Functional and Manofluorographic Outcomes After Transoral Endoscopic Pharyngoesophageal Diverticulostomy

Ozan B. Ozguroy, MD; John R. Salassa, MD

Objectives: To investigate functional and manofluorographic findings of patients with pharyngoesophageal diverticulum before and after transoral endoscopic pharyngoesophageal diverticulostomy (TEPD) and to comment on outcomes relative to predictors of successful treatment and pathogenesis of pharyngoesophageal diverticulum.

Design: Retrospective medical record review.

Setting: Academic center.

Patients: Thirty patients underwent TEPD between July 1, 1997, and June 30, 2007, and met the study inclusion criteria. According to the depth of their pharyngoesophageal diverticulum, patients were categorized as having small (<20 mm) or large (≥20 mm) diverticula.

Intervention: Manofluorography before and 6 months after TEPD.

Main Outcome Measures: Functional and manofluorographic findings before and 6 months after surgery.

Results: Functional Outcome Swallowing Scale stage was significantly decreased in patients after surgery. Video-fluoroscopy demonstrated normal swallowing coordination and a significant decrease in pouch depth after surgery (from 29.62 to 4.78 mm). Manometry confirmed normal swallowing coordination and showed significant mean postoperative pressure reductions in the following: cricopharyngeal (CP) resting pressure (from 16.23 to 9.26 mm Hg), CP midbolus pressure (from 32.86 to 19.26 mm Hg), intrabolus pressure gradient across the CP region (from 22.48 to 10.16 mm Hg), and CP peak clearing pressure (from 41.98 to 26.99 mm Hg). The mean preoperative intrabolus pressure gradient across the CP region and the mean postoperative CP nadir were significantly greater in patients having large diverticula.

Conclusions: Statistically significant decreases in functional and objective measures occurred after TEPD. High CP midbolus pressure and high intrabolus pressure gradient across the CP region are reliable objective indicators of patients who might benefit from TEPD and are appropriate variables for follow-up after surgery. There was no manofluorographic evidence of abnormal swallowing coordination in this small series. Our study supports the hypothesis that anatomical hypopharyngeal wall weakness has a major role in the pathogenesis of pharyngoesophageal diverticulum.


The cricopharyngeal (CP) muscle contributes to the valve of the pharyngoesophageal segment (PES).1,2 The terms PES and upper esophageal sphincter are used synonymously in the literature; PES is used herein. The PES valve is closed at rest to help prevent esophageal reflux and opens to allow bolus passage during swallowing. PES resting pressure results from the CP muscle and the pressure of the posterior cricoid plate against the curved anterior cervical spine due to actions of the strap muscles. During swallowing, the CP muscle relaxes, and the larynx and posterior cricoid plate move off the anterior cervical spine to allow bolus passage.1,3 This action produces the negative pressure CP nadir seen on pharyngeal manometry.

A triangular weak zone in the hypopharyngeal wall (Killian dehiscence) between the oblique fibers of the pharyngeal constrictor muscle and the horizontal fibers of the cricopharyngeal muscle has been postulated as the anatomical genesis of pharyngoesophageal diverticulum (PD). Two major hypotheses have been proposed to explain the pathogenesis of PD.1,3,4 The first hypothesis is that the pouch herniates posteriorly at this weak zone as a result of increased hypopharyngeal pressure; therefore, an abnormal (increased) pressure gradient between the hypopharyngeal lumen and the prevertebral space occurs during swallowing. The second hypothesis targets incoordination or failed relaxation at the PES during swallowing as the cause of abnormal (increased) hypopharyngeal pressure during swallowing.
The barium swallow test, videofluoroscopy, and manometry are used in the evaluation of dysphagia due to pharyngeoesophageal disorders, including PD.2 More recently, simultaneous use of videofluoroscopy and manometry (manofluorography [MFG]) provides fluoroscopic images linked in time to manometric data, allowing accurate interpretations of manometric pressure readings relative to fluoroscopic anatomical events.2,6 This method measures extrabolus and intrabolus pressures, which are indirect measures of muscular contraction of the pharynx. Manofluorography has been advocated as the most accurate method for evaluating pharyngeal and esophageal swallowing disorders.2,3,5,6

Increased hypopharyngeal intrabolus pressure during swallowing has been confirmed in patients with pharyngeal dysphagia. The normal intrabolus pressures of the PES have been determined by MFG and reported at our institution, and an intrabolus pressure gradient across the CP region (IB-Gra) has been defined as the difference between the intrabolus pressure readings from above and below the 3-cm CP region.6 The objectives of this study were to investigate functional and MFG findings of patients with PD before and after TEPD and to comment on outcomes relative to predictors of successful treatment and pathogenesis of PD.

### METHODS

#### STUDY DESIGN

A retrospective medical record review from July 1, 1997, to June 30, 2007, was performed to identify patients undergoing TEPD at the Department of Otolaryngology–Head and Neck Surgery, Mayo Clinic Florida, Jacksonville. This study was approved by the Institutional Review Board of Mayo Clinic.

Medical and surgical records were reviewed to determine demographics, surgical complications, and clinical and MFG findings before and 6 months after TEPD. Functional outcomes were noted and were categorized according to Functional Outcome Swallowing Scale (FOSS) stage (Table 1).7 FOSS stage was recorded by one of us (J.R.S.) and reviewed by the other (O.B.O.). Preoperative and 6-month postoperative MFG records of each patient were viewed using a commercially available system (Kay Emetrics Swallowing Work Station; Kay Pentax, Lincoln Park, New Jersey). Manometric examinations used a solid-state unidirectional catheter with 4 sensors spaced 3 cm apart (Gaeltec Medical Measurements Inc, Hackensack, New Jersey). Fluoroscopic examinations noted laryngeal elevation, swallowing coordination, and bolus residue and measured the depth of the diverticulum. The depth was measured from the top of the neck of the pouch to its base in the lateral view. This measurement was calibrated to the constant 30-mm distance between the sensors of the MFG catheter. Postoperative residual pouches or shelves were also measured by this method. The following 7 manometric variables were noted: tongue base peak clearing pressure, hypopharyngeal peak clearing pressure, CP resting pressure, CP nadir, CP midbolus pressure (CP-mid), IB-Gra, and CP peak clearing pressure. Three or four swallows were measured in each patient, and a mean value was obtained.

The following 2 patient groups were established according to the depth of PD diverticula: (1) small group (patients with pouches <20 mm) and (2) large group (patients with pouches ≥20 mm).

### STATISTICAL ANALYSIS

Preoperative and 6-month postoperative FOSS stages of patients were compared using sign test (exact significance [2 tailed]). Preoperative and 6-month postoperative manometric readings were compared among patients using repeated-measures analysis of variance and within the 2 groups using t test. Moreover, postoperative changes in the manometric readings of the small group were compared with those of the large group using repeated-measures analysis of variance.

### RESULTS

One hundred sixteen patients underwent TEPD over a 10-year period at Mayo Clinic Florida. Twenty patients were excluded because of anterior cervical osteophytes or medical history of attempted esophagodiverticulotomy, CP myotomy, or gastrointestinal interventions such as esophageal dilations or esophagocardiodiomyotomy. Thirteen patients were unable to be contacted. Twenty-nine patients who did not undergo preoperative or postoperative MFG were excluded from the study. Twenty-two patients whose manometry catheters could not be placed in the esophagus (catheters were within the diverticula) were excluded because of inadequate preoperative manometry records. A patient with acute idiopathic polynucleritis syndrome and another patient with esophageal dysmotility were excluded after review. The remaining 30 patients were analyzed in this study.

Other than PD, no patients had another disorder that may contribute to dysphagia. Results of flexible fiberoptic examination of the pharynx and larynx were unremarkable in all patients, except for frequent pooling of secretions in the pyriform fossae.

### Table 1. Functional Outcome Swallowing Scale

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Normal physiologic function without symptoms</td>
</tr>
<tr>
<td>1</td>
<td>Normal function with daily or episodic symptoms of dysphagia</td>
</tr>
<tr>
<td>2</td>
<td>Compensated abnormal function manifest by significant dietary modifications or prolonged mealtime (without weight loss or aspiration)</td>
</tr>
<tr>
<td>3</td>
<td>Decompensated abnormal function with weight loss of ≤10% of body weight over 6 mo due to dysphagia; or daily cough, gagging, or aspiration during meals</td>
</tr>
<tr>
<td>4</td>
<td>Severely decompensated abnormal function with weight loss of &gt;10% of body weight over 6 mo due to dysphagia; or severe aspiration with bronchopulmonary complications, nonoral feeding for most nutrition</td>
</tr>
<tr>
<td>5</td>
<td>Nonoral feeding for all nutrition</td>
</tr>
</tbody>
</table>

### Table 2. Preoperative and Postoperative Functional Outcome Swallowing Scale Stages of Patients

<table>
<thead>
<tr>
<th>Stage</th>
<th>Valuea</th>
<th>Preoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.008</td>
<td>0.008</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.016</td>
<td>0.016</td>
<td></td>
</tr>
</tbody>
</table>

aSign test (exact significance [2 tailed]).
In the small group, there were 6 men and 2 women (mean age, 63.7 years [age range, 40-80 years]). In the large group, there were 15 men and 7 women (mean age, 73.8 years [age range, 61-92 years]). The chief complaint was FOSS stage 2 dysphagia manifest by dietary modifications or prolonged mealtime among all 8 patients in the small group and among 16 of 22 patients in the large group. The remaining 6 patients in the large group had FOSS stage 3 dysphagia, defined as weight loss of no more than 10% of body weight over 6 months due to dysphagia. All patients improved at least 1 FOSS stage after surgery, and this improvement reached statistical significance (Table 2).

Videofluoroscopy demonstrated normal anterior and superior elevation of the larynx during swallowing without coordination abnormalities before and after surgery. Most patients had preoperative tongue base or hypopharyngeal bolus residuals cleared by successive swallows. No preoperative aspiration was noted. Videofluoroscopy after surgery demonstrated a significant decrease in pouch depth (from 29.62 to 4.78 mm) (Table 3). As expected, the decrease was significantly greater in the large group.

Manometry records showed normal CP coordination, reflected by negative or normal mean CP nadir and sequential peak clearing pressures. Statistically significant mean postoperative pressure reductions occurred in the following: (1) CP resting pressure (from 16.23 to 9.26 mm Hg), (2) CP-mid (from 32.86 to 19.26 mm Hg), (3) IB-Gra (from 22.48 to 10.16 mm Hg), and (4) CP peak clearing pressure (from 41.98 to 26.99 mm Hg) (Table 3). Preoperative to postoperative changes in CP-mid, IB-Gra, and CP peak clearing pressure were significantly greater in the large group. When comparing preoperative and postoperative manometry readings, the mean preoperative IB-Gra (P = .02) and the mean postoperative CP nadir (P = .001) were significantly greater in the large group. The mean preoperative CP nadir tended to be greater in the large group (P = .06).

Transoral endoscopic pharyngoesophageal diverticulostomy was performed using carbon dioxide laser in 7 of 8 patients in the small group, whereas stapling technique with or without laser was used for all patients in the large group and the remaining patient in the small group. Transoral endoscopic pharyngoesophageal diverticulostomy was not performed in any PD exceeding 7 cm. There were no surgical complications in the large group (stapling technique diverticulostomy), whereas complications were noted for 2 patients in the small group (carbon dioxide laser diverticulostomy). One patient had marked postoperative odynophagia that resolved in 2 weeks with swallowing therapy and analgesics. In the other patient, neck pain and a small amount of retropharyngeal air on lateral neck radiograms were noted on the first postoperative day. Immediate rigid esophagoscopy and left-sided surgical exploration of the neck were performed; however, no retropharyngeal leakage was identified. On the sixth postoperative day, a pharyngocutaneous fistula appeared on the left side, which was

Table 3. Preoperative and Postoperative Manofluorography Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Small Diverticula Group (n=8)</th>
<th>Large Diverticula Group (n=22)</th>
<th>P Value</th>
<th>Mean (SD), mm Hg</th>
<th>Small Diverticula Group (n=8)</th>
<th>Large Diverticula Group (n=22)</th>
<th>P Value</th>
<th>Mean (SD), mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tongue base peak clearing pressure</td>
<td>84.50 (24.57)</td>
<td>89.14 (20.13)</td>
<td>.51</td>
<td>87.22 (21.58)</td>
<td>84.13 (24.33)</td>
<td>.25</td>
<td>84.13 (24.33)</td>
<td></td>
</tr>
<tr>
<td>Postoperative</td>
<td>76.38 (22.41)</td>
<td>86.91 (26.86)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypopharyngeal peak clearing pressure</td>
<td>107.50 (16.19)</td>
<td>105.00 (20.06)</td>
<td>.67</td>
<td>98.18 (21.39)</td>
<td>98.42 (23.10)</td>
<td>.91</td>
<td>98.42 (23.10)</td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>94.68 (19.89)</td>
<td>96.18 (24.98)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP resting pressure</td>
<td>17.12 (6.11)</td>
<td>16.18 (5.28)</td>
<td>.33</td>
<td>16.23 (5.20)</td>
<td>9.26 (3.83)</td>
<td>.001</td>
<td>9.26 (3.83)</td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>11.50 (4.66)</td>
<td>9.09 (3.69)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP nadir</td>
<td>-4.88 (4.67)</td>
<td>-0.73 (5.61)</td>
<td>.90</td>
<td>-1.59 (5.72)</td>
<td>-1.22 (3.43)</td>
<td>.81</td>
<td>-1.22 (3.43)</td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>-4.75 (2.25)</td>
<td>-0.32 (3.27)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP-mid</td>
<td>27.75 (6.54)</td>
<td>34.64 (13.71)</td>
<td>.04</td>
<td>32.86 (12.32)</td>
<td>19.26 (6.11)</td>
<td>.001</td>
<td>19.26 (6.11)</td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>20.63 (6.59)</td>
<td>19.18 (6.01)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IB-Gra</td>
<td>17.00 (6.99)</td>
<td>24.41 (6.95)</td>
<td>.03</td>
<td>22.48 (7.40)</td>
<td>10.18 (5.23)</td>
<td>.001</td>
<td>10.18 (5.23)</td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>10.25 (4.86)</td>
<td>10.14 (5.26)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP peak clearing pressure</td>
<td>40.08 (10.31)</td>
<td>43.05 (11.78)</td>
<td>.045</td>
<td>41.98 (11.21)</td>
<td>26.99 (8.56)</td>
<td>.001</td>
<td>26.99 (8.56)</td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>30.75 (9.65)</td>
<td>26.14 (8.06)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: CP, cricopharyngeal; CP-mid, CP midbolus pressure; IB-Gra, intrabolus pressure gradient across the CP region.

a Values represent a comparison between preoperative and postoperative parameters in the small diverticula group.

b Values represent a comparison between postoperative changes in the small diverticula group vs postoperative changes in the large diverticula group.

c Values represent a comparison between preoperative and postoperative parameters in the large diverticula group.

d Values represent a comparison between preoperative and postoperative parameters in the entire study group (the small plus the large diverticula groups).
FOSS has been routinely used at our institution since 1994 by one of us (J.R.S.) for staging of dysphagia. All patients here improved at least 1 FOSS stage after surgery, and overall improvement in FOSS stage was statistically significant. All patients had stage 0 or 1 symptoms after surgery. FOSS is a clinically useful functional scale. However, it lacks information pertaining to the psychosocial and emotional effects of dysphagia in patients. Because it is a clinician-based assessment tool, it does not include the patient perspective and is not a comprehensive measure of quality of life.

Videofluoroscopic swallowing study is considered the gold standard in evaluation of pharyngeal dysphagia. It is noninvasive and provides real-time assessment of the swallowing process that can be reviewed in slow motion. However, the following 2 basic limitations of videofluoroscopy have been reported: controversial interrater reliability and inability to objectively quantify pharyngeal dynamics. Manometry has been extensively used to investigate pharyngeal motility and swallowing disorders. However, technical problems in the pharynx include sensor positioning errors (particularly in the absence of normal PES function), catheter movement by contraction of the soft palate, and variable laryngeal movement and pharyngeal length. Videofluoroscopy and manometry by combining dynamic fluoroscopic visualization with simultaneous objective quantitative pressure recordings during swallowing allow accurate positioning of the sensors relative to anatomical structures. These objective pressure recordings reflect muscular strength at the sensor locations.

Since 1997, MFG has been used by one of us (J.R.S.) for selected patients with unusual or questionable videofluoroscopic results and in all patients undergoing surgery for swallowing disorders. Previously published MFG studies at our institution include proposed catheter standards, intrabolus pressure determination, and normal CP intrabolus pressures and gradient pressures in young and older populations. We considered these data in commenting on the present data. In the study by Bamber et al., the mean (SD) CP-mid in older subjects was 10.8 (8.8) mm Hg, and the mean (SD) IB-Gra was 4.4 (3.1) mm Hg. Based on a single case, the authors suggested that patients with an IB-Gra might benefit from CP myotomy. Since that study, we used the intrabolus pressure gradient across a pharyngeal obstruction (striction, CP bar, anterior cervical osteophyte, or PD) as a possible indication for surgery. When comparing manometric results in the present study with normal pressures previously reported at our institution, preoperative and postoperative mean CP-mid and IB-Gra were higher in patients with PD than in healthy control subjects. Herein, the mean CP-mid and IB-Gra tended to be significantly greater in the large group, as was the mean preoperative IB-Gra. We believe that these findings relate to the mass effect of PD wherein larger diverticulum (obstruction) is associated with higher intrabolus pressure and pressure gradient.

We anticipated and found a significant postoperative reduction in the mean CP resting pressure after TEPD. A CP myotomy is the expected result of TE PD, which eliminates the CP muscle portion of CP resting pressure. The CP resting pressure has been variably found to be low, normal, or high in patients with PD, and correlation of CP resting pressure with the pathogenesis of PD was refuted. Moreover, other investigators report that PES relaxation (CP nadir) is complete and irrelevant to the pathogenesis of PD. Cook et al. studied patients with PD and found no manometric evidence of functional PES abnormality. According to van Overbeek, functional or structural abnormalities in the PES might cause dysphagia even before formation of PD. He added that patients with PD generally become asymptomatic after simple diverticulectomy without myotomy. Furthermore, he noted that few small diverticula are reported in large series of patients with PD, indicating that dysphagia is caused by the already formed diverticulum. Based on evaluation of 646 patients with PD, van Overbeek concluded that an anatomical predisposition to weakness in Killian dehiscence has a predominant role in the formation of PD.

The findings of this study support the conclusions of the investigators in the preceding paragraph. In our small series, we found no evidence of abnormal swallowing coordination on MFG. Furthermore, manometric findings of negative mean preoperative CP CP-mid and IB-Gra in both study groups reflected normal swallowing coordination and probable normal CP relaxation. However, 2 patients in the large group had high positive CP nadir. Large diverticulum sometimes cause a mass effect that results in high positive PDs during swallowing. Because all patients in the small group had normal or negative CP, abnormal CP relaxation was attributed to this mass effect and not to CP coordination abnormalities. Although CP coordination abnormalities do not seem to be an issue, CP fibrosis leading to stenosis may be an unrecognized factor.

When comparing our data with those of healthy older patients, persistently elevated 6-month postoperative CP-mid and IB-Gra were noted in both study groups. The explanation is speculative but points to persistent obstruction that does not increase hypopharyngeal peak clearing pressure or cause abnormal coordination. It is possible TEPD leaves scarring that affects the PES. Despite persistently elevated postoperative pressures, all patients in our study had markedly improved FOSS stage after surgery.

Postoperative videofluoroscopic examinations revealed a persistent pouch or shelf in most patients. These were located in the cervical esophagus and were in-
increased in the large group. We speculate that these postoperative remnants are due to scar contracture or an inability to completely staple the distal pouch. Preoperative symptomatic pharyngeal pouches were largely converted to asymptomatic self-emptying esophageal pouches or shelves after surgery.

Complications of untreated PD include foreign body retention and bezoar, tracheoesophageal fistula, fistula to the prevertebral space with cervical osteomyelitis, ulceration, and hemorrhage. Another less obvious problem caused by PD is poor control of other medical conditions due to retention of oral medications and resulting uneven dosage. Rarely, squamous cell carcinoma may arise in PD. Hence, treatment of PD is indicated for all symptomatic patients with PD.

Open and endoscopic surgical techniques are successfully used in the treatment of patients with PD. In this study, TEPD was performed using carbon dioxide laser in 7 of 8 patients in the small group, whereas stapling technique with or without carbon dioxide laser was used in all 22 patients of the large group and in the remaining patient in the small group. Transoral endoscopic pharyngoesophageal diverticulostomy was not performed in any PD exceeding 7 cm. Pharyngoesophageal diverticulostomy exceeding 7 cm should be treated by open diverticulectomy or CP myotomy rather than by TEPD. By dividing the circular fibers of the esophagus, TEPD creates an axially adynamic esophageal segment. By limiting this adynamic segment to the upper third (7 cm) of the esophagus (22 cm), function of the lower segment is preserved. We prefer stapling technique because of better sealing of incisions. However, very small PDs generally are unamenable to stapling technique using commercially available staplers. Surgical complications herein were noted only in the small group, and both complications (odynophagia and retropharyngeal leakage [pharyngocutaneous fistula]) occurred after laser diverticulostomy. Transient odynophagia was likely caused by esophageal spasm related to the burning effect of carbon dioxide laser and a fistula from a microscopic esophagocutaneous fistula occurred after laser diverticulostomy or shelves after surgery.

In conclusion, this study presents preoperative and postoperative functional and MFG data from a series of patients undergoing TEPD. Functional and objective MFG changes in these patients occurred after TEPD. High CP-mid and high IB-Gra are reliable objective indicators of patients who might benefit from TEPD and are appropriate variables for follow-up after surgery. There was no MFG evidence of abnormal swallowing coordination in this small series. Our study findings support the hypotheses that anatomical hypopharyngeal wall weakness has a major role in the pathogenesis of PD and that the mass effect of diverticular sac expansion during swallowing causes incomplete PES opening and high intrabolus pressures.

Submitted for Publication: May 4, 2009; final revision received August 29, 2009; accepted December 12, 2009.

Correspondence: Ozan B. Ozgursoy, MD, Department of Otolaryngology–Head and Neck Surgery, Mayo Clinic Florida, 4500 San Pablo Rd, Jacksonville, FL 32224 (OzanOzgursoy@yahoo.com).

Author Contributions: Both authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Ozgursoy and Salassa. Acquisition of data: Ozgursoy and Salassa. Analysis and interpretation of data: Ozgursoy and Salassa. Drafting of the manuscript: Ozgursoy. Critical revision of the manuscript for important intellectual content: Ozgursoy and Salassa. Study supervision: Salassa.

Financial Disclosure: None reported.

Previous Presentation: This study was presented at the American Head and Neck Society Annual Meeting during the Combined Otolaryngology Spring Meetings; May 30, 2009; Phoenix, Arizona.

REFERENCES