European Archives of Oto-Rhino-Laryngology
https://doi.org/10.1007/s00405-019-05374-z

LARYNGOLOGY

Outcomes in modified transoral resection of diverticula for Zenker's diverticulum

Attapon Junlapan[1,2] · Sara Abu-Ghanem[1] · C. Kwang Sung[1] · Edward J. Damrose[1]

Received: 17 December 2018 / Accepted: 9 March 2019

Abstract

Purpose Transoral resection of Zenker's diverticulum (TORD) was first reported in 2010. We present results for our modified approach to transoral resection (MTORD)—full-thickness cricopharyngeal myectomy, diverticulum sac excision, and suture closure of the pharyngotomy—and evaluate its safety and efficacy compared to endoscopic stapling and open approaches.

Methods A retrospective study was performed in patients who underwent transoral resection of Zenker's diverticulum using MTORD, endoscopic stapler-assisted diverticulotomy (ESD), or trancervical diverticulectomy (TCD) from July 2009 to August 2017. Pre-operative evaluation included barium swallow and subjective characterization of swallowing dysfunction using the EAT-10 and Reflux Symptom Index (RSI). Complications, length of hospitalization, recurrence, and revision rates were also evaluated.

Results Of 92 patients reviewed, 18 underwent MTORD, 45 underwent ESD and 29 underwent TCD. Major complications were only observed in ESD and TCD. Recurrence which required revision surgery was only observed in ESD. EAT-10 and RSI scores significantly improved and RSI scores normalized post-operatively for all approaches in short-term (< 1 year) follow-up.

Conclusions MTORD is a safe and effective option for complete Zenker's diverticulectomy. Complication rates are low. To date, no patient has required reoperation, although more cases and longer term follow-up are needed for more complete comparison to ESD and traditional open excision.

Keywords Modified transoral resection of diverticulum · Endoscopic laser approach · Diverticulectomy · Zenker's diverticulum · Outcomes · Recurrence

Introduction

Zenker's diverticulum is a rare disease affecting 2 in 100,000 people. The incidence is most common in elderly men. Zenker's diverticulum is a herniation of esophageal mucosa and submucosa at Killian's triangle, a diastasis between the inferior pharyngeal constrictor and the cricopharyngeus muscles, that is caused by excessive contraction or discoordination in the pharyngeal muscles in conjunction with a hypertensive cricopharyngeus (CP) muscle [1, 2]. Dysphagia is the most common complaint in patients with Zenker's diverticulum. A large diverticulum can produce regurgitation of undigested food, aspiration, gurgling in the throat, neck mass, dysphonia, halitosis, and malnutrition. Diagnosis is confirmed by barium esophagography which demonstrates a pouch filled with contrast material. The pouch's depth can be estimated and used to counsel patients on the possible surgical options. Furthermore, concomitant esophageal diseases or motility disorders can be evaluated by the barium study. Esophagoscopy is performed at the time of surgery to confirm the diagnosis and suitability for an endoscopic approach, and to exclude concurrent esophageal pathology (i.e., stricture, eosinophilic esophagitis, carcinoma, etc.) [3].

The mainstay of treatment is surgery. Conventional transcervical diverticulectomy (TCD) has excellent outcomes

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00405-019-05374-z) contains supplementary material, which is available to authorized users.

✉ Edward J. Damrose
edamrose@stanford.edu

[1] Department of Otolaryngology-Head and Neck Surgery, Stanford University School of Medicine, Stanford, CA, USA

[2] Department of Otolaryngology-Head and Neck Surgery, Faculty of Medicine, Naresuan University, Phitsanulok, Thailand

Published online: 15 March 2019

although a higher complication rate. Endoscopic surgical treatment of Zenker's diverticulum was first performed by Mosher in 1917 and a large series was later reported by Dohlman [4, 5]. The carbon dioxide laser was first introduced to the endoscopic technique by van Overbeek [6]. The endoscopic approach can be performed by flexible or rigid endoscopy; the latter technique is usually completed with a laser or stapler. Endoscopic stapler-assisted diverticulotomy (ESD) offers a lower complication rate and more rapid recovery, but has a greater rate of recurrence, likely owing to incomplete transection of the CP muscle and preservation of remnant diverticulum. The endoscopic laser approach is considered superior to endoscopic stapling approach for addressing small diverticula (< 2 cm) since the distal 1 cm of current staplers does not cut or staple [7].

Transoral resection of diverticula (TORD) was reported by Mortensen et al., but no studies have evaluated long-term outcomes and efficacy [8]. In this procedure, the diverticular sack is grasped, everted and resected with endoscopic scissors, followed by division of the cricopharyngeus muscle by electrocautery. The modified transoral resection of diverticula (MTORD) is theorized to reduce recurrence rates by performing a complete wedge resection of cricopharyngeus muscle, removal of the pouch, and suture closure of the resultant pharyngotomy. MTORD can be performed in patients with prior neck surgery, significant comorbidities, elderly patients or patients with recurrent symptoms. This study seeks to establish the outcomes of MTORD when compared to other approaches.

Methods

This study was approved by the Stanford Institutional Review Board and Research Compliance Office. A retrospective study was conducted on patients aged 18 and older who underwent transoral resection of Zenker's diverticulum using our modified approach (MTORD), endoscopic stapler-assisted diverticulotomy (ESD) and transcervical diverticulectomy (TCD) from July 2009 to August 2017 in the Department of Otolaryngology-Head and Neck Surgery, Stanford University Medical Center. Pre-operative data collected included patient demographics, barium swallow, and subjective characterization of swallowing dysfunction using the Eating Assessment Tool (EAT-10) and Reflux Symptom Index (RSI). Complications, operative time, estimated blood loss, length of hospitalization, EAT-10, and RSI were evaluated.

The Weerda distending diverticuloscope is placed into position and suspended from the Mayo stand with good delineation of the esophageal lumen, diverticulum and the CP bar in an atraumatic fashion. The operating microscope is then brought into position and the carbon dioxide laser with micromanipulator is prepared with settings of 8 watts in continuous mode. A horizontal incision is made in the mucosa to expose the CP bar. Submucosal flaps are elevated anterior and posterior to the cricopharyngeal bar using Kittners and the laser. The full thickness of muscle is grasped, and then a wedge cricopharyngeal myectomy is performed by cutting through all of the muscle fibers in two vertical incisions in an anterior to posterior direction. The diverticulum is grasped, advanced, and excised with the laser. A tension-free primary closure is performed in a horizontal fashion using interrupted 4-0 vicryl sutures with a TF needle (Ethicon, Inc., a Johnson & Johnson company; Somerville, NJ, USA). A nasogastric feeding tube may then be placed under direct visualization.

Statistical analysis

The quantitative data are presented in mean ± standard deviations (SD). The qualitative data were calculated with Pearson's chi-square test. For comparison of means, we used a t-test for pairwise comparison and one-way analysis of variance (ANOVA) for comparison across three groups. Wilcoxon rank-sum test was used for non-normal distributed data. Chi-square and Fisher's exact tests were used to compare dichotomous variables. SAS 9.4 (SAS Institute Inc., Cary, NC, USA) was used for the statistical calculations in this study. Significance level was accepted at $p < 0.05$ in two-tailed tests.

Results

A total of 92 subjects (62 males and 30 females) with a mean age of 74 ± 12 years were reviewed. There were 18 cases of MTORD, 45 cases of ESD and 29 cases of TCD. Preexisting gastroesophageal reflux disease (GERD) was present in 40% of the patients. The demographic data of subjects are shown in Table 1. Most of the demographic characteristics showed no significant difference among the groups of patients except for age where statistically significant differences were found only between MTORD and ESD. The patterns of pooling of secretions from pre-operative flexible fiberoptic laryngoscopy are shown in Table 2 and 41% of patients had no pooling of secretions.

The procedure characteristics included size of Zenker's diverticulum, type of surgery, operative time, estimated blood loss (EBL) and length of hospital stay (LOS), and are shown in Table 3. Most of the procedure characteristics showed a significant difference among the groups of patients ($p < 0.05$), and most of these statistically significant differences were found between MTORD and ESD.

The subjective characterization of swallowing dysfunction using the EAT-10 and RSI is shown in Tables 4, 5

Table 1 Demographic data of subjects

Groups	MTORD ($n=18$)	ESD ($n=45$)	TCD ($n=29$)	p values
Sex				
Male (%)	10	31	21	0.466
Female (%)	8	14	8	
Age (years)				
Mean	68 ± 14	76 ± 11	74 ± 13	0.020*
Range	35–86	44–95	63–94	
BMI (kg/m^2)				
Mean	25.6 ± 4.4	25.6 ± 5.0	26.5 ± 4.4	0.656
Range	19.7–35.7	16.5–42	17–34.4	
Preexisting				
GERD (%)	8 (44.4)	20 (44.4)	12 (41.4)	0.963
CVA (%)	3 (16.7)	7 (15.6)	4 (13.8)	0.961
Previous open neck surgery (%)	3 (16.7)	4 (8.9)	5 (17.2)	0.511
Smoking				
Never smoker (%)	5 (27.8)	18 (40)	13 (44.8)	0.501
Former smoker (%)	12 (66.7)	26 (57.8)	15 (51.7)	
Current smoker (%)	1 (5.6)	1 (2.2)	1 (3.4)	
Alcohol				
Yes (%)	15 (83.3)	27 (60)	21 (72.4)	0.170
No (%)	3 (16.7)	18 (40)	8 (27.6)	

The quantitative data are presented as mean ± standard deviation (SD), but the qualitative data are presented as number (%)

MTORD modified transoral resection of diverticulum, ESD endoscopic stapler-assisted diverticulotomy, TCD transcervical diverticulectomy, BMI body mass index, *GERD* gastroesophageal reflux disease, *CVA* cerebrovascular accident

*Statistically significant differences were found only between MTORD and ESD

Table 2 Patterns of pooling of secretions

No secretion (%)	37 (40.7)
Left side (%)	23 (25.3)
Right side (%)	4 (4.4)
Both sides (%)	27 (29.7)

The qualitative data are presented as number (%)

and 6. Both EAT-10 and RSI were evaluated pre-operatively and post-operatively short term and long term (at < 1-year follow-up and 1–7-year follow-up). Among all groups (MTORD, ESD, TCD), pre-operative EAT-10 and RSI were the same (Table 4). Statistically significant differences among all groups (MTORD, ESD, and TCD) of EAT-10 and RSI were found between pre-operative and post-operative short-term (< 1 year) follow-up and between pre-operative and long-term (1–7 years) follow-up except for MTORD where statistically significant differences were not found between pre-operative and post-operative long-term (1–7 years) follow-up (Tables 5, 6). Box plots comparing RSI and EAT-10 at pre-operative, short-term and long-term follow-up following MTORD, ESD and TCD are shown in Figs. 1 and 2.

Complications following MTORD, ESD and TCD are shown in Table 7. For intra-operative complications, two esophageal perforations were observed in TCD. Major post-operative complications were defined as complications that required reoperation or prolonged hospitalization. Major post-operative complications were only observed in ESD and TCD. One case of a hematoma needing wound exploration was reported following TCD and three cases of retropharyngeal space abscess requiring wound exploration were reported one for ESD and two for TCD. Other minor complications following TCD were ecchymosis of anterior neck, left vocal fold paresis, left Horner's syndrome, aspiration, and cellulitis. Transient tongue anesthesia was noted following both MTORD and ESD.

Recurrence and revision are shown in Table 8. Of the seven patients with recurrence, five patients were noted following ESD. Moreover, three cases of recurrence with required revision were only observed in ESD.

Table 3 Procedure characteristics

Groups	MTORD ($n=18$)	ESD ($n=45$)	TCD ($n=29$)	p values
Size of Zenker's diverticulum (cm)				
Mean	2.1 ± 1.4	3.1 ± 1.3	3.1 ± 1.4	0.008[ab]
Range	0.5–6.8	1–7	1–6	
Type of surgery				
New patient (%)	10 (55.6)	38 (84.4)	23 (79.3)	0.045[a]
Revision (%)	8 (44.4)	7 (15.6)	6 (20.7)	
Operative time (min)				
Mean	102.4 ± 30.2	42.4 ± 16.2	175.2 ± 46.2	< 0.0001[abc]
Range	53–158	18–87	107–341	
EBL (ml)				
< 25 (%)	18 (100)	44 (97.8)	19 (65.5)	< 0.0001[bc]
25–50 (%)	0 (0)	1 (2.2)	10 (34.5)	
LOS (day)				
Mean	3 ± 0.9	2 ± 2.2	4 ± 3.4	< 0.0001[ac]
Range	1–4	0–12	1–15	

The quantitative data are presented as mean ± standard deviation (SD), but the qualitative data are presented as number (%)

MTORD modified transoral resection of diverticulum, ESD endoscopic stapler-assisted diverticulotomy, TCD transcervical diverticulectomy, *EBL* estimated blood loss, *LOS* length of hospital stay

[a]Statistically significant differences were found only between MTORD and ESD

[b]Statistically significant differences were found only between MTORD and TCD

[c]Statistically significant differences were found only between ESD and TCD

Table 4 Pre-operative scores on reflux and dysphagia

Groups	MTORD ($n=17$)	ESD ($n=38$)	TCD ($n=24$)	p values
RSI	20.3 ± 11.4	20.9 ± 8.2	23.7 ± 7.6	0.437
EAT-10	19.4 ± 9.5	19.3 ± 10.5	19.1 ± 10.9	0.992

The quantitative data are presented as mean ± standard deviation (SD)

MTORD modified transoral resection of diverticulum, ESD endoscopic stapler-assisted diverticulotomy, TCD transcervical diverticulectomy, *RSI* Reflux Symptom Index, *EAT-10* Eating Assessment Tool

Discussion

Endoscopic treatment of Zenker's diverticulum is a popular option because of the early resumption of oral alimentation, shorter hospital stay, and lower complication rates compared to transcervical excision [7–9]. Many endoscopic techniques have been developed and ESD is currently the most commonly performed approach; however, it cannot effectively address small diverticula (< 2 cm). The distal 1 cm of the stapler does not cut or staple, which leaves part of the common party wall, including cricopharyngeus muscle, intact [7]. An endoscopic laser approach with partial resection of

Table 5 Outcomes on reflux and dysphagia on short-term follow-up

Groups	RSI			EAT-10		
	PRE	T1	p values	PRE	T1	p values
MTORD ($n=16$)	20.3 ± 11.4	6.9 ± 6.3	0.0005[a]	19.4 ± 9.5	4.2 ± 5.0	< 0.0001*
ESD ($n=30$)	21.3 ± 8.2	6.7 ± 8.9	< 0.0001[a]	19.0 ± 10.5	3.7 ± 5.6	< 0.0001*
TCD ($n=20$)	23.7 ± 7.6	8.9 ± 8.2	< 0.0001[a]	19.1 ± 10.9	6.0 ± 8.8	< 0.0001*
Total ($n=66$)	21.8 ± 8.8	7.5 ± 8.2	< 0.0001[a]	19.1 ± 10.3	4.5 ± 6.6	< 0.0001*

The quantitative data are presented as mean ± standard deviation (SD)

MTORD modified transoral resection of diverticulum, ESD endoscopic stapler-assisted diverticulotomy, TCD transcervical diverticulectomy, *RSI* Reflux Symptom Index, *EAT-10* Eating Assessment Tool, *PRE* pre-operative, *T1* post-operative < 1 year

*Statistically significant differences were found between PRE and T1

Table 6 Outcomes on reflux and dysphagia on long-term follow-up

Groups	RSI			EAT-10		
	PRE	T2	*p* values	PRE	T2	*p* values
MTORD ($n=3$)	20.3 ± 11.4	9.3 ± 5.1	0.0005	19.4 ± 9.5	6.7 ± 3.5	< 0.0001
ESD ($n=20$)	21.3 ± 8.2	9.6 ± 9.1	< 0.0001[a]	19.0 ± 10.5	5.7 ± 7.9	< 0.0001*
TCD ($n=10$)	23.7 ± 7.6	8.8 ± 8.2	< 0.0001[a]	19.1 ± 10.9	5.0 ± 7.9	< 0.0001*
Total ($n=33$)	21.8 ± 8.8	9.5 ± 8.4	< 0.0001[a]	19.1 ± 10.3	5.5 ± 7.5	< 0.0001*

The quantitative data are presented as mean ± standard deviation (SD)

MTORD modified transoral resection of diverticulum, ESD endoscopic stapler-assisted diverticulotomy, TCD transcervical diverticulectomy, *RSI* Reflux Symptom Index, *EAT-10* Eating Assessment Tool, *PRE* pre-operative, *T2* post-operative 1–7 years

*Statistically significant differences were found between PRE and T2

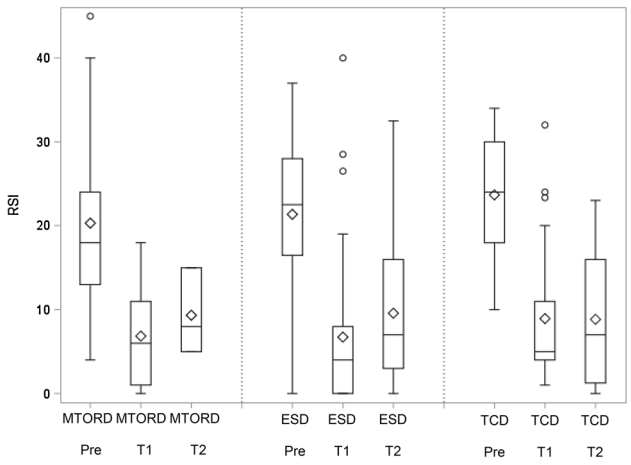

Fig. 1 Box plot comparing pre- and post-RSI following operations

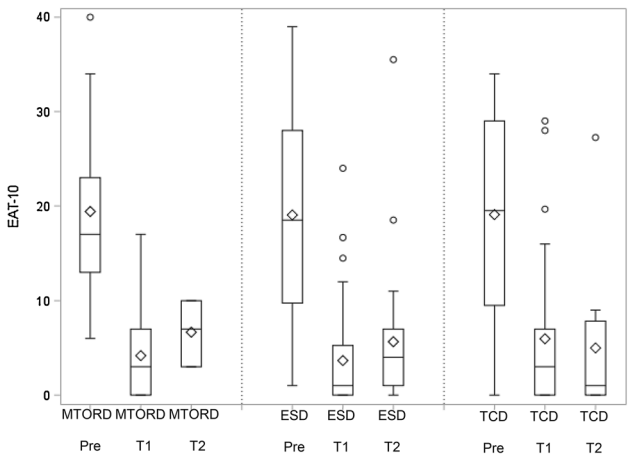

Fig. 2 Box plot comparing pre- and post-EAT-10 following operations

cricopharyngeus muscle has been reported with excellent outcomes [9]. MTORD is our preferred endoscopic laser approach because it allows a cricopharyngeal myectomy that traverses the full thickness of the muscle with diverticular sac removal. To facilitate the partial resection of cricopharyngeus muscle and mucosal closure, a horizontal mucosal opening is performed by our technique.

Candidates for the MTORD technique are the same as for other endoscopic approaches. It is not recommended for patients likely to have limited intra-operative exposure via the Weerda diverticuloscope, such as those with limited mouth opening, prominent front teeth, cervical spine disease, short necks, decreased hyomental distance or high body mass index [10, 11]. Adequate surgical exposure is defined as concomitant visualization of the esophageal opening, Zenker's diverticulum and cricopharyngeal bar using the diverticuloscope. For this reason, pre-operative counseling should be performed for the possibility of conversion to an open transcervical approach due to limited intra-operative exposure or for intra-operative complications. Further counseling, especially for younger and healthy patients, is needed for possible revision surgery due to recurrent or persistent symptoms [12].

In this study, in concordance with other reports, ESD was the most frequently utilized approach, with Zenker's diverticulae occurring most commonly in elderly male patients [13]. Prior reports have revealed the association between GERD and Zenker's diverticulum, presumably secondary to spasm or fibrosis of the cricopharyngeus muscle [14, 15]. In this study, 43.5% of patients had concomitant GERD, supporting prior observations. A previous study by Ongkasuwan et al. reported patients with Zenker's diverticulum had increased pooling of secretions in the left compared with the right piriform 52% of the time, but our study observed this pattern in only 25.3% cases [16]. Most of our patients (40.7%) had no pooling of secretions on pre-operative examination, followed by bilaterally equal hypopharyngeal secretions (29.7%). For this reason, prediction of the presence of a Zenker's diverticulum by patterns of pooling secretions should be made with some caution.

A previous study reported effective treatment of recurrent Zenker's diverticulum with endoscopic laser division

Table 7 Complications

Groups	MTORD ($n=18$)	ESD ($n=45$)	TCD ($n=29$)	Total ($n=92$)
Intra-operative				
Esophageal perforation (%)	0 (0)	0 (0)	2 (6.9)	2 (2.2)
Post-operative				
Major				
Hematoma (%)	0 (0)	0 (0)	1 (3.4)	1 (1.1)
Retropharyngeal abscess (%)	0 (0)	1 (2.2)	2 (6.9)	3 (3.3)
Minor				
Ecchymosis of anterior neck (%)	0 (0)	0 (0)	1 (3.4)	1 (1.1)
Left vocal fold paresis (%)	0 (0)	0 (0)	1 (3.4)	1 (1.1)
Left Horner's syndrome (%)	0 (0)	0 (0)	1 (3.4)	1 (1.1)
Aspiration (%)	0 (0)	0 (0)	1 (3.4)	1 (1.1)
Cellulitis (%)	0 (0)	0 (0)	1 (3.4)	1 (1.1)
Transient tongue anesthesia (%)	1 (5.6)	1 (2.2)	0 (0)	2 (2.2)

The qualitative data are presented as number (%)

MTORD modified transoral resection of diverticulum, ESD endoscopic stapler-assisted diverticulotomy, TCD transcervical diverticulectomy

Table 8 Recurrence and revision

Groups	MTORD ($n=18$)	ESD ($n=45$)	TCD ($n=29$)	Total ($n=92$)
Recurrence				
Without revision (%)	1 (5.6)	2 (4.4)	1 (3.4)	4 (4.3)
With revision (%)	0 (0)	3 (6.7)	0 (0)	3 (3.3)

The qualitative data are presented as number (%)

MTORD modified transoral resection of diverticulum, ESD endoscopic stapler-assisted diverticulotomy, TCD transcervical diverticulectomy

of the remnant party wall [17]. In our study, 22.8% of cases were for revision surgery, and of these 38.1% underwent were treated via MTORD. Operative time and length of hospitalization were lowest in ESD, and longest in TCD. The mean operative time and mean length of hospitalization of MTORD were 102.4 min and 3 days, respectively.

Significantly improved short-term post-operative EAT-10 and RSI were observed in all groups (MTORD, ESD, TCD). There were only three cases of MTORD with follow-up beyond 1 year, so long-term improvement of EAT-10 and RSI did not reach significance. Long-term follow-up with a larger sample size is needed to confirm the improvement of these two scores.

Complications that required prolonged hospitalization or reoperation were defined as major complications; otherwise they were categorized as minor complications. In our study, intra-operative esophageal perforation, post-operative hematoma, and retropharyngeal space abscess were the major complications that occurred. In concordance with previous studies, the open approach had more complications than endoscopic approaches [18, 19]. The overall post-operative complications following TCD (27.6%) were more frequently observed compared to the recent systematic review (11%) [18]; however, the major complications were comparable to our study. Intra-operative esophageal perforation and post-operative hematoma were major complications that were only noted in TCD, but retropharyngeal abscesses were observed in both ESD and TCD. Many previous studies reported endoscopic laser approach is an effective operation associated with low complications rates. MTORD is a novel endoscopic laser approach that can be considered a safe procedure, without major complications [20, 21]. Transient tongue anesthesia, a minor post-operative complication associated with the suspension of the Weerda diverticuloscope, was noted in MTORD and ESD.

Many studies have reported better long-term results with TCD but our study showed that the recurrence rates of MTORD (5.6%), that were comparable to TCD (3.4%) [21–25], has a lower rate of recurrence than the recent systematic review (21.7%) [18] because the selected case for MTORD had a smaller size of Zenker's diverticulum than other approaches. ESD was associated with the highest rate of recurrence (11.1%). However, more cases and longer term follow-up may be needed for more complete comparison to traditional open excision. Limitations of this study include

the retrospective nature and the limited long-term follow-up data on patients.

Conclusions

MTORD is considered a safe and effective endoscopic treatment for Zenker's diverticulum. Complication rates are lower than ESD and TCD. Dysphagia and regurgitation greatly improved after surgery. The long-term recurrence and revision rates are low, comparable to TCD. MTORD offers high success rates and rapid improvement of symptoms because of the complete diverticular sac removal and cricopharyngeal myectomy. However, delayed resumption of oral diet and inpatient observation are disadvantages of this therapeutic approach.

Acknowledgements Our grateful appreciation is expressed to Yifei Ma, our consulting statistician, for his kind contributions.

Compliance with ethical standards

Conflict of interest The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The consent for participation may be required for the study.

References

1. Chokhavatia S, Alli-Akintade L, Harpaz N, Stern R (2013) Esophageal pathology: a brief guide and atlas. Otolaryngol Clin N Am 46(6):1043–1057
2. Westrin KM, Ergun S, Carlsoo B (1996) Zenker's diverticulum—a historical review and trends in therapy. Acta Otolaryngol 116(3):351–360
3. Acar T, Savas R, Kocacelebi K, Ersoz G (2016) Squamous cell carcinoma arising from a Zenker's diverticulum: contribution of FDG-PET/CT to the diagnosis. Dis Esophagus 29(8):1170–1171
4. Mosher HP (1917) Webs and pouches of the oesophagus, their diagnosis and treatment. Surg Gynecol Obstet 25:175–187
5. Dohlman G, Mattsson O (1960) The endoscopic operation for hypopharyngeal diverticula: a roentgencinematographic study. AMA Arch Otolaryngol 71:744–752
6. van Overbeek JJ (1994) Meditation on the pathogenesis of hypopharyngeal (Zenker's) diverticulum and a report of endoscopic treatment in 545 patients. Ann Otol Rhinol Laryngol 103 (3):178–185
7. Prisman E, Genden EM (2013) Zenker diverticulum. Otolaryngol Clin N Am 46(6):1101–1111
8. Mortensen M, Schaberg MR, Genden EM, Woo P (2010) Transoral resection of short segment Zenker's diverticulum and cricopharyngeal myotomy: an alternative minimally invasive approach. Laryngoscope 120(1):17–22
9. Peretti G, Piazza C, Del Bon F, Cocco D, De Benedetto L, Mangili S (2010) Endoscopic treatment of Zenker's diverticulum by carbon dioxide laser. Acta Otorhinolaryngol Ital 30(1):1–4
10. Murer K, Soyka MB, Broglie MA, Huber GF, Stoeckli SJ (2015) Zenker's diverticulum: outcome of endoscopic surgery is dependent on the intraoperative exposure. Eur Arch Oto-rhino-laryngol 272(1):167–173
11. Bloom JD, Bleier BS, Mirza N, Chalian AA, Thaler ER (2010) Factors predicting endoscopic exposure of Zenker's diverticulum. Ann Otol Rhinol Laryngol 119(11):736–741
12. Johnson CM, Postma GN (2016) Zenker diverticulum—which surgical approach is superior? JAMA Otolaryngol Head Neck Surg 142 (4):401–403
13. Aiolfi A, Scolari F, Saino G, Bonavina L (2015) Current status of minimally invasive endoscopic management for Zenker diverticulum. World J Gastrointest Endosc 7(2):87–93
14. Veenker EA, Andersen PE, Cohen JI (2003) Cricopharyngeal spasm and Zenker's diverticulum. Head Neck 25(8):681–694
15. Sasaki CT, Ross DA, Hundal J (2003) Association between Zenker diverticulum and gastroesophageal reflux disease: development of a working hypothesis. Am J Med 115(Suppl 3A):169S–171S
16. Ongkasuwan J, Yung KC, Courey MS (2012) Pharyngeal stasis of secretions in patients with Zenker diverticulum. Otolaryngol head Neck Surg 146(3):426–429
17. Adam SI, Paskhover B, Sasaki CT (2013) Revision Zenker diverticulum: laser versus stapler outcomes following initial endoscopic failure. Ann Otol Rhinol Laryngol 122(4):247–253
18. Verdonck J, Morton RP (2015) Systematic review on treatment of Zenker's diverticulum. Eur Arch Oto-rhino-laryngol. 272 (11):3095–3107
19. Yuan Y, Zhao YF, Hu Y, Chen LQ (2013) Surgical treatment of Zenker's diverticulum. Digest Surg 30(3):207–218
20. Papaspyrou G, Schick B, Papaspyrou S, Wiegand S, Al Kadah B (2016) Laser surgery for Zenker's diverticulum: European combined study. Eur Arch Oto-rhino-laryngol 273 (1):183–188
21. Koch M, Mantsopoulos K, Velegrakis S, Iro H, Zenk J (2011) Endoscopic laser-assisted diverticulotomy versus open surgical approach in the treatment of Zenker's diverticulum. Laryngoscope 121(10):2090–2094
22. Shahawy S, Janisiewicz AM, Annino D, Shapiro J (2014) A comparative study of outcomes for endoscopic diverticulotomy versus external diverticulectomy. Otolaryngol Head Neck Surg 151(4):646–651
23. Rizzetto C, Zaninotto G, Costantini M, Bottin R, Finotti E, Zanatta L, Guirroli E, Ceolin M, Nicoletti L, Ruol A, Ancona E (2008) Zenker's diverticula: feasibility of a tailored approach based on diverticulum size. J Gastrointest Surg 12:2057–2064 **(discussion 2064–2055)**
24. Chang CW, Burkey BB, Netterville JL, Courey MS, Garrett CG, Bayles SW (2004) Carbon dioxide laser endoscopic diverticulotomy versus open diverticulectomy for Zenker's diverticulum. Laryngoscope 114(3):519–527
25. Zaninotto G, Narne S, Costantini M, Molena D, Cutrone C, Portale G, Costantino M, Rizzetto C, Basili U, Ancona E (2003) Tailored approach to Zenker's diverticula. Surg Endosc 17(1):129–133