Pancreaticoduodenectomy with Venous Resection: How I Do It

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16.1 Introduction

The establishment of tertiary referral centers and the well timely management of postoperative complications have largely contributed to the reduction of postoperative mortality of pancreatic resections. These improvements combined with the advances in chemotherapy regimens have let pancreatic surgeons to the development of extensive resection in case of pancreatic tumors abutting or infiltrating the major peripancreatic vessels. In case of pancreatic adenocarcinoma, a local extension with a various degree of infiltration to the superior mesenteric and/or coeliac venous and arterial vessels is a common finding in about one-third of the newly diagnosed cases. The infiltration of the coeliac trunk and the superior mesenteric artery is classically considered as a synonymous of unresectable locally advanced disease. In such circumstances various combinations of neoadjuvant chemotherapy or radiochemotherapy regimens are used for tumor's downstaging. In these circumstances resection will be therefore considered only in some selected patients showing stable or responding disease [1]. On the contrary the infiltration of the splenomesenterico-portal (SMP) venous axis is nowadays no more considered as contraindication to a curative resection [2, 3]. The rationale behind such extensive resection is to obtain a margin-free resection without additional postoperative morbidity and mortality compared with a standard pancreatectomy. Whether patients with venous infiltration should undergo upfront resection or neoadjuvant treatment with secondary resection in case of good response to preoperative treatment remains at the moment debated [4]. It is more likely that with the advent of FOLFIRINOX® regimens which showed a higher rate of pathological response compared with previous gemcitabine-based chemotherapy, all patients presenting with resectable or locally advanced pancreatic cancer will receive preoperative chemotherapy in the near future [5]. Nevertheless the prognostic value related to the presence of a histologically proven venous invasion remains unclear because of the small size of the cohort analyzed, heterogeneity in patients' population, and the lack of information regarding the presence and/or the depth of the venous wall invasion in different comparative studies reported [4, 6]. Some authors identified venous invasion as a consequence of pure tumor localization [7], while others identified venous invasion as a poor prognostic factor [4, 6]. Other studies pointed out the importance of tumor depth infiltration into the venous wall, identifying intimal invasion as a

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poor prognostic factor [8]. In the modern era of pancreatic surgery, different single-center and multicenter studies have shown the safety of pancreatectomy with venous resection. Morbidity and mortality of pancreatectomy with venous resection are not different from those of standard resection in pair comparison [2, 4]. However there is still a lack of a standardized surgical technique described that may limit the diffusion and reproducibility of the good results reported by tertiary centers in different environments. The present chapter will describe a standardized surgical technique used to perform a "safe" pancreaticoduodenectomy with venous resection.

16.2 The "Safe" Venous Resection

The concept of safe venous resection was developed at our center during the last 20 years and refers to a technique that is devoted to minimizing intraoperative bleeding, maintaining an optimal blood flow to the liver and the bowel, and achieving an oncologic radical resection [9–12]. This surgical strategy entails the fact that venous resection should be planned before surgery or at least anticipated early in the course of a pancreatic resection, and venous resection should be performed as en bloc procedure as the last step of the resection phase (Fig. 16.1). This technical issue has several potential advantages. First, it avoids eventual manipulations on a newly constructed vascular anastomosis that can end up to its disruption in the case of venous resection performed before the detachment of the pancreatectomy specimen from the coeliomesenteric arterial axis. Second, it allows for a complete clearance of the retroportal lamina with consequent complete devascularization of the specimen and correct oncologic resection. Third, the complete clearance of the retroportal lamina from the coeliac trunk and the superior mesenteric artery allows for a correct and tension-free venous anastomosis. All attempts made in order to dissect an adherence between the SMP axis and a PD specimen should be proscribed because

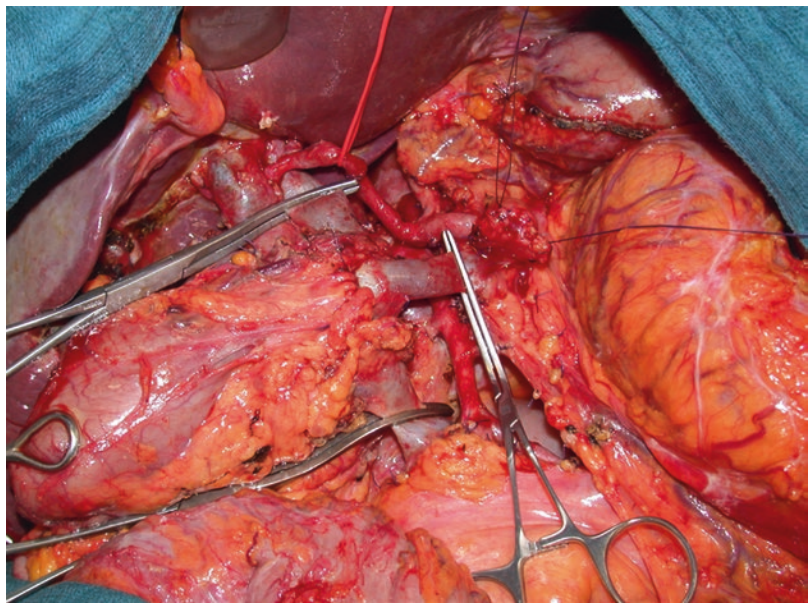

Fig. 16.1 Intraoperative view of a pancreaticoduodenectomy (PD) with resection of the SMP venous axis. The PD specimen is left attached only to the venous axis as the final step before venous resection. The SMA and the CT have been previously completely cleared of the retroportal lamina

source of a life-threatening bleeding and of tumoral seeding. At the same time, wedge resection, in our opinion, should be avoided because of their limited oncologic and technical value. Lateral venous resection can be performed in very few cases when tumoral infiltration does not encompass more than 90° of the venous axis circumference and no more than 2 cm of length. Beyond these particular conditions, a lateral venous resection carries a high risk of venous axis distortion, uncertain oncologic margins, and increased risk of thrombosis. In our experience this type of resection is therefore generally avoided, and segmental resections are routinely performed.

16.3 Planning a Safe Venous Resection

Accurate preoperative imaging by CT scan with venous phase is helpful in correctly detailing the presence and the extent of venous invasion in case of periampullary malignancy. The extension of venous invasion can be therefore classified according to Nakao et al. or Ishikawa et al. [13, 14]. However, even with the best available modern imaging, up to 40% of venous axis tumoral abutments are currently diagnosed intraoperatively [15]. Distortions of the venous axis, unilateral or bilateral abutments, are common finding which may anticipate preoperatively venous infiltration. The length and the location of the future venous resection are then planned by the tumor's location. Isolate resection of the portal vein is quite uncommon in pancreatic adenocarcinoma and more often observed in distal cholangiocarcinoma as a consequence of massive perineural infiltration. For pancreatic adenocarcinoma invasion is more frequent at the level of the SMP venous confluence as a consequence of tumor location in the medial aspect of the pancreatic head. For pancreatic adenocarcinoma located in the uncinate process, infiltration is more frequent at the level of the superior mesenteric vein up to the ileocolic and jejunal branch confluence. We use a simple classification (Fig. 16.2) that can guide the performance of a venous resection according to the type of segment invaded: Type I, tumors infiltrating the portal vein; Type II, tumors infiltrating the SMP venous confluence; Type III,

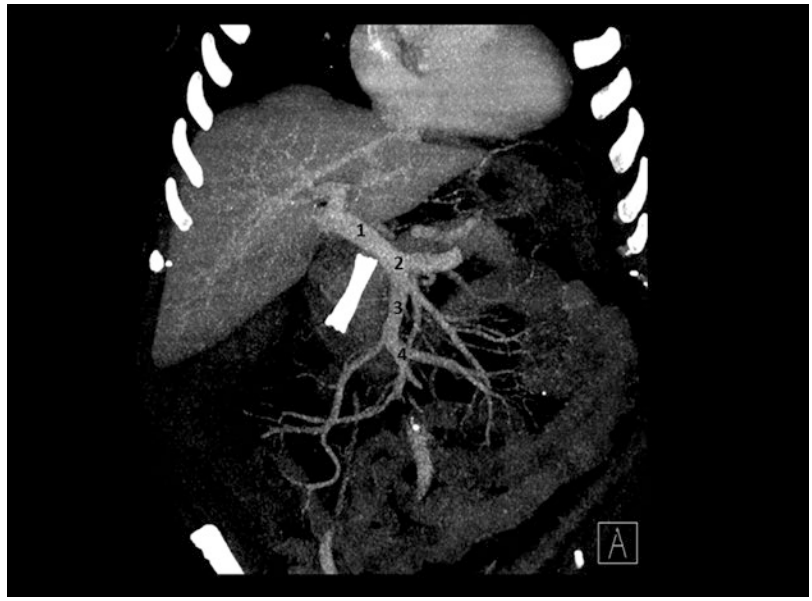

Fig. 16.2 A simple and easy-to-use classification for localization of venous resection according to the type of resected segment

tumors infiltrating the origin of the SMV vein; and Type IV, tumors infiltrating the venous branches at the origin of the SMV [16]. In some cases the extension of invasion to the venous SMP axis can be a combination of the least two types as generally seen in case of locally advanced tumors.

16.4 Common Surgical Steps

Some authors have raised questions about the maximal length of venous segment that can be safely resected during a pancreatectomy [17]. It is more likely that in a common Whipple's procedure, such as originally described, the resection of even 2 cm of the portal vein appears as difficult to be achieved without tension and potential difficulties. For these reasons most of these authors describe and prefer lateral resections of the SMV axis and/or in case of segmental resection the use of graft replacement of the resected segment [4]. In our experience there are no limits in the maximal length of the venous axis to be resected, and graft replacement is not needed in case of pancreaticoduodenectomy or total pancreatectomy when some basic surgical maneuvers are performed.

First, the entire right colon and the insertion of the mesentery are taken down up to Treitz ligament (Cattel-Braasch maneuver). This maneuver allows for an easy and safe lifting of the entire bowel that will facilitate greatly the venous reconstruction. In order to approximate in a better way, the two venous ends to be anatomized in further length can be gained by mobilizing the right liver. However the same effect can be also obtained just by putting some gauze between the segment 8 and the diaphragm. One key point in order to avoid problems of venous approximation without tension is to completely clear the lymphatic tissues by performing an extensive lymphadenectomy. In our experience the lymph node clearance removes all the lymphatic tissues around the hepatic pedicle and the common hepatic artery and around the coeliac trunk and the superior mesenteric artery. In the particular case of tumors located in the uncinate process, the isolation of the superior mesenteric vein is performed low in the mesentery. This dissection begins below the transverse mesocolon that is sectioned far from the anastomotic arcades and left attached to the future specimen (Fig. 16.3). The middle colic and the right superior colic veins as well as the gastrocolic venous trunk of Henle are systematically sectioned in case of resection of the SMP confluence or of the SMV. The middle colic artery is generally sectioned as well, and its section is well tolerated and allows for a good lifting of the entire mesentery toward the liver. A final technical note is directed toward the splenic vein. The optimal surgical management of the splenic vein, in case of segmental resection of the SMP confluence, remains debated (see below). Nevertheless, when the splenic vein is sectioned and not implanted into a SMP neoconfluence, the section of this vessel by itself allows for a good lifting of the SMV toward the portal vein that avoids the use of venous graft [16].

16.5 Abdominal Exploration and Preliminary Steps

Adequate exposure of the operative field is crucial in order to perform a safe radical PD with venous resection. We prefer a bilateral subcostal incision with midline extension. This kind of incision, with an autostatic retractor, provides excellent exposure of the operative field. The abdominal cavity is carefully explored to rule out previously undiagnosed peritoneal carcinomatosis or small subcapsular liver metastasis. A Cattle-Braasch maneuver is first performed and followed by an extensive Kocher maneuver up to the left border of the aorta. Dissecting the greater omentum from the transverse mesocolon enters the lesser sac. The superior mesenteric artery (SMA) is isolated and dissected at its origin just

Fig. 16.3 Intraoperative view of the final aspect of a PD with resection of the SMP confluence. Blue arrows indicate the complete section of the transverse mesocolon and the low section of the mesenteric root. The marginal arcades of the colon have been respected, while the middle colic artery has been sectioned at its origin; the vascularization of the transverse colon is optimal

above the left renal vein. The first 5 cm of the SMA is easily accessed and dissected by this approach. Lymph node sampling in the inter-aortico-caval area below the left renal vein is performed and sent for frozen section. Next the dissection of the plane between the pancreatic neck and the SMV venous axis is performed. At this moment, the decision to proceed with a venous resection will be made. However, this is classically the case of a small venous involvement localized on the lateral wall of the SMP axis (Type II). In these cases the classical tunnel behind the pancreatic neck can be easily made without any risk. On the contrary when venous involvement reaches the anterior face of the SMP confluence, the origin of the portal vein, or the SMV, this step will not be technically possible (Fig. 16.1). In these cases the creation of a retro-pancreatic tunnel will be performed on the pancreatic body and delayed until the entire retroportal lamina is sectioned. This approach known also as the Whipple at the splenic artery (WATSA) has been fully described by Strasberg et al. [18]. Moreover when venous involvement is detected at the level of the SMV, the dissection will begin, as detailed above, below the transverse mesocolon. The MCV, RSCV, and the middle colic artery will be sectioned into the mesocolon while respecting the anastomotic arcades that run close to the colonic wall.

16.6 Lymphadenectomy

The procedure will start with the lymphadenectomy that will remove the lymphatic tissues and nodes along the hepatic pedicle, the common hepatic artery, and the right side of the coeliac trunk and circumferentially on the SMA. The procedure starts with a cholecystectomy. The common hepatic duct will be isolated and charged on a tape below its confluence with the cystic duct. The pedicular posteroinferior and retropancreatic lymph nodes are isolated and dissected on the right border of the hepatic pedicle. The right branch of the hepatic artery is isolated and taped. Dissection proceeds along the anterior face of the hepatic pedicle, the left

branch of the hepatic artery is dissected and taped, and the right gastric artery is ligated at its origin on the proper hepatic artery. The origin of the proper hepatic artery is isolated. Lymph node clearance proceeds on the left side of the hepatic pedicle by removing all the lymphatic tissues between the posterior aspect of the proper hepatic artery and the anterior aspect of the portal vein. At the end of the CBD, the portal vein and the proper hepatic artery, along with its right and left branches, have been isolated and completely freed. Next, the common hepatic artery in front of the upper border of the pancreas is also freed, and the lymphadenectomy is pushed until the origin of the splenic artery. The dissection plane changes and follows the celiac trunk to reach the anterior surface of the abdominal aorta to the right of the diaphragmatic crura. Care should be taken to identify a median arcuate ligament that by this lateral approach can be easily sectioned. Once the anterior surface of the CT and its right border are cleaned, the dissection will move to the SMA. The GDA is generally sectioned at this time of the operation and the stomach sectioned by gastrointestinal stapler. In case of type I tumors, isolation of the SMV is generally performed above the transverse mesocolon. However, in case of type 2, 3, and 4 tumors, the isolation of the SMV will be performed below the transverse mesocolon after having sectioned the MCV, RSCV, and the middle colic artery. Once isolated the SMV is taped. Further dissection is performed to the left of the superior mesenteric vein, removing lymph nodes from the origin of the mesenteric root. The SMA trunk is isolated to the left of the SMV low into the mesentery. The dissection will follow the anterior surface of the SMA trunk; the MCA will be taped and preserved or sectioned according to the tumor's location (see above). The ligament of Treitz is sectioned between ligatures, and a mechanical stapler sections 15 cm below the ligament of Treitz the first jejunal loop. The dissection will follow the left border of the SMA up to its origin on the aorta. The first jejunal arterial branch will be sectioned on the left border of the SMA. The SMA trunk is taped and a gentle traction is put toward the left side; by this approach the dissection will completely clear the right border of the SMA with ligation of the inferior pancreaticoduodenal arteries. The dissection, by this mesenteric left approach, will provide optimal exposure on the inferior and posterior pancreatic veins and the first jejunal venous branches that will be ligated and sectioned as well. At that time the future specimen will remain attached only on the SMP venous axis.

16.7 Preparation for a Safe Mesentericoportal Vein Resection

At this point of the operation, attention is directed toward the pancreatic body. Differently from a classical Whipple, the section of the pancreas will not be performed on the neck in order to reduce the possibilities of tumor breakout and venous injuries. We prefer to section the pancreas on the body at the distance from the neck that is dictated by the tumor location. In case of type 2, 3, and 4 tumors, the section is performed on the superior part of the body on the origin of the splenic artery or by an inferior approach which is quite easier in our opinion. The inferior border of the transverse mesocolon is sectioned far from tumoral attachments, a retropancreatic tunnel is created, and the pancreatic body is taped and lifted. This maneuver ensures optimal control of the splenic vein in case of injury. Then the pancreatic body is dissected progressively from the splenic vein, and both are separately taped. During the separation of the SV from the pancreas, care should be taken in order to avoid injuries to the small venous branches draining the pancreatic body into the SV. These are easily sectioned and sutured, especially, if this dissection has been done far from the area of tumor

infiltration. Once the SV has been taped, the pancreatic body is sectioned, and a frozen section is sent for analysis. The CBD is sectioned just below the hilar plate. At that point according to the type of tumors (see above), the dissection will proceed differently.

16.8 Venous Resection

When an isolated resection of the portal vein is planned, which is quite uncommon in case of pancreatic adenocarcinoma, the dissection is directed from the splenic vein toward the SMP confluence. The anterior surface of the SMP confluence is easily dissected, and the portal vein just below its bifurcation is taped. Next the splenic vein and the SMV will be taped. After having clamped the SMA, the SMV, the SV, and the PV, the section of a short venous segment (generally between 1 and 2 cm long) will complete the demolition phase. Reconstruction will be achieved by reimplanting the basis of the portal vein on the PV pedicular trunk by an end-to-end anastomosis.

Resection of the SMP confluence (type 2 tumors) represents by far the most frequent venous resection performed in case of pancreatic adenocarcinomas. This type of resection poses the problem of the management of the splenic vein. For this kind of resection after having sectioned the pancreas, the pancreatic body is progressively dissected from the splenic vein and artery toward the left at 4–5 cm. All venous and arterial branches will progressively be ligated by selective stiches of 5-6/0 polypropylene sutures. This is necessary in our experience for two reasons. Firstly, we exclusively perform an invaginated telescoped pancreaticogastrostomy, as a pancreaticoenteric reconstruction method. A length of 4–5 cm is necessary to achieve a tension-free anastomosis. Secondly, this dissection will provide enough length of the splenic vein in the case in which this will be reimplanted on the left renal vein (Fig. 16.4).

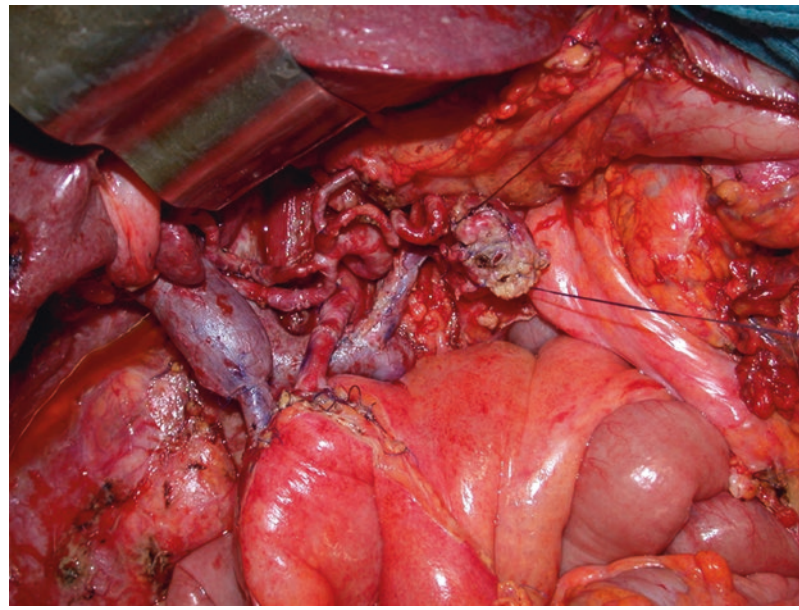

Fig. 16.4 Intraoperative view of the final aspect of a PD with resection of the SMP confluence and of the SMA. The SMV has been reimplanted on the PV, and the SV has been anastomosed in an end-to-side fashion on the left renal vein

At this point the splenic vein, the SMV, and the PV are taped. The dissection is directed toward the SMP confluence, but seldom its anterior surface is not exposed. For a segmental resection of the SMP confluence, the management of the SV will depend by several factors.

Simple ligation of the SV has been associated with the development of sinistral portal hypertension and hypersplenism on the long term. We favor all measures that can be adopted in order to avoid this phenomenon. Ligation of splenic vein without reconstruction can be performed when the natural confluence between the IMV and the SV is preserved and/or when the LGV or the MCV is preserved (Fig. 16.5). This ensures adequate venous drainage of the splenic vein into the portal system. Still secondary portal hypertension has been described using this technique [19].

The creation of an IMV-SV end-to-end anastomosis, which mimics a natural confluence, can be an alternative when the IMV drains directly into the SMV [10]. This can be performed by tailoring the IMV stump to the SV stump by some forms of venoplasty (Fig. 16.6).

Direct reimplantation of the SV vein stump into a newly constructed SMV-PV confluence is in our opinion feasible only when 1–2 cm of the splenic vein is resected (Fig. 16.7). However this type of venous reconstruction can lead, in our experience, to venous axis distortion and potential thrombosis. The interposition of a graft can be a solution in these conditions; the internal jugular vein or the left renal vein can be used with this aim. An easier and more physiologic method is represented by reimplantation of the SV into the left renal vein. This method presents several advantages. The left renal vein runs just below the axis of the SV, and direct reimplantation is quite straightforward. Secondly, the anterior surface of the LRV can easily accommodate the SV stump without any problem of caliber's incongruences. Thirdly this method avoids completely the development of any form of portal hypertension (Fig. 16.4).

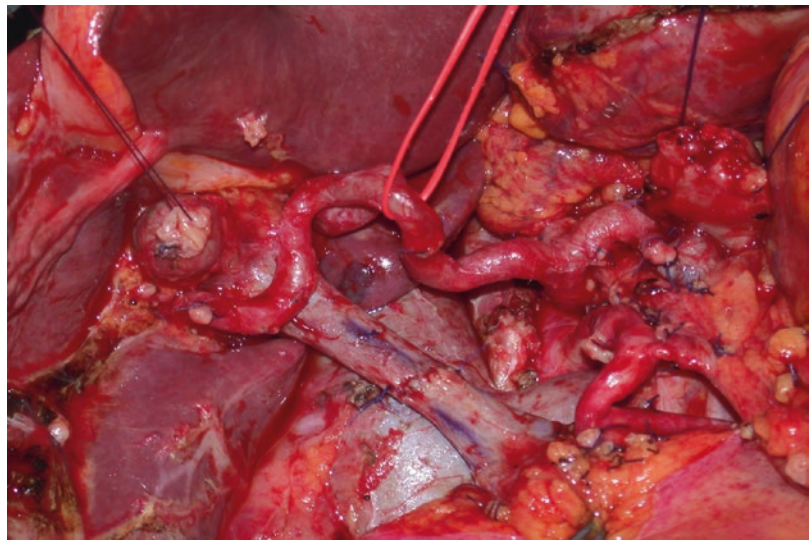

Fig. 16.5 Intraoperative view of the final aspect of a PD with resection of the SMP confluence. The SV has been ligated while preserving the natural confluence between the SV and the IMV

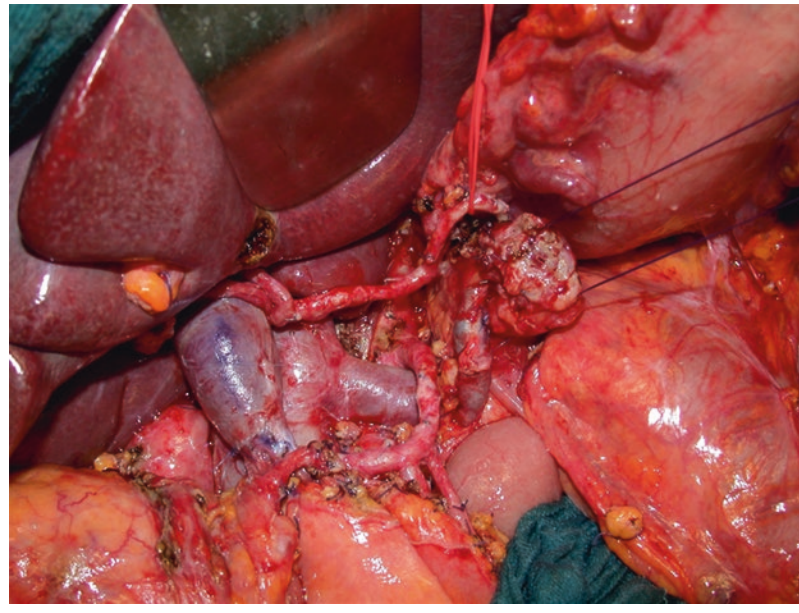

Fig. 16.6 Intraoperative view of the final aspect of a PD with resection of the SMP confluence; the SV has been anastomosed in an end-to-end fashion to the IMV

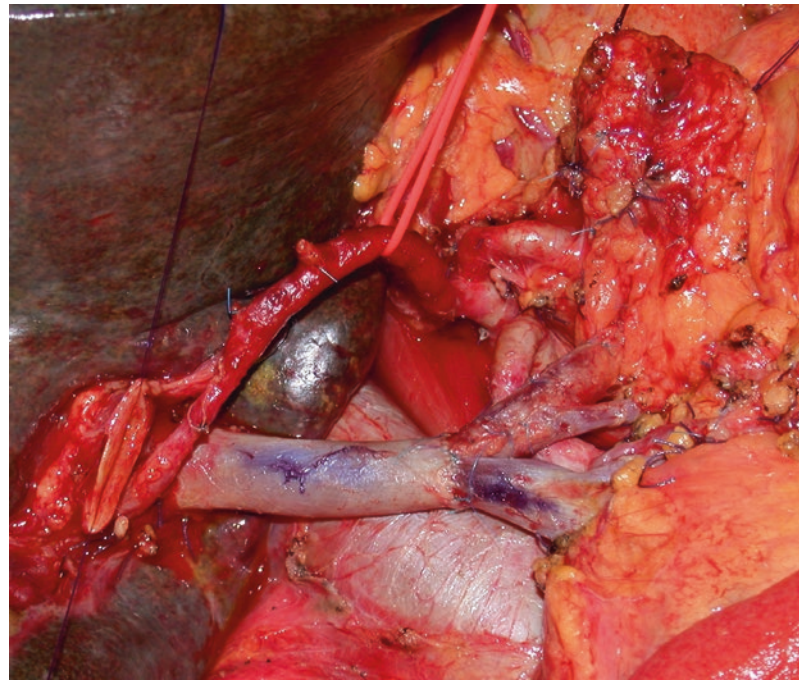

Fig. 16.7 Intraoperative view of the final aspect of a PD with resection of the SMP confluence. The SV has been anastomosed in an end-to-end fashion to the PV after having been sutured side to side to the SMV

Whatever the method chosen to manage the SV stump, the SV is at this moment sectioned. The SMA, the SMV, and the PV are clamped and sectioned, and the specimen is sent for pathology. Direct reconstruction by an end-to-end anastomosis between the SMV and the PV is fashioned by polypropylene running 6/0 sutures with a growth factor. Care should be taken in order to avoid twisting of the two ends to be anastomosed. This can be easily avoided just by marking with colors, before clamping and sectioning venous axis, the correct direction of the venous axis. This has been adopted at our unit for more than 25 years.

In case of type 3 tumors, the resected venous segment involves the origin of the SMV vein. According to the precise tumor location, the previous dissection in the mesentery has isolated either the origin of the SMV trunk or the jejunal or the ileocolic branches or both at its origin. The dissection, which follows exactly the rules described above, allows dissecting the anterior surface of the SMP venous confluence since the infiltration is seldom located on the posterior surface of the SMV by tumors of the uncinate process. At that point of the dissection, the SV, PV, SMV origin or its branches, and the SMA will be clamped. The specimen will be excised en bloc with a segment of the SMV. Reconstruction will be achieved by a direct end-to-end reconstruction with polypropylene running 6/0 sutures with a growth factor

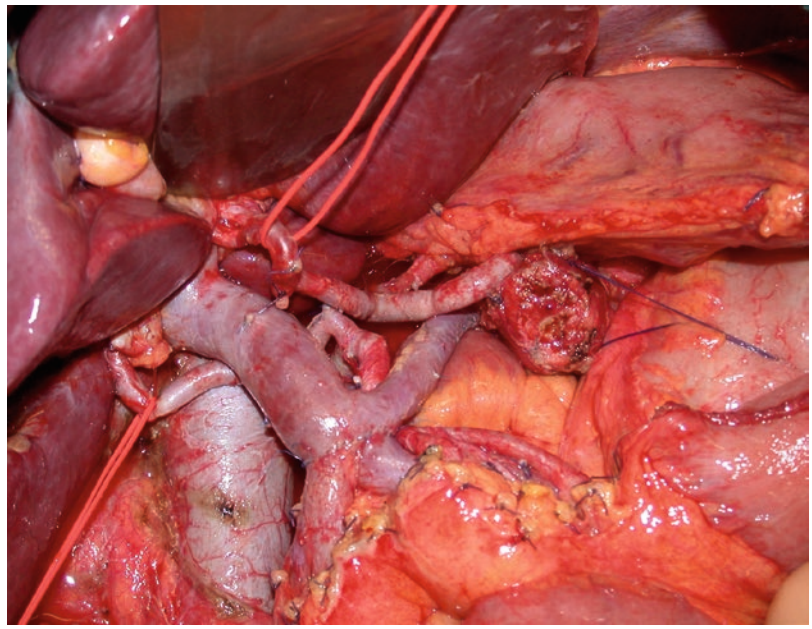

Fig. 16.8 Intraoperative view of the final aspect of a PD with resection of the SMV trunk. The origin of the SMV has been anastomosed in an end-to-end fashion to SMP venous confluence

(Fig. 16.8). When the SMV tract resected encompasses the origin of its trunk, the jejunal and the ileocolic branches will be joint together by a side-to side anastomosis on their medial aspect in a new confluence and the anastomosed in an end-to-end fashion to the basis of the SV-PV confluence.

Figures 16.9 and 16.10 depict a short intraoperative breakout of a "safe" PD with resection of the SMP venous confluence and fashioning of the venous anastomosis.

After venous anastomosis, the digestive reconstruction will follow according to surgeon's preference.

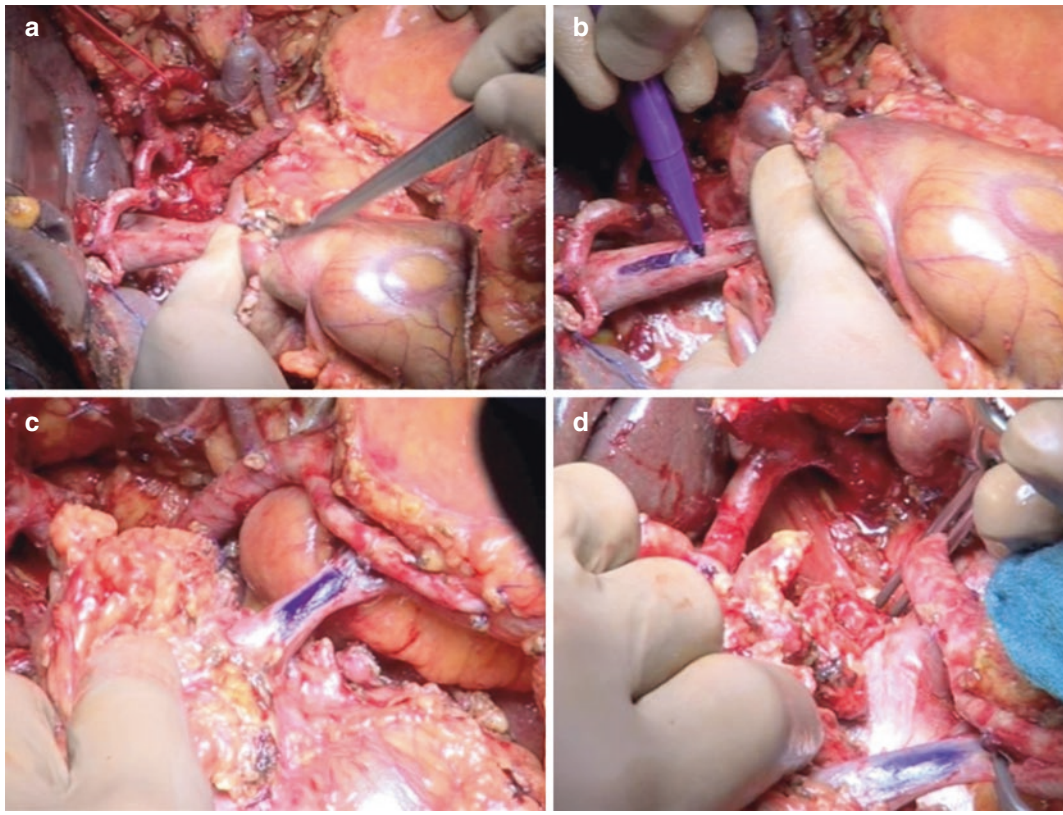

Fig. 16.9 Intraoperative view of a "safe" venous resection of the SMP confluence; (**a**) The PD specimen has been left attached to the venous axis. The splenic vein has been previously ligated and the confluence between the IMV and the SV respected. The dissection of the retroportal lamina around the CVT and the SMA is already completed; (**b**, **c**) the venous axis orientation is marked with ink in order to have correct orientation of the venous anastomosis; (**c**) The superior mesenteric artery is clamped and the venous end are transected

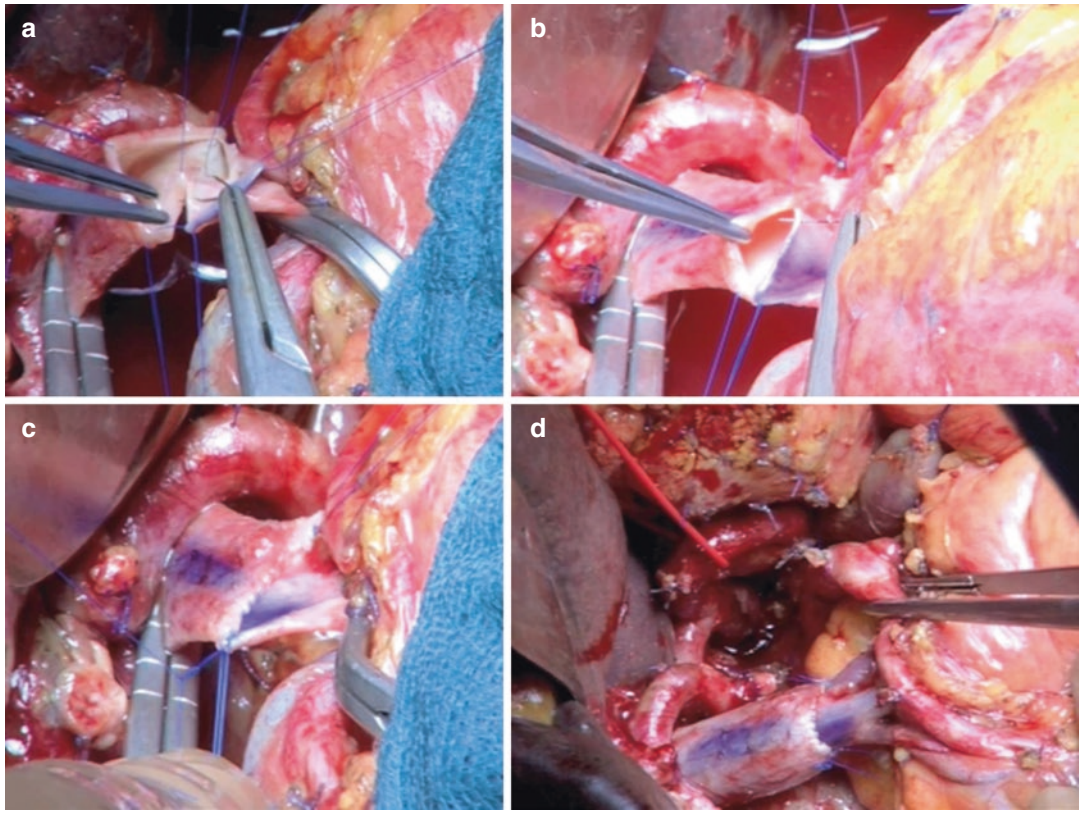

Fig. 16.10 Fashioning the venous anastomosis; The SMV and the PV are sutured in an end to end fashion. (**a**) The back wall is performed first using a 6-0 running polypropylene suture; Stays sutures are applied on the anterior wall in order to give excellent exposure of the posterior wall. (**b**) the anterior wall is performed using the same technique; (**c**) the two tunning sutures are knotted togheter with a "growth" factor. (**d**) the SMA and the venous anastomosis have been unclamped. There are no discrepancies in caliber nor in orientation

Conclusions

We describe a standardized technique used to perform a safe pancreaticoduodenectomy with venous resection, which has been used for performing more than 400 various types of pancreatectomy combined with vascular resection at our unit. The basic principles of this technique are based on the large mobilization of the mesentery, the complete clearance of the retroportal lamina around the arterial mesenteric and coeliac axis, and the optimal management of the splenic vein. These technical refinements allow the safe performance of PD with venous resection without graft interposition. PD with venous resection should be performed in high-volume HPB tertiary referral centers by surgeons with extensive experience in standard pancreatectomy and vascular reconstruction.

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