6 Pancreatoduodenectomy with Venous Reconstruction

Ji-shu Wei and Yi Miao

6.1 Introduction

Even in the ear of neoadjuvant therapy being in the spotlight, surgical resection still remains the only hope for cure of pancreatic cancer, while other treatment options were considered with the surgery as the mainstay. The most important goal of surgery was to achieve an R0 resection because R0 resection can provide unique benefit to patient. *En bloc* resection with combined vessels is an important technique to achieve an R0 resection and could attain reportedly an R0 resection rate of over 90% [1]. Due to the close position to venous axis, adenocarcinoma of the pancreatic head is easily with infiltration of portal vein (PV) and superior mesenteric vein (SMV). Therefore, it is inevitable for pancreatic surgeons to encounter PV and SMV resection and reconstruction (during the resection of pancreatic cancer), which was challenging decades ago. In 1951, Moore et al. [2] reported the first case of a pancreatoduodenectomy (PD) with superior mesenteric vein resection and reconstruction. In 1973, Fortner [3] reported the first case of a "regional pancreatectomy" involving portal vein resection. However, these procedures were later abandoned due to the high morbidity and mortality in the first decades after their introduction, with the improvement of surgical techniques, vascular suture material and critical care support, the morbidity, mortality, and survival outcome after PD are comparable in patients with and without venous resection.

Nowadays, PD with venous resection and reconstruction has become the standard procedure for patients with infiltration of the portomesenteric venous axis at high-volume center, accounting approximately 20–40% of all cases undergoing PD. It can be concluded from published data that PD combined with venous resection is a safe and effective surgical approach for pancreatic head cancer in high-volume centers, some of which even without vascular surgeon's assistance.

Due to the existence of abnormal confluence of the inferior mesenteric vein and the left gastric vein, there are many anatomical abnormalities in the portal venous system. Nevertheless, venous resection during the PD could be mainly categorized into **two major types**: partial resection of venous wall (Fig. 6.1a) and segmental venous resection. According to the resection position, the segmental resection could be further divided **into four subtypes** (Fig. 6.2b–e): (1) simple portal vein resection; (2) simple SMV trunk resection; (3) T-shaped resection of confluence SMV/SV/PV; and (4) resection of trunk and branch SMV.

It is of importance to acquire a tension-free anastomosis during venous reconstruction, which demands careful/cautious preoperative and intraoperative assessment. After adequate mobilization

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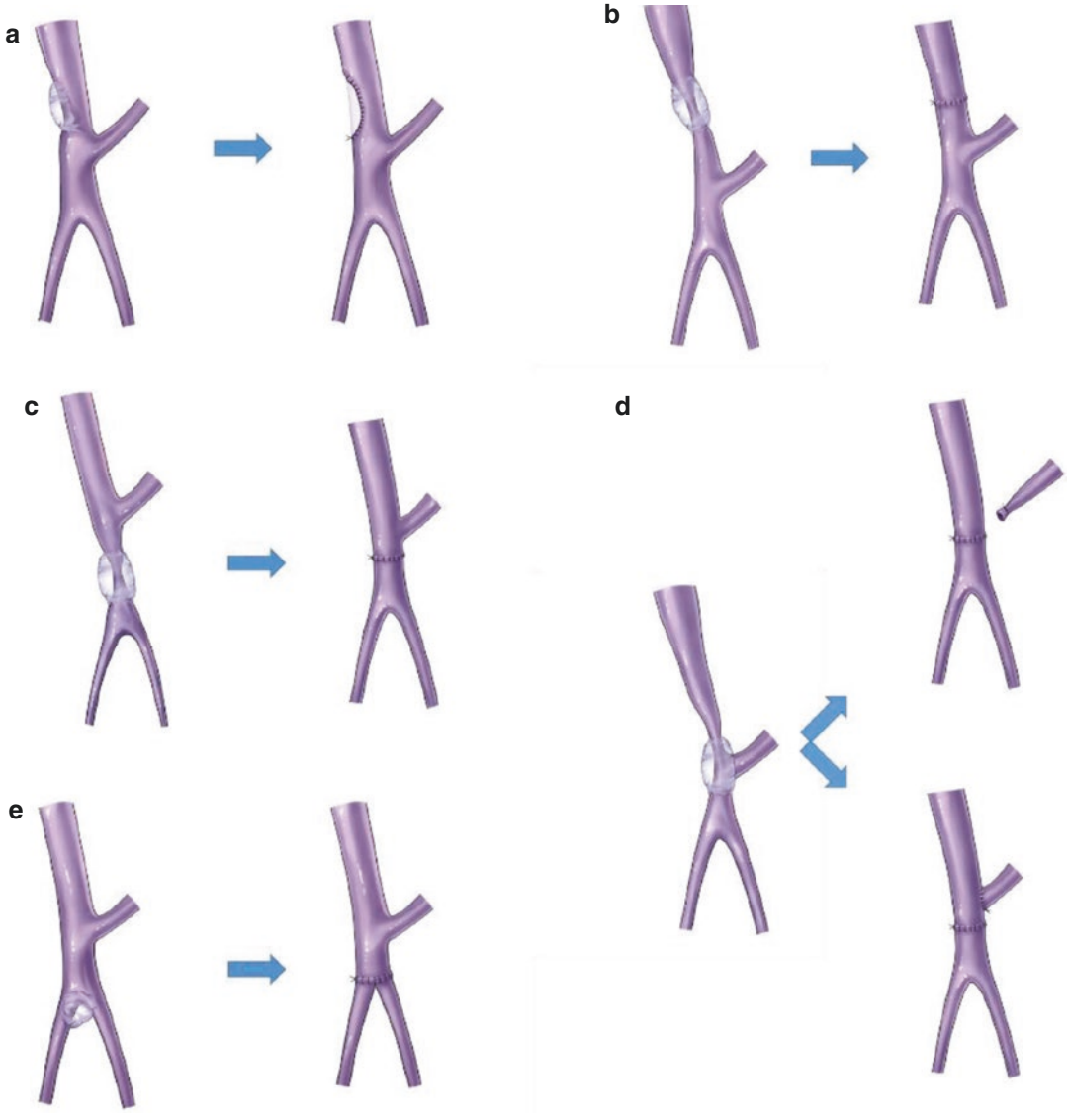

Fig. 6.1 Types of venous resection and reconstruction during PD. (**a**) Partial resection of venous wall; (**b**) simple portal vein resection; (**c**) simple SMV trunk resection; (**d**) T-shaped resection of confluence SMV/SV/PV; (**e**) resection of trunk and branch SMV

of liver, bowel, and SMV, especially the full dissociation between the SMV and the SMA, a tension-free anastomosis could be obtained when the resected vein was less than 3 cm. If the resected vein was longer than 3 cm, an artificial or an autologous vein is usually needed to avoid a tension anastomosis. It is also reported that after adequate mobilization of liver, portal vein, superior mesenteric vein, and mesentery of the small intestine, a tension-free end-to-end anastomosis could be achieved without using an interposition graft when the resected vein was less than 5 cm. In addition, it is also important to avoid local stenosis and vascular distortion after anastomosis, which are important causes of venous thrombosis.

Depending on if an interposition graft is needed, venous reconstruction could be divided into 2 types: (1) requiring interposition graft, which included autologous vessel graft and synthetic vascular graft; (2) no requiring interposi-

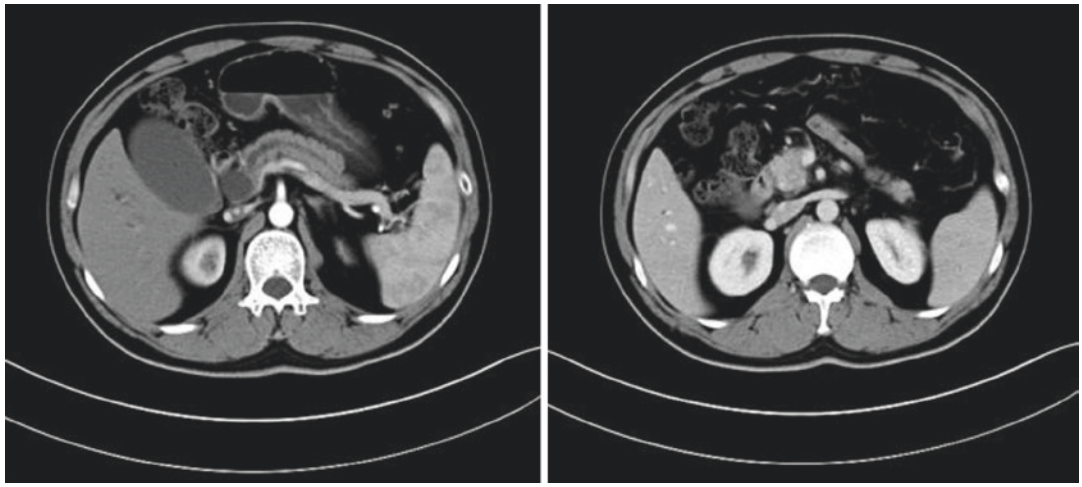

Fig. 6.2 CT images showed a mass in the head of the pancreas with infiltration of the portal vein

tion graft, which included (i) primary end-to-end anastomosis, (ii) venorrhaphy. Currently the application of synthetic vascular graft remains controversial, and autologous vein was used in most situations, such as the great saphenous vein, internal jugular vein, and renal vein. The most commonly reported reconstruction methods were primary end-to-end portal vein and/or SMV anastomosis, except the rarely reported end-to-side SMV-inferior vena cava anastomosis. The suture method of venous anastomosis can be divided into continuous suture, interrupted suture, and mixed suture. The outcomes of these suturing methods are not different, and the choice is up to the comfortable level of the surgeon.

In next section, we presented a case of Whipple procedure combined with segmental SMV resection and reconstruction with primary end-to-end anastomosis.

6.1.1 Case

The patient was a 39-year-old man admitted to our center due to a 3-month history of abdominal pain and a 10-day history of jaundice.

Laboratory examinations showed an elevation of liver function tests: total bilirubin (TB) 124.3 μmol/L, direct bilirubin (DB) 73.6 μmol/L, alanine aminotransferase (ALT) 534.6 U/L, aspartate aminotransferase (AST) 259.1 U/L, alkaline phosphatase (ALP) 366 U/L, and r-glutamyl transpeptidase (r-GTP) 1126 U/L. Serum CA19-9 was increased 138.6 kU/L, and others were normal.

The abdominal computed tomography (CT) confirmed the mass in the head of the pancreas, and a dilation of common bile duct and pancreatic main duct (Fig. 6.2). The superior mesenteric vein was involved. Pancreatic head adenocarcinoma was considered.

Based on these findings, a diagnosis of pancreatic head adenocarcinoma with venous invasion was made, and artery first approach PD with venous reconstruction and extended lymphadenectomy was performed.

Informed consent was obtained from all participating patients, and the ethics committee of the First Affiliated Hospital of Nanjing Medical University approved this study.

6.2 Details of Procedure

The Whipple surgery team of the First Affiliated Hospital of Nanjing Medical University usually has 8 medical staffs, including 2 anesthesiologists, 1 scrub nurse, and 1 circulating nurse, the 4-surgeon team consists of 1 professor of surgery, 1 senior surgeon, 1 resident, and 1 intern.

After the successful induction of general endotracheal anesthesia, the abdomen, perineum were

then both prepared and draped in routine method by using iodophor. A Foley catheter was inserted in sterile fashion into the bladder, and urine drainage bag was hanged on the right side of operation bed.

A vertical midline incision from the xiphoid to 3 cm below the umbilicus was made byskin knife, and the abdomen was entered by electrocautery. After entering the abdomen, a thorough exploration of abdominal cavity was performed. The sequence of exploration is pelvis, the various peritoneal surfaces, liver, omentum, and the mesentery. There were no evidences of metastasis or implants, and then a lap-protector and abdominal wall retractors were placed for good exposure.

6.2.1 Extensive Kocher Maneuver

Mostly, extirpative phase started with the extensive Kocher maneuver, elevating the head of the pancreas and the duodenum up out of the retroperitoneum. Lymphadenectomy was performed if the interaortocaval lymph nodes enlarge (group 16), and the harvested lymph nodes were sent for frozen section. After dissecting the right mesocolon mesentery from the hepatorenal ligament, the Kocher maneuver could be extended well beyond the IVC, aortocaval window, and reached the right side of root of CA and SMA (Fig. 6.3).

The second process was to dissect the transverse mesocolon from the omentum majus. Normally, the surgical assistant hold the stomach and the surgeon hold the transverse colon, dissect along the plane between the colon mesentery and omentum. The posterior wall of stomach and the anterior of pancreas will be well exposed.

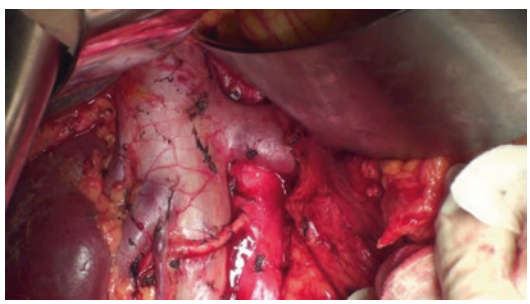

Fig. 6.3 The Kocher maneuver

Carefully dissect the Henle trunk along with the middle colon vein, ligate the Henle trunk with 2/0 silk, and divide. Along the plane between the uncinate process of the pancreas and the transverse mesocolon, identify and dissect out the proximal of the superior mesenteric vein. Carefully identify and dissect out the superior mesenteric vein inferior to the pancreatic neck, then elevate the inferior border of the pancreatic neck, and were able to complete the dissection of the tissues around the pancreatic neck at the level of the SMV-portal vein confluence. Because the tumor invades the SMV segment, it is unable to completely dissect the pancreatic head and uncinate process from the SMV wall, en bloc resection by removing the SMV combined with the whole specimen were performed.

After confirming the resectability carefully, the operation moved to the resection phase. The sequence of standard Whipple procedure combined with SMV resection at our center is dividing doudenum, resecting gallbladder, dividing hepatic duct, dividing pancreas neck, dividing jejunum and SMV/PV resection.

6.2.2 Transection of the Jejunum

Take the adhesions posterior to the distal stomach off the anterior aspect of the pancreas. Identify the right gastroepiploic artery (downstream GDA) as it tethered the stomach, ligate, and divide this vascular bundle with 2-0 silk in its retained, caudal aspect. The right gastric artery and vein were ligated with 2-0 silk and divided. The duodenum was dissected off from the anterior aspect of the pancreatic head and neck approximately 3 cm below the pylorus. Two Kocher forceps clamped the dissected distal duodenum and divided by scalpel. Then put the stomach in the left side of abdominal cavity with one Kocher clamping the duodenal stump.

6.2.3 Resection of the Gallbladder

After dividing the jejunum, resect the gallbladder using the electrocautery and the fundus up

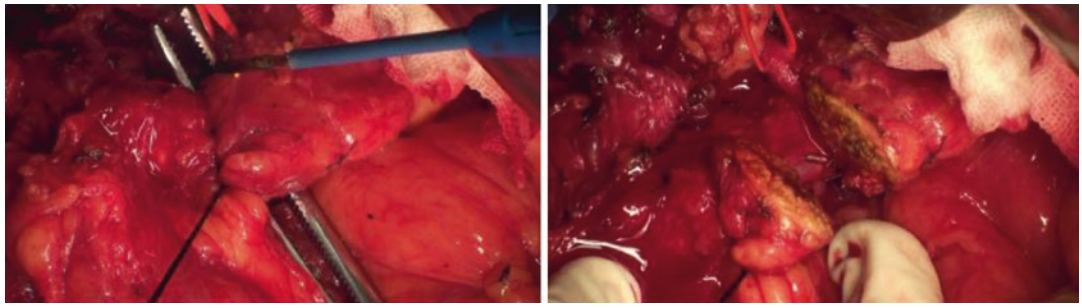

Fig. 6.4 To ligate and transect the neck of pancreas

technique. The cystic duct was dissected out and identified first, and then the cystic artery was dissected. These two tracts were identified and divided only after the hepatic duct and right hepatic artery was confirmed. The cystic artery was ligated with 2-0 silk and divided. The gallbladder was dissected from the gallbladder fossa by electrocautery. Dissect out the extrahepatic biliary tree from the hepatoduodenal ligament. Identify the hepatic duct, elevated it off the portal vein and right hepatic artery. Ligate the hepatic duct by 1-0 silk two times spacing about 1cm, and divide the duct with the scissor between the 2 ligated site. The proximal bile duct was controlled with a silk ligation, thereby preventing the intraperitoneal contamination from ongoing bile drainage. Grasp the distal bile duct with the ligation silk stich, elevate it ventrally, and then work on the anterior aspect of the portal vein, dissecting this behind the bile duct and behind the superior aspect of the pancreatic neck. At this point, the gastroduodenal artery was identified and test-clamped. After confirming the palpable pulses in both the common hepatic artery and the proper hepatic artery, the gastroduodenal artery was then doubly tied by 2-0 silk, suture-ligated on the cephalad aspect, and divided by scalpel.

6.2.4 Transection of the Pancreas

Curved clamps were used to pass between the inferior aspect of the pancreatic neck and the plane anterior to PV-SMV; 1-0 silk was used to ligate the head side of the pancreas neck tightly in case of hemorrhage from the resected side of pancreas stump after dividing the pancreas neck. Four stay sutures were placed, two along the inferior aspect of the pancreatic neck, and two along the superior aspect of the pancreatic neck by 4-0 vicryl. A forcep was then used as the chopping board under the pancreatic neck, and the neck of pancreas was divided with electrocautery without incident in the vertical plane of the SMV-portal vein axis. Hemostasis was obtained by using the electrocautery and suture ligatures by 5/0 proline (Fig. 6.4).

6.2.5 Transection of Jejunum

After transecting the pancreas, move to the ligament of Treitz and take down the ligament using the Harmonic. The proximal jejunum was divided about 20 cm distal to the Treitz ligament using GIA stapler. The short jejunal vessels to the proximal-most jejunum were taken over clamps and 4-0 silk ties. The retained jejunum had its stapled end ironed by electrocautery. The duodenojejunal junction was then mobilized behind the mesenteric vessels to the patient's right side, thereby allowing us to work carefully to separate the specimen from the SMA combined SMV resection.

6.2.6 Vein Resection and Reconstruction

Hold the second segment of duodenum with sponge clamps and pull the Whipple specimen to

the right side of patient. Dissect carefully the tissue between the SMV and SMA; normally there are no artery branches form the SMA. Then dissect the right side of the SMA through the tissue, which was sometimes referred to as the mesopancreas. The IPDA was tied by 2/0 silk and divided. The first jejunum artery was preserved when possible. Skeletonize the SMA routinely on its right side, and no tissue is attached to the right lateral aspect of the SMA. When this step was completed, the Whipple specimen was found bound to the SMV. Divide carefully the superior mesenteric vein till the invaded section by the tumor.

Clamp the invaded SMV trunk with two Baby-Satinsky Anastomosis (Vena Cava) Clamps. The two clamps were 0.5 cm apart from each side of predetermined resection line. Divide the SMV using fine tissue scissor and remove the Whipple specimen. Then put the two clamps together to assess the tension and if a primary end-to-end anastomosis was suitable. If the answer was yes, then anastomose the superior mesenteric vein with 5-0 monofilament proline. The first stitch was in a "tunica externa-tunica intima-tunica intima-tunica externa"endothelium-endothelium-adventitia" at the right edge of the vein. Then the anterior venous wall was sutured first and was followed by the anterior venous wall by running suture with a distance of 1 mm between the stiches. Before tying the last knot, loose the distal clamp first and tie the knot with blood flowing. Next, loosen the Baby-Satinsky clamps, and check that there was no bleeding, stenosis of the superior vein, and intestinal congestion (Fig. 6.5). Depending on the length of resected vein, when the tension was too high, an interposed graft may be necessary. Record how long the blood flow to the liver was stopped, and make sure it was shorter than 15 min. In the present case, the anastomsis time was 9 min. Heparin was not routinely used for anticoagulation before portal vein or SMV resection and reconstruction.

So far, the tumor was removed en bloc with head of the pancreas, duodenum, and the invaded section of the superior vein. Mark the cutting edges and send the resected specimens for pathology.

6.2.7 Pancreaticojejunostomy

Gastrointestinal reconstruction was performed with Child method and began with an end-to-side pancreaticojejunostomy. Mobilize the pancreatic remnant for approximately 2 cm. Identify the main pancreatic duct. If the main pancreatic duct was smaller than 3 mm, insert an internal pancretic stent and fix it with purse-string suture. Then lift the transverse colon and make an opening at the avascular area to the right of the middle colic vessels in the transverse mesocolon. Bring the retained jejunum up through the small opening in the transverse mesocolon. At around 4 cm distal to the jejunal end, make an incision equal to the diameter of the pancreatic stump on the jujunal wall opposite to the jejunal mesentery. The pancreaticojejunostomy was then performed with one-layer interrupted technique with 3-0 Vicryl. The anastomosis began with the posterior layer and followed by the anterior layer.

Sutures in the posterior layer are placed through the pancreas from the cutting face to posterior pancras capsule then through the full-layer jejunum

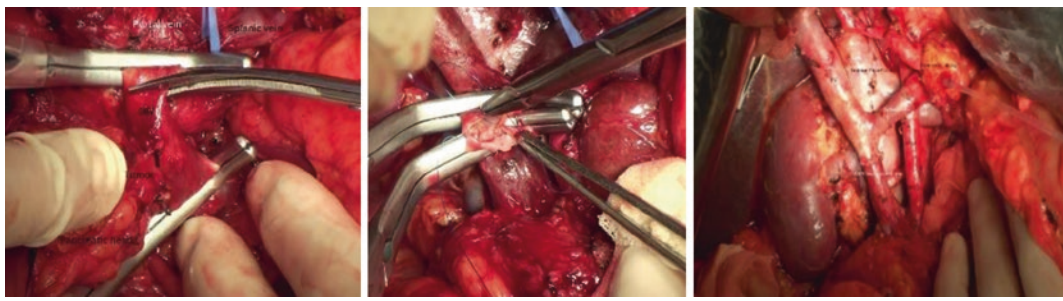

Fig. 6.5 To resect and reconstruct the invaded SMV

(serosa to mucosa). The entry point of the suture at the cutting face of the pancreas should be close to the main pancreatic duct (but not injuring the main pancreatic duct), and the exit point of the suture in posterior pancreas capsule should be at least 1 cm away from the edge of the remnant, make a **wide** bite of the pancreas. Sutures placed in the posterior layer were not tied at first but instead are secured in mosquito clamp at first and were tied father all sutures have been placed and secured.

Sutures in the anterior layer are placed through the pancreas from posterior pancras capsule to the cutting face then through the full-layer jejunum (mucosa to serosa). These sutures were tied one by one with the knots on the outside (Fig. 6.6). These stiches are placed **sparsely** with a distance between adjacent stiches around 1 cm. futures were tied **loosely** with pancreas tissue and jejunal wall touching each other and knots on the inside.

6.2.8 Hepaticojejunostomy

Approximately 8 cm distal to the pancreaticojejunostomy, perform a standard biliary-enteric reconstruction as an end-to-side hepaticojejunostomy. Trim the common hepatic duct and cut an opening in the jejunum opposite to the jejunal mesentary. The length of the opening corresponds to the size of the common hepatic duct. Then perform the hepaticojejunostomy using single-layer 4-0 Vicryl with running sutures. Suture the posterior wall first and the anterior wall second. The anastomosis was checked watertight and without undue tension (Fig. 6.7).

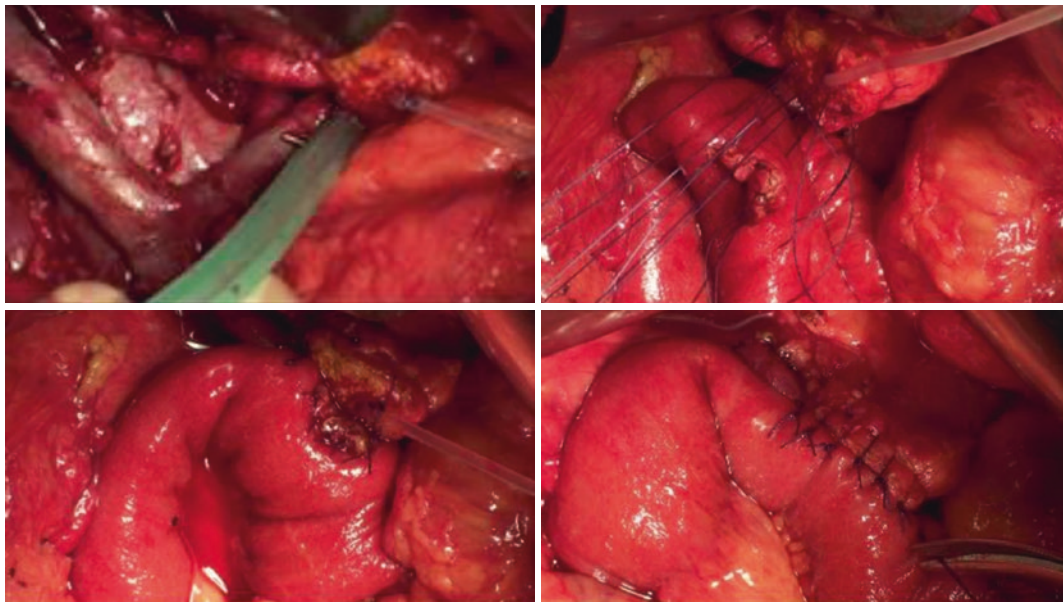

Fig. 6.6 To perform the pancreaticojejunostomy

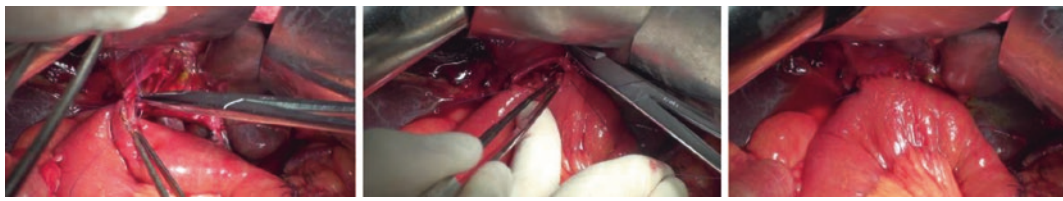

Fig. 6.7 To perform the hepaticojejunostomy

6.2.9 Duodeneojejunostomy

Approximately 50 cm distal to the hepaticojejunostomy, perform an antecolic side-to-side isoperistaltic end-to-side duodenojejunostomy. Take out the stomach from the left side of the abdominal cavity and take the Kocher clamp off the duodenal stump, leaving the edge of the stump being compressed to be 3 mm in thickness. Immediately electrocoagulate the compressed edge of the stump by electrocautery, so that the serosa, muscularis, submucosa, and mucosa of the duodenum were merged to be one single layer. Separate the anterior and posterior walls of the duodenum using tissue forceps. Then cut a 3 cm longitudinal incision in the jejunum opposite to the mesentery. The anastomosis was done in a continuous one-layer fashion with 4-0 Vicryl. The bites of the intestinal wall were 3 mm and between the stiches were also 3 mm (Fig. 6.8). The anastomosis palpated to be patent and normal. Suture the opening in the transverse mesocolon to the jejunum.

6.2.10 Close of Abdomen

At this point, check for hemostasis thoroughly throughout the operative field, then irrigate the abdominal cavity with warm saline. Then place two flat drains through separate stab incisions in the right flank with one drain posterior to the pancreaticojejunostomy and the other one anterior to the pancreaticojejunostomy. The abdomen abdominal fascia was then closed in running fashion using 0-PDS-II, taking 1 cm bites of the fascia, and having each stitch be approximately 1 cm apart. The subcutaneous tissue was irrigated with saline, and the skin was then closed with skin stapler.

6.2.11 Pathology and Prognosis

Pathological diagnosis confirmed the preoperative diagnosis with a moderately to poorly differentiated pancreatic ductal adenocarcinoma (grade II-III). The tumor was 2.5 cm in diameter with infiltration of the intrapancreatic nerve and

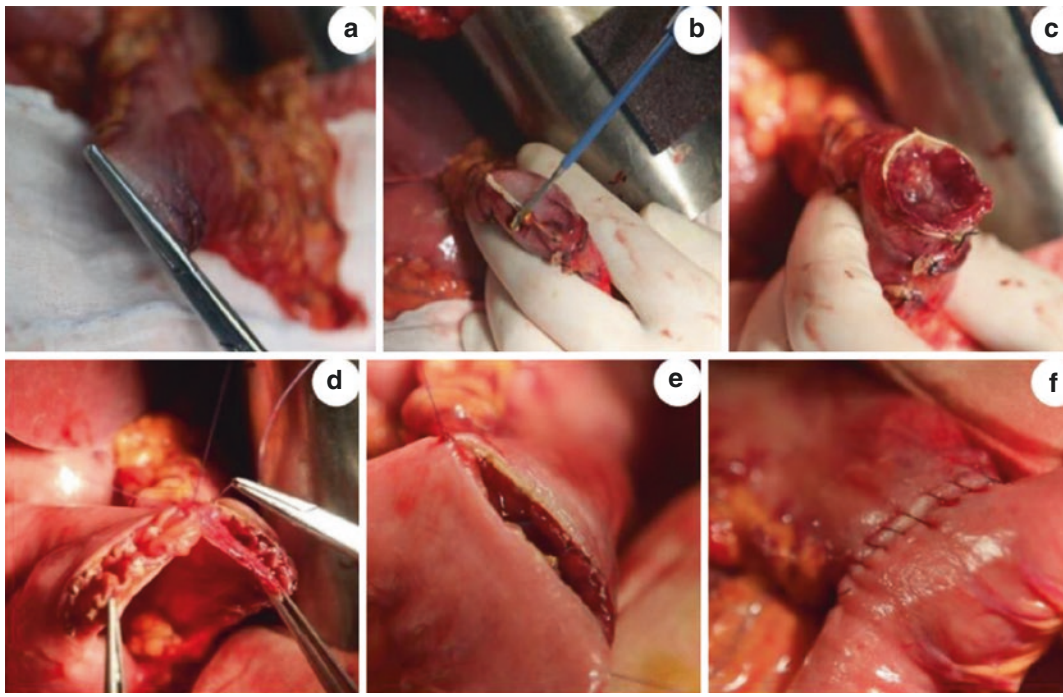

Fig. 6.8 To perform the duodeneojejunostomy

invasion of the peripancreatic fat tissue, invasion, full layer of common bile duct, the muscle layer of the duodenum, and superior mesenteric vein. Out of 17 examined lymph nodes, 3 were positive. The resection margin of common bile duct, pancreatic margin, stomach, and duodenal was tumor negative.

The patient had a smooth postoperative course and was discharged on postoperative day 13. The patient received six courses of adjuvant therapy consisting of gemcitabine and tegafur-gimeracil-oteracil potassium capsule. The reconstructed vein was without stenosis 12 months after the operation. The patient had a recurrence-free survival of 12 months and deceased 21 months after the operation. The wound was disinfected with iodophor and covered with dry dressing.

The operation time lasts 480 min, and the estimated intraoperative blood loss was 300 mL. The patient tolerated the procedure well and sent back to the ward in satisfactory condition.

6.2.12 Comment

Pancreatic duct adenocarcinoma has a dismal prognosis. While resection was the only chance to offer long-term survival, only 20% of the patients present with a resectable tumor at the time of diagnosis. Due to the aggressive tumor biology and the anatomical proximity to the portal/superior mesenteric veins, about 30% of patients were diagnosed with locally advanced disease. The en bloc resection of the for locally advanced pancreatic cancer with SMV, PV, and/or splenic vein (SV) might shed light on this group of patients.

Early studies showed when compared to standard pancreatectomy pancreatic resection with PV-SMV resection is associated with increased postoperative mortality, higher rates of nonradical surgery, and worse survival [4, 5]. However, more recent studies showed that pancreatectomy with SMV-PV resection has similar overall morbidity and mortality rates [6, 7]. Previous studies showed type of venous reconstruction did not significantly affect short-term morbidity and long-term survival, therefore it is recommended to employ appropriate complex type of reconstruction as long as a radical resection can be achieved [8, 9]. As all the previous studies were of retrospective design, well-designed, randomized comparative studies define the true role of pancreaticoduodenectomy with venous reconstruction and the best type of venous reconstruction.

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