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Effects of enhanced bolus flavors on oropharyngeal swallow in patients treated for head and neck cancer

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Abstract

Background—Treatment for head and neck cancer can reduce peripheral sensory input and impair oropharyngeal swallow. This study examined the effect of enhanced bolus flavor on liquid swallows in these patients.

Methods—Fifty-one patients treated for head and neck cancer with chemoradiation or surgery and 64 healthy adult control subjects served as subjects. All were randomized to receive sour, sweet, or salty bolus flavor. Patients were evaluated at 7–10 days, 1 month, and 3 months after completion of tumor treatment. Control subjects received 1 assessment.

Results—All bolus flavors affected oropharyngeal swallow; sour flavor significantly shortened pharyngeal transit time across all evaluations.

Conclusions—Sour flavor influenced the swallow of patients treated for head and neck cancer, as well as that of control subjects in a manner similar to those with neurologic impairment observed in an earlier study. Sour flavor may improve the speed of pharyngeal transit regardless of whether a patient has suffered peripheral or central sensory damage.

Keywords

dysphagia; sensory; flavor; videofluorography; head and neck cancer

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INTRODUCTION

Despite the importance of flavors to our appetite, interest, and pleasure in eating, there have been very few studies of the effects of flavors of food on swallowing physiology.[1–3] In contrast, there are a number of studies of other bolus characteristics and their systematic effects on oropharyngeal swallow, particularly bolus volume and viscosity.[4–7] Peripheral taste receptors are directly linked neurologically to the nucleus tractus solitarius in the brainstem, one of the key swallowing centers believed to serve as the recognition center for sensory input from the periphery. Earlier work in our laboratory demonstrated that patients who had had central neurologic impairment affecting swallow exhibited significant improvement in the sensory aspects of the oropharyngeal swallow, that is, the onset of the oral stage and the triggering of the pharyngeal swallow with a sour bolus.[1] We hypothesized that enhancing the flavor of the bolus provides heightened sensation to the brainstem, alerting it to the need for a swallow both in the mouth and in the pharynx. On the basis of the our earlier research[7,8] with patients who exhibited dysphagia because of central neurologic impairment and the work of others,[9] we hypothesized that similar improvement in the sensory aspects of swallow would result from enhancing the flavor of the food to be swallowed in patients who had experienced peripheral sensory loss because of treatment for head and neck cancer. Chemotherapy and radiation for head and neck cancer can affect sensory nerve endings in the mouth, whereas surgical procedures involving the oral cavity and tongue can remove or damage sensory nerve endings. We hypothesized that delayed onset of the swallow and pharyngeal delay time would be diminished in patients treated for head and neck cancer, as it was in patients with central nervous system damage[1] when the flavor of the bolus was enhanced. The aim of this study was to define the effects of enhanced bolus flavors on oropharyngeal swallow physiology in patients treated for head and neck cancer and a group of healthy control subjects.

METHODS AND MATERIALS

Subjects

The study protocol was approved by the Institutional Review Board of all participating institutions: Northwestern University, University of Miami, University of Tennessee College of Medicine, and Edward Hines, Jr. Veterans Administration Medical Center. Subjects included 51 consecutive patients between the ages of 36 and 76 (mean age, 57 years), 44 men and 7 women, who had undergone treatment for head and neck cancer with primary radiotherapy ± chemotherapy or primary surgery. Table 1 presents each patient's age, sex, tumor site, T/N/M classification, nature of treatment (surgery, primary radiotherapy ± chemotherapy), and specific chemotherapeutic agents if applicable. Twenty patients were treated with primary radiation ± chemotherapy, and 31 were treated with surgery ± radiation/chemotherapy (7 supraglottic laryngectomy, 12 anterior composite resection, and 12 posterior composite resection). None of the surgical patients received sensate flaps. Sixty-four control subjects (52 men and 12 women) had a mean age of 56 (range, 28–76 years).

Study protocol

Subjects were examined by use of the modified barium swallow procedure with videofluoroscopy. Each was randomized to receive a swallow study protocol that included baseline swallows of thin liquid barium 3 mL and 10 mL and salty, sweet, or sour thin liquid barium preparations 3 mL and 10 mL. Two trials of each volume and flavor were given. For patients treated for head and neck cancer, the protocol included 3 assessment points: (1) at 7 to 10 days after treatment completion (first posttreatment); (2) 1 month after treatment completion; and (3) 3 months after treatment completion. Posttreatment testing times were measured from the completion of primary treatment (ie, after surgery or after completion of all primary chemoradiotherapy). Healthy control subjects received a single assessment. The videofluoroscopy studies were conducted in the lateral plane according to the procedure outlined by Logemann[10] in 1993 and recorded on videotape.

Recipes for the 3 flavors were as follows: (1) sour bolus: 1/4 cup liquid barium and 1/4 cup RealLemon Brand lemon juice (Dr Pepper Snapple Group, Inc., Plano, TX) at room temperature; (2) sweet bolus: 1/4 cup liquid barium, 1/4 cup water at room temperature, and 2 mL Sweet ‘N Low Brand liquid sweetener (Cumberland Packing Corporation, Brooklyn, NY); (3) salty bolus: 1/4 cup liquid barium, 1/4 cup water at room temperature, and 1/2 teaspoon table salt.

At each evaluation point, patients also received a xerostomia assessment by use of weight of stimulated saliva. Stimulated whole-mouth saliva production (from all salivary glands) was quantified by taking the difference of the weight of a 4-inch by 4-inch sterile gauze pad before and after chewing for 2 minutes.[11] Weight was reported in grams. Lower saliva weight indicates greater salivary dysfunction.

Data reduction

The main outcome measures were oral onset time, oral transit time, pharyngeal transit time, and pharyngeal delay time. We hypothesized that heightening oral sensation by intensifying bolus flavor would have a significant effect on these measures of the swallow. Videotapes of the swallow studies were viewed in slow motion and frame-by-frame to obtain timing information to compute the swallowing outcome measures as follows: onset of oral swallow, time in seconds from the command to “Swallow now” until the onset of the oral swallow (first backward movement of the bolus); oral transit time, the time in seconds it takes the bolus to move through the oral cavity, measured from the first backward movement of the bolus until the head of the bolus passes the point where the ramus of the mandible crosses the tongue base; pharyngeal delay time, the time in seconds required to trigger the pharyngeal swallow, measured from the time the head of the bolus passes the ramus of the mandible until the onset of laryngeal elevation; and pharyngeal transit time, the time in seconds required for the bolus to move through the pharynx, measured from the time the head of the bolus passes the ramus of the mandible until the tail of the bolus leaves the cricopharyngeal region.

Ten percent of the swallows were randomly selected for reanalysis by the same research technician and a second research technician as a measure of intrajudge and interjudge

reliability. Average interobserver and intraobserver reliability for these judgments were 0.94 and 0.99, respectively.

Statistical analysis

With SAS statistical software (SAS Institute, Cary, NC),[12] a linear model analysis was used to assess the joint significance of the flavor effect (no flavor, with flavor), group (patient, control subject), and bolus size (3 mL, 10 mL). Separate analyses were performed by type of flavor and evaluation point. The analysis took into account that there were 4 conditions repeated within person (3 mL no flavor, 3 mL with flavor, 10 mL no flavor, 10 mL with flavor) and that patients and control subjects were different people. The variance structure of the repeated measures was modeled as compound symmetry, meaning that any 2 measurements within person had the same correlation, but were uncorrelated with measurements from another person. The linear model included all main effects (flavor, group, size), as well as all 2-factor interactions and the 3-factor interaction. Significance of the main effects or interactions was indicated when $p < .05$.

RESULTS

Twenty-one patients and 20 control subjects were randomized to the sour flavor protocol; 15 patients and 22 control subjects were randomized to the sweet flavor protocol; and 15 patients and 22 control subjects were randomized to the salty flavor protocol. Not all patients were able to complete all 3 evaluations. Table 2 summarizes the number of patients who participated in each evaluation. Data from the single control subject evaluations were used to compare to the patient data at each patient evaluation point.

Analysis of xerostomia level in the patients as represented by the weight of chewed gauze in a stimulated whole-mouth saliva task indicated that there were no significant differences among the patient flavor groups, that is, by sour, sweet, or salty flavor protocols ($p = .46$). Therefore any impact that xerostomia might have had on the effects of enhanced bolus flavor were not a confounding factor because there were no differences in xerostomia level by patient flavor groups. Swallow outcome measures with significant 3-way and 2-way interactions were interpreted before investigation of the main effects of bolus flavor, subject group, or bolus size.

Interaction effects

Three-way interaction of flavor by group by size—For pharyngeal delay time, there was a significant 3-way interaction of flavor by group by bolus size for the salty bolus condition at the first posttreatment evaluation. Table 3 presents the summary statistics separately by subject group. Patients demonstrated a shorter pharyngeal delay time as a function of bolus size for the salty flavored bolus, with less of a delay for the 3-mL bolus ($p = .0006$). The patients did not demonstrate an effect of bolus size for the unflavored bolus ($p = .60$). Patients also demonstrated an effect for bolus flavor that varied by bolus size: for the 3-mL bolus, the salty bolus had a shorter pharyngeal delay ($p = .05$), but for the 10-mL size, the salty bolus had a longer pharyngeal delay time when compared with the unflavored bolus ($p = .016$). There was no effect of bolus size or flavor for the control subjects.

Two-way interactions

Flavor by bolus size—The salty bolus was the only flavor condition that demonstrated significant 2-way interactions between bolus flavor and bolus size. Table 4 presents the summary statistics for the swallow outcome measures for the salty bolus that had significant interactions. At the first posttreatment evaluation, pharyngeal transit time and pharyngeal delay time varied as a function of flavor and size. For pharyngeal transit time and pharyngeal delay time, the effect of bolus size was significant for the salty flavor only, with longer durations on the 10-mL bolus ($p = .025$ and $p = .0007$, respectively). Pharyngeal delay time also demonstrated an effect of bolus flavor on the 10-mL bolus size only, with the salty flavor having a longer delay time ($p = .013$).

Pharyngeal transit time also demonstrated a significant flavor by bolus size interaction at the 1-month posttreatment evaluation. The effect of bolus size was significant for the salty flavor only, with longer transit time on the 10-mL bolus ($p = .0007$). The effect of bolus flavor was significant on the 10-mL bolus size only, with the salty flavor having a longer transit time ($p = .0013$).

At 3 months after treatment, swallow onset time varied by bolus flavor and bolus size, with the effect of flavor significant for the 3-mL size; the salty bolus had a longer swallow onset time ($p = .004$).

Flavor by group—The salty bolus condition also demonstrated a significant flavor by group interaction at the 1-month posttreatment evaluation for pharyngeal transit time (Table 5). The effect of group was significant for both the salty and unflavored bolus, with the control subjects demonstrating significantly shorter pharyngeal transit times ($p = .0006$ and $p = .035$ respectively). The effect of flavor was significant for the patients only, with longer pharyngeal transit time on the salty bolus ($p = .018$).

Group by bolus size—Table 6 presents the summary statistics for those swallow outcome measures that demonstrate a significant subject group by bolus size interaction. Oral transit time at the 1-month posttreatment evaluation, pooled over bolus flavor for the sweet condition, showed a significant effect of group for the 3-mL bolus size only ($p = .013$), with control subjects having shorter oral transit time. There was also a significant bolus size effect for the patients only ($p = .038$), who had shorter oral transit time on the 10-mL bolus.

Pharyngeal delay time at 3 months after treatment also demonstrated a significant group by bolus size interaction when pooled over the sweet bolus condition. The effect of bolus size was significant for patients only with a shorter delay on the 10-mL bolus ($p = .0008$). Also at 3 months after treatment, oral transit time demonstrated a significant group by bolus size interaction. For patients only, the bolus size effect was significant with shorter oral transit time on the 10-mL bolus size ($p = .025$).

Main Effects

Bolus flavor effect—Table 7 summarizes the main effect of bolus flavor; data were pooled over group and bolus size for this analysis. At all 3 evaluation points (first

posttreatment, 1 month after treatment, and 3 months after treatment), the main effect of sour flavor was significant for pharyngeal transit time, which was faster on boluses with the sour flavor when compared with unflavored boluses. The main effect of sweet flavor was significant at the first posttreatment evaluation for pharyngeal transit time, which was faster on boluses with the sweet flavor when compared with unflavored boluses. At the 1-month post-treatment evaluation, the main effect of flavor for the salty bolus was significant for swallow onset, which was significantly longer for the salty bolus when compared with the unflavored bolus.

Group effect—Table 8 summarizes the main effect of subject group; data were pooled over bolus flavor and bolus size for this analysis. For the sour bolus condition, the main effect of group (patients vs control subjects, pooled over flavor and bolus size) was significant for oral transit time at all 3 evaluation points and for pharyngeal transit time at the first posttreatment and 1-month posttreatment evaluations. Both oral transit time and pharyngeal transit time were significantly shorter for the control subjects. At the 3-month posttreatment evaluation, the main effect of group also was significant for pharyngeal delay time, with control subjects demonstrating a significantly shorter delay time when compared with patients. The main effect of group was also significant at the first posttreatment evaluation for the sweet and salty conditions for oral transit time, which was significantly shorter for the control subjects.

Bolus size effect—Table 9 summarizes the main effect of bolus size; data were pooled over bolus flavor and subject group for this analysis. For the sour bolus condition, the main effect of bolus size (3 mL vs 10 mL) was significant for oral transit time, which was shorter for the 10-mL bolus at all evaluation points. For the sweet bolus condition, the main effect of bolus size was significant for swallow onset time at the first posttreatment evaluation and for pharyngeal delay time at the 1-month post-treatment evaluation. Swallow onset was earlier and pharyngeal delay time was shorter for the 10-mL bolus.

DISCUSSION

An earlier study from this research group that focused on the effect of a sour bolus on swallow function in patients with dysphagia resulting from central nervous system damage[1] found significant improvements in 2 measures of swallow (shorter oral onset time and shorter pharyngeal delay time). This study also indicated that manipulation of bolus flavor had a positive impact on the temporal aspects of bolus transit in treated head and neck cancer patients with peripheral damage. Flavor enhancement with sour or sweet affected pharyngeal transit time in particular, shortening it in comparison to swallows of unflavored boluses (Table 7). The sour bolus in particular consistently reduced pharyngeal transit time in patients treated for head and neck cancer across all 3 evaluation points, as well as in healthy control subjects. The sweet bolus also shortened pharyngeal transit time but only within the first week after completion of cancer treatment. Only the sour bolus had a positive effect on the swallow at 3 months after treatment. The salty bolus flavor appeared to have a negative effect on the swallow, resulting in longer swallow onset times, longer pharyngeal delay, and longer pharyngeal transit times when compared with the unflavored bolus. In other research, an infusion of salt solution to the pharyngeal region has been

demonstrated to prolong the swallow interval, resulting in a prolonged swallow,[13] as observed in this study. The salty flavor is often used as an aversive stimulus in comparative studies of taste.[14] The negative influence of the salty flavor in this study was especially apparent on the 10-mL bolus; possibly the large volume of salty liquid was sufficiently aversive that the subjects hesitated to swallow it. This is speculative, however, because we did not ask the subjects for their impressions of the flavors.

Unlike our previous work with a sour bolus in patients with central nervous system damage, sour did not speed the onset of the swallow in patients treated for head and neck cancer. This result suggests a difference between patients whose sensory damage is peripheral (patients with head and neck cancer) and those whose problem with sensory recognition is central in processing. Although increasing peripheral sensory input with intensified flavor does have a positive impact on the speed of pharyngeal transit, it does not seem to improve central recognition of the swallow stimulus in patients with peripheral damage for the onset of the swallow.

This study investigated the effect of several bolus flavors at 3 evaluations spanning up to 3 months after treatment completion in an effort to determine whether the response to enhanced bolus flavor, if any, would persist over time. The sour bolus was the only flavor that demonstrated a consistent and positive effect over time, with the sour flavor resulting in a shorter pharyngeal transit time at all 3 evaluation points. The sweet bolus flavor also elicited a shorter pharyngeal transit time at the first posttreatment evaluation only; this positive effect did not persist over time as it did for the sour bolus flavor. Conversely, the salty bolus flavor had a negative impact on the swallow, resulting in longer pharyngeal transit times and longer pharyngeal delay times on the 10-mL bolus at the first posttreatment and 1-month posttreatment evaluations. This negative finding did not persist at the 3-month posttreatment evaluation. Accommodation to sweet and salty tastes within a single testing session has been reported in other investigations,[15–18] whereas response to sour did not decline.[16] It is possible that subjects accommodated to the sweet and salty tastes to the extent that the flavors no longer made an impact on the swallow over the 3-month study period. The persistence of the positive effect of the sour bolus over time is a novel finding in this study.

As would be expected, there were some significant differences in swallow measures between patients and control subjects. Healthy control subjects had shorter oral transit times, shorter pharyngeal transit times, and shorter delay times when compared with the patients when pooled over bolus flavor and size. These results are consistent with previous work comparing patients treated for head and neck cancer and control subjects.[19,20] Swallow measures also varied systematically by bolus size. With the exception of measures from the salty bolus, swallows of the 10-mL bolus size were characterized by shorter swallow onset time, shorter oral transit times, and shorter pharyngeal delay times. These changes with bolus volume are consistent with those observed in our previous work.[7,8,21,22]

The results of this study and our previous work with the sour bolus[1] highlight the importance of examining the impact of taste during a diagnostic imaging study such as the modified barium swallow procedure. If a patient demonstrates improvements in the

oropharyngeal swallow while using a bolus flavor, then that enhancement could possibly be introduced in feeding management of the patient. Further studies of enhanced sensory input also are needed with other bolus variables, including textured boluses, carbonated boluses, and other more complex flavors in carefully defined groups of patients with various loci or types of central nervous system damage and peripheral oral/pharyngeal damage. Studies of larger groups of patients with head and neck cancer with a similar treatment paradigm by use of flavors would also be valuable, as would studies with carbonation, menthol, or bitter flavor.[2,3,9] No information was available concerning patient report of dysgeusia or hypergeusia in this study. This information was not collected as part of the protocol and the case report forms did not include any patient comments concerning taste issues. This type of information would be very important to collect in future studies of taste effects. It is also important to assess subject acceptance of various bolus enhancements as patient preference would be expected to have an impact on our ability to integrate flavor or textural changes that have a positive impact on the oropharyngeal swallow into patient diet.

Acknowledgments

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TABLE 1

Age, sex, tumor site, T/N/M classification, type of treatment received, total radiation dose in cGy, and chemotherapy (chemo) drugs used for the 51 patients.

Subject no.	Age	Sex	Tumor site	T/N/M classification	Primary surgery or RT±chemo	Total RT delivered dose, cGy	Chemo (y/n)	Chemotherapy drugs
1	52	Male	Hypopharynx	T2N2cM0	RT	7050	N	
2	69	Male	Larynx	T2N0M0	RT	6500	N	
3	58	Male	Oropharynx	T1N2aM0	RT	5400	N	
4	74	Male	Oropharynx	T2N2aM0	RT	7400	N	
5	54	Male	Hypopharynx	T3N1M0	RT/Chemo	7000	Y	Cisplatin
6	54	Male	Hypopharynx	T4N3M0	RT/Chemo	7040	Y	Cisplatin
7	36	Male	Larynx	T2N2cM0	RT/Chemo	7345	Y	HU, 5-FU, paclitaxel
8	61	Male	Larynx	T3N0M0	RT/Chemo	6900	Y	HU, 5-FU
9	59	Male	Larynx	T3N0M0	RT/Chemo	7000	Y	Cisplatin
10	71	Male	Nasopharynx	T4N3M0	RT/Chemo	7570	Y	HU, 5-FU, cisplatin
11	50	Female	Nasopharynx	T3N2cM0	RT/Chemo	7000	Y	HU, 5-FU, paclitaxel, epoetin alfa
12	63	Male	Oral cavity	T4N2cM0	RT/Chemo	6000	Y	Cisplatin
13	56	Male	Oropharynx	T4N2cM0	RT/Chemo	7200	Y	Cisplatin
14	66	Male	Oropharynx	T2N0M0	RT/Chemo	7350	Y	HU, 5-FU, paclitaxel
15	60	Male	Oropharynx	T3N2bM0	RT/Chemo	7000	Y	Cisplatin
16	52	Male	Oropharynx	T3N2bM0	RT/Chemo	6630	Y	Cisplatin
17	43	Male	Oropharynx	T4N0M0	RT/Chemo	7000	Y	Cisplatin
18	69	Male	Oropharynx	T3N2aM0	RT/Chemo	7000	Y	Cisplatin
19	47	Male	Oropharynx	T2N3M0	RT/Chemo	7350	Y	HU, 5-FU, paclitaxel
20	64	Female	Oropharynx	T3N0M0	RT/Chemo	7050	Y	HU, 5-FU
21	68	Male	Hypopharynx	T2N0M0	Surgery	6000	N	
22	49	Male	Larynx	T2N2bM0	Surgery	6000	Y	cisplatin
23	41	Male	Larynx	T3N0M0	Surgery	0	N	
24	60	Male	Larynx	T3N1M0	Surgery	6000	N	
25	62	Male	Larynx	T2N0M0	Surgery	6480	N	
26	76	Female	Larynx	T2N0M0	Surgery	0	N	
27	74	Male	Larynx	T2N2cMx	Surgery	6000	N	

Subject no.	Age	Sex	Tumor site	T/N/M classification	Primary surgery or RT±chemo	Total RT delivered dose, cGy	Chemo (y/n)	Chemotherapy drugs
28	47	Male	Larynx	T2N2bM0	Surgery	5940	N	
29	40	Male	Oral cavity	T4N2bM0	Surgery	4500	N	
30	48	Male	Oral cavity	T2N2bM0	Surgery	1600	N	
31	50	Male	Oral cavity	T4N2cM0	Surgery	6000	N	
32	50	Male	Oral cavity	T1N0M0	Surgery	0	N	
33	52	Female	Oral cavity	T4N0M0	Surgery	5150	N	
34	52	Male	Oral cavity	T2N2aM0	Surgery	6640	N	
35	56	Male	Oral cavity	T4N0M0	Surgery	6480	N	
36	67	Male	Oral cavity	T2N0M0	Surgery	6300	N	
37	70	Male	Oral cavity	T3N0M0	Surgery	6480	N	
38	71	Male	Oral cavity	T3N2bM0	Surgery	7000	N	
39	52	Male	Oral cavity	T3N1M0	Surgery	6760	N	
40	67	Male	Oral cavity	T3N1M0	Surgery	0	N	
41	64	Male	Oropharynx	T3N2bM0	Surgery	6660	Y	5-FU, cisplatin
42	44	Female	Oropharynx	T3N3M0	Surgery	5760	N	
43	51	Female	Oropharynx	T3N3M0	Surgery	0	N	
44	51	Male	Oropharynx	T3N2bM0	Surgery	6000	N	
45	51	Male	Oropharynx	T3N2M0	Surgery	6300	N	
46	54	Male	Oropharynx	T3N2bM0	Surgery	6480	N	
47	56	Male	Oropharynx	T4N2bM0	Surgery	6600	N	
48	61	Male	Oropharynx	T3N2cM0	Surgery	6600	N	
49	62	Male	Oropharynx	T1N2aM0	Surgery	5940	N	
50	70	Male	Oropharynx	T3N0M0	Surgery	5960	N	
51	50	Female	Oropharynx	T2N2bM0	Surgery	5940	N	

Abbreviations: RT, radiation; CHEMO, chemotherapy; HU, hydroxyurea; 5-FU, fluorouracil.

TABLE 2

Number of patients at each evaluation point by swallow protocol.

Evaluation point	Sour protocol	Sweet protocol	Salty protocol
First posttreatment	16	9	10
One month after treatment	15	9	9
Three months after treatment	15	9	8

TABLE 3

Means, SE, and *p* values for the 3-way interaction among bolus flavor, subject group, and bolus size for the salty bolus at the first posttreatment evaluation for pharyngeal delay time(s).

	Bolus size				
Flavor condition	**3 mL**	**10 mL**	**Difference**	**SE**	***p* value**
Patients					
No flavor	−0.201	−0.241	−0.040	0.074	.60
Salty flavor	−0.344	−0.020	0.324	0.083	.0006
Difference	−0.143	0.221			
SE	0.070	0.086			
Flavor *p* value	0.05	0.016			
Control subjects					
No flavor	−0.036	−0.052	−0.016	0.045	.72
Salty flavor	−0.052	−0.013	0.038	0.046	.40
Difference	−0.016	0.039			
SE	0.045	0.045			
Flavor *p* value	0.72	0.39			

Abbreviation: SE, standard error.

Statistics are based on a total of 235 swallows in 32 people (10 patients and 22 control subjects).

TABLE 4

Means, SE, and *p* values for the 2-way interaction of salty bolus flavor and bolus size, pooled over subject group.

	Bolus size				
	3 mL	**10 mL**	**Difference**	**SE**	***p* value**
First posttreatment evaluation*					
Pharyngeal transit time(s)					
No flavor	0.828	0.806	−0.022	.030	.47
Salty flavor	0.772	0.850	0.078	.033	.025
Difference	−0.055	0.044	0.099		
SE	0.028	0.033			
Flavor *p* value	.062	.20			
Pharyngeal delay time(s)					
No flavor	−0.112	−0.147	−0.028	0.043	.52
Salty flavor	−0.198	−0.017	0.182	0.047	.0007
Difference	−0.080	0.130	0.210		
SE	0.041	0.049			
Flavor *p* value	.066	.013			
One-month posttreatment evaluation†					
Pharyngeal transit time(s)					
No flavor	0.887	0.873	−0.014	0.034	.68
Salty flavor	0.861	1.008	0.147	0.038	.0007
Difference	−0.026	0.135	0.161		
SE	0.035	0.037			
Flavor *p* value	.47	.0013			
Three-month posttreatment evaluation‡					
Swallow onset time(s)					
No flavor	−1.021	−0.778	0.243	0.135	.083
Salty flavor	−0.589	−0.839	−0.242	0.136	.088
Difference	0.427	−0.061	0.488		
SE	0.135	0.135			
Flavor *p* value	.004	.66			

Abbreviation: SE, standard error.

[*] Statistics are based on a total of 235 swallows in 32 people (10 patients and 22 control subjects).

[†] Statistics are based on a total of 236 swallows in 31 people (9 patients and 22 control subjects).

[‡] Statistics are based on a total of 224 swallows in 30 people (8 patients and 22 control subjects).

TABLE 5

Means, SE, and *p* values for the 2-way interaction of salty bolus flavor and subject group, pooled over bolus size.

	One-month posttreatment evaluation				
Pharyngeal transit time(s)	**Patients**	**Control subjects**	**Difference**	**SE**	***p* value**
No flavor	0.952	0.808	0.144	0.065	.035
Salty flavor	1.063	0.806	0.257	0.067	.0006
Difference	0.111	−0.002	0.113		
SE	0.044	0.026			
Flavor *p* value	.018	.93			

Abbreviation: SE, standard error.

Statistics are based on a total of 236 swallows in 31 people (9 patients and 22 control subjects).

TABLE 6

Means, SE, and *p* values for the 2-way interaction of subject group and bolus size, pooled over bolus flavor.

	Group				
	Patients	**Control subjects**	**Difference**	**SE**	***p* value**
1-Month posttreatment evaluation: sweet bolus condition*					
Oral transit time(s)					
3-mL bolus	0.448	0.249	0.199	0.076	.013
10-mL bolus	0.311	0.310	0.001	0.076	.982
Difference	−0.137	0.060	0.198		
SE	0.063	0.039			
Bolus size *p* value	.039	.134			
Three-month posttreatment evaluation: sweet bolus condition†					
Pharyngeal delay time(s)					
3-mL bolus	0.073	−0.002	0.075	0.105	.482
10-mL bolus	−0.133	−0.058	−0.075	0.107	.490
Difference	−0.206	−0.056	0.150		
SE	0.055	0.033			
Bolus size *p* value	.0008	.101			
Three-month posttreatment evaluation: salty bolus condition‡					
Oral transit time(s)					
3-mL bolus	0.366	0.304	0.062	0.064	.344
10-mL bolus	0.223	0.336	−0.113	0.065	.092
Difference	−0.143	0.031	0.174		
SE	0.060	0.036			
Bolus size *p* value	.025	.392			

Abbreviation: SE, standard error.

*Statistics are based on a total of 235 swallows in 32 people (10 patients and 22 control subjects).

†Statistics are based on a total of 234 swallows in 31 people (9 patients and 22 control subejcts).

‡Statistics are based on a total of 232 swallows in 30 people (8 patients and 22 control subjects).

TABLE 7

Means, SE, and *p* values for the main effects of bolus flavor (unflavored barium vs flavored barium) pooled over group and bolus size for each of the posttreatment swallow evaluations.

Evaluation point	No. of people	No. of swallows	No flavor	Flavor	Difference	SE	*p* value
Sour bolus							
First posttreatment pharyngeal transit(s)	36	261	0.95	0.83	−0.12	0.04	.011
1-Month posttreatment pharyngeal transit(s)	35	259	0.93	0.80	−0.13	0.04	.001
3-Month posttreatment pharyngeal transit(s)	35	252	0.89	0.79	−0.10	0.03	.0007
Sweet bolus							
First posttreatment pharyngeal transit(s)	31	225	0.9	0.8	−0.10	0.03	.006
Salty bolus							
1-Month posttreatment swallow onset(s)	31	223	−1.02	−0.74	0.28	0.1	.007

Abbreviation: SE, standard error.

TABLE 8

Means, SE, and *p* values for the main effects of group (patients vs control subjects) pooled over flavor and bolus size for each of the posttreatment swallow evaluations.

			Group				
Evaluation point	**No. of people**	**No. of swallows**	**Control subjects**	**Patients**	**Difference**	**SE**	***p* value**
Sour bolus							
First posttreatment							
Oral transit time(s)	36	270	0.25	0.41	0.16	0.06	.01
Pharyngeal transit time(s)	36	261	0.78	1.01	0.23	0.09	.022
1 Month after treatment							
Oral transit time(s)	35	259	0.25	0.46	0.21	0.07	.004
Pharyngeal transit time(s)	35	259	0.78	0.95	0.17	0.07	.03
3 Months after treatment							
Oral transit time(s)	35	260	0.25	0.41	0.16	0.05	.002
Pharyngeal delay time(s)	35	264	0.06	−0.12	−0.18	0.08	.04
Sweet bolus							
First posttreatment							
Oral transit time(s)	31	225	0.28	0.48	0.20	0.09	.04
Salty bolus							
First posttreatment							
Oral transit time(s)	32	233	0.32	0.55	0.23	0.09	.01

Abbreviation: SE, standard error.

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TABLE 9

Means, SE, and *p* values for the main effects of bolus size (3 mL vs 10 mL) pooled over flavor and group for each of the posttreatment swallow evaluations.

Evaluation point	No. of people	No. of swallows	3 mL	10 mL	Difference	SE	*p* value
Sour bolus							
First posttreatment							
Oral transit time(s)	36	270	0.39	0.27	−0.12	0.03	.0002
1 Month after treatment							
Oral transit time(s)	35	259	0.41	0.30	−0.11	0.03	.0006
3 Months after treatment							
Oral transit time(s)	35	260	0.37	0.29	−0.08	0.03	.038
Sweet bolus							
First posttreatment							
Swallow onset time(s)	31	197	−0.87	−1.34	−0.47	0.17	.015
1 treatment Month after							
Pharyngeal delay time(s)	31	236	−0.03	−0.14	−0.11	0.03	.004

Abbreviation: SE, standard error.