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Original Article

Primary and Rescue Endoluminal Vacuum Therapy in the Management of Esophageal Perforations and Leaks

Sasha Still, MD,[1] Marissa Mencio, MD,[1] Estrellita Ontiveros, MA,[1] James Burdick, MD,[2] and Steven G. Leeds, MD[3]

Background: To investigate the efficacy of primary and rescue endoluminal vacuum (EVAC) therapy in the treatment of esophageal perforations and leaks.
Methods: We conducted a retrospective review of a prospectively gathered, Institutional Review Board (IRB) approved database of EVAC therapy patients at our center from July 2013 to September 2016.
Results: In all, 13 patients were treated for esophageal perforations or leaks. Etiologies included iatrogenic injury (n = 8), anastomotic leak (n = 2), Boerhaave syndrome (n = 1), and bronchoesophageal fistula (n = 2). In total, 10 patients underwent primary treatment and three were treated with rescue therapy. Mean Perforation Severity Scores (PSSs) in the primary and rescue treatment groups were 7 and 10, respectively. Average defect size was 2.4 (range: 0.5–6) cm. The rescue group had a shorter mean time to defect closure (25 vs. 33 days). In all, 12 of 13 defects healed. One death occurred following the implementation of comfort care. One therapy-specific complication occurred. Hospital length of stay (LOS) was longer in the rescue group (72 vs. 53 days); however, the intensive care unit (ICU) duration was similar between groups. Totally, 10 patients (83%) resumed an oral diet after successful defect closure.
Conclusion: Utilized as either a primary or rescue therapy, EVAC therapy appears to be beneficial in the management of esophageal perforations or leaks.

Keywords: esophageal perforation, endosponge, endoluminal vacuum therapy, anastomotic leak

[1]*Department of Surgery, Baylor University Medical Center at Dallas, Texas, USA*
[2]*Department of Gastroenterology, Baylor University Medical Center at Dallas, Texas, USA*
[3]*Division of Minimally Invasive Surgery, Baylor University Medical Center at Dallas, Texas, USA*

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Corresponding author: Steven G. Leeds, MD. Department of Surgery, Baylor University Medical Center at Dallas, 3500 Gaston Avenue, 1st Floor Roberts Hospital, Dallas, TX 75246, USA
Email: Steven.Leeds@BSWHealth.org

Introduction

Esophageal perforations and anastomotic leaks are devastating events associated with high rates of morbidity and mortality.[1)] Early diagnosis and management are imperative to minimize complications of enteric leakage into the thoracic or abdominal cavity leading to consequent sepsis and multisystem organ failure. Historically, esophageal perforations were managed by operative means such as primary repair, esophagectomy with or without reconstruction, or esophageal diversion.[2,3)] More recently, endoscopic interventions such as stents, clips, endoscopic suturing devices, and complex

Table 1 Patient demographics and characteristics of perforations

Demographics	Total (N = 13)	Primary (N = 10)	Rescue (N = 3)
Age, median, years	63 (50–82)	63	62
Female	7 (54%)	6 (60%)	1 (33%)
BMI	23	23	23
Mean defect size (range)	2.4 (0.5–6 cm)	3 (1–6 cm)	1.5 (0.5–2 cm)
Non-contained perforation	11 (84%)	9 (90%)	2 (67%)
Mean PSS score	8 (2–11)	7	10
Delayed diagnosis	7	4	3
Type of perforation			
Iatrogenic	8 (62%)	5	3
Anastomotic	2 (15%)	2	0
Bronchoesophageal fistula	2 (15%)	2	0
Spontaneous	1 (8%)	1	0
Method of diagnosis			
CT/esophagram	9 (70%)	6	3
EGD	3 (23%)	3	0
Intraoperatively	1 (7%)	1	0
Location of esophageal perforation			
Proximal third	1 (8%)	1	0
Middle third	2 (15%)	2	0
Distal third	7 (54%)	5	3
Gastric conduit	3 (23%)	3	0
Pre-existing esophageal pathology			
Achalasia	2 (20%)	2	0
Stricture	2 (20%)	2	0
Cancer	0	0	0
Other			
Tube thoracostomy drainage	9 (70%)	6	3
Surgical interventions following initiation of EVAC therapy	3 (23%)	3	0

CT: computed tomography; EGD: esophagogastroduodenoscopy; PSS: perforation severity score; BMI: body mass index; EVAC: endoluminal vacuum

drainage procedures have emerged as beneficial therapeutic adjuncts.[2,4–8] Self-expanding metal stents or plastic stents (SEMS or SEPS) are most commonly used and have a reported success rate of 77%–84%.[2,9] However, stenting is associated with clinically significant complications such as migration, obstruction, and stricture.[4,10]

Endoluminal vacuum (EVAC) therapy is a novel treatment modality for managing gastrointestinal (GI) leaks of the esophagus, stomach, and rectum.[11–17] EVAC therapy facilitates tissue healing by overcoming physiologic negative pressure in the thorax,[18] thereby preventing extra-luminal contamination and enabling tension-free approximation of tissue. Multiple reports suggest EVAC therapy is feasible as a primary treatment for esophageal perforations and leaks.[17,19] In this study, we evaluate and compare EVAC therapy employed as either primary treatment or rescue modality following the failure of surgical intervention for esophageal perforations and leaks.

Methods

We conducted a retrospective review of an Institutional Review Board (IRB) approved prospectively gathered database of patients who underwent EVAC therapy from July 2013 to September 2016. Informed consent was obtained from all patients. Of 54 patients treated with EVAC therapy during this period, 13 underwent esophageal EVAC therapy. Iatrogenic (instrumentation) and spontaneous (Boerhaave syndrome) esophageal perforations, anastomotic leaks, and bronchoesophageal fistulae (BEF) were included in this analysis.

Data collection

Patient demographics and perforation characteristics are shown in **Table 1**. The initial diagnosis of esophageal perforation or leak and the extent thereof were confirmed by contrast imaging (computed tomography [CT] or esophagram). An esophageal injury diagnosed >24 hours after the initial insult was considered a delayed diagnosis. The extent

of perforation was classified as contained or non-contained. A non-contained perforation was defined by extravasation of contrast or air into mediastinal, pleural, or peritoneal cavity; contained perforation was defined as minimal extravasation of contrast at the perforation site with no evidence of contrast passage into mediastinal, pleural, or peritoneal cavities by contrast-based radiographic studies.

Treatment variables such as the nature of EVAC application (primary or rescue), type of endosponge placement (intra-luminal or intra-cavitary), tube thoracostomy drainage, type of surgical repair, time to placement of EVAC following diagnosis of perforation or leak, time to esophageal defect closure, number of EVAC changes, number of days between EVAC changes, total length of EVAC therapy; and patient outcome measures such as 30-day mortality, hospital length of stay (LOS), intensive care unit (ICU) LOS, EVAC therapy-specific complications (migration, dislodgement, erosion), and time to oral diet initiation following successful defect closure were collected. Primary EVAC therapy was defined as the utilization of EVAC as first-line therapy for perforation or leak. Rescue EVAC therapy was defined as EVAC placement following failure of definitive surgical repair for an esophageal perforation or leak. We define esophageal defect closure following EVAC placement as 1) no evidence of continued leak under direct endoscopic visualization and 2) a negative esophagram following discontinuation of EVAC therapy.

The Perforation Severity Score (PSS) is an externally validated point-based score system based on clinical variables at the time of presentation. PSS value has been shown to correlate with LOS, morbidity, and mortality.[20,21] In the present study, PSS was adapted only as a marker of clinical severity and not utilized to assess outcomes. The scoring system is based on 10 clinical indicators of injury severity at the time of presentation. Variables are assigned points (range: 1–3) for a total possible score of 18.

EVAC therapy

The EVAC procedure is performed under general anesthesia and endotracheal intubation to ensure airway protection. We use a 16-Fr Silastic nasogastric tube (NGT; Covidien, Medtronic, Dublin, Ireland) which is passed through one of the nostrils and pulled out the mouth through a bite block. The EVAC device utilized at our institution is adapted from the KCI/Acelity (San Antonio, Texas, USA) negative pressure system. A KCI open pore, polyurethane sponge is obtained and cut to size. The size of the endosponge can be customized to span the length of a luminal defect or fit inside a perforation cavity. The width should be no greater than 3–4 cm (due to the limitation of esophageal lumen width). Once cut to appropriate size (**Fig. 1A**), a tunnel is created through its center to the distal end without exiting the other end of the endosponge (**Fig. 1B**). The NGT is placed inside the tunnel (**Fig. 1C**). Once in place, the tube is fixed to the endosponge using a 2-0 Prolene suture (Ethicon, Somerville, NJ, USA) in a U-stitch fashion. Another suture, in an interrupted fashion, is placed through the endosponge and the tip of the NGT at the distal end and tied down with an air knot to facilitate a point of grasping for transport of the endosponge down the esophagus into place using rat tooth graspers. Prior to placement, an endoscope is used to locate the site of perforation (**Fig. 1D**). If a perforation cavity is present, it is debrided and lavaged. Next, the endosponge is placed into the esophagus, carried down to the perforation site, and then placed into the cavity or across the luminal defect (**Fig. 1E**). If a perforation cavity is present and deemed large enough to negotiate endosponge placement, then an endosponge is placed inside the cavity.

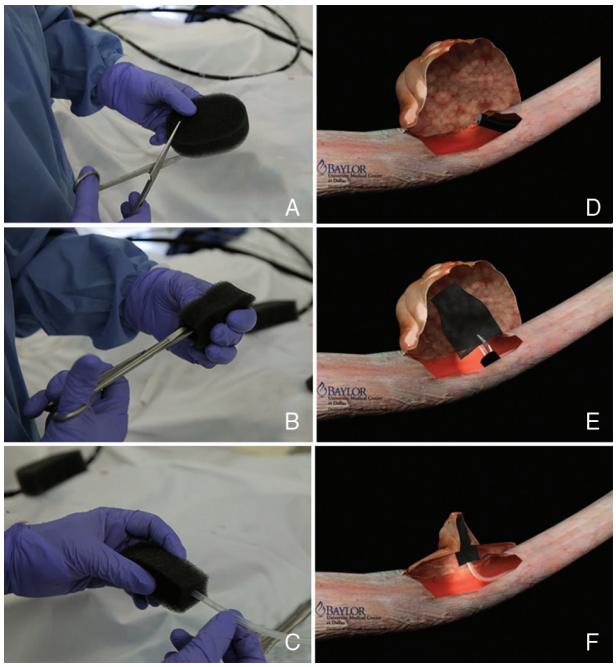

Fig. 1 Creation of the endosponge includes cutting the granulofoam to the appropriate size (**A**) and creating a tunnel through the endosponge for placement of the NGT (**B**). The completed endosponge has the NGT fixed to the endosponge with a suture (**C**). The endoscope is advanced to visualize the perforation (**D**), and then the endosponge is placed within the cavity (**E**). Negative pressure is applied to collapse the cavity around the endosponge (**F**). NGT: nasogastric tube

This will subsequently be referred to as an intra-cavitary endosponge placement. Once in the appropriate position, the NGT is connected to the KCI negative pressure machine through the canister tubing that is modified to fit the open end of the NGT. When suction is applied, the wound cavity collapses (**Fig. 1F**). We use settings without any recommendations from the manufacturer at 175 mmHg, continuous, and high. This procedure is repeated at 3- to 5-day intervals to change out the endosponge, evaluate the healing process, and terminates when the cavity is walled off, or the GI continuity is restored.

Decision to treat

Treatment decisions were made at the discretion of a multi-disciplinary physician group who participated in the care of the patients. The therapeutic method(s) chosen were dependent upon patient clinical severity, type, location, extent of perforation, and physician preference.

Results

Table 1 shows the patient and perforation characteristics among study groups. In all, 10 patients (77%) underwent primary treatment with EVAC and 3 (23%) were treated with rescue therapy. The primary group had a larger proportion of females and body mass index (BMI) was similar between groups. Mean PSSs in the primary and rescue treatment groups were 7 and 10, respectively. Mean defect size across the entire cohort was 2.4 cm and larger among the primary group compared to the rescue group (3 vs. 1.5 cm). Four patients did not have defect size dictated in the original operative notes. The majority of perforations in both groups were non-contained (90% vs. 67%). Perforations were diagnosed either by esophagogastroduodenoscopy (EGD) (3), contrast imaging (9), or intraoperatively (1). Seven patients had a delayed diagnosis. Among our entire cohort, the most common etiology was iatrogenic injury (8) followed by anastomotic leak (2), bronchoesophageal fistula (2), and Boerhaave syndrome (1). Iatrogenic perforations were due to balloon dilatation of esophagus (3), stent manipulation (1), NGT placement (2), and operative manipulation of stomach or esophagus (2). Anastomotic leaks occurred at the gastroesophageal anastomosis following esophagectomy (Ivor-Lewis (1), distal esophagectomy [1]). Two patients were treated for bronchoesophageal fistulas and underwent bronchial stent placement in addition to EVAC therapy. One BEF occurred in a patient with a recent history of bilateral lung transplantation complicated by right mainstem bronchial dehiscence; the other in a patient with a history of a remote Ivor-Lewis esophagectomy complicated by esophageal stricture necessitating recent balloon dilatation. The majority of patients (7/13) had perforations or leaks in the distal one-third of the esophagus. Preoperative esophageal pathology was present in four patients (achalasia [2], stricture [2]). Nine patients had tube thoracostomy procedures, 6 of which were placed at the time of operative intervention (primary reinforced repair [3], video-assisted thoracoscopic surgery (VATS) procedure [1], esophagectomy [2]). Three patients received chest tubes for drainage of pleural effusions during their hospitalization.

Three patients underwent additional surgical interventions in addition to EVAC therapy in the primary group. One patient underwent VATS and decortication, the second patient underwent a neck incision and drainage following anastomotic leakage after esophagectomy, and the third patient required a gastrojejunostomy revision.

The operative procedures which proceeded EVAC placement in patients undergoing rescue therapy are as follows. One patient underwent thoracotomy with single layer closure and obliteration of abscess cavity, two patients had a thoracotomy and primary reinforced two-layer closures of esophageal defects with associated decortication. Of the two patients that underwent primary reinforced repairs, one had a defect reinforced with a pleural flap and the other had a pleural and latissimus dorsi flap created at the time of operative repair. Mean time to operative repair failure was an average of 19 days (range: 18–21).

EVAC therapy parameters

Table 2 outlines the EVAC parameters in primary and rescue cohorts. Ninety-two percent (12/13) of esophageal defects healed, representing 90% (9/10) closure in the primary group and 100% (3/3) closure in the rescue group. The one failed defect closure was a patient who expired prior to completion of EVAC therapy after comfort care measures were initiated. Seventy percent (7/10) of primary group perforations required intra-luminal EVAC therapy while three underwent intra-cavitary endosponge placement due to the size and location of the esophageal defect. All rescue group perforations were intra-luminal endosponge placements. The primary group had a longer mean time to defect closure (33 vs. 25 days). Two patients in the primary EVAC group exhibited the longest treatment durations, namely 61 and 69 days. One patient with Boerhaave syndrome had a 3 cm defect and required intra-cavitary endosponge placement; the other had a 3 cm defect with 50% circumferential tear and was also treated

Table 2 EVAC parameters, primary versus rescue EVAC therapy

	Primary EVAC (N = 10)	Rescue EVAC (N = 3)
Mean duration EVAC therapy/time to defect closure, days	33 (6–69)	25 (17–35)
Mean number EVAC changes	6	4
Mean duration between EVAC changes, days	5	6
Mean time to placement of EVAC from leak diagnosis (range), days	3 (0–13)	2 (0–6)
Successful closure	9 (90%)	3 (100%)
Intra-cavitary sponge placement	3 (30%)	0
EVAC-specific complications	1 (10%)	0

EVAC: endoluminal vacuum

Table 3 Outcomes, primary versus rescue EVAC therapy

	Primary EVAC (N = 10)	Rescue EVAC (N = 3)
Hospital LOS (range), days	54 (20–122)	72 (38–110)
ICU LOS (range), days	22 (0–73)	26 (8–54)
30-day mortality	1	0
Mean time to initiation of oral diet from start of EVAC therapy (days)	39	43

LOS: length of stay; ICU: intensive care unit; EVAC: endoluminal vacuum

with an intra-cavitary endosponge therapy. Days between endosponge changes (5 vs. 6 days) and number of changes (6 vs. 4 days) between groups were similar. EVAC therapy was initiated on average 3 days (range: 0–13) from time of diagnosis of leak in the primary group, and 2 days (range: 0–6) in the rescue group.

Outcomes

Table 3 includes patient outcomes. Hospital LOS was longer in the rescue group (72 vs. 53 days); however, ICU duration was relatively similar between both groups (26 vs. 22 days). There was one 30-day/in-hospital mortality within our patient cohort when comfort care measures were instituted by family prior to completion of EVAC therapy. Mean time to resumption of oral diet from EVAC therapy initiation was 40 days (Rescue, 43 days; Primary, 39 days). Of the 12 patients who achieved defect closure, 10 (83%) were able to resume *per oral* feeds. As a result of persistent encephalopathy, two patients were restricted to small bowel feeds only. **Table 4** compares the duration of EVAC therapy with time to oral diet initiation.

Table 4 EVAC therapy duration compared to timing of oral diet initiation

	Duration EVAC therapy (days)	Time to oral diet initiation from EVAC placement (days)
Rescue group		
Patient 1	35	61
Patient 2	17	30
Patient 3	24	38
Primary group		
Patient 4	6	6
Patient 5	61	72
Patient 6	21	24
Patient 7	38	59
Patient 8	32	34
Patient 9	38	40
Patient 10	39	39

EVAC: endoluminal vacuum

Discussion

Our series demonstrates that EVAC therapy, employed as either a primary intervention or as rescue modality for operative failure, successfully treats esophageal perforations and leaks. We achieved a defect closure rate of 92%, allowing for 10 patients to resume an oral diet. Our 30-day mortality was 8% (1/13) and we experienced one clinically significant endosponge dislodgement of 89 total endosponge placements. Our 100% defect closure rate in the rescue therapy group demonstrates that EVAC therapy may be successfully used in the setting of failure of an operative repair. These data reiterate the advantages of EVAC therapy such as regular inspection of the luminal defect and repeated wound cavity debridement. Moreover, negative pressure communicated through an open-pore, polyurethane endosponge prevents extraluminal contamination maintaining source control, visually reduces local tissue edema, and aids in perfusion and

granulation of the esophageal wall.[22] Our results mirror those of numerous studies which affirm the association of EVAC therapy with a high rate of defect closure, low complication rate, and acceptable morality.[10,13,14,18,23,24] EVAC therapy should be integrated in the treatment algorithm for esophageal perforations and leaks given these therapeutic advantages.

The greatest concern associated with EVAC therapy is the prolonged hospitalization as numerous endoscopic procedures are required to assess and achieve defect closure. In our study, the hospital LOS was longer in the rescue group as compared to the primary group (72 vs. 54 days) which we would expect. Despite the shorter hospital LOS in the primary group, it is still longer than the average hospital duration (33 days) noted in a meta-analysis examining 75 reports of esophageal perforations.[2] Two studies utilizing EVAC therapy for esophageal perforations and leaks had a hospital LOS similar to ours.[14,25] In the current study, ICU LOS was similar between the primary and rescue groups (22 vs. 26 days). This similarity may reflect the ability of EVAC therapy to achieve source control, treat sepsis, and negate further intensive care needs regardless of previous interventions or stage of contamination. Schneiwind et al. had a mean ICU LOS of 26 days, again similar to our data.[25] EVAC therapy in the treatment of esophageal perforations and leaks may prolong the hospital LOS; however, our hospital and ICU durations are comparable to previous published reports.

Oral diet was able to be resumed in all patients who could safely eat without risk of aspiration. On average, oral feeds were initiated at 43 days in the rescue group and 39 days in the primary group. This discrepancy appears to be due to differences in surgeon-specific management. Resumption of oral diet represents a meaningful clinical endpoint which impacts patient quality of life and should be further investigated in studies evaluating EVAC therapy.

In the current study, the majority of esophageal defects healed despite both groups having a high PSS, with a higher score among the rescue group (10 vs. 7) representing the more critically ill cohort. We also noted that the duration of EVAC therapy was shorter in the rescue group compared to the primary group (25 vs. 33 days). The patients were more ill, but were able to heal faster than the primary group. Further examination of the defect characteristics revealed that a larger average defect size was seen in the primary group which likely accounts for this discrepancy. Furthermore, the primary group had a greater number of intra-cavitary endosponge placements (Primary, 30%; Rescue, 0%) and two patients in this group exhibited the longest treatment durations. We hypothesize that large extra-luminal cavities in addition to degree of clinical severity, concomitant chest tube drainage, and recent surgical repair may affect the duration of EVAC therapy, but larger cohort numbers are needed to determine the cause of these findings.

Despite the advantages of EVAC therapy, management of esophageal perforations still presents therapeutic challenges complicated by the absence of standardized treatment guidelines, surgeon preference, presence of diverse therapeutic options, and clinical heterogeneity for each esophageal injury based on location, extent of contamination, and presentation in clinical course.[1] Although surgery remains mainstay of treatment for early perforations, especially in the hemodynamically unstable patient, advances in endoscopy, total parenteral nutrition, and the medical treatment of sepsis have encouraged the utilization of non-surgical interventions to avoid surgical morbidity and mortality. In 2013, Schneiwind et al. performed a retrospective, comparative outcomes analysis evaluating surgical intervention, EVAC therapy, stenting, and conservative management for anastomotic leaks following esophagectomy. EVAC was associated with superior survival compared to surgical intervention and stenting among systemically ill patients matched by APACHE II scores.[25] In a retrospective, comparative analysis of stenting and EVAC for esophageal perforations, EVAC therapy was associated with superior closure rates and improved mortality.[10] Although these findings are compelling, few centers use EVAC therapy for the treatment of GI tract leakage. We feel this is related to the relative small body of literature supporting its use, a gap in industry involvement to produce readily available devices, prolonged hospital LOS, and a limited endoscopic skill set among surgeons. Continued investigation and reporting of EVAC therapy through multi-institutional studies are necessary to accrue larger study populations, perform statistically valid comparisons, and ultimately determine where EVAC therapy should be employed in the treatment algorithm for esophageal perforations.

Limitations of the present study include the retrospective nature of the analysis, small sample size, discrepancy in numbers between primary and rescue groups, and lack of comparison with other treatment modalities. Comparisons drawn between our primary and rescue cohorts are not validated by statistical analysis, and therefore should be considered observations within a proof of concept study.

Our data demonstrate that EVAC therapy can be utilized in critically ill individuals, early and late perforations, and following operative repair failure. Although

disadvantages of this method of treatment are prolonged hospital stay and the need for multiple endoscopic procedures, EVAC therapy results in a high rate of defect closure, few short-term complications, and the ability to resume an oral diet.

Disclosure Statement

Steven G. Leeds is a consultant for Ethicon but has no conflict of interest with regard to this manuscript.

The other authors have no conflict of interest.

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