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Impedance planimetry during per-oral endoscopic myotomy is associated with decreased inadvertent capnoperitoneum

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Abstract

Background Per-oral endoscopic myotomy (POEM) has become an accepted minimally invasive alternative to Heller myotomy for the treatment of achalasia and other disorders of esophageal dysmotility. One associated adverse event is the inadvertent creation of capnoperitoneum. A proposed mechanism is that extension of the submucosal tunnel below the esophageal hiatus and onto the gastric wall leads to transmural perforation. We hypothesized that the use of impedance planimetry with the endoscopic functional luminal imaging probe (EndoFLIP) more accurately identifies the esophagogastric junction and helps to better define the myotomy's ideal limits, thus lowering the incidence of inadvertent capnoperitoneum.

Methods This is a single-center, retrospective review of consecutive POEM cases from 06/11/2011 to 08/08/2022, with EndoFLIP introduced in 2017. Patient and procedural characteristics, including the incidence of clinically significant capnoperitoneum and decompression, were analyzed using univariate and multivariable linear regression statistics.

Results There were 140 POEM cases identified, 74 (52.9%) of which used EndoFLIP. Clinically significant capnoperitoneum was encountered in 26 (18.6%) cases, with no differences in patient characteristics between those who had capnoperitoneum and those who did not. There was a decreased incidence of capnoperitoneum in cases using EndoFLIP compared to those without ($n=6$, 23% vs $n=20$, 77%, $p=0.001$), with zero instances in the final 56 cases. After adjusting for potentially confounding factors, EndoFLIP use was associated with a − 15.93% (95% confidence interval − 30.68%, − 1.18%) decrease in procedure duration.

Conclusions The routine use of EndoFLIP during POEM was associated with decreased incidence of clinically significant capnoperitoneum, potentially due to improved myotomy tailoring and decreased duration of insufflation with shorter procedure times.

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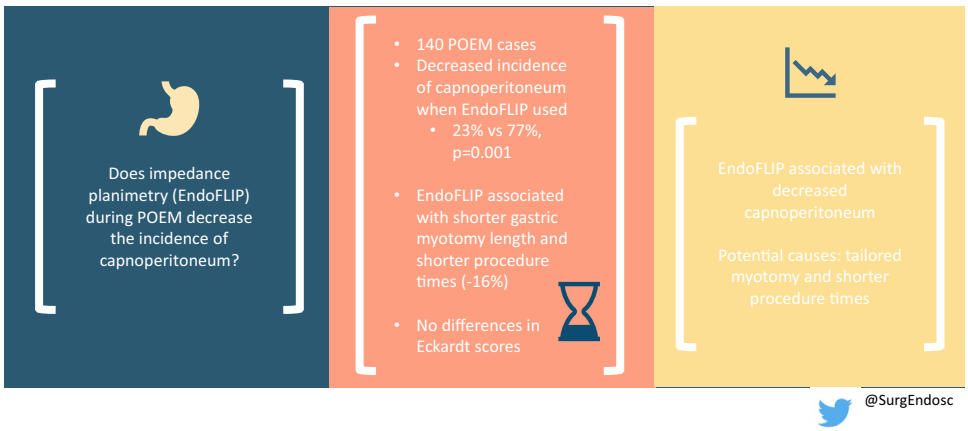
Extended author information available on the last page of the article

Graphical abstract



Keywords Per-oral endoscopic myotomy · Impedance planimetry · Capnoperitoneum

Abbreviations

AE	Adverse events
CI	Confidence interval
EGJ	Esophagogastric junction
EndoFLIP	Endoluminal functional luminal imaging probe
IQR	Interquartile range
NAEDD	Non-achalasia esophageal dysmotility disorders
POEM	Per-oral endoscopic myotomy

Achalasia is a neuromuscular disease of the esophagus characterized by elevated lower esophageal sphincter pressures with a lack of peristalsis. This induces intolerance to solid meals and eventually progresses to intolerance to liquids, including secretions. It has an incidence of 1.6 in 100,000 people, and a prevalence of 10.8 in 100,000, which has risen sharply in recent years [1]. Other non-achalasia esophageal dysmotility disorders (NAEDD) can present similarly to achalasia, despite different pathophysiologies. According to the Chicago Classification Version 4.0, NAEDD includes esophagogastric junction (EGJ) outflow obstruction, distal esophageal spasm, hypercontractile esophagus, and other minor disorders of peristalsis (formerly known as nutcracker esophagus in Chicago Classification version 3.0) [2–4].

Treatment for both achalasia and NAEDD has consisted of medical management with nitrates and calcium channel blockers, endoscopic interventions including injection of botulinum toxin and pneumatic dilation, and surgical management with laparoscopic or thoracoscopic Heller myotomy [5, 6]. Per-oral endoscopic myotomy (POEM) has gained traction as a less invasive alternative to Heller myotomy with fundoplication in the treatment of achalasia and, increasingly, has been employed in treating NAEDD [7–11]. POEM consists of an endoscopic mucosal incision and creation of a submucosal tunnel before performing an endoscopic myotomy and closure of the mucosal incision, although the ideal length of the gastric myotomy remains up for debate [7, 12]. Multiple case series and retrospective reviews have proven its safety and efficacy and show decreased postprocedural hospital stay and recovery time [13–17]. One potential disadvantage to the per-oral endoscopic technique is the difficulty understanding extraluminal anatomy and knowing where in the esophagus the dissection is taking place. This can cause dissection to proceed beyond the diaphragmatic hiatus onto the gastric wall. Therefore, a widely reported adverse event associated with POEM is the inadvertent creation of capnoperitoneum during the myotomy [18–20]. When clinically significant, this can be successfully treated with needle decompression without long-term sequelae, particularly when carbon dioxide insufflation is preferentially used over room air [20]. The exact underlying mechanism has not been clearly defined, but it may be that when the submucosal tunnel is extended below the esophageal hiatus and onto the gastric wall (with potential differences in angle or length of the gastric myotomy), transmural perforation can occur. Although the esophagus does not have a serosal layer, adherent mediastinal tissues prevent gross capnomediastinum when this space is entered and can serve the same function that the serosa does in other parts of the gastrointestinal tract [21].

Previously, many surgeons relied on anatomic measurements using the endoscope to delineate the myotomy's length and location; this can be notoriously unreliable as the endoscope is nonlinear and the scope can bow in the submucosal tunnel. The endoluminal functional luminal imaging probe (EndoFLIP; Medtronic, Dublin, Ireland) is an endoscopic device that utilizes a catheter-directed balloon to measure impedance planimetry and thereby assess cross-sectional area, maximum diameter, and distensibility index of the lumen (i.e., cross-sectional area of the EGJ divided by the intra-balloon pressure at that time) in real time [22]. While submucosal anatomy is traditionally used to identify the EGJ, such as identification of palisade vessels or tunnel narrowing, EndoFLIP more accurately identifies the anatomic location of the EGJ and allows for the tailoring of the myotomy to the most directed area [23]. It has emerged as a useful adjunct to guide myotomy creation, and several studies have demonstrated its utility and safety [22, 24–26].

At our institution, we have performed over 140 cases of POEM for achalasia and other NAEDD and have adopted routine use of EndoFLIP to guide myotomy limits. We present a retrospective case series of patients who have undergone POEM and report the incidence of capnoperitoneum before and after the adoption of EndoFLIP. We hypothesized that the use of EndoFLIP, with its ability to more accurately identify the EGJ and define the myotomy's ideal limits, would lower the incidence of inadvertent clinically significant capnoperitoneum.

Materials and methods

Approval for this study was obtained by the Institutional Review Board of the University of Massachusetts Chan Medical School at Baystate Medical Center. This is a single-center retrospective review of consecutive POEM cases of patients ≥ 18 years old from June 10, 2011, to August 8, 2022. Exclusion criteria included any POEM cases that were converted to Heller myotomy in the same case. All patients underwent preprocedural high-resolution manometry. Patients were divided into two groups based on the indication for the procedure, achalasia, or NAEDD, with NAEDD cases initially characterized according to the Third Edition of the Chicago Classification [4] and were reviewed and reclassified according to the Fourth Edition [2, 3] when applicable.

Procedure

POEM was performed by a single surgeon-endoscopist team under general anesthesia. Full details of the procedure from our institution have been previously described [11, 21]. In brief, after induction of general anesthesia, a standard gastroscope is inserted orally and the EGJ is identified. A submucosal cushion is created with saline and methylene blue dye and the mucosa is opened with monopolar cautery. Dissection is carried to the level of the visualized circular muscle fibers, extended distally to the level of the EGJ, and then extended beyond it 2 cm onto the stomach. A retroflexed view of the stomach is obtained. Dye from the submucosal tunnel is often visualized extending onto the stomach confirming adequate distal dissection. The tunnel is re-entered and the myotomy is performed. Gentamicin 80 mg in 60 cc saline is injected through the endoscope into the tunnel to help prevent bacterial contamination from oral flora in the closed space of the tunnel, and the mucosal incision is closed.

An EndoFLIP 1.0 unit and an 8 cm catheter (EF-325) were used during this study period using the methods described at other centers [27]. Regardless of preprocedural diagnosis, the catheter is zeroed to atmospheric pressure after completing the pre-check and purge process. Once the patient is intubated, the EndoFLIP catheter is advanced under endoscopic guidance into the stomach. The scope is then removed and the balloon is filled to 30 mL, then slowly withdrawn until an hourglass shape is seen on the monitor. After allowing the readings to stabilize, minimum diameter, cross-sectional area, intra-bag pressure, and distensibility index are recorded. The narrowest aspect of the hourglass has the tightest diameter and indicates the highest pressure zone, accurately depicting the lower esophageal sphincter. The balloon is subsequently deflated and the catheter is removed. Following myotomy, the catheter is again inserted under endoscopic guidance to prevent intubation of the submucosal tunnel, and the measurements are repeated.

Since radiographic capnoperitoneum after POEM is very frequent, capnoperitoneum is defined as *clinically significant* if abdominal distention is visible to the naked eye and the abdomen is tense and firm, akin to capnoperitoneum created during laparoscopy. When encountered, Veress needle decompression in the left upper quadrant of the abdomen is performed at the end of the case, allowing the abdomen to decompress until visible collapse of the abdominal wall is seen.

Procedure time is defined as the duration of time between mucosal opening until the endoscope is withdrawn at the end of the case—thus anesthesia-related operating room time, initial diagnostic esophagogastroduodenoscopy, first EndoFLIP measurement when implemented, and Veress needle decompression when performed are not counted in this measure.

Statistical analyses

Numeric values are represented as *n* (%). Continuous variables with normal distribution are presented as

mean ± standard deviation (SD) and non-normal distributions are presented as median [interquartile range (IQR)]. Pearson's χ^2 test was utilized for categorical comparisons, unpaired t-test was used for continuous variables with normal distribution, and Wilcoxon signed-rank test was utilized for continuous, non-normally distributed comparisons. Multivariable linear regression was utilized to analyze the procedure time of POEM while adjusting for potentially confounding factors. Factors considered clinically relevant were included in the model. As part of the model, the first 40 POEM cases in the series were designated as part of a "learning curve" in the initial adoption of POEM. This number was decided with the opinion and experience of the surgeon-endoscopist team along with support from three high-volume studies in which 25–40 cases were required by experienced endoscopists to achieve technical efficiency in POEM, which we erred on the conservative side of these reports [28–30]. All variables in the model were assessed for collinearity. All tests were two-tailed and $p < 0.05$ was considered significant. Statistical analyses were performed using R [31].

Results

Patient population and baseline characteristics

There were 143 patients who underwent POEM. Three patients were excluded from analysis: one procedure was aborted intraoperatively prior to POEM completion for tension capnopericardium resulting in cardiac arrest [32], one was aborted in a patient with prior laparoscopic Heller myotomy because the team was unable to safely create the submucosal tunnel sufficiently to reach the EGJ and perform the myotomy, and the third was converted intraoperatively to a Heller myotomy (it was later discovered that the patient had had Botox administration 1 week prior at an outside institution without disclosing this information). This left 140 cases in final analysis. Patients were mean 57 ± 16.5 years old at POEM, 77 (55%) were female, and median body mass index was 29 [IQR 23.3–34.4]. POEM was most commonly performed for achalasia ($n = 119$, 85%). Patient histories prior to POEM included 9 (6%) who had previously undergone Botox injection, 45 (32%) had previously undergone endoscopic dilation, and 9 (6%) had previous Heller myotomy.

EndoFLIP characteristics

EndoFLIP was utilized starting in 2017 and has been used on all cases since 2018 for a total of 74 (53%) cases. Characteristics of patients who underwent EndoFLIP and those who did not are depicted in Table 1. EndoFLIP patients were associated with increased frequency of NAEDD diagnosis ($n = 17$, 23% vs. $n = 4$, 6%, $p = 0.005$) and had fewer instances of pre-POEM esophageal dilation ($n = 17$, 23% vs. $n = 28$, 42%, $p = 0.014$) than no EndoFLIP. EndoFLIP was additionally associated with shorter median overall myotomy lengths (12 [IQR 11–13] vs 13 [IQR 12–15] cm, $p = 0.002$) and gastric myotomy lengths (2 [IQR 2–2] vs. 2 [IQR 2–3] cm, $p < 0.001$) compared to no EndoFLIP.

Clinically significant capnoperitoneum

Capnoperitoneum was encountered in 26 (18.6%) cases (Table 2). No cases caused hemodynamic instability and all were decompressed with Veress needle intraoperatively without significant immediate or delayed adverse effects. Cases of capnoperitoneum correlated with volume per year from 2011 to 2018 (Fig. 1a). Percent incidence of capnoperitoneum declined over time, with no cases encountered from 2019 to 2022 (Fig. 1b). There were no differences between patients that developed capnoperitoneum and those that did not in terms of demographics, preprocedural diagnosis or interventions, or pre- or postprocedural Eckardt scores (Tables 1 and 2). EndoFLIP was associated with a lower incidence of capnoperitoneum compared to those without EndoFLIP use ($n = 6$, 23% vs $n = 20$, 77%, $p = 0.001$) and the median gastric myotomy length was longer in patients who developed capnoperitoneum compared to those who did not (2 [IQR 2–3] cm vs. 2 [IQR 2–2] cm, $p = 0.023$). Patients who had capnoperitoneum additionally had slightly longer post-POEM length of stay compared to those without capnoperitoneum (median 1 [IQR 1–2] vs. 1 [IQR 1–1] days, $p = 0.028$).

Procedure time

Procedure time declined steadily throughout the early part of the study with subsequent trend toward increasing procedure time in the latest years, likely due to increased participation from gastrointestinal and surgical fellows (Fig. 2). Median procedure time was shorter in patients where EndoFLIP was used compared to those in whom it was not (97 [IQR 82.3–119.5] vs. 133 [IQR 107–155], $p < 0.001$). Additionally, median procedure time was longer in patients that developed capnoperitoneum compared to those that did not (136.5 [IQR 103–158.2] vs. 110 [IQR 86–136] min, $p = 0.009$).

After identifying that capnoperitoneum cases and EndoFLIP cases were each longer in duration, thereby having increased duration of insufflation, a multivariable linear regression was performed to determine if procedure duration was independently associated with these factors (Table 3). After adjustment, historical manipulations such as Botox, endoscopic dilation, or Heller myotomy, learning curve cases, and clinically significant capnoperitoneum

Table 1 Baseline characteristics of patients stratified by use of EndoFLIP

Factor	Total *n* = 140	EndoFLIP *n* = 74	No EndoFLIP *n* = 66	*p* value
Demographics				
Mean age (years) ± SD	57 ± 16.5	58.9 ± 16.7	55 ± 16.2	0.166
Female *n* (%)	77 (55%)	36 (49%)	41 (62%)	0.110
Median body mass index [IQR]	29 [23.3–34.4]	26.7 [23.8–34.8]	27.6 [22.4–34.3]	0.767
Diagnosis				
Achalasia *n* (%)	119 (85%)	57 (77%)	62 (94%)	**0.005**
NAEDD *n* (%)	21 (15%)	17 (23%)	4 (6%)	
Pre-POEM intervention				
Botox *n* (%)	9 (6%)	2 (3%)	7 (11%)	0.057
Esophageal dilation *n* (%)	45 (32%)	17 (23%)	28 (42%)	**0.014**
Laparoscopic Heller myotomy *n* (%)	9 (6%)	3 (4%)	6 (9%)	0.225
Median Eckardt score				
Pre-POEM [IQR]	7 [6–9]	7 [5.5–9]	7.5 [6–9]	0.432
Post-POEM [IQR]	0 [0–0]	0 [0–0]	0 [0–1]	0.118
Procedural characteristics				
Median procedure duration (min) [IQR]	115 [88–141.5]	97 [82.3–119.5]	133 [107–155]	**< 0.001**
Myotomy approach				
Anterior *n* (%)	126 (90%)	70 (95%)	56 (85%)	0.055
Posterior or lateral *n* (%)	14 (10%)	4 (5%)	10 (15%)	
Median esophagogastric junction location (cm) [IQR]	40 [39–42.3]	40.5 [39–42]	40 [39.3–43]	0.853
Median total myotomy length (cm) [IQR]	12 [12–14]	12 [11–13]	13 [12–15]	**0.002**
Median gastric myotomy length (cm) [IQR]	2 [2–2]	2 [2–2]	2 [2–3]	**< 0.001**
Median length of stay (days) [IQR]	1 [1–1]	1 [1–1]	1 [1–1]	0.051

Bold values denote the statistical significance

IQR interquartile range, *NAEDD* non-achalasia esophageal dysmotility disorder, *POEM* per-oral endoscopic myotomy

creation were not associated with procedure times. Patients with an achalasia diagnoses were associated with an 18.65% (95% CI 2.99%, 34.32%, $p = 0.021$) longer procedure time. Factors associated with decreased procedure times included female sex (− 12.93% (95% CI − 24.9%, − 0.96%, $p = 0.036$) decrease) and use of EndoFLIP (− 15.93% (95% CI − 30.68%, − 1.18%, $p = 0.036$) decrease).

Subgroup analysis of immediately before and after adoption of EndoFLIP

Because capnoperitoneum and procedural time differences might be a product of the learning curve in the adoption of POEM in general and not attributed to EndoFLIP, a subgroup analysis of the twenty procedures immediately preceding and following the adoption of EndoFLIP was performed (Table 4). These cases were all beyond the first 40 cases of POEM in the series. This analysis found the first 20 EndoFLIP cases were in older patients (61.9 ± 13.3 vs. 51.8 ± 13.5, $p = 0.04$) compared to the preceding 20 cases without EndoFLIP, as well as EndoFLIP being associated with decreased procedural times (median 91 [IQR 81–104.5] vs 125.5 [IQR 104.2–141] min, $p = 0.004$) compared to no EndoFLIP. Of note, there was no difference in the rate of capnoperitoneum between these groups. There were no other associations among underlying diagnosis, pre-POEM interventions, Eckardt scores, or procedural characteristics including overall and gastric myotomy lengths.

Discussion

This study, to the authors' knowledge, is the first to investigate the use of EndoFLIP and its association with clinically significant capnoperitoneum during POEM. We found capnoperitoneum to be a fairly common occurrence with an incidence of 18.6% in our series. We additionally found a decreased incidence of capnoperitoneum, potentially due to shorter gastric myotomy lengths and ~ 16% shorter procedure times leading to decreased insufflation through the routine adoption of EndoFLIP during POEM.

Table 2 Patient characteristics and univariate analysis of clinically significant capnoperitoneum

Factor	Total *n* = *140*	Capnoperitoneum *n* = *26*	No capnoperitoneum *n* = *114*	*p* value
Demographics				
Mean age (years) ± SD	57 ± 16.5	61.7 ± 14	56 ± 17	0.08
Female *n* (%)	77 (55%)	18 (69%)	59 (52%)	0.106
Median body mass index [IQR]	29 [23.3–34.4]	26.3 [21.9–34.2]	29.8 [23.6–34.5]	0.413
Diagnosis				
Achalasia *n* (%)	119 (85%)	23 (89%)	96 (84%)	0.584
NAEDD *n* (%)	21 (15%)	3 (12%)	18 (16%)	
Pre-POEM intervention				
Botox *n* (%)	9 (6%)	2 (8%)	7 (6%)	0.771
Esophageal dilation *n* (%)	45 (32%)	11 (42%)	34 (30%)	0.219
Laparoscopic Heller myotomy *n* (%)	9 (6%)	1 (4%)	8 (7%)	0.552
Median Eckardt score				
Pre-POEM [IQR]	7 [6–9]	8 [6–8.3]	7 [6–9]	0.984
Post-POEM [IQR]	0 [0–0]	0 [0–1.5]	0 [0–0]	0.259
Procedural characteristics				
Median procedure duration (min) [IQR]	115 [88–141.5]	136.5 [103–158.2]	110 [86–136]	**0.009**
Myotomy approach				
Anterior *n* (%)	126 (90%)	24 (92%)	102 (90%)	0.664
Posterior or lateral *n* (%)	14 (10%)	2 (8%)	12 (11%)	
Median esophagogastric junction location (cm) [IQR]	40 [39–42.3]	40 [40–42]	40 [39–42.8]	0.974
Median total myotomy length (cm) [IQR]	12 [12–14]	12 [11–15]	12 [12–13]	0.876
Median gastric myotomy length (cm) [IQR]	2 [2–2]	2 [2–3]	2 [2–2]	**0.023**
EndoFLIP used *n* (%)	74 (53%)	6 (23%)	68 (60%)	**0.001**
Length of stay (days) [IQR]	1 [1–1]	1 [1–2]	1 [1–1]	**0.028**

Bold values denote the statistical significance

IQR interquartile range, *NAEDD* non-achalasia esophageal dysmotility disorder, *POEM* per-oral endoscopic myotomy

Clinically significant capnoperitoneum

As the adoption of POEM broadens to non-achalasia diagnoses and to cases of higher complexity, the potential for adverse events remains high [8–11, 30, 32–35]. Capnoperitoneum during POEM has the potential to cause severe complications, especially in those patients who cannot tolerate the physiologic consequences associated with capnoperitoneum. Additionally, the treatment of clinically significant capnoperitoneum requires decompression through Veress needle insertion, which introduces risks inherent to abdominal wall penetration such as violation of abdominal viscera, even if that adverse event was not encountered in this series. This becomes more poignant if POEM is performed in an endoscopy suite and potentially without a provider trained in surgical decompression of the abdomen. This study found that the utilization of EndoFLIP, potentially secondary to more precise tailoring and shortening of the overall and gastric myotomies and decreased duration of insufflation through shorter procedure times, was associated with a decreased incidence of clinically significant capnoperitoneum, and this adverse event was not found in the last 3.5 years of the study after the adoption of EndoFLIP.

Our interpretation of "clinically significant" capnoperitoneum should be viewed in the light that there were no objective measures employed other than gross visualization and feel of the abdomen, which may differ depending on a patient's body habitus. Additionally, no patients had hemodynamic instability secondary to the capnoperitoneum, but this would not be expected, akin to laparoscopy insufflation. However, capnoperitoneum causing visible abdominal distention that goes beyond slight radiographic capnoperitoneum is substantially uncomfortable and could lead to increased postprocedural pain medications, can increase patient anxiety, and could take time to dissipate, prolonging hospital stays, and therefore, it is still clinically meaningful even if not a high-morbidity occurrence.

Importantly, historical factors such as Botox injection, esophageal dilation, or Heller myotomy, or periprocedural factors such as myotomy approach and overall myotomy length, were not associated with the development of capnoperitoneum. These suggest that complexity of the case and

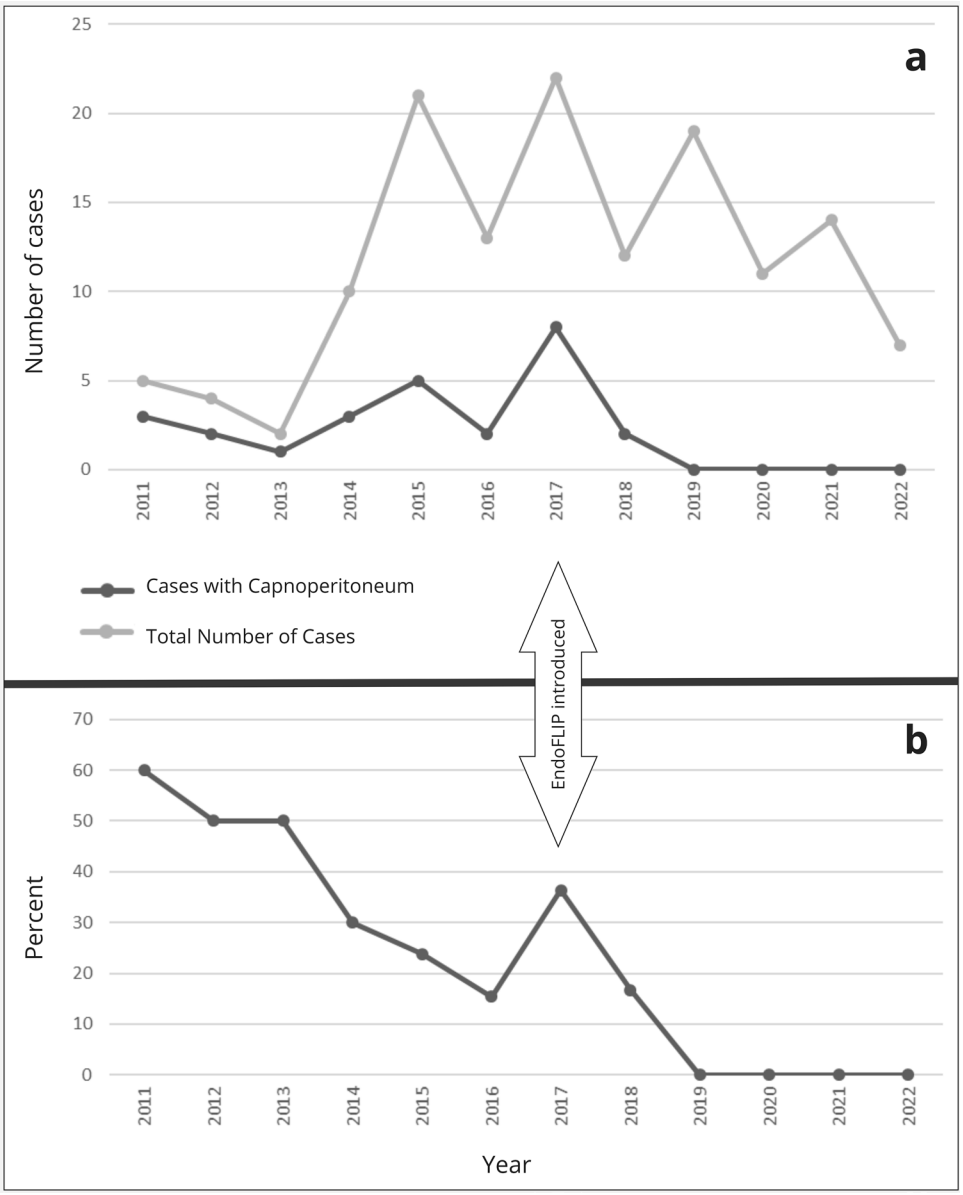


Fig. 1 **a** Displays the distribution of POEM cases and incidence of clinically significant capnoperitoneum cases over time. **b** Displays the percent incidence of clinically significant capnoperitoneum over time

fibrosis from previous manipulation were not risks for capnoperitoneum development. It should be reiterated that the ideal overall and gastric myotomy lengths have not yet been established for POEM, but EndoFLIP was associated with shorter overall and gastric myotomy lengths in our series without any impact on post-POEM Eckardt scores. Additionally, while there are multiple methods of determining the EGJ location, such as placement of clips with fluoroscopy, double endoscopy, and indocyanide green injection, some are fairly resource-intensive or newer techniques. EndoFLIP, however, is a relatively established method and suits mid-size regional programs such as ours [36].

It is important to note that, in our region, the use of Botox and dilation to treat achalasia prior to POEM has fallen substantially in part due to the widespread acceptance of POEM, which was reflected in the lower proportion of EndoFLIP patients having undergone previous endoscopic esophageal dilation. Thus, later cases in the series may have had less difficult dissections and the chances of inadvertent capnoperitoneum might be reduced. The authors acknowledge that the declining rate of capnoperitoneum even before the routine use of EndoFLIP could represent the learning curve in POEM–as it has been reported that up to 100 cases are required to achieve proficiency [37] in contrast to the 25–40 reported in other studies [17, 28, 30]. However, the 56 consecutive cases without clinically significant capnoperitoneum from 2019 to 2022 after adoption of EndoFLIP remains an important designation.

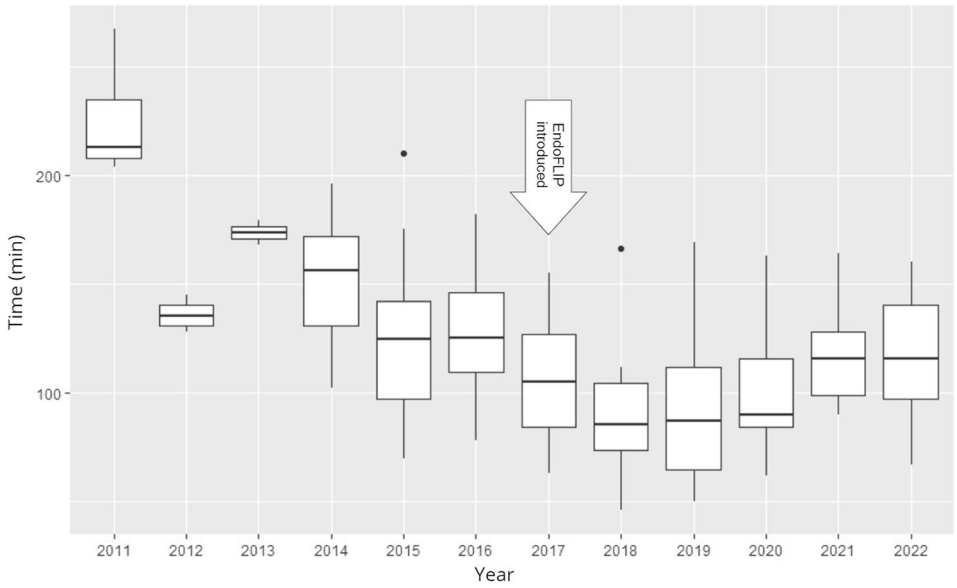


Fig. 2 Box-and-whisker plot of procedure time per year. *Key* box (bottom to top) = quartile 1, median, quartile 3; whiskers (bottom to top) = minimum, maximum; dot = significant outlier

Table 3 Multivariable linear regression of POEM procedure duration

Factor	Percent change	95% confidence interval	*p* value
Patient characteristics			
Age (per year increase)	0.08%	(− 0.25%, 0.41%)	0.649
Female	− 12.93%	(− 24.9%, − 0.96%)	**0.036**
Body mass index	0.35%	(− 0.31%, 1%)	0.302
Achalasia diagnosis	18.65%	(2.99%, 34.32%)	**0.021**
Historical considerations			
Pre-POEM Botox	− 3.79%	(− 25.05%, 17.47%)	0.727
Pre-POEM endoscopic dilation	3.29%	(− 8.8%, 15.38%)	0.595
Pre-POEM Heller myotomy	14.13%	(− 15.28%, 43.55%)	0.348
Learning curve (first 40 cases)	14.87%	(− 0.2%, 29.93%)	0.056
Procedural considerations			
Esophagogastric junction location (per cm increase)	− 0.37%	(− 2.19%, 1.44%)	0.687
Anterior myotomy approach	3.44%	(− 19.34%, 26.23%)	0.768
Length of myotomy (per cm increase)	1.23%	(− 0.98%, 3.43%)	0.277
Capnoperitoneum encountered	9.93%	(− 3.61%, 23.48%)	0.153
EndoFLIP use	− 15.93%	(− 30.68%, − 1.18%)	**0.036**

Bold values denote statistical significance

POEM per-oral endoscopic myotomy

Limitations

We present a retrospective series by a single surgeon-endoscopist team, potentially limiting its generalizability. While clinically significant capnoperitoneum was evacuated in all cases in this series when encountered, it is unclear if this is a necessary step in all cases. The prevalence of capnoperitoneum in this series was not sufficient to perform multivariable analysis to find independent associations with capnoperitoneum creation and thus our associations with shorter gastric myotomy lengths and decreased procedure times will need further verification. Lastly, it was not documented if cases had resident or fellow participation, and to what degree; therefore, the procedure times might be skewed, but the consistency of the surgeon-endoscopist team and performance of the procedure consistently at this tertiary teaching hospital mitigate some of these concerns.

Table 4 Subgroup analysis of first twenty cases of before and after the adoption of EndoFLIP

Factor	Total *n* = 40	EndoFLIP *n* = 20	No EndoFLIP *n* = 20	*p* value
Demographics				
Mean age (years) ± SD	56.8 ± 14.2	61.9 ± 13.3	51.8 ± 13.5	**0.04**
Female *n* (%)	26 (65%)	13 (65%)	13 (65%)	> 0.999
Median body mass index [IQR]	29.7 [25.4–34.3]	30 [27–36.9]	28.2 [24.5–33.4]	0.399
Diagnosis				
Achalasia *n* (%)	31 (%)	13 (65%)	18 (90%)	0.058
NAEDD *n* (%)	9 (%)	7 (35%)	2 (10%)	
Pre-POEM intervention				
Botox *n* (%)	2 (5%)	1 (5%)	1 (5%)	–
Esophageal dilation *n* (%)	12 (30%)	6 (%)	6 (30%)	> 0.999
Laparoscopic Heller myotomy *n* (%)	1 (3%)	0 (0%)	1 (5%)	–
Median Eckardt score				
Pre-POEM [IQR]	7 [6–8]	7 [5.5–8]	6 [6–8]	0.745
Post-POEM [IQR]	0 [0–1]	0 [0–1]	0 [0–1]	0.796
Procedural characteristics				
Median procedure duration (min) [IQR]	104.5 [83.5–128]	91 [81–104.5]	125.5 [104.2–141]	**0.004**
Myotomy approach				
Anterior *n* (%)	36 (90%)	19 (95%)	17 (85%)	0.292
Posterior or lateral *n* (%)	4 (10%)	1 (5%)	3 (15%)	
Median esophagogastric junction location (cm) [IQR]	40 [39–42]	40.5 [38.8–42]	40 [39–43]	0.622
Median total myotomy length (cm) [IQR]	12.5 [11.8–15.3]	12 [10–14.8]	13 [12–15.3]	0.185
Median gastric myotomy length (cm) [IQR]	2 [2–2]	2 [2–2]	2 [2–2]	0.654
Capnoperitoneum encountered	10 (25%)	6 (30%)	4 (20%)	0.465
Median length of stay (days) [IQR]	1 [1–1]	1 [1–1]	1 [1–2]	0.084

Conclusion

The routine use of EndoFLIP during POEM is associated with a decrease in clinically significant capnoperitoneum, potentially secondary to more tailored and accurate esophageal and gastric myotomy and decreased procedure times leading to decreased duration of insufflation.

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Declarations

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