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Innovative laparoscopic 'Tunnel' approach in managing hiatal hernia with gastroesophageal reflux disease: a retrospective study

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Abstract

Background Hiatal hernia (HH) is a major cause of gastroesophageal reflux disease (GERD), and laparoscopic repair combined with anti-reflux surgery is a common treatment. However, postoperative complications such as vagus nerve injury remain a concern. This study introduces a novel Laparoscopic "Tunnel" Approach aiming to minimize damage to the vagus nerve and preserve perigastric vessels.

Methods Clinical data were consecutively collected from patients who underwent laparoscopic "tunnel" approach for the treatment of hiatal hernia combined with gastroesophageal reflux disease at the First Affiliated Hospital of Ningbo University between June 2023 and June 2024. Data collected included age, gender, BMI, DeMeester score, surgical time, and postoperative symptoms. Follow-ups were conducted at 1, 3, and 6 months postoperatively.

Results The average age was 54 ± 9 years, BMI was 25.56 ± 4.32 kg/m^2, DeMeester score was 118.05 ± 17.71, and GERD-Q score was 13 ± 2. The average surgical time was 115 ± 15 min. Postoperatively, symptoms significantly improved, with an average GERD-Q score of 5 ± 1 at 6 months. At 1 month, dysphagia was observed in 14 patients, belching in 19, abdominal distension in 5, nausea in 16, and diarrhea in 8. By 6 months, only 2 patients exhibited belching, with no other symptoms persisting. No cases of vomiting or gallstones were reported.

Conclusions The Laparoscopic "Tunnel" Approach may effectively minimizes vagus nerve injury and preserves perigastric vessels, resulting in improved postoperative outcomes and quality of life. This method shows potential for wider application in treating HH and GERD. However, since this study was retrospective and lacked a control group, further studies are needed to verify our conclusions.

Keywords Hiatal Hernia, Gastroesophageal reflux disease, Laparoscopic surgery, Vagus nerve

Background

Hiatal hernia (HH) refers to the condition where abdominal contents enter the thoracic cavity through the esophageal hiatus of the diaphragm and is considered a primary cause of gastroesophageal reflux disease (GERD) [1]. Laparoscopic repair of HH combined with anti-reflux surgery is suitable for patients with chronic symptoms of HH and GERD, those who are refractory to proton pump inhibitors (PPI), or those unwilling to take PPIs for life.

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The treatment goal for HH combined with GERD is to achieve optimal long-term control of reflux symptoms and signs with minimal or no side effects. Despite continuous improvements in surgical techniques [2], postoperative complications still occur [3–5]. Vagus nerve injury is a common complication of laparoscopic HH repair combined with fundoplication [6, 7]. Due to the anatomical variations of the vagus nerve trunk and its hepatic branches, in some patients, the vagus nerve does not form a clearly visible "trunk" but is instead diffusely distributed within the tissue. Studies have shown that approximately 10% to 20% of GERD patients experience vagus nerve injury after anti-reflux surgery [6, 8, 9]. Vagus nerve injury can lead to postoperative symptoms such as diarrhea, nausea, vomiting, gastric emptying disorders, belching, and abdominal bloating, and can also increase the incidence of gallstones [7, 10, 11]. In 20-year follow-up data, patients with vagus nerve injury had significantly worse outcomes in terms of gastroesophageal reflux symptoms, satisfaction rates, and reoperation rates [6].

The traditional bilateral surgical approach (TBSA) is the main surgical method for laparoscopic HH repair combined with fundoplication [12]. A disadvantage of TBSA is that although it can provide local protection of the vagus nerve during surgery, it cannot assess the integrity of the vagus nerve, potentially causing undetected nerve damage [13]. Other surgical approaches, such as the total left-sided approach (TLSA), can effectively avoid iatrogenic damage to the main trunk of the vagus nerve and its hepatic branches [14]. However, TLSA requires incision of the gastrocolic ligament, inevitably splitting some short gastric and gastroepiploic vessels, restricting the venous blood flow around the stomach, and increasing the risk of gastric emptying disorders. Moreover, the ligation of short gastric vessels poses a potential hazard for preserving the proximal stomach in subsequent gastric surgeries.

Therefore, based on the existing surgical defects, our center innovatively proposes a new surgical approach—the Laparoscopic "Tunnel" Approach. The potential advantages of this method are that it not only minimizes damage to the main trunk of the vagus nerve and its hepatic branches but also preserves all perigastric vessels, such as the short gastric vessels.

Methods

Clinical data were consecutively collected from patients who underwent laparoscopic “tunnel” approach for the treatment of hiatal hernia combined with gastroesophageal reflux disease at the First Affiliated Hospital of Ningbo University between June 2023 and June 2024. Inclusion criteria: 1) Patients with a definitive diagnosis of gastroesophageal reflux disease; 2) Age 25–80 years; patients and their families have good compliance and can cooperate with the treatment; 3) No severe diseases of important organs such as heart, brain, and lungs; 4) No patients with severe anxiety or depression; 5) Meet the surgical indications. Exclusion criteria: 1) Change of surgical method due to special circumstances during surgery; 2) Loss to follow-up, accidental events, or severe somatic diseases.

Surgical indications: 1) Major complications of hiatal hernia or gastroesophageal reflux disease, such as severe esophagitis, Barrett’s esophagus, etc. 2) Patients who have undergone full and systematic drug therapy for more than half a year but still cannot alleviate and eliminate the complications of reflux disease. 3) Patients who have undergone Heller myotomy for esophageal motility disorders to prevent recurrence of gastroesophageal reflux. 4) Patients whose recurrent laryngeal and pulmonary diseases are determined to be caused by reflux disease, as well as those with asthma caused by reflux disease. 5) Patients who have relapsed after surgery and have severe reflux symptoms, or patients with paraesophageal hernia with reflux symptoms that are not successfully treated with drugs. 6) Patients with severe atypia or cancerous changes in pathological examination of cells.

All patients signed an informed consent form before surgery. The collected clinical data included: age, gender, height, weight, BMI, DeMeester score, hiatal hernia classification, quality of life score (GERD-Q score) [15], surgical time, blood loss, etc. The present study was approved by the Ethics Committee of the First Affiliated Hospital of Ningbo University (Approval No. 2025-024RS). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Laparoscopic "Tunnel" surgical approach steps

Expose the hepatogastric ligament at the lesser curvature of the stomach. Incise an area on the hepatogastric ligament that is free of blood vessels, nerves, and adipose tissue. Anatomically, this area is devoid of nerve passage (Fig. 1a).

Incise the peritoneum at the outer edge of the right crus of the diaphragm, and bluntly dissect the loose tissue at the lower end of the esophagus to expose the junction of the left and right crus of the diaphragm (Fig. 1b). Lift the gastroesophageal junction to further expose the left crus of the diaphragm.

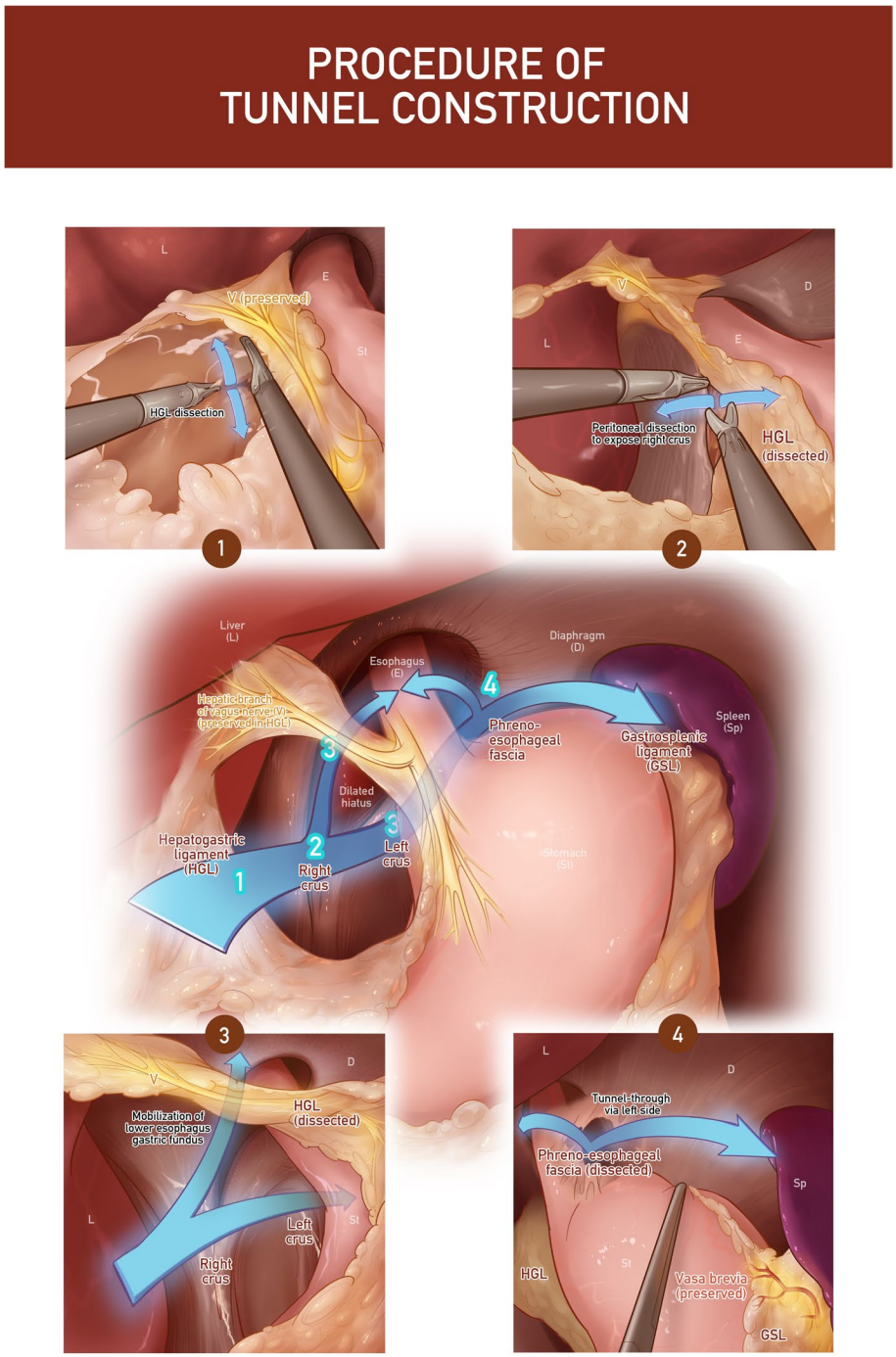

Fig. 1 Procedure of laparoscopic "tunnel" surgical approach. **a** Expose the hepatogastric ligament at the lesser curvature of the stomach. Incise an area on the hepatogastric ligament that is free of blood vessels, nerves, and adipose tissue. Anatomically, this area is devoid of nerve passage. **b** Incise the peritoneum at the outer edge of the right crus of the diaphragm, and bluntly dissect the loose tissue at the lower end of the esophagus to expose the junction of the left and right crus of the diaphragm. **c** Lift the gastroesophageal junction to further expose the left crus of the diaphragm. Thus, a "tunnel" is successfully created at the lower end of the esophagus. **d** Incise the phrenoesophageal ligament on the left side of the esophagogastric junction and connect the "tunnel". Further separate to the left along the fundus of the stomach, cut the gastrophrenic ligament until the upper pole of the spleen

Thus, a "tunnel" is successfully created at the lower end of the esophagus (Fig. 1c).

Turn to the front of the esophagogastric junction. Incise the phrenoesophageal ligament on the left side of the esophagogastric junction and connect the "tunnel". Further separate to the left along the fundus of the stomach, cut the gastrophrenic ligament until the upper pole of the spleen (Fig. 1d). Incise the phrenoesophageal ligament on the right side of the esophagogastric junction, complete extensive mobilization of the lower segment of the esophagus and the fundus of the stomach, and further mobilize the lower segment of the esophagus for about 6 cm.

Use 2–0 non-absorbable sutures for intermittent suturing of the left and right crus of the diaphragm, and reconstruct the esophageal hiatus. Insert biological or synthetic mesh to prevent recurrence.

Determine the appropriate fundoplication technique (360° Nissen, 270° Toupet, or 180° Dor) based on the patient's specific condition, and complete the fundoplication surgery (Fig. 2).

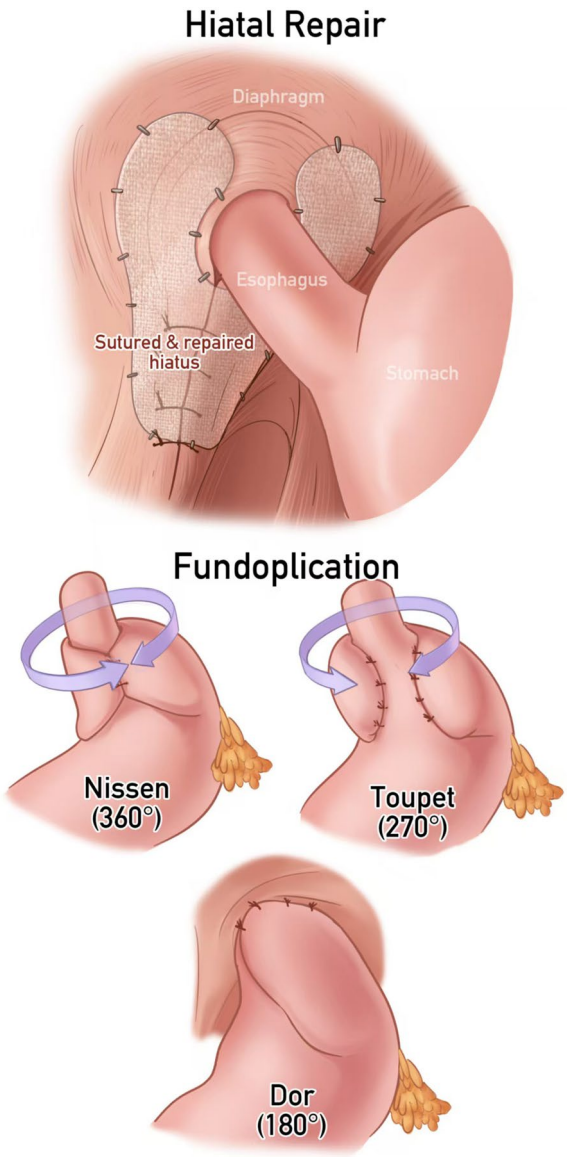

Fig. 2 Hiatal hernia repair and fundoplication

Postoperative follow-up

Follow-ups were conducted at 1, 3, and 6 months postoperatively, through outpatient visits, hospitalization, or telephone calls. The follow-up content included gastroscopy, upper gastrointestinal radiography, quality of life score (GERD-Q score), abdominal ultrasound, and suspected symptoms of vagus nerve injury (such as diarrhea, nausea, vomiting, belching, abdominal distension, etc.).

Statistical analysis

Descriptive statistical analysis was performed on all variables. Comparisons were made between patients who developed vagal symptoms and those who did not during the 1—and 3—month follow—ups after surgery. Normally distributed continuous variables are expressed as mean (± SD), non-normally distributed continuous variables as median and interquartile range. Categorical variables are summarized as proportions. Differences between categorical variables were assessed using χ^2 test, differences between continuous variables using analysis of variance, and non-normally distributed data using Kruskal–Wallis test. All statistical analyses were conducted using R Studio (version 4.3.3, USA). Statistical significance was defined as a two-sided p-value less than 0.05.

Results

A total of 106 patients underwent Laparoscopic "Tunnel" Approach for the treatment of hiatal hernia combined with gastroesophageal reflux disease. There were 65 females and 41 males, with an average age of 54 ± 9 years, average height of 165 ± 6 cm, average weight of 69.4 ± 9.9 kg, and average BMI of 25.56 ± 4.32 kg/m^2 (Table 1). The average DeMeester score was 118.05 ± 17.71, and the average GERD-Q score was 13 ± 2. All patients underwent fundoplication surgery, and the main trunk of the vagus nerve and its

Table 1 Demographic characteristics

	N **= 106**
Age (years)	54 ± 9
Sex	
Male	41 (38.7%)
Female	65 (61.3%)
Height (cm)	165 ± 6
Weight (kg)	69.4 ± 9.9
BMI (kg/m2)	25.56 ± 4.32
Smoking (years)	
Never or < 1	42 (39.6%)
1–10	27 (25.5%)
≥ 10	37 (34.9%)
DeMeester score	118.05 ± 17.71
GERD-Q score	13 ± 2
Surgical time (min)	115 ± 15

N=106 indicates that the sample size is 106 patients. Age, height, weight, DeMeester score, and GERD−Q score are presented as mean ± standard deviation. Sex and smoking history are shown as number of cases (percentage). The DeMeester score is used to assess the severity of gastroesophageal reflux disease (GERD), while the GERD−Q score evaluates the patient's quality of life. Surgical time refers to the average duration of the surgery. BMI (Body Mass Index) is an indicator that measures the ratio of weight to height, calculated by dividing weight (kg) by the square of height (m)

Table 2 Incidence of vagus nerve injury-related complications following surgical procedures

	1 month	**3 months**	**6 months**
Dysphagia	14 (13.2%)	3 (2.8%)	0
Belching	19 (17.9%)	13 (12.3%)	2 (1.9%)
Abdominal Distension	5 (4.7%)	0	0
Nausea	16 (15.1%)	5 (4.7%)	0
Vomiting	0	0	0
Diarrhea	8 (7.5%)	0	0
Gallstones	0	0	0

This table presents the follow-up data at 1 month, 3 months, and 6 months after surgery, with a sample size of 106 patients. The incidence of each symptom is expressed as number of cases (percentage)

hepatic branches were avoided during the operation. The average surgical time was 115 ± 15 min.

Postoperative conditions

The symptoms of all patients were significantly relieved after surgery, with an average GERD-Q score of 5 ± 1 after 6 months. Table 2 delineates the clinical manifestations observed among patients at distinct temporal junctures throughout the follow-up duration. During the 1—month follow—up, 49 patients experienced symptoms of vagus nerve injury, among whom 14 had dysphagia, 19 had belching, 5 had bloating, 16 had nausea, and 8 had diarrhea. Importantly, no occurrences of vomiting or gallstones were noted during this initial assessment period. At the 3-month follow-up after surgery, 16 patients exhibited symptoms of vagus nerve injury, including 3 patients with dysphagia, 13 with belching, and 5 with nausea. At the 6-month follow-up milestone, only two cases exhibited symptoms of belching, with all other patients experiencing a complete resolution of symptoms. In these 2 cases, preoperative esophageal manometry revealed ineffective esophageal motility, making it impossible to determine whether it was caused by vagus nerve injury.

The demographic and clinical characteristics of patients with and without vagus nerve injury during the 1—and 3—month follow—ups are detailed in Table 3. At the 1—month follow—up, symptomatic patients had a significantly higher mean age compared to asymptomatic patients (59.4 ± 6.7 years vs. 49.8 ± 8.4 years, $p < 0.001$). No significant differences were observed in sex distribution ($p = 0.985$), BMI ($p = 0.617$), DeMeester score ($p = 0.070$), GERD—Q score ($p = 0.569$), or surgery time ($p = 0.461$) between the two groups.

At the 3—month follow—up, symptomatic patients again exhibited a significantly higher mean age

Table 3 Comparison of patients with and without vagus nerve injury during the 1- and 3-month follow-ups

	1-month follow-up			**3-month follow-up**		
	Asymptomatic patients (*n* = 57)	**Symptomatic patients (*n* = 49)**	***P***	**Asymptomatic patients (*n* = 90)**	**Symptomatic patients (*n* = 16)**	***P***
Age (years)	49.8 ± 8.4	59.4 ± 6.7	< 0.001	53.11 ± 9.02	60.44 ± 6.14	0.002
Sex			0.985			0.508
Male	22	19		36	5	
Female	35	30		54	11	
BMI (kg/m2)	25.75 ± 4.85	25.33 ± 3.63	0.617	26.17 ± 4.17	22.09 ± 3.46	< 0.001
DeMeester	120.93 ± 19.15	114.69 ± 15.38	0.070	119.01 ± 18.27	112.63 ± 13.32	0.185
GERD-Q	12.91 ± 2.06	13.13 ± 1.89	0.569	13.01 ± 2.027	12.98 ± 1.75	0.951
Surgery time (min)	116.18 ± 14.39	114.00 ± 16.06	0.461	115.23 ± 14.00	114.85 ± 21.06	0.928

Data are presented as mean±SD or number of patients

*BMI*Body Mass Index, *DeMeester*DeMeester score, *GERD−Q*Gastroesophageal Reflux Disease Questionnaire

(60.44 ± 6.14 years) compared to asymptomatic patients (53.11 ± 9.02 years, $p = 0.002$). A significant difference was also observed in BMI, with symptomatic patients having a lower mean BMI (22.09 ± 3.46 kg/m^2) compared to asymptomatic patients (26.17 ± 4.17 kg/m^2, $p < 0.001$). No significant differences were noted in sex distribution (p = 0.508), DeMeester score ($p = 0.185$), GERD—Q score ($p = 0.951$), or surgery time ($p = 0.928$) between the two groups at this time point.

Discussion

Unlike the treatment of malignant tumors, the treatment of benign diseases (such as hiatal hernia and gastroesophageal reflux disease) not only aims to achieve surgical efficacy but also to minimize collateral damage and maintain the patient's current quality of life. Protection of the vagus nerve is particularly important [16]. The left and right vagus nerves descend to the anterior and posterior surfaces of the ventral esophagus, respectively. The hepatic branch of the anterior vagus nerve joins the gastric anterior branch at the foot and runs along the lower edge of the left lobe of the liver. The hepatic branch runs to the right along the upper part of the lesser omentum, and its terminal branches are mainly distributed in the liver and bile ducts, closely related to gallbladder contraction and bile secretion [17–19]. The abdominal branch is widely distributed in the upper digestive tract organs such as the stomach, duodenum, jejunum, and pancreas, playing an important regulatory role in gastrointestinal motility and intestinal secretion [20–22]. The anterior and posterior branches of the stomach run along the lesser curvature of the stomach and are distributed on the anterior and posterior walls of the stomach. Their terminal branches enter the antrum of the stomach in a "claw" shape, controlling gastric motility, gastric secretion, and pyloric emptying [23, 24]. Hashimoto et al. found that the hepatic branch of the vagus nerve plays an important role in lipid regulation in mice [25]. López-Soldado et al. found that the regulation of hepatic glycogen depends on the hepatic branch of the vagus nerve, affecting food intake and glucose homeostasis [26]. Studies have confirmed that preserving the ventral branch of the vagus nerve can significantly improve postoperative gastrointestinal motility in patients with hiatal hernia and reduce the incidence of gastroparesis [8, 27]. Given the crucial roles these nerve branches play in gastrointestinal and biliary physiology, preserving the corresponding regional blood supply and nerve innervation is a necessary requirement for maintaining the patient's postoperative quality of life.

Protecting the short gastric vessels is also key to ensuring postoperative gastric function. These vessels maintain the blood supply and function of the corresponding gastric wall. Ligation of the short gastric vessels can affect the blood supply, peristalsis, and secretory function of the corresponding gastric wall to a certain extent, leading to delayed gastric emptying and functional recovery. It can also increase the risk of surgical bleeding and infection [28]. It has been reported that extensive dissection of the short gastric vessels in surgeries such as laparoscopic sleeve gastrectomy often leads to bleeding due to separation of these vessels and sutures [29, 30].

Based on the significance of the vagus nerve and short gastric vessels, we observed that a thin layer of visceral peritoneum covers between the hepatogastric ligament and the lesser curvature of the stomach, lacking blood vessels, nerves, and adipose tissue, serving as the boundary between various ligaments. Laparoscopic repair of hiatal hernia combined with fundoplication through stripping the boundary area free of blood vessels, nerves, and fat can maximally protect the main trunk of the vagus nerve and its branches while preserving the short gastric vessels. Through retrospective analysis, we confirmed the feasibility of this method. At the 6—month follow—up after surgery, only 2 patients experienced symptoms of belching, which may be the result of the combined effects of vagus nerve injury and esophageal motility disorders. No patient exhibited symptoms of vagus nerve injury such as gallstones, nausea and vomiting, or gastric emptying disorders. Correspondingly, Bang et al. conducted a study on 164 patients who underwent fundoplication, with a median follow-up period of 4.8 years. The study showed that 26% of patients experienced dysphagia postoperatively [7].

In clinical practice, the inability to directly measure or assess abdominal vagus nerve function and the lack of intraoperative monitoring are noteworthy facts. Therefore, the incidence of vagus nerve dysfunction after anti-reflux surgery is based on feedback from symptoms such as diarrhea, nausea, and vomiting. Studies have developed an indirect method to measure vagus nerve function, namely the insulin hypoglycemia-pancreatic polypeptide (IH-PP) test, by measuring the secretion of plasma pancreatic polypeptide (PP) during insulin-induced hypoglycemia [6, 31, 32]. Moreover, the use of claw-shaped stimulating electrodes has successfully achieved intraoperative monitoring of vagus nerve abdominal branch stimulation signals, suggesting that intraoperative neurophysiological examination is a feasible method for monitoring the vagus nerve around the stomach [33]. These studies provide more effective means for future monitoring and protection of the vagus nerve and offer new directions for the protection of the vagus nerve during surgery.

The present study has several limitations. First, this study is only an observational retrospective study and

lacks a corresponding control group. We will conduct further in-depth research to better support our conclusions. Second, the follow-up period in our study is insufficient, and we lack data on the long-term survival impact of vagus nerve injury symptoms on patients. Finally, we do not have a direct method for detecting vagus nerve injury. At present, there is no precise method for directly detecting vagus nerve injury, which is also one of the directions for future research.

Conclusions

It cannot be denied that compared with other surgical approaches, the laparoscopic "tunnel" approach benefits from a more comprehensive anatomical theoretical basis. Compared with the traditional surgical approach, the laparoscopic "tunnel" approach may be better able to avoid the vagus nerve injury. In the surgical treatment of functional diseases, the necessity of preserving function while reconstructing function is unquestionable. Although this study lacks direct objective indicators to confirm the superiority of the laparoscopic "tunnel" approach, this study provides important data for future research iterations. It is hoped that more research centers and patients will be recruited to develop more precise treatment methods for hiatal hernia and to perfect more precise surgical models. The goal is to improve the short-term and long-term treatment outcomes for patients with gastroesophageal reflux disease and hiatal hernia.

Supplementary Information

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Supplementary Material 1.

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Authors' contributions
Conceptualization, Zhewen Feng and Zhiping Zhang.; methodology, Zhewen Feng; software, Zhewen Feng; validation, Zhewen Feng; formal analysis, Zhewen Feng; investigation, Zhewen Feng; resources, Zhewen Feng; data curation, Zhewen Feng; writing—original draft preparation, Zhewen Feng; writing—review and editing, Zhewen Feng; visualization, Zhewen Feng; supervision, Feng Gao and Zhilong Yan; project administration, Qingfeng Chen; funding acquisition, Qingfeng Chen. All authors have read and agreed to the published version of the manuscript.

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Data availability
The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request. All supplementary materials are available through the journal's portal.

Declarations

Ethics approval and consent to participate
The present study was approved by the Ethics Committee of the First Affiliated Hospital of Ningbo University (Approval No. 2025-024RS). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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