Achalasia is a rare disorder of the esophagus that results in aperistalsis and incomplete, or failed, relaxation of the lower esophageal sphincter (LES) muscle (1). The treatments for achalasia consist of disruption of the LES muscle fibers, relieving the outflow obstruction, which include laparoscopic Heller myotomy (LHM), per-oral endoscopic myotomy (POEM), pneumatic dilation, and temporary relief using botulinum toxin injection (2). It has been shown that LHM and pneumatic dilation have similar outcomes at 2 years with regard to symptom relief (3, 4), but meta-analyses and systematic reviews favor LHM as the procedure of choice for its superior response rates long term (5–7). The introduction of POEM has provided another option for management of achalasia; with POEM, an endoscopic submucosal tunnel is created in the wall of the esophagus to access the LES muscle fibers without making incisions for laparoscopic instruments. The endoscopic approach to the LES muscle fibers was originally characterized with a full thickness endoscopic exit of the lumen (8), but was refined with a submucosal tunnel to prevent full thickness leak in a porcine model (9). Inuoe et al had the first successful treatment for clinical application published in 2010 (10). POEM has become a reasonable option for patients because of its minimal pain scores (11), sparing use of narcotics (11), ability to create longer myotomies (12), versatility with other disorders such as jackhammer esophagus (12), and ability to be repeated for recurrence of symptoms (13), and it has become the treatment of choice in some centers (2). Despite the robust data supporting POEM’s long-term use to treat achalasia (14–18), early experience integrating this procedure into clinical practice needs to be carefully monitored to ensure adequate results (19) and must take into account the learning curve (16, 20, 21). We report here our early experience integrating POEM into clinical practice, comparing its outcomes to those of LHM.

METHODS

A prospectively gathered, and institutional review board approved, registry for achalasia patients at Baylor University Medical Center at Dallas was queried. A total of 48 patients were enrolled in the database from September 2014 to February 2017. Twenty-two patients were eliminated from the study. Of these, 12 patients were pending surgery, 4 patients were lost to follow-up, and 6 patients were screen failures. The remaining 26 patients underwent operative treatment. Thirteen patients underwent POEM, but only 12 patients had surgery for achalasia. One patient was a screen failure for jackhammer esophagus, not achalasia. Thirteen patients underwent LHM, but only 11 patients were available for follow-up. Inclusion criteria for the study included patients with a preoperative Eckardt score, at least one postoperative visit with an Eckardt score, and completion of either LHM or POEM. Each category of surgery was further divided into primary surgery for achalasia and redo surgery. In the POEM category, one patient had a prior LHM, and in the LHM category, three patients had a prior LHM (Figure 1).

Data on patient characteristics were collected, including gender, age, body mass index, LES basal pressure, LES residual pressures with failure to relax. Procedure length and hospital length of stay were similar between the two groups. There were three adverse events in each group, but none altered the patient’s postoperative clinical course. Eckardt scores, used to assess success of the surgery, were 82% for POEM patients and 66% for LHM patients after 6 months. The outcomes for POEM and LHM in our early experience are similar to those reported in the literature for high-volume centers managing achalasia.
pressure, percentage of patients with aperistalsis, and type of achalasia based on Chicago classification. Data on the operations included length of procedure and hospital length of stay. Adverse events were noted as any event that was a deviation from the normal expected course. Eckardt scores were collected preoperatively and postoperatively. The postoperative collection was done at an interval of immediately after surgery (<1 month) and long-term follow up (>6 months). The Eckardt score is a validated scoring system to grade symptoms of achalasia patients on a scale of 0 to 12. There are four components: regurgitation, chest pain, dysphagia, and weight loss. The first three receive a score of 0 for none, 1 for occasionally, 2 for daily, and 3 for each meal. Weight loss receives a score of 0 for no weight loss, 1 for <5 lb, 2 for 5–10 lb, and 3 for >10 lb (22). Success of myotomy is based on a total Eckardt score of ≤3 at follow-up (23). Information on all complications for the procedures was also collected. There were no definite criteria to determine the surgical intervention for each patient. Most patients were offered POEM and LHM and were allowed to choose. However, in some cases insurance reimbursement prevented POEM and patients defaulted to LHM. The redo LHM cohort was not offered POEM because their recurrent symptoms appeared to possibly be related to the fundoplication on preoperative workup as well as inadequate myotomy.

We compared characteristics and outcomes of patients who underwent POEM versus LHM using independent sample t test, Wilcoxon two-sample test, and Fisher's exact test. Paired t test was used to assess changes in Eckardt score between preoperative and postoperative data within procedure groups. Statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC). Two-tailed P values < 0.05 were considered statistically significant.

The per-oral endoscopic myotomy procedure

The patient is taken to the operating room in a supine position to undergo endotracheal intubation and general anesthesia. A bite block is placed in the patient’s mouth, and the endoscope is used to remove any bezoar in the esophagus or stomach. An overtube is used. Once in place, the overtube is secured in place at the mouth and will be used to measure the anatomic landmarks. The high pressure zone is identified and recorded at the distal esophagus outlining the hypertensive LES. Two centimeters is then added to each end of the high pressure zone to encompass the length of the myotomy, usually around 6 cm. Four centimeters is then added to the proximal margin of the myotomy to identify the level of the mucosotomy. A solution of diluted methylene blue is created containing saline, epinephrine, and methylene blue. Two milliliters of concentrated methylene blue is loaded into an endoscopic needle injector, followed by the dilute solution. The endoscope is then passed down the esophagus to the stomach and, on retroflexion, 2 mL of concentrated methylene blue is injected in the submucosa on the lesser curvature of the stomach 2 cm from the LES. This will act to mark the distal extent of the myotomy so it can be seen in the submucosal tunnel. The endoscope is then withdrawn and a dissecting cap is placed on the end of the endoscope. It is passed down the esophagus, and a 10 mL injection of dilute methylene blue solution is injected into the submucosal plane at the previously obtained mucosotomy measurement contiguous with the lesser curvature of the stomach along the right side of the esophagus. The injection serves to separate the mucosa from the circular muscle as the fluid collects in the submucosa.

A triangle tip knife is used to incise the mucosa at the level of the planned mucosotomy. The endoscope and cap enter the submucosal plane through the mucosotomy; a 3 mL biliary balloon dilator can be used to assist. Using cautery on the triangle tip knife, a submucosal tunnel is created separating the submucosa from the circular muscle down to the concentrated methylene blue mark in the submucosa on the stomach side of the LES. Cautery is then used to cut the circular muscle fibers, exposing the longitudinal fibers the length of the predetermined myotomy length. The endoscope is then removed from the submucosal plane and hemoclips are used to close the mucosotomy.

In instances of capnoperitoneum and respiratory alterations reported by anesthesia personnel, a Veress needle is used to decompress the peritoneal insufflation. The CO₂ insufflation will

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**Figure 1.** Patients enrolled in the achalasia registry. POEM indicates per-oral endoscopic myotomy; LHM, laparoscopic Heller myotomy.
cross the thin remaining longitudinal muscle layer to enter the peritoneal cavity below the phrenoesophageal ligament when making the myotomy. Patients can get significant subcutaneous emphysema for the same reason above the phrenoesophageal ligament. Because CO₂ is used, this will dissipate in the early postoperative phase.

The patient is admitted postoperatively and undergoes an esophagram the following morning, where leak and passage of contrast through the LES is assessed. A liquid diet is started after the esophagram is cleared and the patient is discharged. The patient undergoes another esophagram 1 week later to assess for a healed mucosotomy, and the diet is advanced as tolerated. The patient follows up 3 to 4 weeks postoperatively and at 6 to 12 months. Eckardt scores are taken at both follow-up visits.

The laparoscopic Heller myotomy procedure

The patient is taken to the operating room and placed in supine position with a footboard in place. Laparoscopic access is obtained with a liver retractor elevating the left lobe of the liver. In the primary surgery group, the gastrohepatic ligament is incised to expose the lesser sac. The caudate lobe is identified and the gastrohepatic ligament is taken down following the edge of the caudate lobe until the right crus is seen. The anterior phrenoesophageal ligament is incised to access the mediastinum. The anterior vagus nerve is identified and preserved. The mediastinal dissection is done only to the extent of the gastrohepatic junction outflow obstruction. The mean procedure time was shorter in the POEM group, at 136 minutes compared with 154 minutes in the LHM group. The postoperative length of stay was a mean of 1.6 days for the POEM group and 2.0 days for the LHM group.

As shown in Table 2, mucosal injury occurred in 1 patient in the POEM group and 3 patients in the LHM group. For the POEM mucosal injury, a hemoclip was placed when it was possible. Patients with a mucosal injury occurred in 1 patient undergoing POEM vs LHM for management of achalasia. Anterior fundoplications are created extending up the esophagus. Using the harmonic scalpel, the muscle fibers are incised down to the mucosa of the stomach. The submucosal plane is then accessed and the myotomy is created measuring 6 cm cephalad. If a mucosal injury is made, a 4-0 vicryl suture is used in a figure-of-eight fashion to approximate the edges of the mucosa. Once the myotomy is complete, an upper endoscopy is done to perform a leak test and verify the patency of the LES. Short gastric vessels are then taken down to mobilize the fundus. Anterior fundoplications are created using 0-Ethibond sutures, tacking the greater curvature of the fundus to the hiatus and laying the fundus over the myotomy, creating an approximate 90 degree fundoplication. Three total sutures are used to create the fundoplication by suturing the greater curvature of the fundus to the hiatus. No drains are used. The capnoperitoneum is released, and the liver retractor and all trocars are removed. Skin closure is done with 4-0 mononyl sutures and then dermabond.

The patient is admitted postoperatively for an esophagram to assess for leak and passage of contrast into the stomach. A liquid diet is started after the esophagram is cleared and the patient is discharged. The patient follows up 3 to 4 weeks postoperatively and 6 to 12 months postoperatively. Eckardt scores are taken at both follow-up visits.

In redo surgery, the procedure is similar except that the enterotomy is performed with the harmonic scalpel, blunt dissection, and sharp dissection to return the stomach to its anatomical position and to evaluate the myotomy. Extension of the myotomy is performed if it appears inadequate. Upper endoscopy is used to guide the dissection and further myotomy. Postoperative management is the same as with the primary LHM cohort.

RESULTS

A total of 12 patients underwent POEM (4 men and 8 women) and 11 patients underwent LHM (6 men and 5 women). The demographic and clinical characteristics of the two groups are compared in Table 1; no differences were statistically significant. Patients’ mean age was similar between the groups: 52 in the POEM group and 53 in the LHM group. Those in the LHM group had a higher mean body mass index than those in the POEM group (28.8 vs 25.7 kg/m²). In the LHM group, 8 patients (73%) had type 1 achalasia, 2 patients (18%) had type 2 achalasia, and 1 patient (9%) had type 3 achalasia; in the POEM group, 10 patients (83%) had type 1 achalasia, 1 (8%) had type 2 achalasia, and 1 (8%) had esophagogastric junction outflow obstruction. The mean procedure time was shorter in the POEM group, at 136 minutes compared with 154 minutes in the LHM group. The postoperative length of stay was a mean of 1.6 days for the POEM group and 2.0 days for the LHM group.

As shown in Table 2, mucosal injury occurred in 1 patient in the POEM group and 3 patients in the LHM group. For the POEM mucosal injury, a hemoclip was placed when it was possible. Patients with a mucosal injury occurred in 1 patient undergoing POEM vs LHM for management of achalasia.

Table 1. Demographic and clinical characteristics of patients undergoing POEM vs LHM for management of achalasia

<table>
<thead>
<tr>
<th>Variable</th>
<th>POEM (N = 12)</th>
<th>LHM (N = 11)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td>8 (67%)</td>
<td>5 (46%)</td>
<td>0.41*</td>
</tr>
<tr>
<td>Age (years), mean ± SD</td>
<td>52.0 ± 16.9</td>
<td>52.7 ± 12.4</td>
<td>0.01†</td>
</tr>
<tr>
<td>BMI (kg/m²), mean ± SD</td>
<td>25.7 ± 4.0</td>
<td>28.8 ± 5.2</td>
<td>0.12†</td>
</tr>
<tr>
<td>Preop LES basal, mean ± SD</td>
<td>33.6 ± 18.8</td>
<td>28.8 ± 14.0</td>
<td>0.52†</td>
</tr>
<tr>
<td>Preop LES residual, mean ± SD</td>
<td>23.3 ± 14.9</td>
<td>15.6 ± 9.8</td>
<td>0.09†</td>
</tr>
<tr>
<td>Patients with aperistalsis preop</td>
<td>9 (75.0%)</td>
<td>9 (81.8%)</td>
<td>0.96*</td>
</tr>
<tr>
<td>Achalasia type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 1</td>
<td>10</td>
<td>8</td>
<td>N/A</td>
</tr>
<tr>
<td>Type 2</td>
<td>1</td>
<td>2</td>
<td>N/A</td>
</tr>
<tr>
<td>Type 3</td>
<td>0</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td>EGJOO</td>
<td>1</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>Procedure length (min), mean ± SD</td>
<td>136 ± 64</td>
<td>154 ± 37</td>
<td>0.43†</td>
</tr>
<tr>
<td>Hospital LOS (days), mean ± SD</td>
<td>1.6 ± 1.2</td>
<td>2.0 ± 1.9</td>
<td>0.53†</td>
</tr>
</tbody>
</table>

*P value based on *Fisher’s exact test; †Student t test.

BMI indicates body mass index; EGJOO, esophagogastric junction outflow obstruction; LES, lower esophageal sphincter; LHM, laparoscopic Heller myotomy; LOS, length of stay; POEM, per-oral endoscopic myotomy.
noticed intraoperatively immediately distal to the LES on the gastric mucosa. The three mucosal injuries in the LHM group were noticed at the time of surgery and were repaired with a figure-of-eight 4-vicryl suture. There was one area of necrosis of the mucosa in the POEM group. The creation of the submucosal tunnel compromised the perfusion of the overlying mucosa. No perforation was seen, and nothing was done at the time of surgery. Follow-up esophagram did not show a leak. One contained leak was seen on the postoperative esophagram in the POEM group. The mucosal approximation with hemoclips was not adequate, and a small amount of contrast leaked into the submucosal tunnel. The patient was immediately taken to the endoscopy suite for an additional hemoclip to be placed. Once the hemoclip was placed, a follow-up esophagram showed resolution of the contained leak. The patient never experienced tachycardia or fever. No clinical difference was seen from the rest of the cohort. No patients needed to return to the operating room. No patients were readmitted within 30 days of their procedure.

Postoperative outcomes were evaluated with Eckardt scores to indicate the success of the procedure (Table 2). In the immediate postoperative period, Eckardt scores significantly improved to a mean of \(1.3 \pm 1.0\) \(P < 0.0001\) in 7 of 12 patients in the POEM group and \(0.7 \pm 1.2\) \(P = 0.03\) in 3 of 11 patients in the LHM group. The other patients failed to follow up in the immediate phase due to distance from the facility. In follow-up at least 6 months after surgery, patients were called to obtain Eckardt scores. The mean score in the POEM group was \(1.2 \pm 1.6\) for 11 of 12 patients at a mean of 483 days, and \(3.0 \pm 0.7\) for 9 of 11 patients in the LHM group with a mean of 273 days. The remaining patients did not have 6 months elapse from the operation to report a score. Success of the procedure with Eckardt scores \(\leq 3\) after 6 months was 82% in the POEM group and 66% in the LHM group \(P = 0.62\).

A subset analysis was done for patients who had the procedure as a primary surgery versus a redo surgery. One patient in the POEM group had a prior LHM and reported an Eckardt score of 2, indicating success. Three patients in the LHM group had prior LHM, and only one reported a successful score of \(3\). The other 2 patients reported scores of 5 and 6. No significant differences were observed in the success rate between the two groups (Table 2).

**Table 2. Outcomes of patients undergoing POEM vs LHM for management of achalasia**

<table>
<thead>
<tr>
<th>Complications (n)</th>
<th>POEM (N = 12)</th>
<th>LHM (N = 11)</th>
<th>(P) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mucosal injury during surgery</td>
<td>1</td>
<td>3</td>
<td>NA</td>
</tr>
<tr>
<td>Mucosal necrosis</td>
<td>1</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>Postoperative leak</td>
<td>1</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>Return to operating room</td>
<td>0</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>30-day readmission</td>
<td>0</td>
<td>0</td>
<td>NA</td>
</tr>
</tbody>
</table>

Eckardt scores (mean ± SD)

- **Preoperative**: POEM 8.3 ± 1.8, LHM 6.9 ± 3.2, \(P = 0.20\)
- **Immediate postoperative**: POEM 1.3 ± 1.0, LHM 0.7 ± 1.2, \(P = 0.39\)
- **Late postoperative**: POEM 1.2 ± 1.6, LHM 3.0 ± 0.7, \(P = 0.08\)
- Follow-up days, median (IQR): POEM 385 (274–500), LHM 285 (217–473), \(P = 0.59\)
- **Success after 6 months**: POEM 82% (9/11), LHM 66% (6/9), \(P = 0.62\)
- **In primary surgery group**:
  - POEM: 80% (8/10), LHM: 83% (5/6)
  - \(P = 0.99\)
- **In redo group**:
  - POEM: 100% (1/1), LHM: 33% (1/3)
  - \(P = 0.99\)

\(P\) value based on *Fisher’s exact test; †Wilcoxon two-sample test.

IQR indicates interquartile range; LHM, laparoscopic Heller myotomy; POEM, per-oral endoscopic myotomy; SD, standard deviation.

**DISCUSSION**

These results indicate a favorable success rate in our institution’s early experience with POEM and LHM. The success rate was 82% for POEM and 66% for LHM at a follow-up of at least 6 months. There were no complications related to either procedure that altered the patient's postoperative course, except for one patient with a contained leak in the POEM group. This was identified with an immediate postoperative esophagram without further morbidity.

POEM has become more widespread, and a significant amount of data has been reported on its efficacy and outcomes. Inoue et al reported their 500-patient experience with an adverse event rate of 3.2% (14), and Sharata et al showed a 6% morbidity rate in 100 patients (15). We show a 25% adverse event incidence in our 12 patients with no Clavien Dindo grade IV or V and only one grade III event. This is a much higher rate but related to our early experience and low patient numbers. This rate is much more comparable to other reports of early experiences, such as Hungness et al (20), who reported an approximate 18% adverse event rate. We anticipate this rate will decrease once the number of procedures increases. Despite the high adverse event rate, there was very little alteration in the patients' postoperative clinical courses. The hospital length of stay was 1.6 days in our data, which is similar to other reports noting a length of stay of 1 to 3 days (15, 24, 25) in high-volume analysis.

A large meta-analysis by Marano et al compared POEM and LHM (26). It revealed that POEM has a slightly better maintenance of a lower Eckardt score than LHM, but the difference didn’t reach statistical significance. Our data reflect the same trend (Figure 2). There was also no significant difference between operative times in the meta-analysis. Our data reflect the same finding, with 136 minutes for POEM and 153 minutes for LHM. We did see a difference in our complication rates for POEM and LHM, where the meta-analysis showed no difference. Finally, POEM has produced Eckardt scores of \(\leq 3\) in 90% to 98% of patients in several studies (18, 24, 27, 28). These success rates seem to surpass the success of LHM and pneumatic dilation (86% and 76%, respectively) (7). Overall, our data, showing success rates of 82% for POEM and 66% for LHM, follow the trend reported in the literature.

A major limitation to this study is statistical power due to the low numbers of patients for each procedure. Even though the cohort numbers were low, they could adequately illustrate our early experience with POEM and LHM for evaluation.
In conclusion, POEM and LHM have been shown to be acceptable procedures to treat achalasia. This small cohort shows endpoints and outcomes consistent with larger published series. We have appeared to overcome the learning curve based on operative time and should expect outcomes to be consistent with those of larger-volume centers with a longer experience.