Concepts in Esophageal Surgery

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Advances in diagnostic studies, perioperative management, and the techniques of esophageal surgery have greatly reduced mortality, morbidity, and length of hospital stay. Multidisciplinary approaches have even begun to improve the long-term results of treatment for esophageal malignancy. Long-term survival following resection of a carcinoma of the esophagus is usually limited to those patients without regional spread whose tumors are confined to the wall of the esophagus. Successful esophageal surgery still requires knowledge of the anatomy and physiology of the esophagus and attention to the details of the operative technique.

Carcinoma of the Cardia Region

Resection of lesions of the distal esophagus and gastric cardia with esophagogastric anastomosis is no longer an operation with high mortality, significant complications, and intractable reflux esophagitis. Resection with an overall mortality of 2 % should be routine, and anastomotic leakage should be a rare event today. Operation without an intensive care unit stay, with early ambulation, return to oral intake within 48 h, and hospitalizations of 1 week are achievable even for patients over age 70 with either open or minimally invasive approaches. Continuing epidural analgesia with patient control after surgery has been an important advance. Although return of normal appetite and meal volume is slow, most patients have no dietary restrictions after the early narrowing of the anastomosis due to edema has resolved.

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Important concepts are resection with adequate margins of normal esophagus and stomach, resection of the fibroareolar tissue around the tumor to ensure local circumferential margins, and adequate lymphadenectomy for staging. The stomach must be well mobilized with preserved vascularity and esophagogastric continuity restored with an end-to-side or side-to-side anastomosis. The gastroepiploic arcade must be carefully preserved and the esophageal hiatus widened to prevent a tourniquet effect with obstruction to venous outflow. Properly performed, esophagogastrectomy is a safe operation with good symptomatic and nutritional results.

If a tumor extends into the stomach, a significant distance either along the lesser curvature or into the fundus, a significant proximal gastrectomy is necessary for adequate tumor margin. If resection of more than 50 % of the stomach is required for tumor margins or if the anastomosis is less than 10 cm from the pylorus, a total gastrectomy with Roux-en-Y esophagojejunostomy gives a much more satisfactory result. Intra-abdominal esophagogastric anastomoses near the pylorus leave too small a gastric remnant to construct a satisfactory end-to-side anastomosis. Such end-to-end anastomoses have a higher leak rate and severe problems with uncontrolled bile reflux esophagitis.

An abdominal and right chest approach can be used for lesions at any level of the thoracic esophagus, and transhiatal esophagectomy is an option for lesions in the distal 10 cm of the esophagus. The use of minimally invasive approaches utilizing laparoscopy and thoracoscopy have largely supplanted the left thoracoabdominal approach with the patient in the lateral position for tumors whose proximal extent on computed tomography is clearly below the carina. A combined minimally invasive operation is rapidly becoming the approach of choice. Although minimally invasive mobilization and resection can significantly increase the operating time, especially in the learning phase, it provides superb exposure without the increased morbidity of prolonged open surgery and it decreases blood loss. Minimally invasive techniques can refine both transhiatal and transthoracic surgery. I continue to prefer a left thoracoabdominal approach in the

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lateral position for bulky tumors of the distal esophagus and for salvage surgery when neoadjuvant therapy has failed to down stage a tumor. The direct visualization of both chest and abdomen is a great advantage for this palliative surgery, and anastomosis in the chest is easily accomplished.

Carcinoma of the Middle and Upper Esophagus

The operation of choice for lesions in the midthoracic esophagus is subtotal resection following full mobilization of the stomach. We routinely place a feeding jejunostomy as part of the abdominal phase. The anastomosis should be constructed with an end-to-side or side-to-side technique at the apex of the right chest or in the neck. A stapled anastomosis at the apex of the chest usually provides at least as much esophageal margin as a cervical anastomosis. The success rate of cervical anastomoses has been improved by the development of the semi-mechanical technique of anastomosis (Orringer et al. 2000). The same considerations of blood supply and lack of tension apply. Good vascularity ensured by preservation of the gastroepiploic arcade, enlargement of the hiatus to prevent compression, and wide mobilization of the stomach and duodenum to eliminate tension are essential to a satisfactory anastomosis. With appropriate preparation the operation can be done safely with resultant good digestive function and little or no reflux problems. The tumor must be staged as completely as possible prior to operation to ensure resectability because the surgeon cannot assess local fixation until after completion of the abdominal mobilization if the thoracic phase is done second. Bronchoscopy and endoscopic ultrasonography are the most accurate studies to determine the extent of invasion for these tumors. Doing the thoracic mobilization first has the advantage of evaluating the local condition early in the operation, and a minimally invasive approach with thoracoscopy decreases the need for position changes and the morbidity of thoracotomy so the substantial increase in operating time is not an issue.

I prefer dissection under direct vision (video assisted) for these lesions even though the same thing can be accomplished by the transhiatal approach. I use a transhiatal approach only for mid-esophageal lesions that are clearly confined to the wall of the esophagus to avoid injury to major vessels and the trachea. Wide resection around the esophagus is not as feasible in the mid- and upper esophagus as it is in the lower third and cardia because of the adjacent respiratory and vascular structures.

My preference has been for a high intrathoracic anastomosis when the location of the tumor permits rather than using a cervical anastomosis on principle in open surgery. The amount of esophagus resected with an anastomosis in the neck is minimally (if any) longer than for an anastomosis at the apex of the thorax. Although the trend has been toward anastomosis in the neck, with experience an intrathoracic anastomosis is no more difficult in minimally invasive surgery than in an open transthoracic operation. As the incidence of anastomotic failure of intrathoracic anastomoses has been reduced to an uncommon event, the previous arguments about safety have lost their force.

Anastomosis in the neck has a higher leak rate than intrathoracic anastomosis and introduces the problems of recurrent laryngeal nerve injury. As already mentioned, the use of the combined or semi-mechanical anastomosis in the neck may change this paradigm. With the use of a linear stapler for the back of the anastomosis and sutures for the front, cervical leaks are more likely to remain localized or drain anteriorly. If it does not drain exteriorly, a cervical leak can track caudad and cause thoracic mediastinitis. Cervical leaks have often caused strictures that require dilation and can be difficult to manage with circular anastomoses, but the problem seems less common with the combined technique. Cervical anastomosis has improved neither local recurrence nor long-term survival.

Unresectable Carcinoma

Patients whose lesions appear locally unresectable on initial evaluation by CT scan or ultrasonography should be treated with radiation and chemotherapy and then reevaluated for surgical treatment after completing the course of neoadjuvant therapy. For patients with significant invasion beyond the esophageal wall, a multimodality approach with radiation and chemotherapy has the potential to reduce significantly or even eliminate the tumor mass. Resection may be feasible for palliation or even with curative intent after such treatment.

Tumors that invade the aorta or the tracheobronchial tree must be approached with extreme caution. It is doubtful that heroic measures can prove more beneficial than a palliative approach and the chance of creating an unsalvageable situation is great.

How extensive a search one should do for distant metastases is both a practical and theoretical question. Distant metastases are not a contraindication to palliative resection of a locally resectable tumor, but they do preclude cure at the current level of knowledge. The patient's condition and the potential benefit must be carefully weighed when deciding whether to resect for palliation. A suitable patient is one whose tumor has caused obstruction or bleeding and who can easily withstand the operation. For such a patient, the ability to swallow can significantly enhance the quality of life. A palliative resection can be accomplished during a short hospitalization in appropriately selected patients.

Although it is feasible to interpose a colon segment between the proximal esophagus and the stomach for palliation of obstruction caused by an unresectable carcinoma, the operation has a high mortality rate and provides poor palliation for the short expected survival of such patients. The development of new techniques including endoscopic treatment with dilators, lasers, and stents provides a much more acceptable means of palliation.

Carcinoma of the Esophagus: Transhiatal or Transthoracic Approach

Each approach to resection of esophageal cancers has had strong proponents. Each also has advantages and disadvantages, and no series has demonstrated a clear superiority of one over the others. Although the left-sided approach I favor for certain distal lesions has been widely accepted, some have reported excessive mortality and leak rates. We have not had this experience, and others have also noted exceedingly low mortality and complication rates. Akiyama (1980), Ellis et al. (1983), and Mathiesen et al. (1988) have reported the same experience we have had with complications and mortality, both in the 2 % range and lower. With a large experience, Orringer and John (2008) results with transhiatal resections are similar. The minimally invasive and minimally invasive-assisted approaches are rapidly gaining adherents after the pioneering work by many surgeons around the world who championed the approach and demonstrated its equivalency and perhaps superiority. There is also intense interest in the use of robotic-assisted surgery, but it has yet to prove itself.

Each operative approach requires knowledge of the anatomy, appropriate staging and preparation of the patient, a well-orchestrated team approach in the operating room and afterward with meticulous and delicate surgical technique, careful anesthetic technique and monitoring, and devoted postoperative care to achieve comparable results.

Replacing or Bypassing the Esophagus: Stomach, Colon, or Jejunum

The stomach is the closest we have to the ideal esophageal replacement. When fully mobilized and based on the gastroepiploic arcades, the apex of the stomach reaches the nasopharynx. When the stomach is stretched out to reach the neck, it becomes a tubular organ of modest diameter, with the fundus at its apex and the site of the gastroesophageal junction one-third of the way down the lesser curvature side. Its arterial supply and venous drainage are reliable and difficult to compromise even if the lesser curvature arcades are divided to gain length. The stomach is thick walled and resistant to trauma when passed up to the neck by any route. Restoration of continuity to the esophagus or pharynx is straightforward and requires only a single anastomosis.

Although end-to-side anastomosis and creation of a partial antireflux "fundoplication" by wrapping or "ink welling" the anastomosis help decrease the amount of reflux, all patients with an esophagogastrostomy have abnormal gastroesophageal reflux. Significantly symptomatic reflux, however, is seen primarily with low anastomoses and rarely with higher anastomoses. Deprived of vagal innervation, the stomach is only a passive conduit, but its function is usually satisfactory. High anastomoses (in the neck or apex of the pleural space) help minimize the amount of reflux. I believe this improvement is on a purely mechanical basis. The complete vagotomy that occurs as part of an esophageal resection makes acid secretion minimal. Bile is the main culprit. A long, thin gastric tube helps minimize pooling in the intrathoracic stomach and facilitates emptying, thereby decreasing the amount of bile reflux. When the stomach is available, we have used it preferentially and reserved intestinal interposition for special circumstances. I have not had the opportunity to use gastric tube techniques and prefer other techniques in adults.

The use of the jejunum or colon to replace a resected segment of esophagus preserves a functioning stomach intact. Although less used today than previously, colon or jejunal interposition is an essential technique if the stomach is diseased or was previously resected. Most of the benign strictures formerly treated by short-segment colon interposition are now managed without resection. The colon is easily mobilized and can be supported on one of several major vascular pedicles and the marginal arcades. The transverse and descending colon based on the ascending branches of the left colic artery in isoperistaltic position is the appropriate size and length for substernal or intrathoracic interposition. The arterial supply of that segment is reliable and the venous pedicle short and less prone to kinking or twisting. Although sufficient length of colon can usually be achieved to reach the neck, use of the colon presents some special problems. The colon serves as a passive conduit and does not have effective peristalsis. Gastrocolic reflux occurs routinely, and the refluxate is slowly cleared, but the reflux is seldom symptomatic. The transit time for a bolus of food to pass into the stomach is invariably slow but variably symptomatic. Benign or malignant disease of the colon may preclude its use; and the mesenteric vascular arcade is variable, especially on the right. The interposed colon is also subject to venous infarction by trauma to the colon mesentery or compression at the hiatus.

The jejunum retains effective peristalsis when used to replace a segment of the esophagus. Short-segment jejunal interposition has been used effectively as a salvage operation to prevent reflux when multiple direct operations on the

gastroesophageal junction for reflux esophagitis have failed. The shape of the jejunal mesentery limits the length of the interposition that can be achieved with a conventional technique. Without special techniques, the jejunum does not reach above the inferior pulmonary vein. Some of the limitations of jejunal interpositions have been solved by microvascular techniques, which allow either free transfer of jejunum to replace segments of the pharynx or proximal esophagus or interruption of the mesentery with a second proximal vascular anastomosis.

Even without microvascular techniques, the major objection to using jejunum or colon as an esophageal substitute has been the time involved in the additional dissection and the three required anastomoses. Mobilizing the bowel with careful preservation of both arterial and venous circulation can be difficult and time-consuming. Although experienced surgeons have reported excellent results with both colon and jejunum, higher mortality and morbidity rates are the rule. The higher complication rate for interposition operations likely reflects both the additional surgery required and the more complicated nature of the patients who require such an approach. When approaching a patient who needs an intestinal interposition, the surgeon must know as much as possible about the condition of the bowel and its vascular supply. Endoscopy, contrast studies, and vascular studies by angiography or magnetic resonance angiography should be performed and the bowel prepared both mechanically and with antibiotics in every case. The surgeon must have alternatives well thought-out if the originally selected segment of bowel is not usable or the adequacy of the blood supply is questionable.

Effective complete vagotomy is likely after any esophageal resection. Although it may not be necessary in more than a minority of cases, I do not hesitate to do a pyloromyotomy to facilitate gastric emptying. It is a simple maneuver if the patient does not have scarring from peptic disease. I have not found it harmful, and it avoids the need for balloon dilation or reoperation. Although a matter of judgment, a pyloromyotomy, or other drainage procedures should be done any time, the pyloroduodenal segment is within the hiatus when the stomach is pulled up. Although balloon dilation is usually sufficient, reoperation in this area is extremely difficult if it fails.

Hiatus Hernia and Reflux Disease

With the exception of traumatic diaphragmatic rupture, virtually all acquired diaphragmatic hernias enter the chest through the esophageal hiatus. Parahiatal hernia occurs but is a rare finding of no particular significance. On the other hand, it is essential for a surgeon to understand the difference between a sliding and a paraesophageal hiatus hernia and to differentiate them from posttraumatic hernias caused by blunt or penetrating trauma.

A sliding hiatus hernia may be thought of as a disease of the esophagus whose significance depends on the severity of associated gastroesophageal reflux and its consequences. A sliding hiatus hernia is sliding both in the anatomic sense (one wall of the hernia is made up of the visceral peritoneum covering the herniated stomach) and in the direction it herniates (the gastroesophageal junction migrates cephalad along the axis of the esophagus): hence the synonym axial hiatus hernia. The hiatus hernia must be reduced and the hiatus repaired as part of the operation to control reflux.

A paraesophageal hernia, also known as a rolling hiatus hernia, is best conceived as a disease of the diaphragm. In this case the gastroesophageal junction is in its normal position, and the stomach with the attached greater omentum and transverse colon herniates into the posterior mediastinum through an anterior widening of the hiatus. This hernia has a true sac of parietal peritoneum. The problems associated with paraesophageal hernias are the same as those with any abdominal wall hernia with the additional special problems of having the acid-secreting stomach involved. Patients with paraesophageal hernia are more often older and frequently have kyphoscoliosis. They usually do not have significant reflux but often have abnormal esophageal peristalsis. Many are entirely asymptomatic, and the diagnosis is suggested by the presence of a mediastinal air-fluid level on chest radiography. Unlike sliding hernias, all patients who have a significant paraesophageal hernia should undergo repair to avoid the mechanical complications of the hernia unless they are unfit candidates for general anesthesia. All symptomatic patients require surgical repair because this disease is caused by a mechanical problem for which there is no medical therapy. The essentials of the operation are reduction of the stomach and repair of the hiatus. Patients who do not have reflux do not benefit from an antireflux operation.

Complicating the matter is the combined hernia with features of both paraesophageal hernia and sliding hernia with reflux. These hernias are usually large and symptomatic. They should be repaired anatomically and to control reflux. They require an anatomic repair *and* an antireflux procedure.

Laparoscopy has become the standard approach for both antireflux surgery and for repair of paraesophageal hernias.

A posttraumatic hernia may involve any injured portion of the diaphragm. Deceleration injuries from blunt trauma usually involve the apex of the left hemidiaphragm. These hernias are usually large and are detected soon after injury from a fall or motor vehicle accident. Posttraumatic hernias involving penetrating trauma, on the other hand, can be small and may miss initial detection. Any atypical diaphragmatic hernia that appears to arise away from the hiatus should raise the suspicion of previous injury. Because these hernias do

not have sacs, the abdominal contents are adherent to intrathoracic structures if time has passed between the time of injury and the time of repair. Consequently, all such hernias should be approached through the abdomen if repaired at the time of the injury and through the chest if operated late. Immediately after the trauma, the concern should be for the abdominal viscera; reduction should be a simple matter of traction. Late recognition of injury leads to incarceration of the viscera in the chest. The primary risk under these circumstances is injury to both the viscera and the lung. The abdominal contents are adherent to the edges of the diaphragmatic hernia, the lung, and the pleura and can much more safely be freed via the thoracic approach.

Complicated Paraesophageal Hiatus Hernia: Obstruction, Gastric Volvulus, and Strangulation

The patient with a large paraesophageal hernia may have a large portion of the stomach in the chest. As more and more stomach herniates, the fixed ends at the pylorus and the esophagogastric junction come close together, and volvulus becomes likely with intermittent obstruction. More complete volvulus leads to the rare but lethal complication of strangulation with necrosis and perforation. The development of a paraesophageal hernia after repair of any hiatal hernia is especially dangerous and unpredictable. It must be considered an incarceration with a high potential for complications. More commonly, patients develop gastric ulcer with bleeding or obstruction with pain. An incarcerated hernia usually causes severe substernal or epigastric pain, often with an inability to vomit because of obstruction at the esophagogastric junction. All patients with these symptoms should have surgery as soon as the diagnosis has been confirmed with a chest radiograph and contrast esophagram unless the obstruction can be relieved. It may be hazardous to insert a nasogastric tube for the same reason the patients cannot vomit. If the patient is vomiting, a tube can be passed safely, but in either case it should be inserted carefully with the distances measured out prior to insertion. Endoscopy or fluoroscopy should be used if there is any resistance to avoid perforation.

Surgical repair of a paraesophageal hernia should include resection of the sac, closure of the hiatus, and gastropexy either anteriorly or posteriorly. Anterior fixation of the anterior wall of the stomach to the abdominal wall with or without gastrostomy is straightforward if the esophagogastric junction is in normal position. The esophagogastric junction should be reduced and fixed in the abdomen if it has migrated cephalad. Posterior gastropexy as originally described by Hill (1967) works especially well under those circumstances.

Sliding Hiatus Hernia

The presence of a sliding hiatus hernia is not an indication for operation. An asymptomatic patient with a sliding hernia who has normal sphincter pressures and no significant reflux cannot be made better by either medical or surgical therapy. The patient without a hiatus hernia who has significant reflux and esophagitis may be greatly improved by medical therapy or operation. It is generally agreed that medical management is the treatment of choice for patients who have symptomatic reflux with minimal esophagitis. Surgery is most clearly indicated for patients with reflux that causes significant esophagitis and its complications of ulceration and stricture. Patients whose symptoms are completely relieved or greatly improved by modern medical management are also excellent candidates for surgery if their symptoms recur after the withdrawal of therapy (as is likely but not certain). Patients whose reflux symptoms cannot be controlled even by escalating doses of proton pump inhibitors should be carefully evaluated prior to operation to exclude other causes for their symptoms. Atypical symptoms not clearly related to reflux episodes are rarely improved by antireflux operations. The use of antireflux surgery for patients with Barrett's esophagus (columnar-lined esophagus with intestinal metaplasia) is still an unresolved issue at this time. Although Barrett's esophagus is clearly a premalignant lesion, it is less clear that it can be eliminated by antireflux surgery. Comparisons of medical and surgical treatment in controlled studies have proven the superiority of surgical control of reflux during every era of medical treatment: antacids, H_2 blockers, and proton pump inhibitors (Spechler 1992). Surgical control of reflux also has the advantage of controlling all the refluxate—duodenal as well as gastric—whereas medical therapy at best reduces only the amount of acid refluxed.

The minimal preoperative evaluation of a patient with gastroesophageal reflux disease (GERD) and classic symptoms should include esophagoscopy with biopsy to confirm the presence of esophagitis and a barium contrast foregut study. A timed esophageal pH study confirms the relation of symptoms to episodes of acid reflux. Manometry is useful for defining any abnormalities of sphincter location and pressure. It is also essential for pH-metry of any kind to place the probe at the proper place. Manometry can define the strength and regularity of the contractions of the body of the esophagus and can exclude defined motility disorders such as achalasia. It is not clear, however, how the surgeon can use manometric information to modify antireflux surgery. I have been able to plan antireflux surgery much more effectively by looking at the results of a standard barium meal, which clearly demonstrates the size and reducibility of the sliding hiatus hernia, the amount of shortening, and the effectiveness of peristalsis in the body of the esophagus, information that endoscopy does not provide.

Minimally invasive approaches can clearly replicate open antireflux surgery, and they have largely replaced open operations. The excellent short-term results with laparoscopy have now been confirmed by long-term results from many centers. With the availability of effective acid reduction, fewer patients have peptic stricture, severe ulceration, or dramatic shortening of the esophagus. I continue to recommend open operations to patients with peptic stricture, nonreducing hernias, or an esophagus shortened enough that the gastroesophageal junction never returns to the abdomen. But with increased experience, minimally invasive operations have been successfully used for increasing numbers of patients with reflux disease, and a laparoscopic approach by an experienced surgeon is an equally valid option.

Antireflux Operations

The multiple operations developed to prevent gastroesophageal reflux were developed empirically and only later validated. They have in common the principles of successful antireflux surgery, which seek to reproduce normal reflux control:

1. Reduce the gastroesophageal junction into the abdomen to restore the intra-abdominal segment of esophagus.
2. Narrow the esophageal hiatus posteriorly to increase the intra-abdominal length of esophagus and prevent the development of an iatrogenic paraesophageal hernia.
3. Restore the lower esophageal sphincter mechanism by creating a high-pressure zone in the distal esophagus with a fundoplication.

They differ in the degree of fundoplication, the method of fixation, and the approach required. Although known by the name of one or more of a technique's primary developers, it is preferable for the surgeon to define the operation by what is done than by the use of an eponym, as the current operation may little resemble the original description.

A complete (360°) fundoplication done by either the abdominal or thoracic approach is termed a Nissen-type operation (Donahue et al. 1985). Lesser degrees of anterior fundoplication follow the models of Hill (1967), Watson et al. (1991), or Dor et al. (1967), which can only be done by the abdominal approach, or that of Belsey (1976), which can only be done by the thoracic approach. Partial posterior fundoplication is termed a Toupet (1963) procedure. It can be done effectively only through the abdomen. All these operations can be done by minimally invasive and open techniques. Aye RW in "Current therapy in thoracic and cardiovascular surgery" has refined the minimally invasive Hill and Jamieson and Watson have proven the laparoscopic Dor (Chen et al. 2011).

Personal preference aside, the more complete the fundoplication, the more complete is control of reflux. The advantages of greater reflux control are offset by the more numerous postfundoplication symptoms created by a complete fundoplication. Fundoplication is associated with a reduced gastric reservoir and more rapid emptying of the stomach in addition to the abolition of both physiologic and pathologic reflux. The patient experiences postfundoplication symptoms as a result of these changes. Most patients have symptoms of early satiety, diarrhea, and increased flatus, which are usually mild and resolve over weeks to months. Some patients have a sensation of upper abdominal pressure or fullness, called the gas bloat syndrome. These symptoms are related to the changes created by the fundoplication and the habit of frequent swallowing or aerophagia common to refluxers. As the reflux resolves, the postfundoplication symptoms usually abate as well.

The inevitable results of surgery to control reflux must be distinguished from the consequences of surgery done incorrectly. Dysphagia and the inability to belch or vomit are often listed as postfundoplication symptoms. I believe they are most often the result of too long or too tight a fundoplication and are rarely seen with appropriate narrowing of the hiatal opening, full mobilization of the fundus with division of both the short gastric vessels and posterior gastropancreatic folds, and a floppy fundoplication. Whichever operation is chosen, the fundoplication should be kept to the physiologic length, and too tight a closure of the hiatus should be avoided to minimize the undesirable effects of the antireflux surgery. The most reproducible operation with the best combination of durability and reflux control is the complete, loose (floppy) fundoplication done with posterior crural closure and complete mobilization of the fundus.

Benign Reflux Stricture

The most important step when dealing with a stricture in a patient with reflux is to be certain that the stricture is benign. Most carcinomas of the cardia present with symptoms of obstruction. The possibility of Barrett's esophagus with malignancy must be considered, especially in white males over age 50 who have a long history of heartburn. If carcinoma can be excluded, the patient should undergo aggressive medical treatment with proton pump inhibitors and sequential dilation to at least 40 French prior to surgery. Almost all strictures regress with this treatment, and surgery is then greatly simplified. All patients who are good candidates for operation should undergo this initial treatment followed by antireflux surgery. Strictures that do not respond to acid reduction therapy and that cannot be dilated preoperatively with available techniques have a substantial chance of being malignant. When operating for such lesions, the surgeon must be prepared to resect the stricture, as for carcinoma. If the strictured esophagus splits open during aggressive dilation, resection is the only option. Some strictures that appear resistant to dilation dilate readily at operation

with the esophagus mobilized. In my experience, all strictures not dilatable in the operating room or that split during operative dilation proved to be malignant.

The approach used when operating for stricture depends on the level of the stricture and the degree of esophageal shortening. In most cases with sliding hiatus hernia, the shortening is more apparent than real, and I would approach these from the abdomen. Mobilization through the hiatus allows the surgeon to have the stricture under vision when dilators of increasing size are passed through the mouth to dilate the stricture. After dilation, an ample length of intra-abdominal esophagus can ordinarily be restored. In the unusual case where mobilization does not allow reduction of the esophagogastric junction into the abdomen without tension, an esophageal lengthening procedure such as the standard Collis gastroplasty (Pearson et al. 1971) or the uncut Collis gastroplasty described by Demos (1984) can be used.

With long-standing reflux and columnar-lined esophagus, the stricture may be in the mid-esophagus and the shortening real. Such cases are best approached through the chest with plans for an esophageal lengthening procedure. The surgeon must always be prepared to resect the esophagus under these circumstances. The bowel should be prepared to allow for colon or jejunal interposition as well as gastric advancement in all cases when an esophageal lengthening operation is done.

Dilation is safest when it can be done with the esophagus completely mobilized using soft, tapered, mercury-filled, rubber (Maloney) bougies. With the stricture in hand, the surgeon can see and feel the stricture and dilator and can then guide the dilator precisely into the stricture and assess the pressure required to achieve dilation. Only when the esophagus is pliable and easily reducible after mobilization should transthoracic fundoplication alone be done. All other patients should have a Collis gastroplasty combined with fundoplication.

Intrathoracic fundoplication is a potentially dangerous condition. Incomplete intrathoracic fundoplication does not prevent reflux. A complete intrathoracic fundoplication is an incarcerated paraesophageal hernia and has all the associated complications of that condition including ulceration and perforation. The intra-abdominal segment of tubular esophagus should be restored in all cases, and the fundoplication should always be comfortably within the abdomen. Patients with these complications have advanced reflux disease and should always be treated with an effective fundoplication to control their reflux.

Failed Antireflux Operation

Secondary operations for reflux are a challenge at best and are associated with increased mortality and failure rates. After abdominal operation, the decisions to reoperate and by what technique can be very difficult. Following thoracic antireflux surgery an abdominal approach may provide relatively easy access for successful fundoplication provided the esophagus is not significantly shortened or adherent to the mediastinum. Likewise, following abdominal antireflux operations, a transthoracic approach has the advantage of going through a previously unoperated body cavity. In general this plan has merit, but the surgeon must be prepared to use the alternative approach of a thoracoabdominal operation or another type of surgery when dealing with this clinical problem. For the abdominal surgeon the secondary approach should be a diversion procedure (Fekete and Pateron 1992). Distal gastrectomy and Roux-en-Y gastrojejunostomy prevents reflux of either acid or bile into the esophagus if the defunctionalized limb is 40–50 cm long. This operation usually provides relief of symptoms at minimal surgical risk. Especially in poor risk patients, it has much to recommend it over extensive operations, such as thoracoabdominal reoperation with resection and interposition. If a resection has been done previously, a complete vagotomy can be correctly assumed. Even if vagal trunks remain, an adequate distal gastrectomy prevents marginal ulcer formation. The possibility of delayed gastric emptying following the Roux-en-Y reconstruction is a concern that has been overstated. An individualized decision based on the situation and the surgeon's expertise should be used because of the complex nature of the disease and the understandable lack of consensus among experts.

Pharyngoesophageal Diverticulum

Normal swallowing is an elegant, complex series of events coordinated by the swallowing center in the medulla. In the peristaltic sequence, both the upper and lower esophageal sphincters must relax to ensure proper timing to allow the bolus to pass. The upper esophageal sphincter—the cricopharyngeus muscle and the adjacent upper cervical esophagus—and the lower esophageal high-pressure zone are physiologic sphincters. They are in a state of contraction in the resting state and then relax on stimulation. A pharyngoesophageal (Zenker's) diverticulum develops in the posterior midline just above the cricopharyngeus muscle. The pathophysiology appears to be a lack of coordination in the relaxation of the upper sphincter with a resultant false diverticulum through the weak area of the distal pharyngeal constrictor. Whatever the cause, Zenker's diverticulum is a progressive disorder with no known medical treatment that should be corrected by surgery when diagnosed. The diverticulum almost always projects toward the left, so it is best approached through a left cervical incision. Although the operation can be performed under local anesthesia, with current technology, it is far better done under general anesthesia

to control the airway and allow intubation of the esophagus. The operation is well tolerated in the elderly, poor risk patients who characteristically have this disease. Diverticulectomy is straightforward with the use of surgical staplers, and excising the diverticulum opens the plane of dissection for the cricopharyngeal myotomy. We have not seen any advantage to diverticulopexy and have not used the technique.

The size of the diverticulum is not predictive of the severity of the patient's symptomatology. Small diverticula can be associated with severe dysphagia. Both that and the average length of the upper sphincter of >3 cm make combining myotomy and diverticulectomy the most logical operation for both the more common Zenker's diverticula, which are easily diagnosed radiographically, and those rare patients with dysphagia caused by upper esophageal sphincter disorders and so-called cricopharyngeal achalasia, which are related to neurologic dysfunction and which must be proven by manometry. Minimally invasive and endoscopic techniques have also been developed to treat Zenker's diverticula. Collard (Gutschow et al. 2002) has reported modifications of staplers to divide the spur endoscopically with excellent results. The technique requires specialized equipment and experience to choose the appropriate candidates and is only suitable for the large diverticula that used to be seen more commonly.

Perforations and Anastomotic Leaks

"Conservative" Management

Left untreated, esophageal perforations are uniformly fatal. Expectant or nonoperative management of esophageal perforations is hardly "conservative." Although nonoperative treatment has a place in highly selected situations such as small perforations of the pharynx from endoscopy and clinically insignificant anastomotic leaks, its use must be confined to those settings in which the leak is proven to be small, contained or adequately drained, and minimally symptomatic with no sign of systemic sepsis. The posterior mediastinum has no compartments and poor defenses against the spread of infection. Perforation of the cervical esophagus can track through the mediastinum and into the retroperitoneum. A radiographically "small" thoracic perforation can cause a fulminant mediastinitis and lead to hydropneumothorax and empyema. Any pleural air or fluid is a contraindication to continued expectant management.

The essentials for treating perforations are:

1. Early identification of the perforation
2. Accurate localization of the site of perforation
3. Control of the airway and pulmonary decompression
4. Adequate drainage of the leak
5. Broad-spectrum antibiotic coverage
6. Supportive care
7. Operation for debridement and closure of the perforation whenever it is appropriate and possible

Adequate drainage can be accomplished surgically or by image-guided intervention. Adequate drainage implies that the drain goes to the site of the perforation and completely controls the leakage. Debridement of devitalized mediastinal tissues and decortication of the pleural space are necessary to restore pulmonary function and treat the infection.

The mixture of digestive enzymes and foreign material characteristic of traumatic and postemetic perforations creates a fertile ground for microbial growth. Antibiotic therapy should cover both aerobic and anaerobic bacteria as well as yeasts. Although proximal perforations contain mouth organisms generally sensitive to penicillin, the bacterial flora quickly changes to resemble that in the colon, so the antibiotic regimen appropriate for a colon perforation should be used. The esophagus also contains large numbers of yeast, especially *Candida* species, which become progressively more of a problem the longer the perforation is incompletely treated.

Supportive care must include adequate parenteral and/or enteral nutritional support. A feeding jejunostomy should be used in most cases.

Surgical Repair

Sutured or stapled repair alone is unwise unless the perforation occurs during operation, occurs in normal tissue, and can be immediately repaired. Even under those circumstances, buttress of the repair with viable tissue is a logical approach. Consideration should always be given to providing drainage of the repair. For all other circumstances, the surgeon should always buttress the repair with viable tissue and provide always adequate drainage (Richardson et al. 1985). Parietal pleura, intercostal muscle, pericardium, diaphragm, and stomach have all been used successfully; the choice depends on location and available tissue. Successful repair can still be achieved more than 48 h after perforation with a buttress of viable tissue as long as the esophagus was normal prior to perforation and there is no distal obstruction (Gouge et al. 1989). Proximal and distal tube decompression is a useful adjunct but not a substitute for an adequate repair.

When the esophagus is abnormal, resection is the best treatment. The resection can be done by a cervical approach combined with an abdominal and transhiatal or by a transthoracic approach. Primary anastomosis is unwise in this setting, and even cervical anastomoses should be used very selectively.

The most effective proximal esophageal diversion is total thoracic esophagectomy with end-cervical esophagostomy.

The esophagogastric junction should be closed, the stomach decompressed with a gastrostomy, and a jejunostomy inserted. Reconstruction with stomach or colon can follow at an appropriate interval. In the special case of perforation following balloon dilation for achalasia, a complete myotomy of the distal sphincter must be done along with the buttressed repair.

Esophageal Perforation at Various Anatomic Levels

Cervical Esophagus

The cervical esophagus may be perforated during endoscopy, during endotracheal intubation, by swallowing a foreign body, or by external trauma. Although endoscopic perforations of the pharynx can almost all be managed with antibiotics and usually do not need surgical drainage, cervical perforations below the cricopharyngeal sphincter are a much more serious matter. An esophageal perforation in this location may be several centimeters long, and prompt surgical exploration should be the rule. Exploration of the cervical esophagus is a simple procedure, and adequate drainage prevents spread of the contamination into the thoracic mediastinum. All patients who are febrile or have tenderness or swelling in the neck should undergo exploration and drainage of the retropharyngeal space. All cervical esophageal perforations should be repaired. Repair of pharyngeal perforations is usually neither feasible nor necessary.

Thoracic Esophagus

Perforation During Instrumentation: Dilator or Endoscope

Pain, crepitation, fever, leukocytosis, mediastinal emphysema, and pneumothorax or hydropneumothorax are evidence of esophageal perforation following instrumentation as under other circumstances, but these findings develop gradually over 12–24 h. When selecting the proper treatment for a patient with an iatrogenic perforation diagnosed within a few hours of the event, remember that the patient may look quite well during the first few hours only to collapse hours later with fulminant mediastinitis. Water-soluble contrast can define the presence and location of a perforation in almost most all cases, but the study cannot accurately define the size of the perforation or the extent of spread of contamination in the mediastinum. If the signs and symptoms suggest a perforation but the contrast study is negative, a follow-up study with computed tomography or repeat esophagram with high density barium should be used to confirm the absence of perforation. Flexible endoscopy has only a limited role. Although intact esophageal mucosa excludes perforation, if a perforation is present, insufflation can lead to tension pneumothorax. For that reason, flexible endoscopy should be used only after decompressive tube thoracostomy or negative contrast studies.

All patients with instrumental perforation should be treated by exploration and drainage. Closed tube thoracostomy is ineffective as definitive therapy. Buttressed repair or resection should be done depending on the esophageal pathology. Obstruction of the esophagus must be relieved if treatment is to be successful.

Barotrauma: Boerhaave's Syndrome and External Pressure

Postemetic perforations of the thoracic esophagus (Boerhaave's syndrome) are dangerous because they occur in a patient with a full stomach. Vomiting against a closed glottis floods the mediastinum with food, microbes, and digestive secretions. Rapidly developing, fulminant mediastinitis is the result and patients often present late for medical care. Diagnosis is often further delayed because esophageal perforation is not considered in the differential after the patient presents to the emergency department. Mediastinal emphysema on the chest radiograph is diagnostic and should lead to a water-soluble contrast study to confirm the diagnosis and location of the perforation even though the site of perforation is almost always in the distal esophagus and typically ruptures into the left pleura. In the absence of penetrating trauma, hydropneumothorax is diagnostic of esophageal perforation. With a blast injury from external pressure, the perforation may be anywhere in the esophagus.

After resuscitation, chest decompression, and control of the airway, thoracotomy for decortication, repair of the esophagus with a parietal pleural flap, and adequate drainage are almost always successful even if the delay to operation is more than 24 h. Although primary closure without leak is not achieved in every case, the fistula can be well controlled by the flap and drainage. Spontaneous closure usually occurs within weeks. After completion of the thoracic phase, a separate abdominal procedure (laparotomy or laparoscopy) to place a gastrostomy and jejunostomy should be done in all patients.

Anastomotic Leaks

Patients who develop a leak following a cervical anastomosis respond well to drainage as long as the interposition is viable. Although an anastomotic stricture may develop secondary to the leak, systemic or mediastinal sepsis is unusual and recovery is expected. These strictures usually respond to sequential dilations.

Anastomotic failure following intrathoracic anastomosis is a far more serious occurrence. Although most patients

survive, their hospitalizations are usually long and complicated. Without prompt, adequate treatment, death from sepsis and organ failure is probable. I believe that virtually all anastomotic leaks result from technical errors at operation. They are present but not clinically apparent early when the defect could be corrected by reoperation. The best time to check for leakage is in the operating room. In addition to inspection of the anastomosis, insufflation through the nasogastric tube distends the stomach and reveals gross defects in a stapled or sutured anastomosis. In the past, we conducted studies at 5–7 days, if at all, before allowing oral intake. I have been doing contrast studies on the first postoperative day if the patient is able to swallow and to safely go to the radiology suite. The study is done first with a small amount of water-soluble contrast and then with barium if the first part of the swallow shows no leak. If the study is normal, patients are allowed liquids immediately. If the study is equivocal, a CT scan is obtained to look for extraluminal contrast. If none is seen, I leave the chest tube in place to maintain the seal of the lung around the anastomosis and withhold oral intake until a repeat study is normal. Using this plan, we have seen very few leaks presenting late in the clinical course. If a leak is demonstrated very early, the patient can be returned to the operating room for repair with a viable tissue buttress and wide drainage before extensive tissue reaction and infection limit the chance of success. Even if the leak is not completely sealed, the resulting lateral fistula is well controlled and closes spontaneously. If a jejunostomy was not done at the original operation, it should be done at this time.

If a leak is recognized late, reoperation should be done as soon as the patient can be prepared for anesthesia. Debridement, decortication, and closure can be attempted if the defect is small; but the realistic goal is control of sepsis and creation of a controlled fistula. Endoscopically placed stents can be a very effective adjunct in these circumstances. Antibacterial and antifungal therapy is essential under these circumstances. Enteral feeding by jejunostomy is a necessary part of management.

Nonoperative treatment is a tenable plan only if strict criteria are met (Cameron et al. 1979). The leak must be an insignificant radiographic finding. It must be a small, localized sinus that drains completely back into the lumen and does not involve the pleural space. The presence of pneumothorax or significant effusion mandates exploration, as does any sign of systemic toxicity. Contrast-enhanced computed tomography is essential to confirm that the sinus is behaving like a diverticulum that will resolve by itself. Broad-spectrum antibiotics and parenteral or enteral nutrition should be used until healing is confirmed by a contrast study. Oral intake should await proof that no leak is present.

In the catastrophic situation of complete anastomotic dehiscence or necrosis of the interposition, the source of sepsis must be completely eliminated to avoid death from multiple organ failure. All nonviable tissue must be resected. Decortication and wide pleural drainage help the antibacterial and antifungal therapy clear the sepsis. The anastomosis should be resected and the esophagus exteriorized as an end esophagostomy. The stomach should be returned to the abdomen, closed, and drained with a gastrostomy. Reconstruction usually requires colon interposition and can be done at an appropriate time.

Occult perforation is a problem during esophageal surgery, especially with minimally invasive approaches. For this reason, testing for leaks should be done in the operating room and early postoperatively day in all patients who undergo resection, myotomy, and fundoplication.

Achalasia

Achalasia, an acquired disease of unknown etiology, is characterized by denervation pathology. The ganglion cells of the myenteric plexus are lost, and the patient develops a hypertonic, non-relaxing distal esophageal sphincter with an aperistaltic body of the esophagus. The esophagus progressively dilates and then elongates. In the long term, patients with achalasia have an increased risk of epidermoid carcinoma. Their nutrition is usually well preserved, and patients typically present with a long history of slow eating and dysphagia to liquids more than solids that is not progressive. All treatment modalities rely on ablation of the lower esophageal sphincter mechanism to allow more normal but passive emptying of the esophagus. In all cases, the striated muscle proximal to the esophagus retains its normal size and contraction. The methodologies available today include temporary paralysis of the muscle of the sphincter with botulinum toxin, disruption of the muscle by balloon dilation, and surgical myotomy. Botulinum injection has had a predictably transient effect. The only difference between surgical and balloon myotomy is that the modified Heller myotomy is more controlled and more effective than the balloon procedure. The availability of minimally invasive surgical approaches has largely rendered balloon myotomy irrelevant. Because of the possibility of perforation, all patients with balloon disruption of the sphincter should have surgical backup, and all should have follow-up contrast studies as soon as possible to exclude perforation.

All patients should be studied with radiography, manometry, and endoscopy to confirm the diagnosis and to exclude other causes of pseudoachalasia in even the most typical cases. When the diagnostic combination of an aperistaltic body of the esophagus with a non-relaxing distal sphincter is present, the surgeon must chose among the available surgical approaches. The sphincter can be approached to perform a myotomy from the left chest or from the abdomen. The

surgeon may use either a minimally invasive or open technique with or without an antireflux fundoplication. The most important principle is to complete the division of the sphincter. Although a complete myotomy can be done by any of the approaches, only a myotomy done by an expert through a left thoracotomy can be done accurately enough to complete the myotomy and not have an unacceptable amount of reflux (Ellis et al. 1992). Approached by left thoracotomy, the pattern of vessels that mark the cephalad margin of the stomach can be identified as the lower limit of the sphincter and of the myotomy without disrupting the anatomy of the cardia. This anatomic landmark cannot be visualized adequately by thoracoscopy or through the abdomen. To do so by any of the other approaches, the myotomy must be carried down well onto the stomach, and the operation must include a partial circumference fundoplication to minimize reflux. At present, a laparoscopic myotomy with anterior, partial fundoplication is the operation most acceptable to patients and physicians and most easily done by many surgeons. The integrity of the mucosa must be ensured in the operating room and should be confirmed by a contrast study within 24 h to identify incomplete myotomy and exclude perforation. Perforations can be repaired primarily when identified in the operating room or early postoperatively. The repair should always be buttressed with viable tissue as with any perforation. The stomach is readily available for this purpose.

The morbidity associated with laparotomy is little different than that seen with laparoscopy for myotomy and fundoplication. The surgeon must exercise good judgment when choosing the approach best suited to the individual patient. Extensive previous abdominal surgery may make a laparotomy or thoracic approach a better choice for such a patient. Reoperative surgery for achalasia can be challenging. For patients with failed operations for achalasia and for end-stage disease with sigmoidization of the esophagus, resection with gastric interposition and esophagogastrostomy in the neck or at the apex of the right thorax is an effective, durable option.

Other Motility Disorders

Diverse motility disorders of the esophagus—diffuse esophageal spasm, corkscrew esophagus, nutcracker esophagus, and others—have been described. They are poorly understood disorders of the body of the esophagus that do not affect the distal sphincter. The various diseases can be diagnosed and distinguished from achalasia and reflux by motility and pH studies. In the past, there has been enthusiasm for surgical procedures such as long myotomy of the body of the esophagus, but the results are mediocre at best. Although there may be a place for long myotomy in carefully selected patients who have failed medical therapy, almost all these patients should be treated pharmacologically.

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