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Dysphagia

Oropharyngeal Dysphagia in Esophageal Cancer Before and After Transhiatal Esophagectomy

Ruth E. Martin, PhD,[1,2,5] Penelope Letsos, MClSc,[1,6,7] Donald H. Taves, MD,[2,4] Richard I. Inculet, MD,[2,3] Heather Johnston, MClSc,[1] and Harold G. Preiksaitis, MD, PhD[2,4,5]

[1]Faculty of Health Sciences and [2]Faculty of Medicine and Dentistry, University of Western Ontario, London, Ontario, Canada; [3]London Health Sciences Centre–SSC, London, Ontario, Canada; [4]St. Joseph's Health Centre and [5]Lawson Research Institute, London, Ontario, Canada; [6]York County Hospital, Newmarket, Ontario, Canada; and [7]Toronto East General Hospital, Toronto, Ontario, Canada

Abstract. Although dysphagia is the predominant symptom of esophageal cancer, the nature of the swallowing deficit remains unclear, particularly regarding an oropharyngeal motor component. The present study examined the oropharyngeal swallow in patients with esophageal cancer before and following transhiatal esophagectomy. Videofluoroscopic data were obtained from ten patients with esophageal cancer before and following transhiatal esophagectomy as they swallowed 2-, 5-, and 10-cc aliquots of liquid and puree, and 0.5 and 1 tsp of solid. Each swallow was rated on 36 parameters by three independent judges. Swallow-related hyoid bone movement, computed from digitized segments of the videofluoroscopic data, was compared pre- and postsurgically. All patients showed at least mild abnormality of the oropharyngeal swallow preoperatively. Abnormalities involved all stages of swallowing in nine of the ten patients; however, the oral preparatory/oral stage was relatively more impaired than the pharyngeal stage in the majority of patients. Postsurgically, all patients exhibited at least a mild oropharyngeal swallowing impairment. New or increased postoperative deficits involved the pharyngeal stage of swallowing, whereas oral stage abnormalities were generally improved or unchanged following surgery. Swallow-related hyoid kinematics were highly variable both before and following surgery. Anterior hyoid bone excursion was significantly reduced postoperatively in one patient and significantly increased in one patient. Patients with esophageal cancer exhibit oropharyngeal dysphagia, with different profiles of abnormality before and following esophagectomy.

Key words: Deglutition—Dysphagia—Esophageal cancer—Esophagectomy—Deglutition disorders.

The predominant symptom of esophageal cancer is dysphagia [1,2]. It is unclear whether subjective complaints of dysphagia by patients with esophageal cancer reflect esophageal obstruction only, or whether there also is a significant oropharyngeal or esophageal motor abnormality. A small number of studies have suggested that oropharyngeal dysphagia may occur in esophageal cancer. Oropharyngeal abnormalities have been noted in patients awaiting esophagectomy [3,4]. New-onset swallowing abnormalities have been identified following surgical resection, including aspiration, deficient airway protection, and reduced laryngeal movement [3,4]. These abnormalities have been attributed to the effects of surgery. The possibility that swallowing deficits arise following surgical resection is clinically important given that surgery is often aimed at palliating dysphagia [5]. Most previous studies have focused on describing the postoperative swallow, with little information on the preoperative swallow [3,6–8]. Therefore, the extent to which deficits observed postoperatively are related to surgery, or reflect presurgical alterations, remains unclear. The present study was undertaken to (1) characterize the oropharyngeal swallow in patients with esophageal cancer and (2) determine the effects of transhiatal esophagectomy on oropharyngeal swallowing by comparing pre- and postoperative swallowing patterns within subjects. Some data from this study have been briefly reported [9–11].

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Correspondence to: Ruth E. Martin, Ph.D., Faculty of Health Sciences, University of Western Ontario, Elborn College, London, Ontario, Canada N6G 1H1. E-mail: remartin@julian.uwo.ca

Method

Subjects

Ten patients with esophageal cancer who were awaiting esophagectomy participated in the study. Potential patients underwent a standard oral peripheral/oral motor examination by a speech–language pathologist; those patients with abnormal findings (e.g., oromandibular tremor) were excluded from the sample. Furthermore, patients with conditions other than esophageal cancer known to affect swallowing or gastrointestinal function were excluded. The patients ranged in age from 49 to 76 years (mean age: 66.7 years); 9 were male. Three patients had squamous cell carcinoma of the middle ($N = 2$), or distal ($N = 1$) third of the esophagus, while 7 had adenocarcinoma of the middle ($N = 1$) or distal ($N = 6$) third of the esophagus (Table 1). The study protocol was approved by the University of Western Ontario Review Broad for Health Sciences Research Involving Human Subjects.

All patients underwent uncomplicated transhiatal esophagectomy with gastric pull-up essentially as described by Orringer [12] and outlined below. None of the patients received preoperative radiation or chemotherapy. The patient is in the supine position, head turned to the right, under general anesthesia, with ventilatory support via an endotracheal tube. The abdomen is entered through a supraumbilical incision, the stomach is mobilized, and a standard pyloromyotomy is performed. The distal esophagus is mobilized by blunt dissection upward into the mediastinum. A jejunal feeding is placed and brought out through a separate incision. The cervical phase is performed via an incision along the sternocleidomastoid muscle, the sternohyoid and sternothyroid muscles being routinely divided. The sternocleidomastoid muscle, carotid sheath, and contents are gently retracted laterally while the larynx and trachea are retracted medially, further exposing the cervical esophagus. The recurrent laryngeal nerve is identified and protected. The ansa cervicalis is not divided. The esophagus is freed from above by downward dissection to the carina. Transhiatal blunt dissection of the midesophagus completes mobilization of the esophagus which is delivered into the abdomen after transection in the neck. The esophagus and stomach are divided after identification of the vascular arcades. The stomach is not tubularized and is positioned through the mediastinum. The cervical esophagogastric anastomosis is hand sewn using Vicryl (3-0).

Data Collection and Analysis

Patients completed written questionnaires during their pre- and postsurgery fluoroscopic swallowing examinations (see below). They were asked to describe any swallowing or eating problems, rate the severity of the swallowing problem on a 10-point scale (10 being most severe), and describe current diet, dietary alterations, other compensations, and weight loss.

A videofluoroscopic swallow study (VFSS) was obtained on each patient 2–21 days preoperatively and repeated at 44–134 days postoperatively. Studies were performed in the early morning after the patient fasted for 8 hours. Fluoroscopic studies were performed with the patient in the erect lateral and frontal positions. A light-weight calibration ring was taped to the patient's neck midsagitally over the thyroid cartilage. The patient was then administered 2-, 5-, and 10-cc aliquots of liquid barium (thin) and barium pudding (thick) via a catheter-tipped syringe, and 0.5- and 1-tsp amounts of barium-coated cookie from a spoon. Two repetitions of each volume and consistency combination were obtained, beginning with 2-cc thick liquid. The patient was instructed to swallow the entire aliquot as a single bolus; piecemeal swallows were excluded from the analysis. Concentrations of thin and thick liquid barium were 33% and 100% wt/vol Unibar-100 barium, respectively. Barium pudding was 20 cc of 250% wt/vol E-2 high-density barium in 60 ml of pudding. Fluoroscopic data were obtained with a Siemens high-scan camera and recorded on S-VHS videotape at 30 frames/s using a Panasonic model 7300 videocassette recorder.

The VFSSs were analyzed independently by three trained judges (REM, PL, HJ) who were blind with respect to patient identification and pre/postsurgical status. Videotapes were replayed on a Panasonic model AG-7350 cassette recorder and viewed on a Trinitron RGB monitor PVM-1351Q. Each swallow was viewed 5 times (twice in real-time and 3 times in slow motion) and rated on 36 parameters which were adapted from Dodds et al. [13] and corresponded to bolus flow or aerodigestive tract function. Each parameter was rated on a 4-point nominal severity scale as normal or mildly, moderately, or severely impaired. Adequacy of pharyngeal contraction was judged based on the degree of contact between the tongue base and pharyngeal walls and the amount of residue on the pharyngeal walls following the swallow. Upper esophageal sphincter (UES) opening was judged based on the diameter of the UES opening during the pharyngeal swallow and on the presence and amount of residue in the pyriform sinuses following the swallow. Esophageal obstruction was judged preoperatively using the same nominal scale (mild: some holdup of barium but prompt clearance; moderate: delay in clearance; severe: progressive filling of the esophagus with each successive swallow). Postoperatively, the anastomosis was not stressed with barium and, therefore, a full-caliber assessment could not be made. Emptying only was assessed and was graded as mildly abnormal if minimal holdup was seen proximal to the anastomosis, severe if prolonged holdup occurred, and moderately abnormal between these two extremes.

Consistency of ratings was determined within and across judges by analyzing 12 pseudorandomly selected swallows (i.e., 1 swallow representing each of the 4 bolus consistencies for 3 subjects). Percent agreement was computed across all parameters. Intrajudge agreement was at least 89% and 82% for (a) normal/abnormal ratings and (b) severity ratings, respectively. Interjudge agreement was at least 78% and 70% for normal/abnormal and severity ratings, respectively.

Quantification of Hyoid Movement

Because previous studies have reported reduced laryngeal elevation following transhiatal esophagectomy [3,4], we sought to measure and compare hyoid excursions pre- and postsurgery. Swallow-related hyoid movements were computed from the lateral plane fluorographic images. Each videotape was time-coded (i.e., 1/100 s). Image sequences corresponding to liquid and pudding swallows were digitized at 30 frames/s using the Peak Performance Technologies (Englewood, CO) proprietory frame grabber board and Peak5 version 5.2 analysis package. Hyoid movement onset was defined as the point at which the hyoid began to move superiorly during oral transport. Hyoid movement offset was defined as the point at which the hyoid came to rest following its descent. For each swallow, the *x,y* coordinates of pixels corresponding to 5 anatomic landmarks were marked on sequential video frames and stored for subsequent analysis. Two midsagittal reference points were marked on the maxilla, the first corresponding to the anterior nasal spine and the second to a point on the palatine bone, 3 cm from the first point. By fixing the position of the first reference point and the orientation of the line running beween the two reference points, in all frames, the raw data were corrected for slight, two-dimensional head movements. These reference points also defined a coordinate space in which the origin was the anterior nasal spine, the *x*-axis was the line running between the two reference points, and the *y*-axis was the line passing through the point of origin, normal to the *x*-axis. Mandibular movement was determined by marking one point on the mental protu-

Table 1. Demographic information and subjective preoperative complaints

Patient	Age	Type/location of cancer and cancer staging[a]	Subjective dysphagia severity rating[b]	Duration of dysphagia (months)	Subjective complaints[c]	Diet alterations[d]
1	70	AD/GEJ T2,N0,M0	2.5	2.5	R, P	All solids
2	67	SC/MID T2,N0,M0	4	4	R, P	Toast
3	74	AD/GEJ T2,N0,M0	5	3	R, S, U, C	All solids
4	76	SC/MID T2,N0,M0	5	2	R, C, H	None
5	75	AD/GEJ T3,N1,[e]M0	5	4	R, S, P, U, C, G	Coarse meat
6	54	AD/GEJ T3,N1,[e]M0	6	3	R, P	None
7	49	AD/MID T3,N0,M0	7	2.5	R, S, P, C, H, F	Bread
8	76	AD/GEJ T1,N0,M0	7	1.5	R, S, U, F, G	All solids
9	65	AD/GEJ T3,N1,[e]M0	7	3	R, S, P, U, Hi	All solids
10	61	SC/GEJ T3,N1,[e]M0	9.5	3.5	R, S, P, H	All solids

[a]AD = adenocarcinoma, SC = squamous cell carcinoma, MID = middle third of esophagus, GEJ = gastroesophageal junction.
[b]10-point rating scale with 10 representing most severe.
[c]Subjective complaints: R = retrosternal sticking of solid foods; P = pain; S = excessive saliva; U = spitting up of undigested food; C = coughing or choking during/after meals; H heartburn; F = fear of swallowing; G = globus; Hi = hiccups.
[d]Refers to avoided foods.
[e]Lymph node involvement: Subject 5: one node, left supraclavicular; Subject 6: one node, region of hepatic artery; Subject 9: two nodes, within perigastric fat; Subject 10: one node, pulmonary ligament location 9.

berance. Hyoid bone movement was computed by digitizing one point that corresponded to its anterior–superior corner. Pixel coordinates were converted to units of measurement by digitizing the outer diameter of the calibration ring (i.e., 17.44 mm).

Displacement functions were smoothed by applying a digital, low-pass filter (bidirectional, third-order Butterworth, f_c = 10 Hz). Hyoid displacement in the *x* dimension was defined as the difference between the maximum *x* value achieved during the initial upward movement and the minimum *x* value, achieved during either the offset of the anterior movement or the subsequent downward displacement. Displacement in *y* was defined as the difference between the maximum *y* value achieved during the initial upward movement and the minumum *y* value that corresponded to either the movement onset or the return to rest position. Hyoid displacements in the *x* and *y* dimensions were examined statistically as a function of surgery (i.e., pre/postesophagectomy) and bolus volume (i.e., 2, 5, 10 cc) with a two-factor analysis of variance (ANOVA) for each subject. An alpha level of 0.05 was considered significant.

Results

Subjective Complaints

All patients complained of dysphagia preoperatively, as indicated by their subjective ratings of dysphagia severity (Table 1). The two patients with severe esophageal obstruction gave the highest dysphagia severity ratings (Table 2). The duration of perceived dysphagia ranged from 1.5 to 4 months, with increasing severity over time for all patients. The predominant complaint was retrosternal sticking of solid foods. Other subjective complaints included excessive saliva, pain on swallowing, spitting up of undigested food, coughing during or after meals, and heartburn (Table 1). Dietary alterations ranged from no modification to avoidance of all solids.

Videofluoroscopic Findings

All 10 patients were judged to have at least a mild abnormality of the oropharyngeal swallow before esophagectomy, as summarized in Table 2. However, the degree and nature of the abnormality varied within patients and also between patients. For example, three patients, two of whom had severe esophageal obstruction (P9 and P10), showed a progressive deterioration from mild to severe swallowing abnormality over the course of the fluoroscopic examination. Seven patients showed relatively greater oral preparatory/oral stage impairment than pharyngeal stage impairment, whereas the remaining three patients showed more uniform abnormality of the oral and pharyngeal phases.

Oral preparatory deficits were observed in 9 pa-

Table 2. Salient preoperative videofluoroscopic swallowing abnormalities

Patient	1	2	3	4	5	6	7	8	9	10
Oral preparatory stage[a]										
Abnormal bolus formation	M	—	M	M	M	M	MO	M	MO	MO
Posterior leakage	M	—	—	M	M	M	M	MO	M	MO
Oral stage[a]										
Hesitancy	M	M	M	M	MO	M	M	MO	M	M
Abnormal tongue movement pattern	M	M	M	M	M	M	MO	M	M	MO
Oral residue	M	M	M	M	M	M	MO	M	M	MO
Pharyngeal stage[a]										
Delayed initiation	M	—	—	M	M	M	M	MO	M	M
Reduced peristalsis	M	—	—	M	—	M	M	M	—	M
Reduced laryngeal elevation	—	—	—	—	—	—	—	—	M	—
Penetration/aspiration	M	—	—	M	—	—	—	—	—	—
Postswallow residue[b]	M	M	M	MO	M	M	MO	M	M	MO
Impaired UES opening	—	—	M	—	—	—	M	—	M	M
Esophageal obstruction[a]	MO	M	M	M	MO	M	M	MO	S	S

[a]M = mild abnormality, MO = moderate abnormality, S = severe abnormality, — = within normal limits.
[b]Residue in the valleculae, pyriform sinuses, and/or coating the posterior pharyngeal wall.

tients, the most common being deficient bolus formation ($N = 9$) and leakage of the bolus into the pharynx prior to the oral phase ($N = 8$). Although most deficits were mild, at least one oral preparatory abnormality was judged as moderate in 4 patients, 2 of whom had severe esophageal obstruction. All patients showed oral stage abnormalities, the most common being deficient tongue movement ($N = 10$), oral residue ($N = 10$), hesitancy in initiating the tongue stripping wave ($N = 10$), and repetitive tongue pumping ($N = 5$). Across patients and swallowing parameters, abnormalities were rated as mild or moderate in 83% and 17% of the cases, respectively.

All patients showed at least one mild abnormality of the pharyngeal swallow, most commonly postswallow pharyngeal residue ($N = 10$) and mild delay in initiation ($N = 8$). Two patients showed laryngeal penetration or aspiration. Six patients showed mildly reduced pharyngeal contraction, including 3 with asymmetric bolus flow through the pharynx (bolus flow was greater on the right for 2 of the 3 patients). One patient had mildly reduced laryngeal movement.

Swallow-Related Hyoid Kinematics

Preoperatively, the swallow-related hyoid trajectories varied markedly within and also across patients. Two patterns of hyoid movement were observed across the patients. In one pattern, the hyoid moved up and forward toward movement endpoint (Fig. 1a). In the contrasting pattern, the hyoid bone moved anteriorly from an elevated position with little further upward movement (Fig. 1e). Hyoid trajectories also varied in terms of the relative timing of the superiormost and anteriormost points. The hyoid elevated to its superiormost point and then moved anteriorly to its anteriormost point, in a counterclockwise fashion, for patients P3 and P4 (Fig. 1a). However, for patients P2 and P7, the hyoid bone often achieved its anteriormost position before its superiormost point and thus appeared to move in a clockwise direction (Fig. 1c,e).

Effects of Surgery

Subjective Complaints

Of 5 patients studied pre- and postsurgically, 3 reported no postoperative swallowing difficulties while 2 perceived dysphagia (Table 3). The most common new-onset complaint was globus ($N = 3$). Other complaints included coughing during or after meals, dry mouth, and spitting up of saliva or mucus. Self-ratings of dysphagia severity were reduced postoperatively for all patients. Diet alterations ranged from none to avoidance of specific foods.

Videofluoroscopic Findings

All 5 subjects demonstrated at least a mild oropharyngeal swallowing abnormality postoperatively (Table 4). Oral preparatory stage deficits were present in 4 of the 5 subjects, the most common being abnormal bolus formation. Relative to preoperative levels, abnormality of the oral preparatory stage was reduced in one patient (P9), unchanged in three (P2, P3, P4), and increased in one (P7). All 5 subjects also showed mild oral stage abnormality postsurgically, including abnormal tongue movement, hesitancy, and oral residue. However, the oral stage was

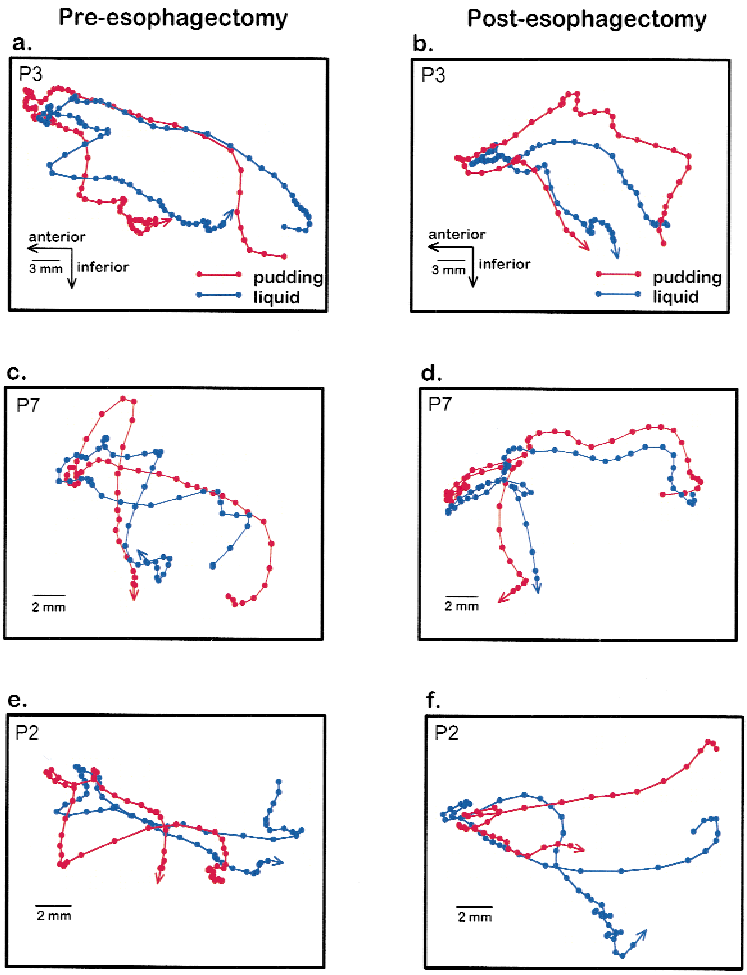

Fig. 1. Representative examples of swallow-related hyoid bone trajectories before and after esophagectomy from 3 patients (P7, P2, P3). Bolus volume was 10 cc in all cases. Arrowheads indicate trajectory endpoints.

judged to be improved in 3 of the 5 subjects postoperatively. There were no instances of new or increased oral stage deficits postoperatively.

A mild pharyngeal stage deficit was found for all 5 subjects postoperatively. However, in contrast to the oral stage, 4 of the 5 subjects showed at least one new postsurgical pharyngeal stage abnormality such as reduced pharyngeal contraction ($N = 3$) or reduced laryngeal elevation ($N = 2$). The two patients who showed right-sided asymmetry of bolus flow presurgically also showed this pattern postoperatively. One patient showed a new-onset delay in initiation of the pharyngeal swallow, while another showed laryngeal penetration. For patient P4, the frequency and amount of aspiration were increased relative to presurgical levels, although overall aspiration was still judged as mild. All patients

Table 3. Subjective postoperative complaints

Patient	Perceived dysphagia	Subjective dysphagia severity rating[a]	Surgery to VFSS Interval (days)	Subjective Complaints[b]	Diet alterations[c]
2	No	1	105	G, C	None
3	No	1	107	None	Hot beverages
4	Yes	3	134	C, Sp, D, G	Spicy food, dry meats, carbonated beverages
7	Yes	3	44	G	Steak, milk
9	No	N/A	52	N/A	None

[a]10-point rating scale with 10 representing most severe.
[b]Subjective complaints: G = globus; C = coughing during/after meals; D = dry mouth; Sp = spitting up of saliva/mucus.
[c]Refers to avoided foods.

Table 4. Salient postoperative videofluoroscopic swallowing abnormalities

Patient	2	3	4	7	9
Oral preparatory stage[a]					
Abnormal bolus formation	− (→)	M (→)	M (→)	MO (→)	M (↓)
Posterior leakage	− (→)	− (→)	M (→)	MO (↑)	− (↓)
Oral stage[a]					
Hesitancy	M (→)	M (↓)	M (→)	M (→)	— (↓)
Abnormal tongue movement	M (→)	M (↓)	M (↓)	MO (→)	M (→)
Oral residue	M (↓)	M (↓)	M (↓)	MO (→)	M (→)
Pharyngeal stage[a]					
Delayed initiation	— (→)	M (↑)	M (→)	M (→)	— (↓)
Reduced peristaliss	M (↑)	M (↑)	M (↑)	M (→)	M (↑)
Reduced laryngeal elevation	— (→)	M (↑)	M (↑)	— (→)	— (↓)
Penetration/aspiration	— (→)	— (→)	M (↑)	— (→)	M (↑)
Postswallow residue[b]	M (→)	M (↑)	MO (→)	MO (→)	M (→)
Impaired UES opening	— (→)	— (↓)	M (↑)	M (→)	M (→)

[a]M = mild abnormality; MO = moderate abnormality; — = within normal limits. (↑) = severity of abnormality increased relative to preoperative level. (↓) = severity of abnormality decreased relative to preoperative level. (→) = severity of abnormality unchanged relative to preoperative level.
[b]Residue in valleculae, pyriform sinuses, and/or coating the posterior pharyngeal wall.

were judged to have adequate emptying at the anastomosis.

The preoperative (Table 2) and postoperative (Table 4) swallowing deficits were compared for both the oral preparatory/oral and pharyngeal stages. New-onset abnormalities, or abnormalities of increased severity, postoperatively were more likely to involve the pharyngeal than the oral preparatory/oral stage of swallowing (Fisher's exact test, $p < 0.05$).

Comparison of Hyoid Kinematics Before and After Surgery

Postoperatively, hyoid trajectories differed in patterns similar to those seen preoperatively. That is, across patients, the movements varied in terms of (a) the degree of superior movement (Fig. 1a,b,e,f) and (b) the relative timing of the anteriormost and superiormost points within the trajectory. Hyoid movement patterns were similar pre- and postsurgically for 3 of the 4 patients. For the remaining patient (P7), there were substantially more trajectories in which the hyoid moved in a counterclockwise direction (i.e., the superiormost point preceded the anteriormost point) postsurgically compared with presurgically.

Mean hyoid displacements in the *x* and *y* dimensions are shown in Figure 2. Across subjects, bolus volumes, and consistencies, mean amplitude in the *x* dimension (i.e., anterior–posterior) ranged from 12.1 to 23.0 mm preoperatively and from 12.2 to 20.7 mm postoperatively. Within subjects, hyoid displacement in the *x* dimension was significantly decreased postoperatively for 1 subject (GH; $F = 4.45$, $p < 0.05$) and significantly increased for 1 subject (DG; $F = 10.46$, $p < 0.05$). The effect of surgery on hyoid movement in the *x* dimension varied depending on bolus volume for one subject (GH; $F = 5.47$, $p < 0.05$), with movement decreasing postsurgically for the largest volume swallow. There were no significant main effects of volume indicating that hyoid movement in the *x* dimension did not differ across bolus volumes. Mean hyoid displacement in the *y* dimension (i.e., superior–inferior) ranged from 6.2 to 14.8 mm before surgery and from 6.7 to 14.6 mm after surgery across subjects, bolus volumes, and consistencies. There were no significant differences in *y* dimension hyoid movement with surgery or across bolus volumes, and no significant interactions.

Discussion

The present study has shown that (a) patients with esophageal cancer exhibit oropharyngeal dysphagia before surgery, and (b) new-onset oropharyngeal swallowing abnormalities, involving primarily the pharyngeal stage, may arise following transhiatal esophagectomy and persist beyond 3 months postsurgically. These findings suggest that the esophagus and oropharynx function as components of an interactive system within which the swallow-related oropharyngeal motor pattern is modulated by the esophagus. Dysphagia in esophageal cancer is complex, with different contributing pathogenic mechanisms before and after surgery.

Presurgical Oropharyngeal Dysphagia

The detailed qualitative and kinematic findings reported here extend and clarify previous accounts of preoperative oropharyngeal deficits in this patient group. Hambraeus

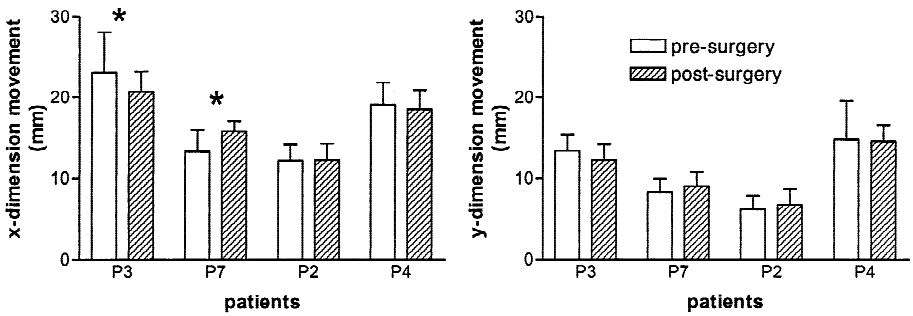

Fig. 2. Mean hyoid bone movement amplitude in the *x* dimension and *y* dimension during swallowing before and after esophagectomy for 4 subjects (see text). Error bars indicate standard deviations. Asterisks indicate statistically significant differences ($p < 0.05$).

et al. [3] briefly reported mild pharyngeal swallowing dysfunction in 3 of 5 patients prior to surgery for cancer of the esophagus, or cardia which they attributed to prior irradiation of the neck. However, our study clearly documents preoperative oropharyngeal deficits unrelated to radiation or other intervention. Heitmiller and Jones [4] identified at least one oropharyngeal swallowing abnormality in 10 of 14 esophageal cancer patients, and judged 2 to have "significant baseline swallowing disorders." The present findings differ from those authors' findings, however, in terms of the frequency and nature of abnormalities found; they reported pharyngeal stage abnormalities but no tongue abnormalities, whereas our findings indicated at least a mild oral preparatory/oral stage abnormality in all 10 patients. Indeed, we judged the oral preparatory/oral stage to be relatively more impaired than the pharyngeal stage in the majority of patients. This discrepancy may be related to different criteria or thresholds for identifying oral stage abnormality. Alternatively, the discrepancy may reflect the use of different fluoroscopic protocols. Given our finding of marked variability in swallowing abnormality over the course of the fluoroscopic examination, it is possible that differences in the total number of swallows examined or in the relative weightings of swallows in overall ratings of abnormality could result in different impressions of swallowing abnormality. Details of the radiographic protocol were not reported by Heitmiller and Jones [4].

The present finding of oropharyngeal dysphagia in esophageal cancer also is in keeping with reports of oropharyngeal abnormalities occurring simultaneously with other types of esophageal dysfunction such as achalasia [14,15], esophageal dysmotility [15], stricture, Schatzki's ring, and gastroesophageal reflux with spasm [16]. In relation to our finding of oral stage abnormalities, it is noteworthy that Triadafilopoulos et al. [15] reported disturbed lingual peristalsis in 62% of patients with esophageal motor dysfunction and nonobstructive dysphagia.

We suggest that oropharyngeal abnormalities represent modulation of the swallow-related oropharyngeal motor sequence by factors associated with esophageal disease. Such factors might include esophageal obstruction and distension, esophageal bolus retention, gastroesophageal reflux, or the sensation of retrosternal sticking and swallow-related pain. A role for esophageal distension and/or its correlates in the pathogenesis of the oropharyngeal abnormalities is suggested by our findings that the two patients with severe esophageal obstruction and progressive pooling of barium showed (a) the greatest degree of oropharyngeal abnormality and (b) marked deterioration of swallowing function over the course of the fluoroscopic examination. Nevertheless, the fact that oropharyngeal abnormalities also were found in patients with mild obstruction, who did not show progressive pooling or esophageal distention, indicates that other causal factors must be involved.

Jones et al. [16] have proposed that the simultaneous disorders of the pharynx and esophagus seen in various esophageal diseases represent related phenomena mediated by altered cricopharyngeal (CP) function. However, the present finding of UES dysfunction in only 4 of 10 presurgical patients who had oropharyngeal abnormalities, as well as the data of Heitmiller and Jones [4] indicating no abnormality of the cricopharyngeal segment in the two esophageal cancer patients judged to have pharyngeal dysphagia, suggests that factors other than CP dysfunction are involved in the pathogenesis of oropharyngeal deficits in esophageal cancer.

A variety of reflex mechanisms which originate in the esophagus and modulate pharyngeal and UES function have been identified in experimental and clinical studies [17–19]. For example, esophageal distension in normal subjects causes an increase in UES pressure [20,21]. Thus, modulation of the oropharyngeal swallow could be mediated by esophagopharyngeal reflexes representing normal mechanisms responding to cancer-related esophageal alterations. It is also noteworthy, however, that esophagopharyngeal reflex mechanisms have been shown to be altered in esophageal disease [23]. Therefore, it is conceivable that oropharyngeal abnormalities in esophageal cancer represent direct manifestations of, or responses to, alteration of esophagopharyngeal reflex mechanisms. Alternatively, since many

aspects of the oropharyngeal swallow can be modulated volitionally [22,23], compensatory mechanisms may have a role.

The presurgical swallowing abnormalities found in the present study are unlikely to be explained on the basis of normal aging for the following reasons: (1) The profile of abnormality is not consistent with known age-related changes in swallowing physiology [24]. (2) Oropharyngeal abnormalities were found in all subjects presurgically, and there was no relationship between age and severity of oropharyngeal dysphagia. Indeed, the youngest subject in our study, aged 49 years, exhibited significant oropharyngeal abnormality.

Effects of Surgery

Previous studies have reported oropharyngeal swallowing abnormality following transhiatal esophagectomy. Hambreus et al. [3] found aspiration in association with pharyngeal abnormality and attributed these deficits to damage of the pharyngeal musculature and plexus during intraoperative manipulation. Heitmiller and Jones [4] reported at least one new-onset swallowing abnormality in 67% of patients one week after transhiatal esophagectomy. Although these abnormalities resolved or improved within the first postoperative month in most cases, two patients judged to have significant preoperative swallowing disorders had long-term postoperative dysphagia. In preliminary reports, Easterling et al. [8] described aspiration, laryngeal penetration, pharyngeal residue, and absent epiglottic movement in a group of eight patients studied postoperatively. Compared with age-matched controls, aspirating patients had smaller UES opening diameter and anterior hyoid bone excursion.

In the present study, all subjects reported reduced or no swallowing difficulty 6–19 weeks after surgery, but radiographic evidence of oropharyngeal abnormality persisted. Furthermore, new or increased postoperative deficits involved the pharyngeal stage of swallowing in almost all cases. In contrast, oral stage swallowing abnormalities were improved or unchanged following surgery, indicating a dissociation of oral and pharyngeal stage abnormalities with surgery.

Our kinematic analyses indicated that swallow-related laryngeal movement, as reflected in hyoid movement, was significantly reduced in 1 of 4 subjects 15 weeks after surgery. This suggests that reduced laryngeal movement, as reported in previous qualitative studies [3,4], may represent a long-term deficit in some patients. However, our findings that one subject showed significantly *increased* hyoid movement 6 weeks after surgery and that two other subjects showed no significant differences indicate that, relative to preoperative patterns, postsurgical hyoid kinematics are quite variable.

New-onset oropharyngeal dysphagia has been reported following other surgical procedures involving the neck, including anterior cervical spine surgery [25,26] and endarterectomy [27], and has been attributed to surgical damage to the innervation of the swallowing mechanism. Oropharyngeal swallowing deficits following esophagectomy also have been interpreted as resulting from inadvertent damage to the pharyngeal plexus and other nerves mediating swallowing [3,4,28,29]. The present study, which compared pre- and postoperative swallowing deficits in detail, provides further support for the view that normal intraoperative manipulation during esophagectomy may result in pharyngeal weakness during swallowing, possibly caused by mechanical denervation of the pharyngeal constrictor muscles [3,28,29]. In particular, our finding that new-onset abnormalities or abnormalities of increased severity following surgery were almost exclusively *pharyngeal stage* deficits is consistent with this view. Nevertheless, the tacit implication that surgical trauma leads to *all* residual postsurgical swallowing difficulties needs to be reconsidered, particularly given our finding that the two patients who showed defective pharyngeal contraction with right-sided asymmetry of bolus flow through the pharynx following surgery also exhibited this pattern prior to surgery. Finally, it is noteworthy that, although the cervical anastomosis is distal to the major pharyngeal neural plexus and great care is taken not to traumatize the recurrent laryngeal nerve or its branches during surgery, other effects of surgery such as scarring at the anastomosis, adhesion formation, and inflammation cannot be avoided or readily controlled and could contribute to postoperative abnormalities (e.g., globus sensation).

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