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Laparoscopic and thoracoscopic whole-stomach esophagectomy with preoperative pyloric balloon dilatation for esophageal cancer: a prospective multicenter case-series outcome

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Abstract

Introduction To mitigate gastroparesis as well as other post-operative complications, we undertook a prospective multicenter study to assess the feasibility, safety, and efficacy in the short-term outcomes of laparoscopic and thoracoscopic whole stomach esophagectomy with preoperative pyloric balloon dilatation.

Methods A prospective descriptive study on 37 patients with laparoscopic and thoracoscopic whole stomach esophagectomy with preoperative pyloric balloon dilatation from January 2019 to March 2023. The perioperative indications, clinical data, intra-operative index, pathological postoperative specimens, postoperative complications, and follow-up results were retrospectively evaluated.

Results In our study, all patients were male, with dysphagia as the predominant symptom (45.9%). Esophageal cancer incidence was similar between middle and lower thirds. Nodules were the primary finding on esophagoscopy (48.6%). Preoperative pyloric dilation averaged 31.2 min without complications. Surgical duration ranged from 225 to 400 min (mean 305). Gastric tube fluid volume averaged 148.9 ± 110.66 ml per day. Among 34 post-operative cases underwent gastric transit scans, most had non-dilated stomachs with efficient pyloric drug circulation. Three cases required prolonged ventilation, precluding pyloric circulation scans. Four patients developed chylous fistula, one requiring chest tube embolization. Recurrent laryngeal nerve damage occurred in 10.8% of cases.

Conclusion After evaluating esophageal cancer patients undergoing laparoscopic whole-stomach esophagectomy with preoperative pyloric balloon dilatation, it was found that this procedure is safe, effective, and significantly reduces postoperative gastroparesis and related complications.

Keywords Laparoscopic and thoracoscopic esophagectomy, Whole stomach esophagoplasty, Preoperative pyloric balloon dilatation, Case series

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Intruction

Esophageal cancer (EC) stands as the eighth most prevalent cancer worldwide, with 510,71 new cases reported annually. Moreover, the mortality rate demonstrates an escalating trajectory, culminating in 445,129 deaths in 2022 as documented by Globocan [1]. Managing Esophageal cancer remains challenging and multifaceted, necessitating the collaboration of various specialties including chemotherapy, radiotherapy, surgery, and nutritional interventions. Of these, surgery stands out as the primary treatment modality. Minimally invasive esophagectomy offers numerous notable advantages in comparison to open surgery. Presently, the practice of replacing the esophagus with the stomach post-esophagectomy is widespread. Several studies have indicated that utilizing the entire stomach yields numerous benefits over employing a gastric tube, primarily due to the ample blood supply to the anastomosis and the preservation of gastric capacity, with no significant differences between the two groups regarding the rates of anastomotic leakage, anastomotic stenosis, pneumonia, or delayed gastric emptying [2, 3].

Nonetheless, some complication such as thoracic stomach syndrome, delayed gastric emptying, caused by acquired pyloric stenosis (APS), after whole-stomach esophagectomy can elevate the incidence of respiratory complications, the likelihood of anastomotic leakage, and prolong hospitalization [2, 4, 5]. Due to the 15% incidence of acquired pyloric stenosis (APS) resulting from truncal vagotomy, numerous surgeons opt to conduct pyloroplasty or pyloromyotomy concurrently with esophagectomy. An alternative approach to manage APS is through endoscopic pyloric balloon dilatation (EPBD), preoperatively or postoperatively [2, 6]. In recent years, minimally invasive esophagectomy (MIE) techniques, particularly laparoscopic esophagectomy, have demonstrated superiority over traditional open esophagectomy in terms of postoperative outcomes, notably reducing pulmonary complications, while maintaining comparable disease-free survival (DFS) and overall survival (OS) rates [7]. To mitigate delayed gastric emptying, or Gastroparesis, as well as other post-operative complications, we undertook a prospective multicenter study to assess the feasibility, safety, and efficacy in the short-term outcomes of Laparoscopic and Thoracoscopic Whole-Stomach Esophagectomy with Preoperative Pyloric Balloon Dilatation.

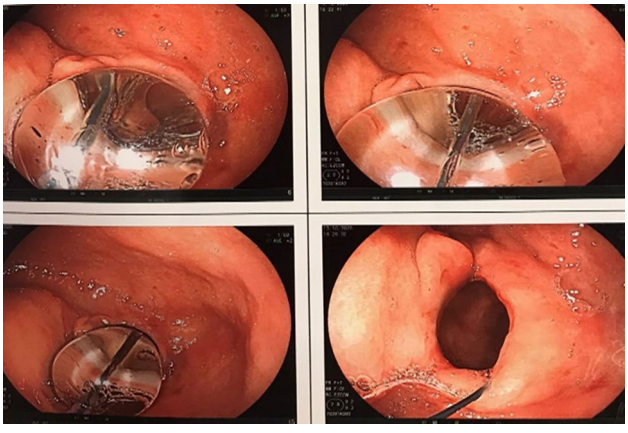

Fig. 1 Preoperative endoscopic pyloric balloon dilatation

Methods

Data collection

This case series has been reported following the PROCESS guidelines at the conclusion of the methods section (with citation included in the references section) [8] and was registered in compliance with the principles of the declaration of Helsinki. After an Institution Review Board approval, all patients with a histologically proven diagnosis of resectable esophageal squamous carcinoma according to the 8th edition of AJCC/UICC and the TNM classification, who underwent laparoscopic and thoracoscopic whole-stomach esophagectomy with two-field lymphadenectomy and preoperative pyloric balloon dilatation at the Department of Gastrointestinal and Hepato-pancreato-biliary surgery, Hanoi Medical University Hospital and the Department of Gastrointestinal surgery, Viet Duc University Hospital from January 2020 to March 2023 were prospectively enrolled.

Surgical procedure

All surgeons included in our study were highly experienced with at least 50 cases of esophagectomy (open or laparoscopic). Preoperative endoscopic pyloric balloon dilatation was conducted one day prior to surgery (Fig. 1). The dilation of the pylorus using a balloon (20–25 mm in diameter) was carried out thrice, with each dilation session lasting between 2 and 5 min. Following each dilation, the pylorus consistently exhibited enlargement upon re-examination.

Laparoscopic and thoracoscopic esophagectomy was performed, including lymph node dissection and esophagoplasty utilizing the entire stomach in accordance with established technical protocols:

- Patient positioning: The patient is placed in a lateral decubitus position on the left side, with the potential for positional adjustments during the surgical procedure.
- Thoracoscopy stage: This involves the dissection of the thoracic esophagus and the mediastinal lymph node dissection (Fig. 2).
- Laparoscopic abdominal stage: The entirety of the stomach is mobilized, with preservation of the pyloric artery and the right omental vascular bundle.

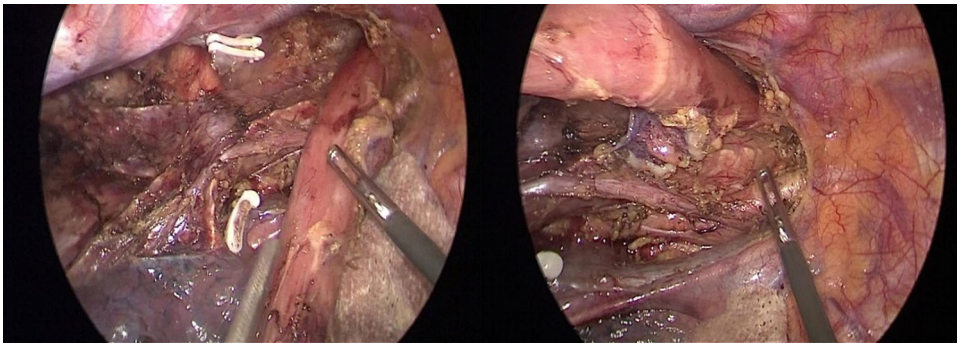

Fig. 2 Dissection of the thoracic esophagus and the mediastinal lymph node

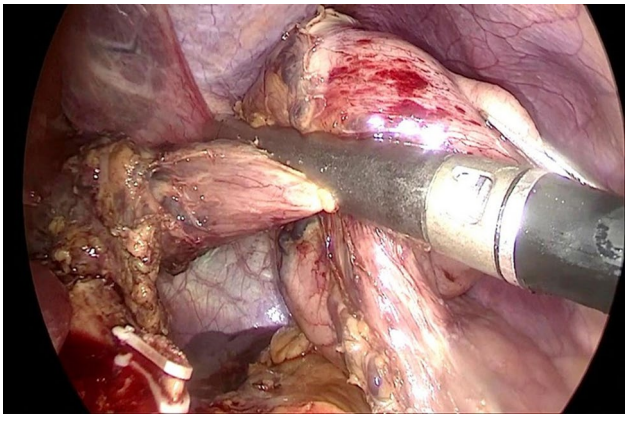

Fig. 3 Utilizing a 60 mm endoscopic cutter, the cardia is transected

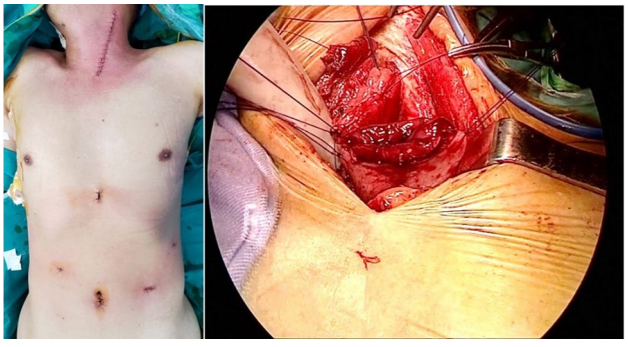

Fig. 4 Neck incision and trocar placement for establishing cervical esophageal-stomach anastomosis

Lymph node dissection encompasses groups 8a and 12a, while the left gastric vascular bundle is dissected and lymph node groups 7, 9, and 11p are scraped. Complete separation of the abdominal esophagus from the diaphragm is achieved, along with diaphragmatic widening and removal of lymph node groups 1 and 2. Utilizing a 60 mm endoscopic cutter, the cardia is transected (Fig. 3), and the lower end of the esophagus is sutured to the stomach using Vicryl 3.0 thread to facilitate its mobilization towards the neck.

- Neck phase: A J-shaped incision is made at the anterior edge of the left sternoclavicular muscle (Fig. 4). The cervical esophagus is transected horizontally at the level of the lower border of the thyroid gland. Subsequently, the lower end of the esophagus is closed, and the entirety of the esophagus and stomach is mobilized upwards towards the neck via the posterior mediastinum. An esophageal-stomach anastomosis is then established.

Postoperative monitoring and treatment

1. Circulation Evaluation through the Pylorus:

- Conduct a scan on the 3rd day post-surgery to assess pyloric circulation.
- Administer medication under a fluorescent screen or at specified intervals: immediately upon contrast agent ingestion, and 3 h and 6 h post-ingestion.

2. Gastric Tube Monitoring:

- Monitor daily discharge volume and color of fluid from the gastric tube.

3. Early Feeding via Gastric Tube:

- Initiate early feeding through the gastric tube once pyloric circulation is confirmed.
- Administer feeding via nasogastric tube drip.

4. Pleural Drainage Management:

- Remove pleural drainage when fluid output is less than 100 ml/24 hours and lung expansion is satisfactory.

5. Anastomosis Assessment:

- Perform anastomosis evaluation after 7 days.
- Initiate oral feeding post-assessment of anastomosis.

Results evaluation: assessing Gastroparesis based on Delphi standards (2020) [9]

Criteria for Diagnosing Early Gastroparesis (Within 14 Days After Surgery):

1. Gastric fluid volume exceeding 500 ml/24 hours, measured on the morning of the 5th day post-surgery or later (within 14 days).
2. Doubling of the transverse diameter of the gastric tube observed on plain chest radiographs (compared to images acquired on the day of surgery), accompanied by the presence of air-fluid levels.

Criteria for Diagnosing Late Gastroparesis (After 14 Days Post-Operation): Both of the following criteria must be met:

1. Patient reports experiencing "a little" or "a lot" for at least 2 of the following symptoms: early satiety, vomiting, nausea, belching, and inability to satisfy caloric needs orally.

Table 1 Patients' demographics with preoperative laboratory results

Index	N = 37	
Age (mean ± SD)	57,1 ± 8,7 years old	
Gender	100% Male	
Initial physical symptoms (n, %)	Dysphagia	17 (45,9%)
	Weight loss	10 (27%)
	Chest pain	6 (16,2%)
	Fatigue	2 (5,4%)
	Accidentally discovered	2 (5,4%)
Tumor location determined on gastroesophageal endoscopy	The middle third	21 (56,8%)
	The lower third	16 (43,2%)
Macroscopic image on gastroesophageal endoscopy	Wart-like lesion	18 (48,6%)
	Ulcer	5 (13,5%)
	Malignant stricture	1 (2,7%)
	Infiltrative	8 (21,6%)
	Unknown	5 (13,5%)
Preoperative pyloric balloon dilatation	Time (minutes, min-max)	31,2 ± 12,3 (20–45)
	Complications	no

2. Delayed excretion of contrast agent from the upper gastrointestinal tract.

Statistical analysis

Categorical variables were depicted as proportions of individual categories. Discrete variables comprised numerical values with a finite countable range between any two points. Continuous variables were portrayed as either mean values or medians in cases of non-normal distribution, along with their respective ranges. The analysis of continuous variables was conducted using the Wilcoxon rank sum test. Categorical variables underwent scrutiny via the chi-square test or Fisher's exact test. Statistical analyses were executed utilizing SPSS for Windows, version 22.0 (SPSS Inc., Chicago, IL, USA).

Results

From January 2019 to March 2023, a total of 37 patients underwent laparoscopic and thoracoscopic whole-stomach esophagectomy with two-field lymphadenectomy and preoperative pyloric balloon dilatation.

Patients' demographics with preoperative laboratory results (Table 1)

In our research, the entire patient cohort consisted of male individuals. Predominantly, patients presented at the hospital with symptoms indicative of dysphagia, constituting 45.9% of cases. The incidence of esophageal cancer in the middle third segment mirrored that of the lower third. Notably, nodules were the primary pathological findings observed during esophagoscopy, representing 48.6% of cases. The mean duration of pyloric dilation procedure was 31.2 min, during which no complications occurred.

Technical details (Table 2)

The mean operative duration is 305 min, with the longest operation lasting 400 min and the shortest lasting 225 min. The average volume of fluid passing through the gastric tube was 148.9 ± 110.66 ml/24 hours.

Short-term outcomes (Table 3)

In the study, 34 post-operative cases underwent gastric transit imaging, revealing that the majority exhibited non-dilated stomachs with efficient drug circulation through the pylorus. However, in three instances, complications necessitated prolonged mechanical ventilation, precluding pyloric circulation scans. Additionally, four patients developed chylous fistula, requiring hospitalization for over 20 days, with one case requiring chest tube embolization. The rate of recurrent laryngeal nerve damage was 10.8%. Notably, our investigation reported two cases of anastomotic leak (graded as grade 2 according

Table 2 Technical details

Index	Mean	Max	Min
Total surgical time (minutes)	305,9	400	225
Ventilation time (hours)	32,3 ± 28,42	192	24
The daily volume of fluid passing through the gastric tube (ml)	148,9 ± 110,66	500	320
The postoperative duration for initiating refeeding via the gastric tube (day)	5,2 ± 2,98	2	7
The interval for the removal of pleural drainage (day)	9,1 ± 5,76	20	5
Duration of hospitalization (day)	13,6 ± 6,28	9	32

Table 3 Short-term outcomes

Index			N (%)
Postoperative results of gastric transit scans (N = 34)	Gastric condition	Dilated	2 (5,4%)
		Normal	32 (94,1%)
	Circulation through the pylorus	Good	28 (82,4%)
		Immediate	4 (11,8%)
		Stalled	2 (5,4%)
Postoperative Complications	Pneumonia		3 (8,1%)
	Anastomotic leakage		2 (5,4%)
	Recurrent Laryngeal Nerve Injury		4 (10,8%)
	Chylous fistula		4 (10,8%)
Slow gastric transit (according to Delphi criteria)			2 (5,4%)
Number of lymph nodes retrieved`	Chest area		15,9 ± 9,91
	Abdominal area		9,5 ± 4,99
	Total		26,3 ± 11,56
TNM Staging	0		1 (2,7%)
	I		16 (43,2%)
	II		5 (13,5%)
	III		13 (35,1%)

to the Clavien Dindo classification) and four cases of anastomotic stenosis, which manifested late postoperatively, typically occurring 2–3 months after the surgical procedure.

Discussion

Laparoscopic and thoracoscopic esophagectomy offers clear benefits regarding surgical trauma, duration of operation, and postoperative recovery. Tsujimoto et al. reported that, compared to open gastric tube reconstruction, laparoscopy-assisted gastric tube reconstruction significantly reduces the postoperative systemic inflammatory response syndrome, which is often linked with increased postoperative complications [10]. Additionally, several innovative minimally invasive approaches, such as robot-assisted esophagectomy, mediastinoscopic esophagectomy, and flexible gastroscopic esophagectomy, have been developed [11–13]. These methods promise to further decrease surgical trauma and the incidence of postoperative complications. Future research is necessary to verify the effectiveness of these new techniques.

Gastric esophagoplasty for esophagectomy, first introduced by Akiyama in 1972, is now employed by approximately 90% of surgeons in Europe, 80% in Asia, and 79% in North America, owing to its superior advantages. This technique benefits from the anatomical proximity and rich vascularization of the stomach and has demonstrated improved long-term outcomes in terms of quality of life and nutritional status post-esophagectomy [4, 14–16]. Research by Wenxiong Zhang et al. has shown a significant reduction in the incidence of reflux and intrathoracic gastric syndrome in patients undergoing esophageal reconstruction with a gastric tube. The authors attribute these improvements to the gastric tube of the reconstructed esophagus, which minimizes the duration that food remains in the gastric tube. Additionally, the surgical creation of the gastric tube often involves the removal of the portion of the stomach that contains acid-secreting glands, thereby decreasing the gastric acid concentration and further reducing postoperative reflux rates [4].

However, some studies advocate for the advantages of using the whole stomach approach over the gastric tube method for esophagectomy. The whole stomach maintains superior blood supply, primarily due to the submucosal vessels that predominantly nourish the distal part of the stomach and the anastomosis, thereby reducing the risk of esophagogastric anastomosis leakage. Additionally, this approach enhances the stomach's capacity for food storage and improves its ability to absorb and digest nutrients, potentially mitigating the risk of anemia resulting from impaired absorption. These benefits are underscored by angiographic comparisons among three types of esophagoplasty: the narrow gastric tube, the wide gastric tube, and the whole stomach. The findings indicate that both the wide gastric tube and the whole stomach maintain adequate blood supply, whereas the anastomosis site in the narrow gastric tube configuration exhibits significantly poorer vascularity. However, the whole-stomach method has drawbacks, including a higher incidence of reflux esophagitis and thoracic stomach syndrome, both of which are associated with gastroparesis. These complications can be mitigated through preoperative pyloric balloon dilation, reducing the incidence of gastroparesis to only 5.4%, a comparable rate. In terms of other disadvantages, no significant differences were observed between the whole-stomach gastroplasty group and the gastric tube gastroplasty group regarding the rates of anastomotic leakage, anastomotic stenosis, pneumonia, or delayed gastric emptying. Consequently, the authors recommend a personalized treatment approach for selecting the most appropriate reconstruction procedure could be developed by considering the rates of anastomotic leakage, anastomotic stenosis, pneumonia, and delayed gastric emptying, alongside oncological factors and patient-specific risk profiles, with a focus on mid- to long-term quality of life [3].

In a study involving 37 cases of whole stomach esophagoplasty with preoperative pyloric balloon dilatation, the entire gastric tube was successfully inserted into the neck via the posterior mediastinum. Our findings suggest that this anatomical location offers optimal conditions for the gastric tube within the mediastinal cavity due to its spaciousness and relatively shorter distance compared to alternative placements. Notably, our investigation reported two cases of anastomotic leak (graded as grade 2 according to the Clavien Dindo classification) and four cases of anastomotic stenosis, which manifested late postoperatively, typically occurring 2–3 months after the surgical procedure. JM Collard conducted a comparative study involving two groups of patients undergoing esophagoplasty, one with a gastric tube and the other with a whole stomach. The results revealed that the whole stomach group exhibited a significantly lower incidence of anastomotic stenosis (22.3% vs. 6%, $p=0.008$). Additionally, patients in the whole stomach group reported improvements in the number of daily meals, reduced sensations of early fullness, enhanced comfort during eating, and preserved stomach capacity. Furthermore, examination of blood vessels beneath the mucosa was found to be more effectively conducted in the whole stomach group [17].

Postoperative delayed gastric emptying, or gastroparesis, commonly occurs following esophagectomy with gastric bypass surgery, with reported rates ranging from 2.2 to 47% [18]. In 2020, diagnostic criteria for gastroparesis after esophagectomy were established by Delphi consensus following a conference of leading experts in esophageal surgery from Europe, North America, and Asia, representing regions with advanced surgical expertise in esophageal procedures [9]. In our study, patients were clinically monitored for signs such as gastric tube fluid output and respiratory difficulties. Additionally, on the third day post-surgery, circulation imaging with water-soluble contrast was conducted and evaluated according to the Delphi standards. The primary cause of postoperative gastroparesis is attributed to pyloric dysfunction, characterized by reduced motility of the digestive tract resulting from the excision of the vagal nerves during esophageal surgery. This "dullness" of the pylorus contributes significantly to gastroparesis. Furthermore, other factors, such as impedance to food circulation from the chest to the abdomen due to pressure differentials or twisting of the gastric tube, may also play a role in exacerbating this condition. According to Lei Zhang's study, which evaluated 285 patients undergoing esophagoplasty with either whole stomach or gastric tube without pyloroplasty following esophagectomy for cancer, the overall incidence of gastroparesis was 18.2%. Specifically, the incidence of gastroparesis was higher in the whole stomach gastroplasty group compared to the gastric tube gastroplasty group (13.2% vs. 22.4%, $p=0.05$) [14]. However, in our study, the rate of gastroparesis was lower at 5.8%. A retrospective review of 50 studies by Ronald D.L. Akkerman et al. yielded similar findings, suggesting that esophagoplasty with the whole stomach increases the risk of gastroparesis compared to gastric tube esophagoplasty [19]. Notably, factors such as intraoperative pyloric drainage, post-operative esophageal position (sternum or posterior mediastinum), and the location of the anastomosis (intrathoracic or cervical) did not significantly affect the incidence of gastroparesis [19]. Gastroparesis can significantly impact both short-term and long-term outcomes following surgery, particularly affecting the quality of life. In Frank Benedix's study involving 182 patients, where the rate of delayed gastric emptying was 39%, those experiencing gastroparesis demonstrated prolonged hospital stays and increased incidence of postoperative complications such as pneumonia, despite no significant difference in mortality rates compared to those without gastroparesis. In the long term, delayed gastric emptying can impair nutrient absorption, weight gain, and functional capacity, thereby impacting overall well-being and productivity [20].

The most widely proposed and debated preventive measure aimed at mitigating the occurrence of gastroparesis postoperatively involves intraoperative pyloric drainage, which encompasses techniques such as pyloric muscle opening, pyloroplasty, or Botox injection into the pyloric muscle. Across six randomized clinical trials and seven cohort studies comparing patients who underwent pyloric drainage with those who did not, it was observed that pyloric drainage failed to decrease the incidence of gastroparesis following esophagectomy [19]. Moreover, it was found to significantly elevate the risk of bile reflux and dumping syndrome [19]. However, Urschel et al. conducted a meta-analysis of studies comparing pyloric drainage versus non-drainage methods, revealing a significant reduction in gastroparesis risk within the pyloric drainage group, while other parameters such as anastomotic leak rate and respiratory complications remained unaffected [21]. Discrepancies among these studies arise from the lack of standardized diagnostic criteria for postoperative gastroparesis, alongside other influential factors like the method of esophagoplasty employed. In our study, none of the patients underwent pyloric drainage procedures, yet the incidence of gastroparesis was merely 5.4%.

One of the effective minimally invasive intervention methods recommended by numerous authors is endoscopic balloon dilation of the pylorus. In Jae-Hyn Kim's study (2008) involving 257 patients who underwent esophagectomy and gastric tube reconstruction between 2003 and 2006, 21 patients (8%) diagnosed with gastroparesis underwent pyloric dilation. Employing a balloon

with an average diameter of 20 mm yielded positive outcomes, with clinical symptom improvement almost immediately post-intervention and favorable long-term results. Only 2 patients required a second dilation at 3 and 4 months post-initial treatment [22]. According to M. Lanuti (2011), out of 436 patients, 98 (22%) exhibited symptoms of postoperative gastroparesis, with 51 patients undergoing pyloric myotomy (52%). Among these, 38 patients (39%) underwent endoscopic balloon dilation with a success rate of 95%, while the remaining 60 patients were conservatively managed with medications to enhance motility, gastric decompression, or close monitoring [15]. Therefore, post-operative balloon dilation of the pylorus emerges as a positive and safe treatment method for patients with postoperative gastroparesis, even in those who have undergone pyloric drainage surgery.

According to E. Hadzijusufovic's retrospective study involving 115 patients undergoing esophagectomy utilizing the Ivor-Lewis method from 2015 to 2017, and divided into two groups – one with preoperative pyloric balloon dilation and the other without – those who underwent preoperative pyloric dilation exhibited lower rates of anastomotic leak, respiratory complications, and shorter hospital stays [23]. In our research, preoperative endoscopic balloon dilation of the pylorus was implemented in 37 patients undergoing thoracoscopic esophagectomy and whole stomach gastroplasty, resulting in success in 32 cases. In instances where postoperative pyloric circulation was assessed to be satisfactory, patients exhibited no symptoms of gastroparesis. Early nasogastric tube feeding commenced with incremental volume adjustments, while patient response and recovery time were closely monitored. The average duration until refeeding postoperatively was 5.2 days, with the earliest instance occurring on the 4th day postoperatively. Despite successful interventions, complications arose in 2 patients, involving gastroparesis, along with 2 cases of anastomotic leakage and 1 case of pneumonia necessitating prolonged mechanical ventilation, which hindered the evaluation of postoperative gastroparesis. The average postoperative follow-up period was 6.5 months, ranging from 1 to 14 months, during which no signs of gastric stasis were observed. Retrospectively reviewing existing medical literature revealed scant information regarding studies on the utilization of preoperative pylorus balloon dilation. Most studies primarily reported outcomes of postoperative pylorus balloon dilation when delayed gastric transit occurred postoperative due to pyloric spasm.

Our study showed a feasible approach in EC by using laparoscopic whole-stomach esophagectomy with preoperative pyloric balloon dilatation to reduce postoperative gastroparesis and related complications. Further randomized trials with larger sample sizes and longer follow-up should be conducted to prove their effectiveness.

Conclusion

Following an investigation and assessment of 37 cases involving patients diagnosed with esophageal cancer undergoing laparoscopic whole-stomach esophagectomy with preoperative pyloric balloon dilatation, it was observed that pyloric dilatation conducted preoperatively is a secure, viable, and efficacious procedure. This intervention substantially diminishes the occurrence of postoperative gastroparesis and associated postoperative complications.

Author contributions

HN the first author conceived the original idea and wrote the manuscript; DHP conceived the original idea and operated the patients, edited manuscript; THL provided histological imaging diagnosis as well as illustrated figures to the article and wrote the manuscript; XHN, DHN, AKN operated the patients, edited manuscript. All authors read and approved the final manuscript.

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Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to patients' personal right of secret but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Ethics approval of this study was given by the Research Ethics Committees of Hanoi Medical University Hospital. Written informed consent for publication of their clinical details and clinical images was obtained from the patient and patient's family.

Provenance and peer review

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Competing interests

The authors declare no competing interests.

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