Effects of Change in Tongue Pressure and Salivary Flow Rate on Swallow Efficiency Following Chemoradiation Treatment for Head and Neck Cancer

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Abstract

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Purpose—Patients treated with chemoradiation for head and neck cancer frequently develop dysphagia. Tissue damage to the oral tongue causing weakness and decreases in saliva production may contribute to dysphagia. Yet, effects of these variables on swallowing-related measures are unclear. The purpose of this study was (1) to determine effects of chemoradiation on tongue pressures, as a surrogate for strength, and salivary flow rates and (2) to elucidate relationships among tongue pressures, saliva production, and swallowing efficiency by bolus type.

Methods and Materials—21 patients with head and neck cancer treated with chemoradiation were assessed before and after treatment and matched with 21 healthy control participants who did not receive chemoradiation. Each participant was given a questionnaire to rate dysphagia symptoms. Videofluoroscopic evaluation of swallowing was used to determine swallowing efficiency; the Saxon test measured salivary flow rate; and the Iowa Oral Performance Instrument (IOPI) was used for oral tongue maximum and endurance measures.

Results—Results revealed significantly lower tongue endurance measures for patients post-treatment as compared to controls (p=.012). Salivary flow rates also were lower compared to pre-treatment (p=.000) and controls (p=.000). Simple linear regression analyses showed that change in salivary flow rate was predictive of change in swallow efficiency measures from pre- to post-treatment for 1mL thin liquid (p=.017), 3mL nectar-thick liquid (p=.026), and 3mL standard barium pudding (p=.011) boluses.

Conclusions—Based on these findings, it appears that chemoradiation treatment affects tongue endurance and salivary flow rate and these changes may impact swallow efficiency. These factors should be considered when planning treatment for dysphagia.

Introduction

Patients with head and neck cancer who receive chemoradiation treatment frequently develop dysphagia, or swallowing dysfunction, as a result of radiation-induced fibrosis to the critical tissues of the head and neck region [1–3]. The oral tongue is a critical structure involved in the coordination of a successful swallow and often is included in the radiation field during head and neck cancer treatment. Lingual necrosis and decreased lingual strength may result from radiotherapy to the oral tongue, base of tongue, or oropharynx [4,5]. If oral tongue function is impaired, patients will have difficulties with oral control and bolus transport, increasing the likelihood for aspiration [6–8]. Decreased maximum isometric lingual pressures, or pressures produced when the oral tongue is pushed as hard as possible against the hard palate, have been documented in patients with dysphagia [9–13]. Measures of tongue endurance, or maintenance of a percentage of maximal tongue pressure, reduce as well [14].

Previous research examining oral tongue strength and endurance in patients with head and neck cancer treated with chemoradiation has been conflicting. For example, several studies have demonstrated that neither tongue strength nor endurance measures were significantly different from pre- to post-treatment [15–17]. However, one of these studies also reported lower tongue strength as compared with a healthy cohort [15]. Comparisons between physiologic measures and tongue strength also have produced mixed results. In a study by Lazarus and colleagues [15], for several bolus types, the number of swallows per bolus was

found to be lower in patients with greater tongue strength [15], which contrasted with longer oral transit times found for those with greater tongue strength [15]. The authors hypothesized that these conflicting results may be due to the role of saliva as a mediating factor [15]. While salivary flow rate was not measured in this study, the authors stated that the majority of participants reported a reduction in saliva production that affected their swallowing [15]. Given the role of saliva in providing lubrication and previous findings of longer oral transit times with reduced salivary flow [18], the authors suggested that the effects of xerostomia might have overridden the effects of tongue strength in this study.

Salivary flow rate often is reduced following radiation treatment for head and neck cancer due to high dosages to the salivary glands bilaterally [19,20]. Saliva is important in providing lubrication to the bolus that adds a source of sensory input to the oral cavity and impacts swallow initiation [21]. Patients with head and neck cancer have a significant decrease in saliva production from pre- to post-treatment and an increased number of perceived swallowing problems following treatment [22,23]. In a previous publication, we reported increased perception of swallowing dysfunction as well as decreased swallow efficiencies, higher percentages of oropharyngeal residue, and more occurrences of penetration and aspiration following chemoradiation treatment in a cohort of patients with head and neck cancer [24]. However, it is unclear how chemoradiation treatment impacts tongue strength, tongue endurance and salivary flow rate and how these predict change in swallowing-related measures following treatment. This is important information as it will impact treatment planning for patients with dysphagia following chemoradiation treatment for head and neck cancer.

The aim of the present study utilizing the same cohort as our previous study [25] was two-fold: 1) to determine the chemoradiation treatment effects on the additional variables of maximum tongue strength, tongue endurance, and salivary flow rate in this same group of head and neck cancer patients, and 2) to examine the ability of these variables to predict change in swallowing-related measures by bolus type following chemoradiation treatment. We hypothesized that: 1) tongue strength, tongue endurance, and salivary flow rate would decrease following chemoradiation treatment, 2) tongue strength, tongue endurance, and salivary flow rate would be lower in the patients following chemoradiation treatment as compared to a healthy control group; 3) change in each of these variables (tongue strength, tongue endurance, and salivary flow rate) would be predictive of change in swallowing measures from pre- to post-chemoradiation treatment with the strength of these relationships greater on thicker bolus types.

Methods and Materials

Participants

There were two groups of participants: 1) 21 patients diagnosed with head and neck cancer and treated with chemoradiation treatment, and 2) 21 age and gender matched healthy control participants. Patients were recruited through referrals from the Radiation Oncology and Medical Oncology centers and the Speech and Swallowing Clinic.

Patient participants ranged in age from 36 to 80 years (mean age= 56 years). Inclusion criteria for the patient group were: 1) diagnosis of head and neck cancer, 2) age 30 to 80 years, and 3) planned total radiation dosage of at least 50 Gy with concurrent chemotherapy. Exclusion criteria were: 1) other medical problems known to cause xerostomia and/or dysphagia (e.g., neurological problems, gastroenterologic problems), 2) previous treatment for head and neck cancer (chemotherapy, radiation, surgical intervention); 3) prior swallowing treatment, and 4) prescribed medication that could affect swallowing[26] (Table 1). Healthy control participants ranged in age from 31 to 77 years (average age= 56 years). These participants were recruited from the general community through posted flyers and were eligible for participation if they: 1) matched with a patient on gender and age (+/− 5 years), 2) did not complain of or have a history of dry mouth, 3) did not have a history of dysphagia, and 4) were not taking medication that could affect swallowing.

Study Procedures

The protocol was approved by the University's Institutional Review Board. All participants provided informed consent prior to being enrolled in the study. Each patient with head and neck cancer was evaluated twice, once before and once after chemoradiation treatment. The pre-treatment assessment point took place an average of 3.5 weeks before treatment. The post-treatment assessment was between 3 months and 1 year post-treatment (mean= 218 days; SD= 216 days; Range= 78 to 809 days) for the majority, with two patients up to two years and one just past two years due to difficulty with follow-up. The control participants were only evaluated once.

Data collection procedures at each assessment point included: 1) Patient Perception of Swallow Function Questionnaire (PPSFQ), 2) Videofluoroscopic evaluation of swallowing (VFES), 3) Saxon test for measure of salivary flow rate, and 4) Tongue strength and endurance measurements. The methods for the Patient Perception of Swallow Function Questionnaire (PPSFQ) and Videofluoroscopic Evaluations of Swallowing (VFES) have been previously published [24]. In brief, the PPSFQ consisted of 12 questions regarding swallowing function and dry mouth (see Table 2 for a list of items on the questionnaire). Each item required a rating of 1 to 7 (1= no difficulty; 7= severe difficulty).

Each participant's swallowing was examined using videofluoroscopy. Each participant was administered two boluses of each of the following in randomized order within the lateral plane: 1 and 10 ml of thin liquid barium, 3 and 10 ml of nectar thick liquid barium, 3 ml of thin barium pudding, 3 ml of standard barium pudding; and ¼ of a Lorna Doone cookie covered with 1 ml of EZ EM barium pudding.

Details regarding the methods utilized for data reduction of videofluoroscopic recordings have been previously published [24]. In summary, two types of measures were made: 1) approximate amount (percentage) of residue as well as approximate amount (percentage) and frequency of penetration and aspiration, and 2) selected temporal measurements of structural and bolus movement.

The timing of the following events (in seconds) were taken from videofluoroscopic recordings: (a) first backward movement of the bolus (defined as the onset of oral transit) (b)

head (leading edge) of the bolus reaches the point where the ramus of the mandible crosses the tongue base, which is the point by which the pharyngeal swallow should trigger, (c) beginning of laryngeal elevation (first elevation associated with the onset of the pharyngeal stage of the swallow), and (d) end of cricopharyngeal opening (the tail of the bolus leaves the cricopharyngeal region, defined as the termination of the pharyngeal swallow). From these events, the following durational measures were then calculated (also in seconds) : oral transit time (OTT; b-a)-time it takes the bolus to move through oral cavity; pharyngeal response time (PRT; d-c)-time from onset of laryngeal elevation until bolus tail passes through the cricopharyngeal sphincter; pharyngeal delay time (PDT; c-b)-time from bolus head passing the posterior edge of mandibular ramus until initial observation of laryngeal elevation; pharyngeal transit time (PTT; d-b)-time required for bolus to move through pharynx.

The Oropharyngeal Swallow Efficiency (OPSE) for each swallow also was calculated by using the following equation:

$$\frac{100 - (\text{oral residue} + \text{pharyngeal residue} + \text{aspiration during swallow} + \text{aspiration after swallow})}{\text{OTT} + \text{PDT} + \text{PRT}}$$

The numerator of the OPSE equation consists of estimates of oral and pharyngeal residue as well as estimates of aspiration during and after the swallow (recorded in percentages of the total bolus (100%)). The denominator consists of three of the temporal measures recorded in seconds: oral transit time (OTT), pharyngeal delay time (PDT), and pharyngeal response time (PRT). OPSE scores typically range from 100 (100% of the bolus is swallowed in 1 second) to 140 in normal participants as the bolus becomes thicker.

The Saxon test [27] was used to measure stimulated whole saliva production. For this test, participants chewed on a $4'' \times 4''$ gauze pad for 2 minutes. The gauze pad was weighed before and after chewing and the difference in weight (gm) represented the amount of saliva produced in 2 minutes. The test was completed twice at each time point, and the average weight was calculated. This assessment was completed in the afternoon when saliva production is at its peak [28]. For two hours prior, participants refrained from smoking, eating, using mouth wash, or drinking anything but water.

Oral tongue strength was measured using the Iowa Oral Pressure Instrument (IOPI) [29]. The IOPI consists of an air-filled plastic bulb connected to a pressure transducer. The plastic bulb is placed between the participant's oral tongue and hard palate. As the individual applies pressure to the bulb, any pressure change is shown on a LED display in kilopascals (kPa). To ensure accurate measurement, calibration was checked once per week.

An isometric resistance task was used to determine maximum oral tongue pressure. The IOPI bulb was placed on top of the center of the tongue. The bulb placement along the central groove of the tongue blade was demonstrated for each participant to ensure as standard placement as possible [30]. Instructions were then to "push the bulb against the roof of your mouth as hard as possible using your tongue and not your teeth." This measure

was completed three times with two minutes of rest in between each trial. The greatest value for the three trials was the maximum pressure produced (Pmax).

A durational measure was used to determine oral tongue endurance. Each individual's Pmax was set in the IOPI. 50% of the Pmax was manually calculated at entered into the device as a target for the endurance task. The participant was instructed to push the bulb against the hard palate with their tongue and to hold it as long as possible. The display showed a series of lights that changed from red to green as the participant reached 50% of the Pmax. The participant was instructed to keep the green light on as long as possible. The length of time that the participant maintained 50% of the Pmax was recorded (sec). This measure was completed 3 times with 2 minutes of rest in between. The greatest value for the 3 trials was the maximum endurance value (Emax).

Statistical Analysis

Repeated measures analyses of variance were conducted for each dependent variable (salivary flow rate, tongue maximum pressures, tongue endurance measures) to test for significant differences from pre- to post-treatment. Between-groups analyses of variance also were conducted for each dependent variable to test for differences between groups (control versus patients pre- and post-treatment). Pearson product-moment correlation coefficients allowed for examination of associations among the dependent variables at the post-treatment point. These same correlations were calculated using change scores (difference between post- and pre-treatment points) for saliva weight, tongue maximum pressures, tongue endurance measures, and biomechanical measures (OTT, PDT, PRT, PTT, OPSE) for each bolus type. Simple linear regression analyses with change scores were used to determine whether change in saliva weight, tongue maximum pressures, and tongue endurance measures following treatment were predictive of change in overall OPSE values as well as OPSE by bolus type. The critical value for obtaining statistical significance was set at $\alpha = 0.05$. If a participant had missing data due to difficulties with equipment or the image, then data missing specific to each analysis were excluded. Analyses were conducted using IBM SPSS (Version 22) [31].

Results

Treatment Effects on Tongue Pressures and Salivary Flow Rate

Although no significant differences in pre- to post-treatment tongue maximum pressure measurements ($F(1,14)=1.08$, $p=.316$) or endurance pressure measurements ($F(1,14)=2.34$, $p=.148$) were noted, significant decreases in salivary flow rates were observed ($F(1,20)=58.26$, $p=.000$, partial eta squared= .744) (Figure 1).

There was no significant difference between the patient group at pre-treatment point and the control group in Pmax values ($F(1,34)=1.96$, $p=.171$), E max values ($F(1,34)=2.17$, $p=.15$), or salivary flow rate ($F(1,40)= .07$, $p=.792$).

While Pmax was lower post treatment in the patient group versus the control group, this difference approached but did not reach significance ($F(1,40)=3.92$, $p=.055$). Emax ($F(1,39)=6.9$, $p=.012$; partial eta squared= .15) and salivary flow rate ($F(1,40)=82.8$, $p=.000$;

partial eta squared= .67) were found to be significantly lower post-treatment in the patient group as compared to the control group. Table 3 includes the means (averages) and standard deviations for Pmax, Emax, and salivary flow rate by group and assessment point.

Correlations among Salivary Flow Rate, Tongue Pressures, PPSFQ scores, and Swallowing Biomechanics in the Patient Group at the Post-Treatment Point

There were no significant correlations among Pmax, Emax, and saliva weight values at the post-treatment point.

In the patient group at the post-treatment point, there was a moderate, negative correlation between ratings on the PPSFQ individual item "I have a dry mouth" and salivary flow rate ($r=-.492$, $n=21$, $p=.024$) with higher ratings associated with lower flow rates. Ratings on another PPSFQ item "I wake up at night coughing and gagging" were also moderately, negatively correlated with salivary flow rate in the patient group post-treatment ($r=-.453$, $n=21$, $p=.04$), with higher ratings associated with lower flow rates (Table 4).

There were no significant correlations between salivary flow rate and swallowing biomechanical measures averaged across bolus type at the post-treatment point. However, a significant moderate, positive correlation was found between OPSE on the 10mL thin liquid bolus and salivary flow rate ($r=.461$, $p=.047$).

In the patient group at the post-treatment point, a negative correlation between overall amounts of oral residue and Pmax approached but did not reach significance ($r=-.43$, $p=.055$). Moderate, negative correlations were found between oral residue on 10mL thin liquid bolus and 10mL nectar-thick liquid bolus and Pmax ($r=-.48$, $p=.036$; $r=-.55$, $p=.012$, respectively).

Regression Analyses with Change Scores

Change in saliva weight from pre- to post-treatment for the patient group was not predictive of change in Pmax ($F_{(1,13)}= .134$; $p=.72$) or Emax ($F_{(1,13)}= .002$; $p=.964$).

While change in saliva weight from pre- to post-treatment did not significantly predict change in average OPSE scores, this relationship approached significance ($F_{(1, 19)}= 4.07$, $p=.058$). Similarly, change in tongue endurance measures did not significantly predict change in average OPSE scores ($F_{(1,13)}= 3.88$, $p=.07$) or OTT values ($F_{(1,13)}= 3.83$; $p=.07$) but these relationships approached significance.

Change in saliva weight from pre- to post-treatment significantly predicted change in OPSE scores on 1mL thin liquid boluses ($F_{(1,19)}= 6.89$; $p=.017$), 3mL nectar-thick liquid boluses ($F_{(1,19)}= 5.80$; $p=.026$), and 3mL standard barium pudding boluses ($F_{(1,19)}= 8.01$; $p=.011$). Change in saliva weight accounted for 6.9%, 5.8%, and 8% of the variability in OPSE scores for 1mL thin liquid, 3mL nectar-thick, and 3mL standard barium pudding boluses, respectively. The regression equation for 1mL thin liquid was: predicted change in OPSE= $1.38 + 7.09 \times$ (change in saliva weight) (Figure 2a). The regression equation for 3mL nectar-thick liquid was: predicted change in OPSE= $.102 + 7.65 \times$ (change in saliva weight) (Figure

2b). The regression equation for 3mL standard barium pudding was: predicted change in OPSE= 27.1 + 12.82 × (change in saliva weight) (Figure 2c).

Discussion

The purpose of this study was to examine chemoradiation treatment effects on oral tongue strength and salivary flow rate and to define relationships with perceived swallowing difficulty and swallowing biomechanics by bolus type. We hypothesized that chemoradiation treatment for patients with head and neck cancer would lead to changes in oral tongue strength and salivary flow rate. We also hypothesized that these variables would predict change in swallowing measures, with stronger relationships observed on thicker boluses. Our findings supported this hypothesis in part in that we discovered significant decreases in salivary flow rates from pre- to post-treatment and significantly lower tongue endurance measures for the patients post-treatment as compared to the control group. Additionally, salivary flow rate was found to significantly predict swallow efficiency for specific bolus types, with the strongest relationships occurring on thicker boluses.

The decrease in salivary flow rate from pre- to post-chemoradiation treatment observed in this study is consistent with previous findings [19,20,32]. It is known that radiation damage to salivary gland tissue leads to lower amounts of saliva production [19,20]. Patients post-treatment with lower salivary quantity reported greater mouth dryness [33–37]. Those with lower salivary quantity also reported greater frequency of waking in the night, consistent with previous research.[38], [39] Symptoms of mouth dryness in those with lower salivary production, especially in individuals who are mouth breathers during sleep, may lead to a need to drink water in the night more frequently. Interestingly, there are patients who have been found to report mouth dryness without a documented decrease in salivary quantity [40–44]. Given the finding of only a moderate correlation between xerostomia and hyposalivation in this study, it may be that other aspects of saliva (e.g., viscosity and alterations in protein components) are contributing to perceived mouth dryness.

While salivary flow rate is known to decrease following chemoradiation, its impact on swallowing biomechanics is not well-established [32,45]. Findings from this study suggest that a reduction in salivary flow does contribute to changes in swallow efficiency and that these effects may be dependent upon bolus type. A decrease in salivary quantity was found to significantly predict change in swallow efficiency from pre- to post-treatment for 1mL thin liquid, 3mL nectar-thick, and 3mL standard barium pudding boluses only. This relationship was strongest for the standard barium pudding boluses suggesting that, while salivary lubrication is necessary for all bolus types, the influence of inadequate saliva production on swallowing safety may be greater with thicker bolus consistencies.

There was a lack of significant change in tongue maximum pressures and tongue endurance pressure from pre- to post-treatment [16]. One possible explanation is the presence of the tumor pre-treatment could lead to a reduction in tongue strength that may be reversed with effective treatment of the tumor (tumor debulking), thereby minimizing the change observed in tongue strength from pre- to post-treatment [16]. Interestingly, while lower than the control group (68.9 secs) in this study, tongue endurance measures at each assessment point

(pretreatment=45 secs; posttreatment=42 secs) were similar to those previously reported for healthy participants [15,46]. This highlights the need for more normative data on tongue endurance for comparison with dysphagic patients.

Significantly lower tongue muscle endurance measures in the patient group posttreatment compared to the control group may be a sign of tongue muscle fatigue [46,47]. Muscle endurance is the ability to maintain repeated muscle contractions against resistance for an extended period of time [48], and a reduction in muscle endurance may represent fatigue [46]. As demonstrated by Kays et al [46], tongue endurance measures have been found to decrease following a meal in both young and older healthy adults. Lower tongue muscle endurance may place patients at risk for greater fatigue following a meal, thereby increasing the risk of airway invasion and swallow inefficiency. However, it is important to note that the slight decrease in tongue endurance from pre- to post-treatment was not statistically significant (45 secs versus 42 secs), which may indicate this patient group is at increased risk of fatigue even before undergoing chemoradiation treatment.

With higher volume liquid boluses, lower tongue maximum pressures were associated with greater oral residue. Consistent with previous studies in healthy participants [49–51], tongue strength may have a greater influence on bolus clearance with larger volumes. Despite the hypothesis that salivary flow rate mediates the effect of tongue strength or endurance on swallowing [15], no clear associations among these variables were established.

There were several limitations to this study. The patients in our head and neck cancer group varied in terms of tumor site, exact chemoradiation treatment protocol, and smoking/alcohol history. The time from completion of treatment to post-treatment assessment varied between patients. Due to difficulty with follow-up closer to treatment completion secondary to acute effects, three patients were assessed beyond one year. While possible for the results to have been affected by these later follow-up points, given that the majority of patients were seen within a year from treatment completion, it seems unlikely. Also, measures of tongue strength and endurance were taken in an isolated task and not during swallowing. Relationships may become stronger with measures taken during a swallowing task. Additionally, while utilized in previous studies [22,23], the Patient Perception of Swallowing Function Questionnaire (PPSFQ) has not yet been validated and reliability has not been established.

Despite these limitations, findings of this study suggest that decreases in saliva production following chemoradiation may at least partially underlie the previously documented [25,52,53] decreases in overall efficiency of the swallow in patients with head and neck cancer treated with chemoradiation, especially with thicker bolus types. This has important implications for clinicians treating these patients in that they should consider recommending saliva substitutes, water swallows following thicker boluses, and modifications of thicker foods to improve swallow efficiency. Findings related to tongue strength and endurance only partially support our hypotheses. While there were decreases in both tongue strength and tongue endurance from pre- to post-treatment, these changes did not reach statistical significance. Additionally, neither tongue strength nor tongue endurance were found to be predictive of swallow efficiency. The post-treatment tongue endurance values were

significantly lower than the control group which may have clinical significance in terms of fatigue during meals but larger studies are required to address this. Overall, results of this study support consideration of salivary flow rate and tongue pressures when designing treatment plans and in the management of swallowing dysfunction following chemoradiation treatment.

Acknowledgments

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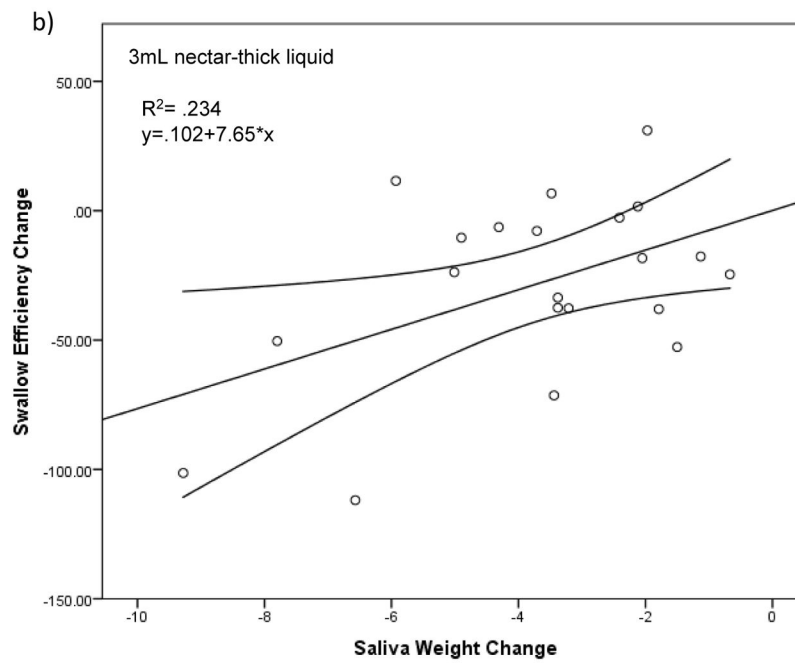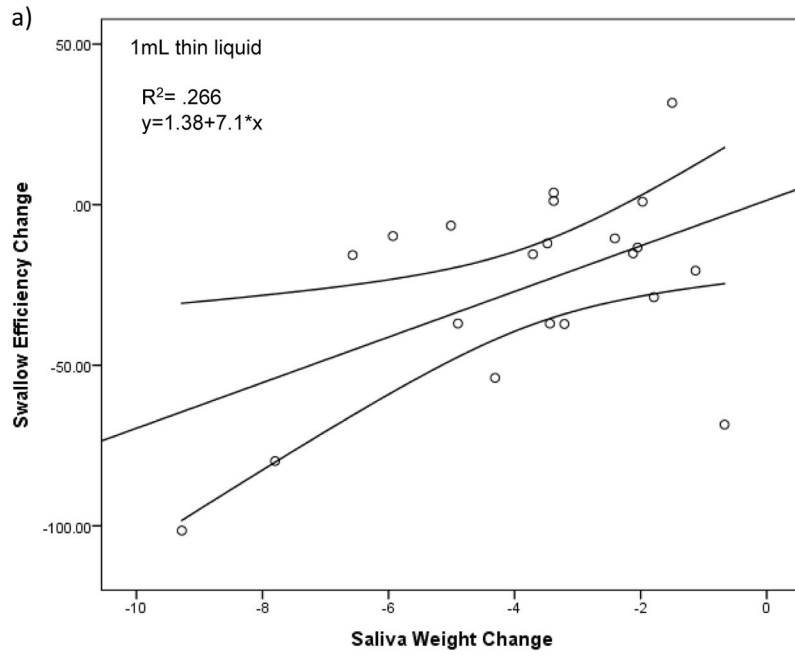
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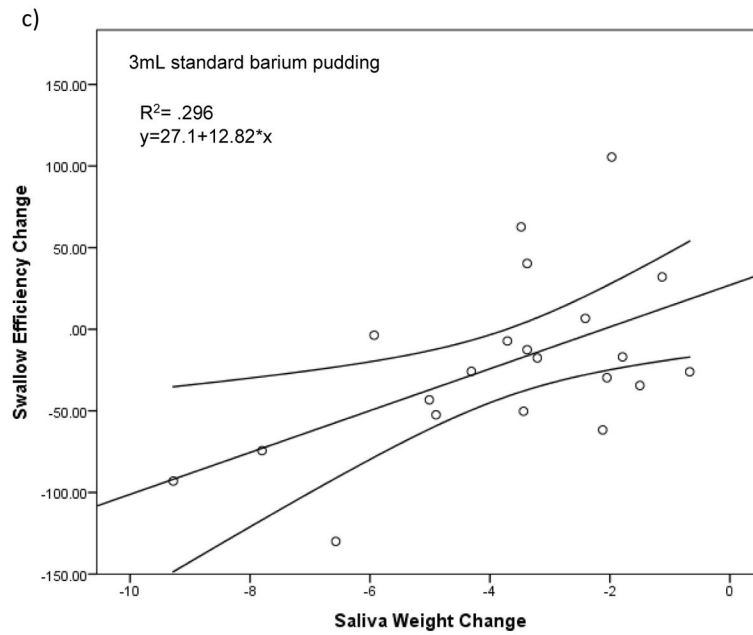
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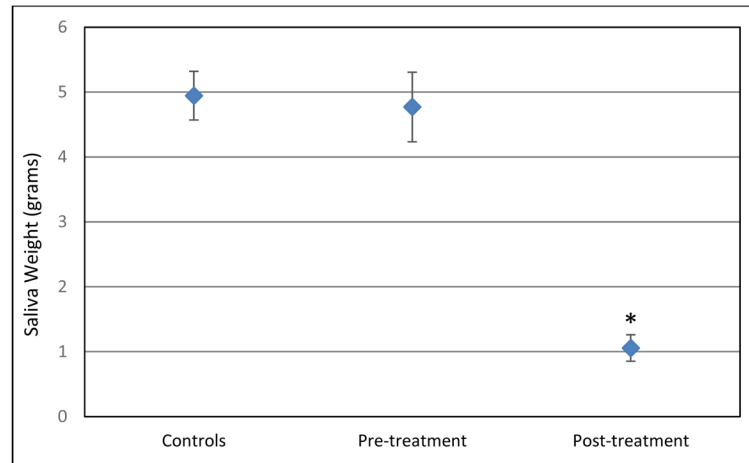
Figure 1.
Mean (average) saliva weights with standard error bars for each group. Asterisk= statistical significance. This graph shows a significant decrease in mean saliva weight from pre- to post-treatment as well as a significant difference between the post-treatment saliva weights and the saliva weights of the control group.

a)

Figure a) 1mL thin liquid. $R^2 = .266$, $y = 1.38 + 7.1*x$. Scatterplot of Swallow Efficiency Change versus Saliva Weight Change.

b)

Figure b) 3mL nectar-thick liquid. $R^2 = .234$, $y = .102 + 7.65*x$. Scatterplot of Swallow Efficiency Change versus Saliva Weight Change.

c)

3mL standard barium pudding

$R^2 = .296$
$y = 27.1 + 12.82*x$

Figure 2.
Each scatterplot (a–c) represents statistically significant (p<.05) simple linear regression models with saliva weight as a predictor of swallow efficiency for each bolus type. Line of best fit and 95% confidence intervals are shown. The graph illustrates that a larger reduction in salivary flow results in a negative change in swallow efficiency for these specific bolus types.

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Table 1

Patient Characteristics

Characteristics	Percentages				
Age	18–39 years	40–59 years	60–79 years	80–99 years	
	5%	61%	29%	5%	
Sex	Male		Female		
	61%		19%		
Tumor site	Oropharyngeal		Nasopharyngeal	Other	
	57%		14%	19%	
Tumor size	T0	T1	T2	T3	T4
	9%	31%	42%	0%	18%
Nodal involvement	Yes			No	
	95%			5%	
Metastasis	Yes			No	
	0%			100%	
Induction chemotherapy	Yes			No	
	29%			71%	
Concurrent chemoradiation	Yes			No	
	100%			0%	
Intensity-modulated radiation delivery	Yes			No	
	95%			5%	
Surgery (tonsillectomy, neck dissection, tumor debulking)	Yes			No	
	38%			62%	
Smoking history	Yes			No	
	48%			52%	
Alcohol abuse history	Yes			No	
	38%			62%	

Table 2

PPSFQ Items

1. Difficulty swallowing
2. Dry mouth
3. Food sticks in mouth
4. Food sticks in throat
5. Food won't go down
6. Need water to help food go down
7. Choke on food/liquid
8. Cough when eating and/or drinking
9. Food/liquid come back up after swallow
10. Heartburn
11. Wake up at night coughing and/or gagging
12. Change in my sense of taste

Table 3

Means for Salivary Flow Rate, Tongue Maximum Pressures, and Endurance Measures

Variables	Control Participants		Pre-treatment		Post-treatment	
	Mean	SD	Mean	SD	Mean	SD
Salivary flow rate (SFR)	4.94 g	1.72	4.77 g	2.46	1.06 g	0.94
Tongue maximum pressures (Pmax)	58 kPa	15.8	51 kPa	13.7	49 kPa	13.4
Tongue endurance measures (Emax)	68.9 secs	43.8	45 secs	16.4	42 secs	15.0

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Table 4

Correlations between PPSFQ items and Saliva Weight

Items on PPSFQ	Correlation	p value
Difficulty swallowing	−.244	.286
Dry mouth	**−.492***	**.024**
Food sticks in mouth	−.054	.816
Food sticks in throat	−.214	.352
Food won't go down	−.223	.331
Need water	−.239	.297
Choke	−.215	.348
Cough	−.233	.309
Comes back up	−.133	.564
Heartburn	−.206	.371
Wake at night	**−.453***	**.039**
Change in taste	−.206	.371
Total scores	−.374	.095