The patients remained seated and images were taken from a lateral position. Patients were instructed to swallow, without needing to wait for the swallow command, and they must swallow in a normal manner, by putting the bolus into his/her mouth and immediately initiating swallowing. Each individual was observed during swallowing of a 5-ml paste bolus given by spoon. A total of four different stimuli were offered (natural, cold, sour, and sour-cold).

The preparation of paste bolus was performed with a measure of thickener (4g) composed of a mixture of carbohydrate and minerals containing 360Kcal / 100g, added to water (40ml). Four different stimuli were prepared: 1. natural – 4g of thickener + 40 ml of water in the room temperature (22°C), 2. cold - 4g of thickener + 40 ml of water in the cold temperature (8°C), 3. sour - 4g of thickener + 40 ml of water in the room temperature (22°C) $_{+}$ Lemon flavor diet juice (pH 2.84), 4. sour and cold - 4g of thickener + 40 ml of water in the cold temperature (8°C)$_{+}$ Lemon flavor diet juice (pH 2.84).

Between one offer stimulus and another it was expected that the patient perform spontaneous swallowing following stimulus. This procedure comprised an average of approximately 30 seconds before offering the next stimulus.

The first twenty-four patients who meet the requirements were included in the G2 and the others twenty-eight that also meet the requirements were listed in the G1. The offering order was divided into two groups: G1 received a randomized sequence of stimuli, and G2 received sequential order of stimuli (natural, cold, sour, sour-cold). For order of the sequence of stimuli in the random group was made a previous raffle. G1 was composed by 24 individuals (12 females and 12 males, 9 right lesion and 15 left lesion) and G2 was composed by 28 individuals (12 females and 16 males, 14 right lesion and 14 left lesion). For the quantitative analysis, the following parameters were considered:

Initiation of the pharyngeal swallow (IPS) was defined as the interval, in miliseconds, between the first frame showing the arrival of the bolus head at the end of the hard palate and at the beginning of the soft palate, where the lower rim of the mandible crosses the tongue base until the first laryngeal elevation frame.[7,11]

Bolus location at pharyngeal swallow onset: Bolus head position at the onset of the pharyngeal response. The below levels were adapted from parameters proposed by Martin-Harris et al.[18] and Saitoh et al.[19] Examples can be seen in Fig. 1.

Specific software was used to analyze these parameters, allowing analyses in slow motion, frame by frame or conventional speed.[20,21] The software enabled the accurate analysis of the time in milliseconds and the frame that was the onset of the pharyngeal response. The videos were analyzed by two speech language pathologists with training in dysphagia and experience in videofluoroscopy swallowing. All tests were quantitatively analyzed by both separately.

Statistical analysis

For random and sequential group, an analysis was made to compare the judges separately. Since there was no difference between the judges, the average of the both

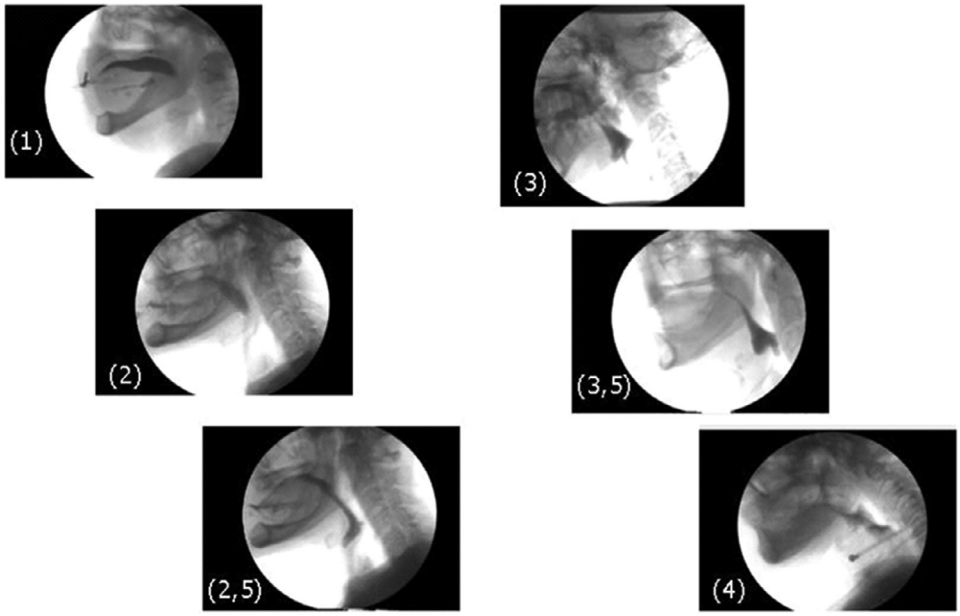

Fig. 1. *Parameters proposed in this study to analyze different bolus positions at the onset of the pharyngeal response.*

judges for statistical analysis was used. Like variables are not normally distributed, non-parametric analyzes were done using the Friedman test for each group. To the bolus head location at swallow response onset, the test was used to compare proportions between stimuli in each category. The level of significance was 0.05.

Results

The first parameter analyzed was the initiation of the pharyngeal swallow in the different stimuli. In G1 group (random offer) no statistical difference was observed, however in G2 group (sequential offer), both the sour stimulus and the sour-cold showed statistical difference compared to natural stimuli and cold. Table 1 summarizes these results.

In the same way, in Tables 2 and 3, the distribution of swallowing according to the stimulus and the Bolus location at pharyngeal swallow onset in G1 and G2 was observed respectively. Although there were no statistical differences, a higher frequency of swallows at level 1 with cold sour stimulation in G2 was observed.

Table 1. *Median, 1st and 3rd quartile, referring to time (ms) according stimuli and groups (G1, n = 24 e G2, n= 28).*

	Stimulus			
Group	natural	Cold	Sour	sour/cold
G1	1367[700,1729]a	1393[707,1944]a	1320[673,2275]a	1361[590,2315]a
G2	1302[1048,1993]a	1349[715,1863]a	1270[547,1861]b	1205[463,1877]b

Stimulus followed by same letter do not differing statistically.

Table 2. *Frequency distribution of swallowing according to the stimulus and Bolus location at pharyngeal swallow onset in the G1.*

	Stimuli							
	Natural		Cold		Sour		Sour/cold	
Level	**N0**	**%**	**N0**	**%**	**N0**	**%**	**N0**	**%**
1	6	25.0	5	20.8	10	41.7	10	41.7
2	-	0.0	-	0.0	-	0.0	-	0.0
2.5	9	37.5	8	33.3	8	33.3	4	16.7
3	3	12.5	7	29.2	1	4.2	8	33.3
3.5	3	12.5	4	16.7	4	16.7	2	8.3
4	-	0.0	-	0.0	-	0.0	-	0.0
Total	24	100.0	24	100.0	24	100.0	24	100.0

P>0,05,

Table 3. *Frequency distribution of swallowing according to the stimulus and* Bolus location at pharyngeal swallow onset *in the G2.*

	Stimuli							
	Natural		Cold		Sour		Sour/cold	
Level	**N0**	**%**	**N0**	**%**	**N0**	**%**	**N0**	**%**
1	8	28.6	7	25.0	7	25.0	14	50.0
2	2	7.1	3	10.7	2	7.1	1	3.6
2.5	8	28.6	7	25.0	9	32.1	4	14.3
3	3	10.7	5	17.9	7	25.0	3	10.7
3.5	5	17.9	3	10.7	0	0.0	6	21.4
4	0	0.0	2	7.1	2	7.1	0	0.0
Total	28	100.0	28	100.0	28	100.0	28	100.0

P>0,05

Discussion

Dysphagia is a common and potentially fatal complication of stroke[22] and the delayed onset of pharyngeal response is commonly observed in these patients.[23,24]

The initiation of the pharyngeal swallow in elderly patients is approximately 0 to 0.3seconds.[25,26] Studies with post-stroke individuals and normal individuals considered that this time from 0.50 to 0.75 seconds is still considered safe and not associated with aspiration.[27] However, values between 0.9 and1.0 seconds can be considered predictive of risk for tracheal aspiration, but the authors in[27] emphasized that more rigorous data analysis still necessary, due to the small sample analyzed in.[27] These authors also commented that these data can, at the moment, be used as a warning to the clinic, and it is necessary to consider other parameters such as: reduced elevation of the larynx, pharynx and valecule waste, and poor protection of the lower airways.[28,29]

The association of kinematic or temporal parameters of swallowing and aspiration in normal and others population was studied. The parameters of temporal or kinematic quantitative analysis of swallowing included: laryngeal closure duration, upper esophageal sphincter (UES) opening duration, hyoid movement duration, laryngeal closure to UES opening, pharyngeal transit time, stage transit duration and bolus dwell time. Only the UES opening duration could distinguish aspirators from non aspirators.[30] In 2019, meta-analysis study carried out by Furkim et al. identified that patients with longer pharyngeal transit time, prolonged esophageal opening, and prolonged initiation of the pharyngeal swallow present greater risk for aspiration.[31]

In the stroke population many dysphagic patients presented prolonged initiation of the pharyngeal swallow. The individuals who suffered a right side stroke have presented more difficult pharyngeal components and higher association with penetration/aspiration, than those with left side stroke.[32] The prolonged transition between the end of the oral stage and the onset of the pharyngeal stage has been associated with aspiration in this population. The similar results by previous studies showed the delayed initiation of swallow response onset may be linked to higher incidence of aspiration.[27,28]

However, the delay onset of the pharyngeal stage alone may not be related to swallowing disorders. On the other hand, when associated with other disorders in the physiology of swallowing, it could be a complication.[27,18]

Oropharyngeal sensory inputs play a major role in the generation of the swallow response. Patients with dysphagia after stroke present severe impairments in oropharyngeal neuromodulation. Oropharyngeal sensitivity impairment is a critical component of the impaired oropharyngeal swallowing response in dysphagia patients that can be targeted to treat oropharyngeal dysphagia. Strong stimuli, as sour taste and cold temperature has been used with the aim of increase the sensorial input to the swallowing centre of the brain stem, thus triggering the swallow response earlier and protecting the respiratory airway and a more coordinated swallowing.[33] These sensorial stimuli may promote brain plasticity and helping the recovery of deglutition.

Some studies have been carried through aiming to understand what therapy would reduce the time of the transition between phases.[34,35]

In the same way, this study evaluated the effect of sour taste and cold temperature in the IPS time. As shown in Table 1, in G1group, in which the offer was random, it could not be verified statistical difference between the different offered stimuli. However, in G2, in which the stimuli were offered always in the same sequence, the sour stimulus and sour associated with cold temperatures showed statistical difference when compared to cold stimulus and natural stimulus.

Positive effects of the sour taste in IPS time was observed in other studies,[11,14] but these studies did not evaluate the combination of thermal and gustatory stimuli. Moreover, they did not investigate the two forms of offer, these being random and sequential offer.

The influence of the sequence of stimulus offer in the initiation of the pharyngeal swallow has been considered in the literature. The authors[36] found that when the stimulus is offered at random sequence, the strongest stimulus (sour

/ cold) can influence the sequential swallowing, also could reducing the time between phases of swallowing.[36] This hypothesis could explain the absence of statistical difference in G1 and the reduction of IPS time in G2.

We believe that this may be a hypothesis to find only a statistically significant difference in group 2, in which the most intense stimuli were offered last and without possibility of influencing the next stimulus. Based on the same hypothesis, the group that received the stimuli in a randomized way, received in some patients the most intense stimuli first, in this way could influence the subsequent swallows. Probable the 30 sec between stimuli may not be enough to eliminate the effects of the prior stimuli. It could explain the difference findings in G1 and G2.

Thus, the difference of results between groups may suggest the influence of the most intense stimuli (sour and sour / cold) on the subsequent stimuli of G1, not showing statistical difference. Within this hypothesis the sour and cold stimuli could help the swallowing therapy of these patients.

When the influence of stimuli tested at different levels of bolus location at pharyngeal swallow onset is compared, a statistical difference was not found, as shown in Tables 2 and 3. However, the fact that the cold-sour stimulus starts the pharyngeal response more often at level 1, comparing with natural stimulus, might suggest that the most intense stimulation favors a more coordinated swallowing. Considering this hypothesis, there seems to be a tendency for pharyngeal response at higher levels in this population, in the presence of cold sour stimulus. To prove this hypothesis we suggest a future study involving more patients with severe dysphagia.

Study in the literature shows the largest association of swallowing disorders when the beginning of the pharyngeal response occurs when the food is in piriform sinus.[37] Whereas, longer times of transition between deglutition phases may be more strongly related to the aspiration,[27,28] as well as bolus location at pharyngeal swallow onset occurring at lower levels (e.g.: piriform sinus) are more strongly related to swallowing disorders.[37] It is suggested that individuals with severe dysphagia, and hence, longer IPS, could benefit from stimulation with strong sensory characteristics.[15,38] For rehabilitation, the increase in sensory information would help the oral control, resulting in a more organized swallowing, with reduction of spillage on all or part of the bollus to the sinuses pyriforms.[37] For confirmation of this hypothesis would be relevant, in future, research including individuals with severe dysphagia.

Thus, our results suggest that the order of the sour-cold stimulus influences the swallowing response. Therefore, we suggest considering the use of sour-cold stimulus for swallowing as treatment for dysphagic stroke patients.

Conclusion

The sour and sour-cold stimuli influenced the initiation of the pharyngeal swallow when they were offered in a non-random sequence. Moreover, the IPS time and bolus location at pharyngeal swallow onset were not influenced in a random sequence.

Declaration of Competing Interest

None.

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