Technical Modifications for Motility Disorders: Dimensions of Dissection

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Introduction

Achalasia is an uncommon esophageal motility disorder defined as incomplete LES relaxation and aperistalsis of the esophageal body without a structural explanation (e.g., tumor, stricture) for these abnormalities [1]. The patients often present with dysphagia to solids and liquids. Symptoms may also include chest pain, heart burn, and regurgitation. There is no curative treatment that reverses the pathophysiology of achalasia and therefore treatment is geared towards optimizing the passage of solids and liquids through the gastroesophageal junction (GEJ.) [2]. Treatment options for achalasia traditionally involve both endoscopic and surgical options. Endoscopic options include injection of botulinum toxin to the GEJ and endoscopic balloon dilation [3]. Laparoscopic Heller myotomy (LHM) with partial fundoplication is the surgical gold standard for achalasia [4]. Campos et al. [3] performed a meta-analysis to look at treatment success of achalasia using 105 articles reporting on 7855 patients. Botox injections have a reported initial success in 78.7% of patients, but over time this percentage has declined to 40.6% of patients at 12 months, which correlates with the temporary effects of botox. Balloon dilation improved symptoms in 84.8% of patients at 1 month; however, by 1 year, only 58.4% of patients continued to have symptomatic improvement. Additionally, 25% of patients required repeat pneumatic balloon dilation. Treatment success with laparoscopic Heller myotomy was the highest with 89.3% of patients reporting improvement in symptoms. These patients continued to have relief at 1- and 2-year follow-up.

Peroral endoscopic myotomy (POEM) was introduced as an alternative treatment for achalasia in 2008. POEM emerged as a natural orifice transluminal endoscopic surgery (NOTES) procedure for the treatment of achalasia from a modification

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of endoscopic submucosal dissection for treatment of esophageal masses [5]. In 2007, Pasricha et al. [6] first described a novel approach for the endoscopic treatment of achalasia by creation of a submucosal tunnel followed by myotomy of the circular muscle of the lower esophageal sphincter in a porcine model. In 2008, Inoue et al. [7] performed the first successful POEM procedure in a human patient; then went on to report the first case series in 2010. Since this time, several studies have shown its efficacy and safety. Recently, several large studies have been published which confirm safety and efficacy [8–11]. In a recent meta-analysis, outcomes between POEM and laparoscopic Heller myotomy (LHM) are comparable with respect to complications, incidence of Gastroesophageal reflux, symptomatic recurrence rates, and other short-term outcomes [12], validating its use as an alternative to the current gold standard LHM.

Preoperative Evaluation

The preoperative work up of patients with achalasia is important for characterizing the disease, ruling out the presence of pseudoachalasia and to evaluate the anatomy of the esophagus and GEJ prior to surgical intervention [13, 14]. Once there is clinical suspicion for a diagnosis of achalasia, work up must include esophagogastroduodenoscopy (EGD), Barium swallow study, and manometry. The EGD is important to evaluate the esophageal anatomy and to ensure that there is no obstructive process such as a tumor near the GEJ which would lead to pseudoachalasia. Hallmarks on barium swallow include a dilated esophagus with a bird's beak appearance of the GEJ [15]. It is important, however, to recognize that the barium swallow will vary based on the type of achalasia. Manometry is the hallmark diagnostic study used to confirm failure of LES relaxation and aperistalsis of the esophageal body [16]. The Chicago classification then uses manometric measurement to classify achalasia into three subtypes, which will be discussed in the next section (Fig. 6.1).

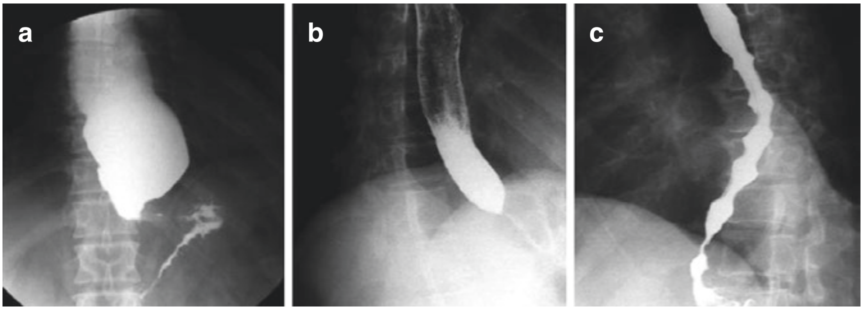

Fig. 6.1 Barium esophagram demonstrating each type of achalasia. Type 1 achalasia (**a**) with dilated esophagus and bird's beak appearance at the lower esophageal sphincter (LES). Type II achalasia (**b**) with non-dilated esophagus but narrowing at the LES. Type III achalasia (**c**) with corkscrew appearance from spasm in the esophageal body [17]

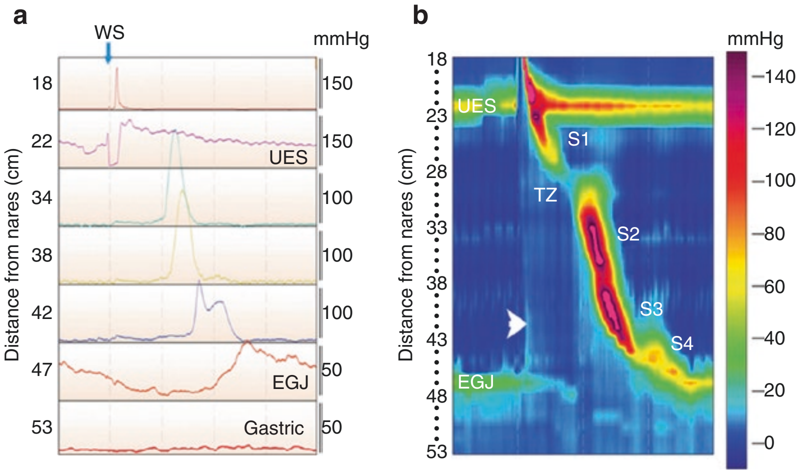

Fig. 6.2 Comparing conventional recordings of manometric pressure with the Clouse plot or esophageal pressure topography (EPT). Conventional manometry tracings came from catheters made with pressure sensors spaced at relatively wide intervals, usually at 3- to 5-cm. (**a**) Is a representation of conventional manometric recordings. (**b**) Is a representation of the widely adopted Clouse plot [20]

Manometry

While EGD and barium swallow are mandatory for the work up of achalasia, manometry is the gold standard diagnostic test [16]. Providers must have a thorough working knowledge of manometry in order to diagnose achalasia, classify patients according to the Chicago classification, and differentiate achalasia from other motility disorders such as diffuse esophageal spasm and jackhammer esophagus [18].

Manometry became possible in 1970s when Wyle Jerry Dodds and Ron Arndorger developed the first high-fidelity manometry system. In the 1990s, Ray Clouse and his colleagues developed high-resolution manometry (HRM) which included several modifications allowing for capture of the motor function from the upper esophageal sphincter (UES) and the lower esophageal sphincter (LES) simultaneously with each swallow, giving us a complete spatial and temporal depiction of the esophageal motor function for the first time. HMR manometry also converts the pressure data to a topographical plot providing a pictoral representation of pressure waves called esophageal pressure topography (EPT) [19]. Colors are assigned to pressures, with high pressures represented by warmer colors (reds and yellows) and low pressures by cool colors (blues and greens) (Fig. 6.2).

High-Resolution Manometry Analysis

Analysis of HRM starts by noting the pressures of the upper and lower esophageal sphincters at rest. Then the pressure waves are analyzed during ten wet swallows taking note of three important characteristics: (1) The function of the lower esophageal sphincters during bolus transit, (2) Peristaltic integrity of the esophageal body, and (3) Distinguishing pressure patterns [1].

In order to evaluate the resting characteristics of the esophageal sphincters, a 30-s period during which no swallow occurs must be observed. The upper and lower esophageal sphincters are identified as zones of higher pressure depicted on the EPT as horizontal bands of color, as seen in Fig. 6.3. The location of the LES relative to the pressure inversion point (PIP) can indicate the presence of a hiatal hernia.

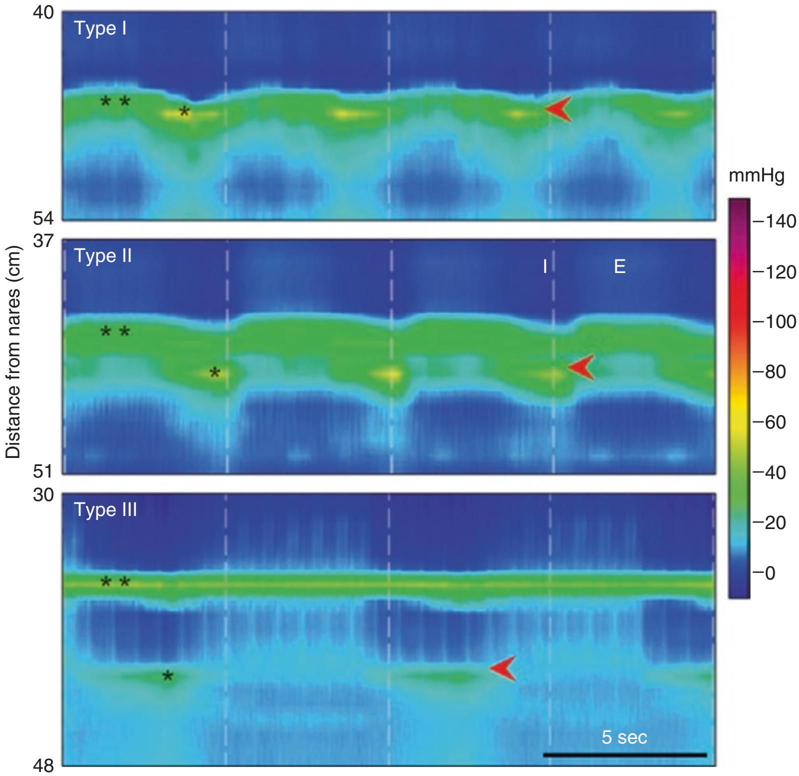

Fig. 6.3 Pressures recorded from the esophagogastric junction (EGJ) are a composite of tonic lower esophageal sphincter (LES) contraction (*double asterisks*) and cyclical crural diaphragm contraction with inspiration (*asterisk*). During inspiration, pressure decreases in the thoracic cavity, and during expiration it increases. The opposite is true in the abdominal cavity. The point at which pressure across the EGJ during inspiration becomes negative relative to intra-abdominal pressure is called the respiratory or pressure inversion point (PIP). It indicates the location of the crural diaphragm. The *red arrowhead* denotes the location of the PIP. The *top panel* is an example of a normal (Type I) EGJ in which the LES and crural diaphragm are coincident. In the *middle panel,* there is a small spatial separation (<2 cm) of the diaphragm from the LES, indicating a small hiatal hernia (Type II EGJ). In the *bottom panel,* there is a large spatial separation (>2 cm) between the crural diaphragm and LES, indicating the presence of a large hiatal hernia (Type III EGJ). *I* inspiration, *E* expiration [20]

The PIP identifies where the diaphragm separates the chest from the abdomen and usually is found close to the LES. Spatial separation of the LES and PIP in the EPT indicates a hiatal hernia [20].

Next, the manometry is evaluated during a series of at least ten wet swallows (5 mL water) to observe the function of the lower esophageal sphincter (LES). The integrated residual pressure (IRP) is a tool developed to measure the resistance to bolus movement across the EGJ. IRP greater than 15 mmHg indicates outflow obstruction at the GEJ, which can be due to achalasia or mechanical obstructions such as neoplasms or strictures [21]. Differentiation between achalasia and mechanical obstruction is determined by non-peristaltic esophageal pressurization patterns which indicate achalasia [1].

The peristaltic integrity is determined by the 20 mmHg isobaric contour line. It is a black line drawn around all parts of the EPT where the pressure is 20 mmHg. This threshold value of 20 mmHg is chosen because this is the peristaltic pressure required for normal bolus transit when the EGJ is functioning normally [1]. Peristaltic integrity is assessed by measuring gaps in the 20 mmHg contour line along the length of the esophagus.

The third step in analyzing EPT is to determine if there is a pressurization pattern. Pressurization is recognized as isobaric pressure along varying lengths of esophagus. It indicates bolus entrapment. Once all the swallows are analyzed with the tools described above, the data are used in the Chicago classification to make a diagnosis (Table 6.1).

Table 6.1 Esophageal pressure topography metrics utilized in the Chicago classification [16]

Pressure topography metrics	
Metric	Description
Integrated relaxation pressure (mmHg)	Mean EGJ pressure measured with an electronic equivalent of a sleeve sensor for four contiguous or non-contiguous seconds of relaxation in the 10-s window following deglutitive UES relaxation
Distal contractile integral (mmHg s cm)	Amplitude × duration × length (mmHg s cm) of the distal esophageal contraction >20 mmHg from proximal (P) to distal (D) pressure troughs
Contractile deceleration point [(CDP) (time, position)]	The inflection point along the 30 mmHg isobaric contour where propagation velocity slows demarcating the tubular esophagus from the phrenic ampulla
Contractile front velocity (cm s^{-1})	Slope of the tangent approximating the 30 mmHg isobaric contour between P and the CDP
Distal latency (s)	Interval between UES relaxation and the CDP
Peristaltic breaks (cm)	Gaps in the 20 mmHg isobaric contour of the peristaltic contraction between the UES and EGJ, measured in axial length

All pressures referenced to atmospheric pressure except the integrated relaxation pressure (IRP), which is referenced to gastric pressure

The Chicago Classification

The Chicago classification was derived using the ManoScan™ (Sierra Scientific Instruments, Los Angeles, CA, USA) HMR system. It is important to note that measurements may vary based on HMR transducer used. The Chicago classification is indicated to classify primary motility disorders. It is not intended for post-surgical patients as procedures such as the lap band, fundoplication, and even balloon dilation alter manometry characteristics [16]. The Chicago classification uses five main metrics to classify motility disorders: (1) The integrated relaxation pressure (IRP), (2) Distal Latency (DL), (3) contractile deceleration point (CDP), (4) Peristaltic Breaks, and (5) Distal contractile Integral (DCI) [21]

1. The integrated relaxation pressure is a tool to measure the resistance to bolus movement across the EGJ. The HMR catheter is positioned to straddle the LES and measure pressures over a 6 cm segment. It calculates the maximum pressure along the 6 cm segment at each time point within a 10-s window. The 4-s IRP algorithm takes these pressures and averages the lowest pressures of any 4 s within the 10-s timeframe [21]. IRP greater than 15 mmHg indicates outflow obstruction at the GEJ [1].
2. Distal latency is a measurement of the time from start of swallow-induced UES opening to time of arrival of the esophageal contraction to the contractile deceleration point [21]. The lower limit of normal is 4.5 s.
3. The contractile deceleration point is defined as the inflection point along the 20 mmHg isobaric contour line where the propagation velocity slows demarcating the time at which esophageal peristalsis terminates and the LES begins.
4. Peristaltic breaks are gaps in the 20 mmHg isobaric contour of the peristaltic contraction between the UES and GEJ. According to the Chicago classification, small defects measure 2–5 cm and large defects are >5 cm [1]
5. Distal Contractile Integral is used to measure the robustness of peristaltic contraction in the smooth muscle esophagus. The DCI integrates pressure, distance, and time along the esophagus to describe the mean contractile amplitude of the small bowel esophagus, the length over which the contraction propagates, and the duration of the contraction. DCI >8000 is seen in symptomatic patients (Fig. 6.4).

The Chicago Classification can help classify esophageal motor abnormalities into four general groupings: Achalasia, esophageal outlet obstruction, abnormalities of esophageal motor function, and boarder line abnormalities, which are usually seen in asymptomatic patients.

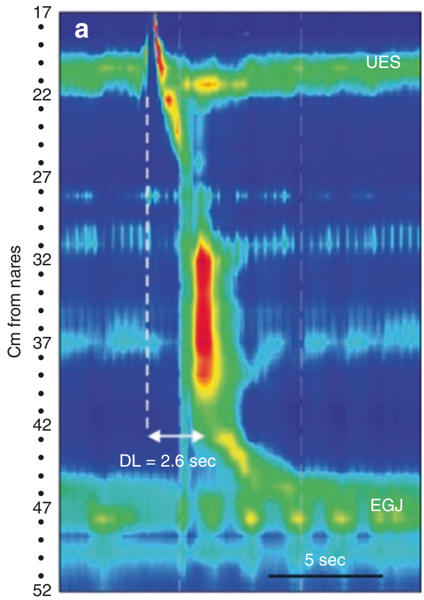

Fig. 6.4 Evaluation of peristalsis with the distal latency and contraction front velocity. (**a**) Distal esophageal spasm is characterized by normal lower esophageal sphincter relaxation and a short distal latency (<4.5 s). It is the arrival of the swallow-induced contraction in the distal esophagus too rapidly, producing a simultaneous contraction [20]

Achalasia

Achalasia is defined by failure of normal peristalsis and inadequate lower esophageal sphincter relaxation (integrated residual pressure (IRP) greater than normal 15 mmHg). This disorder is then subclassified into three subtypes based on analysis of esophageal pressure patterns, defined by the Chicago classification [21]. All types have failure of LES relaxation (IRP >15 mmHg), but have different pressurization patterns. Type I achalasia has no appreciable motor activity, type II is characterized by abnormal peristalsis with pan-esophageal pressurization following at least 20% of wet swallows, and type III exhibits premature spastic contractions with at least 20% of wet swallows [1]. The EPT patterns are shown in figure below. These subtypes account for the variability seen on barium swallow studies demonstrating the different pattern of achalasia as seen in Fig. 6.1 (Fig. 6.5).

It has been shown that patients with achalasia have different responses to therapy depending on their subtype. Type II is the strongest predictor of treatment response and type III is a negative predictor of response [1]. In the study by Pandolfino et al., type 1 patients underwent a mean number of 1.6 therapeutic interventions (botox, pneumatic dilation, or laparoscopic Heller myotomy) during a mean follow-up

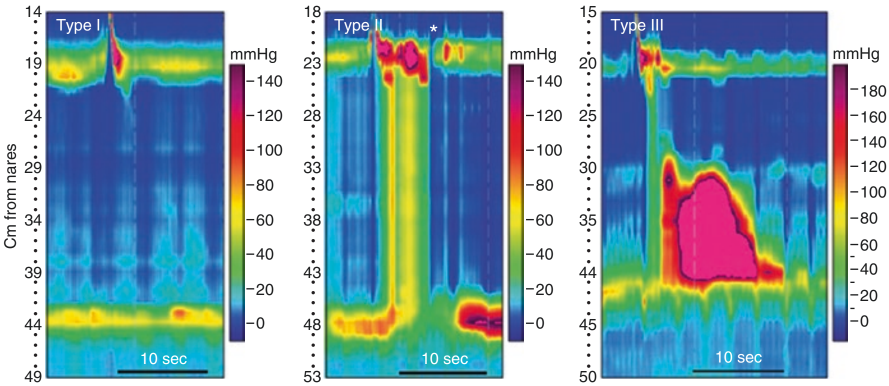

Fig. 6.5 Type I achalasia has no appreciable motor activity, type II is characterized by abnormal peristalsis with pan-esophageal pressurization following at least 20% of wet swallows, and type III exhibits premature spastic contractions with at least 20% of wet swallows [20]

period of 19 months and experienced a response rate of 56% after most recent therapy. Interestingly, these patients did significantly better with LHM than balloon dilation or botox. Type II patients underwent an average of 1.2 interventions during a mean follow-up of 20 months and had an excellent response to all three interventions with 96% success. Type III patients had the worst response to therapy despite having significantly greater number of therapeutic interventions during a mean follow-up period of 20 months. These patients had a 29% response rate. Although POEM was not available and therefore not included in this study, we can extrapolate that type I and type II achalasia patients may have better results than type III to POEM as well.

Outflow Obstruction

It is just as important to determine what is not achalasia as it is to recognize achalasia on manometry. Esophageal junction outflow obstruction is characterized by failed or incomplete opening of the EGJ, but is distinguished from achalasia by retained peristalsis in the smooth muscle esophagus [1]. Pressurization of the esophagus occurs due to the entrapment of the swallowed bolus between unyielding EGJ and peristaltic contractions. This pattern of manometry should trigger further evaluation with endoscopy to look for mechanical obstruction. When no mechanical obstruction is found, this EPT pattern might indicate a variant of achalasia, which often responds to achalasia treatment [1].

Esophageal Motor Dysfunctions

Diffuse esophageal spasm is an uncommon motor dysfunction characterized by at least 20% of wet swallows producing a short Distal Latency (DL) <4.5 s with

Table 6.2 The Chicago classification of esophageal motility [16]

Diagnosis	Diagnostic criteria
Achalasia	
Type I achalasia	Classic achalasia: mean IRP > upper limit of normal, 100% failed peristalsis
Type II achalasia	Achalasia with esophageal compression: mean IRP > upper limit of normal, no normal peristalsis, pan-esophageal pressurization with ≥20% of swallows
Type III achalasia	Mean IRP > upper limit of normal, no normal peristalsis, preserved fragments of distal peristalsis or premature (spastic) contractions with ≥20% of swallows
EGJ output obstruction	Mean IRP > upper limit of normal, some instances of intact peristalsis or weak peristalsis with small breaks such that the criteria for achalasia are not met
Motility disorders	[Patterns not observed in normal individuals]
Distal esophageal spasm	Normal mean IRP, ≥20% premature contractions
Hypercontractile esophagus (Jackhammer esophagus)	At least one swallow DCI > 8000 mmHg s cm with single peaked or multipeaked contraction

normal IRP. A short DL indicates early arrival of the esophageal contraction to the distal esophagus depicting spasm [1]. This differs from type III achalasia where the DL is also low but the IRP is high.

Hypertensive LES can overlap with other motility disorders, but the hallmark is LES pressures greater than 35 mmHg and failure or relaxation below IRP of 15 mmHg. This leads to a degree of outflow obstruction which can lead to high distal esophageal pressures or even spasms [22].

Nutcracker Esophagus is characterized by prolonged, hypertensive contractions in the context of normal propagation of the swallow waveform. DCI is over 5000 and the pressure wave shows vigorous contractions, with normal DL and IRB [22].

Jackhammer esophagus is represented by high mean contraction amplitude of the smooth muscle esophagus over the length the contraction propagates. This is measured by Distal contractile integral (DCI). DCI >8000 represents symptomatic contractile strength or jackhammer esophagus. DCI <5000 is associated with asymptomatic controls [21] (Table 6.2).

POEM Technique

Indications for POEM were initially limited to achalasia type I and II [7]; however, since then modifications of the technique have been described which allow its use for extended indications, which will be discussed in the next section. Inuoe et al. describe POEM using a mucosotomy at the 2 o'clock (anterior) position and performing the myotomy through the circular muscle layer leaving the longitudinal muscle layer intact [7]. Several centers now favor the 5 o'clock (posterior) position with a full thickness myotomy which includes the longitudinal muscle [23, 24].

POEM can be broken down into eight steps: (1) Submucosal injection is performed with saline stained with indigo carmine, (2) Mucosotomy is performed along the right anterior wall of the esophagus in the 2 o'clock position (anterior myotomy), (3) Submucosal dissection is performed with hybrid knife or triangle-tip knife, (4) Submucosal tunnel is extended into the gastric cardia and a completed submucosal tunnel is seen, (5) Myotomy is initiated 2–4 cm below the site of mucosotomy, (6) LES myotomy is performed, (7) Complete full thickness myotomy is seen on withdrawal of the endoscope, and (8) Mucosotomy closed with endoscopic clips [13].

POEM is performed under general anesthesia with the patient in the supine position. The specifics will be described based on the author's technique, which is consistent with anterior, circular muscle myotomy described by Inoue [7] and is currently the most favored technique among providers [25]. Specific modifications for situations such as achalasia type III, sigmoid esophagus, and diffuse esophageal spasm will be discussed in detail later in the chapter.

Mapping EGD

Using a high-definition upper endoscope (GIF-180, Olympus, Tokyo, Japan), an initial mapping esophagogastroscopy is performed. CO_2 is used for insufflation. The GEJ is identified and the distance from the top of the gastric folds to the incisors is recorded. The anterior and posterior orientations are defined using fluid meniscus, which will be posterior in the supine position and abdominal palpation.

Dissection of the Submucosal Tunnel

Once the mapping EGD is completed and orientation is confirmed, the endoscope is introduced with a transparent distal cap (M1-I 588, Olympus) fitted at its distal tip. An anterior location inside the esophageal lumen 10 cm above the GEJ and at the 2 o'clock position is chosen for initiation of the submucosal tunnel. Injection of normal saline mixed with indigo carmine into the submucosal space at the selected location is used to lift the mucosa away from the deeper muscular layers. An endoscopic injection needle (Carr-Locke 711811, US endoscopy, USA) is used for this injection (step1). A 2-cm mucosotomy is then made on the elevated mucosal cushion with a triangle-tip knife (KD-640L, Olympus), using electrocoagulation (ERBE, Tubingen, Germany) (Step 2). Once access to the submucosal space is achieved, the endoscope is advanced into the submucosal plane and dissected caudally to create a tunnel (step 3). Cautery and repeated injections of the saline mixture can be used to help define the planes and develop the tunnel. The tunnel is extended distally until the tip of the scope reaches 2 cm beyond the distance measured at the GEJ. The anterior orientation of the tunnel at the 2 o'clock position is confirmed by withdrawing the scope out of the submucosal tunnel and advancing through the lumen to the stomach. Using the retroflexed view presence of the blue-stained mucosa extending onto the lesser curvature confirms adequate length of the myotomy (step 4).

Myotomy and Closure

Now that the length and location of the submucosal tunnel are confirmed, the scope is reinserted into the tunnel to perform the myotomy. The circular muscle fibers are identified and selectively incised using the triangle-tip knife, beginning 6–8 cm above the GEJ (step 5). The myotomy is extended distally 2 cm below the GEJ. The muscle fibers are hooked and pulled into the distal cap to avoid injury to deeper issue (step 6). Once the myotomy is completed, the scope is once again inserted through the lumen to evaluate the immediate effects of the myotomy (step 7). The esophageal mucosal incision is then closed using endoscopic clips (HX-201LR--135.A, Olympus) (step 8) [26] (Figs. 6.6 and 6.7).

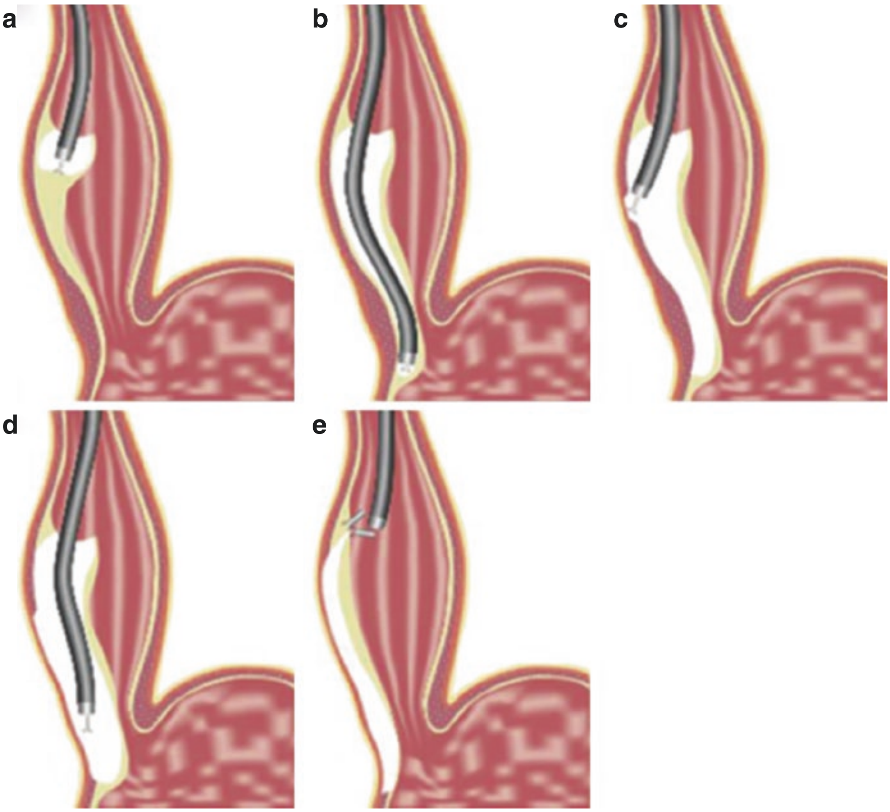

Fig. 6.6 Per oral endoscopic myotomy technique (S.N. Stavropoulos, Winthrop University Hospital, 2012). (**a**) Submucosal injection, and mucosal entry. (**b**) Creation of the submucosal tunnel. (**c**) Esophageal myotomy. (**d**) Lower esophageal sphincter and gastric cardia myotomy. (**e**) Closure of the mucosal incision

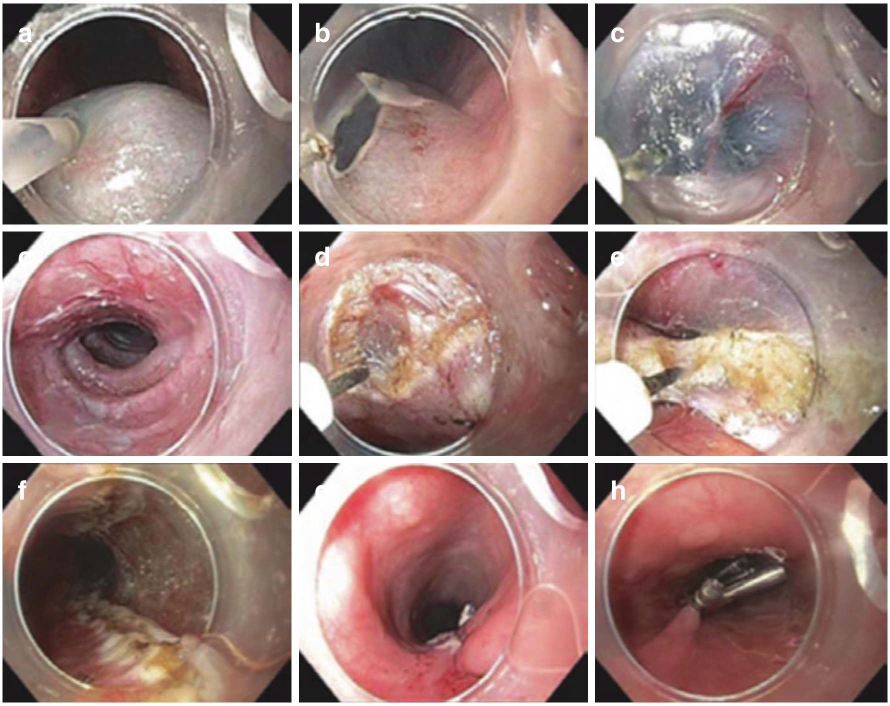

Fig. 6.7 Per oral endoscopic myotomy endoscopic steps. (**a**) Submucosal injection is performed with saline stained with indigo carmine. (**b**) Mucosotomy is performed along the right anterior wall of the esophagus in the 5 o'clock orientation. (**c**) Submucosal dissection is performed with hybrid knife. (**d**) Submucosal tunnel is extended into the gastric cardia and a completed submucosal tunnel is seen. (**e**) Myotomy is initiated 2 cm below the site of mucosotomy. (**f**) LES myotomy is performed. (**g**) Complete full thickness myotomy is seen on withdrawal of the endoscope. (**h**) Mucosotomy closed with an endoscopic suturing device. (**i**) Mucosotomy closed with endoscopic clips [13]

EndoFLIP

At the end of the procedure, the surgeon is able to immediately assess the adequacy and completeness of the myotomy by passing the endoscopic through the GEJ at the end of the procedure [27]. However, endoscopic measurements of adequate myotomy are subjective, often imprecise and may be affected by biases [28]. Some groups have looked at the use of EndoFLIP (Endoluminal Functional Lumen Imaging Probe) system to try to objectively confirm the adequacy of the myotomy [29, 30]. The EndoFLIP system (Crospon LTD. Galway, Ireland) uses impedance planimetry for real-time measurements of the EGJ diameter, through a specific balloon-tipped catheter [30]. According to these studies, EndoFLIP was found to be potentially useful during LHM, but no real benefit was proved in POEM Cases [29, 30]. It was thought to be confusing, time-consuming, troublesome, and costly.

Extended Criteria

The initial indications for POEM include the treatment of classic achalasia as described first by Inoue in 2010 [7]. However, due to the safety profile in his first five patients, he extended the criteria to include sigmoid esophagus. Since this time, there is data to support the use of POEM for the treatment of hypertensive motor disorders such as diffuse esophageal spasm and type III spastic achalasia, end-stage achalasia with sigmoid esophagus, patients after failed conventional treatments, children, and obese patients. Treating patients with these extended indications may require modification to the POEM procedure to tailor it to the specific condition.

Hypertensive Motor Disorders

Hypertensive motor disorders including diffuse esophageal spasm, hypertensive LES, Type III spastic achalasia, nutcracker esophagus, and jackhammer esophagus are rare, accounting for approximately 2% of all motility disorders [31]. These patients tend to present with both chest pain and dysphagia with chest pain as the prominent symptom rather than dysphagia [32], the prominent symptom of classic achalasia. In the international POEM survey, 11 of the 16 participating centers reported performing POEM for these extended manometric indications, accounting for 28% of the POEMs performed [25].

Diffuse esophageal spasm is differentiated from type III spastic achalasia on manometry by IRP greater or less than 15 mmHg. Both disorders have premature distal contractions (DL <4.5 s) [1]. Patients with both type III achalasia and DES have a longer LES [32]. As far back as 1960, it has been recognized that the best results after myotomy were achieved if the surgical myotomy was extended to the upper limit of the motility disorder [33–35]. For this reason, there was experimentation with thoracic approaches to achieve adequate length of myotomy [4, 18]. Due to the ease of creating a longer myotomy, POEM is thought to have an advantage over LHM in treating these diseases [36, 37]. Treatment of DES and type III achalasia with POEM should therefore include a longer myotomy (12–20 cm long) as the diseased segment is usually longer than that in classic achalasia [38]. Type III achalasia and DES are reported to respond worse to POEM, even when a longer myotomy is done, compared to patients with classic type I/II achalasia [9]. However, several sources report successful treatment of both conditions with 93% of patients having clinical improvement based on Eckardt scores [37, 39, 40], which is better than 70–85% success in this population with LHM [40].

The initial treatments for patients with nutcracker esophagus are with medications that target esophageal muscle relaxation such as calcium channel blockers (diltiazem) or nitrates in combination with acid suppression. Tricyclic antidepressants, specifically amitriptyline or imipramine, are also used. Botox injections and balloon dilations can also have some success, but need to be repeated [41]. Surgery has classically been reserved for patients who fail medical management. Interestingly, patients with hypertensive LES and nutcracker esophagus have the same or better reported outcomes than patients with classic achalasia when treated with POEM [25, 42].

Patients with Jackhammer esophagus have the least optimal results, with 70% of patients improving with POEM [31]. These patients also require a long myotomy, and although the worst responders, the majority of patients still have symptomatic relief with POEM [43].

In conclusion, POEM should be considered when treating patients with hypertensive motor disorders. The length of the myotomy should be tailored based on manometry, endoscopy, and upper GI studies to encompass the entire diseased portion of the esophagus [35]. POEM may have an advantage over LHM as greater length of myotomy is achievable in POEM.

End-Stage Achalasia

End-stage achalasia includes patients with severe sigmoid esophagus and mega-esophagus (diameter > 8 cm). Most published series exclude these patients as it is considered a relative contraindication. Inoue originally excluded sigmoid esophagus, but then included it as long as it was not considered severe [7]. Traditionally, esophagectomy has been recommended as primary treatment for sigmoid-type achalasia as it was believed that myotomy will not improve emptying [44, 45]. However, esophagectomy for sigmoid esophagus is associated with significant morbidity and mortality [46]. There are several studies that have demonstrated success with treatment of sigmoid esophagus with LHM and the morbidity and mortality profile is much less severe [4]. Therefore, LHM is gaining support as the primary surgical option. Adhesions after surgical intervention with LHM, however, can make subsequent esophagectomy more difficult. POEM does not "burn any bridges" as it results in minimal adhesions. Therefore, it could be considered as an initial treatment in these patients instead of LHM, with esophagectomy reserved for those with inadequate clinical response [2].

Hu et al. [47] reported on a series of 32 consecutive patients with end-stage achalasia treated with POEM. The patients were subdivided based on descriptions by Inoue et al. [7] into sigmoid type I (S1) and sigmoid type II (S2) achalasia. They are subdivided based on tortuosity seen on CT scan. In S1, the esophagus is significantly dilated and tortuous, but only a single lumen is seen on CT scan. In S2, the esophagus is very dilated and severely tortuous with U-turns in a proximal direction resulting in a double lumen identified on CT scan (Fig. 6.8).

The degree of dilation was also determined and classified into three grades according to maximum diameter of the esophageal lumen on barium swallow or CT scan: Grade 1 (<3.5 cm), grade II (3.5–6 cm), and grade III (>6 cm) [47]. In this case series, 29 patients had S1 and 3 patients had S2 type achalasia. Submucosal

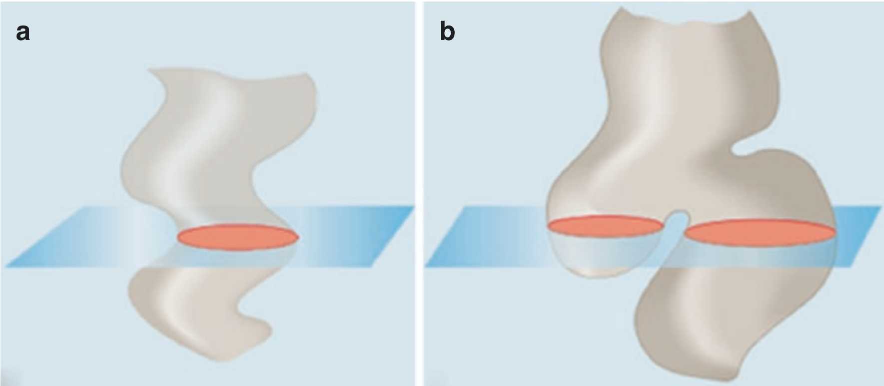

Fig. 6.8 Subclassification of sigmoid-form achalasia. (**a**) Sigmoid type I (S1): the esophagus is significantly dilated and tortuous, but only a single lumen is seen on any computed tomography (CT) slice. (**b**) Sigmoid type II (S2). The esophagus is very dilated and tortuous and some CT slices show a double lumen

tunneling was described as difficult and time-consuming in these patients as it was hard to maintain the direction of the submucosal tunnel. A posterior myotomy is recommended for this reason as the spine can be used as a steady landmark and allows for a lesser degree of tortuosity. A standard length myotomy (average 10 cm) was made and there was a preference for full myotomy dividing both circular and longitudinal muscle fibers as it was felt to give superior results.

Lv et al. [48] reported a series of 23 patients, 19 with S1 type achalasia and 4 with S2 type achalasia. All 23 patients were treated with a 7–10 cm full thickness posterior myotomy. An additional modification was made by starting the myotomy 0–1 cm below the mucosotomy instead of 2–3 cm below in order to shorten the distance needed to travel in the challenging submucosal plane. Treatment success defined as postoperative Eckardt score of three or less was achieved in 95% of patients. A change in the morphology of the esophagus was reported in a majority of patients which included curvature straightening and diameter reduction. The major complication was subcutaneous emphysema or capnomediastinum which was self-resolving in all but one case which required deflation via subcutaneous puncture.

In summary, end-stage achalasia is challenging to treat with POEM and may include longer OR times, but when done successfully, has shown safety and efficacy. A posterior myotomy is recommended as this may lead to the straightest submucosal tunnel. A full thickness myotomy may allow for better results; however, there is no reported study to show that a circular muscle myotomy is an inferior approach. A shorter distance between mucosotomy and start of myotomy may allow for a shorter submucosal tunnel. There is more experience with S1 type achalasia than S2 type achalasia, which may present even more challenging anatomy to navigate. POEM in sigmoid-type achalasia should be attempted with caution and only by experienced providers (Fig. 6.9).

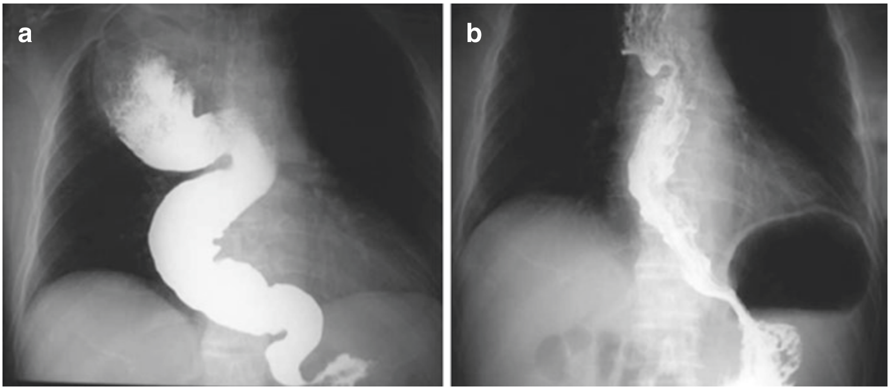

Fig. 6.9 Pretreatment and posttreatment barium esophagogram. (**a**) Before POEM, esophagogram indicated type S2 achalasia with a typical beak sign and U-turn. (**b**) The shape of the esophagus improved after POEM and the passage of the contrast agent was remarkably improved. *POEM* peroral endoscopic myotomy [48]

Previous Endoscopic and Surgical Interventions

Traditional treatment for esophageal motility disorders ranges from endoscopic botox injection or balloon dilation to laparoscopic or open surgical myotomies. The success rate of pneumatic dilation and surgical myotomy for treatment of achalasia is comparable at 90%; however, 10–20% of patients will go on to have recurrent symptoms due to treatment failure or disease progression [3]. The treatment option for failure after endoscopic treatment is currently surgical myotomy [49]; however, treatment after failed surgical myotomy is controversial and includes pneumatic balloon dilation [50], re-do myotomy [51], and esophagectomy [52]. Experience shows that performing a re-do Heller myotomy in the setting of previous endoscopic therapy or surgical myotomy proves to be technically challenging and associated with higher complication rates and conversion to open surgery [53–55]. Submucosal fibrosis is a common consequence of balloon dilation and botox injection and can make subsequent dissection difficult. As a result, mucosal perforation is not uncommon during Heller myotomy after endoscopic procedures. In addition, intraoperative and postoperative complications have been reported to be twofold or higher after previous Heller myotomy [56, 57]. As POEM becomes more common, it is important to understand how it prevails in situations of recurrent symptoms after previous interventions. We will discuss several studies that looked specifically at safety and outcomes of POEM after previous surgical or endoscopic interventions.

The first study conducted by Orenstein et al. [58] is an evaluation of a database collected prospectively of POEM procedures performed by two surgeons at a single institution between 2011 and 2013. Forty patients received a POEM procedure, of which 16 patients (40%) had prior interventions. Six had prior Botox injections, four had balloon dilations, three had both Botox and dilations, and three received prior laparoscopic Heller myotomy (two with Dor fundoplication). Anterior POEM at the 12 or 2 o'clock position was performed for all patients in the prior intervention group. This study showed no significant difference between the current therapy and the previous therapy group with respect to operative time, perioperative complications, or treatment success.

Sharata et al. [42] looked specifically at patients with prior endoscopic treatment. Twelve patients with previous endoscopic intervention were compared to 28 patients with no previous intervention between 2010 and 2012. Again, this study showed no difference in operative time, perioperative complications, or symptomatic relief. Modifications from the standard anterior POEM was not mentioned in either of these studies. However, it has been suggested that, for patients with prior Heller myotomy, the submucosal tunnel should be made at the 5 o'clock position (posterior myotomy), thus avoiding area of maximal scarring during POEM [24, 57, 59].

In summary, POEM is safe and leads to comparable outcomes as traditional interventions for patients with recurrent symptoms after failed endoscopic and surgical treatments and therefore should be added to the armamentarium for treating these patients. Considering modification to a posterior myotomy is recommended.

POEM in the Pediatric Population

Currently, treatments for pediatric achalasia can be endoscopic or surgical. Endoscopic treatments are unlikely to provide long-lasting resolution of symptoms, with most patients relapsing warranting repeated procedures and inevitably necessitating surgical myotomy [60]. It has been suggested that young age is an independent negative predictive factor for successful clinical outcome after balloon dilation [61]. LHM is therefore the treatment of choice in the pediatric population.

Chen et al. [62] report on a series of POEM done in 27 pediatric patients. The technique used was almost identical to that used in adults; however, due to the shorter physiologic length of the esophagus, sometimes a shorter myotomy length is made (5–7 cm) ensuring at least 2 cm onto the cardia. The group preferred the posterior full thickness myotomy; however, anterior, circular muscle myotomy has also been successful [63, 64]. Nineteen percent of these patients had mucosal perforations requiring clipping during the procedure, which did not result in any adverse outcomes. GERD was a significant concern with 19% having symptomatic GERD, which does not differ significantly from that seen with patients treated with LHM [65].

In conclusion, myotomy is safe and effective in children as young as 3 years old [64]. Due to shorter esophageal physiology, a shorter myotomy (5–7 cm) may be required. GERD is a critical concern in these patients and must be monitored closely.

POEM in the Obese Population

Achalasia in the morbidly obese population is rare (incidence 1%) [66] and there is not much reported experience in treating these patients since most studies to date exclude patients with BMI >40. Successful treatment of achalasia in a patient with a history of roux-en-y gastric bypass using the standard anterior, circular muscle myotomy has been described [67]. It will take more experience with POEM in this population to fully understand its efficacy.

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