7 Pylorus-Preserving Pancreaticoduodenectomy for Pancreatic Cancer: How I Do It

Norbert Hüser, Volker Aßfalg, Matthias Maak, and Helmut Friess

Abbreviations

BDA	Biliodigestive anastomosis
IPMN	Intraductal papillary mucinous neoplasm
PDS	Polydioxanone suture
PJ	Pancreaticojejunostomy
PPPD	Pylorus-preserving pancreaticoduodenectomy
SMA	Superior mesenteric artery
SMV	Superior mesenteric vein

7.1 Pylorus-Preserving Pancreaticoduodenectomy: Are We Spoiled for Choice?

Pylorus-preserving pancreaticoduodenectomy (PPPD) is the standard resection procedure for pancreatic carcinoma besides the classical Kausch-Whipple operation whenever oncologically possible. Initially upcoming queries concerning oncological radicality and postoperative morbidity and mortality could be refuted by numerous randomized controlled trials [1]. Consequently this procedure increasingly gains acceptance not least because of the negative impact of partial gastrectomy on the development of jejunal ulcer and biliary reflux. The preference of either procedure belongs to the individual surgeon's expertise, and both are recommended for tumors of the pancreatic head [2].

The pancreatic anastomosis is usually performed by a mobilized jejunal loop. There are different techniques for reconstruction of the biliary drainage and intestinal passage like retromesenteric, antecolic, and retrocolic position of the loop. Dependent on the method used, either the whole loop is placed into the upper abdomen or the loop is cut and anastomosed [3].

The main focus of the entire operation is on the anastomosis of the pancreatic duct to the jejunal loop. One reason for the numerous techniques reported in literature is the serious consequence of any complication at the pancreatic anastomo-

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sis because of fistula, dehiscence, necrosis, or severe bleeding. Mainly two different anastomotic techniques are discussed: the so-called telescope anastomosis completely invaginates the pancreatic stump into the connected small bowel segment. This technique considers the hypothesis that fistulas generally start from the resection margin. However, the surgeon always has to bear in mind the risk that deep invagination of the pancreas may cause devascularization and ischemia because of too extended mobilization of the stump. Besides this technique, which is called *pancreatojejunostomy*, a distichous enlarged "duct-to-mucosa" anastomosis called *pancreaticojejunostomy* can be performed alternatively, as usually performed in our center. During this procedure the pancreatic duct is stitched directly to the jejunal mucosa and the slightly wider-opened intestinal wall, which is sutured to the pancreatic capsula and covers the stump's resection margin. However, no differences in regard to the occurrence of fistulas and general morbidity and mortality could be found [4]. Recently, the end-to-side anastomotic technique gains more and more attention besides the end-to-end anastomosis to meet the special requirements of an incongruity of the pancreatic resection margin and the jejunal lumen. In doing so, the anti-mesenteric cut of the priorly sealed jejunal loop can be much better adapted in regard to length and width to the cross-section of the pancreas.

A safe alternative to these techniques is the *pancreatogastrostomy* which does not show any differences in respect to fistulas, intra-abdominal colliquation, gastric emptying disorders, and overall morbidity and mortality, too [5, 6].

During the pancreatic anastomosis, there is the option for an intraluminal drainage to prevent the contact of alkaline pancreatic secretion with the anastomosis until wound healing is terminated. This drainage can either be performed by draining the jejunal loop (a drainage placed into the jejunal loop between biliodigestive anastomosis and pancreaticojejunostomy) or by a small silicone drainage (placed into the lumen of the pancreatic duct and tunneled through the jejunal wall). Numerous studies comparing these methods as well as the perioperative pancreatic duct stenting could not reveal any statistically significant advantages [7, 8] except for some specific conditions such as in the case of a small duct and soft pancreatic tissue [9]. Because of the potential risk of pancreatitis due to drainages and their uncertain effectivity and benefit, they are about to lose relevance [10, 11].

7.2 Pylorus-Preserving Pancreaticoduodenectomy: Surgical Procedure

Whenever interventional and conservative approaches failed to relieve of symptomatic duodenal, portal, pancreatic, or bile duct obstruction and especially in the case of (suspected) malignancy within the pancreatic head, partial pancreaticoduodenectomy is indicated. The most frequent diagnoses leading to this procedure are ductal pancreatic carcinoma, chronic pancreatitis, and papillary carcinoma. However, both malignant tumors like duodenal cancer or distal bile duct carcinoma and precursor lesions like intraductal papillary mucinous neoplasm (IPMN) may also require this surgical procedure. Of course, the necessity for an oncologically radical duodenopancreatectomy for IPMN has to be evaluated carefully in every single case. During the following explanations, we refer to the surgical steps in partial duodenopancreatectomy for pancreatic head cancer.

Hypothetically we present a patient with a suspicion for malignant lesion in the uncinate process of approximately 3.5 cm in diameter. An endo-ultrasound-guided biopsy was taken and confirmed the suspected malignancy in addition to an increased CA19-9 tumor marker serum concentration of 87 U/mL but normal CEA value. Anamnestically, the patient lost about 10 kg of body weight during the last 6 months, and the interdisciplinary tumor conference recommended surgical resection.

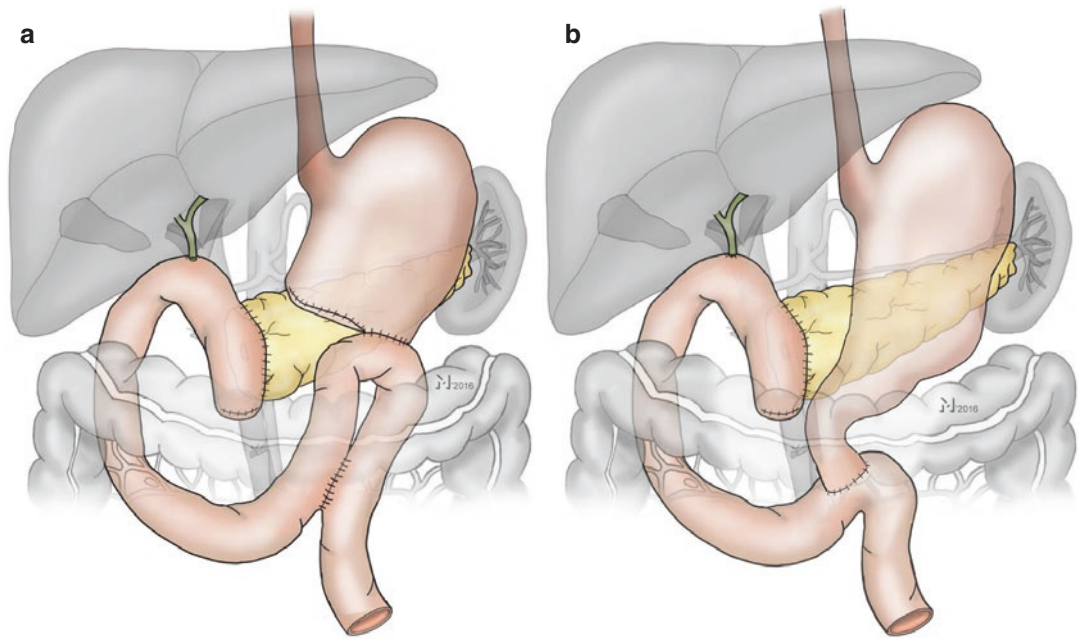

Fig. 7.1 Differences of classical Whipple procedure and pylorus-preserving Whipple. (**a**) The "classical Whipple procedure" is named after its describer and includes a total resection of the duodenum, the gallbladder and the common bile duct, the pancreatic head, and the distal third of the stomach. (**b**) The duodenopancreatectomy according to Traverso-Longmire recommends a post-pyloric duodenal cut. Both procedures require reconstruction by hepaticojejunostomy and pancreaticojejunostomy. The reconstruction may be performed by either one or more jejunal loops. However, we favor anastomoses to the first jejunal loop

In our center, we perform the pylorus-preserving pancreaticoduodenectomy (PPPD) according to Traverso and Longmire [12] and first described by Watson [13]. With this technique the stomach remains unaffected, and the duodenum is cut 2–3 cm distal of the pylorus. The required duodenojejunostomy for reconstruction of the intestinal passage is performed by an antecolic omega loop of the first jejunal loop. A Braun's foot-point anastomosis or a Roux-en-Y reconstruction is not necessary, respectively (Fig. 7.1). All patients are informed preoperatively regarding possible surgical extensions such as (partial) portal vein resection or total pancreatectomy for complete oncological tumor resection. It is a matter of course that patients are informed in detail about general risks (bleeding, thrombosis, embolism, an injury of organs, vessels, and nerves) and specific complications and risks of complex pancreatic surgery (anastomotic leakage or fistula of the biliodigestive anastomosis or the pancreaticojejunostomy, abscess, development of diabetes mellitus, exocrine pancreatic insufficiency, and arrosion bleeding).

The operative procedure can be divided into three major phases:

- Exploration and clarification of tumor resectability
- Resection
- Reconstruction

7.3 Exploration

The aim of the explorative phase is to give information on distant metastases, peritoneal carcinosis, and local resectability of the tumor, respectively. In the case of unresectable tumor spread, the strategy can be changed from the originally curative approach to a palliative procedure, e.g., a biliodigestive anastomosis or a double bypass operation with an additional gastroenterostomy [14, 15].

These are the surgical steps in detail:

- Team time-out, control of correct positioning of the patient, and application of a single-shot antibiosis approximately 15 min before skin incision.
- Skin disinfection and placing of surgical drapes.
- Longitudinal or transverse laparotomy of the upper abdomen by layer, correct dissection, opening of the abdomen and palpation of the liver, the whole small bowel, and the colon, and exclusion of peritoneal carcinosis.
- Application of a wound-edge protection device according to recent research results [16], an abdominal frame, and a retractor system (Fig. 7.2).
- Opening of the omental bursa after dissection of the gastrocolic omentum from the transverse colon and exposure of the ventral pancreatic surface. Dissection of the mesenterium of the transverse colon from both the pancreatic head and the duodenum (Fig. 7.3). This step allows for exclusion of an infiltration of both the stomach and the post-pyloric duode-

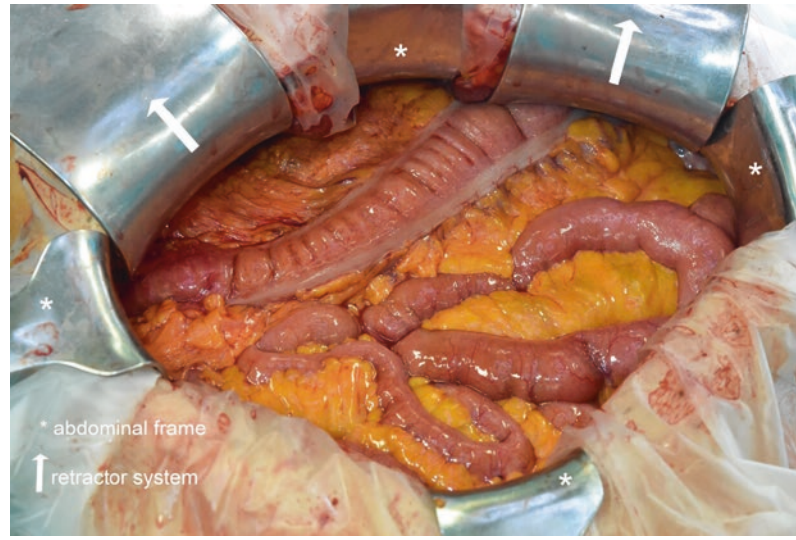

Fig. 7.2 Operating area with wound-edge protection, abdominal frame, and retractor system

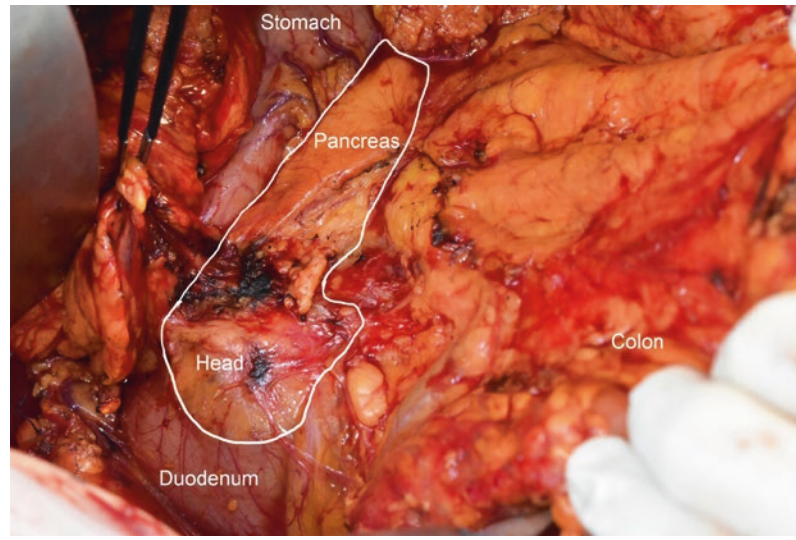

Fig. 7.3 Exposition of the pancreas after opening of the omental bursa

nal segment. Furthermore, the pancreas can now be easily explored to the left side. In case of an infiltration of the pyloric region, partial gastrectomy according to classical Whipple procedure should be considered.

- Performance of an extensive Kocher's maneuver for mobilization of the pancreatic head. Hereby exposition of the vena cava, the left renal vein, and the right ovarian/testicular vein which can be preserved. Extension of the mobilization of the duodenum and the pancreas towards the aorta and the entrance of the last duodenal part into the peritoneal cavity at the ligament of Treitz (Fig. 7.4).
- Bimanual palpation and examination of the pancreatic head from the omental bursa and the retroperitoneal space.
- Exposition of the superior mesenteric vein (SMV) at the inferior pancreatic margin (Fig. 7.5) and careful ligation with stitches (polybutester, e.g., Novafil 4/0) of both the anterior inferior and the posterior inferior pancreaticoduodenal veins.
- Blunt preparation and tunneling under the pancreas body straight on the SMV's plane

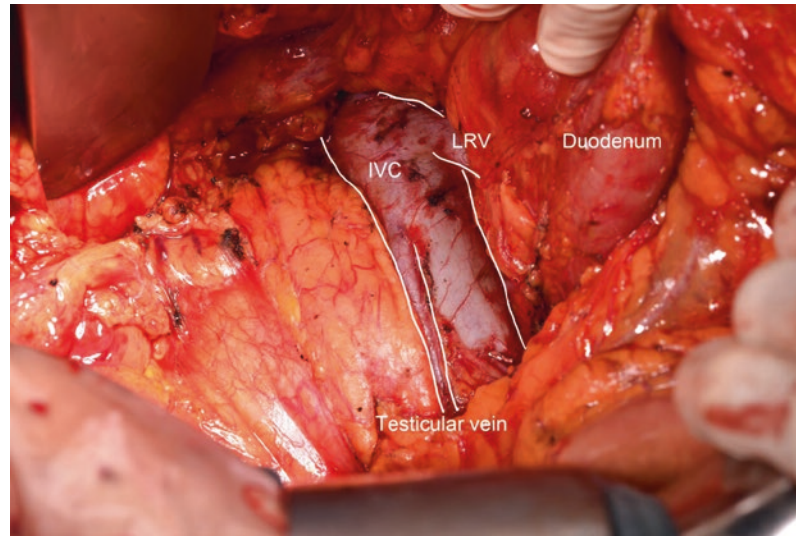

Fig. 7.4 Kocher's maneuver; IVC (inferior vena cava), LRV (left renal vein)

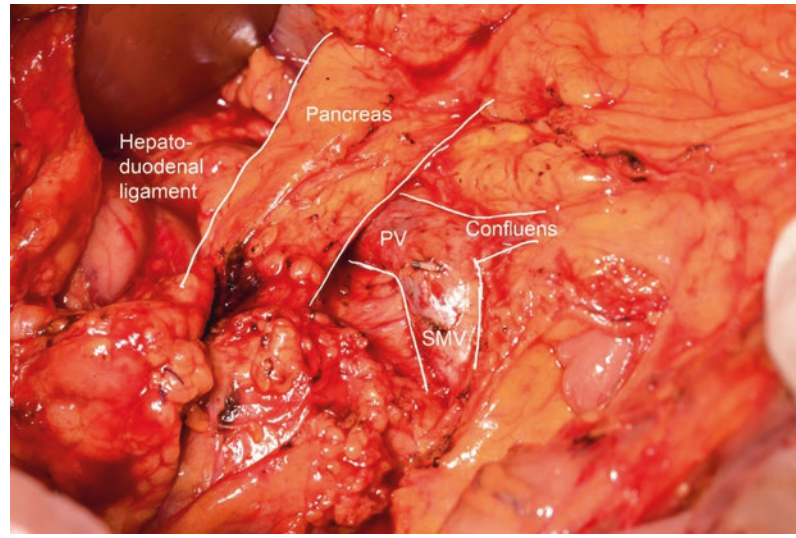

Fig. 7.5 Exposition of the SMV (superior mesenteric vein), venous confluence, and the PV (portal vein) at the inferior pancreatic margin

upwards to the venous confluence and application of support threads (polybutester, e.g., Novafil 5/0 or 4/0) at the inferior pancreatic margin. Evaluation of the resectability at the SMV and the superior mesenteric artery (SMA), which is also dissected carefully.

- Dissection and separate labeling of the structures in the hepatoduodenal ligament, which is usually started at the hilum of the liver and continued towards the pancreatic head. Careful identification of the anatomical course of the hepatic artery and identification of the branches towards the right and the left lobe (Fig. 7.6) with special attention to a potentially aberrant vascular supply. Dissection of the right gastric artery and investigative clamping of the gastroduodenal artery to verify the preserved arterial blood flow of the liver. Dissection of the common bile duct and finally labeling of the right and left hepatic artery, portal vein, and the common bile duct.
- Change towards the upper pancreatic margin and dissection of the local lymph nodes next to the hepatic artery straight down towards the coeliac trunk. Preparation of the portal vein and tunneling of the pancreas from the upper margin to conjoin both preparation planes. A silicone tube is placed under the pancreas to enable soft lifting, and support threads (polybutester, e.g., Novafil 4/0) are placed at the superior pancreatic margin, too (Fig. 7.7).
- Final evaluation of the resectability of the tumor when the pancreas can be tunneled completely in the portal vein's plane and arterial infiltration can be excluded.

7.4 Resection

In case of resectability, the duodenum, the gallbladder, and the pancreatic head are resected next.

- Dissection of the distal stomach and post-pyloric duodenum. Clip closure of the right gastroepiploic artery and vein at the prepyloric level and the right gastric artery by use of clips or an ultrasonic dissection device.
- Cutting of the post-pyloric duodenum with a linear stapler (Fig. 7.8) and wrapping of the closed stomach into a humid abdominal bandage before it is placed into the left upper abdomen for better overview.
- Cholecystectomy: antegrade dissection of the gallbladder, identification of both the cystic duct and the cystic artery, and closure with 3/0 Prolene sutures.
- Sectioning of the bile duct above the junction with the cystic duct with the scissor (to avoid

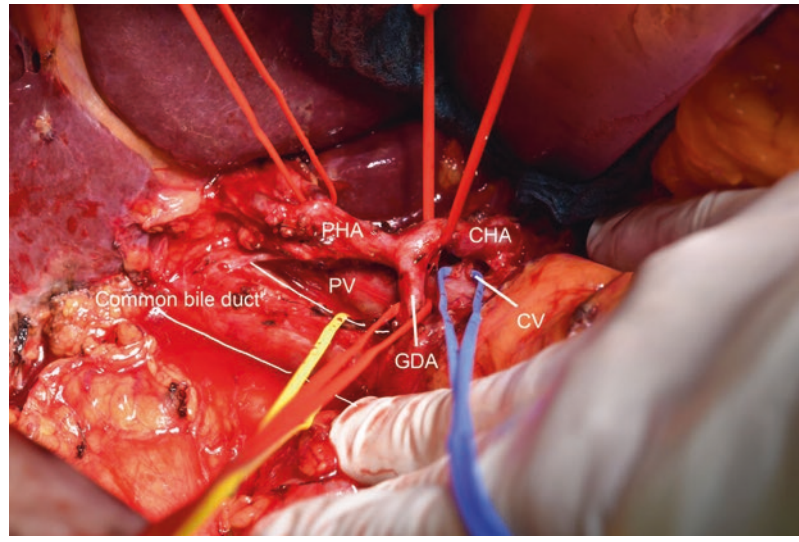

Fig. 7.6 Identification and labeling of the structures in the hepatoduodenal ligament; CHA (common hepatic artery), PHA (proper hepatic artery), PV (portal vein), GDA (gastroduodenal artery), CV (coronary vein)

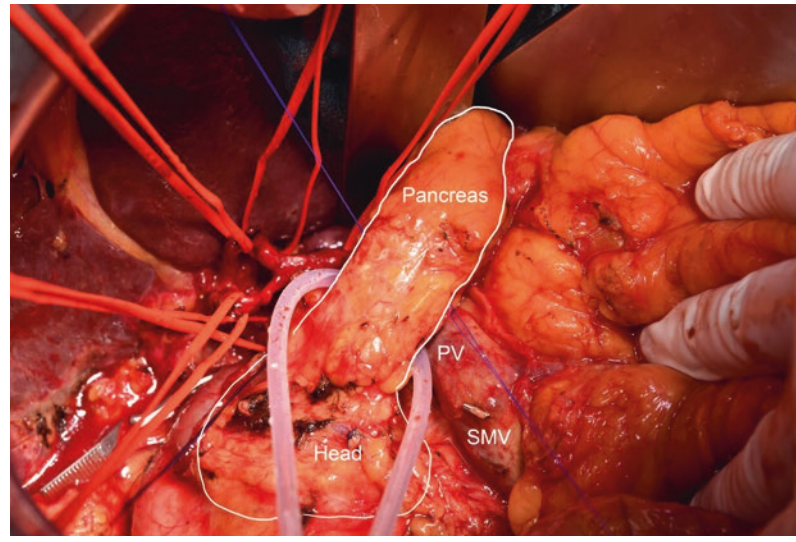

Fig. 7.7 Tethers at the mobilized pancreas; SMV (superior mesenteric vein), PV (portal vein)

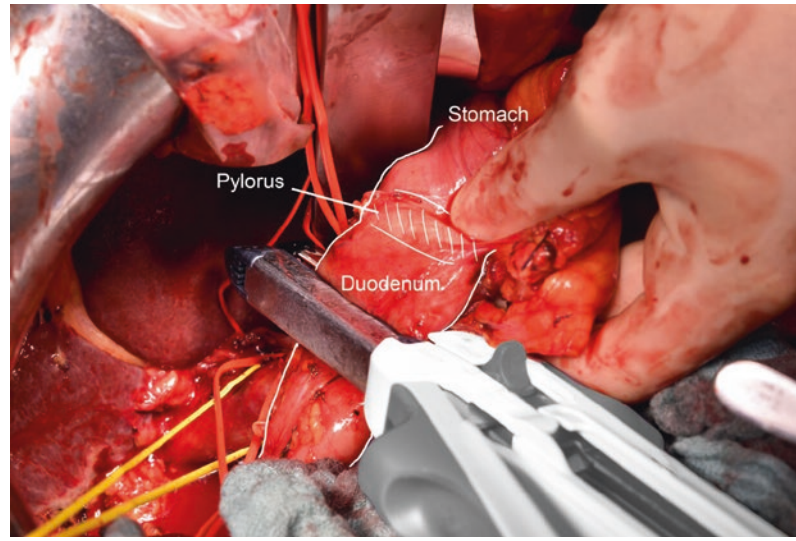

Fig. 7.8 Stapler cutting of the post-pyloric duodenum

thermic damage), acquisition of a microbiological swab, and flushing of the duct towards the intrahepatic distribution. Transient closure of the cut duct with a bulldog clamp. Further preparation of the duct towards the duodenum and intraoperative frozen section investigation of a bile duct resection margin specimen. Bleeding from the bile duct can be stopped by use of 5/0 PDS stitches.

- Continuation of dissection of the hepatoduodenal ligament after resection of the small omentum.
- Finishing lymph node dissection from the liver to the duodenum by use of bipolar pincette or ultrasonic dissection device and continuation of the dissection towards the celiac trunk including exposition of the left gastric artery and the splenic artery (Fig. 7.9).
- Sectioning of the gastroduodenal artery with three clips after investigative clamping (see exploration) to exclude an unexpected arterial blood supply of the liver via the superior mesenteric artery (Fig. 7.10).
- Dissection of the first jejunal loop after the ligament of Treitz has been dissolved and identification of the supplying mesenteric vessels by use of diaphanoscopy. Preparation

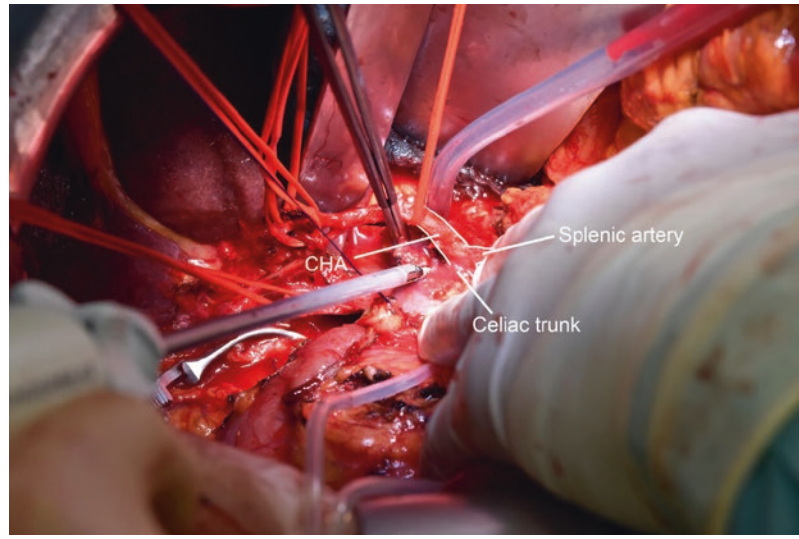

Fig. 7.9 Lymphadenectomy, exposition of the splenic artery and the celiac trunk; CHA (common hepatic artery)

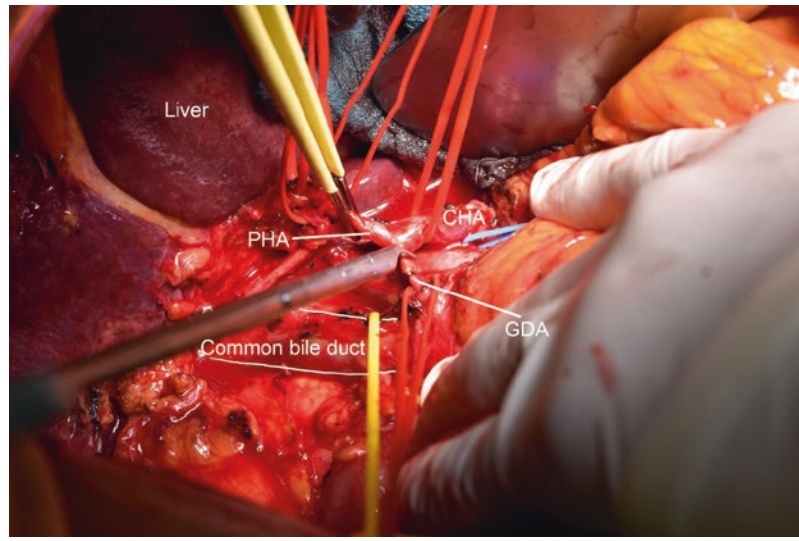

Fig. 7.10 Clipping with three clips and cutting of the GDA (gastroduodenal artery); CHA (common hepatic artery), PHA (proper hepatic artery)

of the vascular arcade with an ultrasonic dissection device and finally sectioning of the jejunum with the linear stapler-cutter device at an appropriate site.

- Tubular resection with an ultrasonic dissection device of the oral jejunal loop towards the former ligament of Treitz, sub-mesenteric pull-through of the mobilized jejunal loop to the right upper abdomen, and closure of the resulting hole with polybutester, e.g., Novafil 3/0 single stitches.
- Ligation of the pancreas towards the head and surgical sectioning of the pancreatic body over the portal vein (Fig. 7.11). Meticulous hemostasis with polybutester, e.g., Novafil 5/0 single sutures, at the left-sided resection margin and left dorsal mobilization of the pancreatic stump for approximately 2–3 cm.
- Inspection of the left resection margin and probing and flushing of the pancreatic duct with a buttoned cannula. Sending away of a frozen section for histopathologic investigation of the right resection margin.
- Radical completion of the resection of the pancreatic head and the uncinate process by use of an ultrasonic dissection device along the dorsal

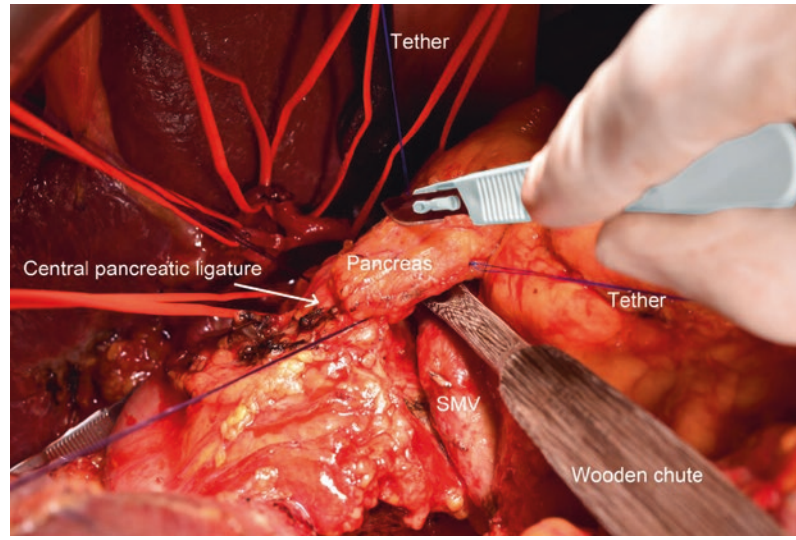

Fig. 7.11 Central pancreatic ligature and sectioning with the scalpel; SMV (superior mesenteric vein)

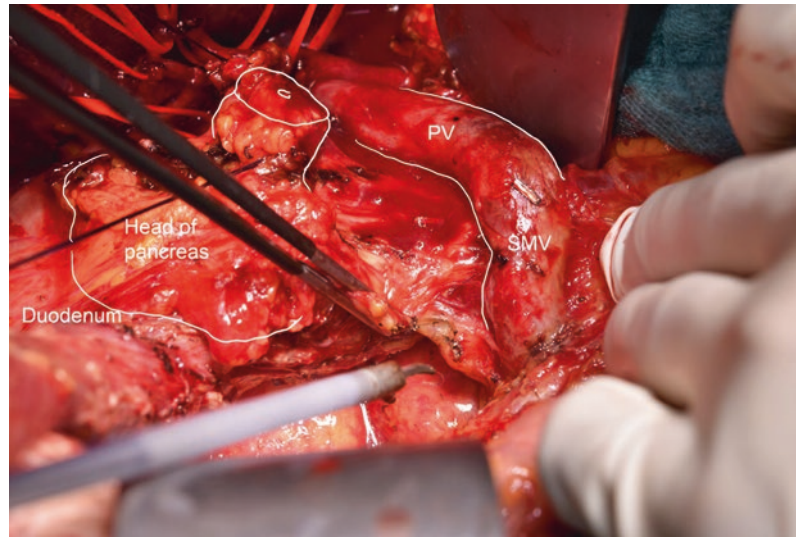

Fig. 7.12 Completion of the resection at the pancreatic head by use of a diathermia device and ligature of small vessels; PV (portal vein), SMV (superior mesenteric vein)

contact plane with the superior mesenteric artery and vein which ends on the left side of the vein (Fig. 7.12). Small vessels and the pancreaticoduodenal artery are dissected with a small Overholt and closed with clips or sutures. In case of infiltrative tumor spread into the portal vein or the superior mesenteric vein, the vessel segment can be resected en bloc together with the pancreatic head, and the blood flow can be rebuilt by direct end-to-end anastomosis with 5/0 Prolene or interposition of a vascular graft.

- Completion of the lymph node dissection around the superior mesenteric artery towards the celiac trunk. Careful inspection of the ventral and especially the dorsal resection plane at the retroperitoneal resection margin. Release of the histological specimen for pathological investigations.

7.5 Reconstruction

The reconstruction of the gastrointestinal passage is being performed during the reconstruction phase. For reconstruction of the gastrointestinal continuity, we perform the one-loop technique with a pancreaticojejunostomy (PJ) and a biliodigestive anastomosis (BDA).

In detail:

- Retrocolic elevation of the stapled jejunal loop after diaphanoscopy and creation of a passage through the transverse mesocolon on the right side of the middle colic artery.
- Tension-free placement of the jejunal loop at the pancreatic stump (Fig. 7.13) and additional inverting running suture over the stapler line for more safety.
- Suture of the *pancreaticojejunostomy in a two-layer technique* (Fig. 7.14a; the colors on both the jejunal loop and the pancreatic resection margin indicate the corresponding layers of the resulting anastomosis: I, dorsal outer layer; II, dorsal inner layer; III, ventral inner layer; IV, ventral outer layer): before the first row of stitches of the posterior wall is performed, we put three stitches at the front (Fig. 7.14b) and three stitches at the posterior wall (Fig. 7.14c) of the pancreatic duct, respectively. Dependent on the diameter of the pancreas, the exit of the 5/0 PDS stitches is placed within the parenchyma or even reaches the resection margin. The direction of the stitches at the posterior wall of the duct is *inside-out* and at the front wall is *outside-in*, respectively. It is important to leave the needle at the thread. The ends of the threads all have the same length and each of them is being marked with a small clamp. Next a humid abdominal bandage is placed around the retractor system, and the clamps of the front row are positioned on the bandage in a circle. To guarantee a maximum overview, a second humid bandage is placed on top, and the clamps of the posterior suture row are then placed on this bandage. In the next step, the first row of the posterior wall of the end-to-side anastomosis can be performed by 5/0 PDS *ventral-to-dorsal* stitches at the pancreas and seromuscular stitches at the jejunum (Fig. 7.14d). The number of single stitches depends on the diameter of the organ, and the distance between them is approximately 0.4 cm (direction of the stitches: pancreas, *inside-out*; jejunum, *outside-in*). In the next step, all threads of the posterior wall are tied. Now the jejunal lumen can be opened antimesenterically over a length of approximately 0.8–1 cm (Fig. 7.14e). Afterwards the stitches of the second posterior row are performed including the initially placed three posterior ductal stitches (Fig. 7.14f). For better overview these three stitches are completed first (direction of the stitches: jejunum, *outside-in*; *full-wall technique*). Afterwards the row of stitches can be finished to both sides. The stitches are separated by clamps, and then the clamps are stringed on a large Overholt clamp before the second posterior row is tied (Fig. 7.14g). It has to be noticed that the resulting incongruence of the opening of the jejunum on the one side and the smaller pancreatic duct on the other side needs to be closed by a

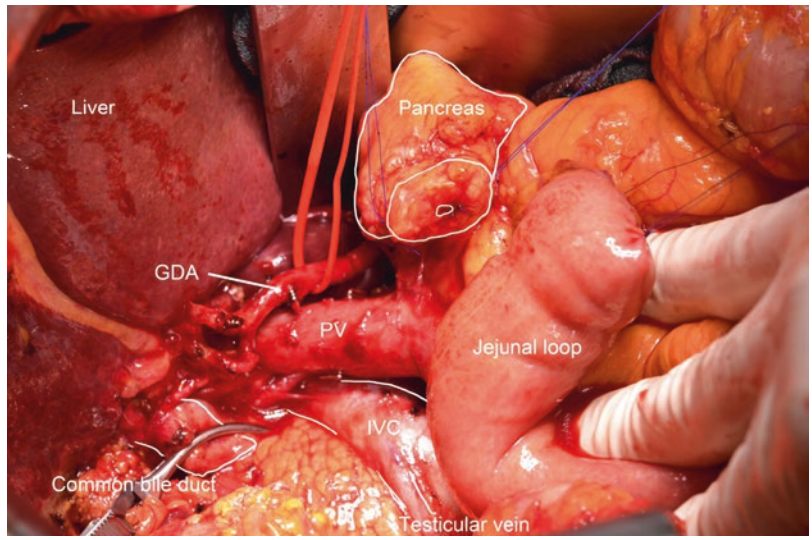

Fig. 7.13 Retrocolic tunneling of the jejunal loop and positioning for anastomoses; GDA (gastroduodenal artery), PV (portal vein), IVC (inferior vena cava)

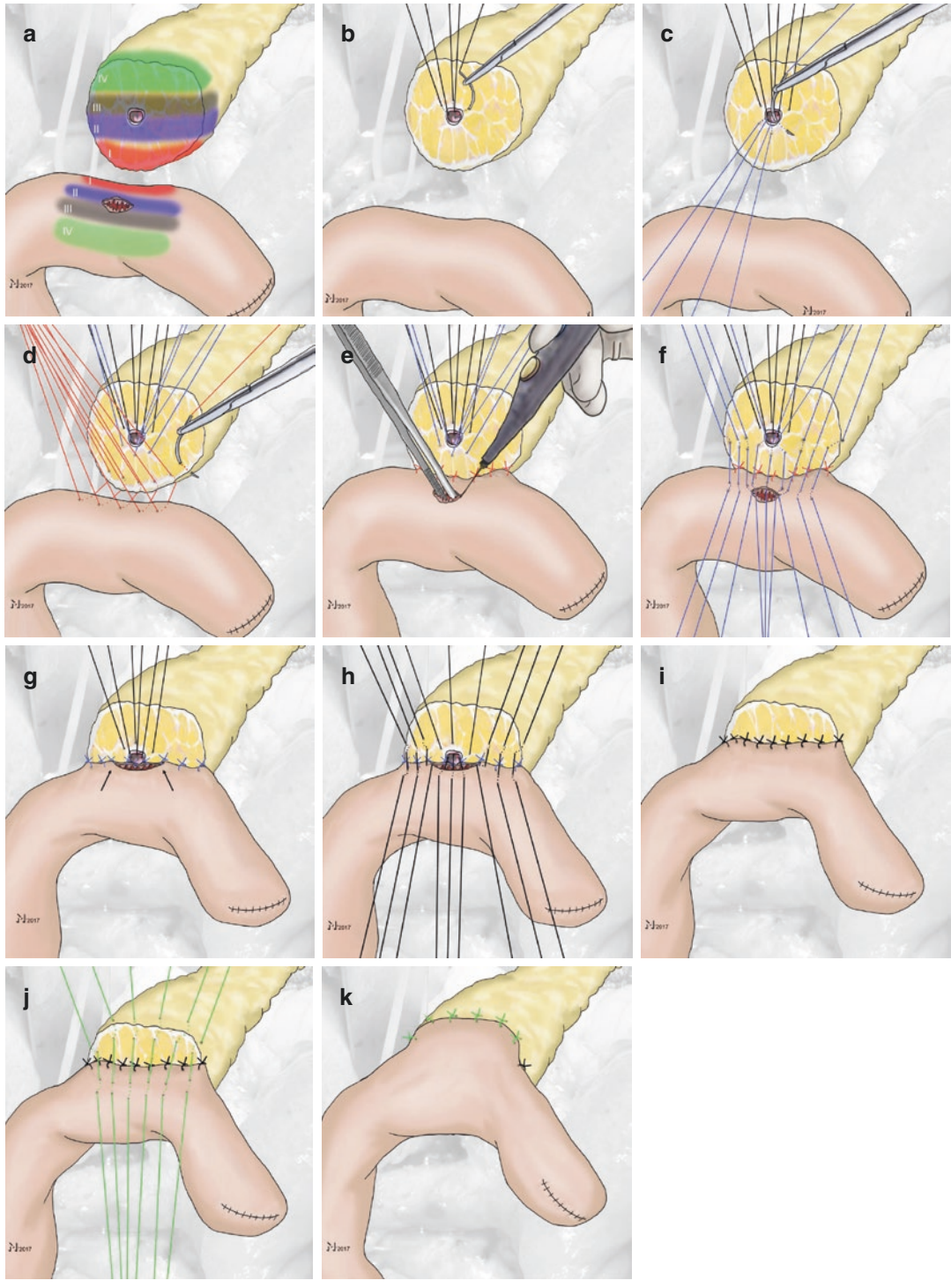

Fig. 7.14 Pancreaticojejunostomy (*detailed procedure see main body*)

single stitch between the pancreatic parenchyma (outside the duct) and the jejunal opening at each end of the duct-to-mucosa anastomosis (Fig. 7.14g arrow). The laterally extended lancing of the jejunal wall as compared to the diameter of the pancreatic duct ensures the direct flow of the aggressive pancreatic secretions into the bowel without resistance due to narrowing due to the sutures. After this step the first ventral row can be performed (Fig. 7.14h). The previously placed ductal sutures have to be completed at the jejunal side (direction of the stitches: jejunum, *inside-out*). Importantly, the stitches are placed again, separated with clamps, stringed by use of a large Overholt clamp, and finally tied like described before for the dorsal inner anastomotic row (Fig. 7.14i). In the last step, the second ventral row now can be performed placing stitches between the pancreatic parenchyma/capsule and the jejunal seromuscular wall (Fig. 7.14j) until the pancreatic resection margin is completely covered by the bowel serosa (direction of the stitches: pancreas, *outside-in*; seromuscular jejunum, *inside-out*) (Fig. 7.14k).

- *Biliodigestive Anastomosis (BDA)*: Approximately 8–10 cm distal of the pancreatic anastomosis, the BDA is being performed with 5/0 or 6/0 PDS single-stitch sutures (depending on the diameter and the consistency of the common bile duct's wall) after flushing the bile duct with sodium chloride 0.9%. Therefore an anti-mesenteric jejunal incision (length depends on the diameter of the bile duct) is necessary. The bile duct is usually stretched with two PDS 5/0 threads and a small clamp each at its left and right corners (Fig. 7.15a). First the two sutures at the corners of the BDA are placed (direction of the stitches: jejunum, *inside-out*; bile duct, *outside-in*; Fig. 7.15b). The two tethers can now be removed. Next, the ventral row with four to five threads is put at the jejunum (transmural; direction of the stitches: jejunum, *outside-in*; Fig. 7.15c). Importantly, the needle remains at the thread, and both ends of each thread are pooled with a small clamp and stringed with an Overholt clamp as described above. In the next step, four to five stitches can be performed to adjust the dorsal jejunal wall and the dorsal wall of the bile duct (Fig. 7.15d). The central stitch is put first and the row is then completed to both sides (direction of the stitches: jejunum, *inside-out*; transmural; bile duct *outside-in*). Dependent on the size of the bile duct, additional stitches are necessary for maximum tightness. The needles can be removed after every stitch, and the two ends of each thread are, respectively, pooled with small clamps and stringed with a large Overholt clamp. When all stitches are placed, the bowel can be moved carefully towards the bile duct. During this maneuver the tension of all threads has to be controlled carefully. Now the threads of the posterior wall can be sutured, the knots are automatically placed to the inner surface, and the threads are cut except for the two corner stitches (Fig. 7.15e). Afterwards the ventral wall of the BDA can be closed by using the previously placed stitches at the jejunum (direction of the stitches: bile duct, *inside-out*; Fig. 7.15f). Note that the threads of the two corner stitches are pulled towards the opposite side, while we perform the lateral stitches of the ventral wall to ensure an invaginating effect and safe closure of the posterior suture row (Fig. 7.15f arrow). However, after this maneuver the two threads are finally cut. The knots of the ventral part of the anastomosis are placed on the outside of the BDA (Fig. 7.15g).
- Finally, we place a white compress close to the BDA to identify potential anastomotic leakage by extravasating bile.
- The antecolic side-to-side *duodenojejunostomy* is performed with two continuous rows of PDS sutures at approximately 40 cm distal of the biliodigestive anastomosis. The stapler row at the duodenum is fixed with an Allis clamp, and the anastomosis starts with the posterior, seromuscular suture of the post-pyloric duodenum to the jejunum in end-to-side technique. Next, we perform an anti-mesenteric incision of the jejunum, which has exactly the same length as the duodenal width after resection of the GIA stapler line by use of the electric scalpel. Now the posterior wall is fixed with another Allis clamp for better overview, too. To prevent postoperative gastric emptying disorders, we insert a strong clamp into the pylorus and spread it gently. During the following step, the inner, transmural, continu-

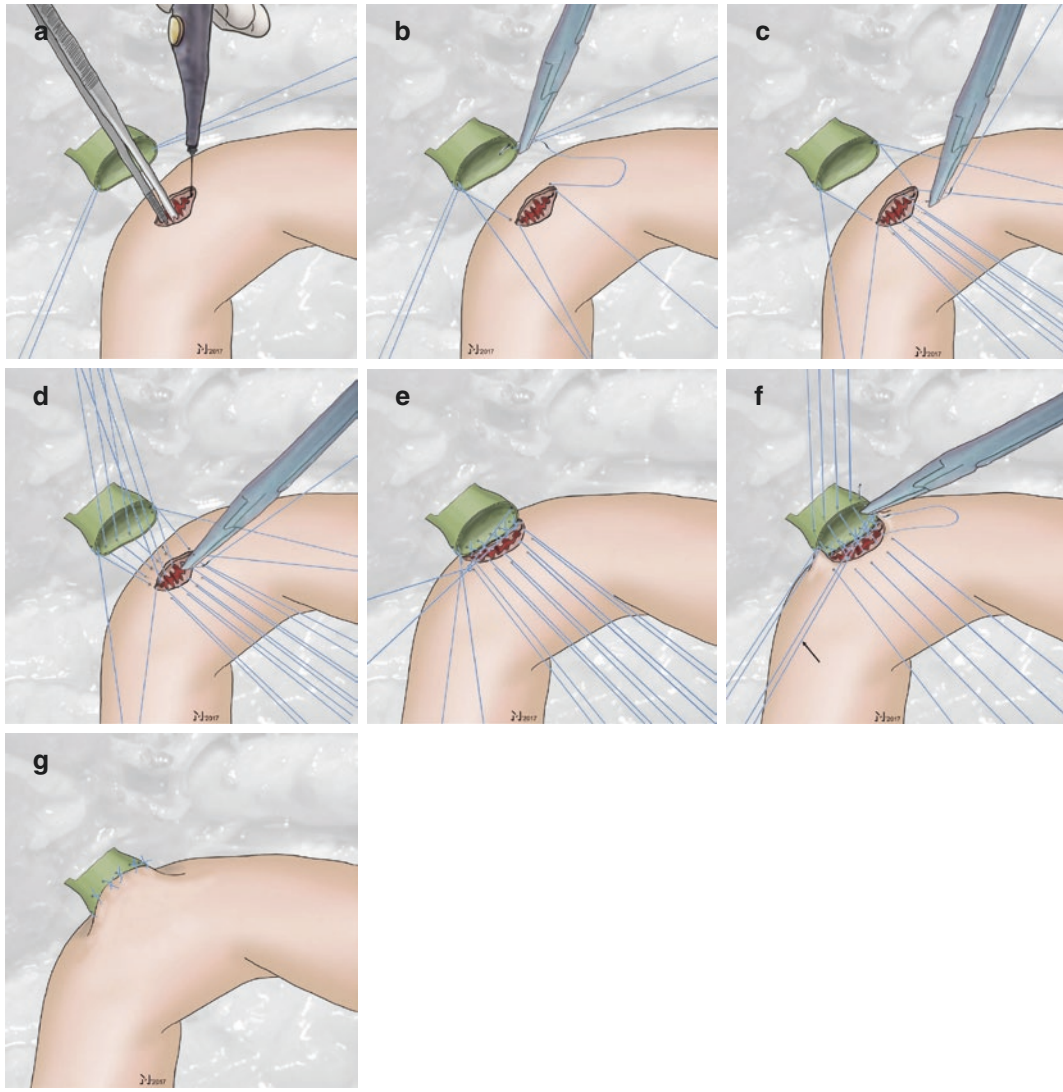

Fig. 7.15 Biliodigestive anastomosis (*detailed procedure see main body*)

ous posterior suture is completed and proceeds as far as one-third of the ventral wall before the intraluminal knot is made. Afterwards the inverted, transmural suture of the ventral wall starts in the corner and is completed at the just-mentioned knot. Finally, the continuous suture of the second (external) row (seromuscular–seromuscular) of the ventral wall is the last step of this anastomosis (Fig. 7.16).

- The mesenteric slit in the transverse mesocolon tunneled by the jejunal loop is then closed by several 5/0 PDS single-interrupted stitches to avoid obstruction of the jejunal loop.
- The whole procedure ends after all surgical cloths and gauze compresses are removed, the abdomen is flushed with warm saline, and in general two easy-flow drainages are placed at the pancreatic anastomosis and the bile duct anastomosis, respectively.
- The abdomen is closed by use of four continuous CTX sutures (two for the posterior and two for the anterior rectus fascia) and skin closure by a skin stapler.

Usually, the patient is monitored on the post-anesthesia care unit for 12–24 h.

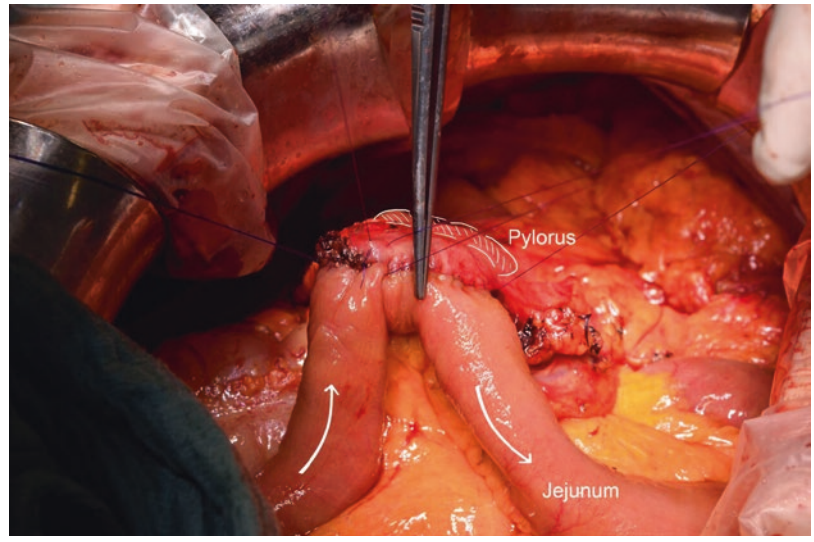

Fig. 7.16
Duodenojejunostomy

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