Techniques and results of portal vein/superior mesenteric vein reconstruction using femoral and saphenous vein during pancreaticoduodenectomy

Dae Y. Lee, MD,[a] Erica L. Mitchell, MD,[a] Mark A. Jones, MD,[a] Gregory J. Landry, MD,[a] Timothy K. Liem, MD,[a] Brett C. Sheppard, MD,[b] Kevin G. Billingsley, MD,[b,c] and **Gregory L. Moneta, MD,[a]** *Portland, Ore*

Background: **Patients with pancreatic tumors may have portal vein (PV) and/or superior mesenteric vein (SMV) invasion. In such cases, lower extremity veins can provide an autogenous conduit for PV/SMV reconstruction. Little data exist, however, describing the technique of PV/SMV reconstruction, patency of such reconstructions, and the morbidity of using lower extremity veins for PV/SMV reconstruction during pancreaticoduodenectomy.**

Methods: **Thirty-four patients underwent PV/SMV reconstruction during pancreaticoduodenectomy using lower extremity vein. The saphenous vein was preferred for patching and femoral vein for replacement. We analyzed preoperative imaging, reconstruction patency, vein harvest morbidity, and late mortality.**

Results: **The mean age was 62.6 years. All 34 patients had preoperative computed tomography (CT) imaging and/or endoscopic ultrasound (EUS) scan. Fourteen of the 34 patients had evidence of PV/SMV invasion on CT or EUS scans, 14 did not, and six studies were indeterminate. Twenty-five patients had follow-up imaging, and 22 (88%) had patent reconstructions. Fifteen patients had PV/SMV replacement using femoral vein. Seven of these 15 had minor postoperative lower extremity edema that resolved over time, five had wound complications from the femoral vein harvest site, three of which required minor operative procedures for treatment. Fifteen patients had PV/SMV patching with the great saphenous vein, none had postoperative wound problems, and one had minimal postoperative lower extremity edema. Four patients had PV/SMV patching using femoral vein, none had postoperative wound problems, and one had minimal postoperative lower extremity edema. Compared with patients undergoing pancreaticoduodenectomy without PV/SMV reconstruction, by Kaplan-Meier analysis, there was no difference in late mortality.**

Conclusion: **Preoperative imaging may fail to detect PV/SMV involvement in patients undergoing pancreaticoduodenectomy. The PV/SMV reconstruction with leg vein provides good patency with minimal postoperative lower extremity complications and no increase in late mortality. The lower extremities should be routinely included in the operative field of patients undergoing pancreaticoduodenectomy. (J Vasc Surg 2010;51:662-6.)**

Adenocarcinoma of the pancreas is the fifth leading cause of cancer death in the United States with 30,300 new cases and 29,700 deaths reported in 2002.[1] The management of pancreatic tumor invasion into the lateral wall of the portal vein (PV) or superior mesenteric vein (SMV) represents a difficult challenge to the surgeon performing pancreaticoduodenectomy. Invasion of the PV/SMV is currently not a contraindication to resection as long as the veins are patent.[2] Preoperative involvement of the PV/SMV is difficult to ascertain, and in many instances, the vascular surgeon may be consulted intraoperatively for assistance in reconstructing the PV/SMV during resection of the tumor.

The purpose of this study was to evaluate our experience with PV reconstruction during the course of pancreaticoduodenectomy using either the femoral vein (FV) or great saphenous vein (GSV). Patency of the reconstructions was determined along with morbidity of the vein harvests and late mortality.

PATIENTS AND METHODS

All patients undergoing PV/SMV reconstruction during pancreaticoduodenectomy at our institution from January 1999 to February 2009 were identified from a prospectively established vascular surgery and general surgery registry and via Current Procedural Terminology (CPT) codes. Institution Review Board (IRB) approval was obtained before starting this study. Hospital medical records along with vascular laboratory studies, radiologic studies, and endoscopic ultrasound (EUS) scan studies were evaluated and entered into a database. Information included preoperative diagnosis, vein mapping studies, type of reconstruction, preoperative computed tomography (CT) scan reports, EUS scan reports, final pathology, complications of the vein harvest, follow-up patency of the PV/SMV reconstruction, and survival. Mortality was determined by

From the Division of Vascular Surgery,[a] the Division of General Surgery,[b] and the Division of Surgical Oncology,[c] Department of Surgery, Oregon Health & Science University.

Competition of interest: none.

Presented at the 2009 Vascular Annual Meeting; Denver, Colo, June 10-14, 2009.

Reprint requests: Gregory L. Moneta, MD, Oregon Health & Science University, 3181 SW Sam Jackson Park Road, OP 11, Portland, OR 97201-3098 (e-mail: monetag@ohsu.edu).

The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a competition of interest.

0741-5214/$36.00

doi:10.1016/j.jvs.2009.09.025

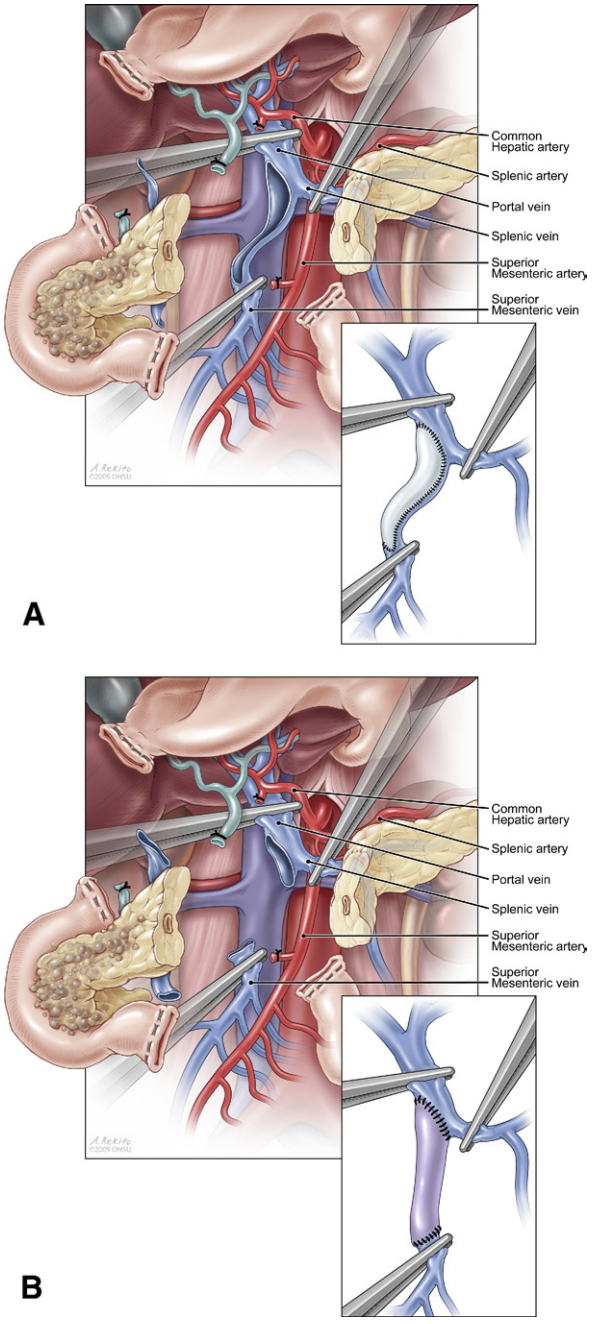

Fig 1. A, Reconstruction using vein patch. **B,** Reconstruction using a femoral vein interposition graft.

medical records and through review of the social security death index.

In cases where PV/SMV involvement was suspected preoperatively, vein mapping was performed to evaluate the diameter and wall characteristics of the GSV and FVs of both lower extremities. The technique of PV/SMV reconstruction was dictated at the time of operation by the extent of involvement of the portal vein, SMV, or PV/SMV confluence. In general, if the involvement of the PV/SMV was less than one-third of the circumference of the vein, the involved portion was excised in an elliptical fashion, and a GSV patch was placed (Fig 1, *A*). Patch repairs were performed with continuous polypropylene sutures. If the tumor involvement was more extensive (ie, greater than one-third the circumference of the vein), then an interposition graft using FV was performed. The posterior wall of the interposition graft was performed with interrupted 6-0 polypropylene sutures, and the anterior wall of the anastomosis was performed with either interrupted or running 6-0 polypropylene sutures to avoid anastomotic purse-stringing (Fig 1, *B*). The segment of vein that is patched or replaced is usually 4-5 cm in length, and an appropriate length of GSV or FV is harvested before resection of the involved segment of vein. Interposition grafts were performed with a moderate amount of tension, as once the specimen is removed and the retractors are released, some laxity on the reconstruction occurs. When interposition grafts extended above the level of the splenic vein, the splenic vein was selectively ligated or reconstructed depending on the request of the oncologic surgeon. Reconstruction of the splenic vein was either by reimplantation directly into the side of the interposition graft or with an additional piece of FV end-to-end to the splenic vein and end-to-side to the interposition graft. Three thousand to 4000 units of heparin were given before clamping the splanchnic veins. If necessary, an additional 1000 units of heparin was given after 1 hour. Inflow occlusion of the superior mesenteric artery was not utilized during clamping of the PV, SMV, and splenic vein. The heparin was not reversed after the reconstruction was completed.

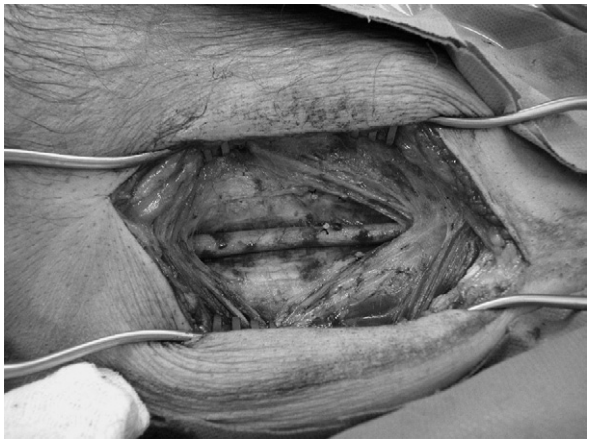

Fig 2. Femoral vein harvest.

Leg veins were harvested through continuous incisions. If the FV was harvested, a closed suction drain was left in place until the output was less than 40 mL/day. The FVs were harvested from the mid to proximal thigh up to the profunda femoris vein (Fig 2) and great saphenous veins harvested from the saphenofemoral junction distally. Drains were not placed after saphenous vein harvest.

Fig 3. Superior mesenteric vein reconstruction with an interposition femoral vein graft. The vessel loop is around the splenic vein.

Data were collected in a database (Microsoft Excel, Redmond, Wash) and analyzed using statistical software (SPSS v 17, Chicago, Ill). Independent sample *t* tests and Kaplan-Meier curves were performed.

RESULTS

From January 1999 to February 2009, 34 of 323 patients (11%) undergoing pancreaticoduodenectomy at our institution also underwent PV/SMV reconstruction using saphenous vein or FV. Of the 34 patients who underwent PV reconstruction for tumor adherence or invasion of the PV/SMV, only 14 had evidence of PV/SMV involvement on preoperative CT or EUS scans. Six patients were not clear as to the involvement of the PV/SMV on preoperative studies, and 14 had CT scans or EUS scan studies that were read as negative for PV/SMV tumor involvement. During the pancreaticoduodenectomies, the PV was patched in 19 cases, and interposition grafts were placed in 15 cases. The GSV was used for the patch in 15 cases and FV in four cases where the GSV was too small. Interposition grafts were performed exclusively with FV (Fig 3).

Few complications were seen with the leg vein harvests. Three patients required seroma drainage after an FV harvest and two had minor wound dehiscences after FV harvest. Nine patients were noted to have minimal transient postoperative edema in the operative leg, eight who had undergone FV harvest and one who had undergone saphenous vein harvest.

Follow-up of the patients with venous duplex of the lower extremity was not routine and was performed only for clinical indications. There were 11 patients who had follow-up venous duplex scan examinations of the lower extremities. Three were found to have a deep venous thrombosis (DVT). One of the three had thrombosis of the vein distal to where the FV was ligated at an examination performed 2 years after the vein was harvested. Two patients were found to have ipsilateral DVT proximal to the ligation of the FV. Both of these patients also had leg edema and both required seroma drainage.

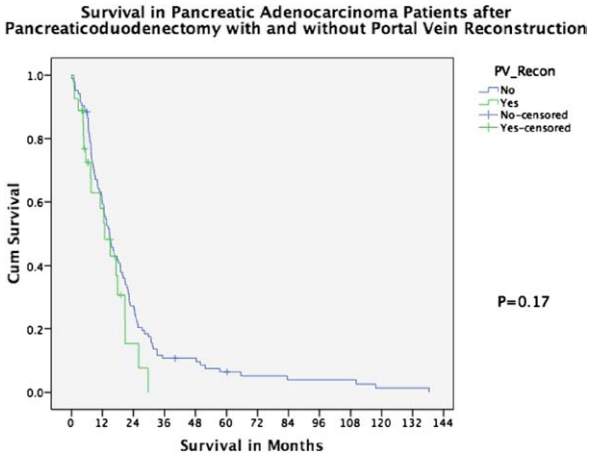

Fig 4. Kaplan-Meier curves for patient survival after pancreaticoduodenectomy in patients with adenocarcinoma of the pancreas with (*green line*) and without (*blue line*) reconstruction of the portal or superior mesenteric veins.

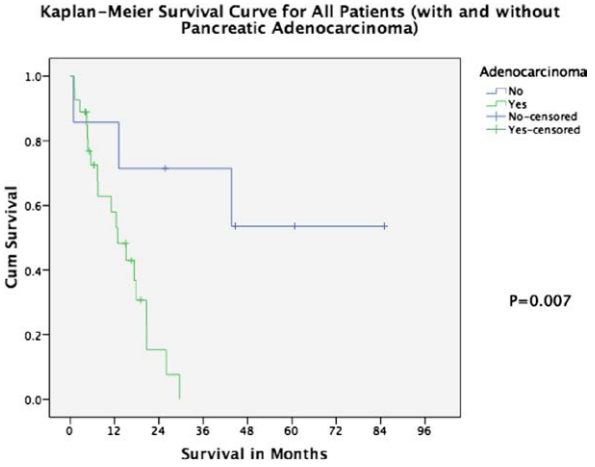

Fig 5. Kaplan-Meier curves for patient survival after pancreaticoduodenectomy in patients with (*green line*) and without (*blue line*) adenocarcinoma of the pancreas.

The final pathology in 27 of the 34 patients with PV/SMV reconstruction was adenocarcinoma. Mean survival for all 34 patients was 26.2 ± 5.7 months. The median survival for all 34 patients was 17.3 ± 3.0 months. The majority of the patients (n = 22, 65%) underwent the operation more than 2 years before this study with 10 patients undergoing pancreaticoduodenectomy with PV/SMV reconstruction over 4 years before the study. Kaplan-Meier curves comparing survival in patients with pancreatic adenocarcinoma, with and without PV/SMV reconstruction, were not statistically different ($P = .17$; Fig 4). However, survival for all patients with adenocarcinoma was worse than that for those without adenocarcinoma ($P = .007$; Fig 5).

Follow-up imaging studies were selectively performed at the discretion of the oncologic surgeon and primarily to

assess for tumor recurrence. Twenty-five of 34 patients had follow-up imaging studies. The mean time to imaging studies was 5 months ± 7 months (range, 5-792 days). Twenty-two of the 25 studies (88%) showed patency of the PV/SMV reconstruction. Two patients occluded their interposition graft within 3 weeks after undergoing pancreaticoduodenectomy. These two patients survived their hospitalization, but death was at 80 days in one patient and 130 days in the other. One additional patient with mucinous noncystic carcinoma developed eventual extrinsic compression and occlusion of the PV/SMV reconstruction at 200 days postoperatively from recurrence of disease but was still alive at 783 days postoperatively.

DISCUSSION

A PV/SMV reconstruction with either patch venoplasty or an interposition vein graft is a viable option to facilitate pancreaticoduodenectomy when there is suspected tumor invasion or adhesion to the PV/SMV. Previous studies, in addition to ours, have shown that survival after pancreaticoduodenectomy for pancreatic cancer, with reconstruction of the PV/SMV, is similar to patients undergoing pancreaticoduodenectomy for pancreatic cancer with no PV/SMV invasion. Fuhrman et al[3] reported 23 patients with localized invasion of the PV/SMV confluence that required resection and reconstruction to complete the pancreaticoduodenectomy. There was no difference in median survival when compared with 36 control patients who did not require PV/SMV reconstruction. In a follow-up study, the authors report 31 patients who required resection of the PV/SMV confluence along with the pancreatic resection. These patients were compared with 44 controls (patients undergoing standard pancreaticoduodenectomy without PV/SMV reconstruction). Again, no difference in survival was noted. The authors suggest venous invasion is more a marker of tumor location and not a marker of tumor aggressiveness.[4] In another large study, Tseng et al[5] evaluated survival in 126 patients who underwent PV/SMV reconstruction after pancreaticoduodenectomy using internal jugular vein. They also found that properly selected patients with adenocarcinoma of the pancreatic head who require venous reconstruction have a median survival that does not differ from those that undergo a standard pancreaticoduodenectomy.

In our study, there was also no statistical difference in survival in the patients undergoing pancreaticoduodenectomy for pancreatic cancer with and without PV/SMV reconstruction. However, the overall number of patients requiring PV/SMV reconstruction to facilitate a Whipple resection for cancer is relatively small in any series. Dogmatic conclusions regarding equal survival of patients undergoing PV/SMV reconstruction during pancreaticoduodenectomy are probably not warranted at this time. It does, however, seem they do not do dramatically worse than those patients not requiring PV/SMV reconstruction. This would seem a fertile area for a meta-analysis of the available literature on this subject.

The type and extent of PV/SMV reconstruction during pancreaticoduodenectomy is dependent upon the extent of involvement of the SMV and PV. In cases where the tumor involves only a portion of the wall of the PV/SMV, the involved portion can be excised in an elliptical fashion and reconstruction of the PV/SMV achieved with a vein patch.[6] It is our opinion that this requires less than one-third of the vessel circumference to be involved. In the event that a greater degree of vessel involvement is found, we believe reconstruction is best achieved with placement of an interposition graft using a reversed FV graft.

There have been studies using polytetrafluoroethylene for PV/SMV reconstruction.[7] However, the poor durability and increased risk of infection have made the autogenous vein graft the preferred material for reconstruction. Autogenous PV/SMV reconstruction has previously been reported primarily using internal jugular vein as the venous conduit. Use of FV[8] and the left renal vein[9] has also been reported, although to our knowledge, this is the largest series employing lower extremity veins.

The PV/SMV involvement with tumor can sometimes be determined preoperatively. The CT scan findings such as PV or SMV narrowing, PV wall irregularity, or circumferential involvement of the PV >90 degrees raise the suspicion of tumor involvement.[10] An EUS scan can also be utilized to help identify PV involvement. Findings of irregular venous walls, loss of interface, and proximity of the tumor mass can also raise the suspicion of PV involvement.[11] An EUS scan, however, is rather insensitive for detecting SMV involvement. The specificities of the preoperative imaging studies increase as the number of pertinent findings increase. However, the sensitivities of these studies remain marginal at best.

The lower extremities can be easily prepped into the sterile field. We believe this should be routine for pancreaticoduodenectomy, as many times preoperative imaging studies do not adequately demonstrate tumor adherence or invasion of the PV/SMV. In fact, only 14 of the 34 patients in this series had suspected PV/SMV involvement with preoperative endoscopic ultrasound scan or CT scanning. Routine prepping of the lower extremities for pancreaticoduodenectomy will avoid the inconvenience of having to prepare a new sterile field for harvest of a venous conduit, should PV/SMV reconstruction unexpectedly become required. Once the anatomy is visualized, and suspected tumor adhesion or invasion of the PV/SMV identified, the lower extremities can easily be positioned for harvest of the GSV or FV without the need to reposition the mechanical retractors already in place for the pancreaticoduodenectomy. Because many times the venous reconstruction can be achieved with a vein patch rather than an interposition graft, prepping the lower extremities into the field allows use of the GSV for the venous reconstruction, avoiding harvest of a major vein such as the internal jugular vein or left renal vein.

When PV/SMV reconstruction is anticipated preoperatively, the suitability of the FV and GSV to serve as a venous conduit or patch can be determined with ultra-

sound scan vein mapping before surgery to assess for adequate diameter and length. In such cases, it is then necessary to prepare only the lower extremity with the best potential venous conduits into the operative field.

The FV is a very versatile conduit for vascular reconstructions. Although it does not elongate under arterial pressure like a saphenous vein and is a bit tedious to harvest, it is a very useful conduit for arterial and venous reconstructions. Among other indications, in our practice, in addition to using FV for PV/SMV reconstruction, we have used FV as a replacement for infected lower extremity and intra-abdominal prosthetic grafts, as a replacement for the common carotid artery during resection of head and neck tumors, for splanchnic artery reconstruction in the setting of bowel infarction, and for reconstruction of traumatic intra-abdominal vascular injuries when there is concomitant bowel injury.

There is little in the way of reported harvest-related complications of the FV as long as the profunda femoris vein is preserved and the harvest does not extend into the popliteal fossa.[12] Morbidity related to harvest of lower extremity veins was also acceptable in this series with no severe cases of postoperative edema and minimal need for operative intervention to treat a harvest site wound complication. There were, however, three cases of known DVT in this series. Although one of these was below the harvest site and not diagnosed until 2 years postoperatively, it may be prudent to perform routine postoperative surveillance venous ultrasound scan studies after FV harvest.

Survival after PV/SMV reconstructions is routinely reported but patency is not. Patency does, however, seem to be quite good. In our study, patency was excellent in patients with follow-up imaging studies. Twenty-five patients had follow-up imaging studies at a mean of 5 months $\pm$ 7 months (range, 5-792 days), and 22 had patent reconstructions. Perioperatively occluded reconstructions were likely due to technical errors with kinking of an interposition graft, clearly the etiology in one of the two early occlusions.

CONCLUSIONS

A PV/SMV reconstruction with either GSV or FV is a viable option during pancreaticoduodenectomy. In this study, we have shown good patency of the reconstructions with minimal morbidity from the harvest sites. Lower extremities should be prepared within the operative field for possible GSV or FV use during pancreaticoduodenectomy.

AUTHOR CONTRIBUTIONS

Conception and design: EM, MJ, GL, TL, GM
Analysis and interpretation: DL, EM, MJ, GL, TL, GM
Data collection: DL, EM, MJ
Writing the article: DL, EM, MJ, GM
Critical revision of the article: DL, EM, GL, TL, BS, KB, GM
Final approval of the article: GM
Statistical analysis: DL, MJ, GL
Obtained funding: Not applicable
Overall responsibility: GM

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Submitted Jul 30, 2009; accepted Sep 12, 2009.