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REVIEW

Development and current status of anti-reflux esophagogastrostomy after proximal gastrectomy: a literature review

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Abstract

Background The selection of an appropriate gastrointestinal (GI) reconstruction procedure after proximal gastrectomy (PG) has long been a challenge. Surgeons have had a long history of exploring anti-reflux gastroesophageal anastomosis. The aim of this article is to systematically summarize the anti-reflux principles of GI reconstructive procedures through a review of the previous literature and to provide a theoretical basis for clinicians to select or innovate procedures.

Methods The PubMed, Google Scholar, China National Knowledge Infrastructure, Cochrane Databases and Medline were searched using Medical Subject Headings terms and keywords from inception until May 1, 2023. We traced the early research on the anti-reflux mechanisms of the esophagogastric junction and analyzed each piece of literature.

Results Three principles according to the current mainstream anti-reflux esophagogastrostomy: (1) reduction of the acid secreting glands; (2) reconstruction of the His angle or fundus; (3) reconstruction of the anti-reflux valve resembles the cardiac (including barrier method, rotation method, and compression method). This article provides a literature review of anti-reflux esophagogastrostomy after PG.

Conclusions Anti-reflux esophagogastrostomy, represented by seromuscular flap valvuloplasty, which restored the natural physiological structure, had better feasibility and safety theoretically. However, this still needs to be supported by evidence from large multi-center prospective randomized controlled studies.

Keywords Proximal gastrectomy · Esophagogastrostomy · Reflux esophagitis · Function- preserving surgery

Introduction

The prevalence of esophagogastric junction adenocarcinoma has been increasing continuously in recent years [1–4]. Many retrospective studies have revealed the functional benefits of proximal gastrectomy (PG) over total gastrectomy (TG) [5]. However, no appropriate reconstruction method with a reflux prevention mechanism can be selected to address the consequent reflux esophagitis after PG.

Esophagogastric anastomosis with anti-reflux characteristics has become a popular research direction in recent years. Simple end-to-end esophagogastrostomy is the early form of esophagogastric anastomosis [6], which is the most convenient physiological reconstruction method. However, without an anti-reflux mechanism, postoperative reflux esophagitis is inevitable. Additionally, this reconstruction method results in a high rate of stenosis of the anastomosis due to scarring and inflammation caused by reflux, which can lead to decreased dietary intake and worsened nutritional status. In the 1950s, thoracic surgeons studied the anatomy and anti-reflux mechanisms of the cardia in the treatment of benign esophageal strictures and hiatal hernias and explored the appropriate anti-reflux procedures in open surgery [7]. In the treatment of malignant tumors, the appropriate extent of lymph node dissection and the adequate length of resection make GI reconstruction more difficult.

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In recent years, with the development of laparoscopic technology and the popularization of the "minimally invasive, individualized, precise and function-preserving" surgical concept, the stage has been set for gastrointestinal surgeons to adopt the transthoracic pathway (TH pathway). Several cases have been reported with experience of opening the diaphragm under the TH pathway to remove a higher lesion with a high-level anastomosis. Anti-reflux techniques have gradually become a hot topic in the study of post-PG GI reconstruction. Surgeons should understand the anti-reflux anatomy and mechanism of the cardia and choose a suitable procedure of digestive tract reconstruction.

Anti-reflux anatomy and mechanism of the cardia

Research into the anatomy of the cardia and the anti-reflux mechanism can be traced back as far as the 1950s. Geoffrey Wooler, MD, of the United Hospital in Leeds, UK, was the first to systematically present his ideas in the treatment of esophageal strictures and ulcers in 1955 [7]. He believed that the following anatomical structures were involved in the anti-reflux function of the cardia, and a similar idea was mentioned by Dr Watkins at the 39th Annual Meeting of the American Association for Thoracic Surgery in 1959 [8]:

1. **Lower esophageal sphincter (LES)**: This structure is essential in maintaining the high-pressure zone in the lower esophagus. The idea has been recognized by many scholars in the following decades [9~11].
2. **His angle and fundus**: When the fundus is dilated, the stomach at His angle become flap-like, closing the gastroesophageal channel to prevent the reflux of gastric contents into the esophagus, acting as a "one-way valve". This movable mucosal flap which is formed by His angle and the fundus at the cardia, often called the Gubaroff flap. In 1886, Von Gubaroff et al. demonstrated by water injection that this valve adheres to the right wall of the esophagus when the pressure in the stomach increases, preventing water from flowing back into the esophagus. The fundus also serves to store gas in the stomach to form gastric bubbles so that gas does not escape into the esophagus at any time and cause hiccups.
3. **Cleft muscle at the foot of the right diaphragm**: The cleft muscle at the foot of the right diaphragm wraps around the esophageal cleft and resembles a sling. In 1951 Allison compared it to the puborectalis muscle, which controls the anal canal, and concluded that its contraction facilitated the maintenance and reduction of the His angle [12].
4. **Oblique muscle fibers or sling fibers of stomach**: The sling fibers are in the smooth muscle of the stomach wall and act in a similar way to the cleft muscle of the right diaphragm foot. In 1954 Barrett argued in an article that its role was key [13]. Its earliest description and anatomical drawing can be attributed to Thomas Willis of Oxford University [8].
5. **Diaphragmatic-esophageal membrane**: Dr Watkins suggests that the membrane structure extending up and down between the esophagus and the mediastinum, like a cuff, prevents the cardia from entering the posterior mediastinum and is involved in the anti-reflux mechanism.
6. **Mucosal flap of the cardia**: This structure was first described by Dornhurst et al. in 1954 [14]. The mucosal fold-like structure of the pancreatic orifice can be observed endoscopically and has been compared to a cardia rosette by some scholars because of its endoscopic resemblance to a wreath [15, 16].

Dr Wooler suggested that there are two key factors in anti-reflux GI reconstruction: maintaining the right angle of the esophagus to the stomach and maintaining pressure in the lower esophagus and at the cardia [7]. Reconstruction of the anti-reflux structure at the cardia to control reflux allows better restoration of the natural physiological anatomy, thus reducing the complexity of the operation and the occurrence of complications and has attracted many scholars to study it. During nearly a century of exploration, anti-reflux gastroesophageal anastomosis can be summarized in three anti-reflux methods: reduction of the number of acid-secreting glands, reconstruction of the His angle and fundus, and reconstruction of the cardia valve function (including barrier method, rotation method, compression method).

Anti-reflux gastroesophageal anastomosis

Reduction of the number of acid-secreting glands

Tube-like stomach esophagogastrostomy is a technically mature anti-reflux procedure that still has an unassailable place in thoracic surgery for the treatment of esophageal cancer and Siewert I AEG. Tube-like stomach esophagogastrostomy was first reported in 1998 during open surgery [17], and it was performed in a laparoscopic approach reported by Uyama et al. in 2001 [18]. Tube-like stomach esophagogastrostomy reduces the mucosal area of the stomach and the number of acid-secreting glands, resulting in lower acid secretion and reduced reflux of digestive juices. A tubular remnant stomach also extends the distance of acid reflux and reduces reflux symptoms [19, 20]. This procedure

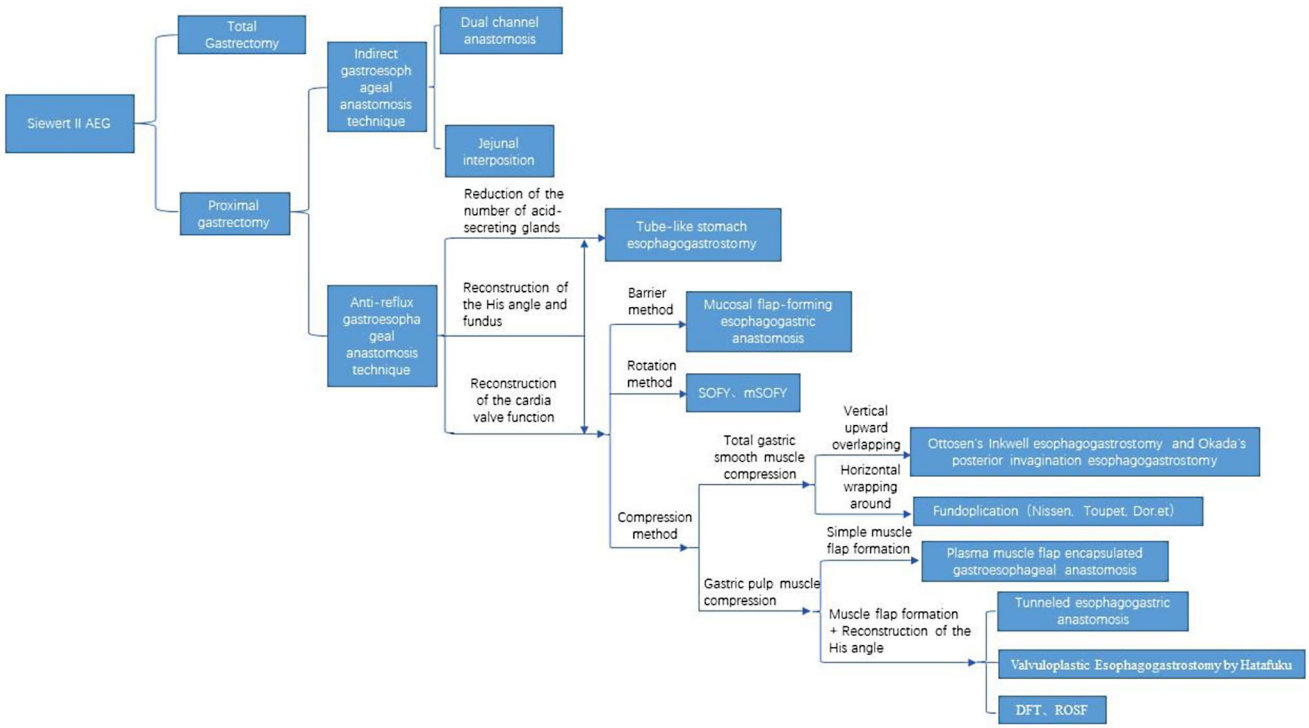


Fig. 1 Surgical treatment strategy for Siewert II AEG mentioned in this article

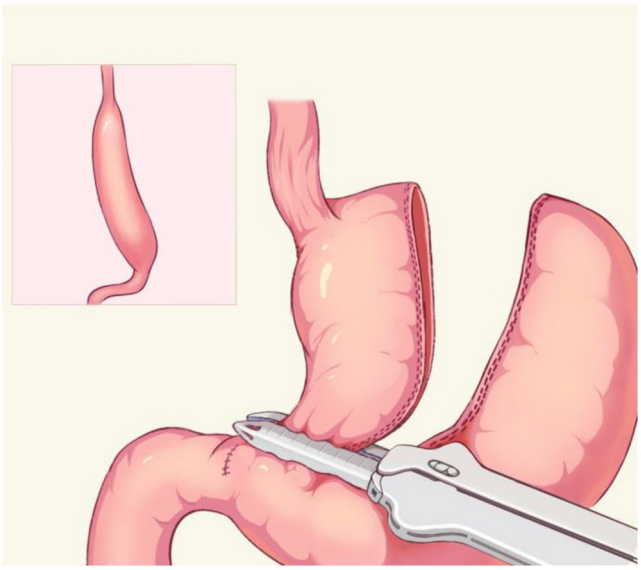


Fig. 2 Surgical diagram of tube-like stomach esophagogastrostomy

also has significant disadvantages, including the presence of a long margin that increases the possibility of bleeding, high consumption of stapler cartridges, and possibility of distant narrowing due to poor healing of the tubular stomach. Furthermore, the anastomosis between the tubular stomach and the esophagus is usually performed by a circular stapler, which typically causes anastomotic stricture (Figs. 1 and 2).

Reconstruction of the his angle and fundus

The initial reconstruction of the His angle and fundus is to lift upwards the greater curvature of the remnant stomach and then fix it to the diaphragm and the left side of the lower esophagus. This method allows the closure of flap-like structures to form a physical anti-reflux barrier and the lateral compression of the stomach from the lower esophagus to create a high-pressure region when the pressure in the stomach increases. This method was first reported by Dr Watkins in 1959 in the treatment of hiatal hernia and esophageal strictures, which had shown good results in animal studies and in three patients. None of the patients had reflux after the operation and received weight gain [8]. However, the reconstruction of the His angle and fundus alone cannot support the residual stomach firmly on the dorsal side of the esophagus and still has a high incidence of reflux, as summarized by Dr Franke in Germany as early as 1968 [21]. Therefore, it is often used in combination in other procedures, such as Dr. Watkins' simultaneous use of fundoplication. Chinese gastroenterologist Cheng XD reported "Cheng's Giraffe reconstruction" based on this method and tubular gastric anastomosis to enhanced the anti-reflux effect [22]. Franke et al. [21] also made some modifications, folding the line off the stomach to preserve more of the remnant stomach in the greater curvature of the stomach, thereby reconstructing a long mucosal flap and a large area

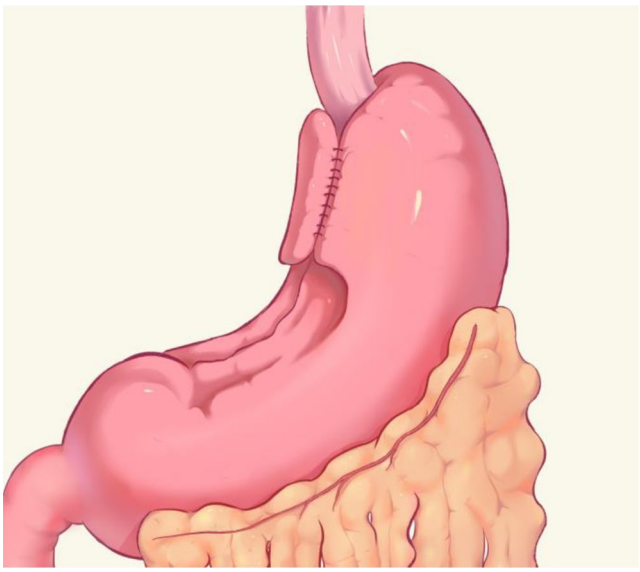


Fig. 3 Reconstruction of His angle and fundus in fundoplication

of the lower esophageal high-pressure region when adding fundoplication (Figs. 3 and 4).

Reconstruction of the cardia valve function

Reconstruction of cardia valve function is a hot research topic in anti-reflux gastroesophageal anastomosis, which is mainly achieved by barrier method, rotation method, and compression method. The barrier method mainly refers to the formation of a mucosal flap at the anastomosis site to partially prevent the reflux of gastric acid, represented by mucosal-flap forming and global-type techniques. The typical representatives of the rotational method are side overlap and fundoplication by Yamashita (SOFY) and modified SOFY (mSOFY). This procedure anastomoses the lateral esophageal wall to the anterior gastric wall, avoiding the disruption of the Gubaroff valve-like living flap structure. The representative procedure of the compression method is fundoplication, which uses the whole layer or muscle seromuscular flap valvuloplasty of the gastric wall to compress the lower esophagus to form a high-pressure region.

Barrier method (representative techniques: mucosal flap-forming esophagogastric anastomosis, globe-type anti-reflux surgical techniques)

Representative techniques of the barrier method are rarely performed in clinical settings. However, the barrier method can be performed in combination with other anti-reflux procedures. Folding the stomach inward near the esophagogastrostomy to form a raised barrier, which is practical with other anti-reflux reconstruction procedures, is infeasible.

Reconstruction of the cardia mucosal flap prevents reflux by partially blocking the gastric and esophageal lumen. Mucosal flap formation mainly relies on the prefabricated mucosal flap of the esophagus and remnant stomach and the layered anastomosis of the esophagus and remnant stomach. Jin JY et al. [23–25] first reported animal experiments of mucosal flap-forming end-to-end esophagogastrostomy in 2002 and observed body weight, feeding, vomiting, esophageal pressure and post-dissection mucosal flaps in experimental dogs at 3 months after surgery. They reserved the anastomotic flap on the side of the greater curvature of the remnant stomach, peeled off the muscle layer of the lower esophagus and the anastomotic flap and sutured the mucosal layer to the muscle layer in layers to form a double-layered mucosal flap (width about 1.5–2 cm) in the gastric lumen. In 2013, Li Bin et al. reported that mucosal flap-forming esophagogastric anterior wall anastomosis through a similar approach, which required stripping the muscular layer in the lower esophagus and the anterior wall of the remnant stomach [26]. In this procedure, the anterior wall of the mucosal canal of the anastomosis is about 3 cm long, the posterior wall was about 2 cm, and the final mucosal flap width was about 1–1.5 cm. They followed 136 patients who underwent

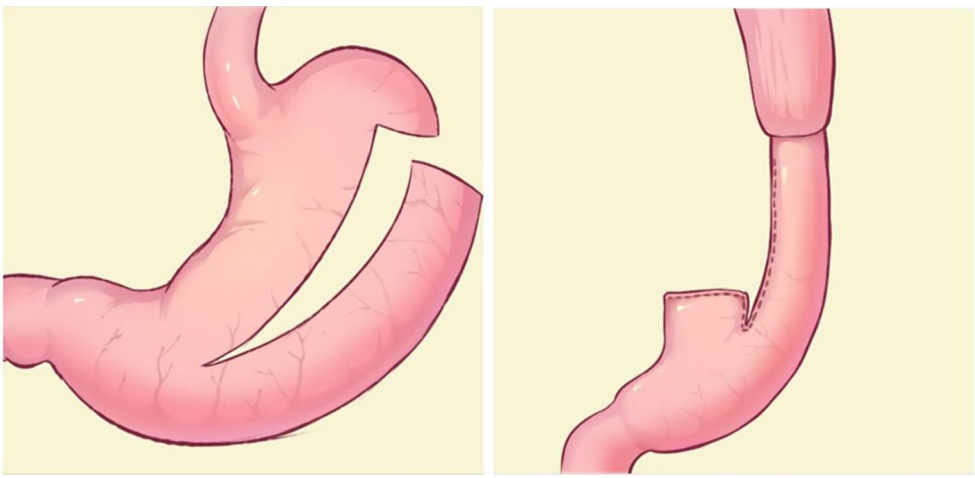


Fig. 4 "Cheng's Giraffe reconstruction"

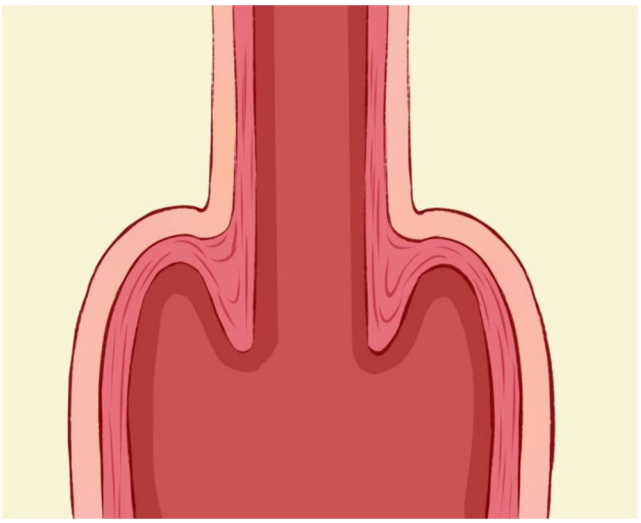


Fig. 5 The mucosal canal formed by a double-layered mucosal flap

this procedure between 2005 and 2010, of whom there were no anastomotic leaks and 5 cases with anastomotic stenosis.

Postoperative gastroscopic review was performed in 66 of 136 patients, and gastroscopic grade B or higher reflux esophagitis was present in 8 cases (Figs. 5 and 6).

In 2000, Yalav et al. [27]reported globe-type anti-reflux surgical techniques. The gastric wall was pressed into the gastric lumen, forming a globe-type tissue mass (slightly smaller in diameter than the anastomosis) at the anastomosis between the esophagus and the anterior wall of the remnant stomach, which acts as a viable flap. A total of 89 patients underwent the procedure between 1973 and 1982, and 93% had no reflux on barium contrast postoperatively 6 months. 20 patients underwent pressure measurement near the anastomosis with the continuous water perfusion technique, and the mean pressure in the lower esophagus was 14.2 mmHg (Fig. 7).

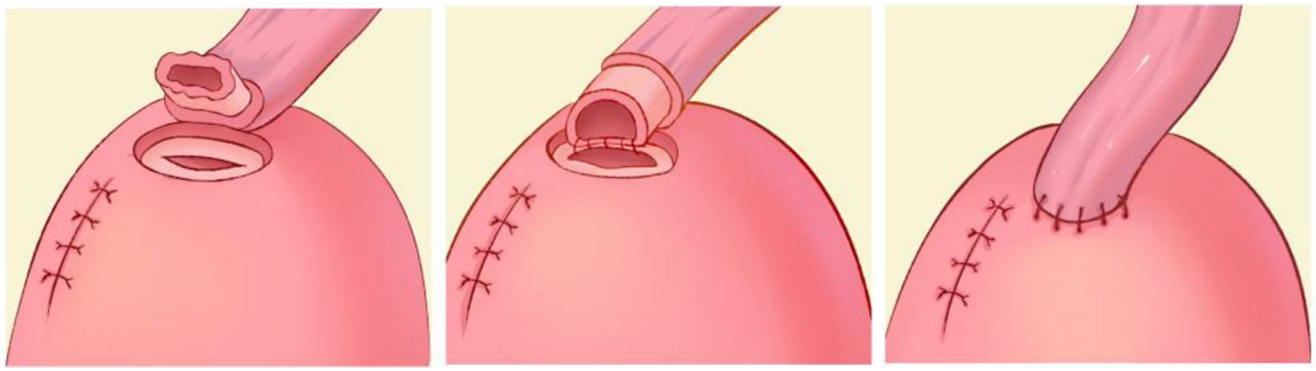


Fig. 6 Mucosal flap-forming esophagogastric anastomosis (esophagogastric anterior wall anastomosis)

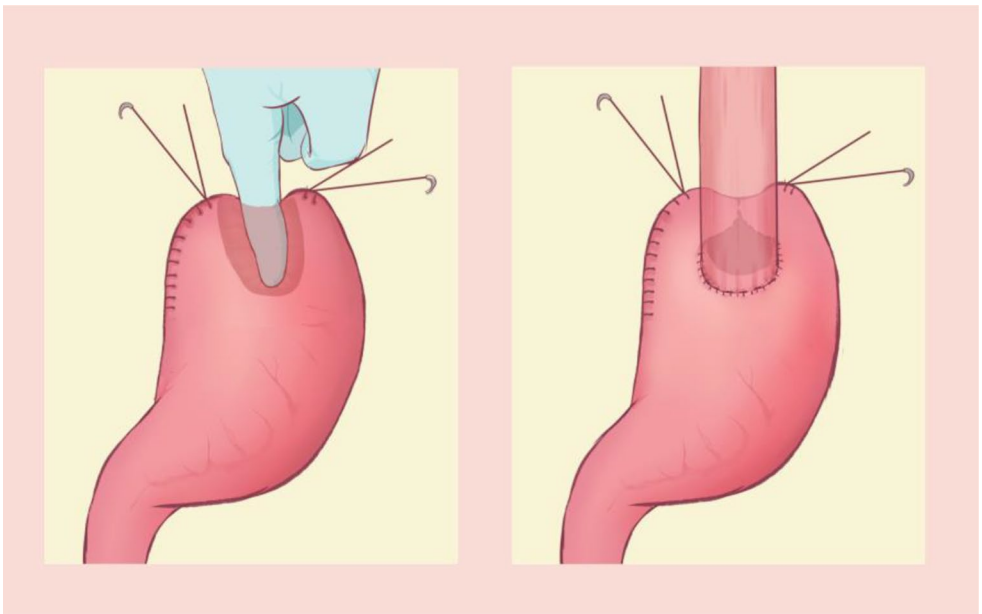


Fig. 7 Surgical diagram of globe-type anti-reflux surgical techniques

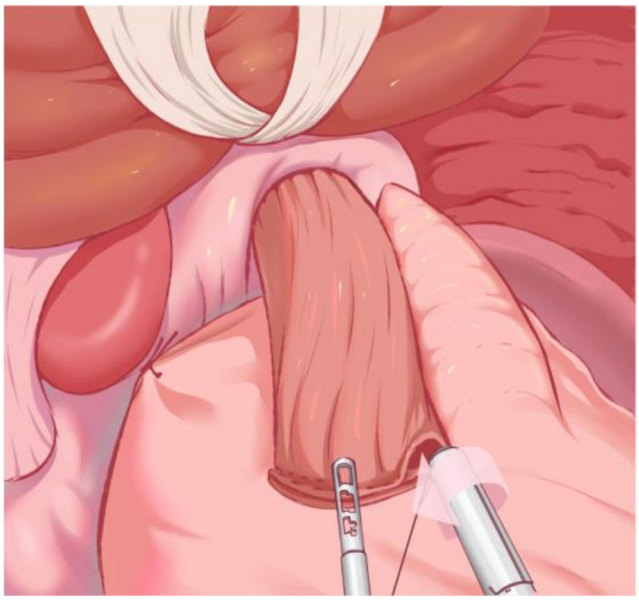


Fig. 8 Surgical diagram of SOFY

Rotation method (representative techniques: side overlap and fundoplication by yamashita and modified side overlap and fundoplication by yamashita)

SOFY is a procedure that has emerged and received more attention in recent years, first reported by Japanese scholar Yamashita et al. in 2016 [28]. Surgeons are becoming aware that anastomotic stenosis is more likely to occur after circular anastomosis than with linear cutting closures. However, the use of linear cutting closures for anastomosis of the posterior esophageal wall to the anterior gastric wall tends to disrupt the function of the reconstructed His angle, that is, the Gubaroff valve-like structure. Yamashita rotated the linear anastomosis clutch 90° counterclockwise along the long axis to anastomose the lateral wall of the lower esophagus with the antral wall of the stomach, thereby effectively preserving the His angle and fundus pressure while spreading the lower esophagus and fixing the edges with sutures. This can provide a better anti-reflux effect by increasing the pressure in the lower esophagus through the tissue tension after spreading and the pressure from the fundus. However, rotation is unstable and difficult to perform. Moreover, the anastomotic position may be shifted, and the overlap distance may be shortened during the rotation process, which can lead to a decrease in the anti-reflux effect. Thus, the modified SOFY method involves rotating the esophagus to avoid axis shift and anastomosis displacement during rotation of the closure [29]. This procedure is simple to perform laparoscopically, with short anastomosis time and fast postoperative recovery. The use of linear cutting closures can effectively avoid anastomotic stenosis. This procedure is currently receiving increasing attention and research in Japan, but its efficacy still needs to be supported by more high-level evidence (Figs. 8 and 9).

Compression method

Compression method is used to reconstruct the high-pressure region of the lower esophagus through the skillful use of gastric smooth muscle. According to the method of utilization, it can be divided into total gastric wall compression and seromuscular layer compression. On the basis of the extent of compression, it can be divided into total circumferential compression and partial compression.

Total gastric smooth muscle compression method Fundoplication prevents reflux by folding the remnant stomach around the lower esophagus and compressing it to create the pressure in the lower esophagus. The two representative procedures of this method are vertical upward overlapping and horizontal wrapping around:

Vertical upward overlapping Ottosen et al. [30] first described the Inkwell esophagogastrostomy in 1959. They attempted to construct a high-pressure region in the lower

Fig. 9 Surgical diagram of mSOFY

esophagus by lapping the gastric wall on both sides to the mediastinum and encasing the lower esophagus; a satisfactory long-term anti-reflux effect was reported in 1969 [31]. In 1974, Okada et al. [32] treated esophageal cancer by anastomosing the esophageal stump with the posterior wall of the remnant stomach and folding both sides of the stomach walls to wrap around the anastomosis through a process called posterior invagination esophagogastrostomy. Posterior invagination esophagogastrostomy has the advantage over Inkwell esophagogastrostomy for residual gastric compression on the lower esophagus. However, in 1978, Wara P et al. [33] studied 45 patients who underwent Inkwell esophagogastrostomy after resection of esophageal strictures (20 of which were malignant tumors). And he followed 19 of them for up to 10 years, and 16 of them had evidence of gastroesophageal reflux [33]. Dr. Ottosen also was involved in this study. They found that this sleeve technique exposed the lower esophageal mucosa to gastric acid, and the squamous epithelium was replaced by a cardia-type glandular epithelium, which gradually became inflamed and fibrotic, forming a rigid "orifice". Ultimately, they did not observe an area of high pressure in the lower esophagus and noted that Posterior invagination esophagogastrostomy may also have such problems and should not be considered an appropriate anti-reflux procedure (Fig. 10).

Horizontal wrapping around Watkins DH [8] first reported the method of wrapping around the lower esophagus in the horizontal plane by pulling the anterior and posterior walls of the stomach to the right side of the anastomosis while reconstructing the fundus and His angle. The Nissen fundoplication for the surgical treatment of reflux esophagitis was first reported in 1961 [34]. At present, the fundoplication is usually performed by inserting the fundus of the remnant stomach into the posterior part of the lower esophagus, fixing the remnant stomach at the left and right diaphragmatic feet, anastomosing the esophagus with the anterior wall of the remnant stomach, folding, and lifting the artificial "fundus", diagonally snapping the esophagus, and fixing it close to the esophagus. Horizontal wrapping has had major developments, and it can be mainly divided into total circumferential fundoplication (Nissen fundoplication and Nissen-Rossetti fundoplication) and partial fundoplication (Toupet fundoplication and Dor fundoplication) [35~37]. According to long-term follow-up, fundoplication with total or partial circumferential encasement of the esophagus is likely to lead to anastomotic stricture and dysphagia after surgery. Slippage of the fold after fundoplication has also been reported. This procedure requires a high residual gastric size, so it has been widely used to treat esophageal hiatal hernia since the 1980s.

Gastric seromuscular layer compression method Gastric muscle seromuscular layer compression cleverly utilizes the thin structure of the gastric seromuscular layer and sub-seromuscular-layer smooth muscle to wrap around the anastomosis and lower esophagus, thereby reconstructing a high-pressure region to achieve anti-reflux and enhance anastomotic safety. Four representative procedures use gastric seromuscular layer compression:

Tunneled esophagogastrostomy Tunneled esophagogastric anastomosis is the earliest esophagogastric anastomosis using the gastric seromuscular layer to recreate the cardia sphincter. The "tunnel" is created under the seromuscular layer on the anterior wall of the remnant stomach. The lower part of the esophagus penetrates the "tunnel" and anastomoses with the stomach at the end of the "tunnel," thereby entering the stomach lumen [7]. When the pressure of the stomach increases, the contraction of the stomach smooth

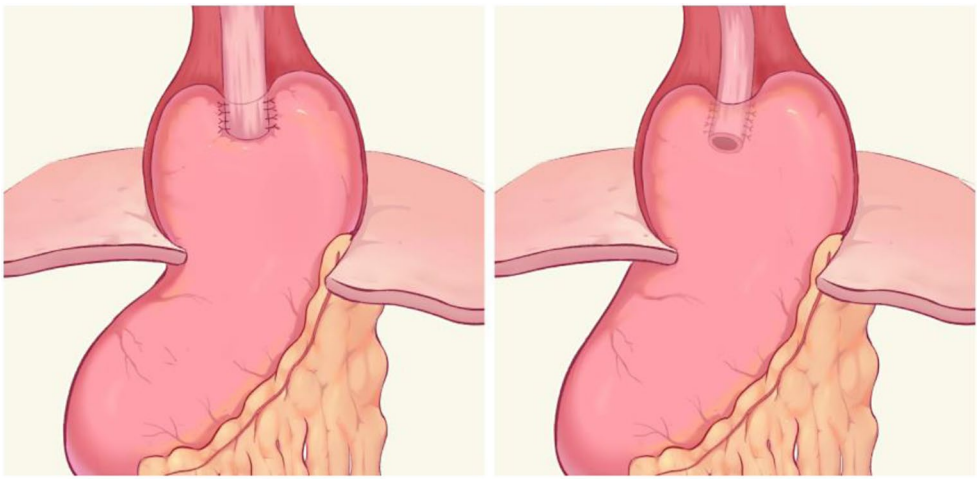


Fig. 10 Surgical diagram of Ottosen's Inkwell esophagogastrostomy and Okada's posterior invagination esophagogastrostomy

muscle is enhanced and compresses the tunnel to close, which avoids the reflux of gastric contents.

The procedure was proposed by Dr. Geoffrey Wooler in 1956 [7]. He also reported 3 cases of ulcerated lesions involving the cardia and lower esophagus. Redo SF et al. [38] conducted further studies on tunneled esophagogastrostomy in 1960. They also conducted animal experiments to explore the length of the tunnel, the necessity of pyloroplasty, and bilateral partial vagotomy. They imagined tunneled esophagogastrostomy as the anatomy of the natural sphincter, such as the circumferential sphincter of the ureter running diagonally into the smooth muscle wall of the bladder. Their study found that this procedure effectively prevented reflux esophagitis by confining reflux to the mucosal anastomosis between the esophageal stump and the antrum of the stomach. And the tunnel length (4–10 cm) had no significant effect on the anti-reflux effect. In 1961, Lortat JL et al. [39] reported that a tunnel length with 2.5–4 cm can ensure an exact anti-reflux effect. Animal experiments and case applications of tunneled esophagogastric anastomosis were also reported by Liu K et al. in 1964, in which a tunnel length of about 3 cm was recommended and routinely performed [40~41].

Its disadvantages may be mainly in the establishment of the tunnel requires a certain length of esophagus overlapping with the remnant stomach, which places high demands on the size and location of the lesion. And too short a tunnel length (less than 2.5 cm) will lead to a reduction in the anti-reflux effect. The anti-reflux effect of tunneled esophagogastric anastomosis is greatly improved, but there is still a gap compared to the current popular procedure (Fig. 11).

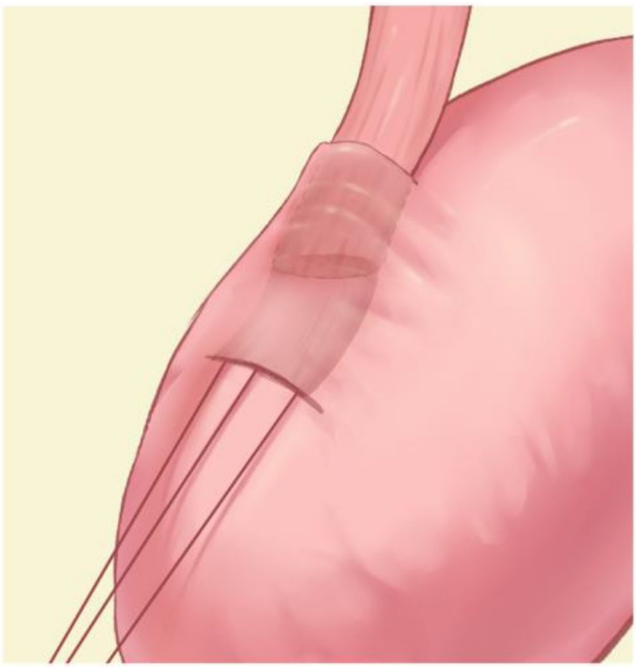


Fig. 11 Surgical diagram of tunneled esophagogastric anastomosis

Valvuloplastic esophagogastrostomy by hatafuku Valvuloplastic esophagogastrostomy by Hatafuku [11, 42] is an innovative mucosal and muscular layered anastomosis to obtain a larger area and higher-pressure zone in the lower esophagus, borrowing from Dr. Franke's modified valve-forming [21] and Nissen fundoplication [34]. This procedure was first reported by Dr. Hatafuku and Dr. Seta in Japan in 1978, and animal experiments and clinical applications in 10 patients were completed. Dr. Hatafuku's team performed pressure and pH measurements of the lower esophagus after GI reconstruction following animal experiments and measured the area of the high-pressure zone. Then they compared it with conventional direct esophagogastric anastomosis and esophagogastric antral anastomosis (reconstruction of the fundus and His angle alone), which was recognized by several famous scholars at the time. This procedure uses a linear anastomosis to dissect the stomach in 2 passes. The margin of the preserved stomach is a folded line with the fold point approximately at its midpoint. And then the mucosal layer at the anastomotic end of the remnant stomach was separated from the muscular layer with a width of 2 cm. The lower end of the esophagus is anastomosed with the mucosal layer of the stomach to the right of the fold point. After completion of the anastomosis, the fundus and His angle were reconstructed according to Dr. Frank's modified valve-forming, and the separated remnant gastric seromuscular flap was wrapped around the lower esophagus. In the coronal surface dissection of the stomach in animal experiments, the mucosal flap formed by the His angle structure can be clearly observed. Hatafuku reported no anastomotic leak or gastroesophageal reflux in the 10 patients who underwent this procedure. However, some of the patients developed dysphagia, and one of them was a more severe stenosis that required gastroscopic mechanical dilatation.

In 1986, Matsushiro et al. [43] reported a modification of this procedure. They constructed an equilateral triangle with a side length of approximately 2.5–3 cm on the lateral side of the greater curvature of the stomach at the time of fracture dissection, and the mucosal layer was separated from the muscular layer with an expanded width of 2.5 cm. 17 patients underwent modified surgery. 11 of them were followed up for more than 1 year and 3 for more than 3 years, with no abnormalities on imaging and mucosal biopsy, and their high-pressure areas and pressures were similar to those of the healthy controls. 1 case presented with reflux manifested by multiple small ulcers in the lower esophagus,

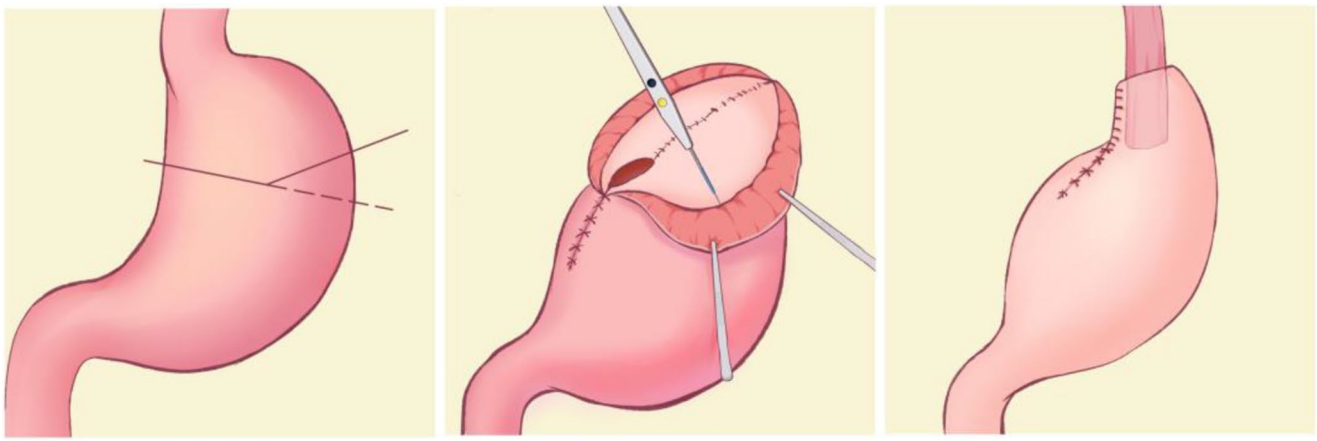
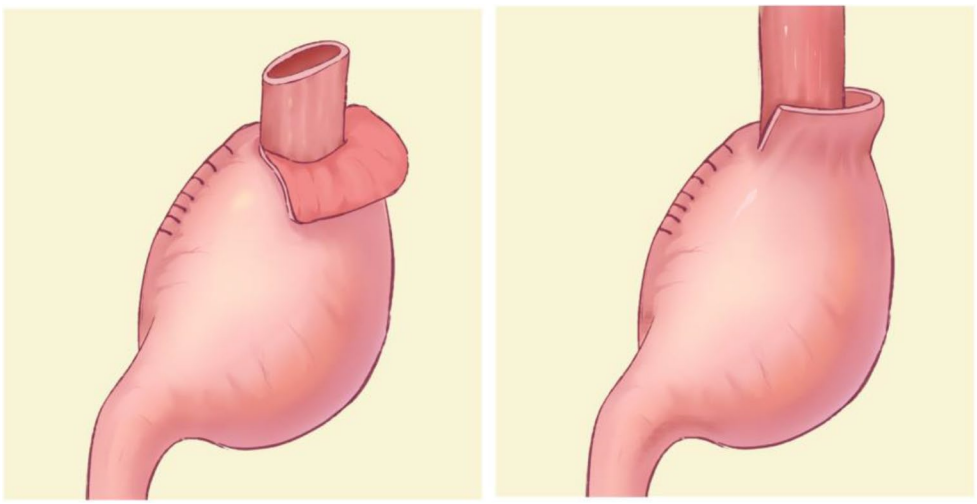


Fig. 12 Surgical diagram of Valvuloplastic Esophagogastrostomy by Hatafuku

Fig. 13 Surgical diagram of seromuscular flap encapsulated gastroesophageal anastomosis



which Dr. Matsushiro et al. suggested could be related to loosening of the wire knot and failure of valvuloplasty (Fig. 12).

Seromuscular flap encapsulated gastroesophageal anastomosis This procedure was reported by Chinese surgeon Han CY et al. in 1999 [44]. They prepped the anastomotic flap (anterior wall height of 2.5 cm and posterior wall of 3 cm) on the greater curvature of the remnant stomach, stripping the mucosal layer and preserving the muscular layer. Subsequently, they trimmed the lower end of the esophagus into an arc, performed an end-to-end anastomosis between the esophageal and the remnant stomach, and wrapped the anastomotic flap muscularly around the lower segment of the esophagus. A total of 145 cases underwent this procedure at four centers from 1988 to 1997 and were followed up for more than 1 year. No anastomotic leakage or anastomotic stricture occurred in 145 patients, and 10 cases of reflux esophagitis (6.8%). The relaxation and contraction of the cardia were observed under the endoscope, which reflected good functional reconstruction. This procedure not only uses the anastomosis flap to reconstruct the function of the cardia flap valve, but also utilized a curved anastomosis, which gives the esophagogastric anastomosis a "flared" shape, enlarges the esophageal outlet, and avoids contracture of the anastomotic stenosis after scar healing. Notably, the serosal muscle layer flap in this procedure preserves more muscle layers, which is thicker and more powerful. Han et al. observed under the endoscope that the internal diameter of the anastomosis was 1.3 to 1.5 cm. The diameter of the anastomosis is influenced both by the strong muscle flap action and by the scar repair. Therefore, it is necessary to avoid the occurrence of anastomotic stenosis (Fig. 13).

Seromuscular flap valvuloplasty (including: double flap technique and right-sided overlap with single flap valvuloplasty) Double flap technique (DFT) was first reported by Kamikawa et al. [45] in Japan in 1998. Kuroda et al. [46] firstly reported the laparoscopic application of this procedure and made a long-term follow-up study in 2016. The

critical parts of this reconstruction involve the creation of a seromuscular double-flap and the implanted length of the esophagus. An H-shaped 2.5 × 3.5 cm seromuscular double-flap was generated on the anterior surface of the remnant stomach, which was positioned to cover the anastomosed site in a Y-shape. This procedure provides a good anti-reflux effect by artificially constructing a "valve" in the esophagogastric anastomosis and closing the "valve" when gastric movements increase. In addition, this procedure has only one anastomosis which is wrapped by a seromuscular flap, providing good safety of the anastomosis and low incidence of anastomotic fistula. The main disadvantage of this procedure is the large number of sutures involved and long time it takes. The difficulties lie in reducing the occurrence of anastomotic stenosis by appropriately extending the width of the muscle flap or adjusting the esophageal fixation position and in maintaining the blood supply of the muscle flap by appropriate operations (Fig. 14).

Ken Omori et al. first performed a modified procedure on the basis of DFT, called left-sided overlap with single flap valvuloplasty, but no relevant articles were published [47]. This procedure may have some negative effects on the blood supply of the muscle flap due to the dissociation of the left-to-right blood flow in the muscle flap, thus it may become necrotic and lose its anti-reflux effect. Wu YY et al. [47] modified the procedure, and it was termed right-sided overlap with single flap valvuloplasty (ROSF). The key step is to create a ⊏-shaped (3.0 cm×3.5 cm) seromuscular flap and rotate the linear cutting closures counterclockwise during anastomosis. This procedure inherits and further combines the characteristics of DFT and SOFY. ROSF also employs a seromuscular flap to cover the anastomosis, creating a full circumferential compression. Rotation of the linear cutting closures, drawing on SOFY, preserves a complete and large area of high pressure in the posterior esophageal wall. Furthermore, it maintains the blood supply of the seromuscular flap and has a larger high-pressure region in the lower esophagus than DFT. The patients exhibited a well-moving mucosal flap at the cardia during endoscopy examination post operation.

Patients who underwent ROSF were able to observe a well-moving mucosal flap at the "cardia" with endoscopy examination after operation. Until March, 2023, Wu's team has maintained follow-up of 38 patients who underwent ROSF. Symptomatic reflux was observed in 1 patient (5%) while reflux esophagitis (Los Angeles Grade A) was observed in another patient (5%). 4 patients (20%) had mild dysphagia (Visick score = II). And 1case underwent endoscopic stricturotomy because of Stooler grade II anastomotic stenosis [48] (Fig. 15).

Summary

During the development of the post-PG GI reconstruction, numerous scholars have studied the anatomical and anti-reflux mechanism of the cardia, which have greatly helped us to explore and improve the surgical procedure. With the increasing incidence rate of AEG and the trend of "individualized, function-preserving" surgery, surgeons pay more and more attention on surgical procedures of function reconstruction for individual physiological characteristics of patients. In addition to the anti-reflux GI reconstruction procedures mentioned in this paper, Double tract reconstruction (to shunt acidic reflux fluid) and Jejunal interposition reconstruction (to extend reflux distance and create an anti-acid environment) are also popular. In terms of distant nutrition, a research team has comparatively studied single-channel reconstruction versus dual-channel reconstruction. They demonstrated the importance of digestion of food all through the gastroduodenal route after gastroduodenal single-channel reconstruction for the recovery of patients' postoperative nutritional status, which was significantly better than the dual-channel group [48–50]. Jejunal interposition has the disadvantages of complicated operation, large

Fig. 14 Surgical diagram of DFT

Fig. 15 Surgical diagram of ROSF

trauma, expensive, and low safety. In addition, the appropriate length of jejunal loops still needs to be discussed. Jejunal interposition has the potential for adhesions, internal hernias, and intestinal obstruction in the long term due to the intestinal tract involved in the procedure. From some meta-analysis, it is usually possible to conclude that esophagogastrostomy with valvuloplasty is superior in terms of anti-reflux, anastomotic safety, and preservation of gastrointestinal function [52–54].

We summarized the anti-reflux methods in esophagogastrostomy based on the current mainstream and modified procedures. In the last hundred years of research on anti-reflux technology, surgeons from different countries continue to innovate and practice, reflecting the relentless pursuit of excellence by surgeons. The development of anti-reflux gastroesophageal anastomosis also places high demands on the surgeon, who needs to be familiar with the characteristics of each type of procedure. Therefore, surgeons can choose the appropriate reconstructive procedure from the perspective of minimal damage and good prognosis according to the patient's specific situation. At the same time, surgeons can explore new anti-reflux procedures based on the basic methods and principles in this article. Anti-reflux gastroesophageal anastomosis, represented by seromuscular flap valvuloplasty, which restores the natural physiological structure, has better utility and safety and a broader application than other methods. Further multi-centre large sample randomized controlled trials are worthwhile.

Author contributions All authors contributed to the study conception and design. Yongyou Wu proposed the idea for the article and the first draft of the manuscript was written by Yuan Tian. All authors commented and critically revised on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability No datasets were generated or analysed during the current study.

Declarations

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