

# Role of gastric per-oral endoscopic myotomy (G-POEM) in post-lung transplant patients: a multicenter experience



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## ABSTRACT

**Background and study aims** Gastroparesis post-lung transplant (LTx) can lead to increased risk of gastroesophageal reflux (GER) and accelerated graft dysfunction. We aimed to evaluate the efficacy and safety of gastric per-oral endoscopic myotomy (G-POEM), a promising tool in patients with refractory gastroparesis, for managing refractory gastroparesis and GER in post-LTx patients.

**Patents and methods** This was a multicenter retrospective study on post-LTx patients who underwent G-POEM for management of gastroparesis and GER that were refractory to standard medical therapy. The primary outcome was clinical success post-G-POEM. Secondary outcomes included the rate of post-G-POEM objective esophageal pH exam normalization, rate of gastric emptying scintigraphy (GES) normalization, technical success, and adverse events.

**Results** A total of 20 patients (mean age 54.7 ± 14.1 years, Female 50%) underwent G-POEM at a median time of 13 months (interquartile range 6.5–13.5) post-LTx. All G-POEM procedures were technically successful. Clinical success was achieved in 17 (85%) patients during a median follow-up time of 8.9 (IQR: 3–17) months post-G-POEM. Overall GCSI and two of its subscales (bloating and postprandial fullness/early satiety) improved significantly following G-POEM. Two patients (10%) developed post-procedural AEs (delayed bleeding 1, pyloric stenosis 1, both moderate in severity). Post-G-POEM GES improvement was achieved in 12 of 16 patients (75%). All 20 patients were on proton pump inhibitors pre-G-POEM, as opposed to five post-G-POEM. Post-G-POEM PH study normalization was noted in nine of 10 patients (90%) who underwent both pre- and post-G-poem pH testing.

**Conclusions** G-POEM is a promising noninvasive therapeutic tool for management of refractory gastroparesis and GER post-LTx.

## Introduction

The underlying end-stage lung disease [1], operative vagal nerve disruption [2, 3], and postoperative chronic use of immunosuppressive drugs [4] all have been reported to be risk factors for development of esophageal dysmotility and gastroparesis in lung transplant (LTx) patients. This increases their risk of gastroesophageal reflux (GER), microaspiration, and ultimately accelerated graft dysfunction [2, 3]. While modestly researched, the available literature suggests that the incidence rate of post-LTx, new-onset abnormal gastric emptying scintigraphy (GES) ranges from 63% to 91% [5, 6], with a propensity to cause GER [7] or even difficult-to-manage GER [8,9]. GER, in turn, was found to be independently associated with the development of bronchiolitis obliterans syndrome (BOS), the leading cause of primary graft failure and mortality in LTx patients [5, 10]. Hence, it is imperative to entertain the diagnosis of gastroparesis and early manage patients with high clinical suspicion.

Despite its burden, treatment options for gastroparesis remain limited when diet modification and prokinetic use fail to alleviate symptoms. In a large multicenter prospective study, it was found that only 28% of patients with gastroparesis had clinical success at 48 weeks after receiving standard of care treatment [10]. This is partially due to the complex pathophysiological pathways but also due to the prevalent side effects and limited efficacy of the current available first-line therapies [11, 12]. When conservative measures fail, other treatment modalities such as botulinum toxin injection, pneumatic dilation, transpyloric stenting, gastric electric stimulation, and surgical pyloromyotomy have been used; however, they are limited by their suboptimal efficacy and significant invasiveness [13–17].

More recently, gastric per-oral endoscopic myotomy (G-POEM) was introduced, which for the first time offered a minimally invasive, pyloric-directed endoscopic procedure for the management of refractory gastroparesis [18, 19]. Several subsequent studies, mostly retrospective, have reported promising results of G-POEM for symptomatic improvement including two meta-analyses showing clinical success rates of 82–84% along with adverse event (AE) rates of 6% to 7% [20, 21]. The first published international prospective trial [19] revealed a lower clinical success rate of 56% at 12 months in patients with refractory gastroparesis; further highlighting the importance of selecting the best candidates who might benefit the most from G-POEM. Still, although G-POEM is an emerging tool in patients with difficult to manage post-surgical gastroparesis, its role in the subpopulation of post-LTx patients who might particularly benefit from limiting concurrent gastroparesis and GER has yet to be explored. Therefore, in this study, we aimed to evaluate the efficacy and safety of G-POEM in LTx patients with refractory gastroparesis and GER.

## Patients and methods

This was a multicenter retrospective study that involved four US tertiary care centers (**Supplementary Table 1**). All participating centers had Institutional Review Board approval to conduct human subject research and informed consent was not required from the enrolled participants as this was a chart review study. Consecutive patients who underwent G-POEM for management of refractory gastroparesis diagnosed post-LTx during the period between December 2018 and April 2021 were included. Gastroparesis was defined as patients having de-novo symptoms of gastroparesis post-lung transplant (nausea, vomiting, early satiety, belching, bloating, and/or upper abdominal pain) in the absence of underlying mechanical obstruction with abnormal GES. Prior to referral to G-POEM, a trial of diet modification and prokinetics use was tried, and patients who failed to achieve clinical improvement were deemed to have refractory gastroparesis. Exclusion criteria included patients who underwent G-POEM for diabetic, idiopathic, or postsurgical (other than LTx) gastroparesis, and patients with prior esophagus or stomach surgery, or active gastroesophageal malignancy. A total of 11 cases from one center were previously published in a study [22].

### G-POEM technique

All the G-POEM steps were performed as described previously [23], by gastroenterologists with prior training in interventional procedures. Initially, proximal to the pylorus, a submucosal bleb was created along the greater curvature by injecting saline and 0.25% indigo carmine or methylene blue solution, and this was followed by accessing the submucosal space by performing a 1.5-cm mucosal incision. Using the cautery-assisted knife, a submucosal tunnel, oriented toward the pylorus, was then created. Once the pyloric ring is identified, dissection of both circular and oblique muscle bundles was performed hence achieving full-thickness pyloromyotomy. Lastly, the endoscope was retracted from the submucosal tunnel, and the mucosal incision site was closed using endoscopic clips or endoscopic sutures. Post-G-POEM, all patients were admitted for overnight monitoring, and full-liquid diet was started following an upper gastrointestinal series indicating no signs of leakage. At discharge, the standard-of-care practice was followed with progressive advancement of diet.

### Study endpoints and definitions

The primary outcome was clinical success post-G-POEM, defined as having at least one score decrease in the total Gastroparesis Cardinal Symptom Index (GCSI) scoring system with more than a 25% decrease in at least two of the subscales [24]. GCSI, a tool for subjective evaluation of gastroparesis, assesses and ranks three subscales; postprandial fullness/early satiety, nausea/vomiting, and bloating [25].

Secondary outcomes included the rate of objective esophageal pH exam normalization post-G-POEM. Normal esophageal pH testing was defined by DeMeester score <14.72 and/or distal esophageal acid exposure time (AET) <6% [26]. Esophageal pH testing was performed according to the standard of care

[27] using a traditional pH probe, impedance, or wireless pH capsule. Other secondary outcomes included change in the rate and frequency of proton pump inhibitor (PPI) use, technical success, defined as completion of all the G-POEM steps, rate and severity of AEs according to the American Society for Gastrointestinal Endoscopy (ASGE) Lexicon scoring system [28], rate of GES normalization post-G-POEM, defined by having post-G-POEM GES with retention less than 10% at 4 hours after ingestion [29], and rate of GES improvement post-G-POEM, defined as at least 50% reduction in gastric retention at 4-hours when comparing pre- and post-G-POEM values. GES was performed as per the standard of practice, in which percentage of gastric retention using scintigraphy after ingestion of radioactively labeled low-fat, egg-white meal was measured (**Supplementary Table 2**).

### Statistical analysis

All the de-identified data were extracted into a pre-designed spreadsheet and shared with the lead coordinating center, Johns Hopkins Hospital, for data management and analysis. The statistical analysis of this study aimed at providing exploratory data. SPSS software (version 25.0; SPSS, Chicago, Illinois, United States) was used to perform all the statistical analyses. Categorical variables were reported as percentages, and quantitative variables were reported as mean (standard deviation) (SD) and median (interquartile range) (IQR). For variables comparison, pre- and post-G-POEM, paired t-test, and Wilcoxon signed-rank test, for nonparametric data, were used. The utilized statistical tests were all two-sided, and  $P < 0.05$  was considered statistically significant.

## Results

A total of 20 patients (mean age  $54.7 \pm 14.1$  years, female 50%) underwent G-POEM for the management of post-LTx refractory gastroparesis and were included in the study. At the time of G-POEM, patients had a median American Society of Anesthesiologists score of 3 (IQR: 2–3), and a mean BMI of  $24.5 (\pm 9.2)$  (**Table 1**). Patients in this cohort underwent lung transplant during the period between 01–2016 and 02–2020 (**Table 1**). Pre-transplant objective pH testing was available in nine patients (45%), and they all had normal DeMeester scores ( $< 14.72$ ), with a median DeMeester score of 5.1 (IQR: 4.3–9.8), and seven of nine (77.8%) had normal AET ( $< 6\%$ ), with median AET of 4.6%, with (IQR: 3.1–5.2) (**Table 2**).

### Post-lung transplant and pre-G-POEM

Gastroparesis was diagnosed at a median time of 9.3 months (IQR 6.3–9.6) following LTx, with a mean total GCSI score of  $14.1 \pm 2.6$ . All patients were on prokinetic drugs at the time of G-POEM evaluation (metoclopramide 17, erythromycin 3). Prior failed interventions included: botulinum toxin injection, 12 (60%), transpyloric stenting 1 (5%) (**Table 3**).

Pre-G-POEM GES was performed in all patients demonstrating abnormal study in all, with mean retention of  $36.5 \pm 25.6\%$  at 4 hours. Pre-G-POEM esophageal manometric studies were available in 11 patients, and they had a median basal resting

pressure (BRP) and integrated relaxation pressure (IRP) of 15.2 (IQR 12.7–18.3) and 4.9 (IQR 4.1–7.5), respectively. None of the patients had an LES IRP  $> 15$  mm Hg or an LES BRP  $< 10$  mm Hg. At the time of G-POEM evaluation, 19 patients (95%) were on PPI (daily 19, occasionally 1) (**Table 3**). A total of 16 patients underwent additional objective pH evaluation pre-G-POEM and 13 of 16 (81.3%) had abnormal DeMeester score ( $> 14.72$ ), with a median DeMeester score of 18.5 (IQR: 13.7–31.8), and 14 of 16 (87.5%) had abnormal AET ( $> 6\%$ ), with a median AET of 23.1% (IQR: 11.3–54.5), (**Table 2**).

### G-POEM procedural outcomes

G-POEM was performed at a median time of 13 months (IQR 6.5–13.5) post-LTx. At the time of the procedure, one patient was on aspirin, and one patient was on anticoagulants, which were appropriately discontinued and resumed post-procedure. Technical success was achieved in all patients, with a mean total procedure time of  $84.2 \pm 24.5$  minutes. The mean length of the mucosal incision and submucosal tunnel were  $1.5 \pm 1.4$  and  $5.3 \pm 1.3$  cm, respectively, and all patients underwent full-thickness myotomy with a mean length of  $2.5 \pm 2.4$  cm. Mucosal incisions were closed with clips in the majority, 18 (90%), and endoscopic suturing in two (10%) (**Table 3**).

Six patients had minor, controlled intra-procedural bleedings that were managed successfully by soft coagulation. All patients were admitted for at least an overnight monitoring, with a median length of hospital stay of 2.5 (1.8–4) days. Only two patients had prolonged hospital stays more than 2 days for other unrelated medical comorbidities (**Table 3**).

### G-POEM clinical outcomes

#### Primary outcome

At a median clinical follow-up time of 8.9 months (3–17) post-G-POEM, clinical success was achieved in 17 of the 20, 85% (95% CI, 77.3 to 89.9). All patients with clinical success had a GCSI score  $< 2$ . The three patients who failed to have clinical success post-G-POEM had a GCSI score of 4, 12, and 10.

#### Secondary outcomes

In general, the mean GCSI score decreased from  $14.1 \pm 2.6$  to  $5.3 \pm 4.3$ , ( $P < 0.001$ ), with a noted decrease in GCSI score in 18 of 20 (90%). Nausea/vomiting subscale score decreased from a mean value of  $2.5 \pm 1.1$  pre-G-POEM to  $0.8 \pm 2.3$  post-G-POEM, (0.05), postprandial fullness or early satiety subscale from  $7.3 \pm 6.7$  to  $1.2 \pm 1.3$ , ( $P = 0.02$ ), and bloating subscale from  $3.6 \pm 2.9$  to  $0.3 \pm 0.8$ , (0.03). There was a significant reduction in prokinetics use from 100% pre-G-POEM to only five patients (25%) post-G-POEM, ( $P < 0.02$ ) (**Table 3**, **Fig. 1**).

Post-G-POEM GES was performed in 16 of 20 patients (80%) at a median time of 2.6 months (IQR 1–4.5) post-procedure. The rate of abnormal GES post-G-POEM was eight of 16 (50%) and mean gastric retention at 4 hours decreased from a value of  $36.5 \pm 25.6\%$ , pre-G-POEM, to  $25.3 \pm 28.1\%$ , post-G-POEM,  $P < 0.02$ . In general, this was reflected in normalization and improvement of GES in 11/16 (68.8%) and 12 of 16 (75%), respectively (**Fig. 1**). There was a nonsignificant, positive correlation

► **Table 1** Pre-lung transplant baseline patient and disease characteristics.

Variable	Value
Total number	20
Age; mean ± SD	54.7 ± 14.1
Sex; F n (%)	10 (50%)
ASA; median (IQR)	3 (2–3)
BMI, mean ± SD	24.5 ± 9.2
<b>Lung transplant indication; n (%)</b>	
▪ Chronic interstitial lung disease (CILD)	2 (10%)
▪ Chronic obstructive pulmonary disease (COPD)	4 (20%)
▪ Idiopathic pulmonary fibrosis (IPF)	7 (35%)
▪ Nonspecific interstitial pneumonitis (NSIP)	1 (5%)
▪ Connective tissue disease-associated ILD	1 (5%)
▪ Pulmonary hypertension (PH)	3 (15%)
▪ Cystic fibrosis (CF)	2 (10%)
<b>Immunosuppressive medications, n (%)</b>	
▪ Tacrolimus	4 (20%)
▪ Prednisone + tacrolimus	3 (15%)
<b>IPF (Idiopathic pulmonary fibrosis) medications; n (%)</b>	
▪ Nintedanib	3 (15%)
Pre-lung transplant oxygen requirement; liters per minute (LPM); median (IQR)	3.5 (3–5)
<b>Most recent pre LTx pulmonary function tests (PFTs); median (IQR)</b>	
▪ FEV <sub>1</sub> % predicted	34 (28–47.5)
▪ FVC % predicted	47 (36.5–66.5)
▪ TLC % predicted	73.5 (72.3–87.5)
▪ DLCO % predicted	29 (17.3–46.3)
<b>Most recent pre LTx CT findings, n (%)</b>	
▪ Nodules	3 (15%)
▪ Cyst formation	1 (5%)
▪ Reticular lines	3 (15%)
▪ Traction	3 (15%)
▪ Bronchiectasis	7 (35%)
▪ Honeycombing	4 (20%)
▪ Ground glass opacity	4 (20%)
▪ Pleural effusion	2 (10%)
Pre-lung transplant right ventricular systolic pressure (mm Hg); mean ± SD	53 ± 26.7

► **Table 1** (Continuation)

Variable	Value
<b>Pre-lung transplant proton pump inhibitors (PPI) use: n (%)</b>	
▪ Occasionally	2 (10%)
▪ Daily	2 (10%)
Lung transplant dates (MM-YYYY)	01–2016 and 02–2020
<p>ASA, American Society of Anesthesiologists; BMI, body mass index; LTx, lung transplant; FEV<sub>1</sub>, forced expiratory volume in 1 second; FVC, forced vital capacity; TLC, total lung capacity; DLCO, diffusion capacity for carbon monoxide; PFC, pulmonary function test; CT, computed tomography.</p>	

( $r=0.19$ ,  $P=0.06$ ), between the decrease in mean gastric retention at 4 hours and mean GCSI score improvement (► **Table 3**).

During the duration of follow-up, five patients were still on PPI (daily 4, occasionally 1) post-G-POEM, as opposed to 19 (95%) pre-G-POEM, ( $P<0.04$ ) (► **Table 3**). Ten patients underwent post-G-POEM objective pH testing at a median time of 3.5 (IQR 3.1–5.1) months post-G-POEM; nine of 10 (90%) had a normal DeMeester score ( $<14.72$ ), with a median DeMeester score of 8.1 (IQR: 1.65–12.95), and six of 10 (60%) had normal AET ( $<6\%$ ), with a median AET of 5.4% (IQR: 1.18–6.18). In general, the median DeMeester score decreased from 29.05 (IQR: 20.25–58) to 8.1 (IQR: 9.68–23.52), ( $P<0.03$ ), and median AET decreased from 11.5% (IQR: 1.65–12.95) to 5.4% (IQR: 1.18–6.18), ( $P<0.04$ ), post-G-POEM. All 10 patients had abnormal pH testing pre-G-POEM as opposed to one post-G-POEM; therefore, the rate of pH testing normalization in patients who underwent formal testing before and after G-POEM was 90% (9/10) (► **Table 2**).

### Delayed AEs and post-G-POEM pulmonary surveillance

Late post-procedural AEs were reported in two patients (10%); one case of delayed bleeding from the mucosotomy site 14 days post-procedure in a patient who was on both antiplatelets and anticoagulation, and this necessitated readmission and was managed successfully with bipolar cautery; and one case of symptomatic pyloric stenosis 14 days post-procedure, and this required re-admission with feeding tube placement and subsequent balloon dilation. Both delayed AEs were labeled as moderate based on the ASGE Lexicon classification (**Supplementary Table 3**) [28].

All patients underwent pulmonary clinical evaluation at a median time of 2 months (1–6) post-G-POEM. During the duration of the study, none of the patients had a new oxygen requirement. The two patients who were on oxygen pre-G-POEM continued to have the same oxygen requirement post-G-POEM and both were deceased at 5 months and 6 months post-G-POEM due to complications related to chronic graft rejection and obliterative bronchiolitis syndrome. No patient was hospitalized for pneumonia or a new diagnosis of acute rejection during the duration of the study (**Supplementary Table 4**).

► **Table 2** Changes in objective pH findings pre-LTx, post-LTx, and post-G-POEM<sup>1</sup>.

Patient ID	Pre-lung transplant			Post-lung transplant and pre-G-POEM				Post-lung transplant and post-G-POEM			
	PPI Use	DeMeester score	Total % time of abnormal acid exposure	Total GCSI score	PPI use	DeMeester score	Total % time of abnormal acid exposure	Total GCSI score	PPI Use	DeMeester score	Total % time of abnormal acid exposure
#1	None	4.3	5.2	25	Daily	96.8 <sup>†</sup>	23.7 <sup>2</sup>	1	Daily	13	6.1
#2	Occasionally	4.8	6.4	16	Daily	4.7	0.8	1	None	–	–
#3	None	5.1	2.4	13	Occasionally	2.6	4.3	0	Occasional	–	–
#4	Daily	12.1	4.6	21	Daily	28	6.9	3	None	7.2	6.2
#5	Daily	10.2	7.8	15	Daily	12	6.9	3	None	–	–
#6	Occasionally	9.4	2.7	13	Daily	65	31	4	Daily	12.8	5.7
#7	None	4.1	3.1	22	Daily	73	28	1	None	9	4.4
#8	None	3.1	4.3	9	Daily	15	9	5	None	–	–
#9	None	5.2	4.7	24	Daily	30.1 <sup>2</sup>	23 <sup>2</sup>	12	Daily	15.2	7.1
#10	None	–	–	12	Daily	12.6	7.3	6	None	–	–
#11	None	–	–	15	Daily	16.6	11	5	None	0.3	0
#12	None	–	–	14	Daily	18	7.3	4	None	0.7	0.1
#13	None	–	–	12	Daily	19	10.8	1	Daily	3.9	5.1
#14	None	–	–	11	Daily	37	9.3	10	None	0.9	0.1
#15	None	–	–	7	Daily	24	12	1	None	14.1	8.7
#16	None	–	–	8	Daily	14	8.3	2	None	–	–

LTx, lung transplant, G-POEM, gastric-peroral endoscopic myotomy; GCSI, gastroparesis cardinal symptom index; PPI, proton pump inhibitor.

<sup>1</sup> Includes patients who had at least one objective pH evaluation during the duration of the study. All objective pH testing were performed off PPI unless specified otherwise.

<sup>2</sup> Objective pH testing performed while on PPI.

## Discussion

Lung transplantation is a morbid yet often life-saving therapeutic option in patients with end-stage lung disease. Unfortunately, patients' quality of life and long-term survival post-LTx is often dictated by the degree and severity of a wide range of anticipated infectious and noninfectious complications [30]. One of these noninfectious complications is the development of a spectrum of inter-related upper gastrointestinal dysmotility disorders that could be attributed to multiple pre-operative, operative and postoperative factors [2, 3, 31]. The literature on the prevalence and the long-term effects of gastroparesis post-LTx is scarce and limited to retrospective case series [32–37]. However, there has been a growing concern over the years on its role in promoting microaspiration into the lung allograft, and subsequent development of BOS and early graft rejection [38–40].

Although there is no good estimate on the percentage of patients who are deemed to have refractory gastroparesis in the

post-LTx population [6, 35], early and effective management of patients in this group is important considering its potential repercussions that can result from GER and aspiration [5]. Despite advances in both diagnostic and therapeutic tools made in the last two decades, gastroparesis with its complex pathophysiology continues to be a significant burden on both the patients and the health care system [41–43].

The role of G-POEM in the management of patients with refractory post-LTx gastroparesis has recently been explored. To the best of our knowledge, there has been only a single-center case series of 11 patients reporting clinical success (defined by 1-point decrease in the absolute GCSI score) of 100% during a mean follow-up time of 140.5 ± 54.2 days [22], however, there have been no attempts made to assess the effect of G-POEM on improving GER in these patient population. As GER is implicated as having a major negative impact on graft survival, this information is essential.

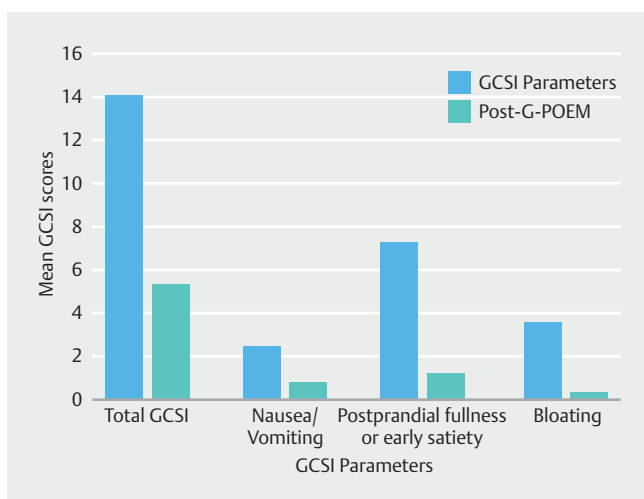
► **Table 3** Summary of pre- and post-lung transplant characteristics, pre-G-POEM evaluation, and G-POEM procedural details.

	Pre-G-POEM <sup>1</sup>	Post-G-POEM <sup>2</sup>
<b>Pre-G-POEM gastroparesis treatment; n (%)</b>		
▪ Prokinetic only	6 (30%)	5 (25%)
▪ Prokinetic and botulinum toxin injection	12 (60%)	–
▪ Prokinetic and transpyloric stenting	1 (5%)	–
▪ Prokinetic and gastro-jejunostomy tube	1 (5%)	–
<b>Gastric emptying scintigraphy</b>		
▪ Abnormal test n (%)	100%	5 (31.3%)
▪ Percentage gastric retention at 4-hours, mean ± SD	36.5 ± 25.6%	25.3 ± 28.1%
<b>Objective esophageal manometric testing; median (IQR)</b>		
▪ Basal resting pressure (BRP) (mmHg)	15.2 (IQR 12.7–18.3)	–
▪ Integrated relaxation pressure (IRP) (mmHg)	4.9 (IQR 4.1–7.5)	–
<b>Objective pH monitoring; median (IQR)</b>		
▪ DeMeester score	18.5 (IQR: 13.7–31.8)	8.1 (IQR: 1.65–12.95)
▪ Abnormal DeMeester score	13/16 (81.3%)	2/10 (20%)
▪ % time of abnormal acid exposure	23.1% (IQR: 11.3–54.5)	5.4% (IQR: 1.2–6.2)
<b>proton pump inhibitors (PPI) use; n (%)</b>		
▪ Occasionally	1 (5%)	1 (5%)
▪ Daily	19 (95%)	4 (20%)

G-POEM, gastric-peroral endoscopic myotomy; IQR, interquartile range; PPI, proton pump inhibitor.

<sup>1</sup> Variables on objective manometric testing were available for 11 patients.

<sup>2</sup> Variables on objective pH evaluation were available for 10 patients



► **Fig. 1** Gastroparesis Cardinal Symptom Index (GCSI) scoring system parameters pre- and post- G-POEM.

In our multicenter study, a total of 20 patients underwent G-POEM with an 85% rate of clinical success during a median clinical follow-up time of 8.9 months (3–17), with 75% having at

least 50% reduction in gastric retention at 4 hours post-G-POEM. Moreover, as anticipated, use of PPI was significantly reduced post-G-POEM, 95% to 25% ( $P < 0.03$ ), and normalization of objective pH findings post-G-POEM was noted in 90% of the patients who underwent both pre- and post-G-POEM evaluation ( $n = 10$ ).

G-POEM is considered a minimally invasive procedure with an acceptable safety profile [44], which is an essential element of any therapeutic modality that is offered to a vulnerable population such as post-LTx patients. Based on the most recent meta-analysis [21] and an international prospective trial [19], the rates of AEs post-G-POEM were reported to be 6.1% and 6.2%, respectively. The rate of AEs in our cohort was 10% ( $n = 2$ ), with both being moderate in severity [28] requiring re-admission and additional procedures. While it is premature to conclude that post-LTx patients are at a higher AEs risk post-G-POEM compared to the general population, it is crucial to appreciate that the multiple comorbidities and the use of immunosuppressive medications may place this population at a higher risk of developing late AEs.

Although not reported in our cohort, similarly to acid reflux, non-acid reflux has been associated with increased mortality in post-LTx patients through lung graft injury [45–47]. With the decreased pyloric contractility post-G-POEM, there has been

growing concern of non-acid, bile, reflux post-G-POEM, however, with the lack of literature with long-term follow-up, the burden and the incidence of bile reflux post-G-POEM remains inconclusive. Therefore, it is crucial to evaluate patients with PPI refractory GER symptoms with objective pH testing both pre-and post- G-POEM to assess for non-acid reflux [48].

Despite the early promising outcomes, the results of our study should be cautiously interpreted due to the limited evidence on the efficacy and the long-term outcomes of G-POEM in post-LTx patients. G-POEM is a procedure that is directed toward relieving the pressure at the level of the pylorus without modifying the underlying gastric motility dysfunction, therefore, the efficacy of G-POEM is still variable among patients. This has been mirrored in the heterogeneous outcomes presented in the literature [20,21] and highlighted in the recent multicenter prospective study [19]. It is still premature to recommend G-POEM for all patients with refractory gastroparesis post-LTx, however, it is a promising non-surgical alternative for managing refractory gastroparesis and resulting GER.

This study has multiple limitations. Due to the retrospective design, small sample size, and missing important objective and subjective (quality of life, GER) measures, the study was subject to selection bias as well as uncontrolled confounding effects that could negatively impact the study's internal validity. Furthermore, the relatively short follow-up time interval prevents us to conclude the role of G-POEM in decreasing the rate of BOS and the potential survival benefit in this population. Nevertheless, this was the first multicenter study looking into this new promising G-POEM indication and highlighting its potential role in improving severe gastroparesis symptoms as well as limiting GER. Future prospective trials are required to better understand the prevalence and the implications of different management approaches in this population.

## Conclusions

In conclusion, G-POEM is a promising noninvasive therapeutic tool for management of refractory gastroparesis and GER post-LTx. Its safety in this patient population and potential impact on graft survival deserve further study in a prospective fashion.

## Competing interests

Dr. Hwang is a consultant for Boston Scientific, Olympus, and Medtronic, Dr. Draganov is a consultant for Olympus, Boston Scientific, Cook, Lumendi, Microtech. Dr. Zuchelli is a consultant for Boston Scientific, Dr. Piraka is a recipient of study funding from Aries and US Endoscopy, Dr. Khashab is a consultant for Boston Scientific, Olympus, and Medtronic.

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