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ORIGINAL ARTICLE

Open Versus Endoscopic Surgery of Zenker's Diverticula: A Systematic Review and Meta-analysis

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Abstract

Most Zenker's diverticula (ZD) cohort studies are single-institution retrospective observational studies of recurrence rates. There is a gap in the literature regarding patient-reported outcomes after ZD surgery. This study was conducted to compare if open transcervical diverticulectomy (OD) is better than endoscopic laser diverticulectomy (ELD) or endoscopic stapler-assisted diverticulectomy (ESD). The study design is of systematic review and meta-analysis. The following databases were searched: SCOPUS, EMBASE, PubMed, and Word of Science through December 2017. The quality of the studies was evaluated using 22-item STROBE checklist with 3 independent physician reviewers. The Inter-rater reliability was calculated both as a percent and utilizing Cohen's Kappa. For the meta-analysis, Cohen's *d* for an effect size was calculated for all studies comparing dysphagia results before and after surgery. A total of 865 patients were treated across 11 selected publications, of which 106 patients were treated OD, 310 ELD, and 449 with an ESD approach. Patient-reported dysphagia outcomes were reported as Cohen's *d* (confidence interval): OD, ELD, and ESD were 1.31 (0.88, 1.74), 1.91 (1.62, 2.20), and 2.45 (2.04, 2.86), respectively. The pooled effect of all studies for dysphagia was 2.22 (1.85, 2.59) and regurgitation 2.20 (1.80, 2.59). We did not prove that OD has superior outcomes compared to ESD and ELD. Any method of surgical intervention yields a large effect (i.e., improvement in dysphagia and regurgitation) comparing patient-reported symptoms before and after surgery. Future research, currently underway, includes a prospective, multi-institutional study comparing standardized outcomes between treatments of ZD including symptom resolution, complications, and recurrences using validated measures to define long-term outcomes.

Level of Evidence 3

Keywords Zenker diverticulum · Esophageal diverticulectomy · Surgical dysphagia · Dysphagia outcomes · Deglutition · Degluitition disorders

Introduction

Zenker's diverticulum (ZD) is a pulsion-type diverticulum that develops between the inferior constrictor and the cricopharyngeus (CP) muscles in an area of muscular weakness termed Killian's Triangle causing a deglutition disorder [1]. Patients present with symptoms including dysphagia, regurgitation, aspiration, cough, globus sensation, and reflux. Treatment for ZD is surgical. Initially treated exclusively by an open, transcervical diverticulum (OD) approach with CP myotomy, in recent years, treatment has trended towards endoscopic approaches including endoscopic laser (ELD) and endoscopic stapling (ESD) [2, 3] all of which are presumed to include a cricopharyngeal myotomy.

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Despite the trend towards minimally invasive surgery, there remains a paucity of high-quality data comparing outcomes between surgical approaches, especially open transcervical versus endoscopic treatment of ZD. Most data evaluating outcomes for patients undergoing operative repair of ZD are single-institution observational studies [4, 5]. Furthermore, few studies use validated, standardized reporting guidelines. The challenges using observational studies include a lack of control group, discrepancies in identifying confounding variables, and a high risk of selection bias [6]. ZD treatment bias currently depends on surgical training and surgeon preference.

This study sought to evaluate patients diagnosed with ZD (Patient/Population/Problem) undergoing surgical treatment (Intervention) using either OD, ELD, or ESD (Comparison) using patient-reported scales of dysphagia (Outcomes, Primary). Secondary outcomes reviewed patient-reported scales of regurgitation, diagnostic, and complications data. We hypothesized that ZD patients undergoing open transcervical diverticulectomy (OD) would report improvement in post-operative dysphagia that were *superior* to endoscopic techniques (ELD or ESD). This critical review of the literature was performed to evaluate markers for dysphagia outcome tools in order to design a prospective multi-institutional prospective ZD study with long-term follow-up.

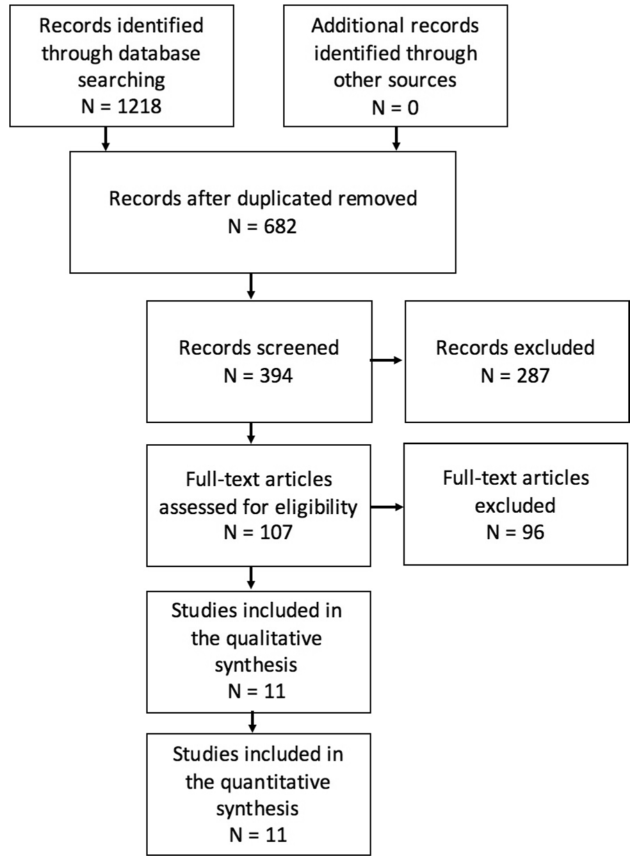


Fig. 1 PRISMA flow diagram

Materials and Methods

Figure 1 demonstrates the systematic review using the PRISMA flow diagram [7]. With the help of our associate librarian, the literature search included the SCOPUS, EMBASE, PubMed, and World of Science electronic databases (all indexed years through December 2017). The search identified 682 unique citations of which 394 abstracts were selected for review. 107 entire articles were reviewed which yielded the final 11 citations [8–18].

The inclusion criteria were (1) ZD surgically treated endoscopically using CO_2 laser or stapler or through an open transcervical approach (2) studies which included post-operative patient-reported outcome (PRO) using ordinal Likert-scaled dysphagia outcomes with a 0–5 scoring system (where low score denotes minimal symptoms and increasing score represents worsening dysphagia). The exclusion criteria were (1) other esophageal diverticula (i.e., Killian Jameson, iatrogenic, Laimer, etc.), (2) ZD case reports, and (3) use of HARMONIC®, electrocautery or flexible endoscopic approaches.

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement was used to perform a systematic review and meta-analysis comparing these intervention groups [4, 5, 7, 19, 20]. Eleven (11) citations met the inclusion criteria by agreement between 3 physician reviewers (R.H., J.G., J.H.). When data were missing from the original publications, we contacted the authors for more information [10]. The percent adherence of each publication was calculated based on an evaluation of the adherence of each section of the STROBE criteria for each publication. The Inter-rater reliability was calculated both as a percent and utilizing Cohen's Kappa.

Statistical Analysis and Effect Size Calculation

The papers reported means, medians, standard deviation, and ranges. An estimation of the standard deviation occurred when only medians and ranges were reported. For the meta-analysis, Cohen's d for an effect size was calculated for all studies comparing dysphagia scores prior to and after surgery. Since 10 of 11 studies [15] also included regurgitation scoring, we included this information in our final analysis. Cohen's d effect sizes were calculated for each of the content areas separately by dividing the mean difference between pre- and post-measures (within-group difference) by their pooled standard deviation. The correlations between pre- and post-measures are needed for the Cohen's d calculation. Because this correlation was unknown for the reported studies, we entered a global estimation of $r = 0.7$ into the formula [21].

Because the sample size varied across studies, we computed a weighted mean across all studies where the inverse of the estimated standard deviation for each study served as a weight [21]. Confidence intervals were calculated based on the standard error of the overall mean (pooled) effect size.

Descriptive statistics were used for the secondary outcomes which includes complications and secondary esophageal lesions assessments.

Results

A total of 865 patients were treated across 11 publications, of which 106 patients were treated using OD, 310 ELD, and 449 with an ESD approach (included one laser-assisted, Stoeckli 2002) [18]. Those citations including OD [11, 13], ELD [9, 10, 13–15], ESD [8, 9, 12–18] were 2, 5, and 9 citations, respectively. Table 1 demonstrates the STROBE criteria ratings in the 11 included publications [7–17]. A comparison of the percent adherence of each paper to the STROBE criteria between all three physicians demonstrated 85% concordance with a Cohen's kappa = 0.632 indicating substantial inter-rater agreement.

Seven of eleven or 64% of articles included time to follow-up, on average ranging from 13.2 to 66 months post-operative, as depicted in Table 2. Mean age ranged from 64 to 80 years old with 63.8% female gender distribution. Colombo et al. [11] used the Brombart classification with remaining 8/11 citations using mean size in cm, ranging from 2.6 to 4.5. Adam et al. [8] distinguished primary ZD patients, where the follow-up publication, Adam et al. [9], included secondary ZD patients. Only Peracchia et al. [16] did not specifically identify primary from secondary (or revision) ZD. All remaining citations included primary cases only, excluding secondary data.

The pooled effect size denoted as Cohen's d (95% confidence interval) indicating the improvement in dysphagia scores among all approaches was 2.22 (1.85, 2.59), suggesting a large effect size overall. The effect size for each of the different surgical approaches (OD, ELD, ESD) was 1.31 (0.88, 1.74), 1.91 (1.62, 2.20), and 2.45 (2.04, 1.74), respectively. This is depicted by a forest plot in Fig. 2.

The pooled effect size indicating the improvement in regurgitation scores among all approaches was 2.20 (1.80, 2.59). The effect size for each of the different surgical approaches (OD, ELD, ESD) was 2.10 (1.71, 2.49), 2.58 (2.27, 2.89), and 1.83 (1.36, 2.30), respectively. Figure 3 is a forest plot illustrating regurgitation outcomes by surgical approach.

Table 3 describes a limited data set evaluating secondary esophageal diagnosis using manometry, swallow imaging, or esophagoscopy. Peracchia 1998 identifies a change in upper esophageal sphincter (UES) resting pressures from an average of 52.4 pre-operative to 31.5 post-operative [16]. Secondary esophageal diagnosis includes hiatal hernia in 13.5% ($n = 23/171$); reflux esophagitis in 4.7% ($n = 8/171$); peptic ulcer disease 5% ($n = 4/79$); and chronic gastritis in 10% ($n = 8/79$).

Data listed in Table 4 demonstrate the complications as listed in the studies as our secondary outcomes. Complications specific to OD include esophageal leak reported in 4.7%, recurrent laryngeal nerve injury/hoarseness in 5.7%, and pneumonia in 2.8%. Dental injuries were found in 2.3% and 1.6%, of ELD and ESD patients, respectively. Subcutaneous air was found in 2.6% and 0.9%, of ELD and ESD patients, respectively. Interestingly, 9.4% of those undergoing OD underwent reoperation in contrast to 4.5% of ELD patients and 6.9% having ESD.

Discussion

Treatment for ZD is surgical. First described by Ludlow in 1769, surgical treatment of esophageal diverticula was reported around the same time von Zenker published his landmark paper in 1877 [22, 23]. Initially treated exclusively by an open transcervical approach, treatment has trended towards endoscopic methods including endoscopic stapling (ESD) and endoscopic laser (ELD) [2]. In another ZD meta-analysis comparing open and endoscopic techniques, Verdonck and Morton demonstrate surgery-related mortality is rare in either method (< 0.9%) [5]. Also, surgery-related morbidities are low for both endoscopic and open, 7 and 11%, respectively [5]. However, the pattern of complications is different. Endoscopic techniques are more often associated with mediastinitis or subcutaneous emphysema, while post-operative complications of transcervical surgery include hematoma, fistula, and recurrent laryngeal nerve palsy [5].

Comparison of surgical outcomes, however, currently relies on rates of revision, i.e., surgical failures. Again, Verdonck and Morton comparing open and endoscopic ZD treatment found an overall failure rate (defined as "failure to resolve dysphagia") of 18.4% with endoscopic versus 4.2% for open procedures [5]. However, a significant contributor to the high failure rate with the endoscopic approach in this single report was due to failure of exposure. Even in the largest single-surgeon series of endoscopic ZD (337), Wilken et al. report a 3.9% rate of failed exposure [3]. Failure to expose was not evaluated in this review, but we did find a higher rate of revision surgery in OD > ESD > ELD. In the OD treatment group, we did not differentiate (due to low numbers of OD studies) excision, inversion, and pexy with or without cricopharyngeal myotomy which may have a real effect on outcome data. On the other hand, in the only other

Table 1 The STROBE criteria ratings

	Adam et al. [8]	Adam et al. [9]	Bonavina et al. [10]	Colombo et al. [11]	Lang et al. [12]	Leibowitz [13]	Miller et al. [14]	Murer et al. [15]	Peracchia et al. [16]	Rodella et al. [17]	Stoeckli and Schmid [18]
Title and abstract	1	1	1	1	1	1	1	1	1	1	1
Introduction											
Background/rationale	1	1	1	1	1	1	1	1	1	1	1
Objectives	1	1	1	1	0	1	1	1	0	1	1
Methods											
Study design	1	1	1	1	1	1	1	1	1	1	1
Setting	1	1	1	0	1	1	1	1	1	1	1
Participants	1	1	1	1	1	1	1	1	1	1	0
Variables	1	1	1	0	0	1	1	1	1	1	0
Data sources/measurement	1	1	1	0	0	1	1	1	1	1	1
Bias	0	0	0	0	0	0	0	0	0	0	0
Study size	0	0	0	0	0	0	0	0	0	0	0
Quantitative variables	1	1	1	1	1	1	1	1	1	1	1
Statistical methods	1	1	1	1	1	1	1	1	1	0	1
Results											
Participants	1	1	1	1	1	1	1	1	1	1	0
Descriptive data	0	1	1	0	1	1	1	1	1	1	0
Outcome data	1	1	1	1	1	1	1	1	1	1	1
Main results	0	1	0	1	1	1	1	1	1	1	1
Other analyses	0	0	0	0	0	0	0	0	1	0	0
Discussion											
Key results	1	1	1	1	1	1	1	1	1	1	1
Limitations	1	1	0	1	0	1	0	1	1	0	0
Interpretation	1	0	1	1	0	1	0	1	1	0	0
Generalisability	1	1	1	0	1	1	1	1	1	0	1
Other information											
Funding	1	1	0	0	0	1	0	1	0	0	0
Total STROBE Score	17	18	16	13	13	19	16	19	18	14	12

Table 2 List of demographics for each publication by surgical approach

	Follow-up in months (range)	n	Primary cases	Mean age (SD)	Female (%)	Size in cm (SD)
Open						
Colombo et al. [11]	60 (5–173)	79	79	69 (12)	29 (37%)	–[d]
Leibowitz [13]	–	27	27	71.33	14	3.78
Laser						
Adam [9]	–	8	0	74 (17.875)	–	3.063
Bonavina et al. [10]	63 (12–139)	100	100	75 (19.034)	43 (43%)	3.5
Leibowitz [13]	–	68	68	74.71 (3.26)	47 (69%)	3.26
Miller et al. [14]	–	16	16	75	12	3.8
Murer et al. [15]	56 (13–126)	29[a]	29	73	19	
Stapler						
Adam et al. [8]	–	67	67	70.1 (13.6)	–	3.529
Adam et al. [9]	–	4	0	80 (7.274)	–	2.75
Lang et al. [12]	46	30	30	–	–	
Leibowitz [13]	–	69	69	74.45	52 (75%)	4.5
Miller et al. [14]	–	19	19	74	14	4.4
Murer et al. [15]		45[b]	45	75	32	3.9
Peracchia et al. [16]	23 (13–48)	92	–	64	74	4
Rodella et al. [17]	66 (7–120)	123	123	–	87	4.1
Stoeckli et al. [18]	13.2	28[c]	30	72	22	2.6

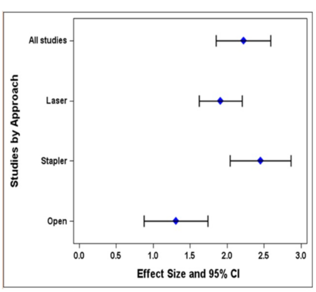
SD standard deviation (reported when available), – data not available or reported

[a] 17 patients returned survey

[b] 19 patients returned survey

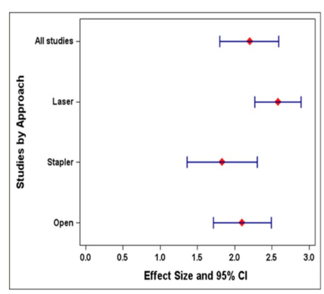
[c] 2 lost to follow-up

[d] Brombart classification was used



	Pooled effect size (95% CI)
All included studies	2.22 (1.85 - 2.59)
Laser (n=5)	1.91 (1.62 - 2.20)
Stapler (n=7)	2.45 (2.04 - 2.86)
Open (n=2)	1.31 (0.88 - 1.74)

Fig. 2 Dysphagia outcomes: pooled effect sizes based on surgical approach



	Pooled effect size (95% CI)
All included studies	2.20 (1.80 – 2.59)
Laser (n=5)	2.58 (2.27 – 2.89)
Stapler (n=7)	1.83 (1.36 – 2.30)
Open (n=2)	2.10 (1.71 – 2.49)

Fig. 3 Regurgitation outcomes: pooled effect sizes based on surgical approach

ZD meta-analysis, Parker and Misono found no difference in revision surgery between laser- and stapler-assisted treatment for ZD [4].

A shortcoming of the current review of ZD literature confirmed the challenge in comparing observational studies. Using the STROBE criteria for inclusion and three reviewers (R.H., J.G., J.H.), we demonstrated 85% concordance with a Cohen's kappa = 0.632 indicating substantial inter-rater agreement [24]. We carefully excluded articles that had overlapping or duplicate data on the same patient cohorts from the same institutions or the same authors. We chose the three surgical approaches with the highest volume of quality data (excluding newer flexible endoscopic techniques due to low quality and quantity of data). The current ZD literature more frequently uses *validated* dysphagia PROs, such as the SWAL-QOL [25] or EAT-10 (which was in part validated using ZD patients) [26]. Non-validated scoring using ordinal scales were used for this review to optimize the number of studies and to insure varied representation across the 3 surgical techniques. Since endoscopic surgery has trended

Table 3 Secondary outcomes: esophageal diagnosis

	Manometry		Other upper GI diagnoses			
	UES resting pre Op (SD)	UES resting post op (SD)	Hiatal hernia	Reflux esophagitis	Peptic ulcer disease	Chronic gastritis
Adam et al. [8]	–	–	–	–	–	–
Adam et al. [9]	–	–	–	–	–	–
Bonavina et al. [10]	–	–	–	–	–	–
Colombo et al. [11]	–	–	15/79 (19%)	5/79 (6%)	4/79 (5%)	8/79 (10. %)
Lang et al. [12]	–	–	–	–	–	–
Leibowitz [13]	–	–	–	–	–	–
Miller et al. [14]	–	–	–	–	–	–
Murer et al. [15]	–	–	–	–	–	–
Peracchia et al. [16]	52.4 (25.8)	31.5 (12.2)	8/92 (9%)	3/92 (3%)	0	–
Rodella [17]	–	–	–	–	–	–
Stoeckli [18]	–	–	–	–	–	–

UES upper esophageal sphincter, *SD* standard deviation, *GI* gastrointestinal

in popularity, using these newer validated PROs would not have captured the OD patients. Furthermore, it would have excluded literature from thoracic or general surgery including robust studies such as Bonavina 2015 (generously supplied specific details for inclusion in the study).

There remains little debate that surgical treatment for ZD is effective. However, as Johnson and Postma further elucidated, the best surgical approach remains controversial [27]. In an effort to better understand how effective surgical treatment is, we sought to determine the size of the effect comparing pre- and post-operative PROs. (Effect size = [mean preop score] – [mean postop score]/standard deviation, where effect size > 0.8 is considered large). Therefore, by comparison of any method, OD, ELD, and ESD, have a large effect after surgery for both dysphagia and regurgitation scores. Another challenge we faced comparing studies is the heterogeneity of PROs used. We chose a 0–5 linear scale; however, some studies used 0–3 [14–16, 18], 0–4 [17], 1–4 [9, 10, 12, 13], compared to 0–5 [11]. In order to account for the arbitrary scales, we opted to use the effect size (see "Statistical Methods" above) to compare a change in pre- and post-operation. In doing so, we can compare dysphagia outcomes after various methods of surgery. However, this makes several assumptions which will be further elucidated below.

For 10 of 11 studies, patients were given separate scoring for two symptoms of ZD "dysphagia" and "regurgitation." In reviewing the pooled effect size for regurgitation, our effect size is 2.20 (1.80–2.59). In short, regardless of technique, regurgitation improves after surgery (ELD, OD, ESD). We cannot directly compare the three methods against each other; however, if we *assume* that patients were randomly selected for each method, then we can roughly compare treatments where ELD and OD > ESD; ESD was also the least precise (i.e., more variability in results). Dysphagia also improves comparing before and after surgery, Cohen's *d* of 2.22 (1.85–2.59). Applying the same assumption, a random selection of surgical procedure, then the opposite is true where ESD > ELD and OD. OD has the least effect and the least precision in dysphagia scores before and after surgery. These data suggest that dysphagia and regurgitation are two distinct symptoms of ZD patients, and patients undergoing ELD and OD have similar expected outcomes (compared to ESD).

In a secondary analysis, we also reviewed secondary esophageal diagnosis as this is less clearly defined in the current literature. In our review, only 2/11 studies [11, 16] reported secondary esophageal diagnosis (limited to hiatal hernia, reflux esophagitis, peptic ulcer disease, and chronic gastritis), but none included motility disorders. At this time, it is unclear if size, age, or secondary esophageal diagnosis (such as motility disorders) affects the initial presentation which we assumed was a homogenous group in this model. Further literature review using symptomatic improvement or radiologic changes are sparse [3, 28–31]. In a small cohort study, surgical "success" was defined as > 50% change or 10-point decrease in EAT-10 scoring (a validated self-administered survey instrument to measure patient-reported dysphagia) *and* 50% reduction in size of diverticulum measured on videofluorographic swallowing study pre- and post-surgery. Venkatesan further demonstrated improvement of the pharyngeal constriction ratio (PCR) and the pharyngoesophageal segment (PES) opening after endoscopic ZD surgery [28, 29]. Rosen et al. presented higher PES pressures post-opening in ZD patients with select patients demonstrating high pharyngeal contractile pressures [32]. An improved understanding of the pathophysiology of ZD may ultimately aid in the stratification of surgical candidates and treatments.

Table 4 Secondary outcomes: complications

	n	Esophageal leak	RLN injury or hoarse-ness	Wound infec-tion	PNA	Dental injury	Subcutaneous air	Reoperation	Converted to open
Open									
Colomb et al. [11]	79	3 (3.8%)	6 (7.6%)	1 (1.3%)	2 (2.5%)	–	–	5 (1.7%)	–
Leibowitz [13]	27	2 (7.4%)	–	0	1 (3.7%)	0	0	5 (18.5%)	–
Total	106	5 (4.7%)	6 (5.7%)	1 (0.9%)	3 (2.8%)	0	0	10 (9.4%)	
Laser									
Adam et al. [8]	61	0	–	–	–	2 (3.2%)	4 (6.6%)	0	–
Adam et al. [9]	8	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]	0[b]	0[a]
Bonavina et al. [10]	100	–	–	1 (1%)	–	2(2%)	–	10 (10%)	–
Leibowitz [13]	68	0	–	1 (1.5%)	0	0	1 (1.5%)	–	0
Miller et al. [14]	16	–	–	–	–	2 (12.5%)	3 (18.8%)	3 (18.8%)	–
Murer et al. [15]	29	0	0	0	0	1 (3.4%)	0	–	0
Stoeckli et al. [18]	28	0	0	0	0	0	0	1 (3.6%)	0
Total	282	0	0	2 (0.6%)	0	7 (2.3%)	8 (2.6%)	14 (4.5%)	0
Stapler									
Adam et al. [8]	67	0	–	–	–	4 (6.0%)	3 (4.4%)	11 (16.2%)	–
Adam et al. [9]	4	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]	0[b]	0[a]
Lang et al. [12]	30	–	–	–	–	–	–	1 (3.3%)	–
Leibowitz [13]	69	0	–	1 (1.4%)	0	0	1 (1.4%)	–	0
Miller et al. [14]	19	–	–	–	–	2 (10.5%)	0	3 (18.8%)	–
Murer et al. [15]	45	0	0	1 (2.2%)	0	1 (2.2%)	0	1 (2.2%)	0
Peracchia et al. [16]	92	–	–	–	–	–	–	10 (10.9%)	3 (3.3%)
Rodella et al. [17]	123	–	–	–	–	–	–	5 (4.1%)	–
Total	449	0	0	2 (0.4%)	0	7 (1.6%)	4 (0.9%)	31 (6.9%)	3 (0.7%)

RLN recurrent laryngeal nerve, *PNA* pneumonia, – not reported

[a]No complications noted

[b]All patients were re-operative cases

Future directions should include the utilization of more sophisticated swallowing diagnostics such as fluororadiographic imaging and pharyngeal high-resolution manometry.

A review of ZD comparing open and endoscopic methods is not complete without also considering surgical morbidity. Patterns of complications are similar to Verdonck and Morton [5]. In our review, dental injuries were found in 2.3% and 1.6%, of ELD and ESD patients, respectively. Subcutaneous air was found in 2.6% and 0.9%, of ELD and ESD patients, respectively. While ESD has lower complication rates compared to ELD, ESD has a higher reoperation rate, 6.9% compared to 4.5%. Complications specific to OD include esophageal fistula reported in 4.7%, recurrent laryngeal nerve injury/hoarseness in 5.7%, and pneumonia in 2.8%.

Unsurprisingly, OD has a greater risk of fistula compared to endoscopic methods, but it has higher rate of revision surgery (9.4%). The higher recurrence rate cannot be elucidated here but could be for a variety of reasons including surgeon preference/experience, incomplete cricopharyngeal myotomy, or the possibility of a different pre-operative cohort of ZD patients that preferentially had OD versus ELD/ESD.

Limitations in the size effect model include the assumption of the "control"—this assumes that every patient preoperatively experiences similar symptoms and each patient is accurately diagnosed. For example, size of the diverticulum is variable; most studies reported size criteria in centimeters ranging from 2.5 to 4.3. Furthermore, age ranges from averages of 64–80 years. Age has been a suggested factor where younger patients may be more appropriate for an open procedure, but this cannot be elucidated with the current data [27]. Further limitations include (1) current body of literature consisted of non-randomized, retrospective case series and cohort studies, (2) ordinal scales were not standardized or validated, (3) several well-designed studies using validated dysphagia questionnaires were excluded because they could not be compared in a pooled analysis, (4) patient follow-up was highly variable and sometimes not reported, and (5) an open transcervical approach to treatment was less represented ($n = 106$) compared with rigid endoscopic approaches (ELD $n = 310$; ESD $n = 449$). However, the discrepancy in representation is consistent with the temporal trend towards rigid endoscopic approaches [2].

Our review of the literature and meta-analysis demonstrates the challenge in comparing non-standardized patient-reported outcome measures. Further controversy remains regarding bioimaging or manometric markers for "successful" ZD surgery [28, 29, 31]. Currently, there are no prospective multi-institutional studies in ZD and surgical intervention that relies solely on surgeon preference and experience.

Conclusion

Both open transcervical and endoscopic approaches to the treatment of ZD result in improvements in dysphagia and regurgitation among patients; however, the data suggest that dysphagia and regurgitation may be two distinct symptoms of ZD. We did not prove that OD has superior outcomes compared to ESD and ELD. This study suggests that OD and ELD may be more similar, but any method of surgical intervention yields a large effect (i.e., improvement in dysphagia and regurgitation) comparing patient-reported symptoms before and after surgery. Future research, currently underway, includes a prospective, multi-institutional long-term study comparing standardized outcomes between open transcervical and rigid endoscopic treatments of ZD including symptom resolution, complications, and recurrences using validated outcome measures.

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Compliance with Ethical Standards

Conflict of interest All authors declare no conflict of interest.

Ethical Approval This article does not contain any studies with human participants performed by any of the authors.

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