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Effects of a Sour Bolus on Oropharyngeal Swallowing Measures in Patients With Neurogenic Dysphagia

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This study examines the effects of a sour bolus (50% lemon juice, 50% barium liquid) on pharyngeal swallow measures in two groups of patients with neurogenic dysphagia. Group 1 consisted of 19 patients who had suffered at least one stroke. Group 2 consisted of 8 patients with dysphagia related to other neurogenic etiologies. All patients were selected because they exhibited delays in the onset of the oral swallow and delays in triggering the pharyngeal swallow on boluses of 1 ml and 3 ml liquid barium during videofluoroscopy. Results showed significant improvement in oral onset of the swallow in both groups of patients and a significant reduction in pharyngeal swallow delay in Group 1 patients and in frequency of aspiration in Group 2 patients with the sour as compared to the non-sour boluses. Other selected swallow measures in both subject groups also improved with the sour bolus. Volume effects were present but not as consistently as in prior studies. Implications for swallow therapy are discussed.

KEY WORDS: sour, neurogenic, swallowing, dysphagia, videofluorography

The systematic effects of bolus volume and viscosity characteristics have been explored in selected groups of normal subjects and patients with neurologic lesions (Cook, Dodds, Dantas, Kern, Massey, Shaker, & Hogan, 1989; Jacob, Kahrilas, Logemann, Shah, & Ha, 1989; Kahrilas, Logemann, Krugler, & Flanagan, 1991; Lazarus, Logemann, Rademaker, Kahrilas, Pajak, Lazar, & Halper, 1993; Logemann, Kahrilas, Cheng, Pauloski, Gibbons, Rademaker, & Lin, 1992; Ren, Shaker, Zamir, Dodds, Hogan, & Hoffmann, 1993). Increases in bolus volume have been found to increase duration of cricopharyngeal opening and airway closure, and to result in later tongue base posterior motion and pharyngeal wall contraction in normal subjects. A recent study from this laboratory defined the effects of a cold bolus on two groups of patients with neurogenic dysphagia and a group of normal subjects (Bisch, Logemann, Rademaker, Kahrilas, & Lazarus, 1994). The cold bolus was found to facilitate triggering of the pharyngeal swallow on 1 ml boluses in the milder dysphagic neurogenic group, but not in the more severely dysphagic group. That study also revealed that bolus volume had a greater effect than bolus temperature on improving the speed of triggering of the pharyngeal swallow in these patients. Ren et al. (1993) found no effect of bolus temperature on the duration of deglutitive vocal cord adduction in healthy young and elderly volunteers. There are no studies of the effects of other bolus characteristics, particularly taste, on oropharyngeal swallow measures in normal subjects or patients with dysphagia. However, clinical observations by Kagel and Leopold (1992) suggest that a cold sour stimulus can facilitate a more organized oral stage of swallow and faster triggering of the pharyngeal swallow. Unfortunately, no data have been presented to support this clinical

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observation. This study was designed to examine the effects of a sour bolus in patients with dysphagia of neurogenic origin.

Because taste is an important oral sensory stimulus, we hypothesized that bolus taste, specifically a sour bolus, might increase the preswallow sensory input to the cortex and brainstem, thus lowering the swallow threshold. Lowering the swallowing threshold might reduce the oral onset time of the swallow (i.e., the time from command to swallow until onset of oral transit) and improve triggering of the pharyngeal swallow in patients with neurogenic dysphagia. We hypothesized that these two swallow measures would be most sensitive to the preswallow sensory input provided by the bolus taste and that other measures of swallow physiology would be less affected. Prior research with cold and volume characteristics of the bolus indicated that triggering the pharyngeal swallow was the variable most often affected by these bolus characteristics in patients with neurogenic dysphagia, whereas other swallow measures were affected less by the change in these bolus characteristics.

Method

Twenty-seven consecutive patients with dysphagia of neurogenic origin referred for videofluorographic (VFG) evaluation of oropharyngeal swallow and who met the following criteria were studied. Each subject exhibited a delayed onset of the oral stage of the swallow in relation to the command to swallow, and/or a delay in triggering the pharyngeal swallow as viewed videofluorographically. Patients with neurogenic dysphagia who did not exhibit one of these two swallow disorders were not included in this sample. Patients were then divided into two groups. *Group 1* consisted of 19 patients who had suffered at least one stroke (infarct). Table 1 presents each subject's age, stroke locus if only 1 CVA had occurred, and the interval from the most recent stroke until the time of the radiographic study.

TABLE 1. Age, gender, site of lesion (Group 1) or nature of neurologic damage (Group 2), and weeks post onset of damage when videofluorographic study with sour protocol was introduced for each subject in Group 1 (patients who suffered at least one stroke) and Group 2 (patients who suffered other neurologic damage).

Subj. #	Age	Gender	Lesion	Weeks post onset when VFG completed
			Group 1: Stroke Patients	
1	64	F	L Brainstem (pontine)	1
2	66	F	L Cortical	23
3	88	F	L Cortical	3
4	78	M	L Cortical & subcortical	3
5	49	M	L Brainstem (pontine)	12
6	72	M	L Cortical & Subcortical	4
7	55	M	L Cortical & Subcortical	4
8	63	F	Multi stroke	8
9	66	F	R Subcortical	22
10	61	F	R Cortical	6
11	71	F	R Cortical & Subcortical	8
12	69	M	R Brainstem (pontine)	10
13	87	M	L Cortical	24
14	43	M	L Cortical & Subcortical	3
15	58	M	Multi stroke	8
16	58	M	Multi stroke	8
17	59	M	Multi stroke	unknown
18	54	F	R Cortical & Subcortical	20
19	62	M	Multi stroke	unknown
			Group 2: Other Neurologic Patients	
1	39	M	Closed Head Injury	21
2	20	F	Closed Head Injury	44
3	59	M	Spinal Cord Injury & Stroke	16
4	29	M	Spinal Cord Injury & Closed Head Injury	44
5	38	F	Multiple Sclerosis	unknown
6	43	M	AIDS	unknown
7	67	F	Brain Tumor	120
8	13	F	Anoxia	25

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Group 2 included 8 patients who exhibited other neurologic etiologies for their dysphagia, as shown in Table 1. Subjects were separated into the two groups on the theory that patients with stroke as an etiology might behave differently in relation to enhanced bolus taste from patients who had other neurogenic etiologies for their dysphagia. Patients may have exhibited other swallowing problems in addition to delayed oral or pharyngeal triggering of the swallow.

During the VFG study, patients were given 3 boluses each of 1 ml and 3 ml amounts of liquid barium (50% water, 50% E-Z-M barium sulfate liquid). Then, they were asked to swallow 3 boluses each of 1 ml and 3 ml liquid consisting of 50% Real Lemon Juice and 50% liquid barium. On each bolus, the liquid was placed in the patient's mouth on a spoon and the command "*swallow*" was given. Even if patients aspirated on the non-sour liquid, they were given sour liquid in the same volume to see if the sour bolus had an effect on aspiration. Several earlier studies in which postural interventions were introduced when patients aspirated during the radiographic study revealed no increase in risk to the patient by several additional swallows of small (1–3 ml) volumes on which they might aspirate (Logemann, Rademaker, Pauloski, & Kahrilas, 1994; Rasley, Logemann, Kahrilas, Rademaker, Pauloski, & Dodds, 1993). However, in the present study, if aspiration was more than approximately 10% of the bolus on a particular volume, patients were not given all 3 swallows of that volume. All videofluorographic studies were recorded on ¾ inch videotape, using a Sony model VO5800 videocassette recorder coupled to a counter timer (Thalner Electronics).

During the videofluorographic study, each patient's physiologic swallowing disorders were identified by clinical observation of the videofluorographic image on the monitor. Table 2 presents the oropharyngeal swallowing disorders in the two groups of patients. Most patients in both groups exhibited delayed oral transit and delayed pharyngeal swallow. Delayed oral onset occurred less frequently (6 of the 19 patients) in Group 1 than in Group 2, in which 5 of the 8

TABLE 2. Oropharyngeal swallowing disorders in the two groups of patients on 1 ml and 3 ml liquid swallows. No differences in the occurrence of swallowing disorders were observed on the 2 bolus volumes except aspiration, which occurred only on 3 ml volumes in these patients.

Subj. #	Reduced lip closure	Delayed oral onset	Delayed oral transit	Delayed pharyngeal swallow	Reduced laryngeal elevation	Reduced tongue base movement
			Group 1: Stroke Patients			
1			x	(x)		
2	x		x	x		
3				x		
4			x	x		
5				(x)		
6			x	x		
7		x	x		x	
8				(x)		
9		x				
10			x	x		
11		x	x	(x)		
12	x	x	x	(x)*		x
13		x	x	(x)*		
14				(x)		
15				x	x	(x)
16				(x)		
17		x	x	x	(x)	
18				x		
19				(x)*		
			Group 2: Other Neurologic Patients			
1				x		
2			x	(x)		
3		x	x	(x)*	x	(x)
4		x	x	x		
5		x	x	(x)*		
6				(x)		x
7		x	x	x		
8		x	x			

Note. ( ) indicates aspiration because of this swallowing disorder. * indicates a cough in response to aspiration.

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patients exhibited this problem. Interestingly, of the 11 patients in Group 1 who aspirated, only 3 coughed in response to this aspiration. In Group 2, two of the four who aspirated coughed in response.

Videotapes were then analyzed for the following temporal measures of oropharyngeal swallowing: (a) time between the end of swallow command until onset of bolus movement in the mouth (ONSET); (b) oral transit time (OTT)—onset of bolus movement in the mouth until the head of the bolus reached the point where the lower rim of the mandible crosses the tongue base; (c) pharyngeal delay time (PDT)—bolus head arrival at the point where the lower rim of the mandible crosses the tongue base until first laryngeal elevation; (d) pharyngeal transit time (PTT)—bolus head arrival at the point where the lower rim of the mandible crosses the tongue base until the bolus tail passes through the cricopharyngeal (CP) region; (e) pharyngeal response time (PRT)—pharyngeal transit time minus pharyngeal delay time; (f) onset of base of tongue motion toward the posterior pharyngeal wall (OTBM); (g, h, i) duration of contact of the tongue base to the posterior pharyngeal wall at the level of the middle of the second cervical vertebra (DURMC2), the inferior edge of the second cervical vertebra (DURIC2), and the superior corner of the third cervical vertebra (DURSC3)—time from onset to termination of contact at each level; (j) duration of velopharyngeal closure (DVC)—onset to termination of velar contraction to the posterior pharyngeal wall; (k) duration of hyoid movement (DHM)—onset to termination of hyoid motion; (l) duration of laryngeal elevation (DLE)—onset to termination of laryngeal elevation; (m) duration of laryngeal closure (DLC)—onset to termination of closure of laryngeal vestibule; (n) duration of cricopharyngeal opening (DCPO)—onset to termination of cricopharyngeal opening; and (o) time from first cricopharyngeal opening to first airway closure (LCPO). In addition to these temporal measures, the following five observations were made on the first swallow of each bolus: (a) percent of oral residue, (b) percent of pharyngeal residue, (c, d, e) percent of aspiration (c) before, (d) during, or (e) after the swallow. Number of swallows on each bolus was also noted. Inter- and intraobserver reliability on all of the temporal measures and observations was at least .82 and .98, respectively, as shown on Table 3.

All of these measures and observations were made on the first swallow of each bolus. From observations of oral and pharyngeal residue and total percent of aspiration and transit times, oral pharyngeal swallow efficiency (OPSE) was calculated by dividing the percent of bolus swallowed into the esophagus (minus any oral or pharyngeal residue and aspiration) by the total oral and pharyngeal transit time. Though OPSE is calculated on the basis of observations of residue and aspiration, the observations have high inter- and intraobserver reliability, and OPSE has been found to represent overall swallow function in various groups of dysphagic patients and normal subjects (Rademaker, Pauloski, Logemann, & Shanahan, 1994).

Statistical Analysis

Data were analyzed using two-factor repeated measures analysis of variance (ANOVA), with volume and taste as the factors. A "person" factor in the ANOVA accounted for multiple swallows observed under the same conditions. For variables that had a significant interaction between volume and taste, the volume effect was analyzed separately at the two levels of taste (stratified analysis), and the taste effect was analyzed at the two levels of volume. For variables without significant interactions, the statistical test for the main effects reflect the unstratified analysis. Analyses were conducted for the two groups separately using SAS statistical software. Least squares means are reported because of the different numbers of swallows for the different conditions. *P*-values less than .05 were considered statistically significant.

TABLE 3. Inter- and intrajudge reliability for each temporal measure and observation.

	Reliability	
	Interjudge	Intrajudge
Temporal Measures		
Onset of swallow	1.00	1.00
Oral transit time	.99	.99
Pharyngeal delay time	1.00	1.00
Pharyngeal response time	1.00	1.00
Pharyngeal transit time	1.00	1.00
Velopharyngeal closure	.98	.99
Tongue base to posterior pharyngeal contact		
at mid C2	.93	.99
at Inferior C2	.96	.99
at Superior C3	.96	.99
Hyoid movement	.82	.98
Laryngeal elevation	.94	.99
Laryngeal closure	.94	.99
Cricopharyngeal opening	.93	.98
Onset of laryngeal closure re: CP opening	.87	.98
Pharyngeal delay time	.96	.99
Observations		
Percent oral residue	.94	.99
Percent pharyngeal residue	.94	.99
Percent aspiration	1.00	1.00

Results

Analysis of Group 1 (Stroke Patients)

First, the analysis identified any significant interactions. For the patients in Group 1, significant interactions were identified for duration of cricopharyngeal opening (DCPO) and pharyngeal response time (PRT), indicating that these measures had different responses to the sour bolus, depending on the volume. On 3 ml boluses there was a significant decrease in pharyngeal response time ($p = .007$) and in duration of cricopharyngeal opening ($p = .01$) on sour as compared to non-sour boluses. This was not seen at 1 ml volume. Cricopharyngeal opening was significantly pro-

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longed as volume increased (1 ml vs. 3 ml) on non-sour boluses ($p = < .0001$). Pharyngeal response time decreased significantly ($p = .03$) as volume increased for sour boluses, and increased as volume increased for non-sour boluses, although this change was not significant.

Sour effects. For all other swallow measures with no significant interactions, data from the two bolus volumes did not require a stratified analysis. As shown in Figure 1, five swallow measures were significantly changed with the presence of the sour bolus in the Group 1 patients. Swallow onset time was significantly reduced with the sour bolus ($p = .02$), oral transit time was significantly shortened ($p = .04$), pharyngeal delay time was significantly shortened ($p = .04$), pharyngeal transit time was significantly shortened ($p = .03$), and oropharyngeal swallow efficiency was significantly increased ($p = .01$). All of these changes represent significant clinical improvement in swallow measures.

Volume effects. Because there were no interactions, sour and non-sour boluses were combined to examine volume effects. In the Group 1 patients, there were also several significant differences in swallow measures as a result of bolus volume (1 ml vs. 3 ml) (Figure 2). Specifically, oral residue increased significantly as bolus volume increased ($p = .02$), pharyngeal swallow delay significantly decreased as volume increased ($p = .007$), duration of tongue base contact to the posterior pharyngeal wall at the level of the superior aspect of C3 increased ($p = .05$), duration of airway closure increased as volume increased ($p = .01$), pharyngeal transit time significantly decreased as volume increased ($p = .01$), and the number of swallows required to clear the entire bolus increased as volume increased ($p = .03$).

Analysis of Group 2 (Other Neurologic Etiologies)

Results in the Group 2 patients were different from those in the Group 1 patients. No patient aspirated on 1 ml volumes. Three patients aspirated on 3 ml volumes of non-sour liquid. On 3 ml sour boluses, aspiration was eliminated. This change was not noted at 1 ml volumes because no aspiration occurred at this volume. On the non-sour condition, aspiration increased as bolus volume increased. This was not observed in the sour bolus conditions. Because of the small number of patients who aspirated, formal statistical analysis was not done.

Sour bolus. For all other swallow measures with no significant interactions, data on all swallows of both volumes were pooled to examine the effects of a sour bolus. In Group 2 patients, four swallow measures changed significantly with the sour bolus as compared to the non-sour bolus (see Figure 3): Onset of the oral swallow was significantly shortened with the sour bolus ($p = .01$), onset of tongue base movement to the pharyngeal wall began later with the sour bolus ($p = .03$), and duration of tongue base contact to the posterior pharyngeal wall at the level of the inferior aspect of C2 ($p = .004$) and at the superior aspect of C3 ($p = .04$) was shortened.

Volume effects. Effects of bolus volume in Group 2 were similar in some respects to these effects on the Group 1 patients. As shown in Figure 4, Group 2 patients revealed significantly reduced oral transit times ($p = .03$), and increased oral residue ($p = .03$), as bolus volume increased from 1 ml to 3 ml. Group 2 patients also exhibited reduced pharyngeal delay ($p = .02$) and reduced pharyngeal transit time ($p = .02$). OPSE increased significantly ($p = .02$) as bolus volume increased from 1 ml to 3 ml. Number of

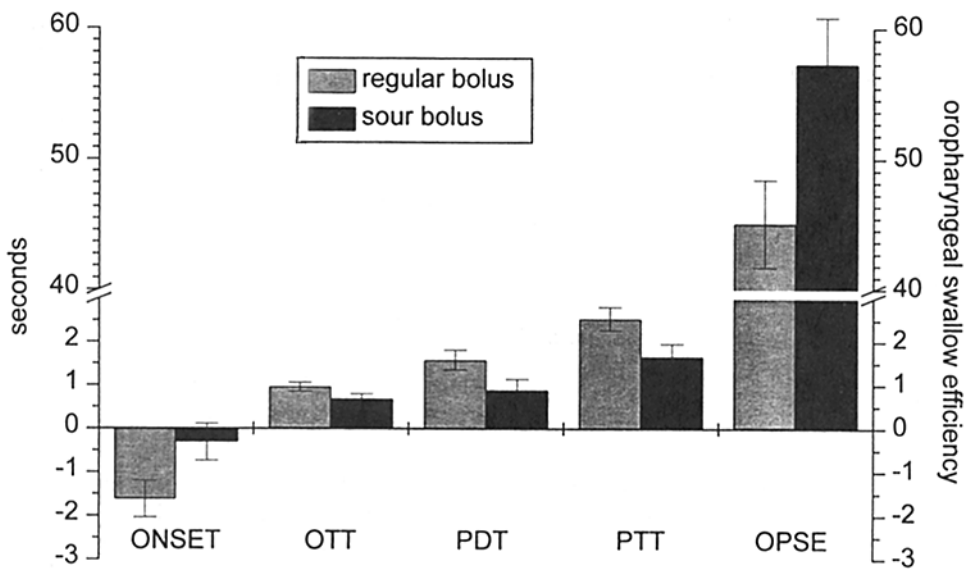

FIGURE 1. Significant mean effects (±SE) of a sour bolus on five swallow measures in Group 1 (CVA) patients: onset of the oral swallow (ONSET), oral transit time (OTT), pharyngeal delay time (PDT), pharyngeal transit time (PTT), and oropharyngeal swallow efficiency (OPSE).

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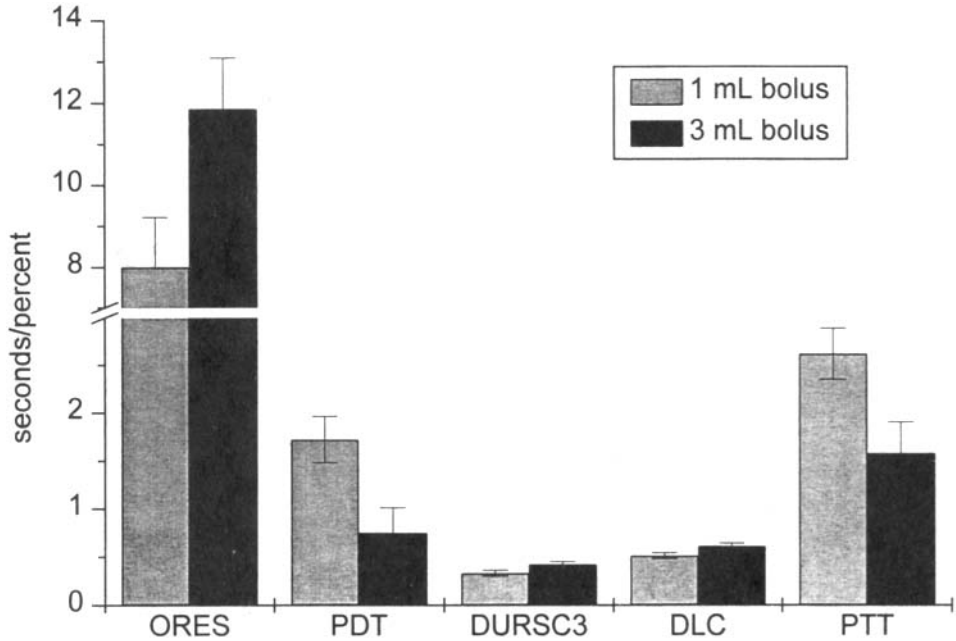

FIGURE 2. Significant mean effects (±SE) of bolus volume (1 ml and 3 ml) on five swallow measures in Group 1 (CVA) patients: oral residue (ORES), duration of pharyngeal delay (PDT), duration of tongue base contact to the posterior pharyngeal wall at the superior aspect of C3 (DURSC3), duration of laryngeal closure (DLC), and pharyngeal transit time (PTT).

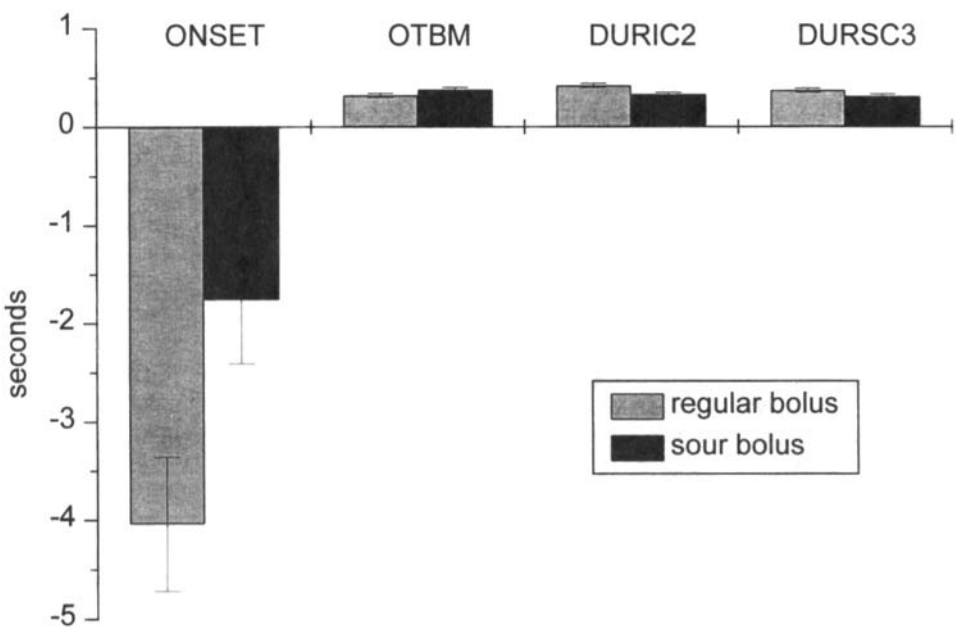

FIGURE 3. Significant mean effects (±SE) of a sour bolus on four swallow measures in Group 2 patients (mixed neurologic etiologies): onset of the oral swallow (ONSET), onset of base of tongue contact to the posterior pharyngeal wall (OTBM), duration of tongue base contact to the posterior pharyngeal wall at the level of the inferior aspect of C2 (DURIC2), and duration of tongue base contact to the posterior pharyngeal wall at the level of the superior aspect of C3 (DURSC3).

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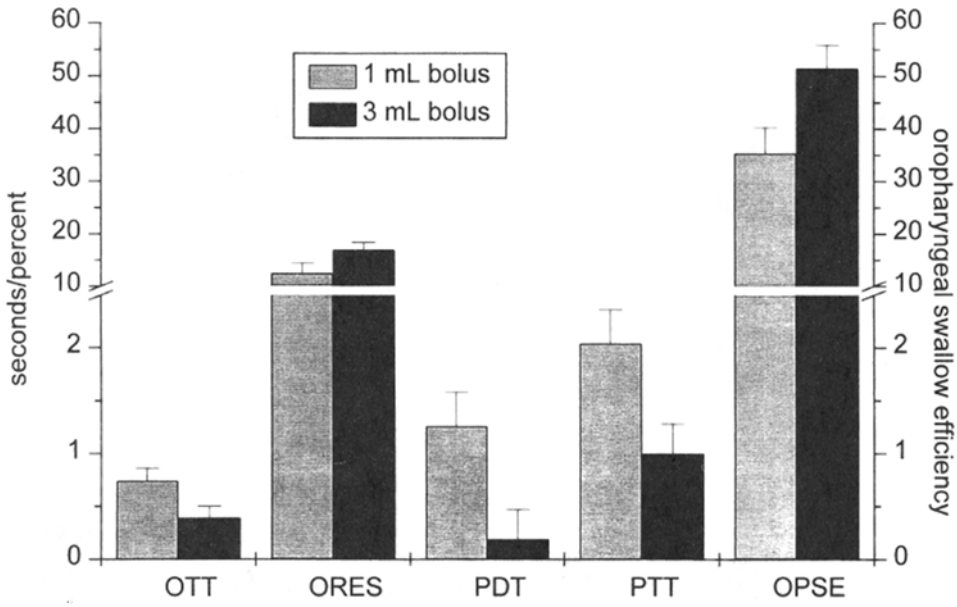

FIGURE 4. Significant mean effects (±SE) of bolus volume (1 ml and 3 ml) on five swallow measures in Group 2 patients (mixed neurologic etiologies): oral transit time (OTT), oral residue (ORES); pharyngeal delay time (PDT), pharyngeal transit time (PTT), and oropharyngeal swallow efficiency (OPSE).

swallows increased significantly (p = .04) as bolus volume increased in Group 2 patients.

Discussion

This study was designed to examine effects of the sour bolus on oropharyngeal swallow measures in patients with neurogenic dysphagia, including those whose etiology was stroke and those with other neurologic damage. Both groups of subjects revealed significantly improved onset of the oral swallow in response to the sour bolus as compared to the non-sour bolus. The subjects who had suffered a stroke (Group 1) exhibited a number of other improvements in the swallow as a result of the sour bolus, including reduced pharyngeal delay time, reduced oral transit time and pharyngeal transit time, and improved oropharyngeal swallow efficiency. The subjects in Group 2 also exhibited reduced aspiration as a result of the sour bolus. All of these changes are improvements in the oropharyngeal swallow speed and efficiency. In no case did the sour bolus significantly worsen the oropharyngeal swallow measures.

The patient groups studied were homogeneous relative to the two swallowing disorders that we hypothesized would be affected by the sour bolus, but heterogeneous in their lesion sites, age, gender, and time post onset of neurologic damage. Because this was a pilot investigation, looking to identify whether an effect occurred or not, we believed that including all consecutively referred patients with neurogenic dysphagia who exhibited the target disorders was the best way to define the effects of a sour bolus. Also, advocates for the sour/cold stimulus recommend such sensorimotor facilitation for all patients with these swallowing disorders, not a specific target population (Leopold & Kagel, 1983). Follow-up studies are now needed in more homogeneous populations to determine whether patients with specific lesions in the central nervous system respond best to sour. Because of the small sample size, analysis by lesion site was not possible.

Patient reactions to the sour bolus were uniformly negative. They found it tolerable but not pleasant. Studies with varying titrations of sour would also be helpful to identify when an optimum balance is achieved between acceptable taste and best physiologic effect. Also, examinations of a combination of the cold and sour stimulus are needed. This present study was not designed as a taste perception experiment. Rather, the sour stimulus was used to represent an intense sensory input. No other studies have examined bolus taste effects in normal or abnormal swallows. We did not compare sour to other taste stimuli, such as bitter, sweet, or salty, which may have similar effects and should be examined.

There may be several reasons for the improvement in oropharyngeal swallow physiology as a result of the introduction of a sour bolus. First, the sour bolus may rapidly increase salivation, which increases bolus volume. Increasing bolus volume, as noted in prior work (Bisch et al., 1994; Lazarus et al., 1993; Logemann, Shanahan, Rademaker, Kahrilas, Lazar, & Halper, 1993), can also reduce the pharyngeal delay time and oral transit time. However, the results of this study would argue against hypersalivation resulting from the sour effect because none of the swallow measures that are sensitive to volume effects were significantly changed by the sour bolus within the same bolus volume—except for DCPO, which diminished with the sour bolus at 3 cc in CVA patients. In the present study, bolus volume did reduce oral transit time and pharyngeal delay time, which partially supports earlier work in stroke patients (Bisch et al., 1994; Lazarus et al., 1993; Logemann et al., 1993). A second

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reason that the sour bolus may facilitate oropharyngeal swallow is the increased or differing sensory input provided by the sour taste. We believe our results support the hypothesis that the sour bolus serves as a preswallow sensory alert to the nervous system—an alert that is stronger than the presentation of normal liquid barium. A very recent study by Issa (in press) in which 4 dogs were infused with tap water, saline, glucose, and acetic acid during sleep and wakefulness using a special feeding tube indicates that an acetic acid solution elicited swallows of the shortest latency in all experimental conditions: perfusion on the anterior tongue, posterior tongue, or during sleep. Though all taste receptor cells are capable of responding to more than one taste (McLaughlin & Margolskee, 1994), receptor cells at the sides of the tongue are more sensitive to sour substances. Cell bodies of the first group of sensory receptors project to the brain via the facial nerve and the chorda tympani or greater (superficial) petrosal nerve and the otic ganglion. These taste fibers project to the rostral part of the nucleus tractus solitarius (NTS), the region of the medulla thought to be important in the identification of a swallow stimulus. In the NTS, second-order relay neurons project to neurons in the pons, which in turn project to the thalamus, lateral hypothalamic area, and amygdala. From the thalamus the fibers project to the sensory cortex located below the face (Netter, 1986). With these neural pathways for taste, a strong taste such as sour may well serve as an alerting stimulus to the brainstem and cortical swallowing centers, accounting for the significant improvements in timing measures of the swallow observed in this study.

The bolus volume effects seen in this study in the Group 1 patients were similar to those reported in other studies (i.e., prolongation in duration of cricopharyngeal opening and airway closure as bolus volume is increased). Changes in these measures related to volume were not seen in the Group 2 patients. This may have related to the heterogeneity of this patient group, which represented a variety of types of neurologic damage. Clearly, this study should be replicated with a number of more homogeneous patient groups before conclusions regarding the effects of neurologic damage on volume regulation can be made.

This study has some important clinical implications. Presentation of small (1 ml) amounts of sour liquid may facilitate swallowing function in neurologically impaired patients as a part of a therapy protocol. Presentation of sugarless sour candies versus other types of sugarless candy may facilitate oral management of secretions and improved and more frequent swallowing of saliva. Clearly, a variety of therapeutic protocols with sour boluses and other types of sour stimuli need to be designed and investigated. However, the results of this pilot investigation are encouraging and indicate the importance of further investigations into the effects of bolus taste on normal and abnormal oropharyngeal swallow physiology.

Acknowledgments

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