Chapter 22
Peroral Endoscopic Myotomy (POEM)

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Abbreviations

DES	Distal esophageal spasm
DI	Distensibility index
EGD	Esophagogastroduodenoscopy
EGJ	Esophagogastric junction
EMR	Endoscopic mucosal resection
EPT	Esophageal pressure topography
ES	Eckardt score
ESD	Endoscopic submucosal dissection
FLIP	Functional lumen imaging probe
GERD	Gastroesophageal reflux disease
GERDQ	Gastroesophageal reflux disease questionnaire
HRIM	High-resolution impedance manometry
HRM	High-resolution manometry
IDQ	Impaction-dysphagia questionnaire
LES	Lower esophageal sphincter
NOTES	Natural orifice translumenal endoscopic surgery

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POEM	Per-oral endoscopic myotomy
TBE	Timed barium esophagram
VSI	Visceral sensitivity index

Indications

Achalasia

Achalasia is a rare disease characterized by failure of swallow-induced relaxation of the lower esophageal sphincter (LES) and loss of coordinated peristalsis in the esophageal body. It is the most common primary esophageal motor disorder with an annual incidence historically estimated at 1 per 100,000 individuals [1]. With the advent of the widespread use of high-resolution manometry (HRM), newer studies suggest that actual incidence could be 2–3× higher [2]. Initially described in 1674 by Sir Thomas Willis, our current understanding of the etiology of achalasia has developed thanks to histopathologic analysis over the last two decades. Immunohistochemical studies have suggested an auto-immune response, potentially triggered by a neurotropic virus such as herpes simplex virus 1 in genetically susceptible hosts, with selective loss or impairment of ganglions in the myenteric plexus resulting in unopposed cholinergic stimulation of the distal esophagus and LES [3]. Presenting symptoms include dysphagia to solids and liquids (>90%), regurgitation of undigested food and saliva (76–91%), weight loss (35–91%), and chest pain (25–64%). Patients may also report respiratory complications of aspiration such as nocturnal cough and pneumonia and heartburn and esophagitis secondary to stasis [4]. There is no known cure for achalasia; current treatment options aim to palliate symptoms through elimination of outflow obstruction at the EGJ.

Emerging Indications

Based on case series reporting excellent early results, POEM operators have applied the minimally invasive technique to esophageal motor disorders other than type I and type II

achalasia, including type III achalasia, distal esophageal spasm (DES), Jackhammer (hypercontractile) esophagus, and hypertensive LES [5, 6]. POEM has also been utilized as a salvage operation following failed Laparoscopic Heller Myotomy (LHM). In general, EGJ outflow obstruction caused by high LES pressure responds favorably to the division of the obstructing muscle fibers. In contrast, symptoms such as chest pain, attributed to esophageal body contraction (DES and type III achalasia), have lower rates of symptom remission following myotomy [7].

History/Background

In the 100 years since Dr. Heller first described the "transabdominal, extra mucosal cardioplasty performed onto the anterior and posterior walls of the cardia," the procedure has been transformed by laparoscopy, modified in length, and augmented by anti-reflux procedures [8]. In the last 10 years, however, the complementary fields of natural orifice translumenal endoscopic surgery (NOTES) and endoscopic submucosal dissection (ESD) have expanded from simple proof-of-concept studies to a wide variety of fully incisionless operations in use today. Early animal models demonstrated the feasibility of both safe access to the submucosal space using the mucosal flap technique and endoscopic myotomy [9, 10]. Based on these techniques, Dr. Haruhiro Inoue performed the first human POEM procedure in Japan in 2008 and presented his results at the 2009 Digestive Diseases Week in Chicago with subsequent publication in Endoscopy in 2010 [11]. Following his landmark publication, the procedure as described by Inoue grew exponentially with an estimated number of POEM cases exceeding 2000 worldwide by the end of 2012, when the global experience in POEM was summarized in the international POEM survey (IPOEMS) as part of the NOSCAR conference in July 2012 [7]. Current estimates approximate that well over 10,000 POEMs have been performed worldwide. However, no such global survey has been re-created.

Patient Selection

Symptom Assessment Questionnaires

Validated, disease-specific questionnaires can help establish the diagnosis of achalasia, assess disease severity, and establish baseline values to allow postoperative evaluation of treatment effect. The most widely used and reported instrument for achalasia is the four-item Eckardt score that evaluates the frequency of occurrence of chest pain, regurgitation, dysphagia, and amount of weight loss on a 0–3 scale [12]. Higher scores represent increasingly severe disease, while post-intervention scores less than or equal to three are associated with treatment success [13]. While simple to obtain, the ES does not measure disease impact on the overall quality of life and is limited by patient subjectivity. More extensive and sensitive surveys include the Mayo Dysphagia Questionnaire-30, Achalasia Disease-Specific Quality of Life measure, Visceral Sensitivity Index, and EORTC QLQ-OES18 [14].

Physiologic Tests

High-Resolution Manometry

Esophageal manometry has long been considered the "gold standard" for the diagnosis of idiopathic achalasia. Over the last decade, High-Resolution Manometry (HRM) has begun to replace conventional manometry (CM) as the diagnostic test of choice given its relative ease of interpretation and superior diagnostic accuracy [2]. The improved HRM catheters, utilizing 36 or more pressure sensors at 1 cm intervals, accompanied by the development of esophageal pressure topography (EPT), or Clouse plots, have allowed easier and more reliable manometry analysis. A prospective randomized control trial comparing HRM to CM showed a twofold increase in achalasia diagnosis (26% vs. 12% $p < 0.01$) with a 97% sensitivity and a false positive rate of only 3% [15].

Pandolfino et al. proposed the Chicago classification based on manometric profiles, dividing patients into three subtypes of achalasia [Fig. 22.1] with well-described prognostic implications [16, 17]. Type I, or "classic" achalasia, is defined by absent peristalsis and impaired EGJ relaxation in response to swallowing, quantified as a 4-s integrated relaxation pressure (IRP) >10 mmHg. Type II achalasia is diagnosed by the presence of pan-esophageal pressurization (>30 mmHg) and is associated with the best outcomes following myotomy. Type III achalasia, associated with premature, spastic contractions of the distal esophagus (two or more swallows with a distal latency of <4.5 s) and impaired EGJ relaxation, has the least reliable response to myotomy or pneumatic dilatation [17].

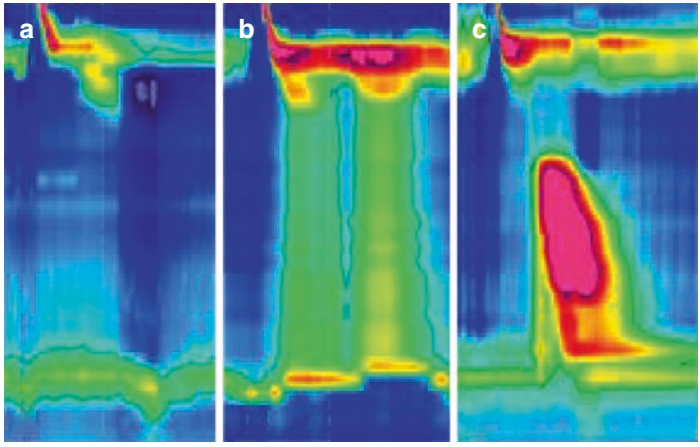

FIGURE 22.1 High-resolution manometry. Distinct manometric patterns are observed in the subtypes of achalasia according to the Chicago classification. In the setting of elevated 4-s integrated relaxation pressures, (**a**) type I patients are recognizable by the absence of peristalsis, (**b**) type II patients exhibit pan-esophageal pressurization at the 30 mmHg isobaric contour, and (**c**) type III patients are defined by a spastic distal esophageal contraction with a distal latency less than 4.5 s

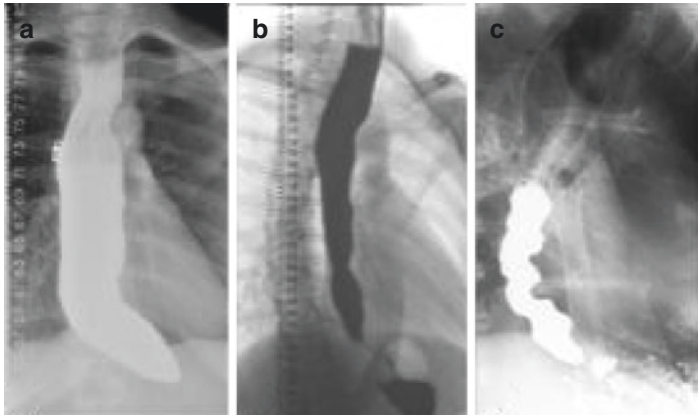

FIGURE 22.2 Timed barium esophagram. Characteristic findings in achalasia include (**a**) increased esophageal width as seen in a patient with type I achalasia, (**b**) so-called "bird's beak" appearance of the contrast column as it tapers in the distal esophagus of a patient with type II achalasia and (**c**) retained contrast with a "corkscrew" appearance seen in type III achalasia and other spastic disorders of the esophagus such as DES

Timed Barium Esophagram (TBE)

TBE [Fig. 22.2], comprised of chest radiographs obtained 1, 2, and 5 min after ingestion of 200–250 mL of dilute barium contrast, is useful for evaluation of both esophageal body and EGJ anatomy (classic appearance of the "bird-beak" esophagus). TBE quantifies the barium column's baseline height, degree of esophageal emptying, and esophageal width. TBE also allows detection of the sigmoid esophagus (representing so-called "end-stage achalasia"), hiatus hernia, and epiphrenic diverticula.

Esophagogastroduodenoscopy (EGD)

EGD is required as part of the pre-operative work-up of all patients before treatment for achalasia to rule out pseudoachalasia (EGJ outflow obstruction secondary to an infiltrat-

ing malignancy). If the index of suspicion remains high for pseudo-achalasia (older patients with prominent weight loss and a short duration of symptoms) despite a negative EGD, adjunctive studies such as endoscopic ultrasound or computed tomography scan should be performed [18]. EGD also allows for the assessment of retained solids or liquids, stasis or reflux esophagitis, and candidiasis.

EndoFLIP

The functional lumen imaging probe, or EndoFLIP (Medtronic, Minneapolis, MN), is a novel diagnostic catheter that utilizes impedance planimetry, with sensors positioned at 0.5–1 cm intervals within an infinitely distensible balloon to generate a geometric representation of the lumen of the esophagus and LES [Fig. 22.3]. When combined with a pres-

Figure 22.3 EndoFLIP Catheter (Medtronic, Minneapolis, MN). EndoFLIP catheter filled with 0 cc (**a**) and 60 cc (**b**) fluid

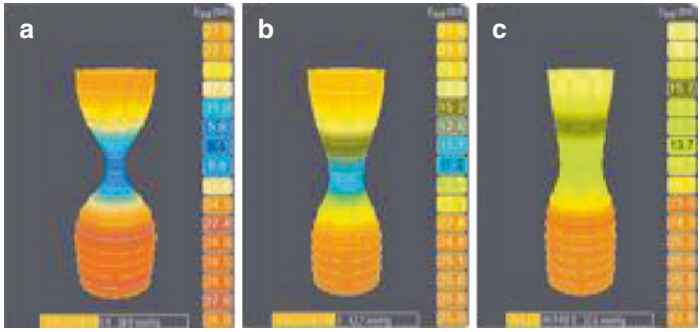

FIGURE 22.4 Intraoperative EndoFLIP. The lower esophageal sphincter is identified on EndoFLIP by the characteristic "hourglass" shape (**a**) following induction of general anesthesia during a POEM procedure. Increased distensibility is noted after (**b**) creation of the submucosal tunnel, with a doubling of the minimum diameter and (**c**) completion of myotomy; final EndoFLIP measurements revealed a further increase in diameter and a nearly 50% pressure decrease at the EGJ

sure sensor in the distal portion of the balloon, the FLIP allows quantification of the EGJ response to volumetric distention, calculated as the distensibility index, or DI (DI = cross-sectional area/intra-balloon pressure) [Fig. 22.4] [19]. Normal EGJ-DI has been defined as greater than 2.8 mm^2/mmHg with a maximal EGJ diameter greater than 18 mm [20].

Teitelbaum et al. [21] demonstrated in their study that intraoperative FLIP analysis can be used to predict postoperative outcomes following POEM [21]. We routinely perform EndoFLIP during POEM. Our updated protocol involves the insertion of the endoFLIP under endoscopic guidance for initial EGJ DI and maximal diameter measurement following induction. Subsequent measurements are taken following the creation of the submucosal tunnel and after the myotomy. Although the relationship of intraoperative measurements and postoperative outcomes has not been reliably demonstrated across subsequent studies, it does provide objective data to the surgeon during the myotomy. It has the potential to act as an effective calibration tool.

Contraindications

Patient Factors

Patients should undergo evaluation in a pre-operative clinic in coordination with anesthesiology and additional workup as indicated. The less invasive nature of the POEM procedure minimizes the list of comorbidities that preclude the procedure. Absolute contraindications to POEM include the inability to tolerate general anesthesia, secondary to prohibitive cardiopulmonary disease, uncorrectable coagulopathy/thrombocytopenia, and the presence of advanced cirrhosis, with or without evidence of esophageal varices. Additionally, the POEM procedure relies on access to the submucosal space, so extensive fibrosis secondary to external-beam radiation to the mediastinum, extensive mucosal ablations, or prior EMR generally prohibit the operation. Published reports have included patients ranging in age from 3 to 97 years old [7]. Prior treatments that can cause inflammation and/or fibrosis of the submucosal space, such as botulinum toxin injection, pneumatic dilation, prior LHM, or prior POEM can all contribute to the difficulty of the dissection and in some cases increase the rate of inadvertent mucosotomies or duration of the procedure. While none of the prior treatment modalities, other than esophagectomy, represent absolute contraindications to POEM, the added complexity should preclude such cases from being attempted during the initial learning curve [22].

Technical/Training

Safe conduct of the POEM procedure relies on the availability of all necessary equipment, adequately trained and well-coordinated support staff, and sufficient pre-clinical training. Prior experience with EMR/ESD techniques and/or NOTES procedures has been reported as helpful, as have simulations using live animals, ex vivo models, and cadavers. Most operators reported having expert proctoring during the initial human cases (median 2, range 1–7) [7].

Pre-operative Care

Before surgery, a multidisciplinary team including gastroenterologists and minimally invasive surgeons should evaluate the patient.

Patient Instructions

Pre-operatively, the patient is prescribed daily oral fluconazole 100 mg for 7 days. They are instructed to maintain a clear liquid diet for 48 h before surgery and remain NPO 12 h before surgery. Some centers report conducting routine EGD 1–3 days pre-operatively to screen for candidiasis, while others evaluate at the start of the procedure. Management of peri-operative medications should be performed in consultation with the pre-operative clinic and patients primary care provider. In general, we continue beta blockers peri-operatively and Aspirin when indicated for a history of stent placement, coronary artery disease, or coronary artery bypass graft. Prophylactic Plavix and Aspirin are typically held for 5 and 7 days pre-operatively, respectively. Decisions regarding the management of therapeutic anticoagulation are made on an individual basis.

Anesthetic Considerations

Pre-operative and intraoperative coordination with the anesthetic team is crucial to the safe conduct of the POEM procedure. Issues of particular importance include positioning and securing the endotracheal tube as far laterally as possible and potentially utilizing a preformed, right-angled Oral RAE™ tracheal tube (Moore Medical). Given the inherent risk of aspiration, all airways should be secured utilizing Rapid-Sequence Intubation (RSI) protocols. In addition, the anesthesia team should be aware of the potential for unplanned extubation given the frequent passage of the endoscope through the oropharynx, with the equipment necessary for

re-intubation readily available. It is also helpful to discuss blood pressure management, specifically maintaining the systolic blood pressure below 120 mmHg, if feasible, as this is anecdotally associated with fewer bleeding complications.

Room Set-Up and Equipment

For a list of equipment recommended for POEM, see Table 22.1. Sequential compression devices are utilized for thromboprophylaxis, and a second-generation cephalosporin or comparable pre-operative antibiotic (Ancef at our institution) is given. After successful induction of general anesthesia

Table 22.1 Equipment checklist

Room set-up	Forward viewing, high-definition gastroscope with 2.8 mm working port (GIF-H190, Olympus)
–	Clear cap with ¼″ tape to secure at the end of the gastroscope
–	Carbon dioxide (CO_2) insufflation system (Olympus)
–	High-frequency electrosurgical generator
Intraoperative tools	Bite-block
–	60–90 mL syringes with saline for irrigation +/− simethicone
–	Indigo carmine injection solution with normal saline
–	Dilute bacitracin irrigation
–	¼″ red tape to mark insertion depth for endoscopic instruments
–	Sterile toothbrush for cleaning knife

(continued)

Table 22.1 (contiued)

Endoscopic instruments	Endoscopic injection/sclerotherapy needle
–	Triangular-tip endoscopic submucosal dissection knife (Olympus)
–	Coagrasper hemostatic forceps (Olympus)
–	Resolution 360 (Boston Scientific) hemostatic clips
–	OverStitch (Apollo Endosurgery) endoscopic suturing system

and secured positioning of an endotracheal tube, the patient is positioned supine, flush with the head of the OR table, the right arm is supported on an arm board, and the left arm is appropriately padded and tucked next to the torso. The bed should be lowered and step stools positioned at the head of the bed as needed to minimize strain and fatigue on the part of the operator. An endoscopy tower, equipped with a forward viewing, 2.8 mm single-channel, high-definition flexible gastroscope (GIF-H190; Olympus America, Inc., Center Valley, PA), with carbon dioxide (CO_2) insufflation, is positioned near the midpoint of the OR table and the cautery foot pedal is placed within reach of the operator. A minimum of one assistant is required to coordinate the operation of the injector and triangular-tip ESD knife and should be positioned to the operator's left. To the operator's right, a second assistant can stabilize the endoscope at the mouth, allowing simultaneous manipulation of the deflection wheels and the injector or cautery knife. The second assistant can also assist with the passage of intraoperative measurement devices such as the endoFLIP catheter. A time-out should be performed before the procedure to confirm patient identity, procedure, availability of endoscopic equipment (clips, coagulation forceps, etc.) and ensure that the endoscopy tower utilizes CO_2 insufflation and that correct electrocautery levels are set.

Operative Technique [Fig. 22.4]

Diagnostic Endoscopy

Once the anesthesiologist is satisfied with the positioning and security of the endotracheal tube, the abdomen is prepped and draped to provide access if Veress needle decompression of a capnoperitoneum is required. A bite-block is placed to facilitate the passage of the endoscope [Fig. 22.5a]. Thorough clearance of impacted food is required for complete assess-

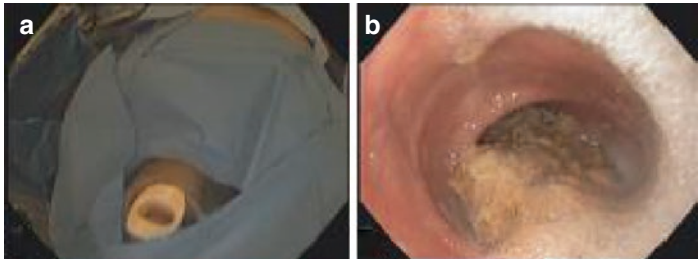

FIGURE 22.5 (**a–f**) Operative steps for POEM. Patients are (**a**) prepped and draped with the abdomen exposed, and a bite-block is placed to facilitate passage of the endoscope. Findings during initial EGD can include (**b**) impacted food and (**c**) copious frothy sputum that should both be cleared to allow for the detection of (**d**) active candidiasis. Identification of the (**e**) squamocolumnar junction provides an approximation distance to the EGJ. A combination of dilute indigo carmine is injected to (**f**) elevate the mucosa. (**g–l**) Operative steps for POEM. The submucosal space is accessed through (**g**) creation of a longitudinal mucosotomy. The submucosal tunnel is extended distally with a combination of (**h**) dilute indigo carmine injection for marking and hydro-dissection and (**i**) cautery to divide the tissue of the submucosa. Withdrawal from the tunnel and retroflexion in the stomach allow (**j**) endolumenal verification of adequate extension onto the gastric cardia. Starting 6–7 cm proximal to the EGJ, (**k**) a selective myotomy of the inner, circular muscle layer is performed to 2–3 cm distal to the EGJ. After ensuring hemostasis and irrigation of the submucosal tunnel with dilute bacitracin, (**l**) endoscopic clips are used for mucosotomy closure

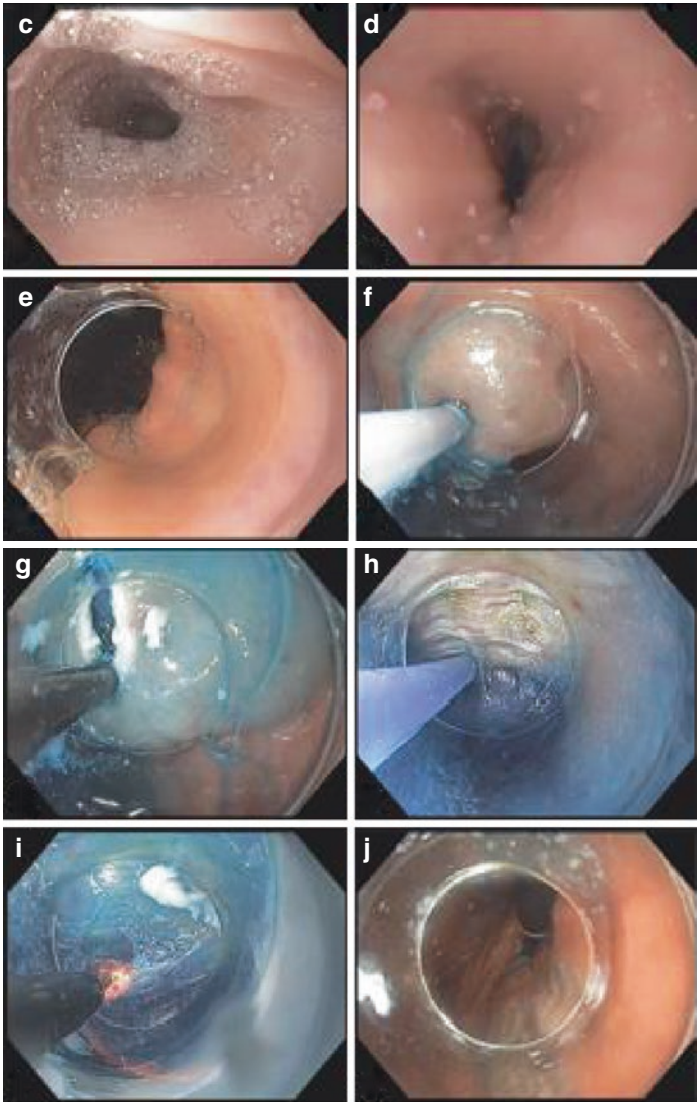

FIGURE 22.5 (continued)

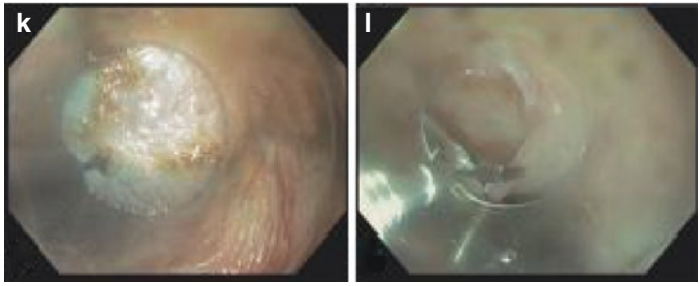

FIGURE 22.5 (continued)

ment of the esophageal mucosa [Fig. 22.5b] and to minimize soilage of the submucosal tunnel. Placement of a 16- or 18-French orogastric tube can facilitate clearance, as can the availability of 60–90 mL flushes or a power-flush system for the working port. It is not uncommon to encounter copious frothy sputum in the esophagus [Fig. 22.5c], a condition that resolves quickly with irrigation using dilute simethicone. Initial EGD is performed to assess for the presence of active candidiasis [Fig. 22.5d], an indication to abort the procedure and reschedule the myotomy pending resolution of the infection. Following a visual inspection of the esophagus and stomach, note should be made of the location of the esophagogastric junction as determined by the distance from the incisors to the squamocolumnar junction [Fig. 22.5e] using the external markings on the endoscope for reference. In the absence of a hiatal hernia, the SCJ is typically located between 38 and 42 cm from the incisors.

Mucosal Lift and Mucosotomy

In the case of a standard length myotomy (extending 6–7 cm proximal to the EGJ), the mucosotomy should be made 12–14 cm above the EGJ. Most operators performing POEM

report creating an anterior submucosal tunnel in the 1–2 o'clock position [7]. An endoscopic needle is inserted just below the mucosa, and a 3–4 cm wheal is raised using 10 mL of a solution containing indigo carmine and 0.9% saline [Fig. 22.5f]. A longitudinal mucosotomy is created (using a few drops of liquid to create a meniscus to assess positioning relative to the most anterior aspect, designated 12 o'clock). Mucosotomy length should be just large enough to accommodate the clear cap on the endoscope (approx. 2 cm) [Fig. 22.5g], as excessive length will add time and cost to the procedure during clip closure of the mucosotomy.

Creation of the Submucosal Tunnel

After the initial mucosal lift, subsequent injections during the creation of the submucosal tunnel should be diluted dye without epinephrine to limit total exposure to the adrenergic agent. Distal progression of the submucosal tunnel is facilitated by alternating hydro-dissection to enlarge the submucosal space [Fig. 22.5h] and cautery to divide the thin fibers connecting the mucosa to the inner, circular muscle layer [Fig. 22.5i]. Careful advancement of the endoscope and slight posterior deflection of the cap can be used to put the submucosal fibers on stretch and guide dissection. Frequent reference to the fluid meniscus can help prevent spiraling as the tunnel is carried distally on the esophagus. Extra care should be taken near the EGJ as this area is prone to inadvertent mucosotomy given the increased muscle tone and anecdotally described "stickiness," attributed to prior episodes of inflammation or previous treatment modalities. Beyond the EGJ, switching back to an injection solution containing both dye and dilute epinephrine can aid in demarcating the distal extent of the submucosal tunnel. To confirm adequate extension onto the gastric cardia, the endoscope can be withdrawn from the submucosal tunnel and passed into the stomach lumen to obtain a retroflex view of the EGJ [Fig. 22.5j].

Anterior Myotomy of the Circular Muscle Layer

Using the endoscopic markings, the selective myotomy of the circular muscle layer should be initiated 6 cm proximal to the EGJ for a standard length of the myotomy. Variations in myotomy length have been suggested when treating conditions that predominantly affect the esophageal body, such as type III achalasia or jackhammer esophagus; in these cases, the myotomy can be started just proximal to the spastic segment, ensuring at least 2–3 cm of mucosal flap coverage in the submucosal tunnel [23]. Once the plane between the inner circular muscle layer and the thin, outer, longitudinal muscle layer is accessed, the triangular-tip ESD knife can be used to hook the circular muscle fibers and extend the myotomy distally [Fig. 22.5k]. Full-thickness myotomy or splaying of the thin, outer longitudinal muscle fibers is common, especially around the EGJ. The myotomy should be extended 2–3 cm distal to the EGJ onto the gastric cardia. After the myotomy, after assuring hemostasis in the tunnel, irrigation is performed with dilute bacitracin solution.

A variety of intraoperative techniques have been described to evaluate for adequacy of myotomy in relieving esophageal outflow obstruction at the level of the EGJ. These range from purely subjective, based on laparoscopic inspection or ease of passage of the endoscope during EGD post-myotomy, to quantitative but time-consuming, in the case of intraoperative manometry. Several centers in the US employ the EndoFLIP device, described earlier, for intraoperative assessment of myotomy adequacy as measured by an increase in EGJ distensibility index and obtaining a Schatzki diameter of at least 12 mm [19].

Closure of Mucosotomy

The mucosotomy is closed with approximately 5–10 endoscopic clips depending on the size of the mucosotomy. We routinely use Resolution 360™ (Boston Scientific,

Marlborough, MA) clips given the 1:1 torque ratio that helps facilitate precise placement [Fig. 22.5l]. Care should be taken to ensure the eversion of the mucosal edges during clip placement. Alternative closure methods have been described utilizing proprietary endoscopic suturing devices such as the OverStitch or X-Tack (Apollo Endosurgery, Austin, TX, USA) to allow a running closure of longer mucosotomy defects.

Troubleshooting

Retained Debris

It is relatively common to find extensive debris and food particles during the initial diagnostic endoscopy of a POEM. Typically, standard irrigation and suction via the endoscope are enough to clear the esophagus. However, if large debris persists, the use of an endoscopic over-tube (Guardus® Overtube, STERIS, Mentor, OH) can stabilize access to the esophagus and permit multiple passes of the endoscope for foreign body removal [Fig. 22.6]. Additionally, we have found the Roth Net® standard retriever (STERIS, Mentor, OH) useful in snaring large food debris [Fig. 22.7]. Rarely, the procedure has to be aborted and rescheduled because the debris burden is too great.

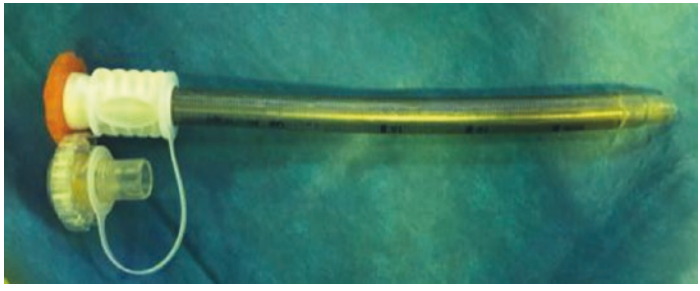

FIGURE 22.6 Guardus® Overtube-Esophageal (STERIS, Mentor, OH)

FIGURE 22.7 Roth Net® Standard Retriever (STERIS, Mentor, OH)

Avoiding Complications

Implications of COVID-19 Pandemic

The COVID-19 pandemic has created unique challenges to surgical endoscopy. However, surgical endoscopy can and has been safely performed since the onset of the pandemic. Current surgical guidelines recommend mandatory testing of all patients within 24–48 h of their planned surgery and are screened for any high-risk symptoms or contacts on the day of surgery. Any patient with a positive test or symptom screen should be rescheduled and advised to quarantine per local guidelines. Given that upper endoscopy is a high-risk, aerosolizing procedure, it is recommended that the operating surgeon and assistants wear personal protective equipment that consists of, at minimum, N95 respirator mask, protective eyewear/shield, surgical gown and hat, surgical gloves, and shoe covers regardless of the patient's COVID-19 status [24]. Care should be taken to don and doff PPE appropriately. The anesthesiology team should take similar care during intubation and extubation.

Aspiration

Pre-operative dietary restriction to clear liquids in preparation for the procedure and use of a rapid-sequence intubation protocol by the anesthesia team (limited pre-oxygenation/bag-masking) can help minimize the risk of aspiration during induction. If needed, awake fiberoptic intubation in the upright position can be utilized in extra high-risk patients.

Capnothorax

Given the frequency of full-thickness myotomy or splaying of the outer, longitudinal muscle fibers, the development of unilateral or bilateral capnothorax and capnoperitoneum is common [7]. No data supports routine postoperative chest radiographs, assuming CO_2 is utilized for insufflation in place of air. Capnothorax progressing to tension physiology or hemodynamic compromise is exceedingly rare. Still, the instruments should be available and staff capable of performing an emergent needle or tube thoracostomy if needed. Self-limited subcutaneous emphysema is also common with expected resolution within 24 h post-operatively. In addition, roughly 50% of POEM cases are accompanied by the development of some degree of capnoperitoneum secondary to CO_2 tracking from the mediastinum or full-thickness gastric myotomy [7]. Care should be taken to distinguish capnoperitoneum (diffuse abdominal distension) from an over-insufflated stomach (isolated epigastric fullness). Capnoperitoneum accompanied by hemodynamic instability or impaired ventilation is an indication for decompression with a Veress needle (typically in the left upper quadrant, just inferior to the costal margin) or laparoscopic port. While not necessarily a complication, the relative frequency with which insufflation-related events are encountered highlights the necessity of utilizing CO_2 insufflation during POEM.

Bleeding

Based on the global POEM experience to date, bleeding, if it occurs, is most commonly encountered during dissection across and distal to the EGJ. As previously discussed, even mild hypertension will compound the bleeding risk inherent to the increased vascularity in the submucosal space of the EGJ and gastric cardia. Mild bleeding can typically be controlled with the application of monopolar electrocautery. Brisker bleeding, or unavoidable division of larger bridging vessels, should be approached with coagulation forceps. Submucosal tunnel bleeding that obscures endoscopic visualization can occasionally be temporized by removal of the endoscope from the tunnel and application of direct pressure with the scope or cap from the esophageal lumen for 10–20 min. Alternative techniques include hemostatic clip application and judicious injection of dilute epinephrine. Case reports have suggested the option of utilizing tamponade devices such as Sengstaken-Blakemore, Minnesota, or Linton Tubes (All Bard Medical) to staunch brisk bleeding. Given the disastrous consequences of this in the setting of a partial or full-thickness myotomy, these high-pressure balloons should not be considered as part of the endoscopic armamentarium when approaching bleeding during the POEM procedure. Additionally, it is recommended that the use of postoperative ketorolac (Toradol) be limited.

Full-Thickness Perforation

Entry into the mediastinum at the level of the mucosotomy, either during initial access of the submucosal space or subsequently, should prompt close attention to mucosal closure technique, including consideration of alternative methods of closure such as endoscopic suturing [25] or utilization of larger clips. Blunt dissection of the submucosal space has

been described in animal models and human case series to expedite tunnel creation and decrease procedure duration. This technique is associated with increased rates of inadvertent mucosotomy, particularly in the area just proximal to the EGJ, where relative tethering of the mucosa can occur and predispose the proximal tissue to perforation when approached blindly. Significant mucosal defects that occur before myotomy creation should prompt consideration of aborting the procedure and/or attempting submucosal tunnel and myotomy in an alternate position on the esophagus (i.e., posterolateral). Small mucosal defects and those that occur during or after myotomy should be closed from the lumenal side with endoscopic clips or sutures. Note that mucosal injuries, especially in the region of the EGJ can lead to the development of strictures and recurrent dysphagia.

Postoperative Care

Patients are extubated in the operating room and transferred to the post-anesthesia care unit (PACU) after the case. During the initial recovery phase in the PACU, patients are given standing intravenous anti-emetics and analgesia as needed. Once the patient is sufficiently recovered from anesthesia and not experiencing chest pain, fever, or tachycardia, sips of clear liquids are initiated. In the absence of concerning symptoms or signs that suggest leak, patients are given a tray of clear liquids and advanced to a full liquid diet as tolerated. Discharge typically occurs in the afternoon of the first postoperative day (POD#1). Select patients may discharge on the same day provided sufficient recovery has occurred and the patient is tolerating a full liquid diet without adverse effects. Patients are discharged on twice-daily proton-pump inhibitors that are continued until physiologic testing is performed at 6 months to assess for the presence or degree of gastroesophageal reflux. Many centers advocate routine imaging (water-soluble or thin barium esophagram) on POD#1, with some centers performing second-look EGD before diet ini-

tiation or hospital discharge [7]. During our initial experience, the postoperative care pathway included obtaining a POD#1 esophagram, but the lack of impact on patient management and low leak rate has led to the abandonment of asymptomatic screening of all patients post-operatively. There are descriptions of postoperative computed tomography scans of the chest being routinely obtained; however, following the same logic that led to the abandonment of routine esophagram use, there is no clear evidence to support the cost or radiation exposure associated with routine screening CT scans.

Follow-Up

Patients should be seen 2–6 weeks post-operatively to evaluate treatment response and detect potential early failures. In the absence of recurrent symptoms, full physiologic testing with TBE, HRM, EndoFLIP, and pH-impedance is postponed until the 6-month follow-up appointment. TBE, in particular, has been shown to have significant prognostic value following pneumatic dilation in detecting patients with symptomatic relief that are at increased risk for early treatment failure [26]. Patients are seen again at 1 year and then annually for life, completing validated questionnaires and intermittent physiologic testing to track long-term outcomes. Long-term follow-up protocols can also incorporate routine or symptom-triggered screening for esophageal malignancy.

Review of Existing Literature

Efficacy

Studies addressing short-term outcomes for POEM have consistently demonstrated excellent results. Meta-analysis on existing short-term POEM outcomes found that 82–100% (mean of 90%) of patients reported symptomatic improve-

ment [27]. The IPOEMS reported an overall treatment success of 98% at a mean follow-up of 9.3 months, with 40% of patients having failed prior treatments [7]. Additionally, Teitelbaum et al. reported sustained symptom relief in 83% of their patients who underwent POEM to treat achalasia without the need for reoperation at the 5-year follow-up mark [28]. This is the longest follow-up series to date and demonstrates that POEM can result in durable long-term symptom relief with outcomes equivalent to, if not superior to, LHM or PD. Given that no prospective, randomized trials directly comparing POEM to LHM have been published, further research in this area is warranted.

Rates of GERD

Richards et al. demonstrated in 2004 that in the absence of a concurrent fundoplication, complete division of the lower esophageal sphincter and gastric sling fibers during Heller's cardiomyotomy results in debilitating reflux [29]. Neither Partial nor complete fundoplication is performed following POEM, and concern has been raised regarding the potential for higher long-term rates of GERD. While long-term data is forthcoming, based on visualization of erosive esophagitis on EGD or abnormal pH studies during short-term follow-up (<1 year), the estimated prevalence of GERD following POEM may be in the range of 20–46% [7]. Comparable rates have been reported in patients undergoing LHM with anterior (Dor) fundoplication in multicenter, prospective, randomized trials [30, 31]. Similar to the argument put forth by proponents of anterior (Dor) fundoplication, the lack of posterior mediastinal dissection and preservation of the phreno-esophageal ligament during POEM may mitigate the absence of a surgical anti-reflux barrier. Preservation of the angle of His may also contribute to the anatomic anti-reflux barrier when the 1–2 o'clock position is used for myotomy during POEM, as the natural course of the esophagus (clockwise rotation and right-to-left sweep) favors dissection onto the lesser curve and division of the clasp fibers with the maintenance of the sling fibers.

Conclusion

POEM is a safe and effective procedure for the treatment of achalasia and other esophageal dysmotility disorders. Combining the efficiency of endoscopy with the effectiveness of surgical myotomy, POEM offers the advantage of shorter recovery, less hospitalization, and a wider patient demographic while maintaining excellent short-term outcomes with durable long-term results.

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