Prosthetic Graft Reconstruction after Portal Vein Resection in Pancreaticoduodenectomy: A Multicenter Analysis

Carrie K Chu, MD, Michael B Farnell, MD, FACS, Justin H Nguyen, MD, FACS, John A Stauffer, MD, David A Kooby, MD, FACS, Guido M Sclabas, MD, Juan M Sarmiento, MD, FACS

BACKGROUND: Use of prosthetic grafts for reconstruction after portal vein (PV) resection during pancreaticoduodenectomy is controversial. We examined outcomes in patients who underwent vein reconstruction using polytetrafluoroethylene (PTFE).

STUDY DESIGN: Review of prospectively maintained databases at 3 centers identified all patients who underwent pancreaticoduodenectomy (PD) with vein resection and reconstruction using PTFE grafts between 1994 and 2009. Patient, operative, and outcomes variables were studied. Graft patency and survival were assessed using the Kaplan-Meier technique.

RESULTS: Thirty-three patients underwent segmental vein resection with interposition PTFE graft reconstruction. Median age was 67 years; median Eastern Cooperative Oncology Group score was 1. Most operations were performed for pancreatic adenocarcinoma (n = 28, 85%); 96% were T3 lesions or greater. Standard PD was performed in 12 (36%) patients, pylorus-preservation in 17 (52%), and total pancreatectomy in 4 (12%). Combined resection of portal and superior mesenteric veins (SMV) was required in 49%, with resection isolated to PV in 12% and SMV in 39%. Splenic vein ligation was necessary in 30%. Median graft diameter was 12 mm (range 8 to 20 mm), with the majority being ring-enforced (73%). Median operative and vascular clamp times were 463 and 41 minutes, respectively, with median blood loss of 1,500 mL. The negative margin rate was 64%. Overall morbidity rate was 46%, and 30-day mortality was 6%. No patients developed irreversible hepatic necrosis or graft infection. Pancreatic fistulas occurred in 3 (9.1%). With mean follow-up of 14 months, overall graft patency was 76%. Estimated median duration of graft patency was 21 months. Median survival was 12 months for pancreatic adenocarcinoma.

CONCLUSIONS: With careful patient selection, PTFE graft reconstruction of resected PV/SMV during pancreaticoduodenectomy is possible with minimal risk of hepatic necrosis or graft infection. Comparison studies to primary anastomosis and autologous vein reconstruction are necessary. (J Am Coll Surg 2010;211:316–324. © 2010 by the American College of Surgeons)

Surgeons at high-volume centers are increasingly performing pancreaticoduodenectomy (PD) with concomitant vascular resection.[1-5] Once considered contraindicated for resection, locally advanced tumors involving the portal-mesenteric venous structures are now often resected with curative intent.[6,7] Although the utility of aggressive vascular resection in pancreatic adenocarcinoma continues to be debated,[8-12] several institutional series have demonstrated the feasibility of margin-negative resection with acceptable morbidity rates comparable to those after isolated PD.[2-5,13-15] Recent reports also have shown that patients with vascular tumor invasion who undergo concurrent vascular resection can achieve long-term survival rates equivalent to those without vascular involvement requiring PD alone.[2,3,5,14-17]

Still, extended operative time associated with an inherently complex surgical procedure is one criticism of vascular resection. Depending on the length, position, and extent of the removed segment, patch, or interposition graft,

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Departments of Surgery, Emory University School of Medicine, Atlanta, GA (Chu, Kooby, Sarmiento), Mayo Clinic, Rochester, MN (Farnell, Sclabas), and Mayo Clinic, Jacksonville, FL (Nguyen, Stauffer).

Correspondence address: Juan M Sarmiento, MD, Emory University Hospital, 1364 Clifton Rd, NE, Suite H-124-C, Atlanta, GA 30322. email: jsarmie@emory.edu

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Abbreviations and Acronyms

ECOG = Eastern Cooperative Oncology Group
PD = pancreaticoduodenectomy
PTFE = polytetrafluoroethylene
PV = portal vein
SMV = superior mesenteric vein

reconstruction may require autologous graft procurement at a separate and sometimes distant operative site (jugular, saphenous, renal veins).[2,18-20] Beyond increasing operative time, bleeding, infection, and thrombosis are all potential added morbidities.

Polytetrafluoroethylene (PTFE) grafts are commonly used in vascular reconstruction, but concern for prosthetic infection has restricted their application beyond clean cases.[21] Although synthetic graft use shortens operative time and eliminates possible complications associated with autologous vein harvest, the potential of reduced patency relative to autologous material represents an additional concern.[22,23] Within published institutional reports of vascular resection during pancreatectomy, isolated descriptions of PTFE use exist,[13,15,24] but focused series examining the use of PTFE in portomesenteric venous reconstruction are few.[14,25] This report represents a multicenter evaluation of a large number of patients who underwent pancreatectomy with vein resection and reconstruction using PTFE conduits. Our main goal was to demonstrate technical feasibility, especially with regard to satisfactory patency and minimal infections.

METHODS

Our study protocol was compliant with the Health Insurance Portability and Accountability Act of 1996 and was approved by respective institutional review boards with full waiver of consent.

Patient selection

Prospectively maintained pancreatic resection databases at 3 tertiary centers were queried to identify all cases of interposition PTFE graft reconstruction after segmental portal (PV) and/or superior mesenteric vein (SMV) resection with pancreatic head resection (PD or total pancreatectomy), from January 1, 1994 to July 1, 2009. Patients who underwent patch PTFE venoplasty were excluded. Medical records were reviewed. Demographics, comorbidities, and Eastern Cooperative Oncology Group (ECOG) performance status (scores 1 to 4) were noted. Preoperative evaluation included pancreas-dedicated CT, and, in some cases, MRI and/or endoscopic ultrasonography to assess tumor morphology, vascular involvement, and native anatomy. Mesenteric angiography was not routinely used.

Patient selection for PV reconstruction with PTFE was not standardized in this retrospective study. In the earlier portion of the study period, prosthetic use was generally reserved for cases of failed autologous vein reconstruction or otherwise difficult operations in which avoidance of further extended operative time was prioritized. Toward the latter portion of the study period, in the absence of gross abdominal contamination, in patients with few comorbidities and good performance status, some surgeons preferentially used PTFE grafts when primary anastomosis was unachievable.

Surgical technique

Because this study was not conducted prospectively, technical variations existed among surgeons and institutions. A description of general operative technique follows.

All resections were approached with curative intent. PD is approached in a typical fashion until the point of isolation of the avascular plane between the posterior pancreatic neck and the SMV. Degree of circumferential PV/SMV involvement is evaluated to determine the need for tangential versus segmental resection. PD is continued with transection of the bile duct, stomach/proximal duodenum, distal duodenum, and pancreas. Care is taken to avoid enteric and biliary content spillage. Once the PD specimen is isolated except for the adherent portion to the PV/SMV, 3,000 to 5,000 units of unfractionated heparin may be systemically administered, though some surgeons do not anticoagulate at this stage. After 5 minutes, proximal and distal clamps are applied on the PV and SMV, respectively. Venous clamp time is monitored. The vein is sharply divided and the specimen removed. Depending on tumor location, splenic vein ligation may be necessary. When tension-free end-to-end anastomosis is unachievable, even after mobilization maneuvers such as splenic vein ligation, mesenteric root mobilization, and hepatic ligament transection, options for interposition graft reconstruction are assessed. In general, unless no suitable veins of appropriate caliber are available or if limiting operative duration becomes of utmost importance for the patient, autologous vein (internal jugular, saphenous, iliac, inferior mesenteric, or renal veins) is harvested. If deemed preferable, an appropriately sized ringed or unringed PTFE graft (GORE-TEX; WL Gore & Associates, Inc) is selected. Before placement, the graft may be soaked in antibiotic irrigation solution. The graft is anastomosed first to the PV stump using a running 5-0 or 6-0 PTFE suture. The graft is then cut to length, and similarly sewn to the SMV stump. Before completion of the SMV anastomosis, the graft is irrigated with heparinized saline and flushed by release of the PV

clamp. The second anastomosis is then completed. During reconstruction, bowel and liver are visually monitored to detect signs of ischemia. Patient hemodynamics are also meticulously observed. Should clamp time exceed 30 to 45 minutes, heparinization may be repeated. The PV and SMV clamps are removed in that order, and the graft is observed for leaks. If needed, repair sutures are placed, and thrombin or other hemostatic agents may be applied. Doppler ultrasound may be used for immediate assessment of graft, PV, SMV, and arterial patency. If the splenic vein is divided, reimplantation via end-to-side anastomosis to either the graft or native veins may be performed. Some surgeons also create an omental wrap for graft protection. Pancreatic, biliary, and enteric reconstruction are then completed. Before closure, the peritoneal cavity is copiously irrigated using warmed saline and/or antibiotic solution.

For this analysis, clamp and operative times were noted, along with graft diameter and structure (ringed vs nonringed). Estimated blood loss and transfusion requirements were recorded. Operative reports were examined for variations in resected segments of PV and/or SMV, splenic vein management, and anastomotic anatomy of the interposition graft.

Postoperative management and graft surveillance

As with surgical technique, there was heterogeneity in the algorithm of postoperative graft surveillance. In general, patients were initially monitored in the intensive care setting. Based on surgeon preference and clinical status, Doppler ultrasound was performed in the recovery room or on postoperative day 1 to assess graft patency. Hepatic transaminase levels were monitored daily until normalization. Barring any bleeding or other contraindication, aspirin or low-dose warfarin therapy was initiated by the time of discharge, with continuation for 3 to 6 months. In cases of graft thrombosis without hemodynamic or end-organ compromise, therapeutic heparinization was used. One center continued perioperative antibiotics until resumption of oral diet. Radiographic assessment (ultrasonography, CT, and/or MRI) of the graft was generally performed before discharge.

For the majority of outpatients, radiographic graft surveillance was performed at the first postoperative visit. Subsequent imaging was dictated by clinical evidence of occlusion such as ascites, hepatic dysfunction, or other signs and symptoms of portal hypertension. For patients with adenocarcinoma, radiographic monitoring was continued as would be otherwise indicated.

In this study, graft thromboses detected within 30 days of operation were considered early events; cases diagnosed after 30 days were categorized as late thrombosis.

Outcomes

Pathology reports were reviewed. For neoplasms, margins, American Joint Committee on Cancer 2002 T stage,[26] number of removed and diseased nodes, presence of perineural or angiolymphatic invasion, and presence of true perivascular invasion were noted.

In-hospital recovery periods were assessed, with attention to overall and intensive care lengths of stay, peak serum aspartate aminotransferase and total bilirubin levels, liver-specific complications (hepatic insufficiency), pancreas-specific complications (fistula), infectious complications (abscess, wound infection, bacteremia, etc), and general morbidities. Pancreatic fistulas were defined as drain fluid amylase levels greater than 3 times the upper limit of institutional normal serum values beyond postoperative day 3. Submission of fluid for amylase levels was prompted by clinical suspicion of fistula. Attention was paid to graft-specific complications including thrombosis and infection, defined as bacteremia necessitating graft excision and culture. Overall complication severity was evaluated using the Clavien scale (0 to 5).[27] Events graded ≥ 3 were considered major. After discharge, in addition to graft-related outcomes (dates, types, and results of radiographic studies for patency), patient outcomes including last known disease status and dates of recurrence, last follow-up, and death were recorded.

Statistical analysis

Graft patency and patient survival were estimated using the Kaplan-Meier technique. Log-rank test was used for comparison. Comparison of clinical variables in patients with and without early thrombosis was performed using Fischer's exact and Wilcoxon rank sum tests for categorical and continuous variables, respectively. Statistical significance was defined as 2-tailed p value < 0.05. All analyses were performed using SPSS version 17.0 for Microsoft Windows (LEAD Technologies, Inc).

RESULTS

Patients

Between 1994 and 2009, 33 patients underwent reconstruction using interposition PTFE grafts after portal-mesenteric venous resection during PD at the 3 centers. Table 1 summarizes perioperative- and treatment-related data. Median age at operation was 67 years (range 37 to 78 years). There were 14 women (42.4%) and 19 men (57.6%). Hypertension was the most common comorbidity (n = 18, 54.5%). Additional comorbidities included diabetes mellitus (n = 9, 27.3%), coronary artery disease (n = 3, 9.1%), chronic kidney disease (n = 2, 6.1%), chronic obstructive pulmonary disease (n = 1, 3.0%), and

Table 1. Perioperative and Treatment Variables in 33 Patients who Underwent Portal Vein Reconstruction with PTFE Interposition Grafts with Pancreaticoduodenectomy

Variable	Data
Age, y	67 (37–78)
Gender	
Female	14 (42.4)
Male	19 (57.6)
ECOG score	
0	11 (33.3)
1	20 (60.6)
2	2 (6.1)
Neoadjuvant therapy	1 (3.0)
Preoperative biliary drainage	
None	14 (42.4)
Endoscopic	18 (54.5)
Percutaneous transhepatic	1 (3.0)
Operation	
Standard pancreaticoduodenectomy	12 (36.4)
Pylorus-preserving pancreaticoduodenectomy	17 (51.5)
Total pancreatectomy	4 (12.1)
Vein resection segment	
PV only	4 (12.1)
SMV only	13 (39.4
Combined PV and SMV	16 (48.5)
Splenic vein	
Ligated with or without reimplantation	10 (30.3)
Not ligated	23 (69.7)
Graft diameter, mm	
8	7 (21.2)
10	9 (27.3)
12	7 (21.2)
14	7 (21.2)
16	2 (6.1)
20	1 (3.0)
Graft structure	
Ringed	24 (72.7)
Nonringed	9 (27.3)
Venous clamp time, min*	41 (30–75)
Operative time, min	463 (231–712)
Estimated blood loss, mL	1,500 (200–7,800)
Intraoperative red blood cell transfusion	
None	8 (24.2)
1–4 units	11 (33.4)
> 4 units	14 (42.4)

All values presented as n (%) or median (range) as appropriate.
ECOG, Eastern Cooperative Oncology Group; PTFE, polytetrafluoroethylene; PV, portal vein; SMV, superior mesenteric vein.
*Venous clamp time available in 12 cases only.

previous mechanical valve replacement (n = 1, 3.0%). No patients had hepatic cirrhosis. Preoperative biliary stenting was performed in 19 cases (57.5%). One patient received neoadjuvant chemotherapy.

Table 2. Disease-Related Variables in 33 Patients who Underwent Portal Vein Reconstruction with PTFE Interposition Grafts with Pancreaticoduodenectomy

Variable	n	%
Histology		
Pancreatic ductal adenocarcinoma	28	84.8
Neuroendocrine tumor	1	3.0
Ampullary carcinoma	1	3.0
IPMN with high grade dysplasia	1	3.0
Lymphoplasmacytic sclerosing pancreatitis	2	6.1
AJCC T stage*		
T2	1	3.6
T3	25	89.3
T4	2	7.1
Differentiation*		
Well	0	
Moderately	14	50.0
Poorly	14	50.0
Perineural invasion*	19	67.9
Lymphovascular invasion*	14	50.0
Margin†		
Negative	21	63.6
Retroperitoneal margin positive	8	
Pancreatic neck margin positive	2	
Bile duct margin positive	0	
Vascular margin positive	0	
True tumor invasion of PV/SMV†	17	54.8
Harvested lymph nodes, median (range)	15 (2–67)	
Nodal metastasis†	21	63.6

AJCC, American Joint Committee on Cancer; IPMN, intraductal papillary mucinous neoplasm; PTFE, polytetrafluoroethylene; PV, portal vein; SMV, superior mesenteric vein.
*Includes 28 cases of pancreatic ductal adenocarcinoma only.
†Includes 31 patients with neoplastic disease.

Surgical treatment

Standard PD was performed in 12 patients (36.4%) and pylorus-preserving PD in 17 (51.5%). Four patients (12.1%) underwent total pancreatectomy. In the majority of cases (n = 16, 48.5%), combined PV and SMV resection was performed; resection was limited to PV in 4 patients (12.1%) and SMV in 13 (39.4%). No patients had concomitant arterial resection. Ringed grafts were more frequently used (n = 24, 72.7%). Median graft diameter was 12 mm (range 8 to 20 mm); distribution of graft sizes is shown in Table 1. Median clamp time was 41 minutes (range 30 to 75 minutes); median operative time was 463 minutes (range 231 to 712 minutes); and median estimated blood loss was 1,500 mL (range 200 to 7,800 mL). Intraoperative transfusion was required in 75.8%.

Histology

Table 2 summarizes the indications for resection. Most operations were performed for pancreatic ductal adenocar-

Table 3. Perioperative Outcome in 33 Patients who Underwent Portal Vein Reconstruction with PTFE Interposition Grafts with Pancreaticoduodenectomy

Variable	Results
Length of stay, d	11 (5–51)
ICU length of stay, d	2 (0–8)
30-d complications	
Overall morbidity	15 (45.5)
Major morbidity*	7 (21.2)
Delayed gastric emptying	5 (15.2)
Pancreatic fistula	3 (9.1)
Abscess	1 (3.0)
Bacteremia	1 (3.0)
Wound infection	2 (6.1)
Bleeding	2 (6.1)
Deep vein thrombosis	1 (3.0)
Pulmonary embolus	1 (3.0)
30-d portal vein thrombosis	3 (9.1)
30-d mortality	2 (6.1)

All results presented as n (%) or median (range) as appropriate.
*Major morbidity defined as Clavien complication scale 3 or greater.

cinoma (n = 28, 84.8%). In patients with neoplastic disease, margin-negative resection was achieved in 21 (63.6%). Positive margins occurred at the pancreatic neck in 2 cases, and the retroperitoneal margin in 8. None involved the resected PV or SMV. Confirmed portal-mesenteric venous invasion was identified in 17 (54.8%). Additional histologic data are shown in Table 2.

General perioperative outcomes

Thirty-day outcomes are summarized in Table 3. Median length of stay was 11 days (range 5 to 51 days), with a major morbidity rate of 21.2%. The most common complication was delayed gastric emptying (15.2%). Three patients (9.1%) developed pancreatic fistula (all International Study Group on Pancreatic Surgery grade B). No patients developed irreversible hepatic necrosis as evidenced by continuous rise in hepatic transaminase levels and liver function tests or by imaging. Median peak aspartate aminotransferase and total bilirubin levels were 155 U/L (range 45 to 8,763 U/L) and 2.1 mg/dL (range 0.6 to 19.7 mg/dL).

Thirty-day mortality was observed in 2 of 33 patients (6%). One patient with PV thrombosis died on postoperative day 16 after discharge with ascites, malnutrition, and severe deconditioning. Another patient with postoperative deep venous thrombosis on therapeutic anticoagulation died on postoperative day 16 after discharge, with profound dehydration and diabetic ketoacidosis despite graft patency as documented by CT on the day of death.

Infectious outcomes

No patients developed PTFE graft infection. Two patients experienced wound infections. One patient who had undergone previous distal pancreatectomy for neuroendocrine tumors with middle colic arterial disease extension developed colonic perforation requiring reoperation, at which time the graft was deemed salvageable without gross contamination. Despite extended stay requiring intensive care, the patient recovered and tolerated colostomy takedown less than 1 month later. With this sole exception, there were no other cases of abscess or bacteremia.

Graft patency

Graft patency was assessed before discharge in 21 patients (63.6%). Thrombosis was identified in 3 of these patients (14.2%), 2 of whom developed large-volume ascites requiring paracentesis. All were placed on oral anticoagulation after initiation of heparin. As previously described, 1 of these patients died at postoperative day 16; the other had resolution of portal hypertension symptoms 2 months later. Neither patient developed pancreatic fistulas. The remaining patient with early thrombosis did not manifest clinical signs of portal hypertension, but had a prolonged recovery course due to pancreatic fistula.

Owing to limited power, comparison of preoperative and treatment variables in patients with and without early graft thrombosis failed to identify factors associated with early thrombosis. All 3 patients who developed early thrombosis were male; other demographic and comorbidity data were similar to those of the remaining study population. None of the 3 patients underwent preoperative biliary stenting or neoadjuvant therapy. Standard PD with combined PV and SMV resection was completed in all 3 without splenic ligation. Reconstruction was completed using 8-, 10-, and 14-mm ringed grafts. All 3 patients had pancreatic ductal adenocarcinoma.

Mean follow-up time was 14 months, with all patients returning for at least 1 postoperative visit. After discharge, patency was most commonly assessed using CT (n = 21, 63.6%); MRI was used in 7 cases (21.2%) and ultrasonography in 2 (6.1%). Three patients did not undergo any postoperative imaging of the graft in absence of any occlusive symptoms. Late thrombosis was detected in 5 patients at 2, 6, 19, 21, and 39 months postoperatively. Of these, 4 were associated with concomitant disease recurrence. In contrast to patients with early graft thrombosis, occlusion beyond postoperative day 30 was not associated with other adverse clinical events. Estimated mean graft patency was 25.8 months (median 21 months). For the 22 patients who were alive at 6 months, radiographically confirmed actual graft patency rate was 77.3%. At 12 months, the actual patency rate was 64.3% for 14 survivors. The actual graft

patency rate at last follow-up for the series was 75.8%. Mean patency did not differ significantly based on graft structure (17.5 months ringed, 24.4 months nonringed, $p = 0.65$) or diameter (28.7 months $<$ 12 mm, 20.7 months $\geq$ 12 mm, $p = 0.98$).

Survival

Median ECOG score at last follow-up visit was 2 (range 0 to 4). Actuarial median survival was 12 months for the entire series. Excluding the 2 perioperative deaths, overall median survival for patients with pancreatic adenocarcinoma was also 12 months. Median disease-free survival was 7 months for patients with pancreatic adenocarcinoma.

DISCUSSION

Venous reconstruction after PD with segmental vascular resection is typically performed using autologous vein when tension-free primary repair is unachievable. Despite occasional description of their use in this setting, prosthetic grafts are generally avoided due to concerns of increased infection and decreased patency. In other realms of vascular surgery, PTFE has been shown to be a viable material for vascular replacement. The purpose of this analysis was to examine infection and patency rates in the combined experiences of hepatobiliary surgeons at 3 high-volume centers in using PTFE for reconstruction after portomesenteric venous resection during PD. A secondary aim was to evaluate cancer-related outcomes in the subset of patients with pancreatic adenocarcinoma requiring vein resection.

Infection

Although consensus among vascular surgeons is to avoid synthetic material in the presence of any possible field contamination, intra-abdominal use of PTFE for vascular reconstruction has been described in conjunction with major visceral resections, including the cava, liver, and pancreas.[28-34] Synthetic vascular graft reconstruction has also been used with concurrent intestinal surgery when enteric disruption is created in a controlled manner.[35,36] These experiences collectively suggest that careful selection and technique can allow for intra-abdominal use of prosthetic material with low frequency of infectious complications.

Multiple studies have examined vascular resection in PD. Within these reports are anecdotal descriptions of PTFE reconstruction.[13,15,24,37,38] These sporadic cases preclude meaningful assessment of infectious risk. Recently, Muller and colleagues,[14] from Germany, described 14 cases of PTFE interposition grafts without any graft infection. The current combined experience represents the largest published series evaluating the use of PTFE in PV/SMV reconstruction. None of the 33 patients developed graft infection. Administration of perioperative antibiotics, graft immersion in antibiotic solution, avoidance of enteric and biliary spillage, placement of an omental wrap, and use of antibiotic irrigant, albeit unquantitated in efficacy, are all potential means of minimizing infection. Our results suggest that infectious complications resulting from PTFE graft PV reconstruction are infrequent.

Patency

Medical use of PTFE was first introduced in the 1970s as an alternative means of arteriovenous conduit for hemodialysis access.[39] Since then, its availability, durability, inertness, neointimal integration capacity, and relatively low thrombogenicity have allowed for growing medical applications. In comparison with autogenous material, however, increased occlusion rates have rendered PTFE a secondary choice for extremity bypass and dialysis access. In mesenteric arterial bypass, reduced patency rates typically associated with prosthetic grafts are less definitive.[35,40] With some evidence of equivalence using PTFE and autologous vein, some surgeons preferentially use PTFE in such settings unless clearly contraindicated.[35,40] One explanation for the discrepancy may be the variable graft length required in the different vascular beds. Differences in pressure, flow, and volume in the various systems may also contribute.

The PV is a short-segment, large-diameter, high-volume, low-pressure system presenting unique properties from other mentioned vascular beds. As such, it is unknown whether extrapolated patency data are applicable. Overall rates of occlusion after PV reconstruction range from 0% to 17%, with wide variability in extent of resection, method of reconstruction, and timing and mode of graft surveillance.[2,3,5,15,19,41,42] There are few comparison studies of patency in graft reconstruction. One institutional series, with which this analysis overlaps in some study patients, examined PV reconstruction using PTFE interposition graft ($n = 9$), autologous gonadal/inferior mesenteric vein ($n = 7$), and primary anastomosis ($n = 10$). One hundred percent 1-month patency was seen after PTFE reconstruction as compared with 86% and 60% after autologous vein and primary anastomotic repairs, respectively. Patency of the PTFE grafts was maintained at 6 and 12 months.[29] In another retrospective institutional series, the actual rate of thrombosis was 33% in 18 patients with PTFE reconstruction compared with a combined 12% in 13 primary end-to-end and 29 lateral venorrhaphy repairs, a difference that was not statistically significant ($p = 0.16$). In the 4 patients who underwent reconstruction using autologous renal vein in this series, none developed graft thrombosis.[19]

In this analysis, median PTFE graft patency was 21 months, with actual patency rates of 77.3% and 64.3% at 6 and 12 months, respectively. The actual rate of thrombosis at last follow-up was 24.2%. Of the 8 cases of graft thrombosis, 3 occurred within 30 days of operation. Two were linked to additional postoperative morbidities and prolonged recovery, and 1 was asymptomatic. Of the 5 cases of late thrombosis, 4 were linked to simultaneous locoregional recurrence. None of the 5 experienced other adverse clinical events. Our results suggest that methods to reduce early thrombosis are most important, and identification of factors associated with early thrombosis need further investigation. Intraoperative and postoperative anticoagulation varied and may benefit from additional evaluation. Neither externally reinforced nor larger diameter grafts (≥12 mm) favored graft patency. Graft length may also influence patency, but this parameter was not routinely documented in the operative records.

There is a paucity of data regarding patency of PV reconstruction, especially beyond the immediate postoperative period. In the series by Tseng and colleagues,[2] the 1-year thrombosis rate among 116 patients with available radiologic follow-up was 6.9%. Although the dominant reconstructive material was the internal jugular vein (55 of 145 total vein resections), the reported thrombosis rate was not further stratified by reconstructive method. The limited data specific to even vein grafts make comparison with historical patency rates difficult.[19,25] Presently, there is no definitive evidence showing reduced patency in PTFE grafts compared with other means of PV reconstruction. Our experience suggests that satisfactory patency is achievable using PTFE.

Additional perioperative outcomes

Observed trends of elevated operative time, blood loss, and frequency of intraoperative transfusion are reflective of selection bias. Traditionally, PTFE grafts have not been used unless limiting further operative time becomes critical, often during exceedingly difficult cases in which other reconstructive methods have failed. Because the need for an interposition graft is usually not known until the actual time of PV resection, avoidance of additional vein harvest would otherwise certainly limit operative time. Reasons for selection of PTFE were not assessed in this retrospective analysis spanning a period exceeding 15 years. The overall and major morbidity rates of 45.5% and 21.2%, respectively, approximate those of PD with vein resection in the existing literature.[2,5,7,14,15] The 30-day mortality rate of 6.1% parallels previously reported rates of 0% to 7.7% in PD with PV/SMV resection.[7]

Cancer-related outcomes

The R0 resection rate was 63.6%, with most positive margins occurring at the retroperitoneum. No positive margins due to inadequate venous resection were observed because PTFE grafts harbor no length constraints. The rate of histologically confirmed perivascular tumor invasion was 54.8%, comparable to the range of 56% to 78% in the literature.[2,5,14,15]

Many studies have shown that with complete resection, equivalent survival is achievable in patients who undergo PD with or without PV resection.[7] Evaluation of the impact of vein reconstruction on survival is limited. Muller and associates[14] compared adenocarcinoma patients who underwent PV/SMV resection with subsequent end-to-end anastomosis, lateral venorrhaphy, and prosthetic patch/interposition reconstruction. Median survival estimates for the 3 groups were 13, 21, and 13.8 months, respectively ($p = 0.72$). The reconstructive methods compared likely serve as surrogate measures of the degrees of vascular invasion, a parameter of prognostic importance.[43] The median survival of 12 months in pancreatic adenocarcinoma patients in our series approximates the range of 13 to 22 months in larger studies,[7] and should be interpreted in the context of sample size limitations, evolution in resectability criteria during the extended study period, and omission of prognostic variables such as adjuvant therapy.

Limitations of this study include those typical of retrospective study design and small sample size. The advantages of a collaborative report are countered by nonuniformity in surgical technique, postoperative management, graft surveillance, and follow-up regimens across institutions, although standardization is difficult even within centers in this rare procedure. Prospective evaluations will be challenging because the reality remains that primary repair is sufficient after most PV resections. Consideration was not given to other nonautologous options such as polyethylene terephthalate and cryopreserved homograft because of our preferential use of PTFE. The extended period necessary to acquire the combined experience was associated with evolution in neoadjuvant therapy, adjuvant treatment, and resectability criteria. Ultimate acceptance of PTFE as a viable alternative in PV reconstruction will depend on results of appropriately matched comparisons with primary anastomotic repair and autologous vein conduits.

In conclusion, PTFE grafts may provide a safe and effective option in venous reconstruction after PD with en-bloc portomesenteric venous resection in selected patients. Although uniformity in technique and management are lacking, long-term patency is achievable with minimal hepatic morbidities and, importantly, infrequent infectious complications. Optimal selection criteria for use of prosthetic

grafts in portal vein reconstruction remain to be established. Further studies with well-matched comparisons to cases of primary anastomosis and autologous vein reconstruction are necessary.

Author Contributions

Study conception and design: Chu, Sarmiento, Farnell, Nguyen, Kooby
Acquisition of data: Chu, Stauffer, Sclabas
Analysis and interpretation of data: Chu, Sarmiento, Kooby
Drafting of manuscript: Chu, Kooby, Sarmiento
Critical revision: Chu, Farnell, Nguyen, Stauffer, Sclabas, Kooby, Sarmiento

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