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Surgical Treatment of Zenker's Diverticulum

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Key Words
Zenker's diverticulum · Surgery · Treatment

Abstract
Background: Different surgical techniques have been indicated for the management of Zenker's diverticulum (ZD), including diverticulectomy, diverticulopexy, and diverticular inversion, with or without myotomy, and myotomy alone. More recently, minimally invasive techniques (such as the transoral endoscopic approach) have become increasingly reliable for this disorder. We therefore conducted this systematic review in order to gain a profound understanding of the current trend and evidence in surgical management of ZD. ***Methods:*** Medline and PubMed were searched to identify studies on surgical intervention of ZD published in English between January 1990 and March 2011. ***Results:*** We identified 6,915 patients from 93 studies evaluating the effect of the surgical intervention for ZD. No randomized controlled trials comparing one technique with another were identified. ***Conclusion:*** Diverticulectomy with myotomy has become the mainstream treatment option for ZD. In certain selected patients, endoscopic diverticulotomy may offer some advantages over open surgery, such as less trauma and a lower complication rate. It is important to individualize optimal therapy for each patient. More randomized controlled trials with long-term follow-up results are required to draw a valid conclusion on the best surgical intervention modality for ZD.

Introduction

Zenker's diverticulum (ZD), also known as hypopharyngeal diverticulum, is an acquired protrusion through the weak area between inferior constrictor muscle and cricopharyngeus muscle. The disorder was first reported in 1767 by Ludlow [1]. It was not formally named until Zenker and Von Ziemssen [2] comprehensively and precisely described this condition in 1877. The incidence of ZD was estimated to be 1–2 per 100,000 patients/year and twice as common in males [3]. Over the past several decades, the pathophysiology of this entity has evolved significantly. The most popular pathogenesis theories are structural abnormalities [4], increased hypopharyngeal pressure, increased cricopharyngeal tone and gastroesophageal reflux [5]. Since the first successful resection of ZD by Wheeler [6] in 1886, different surgical techniques have been indicated for the management of ZD, including diverticulectomy, diverticulopexy, diverticular inversion (all with or without cricopharyngeal myotomy), and myotomy alone. Traditionally, these operations were carried out openly through a left cervical incision. In consideration of the fact that ZD is a disease of the elderly and some life-threatening complications are inevitable, minimally invasive techniques have gained some kind of popularity in recent years. After decades of refinements since the first report by Mosher [7] in 1917, endoscopic therapy has become increasingly reliable for the management of ZD. To date, the optimal treatment approach for ZD remains debatable. We therefore con-

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ducted this review in order to gain a profound understanding of the current trend and evidence in surgical management of ZD.

Materials and Methods

Medline and PubMed were searched to identify studies on surgical intervention of ZD. Zenker's diverticulum, pharyngeal pouch, hypopharyngeal diverticulum, and surgery were used as keywords for the search and cross-references were added and reviewed to complete the reference list. Studies published between January 1990 and March 2011 in English were examined by reading abstracts and full articles. Only case series with more than 20 subjects or comparative studies were considered eligible for inclusion. In addition, we excluded studies which failed to provide important information, such as complications and their respective incidences. Data was extracted from each report using a pre-designed form. The complications were restricted to major surgical complications, such as perioperative death, mediastinitis, wound infection, fistula or perforations, bleeding, pneumomediastinum, vocal cord paralysis, aspiration pneumonia, dental injury, esophageal mucosal tears, among others. Minor complications, such as short-term fever, pain, throat burn were not included. Patients with no symptoms or who were significantly improved following one single treatment session were considered as having successful symptom resolution. Recurrence was defined as an increase of the severity of symptoms to the preoperative level or to an even worse condition which required repeated treatment.

Search Results

We identified 6,915 patients from 93 studies evaluating the effect of the surgical treatment for ZD, including 52 studies [8–59] (n = 3,336) on endoscopic surgeries, 22 [60–81] (n = 2,204) on open surgeries, and 19 [3, 82–99] (n = 1,375) on both approaches. The lack of objective measurements in long-term follow-up was a common shortcoming in most studies. There was no randomized controlled trial comparing one technique with another.

Table 1. Open (**A**) and endoscopic (**B**) approaches for treatment of ZD

A

Technique	Studies, n
CPM alone	22
CPM + resection	38
CPM + suspension	16
CPM + inversion	2
Resection alone	10
Suspension alone	3
Inversion alone	3

CPM = Cricopharyngeal myotomy.

B

Rigid	Studies, n	Flexible	Studies, n
Stapler	44	Needle-knife	8
CO_2 laser	19	APC	2
Diathermy scissor	9	Monopolar forceps	1
Harmonic Ace	2	Hook-knife	1

Table 2. Complications for open surgery

Complication	Patients, n	Percentage
Recurrent nerve injury	94	3.3
Leak or perforation	93	3.3
Cervical infection	52	1.8
Hematoma	28	1
Respiratory infection	9	0.3
Stenosis	8	0.3
Mediastinitis	6	0.2
Others	7	0.2
Overall morbidity	297	10.5
Mortality	17	0.6

Open Surgery for Zenker's Diverticulum

It is well established that the treatment choice of ZD should be surgical intervention. Conventionally, an open left cervical incision is usually performed under general anesthesia. The diverticulum is then freed and followed by cricopharyngeal myotomy. Further, the diverticulum is either resected (diverticulectomy), or more conservatively, suspended and fixed on the hypopharyngeal wall (diverticulopexy) or invaginated into esophagus itself (diverticular inversion). It was documented that open surgery can effectively resolve symptoms in 90–95% of the patients with a mortality rate of 0–2.3% and morbidity rate of 2.5–46% [100].

Our literature review yielded 2,826 patients from 41 studies assessing the outcomes of the open surgery for ZD. Of these, 7 different open surgical techniques were evaluated (table 1A). The surgical complications for open surgery are listed in table 2. Overall morbidity was 10.5% (297/2,826) and mortality was 0.6% (17/2,826). When reviewing the trend of the last 20 years, 1,059 out

of 1,877 patients (56.4%) were treated with diverticulectomy plus cricopharyngeal myotomy (absence of information in some studies) which represents the most preferred open surgical approach for ZD. Yet, there was no sound evidence that favors one approach over another. The optimal treatment for ZD continues to be controversial. The ongoing debates about open surgery generally come down to the necessity and extent of myotomy, resection, suspension or inversion of diverticulum.

Necessity of Myotomy

The first concern relates to cricopharyngeal myotomy. The rationale of myotomy is that upper esophageal sphincter (UES) dysfunction could be a pathogenesis factor for the diverticulum. The effects of cricopharyngeal myotomy include normalization of the opening size of the UES [101], reduction of resting UES pressures and the decrease of intrabolus pressures [102]. Some early small-sample case series reported good clinical outcomes when performing myotomy as the sole treatment [78, 103, 104]. Furthermore, Skinner and Zuckerbraun [105] reported their experience in dealing with recurrent ZD, who found that most patients with early recurrence did not have adequate cricopharyngeal myotomy, and all of the 8 patients who were treated with sufficient myotomy gained persistent symptom relief within a mean 53-month follow-up. A more recent study by Gutschow et al. [92] in 2002 compared open diverticulectomy alone (n = 34) with other open approaches along with myotomy (n = 67). The results showed no difference in terms of 'good' or 'excellent' symptomatic outcomes. Of interest, they noticed that the diverticulectomy without myotomy might predispose to the development of postoperative fistula and the recurrence, which may result from persistent high hypopharyngeal pressure. Nowadays, more and more surgeons believe that dividing the cricopharyngeus muscle is a crucial step in the treatment of ZD, and it has been a standard procedure in many major centers. In the 41 studies of open surgeries, only 2 studies did not perform myotomy [80, 95], and 2,526 patients out of 2,826 treated with open surgery for ZD received either myotomy alone or along with other approaches, which reflects that most surgeons consider the dysfunction of UES as an etiologic factor for ZD. The necessity of the myotomy for ZD is still debatable however. The largest case series involving 888 patients from Mayo Clinic failed to show any improvement following the additional application of myotomy to diverticulectomy [79]. A retrospective non-randomized study published in 2003 by Colombo-Benkmann et al. [74] included 79 ZD patients who underwent diverticulectomy alone or diverticulectomy plus myotomy when hypertrophic transverse fiber of cricopharyngeus muscle was clearly visible. No significant impact on the postoperative outcomes was observed after a 60-month follow-up. Some other authors also argue that considerable anatomical variations of the cricopharyngeal muscle exist and the cricopharyngeus muscle may not present in some ZD patients. Consequently, they advocated that myotomy should be performed selectively [74]. Another concern about myotomy was the risk of aspiration pneumonia when the protection barrier of UES is compromised by the myotomy [106]. From our literature review though, the postoperative aspiration pneumonia in open surgery is very rare (0.3%, 9/2,826). Besides, a prospective study enrolling 10 patients, using pH monitoring, revealed that cricopharyngeal myotomy did not increase the risk of esophagopharyngeal acid regurgitation [107].

In the absence of a definitive study, the effect of myotomy in ZD remains obscure. Large, well-designed randomized controlled studies with a sufficiently long-term follow-up and reliable functional measurements are needed to settle this issue in the future.

Extent of Myotomy

When conducting a cricopharyngeus myotomy, the extent of myotomy needs to be clarified. Anatomically, the closing muscles of UES are composed of inferior pharyngeal constrictor, cricopharyngeus muscle and cervical esophagus. Only the cricopharyngeus, the primary muscle which exerts the physiological function of UES [108], contracts and relaxes during all the physiological states [109]. Theoretically, in order to achieve complete myotomy, except for the cricopharyngeus muscle, the inferior pharyngeal constrictor and cervical esophagus should also be dealt with, but there is no general agreement on the exact length of the myotomy, ranging from 2 to 6 cm [60, 62, 110]. Comparing ZD patients with healthy controls, Lerut et al. [81] demonstrated that cricopharyngeal muscle and cervical esophageal striated muscle have the same pathological changes. Therefore, they recommended a long (4–5 cm) myotomy for better outcomes. Except for the commonly employed linear myotomy, Duranceau and colleagues [69, 111] proposed a flap-resected myotomy which could prevent subsequent healing and reconnecting of the muscle fiber.

How to Deal with Diverticulum

For dealing with the diverticulum sac itself, three options are mainly used: resection, suspension or inversion. The primary advantage of the diverticulopexy and diverticular inversion over diverticulectomy is leaving mucosa intact without breach. Logically, the incidence of leakage could decrease. Other merits include shorter hospitalization, earlier resumption of oral intake, and shorter antibiotic treatment [73]. A comparative study by Gutschow et al. [92] indicated that diverticulectomy plus myotomy involved a significantly longer postoperative stay and fasting food period. The fistula rate in the resection group and suspension group was 1/12 and 2/47, respectively. The symptomatic outcomes were not different between the two groups. A more recent study compared myotomy plus diverticulectomy in 14 patients with myotomy plus diverticulopexy in 36 patients, revealing that diverticulectomy required a longer hospital stay and fasting period. Four out of 36 patients with diverticulopexy and 2 out of 14 patients with diverticulectomy developed recurrence of dysphagia within 6 months, but all of them were spontaneously symptom-free within 1 year after operation [60].

As another alternative approach, diverticular inversion itself has not drawn much attention, even though it was shown in some earlier studies to be effective and to have fewer complications than excision [112, 113]. Since 1990, there have been very few studies reporting diverticular inversion. The only one, reported by Morton and Bartley [72], compared 15 cases of diverticulectomy with 18 cases of invagination, and showed better results regarding complications, operation time, and length of hospital stay. Of note, their cases were free of recurrence after 56 months of follow-up.

Strong evidence in favor of one approach over others is still lacking, and it is almost impossible to obtain a conclusion from 'head-to-head' comparisons among a variety of surgical approaches. When taking a look at the trend of open surgery in the last 20 years, myotomy plus diverticulectomy has gained wide popularity (table 1). Considering the pathogenesis of the ZD, it seems that resection of diverticulum and concurrent cricopharyngeus myotomy is a more logical strategy. It addresses not only anatomical abnormality but also dysfunction of UES. The favorable results of this approach can be seen in some large-sample series [75, 88]. With the assistance of a stapler technique the risk of leakage after diverticulectomy has been reduced substantially, and the fistula rate in the studies of Jougon et al. [61] and Bonavina et al. [88] was 1% (1/92) and 1.7% (2/116), respectively. Besides, resection of diverticulum showed another advantage in the very small risk of carcinoma genesis from diverticulum [73, 114].

Endoscopic Diverticulotomy

The first successful endoscopic treatment of ZD was reported as early as 1917 by Mosher [7], who described esophagodiverticulotomy by sharply dividing the esophagodiverticular wall endoscopically. He later abandoned this technique because of the high risk of mediastinitis and death. It was not until 1960 when the endoscopic approach took a leap forward, that Dohlman and Mattsson [115], using electrocautery in endoscopic diverticulotomy, reported a very low risk of mediastinitis and only 7% recurrence in 100 patients. Since then, the endoscopic approach for ZD has evolved over time. The endoscopic approach can generally be accomplished by two means – a flexible or a rigid endoscope.

Rigid Endoscopic Diverticulotomy

The procedures are carried out under general anesthesia and patients are placed supine with their neck overextended. A special diverticuloscope is used to visualize and expose the common septum separating the diverticular sac from the esophageal lumen. After transoral positioning the diverticuloscope in the esophagus, the common wall containing cricopharyngeus muscle fiber between the diverticular sac and esophagus lumen can be exposed with connection to a video system. Division of the septum can then be performed by one of the following techniques: electrocautery, CO_2 laser, KTP/532 laser, stapler, needle-knife, or Harmonic Ace [100].

From the literature research, four techniques were introduced in rigid endoscopic diverticulotomy during the period of 1990–2011, including electrocautery, CO_2 laser, stapler, and Harmonic Ace (table 1B).

Endoscopic Electrocautery

The electrocautery technique, also known as Dohlman's technique, represents the classic method for endoscopic diverticulotomy. Our literature search yielded 9 studies involving 485 patients, with an overall complication rate of 7.8% (38/485) and mortality rate of 0.2% (1/485). The two most common complications were subcutaneous emphysema (14/485, 2.9%) and mediastinitis

(10/484, 2.1%). The largest series about Dohlman's procedure for ZD was reported in 1994 by Van Overbeek [56], who performed Dohlman's technique in 328 patients and endoscopic diverticulotomy in 216 cases. The complication rate was 9.5% in the electrocoagulation group and 6.6% in the other. The 'highly satisfied' rate was 90.6%, with a minimal follow-up period of 10 months. Using the same technique, Von Doersten and Byl [57] reported 18% of 40 patients developed complications and 92.5% reached symptom relief without recurrence in the averaged 42-month follow-up.

Endoscopic CO_2 Laser Technique

In the last 20 years, Dohlman's technique has been largely replaced by the CO_2 laser and stapler technique. The high energy, high focus beam, and less tissue trauma were the advantages over electrocautery [48]. It also provides a better visualization of the diverticular bridge and easier control of the operation [55]. Our literature search identified 1,060 patients from 19 studies who underwent CO_2 laser procedures for ZD. The overall complication rate was 9.3% and mortality was 0.2% (2/1,060). The common complications were subcutaneous emphysema (3%, 32/1,060), mediastinitis (1.3%,14/1,060), fistula (1.1%,12/1,060) and bleeding (1%,11/1,060). Hoffmann et al. [50] reported 119 patients with ZD undergoing endoscopic CO_2 laser treatment. The complication rate was 3.4% (1 mediastinitis, 1 fistula, and 2 dental injuries), and in 1–3 years of follow-up, 93% of the patients were completely symptom-free and 3.9% were suspected to experience recurrence. Van Overbeek [56] used the CO_2 laser technique in 216 patients and found 6.0% of the patients developed complications but without death. Combining with the 328 patients undergoing electrocoagulation treatment, the overall highly satisfied rate was 90.6% and fairly satisfied rate was 8.6%. He also noticed that patients with CO_2 laser experienced less pain and took food more readily during the first postoperative day. The favorable result of the CO_2 laser was also reported by Lippert et al. [97], Krespi et al. [41] and Kos et al. [48].

Endoscopic Stapling Technique

In the last 10 years, endoscopic stapling technique has become increasingly popular. It possesses a theoretical advantage over the other techniques. It can simultaneously cut and seal the wound edge, contributing to a lower incidence of perforation and bleeding. In addition, it is also free of thermal damage to the recurrent laryngeal nerve. We identified 44 studies reporting this technique and involving 1,800 patients. The overall complication rate was 7.1% (127/1,800) and mortality was 0.3% (5/1,800). The common complications were dental injuries (2.0%, 36/1,800), esophageal mucosal damages (1.6%, 29/1,728), and perforations (1.6%, 29/1,728) (table 3). The outcomes varied significantly in different studies. The largest series using the endoscopic stapling approach was reported by Bonavina et al. [88]. They performed endoscopic stapling in 181 cases with ZD, and there were only 2 cases of dental injury and 1 case of mucosal tear in their series (complication rate: 1.7%). They also reported conversions to open surgery in 8 cases, in whom 7 were due to poor exposure and 1 due to mucosal tear during the endoscopy. Of the patients undergoing the endoscopic stapling approach, 92% were symptom-free after a mean follow-up of 27 months. Another study by Chang et al. [15] also evaluated the endoscopic stapling technique in 150 ZD patients, and they reported 9 cases who were converted to open surgery because of poor exposure of diverticulum. The complication rate was 12.7%, but only 2.0% were considered as major complications (1 each of perforation, aspiration pneumonia, and transient vocal cord paralysis). In a mean follow-up of 32.2 months, 88% of the patients gained either an improved or complete relief of symptoms and 10.9% developed recurrence of symptoms.

Table 3. Complications for endoscopic surgery

Complication	Patient	Percentage
Cervical or mediastinal emphysema	86	2.2
Perforation	56	1.4
Dental injury	41	1.1
Bleeding	34	0.9
Esophageal mucosal tear	30	0.8
Mediastinitis	28	0.7
Leak	24	0.6
Respiratory infection	14	0.4
Stenosis	8	0.2
Recurrent nerve injury	6	0.2
Neck abscess	5	0.1
Others	5	0.1
Overall morbidity	337	8.7
Mortality	9	0.2

Endoscopic Harmonic Scalpel

Another technique using the so-called harmonic scalpel was recently introduced for endoscopic treatment of ZD. In a study that included 25 patients treated with an endoscopic harmonic scalpel, 1 developed aspiration

pneumonia and 1 cervical subcutaneous emphysema after surgery. After an average follow-up of 11.3 months, only 1 patient suffered from recurrence [34]. In the other study, Sharp et al. [31] performed endoscopic treatment of ZD in 52 patients, where 20 patients were treated with a harmonic scalpel, 28 received a stapling technique and 2 underwent both techniques. Complications in 5 patients (17.9%) relating to the stapler technique and 1 (5%) to the harmonic scalpel were noted, but the diverticulum size in the harmonic group was smaller compared to the stapler group. Unfortunately, no long-term follow-up information is available for this study. More studies are needed to further assess this technique.

Conversion of Rigid Endoscopic Diverticulotomy

A main drawback of the rigid endoscopic diverticulotomy is that the exposure of diverticulum may be comprised by some anatomic reasons or small diverticulum, under which circumstances a conversion to open surgery might be required. The reported conversion rate could be as low as 0% [28, 50] or as high as 30% [52]. Combining all the data, we found that 18 cases out of 1,060 patients (1.7%) with the CO_2 approach and 101 out of 1,800 (5.6%) patients with the stapling technique underwent conversion surgery. The most common reason for unsatisfying exposure was anatomic limitation (87/119), followed by intraoperative esophageal mucosal injury (12/119) and small/large diverticulum (12/119). Other relatively rare conditions included obesity, cancer, bleeding, abnormal thyroid gland and complex diverticulum. The reported anatomic factors preventing adequate exposure consist of prominent teeth, a short neck, a retrognathic mandible, retrognathia, large tongue, and rigid cervical kyphosis. A prospective study assessing the factors predicting endoscopic exposure of ZD showed that a short neck length, shorter hyomental distance and higher BMI were correlated significantly with the failure of endoscopic exposure [52].

Flexible Endoscopic Diverticulotomy

Flexible endoscopic diverticulotomy was not reported until 1995 [53, 54], which can be performed under conscious sedation without general anesthesia and neck extension – the two major advantages over the rigid endoscopic approach. Using a variety of accessories (nasogastric tube, hood, endoscopic cap, and overtube), the septum between the diverticulum and esophageal lumen can be successfully visualized and stabilized without overextension of the neck. The incision was then made thorough different techniques including needle-knife, hook-knife, argon plasma coagulation (APC), and monopolar forceps [116]. Some authors prefer multiple sessions in order to avoid perforation and mediastinitis. The mean number of treatment sessions varied from 1 to 3 in different studies [9, 13], and usually the operation can be repeated easily at an interval of 1 day to several weeks [13, 53, 54]. From our literature search, there were 472 patients from 12 studies undergoing flexible endoscopic diverticulotomy (table 1B). The overall complication rate for flexible endoscopic diverticulotomy was 15% (71/472) and for mortality it was 0%. The common complications included cervical emphysema (27/472), perforation (19/472) and bleeding (15/472). The recurrence rate varied from 0% (0/28; 20-month follow-up) [17] to 35% (11/31; 26-month follow-up) [14]. Better understanding about the flexible endoscopic technique calls for more studies in the future.

Using the needle-knife technique, Hashiba et al. [35] performed flexible endoscopic diverticulotomy on 47 patients under sedation. Postoperative bleeding (2%) and subcutaneous emphysema (12.8%) were reported in their study. 96% of the patients experienced marked symptom relief after the first session, but most of the patients needed more than one session (mean 2.2 sessions). During their 1-day to 1-year follow-up period, 2 (4%) patients had recurrence of symptoms. Costamagna et al. [10] compared two different assistant techniques for flexible needle-knife diverticulotomy: the cap-assisted technique versus the diverticuloscope-assisted technique. The operation time in the cap group was significantly longer than in the diverticuloscope group, and the complication rate was 32% (9/28) in the cap group and 0% (0/11) in the diverticuloscope group. The recurrence rate was 29% in the cap group and 9% in the diverticuloscope group within a 3- to 60-month follow-up period. Recently, Repici et al. [17] compared the flexible needle-knife technique (n = 28) with the rigid stapling technique (n = 30) and found a similar length of hospital stay, symptom relief percentage and complication rate (1/28 vs. 2/30), however the procedure time in the rigid stapling group was significantly longer than that in the flexible needle-knife group (63 vs. 42 min). Only 1 patient with the endoscopic stapling procedure developed recurrence in the mean 20-month follow-up period. In 1995, Mulder et al. [53] were the first to describe flexible endoscopic diverticulostomy in 20 ZD patients using monopolar biopsy forceps.

A good symptomatic response was seen after a mean of three treatment sessions and there were no major complications. During the 6- to 7-month follow-up, 17 patients remained asymptomatic and the other 3 died of unrelated causes. Mulder [24] later reported their experience of application of the APC technique in 125 cases. Symptom improvement was achieved in all 125 patients after a mean 1.8 treatment sessions, and the overall complication rate was 19.2% (24/125).

Comparison of Open versus Endoscopic Approaches

To date, there is no strong evidence to conclude whether a procedure is superior over another, and the results vary significantly in different studies because of varied inclusion criteria, sample size, length of follow-up period and the percentage lost to follow-up. A summary of the comparative studies is shown in table 4. When combining all the results reported from 1990 to 2011, the overall morbidity and mortality rate for the endoscopic approach is 8.7 and 0.2%, respectively, whereas it is 10.5 and 0.6% for open surgery (tables 2, 3). An extensive review by Chang et al. [15] in 2003 compared publications about endoscopic or open surgery for ZD from 1990 to 2002. They also found the endoscopic stapling technique had a lower major complication rate and mortality rate than open surgery (2.6 vs. 11.8% and 0.3 vs. 1.6%, respectively). It is reasonable that endoscopic treatment has less risk of recurrent nerve injury and wound infection because of the endoluminal approach. Application of the endoscopic technique also has reduced the fistula rate from 3.3% in open surgery to 0.6%. On the contrary, the endoscopic approach has increased the risk for esophageal mucosal damage, intraoperative bleeding, and dental injuries, accounting for a higher risk of conversion during the rigid endoscopic procedure. According to the comparative studies, most studies confirmed the endoscopic approach had a lower complication rate. However, it is notable that the complication rate varied significantly across studies, ranging from 0 to 46%, which reflected the marked inter-study heterogeneity. The different sample size, criteria for patient selection, surgical techniques and their retrospective study design make it difficult to draw a very sound conclusion.

As for the convalescent period, some studies reported that endoscopic approaches needed less anesthetic and operative time, allowed earlier resumption of oral intake, and required a shorter hospital stay [86, 98, 99]. For flexible endoscopic approaches, the operation can be performed in outpatient settings without general anesthesia, though most patients need more than one session until symptoms resolve [35, 53, 54]. Even some patients undergoing the rigid endoscopic procedure can also be safely managed on an outpatient basis [30]. Besides, the hospital costs for endoscopic surgery have proven to be significantly lower than open surgery [91]. It is notable that most of the studies were historical series; these results need to be further verified in randomized controlled trials.

Regarding the long-term outcomes, there is no consistent result for the endoscopic approach. Significant heterogeneity exists among studies. The success rate ranged from 63 to 100% after a single treatment session [14, 36] and the recurrence rate varied from 0 to 35% [14, 18, 26] because of the different follow-up period and different sample size. Since the endoscopic approach for ZD is a relatively new technique, the lack of long-term follow-up is a common drawback for most studies, and the recurrence has not been uniformly defined (i.e. defined as the requirement of more than one treatment session in some studies), rendering it difficult to compare the technique with open surgery. Besides, as most of the studies relied on the subjective methods only to assess treatment effects, it is hard to obtain strong evidence from them.

Discussion

The treatment for ZD has evolved significantly in recent years and the optimal treatment modality for ZD still needs to be clarified. Both open and endoscopic approaches can be accomplished with many techniques, each of which has its own advantages and disadvantages (table 5). Several factors should be taken into account when determining the treatment option, e.g. doctor's preference, patients' will and general condition, and access to facility. Open surgery, as a well-established approach, allows for the direct operation on the diverticulum pouch and the complete conduction of cricopharyngeal myotomy. With the advance of perioperative management and new techniques, diverticulectomy with myotomy has become quite safe and its long-term outcomes are also satisfactory and durable. It is also technically feasible for all sizes of diverticula. Besides, it provides specimens for pathological assessment and eliminates the risk of cancer genesis from the pouch. The open approach however needs general anesthesia, which is a contraindication for some extremely debilitated patients. An alternative procedure, endoscopic diverticulotomy,

Table 4. Studies comparing endoscopic with open approaches for ZD

Study	Mean age, years	Patients, n	Operation approach	Complication rate, %	Mortality, %	Days to oral intake	Hospital stay, days	Operative time, min	Success rate, %	Recurrence rate, %	Follow-up
Zabaren	71	66	resection ± CPM	18.2	1.5	8.1	11.4	NR	93.9	4.2	4.9 y
1999 [96]		31	endoscopic laser	12.9	0	4.9	8	NR	93.5	0	13 m
Lippert	68.8	76	resection + CPM	18.4	0	NR	NR	NR	98.7	NR	NR
1997 [97]		34	endoscopic laser	2.9	0	NR	NR	NR	88.2	NR	NR
Safdar	62.2	9	resection + CPM	22.2	0	6	10	90–120	71.4	22.2	45 m
2004 [99]		10	endoscopic stapler	0	0	1	3.9	20–30	90	10	9 m
Brace	70.1	8	resection/suspension + CPM	0	0	1.1	4.71	110.88	90	0	3–12 m
2010 [98]		10	endoscopic stapler	10	0	2.0	2.30	19.5	100	0	2–6 y
Lang	67	32	resection + CPM	NR	NR	NR	10	75	NR	NR	NR
2007 [83]		31	endoscopic stapler	25.8	0	1	5	35	90.3	6.5	46 m
Zaninotto	70	34	resection ± CPM	11.8	0	NR	NR	80	100	0	41 m
2003 [84]		24	endoscopic stapler	0	0	NR	NR	20	85	0	41 m
Mirza	72	30	resection ± CPM, CPM, suspension, inversion	23.3	0	3.5	4.4	NR	96.7	3.3	NR
2002 [85]		29	endoscopic stapler/diathermy	17.2	3.4	1.9	6.9	NR	75.9	10.3	NR
Keck	69.5	13	resection + CPM	46	0	10	15	most <60	100	NR	NR
2010 [86]		27	endoscopic laser or diathermy	37	0	7.3	11	most >120	95	NR	NR
Rizzetto	66	77	CPM ± resection or suspension	13	0	NR	9	80	94.8	5.2	41 m
2008 [87]		51	endoscopic stapler	5.8	0	NR	5	31	78.5	21.5	36.5 m
Wirth	73	27	CPM ± resection	15	0	NR	12.3	106	93	follow-up rate 51%	41.5 m
2006 [89]		23	endoscopic stapler	15	5	NR	5.5	32	74	follow-up rate 51%	41.5 m
Chang	68	28	resection + CPM	0	0	NR	5	165	100	0	55 m
2004 [90]		26	endoscopic laser	7.7	0	NR	4	45	73	3.8	28 m
Gutschow	71	101	CPM ± resection or suspension, resection alone	8.9	1	4	6	NR	percentage of asymptomatic patients was higher after open procedures		95 m
2002 [92]		86	endoscopic stapler or laser	4.7	0	2	4	NR			48 m
Van Eeden	70.5	17	6 established techniques	6	0	3.6	4	NR	70.6	0	43 m
1999 [94]		17	endoscopic stapler	6	0	3	2.26	NR	88.2	5.9	10.2 m
Smith	74.4	8	resection + CPM	0	0	5.1	5.2	87.6	100	NR	NR
2002 [91]		8	endoscopic stapler	12.5	0	0.8	1.3	25.5	100	NR	NR
Bonavina	63	116	resection + CPM	3.4	0.8	NR	8	70	94	NR	48 m
2007 [88]		181	endoscopic stapler	1.7	0	NR	3	19	92	NR	27 m

CPM = Cricopharyngeal myotomy; NR = not reported.

was introduced as a minimally invasive approach. It may offer advantages as listed in table 5. The rigid endoscopic stapling technique ensures simultaneous dissection and sealing, reducing the risk of bleeding and mediastinitis. The endoscopic approach could however be technically difficult in some patients whose diverticular septum cannot be well exposed, such as small pouch, a stiff neck, poor mouth opening, prominent teeth, a short neck, a retrognathic mandible, retrognathia, large tongue, and rigid cervical kyphosis, etc. Flexible endoscopic treatment is a promising technique which can be conducted without the need of general anesthesia and hyperextension of the

Table 5. Comparison of different surgical approaches

	Open surgery	Rigid endoscopic	Flexible endoscopic
Complication rate	higher	lower	unclear
Hospital charge	more	less	less
Cervical scar	yes	no	no
Conversion	never	occasional	rare
General anesthesia	mandatory	usual	optional
Neck extension	no	mandatory	no
Recurrence	a few	unclear	unclear
Treatment sessions	most 1	most 1	most >1
Anatomic limitations, stiff neck, poor mouth opening, etc.	no	yes	no
Small diverticulum	suitable	unsuitable	unsuitable
Large diverticulum	suitable	unsuitable	unsuitable
Reoperation	hard, risky	easy, safe	easy, safe
Special technique	no	yes	yes
Dental injury	no	occasional	rare
Recurrent nerve injury	yes	rare	rare

neck. However, adequate stabilization of the septum and protection of the anterior esophageal and posterior diverticular walls during dissection are more challenging [10]. This more recently developed technique needs more studies to verify its safety and effectiveness.

With special concern to small and larger diverticula, it seems the endoscopic approach has its limitations. In small diverticulum the exposure of diverticulum could be problematic [19, 21, 22, 31] and has a higher complication rate [59]. Even if successfully visualized, the endoscopic approach could result in incomplete myotomy since the septum of the small diverticulum contains only limited cricopharyngeus muscle. This was confirmed by Bonavina et al. [88]. Gutschow et al. [92] also indicated that the percentage of patients with diverticula <3 cm who achieved an excellent or good symptomatic outcome was higher in patients receiving open treatment than the endoscopic approach. Similar results were reported by Rizzetto et al. [87]. For a very large diverticulum, to achieve a sufficient myotomy, a longer incision of the septum is always needed, in which case the sutureless techniques like laser, APC and diathermy may encounter a high chance of bleeding. The stapling technique therefore seems more suitable in this situation, but application of multiple staple rows as needed in a large diverticulum was associated with higher leak rate as well [45]. Counter et al. [18] also considered a very large diverticulum as a contraindication for the endoscopic approach where the insertion of the stapler with a sufficient distance down the endoscope could be a limiting factor. Ozgursoy and Salassa [46] concur by pointing out that endoscopic diverticulotomy would create an axially adynamic esophageal segment, thus they advocated a large diverticulum >7 cm should be treated by the open approach rather than the endoscopic procedure to limit the adynamic segment to the upper third (7 cm) of the esophagus, and, by doing so, the function of the lower esophagus would not be compromised.

It is also important to point out that the comparisons made in this review were based on retrospective observations and case-control studies, which limits the actual level of evidence for this review. Randomized controlled studies with long-term follow-up results are required to draw the definitive conclusion regarding the effect of each approach.

Conclusions and Recommendations

The surgical treatment options for ZD include open surgery and flexible endoscopic and rigid endoscopic therapy. Based on current evidence, traditional open surgery is suitable for all kinds of diverticula, providing satisfactory long-term outcomes and acceptable complication rates. However, it needs general anesthesia and more invasive procedures. Rigid endoscopic treatment can be done under general anesthesia and hyperextension of the neck. It might be technically difficult where the diverticular septum cannot be well exposed. Flexible endoscopic therapy can be conducted without general anesthesia or neck hyperextension, however it is only suitable for selected patients. Each treatment option has its pros and cons, but it is important to perform individualized therapy for each patient. Minimally invasive endoscopic therapy should be considered for debilitated patents with a middle-size diverticulum, and open surgery would be preferred when difficulty of diverticulum exposure is predicted. However, the poor quality of current evidence renders it difficult to establish a sound conclusion for the optimal treatment of ZD. More randomized controlled trials with long-term follow-up results are necessary to draw a firm conclusion.

References

1 Ludlow A: A case of obstructed deglutition, from a preternatural dilatation of, and bag formed in, the pharynx. Med Obs Inq 1767;3:85.
2 Zenker F, von Ziemssen H: Krankheiten des Oesophagus. Leipzig, F.C. Vogel, 1877, vol 7, pp 1–87.
3 Yeo JC, Mackenzie K: Pharyngeal pouch surgery in north Glasgow: NICE (National Institute for Health and Clinical Excellence) practice or not? J Laryngol Otol 2010;124:533–537.
4 Cook IJ, Blumbergs P, Cash K, Jamieson GG, Shearman DJ: Structural abnormalities of the cricopharyngeus muscle in patients with pharyngeal (Zenker's) diverticulum. J Gastroenterol Hepatol 1992;7:556–562.
5 Hillel AT, Flint PW: Evolution of endoscopic surgical therapy for Zenker's diverticulum. Laryngoscope 2009;119:39–44.
6 Wheeler WI: Pharyngocoele and dilation of the pharynx, with existing diverticulum at lower portion of pharynx lying posterior to the oesophagus, cured by pharyngotomy, being the first of the kind recorded. Dublin J Med Sci 1886;82:349–356.
7 Mosher H: Webs and pouches of the oesophagus, their diagnosis and treatment. Surg Gynecol Obstet 1917;25:175.
8 Peretti G, Piazza C, Del Bon F, Cocco D, De Benedetto L, Mangili S: Endoscopic treatment of Zenker's diverticulum by carbon dioxide laser. Acta Otorhinolaryngol Ital 2010;30:1–4.
9 Case DJ, Baron TH: Flexible endoscopic management of Zenker diverticulum: the Mayo Clinic experience. Mayo Clin Proc 2010;85:719–722.
10 Costamagna G, Iacopini F, Tringali A: Flexible endoscopic Zenker's diverticulotomy: cap-assisted technique vs. diverticuloscope-assisted technique. Endoscopy 2007;39:146–152.
11 Christiaens P, De Roock W, Van Olmen A, Moons V, D'Haens G: Treatment of Zenker's diverticulum through a flexible endoscope with a transparent oblique – end hood attached to the tip and a monopolar forceps. Endoscopy 2007;39:137–140.
12 Miller FR, Bartley J, Otto RA: The endoscopic management of Zenker diverticulum: CO_2 laser versus endoscopic stapling. Laryngoscope 2006;116:1608–1611.
13 Rabenstein T, May A, Michel J: Argon plasma coagulation for flexible endoscopic Zenker's diverticulotomy. Endoscopy 2007;39:141–145.
14 Vogelsang A, Preiss C, Neuhaus H, Schumacher B: Endotherapy of Zenker's diverticulum using the needle-knife technique: long-term follow-up. Endoscopy 2007:39:131–136.
15 Chang CY, Payyapilli RJ, Scher RL: Endoscopic staple diverticulostomy for Zenker's diverticulum: review of literature and experience in 159 consecutive cases. Laryngoscope 2003;113:957–965.
16 Mattinger C, Hormann K: Endoscopic diverticulotomy of Zenker's diverticulum: management and complications. Dysphagia 2002;17:34–39.
17 Repici A, Pagano N, Fumagalli U, Peracchia A, Narne S, Malesci A, Rosati R: Transoral treatment of Zenker diverticulum: flexible endoscopy versus endoscopic stapling. A retrospective comparison of outcomes. Dis Esophagus 2011;24:235–239.
18 Counter P, Hilton M, Baldwin DL: Long-term follow-up of endoscopic stapled diverticulotomy. Ann R Coll Surg Engl 2002;84:89–92.
19 Jaramillo MJ, McLay KA, McAteer D: Long-term clinicoradiological assessment of endoscopic stapling of pharyngeal pouch: a series of cases. J Laryngol Otol 2001;115:462–466.
20 Thaler ER, Weber RS, Goldberg AN, Weinstein GS: Feasibility and outcome of endoscopic staple-assisted esophagodiverticulostomy for Zenker's diverticulum. Laryngoscope 2001;111:1506–1508.
21 Adams J, Sheppard B, Andersen P: Zenker's diverticulostomy with cricopharyngeal myotomy: the endoscopic approach. Surg Endosc 2001;15:34–37.
22 Cook RD, Huang PC, Richtsmeri WJ, Scher RL: Endoscopic staple-assisted esophagodiverticulostomy: an excellent treatment of choice for Zenker's diverticulum. Laryngoscope 2000;110:2020–2025.
23 Omote K, Feussner H, Stein HJ, Ungeheuer A, Siewert JR: Endoscopic stapling diverticulostomy for Zenker's diverticulum. Surg Endosc 1999;13:535–538.
24 Mulder CJ: Zapping Zenker's diverticulum: gastroscopic treatment. Can J Gastroenterol 1999;13:405–407.
25 Peracchia A, Bonavina L, Narne S: Minimally invasive surgery for Zenker's diverticulum: analysis of results in 95 consecutive patients. Arch Surg 1998;133:695–700.
26 Baldwin DL, Toma AG: Endoscopic stapled diverticulotomy: a real advance in the treatment of hypopharyngeal diverticulum. Clin Otolaryngol Allied Sci 1998;23:244–247.
27 Wasserzug O, Zikk D, Raziel A, Cavel O, Fleece D, Szold A: Endoscopically stapled diverticulostomy for Zenker's diverticulum: results of a multidisciplinary team approach. Surg Endosc 2010;24:637–641.
28 Repici A, Pagano N, Romeo F, Danese S, Arosio M, Rando G, Strangio G, Carlino A, Malesci A: Endoscopic flexible treatment of Zenker's diverticulum: a modification of the needle-knife technique. Endoscopy 2010;42:532–535.
29 Khetani JD, Janjua A, Fenton RS: Staple-assisted endoscopic management of Zenker's diverticula: a role in the geriatric population. Indian J Otolaryngol Head Neck Surg 2009;61:200–204.
30 Gross ND, Cohen JI, Andersen PE: Outpatient endoscopic Zenker diverticulotomy. Laryngoscope 2004;114:208–211.
31 Sharp DB, Newman JR, Magnuson JS: Endoscopic management of Zenker's diverticulum: stapler-assisted versus Harmonic Ace. Laryngoscope 2009;119:1906–1912.
32 Palmer AD, Herrington HC, Rad IC, Cohen JI: Dysphagia after endoscopic repair of Zenker's diverticulum. Laryngoscope 2007;117:617–622.
33 Chiari C, Yeganehfar W, Scharitzer M, Mittlböck M, Armbruster C, Roka R, Függer R, Wenzl E, Pokieser P, Bischof G: Significant symptomatic relief after transoral endoscopic staple-assisted treatment of Zenker's diverticulum. Surg Endosc 2003;17:596–600.
34 Fama AF, Moore EJ, Kasperbauer JL: Harmonic scalpel in the treatment of Zenker's diverticulum. Laryngoscope 2009;119:1265–1269.
35 Hashiba K, de Paula AL, da Silva JG, Cappellanes CA, Moribe D, Castillo CF, Brasil HA: Endoscopic treatment of Zenker's diverticulum. Gastrointest Endosc 1999;49:93–97.
36 Narne S, Cutrone C, Bonavina L, Chella B, Peracchia A: Endoscopic diverticulotomy for the treatment of Zenker's diverticulum: results in 102 patients with staple-assisted endoscopy. Ann Otol Rhinol Laryngol 1999;108:810–815.
37 Lippert BM, Folz BJ, Rudert HH, Werner JA: Management of Zenker's diverticulum and postlaryngectomy pseudodiverticulum with the CO_2 laser. Otolaryngol Head Neck Surg 1999;121:809–814.
38 Sood S, Newbegin CJ: Endoscopic stapling of pharyngeal pouches in patients from the Yorkshire region. J Laryngol Otol 2000;114:853–857.
39 Nyrop M, Svendstrup F, Jorgensen KE: Endoscopic CO_2 laser therapy of Zenker's diverticulum: experience from 61 patients. Acta Otolaryngol Suppl 2000;543:232–234.
40 Luscher MS, Johansen LV: Zenker's diverticulum treated by the endoscopic stapling technique. Acta Otolaryngol Suppl 2000;543:235–238.
41 Krespi Y, Kacker A, Remacle M: Endoscopic treatment of Zenker's diverticulum using CO_2 laser. Otolaryngol Head Neck Surg 2002;127:309–314.
42 Evrard S, Le Moine O, Hassid S, Deviere J: Zenker's diverticulum: a new endoscopic treatment with a soft diverticuloscope. Gastrointest Endosc 2003;58:116–120.
43 Visosky AM, Parke RB, Donovan DT: Endoscopic management of Zenker's diverticulum: factors predictive of success or failure. Ann Otol Rhinol Laryngol 2008;117:531–537.
44 Aly A, Devitt PG, Watson DI, Jamieson GG, Bessell JR, Chew A, Krishnan S: Endoscopic stapling for pharyngeal pouch: does it make the cut? ANZ J Surg 2004;74:116–121.
45 Roth JA, Sigston E, Vallance N: Endoscopic stapling of pharyngeal pouch: a 10-year review of single versus multiple staple rows. Otolaryngol Head Neck Surg 2009;140:245–249.

46 Ozgursoy OB, Salassa JR: Functional and manofluorographic outcomes after transoral endoscopic pharyngoesophageal diverticulostomy. Arch Otolaryngol Head Neck Surg 2010;136:463–467.
47 Helmstaedter V, Engel A, Huttenbrink KB, Guntinas-Lichius O: Carbon dioxide laser endoscopic diverticulotomy for Zenker's diverticulum: results and complications in a consecutive series of 40 patients. ORL J Otorhinolaryngol Relat Spec 2009;71:40–44.
48 Kos MP, David EF, Mahieu HF: Endoscopic carbon dioxide laser Zenker's diverticulotomy revisited. Ann Otol Rhinol Laryngol 2009; 118:512–518.
49 Stoeckli SJ, Schmid S: Endoscopic stapler-assisted diverticuloesophagostomy for Zenker's diverticulum: patient satisfaction and subjective relief of symptoms. Surgery 2002;131: 158–162.
50 Hoffmann M, Scheunemann D, Rudert HH, Maune S: Zenker's diverticulotomy with the carbon dioxide laser: perioperative management and long-term results. Ann Otol Rhinol Laryngol 2003;112:202–205.
51 Raut VV, Primrose WJ: Long-term results of endoscopic stapling diverticulotomy for pharyngeal pouches. Otolaryngol Head Neck Surg 2002;127:225–229.
52 Bloom JD, Bleier BS, Mirza N, Chalian AA, Thaler ER: Factors predicting endoscopic exposure of Zenker's diverticulum. Ann Otol Rhinol Laryngol 2010;119:736–741.
53 Mulder CJ, den Hartog G, Robijn RJ, Thies JE: Flexible endoscopic treatment of Zenker's diverticulum: a new approach. Endoscopy 1995; 27:438–442.
54 Ishioka S, Sakai P, Maluf Filho F, Melo JM: Endoscopic incision of Zenker's diverticula. Endoscopy 1995;27:433–437.
55 Benjamin B, Gallagher R: Microendoscopic laser diverticulotomy for hypopharyngeal diverticulum. Ann Otol Rhinol Laryngol 1993; 102:675–679.
56 Van Overbeek JJ: Meditation on the pathogenesis of hypopharyngeal (Zenker's) diverticulum and a report of endoscopic treatment in 545 patients. Ann Otol Rhinol Laryngol 1994;103:178–185.
57 Von Doersten PG, Byl FM: Endoscopic Zenker's diverticulotomy (Dohlman procedure): forty cases reviewed. Otolaryngol Head Neck Surg 1997;116:209–212.
58 Harris RP, Weller MD, Porter MJ: A follow-up audit of pharyngeal pouch surgery using endoscopic stapling. Eur Arch Otorhinolaryngol 2010;267:939–943.
59 Casso C, Lalam M, Ghosh S, Timms M: Endoscopic stapling diverticulotomy: an audit of difficulties, outcome, and patient satisfaction. Otolaryngol Head Neck Surg 2006;134:288–293.
60 Simic A, Radovanović N, Stojakov D, Bjelovic M, Kotarac M, Sabljak P, Skrobić O, Pesko P: Surgical experience of the national institution in the treatment of Zenker's diverticula. Acta Chir Iugosl 2009;56:25–33.
61 Jougon J, Dubois G, Delcambre F, Velly JF: Combination of surgical and endoscopic approach for Zenker's diverticulum. Interact Cardiovasc Thorac Surg 2006;5:261–262.
62 Ruiz-Tovar J, Pérez de Oteyza J, Collado MV, Rojo R, García Villanueva A: 20 years' experience in the management of Zenker's diverticulum in a third-level hospital. Rev Esp Enferm Dig 2006;98:429–435.
63 Feeley MA, Righi PD, Weisberger EC: Zenker's diverticulum: analysis of surgical complications from diverticulectomy and cricopharyngeal myotomy. Laryngoscope 1999;109: 858–861.
64 Crescenzo D, Trastek V, Allen M, Deschamps C, Pairolero P: Zenker's diverticulum in the elderly: is operation justified? Ann Thorac Surg 1998;66:347–350.
65 Bonafede J, Lavertu P, Wood B, Eliachar I: Surgical outcome in 87 patients with Zenker's diverticulum. Laryngoscope 1997;107:720–725.
66 Nguyen H, Urquhart A: Zenker's diverticulum. Laryngoscope 1997;107:1436–1440.
67 Ellis FH Jr, Gibb SP, Williamson WA: Current status of cricopharyngeal myotomy for cervical esophageal dysphagia. Eur J Cardiothorac Surg 1996;10:1033–1038.
68 Cerdan FO, Gonzalez EM, Garcia DH: Diagnostic and treatment of Zenker's diverticulum; review of our series pharyngoesophageal diverticula. Hepatogastroenterology 1998;45: 447–450.
69 Brouillette D, Martel E, Chen LQ, Duranceau A: Pitfalls and complications of cricopharyngeal myotomy. Chest Surg Clin N Am 1997;7: 457–475.
70 Lindgren S, Ekberg O: Cricopharyngeal myotomy in the treatment of dysphagia. Clin Otolaryngol 1990;15:221–227.
71 Barthlen W, Feussner H, Hannig CH, Holscher AH, Siewert JR: Surgical therapy of Zenker's diverticulum: low risk and high efficiency. Dysphagia 1990;5:13–19.
72 Morton R, Bartley J: Inversion of Zenker's diverticulum: the preferred option. Head Neck 1993;15:253–256.
73 Laccourreye O, Menard M, Cauchois R: Esophageal diverticulum: diverticulopexy versus diverticulectomy. Laryngoscope 1994;104: 889–892.
74 Colombo-Benkmann M, Unruh V, Krieglstein C, Senninger N: Cricopharyngeal myotomy in the treatment of Zenker's diverticulum. J Am Coll Surg 2003;196:370–377.
75 Laing MR, Murthy P, Cockburn SW: Surgery for pharyngeal pouch: audit of management with short- and long-term follow up. J R Coll Surg Edinb 1995;40:315–318.
76 Brigand C, Ferraro P, Martin J, Duranceau A: Risk factors in patients undergoing cricopharyngeal myotomy. Br J Surg 2007;94:978–983.
77 Muñoz AA, Shapiro J, Cuddy LD, Misono S, Bhattacharyya N: Videofluoroscopic findings in dysphagic patients with cricopharyngeal dysfunction: before and after open cricopharyngeal myotomy. Ann Otol Rhinol Laryngol 2007;116:49–56.
78 Schmit PJ, Zuckerbraun L: Treatment of Zenker's diverticulum by cricopharyngeus myotomy under local anesthesia. Am Surg 1992; 58:710–716.
79 Payne WS: The treatment of pharyngoesophageal diverticulum: the simple and complex. Hepatogastroenterology 1992;39:109–114.
80 Aggerholm K, Illum P: Surgical treatment of Zenker's diverticulum. J Laryngol Otol 1990; 104:312–314.
81 Lerut T, van Raemdonck D, Guelinckx P, Dom R, Geboes K: Zenker's diverticulum: is a myotomy of the cricopharyngeus useful? How long should it be? Hepatogastroenterology 1992;39:127–131.
82 Mortensen M, Schaberg MR, Genden EM, Woo P: Transoral resection of short segment Zenker's diverticulum and cricopharyngeal myotomy: an alternative minimally invasive approach. Laryngoscope 2010;120:17–22.
83 Lang RA, Spelsberg FW, Winter H, Jauch KW, Hüttl TP: Transoral diverticulostomy with a modified Endo-Gia stapler: results after 4 years of experience. Surg Endosc 2007; 21:532–536.
84 Zaninotto G, Narne S, Costantini M, Molena D, Cutrone C, Portale G: Tailored approach to Zenker's diverticula. Surg Endosc 2003;17: 129–133.
85 Mirza S, Dutt SN, Minhas SS, Irving RM: A retrospective review of pharyngeal pouch surgery in 56 patients. Ann R Coll Surg Engl 2002;84:247–251.
86 Keck T, Rozsasi A, Grün PM: Surgical treatment of hypopharyngeal diverticulum (Zenker's diverticulum). Eur Arch Otorhinolaryngol 2010;267:587–592.
87 Rizzetto C, Zaninotto G, Costantini M, Bottin R, Finotti E, Zanatta L, Guirroli E, Ceolin M, Nicoletti L, Ruol A, Ancona E: Zenker's diverticula: feasibility of a tailored approach based on diverticulum size. J Gastrointest Surg 2008;12:2057–2064.
88 Bonavina L, Bona D, Abraham M, Saino G, Abate E: Long-term results of endosurgical and open surgical approach for Zenker diverticulum. World J Gastroenterol 2007;13:2586–2589.
89 Wirth D, Kern B, Guenin MO, Montali I, Peterli R, Ackermann C, von Flue M: Outcome and quality of life after open surgery versus endoscopic stapler-assisted esophagodiverticulostomy for Zenker's diverticulum. Dis Esophagus 2006;19:294–298.
90 Chang CW, Burkey BB, Netterville JL, Courey MS, Garrett CG, Bayles SW: Carbon dioxide laser endoscopic diverticulotomy versus open diverticulectomy for Zenker's diverticulum. Laryngoscope 2004;114:519–527.
91 Smith SR, Genden EM, Urken ML: Endoscopic stapling technique for the treatment of Zenker diverticulum vs. standard open-neck technique: a direct comparison and charge analysis. Arch Otolaryngol Head Neck Surg 2002;128:141–144.

92 Gutschow CA, Hamoir M, Rombaux P, Otte JB, Goncette L, Collard JM: Management of pharyngoesophageal (Zenker's) diverticulum: which technique? Ann Thorac Surg 2002;74: 1677–1682.
93 Sydow BD, Levine MS, Rubesin SE, Laufer I: Radiographic findings and complications after surgical or endoscopic repair of Zenker's diverticulum in 16 patients. AJR Am J Roentgenol 2001;177:1067–1071.
94 Van Eeden S, Lloyd RV, Tranter RM: Comparison of the endoscopic stapling technique with more established procedures for pharyngeal pouches: results and patient satisfaction survey. J Laryngol Otol 1999;113:237–240.
95 Siddiq MA, Patel PJ: Pharyngeal pouch surgery: a five-year review. Rev Laryngol Otol Rhinol (Bord) 2000;121:37–40.
96 Zbaren P, Schar P, Tschopp L: Surgical treatment of Zenker's diverticulum: transcutaneous diverticulectomy versus microendoscopic myotomy of the cricopharyngeal muscle with CO_2 laser. Otolaryngol Head Neck Surg 1999;121:482–487.
97 Lippert BM, Folz BJ, Gottschlich S, Werner JA: Microendoscopic treatment of the hypopharyngeal diverticulum with the CO_2 laser. Lasers Surg Med 1997;20:394–401.
98 Brace M, Taylor SM, Trites JR, Bethune D, Attia E, Hart RD: Endoscopic stapling versus external transcervical approach for the treatment of Zenker diverticulum. J Otolaryngol Head Neck Surg 2010;39:102–106.
99 Safdar A, Curran A, Timon CV: Endoscopic stapling vs. conventional methods of surgery for pharyngeal pouches: results, benefits and modifications. Ir Med J 2004;97:75–76.
100 Zaninotto G, Rizzetto C: Optimal therapy for cricopharyngeal diverticula; in Ferguson MK (ed): Difficult Decision in Thoracic Surgery: An Evidence-Based Approach, ed 2. London, Springer, 2011, pp 293–301.
101 Yip HT, Leonard R, Kendall KA: Cricopharyngeal myotomy normalizes the opening size of the upper esophageal sphincter in cricopharyngeal dysfunction. Laryngoscope 2006;116:93–96.
102 Shaw DW, Cook IJ, Jamieson GG: Influence of surgery on deglutitive upper oesophageal sphincter mechanics in Zenker's diverticulum. Gut 1996;38:806–811.
103 Zuckerbraun L, Bahna MS: Cricopharyngeus myotomy as the only treatment for Zenker diverticulum. Ann Otol Rhinol Laryngol 1979;88:798–803.
104 Ellis FH, Schlegel JF, Lynch VP, Payne WS: Cricopharyngeal myotomy for pharyngoesophageal diverticulum. Ann Surg 1969; 170:340–349.
105 Skinner KA, Zuckerbraun L: Recurrent Zenker's diverticulum: treatment with cricopharyngeal myotomy. Am Surg 1998;64: 192–195.
106 Lund WS: The cricopharyngeal sphincter: its relationship to the relief of pharyngeal paralysis and the surgical treatment of the early pharyngeal pouch. J Laryngol Otol 1968; 82:353–367.
107 Williams RB, Ali GN, Hunt DR, Wallace KL, Cook IJ: Cricopharyngeal myotomy does not increase the risk of esophagopharyngeal acid regurgitation. Am J Gastroenterol 1999;94: 3448–3454.
108 Skrobić OM, Simić AP, Radovanović NS, Spica BV, Pesko PM: Current concepts in the anatomy and origin of pharyngeal diverticula. Acta Chir Iugosl 2009;56:17–24.
109 Lang I, Shaker M: Anatomy and physiology of the upper esophageal sphincter. Am J Med 1997;103:50S–55S.
110 Kos MP, David EF, Klinkenberg-Knol EC, Mahieu HF: Long-term results of external upper esophageal sphincter myotomy for oropharyngeal dysphagia. Dysphagia 2010; 25:169–176.
111 Duranceau A, Rheault MJ, Jamieson GG: Physiologic response to cricopharyngeal myotomy and diverticulum suspension. Surgery 1983;94:655–662.
112 Bowdler DA, Stell PM: Surgical management of posterior pharyngeal pulsion diverticula: inversion versus one-stage excision. Br J Surg 1987;74:988–990.
113 Freeland AP, Bates GJ: The surgical treatment of a pharyngeal pouch: inversion or excision? Ann R Coll Surg Engl 1987;69:57–58.
114 Wychulis AR, Gunnlaugsson GH, Clagett OT: Carcinoma occurring in pharyngoesophageal diverticulum: report of 3 cases. Surgery 1969;66:976–979.
115 Dohlman G, Mattsson O: The endoscopic operation for hypopharyngeal diverticula: a roentgen cinematographic study. AMA Arch Otolaryngol 1960;71:744.
116 Ferreira LE, Simmons DT, Baron TH: Zenker's diverticula: pathophysiology, clinical presentation, and flexible endoscopic management. Dis Esophagus 2008;21:1–8.