Clinics in Surgery

Research Articles
Published: 08 Mar, 2021

Endoscopic Vacuum Therapy for Spontaneous and Iatrogenic Esophageal Perforations: A Retrospective Study

Chengcheng Christine Zhang[1], Henrik Nienhüser[2], Christian Rupp[1], Ronald Koschny[1], Thomas Schmidt[2], Beat P Müller-Stich[2], Thilo Hackert[2], Peter Sauer[1], Markus W Büchler[2] and Anja Schaible[2]*

[1]*Department of Gastroenterology, Heidelberg University Hospital, Germany*

[2]*Department of General, Visceral, and Transplantation Surgery, Heidelberg University Hospital, Germany*

Abstract

Introduction: Esophageal perforations are associated with high morbidity/mortality. Treatment of this life-threatening condition remains challenging with no consensus on the appropriate management. Endoscopic vacuum therapy represents a novel therapeutic option. This retrospective study aimed to evaluate the feasibility, effectiveness, and safety of endoscopic vacuum therapy for esophageal perforations.

Methods: Twenty-seven consecutive patients with esophageal perforations were treated in our hospital, of which 7 underwent surgery (surgical repair, n=4; diversion, n=3), 1 underwent endoscopic stenting, and 19 were treated with endoscopic vacuum therapy.

Results: Overall, 21 patients were treated with endoscopic vacuum therapy, including two patients following the failure of primary surgical approach. The median number of endoscopic vacuum therapy procedures per patient was 2, with a median duration of therapy of 10 days. A minor complication related to endoscopic vacuum therapy occurred in one patient (n=1/21; 4.8%), and successful closure of esophageal perforations with endoscopic vacuum therapy was achieved in 90.5% (n=19/21). Overall successful treatment of all perforations could be achieved in 77.8% of the patients (n=21/27); of the remaining six patients, five underwent a diversion, whereas one died during endoscopic vacuum therapy. The overall in-hospital mortality rate was 7.4% (n=2/27).

Conclusion: Endoscopic vacuum therapy is a safe and effective approach for spontaneous and iatrogenic esophageal perforations, offers high closure rates, and can potentially reduce perforation-related mortality.

OPEN ACCESS

Correspondence:
Chengcheng Christine Zhang, Department of Gastroenterology, Heidelberg University Hospital, Im Neuenheimer Feld 410, 69120 Heidelberg, Germany, Tel: +49-6221-5635582; Fax: +49-6221-568904; E-mail: christine.zhang@med.uni-heidelberg.de

Received Date: *08 Jan 2021*
Accepted Date: *05 Mar 2021*
Published Date: *08 Mar 2021*

Citation:
Zhang CC, Nienhüser H, Rupp C, Koschny R, Tho-mas Schmidt, Müller-Stich BP, et al. Endoscopic Vacuum Therapy for Spontaneous and Iatrogenic Esophageal Perforations: A Retrospective Study. Clin Surg. 2021; 6: 3103.

Introduction

Esophageal perforations are life-threatening with substantial morbidity and mortality rates [1-3]. The mortality rate is 10% to 25% when therapy is initiated within 24h of perforation and increases to 50% upon delayed treatment [1,2,4-7]. Early diagnosis and management are essential for preventing enteric leakage complications [1,8,9].

Esophageal perforation treatment remains challenging, with no consensus on appropriate management. While conservative procedures are suitable for small tears [1,10,11], surgery serves as main modality, including thoracic cavity drainage, primary repair, and esophageal resections [2,7,12]. Treatment choice depends on several factors (e.g., defect genesis, time to therapy, perforation site, patients' physical condition, systemic inflammatory signs, and extent of contamination) [1,2].

Endoscopic management of esophageal perforations has recently emerged as a beneficial therapeutic strategy [7,13-17]. Several studies could show the effectiveness of endoscopic placement of Self-Expanding Metal Stents (SEMS) for esophageal perforations and anastomotic leakages [13,18-22]. The reported mortality rates of stent therapy are 0% to 33% and successful healing rates widely vary 13% to 84% [7,20,23-27]. Nonetheless, common stent therapy complications include stent dislocation with consequent inadequacy of defect closure, stent in growth with possible difficulties in subsequent stent removal, and local esophageal necrosis due to stent pressure [13,28]. Furthermore, esophageal stenting is often combined with simultaneous external drainage, as wound cavity debridement cannot be performed [9].

Endoscopic Vacuum Therapy (EVT) has recently emerged as a novel therapeutic option for

gastrointestinal leakages [29-32]. Although in contrast to stent placement, EVT requires multiple endoscopic procedures, it still has several advantages over stent therapy: Negative-pressure therapy reduces and prevents extraluminal contamination and promotes perfusion and granulation of the defect; EVT combines defect closure and effective internal drainage [33,34].

But evidence of EVT application in the upper GI tract is scarce and mostly based on small study cohorts, including heterogeneous esophageal defects of different etiologies [18,31,32,35-38]. Only a few studies based on small case series or case reports have evaluated EVT effects on esophageal perforations and reported success rates of 90% to 100% [39-42]. We aimed to evaluate the feasibility, effectiveness, and safety of EVT for spontaneous and iatrogenic esophageal perforations concerning success rate and associated mortality and morbidity.

Methods

Study design and population

This study was conducted at the Interdisciplinary Endoscopy Center of Heidelberg University Hospital. Data from all patients during the study period (March 2014 to March 2020) were prospectively collected and retrospectively analyzed. Written informed consent was obtained from all patients or their legally authorized representative.

Unlike other retrospective studies on EVT, only patients with iatrogenic or spontaneous esophageal perforations were included. A perforation was diagnosed either by endoscopy or computed tomography scan with detected extravasation of contrast or air into the mediastinal, pleural, or peritoneal cavity. Other etiologies of esophageal perforations that were not of spontaneous or iatrogenic genesis were excluded. Data on demographic and clinical patient characteristics were retrieved.

Endpoints

The primary endpoint was the successful closure rate with EVT, defined as endoscopically verified resolution of the perforation and presence of surface epithelium on the former defect. EVT failure was defined as persistent defect/fistula after EVT, change in treatment strategy, and death before confirmation of healing.

Secondary endpoints were EVT duration, number/frequency of sponge changes, procedure-related complications of EVT, duration of Intensive Care Unit (ICU)/Intermediate Care Unit (IMC) hospitalization, overall hospitalization length, and in-hospital mortality.

EVT

EVT was performed as previously reported by Wedemeyer et al. [30,43]. If the perforation size was sufficiently large, a sponge was inserted into the abscess cavity. With diminishing defect size, the sponge was placed from its initial intracavitary position to an intraluminal position. In cases of small defects, the sponge was placed into the esophageal lumen covering the defect. The intracavitary sponge was exchanged after 3 days, whereas the sponge placed in an intraluminal position was exchanged after 5 to 7 days.

Endoscopic procedures were performed under either conscious sedation or general anesthesia, depending on each patient's medical condition. The decision for additional drainage was based on a computed tomography scan report and the patients' clinical course.

Statistical analysis

Descriptive statistics were calculated for all parameters. Results are expressed as mean ± standard deviation or median and interquartile range for continuous variables and as counts and percentages for categorical variables. Statistical analyses were performed using SPSS, version 27.0 (IBM Corp., Armonk, N.Y., USA).

Results

Overall patient characteristics

Twenty-seven patients (16 men, median age: 64 years) presented with esophageal perforations to our institution (Table 1). Of these, 16 (59.3%) had iatrogenic perforation and 11 (40.7%) had Boerhaave syndrome. The mean size of endoscopically detected perforation was 32 mm ± 38 mm (median, 20 mm; range, 5 mm to 200 mm). One patient received SEMS as first-line therapy (3.7%), 19 patients received EVT as initial therapy (n=19/27; 70.4%), and seven patients were primarily operated on (n=7/27; 25.9%). No significant difference in age, sex, and underlying disease were observed between patients primarily treated with EVT and other patients. The mean perforation size in patients treated with EVT was 23 mm ± 15 mm (median, 20 mm; range, 5 mm to 60 mm), whereas, in patients primarily treated by surgery, it was 51 mm ± 69 mm (median, 20 mm; range, 10 mm to 200 mm). Of the seven patients treated by surgery, four (57.1%) underwent surgical repair and three (42.9%) esophageal diversion, respectively. Therapy was changed in four patients: two underwent esophageal diversion after unsuccessful EVT/SEMS therapy, and two others, who were initially treated by surgical repair but showed persistent defects, received successful EVT later.

Characteristics of the EVT collective

Twenty-one patients (13 men; median age, 65 years) were treated with EVT (Table 1). Detailed demographics of the overall EVT collective are summarized in Table 2.

Feasibility of EVT

Overall EVT data are presented in Table 3. Perforations were endoscopically diagnosed mostly on the same day or within 24 h after the perforation event (mean, 0.9 day; median, 1 day; range, 0 to 4 days). Therapy initiation was delayed in three patients >24 h after the initial event (Table 4). The first patient had spontaneous esophageal perforation after repeated vomiting and was transferred from another hospital to our clinic four days after the initial event. The second patient had odynophagia and elevated inflammatory markers and was diagnosed with an iatrogenic perforation four days after a microlaryngoscopic intervention. The third patient was diagnosed with Boerhaave syndrome and transferred from another hospital to our clinic three days after the initial event because of progressive clinical worsening and sepsis. Endoscopy was immediately performed after patient transfer and revealed a large (>60 mm) perforation. Treatment was immediately commenced after diagnosed perforation in all patients. EVT was used as first-line therapy in 19 patients, whereas two patients underwent primary surgical closure and were secondarily treated with EVT because a persistent defect was detectable. At EVT initiation, 18 (85.7%) out of 21 patients underwent intraluminal sponge placement. The median EVT duration was 10 days (range, 2 to 33), and the median number of EVT procedures per patient was 2 (range, 1 to 8). Additionally, the median length of ICU/IMC stay was 20 days (range, 2 to 42 days), and the median overall hospitalization length was 28 days (range, 10 to 68 days). A total of 12 patients (n=12/21; 57.1%) received additional external drainages for pleural or mediastinal effusions or pleural empyema.

Table 1: Patient characteristics.

	Overall patients, *n*	Overall EVT collective, *n*	Initial EVT collective, *n*	Initial surgical collective, *n*
	27	21	19	7
Age, years				
Mean ± SD	64 ± 15	64 ± 17	64 ± 17	64 ± 7
Median	64	65	65	64
Min	27	27	27	56
Max	87	87	87	73
Sex, *n* (%)				
Male	16 (59.3)	13 (61.9)	11 (57.9)	5 (71.4)
Female	11 (40.7)	8 (38.1)	8 (42.1)	2 (28.6)
Initial event, *n* (%)				
Iatrogenic perforations	16 (59.3)	13 (61.9)	11 (57.9)	3 (42.9)
Boerhaave syndrome	11 (40.7)	8 (38.1)	8 (42.1)	4 (57.1)
Defect size, mm				
Mean ± SD	32 ± 38	23 ± 15	23 ± 15	51 ± 69
Median	20	20	20	20
Min	5	5	5	10
Max	200	60	60	200
Defect grade*, *n* (%)				
Small	2 (7.4)	2 (9.5)	2 (10.5)	0 (0)
Intermediate	14 (51.8)	12 (57.2)	10 (52.6)	4 (57.1)
Large	11 (40.7)	7 (33.3)	7 (36.8)	3 (42.9)
Initial therapy, n (%)				
SEMS	1 (3.7)			
EVT	19 (70.4)			
Surgery	7 (25.9)			
Surgical repair	4 (14.8)	2 (9.5)		4 (57.1)
Esophageal diversion	3 (11.1)			3 (42.9)
Additional external drainage, *n* (%)	18 (66.7)	12 (57.1)	10 (52.6)	7 (100)

EVT: Endoscopic Vacuum Therapy; SD: Standard Deviation; SEMS: Self-Expanding Metal Stent
*Grading of defect size performed at initial endoscopy: Small: 0 mm to 9 mm; intermediate: 10 mm to 20 mm; large: >20 mm

Effectiveness of EVT: Successful closure and therapy failure

Overall successful healing of esophageal perforations by EVT was achieved in 19 (90.5%) out of 21 patients (Table 5). The overall failure rate of EVT in our study was 9.5% (n=2/21). The first patient had a central pulmonary embolism and died from cardiogenic shock before confirmation of healing as EVT was still ongoing. The second patient with a 60 mm defect was diagnosed with Boerhaave syndrome and received delayed EVT at >3 days after the initial event, as previously described. After initial improvement, this patient underwent esophageal diversion due to increased inflammatory markers during EVT and progressive clinical worsening with sepsis development. Successful restoration of bowel continuity was performed later.

Safety of EVT: Procedure-related and in-hospital morbidity and mortality

The overall procedure-related morbidity rate in our study was 4.75% (n=1/21; Table 6). Aspiration occurred as minor procedural complication in one patient during esophagogastroduodenoscopy with conscious sedation. This patient fully recovered with intermittent assisted ventilation and subsequently underwent EVT procedure under general anesthesia without further complications.

Two patients (9.5%) developed esophageal strictures after successful EVT during hospital stay. These patients were successfully treated with endoscopic esophageal dilatation.

The in-hospital mortality rate in our study was 9.5% (n=2/21). One patient suffered a central pulmonary embolism while ongoing EVT and died from cardiogenic shock, while the other patient had pneumonia and died from multi-organ failure after successful EVT and defect closure.

Overall successful closure and overall therapy failure

All esophageal perforations were successfully treated in 21 (77.8%) out of 27 patients (Figure 1); five patients received a diversion, and one patient died during EVT. Three patients primarily underwent esophageal diversion. The first patient with Boerhaave syndrome had a large (>200 mm) defect without endoscopically detectable continuity. The second patient had a known esophageal stenosis and deviation after multiple operations and radiotherapy for a hypopharyngeal carcinoma and was diagnosed with 10 mm iatrogenic perforation below the upper esophageal sphincter during

Table 2: Demographics of the overall EVT collective.

Patient no.	Age, years	Sex	Initial event	Defect size, mm	Procedures prior to EVT	External drainage
1	49	M	Iatrogenic	9		No
2	82	F	Iatrogenic	20		Yes
3	56	M	Iatrogenic	12		No
4	69	M	Spontaneous	12	Surgical repair	Yes
5	56	M	Spontaneous	20	Surgical repair	Yes
6	68	F	Spontaneous	20		Yes
7	56	F	Iatrogenic	30		No
8	75	F	Spontaneous	20		Yes
9	31	M	Spontaneous	20		Yes
10	87	M	Iatrogenic	30		No
11	79	F	Iatrogenic	20		No
12	82	F	Iatrogenic	30		No
13	78	M	Iatrogenic	30		Yes
14	27	M	Spontaneous	60		Yes
15	74	M	Iatrogenic	10		Yes
16	65	M	Iatrogenic	30		No
17	63	F	Iatrogenic	10		Yes
18	52	M	Iatrogenic	5		No
19	51	M	Iatrogenic	10		No
20	84	M	Spontaneous	20		Yes
21	54	F	Spontaneous	60		Yes
Median (range)	65 (27–87)			20 (5–60)		

EVT: Endoscopic Vacuum Therapy

Table 3: EVT data.

Diagnosis of perforation and start of EVT after the initial event, days	
Mean ± SD	0.9 ± 1.3
Median	1
Min	0
Max	4
EVT duration, days	
Mean ± SD	13 ± 9
Median	10
Min	2
Max	33
Number of EVT per patient	
Mean ± SD	3 ± 3
Median	2
Min	1
Max	8
Localization of sponge at EVT initiation, *n* (%)	
Intracavitary	3 (14.3)
Intraluminal	18 (85.7)
Length of ICU/IMC stay, days	
Mean ± SD	19 ± 13
Median	20
Min	2
Max	42
Overall hospitalization length, days	
Mean ± SD	35 ± 21
Median	28
Min	10
Max	68

EVT: Endoscopic Vacuum Therapy; SD: Standard Deviation; ICU: Intensive Care Unit; IMC: Intermediate Care Unit

endoscopic bolus removal. EVT/SEMS seemed to be not reasonable due to the localization of perforation and patient's medical history (esophageal scarring/strictures due to radiotherapy/operations. The third patient had spontaneous esophageal perforation with a large (70 mm) defect and was transferred to our clinic with progressive clinical worsening and sepsis. The fourth patient underwent esophageal diversion because of unsuccessful EVT, as previously described above. Lastly, the fifth patient underwent esophageal diversion and received unsuccessful SEMS therapy before. This patient was also diagnosed with Boerhaave syndrome and exhibited progressive clinical worsening, sepsis development, and no further response to endoscopic treatment.

Discussion

The present study indicates the feasibility, effectiveness, and safety of EVT for iatrogenic and spontaneous esophageal perforations.

Operative management of esophageal perforations served as main treatment modality for a long time [1]. No clearly defined recommendations exist for the indications of surgical therapy; nonetheless, potential indications include early post-emetic

Table 4: Detailed EVT data of each patient.

Patient no.	Diagnosis of perforation, days	Start of EVT, days	Number of EVT per patient	Localization of sponge at EVT initiation	Intensive care, days	Hospital stay, days
1	0	0	1	Intraluminal	6	16
2	1	1	4	Intraluminal	29	63
3	1	1	7	Intraluminal	22	40
4	0		2	Intraluminal	20	66
5	0		3	Intraluminal	10	40
6	4	4	9	Intracavitary	41	49
7	0	0	1	Intraluminal	2	13
8	0	0	4	Intraluminal	39	60
9	0	0	6	Intraluminal	33	68
10	1	1	4	Intraluminal	22	22
11	1	1	1	Intraluminal	16	23
12	1	1	1	Intraluminal	4	12
13	0	0	6	Intracavitary	22	31
14	0	0	1	Intraluminal	3	10
15	1	1	2	Intraluminal	12	21
16	4	4	1	Intraluminal	3	20
17	1	1	3	Intraluminal	21	28
18	0	0	2	Intraluminal	14	15
19	0	0	2	Intraluminal	7	16
20	0	0	4	Intraluminal	24	64
21	3	3	2	Intracavitary	42	60
Median (range)	0 (0-4)	1 (0-4)	2 (1-9)		20 (2-42)	28 (10-68)

EVT: Endoscopic Vacuum Therapy

Table 5: Successful closure rate and therapy failure rate of EVT for esophageal perforations.

Overall successful closure rate, *n* (%)	19 (90.5)
Therapy failure, *n* (%)	2 (9.5)
Esophageal diversion	1 (4.75)
Death before confirmation of healing	1 (4.75)

Table 6: Morbidity and in-hospital mortality rates.

Procedure-related morbidity, *n* (%)	1 (4.75)
Aspiration	1 (4.75)
Strictures, *n* (%)	2 (9.5)
In-hospital mortality, *n* (%)	2 (9.5)
Cardiogenic shock	1 (4.75)
Multi-organ failure	1 (4.75)

perforation, esophageal perforation with extensive pleural/mediastinal contamination, hemodynamic instability, intra-abdominal perforation, presence of underlying malignancy, obstruction in the region of perforation, and "surgically fit" patients [1,3,5,44,45]. Accordingly, esophageal perforation management in our institution was based on the size and etiology of the defect, degree of local contamination, and severity of systemic response, and decisions for further conservative, endoscopic (SEMS/EVT), or operative treatment were made by a group comprising a surgeon, endoscopist, and anesthesiologist. The patients primarily treated by surgery in this study were younger and "surgically fitter," whereas the initially EVT-treated group included older patients. The defect size was larger in the first-line surgical treatment group than in the EVT-treated group (mean size: 51 mm ± 69 mm *vs.* 23 mm ± 15 mm).

Recently, different endoscopic options for the management of esophageal perforations have been described. Previous studies proposed EVT as a novel treatment option for esophageal leakages/perforations [29-32]. The majority of studies evaluating the use of EVT have mainly focused on the treatment of anastomotic leakages. To date, only a few existing studies based on case series particularly evaluated the effect of EVT for acute perforations. Kim et al. [42] described a Boerhaave syndrome case successfully treated with EVT after primary closure failure. Smallwood et al. [41] reported successful closure of perforations or leakages by EVT (100% success rate) in six patients without complications. Loske et al. [39] reported successful treatment in a series of 10 patients with iatrogenic perforations (100% success rate). Similarly, Heits et al. [40] reported EVT as a successful treatment for esophageal perforations (iatrogenic, spontaneous, and foreign body-associated) in nine out of 10 patients (90%), with an in-hospital mortality rate of 10%. Thus far, these two studies included the highest number of patients with esophageal perforations.

Loske et al. [39] reported median treatment duration of 5 days (range, 3 to 7 days). In our study cohort, the treatment duration was slightly longer (median, 10 days; range, 2 to 33 days), sponges were changed at a median rate of two per patient (range, 1 to 9), and overall hospitalization length was 28 days (range, 10 to 68 days). However, in this context, it is worth mentioning that the study of Loske et al. [39] only included patients with iatrogenic perforations diagnosed and treated within 24 h after the perforation event. Heits et al. [40] reported a mean sponge change rate of 5.4, a treatment period of 19

± 14.26 days, and mean hospital stay of 48 ± 30 days; they attributed the longer EVT duration to the possible delayed therapy initiation by >24 h in four patients. Smallwood et al. [41] reported a clearly longer average treatment period of 35.8 days (range, 7 to 69 days), a sponge change rate of 7.2 (range, 2 to 12), and an overall hospitalization length of 42.7 days (range, 4 to 73 days) in six patients. Their average EVT duration was longer than other studies (range, 11 to 28 days) [18,31,35,37]. The authors attributed their findings to a possibly longer sponge change interval and a delay in EVT (all but one patient had a delay of >24 h before the start of EVT).

In comparison, several studies and case reports also reported high success rates of EVT for esophageal perforations and leakages with 66.7% to 100% [18,19,32,34,37,43,46]. Although reported successful closure rates of EVT for esophageal perforations and anastomotic leakages were similar, the EVT duration and sponge change rates were markedly lower in patients who received EVT for spontaneous and iatrogenic perforations [18,19,32,34].

Consistent with the results of previously mentioned studies, the overall success rate was 90.5% (n=19/21) for our EVT-treated collective. Besides the abovementioned patient who suffered non-EVT-related cardiogenic shock and received ongoing EVT, the second patient with EVT failure was diagnosed with Boerhaave syndrome and received delayed treatment (>72 h).

One major prognostic factor influencing patient outcome in esophageal perforations is the time between perforation and therapy initiation. The reported mortality rate of esophageal perforations is 10% with early diagnosis and appropriate treatment but increases to 50% with late diagnosis [1]. An interval of less than 24 h has a major impact [8,9]. The location of perforation is also a prognostic factor: Cervical perforations are associated with better prognosis and have a mortality rate of 6% (0% to 16%), whereas thoracic and abdominal perforations have a mortality rate of 27% (0% to 44%) and 21% (0% to 43%), respectively [1,2,44]. Our abovementioned patient received delayed treatment of more than 72h after the perforation event and had a large (60 mm) transmural abdominal perforation, both factors worsening the prognosis. Nevertheless, the patient fully recovered after esophageal diversion.

The in-hospital mortality rate in our overall EVT-treated collective was 9.5% (n=2/21); lower than those reported in the literature. This included one patient who died from non-EVT-related central pulmonary embolism with ongoing EVT and another who died from pneumonia after successful EVT. A major prognostic factor influencing mortality is the cause of perforations: Spontaneous perforations have the highest reported mortality rate (36%; range: 0% to 72%), followed by iatrogenic perforations (19%; range: 7% to 33%) and traumatic perforations (7%; range: 0% to 33%) [1,44,47]. Our study included patients with iatrogenic perforations and patients with Boerhaave syndrome and those with a delay in treatment by >4 days, highlighting the favorable results of our trial. In three patients, therapy was initiated at >24 h after perforation. Patients receiving EVT within 24 h required a significantly shorter hospital stay and EVT duration. These results are in line with previous studies, indicating significantly better outcomes and shorter treatment duration when therapy was initiated within 24 h after diagnosis [8,9,37,40].

Our results indicate the favorable effect of EVT for iatrogenic and spontaneous esophageal perforations with respect to successful closure, complication, and mortality rates. EVT for esophageal perforations compared to anastomotic leakages might be performed with a lower sponge change rate, shorter treatment duration, and be associated with a shorter hospitalization length. Immediate endoscopic treatment, wound drainage, and interdisciplinary cooperation are crucial to the outcomes of EVT.

Our cohort study has certain limitations concerning prospective data collection but retrospective analysis. This study had a non-randomized study design and a limited number of patients. But no prospective randomized trials on this topic have been published thus far. Our study presents the largest single-center cohort of a homogenous population comprising EVT-treated patients with iatrogenic or spontaneous esophageal perforations. Owing to the small number of patients treated with EVT and the lack of studies analyzing this promising new therapeutic approach for esophageal perforations, further studies are required to verify these encouraging results.

In conclusion, EVT is a feasible, effective, and safe treatment option for esophageal perforations. Even among patients in whom other therapies have failed, EVT offers high closure rates and can potentially reduce overall mortality.

References

1. Kaman L, Iqbal J, Kundil B, Kochhar R. Management of esophageal perforation in adults. Gastroenterol Res. 2010;3(6):235-44.
2. Brinster CJ, Singhal S, Lee L, Marshall MB, Kaiser LR, Kucharczuk JC. Evolving options in the management of esophageal perforation. Ann Thorac Surg. 2004;77(4):1475-83.
3. Chirica M, Kelly MD, Siboni S, Aiolfi A, Riva CG, Asti E, et al. Esophageal emergencies: WSES guidelines. World J Emerg Surg. 2019;14:26.
4. Bladergroen MR, Lowe JE, Postlethwait RW. Diagnosis and recommended management of esophageal perforation and rupture. Ann Thorac Surg. 1986;42(3):235-9.
5. Brewer LA, Carter R, Mulder GA, Stiles QR. Options in the management of perforations of the esophagus. Am J Surg. 1986;152(1):62-9.
6. Chirica M, Champault A, Dray X, Sulpice L, Munoz-Bongrand N, Sarfati E, et al. Esophageal perforations. J Visc Surg. 2010;147(3):e117-28.
7. Biancari F, DAndrea V, Paone R, Di Marco C, Savino G, Koivukangas V, et al. Current treatment and outcome of esophageal perforations in adults: Systematic review and meta-analysis of 75 studies. World J Surg. 2013;37(5):1051-9.
8. Wright CD, Mathisen DJ, Wain JC, Moncure AC, Hilgenberg AD, Grillo HC. Reinforced primary repair of thoracic esophageal perforation. Ann Thorac Surg. 1995;60(2):245-8.
9. Schmidt SC, Strauch S, Rosch T, Veltzke-Schlieker W, Jonas S, Pratschke J, et al. Management of esophageal perforations. Surg Endosc. 2010;24(11):2809-13.
10. Altorjay A, Kiss J, Voros A, Bohak A. Nonoperative management of esophageal perforations. Is it justified? Ann Surg. 1997;225(4):415-21.
11. Cameron JL, Kieffer RF, Hendrix TR, Mehigan DG, Baker RR. Selective nonoperative management of contained intrathoracic esophageal disruptions. Ann Thorac Surg. 1979;27(5):404-8.
12. Abbas G, Schuchert MJ, Pettiford BL, Pennathur A, Landreneau J, Landreneau J, et al. Contemporaneous management of esophageal perforation. Surgery. 2009;146(4):749-55.
13. Dasari BV, Neely D, Kennedy A, Spence G, Rice P, Mackle E, et al. The role of esophageal stents in the management of esophageal anastomotic leaks and benign esophageal perforations. Ann Surg. 2014;259(5):852-60.

14. Persson S, Elbe P, Rouvelas I, Lindblad M, Kumagai K, Lundell L, et al. Predictors for failure of stent treatment for benign esophageal perforations-a single center 10-year experience. World J Gastroenterol. 2014;20(30):10613-9.

15. Kirschniak A, Subotova N, Zieker D, Konigsrainer A, Kratt T. The Over-The-Scope Clip (OTSC) for the treatment of gastrointestinal bleeding, perforations, and fistulas. Surg Endosc. 2011;25(9):2901-5.

16. Lazar G, Paszt A, Man E. Role of endoscopic clipping in the treatment of oesophageal perforations. World J Gastrointest Endosc. 2016;8(1):13-22.

17. Still S, Mencio M, Ontiveros E, Burdick J, Leeds SG. Primary and rescue endoluminal vacuum therapy in the management of esophageal perforations and leaks. Ann Thorac Cardiovasc Surg. 2018;24(4):173-9.

18. Brangewitz M, Voigtlander T, Helfritz FA, Lankisch TO, Winkler M, Klempnauer J, et al. Endoscopic closure of esophageal intrathoracic leaks: Stent versus endoscopic vacuum-assisted closure, a retrospective analysis. Endoscopy. 2013;45(6):433-8.

19. Berlth F, Bludau M, Plum PS, Herbold T, Christ H, Alakus H, et al. Self-expanding metal stents versus endoscopic vacuum therapy in anastomotic leak treatment after oncologic gastroesophageal surgery. J Gastrointest Surg. 2019;23(1):67-75.

20. Tuebergen D, Rijcken E, Mennigen R, Hopkins AM, Senninger N, Bruewer M. Treatment of thoracic esophageal anastomotic leaks and esophageal perforations with endoluminal stents: Efficacy and current limitations. J Gastrointest Surg. 2008;12(7):1168-76.

21. Van Boeckel PG, Sijbring A, Vleggaar FP, Siersema PD. Systematic review: Temporary stent placement for benign rupture or anastomotic leak of the oesophagus. Aliment Pharmacol Ther. 2011;33(12):1292-301.

22. Ong GKB, Freeman RK. Endoscopic management of esophageal leaks. J Thorac Dis. 2017;9(Suppl 2):S135-S45.

23. Salminen P, Gullichsen R, Laine S. Use of self-expandable metal stents for the treatment of esophageal perforations and anastomotic leaks. Surg Endosc. 2009;23(7):1526-30.

24. Fischer A, Thomusch O, Benz S, von Dobschuetz E, Baier P, Hopt UT. Nonoperative treatment of 15 benign esophageal perforations with self-expandable covered metal stents. Ann Thorac Surg. 2006;81(2):467-72.

25. Gelbmann CM, Ratiu NL, Rath HC, Rogler G, Lock G, Scholmerich J, et al. Use of self-expandable plastic stents for the treatment of esophageal perforations and symptomatic anastomotic leaks. Endoscopy. 2004;36(8):695-9.

26. Siersema PD, Homs MY, Haringsma J, Tilanus HW, Kuipers EJ. Use of large-diameter metallic stents to seal traumatic nonmalignant perforations of the esophagus. Gastrointest Endosc. 2003;58(3):356-61.

27. Swinnen J, Eisendrath P, Rigaux J, Kahegeshe L, Lemmers A, Le Moine O, et al. Self-expandable metal stents for the treatment of benign upper GI leaks and perforations. Gastrointest Endosc. 2011;73(5):890-9.

28. Aryaie AH, Singer JL, Fayezizadeh M, Lash J, Marks JM. Efficacy of endoscopic management of leak after foregut surgery with endoscopic covered Self-Expanding Metal Stents (SEMS). Surg Endosc. 2017;31(2):612-7.

29. Mennigen R, Senninger N, Laukoetter MG. Novel treatment options for perforations of the upper gastrointestinal tract: endoscopic vacuum therapy and over-the-scope clips. World J Gastroenterol. 2014;20(24):7767-76.

30. Wedemeyer J, Schneider A, Manns MP, Jackobs S. Endoscopic vacuum-assisted closure of upper intestinal anastomotic leaks. Gastrointest Endosc. 2008;67(4):708-11.

31. Bludau M, Holscher AH, Herbold T, Leers JM, Gutschow C, Fuchs H, et al. Management of upper intestinal leaks using an Endoscopic Vacuum-Assisted Closure system (E-VAC). Surg Endosc. 2014;28(3):896-901.

32. Laukoetter MG, Mennigen R, Neumann PA, Dhayat S, Horst G, Palmes D, et al. Successful closure of defects in the upper gastrointestinal tract by Endoscopic Vacuum Therapy (EVT): A prospective cohort study. Surg Endosc. 2017;31(6):2687-96.

33. Loske G. Endoscopic negative pressure therapy of the upper gastrointestinal tract. Chirurg. 2019;90(Suppl 1):1-6.

34. Mennigen R, Harting C, Lindner K, Vowinkel T, Rijcken E, Palmes D, et al. Comparison of endoscopic vacuum therapy versus stent for anastomotic leak after esophagectomy. J Gastrointest Surg. 2015;19(7):1229-35.

35. Schorsch T, Muller C, Loske G. Endoscopic vacuum therapy of perforations and anastomotic insufficiency of the esophagus. Chirurg. 2014;85(12):1081-93.

36. Kuehn F, Schiffmann L, Rau BM, Klar E. Surgical endoscopic vacuum therapy for anastomotic leakage and perforation of the upper gastrointestinal tract. J Gastrointest Surg. 2012;16(11):2145-50.

37. Weidenhagen R, Hartl WH, Gruetzner KU, Eichhorn ME, Spelsberg F, Jauch KW. Anastomotic leakage after esophageal resection: New treatment options by endoluminal vacuum therapy. Ann Thorac Surg. 2010;90(5):1674-81.

38. Schniewind B, Schafmayer C, Voehrs G, Egberts J, von Schoenfels W, Rose T, et al. Endoscopic endoluminal vacuum therapy is superior to other regimens in managing anastomotic leakage after esophagectomy: A comparative retrospective study. Surg Endosc. 2013;27(10):3883-90.

39. Loske G, Schorsch T, Dahm C, Martens E, Muller C. Iatrogenic perforation of esophagus successfully treated with Endoscopic Vacuum Therapy (EVT). Endosc Int Open. 2015;3(6):E547-51.

40. Heits N, Stapel L, Reichert B, Schafmayer C, Schniewind B, Becker T, et al. Endoscopic endoluminal vacuum therapy in esophageal perforation. Ann Thorac Surg. 2014;97(3):1029-35.

41. Smallwood NR, Fleshman JW, Leeds SG, Burdick JS. The use of Endoluminal Vacuum (E-Vac) therapy in the management of upper gastrointestinal leaks and perforations. Surg Endosc. 2016;30(6):2473-80.

42. Kim YE, Do YW, Cho JY, Kim ES, Lee DH. Successful treatment using endoluminal vacuum therapy after failure of primary closure in Boerhaave syndrome. Korean J Gastroenterol. 2019;73(4):219-24.

43. Wedemeyer J, Brangewitz M, Kubicka S, Jackobs S, Winkler M, Neipp M, et al. Management of major postsurgical gastroesophageal intrathoracic leaks with an endoscopic vacuum-assisted closure system. Gastrointest Endosc. 2010;71(2):382-6.

44. Jones WG 2nd, Ginsberg RJ. Esophageal perforation: A continuing challenge. Ann Thorac Surg. 1992;53(3):534-43.

45. Skinner DB, Little AG, DeMeester TR. Management of esophageal perforation. Am J Surg. 1980;139(6):760-4.

46. Wichmann D, Schempf U, Mothes B, Stüker D, Königsrainer A, Schweizer U, et al. Endoscopic vacuum therapy for intrathoracic anastomotic insufficiencies following oncological resections. Ann Esophagus. 2019;2.

47. Eroglu A, Turkyilmaz A, Aydin Y, Yekeler E, Karaoglanoglu N. Current management of esophageal perforation: 20 years experience. Dis Esophagus. 2009;22(4):374-80.