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Acute Management of Esophageal Perforation

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Abstract Esophageal perforation is a challenging and potentially deadly disease process. Diagnosis can be delayed or missed despite optimal imaging, and symptoms are often nonspecific. The optimal treatment strategy continues to be debated among thoracic surgeons, adding to the therapeutic challenge that this disease process presents. While surgery remains the gold standard for treatment, less invasive and endoscopic methods are being explored, and their role is evolving. The purpose of this review is to outline some of the advances of recent years in treating esophageal perforation and to review methods and outcomes of both surgical and endoscopic management.

Keywords Esophageal perforation · Acute management · Acute care · Review · Thoracic surgery · Outcomes · Etiology · Diagnosis · Management · Open surgical · Nonoperative · Minimally invasive

Introduction: Historical outline

Esophageal perforation has been a vexing condition since it was first described by Hermann Boerhaave in 1723. The historically grave prognosis for this condition prompted the first attempts at surgical repair in 1947 and the first esophagectomy for esophageal perforation in 1952 [1–3]. The first significant decreases in mortality for this condition were not realized until the advent of antibiotics in the 1960s, but even in the modern age the overall surgical mortality is as high as 18 % among all etiologies of perforation and time to treatment [4••] (Table 1). Despite modern, refined surgical techniques, critical care advances, antibiotics, and improved diagnostic modalities, esophageal perforation remains a diagnostic dilemma, a therapeutic challenge, and a high-mortality diagnosis. The recent adoption of endoscopic and minimally invasive techniques in the management of esophageal perforation offers the possibility for decreasing morbidity and mortality associated with the condition, and this recent trend will be highlighted in the latter part of this manuscript.

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Etiology

Iatrogenic

The advances in diagnostic and therapeutic endoscopic interventions have led to iatrogenic perforation as the most common etiology [4••]. The risk of perforation ranges from 0.03 % in flexible esophagoscopy to 1–5 % in pneumatic dilation of achalasia and sclerotherapy for esophageal varices, with all other esophageal instrumentation techniques falling within this range of risk [5–7]. The most common site of perforation from instrumentation of a normal esophagus is the triangular portion of the pharyngeal wall between the thyropharyngeus portion of the inferior constrictor pharyngeus and the cricopharyngeus muscles known as Killian's triangle. This area of the esophagus does not have a muscularis layer and has only buccopharyngeal fascia separating the esophageal lumen from the retroesophageal space. Other

Table 1 Frequencies of different etiologies of esophageal perforation, $n = 559$ patients

Etiology	Incidence (%)
Iatrogenic	59
Spontaneous	15
Foreign body ingestion	12
Trauma	9
Operative injury	2
Tumor	1
Other causes	2

Data from Brinster et al. [4••]

normal anatomic narrowings of the esophagus, such as the portions directly adjacent to the aortic arch and left mainstem bronchus, are also at particular risk for perforation during instrumentation. Surgical iatrogenic perforation is quite rare, but procedures associated with esophageal perforation include fundoplication, vagotomy, hiatal hernia repair, lung transplantation, pneumonectomy, thyroidectomy, tracheostomy, thoracic aortic aneurysm repair, esophageal leiomyoma enucleation, mediastinoscopy and cervical spine surgery [8–16]. Intraoperative recognition of perforation results in successful repair with minimal morbidity in the vast majority of instances.

Spontaneous

Spontaneous, barogenic esophageal perforation, or Boerhaave's syndrome, is thought to occur because of a sudden increase in intraluminal pressure associated with vomiting against a contracted cricopharyngeus muscle. This increase in pressure causes transmural rupture, usually in the left posterolateral wall of the lower esophagus 2–3 cm proximal to the gastroesophageal junction. This rupture commonly drains into the left pleural or the peritoneal cavity [17]. Other mechanisms of esophageal perforation include erosion by local or metastatic carcinoma, Barrett's ulcers, infection, immunodeficiency, and consequences of chemoradiation.

Foreign Body

The vast majority of ingested objects pass through the gastrointestinal tract without complication. Objects larger than 2 cm have the potential to lodge within the esophagus, particularly if sharp and particularly at anatomic narrowings such as the upper esophageal sphincter, the level of the aortic arch, the level of the left mainstem bronchus, and the lower esophageal sphincter. Most impacted objects can be removed endoscopically; perforation is quite rare with an incidence of 0.001 % based on a recent series [18].

Trauma

Traumatic injuries to the esophagus are rare, with the number of reported traumatic esophageal perforations in a multicenter review of trauma recording only 344 instances over a 10-year period [19]. The most common location for traumatic perforation is the cervical esophagus (57 %), and the most common mechanism is gunshot wound (78.8 %). Morbidity and mortality usually result from damage to adjacent structures such as the trachea, great vessels, and other mediastinal organs.

Presentation

Esophageal perforation can present in many different ways depending on the extent, mechanism, and location of the perforation, and can present with vague and nonspecific symptoms. Common symptoms include chest pain, dysphagia, dyspnea, subcutaneous emphysema, epigastric pain, fever, tachycardia and tachypnea. The pathognomonic, eponymous signs such as Hammon's sign (systolic crunching sound heard on auscultation) and Mackler's triad (subcutaneous emphysema, chest pain and vomiting) are detected in less than half of the reported cases [20]. Subcutaneous emphysema, while a highly suspicious finding, is detectable by physical exam in only 30 % of patients after thoracic perforation and 60 % of patients after cervical perforation [21].

The presentation of cervical esophageal perforation is generally less severe in nature, as the intense cytokine-mediated reaction to oropharyngeal flora and esophageal contents is relatively contained by the posterior attachment of the esophagus to the prevertebral fascia [22]. In contrast, thoracic esophageal perforation results in rapid mediastinal contamination and often violation of the mediastinal pleura, which initiates a powerful, cytokine-mediated fluid sequestration, mediastinitis, sepsis and hypotension. Pain is often felt on the side where intrapleural contamination has occurred: left in distal esophageal injuries and right in proximal esophageal injuries. Intraabdominal perforation is similarly impressive. Pain is usually felt as sharp epigastric pain in anterior perforations or as dull epigastric pain with radiation to the back in posterior perforations. Rapid deterioration and early progression to septic shock are characteristic of esophageal perforation and may develop within hours of injury [20, 23].

Diagnosis

It is generally accepted that prompt diagnosis of esophageal perforation decreases morbidity and mortality significantly [24–26]. A recent review questioned the teaching that a less than 24-h delay in diagnosis results in increased mortality [27•], but early diagnosis is still very important to managing the intense inflammatory reaction that accompanies perforation. Having a high degree of suspicion is important to making the diagnosis, as symptoms are often vague and equivocal. Particular attention should be paid to patients with a plausible mechanism of perforation such as recent endoscopy, instrumentation or penetrating trauma.

Radiographic studies are instrumental to diagnosing esophageal perforation. Lateral neck roentgenograms may demonstrate subcutaneous emphysema in the prevertebral fascial planes before changes are noted on chest roentgenograms or even on physical exam [28]. Chest and upright abdominal roentgenograms are important in cases of suspected thoracic or abdominal perforation and may demonstrate subcutaneous emphysema, pleural effusions, hydrothorax, hydropneumothorax and/or subdiaphragmatic air in cases of perforation. While a chest roentgenogram can demonstrate evidence of esophageal perforation in as many as 90 % of patients, it must be remembered that subcutaneous emphysema requires at least an hour to develop and that pleural effusions and widening of the mediastinum take several hours to develop [28]. Within 12 h of instrumental perforation, up to 75 % of patients will have chest roentgenogram findings [29].

As important to diagnosis as roentgenograms are, the gold standard for diagnosis is contrast esophagography. It is generally though by no means universally accepted that water-based contrast agents such as gastrograffin should be used initially and, if negative, that barium contrast should be used. Gastrograffin, while being more rapidly absorbed and theoretically safer than barium, can nonetheless trigger an intense necrotizing pneumonitis if aspirated [30]. Additionally, gastrograffin extravasates in only 50 % of cervical and 80 % of thoracic perforations [30]. Barium's higher density and superior mucosal adherence increases its positive predictive value to 60 % in cases of cervical perforation and 90 % in cases of thoracic perforation [21, 31]. The inherent deficiencies of the contrast materials used and the fact that an edematous and inflamed esophagus can initially prevent extravasation of contrast yields an overall false-negative rate of contrast esophagography at around 10 % [32]. Because of this, many centers advocate serial esophagographies if clinical suspicion remains high in the setting of negative studies [20].

Computed tomography (CT) is indispensible as both an adjunct to and in some cases a replacement for contrast esophagography in the diagnosis of esophageal perforation. CT can be used in cases where a patient cannot tolerate contrast esophagography or in the setting of a negative contrast esophagography in a patient with high clinical suspicion. Typical findings include pneumomediastinum, extraluminal air, esophageal thickening, esophagopleural fistula, pleural effusions, paraesophageal abscesses and perceptible communication of the air-filled esophagus with an adjacent mediastinal air-fluid collection [33, 34]. Extraluminal air is the most common finding, occurring in 92 % of cases [35]. CT is also invaluable for any minimally invasive procedure preparation to guide fluid drainage and infection control.

By providing direct visualization of the esophagus, flexible esophagoscopy is a powerful diagnostic modality, but it has significant limitations. In evaluating penetrating esophageal injury, it has been shown to have a sensitivity of 100 % and specificity of 83 % [36]. Flexible esophagoscopy is not routinely performed for other mechanisms of esophageal perforation because it can miss perforations within mucosal folds and because insufflation of the esophagus has the potential to convert a small or partial tear into a large perforation [37].

Management

The principles of management in esophageal perforation, be it surgical or non-surgical, are to eliminate the focus of infection and inflammation, prevent further contamination of the mediastinum with adequate drainage and antibiotics, restore alimentary tract continuity and establish nutritional support [38]. The mechanism, severity and location of the perforation in addition to the time interval between perforation and treatment are critical in determining the appropriate management strategy. Additionally, the overall clinical status of the patient, damage to surrounding tissues, extent of associated injuries and any concomitant esophageal pathology must be considered prior to intervention. While both nonoperative and operative strategies have their place in the management of esophageal perforation, all cases require urgent surgical consultation because of the potential for rapid deterioration [4••].

Open Surgical Interventions

Surgical interventions include primary closure with or without autogenous tissue reinforcement, esophageal resection, exclusion and diversion, T tube drainage and simple drainage. Drainage alone is reserved for contained cervical perforations [38] and is accomplished through a standard cervical incision. The middle third of the esophagus is accessed via right thoracotomy in the sixth intercostal space, while the lower third of the esophagus is accessed via left thoracotomy in the seventh intercostal space. The abdominal esophagus is accessed via upper midline laparotomy.

Primary repair remains the preferred surgical treatment method in thoracic and abdominal esophageal perforation. Successful outcome requires debridement of all necrotic tissue; vertical esophagomyotomy to expose damaged mucosa; relief of distal obstruction in the case of strictures and achalasia; two-layer, tension-free closure over a bougie to prevent stricture; and copious irrigation and drainage of the contaminated area [39]. A VATS approach has been successfully implemented, but further studies are needed to clarify its role in primary repair [40–42]. Despite decades of innovation in primary esophageal closure after esophageal perforation, leak is still a common postoperative morbidity [43]. Various autogenous tissues such as the pleural flap, diaphragmatic pedicle graft, omental only graft, rhomboid and latissimus muscle flaps, intercostal muscle flap and pericardial fat pad have been used to buttress closures. These reinforcement techniques serve to decrease fistula formation and mortality, but leak rates remain 25–50 % even after reinforcement [37, 43].

If primary repair is not possible because of underlying esophageal pathology or severe mediastinal sepsis, surgical options include exclusion and diversion and esophagectomy with delayed or immediate reconstruction. Specific indications for esophagectomy include perforations due to megaesophagus, carcinoma, caustic ingestion or severe strictures not amenable to dilation [44]. Esophagectomy has the advantage of entirely eliminating the source of infection and inflammation, and restoring gastrointestinal continuity. The decision to take a transthoracic versus transhiatal approach should be made on an individual basis after assessing the extent of mediastinal contamination. In general, however, a transhiatal approach is favored in cases of early diagnosis and minimal contamination, while a transthoracic approach is favored in cases of more significant mediastinal contamination and the need to perform concomitant procedures such as thoracic washout and pleural decortication [45]. Additionally, the decision to delay restoration of gastrointestinal continuity or to perform single-stage reconstruction must also be made on an individual basis. Delayed reconstruction is favored in cases of extensive mediastinal contamination and in cases where diagnosis or treatment has been delayed. In single-stage reconstruction, cervical anastomosis is preferred to avoid contamination of the anastomosis and to allow for any leak to be managed with cervical drainage [46, 47].

Exclusion and diversion and T tube placement are indicated for perforations that are beyond repair in patients who cannot tolerate an esophagectomy. Exclusion and diversion is accomplished by closure of the perforation, debridement and drainage, and creation of a cervical esophagostomy, gastrostomy and jejunostomy to exclude the perforated segment. The need for a second operation and the difficulty of restoring gastrointestinal continuity after the initial procedure have made this option less prevalent in modern reports [38, 48]. T tube placement has become more widely adopted in the treatment of these patients and is accomplished by the creation of a controlled esophagocutaneous fistula via a surgically placed T tube. T tubes can be placed directly or via a VATS approach, which is an attractive option for those patients who cannot tolerate an open procedure. Concomitant drainage and debridement (VATS, laparoscopy or percutaneous needle drainage) allow for control of the septic focus, and the continuous drainage that the T tube offers allows surrounding tissues to heal. Because a defect remains in the esophagus after T tube placement, there is still the possibility of ongoing leak, mediastinal contamination and subsequent chronic fistula formation, but it remains the procedure of choice for unstable patients and those who cannot tolerate further surgery [38, 49].

Surgical Outcomes

Mortality associated with each treatment strategy is summarized in Table 2. Etiology and location of perforation affect mortality considerably. Spontaneous esophageal perforation, likely due to its often-delayed diagnosis, has the highest reported mortality at 36 % [4••]. Traumatic perforation is usually detected early and is most frequently associated with cervical injuries, so its mortality was the lowest at 7 % [4••]. Among anatomic locations, cervical esophageal perforations have the lowest mortality at 6 %, while thoracic and abdominal perforations have considerably higher mortality at 27 and 21 %, respectively [4••]. Recently, a prospective mortality prediction scoring system was proposed, which is highlighted in Table 3. All surviving patients had scores ≤ 3.3, while all mortalities had scores ≥ 6.5 [50]. Another multivariate analysis yielded similar findings, with preoperative respiratory failure, malignant perforation and Charlson comorbidity index ≥ 7.1 as the strongest predictors of mortality [27•]. These analyses highlight the importance of early diagnosis and treatment before obvious clinical signs of sepsis and shock develop.

Table 2 Outcome after different treatment modalities for esophageal perforation, $n = 559$ patients

Treatment	Mortality (%)
Primary repair	12
Resection	17
Drainage	36
Exclusion and diversion	24
Nonoperative	17
Overall	18
Other causes	2

Data from Brinster et al. [4••]

Table 3 Mortality prediction scoring system for esophageal perforation

One point for each of the following	Age >75 years
	Tachycardia
	Leukocytosis
	Pleural effusions
Two points for each of the following	Fever
	Noncontained leak on barium esophagram
	Respiratory compromise
	Time to diagnosis >24 h
Three points for each of the following	Presence of malignancy
	Hypotension

Data from Abbas et al. [50]

Primary repair has the lowest mortality among surgical techniques, and this mortality benefit remains significant even when adjusting for delays in diagnosis, so the current trend among larger centers is to carry out repair primarily even in cases of delayed diagnosis [4••, 27•]. There has been no demonstrable difference in mortality among reinforced versus non-reinforced primary repairs. A more recent, single-site review demonstrated an overall operative mortality of 8.3 %. The vast majority of these patients were treated by primary repair, which had a mortality of 12.2 % [51••]. The remaining techniques were used infrequently, and their figures are consequently more challenging to interpret [51••]. Being a rare disease entity, the majority of outcome reports are single-site experiences with relatively small sample sizes. There does seem to be an overall decrease in operative mortality and morbidity, but further studies will be required to assess the extent of this apparent trend.

Nonoperative

Select patients can be managed nonoperatively with cessation of oral intake, maintenance of oral hygiene, broad-spectrum antibiotics, parenteral nutritional support and drainage of fluid collections. Cervical tears after instrumentation, well delineated intramural dissections after pneumatic dilatation, small postoperative anastomotic leak and chronic perforation with minimal symptoms are instances where nonoperative management has been successfully employed [52–54]. Specific criteria for nonoperative management have been proposed and are highlighted in Table 4. Up to 20 % of patients treated nonoperatively will require surgical intervention, so these patients require close monitoring particularly during the first 24 h of nonoperative therapy [53]. In select patient populations, nonoperative therapy is a safe and effective option, and has a mortality rate of 18 % [4••].

Table 4 Criteria for nonoperative management of esophageal perforation

Contained disruption within the mediastinum
Drainage of the cavity back into the esophagus
Early detection of perforation
No evidence of neoplasm
Not an abdominal perforation
Not accompanied by obstructive esophageal pathology
Availability of advanced imaging modalities and thoracic surgery

Data from Altorjay et al. [45] and Cameron et al. [50]

Minimally Invasive

The advent and refining of minimally invasive techniques to manage esophageal perforation has caused a paradigm shift toward their use in many large centers. A recent series reported an increase in the use of minimally invasive techniques from 0 % of cases in 1989 to 75 % of cases in 2009, and some centers use minimally invasive techniques almost exclusively [55•, 56•]. Examples of minimally invasive techniques include endoscopic clipping and stenting. Recent series that have incorporated these modalities have reported significant declines in both mortality and morbidity [56•]. While the specific indications for minimally invasive techniques have not been formalized, they have been successful in treating a wide variety of etiologies and locations of esophageal perforation in certain institutions where they are widely employed [57–60].

Endoscopic Intervention

Endoscopic clipping and particularly stenting have been used with increasing frequency in recent years. Metal clips can be placed via esophagoscopy to small perforations (<1.5 cm) and have been used successfully in several reports [61–64]. Clipping should only be considered in select cases where the perforation is clean and there are minimal clinical signs of infection, so its use has been somewhat restricted. Endoscopically guided placement of coated, self-expanding metal stents has been used to treat various forms of esophageal pathology for the past few decades, but its use has been limited to high-risk patients or as a palliative measure in obstructive, inoperable tumors.

As centers have gained more experience, the indications for stent placement have become more broad and inclusive, to the point where some centers advocate stent placement as first line treatment in most circumstances [55•]. Contraindications to stent placement are long segment perforations (>6 cm), identification of perforation during an operation where a thoracotomy or laparotomy will ultimately be required, anastomotic leak with conduit necrosis, anastomotic leak with near dehiscence and anastomotic leak in a conduit other than stomach and cervical esophageal perforation, as patients do not tolerate stents proximal to the cricopharyngeus muscle [55•]. These contraindications are a direct result of one large center's analysis of unsuccessful stent placements [65••] and are being further developed. It must also be remembered that the use of esophageal stents to seal perforation is still considered an off-label use according to the US Food and Drug Administration. There have not been any formal comparisons between the different kinds of coated esophageal stents, and there is some variability among and within groups concerning which type of stent should be used. Some groups advocate for metal-coated stents, while some argue that silicone-based stent covers have a decreased incidence of stent migration [55•].

Stents are placed via esophagogastroscopic and fluoroscopic guidance. Flexible esophagogastroscopy allows for concurrent placement of a percutaneous endoscopic gastrostomy tube, perforation site visualization and stent sizing. Stents are typically oversized to seal the perforation, and the longest length is used that will not cross the gastroesophageal junction or the arytenoid fold of the posterior oropharynx [55•]. Only one stent is used at a time; no benefit has been found from using multiple stents, and the risk of stent migration increases in this situation [55•]. The stent is inserted over an endoscopically guided guidewire and is positioned under fluoroscopic guidance. Placement and position are confirmed via flexible esophagoscopy, and the stent can be moved proximally via endoscopic graspers if necessary. Because the stent continues to expand after deployment, most centers will wait 48–72 h after stent placement to confirm the perforation seal with contrast esophagogram. Most investigators perform all necessary drainage procedures concurrently with stent placement using VATS, laparoscopy and/or percutaneous needle drainage [55•, 56•, 66•]. Patients are monitored very closely in the immediate postoperative period for evidence of ongoing sepsis. Contrast esophagogram can be performed as early as 24 h after stent placement if ongoing leak is suspected, and repeat CT scans can help identify any additional collections to be drained [55•]. Once repeat esophagogram confirms that the leak has been sealed, patients are advanced to a soft diet, and parenteral feeding is weaned until adequate nutrition can be maintained in its absence. To avoid complications of indwelling esophageal stents such as tracheoesophageal fistulae, aortoesophageal fistulae and bowel obstruction from stent migration, stent removal is considered 10–14 days after placement [67].

Endoscopic Outcomes

Being a relatively uncommon treatment modality for an incredibly rare condition, outcome reports are confined to individual centers and their consecutive case series. The largest single-site experience with stent placement for esophageal perforation, fistula or anastomotic leak is 187 patients over a 7-year period [65••]. This group reports a 92 % rate of perforation seal and a 2.7 % mortality rate among all presentations of perforation, fistula or anastomotic leak [65••]. Stent migration is the most common complication, with an incidence of between 18–57 % [65••, 66•, 68•]. Average length of stay was 6 days for those who had successful stenting and was 11 days for those who ultimately required surgical intervention after stent failure [65••]. Patients who required endoscopic repositioning or re-intervention of their stent maintained a significantly shorter length of stay compared with those patients who required surgical intervention [65••].

Conclusions

Esophageal perforation remains a diagnostic and therapeutic challenge. Surgical management remains the gold standard for most presentations, etiologies and locations of esophageal perforation. While surgical methods have not changed significantly over the past few decades, outcomes continue to improve. The advent of stent placement to seal esophageal perforation was once reserved only for those patients who could not tolerate an open surgical procedure, but is now being used in some centers as fist line treatment. The exact indications for and the ultimate role of esophageal stenting are not fully realized at present, and further studies are needed to compare outcomes between surgical and endoscopic management. Regardless of the treatment modality, esophageal perforation remains a vexing surgical issue because of the potential for rapid decline, so all cases should be managed by a thoracic surgical team. Moving forward, it will be necessary for continued systematic and open-minded reviews of outcomes to determine the best methods for treating this most challenging and deadly disease process.

Compliance with Ethics Guidelines

Conflict of Interest Constantine D. Mavroudis and John C. Kucharczuk declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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