Portomesenteric Reconstruction During Whipple Procedures: Review and Report of a Case

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A 60-year-old man undergoing a Whipple procedure to treat a pancreatic cancer was found to have tumor adherence to the portal vein. An en block pancreaticoduodenectomy with segmental portal vein resection (PVR) was performed. A primary portal vein anastomosis was initially attempted but failed. Hemodynamic deterioration led the authors to perform a temporary prosthetic portal vein interposition graft and abdominal closure. The following morning, once stable, the patient was brought back to the operating room for autologous reconstruction with femoral vein and completion of the pancreaticoduodenectomy. The role of PVR for vein invasion or tumor adherence during a Whipple procedure is still under debate. However, there is growing evidence that the perioperative morbidity and long-term survival in patients who undergo a pancreaticoduodenectomy with PVR are similar to those of patients without vein resection. Therefore a combined resection of the pancreatic head and the portal vein has been suggested in the absence of other contraindications for resection to be able to offer a curative surgical intervention to a larger number of patients. The authors herein report the details of a patient’s case and also review the currently available methods for PVR and reconstruction.

Keywords: Whipple procedure; portal vein resection; portomesenteric reconstruction; pancreatic cancer

Case Report

A 60-year-old man presented with a 5-month history of dark-colored urine, clay-colored stools, jaundice, and vague right upper quadrant abdominal pain. He also reported a 70-pound weight loss in the last 4 years. His past history was remarkable for hypertension, active alcohol and tobacco abuse, and chronic bronchitis. His physical exam showed a patient in no acute distress, with marked jaundice and minimal abdominal tenderness to palpation, mostly in the right upper quadrant. His blood work revealed a direct bilirubin of 24 mg/dL, with elevated values of liver function tests and amylase. His carbohydrate antigen (CA) 19-9 was 46.1 U/mL. An abdominal computed tomographic (CT) scan revealed a prominent common bile duct dilatation without an obvious pancreatic mass identified as a cause for obstruction (Figure 1). An endoscopic retrograde cholangiopancreatography demonstrated a distal common bile duct normal in caliber, with marked dilatation of its proximal segment (Figure 2). An irregular area of abrupt tapering of the distal common bile duct was seen proximal to the ampulla. This biliary stricture was treated with a stent. The pancreatic duct was dilated in the body and tail, with multiple changes suggesting chronic pancreatitis. Cytology was negative for malignancy. Endoscopic ultrasound showed hypoechoic areas in pancreas, and a mass located in the pancreatic head, staged at T3N0M0. Fine needle aspiration revealed irregular cells with large nuclei, suggestive of malignancy. Both CT scan of the chest and a whole-body positron emission tomography failed to reveal conclusive evidence for metastatic disease.
The patient was offered a diagnostic laparoscopy with possible Whipple procedure (WP). On laparoscopic exploration, no evidence of metastatic spread was found. The laparoscopic procedure was converted to an exploratory laparotomy. The pancreas was firm with a mass at the head of the pancreas. The gallbladder was entered in dissection and noted to have purulent material within it. No tumor was adherent to the major arterial structures, although it was found to be adherent to the underlying portal vein, at the confluence of the superior mesenteric vein (SMV) and the splenic vein. The body of the pancreas distal to the portal vein, gastric antrum, proximal jejunum, and hepatic duct was transected. The splenic vein was divided, and proximal and distal control of the portal vein was then obtained. After systemic heparinization was given, vascular clamps were applied. En block resection was completed that included 1.5 cm of portal vein. An end-to-end anastomosis between both portal vein ends was constructed. During the initial reconstruction, the small bowel looked increasingly dusky and congested. Doppler assessment of the portal vein demonstrated flow only proximal to repair but none distal. At this time, the patient was noted to be tachycardic and hypotensive, requiring large amounts of intravenous fluids, blood products, and cardiopressors. Given his critical status, an 8-mm expanded polytetrafluoroethylene (PTFE) interposition graft was placed from the portal vein to the SMV, restoring normal color of the bowel and with good Doppler flow at completion. A temporary abdominal closure was performed, and he was transferred to the intensive care unit where he was resuscitated. The following morning, his condition was stable and he was brought back to the operating room for removal of the PTFE graft and portal vein reconstruction with femoral vein (Figure 3) and completion of WP. A segment of the right femoral vein was harvested from the thigh and used for portal vein reconstruction.
Figure 4. Photomicrograph A (hematoxylin and eosin [H&E] stain, 40×) shows tumor glands of moderately differentiated invasive pancreatic adenocarcinoma amidst a desmoplastic stroma closely adherent to the adjacent portal vein. Photomicrograph B (H&E stain, 100×) is a high magnification view of the malignant tumor glands close to the portal venous wall.

Figure 5. Duplex ultrasound performed 6 days after completion of portal vein reconstruction with femoral vein and Whipple procedures, showing a patent repair, reflected by normal distal portal vein flow going into the liver. Visualization of the actual interposition vein graft was very difficult because of the artifact caused by skin staples and intestinal gas. The two upper panels are images from the main portal vein, and the two at the bottom are from the left portal vein branch.
reconstruction in a nonreversed fashion. It was noted that the jejunum was much less edematous, allowing for safe pancreaticojejunostomy, hepaticojejunostomy, and gastrojejunostomy reconstruction. Pathology examination revealed tumor involving peripancreatic lymph nodes and also adjacent to, but not invading, the portal vein (Figure 4). After further resuscitation he was extubated 4 days later and continued uneventful recovery. Duplex ultrasound performed 6 days after his definitive intervention showed normal intrahepatic portal vein flow (Figure 5). The interposition vein graft was not seen because of the artifact from intestinal gas.

Discussion

Current surgical treatment of pancreatic cancer may include a portal vein resection (PVR) added to the standard WP, although its role is still controversial. Growing evidence shows that the perioperative morbidity and long-term survival in patients who undergo a WP with PVR are similar to those of patients without vein resection.1,2 PVR increases the number of patients who can be offered a potentially curative surgical intervention but is technically more difficult and may increase the periprocedural risk. A combined resection of the pancreatic head and the portal vein has been suggested in the absence of other contraindications for resection.1,2

PVR is a challenging technical aspect of a WP, especially when vascular involvement is not detected preoperatively. Decisions must be made intraoperatively regarding the addition of PVR. The extent of resection may not be clear until the pancreas is divided, such as in the case of our patient. Koniaris et al3 recommended the use of intraoperative ultrasonography to aid in staging the celiac axis and superior mesenteric artery before committing to portomesenteric vein resection. Evidence of metastatic disease, complete portal obstruction, extensive anterior invasion of the portal vein, and superior mesenteric artery encasement are considered relative contraindications to resection.4

Several methods and modifications of portal vein reconstruction and different materials for portal replacement have been proposed (Table 1). Also, several techniques have been described to minimize the degree of bowel congestion and ischemia during PVR. The ideal technique and material are dictated by the intraoperative findings.

Technique Modifications and Adjuncts to Minimize Bowel or Liver Adverse Effects

Visceral congestion and liver ischemia are of great concern during the procedure. Acute experimental portal vein occlusion produces immediate shock and death. Tashiro et al4 recommended simple occlusion if the reconstruction is done within 30 minutes. If reconstruction is done within 30 to 45 minutes, simultaneous occlusion of the superior mesenteric artery was advised. If more than 60 minutes are anticipated, some sort of a mesenteric-systemic bypass is suggested.5 To protect the liver during occlusion of the portal vein, Wake et al6 induced mild hypothermia with surface cooling and assessed the liver oxygen status by hepatic venous saturation monitoring. These tools were found to be clinically useful in detecting hepatic oxygen supply/demand unbalance and in protecting the liver. Shimada et al7 used systemic prostaglandin E1 and a bolus injection of methylprednisolone prior to portal vein clamping to minimize ischemic reperfusion injury.

Dardik et al8 used a polyvinyl intravenous tubing, in a straight or looped configuration, placed into the portal vein cephalad and the mesenteric vein caudad, to allow continued perfusion of mesenteric venous blood directly into the portal system of the liver while they repaired the portomesenteric system. Nakao and Takagi7 described a similar technique in 89 patients using an antithrombogenic portal vein bypass catheter (Anthrón, Toray Industries Inc., Tokyo). Miyata et al10 also used a temporary bypass between a branch of the SMV and the femoral vein via the saphenous vein using heparin-coated plasticized polyvinylchloride tubes. Suzuki et al11 used a centrifugal pump-assisted bypass between the SMV and the umbilical vein. A 12F catheter filled with heparinized saline was inserted into the umbilical vein in the teres hepatica, while another 12F catheter was inserted through the ileocecal vein until the tip reached a main SMV branch. Systemic heparin was given immediately prior to opening the bypass. The catheters were connected to a centrifugal pump (Bio-pump, Medtronic Bio-Medicus, Eden Prairie, MN) that could monitor and control the flow rates. This technique allowed stable bypass flow, and neither bowel edema nor liver ischemia were seen during portal vein reconstruction. No differences were noted in terms of morbidity, mortality, liver enzyme values, or the time to start oral intake after the procedure between patients who required portal
vein reconstruction using the pump and those who did not. Kubota et al\textsuperscript{12} recommended the use of a temporary portosystemic bypass while reconstructing the portal vein during a WP. A portion of the gastrocolic vein trunk is preserved for insertion of an antithrombogenic catheter (heparinized hydrophilic polymer ATC: \{Toray Industries Inc., Tokyo\}). To follow, the left external iliac vein is harvested and the great saphenous vein (GSV) exposed. The end of the catheter is inserted in the SMV via the gastrocolic vein trunk, and the other end is inserted in the GSV. The bypass is achieved as a result of the venous pressure gradient. A 2-step bypass for cases where tumor invasion causes SMV outflow obstruction has been described. In these cases, the blood return to the liver is through collaterals. The marginal colic veins are often dilated, forming a collateral path to the inferior mesenteric and the splenic veins. Because the venous flow in this setting is easily interrupted with manipulation of the transverse colon, Shiraishi et al\textsuperscript{13} suggested introducing a bypass using an Antron tube between an accessory right colic vein and the umbilical vein to decompress the bowel and to enable surgical dissection of the invaded SMV itself. Once the invaded SMV is thoroughly dissected, the bypass is transferred from the right colic vein into the main SMV trunk, which is maintained during portal reconstruction.

A modification to the WP technique has been suggested to achieve vascular resection with the least amount of bowel congestion and securing negative resection margins. This consists of an initial extensive retroperitoneal dissection for the assessment of the extent of tumor involvement of the superior mesenteric vessels and division of retroperitoneal margin before the division of the pancreas.\textsuperscript{14} Machado et al\textsuperscript{15} also modified the standard WP by starting the pancreatic dissection at the posterior aspect of the pancreatic head. The superior mesenteric artery was completely dissected from the pancreas, leaving the section of the pancreas and PVR to the last step. With this modification, portal vein occlusion did not exceed 10 minutes, and they avoided the need of venous grafts in most cases.

### Table 1. Methods and Technique Modifications for Portal Vein Resection and Reconstruction During a Whipple Procedure

<table>
<thead>
<tr>
<th>Methods</th>
<th>Venous Replacement</th>
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<tbody>
<tr>
<td>No reconstruction (collateral preservation + hepatic venous oxygen saturation monitoring)</td>
<td>Jugular vein</td>
</tr>
<tr>
<td>Lateral venorrhaphy without a patch</td>
<td>Femoropopliteal vein</td>
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<tr>
<td>Lateral venorrhaphy with a patch</td>
<td>Common iliac vein</td>
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<tr>
<td>Bovine pericardium</td>
<td>External iliac vein</td>
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<tr>
<td>Dacron</td>
<td>Great saphenous vein</td>
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<tr>
<td>Gonadal vein</td>
<td>Spiral gonadal vein graft\textsuperscript{b}</td>
</tr>
<tr>
<td>Saphenous vein</td>
<td>Splenic vein</td>
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<tr>
<td>Peritoneum\textsuperscript{c}</td>
<td>Reopened umbilical vein</td>
</tr>
<tr>
<td>End-to-end anastomosis</td>
<td>Bovine venous graft</td>
</tr>
<tr>
<td>Proximal SMV venoplasty and end-to-end anastomosis of the neovessel to the cephalad portal vein</td>
<td>Left renal vein\textsuperscript{c}</td>
</tr>
<tr>
<td></td>
<td>Dacron</td>
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<td>PTFE</td>
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Adjuncts to prevent bowel ischemia

- Intravenous prostaglandin E1 + methylprednisolone
- Mild hypothermia + hepatic venous oxygen saturation monitoring
- Temporary portosystemic bypass

| Simultaneous superior mesenteric artery and portal vein occlusion if reconstruction within 30 to 45 minutes |
| Right colon and mesenteric mobilization          |
| Two-step portal bypass                           |

Note: PTFE, expanded polytetrafluoroethylene; SMV, superior mesenteric vein.

\textsuperscript{a} Experimentally in animals only.

\textsuperscript{b} Described in renal transplant.

\textsuperscript{c} In cases of liver transplant.
Primary Repair of the Portal Vein

Other than in rare cases of a well-developed system of periportal venous collaterals, wherein portal resection can be performed under hepatic venous oxygen saturation monitoring, without reconstruction,16 the reconstruction is almost always required. Primary venous reconstruction can be performed through lateral venorrhaphy, end-to-end anastomosis, or patch repair. Regardless of the method, prevention of kinking or twisting of the reconstructed vessel is critical to avoid revision or postoperative acute thrombosis and death. Koniaris et al13 suggested, after excision of the venous area involved by tumor and a 0.5-cm segment of grossly uninvolved vessel in an elliptical fashion, to leave a connecting strip of uninvolved vein to connect the portomesenteric confluence above and below the resected segment. This strip, even if less than 1 cm in diameter, helps by maintaining normal vessel orientation, preventing twisting or kinking. Kubota et al17 used the following rule when deciding among the reconstructive options: If less than half of the vein diameter is judged to be invaded by cancer, or if the involved vein length is 3 cm or less, it can be partially resected. If more, segmental resection is performed. Koniaris et al13 used the following tenet: If less than two thirds of the cross-sectional circumference of the lower portal or SMV has been resected, and a SMV diameter of ≥0.5 cm will result with primary venous reanastomosis, primary closure is chosen. This technique was used in more than 40 venous resections without ensuing mesenteric hypertension. Jain et al14 retrospectively analyzed patients who underwent PVR during a WP. They found that an end-to-end anastomosis after adequate mobilization of the portal vein and SMV was possible in 40/48 of them; in 4, lateral venorrhaphy was used, whereas in the remaining 4, an interposition graft was necessary. This is also in agreement with Miyazaki et al,18 who found that 855 of their patients were well suited for an end-to-end anastomosis. Fortner19 and others20 suggested transection of the falciform ligament, as well as the left and right triangular ligaments, to displace the liver downward toward the mesenteric root. Simultaneously, the aid of an assistant is needed on the left of the operating room table, to displace the small bowel and its mesentery upward, to facilitate a precisely aligned, tension-free anastomosis. Fujisaki et al21 has proposed the mobilization of the right colon and the root of the mesentery to allow a tension-free anastomosis and to avoid the need for interposition vein grafting. This also allows shortening the time of portal blood flow interruption given that only one anastomosis is required, with the ensuing reduction in bowel congestion and ischemia. Their technique, however, requires the routine ligation of the splenic–portal vein junction. Fuhrman et al2 have reported the occurrence of upper gastrointestinal hemorrhage because of sinistral portal hypertension after splenic vein ligation. They recommend preservation of that junction whenever possible, at the expense of using interposition grafts because of the limited portal vein mobilization.

The technique that we initially used in our patient was an end-to-end portal vein reconstruction without colonic or mesenteric mobilization. The reasons why our first attempt failed are likely related to three possible factors: a technical error, excessive tension for a primary repair, or hypotension because of the large blood loss related to the large pancreatic tumor. Kubota et al17 used a vein patch tailored from a gonadal vein segment. This technique consisted of, after mobilizing the duodenum, harvesting and longitudinally dividing the most proximal 5 cm of the vein. Then it is divided into two equal parts that are sutured together to give a patch measuring 2.5 × 2 cm. Koniaris et al13 reported the use of a collagen-impregnated on-lay Dacron patch (Hemashield, Meadox Corp.) with good results. In short-term follow-up, no clinically significant thrombosis or graft infection was observed. Dardik et al8 used a glutaraldehyde-processed bovine pericardium (Vascuguard, BioVascular Inc., St Paul, MN). No problems with an 8-month follow-up period were reported. The peritoneum has been used to repair the portal vein as a patch but only in animal studies.22 A 2.5 × 2.5 cm patch of the peritoneum was excised from the upper quadrant of pigs, and it was dipped in 100% alcohol for 10 minutes. It was then trimmed into an oval patch measuring 15 × 10 mm that was sewn to the portal vein. Endothelialization was noted in a week and was complete 2 weeks after surgery. At least in the experimental arena, its patency as a patch was adequate and its risk of infection was low.

Portal Reconstruction Using Prosthetic Interposition Grafts, Xenografts, or Intraluminal Shunts

Options for vein conduit include synthetic8,23,24 or autogenous vein grafts; however, infection concerns make autogenous tissue preferable. Liberally using antibiotics; performing vein reconstruction walled off
Portal Reconstruction Using Autogenous Interposition Grafts

The autogenous conduit that has been mostly popularized is the jugular vein. Initially described in an animal study in 1961, it is mostly used because of its good size match to the portal vein. Moreover, it does not require reconstruction after unilateral resection because it does not cause head and neck venous insufficiency. However, the vein has proved to be thin and difficult to handle. When unplanned, this also poses a challenge in patients’ positioning, with issues mainly related to airway preservation. Our patient had a very short neck and his intubation was quite difficult.

The deep veins of the lower extremities have been used in different arterial beds. Fleming et al published femoral vein use in portomesenteric vein reconstructions. However, the first description for the use of a deep vein in portomesenteric vein reconstructions was done by Sigel et al. The technique for harvesting the femoral vein has been described in detail, this being the method that we currently use. The incision is made along the lateral border of the sartorius muscle, which is reflected medially and posteriorly to preserve the blood supply entering at the inferolateral aspect. The subsartorial canal is exposed, and care is taken to avoid injury to the saphenous nerve. The femoral vein branches are ligated. The vein is mobilized until an adequate segment is isolated. It is critical to avoid injury to the common femoral–profunda femoris vein junction to avoid postoperative venous insufficiency. Criticism for the preferential use of femoral vein include that the extent of surgery needed is considerable; the need for a Doppler study of the lower extremities to assess femoral vein patency and size prior to surgery; potential injury to the saphenous nerve; deep venous hypertension that ensues in 13% of the patients requiring long-term compression stockings; postoperative deep venous thrombosis in 22%; and need for anticoagulation in 5% of patients. With this approach, the harvest and vein reconstruction adds 30 to 45 minutes to a WP without reconstruction. The femoral vein size (7 to 9 mm) makes an excellent natural size match for the portal vein and can be inset with minimal manipulation. This avoids the extra time from multiple suture lines. Only a short distance of femoral vein (6 to 10 cm) is often needed for this reconstruction, making the incidence of venous hypertension and thrombosis low after harvest. In fact, no cases of the latter two complications were reported among 250 aortic reconstructions using femoropopliteal vein grafts. Even with harvesting of longer segments of deep veins, which in theory could make the risk of deep vein thrombosis higher, Wells and colleagues have not had to use anticoagulation on any of these patients in their considerable experience.

With the development of liver and pancreas transplantation, the portomesenteric system has been approached very aggressively and the common iliocaval veins and other conduits have been used successfully. Kaneoka et al used a 4-cm segment of right external iliac vein harvested extraperitoneally through an upper groin incision. No related adverse events are reported almost 4 years after intervention. Chiu et al experimentally described the spiral vein graft in replacement of the superior vena cava of 13 dogs, which entailed GSV removal, followed by the creation of any size vein to reconstruct. Doty and Baker years later confirmed the clinical applicability of this
technique. The spiral vein graft was fashioned over a 28F Argyle catheter. Sakamoto et al also described the use of the GSV. They transversely divided the vein into three sections, which are aligned side to side. The three pieces are anastomosed to make a sheet $3 \times 2$ cm, which is rolled up into a cylindrical form of approximately 1 cm in diameter and 2 cm in length. The splenic and the renal vein have also been described to replace the portal vein. The latter, however, has only been described in the case of hepatobiliary malignancies. The branches of the vein, such as the renal–azygous branch and the gonadal vein were preserved. No significant renal dysfunction occurred in 6 of their patients who had the left renal vein used to construct a graft. Nghiem reported the construction of a spiral vein graft from the entire right ovarian vein, splitting it longitudinally and wrapping it spirally around a chest tube. This was used in the setting of renal transplantation. Yamanaka et al reported the use of reopened umbilical vein. The lack of vascular endothelium in the latter conduit has raised the possibility of graft thrombosis.

In some cases, the SMV stump is roughly smaller than the portal vein stump. Machado et al proposed the closure of the SMV stump and performing an end-to-end anastomosis between a venous graft and the SMV. An end-to-end anastomosis between the vein graft and the portal vein is needed in the cephalad end of the reconstruction.

**Durability of Portal Vein Reconstruction**

Jain et al reported a venous patency rate of 100% at 3 years after using end-to-end portal vein repair in most cases. However, in one of their cases, repair thrombosis was noted on the third day postoperatively, requiring surgical revision. The patient died on the second day after reoperation. After 64 reconstructions using primary lateral venorrhaphy, PTFE grafts, primary end-to-end repair, and autologous vein grafts, a perioperative mortality of 2% was seen. Eleven thromboses were diagnosed at a mean of 12 months. Three thromboses (5%) were noted within 30 days and full anticoagulation was chosen. Fifty-three percent of patients received anticoagulation with aspirin, warfarin, or clopidogrel based on surgeon preference. There was no difference in thrombosis rates between those receiving anticoagulation and those who did not. In those patients with thrombosis outside the acute time period, morbidity was limited to ascites in 3 patients and splenic vein thrombosis with uncomplicated esophageal varices in another patient. However, anecdotally, it has been shown that portal vein stenosis after a WP may cause gastrointestinal hemorrhage, hepatic abscesses, whereas fatal liver failure has been reported because of thrombus formation after portal reconstruction.

There are no guidelines related to the use of systemic anticoagulation during (intraoperatively) or after (postoperatively) these types of reconstructions. For instance, Norton and Eiseman did not recommend the use of intraoperative systemic anticoagulation. Others, however, do use routine intraoperative anticoagulation, including us. Some have also used anticoagulation with warfarin postoperatively and continued it for about 2 months. Others have not considered this necessary.

**Conclusions**

The literature reports several methods to reconstruct the portal vein when this is needed during the course of a WP. The optimal method depends on the intraoperative findings. In case of hemodynamic deterioration, prosthetic repair of the portal vein can be performed to allow adequate resuscitation in the intensive care unit without bowel compromise, prior to completion of the pancreaticoduodenectomy. Autologous reconstruction is our preference whenever feasible. No guidelines can be obtained as far as the benefit of intraoperative or postoperative systemic anticoagulation. The durability of these reconstructions seems to be adequate, and the complications related to chronic failure of the reconstructions seem to be generally well tolerated, although cases of serious morbidity and also fatality have also been reported.

**References**


