

ORIGINAL ARTICLE

Reconstruction of portal vein and superior mesenteric vein after extensive resection for pancreatic cancer

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Purpose: Tumor invasion to the portal vein (PV) or superior mesenteric vein (SMV) can be encountered during the surgery for pancreatic cancer. Venous reconstruction is required, but the optimal surgical methods and conduits remain in controversies. **Methods:** From January 2007 to July 2012, 16 venous reconstructions were performed during surgery for pancreatic cancer in 14 patients. We analyzed the methods, conduits, graft patency, and patient survival. **Results:** The involved veins were 14 SMVs and 2 PVs. The operative methods included resection and end-to-end anastomosis in 7 patients, wedge resection with venoplasty in 2 patients, bovine patch repair in 3 patients, and interposition graft with bovine patch in 1 patient. In one patient with a failed interposition graft with great saphenous vein (GSV), the SMV was reconstructed with a prosthetic interposition graft, which was revised with a spiral graft of GSV. Vascular morbidity occurred in 4 cases; occlusion of an interposition graft with GSV or polytetrafluoroethylene, segmental thrombosis and stenosis of the SMV after end-to-end anastomosis. Patency was maintained in patients with bovine patch angioplasty and spiral vein grafts. With mean follow-up of 9.8 months, the 6- and 12-month death-censored graft survival rates were both 81.3%. **Conclusion:** Many of the involved vein segments were repaired primarily. When tension-free anastomosis is impossible, the spiral grafts with GSV or bovine patch grafts are good options to overcome the size mismatch between autologous vein graft and portomesenteric veins. Further follow-up of these patients is needed to demonstrate long-term patency.

Key Words: Portal vein, Superior mesenteric vein, Reconstruction, Pancreaticoduodenectomy

INTRODUCTION

Tumor invasion or adhesion to the portal vein (PV) or superior mesenteric vein (SMV) can be encountered during the surgery for pancreatic cancer. Venous resection and reconstruction are required for complete resection of

the tumor in these cases. Since extensive resection and venous reconstruction was found not to increase the post-operative morbidity and mortality, *en bloc* resection with involved vein was performed in many cases [1-4].

Reconstruction of the PV or SMV is a challenge for the vascular surgeon because of the lack of size-matched au-

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togenous conduit. In addition, concerns about graft infection have restricted the use of prosthetic grafts during the intra-abdominal surgery [2]. Reconstructions using various autogenous veins have been performed with different methods for size-matching [5-10]. Each method, however, has limitations and the optimal conduit and surgical methods remains a controversy.

The purpose of this study was to analyze the result of reconstruction of the PV and SMV during extensive resection for pancreatic cancer in terms of the surgical methods, conduits, graft patency and risk factors for graft occlusion.

METHODS

All patients who were diagnosed with pancreatic cancer and underwent reconstruction of the PV or SMV after *en bloc* tumor resection at our institution between January 2007 and July 2012 were identified. Retrospective review of medical records and radiologic studies was performed after the approval by the Institutional Review Board (H-1205-110-411). Information included baseline demographics and clinical characteristics, primary malignancy as determined by pathologic examination, surgical methods, conduits and pathologic results of the involved veins. Vascular complications and other causes of morbidities were recorded. All the patients were evaluated with computed tomographic (CT) scan within postoperative 3 weeks. The results of postoperative imaging study were also reviewed.

Graft patency was determined by CT scan in all cases but one case, in which it was determined by a second-look operation. Severe stenosis was defined as >50% narrowing of the luminal diameter. If distal blood flow was maintained despite severe stenosis, the graft was defined as patent. If total occlusion or segmental thrombosis disturbing blood flow had occurred, the graft was defined as failed. Mortality was determined using recent medical records and government database.

Venous resection and reconstruction were performed according to standard vascular techniques [4]. The tumor was dissected and the extent of venous invasion was

determined. The proximal and distal portions of the involved vein were clamped and *en bloc* tumor resection with the involved vein was performed. The surgical methods for reconstruction and the conduits used were tailored according to the vein involved and the extent of resection. Consultation for venous reconstruction was usually performed preoperatively according to CT images. Preoperative CT scan was also reviewed by a vascular surgeon to analyze the diameter of veins and the extents of involved segments. When primary repair seemed to be difficult, preoperative mapping of great saphenous vein (GSV) was done. Statistical analyses were performed using Fisher exact test, the chi-square test and the Mann-Whitney test. The Kaplan-Meier method was used to calculate graft and patient survival rates. A P-value < 0.05 was considered statistically significant. All statistical analyses were performed using the IBM SPSS ver. 18.0 (IBM Co., Armonk, NY, USA).

RESULTS

Demographics

A total of 330 patients were diagnosed as pancreatic cancer and underwent surgery, mainly pancreaticoduodenectomy, during the study period. Among them, 16 venous reconstructions were performed in 14 patients. Median patient age was 66 years (range, 51 to 73 years). Seven male and 7 female patients were included. All the patients were diagnosed with stage II (n = 10) or III (n = 4) pancreatic cancers. The involved veins were the SMV in 14 cases and the PV in 2 cases. The demographics and surgery-related characteristics are summarized in Table 1.

Operative techniques

Of 14 patients, 10 underwent pancreaticoduodenectomy, 3 total pancreatectomy and 1 distal pancreatectomy. Surgical methods for the PV or SMV reconstruction included segmental resection with end-to-end anastomosis in 7 patients and wedge resection with venoplasty in 2 patients. In 3 patients, lateral resection and bovine patch repair was performed (Fig. 1). In 1 patient, segmental resection of the SMV and interposition graft with bovine

Table 1. Summary of patients, methods of the surgery and the results

No.	Age (yr)	Sex	Name of operation	Involved vein	Surgical method for venous reconstruction	Results of CT scan	F/U (mo)
1	73	F	PD	SMV	SR & EEA	No stenosis	8
2	55	F	TP	SMV	SR & EEA	Mild stenosis ^{a)}	16
3	63	F	PD	SMV	SR & EEA	Segmental occlusion ^{a)}	6
4	68	F	PD	SMV	SR & EEA	Severe stenosis	10
5	62	F	TP	SMV	SR & EEA	No stenosis	22
6	51	M	PD	PV	Wedge resection ^{b)}	No stenosis	18
7	68	F	PD	SMV	Interposition graft with GSV	Total occlusion ^{c)}	6
8	68	F	PD	SMV	Interposition graft with PTFE	Total occlusion ^{c)}	6
9	68	F	PD	SMV	Spiral graft with GSV	No stenosis ^{a)}	6
10	60	M	PD	PV	Bovine patch angioplasty	Mild stenosis	12
11	72	F	PD	SMV	Bovine patch angioplasty	Mild stenosis ^{c)}	8
12	52	M	PD	SMV	SR & EEA	No stenosis	10
13	64	F	PD	SMV	Wedge resection	Mild stenosis	11
14	66	M	PD	PV	SR & EEA	No stenosis ^{c)}	9
15	71	M	DP	SMV	Bovine patch angioplasty	Mild stenosis	4
16	73	M	PD	SMV	Interposition graft with bovine patch	No stenosis ^{c)}	4

CT, computed tomography; F/U, follow-up; PD, pancreaticoduodenectomy; SMV, superior mesenteric vein; SR & EEA, segmental resection and end-to-end anastomosis; TP, total pancreatectomy; PV, portal vein; GSV, great saphenous vein; PTFE, polytetrafluoroethylene; DP, distal pancreatectomy.

^{a)}Intra-abdominal fluid collection. ^{b)}Wedge resection with venoplasty. ^{c)}Anticoagulation therapy or use of antiplatelet agent.

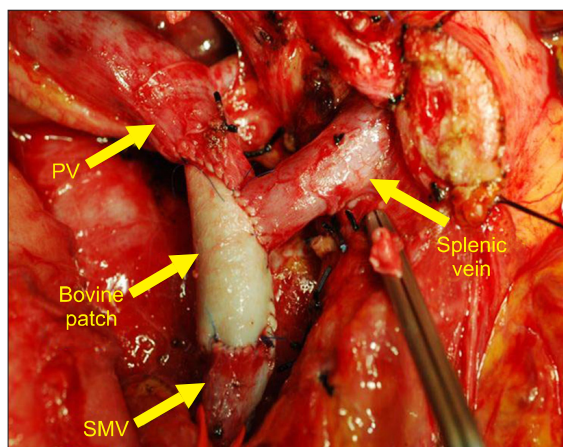


Fig. 1. The superior mesenteric vein (SMV) and portal vein (PV) reconstruction with bovine patch angioplasty.

patch was performed (Fig. 2). In one patient, spiral graft with GSV was performed after the failure of interposition graft with GSV and polytetrafluoroethylene (PTFE) (Fig. 3). Final pathologic examinations of the resected venous segment showed venous invasion by the tumor in 11 patients. In 3 patients, no tumor cells were detected in the resected veins. Negative margins were obtained in all patients.

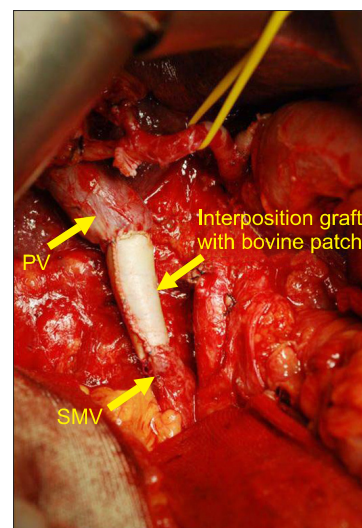


Fig. 2. The superior mesenteric vein (SMV) reconstruction with interposition graft with bovine patch. PV, portal vein.

Patency of the revascularization

All patients were evaluated by CT scans within 3 weeks of the surgery and every 3 to 6 months thereafter. Four cases of vascular complications were observed in 3 patients, a segmental thrombosis of the SMV, severe stenosis of the SMV, and bowel edema after interposition graft with GSV

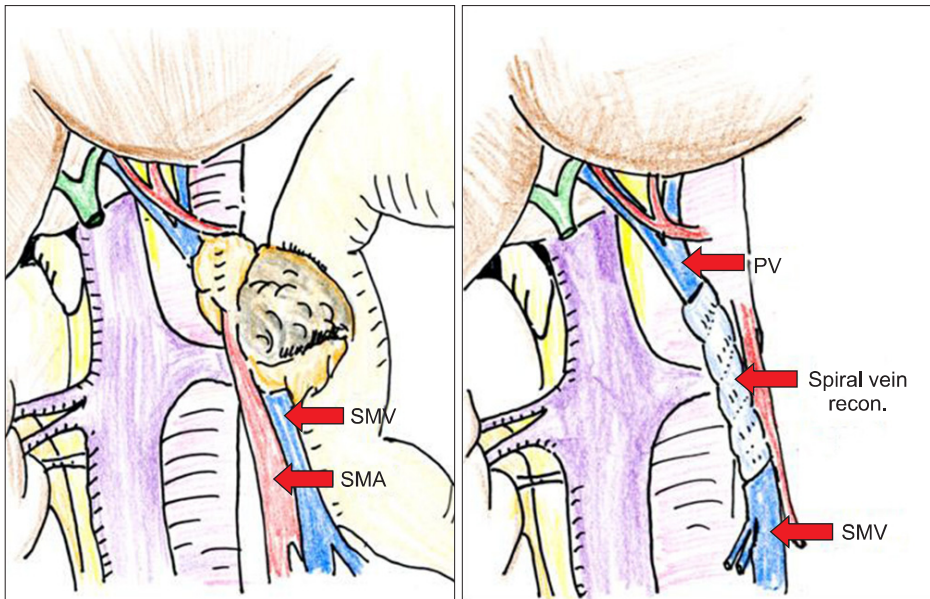


Fig. 3. Schematic illustrations of superior mesenteric vein (SMV) reconstruction with a spiral graft with a great saphenous vein. SMA, superior mesenteric artery; PV, portal vein.

and an occlusion of PTFE interposition graft. The first patient a 63-year-old woman (Table 1, case no. 3) underwent segmental resection with end-to-end anastomosis of the SMV. On follow-up CT scan, a 4.5 cm segmental occlusion with severe stenosis was detected. Loculated fluid collection was observed around the graft. The cause of occlusion was thought to be anastomotic tension and inflammation due to complicated fluid collection. But there was no clinical symptom associated with the stenosis of reconstructed SMV.

The second patient, a 68-year-old woman (case no. 4) underwent segmental resection and end-to-end anastomosis of the SMV. Owing to immediate occlusion with thrombosis, further resection and reanastomosis were performed. Severe stenosis was detected on a CT scan 3 days after the operation. But there was no clinical symptom.

The third patient, a 68-year-old woman (case no. 7) underwent segmental resection of the 4-cm length SMV and reconstruction with a GSV interposition graft. Because of the size mismatch between the SMV and the GSV graft, bowel congestion developed. Therefore, an interposition graft with 8-mm PTFE (case no. 8) was made and delayed closure of abdominal wall was planned. Two days later, however, graft occlusion was observed during a second look operation. To overcome the size discrepancy and pos-

sible infectious complication, the PV was reconstructed with a spiral graft of GSV (case no. 9).

In all of these patients, thrombosis or stenosis was observed within 1 week after the operation. None of these patients showed additional delayed graft failure during follow-up. With mean follow-up of 9.8 months (median, 8.5 months), the 6- and 12-month death-censored graft patency rates were both 81.3%. Three patients died during the study period. The 6- and 12-month patient survival rates were 71.4% and 55.1%, respectively.

Risk factors

Of the 3 patients who experienced complicated fluid collection around the graft, one patient who underwent end-to-end anastomosis developed segmental occlusion with severe stenosis.

Postoperative anticoagulation therapy was done in 4 patients with low molecular weight heparin (LMWH) or antiplatelet agents. Patients underwent end-to-end anastomosis, patch angioplasty, and interposition graft with bovine patch were included and target veins remained patent. They were treated with LMWH for a week, followed by aspirin.

Two of 3 patients with vascular morbidity after reconstruction underwent end-to-end anastomosis. The other patients underwent interposition graft with PTFE fol-

lowed by GSV. All patients who underwent reconstruction with a bovine patch, spiral graft, or wedge resection with venoplasty remained patent.

DISCUSSION

Tumor invasion into the PV or SMV can be met occasionally during surgery for pancreatic cancer. Vascular surgeons are asked to reconstruct the vein appropriately, but it is quite difficult to decide the optimal surgical method and conduit for each patient. When reconstruction with primary repair is impossible, a suitable size-matched conduit is required. GSV is the most widely used autogenous vein graft, but it is too small in diameter to fit the PV or SMV segments. The use of prosthetic grafts is limited due to the concerns about infection, especially during contaminated abdominal surgery.

Various types of autogenous veins have been used. Fleming et al. [7] reported that the superficial femoral vein was an excellent size-matched conduit for reconstruction of the SMV or PV without serious complications associated with venous insufficiency in the leg. The patency of reconstruction of the PV or SMV using the femoral vein or GSV reported by Lee et al. [11] was 88% at mean follow-up of 5 months with only a few patients developing mild lower leg edema. Suzuki et al. [10] demonstrated that reconstruction of the inferior vena cava (IVC) or PV with the left renal vein was durable and safe method without adverse effects on early and long-term renal function. A case report described PV interposition with a cold-preserved homologous iliac vein graft obtained from a deceased donor [12]. To overcome size discrepancy, the gonadal vein had been customized by cutting longitudinally and suturing into a sheet or tube-like graft [5]. Despite of many efforts, the best option for PV and SMV reconstruction during surgery for pancreatic cancer remains unclear.

Five types of surgical method were used in our patients, with resection of the involved venous segment and reconstruction with primary repair being the most common. But sometimes tension-free anastomosis was impossible. Wedge resection with venoplasty was possible when only the lateral wall of the vein was invaded by the tumor.

When the proportion of the circumference of the sacrificed vein was extensive, there was a risk of stenosis. If the involvement was more than 20% of the circumference of the vein, we tried to use a bovine patch for lateral wall reconstruction. Three patients underwent bovine patch angioplasty and any occlusion or significant stenosis was not detected on follow-up CT scans. Bovine patches are widely used in the revascularization of the carotid or femoral artery, but have not been widely used in venous reconstruction. Only a few literatures commented the durability of the bovine patch in venous reconstruction. A study of IVC reconstruction in patients with renal cell carcinoma found that 8 of 17 patients with bovine patch angioplasty remained patent at a mean follow-up of 18 months [13].

Bovine patches have many advantages for anastomosis, including easier handling, no need for additional incisions to harvest the GSV or superficial femoral vein, reasonable costs. Patches in various sizes are readily available for off-the-shelf use. They also have the advantage of strong durability, excellent biocompatibility, and low rate of infection [14,15]. One complication of bovine grafts, pseudoaneurysm, thought to be caused by graft deterioration [16]. But this is expected to occur rarely in venous anastomosis due to reduced pressure and mechanical stress. Little is known to date about the outcomes of venous repair with bovine grafts. Although the follow-up time of the present study was relatively short, bovine patch angioplasty was found to be patent without symptoms. Considering the advanced stages of the original tumors and limited life expectancy of the patients, prompt recovery after surgery seems to be more important to the patient than long-term patency of the target vein.

If the tumor involvement was more extensive (i.e., the involved segment was more than a half of the circumference), we tried to reconstruct the PV or SMV with interposition graft. In arterial bypass of lower extremities, GSV and PTFE are the widely used conduits. However, GSV is too small to overcome the size-mismatch with the PV or SMV. Vascular surgeons are also reluctant to use PTFE graft during contaminated intra-abdominal surgery. Although there were a few studies with acceptable results of PTFE graft in selected patients [1,2], the concerns for in-

fection and thrombosis in contaminated intra-abdominal surgery still exist. As an alternative, bovine patch or spiral graft can be used.

One of our patients underwent a spiral graft with a GSV for reconstruction of the SMV during pancreaticoduodenectomy. Spiral saphenous venous grafts have been used as substitutes for large-diameter veins, such as the internal jugular vein and vena cava [17,18]. Chiu et al. [6] recommended that PV reconstruction with spiral graft could be considered prior to other methods. After calculating the required lengths, the harvested GSV can be wrapped around a chest tube and sutured to make a spiral composite [6]. This type of graft can be tailored to fit a vessel of any size and easy to handle. We utilized this method to salvage a failed interposition graft of the SMV. During the initial operation, the SMV was reconstructed with a GSV, but severe bowel congestion developed due to size mismatch. An interposition graft with PTFE was performed, and a second-look operation was planned. When the PTFE graft was found to be occluded, a spiral vein graft was performed, resulting in the restoration of portal flow and an immediate improvement of bowel edema. A spiral GSV graft may be an ideal conduit in such circumstances, overcoming the drawbacks of small-sized autogenous vein and prosthetic grafts. Despite intra-abdominal fluid collection and hematoma compressing the graft, it remained patent for 6 months in this patient.

Owing to the small sample size, our ability to determine the risk factors for vascular complications was limited. However, our findings provide some clues about factors related to stenosis or thrombosis. Of the 2 patients who experienced severe stenosis or thrombosis, one had intra-abdominal fluid collection around the reconstructed vein. Stenosis was likely caused by adjacent localized fluid collection compressing the graft and inducing inflammation. The other underwent reanastomosis immediately after the first procedure due to immediate thrombosis. Increased tension after further resection and reanastomosis was thought to be the cause of stenosis. Patients who underwent reconstruction with a spiral graft or bovine patch remained patent without stenosis. Primary repair could cause tension or stenosis in the reconstructed vein, especially in patients with adjacent fluid collection. We think

angioplasty or interposition graft with bovine patch can be used easily and widely to prevent anastomotic tension and stenosis.

There are no standard guidelines for anticoagulation therapy in patients who undergo venous reconstruction. In a study of the durability of 64 PV reconstructions by Smoot et al. [19], no significant difference in thrombosis rate was observed between who did and those did not receive anticoagulation. Most patients remained patent without the use of warfarin or aspirin, and that anticoagulation therapy did not seem to influence outcomes. Because of the high flow and the absence of valves in the portomesenteric vein, the risk for thrombosis seemed to be low. However, endothelial injury occurred during surgery and cancer-related hypercoagulability may cause venous thrombosis. Comparative studies on outcomes in patients with and those without anticoagulation are needed to establish a standardized protocol.

This study had several limitations. First, it involved a small number of patients, limiting statistical analysis. Second, the mean follow-up period was relatively short. However, since the expected survival of this group of patients is about 10 to 18 months, good results after 6 months are encouraging.

In conclusion, many of the involved vein segments during surgery for pancreatic cancer can be reconstructed with end-to-end anastomosis or wedge resection with venoplasty. When tension-free anastomosis or venoplasty without stenosis is doubtful, angioplasty with a bovine patch graft are good options to overcome the size mismatch or resultant stenosis. If the tumor involvement was more extensive interposition graft with bovine patch or spiral graft with a GSV can be tried. Revascularization methods and intra-abdominal complicated fluid collection may be related to graft occlusion and severe stenosis. Further follow-up of these patients and evaluation of additional patients are required to determine long-term graft patency and the risk factors for thrombosis or stenosis.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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