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Impact of vagus nerve integrity testing on surgical management in patients with previous operations with potential risk of vagal injury

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Abstract

Background Thoracic and foregut operations can cause vagal nerve injury resulting in delayed gastric emptying or gastroparesis. However, the cause of gastroparesis in these patients is not always from a vagal injury. We hypothesize that vagal nerve integrity (VNI) testing may better define who has vagal nerve dysfunction. This information may change subsequent operations. The aim of this study was to evaluate the impact of VNI testing in patients with prior thoracic or gastric surgery.
Methods From January 2014 to December 2017, patients who had previous operations with the potential risk of vagal injury and had VNI testing were reviewed. Excluded patients were those with no plan for a second operation or the second operation was only for gastroparesis. The main outcome was the percentage of operations altered due to the results of VNI testing.
Results Twelve patients (eight females) were included. Ages ranged from 37 to 77 years. VNI results were compatible with vagal injury in eight patients (67%). VNI test results altered subsequent operative plans in 41.7% (5/12). Pyloroplasty was done in addition to fundoplication in two patients. Plans for hiatal hernia repair with or without redo-fundoplication in three patients were changed by an additional pyloroplasty in one patient and partial gastrectomy with Roux-en-Y reconstruction in two patients. All patients who had secondary surgery had resolution of symptoms and improvement in objective testing.
Conclusion The addition of VNI testing in patients with a previous potential risk of vagal nerve injury may help the surgeon select the appropriate secondary operation.

Keywords Vagus nerve integrity · Vagus nerve injury · Delayed gastric emptying · Gastroparesis · Postsurgical gastroparesis · Pancreatic polypeptide

Previous thoracic and foregut surgery can cause vagotomy or vagus nerve injury, either accidentally or intended. The most common procedures, which can lead to such an injury, include fundoplication, lung or heart transplantation, esophageal, gastric, and bariatric surgery [1–3]. Injury of the vagus nerve can result in delayed gastric emptying or gastroparesis. Gastroparesis is a syndrome of delayed gastric emptying without mechanical obstruction [4]. Causes of gastroparesis can be idiopathic, diabetes-related, post-surgery, medication-induced, associated with connective tissue diseases, neurologic diseases, metabolic abnormalities, infections, and malignancy [5]. Postsurgical gastroparesis is the third most common cause of gastroparesis and has been reported in 3–17% of all diagnosed gastroparesis [5].

The cardinal symptoms of gastroparesis include nausea, vomiting, early satiety, bloating, post-prandial fullness, and upper abdominal pain [4]. If these symptoms occur in the case of previous thoracic or foregut surgery, the clinician should have a high suspicion of a possible vagal injury and consider further investigations.

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However, patient presentations can vary from absence of subjective symptoms to severe symptoms with malnutrition. Also these symptoms can mimic other conditions including gastroesophageal reflux disease (GERD) and functional dyspepsia [6]. Patients with minimal symptoms or less degree of gastroparesis symptoms may be neglected. If these patients undergo a subsequent gastric-related operation, a negative outcome may occur [7–9].

Moreover, the cause of gastroparesis in patients with prior thoracic or foregut surgery is not always from vagal nerve injury. It may be from preexisting diseases such as diabetes, postoperative medications or even idiopathic. It is necessary to evaluate for vagus nerve integrity (VNI) to distinguish vagal nerve injury from other causes in order to choose an appropriate treatment.

Therefore, patients with previous thoracic and gastric surgery who require a secondary gastric operation and have any degree of gastroparesis symptoms should have a vagus nerve function evaluation. Currently, no study has reported on the benefits of VNI testing on subsequent gastric surgery in patients who have had prior thoracic and foregut surgery with delayed gastric emptying. We hypothesize that VNI testing may help determine who has vagal nerve dysfunction. These results can affect patient treatment by altering the subsequent operation. The aim of this study was to evaluate the impact of VNI testing on subsequent surgical treatment in patients with prior thoracic or gastric surgery.

Materials and methods

This study was performed at a metropolitan academic quaternary care center. We retrospectively collected and reviewed data from January 2014 to December 2017 on patients who underwent VNI assessment. Patients were excluded if they did not have a previous surgical history of thoracic or foregut operation or other procedures with the potential risk of a vagus nerve injury (e.g., heart–lung transplantation, anti-reflux procedures, hiatal hernia repair, bariatric surgery, other foregut operations, or endoscopic treatment of GERD) or did not have vagal nerve function tested. Data collected and analyzed were age, gender, previous surgical procedures, clinical presentation, investigations performed, results of VNI assessment, secondary procedure planned or performed, and the results of subsequent intervention. Primary outcomes were the number and percentage of operations which were changed due to the results of the VNI test. Secondary endpoints were the percentage of patients who had an absence of gastroparesis symptoms and overall outcome. The absence of gastroparesis symptoms was defined as no presentation of cardinal symptoms of gastroparesis including nausea, vomiting, early satiety, bloating, post-prandial fullness, or upper abdominal pain. We defined the results of treatments as "resolved" if the patient had no subjective symptoms of the primary disease and no delayed gastric emptying on further objective tests. We defined "improved" when the patient had fewer symptoms than the first visit and "stable" if they had no change in symptoms.

Patient assessment and care

Patients with prior thoracic/foregut surgery and any degree of gastroparesis symptoms who had an indication for a second operation were referred to a surgeon and assessed by medical and surgical experts in gastrointestinal motility disorders. The included assessments were a detailed history, physical examination, comprehensive metabolic panel, and investigations. Patients with symptoms of gastroparesis were investigated by upper endoscopy, esophageal motility, 24-h pH monitoring, and contrast imaging. The purposes of these investigations were to rule out other possible causes (e.g., GERD, mechanical obstruction, and other esophageal/gastric motility disorders). In order to confirm the diagnosis of gastroparesis, a 4-h nuclear medicine gastric emptying study (GES) was used. VNI was evaluated using the response of plasma pancreatic polypeptide to sham feeding to distinguish vagal injury from other causes [10].

Gastric emptying

Gastric emptying of solids was measured by radionuclide scintigraphy using technetium-99m (Tc99m) sulfur colloid. The solid meal consisted of four ounces of liquid egg whites scrambled with 1.0 mCi of Tc99m-sulfur colloid, two slices of white bread and 120 mL of water. After the patient completed the meal, images were obtained at intervals over the abdomen for 4 h. A geometric mean was obtained and the activity within the stomach was quantified using decay correction. Gastric emptying was considered normal if 30–90%, $< 60\%$, $< 30\%$, and $< 10\%$ of gastric content remain in the stomach by 1–4 h, respectively [11].

Vagus nerve integrity

VNI was measured indirectly by the response of plasma pancreatic polypeptide to sham feeding [10, 12, 13]. Patients were required to fast overnight or at least 8 h before starting the test. Two samples of venous blood were obtained at 15 and 30 min before feeding for the baseline measurement. Patients then underwent a standard sham feeding by chewing and spitting out a standard hamburger over a 15-min time period. They were also instructed to avoid swallowing any food or drink during the test. Four blood samples were then obtained at 15, 30, 45, and 60 min after the feeding was complete. An increase of more than 50% in plasma

pancreatic polypeptide level within 30 min of sham feeding indicated a normal function of the vagus nerves. This technique was described by Balaji et al. [10] with a sensitivity of 83%, specificity of 92%, and a positive predictive value of 92% to identify intact vagus nerves.

Results

Thirteen patients underwent the VNI test between January 2014 and December 2017. All patients had a previous history of thoracic or gastric surgery. However, one patient was excluded because the second operation was performed only for gastroparesis and not for any other condition. Therefore, 12 patients were included for analysis and the data are summarized in Tables 1 and 2.

There were eight females and four males with ages that ranged from 37 to 77 years. The 4-h GES was performed in 11 patients and all had delayed gastric emptying. One patient did not undergo the GES due to no vagal response from the VNI testing before undergoing the GES. The VNI results were compatible with vagal nerve injury in eight patients (67%).

Five patients had prior bilateral lung transplantation and six patients had prior hiatal hernia repair and fundoplication. One patient had prior open hiatal hernia. Nine patients (75%) presented with reflux symptoms and eight patients (67%) had at least one symptom of gastroparesis. One lung transplantation patient had no symptoms but his lung biopsy pathology showed chronic micro-aspiration with acute rejection. Two out of eight patients (25%) who did not respond to the vagus nerve integrity test and 50% of those with vagal nerve response had an absence of gastroparesis symptoms at presentation.

Overall, VNI testing changed operative plans in 41.7% (5/12). In the group with no vagal response, operative plans were changed in five out of eight patients (62.5%). Plans for fundoplication in two patients were modified by an additional pyloroplasty. The plans for hiatal hernia repair with or without redo-fundoplication in three patients were changed by an additional pyloroplasty in two and gastrojejunostomy in one. However, two of these three patients had hiatal hernia repair and partial gastrectomy with Roux-en-Y reconstruction in the final treatments. On the other hand, the patients who responded to vagus nerve integrity test had no change in operative plans.

All patients who had secondary surgery had resolution of symptoms and improvement in objective tests (i.e., signs of rejection or micro-aspiration in lung transplant patients).

Discussion

Vagal nerve injury can occur after foregut and thoracic surgeries and may result in delayed gastric emptying. In our study, the most common previous potential surgical procedure was fundoplication with hiatal hernia repair followed by bilateral lung transplantation. These procedures carry a risk for vagal nerve injury that results in various degrees of gastroparesis symptoms.

A literature review by van Rijn et al. [7] showed that the prevalence of unintended vagal nerve injury after anti-reflux surgery ranged from 10 to 42%. The prevalence of diarrhea, nausea and vomiting was higher in the vagal nerve injury group than the vagal intact group. The same authors also reported the short- and long-term results after anti-reflux surgery in patients with or without vagal nerve injury. Short-term results showed postoperative gastric emptying was significantly delayed in the vagus nerve injury group compared with the vagus nerve intact group. Long-term outcomes showed significantly less reflux control and higher reoperation rate in the vagus nerve injury group (7/13 [54%]) versus the vagal intact group (9/58 [16%]) ($p=0.007$) and most patients underwent reoperation because of recurrence of reflux [8]. In our study, patients with previous fundoplication with hiatal hernia repair underwent a second operation due to recurrent hiatal hernia, fundoplication related complications, and GERD.

The incidences of gastroparesis after lung or heart transplantation or both ranged from 8 to 83% [2, 14–16]. Injury of the vagal nerve during lung transplantation, which can result in delayed gastric emptying and esophageal dysmotility, can induce GERD with a high prevalence of reflux from 23 to 73% [15, 17] and can develop an obliterative bronchiolitis from aspiration. Berkowitz et al. [2] reported 44% of patients with symptomatic gastroparesis developed obliterative bronchiolitis possibly due to micro-aspiration. A study from Raviv et al. [18] also reported similar results. All patients with lung transplantation in our study underwent a second operation due to treatment of GERD and micro-aspiration.

Our findings show that reflux and reflux-related complications (i.e., micro-aspiration) were usually the reasons for subsequent surgery. Delayed gastric emptying can be used to explain these findings. Prolonged gastric retention can increase intragastric pressure and lead to reflux. A study from Gourcerol et al. [19] showed that delayed gastric emptying was associated with an increased number of daily and post-prandial liquid/mixed reflux events, a longer bolus clearance time, and increased esophageal proximal extension. A literature review from Emerenziani et al. [20] reported that delayed gastric emptying may increase less acidic reflux without an increase of acid gastroesophageal reflux. Therefore, a less acidic reflux does not produce

Table 1 Patient characteristics, investigations and pre-vagus nerve integrity test diagnosis

Patient number	Age	Gender	Presentation	Previous potential risk operations	Investigations conducted	Diagnosis (pre-vagus nerve integrity test)
1	66	F	Reflux symptoms	• Bilateral lung transplantation due to emphysema	• EGD: normal • UGIS: mild silent aspiration, no reflux, no hiatal hernia • EMS: normal • pH impedance: negative for GERD • Bronchoscopy with biopsy: no rejection	• Post pulmonary transplantation with silent aspiration
2	65	F	Dysphagia, gastric fullness sensation	• Laparoscopic paraesophageal hernia repair with mesh and Nissen fundoplication and anterior and posterior gastroplexy	• EGD: moderately dilated esophageal lumen. The wrap appeared very tight and displaced into the thorax. Medium amount of food at antrum • UGIS: dilated esophagus secondary to a tight fundoplication wrap and paraesophageal hernia • EMS: high wrap pressure at fundoplication	• Recurrent paraesophageal hernia • Esophageal dysmotility secondary to displaced tight wrap
3	59	M	Intractable N/V, severe malnutrition	• Adjustable gastric banding (ABG) • Removal of AGB, hiatal hernia repair and Nissen fundoplication • Gastrojejunostomy and gastrostomy tube	• EGD: narrowing of cardia secondary to the capsule of the gastric banding. Slipped Nissen fundoplication to body of stomach leading to acute angle and narrowing of stomach • UGIS: mild narrowing at gastroesophageal junction, no obstruction	• Gastric stenosis secondary to misplaced fundoplication • Status post gastrojejunostomy and gastrostomy tube
4	39	M	Reflux symptoms, abdominal bloating	• Transoral incisionless fundoplication (TIF) • Undo-TIF and hiatal hernia repair	• EGD: gastritis, medium amount of food in stomach • EMS: normal • pH impedance: positive for GERD	• Recurrent GERD
5	37	F	Reflux symptoms, N/V, dysphagia	• Nissen fundoplication • Redo-fundoplication	• EGD: hiatal hernia, disruption of the wrap at the cardia, chronic gastritis, medium amount of food in the stomach • UGIS: recurrent hiatal hernia	• Recurrent hiatal hernia
6	64	F	Reflux symptoms, N/V	• Hiatal hernia repair and Nissen fundoplication • Gastrojejunostomy (unknown reason)	• EGD: paraesophageal hernia • UGIS: paraesophageal hernia with delayed esophageal emptying, dilated and tortuous esophagus • EMS: failed peristalsis with esophagogastric junction outflow obstruction	• Recurrent paraesophageal hernia
7	61	M	N/V, early satiety, abdominal bloating, reflux symptoms	• Bilateral lung transplantation due to chronic hypersensitivity pneumonitis	• EGD: normal • UGIS: normal • EMS: normal • pH impedance: positive for GERD • GES: delayed gastric emptying • Bronchoscopy with biopsy: no rejection	• Gastroparesis at early post transplantation • GERD
8	64	F	Reflux symptoms, cough	• Bilateral lung transplantation due to sarcoidosis	• EGD: gastritis • EMS: ineffective esophageal motility • pH impedance: positive for GERD • Bronchoscopy with biopsy: no rejection	• GERD • Esophageal dysmotility

Table 1 (continued)

Patient number	Age	Gender	Presentation	Previous potential risk operations	Investigations conducted	Diagnosis (pre-vagus nerve integrity test)
9	73	F	Reflux symptoms, N/V, abdominal bloating (type 2 DM with diabetic gastroparesis)	• Nissen fundoplication • Hiatal hernia repair	• EGD: malpositioned wrap, no hiatal hernia • UGIS: gastroesophageal reflux • pH impedance: negative for pathological GERD, confirming association between symptoms and reflux events • GES: delayed gastric emptying	• Malpositioned fundoplication with reflux • Diabetic gastroparesis
10	66	M	Positive chronic micro-aspiration from lung pathology, no GI symptom	• Bilateral lung transplantation due to chronic obstructive pulmonary disease	• EGD: Barrett's esophagus without dysplasia, large amount of food in the stomach • UGIS: significant gastroesophageal reflux extending up to the level of the carina • EMS: ineffective esophageal motility, hiatal hernia • pH impedance: negative for pathological GERD	• Barrett's esophagus • Esophageal dysmotility • Hiatal hernia • Chronic micro-aspiration
11	60	F	Reflux symptoms (poor controlled type 2 DM)	• Bilateral lung transplantation due to interstitial pulmonary fibrosis	• EGD: hiatal hernia, medium amount of food in the stomach • UGIS: no gastroesophageal reflux • EMS: hypercontractile esophagus • pH impedance: positive for GERD • Bronchoscopy with biopsy: no rejection	• Hiatal hernia • GERD
12	77	F	Reflux symptoms, abdominal pain	• Open hiatal hernia repair	• EGD: esophagitis, hiatal hernia, gastritis • UGIS: moderate size hiatal hernia • EMS: normal • pH impedance: positive for GERD	• Recurrent hiatal hernia • GERD

EGD esophagogastroduodenoscopy, *UGIS* upper gastrointestinal contrast study, *EMS* esophageal manometry study, *GERD* gastroesophageal reflux disease, *N/V* nausea/vomiting, *DM* diabetes mellitus, *GI* gastrointestinal

Table 2 Patient management plans before and after vagus nerve integrity test, final managements and clinical outcomes

Patient number	Initial management plan (pre-vagus nerve integrity test)	GES	VNI test[a]	Management plan after vagus nerve integrity test	Final management	Follow-up period (weeks)	Clinical outcome
1	Laparoscopic fundoplication (reflux prevention)	Delayed	No response	(1) Pyloroplasty (2) Laparoscopic redo-fundoplication	Laparoscopic Nissen fundoplication plus Heineke-Mikulicz pyloroplasty	8	Resolved
2	Laparoscopic paraesophageal hernia repair with mesh and redo-fundoplication	Delayed	No response	(1) Pyloroplasty (2) Laparoscopic paraesophageal hernia repair with mesh and redo-fundoplication	Laparoscopic paraesophageal hernia repair with mesh and redo-Nissen fundoplication plus Heineke-Mikulicz pyloroplasty	24	Resolved
3	Laparoscopic total gastrectomy with RY esophagojejunostomy reconstruction	Not done	No response	Laparoscopic total gastrectomy with RY esophagojejunostomy reconstruction	Laparoscopic total gastrectomy with RY esophagojejunostomy reconstruction	16	Resolved
4	Laparoscopic redo-fundoplication	Delayed	No response	(1) Pyloroplasty (2) Laparoscopic redo-fundoplication	Medical therapy due to refusing surgery	8	Stable symptoms
5	Laparoscopic redo-fundoplication and hiatal hernia repair with mesh	Delayed	No response	(1) Pyloroplasty (2) Laparoscopic redo-fundoplication and hiatal hernia repair with mesh	Laparoscopic hiatal hernia repair with mesh and partial gastrectomy with RY gastrojejunostomy reconstruction	12	Resolved
6	Laparoscopic paraesophageal hernia repair with mesh ± redo-fundoplication	Delayed	No response	(1) Laparoscopic paraesophageal hernia repair with mesh ± redo-fundoplication (2) Drainage procedure (previous gastrojejunostomy)	Laparoscopic paraesophageal hernia repair with mesh and proximal gastrectomy with RY esophagojejunostomy reconstruction	8	Resolved
7	PEG-J then follow by laparoscopic fundoplication plus pyloroplasty	Delayed	No response	PEG-J then follow by (1) Pyloroplasty (2) Laparoscopic fundoplication	PEG-J (Do not perform following operation due to poor patient status)	16	Dead from acute lung rejection
8	Laparoscopic RY gastrojejunostomy bypass	Delayed	No response	Laparoscopic RY gastrojejunostomy bypass	Medical therapy due to improvement of reflux symptoms and cough	44	Improved
9	Laparoscopic redo-fundoplication plus drainage procedure	Delayed	Responded	Laparoscopic redo-fundoplication plus drainage procedure	Medical therapy due to refusing surgery	104	Improved
10	Laparoscopic hiatal hernia repair with RY gastrojejunostomy bypass	Delayed	Responded	Laparoscopic hiatal hernia repair with RY gastrojejunostomy bypass	Laparoscopic paraesophageal hernia repair with RY gastrojejunostomy bypass	112	Normal lung pathology
11	Laparoscopic fundoplication with hiatal hernia repair	Delayed	Responded	Laparoscopic fundoplication with hiatal hernia repair	Scheduled for operation	n/a	n/a
12	Laparoscopic fundoplication with hiatal hernia repair	Delayed	Responded	Laparoscopic fundoplication with hiatal hernia repair	Scheduled for operation	n/a	n/a

GES gastric emptying study, *VNI* vagus nerve integrity, *RY* Roux-en-Y, *PEG-J* percutaneous endoscopic gastrostomy with jejunal extension tube

[a]VNI test was measured indirectly by the response of plasma pancreatic polypeptide to sham feeding

esophagitis but it can induce other esophageal or extra-esophageal symptoms.

The symptoms of a patient with delayed gastric emptying can vary from no symptoms to severe symptoms. Also, the correlation between symptoms and the rate of gastric emptying is poor. Some patients with markedly delayed gastric emptying are asymptomatic [21–23]. Our study found that one-fourth of patients with non-response vagal integrity testing and half of the response patients were asymptomatic. These results might be underestimated because some do not routinely evaluate vagus nerve function before performing a subsequent operation.

Several management strategies were used for patients with gastroparesis. Medical management and pharmacotherapy of gastroparesis are usually the first-line treatments. Other methods include endoscopic intrapyloric botulinum toxin injection, gastric electrical stimulation, and surgical intervention. They are often considered for failed medications, severe symptoms, or refractory gastroparesis [4]. We evaluated patients who required a second operation and selected surgical interventions (e.g., pyloroplasty or completion or subtotal gastrectomy with Roux-en-Y reconstruction) when performing a concurrent treatment for reflux disease and vagal injury. However, we did not perform additional surgical procedures in patients without vagus nerve injury unless otherwise indicated. We waited for at least 6 months from the primary operation, in order to avoid unnecessary treatment. Patients with temporary vagus nerve damage or neurapraxia and no other causes of delayed gastric emptying (e.g., medications) were identified during this evaluation phase.

For intrapyloric botulinum toxin injection, two randomized, double-blind, placebo-controlled trials showed improvement of gastric emptying. However, symptoms improved similar to placebo [24, 25]. A systematic review from Bai et al. [26] concluded there was evidence to support intrapyloric botulinum toxin injection for the treatment of gastroparesis. Regarding gastric electrical stimulation, an initial meta-analysis and systematic reviews from Chu et al. [27] showed that a response from gastric electrical stimulation was less in postsurgical gastroparesis (vagal injury) patients. Furthermore, a recent meta-analysis and systematic reviews from Levinthal and Bielefeldt [28] concluded that gastric electrical stimulation is not superior to sham intervention for gastroparesis. Based on the results of these studies, we did not use intrapyloric botulinum toxin injection or gastric electrical stimulation in our patients with vagal injury.

Few studies have reported the results of additional surgical drainage procedures (e.g., pyloroplasty) when treating primary reflux disease. Alexander et al. [29] reported that pyloroplasty in addition to Nissen fundoplication improved the wrap failure or recurrent reflux outcomes in neurological impaired children with delayed gastric emptying. A study from Khajanchee et al. [30] showed that patients with delayed gastric emptying who underwent Nissen fundoplication only had the poorest control of reflux symptoms and had a higher incidence of gas bloat, hyperflatulence, and abdominal pain or fullness or both when compared to patients who underwent Nissen fundoplication with pyloroplasty. A further study from Masqusi and Velanovich [31] also showed that the addition of pyloroplasty to a fundoplication in patients with gastroparesis and reflux disease had a significant improvement of bloating symptoms and gastric emptying. Completion or subtotal gastrectomy with Roux-en-Y reconstruction can be used cautiously in selected patients with postsurgical gastroparesis [4]. A systematic review from Jones and Maganti [32] showed that completion gastrectomy seems effective by decreasing symptoms in patients with postsurgical gastroparesis. Forstner-Barthell [33] reported that two-thirds of patients with severe postvagotomy gastric stasis improved their health status while maintaining body weight after gastrectomy. However, the authors also reported a high complication rate of 40% which included narcotic withdrawal syndrome (18%), ileus (10%), wound infection (5%), intestinal obstruction (2%), and anastomotic leak (5%). Moreover, Roux-en-Y reconstruction can be a treatment for patients with reflux symptoms and is an option for failed primary or reoperative anti-reflux surgery with a high rate of success [34]. In general, most patients in this study were educated and encouraged to have a Roux-en-Y reconstruction. Besides postsurgical gastroparesis treatment, Roux-en-Y reconstruction can be a treatment of failed primary or reoperative anti-reflux surgery and can prevent bile reflux. Due to high morbidity after Roux-en-Y reconstruction, some patients chose the pyloroplasty. However, pyloroplasty can cause either bile reflux gastritis or bile reflux esophagitis, but bile reflux esophagitis can be prevented by fundoplication and bile reflux gastritis can be treated with medications. Therefore, pyloroplasty or completion gastrectomy with Roux-en-Y reconstruction was considered as our main treatment options.

VNI testing before the second gastric operation altered the course of treatment in almost 40% of patients by changing or performing an additional procedure. This means that nearly half of the patients gained benefits from VNI testing. Furthermore, due to the high percentage of asymptomatic patients in our study, we suggest evaluating vagus nerve function in all patients with previous operations with a high risk of vagal injury when performing a subsequent gastric surgery.

This study has some limitations. This study was a retrospective study with a small number of patients and no comprehensive assessment of symptoms either before or after treatment. Further, some patients did not complete all preoperative investigations and only a few patients had

objective evaluations after treatment. In addition, we did not evaluate small bowel transit in our study. Vagus nerve injury may cause prolonged small bowel transit time and lead to gastroparesis-like symptoms. Delayed small bowel transit might occur concomitant with gastroparesis in these patients. However, the resolution of symptoms in all patients who had secondary surgery for gastroparesis in our study leads us to believe that the symptoms and complaints were limited to the stomach. Besides, if the prolonged small bowel transit time is diagnosed, the primary treatments will be behavioral and diet modification and medical therapy for delayed small bowel transit, but this result has no effect on the treatment of gastroparesis.

Conclusions

Almost 40% of patients who had previous operations that may have led to vagal injury and required a second gastric operation obtained benefits from VNI testing by altering the additional operation. Some patients with delayed gastric emptying can present without symptoms of gastroparesis. The addition of VNI testing can help select the appropriate secondary procedure and should be performed in all patients who have had previous operations with the potential risk of vagus nerve injury. A large prospective study should be conducted to validate these findings.

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Compliance with ethical standards

Disclosures Kamthorn Yolsuriyanwong, Eric Marcotte, Mukund Venu and Bipan Chand have no conflicts of interest or financial ties to disclose.

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