Per-oral endoscopic myotomy, 1000 cases later: pearls, pitfalls, and practical considerations

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Background and Aims: Eight years have passed since the introduction of the per-oral endoscopy myotomy (POEM) procedure. POEM was initially received as an investigational procedure, but since the revelation of promising safety and efficacy data, it is becoming the preferred treatment for achalasia. With the recent completion of our 1000th POEM procedure, we share our experience and knowledge through the discussion of clinical pearls, pitfalls, and practical considerations.

Methods: The various aspects of the procedure and conditions that warrant special attention are discussed from our perspective, with a focus on areas in which there is currently limited evidence.

Results: The key points on patient position, submucosal tunneling, myotomy, closure, intraprocedural bleeding, and advanced sigmoid achalasia are presented.

Conclusions: The dissemination of this information serves as a foundation for new POEM operators and as a catalyst for more-experienced operators to further refine and advance their POEM skills and stimulate international discourse and collaboration. (Gastrointest Endosc 2016;84:330-8.)

The first per-oral endoscopic myotomy (POEM) was performed in 2008. Since then, thousands of POEMs have successfully been performed worldwide.1 With the completion of our 1000th POEM procedure, we share our experience and describe the various clinical pearls, pitfalls, and practical considerations. The dissemination of this information will aid in the advancement, understanding, and quality performance of the POEM procedure. The various aspects of the procedure and conditions that warrant special attention are discussed with a focus on the issues for which there is limited evidence.

ACCESSORIES AND ELECTROSURGICAL SETTINGS

Various endoscopic accessories are used during POEM, and the choice of endoscopic knife and distal attachment typically depends on the endoscopist’s expertise and preference. At our center, the ST Hood Short-type (Fujifilm, Tokyo, Japan), which has been shown to decrease procedure time by quicker entry into the submucosal space, is the distal attachment of choice. The Triangle tip knife (Olympus Medical Systems, Tokyo, Japan) is the preferred needle-knife.2 Recently, the water-jet-assisted Triangle tip knife, which has also demonstrated decreased procedure time, has been used.3 With respect to the electrosurgical unit setting used for the mucosal incision, we suggest using a cut setting with minimal coagulation effect to reduce thermal damage to the mucosa. This is to maximize the mucosal and epithelial integrity and allow for an easier closure at the end of the procedure. Using minimal coagulation current also decreases desiccation of the submucosal injection, maintains maximum cushion during the incision, and facilitates easier entry into the submucosal space. For POEM, the electrosurgical settings used with the Erbe 300D are mucosal incision: Endocut I (ERBE, Tübingen, Germany), effect 1, duration 1, and interval 3; submucosal tunneling: spray coagulation effect 2 and watts 50; and hemostasis with coagulation forceps: soft coagulation effect 5 and watts 80.

PATIENT POSITION

Currently, no evidence supports placing the patient in either the left lateral or supine position for the POEM procedure. From our experience, placing the patient in
the supine position is preferred because as the esophagus becomes severely dilated in achalasia, the proximal segment initially deviates to the right and subsequently deviates back to the midline at the gastroesophageal junction (GEJ). In advanced sigmoid achalasia (sigmoid type 2), there are many acute angulations before reaching the GEJ. In the left lateral position, the severity of the angulations is greater because of the lateral exertion of gravity, which is in the same plane of the angulations, and this can increase the technical difficulty of submucosal tunneling and subsequent myotomy (see Advanced Sigmoid Achalasia, below). Furthermore, with the patient in the left lateral position, compression of the GEJ by the liver is accentuated and further increases the technical difficulty of GEJ tunneling and myotomy. Conversely, with the patient in the supine position, the force of gravity is perpendicular to the plane of the angulations, ergo, the acuity of these angulations is not increased and is potentially lessened. In addition, with the patient in the supine position for the posterior 5 o’clock myotomy (our standard position), the scope shaft and tip lie in the neutral position. This minimizes the tension transferred to the mucosal flap, reducing inadvertent extension of the incision from excessive tension from the endoscope shaft. One limitation of working with the patient in the supine position for the posterior myotomy is the potential for fluid pooling posteriorly, which can obscure the working field or inhibit the application of spray coagulation. Therefore, judicious irrigation and gentle targeted suction is important while working with the patient in the supine position.

LANDMARKS

Before the first cut, luminal landmarks should be identified: upper esophageal sphincter, spine, trachea, left main bronchus, aortic arch, and lower esophageal sphincter (LES) (Fig. 1). These landmarks help to orient the operator to the esophageal walls relative to the GEJ, stomach, mediastinal and peritoneal structures; serve as a guide along the appropriate path; and provide cues to the adjacent mediastinal/peritoneal structures.

INJECTION AND MUCOSAL INCISION

Approximately 10 mL of solution is used for the initial submucosal injection to produce a large cushion, thereby promoting a safe mucosal incision. After submucosal injection, the operator should reorient him- or herself before making an incision by repeated advancement, withdrawal, and reidentification of the landmarks to ensure the incision is performed in the desired location. If the operator is not cognizant of the potential for luminal distortion and disorientation after submucosal injection, the mucosal incision may be significantly deviated from the intended location and result in potential damage to adjacent mediastinal/peritoneal structures.

The choice of injectate for routine (no previous treatment, nonsigmoid, normal mucosa) cases has no significant clinical impact and should be based on the institutional practice, cost, and availability. Because multiple injections are performed with tunnel progression, the
use of expensive solutions with increased retention generally has minimal benefit, especially in cases involving minimal fibrosis. However, where moderate to severe fibrosis is encountered, submucosal injectate with increased viscosity may be of benefit by increasing retention in the fibrotic submucosa.

Currently, we use a saline solution–dextrose mixture with indigo carmine. Indigo carmine is not absorbed and highlights surface topography, which optimizes delineation of submucosa and muscle planes that is fundamental to the POEM procedure. Epinephrine is not included in our injection solution because it does not produce a clinical benefit, and detrimental cardiopulmonary sequelae and mucosal ischemia have been reported.

A spray-tip catheter is used for the submucosal injection within the submucosal tunnel, and a needle-tip injection catheter is used only for the initial submucosal injection before mucosal incision (Fig. 2). This is to prevent bleeding by inadvertent vessel puncture within the tunnel, which can occur with the use of a needle-tip catheter and is prevented with use of the spray-tip catheter.

SUBMUCOSAL TUNNELING

Esophageal

Attentiveness to the orientation of the circular muscle bundles is critical. The orientation of the muscle bundles must be maintained perpendicular to the endoscope to avoid deviation from the intended site of the esophageal and GEJ myotomy. By maintaining the perpendicular orientation of the muscle bundles and symmetric lateral margins, the operator can be confident that the tunnel is progressing in the intended direction (Fig. 3). If one side starts to “lag” behind the other, the submucosal dissection should be advanced in that direction to restore the perpendicular orientation. For example, if the tunnel is drifting to the right, then muscle bundles will run obliquely and appear to run from proximal left to distal right. Therefore, the operator would advance the dissection on the left side.

Gastroesophageal junction

At the GEJ the tunnel becomes tighter, and it is important to maintain enough space to allow safe passage through to the gastric side and ensure sufficient working space during the myotomy. With the presence of fibrosis, the circular muscle bundles can adhere to the submucosa, and if this is not recognized the tunnel may progress into the intermuscular space (Fig. 4D and E) and result in an incomplete myotomy. With recognition of muscle splitting, repeated injections above the muscle should be performed to push the muscle fibers away from the mucosa and allow the dissection to resume in the proper submucosal plane (Fig. 4A-C, F). If this is not possible because of severe fibrosis, then the adherent muscle fibers must be cut with extreme care to prevent mucosal perforation. The muscle should be hooked and pulled away from the mucosa before applying the current. The Hook knife (Olympus Medical Systems) is a particularly useful tool in this situation. At the GEJ there are often accessory longitudinal muscles encountered that can make orientation more difficult to recognize and maintain. In these circumstances, repeated withdrawal and examination of the proximal tunnel should be performed to reorient the operator and confirm the tunnel is advancing correctly.

MYOTOMY

Esophageal myotomy

The techniques used to perform a selective myotomy vary depending on the position of the mucosal incision and endoscopic orientation. When the muscle layer is at the 12 o’clock and the mucosa at the 6 o’clock position (generally for anterior myotomy), acute tip angulation is required to hook the circular muscle layer. In contrast, when the muscle is kept at the 6 o’clock position (generally for posterior myotomy, which is our current practice), much less tip angulation is required and there is less “fling” of the knife (Fig. 5).

LES and gastric myotomy

The circular and longitudinal muscle in this area is typically thinner than in the hypertrophied proximal
circular muscle, and there is increased fat in the connective tissue, which makes muscle planes more difficult to discern. In addition, because of the nature of the pathology of achalasia, the working space is often limited, resulting in close approximation of the muscle layer and contralateral mucosa. Therefore, a slow and meticulous myotomy with prophylactic injection into the overlying mucosa is the safest approach if there is concern of thermal damage to the contralateral mucosa because of limited working space. If the operator is unsure whether the correct muscular layer has been reached, indigo carmine can be sprayed on the muscular surface to identify the muscle bundle orientation. In addition, application of a conical endoscopic hood (e.g., ST Hood Short-type) maximizes tension.

Figure 3. Recognition and correction of tunnel shifting. The dotted line indicates the muscle–submucosa interface. A, Tunnel progressing straight (green arrows) in correct orientation. B, Tunnel shifting excessively to the right. To correct for the shift, the left side should be dissected (green arrows) until fibers are perpendicular to the endoscope. C, Tunnel shifting excessively to the left. To correct for shift, the right side should be dissected (green arrows) until fibers are perpendicular to the scope.

Figure 4. Early splitting of the circular muscle fibers during tunnel formation. A, Recognition of early splitting of circular muscle fibers. B, Injection above the muscle into submucosa. C, Expansion of submucosa, pushing the circular muscle away from the mucosa and preventing dissection into intermuscular space. D, A case with fibrosis with entry into the intermuscular space during tunneling. E, After coagulation of the perforating artery, the submucosa was carefully dissected to restore the correct plane of dissection (note poor delineation of tissue planes with fibrosis). F, Recovery of correct plane of submucosal tunnel.
on the submucosal tissue, which minimizes the thermal energy required for dissection, thereby preventing damage to the overlying mucosa. If the circular muscle layer cannot be selectively hooked with the Triangle tip knife because of muscle thinness, lack of working space, and/or fear of knife “fling” toward the contralateral mucosa, the myotomy can be safely performed with spray coagulation (with reduced effect/watts) applied in short, focused, and controlled pulses in an en-face manner.

To ensure an adequate length of the gastric myotomy, the transillumination technique using a second ultra-slim gastroscope is a valuable, safe, and reliable technique. After the myotomy is completed, the ultra-slim gastroscope is advanced into either the tunnel or the gastric lumen and the adult gastroscope is inserted in the other lumen. The length of the gastric myotomy can be clearly visualized by using transillumination and gentle movements of the scope in the tunnel (Fig. 6). We recently published a randomized control trial of 100 patients demonstrating the safety and benefits of this technique.6 We believe this technique is the most reliable method to confirm the length of the gastric myotomy, and it should be routinely used, if available.

**CLOSURE**

The importance of precise symmetric clip deployment, particularly of the first clip, should be emphasized because it is a crucial step for a safe and successful POEM procedure. The first clip should be placed just at or slightly beyond the distal margin of the mucosal incision with the 2 prongs grasping an equal amount of tissue on either side of the defect, creating a symmetric fold (Fig. 7). With subsequent clips the transparent hood is placed under the preceding clip and gently lifted, further opposing the mucosal edges and allowing a simpler symmetric clip deployment. With the correct deployment of the first clip, the vast majority of mucosal incisions can be completely sealed with 4 to 6 clips. If the first clip veers off-center, this creates an asymmetric fold, which can be challenging to correct with subsequent clips. If the asymmetric fold is not corrected with the subsequent 1 to 2 clips, this can lead to pocket formation and will become increasingly more difficult to correct and can require over 10 clips for closure. The resulting pocket may also lead to subsequent adverse events. This was demonstrated in a series by Li et al after which asymmetric closure resulted in pocket formation, leading to submucosal tunnel infection and rupture of the incision site. The site was eventually sealed with fibrin sealant, and healed 5 days later. Therefore, if the initial asymmetric application of a clip is not corrected with the subsequent 1 to 2 clips, it is often safer and simpler to remove the incorrectly applied clips with a grasping device and redeploy the clips symmetrically.

** SUCTION**

With a distal attachment, the effect of suction on mucosa and submucosa is intensified. Care should be taken to avoid vigorously suctioning the submucosa or mucosa. This point often needs to be emphasized to trainees learning POEM because previous experience with typical luminal endoscopy would have been forgiving to liberal suctioning because it is less delicate than submucosal endoscopy. Excessive suctioning can result in bleeding by shearing of the submucosal vessels or cause hematomas and mucosal lacerations when applied in the submucosal tunnel or overlying mucosal surface, respectively. Gentle and judicious use of suctioning and avoidance of submucosal tissue/overlying tunnel mucosa entrapment should be duly noted because it is a subtle yet important aspect in the minimization of adverse events.

**BLEEDING**

In the submucosal tunnel, maneuverability and space are limited, and brisk bleeding can easily obscure the working space. Maintaining a clear working space is critical because the accumulation of blood and heme staining of the submucosal fibers will lead to charring and poor visibility, predisposing to further vessel dissection, bleeding, and mucosal injury after application of electrosurgical current. During bleeding in the tunnel, pulsed irrigation, gentle suction, and tamponading of the bleeding site allows visibility to be regained (Fig. 8). With careful maneuvers the
vessel can then be precisely coagulated by placing the bleeding point within reach of coagulation forceps. Bleeding within the tunnel on the mucosal side should only be managed by coagulation forceps with grasping, gentle retraction, and soft coagulation to prevent thermal damage to the overlying mucosa. Li et al reported 3 cases of severe delayed bleeding in which Blakemore-Sengstaken tubes were used with both gastric and esophageal balloons inflated. Application of the Blakemore-Sengstaken tube, if used after a completed myotomy, should be conducted with extreme caution because there is no significant barrier preventing

Figure 6. Transillumination method demonstrating the position of the distal myotomy. A, Ultra-slim gastroscope in the tunnel and regular gastroscope in the stomach. B, Regular gastroscope in the tunnel and ultra-slim gastroscope in the stomach.

Figure 7. Closure of the mucosal entry site. A, Asymmetric deployment of the first clip. B, Result of excessive tissue captured on the left, creating a problematic tissue fold. To correct for this, the next clip should grasp more tissue on the right side. C, Correct symmetric deployment of first clip. D, Equal-sized tissue fold on either side of clip, allowing easy symmetric application of the subsequent clip.
continued bleeding into the mediastinum/peritoneum. As such, we have not adopted this technique and do not advocate the use of the Blakemore-Sengstaken tube.

ADVANCED SIGMOID ACHALASIA

With advanced sigmoid achalasia, the esophagus can be tortuous, both distally and proximally. Because of the severe dilation, the spine and trachea indentations on the esophagus are also exaggerated, which can make maneuvering the endoscope more difficult, particularly in the proximal esophagus. In advanced disease, the thoracic esophagus tends to deviate to the right, only to shift back over to the midline at the GEJ. This phenomenon should be taken into account because it can render luminal landmarks less reliable. In addition, while creating the submucosal tunnel, acute angulations in the esophageal body may be mistaken for the GEJ. If the operator is not experienced and fails to correctly advance into the stomach because of misinterpreting an angulation for the GEJ, the result will be a failed POEM procedure. In addition, these advanced cases may have stasis/candida esophagitis, resulting in submucosal fibrosis that can severely impair tissue plane delineation and effectiveness of submucosal injection. This may pose an increased risk of mucosal perforation because of decreased submucosal cushioning or tunneling into the intermuscular space, leaving circular muscle adherent to the mucosal side uncut. If there is the presence of esophageal candidiasis, this should be eradicated with an antifungal agent before performing POEM.

Particular caution is required during the mucosal incision because with fibrosis there is decreased vertical elevation after the initial submucosal injection and if the mucosal incision is performed hastily, a full-thickness incision into the mediastinum may result. This reinforces a common theme in POEM and in all advanced endoscopic procedures: every millimeter of movement must be deliberate and meticulously controlled. With advanced sigmoid achalasia there is also neovascularization, resulting in increased density and caliber of vessels encountered during the procedure, leading to an increased risk of intraprocedural bleeding. In addition, the mucosa can be significantly thickened, leading to challenging closure of the mucosal incision. Indeed, most cases that have reported the use of alternative closure methods, such as fully covered stents, over-the-scope clips, and endoloops with clips, have involved advanced sigmoid achalasia. Thus, for these
reasons cases of advanced sigmoid achalasia should only be performed by highly experienced operators.

LES IN OTHER SPASTIC MOTILITY DISORDERS

In jackhammer esophagus and diffuse esophageal spasm, currently no evidence addresses whether the LES should be preserved or cut if it is not involved in the abnormal motility. Our view is that the LES should be included in the myotomy. The progression of diffuse esophageal spasm and hypercontractile esophagus to achalasia has been previously reported.8,9 If the LES is not included in the myotomy and there is subsequent progression to achalasia, the patient will develop symptoms and require additional treatment. In addition, patients with diffuse esophageal spasm and hypercontractile esophagus generally require longer myotomies. As a result of extended myotomies, there can be a significantly diminished contraction vigor, resulting in ineffective esophageal motility. In some patients the remaining propulsive force is inadequate to push the food bolus across the preserved LES. Although there is a significant risk for the development of reflux after POEM, there are no reports of reflux refractory to PPI and only 1 report of a peptic stricture.1,10

The importance of including the LES has also been demonstrated in a case report by Badillo et al11 in which a 50-year-old woman received a POEM (at another center) for jackhammer esophagus, and her symptoms worsened after the procedure. She subsequently presented with worsening chest pain and dysphagia, and a barium swallow demonstrated an 8-cm anterolateral distal esophageal diverticulum and a tight GEJ. The technical details of the POEM performed were not available, but the immediate postprocedure worsening of symptoms strongly suggest that the LES was not included in the myotomy. We too had a similar experience, albeit less dramatic, with a patient with jackhammer esophagus whose main symptom was chest pain. The LES was not abnormal on manometry and thus was not included in the POEM. Subsequently, he developed dysphagia and regurgitation. A second POEM was performed that included the LES, and the patient’s symptoms completely resolved. Subsequently, we have performed POEM in 5 other patients with jackhammer esophagus, all with the LES included, with excellent clinical results. Thus, it appears that the risk of clinically severe adverse events from reflux as result of LES myotomy are minimal, whereas the risks associated with LES preservation are substantial.

LEARNING CURVE

The learning curve for endoscopic procedures and, in particular, new procedures such as POEM, is an area of debate. For typical procedures such as colonoscopy, older recommendations have stated that 100 procedures were required to achieve competence.12 However, further comprehensive analysis that included defined performance metrics and validated competency thresholds deemed that an average of 275 procedures were required to achieve competence. In recent years there has been a paradigm shift toward evaluation based on achievement of definable metrics rather than a finite number of procedures.13

In a prospective series of the first 40 cases of POEM, 2 metrics were examined: length of procedure and mucosal perforation.14 It was demonstrated that the variability of minutes per centimeter of myotomy and incidence of mucosal perforation plateaued at approximately 20 cases. Based on these early data, the number of cases required for an experienced endoscopist to reach competency in POEM was estimated to be 20. Subsequently, in a retrospective series, the length of procedure and numerous patient and procedural variables were analyzed to define a learning curve. When the procedural and patient variables were considered, the mean length of procedure plateaued after 60 cases. Therefore, it was concluded that relative mastery in POEM was reached after approximately 60 cases.15 Prospective studies are needed to define the specific cognitive and motor skills and accompanying curriculum required to demonstrate competency.

At our center, trainees typically undergo an observer/assistant period of 4 to 6 months to gain cognitive skills involved in the procedure, learn to set up the room, troubleshoot equipment, and function as the primary assistant to the operator. Under supervision by an experienced operator (H.I.), the trainee transitions to submucosal tunneling toward the GEJ. Once that skill has been mastered, the trainee subsequently proceeds to completing the entire tunnel and beginning the myotomy under close proctorship. Thereafter, the trainee graduates to performing the entire POEM procedure for simple cases and subsequently more difficult cases.

CONCLUSION

Since the introduction of POEM as an investigational procedure, it has thrived and gained acceptance throughout the world as a treatment for achalasia and other spastic esophageal motility disorders. We hope the dissemination of the information gained from our experience and reflection serves as a foundation and catalyst to further refine and advance POEM and stimulate international discourse and collaboration.

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