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RESPIRATORY–SWALLOW PHASE PATTERNS AND THEIR RELATIONSHIP TO SWALLOWING IMPAIRMENT IN PATIENTS TREATED FOR OROPHARYNGEAL CANCER

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Abstract

Background—Unstable respiratory–swallowing coordination has been associated with disorders and disease. The goals of this study were (1) to describe respiratory–swallow patterns in patients with dysphagia consequent to treatments for cancers of the oropharynx and (2) to determine the association between respiratory–swallow patterns, airway invasion, and overall severity of swallowing impairment.

Methods—This prospective, cross-sectional design compared respiratory–swallow patterns in 20 patients treated for oropharyngeal cancer and 20 healthy, age-matched control participants. Nasal airflow direction was synchronously recorded with videofluoroscopic imaging in participants who swallowed 5-mL thin liquid barium boluses.

Results—Respiratory–swallow patterns differed between groups. Most control participants initiated and completed swallowing bracketed by expiratory airflow. Swallowing in patients often interrupted inspiratory flow and was associated with penetration or aspiration of the bolus.

Conclusions—We suggest nonexpiratory bracketed respiratory–swallowing phase patterns in patients with oropharyngeal cancer may place patients at greater risk of airway penetration or aspiration during swallowing.

Keywords

oropharyngeal cancer; respiration; dysphagia; radiation; chemotherapy

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New cases of oropharyngeal cancers are quickly approaching one-half million worldwide each year.[1] In the United States alone, there are more than 240,000 men and women either with a history of or living with these diseases,[2] and the National Cancer Institute reported 38,053 new cases between 2001 and 2005.[2] These cancers and their surgical and other treatments often leave patients with severe and long-lasting swallowing impairments. In fact, swallowing impairments are among the highest functional morbidities of oropharyngeal cancer, together with deficits in oral communication, nutrition, and appearance, despite newly emerging organ-sparing protocols.[3–14] Swallowing impairments remain a potentially long-lasting medical and functional concern in patients with oropharyngeal cancer with severe consequences to health and well-being. These include malnutrition, dehydration, aspiration pneumonia, and poor quality of life. Aspiration pneumonia and associated mortality in patients treated for head and neck cancers have been reported to be as high as 27%.[15] We suggest herein that disrupted respiratory–swallowing coordination interacting with impaired oropharyngeal swallowing processes may be contributing to chronic swallowing impairments and aspiration in these patients.[16]

Precise respiratory–swallowing coordination is vital for airway protection, and breathing is inhibited before and during pharyngeal swallowing in all species including human infants and adults.[17–31] Coordination of swallowing with respiration has been assessed by identifying the respiratory phases surrounding swallowing events (referred to as respiratory–swallow phase patterns). Although methodological differences exist among investigators, the overall goal is to determine the respiratory flow events surrounding swallowing and the stability of respiratory–swallowing coordination. Additional attention has been given to identifying the potential airway protective and other mechanical advantages of specific breathing–swallowing coordinative patterns.[20,32,33]

A highly consistent pattern of respiratory–swallow phasing has emerged for liquid swallows in normal subjects. These swallows occur most frequently during a pause in the expiratory phase of the breathing cycle.[17–31,33–39] Swallowing during the expiratory phase has potentially important mechanical advantages, such as effecting a partially adducted true vocal fold position before the initiation of the pharyngeal swallow and later during descent of the larynx.[19,34] Further, swallowing in expiration may facilitate the anterior–superior motion of the hyoid and larynx necessary for complete airway closure and pharyngoesphageal segment (PES) opening in both adults and infants.[18,20,30] Finally, although respiratory inhibition is obligatory, swallowing bracketed by expiratory versus inspiratory flow provides obvious airway-protective advantages in the event of disordered coordinative timing between breathing and swallowing.[19,23,34,35]

Impairments in the normal coordinative relationship between breathing and swallowing have recently been suggested as potential contributors to disordered swallowing in patients with head and neck cancer.[40] Despite this, there has been no experimental investigation of potential impairments in respiratory–swallowing coordination in patients with head and neck cancer. Swallowing impairments in these patients are usually highly resistive to traditional intervention strategies, suggesting that our understanding of impaired processes is highly incomplete. This places additional importance on a better understanding of underlying control processes including respiratory–swallow phase patterning. The present investigation was thus designed to (1) describe respiratory–swallow phase patterns in dysphagic patients treated for cancers of the oropharynx, as contrasted with healthy, age-matched controls; (2) determine the relationship, if any, between respiratory–swallow coordinative patterns and airway invasion (penetration–aspiration); and (3) determine the association between respiratory–swallow phase pattern and overall severity of swallowing impairment.

MATERIALS AND METHODS

Participants

The study protocol was approved by the Institutional Review Board at Medical University of South Carolina. Participants were recruited from 2 institutions (Medical University of South Carolina, Ralph H. Johnson VA Medical Center), and gave written informed consent before completing the study protocol. Two groups of participants were selected for this study. The first group consisted of patients treated for cancer of the oropharynx and who had been previously diagnosed with dysphagia. The second group was composed of healthy, age-matched volunteers who served as experimental controls.

Medical and surgical histories and current medications were obtained by means of interview and written survey for healthy, age-matched controls. Would-be participants who reported a history of upper aerodigestive tract surgical procedures, including oral, nasal, pharyngeal, laryngeal, and esophageal resection, were excluded from this study. Control participants reported no history of swallowing disorders, dysphagia, odynophagia, gastroesophageal reflux disease, pulmonary disease, cancer of the head and neck, neurologic disease, current medications with known effects on swallowing or breathing, or tobacco use during the past 10 years. All control participants were eating solid foods and drinking liquids as part of a regular diet.

Eligible patients were adults over the age of 18 years with oropharyngeal cancer and stratified by treatment type and stage (I–IV) using information-available data from the cancer registries of the MUSC Hollings Cancer Center and the Ralph H. Johnson VA Medical Center. Previous data suggest that swallowing impairments associated with head and neck cancer treatments stabilize after approximately 12 months posttreatment,[6,9,10] when the effects of radiation therapy, including gradual fibrosis of the pharyngeal muscles and other soft tissues, have resolved.[10] Consequently, patients at 12 months after treatment of stage I to stage IV squamous cell carcinoma of the oropharynx were asked to participate. Additionally, we identified patients for which chemotherapy was the primary curative modality. Patients receiving triple therapy (chemotherapy + surgery + radiation) and patients with known histories of neurologic conditions (such as stroke, neurodegenerative diseases) affecting swallowing were excluded.

A complete head and neck examination with flexible laryngoscopy was performed on all patients to rule out persistent or recurrent tumor. Patients suspected of having persistent or recurrent tumor on history and physical examination were ineligible pending further work-up.

Patients with cancer were screened into 2 subgroups: those previously treated using surgery and radiation therapy (SURG-XRT) and those previously treated using chemotherapy with radiation therapy (CHEMO-XRT). This subdivision was completed to assess the potential influence of these 2 different types of medical treatments on respiratory–swallow pattern.

Instrumentation

A high-resolution, dual-modality videofluoroscopic and nasal airflow recording device was used for signal acquisition and digital storage and retrieval of respiratory and non-respiratory related airflow and swallowing data (Digital Swallowing Workstation, model 7100; Kay Elemetrics, Lincoln Park, NJ). Nasal respiratory flow was captured using a standard, 7-foot nasal cannula coupled to the Workstation using the Swallow Signals Lab hardware and software to create a digital display of the respiratory phase and the interruption of nasal respiratory flow associated with swallowing. Air pressure through the nasal cannula was calibrated immediately prior to data collection for each participant.

Expiratory airflow was shown on the respiratory display as a positive-going trace and inspiratory airflow as a negative-going trace.

Respiratory flow was sampled at 250 Hz to more than adequately capture breathing frequency of 10 to 12 times/minute in adults. The resolution of the videofluoroscopic recordings was 60 fields (30 frames) per second (16.6 ms per digital field). All recordings were made simultaneously in a standard fluoroscopy suite. Tight coning of the X-ray beam limited radiation exposure to the superior structures of the aerodigestive tract (ie, oral cavity, pharynx, larynx, and cervical esophagus). Participants were positioned in the left lateral viewing plane while standing and self-administered 2 trials of 5-mL liquid boluses of barium sulfate contrast solution (Liquid Barosperse Barium Sulfate Suspension, catalogue no. 179364; Lafayette Pharmaceuticals, Anaheim, CA) per 30-mL graded medicine cup. This conservative volume was chosen to simulate a safe bolus size typically administered to dysphagic patients during a videofluoroscopic examination. All participants and patients were instructed to “drink the liquid in [their] usual manner.” No instructions regarding timing or manner of swallowing were given to encourage natural liquid swallowing behavior. The fluoroscope was activated during self-administration of the contrast material into the oral cavity, and remained activated until the bolus tail entered the esophagus through the PES. Radiation exposure times were ≤1 minute for all participants.

Measurements

Swallow–Respiratory Phase Pattern: Data were recorded for each of the two 5-mL liquid boluses during 2 sequential trials for each of the participants. The nasal airflow signal was used to determine the respiratory phase (inspiration or expiration), which was interrupted by the swallow, and resumed during the late stage of the pharyngeal swallow or following the pharyngeal swallow. All the measurements were made from the dual-modality digital display in milliseconds using the digital video recorder’s slow-motion and freeze-frame capabilities.

Penetration–Aspiration Scale Scores: To determine the possible consequences of impaired respiratory–swallowing coordination for risk of aspiration, each swallow was scored using the Penetration–Aspiration Scale (PAS). The PAS is a valid and reliable measurement system that rates the presence, depth of, and patient response to aspiration.[41–43] The PAS scores were made by the same speech-language pathologist who scored the Modified Barium Swallowing Impairment Profile (MBSImP; see the following text) for each 5-mL trial. PAS scores were recorded and stratified according to the following schema: scores 1 to 2 were considered normal, scores 3 to 5 indicated penetration, and scores 6 to 8 indicated aspiration.[42] Table 1 describes the scoring schema.

Modified Barium Swallowing Impairment Profile Scoring: To quantify the nature of the physiologic swallowing impairment beyond penetration or aspiration, the MBSImP was used. The MBSImP is a validated and reliable scoring system for the quantification of swallowing impairment from modified barium swallow study (MBSS) recordings tested in 300 patients in a 5-year trial across 2 medical centers and between 8 trained speech-language pathologists.[44] This tool has an ordinal scoring schema that permits quantification of impairment of the oral, pharyngeal, and cervical esophageal components of the swallow. The operational definitions for the component scores represent a unique and unambiguous observation of either structural movement, bolus flow, or both.

Implementation of the MBSImP requires a judgment, or overall impression (OI) score, for each component across all swallow attempts during the MBSS. MBSImP scores range from “0” (no impairment) to as much as “4” (severe impairment). A speech-language pathologist with >10 years of experience assessing MBSSs in patients with head and neck cancer, blinded to group and treatment modality within the patient group, scored all participants' swallows from video recordings using stop-frame and slow-motion analysis. This scorer successfully completed the MBSImP scoring training and met the training requirement of 80% criterion for scoring the MBSImP. PAS scoring reliability was 100%.[44]

RESULTS

Demographics

Forty participants volunteered for this study. Twenty were healthy, age-matched controls and 20 were patients who were treated for cancer and who were previously diagnosed as having swallowing disorders. Eleven patients had stage I or stage II disease; 9 had stage III or stage IV disease. Patient demographics are summarized in Table 2.

Surgery for patients with oropharyngeal cancer consisted of wide excision with primary closure or skin graft ($n = 7$), wide excision with radial forearm free flap ($n = 3$), and wide excision with levator scapula flap ($n = 1$). Three of the patients who underwent oropharyngeal surgery had a transoral resection, with the remaining 8 requiring mandibulotomy or pharyngotomy approaches. The chemotherapy regimen (with concomitant radiotherapy) consisted of cisplatin and fluorouracil in 7 patients and cisplatin and paclitaxel in 2 patients.

At the time of the study, 10 patients (50%) consumed a complex diet of all solids and liquids, 7 patients (35%) consumed only soft solids and liquids, and 3 patients (15%) were limited to ground solids and purees with liquids because of swallowing disorders. Considerably fewer patients in the SURG-XRT group (2/11) than in the CHEMO-XRT group (8/9) were able to consume a complex diet of all solids and liquids after treatment. There was no history of aspiration pneumonia in any study participant.

All participants were able to complete the swallowing evaluation task and all 5-mL measures of barium were consumed in 1 swallow. No participant swallowed more than once per bolus. Respiratory–swallow phase data were analyzed for each of the 5-mL trials except where noted in the following text. Impairments in swallowing physiology were not observed in our normal controls; however, consistent with our previous studies and the swallowing literature,[6–9,11,45–48] the following components were impaired in our patients: (1) time of initiation of the pharyngeal swallow, (2) degree of anterior hyolaryngeal excursion, (3) degree of PES opening, (4) degree of tongue base retraction, and (5) amount of pharyngeal residue. MBSImP scoring and all analyses for this study were limited to these components. Table 3 outlines the scoring schema for the components that were impaired in our patient sample.

Frequency of Respiratory–Swallow Phase Patterns

Respiratory–swallowing coordination was grouped into 4 mutually exclusive patterns based on our previous work: (1) swallows immediately preceded by and followed by expiratory flow (E–E), (2) swallows immediately preceded by expiratory flow and followed by inspiratory flow (E–I), (3) swallows immediately preceded by inspiratory flow and followed by expiratory flow (I–E), and (4) swallows immediately preceded by and followed by inspiratory flow (I–I).[19,20,34,35] No significant differences in respiratory–swallow phase were found between the 2 trials for each of the 2 participant groups (controls: chi-square test = 2.857; degree of freedom [df] = 6, $p = .827$; patients: chi-square test = 8.121, df = 6, $p = .229$).

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Although the E–E dominated in healthy control participants (72.5%, $n = 29$), only 37.5% ($n = 15$) of patients with cancer demonstrated this pattern. This difference was statistically significant (chi-square test = 10.264, df = 3, $p = .016$). The remaining respiratory–swallow phase patterns E–I, I–E, and I–I patterns were seen in 27.5% of the controls and 62.5% in the patients. Results are summarized in Table 4.

Considering the dominance of E–E in healthy control participants, data were collapsed into "E–E" and "Non E–E (ie, I–E, E–I, I–I)" patterns. With these new groupings, a statistically significant ($p = .003$, Fisher's exact test) reversal of dominance in respiratory–swallow pattern was apparent between healthy control participants and patients with cancer. Only 37.5% of the patients with cancer showed the E–E pattern versus 72.5% of the healthy control participants. Looking further within the patient subgroups, 36.4% of the SURG-XRT group and 38.9% of the CHEMO-XRT group had the E–E pattern. There were no statistically significant differences between cancer treatment groups ($p = 1.0$, Fisher's exact test). Data are summarized in Table 5.

Relationship of Respiratory–Swallow Pattern and Penetration–Aspiration Scale Scores

All control participants had PAS scores equal to 1 (ie, normal) for both swallowing trials. Laryngeal penetration (PAS scores 3–5) was observed in 7 patients treated with SURG-XRT and 3 treated with CHEMO-XRT. Aspiration (PAS score 6–8) was observed in 3 patients treated with SURG-XRT and 1 treated with CHEMO-XRT.

Patients with laryngeal penetration demonstrated the non E–E pattern in 13 of the 20 swallows (65%). The 4 patients who showed evidence of aspiration used a predominantly non E–E pattern (7 of the 8 swallows or 87.5%). One SURG-XRT patient who had a PAS score of 6 (aspiration) demonstrated the E–E pattern during 1 swallow but not in the other. The difference in the presence of aspiration (PAS scores 6–8) between the E–E and non E–E patterns was significant ($Z = -2.843$, $p = .004$). Those patients who were inspiring immediately prior to or immediately after the swallow had a greater incidence of aspiration. The CHEMO-XRT patient produced the I–E pattern and aspirated during both trials. The 3 SURG-XRT patients who aspirated produced the I–E pattern for 2 swallows, the E–I pattern for 3 swallows, and the E–E pattern for 1 swallow. Two additional patients (10%) showed evidence of laryngeal penetration (PAS scores 3–5), despite their predominant E–E pattern of respiratory–swallowing coordination. No differences were noted between the SURG-XRT and CHEMO-XRT groups in PAS scores relative to respiratory–swallow pattern for either trial (trial 1: $p = .591$, Fisher's exact test; trial 2: $p = .197$, Fisher's exact test).

Relationship of Respiratory–Swallow Pattern and Severity of Swallowing Impairment

One of the primary aims of this study was to relate respiratory–swallow patterns to severity of physiologic swallowing impairments as measured by the MBSImP. Motion artifact precluded reliable measurement in 1 patient. As a result, data are reported for 19 of the 20 cancer patients with dysphagia. Scoring schema for the 5 MBSImP components scored is detailed in Table 3. All patients with non E–E or inconsistent respiratory–swallow patterns (ie, pattern change between trials), had OI totals ≥5. This indicates that nonoptimal patterns were associated with swallowing impairments in these patients. Delays in the initiation of the pharyngeal swallow (marked by onset of hyolaryngeal excursion) occurred with the greatest frequency and severity ($n = 19$, 100%). Decreased anterior hyolaryngeal excursion was observed in 10 (53%) patients. Reduced PES opening was also observed in 10 (53%) patients. Decreased tongue base retraction was observed in 14 (74%) patients. Finally, pharyngeal residue was also observed in 14 (74%) patients.

As presented in Table 6, the consistency of respiratory–swallow patterning appeared to be related to degree of swallowing impairment in the patients. Patients with the lowest OI scores, indicating less impaired swallowing, produced the E–E pattern *on both* swallows. Patients who were inconsistent in their respiratory–swallowing phase relationships between the 2 experimental trials (ie, E–E on the first swallow and either I–E or E–I on the other swallow, or patients with I–E on the first swallow and either E–I or I–E on the second swallow), also had the highest degree of swallowing impairment, higher than those demonstrating non E–E patterning on both swallows. Significantly higher (worse) MBSImP scores were found in patients with inconsistent patters across trials, compared with patients who produced consistent phase patterning across trials (trial 1: $F = 3.597$, $p = .039$; trial 2: $F = 3.427$, $p = .045$).

DISCUSSION

This prospective, cross-sectional design investigation provides further information concerning respiratory–swallowing coordination in patients with head and neck cancer and the potential relationship between these patterns and airway invasion and swallowing impairment. This preliminary clinical study has identified characteristics of respiratory–swallowing coordination that may place patients with head and neck cancer at greater risk for penetration/aspiration.

Respiratory–swallowing coordination was different in patients treated for oropharyngeal cancer compared with healthy, age-matched controls, regardless of the type of treatment (SURG-XRT or CHEMO-XRT). The E–E pattern appears consistently in the majority of healthy individuals throughout the lifespan.[17,19–21,23,25,27,29,31,34,36,49–53] In contrast, the majority of our oropharyngeal cancer patients was not observed in our patients. Instead, the majority of patients (62.5%) had a respiratory–swallowing coordinative pattern that included inspiratory flow immediately before and/or after the swallow. This indicates a tendency to initiate and/or complete swallows surrounded by potentially risky respiratory flow events acting to bring air into the lungs.

Changes in respiratory–swallowing coordination in at least some of our patient sample appears to be significantly related to impaired airway protection, as evidenced by increased events of penetration and aspiration. Penetration was observed in 10 patients and aspiration was observed in 4 patients, and all of these patients demonstrated the non E–E pattern of coordination. Although it is impossible to know whether these patients were among the majority of normal individuals who swallowed with E–E respiratory–swallow phase patterns before they were diagnosed with head and neck cancer, it is clear that these patients tended to have non E–E patterns and were vulnerable to aspiration. In light of these data, we speculate that patients with head and neck cancer with dysphagia may be swallowing at moments in the respiratory cycle that place this group, or at least a subgroup of these patients, at increased risk of aspiration.

Deviations from normal respiratory–swallowing patterning may increase the risk of swallowing impairment beyond the airway protection problems described earlier.[18,20,30] It has been previously suggested that normal respiratory–swallowing patterning may facilitate laryngeal elevation, PES opening, and vocal fold adduction—all crucial aspects of airway protection and normal swallowing function.[18] It is well known that hyolaryngeal motion is often impaired in patients treated for head and neck cancer secondary to ablation of surgical structures or radiation fibrosis.[6,9,10] Therefore, the mechanical advantages provided by appropriate respiratory–swallowing coordination may be particularly important in these patients.[6,9,10,15,54–56] Overall, our findings of non E–E respiratory–swallow patterning in the majority of our patients with head and neck cancer are consistent with the growing body of literature that suggests that impaired breathing–swallowing coordination may contribute to dysphagia in a variety of patient groups, including those with neurological disease and head and neck cancer,[45,57,58] both in the absence and the presence of significant respiratory disease.[40]

We also found a clear relationship between the severity of swallowing impairment as revealed by the MBSImP[44] and non E–E *or* inconsistent respiratory–swallowing patterning. These preliminary findings appear to indicate that respiratory–swallow phase pattern and the stability of the pattern may be related to the severity of swallowing impairment. Although the number of participants in this sample was relatively small, the current findings lead us to postulate that disrupted respiratory–swallowing coordination observed in the present study may be a significant factor underlying swallowing function in our patients with oropharyngeal cancer. There are at least 3 contributing factors to this disruption in normal respiratory–swallowing synchrony: (1) impairments within the swallowing system (ie, delayed initiation of the oropharyngeal swallow stemming from sensory loss, incomplete tongue base retraction, and impaired anterior motion of the hyoid and larynx, leading to incomplete opening of the PES)[59]; (2) obstruction and/or restriction within the respiratory system; and/or (3) central neural control impairment(s) affecting respiratory–swallowing coordination. Given our understanding of the nature of disease systems and the results of the MBSImP, it is reasonable to assume that the first of these key factors is impaired in patients with head and neck cancer with swallowing disorders. We cannot, however, rule out the contribution of other factors and in particular the impact of disease on neural control processes normally acting to coordinate breathing with swallowing. Additional research is currently under way to explore the nature of the underlying impairments in respiratory–swallowing coordination in this and other target patient populations. Given that intervention strategies for improving chronic swallowing impairments associated with head and neck cancer are limited, the present results suggest that impaired respiratory–swallowing coordination might be an appropriate therapeutic target. That is, patients could be trained to produce optimal patterning. Training experiments such as these are currently under way in our laboratories. Such experiments may not only provide important clinical benefits, but they may also be essential in understanding which of the 3 potential factors listed earlier may underlie impaired respiratory swallowing coordination and long-lasting swallowing impairments in these patients.

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Table 1

Penetration-aspiration scale scoring.[42]

Normal	1 = Does not enter airway
	2 = Enters airway/above folds/ejected
Penetration	3 = Enters airway/above folds/not ejected
	4 = Enters airway/contacts folds/ejected
	5 = Enters airway/contacts folds/not ejected
Aspiration	6 = Enters airway/below folds/ejected
	7 = Enters airway/below folds/not ejected despite effort
	8 = Enters airway/below folds/no effort

Table 2

Demographics by participant type.

		Stage	
	Age, y (SD; range)	**I or II**	**III or IV**
Age-matched controls	60.2 (13.5; 42–79)		
Patients with cancer	59.4 (9.5; 44–78)	*N* = 11	*N* = 9
SURG-XRT	61.3 (8.0; 49–74)	*n* = 7	*n* = 4
CHEMO-XRT	57.1 (11.1; 44–78)	*n* = 4	*n* = 5

Abbreviations: SURG-XRT, patients previously treated with surgery and radiation therapy; CHEMO-XRT, patients previously treated with chemotherapy and radiation therapy.

Table 3

Scoring schema for MBSImP components analyzed.

Initiation of pharyngeal swallow
0 = Bolus head at posterior angle of ramus during first hyoid excursion
1 = Bolus head at vallecular pit during first hyoid excursion
2 = Bolus head at posterior laryngeal surface of epiglottis during first hyoid excursion
3 = Bolus head at pit of pyriforms during first hyoid excursion
4 = No appreciable initiation at any location
Anterior hyoid excursion
0 = Complete anterior movement
1 = Partial anterior movement
2 = No anterior movement
Pharygoesophageal segment opening
0 = Complete distention and full duration; no obstruction of flow
1 = Partial distention and partial duration; partial obstruction of flow
2 = Minimal distention and incomplete duration; marked obstruction of flow
3 = No distention with total obstruction of flow
Tongue base retraction
0 = No bolus between tongue base and posterior pharyngeal wall
1 = Trace column of contrast or air between tongue base and posterior pharyngeal wall
2 = Narrow column of contrast or air between tongue base and posterior pharyngeal wall
3 = Wide column of contrast or air between tongue base and posterior pharyngeal wall
4 = No appreciable posterior motion of tongue base
Pharyngeal residue
0 = Complete pharyngeal clearance
1 = Trace residue within or on pharyngeal structures
2 = Collection of residue within or on pharyngeal structures
3 = Majority of contrast within or on pharyngeal structures
4 = Minimal to no pharyngeal clearance

Abbreviation: MBSImP, Modified Barium Swallowing Impairment Profile.

Table 4

Summary of respiratory-swallow phase patterns for both 5-mL trials.

	No. of patients (%)			
	E–E	**E–I**	**I–E**	**I–I**
Age-matched controls	29 (72.5%)	2 (5.0%)	8 (20%)	1 (2.5%)
Patients with cancer	15 (37.5%)	4 (10.0%)	20 (50%)	1 (2.5%)
SURG-XRT	8 (36.4%)	3 (13.6%)	11 (50%)	0 (0.0%)
CHEMO-XRT	7 (38.9%)	1 (5.6%)	9 (50%)	1 (5.6%)

Abbreviations: E–E, swallows immediately preceded by and followed by expiratory flow; E–I, swallows immediately preceded by expiratory flow and followed by inspiratory flow; I–E, swallows immediately preceded by inspiratory flow and followed by expiratory flow; II, swallows immediately preceded by and followed by inspiratory flow; SURG–XRT, patients previously treated with surgery and radiation therapy; CHEMO–XRT, patients previously treated with chemotherapy and radiation therapy.

Table 5

Summary of respiratory-swallow phase patterns for both5-mL trials collapsed across trials.

	Respiratory phase pattern	
	E–E	**Not E–E**
Age-matched controls	72.5%	27.5%
Patients with cancer	37.5%	62.5%
SURG-XRT	36.4%	63.6%
CHEMO-XRT	38.9%	61.1%

Abbreviations: E–E, swallows immediately preceded by and followed by expiratory flow; SURG–XRT, patients previously treated with surgery and radiation therapy; CHEMO–XRT, patients previously treated with chemotherapy and radiation therapy.

Table 6

Respiratory-swallow phase patterns and MBSImP scores across trials.

Phase pattern	$MBSImP_{S1}$	$MBSImP_{S2}$
Consistent E–E (25%)		
Mean	7.60	7.20
N	5	5
SD	3.130	2.683
Inconsistent E–E (20%)		
Mean	16.75	16.00
N	4	4
SD	3.862	4.243
Consistent Not E–E (35%)		
Mean	9.43	9.86
N	7	7
SD	4.860	4.337
Inconsistent Not E–E (15%)		
Mean	10.00	11.33
N	3	3
SD	5.568	5.774

Abbreviation: MBSImP, Modified Barium Swallowing Impairment Profile; S1, swallow trial 1; S2, swallow trial 2; E–E, swallows immediately preceded by and followed by expiratory flow.

Note: One participant was not included in the analysis because of incomplete data (n = 19).