Step-by-Step Description of Pylorus-Preserving Gastrectomy

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Introduction

While gastric cancer remains one of the most common causes of cancer-related deaths worldwide [1], countries with a high rate of early detection due to screening programs and general awareness, especially Japan and Korea, have developed advanced techniques to perform stomach- and function-preserving surgery. As such, pylorus-preserving gastrectomy (PPG) has been established as a good option for clinically early gastric cancer of the middle portion of the stomach [2, 3]. The principle of this operation is to combine luminal segmental resection of the stomach with preservation of pyloric function with an oncologically accurate extended D1+ lymph node dissection. Prospective studies have shown the long-term oncological safety of this approach compared to distal gastrectomy; and we await the results of a Korean prospective randomized trial regarding the functional outcome (KLASS-04).

The Japanese gastric cancer treatment guidelines list the PPG operation as an option for cT1N0 cancers of the middle portion of the stomach; however, the exact tumor location that is suitable for PPG is still under discussion, especially regarding the proximal extent of the tumor [4]. The distal extent of the tumor should be no closer than 4 cm from the pylorus to achieve a negative resection margin and to preserve sufficient antral tissue for pyloric function. Nevertheless, postoperative gastric stasis caused by pyloric spasm is one of the potential complications and challenges after PPG. Several technical alterations have been suggested to improve this particular outcome, which is a critical endpoint that is necessary to realize the clinical benefits of PPG. As laparoscopic surgery has been confirmed, in Japanese and Korean prospective randomized trials, to be an oncologically safe option for early gastric cancer, the PPG resection is widely performed by the minimally invasive approach followed either by intracorporeal or extracorporeal gastro-gastrostomy [5, 6]. This chapter describes the technical

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steps of PPG for clinically early gastric cancer and suggests anastomotic techniques.

Approach, Placement of Trocars, and the Operative Field

For minimally invasive resection, the laparoscopic and robotic approaches represent possible options. Laparoscopic PPG is the most established and most standardized procedure; and much of the published evidence regarding minimally invasive PPG is based on the use of laparoscopic techniques. However, despite higher costs, the robotic approach may be safe and accurate for gastric cancer surgery as well, although a study comparing laparoscopic and robotic PPG did not reveal differences in outcomes [7].

In the laparoscopic setting, the patient is placed in supine, reverse Trendelenburg position with the legs elevated (Fig. 6.1). Typically, an 11-mm camera trocar is placed in the infraumbilical position. Additional two 12-mm ports can be positioned right and left and cranial of the camera port followed by one 5-mm port each in the right and left upper lateral positions. If the operator stays on the right side of the patient and extracorporeal anastomosis is performed, two 5-mm trocars on the patient's left side are sufficient. The patient's position is similar for the robotic approach; but to achieve the longest distance between the external robotic arms, both 7-mm ports are placed more laterally (Fig. 6.2).

Operative Technique

Partial Omentectomy and Ligation of the Left Gastroepiploic Vessels

After diagnostic laparoscopy, the resection is started near the midline of the omentum. The stomach can be lifted to inflate air into the lesser sac to separate and provide distance between the stomach and the colon for safer division. After finding the correct plane in the lesser sac, omentectomy is proceeded towards the direction of the spleen. Typically, after visualization of the lower splenic pole, the left gastroepiploic vessels can be identified (Fig. 6.3a) and ligated with clips. Two clips on the patient side and one clip on the specimen side are recommended for safe ligation of all landmark vessels during gastrectomy. After ligation, the vessels can be followed to the stomach to prepare the greater curvature for cleaning.

The portion of the greater curvature that will be preserved is cleaned of tissues, vessels, and lymph nodes. This maneuver of cleaning the greater curvature is performed in a distal to proximal direction starting approximately at the location of the proposed transection plane of the stomach and heading proximal to the ligated left gastroepiploic vessels (Fig. 6.3b). To facilitate this step, the greater curvature of the stomach should be aligned with the direction of the energy device and proper traction and counter-traction should be maintained with the assistant's help. The greater curvature should be cleaned layer by layer (posterior and anterior layer) to remove lymphatic tissues close to or on the stomach surface while avoiding bleeding. These tissues remain in continuity with the omentum at the distal stomach. Upon completion of skeletonizing the proximal stomach, partial omentectomy is completed towards the right side of the patient until the infrapyloric area is approached. This first part of the operation is similar to standard laparoscopic distal gastrectomy for early gastric cancer.

Infrapyloric Dissection

The infrapyloric dissection is the most crucial and challenging part of the PPG operation. In order to maintain good pyloric function, both right gastroepiploic artery and vein should be clipped only after it has branched to the pylorus and antrum. On the other hand, the infrapyloric region must be cleared of lymphatic tissues for oncological accuracy and integrity. The partial omentectomy can be finished by heading towards the gallbladder and carefully separating the greater omentum from the underlying fused transverse mesocolon (Fig. 6.3c). In the last step of partial omentectomy, the second portion of the duodenum should be visualized (Fig. 6.3d). Now

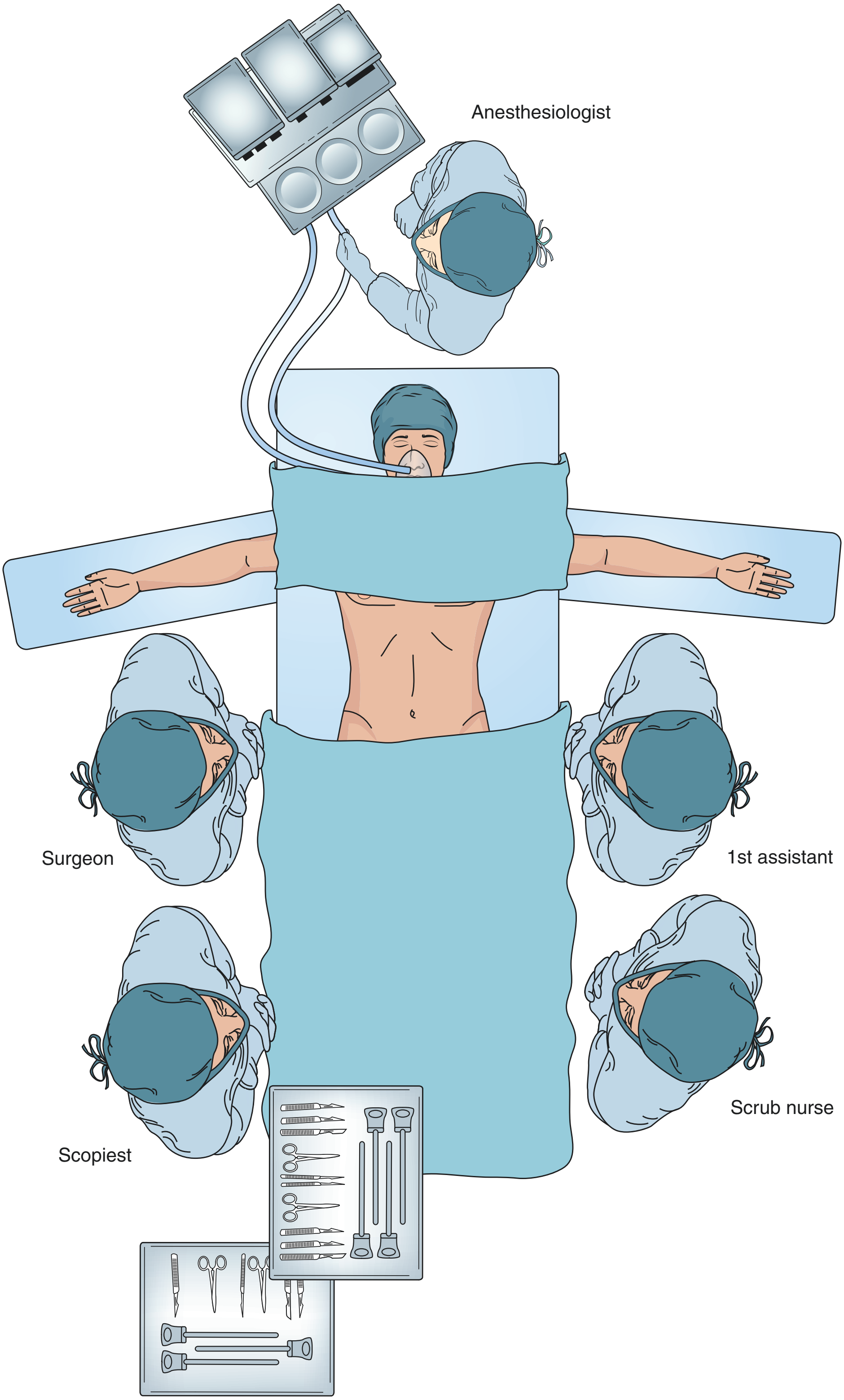

Fig. 6.1 Patient and surgeon positioning for minimally invasive pylorus-preserving gastrectomy

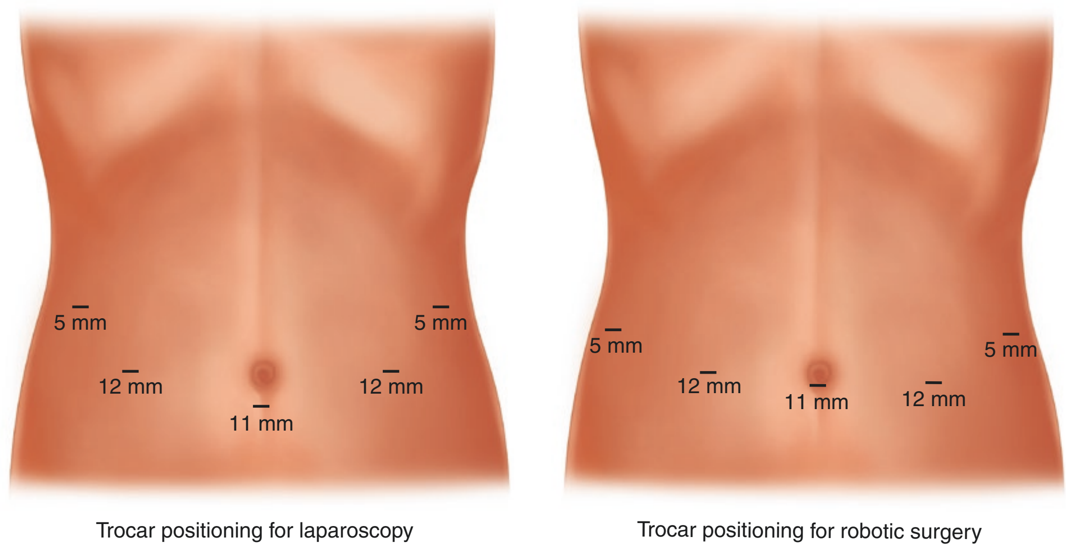

Fig. 6.2 Trocar/port positioning for laparoscopic and robotic pylorus-preserving gastrectomy

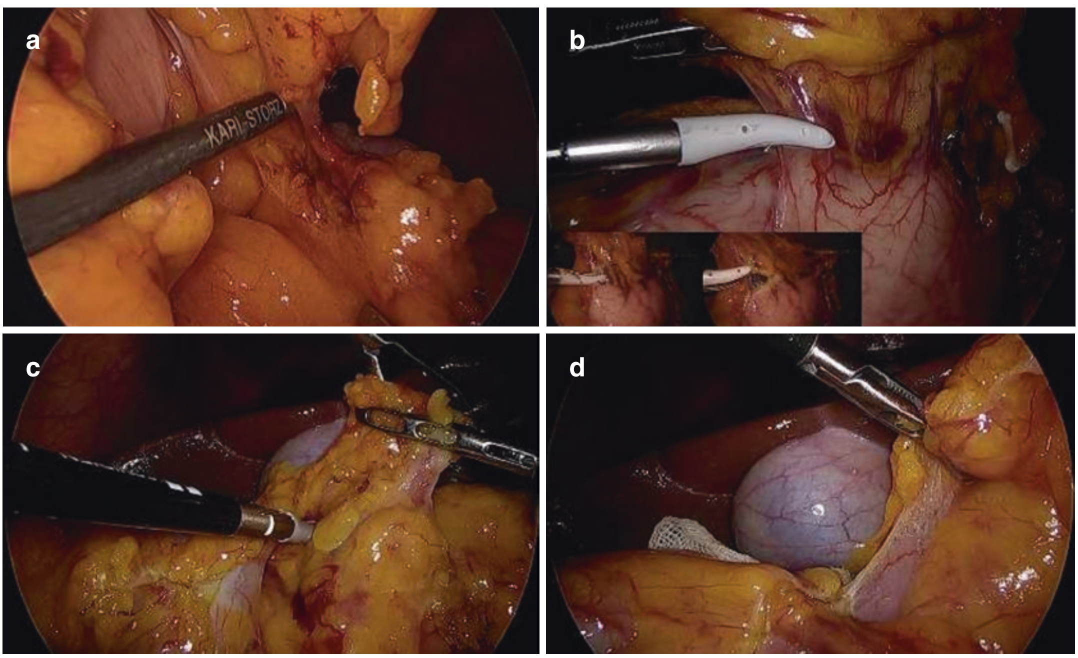

Fig. 6.3 Intraoperative image showing (**a**) isolation of the left gastroepiploic vessels, (**b**) cleaning the greater curvature, (**c**) completion of omentectomy, and (**d**) visualization of the duodenum

the fusion plane of infrapyloric tissue and mesocolon should be identified to initiate the infrapyloric dissection. The assistant lifts up the antrum by gently grasping the posterior wall and carefully retracting the mesocolon downward using gauze to maintain a proper operative field (Fig. 6.4a). The assistant's retraction of the stomach wall can facilitate effective counter-traction during the infrapyloric dissection by altering the direction of traction.

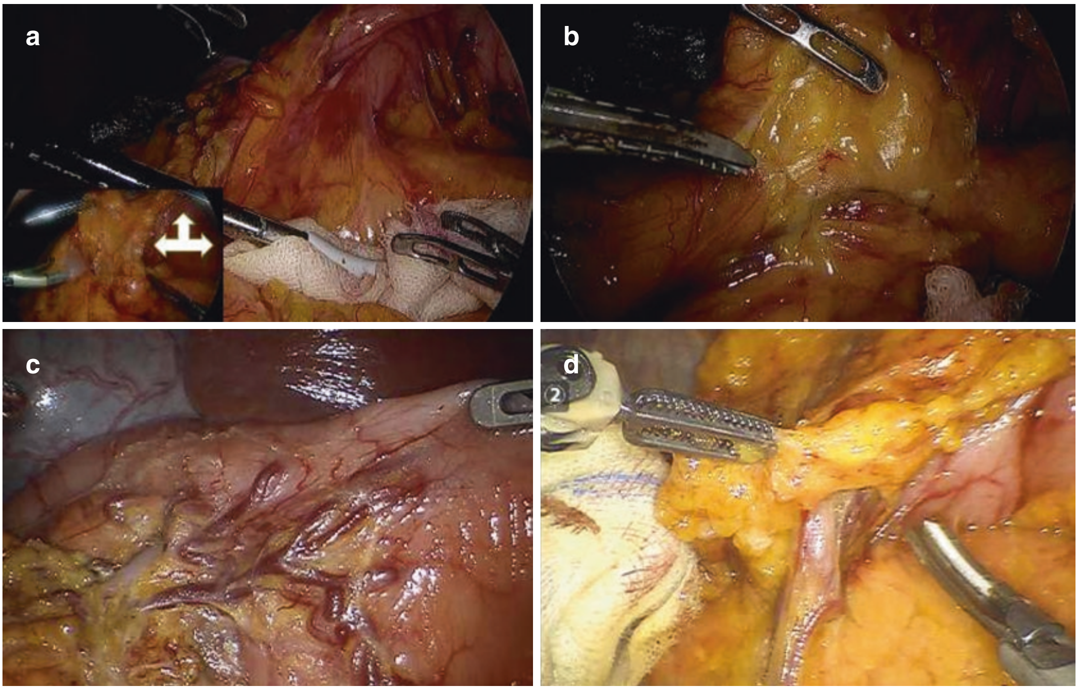

Fig. 6.4 Intraoperative image showing (**a**) the infrapyloric area prior to dissection, (**b**) the fusion plane between the mesocolon and right gastroepiploic vessels, (**c**) the anterior region of the infrapyloric area, and (**d**) dissecting along the right gastroepiploic vessels

The surgeon can approach the fusion plane by dissecting on the posterior aspect of the right gastroepiploic vessels in the direction of the gastroduodenal artery. Depending on its origin, the infrapyloric artery can be isolated and saved. There are several variations to this artery with the infrapyloric artery originating from the anterior superior pancreaticoduodenal artery (64.2%), the right gastroepiploic artery (23.1%), or the gastroduodenal artery (12.7%) [8]. Next, the fusion plane is dissected to separate the mesocolon from the tissues adherent to the stomach (Fig. 6.4b). At this point, the root of the right gastroepiploic vessels can be visualized. If the vessels appear during this step of dissection, it should be determined whether they supply blood to the pyloric region. To perform safe dissection of lymphatic tissues along the infrapyloric vessels, the assistant can retract the antrum towards the left upper quadrant which will place the infrapyloric vessels into a direction that is parallel to the direction of the energy device (Fig. 6.4b). Short bursts of coagulation with the energy device can preclude damage to the pyloric blood supply. As the dissection of the posterior side of the gastroepiploic vessels is completed, the peritoneal layer is opened on the anterior side of the vessels just proximal to the distal end (Fig. 6.4c). Small vessels supplying the pylorus are uncovered. If bleeding is encountered, we suggest compressing with gauze and avoiding thermal damage with an energy or bipolar device.

The distal resection line must be determined. The proximal pyloric branches of the greater curvature are cleaned of their lymphatic tissues. If the antrum cuff is too long, then stasis in this segment can occur due to impaired motility. As the posterior and the anterior sides are dissected, the infrapyloric lymphatic tissues are dissected and harvested along the gastroepiploic vessels in a distal to proximal direction (Fig. 6.4d). Now, the gastroepiploic vessels can be clipped after they have supplied the branches to the pylorus. We recommended saving both the arterial and venous branches to the pylorus to avoid postoperative edema which may lead to malfunction of the pylorus [9]. Before moving to the lesser curvature side, we recommend dividing the connection between lymph node station 5 and 8a under the stomach to facilitate later dissection of lymph node station 8a on the lesser curvature.

Distal Lesser Curvature

In order to elevate and stretch tissues and protect structures such as the common hepatic artery, we place three gauze sponges under the lesser omentum at the under surface of the stomach before approaching the anterior side of the lesser curvature. Lymph node station 5 along the right gastric artery is not harvested in PPG [10]. In this area, important perineural structures for the pyloric region are located, and oncologically, it is not mandatory to harvest nodes from this station for the indicated tumor location. However, if suspicious lymph nodes are visualized in the infrapyloric or suprapyloric regions, we advise dissecting the tissues for frozen section investigation or to abort the PPG procedure and convert to formal distal gastrectomy to achieve radical resection in this area. The right gastric artery arcade (Fig. 6.5a) should be clipped distal from its origin and approx-

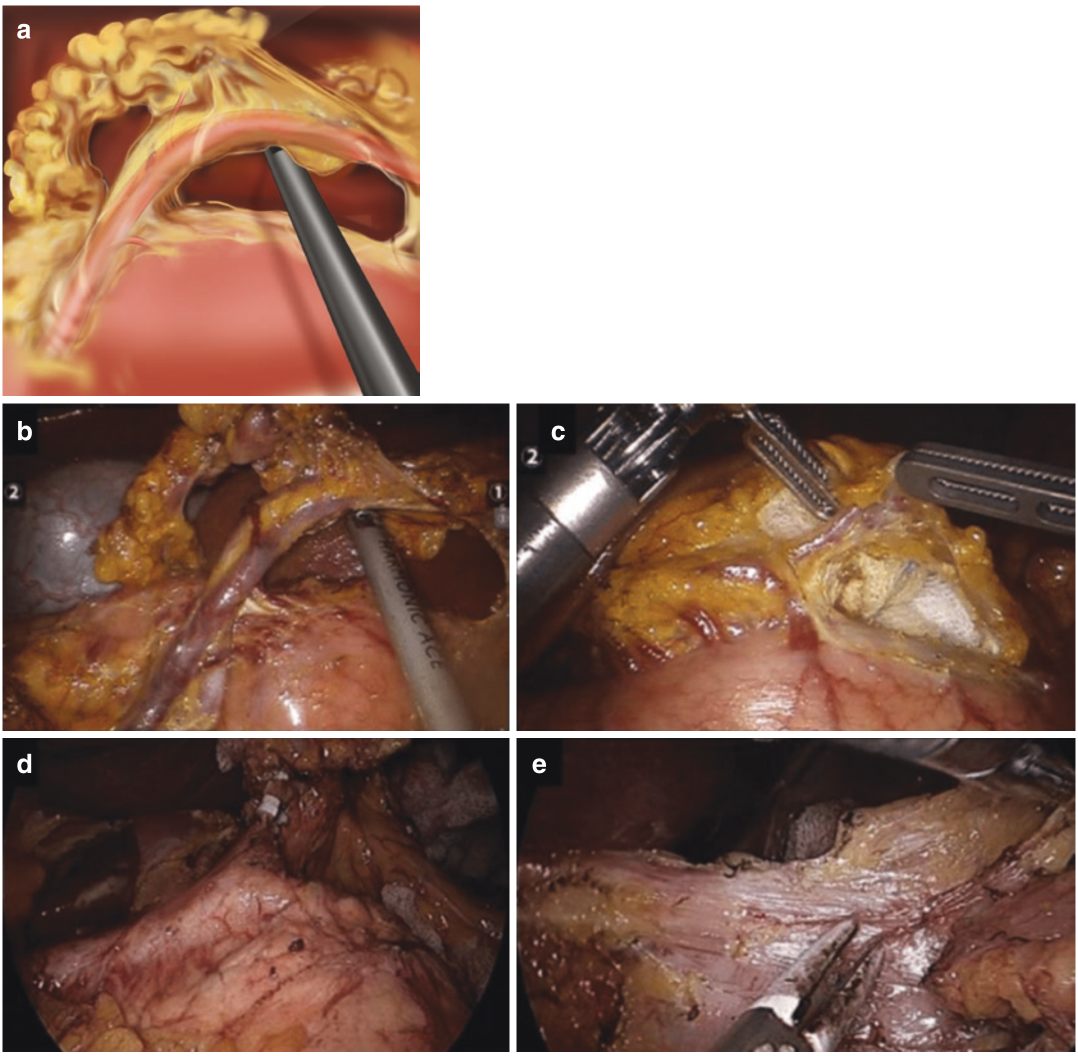

Fig. 6.5 (**a**) Illustration showing the right gastroepiploic vessels with preservation of the pyloric branches. (**b**) Paired intraoperative image with lifting of the right gastroepiploic vessels to highlight preservation of branches to the pylorus. Intraoperative images showing (**c**) the right gastric arcade, (**d**) clipped left gastric artery, and (**e**) cleaning the lesser curvature of the stomach

imately 3 cm from the pylorus. The assistant can place counter-traction on the lesser curvature by retracting the antrum in a caudal direction using gauze to maximize the force of retraction. Similar to dissection of the greater curvature, the lesser curvature can be skeletonized. The lesser omentum is divided in the direction of the gastroesophageal junction. During this step, preservation of the hepatic branches of nervi vagi can be achieved. Potential lymph nodes in this location or an aberrant left hepatic artery can complicate this step. With respect to oncological principles, the preservation of an aberrant left hepatic artery is an appropriate maneuver. The result of these steps now permits the suprapancreatic area to be visualized from above the lesser curvature of the stomach.

Supra-pancreatic Lymph Node Dissection

Lymph node station 8a dissection is performed along the common hepatic artery to the root of the left gastric artery. As mentioned above, it is better to separate tissues between lymph node station 5 and 8a on the posterior aspect of the distal stomach. If a coronary vein is visualized early, it should be clipped and divided. The assistant can grasp and lift the pedicle of the left gastric vessels in an orthogonal position to the supra-pancreatic border (Fig. 6.5b. The assistant's counter-traction on the pancreas using gauze sponge is optional. Attention should be paid to avoid excessive retraction on the pancreas which can lead to injury to the vessels [11]. The left gastric artery and vein are skeletonized and clipped at its roots (Fig. 6.5c). For D1+ dissection, harvesting lymph node station 11p is not mandatory; however, if dissection is desired it can be performed after the left gastric vessels are divided. The tissue behind the root of the left gastric artery should be harvested as part of lymph node station 9.

Lesser Curvature Dissection

After completion of the necessary steps for dissection along lymph node station 8a, the tissues of the supra-pancreatic area along the diaphragmatic crus are dissected towards the direction of the esophagogastric junction. The necessity of dissecting lymph node station 1 in middle stomach for early gastric cancer is controversial and deferring dissection of these nodal tissues could preserve vagal innervation to the pylorus. However, the guidelines for PPG suggest that these nodal tissues should be removed as part of the surgical specimen. The nodal tissues along the lesser curve (i.e., lymph node station 3) are dissected layer by layer similar to the dissection of the greater curvature up to the location of the proximal resection line (Fig. 6.5d). Gentle retraction by the assistant is crucial to stretch the tissues for clean dissection of lymphatic tissues while avoiding bleeding. The lesser curvature of the stomach can be quite thin and tearing or thermal penetration of the stomach should be avoided (Fig. 6.5e).

Gastro-gastrostomy

Extracorporeal Anastomosis

If an extracorporeal anastomosis is performed, a mini-laparotomy (5 cm) is sufficient in most cases. For the exact location of the incision, laparoscopic views can be helpful. For the most common location of early cancer in the middle portion of the stomach (i.e., lower body/corpus), a transverse incision represents a comfortable approach. For higher locations (i.e., mid-body), a vertical midline incision can be used.

After laparotomy, the mobilized stomach can be gently extracted. To easily determine the luminal extent of resection, preoperative endoscopic clipping is a good option. For extracorporeal anastomosis, the clips are palpable and can be located. Distal resection can be performed by clamping the proximal portion of the stomach and dividing the stomach layer by layer with electrocautery. The distal margin is sent for frozen section evaluation.

One maneuver to decrease postoperative pyloric spasm is manual dilatation of the pylorus, which can easily be achieved at this point in the procedure [12]. A ring forceps is inserted into the lumen and the pylorus is gently stretched for 10–15 seconds (Fig. 6.6a). For the proximal resection, an Allen clamp is applied across the

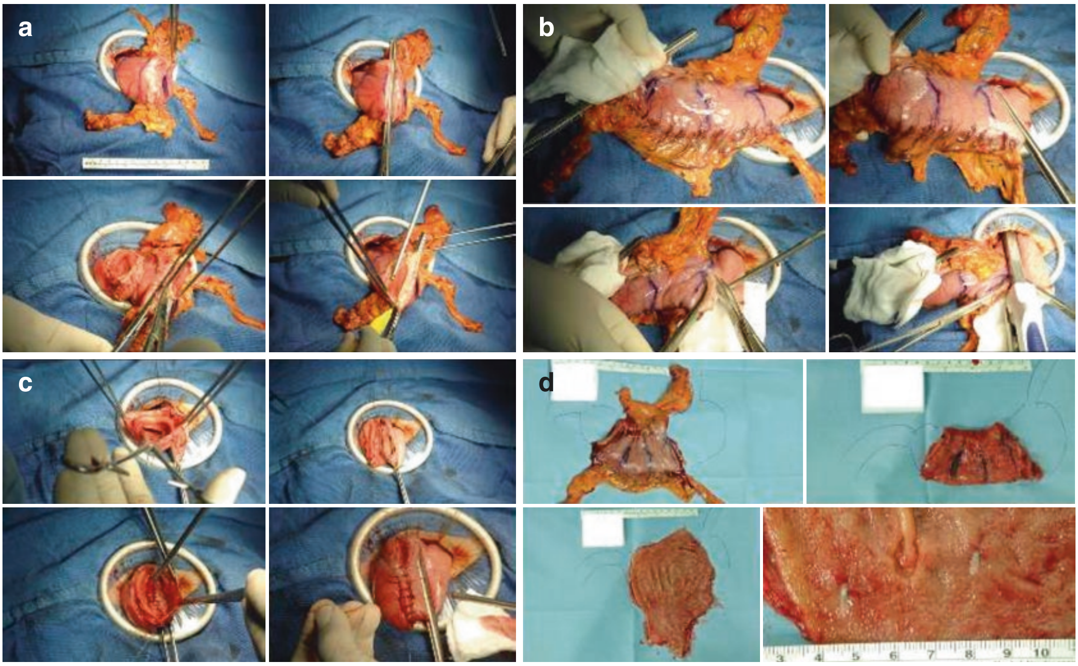

Fig. 6.6 Intraoperative images showing (**a**) distal resection of the stomach and dilatation of the pylorus, (**b**) proximal resection of the stomach, (**c**) creation of the gastro-gastrostomy, and (**d**) the pathologic specimen

proposed transection line from the greater to lesser curvature; and another clamp is placed in a similar fashion at the distal transection line. The proximal clip, the cancer, and the resection lines can all be marked with ink on the external surface of the stomach. Then, the middle portion of the stomach is resected using a linear stapler (Fig. 6.6b). After retrieving the resected stomach, we check the resection margin macroscopically. Then, a proximal margin can be sent for frozen section examination.

At last, the gastro-gastrostomy is performed with a single-layer continuous interlocking hand-sewn anastomosis using 3–0 polyfilament absorbable sutures (Fig. 6.6c). In case of tension or bleeding, the anastomosis can be reinforced with single sutures. Since the specimen without connective tissue represents a segmental resection, it is important to provide orientation for the pathologist to ensure precise documentation of appropriate resection margins before tissues are fixed (Fig. 6.6d).

Intracorporeal Anastomosis

If intracorporeal anastomosis is desired, the luminal extent of resection can be determined using different methods. Endoscopic clipping of the desired margins seems beneficial; and x-ray, ultrasound, or intraoperative gastroscopy can be used to localize the clips. A combination of clipping and intraoperative gastroscopy is a safe option for intracorporeal anastomosis [13]. This intracorporeal technique is performed using linear staplers. For reconstruction, the first option appears similar to the delta-shape intracorporeal anastomosis in Billroth I resection. Both parts of the remnant stomach are opened at the end of the stapler line along the greater curvature. A linear stapler is inserted first in the proximal stomach and followed by the distal stomach and both parts are gently brought together. The staple lines of both parts of the stomach (proximal and distal stomach) should be positioned parallel above the inserted stapler. Special care should be taken to ensure that the distal remnant stomach does not slip in the direction of the pylorus during this maneuver. After firing the linear stapler and connecting the proximal and distal stomach, the common channel/opening can be closed using another firing of the linear stapler, while carefully avoiding narrowing of the lumen.

The second option for intracorporeal anastomosis after PPG was developed by one of our authors (N.H.) as the "piercing method". This technique was developed since a linear stapler that is inserted in the distal remnant stomach cannot transversely reach the opposite side for the widest anastomoses when there are also large distances from the stapler line to the pylorus. For this technique, the distal part of the stomach is opened at both greater and lesser curvature sides and the stapler is gently pushed through both openings (Fig. 6.7). We recommend placing the stapler first in the distal stomach followed by placement in the proximal stomach. The staple lines of the resection are brought into parallel position above the inserted stapler. After firing the stapler and connecting both parts of the stomach, both common channels/openings and the parallel staple lines are closed/resected with another linear stapler (Fig. 6.8). For this purpose,

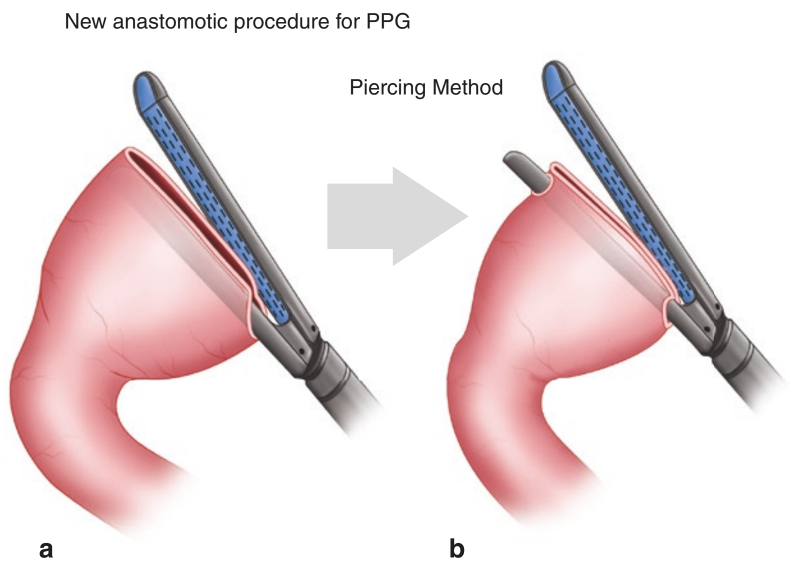

Fig. 6.7 Illustration demonstrating the piercing method. (**a**) For wide remnant antrum, the linear stapler may not fully reach from the greater to lesser curvatures. (**b**) If a small gastrotomy is made at the lesser curvature, the linear stapler can successfully reach from the greater curvature to the lesser curvature

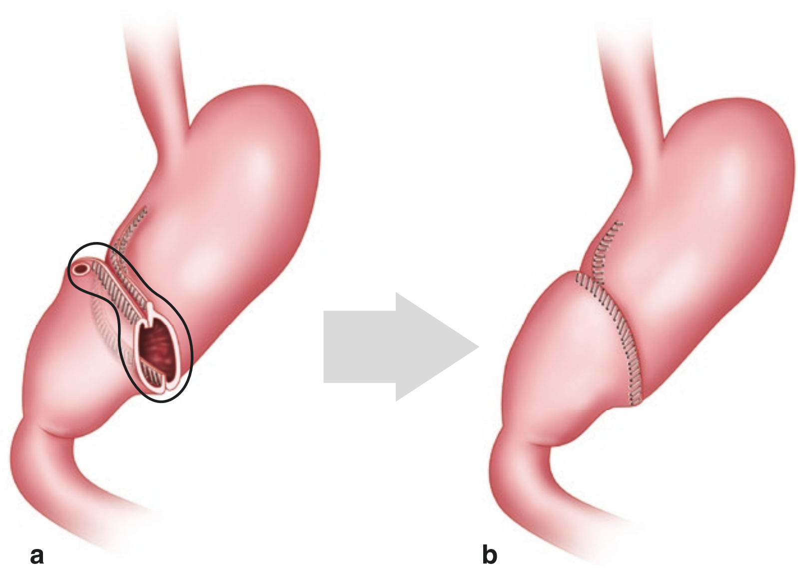

Fig. 6.8 Illustration showing end-to-end gastro-gastrostomy by the piercing method. (**a**) The posterior anastomosis is created by the piercing technique. (**b**) The two linear stapler lines and the common gastrotomy are closed/resected by 3 staple piercing method technique that results in a completed end-to-end gastro-gastrostomy

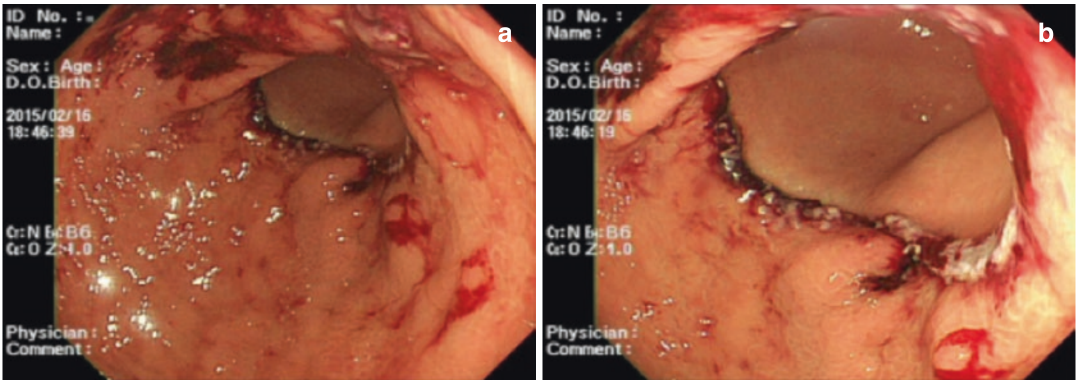

Fig. 6.9 Endoscopic images showing ideal end-to-end gastrogastrostomy by the piercing method. (**a**) There was no sign of bleeding with a widely patent anastomosis. (**b**) The piercing method created an end-to-end gastrogastrostomy using the full length of the transected antral edge

stay sutures should be placed on the edge of the greater and lesser curvature openings, as well as at the parallel staple lines to safely include these tissues/staples in the resected tissues. After applying at least two linear staple lines, the openings should be closed and the parallel staple lines should be replaced by a single one. Endoscopic views show a wide and sufficient anastomosis (Fig. 6.9).

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