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SURGICAL ENDOSCOPY
and Other Interventional Techniques

Tailored approach to Zenker's diverticula

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Abstract
Background: Zenker's diverticula (ZD) can be treated by diverticulostomy or open surgery (upper esophageal sphincter myotomy and diverticulectomy or diverticulopexy). The aim of this study was to compare the outcome of the two alternative treatments.
Methods: Fifty eight patients were scored for symptoms and upper esophageal sphincter (UES) pressure; relaxations and intrabolus pressures were recorded by manometry. Treatment depended on operative risk and ZD size. Twenty-four patients with high surgical risk and/or a <3-cm or >5-cm pouch underwent diverticulostomy; the other 34 had open surgery.
Results: Mortality was nil. Five patients had postoperative complications after open surgery ($p<0.05$). Hospital stay was shorter after diverticulostomy ($p<0.001$). Follow-up (41 months; range, 1–101) was obtained in 53 patients. Postoperative manometry showed a UES pressure reduction, improved UES relaxation, and lower intrabolus pressure in both groups ($p<0.05$). In the diverticulostomy group, three patients complained of severe dysphagia. vs none in the open surgery group ($p<0.05$).
Conclusion: Diverticulostomy is safe, quick, and effective for most patients with medium-sized ZD, but open surgery offers better long-term results and should be recommended for younger, healthy patients with small or very large diverticula.

Key words: Zenker's diverticula — Endoscopic diverticulostomy — Upper esophageal sphincter myotomy — Pharynx — Esophagus

Cricopharyngeal diverticula are protrusions of pharyngeal mucosa through a weak zone in the posterior wall of the pharynx, limited inferiorly by the upper border of the cricopharyngeal muscle and laterally by the oblique fibers of the thyropharyngeal muscle, the so-called Killian's triangle [7]. Though described for the first time by Ludlow [9], the cricopharyngeal pouch is better known by the name of a German pathologist, Frederick Albert von Zenker, who, together with von Ziemssen, published a review of 27 patients with this disease [16]. Though he was not the first to describe this condition, Zenker is credited with recognizing that the pathogenesis of the diverticula derived from an increase in intrapharyngeal pressure.

Nearly a century later, the role of the upper esophageal sphincter (UES) in causing excessive intrapharyngeal pressure during swallowing was demonstrated by manometric and cineradiographic studies [1, 5]. From then on, the standard surgical treatment for Zenker's diverticula has (ZD) consisted of myotomy of the UES and resection or pexis of the pouch, or even myotomy alone for small diverticula [13]. Alternative endoscopic procedures that divided the septum between the diverticula and the esophageal wall using a cautery or laser [4, 8] were also described, but they gained little popularity because of the high risk of severe complications. The situation changed in 1993, when Collard et al. proposed simultaneously dividing and suturing the diverticular and esophageal wall using a laparoscopic stapler introduced through a special endoscope (the Weerda diverticuloscope). With this technique, the anterior wall of the diverticulum and the posterior wall of the esophagus were sealed with a double row of staples along the cut edges, thus preventing leakage, mediastinitis, or bleeding [2]. This procedure rapidly became widespread and is now often considered the treatment of choice for ZD [11, 14].

So far, however, there has been no prospective randomized trial demonstrating that endoscopic diverticulostomy is superior to traditional surgery. Moreover, given the rarity of the disease and its prevalence in elderly patients (often with severe comorbidities), it is unlikely that randomized studies will be performed in the near future. The present study therefore aims to analyze our experience of treating ZD with both tech-

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Table 1. Dysphagia and regurgitation scores in patients with adequate follow-up

	Diverticulostomy (20/24 patients)	Open surgery (33/34 patients)
Dysphagia score		
Preoperative	9 (range, 3–11)	9 (range, 2–11)
Postoperative	0 (range, 0–11)	0 (range, 0–8)
Regurgitation score		
Preoperative	9 (range, 3–11)	9 (range, 3–11)
Postoperative	0 (range, 0–8)	0 (range, 0–8)

niques, tailoring the choice on the basis of the diverticulum's size and the patient's operative risk status.

Material and methods

Patient population

Fifty-eight patients with ZD were referred to our surgical unit between 1993 and July 2001. There were 43 men and 15 women with a median age of 70 years (range, 36–95). The diagnosis of pharyngoesophageal diverticula was established in all patients by means of a barium swallow. The size of the diverticulum was measured in a lateral projection as the distance from the inlet of the diverticulum to the bottom of the pouch. The patient' surgical risk was assessed and graded from 1 to 3 according to the American Society of Anesthesiologists (ASA) risk scale [15].

Symptom assessment

Patient symptoms were recorded using a standard questionnaire for upper foregut diseases. Dysphagia and regurgitation (the most common symptoms in pharyngeal diverticula) were scored according to severity and frequency. The symptom score was calculated by adding the severity of each symptom (0 = none, 2 = mild, 4 = moderate, 6 = severe) to the frequency (0 = never, 1 = occasionally, 2 = once a month, 3 = every week, 4 = twice a week, 5 = daily); the highest score obtainable was 22. Other symptoms (heartburn, sialorrhea, etc.) were assessed but not counted for the symptom score. Respiratory symptoms (cough, episodes of pneumonia per year, asthma) were also recorded. In the postoperative assessment, patients were also asked if they were entirely satisfied, partially satisfied, or dissatisfied with their treatment. Barium swallow was obtained before the operation to assess the size of the diverticula and to see whether there were other abnormalities in the esophagus and hiatal region; it was repeated 1–2 months after the treatment.

Endoscopy and esophageal manometry

Upper gastrointestinal endoscopy was performed under mild sedation using a flexible scope to exclude any concomitant abnormalities in the esophagus or stomach and — in the event of the diverticulum interfering with the placement of the manometric tube — to pass a guidewire for the manometric probe.

Manometry was performed using instruments and a technique described in detail elsewhere [12]. Briefly, an 8-lumen low-compliance infused system with computerized data acquisition and analysis was employed. A high-frequency data acquisition mode (50-Hz) was used, given the rapidity of the events occurring during swallowing. UES pressure was measured while the catheter was withdrawn at a constant rate of 5 mm/sec. The maximum amplitude registered by each probe during its passage through the UES was averaged and considered as the UES pressure.

To evaluate the pharyngoesophageal function at swallowing, the manometric probe with four radially oriented side holes was positioned at the upper edge of the UES, with two other side holes situated 5 and 10 cm above (in the distal and proximal pharynx, respectively) and one situated 5 cm below (in the cervical esophagus). Ten swallows of 10 ml of water were evaluated. The following parameters of pharyngeal contractions were considered: amplitude, duration, and intrabolus pressure — i.e., the pressure generated by the passage of the bolus in the distal pharynx and seen at manometry as a slow pressure increase (shoulder) before the major upstroke generated by contractions of the pharyngeal wall, as described by Cook et al. [3]. The number of complete UES relaxations (expressed as the percentage of UES relaxations with a residual swallowing pressure < 10 mmHg) and the coordination of UES opening with pharyngeal contractions (expressed as the percentage of relaxations with nadir of the UES pressure coinciding with the pharyngeal wave's major upstroke) were recorded.

Treatment of Zenker's diverticula

From January 1993 onward, two options were available for treating patients with ZD: (a) endoscopic diverticulostomy with a stapler, or (b) open surgery for myotomy of the UES with or without diverticulectomy. Both operations were performed under general anesthesia with endotracheal intubation.

For endoscopic diverticulostomy, a Weerda diverticuloscope (Karl Storz, Tuttingen, Germany) was positioned with the anterior blade in the esophageal lumen and the posterior blade in the diverticulum. A 5-mm–diameter telescope was passed through the scope. A disposable surgical endostapler (EndoGIA 30; United States Surgical Corp., Norwalk, CT, USA) was inserted through the Weerda scope to divide the septum between the diverticulum and the esophageal lumen. One or two applications of the stapler were required [14].

For UES myotomy with or without diverticulectomy, a left laterocervical approach was used, anteromedial to the sternocleidomastoid muscle. The diverticulum was isolated. If it was ≥ 3 cm, it was transected with a stapler. Diverticula of ≤ 1 cm were left in place. Diverticula with dimensions nearing 2 cm were inverted below the pharyngeal muscles and sutured to the muscle layer with two reabsorbable stitches. The cricopharyngeal muscle fibers were divided at the midline posteriorly from the neck of the sac down to the esophagus for a length of 4 cm.

Patients at high surgical risk and with diverticula ≥ 3 cm or ≤ 5 cm were advised to have the endoscopic procedure; open surgery was recommended to young, low-risk patients or patients with diverticula < 3 cm or > 5 cm.

In three patients with gastroesophageal reflux disease and hiatus hernia, a Nissen fundoplication was also performed. In one patient, an intrathoracic esophagectomy was performed for esophageal cancer.

Postoperative course and follow-up

Postoperative hospital stay and any adverse effects occurring after surgery were recorded. Patients had a barium swallow 1 month after the operation and esophageal manometry after 6 months, when symptoms were also reassessed using the same questionnaire. Follow-up was yearly thereafter. Patients who failed to show up at the outpatient clinic were interviewed by phone. A procedure was considered to be a failure whenever the postoperative symptom exceeded the 10th percentile of the preoperative score.

Statistical analysis

Data were collected in a database and analyzed using commercially available statistical software (Statview; SAS Institute, Inc., SAS Campus Drive, Cary, NC, USA). Data are expressed as median (range). The Mann-Whitney and Wilcoxon tests were used, as appro-

priate. Fisher's exact test was used to compare categorical data. A difference <0.05 was considered statistically significant.

Results

Twenty-four patients (18 male and six female) with a median age of 76 years (range, 36–95) were treated with endoscopic diverticulostomy. The median size of their diverticulum was 3.5 cm (range, 3–5). In 17 patients, the diverticulum was $\leq$ 4 cm, and seven patients had a diverticulum >4 cm. Thirty-four patients (25 male and 9 female) with a median age of 69 years (range, 41–94) were treated with open UES myotomy. In 21 cases, a diverticulectomy was added; the median size of their diverticulum was 2.5 cm (range, 2–8). The diverticulum was inverted below the pharyngeal muscle layer in eight patients whose diverticulum was a median 2 cm in size (range, 1.5–2.5). In five patients, only UES myotomy was performed; the median size of their diverticulum was 1 cm (range, 1–1.5).

In the diverticulostomy group, five patients were graded as ASA risk 3, and 13 were graded as ASA risk 2. In the open surgery group, only one patient was grade 3 (she had diverticulum <2 cm that was unsuitable for endoscopic treatment, so she underwent open myotomy and diverticulum inversion); 10 patients were grade 2. The distribution of the risk was statistically different in the two groups ($p<0.05$). Five patients expressly asked to have an endoscopic treatment.

Duration of the procedure, mortality, morbidity, and postoperative course

The duration of the operation was shorter in the endoscopic group (20 min; range, 10–40) than in the open surgery group (80 min; range, 35–175) ($p<0.05$). There were no deaths in either group. The overall morbidity rate was 8.6% (five patients). All complications occurred in the open surgery group. There were two leaks, two cases of bleeding with cervical hematoma requiring drainage, and one pericarditis, probably of viral etiology. The two leaks were treated conservatively and healed in 15 days. The morbidity rate was statistically higher in the open surgery group than in the endoscopic group ($p<0.05$). It is worth noting that no injury to the recurrent laryngeal nerve was observed in either group. The postoperative hospital stay was significantly shorter in the endoscopic group. (5 days [range, 2–19] vs 9 days [range, 4–16]; $p<0.05$). (The 19-day hospital stay occurred in a patient who underwent esophagectomy 4 days after diverticulostomy).

The median duration of follow-up was 41 months (range, 1–101). Three patients died of unrelated causes and two were lost to follow-up. An adequate follow-up was obtained in 53 patients, 20 in the endoscopic group and 33 in the open surgery group.

Effect of operations on symptoms

The preoperative symptom scores were similar in the two groups (and in the open surgery subgroups). After the operation, there was a statistically significant improvement in the symptom scores in both groups (Table 1). On a single-patient basis, three patients in the diverticulostomy group complained of severe, daily dysphagia (scores, 11); they were dissatisfied with the treatment and were considered to be treatment failures. In the open surgery group, two patients complained of occasional dysphagia when swallowing large, incompletely chewed boluses (score, 8); they were satisfied with the procedure and were not considered failures. The failure rate was significantly higher in the diverticulostomy group ($p<0.05$, Fisher's exact test).

Barium swallow was obtained in 13 patients after diverticulostomy and in 23 patients after open surgery. In all cases after diverticulostomy, a posterior pouch was still evident, although most of these patients were symptom-free. A small indentation was evident in two patients after myotomy alone and in two patients after myotomy with diverticulectomy (all four patients were symptom-free).

Esophageal manometry was performed before the operation in 48 patients (17 in the group undergoing diverticulostomy and 31 in the group who had open surgery) and again in 26 patients at a median of 8 months after the operation (eight after diverticulostomy and 18 after open surgery). Overall, statistically significant drops in UES resting pressure (preoperative 79 mmHg [range, 20–193] vs postoperative 44 mmHg [range, 22–98]; $p<0.05$) and intrabolus pressure (preoperative 21 mmHg [range, 7–43] vs postoperative 6 mmHg [range, 0–26]; $p<0.05$) were recorded after the treatment. The percentage of complete UES relaxations increased from 20% (range, 0–100) to 80% (range, 0–100) ($p<0.005$). No difference was observed in pharyngeal–UES coordination before and after treatment (pharyngeal–UES coordination was normal in most patients).Figures 1,2,3,4Figures 1–4 show the pre- and postoperative UES pressure, length, pharyngeal intrabolus pressure, and UES relaxations in the two patient groups.

Discussion

Endoscopic surgery for ZD is by no means new. Mosher published the first report in 1917, using a knife blade to perform the diverticulostomy [10]; however, the technique was abandoned, due to a fatal complication. Forty years later, Dohlman and Matlson [4] reported 100 patients who had been treated by dividing the septum with an endoscopic cautery; later on, a laser was similarly employed [8]. Despite generally good results and a relatively low morbidity rate, the risks of contaminating the mediastinal space and bleeding were a major concern. The use of an endostapler, as proposed by Collard et al., for the simultaneous division and suturing of the wall common to the esophagus and diverticulum gave new momentum to the diffusion of endoscopic ZD therapy. When stapling diverticulostomy is performed, the cricopharyngeal muscle fibers lying between the diverticulum and the esophageal wall are divided as well. As a consequence, a reduction in UES

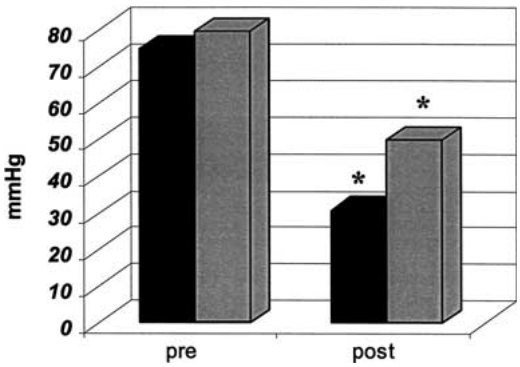

Fig. 1. UES resting pressure pre- and posttreatment in patients with open surgery and diverticulostomy. The asterisks indicate a statistically significant difference ($p < 0.05$). The median values and ranges were as follows: ■ open surgery; preoperative 80 mmHg (range, 20–193) vs postoperative 50 mmHg (range, 24–98); ■ diverticulostomy; preoperative 75 mmHg (range, 29–119) vs postoperative 31 mmHg (range, 22–94).

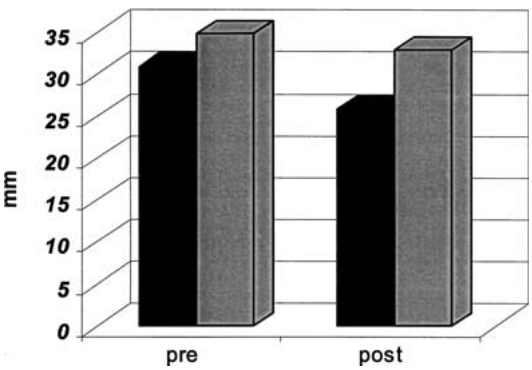

Fig. 2. UES length pre- and posttreatment in patients with open surgery and diverticulostomy. No differences were found in the two groups. The median values and ranges were as follows: ■ open surgery; preoperative 35 mm (range, 5–59) vs postoperative 33 mm (range, 25–60); ■ diverticulostomy; preoperative 31 mm (range, 14–43) vs postoperative 26 mm (range, 12–70).

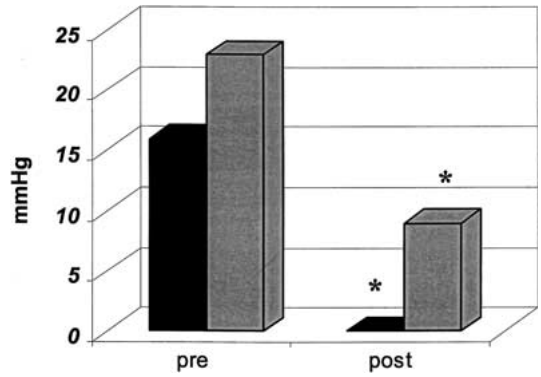

Fig. 3. UES intrabolus pressure pre- and posttreatment in patients with open surgery and diverticulostomy. The asterisks indicate a statistically significant difference ($p < 0.05$).The median values and ranges were as follows: ■ open surgery; preoperative 23 mmHg (range, 15–43) vs postoperative 9 mmHg (range, 0–26); ■ diverticulostomy; preoperative 16 mmHg (range, 7–30) vs postoperative 0 mmHg (range, 0–11).

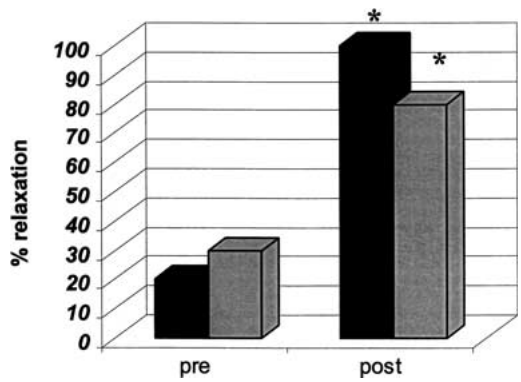

Fig. 4. Percentage of complete UES relaxations pre- and posttreatment in patients with open surgery and diverticulostomy. The asterisks indicate a statistically significant difference ($p < 0.05$). The median values and ranges were as follows: ■ open surgery; preoperative 30% (range, 0–100) vs postoperative 80% (range, 0–100); ■ diverticulostomy; preoperative 20% (range, 0–100) vs postoperative 100% (range, 0–100).

pressure very similar to that achieved by open surgical myotomy was observed in our study and also reported by Ishioka et al. [6]. The functional efficacy of endoscopic UES section in improving the pharyngoesophageal function was confirmed by a reduction in intrabolus pressure comparable to that achieved by open surgery and by generally good symptom control.

These valid functional and clinical results are achieved by endoscopic diverticulostomy — a very quick procedure—with no morbidity and a shorter hospital stay. Its advantages are even more evident when we consider that the ZD patients concerned were older and carried a higher surgical risk than those who underwent open surgery. The drawbacks of endoscopic diverticulostomy are mainly related to the size of the diverticulum. In the case of a small diverticulum (≤ 2 cm), the anvil of the stapler is too long to be properly accommodated inside the pouch, so the cricopharyngeal fibers cannot be completely transected. On the other hand, very large diverticula (>5 cm) that plunge into the mediastinum carry a risk for vascular lesions if they are transected blindly. Moreover, the endoscopic procedure is not indicated in patients who have difficulty in opening their mouth very wide and hyperextending their head to accommodate the diverticuloscope.

Severe daily dysphagia persisted, however, in three of 20 patients (15%).These patients completed the follow-up after diverticulostomy and were considered to be treatment failures. There were no such failures among the patients in the open surgery group (although two patients complained occasionally of mild dysphagia). Manometric studies performed in two of the three patients with severe dysphagia showed incomplete UES relaxation and persistently high pharyngeal intrabolus pressure. The surgical findings in one of these patients who was reoperated revealed uncut muscle fibers just below the end of the stapler line. After completion of the myotomy, the patient became asymptomatic.

Myotomy of the UES is probably more effectively achieved with open surgery when the muscle fibers are cut under direct vision and the edges of the myotomy are further separated by blunt dissection, leaving the submucosa widely exposed. Moreover, open myotomy for ZD is equally effective, regardless of the diverticulum's

size. For small diverticula, simple myotomy may suffice; for larger diverticula, stapler transection or invagination of the diverticula under the pharyngeal muscle layer can be performed.

The major drawbacks of open surgery are the related morbidity—mainly bleeding (a small drain is routinely left in place) and leakage from the suture line. Although our two leaks did not require further surgery and healed spontaneously (after leaving the nasogastric tube in place, avoiding oral feeding, and administering antibiotic therapy), it could nonetheless be a potentially severe complication in patients with concurrent respiratory or heart disease. It is worth noting that both minor leaks occurred in patients whose stapled mucosal line was not protected with a transverse closure of the muscle layer.

In conclusion, ZD can be treated effectively with either endoscopic diverticulostomy or open surgery. Endoscopic diverticulostomy is very safe and effective, but because of the size of the stapler's anvil, it is better suited to medium-sized diverticula (3–6 cm); however, it does carry a greater risk of failure in terms of persistent severe dysphagia, probably due to incomplete section of the UES. Open surgical myotomy, with or without diverticulectomy, is effective, but it carries a higher morbidity rate—something that can have disastrous effects in elderly patients, who often have other diseases. Based on the results of this study, an individual approach to ZD should be recommended. High-risk patients with medium-sized diverticula are probably better served by diverticulostomy. Open surgery should be recommended for small (<2 cm) or giant ZD and for patients with a low surgical risk.

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