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Distal splenorenal and mesocaval shunting at the time of pancreatectomy

Mariana I. Chavez, MD[a], Susan Tsai, MD[a], Callisia N. Clarke, MD[a], Mohammed Aldakkak, MD[a], Michael O. Griffin, MD[b], Abdul H. Khan, MD[c], Paul S. Ritch, MD[d], Beth A. Erickson, MD[e], Douglas B. Evans, MD[a], Kathleen K. Christians, MD[a,*]

[a] Department of Surgery, Division of Surgical Oncology, Pancreatic Cancer Program, Medical College of Wisconsin, Milwaukee, WI
[b] Department of Radiology, Pancreatic Cancer Program, Medical College of Wisconsin, Milwaukee, WI
[c] Department of Medicine, Division of Gastroenterology, Medical College of Wisconsin, Milwaukee, WI
[d] Department of Medicine, Division of Medical Oncology, Pancreatic Cancer Program, Medical College of Wisconsin, Milwaukee, WI
[e] Department of Radiation Oncology, Pancreatic Cancer Program, Medical College of Wisconsin, Milwaukee, WI

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ABSTRACT

Background: When pancreatic neoplasms occlude or encase the superior mesenteric-portal-splenic vein confluence with abutment of the posterior lateral wall of the superior mesenteric artery, a mesocaval shunt with or without a distal splenorenal shunt allows for safe dissection of the porta hepatis and separation of the pancreatic tumor from the superior mesenteric artery. Herein we report long-term results of the largest known series of portosystemic shunts performed at the time of pancreatectomy.

Methods: All patients who underwent pancreatic resection with a mesocaval shunt or distal splenorenal shunt were identified from our prospective database. Demographics, perioperative treatment, and outcomes were reviewed.

Results: A total of 34 patients underwent mesocaval shunt or distal splenorenal shunt, including 25 at the time of pancreatoduodenectomy, 6 during total pancreatectomy, and 3 after prior pancreatectomy. There were 15 mesocaval shunts, 16 distal splenorenal shunts, 2 combined mesocaval/distal splenorenal shunts, and 1 distal splenoadrenal vein shunt. The mesocaval group included 11 temporary and 6 permanent (3 delayed) shunts. Median operative time was 9 hours (range 6.5–13), median estimated blood loss was 950 mL (range 200–5,000), and median duration of hospital stay was 11 days (range 7–35). Four patients experienced complications that required intervention (Clavien-Dindo grade ≥III), but there were no 90-day mortalities. For patients with adenocarcinoma, median overall survival was 31 months at a median follow-up of 19 months. All but 1 shunt (distal splenorenal) were patent at last follow-up.

Conclusion: Mesenteric venous shunting facilitates a safe and complete tumor resection in patients who require a complex pancreatectomy, many of whom would otherwise be deemed inoperable.

Introduction

Operative portosystemic shunts were first introduced into clinical practice in the mid-20th century as a successful method for treating gastroesophageal variceal hemorrhage associated with end-stage liver disease and extrahepatic portal hypertension.[1] Prospective randomized trials in patients with operatively created shunts performed in the 1990s documented long-term shunt patency and prevention of recurrent hemorrhage.[2,3] With the advent of endoscopic banding, transjugular intrahepatic portosystemic shunts, and orthotopic liver transplantation, the use of operatively created portosystemic shunts declined. Nevertheless, these shunts remain an excellent option in patients with pre- or posthepatic portal hypertension when there is limited or no liver dysfunction;[1] this scenario occurs in pancreatic surgery when the tumor occludes the portal vein (PV) or superior mesenteric vein (SMV) resulting in cavernous transformation of the PV. Resection of the SMV-PV and dissection of the porta hepatis is virtually impossible and dangerous without first diverting the mesenteric venous return to eliminate the varicosities in the porta hepatis. If a portosystemic shunt is created, one would plan to restore normal hepatopetal flow to the liver after removal of the tumor. Attempted

* Corresponding author: Medical College of Wisconsin, Department of Surgery, 8701 Watertown Plank Road, Milwaukee, Wisconsin, 53226.
E-mail address: kchristi@mcw.edu (K.K. Christians).

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removal of the pancreatic head and the occluded segment of SMV-PV without first decompressing the mesenteric venous system should not be attempted. In this setting, our group has described the use of mesocaval shunts (MCS) to allow a potentially curative resection.[4,5]

In addition to mesenteric venous hypertension owing to an occluded SMV-PV, isolated occlusion of the splenic vein (SplV) may result in sinistral (left-sided) portal hypertension with the risk for delayed gastrointestinal (GI) hemorrhage months or years after pancreatectomy. Sinistral portal hypertension was first described in 1939 as a form of localized portal hypertension caused by obstruction or thrombosis of the SplV usually seen in the setting of pancreatic disease (often pancreatitis).[6] With SplV occlusion, venous return from the spleen drains through the short gastric veins to the wall of the stomach. The intragastric veins then dilate under pressure resulting in gastric and sometimes esophageal varices.[7] Acute or chronic upper GI hemorrhage is often the first manifestation of sinistral portal hypertension. These patients can present with an acute GI bleed in the setting of normal liver function tests, unexplained splenomegaly, or much more rarely, anemia from indolent chronic blood loss. Several reports in addition to our own have now confirmed this phenomenon after pancreatectomy when the SplV is ligated as part of a segmental resection and reconstruction of the SMV-PV.[4,8–10] Our procedure to prevent the development of sinistral portal hypertension has been to create a distal splenorenal shunt (DSRS) after SplV ligation in the setting when the inferior mesenteric vein (IMV) does not enter the SplV and provide a route for retrograde decompression.[4,5]

Herein, we describe the long-term experience at the Medical College of Wisconsin with MCS and DSRS at the time of pancreatectomy for cancer. To our knowledge, this represents the largest series reported in the literature for this indication.

Methods

We reviewed all patients who underwent pancreatic resection and had an MCS or DSRS performed between 2009 and 2018. Patients were identified from a prospective, institutional clinical database. This study was approved by our Institutional Review Board. Patients were staged at the time of diagnosis as published previously.[11] The patients with adenocarcinoma were treated with an extensive course of neoadjuvant therapy (chemotherapy, chemoradiation), followed by pancreatectomy with or without adjuvant therapy. Patients with pancreatic adenocarcinoma (PDAC) then underwent restaging examination, laboratory analysis, and computed tomography (CT) imaging at 2-month intervals during neoadjuvant treatment and again before operation. Imaging consisted of multidetector CT images obtained during the late arterial and portal venous phases after intravenous administration of iodinated contrast material. Precise timing of the late arterial phase acquisition was individualized to each patient through the use of a small test bolus of contrast to determine the time interval from contrast injection to contrast arrival in the abdominal aorta, which is dependent on cardiac output. In addition to standard coronal and sagittal reformations created for each CT examination, advanced 3D reconstructions were created for the initial staging CT, including multiplanar, curved planar, three-dimensional, volume-rendered reformations and maximum intensity projections. Collectively, this comprehensive data set allowed for optimal anatomic detail of the tumor-vascular relationships and facilitated detailed operative planning to include all potential options for vascular reconstruction. An operative strategy was developed before entering the operating room for all patients.

Before opening the abdomen and during the same anesthetic, diagnostic laparoscopy was completed in the patients with adenocarcinoma to exclude metastatic disease. Demographics, disease stage, neoadjuvant treatment, operative details, and outcomes were reviewed. Importantly, all patients had an Eastern Cooperative Oncology Group (ECOG) performance status $\leq$2 and appropriate socioeconomic support to recover successfully from a major operation. Pancreatic resections were performed as we have described previously in great detail.[12–14]

Operative strategies

Ligation of the splenic vein (SplV) and indications for DSRS

The SplV was ligated for the following indications: (1) when the SMV-PV-SplV confluence was encased by tumor, (2) when superior mesenteric artery (SMA) abutment was present to include the posterior surface of the artery (as noted on preoperative CT imaging) and, therefore, enhanced exposure of the proximal SMA was felt to be essential to avoid inadvertent arterial injury, or (3) when increased mobility of the PV was required to achieve a primary anastomosis of the SMV to the PV, SplV ligation was preferred over interposition grafting. In situations where the SMV-PV was encased at the SplV confluence, the SplV was divided, which widely exposed the SMA, as originally described by Fortner.[15] SplV ligation, however, may predispose the patient to sinistral portal hypertension and GI hemorrhage when the IMV enters the SMV rather than the SplV because retrograde decompression of the SplV through the IMV is then not possible.[4,5,10] In such cases, we performed a DSRS to decompress the SplV and prevent sinistral portal hypertension. We try to preserve the left gastric vein and the middle colic vein whenever possible. However, in patients with borderline resectable or locally advanced disease, these veins are usually ligated and divided; if preserved, these vessels are most often inadequate to prevent gastric-splenic venous hypertension. A DSRS refers to an anastomosis between the distal SplV and left renal vein (end-to-side) known as the splenorenal shunt of Warren (Fig. 1).[16,17] When a DSRS was created at the time of pancreatoduodenectomy (PD), the pancreas was divided at or to the left of the SMV-PV-SplV confluence, and the pancreatic body was elevated off the SplV by ligating the small venous tributaries to the pancreas. Posterior and slightly inferior to the SplV, the left renal vein was exposed. The left adrenal vein was often ligated, and the origin of the adrenal vein was usually incorporated into the venotomy in the left renal vein. The distal SplV was then sutured end-to-side to the left renal vein with a posterior running suture and an anterior row of interrupted sutures of 6-0 polypropylene. The SplV can also be anastomosed end-to-end to the left adrenal vein when the diameter of the adrenal vein is an appropriate size match (distal splenoadrenal shunt); this technique was required in the setting of an anomalous retroaortic left renal vein, which caused the renal vein to be displaced in a posterior direction such that the SplV was not able to reach the renal vein (Fig. 2).

Creation of an MCS

At the time of pancreatectomy

We first described use of a temporary MCS during PD in patients with radiographic evidence of cavernous transformation of the PV caused by short segment SMV-PV occlusion.[18] Chronic PV occlusion results in large venous collaterals around the pancreatic head extending into the porta hepatis where the PV then reconstitutes. This vascular abnormality poses substantial risk of major hemorrhage if one were to attempt PD and, specifically, the portal dissection. In such circumstances, the duodenum was Kocherized, the infrarenal inferior vena cava (IVC) was exposed, and the anatomy of the SMV caudal to the tumor was defined—preferably, at the level of the main trunk of the SMV cephalad to the bifurcation of the SMV into its ileal and jejunal branches. If the tumor

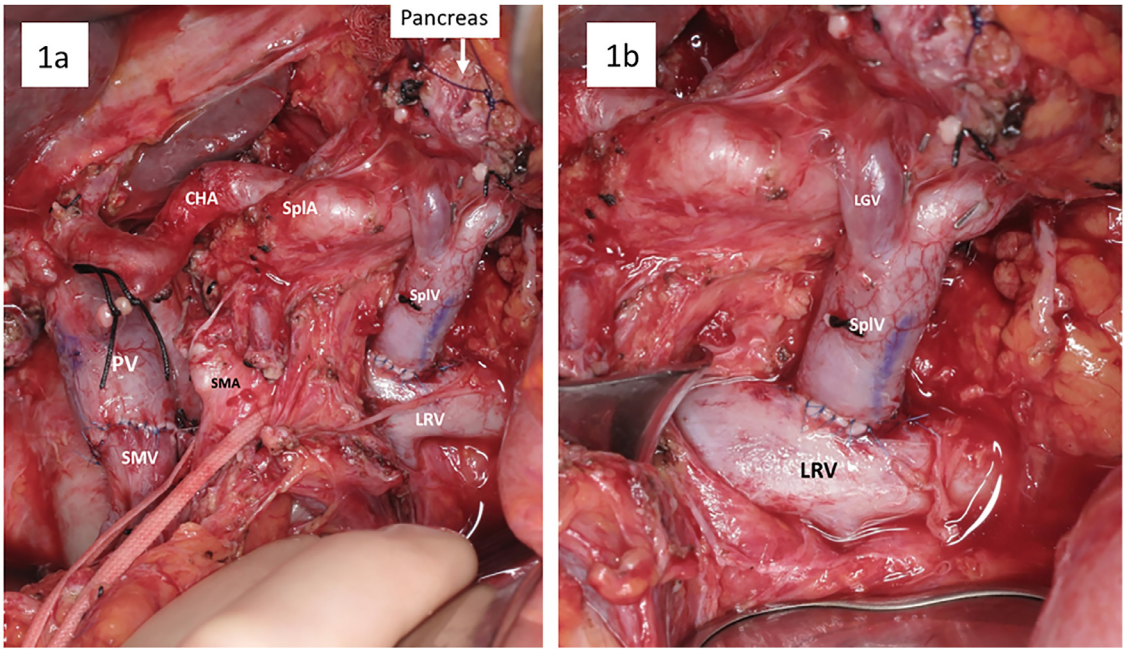

Fig. 1. Intraoperative photograph of a completed pancreatoduodenectomy with venous resection/reconstruction and distal splenorenal shunt (DSRS; Fig. 1, *A*). A magnified view of the DSRS is shown in Fig. 1, *B*. A Rummel tourniquet was placed around the superior mesenteric artery (SMA) for inflow control during superior mesenteric vein–portal vein (SMV-PV) reconstruction. The splenic vein was anastomosed to the left renal vein, which created enough length for primary anastomosis of the SMV to the PV. The left gastric vein arose from the splenic vein and was preserved.
CHA = common hepatic artery; LGV = left gastric vein; LRV = left renal vein.

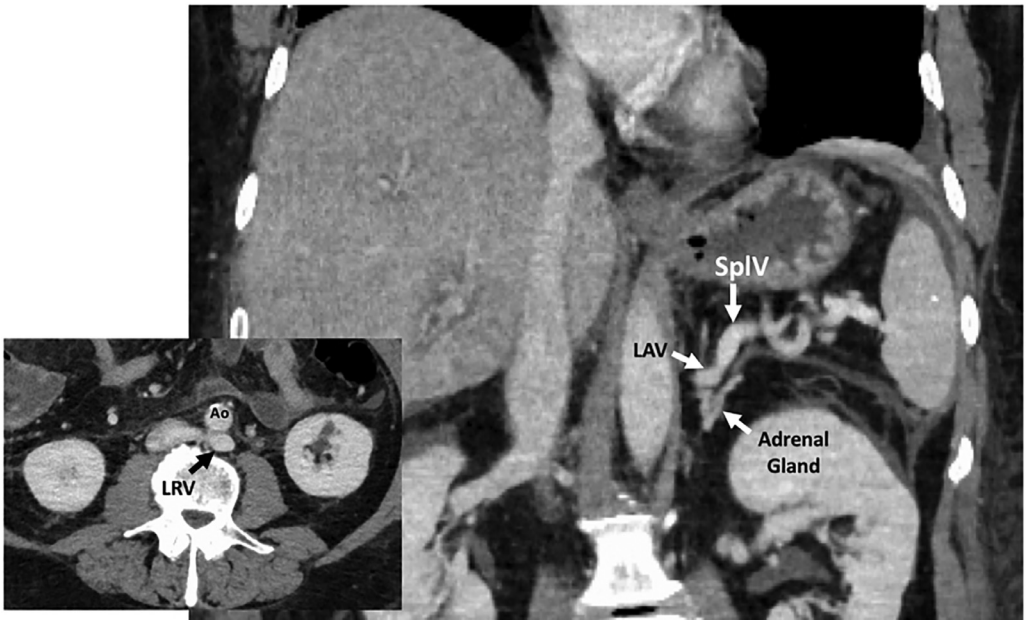

Fig. 2. Coronal computed tomography postoperative image of a variation of the distal splenorenal shunt of Warren; the splenic vein was sutured end-to-end into the left adrenal vein. This variation was created because of an anomalous retroaortic location of the left renal vein (image inset), which created too severe of an angulation to complete a standard distal splenorenal shunt. This patient's inferior mesenteric vein drained into the superior mesenteric vein.
Ao = aorta; LAV = left adrenal vein; LRV = left renal vein.

extends into the root of mesentery and one has to ligate the jejunal branch of the SMV, the ileal branch alone can be used to decompress the midgut. We prefer that the diameter of the ileal branch be 1.5 times the diameter of the SMA. We generally do not use the jejunal branch alone for decompression of the mid-gut because the vessel is very fragile and the anatomic location is usually posterior to the SMA, making an anastomosis difficult to perform. Fine vascular bulldogs are utilized for inflow occlusion of the caudal branches of the SMV (bifurcation of ileal and jejunal, or ileal branch alone). A straight vascular clamp can be used to occlude the more robust proximal SMV.

The left internal jugular vein (IJV) was then exposed in the left neck. The IJV while still in situ was marked longitudinally with a blue marker and then harvested from the neck; this marking maintained orientation when the IJV was sewn in place. The IVC–IJV anastomosis was then completed to the anterior surface of

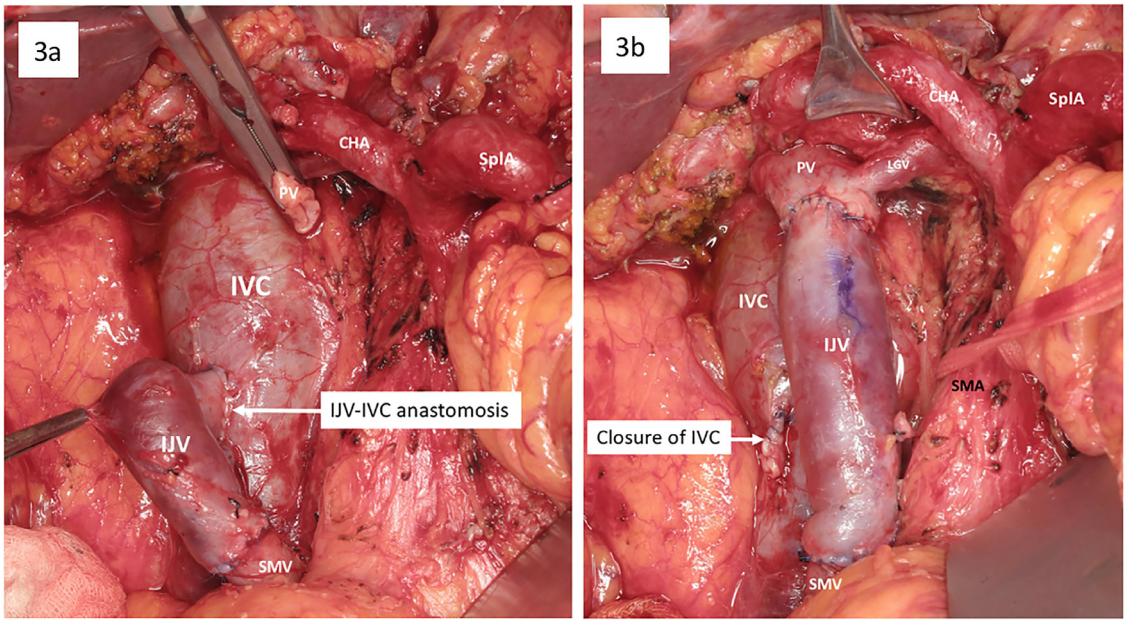

Fig. 3. Intraoperative photographs illustrating the sequence of a temporary mesocaval shunt (MCS). In Fig. 3, *A*, the patient had an MCS (superior mesenteric vein-internal jugular vein graft-inferior vena cava [IVC]) deliberately created with redundancy to facilitate safe removal of the tumor in the setting of complex tumor superior mesenteric artery (SMA) abutment. In Fig. 3, *B*, the internal jugular vein graft was disconnected from the IVC and anastomosed to the portal vein thereby restoring forward flow to the liver.
CHA = common hepatic artery; LGV = left gastric vein.

the infrarenal IVC with running 6-0 polypropylene. Completing the distal anastomosis first minimizes the clamp time on the SMV. The SMV was then transected and sutured end-to-end to the segment of IJV with interrupted 6-0 polypropylene. The pancreatic resection was then completed. After the specimen was removed, the IVC–IJV anastomosis was taken down, the IJV graft cut to the appropriate length, and anastomosed end-to-end to the PV with inflow occlusion of the SMA by a Rummel tourniquet and systemic heparinization (Fig. 3). In the setting of cavernous transformation of the PV, during tumor resection and specifically the portal dissection, the combination of a temporary MCS and a DSRS effectively diverted all mesenteric blood flow into the central circulation. This maneuver is necessary to perform a safe portal dissection and to properly decompress the midgut during the time it takes to complete the pancreatectomy. When performing a total pancreatectomy, DSRS is obviously not needed; however, in such cases, the splenic artery was ligated early in the operation to decrease inflow to the collateral veins contributing to the cavernous transformation of the PV and the short gastric vessels were also all divided. If access to the splenic artery was anticipated to be excessively difficult, the splenic artery could be embolized the day or evening before operation.

Experience with MCS in patients with cavernous transformation of the PV resulted in the clinical observation that this maneuver greatly enhanced the exposure of the entire root of mesentery at the level of the SMA. Therefore, the use of MCS was expanded subsequently to include patients who required both a difficult SMV-PV resection or reconstruction and a challenging SMA dissection. Creation of a MCS resulted in wide exposure of the root of the mesentery and prevented any form of traction injury on the SMV-PV confluence during the SMA dissection. After removal of the tumor, the MCS was usually dismantled and hepatopetal flow reestablished (SMV-IJV-PV; Fig. 3); however, in cases where the MCS was performed and the SplV-PV confluence was preserved (especially when the IMV entered the SplV), the MCS was sometimes left in place as a permanent as opposed to temporary shunt. The MCS was left for 2 reasons: first, to prevent having a long segment of IJV within the bed of the resected pancreatic head and thereby risking compression from a seroma or lymphocele, and second, to prevent distortion of the SplV-PV confluence when it has moved slightly cephalad and medial because of the transection of the SMV just distal to the SplV-PV confluence (Fig. 4).

Importantly, if the encased segment of SMV was distal to the SplV-PV junction, we usually favored preservation of the SplV-PV confluence and reconstruction of the SMV with an IJV interposition graft.[12,13,14] Preservation of the SMV-PV-SplV confluence prevented access to the proximal SMA from an anterior approach and also tethered the PV in place, thereby creating the need for an interposition graft if segmental resection of the SMV is required. This is in contrast to a primary SMV-PV anastomosis, which can often be accomplished if the distal SplV is divided. Preservation of the SplV-PV junction, if possible, should always be considered because preserving the SplV-PV junction nearly eliminates the risk of PV thrombosis or stenosis after SMV resection and reconstruction. When the SMV distal to the SplV-PV junction requires segmental resection, we typically separate the pancreas from the SMA first, as initially described by Leach and colleagues; reconstruction is performed with an IJV interposition graft.[19] If an SMA first approach is not possible (large tumor, poor exposure, SMA abutment, etc), there are 2 alternatives—creation of an MCS or the placement of an IJV interposition graft before removing the specimen from the SMA. This latter technique usually requires redundancy of the interposition graft when first sewn in place and, therefore, the graft may require revision or shortening after removal of the specimen (Fig. 5).

Lastly, if the SMA was skeletonized over a length of greater than 3 cm (especially along its posterior surface), a saphenous vein graft was harvested, and the SMA was wrapped with a spiral saphenous vein graft to try to prevent the development of a pseudoaneurysm of the SMA if the patient were to develop a pancreatic leak or a collection of infected fluid in the bed of the resected pancreas.

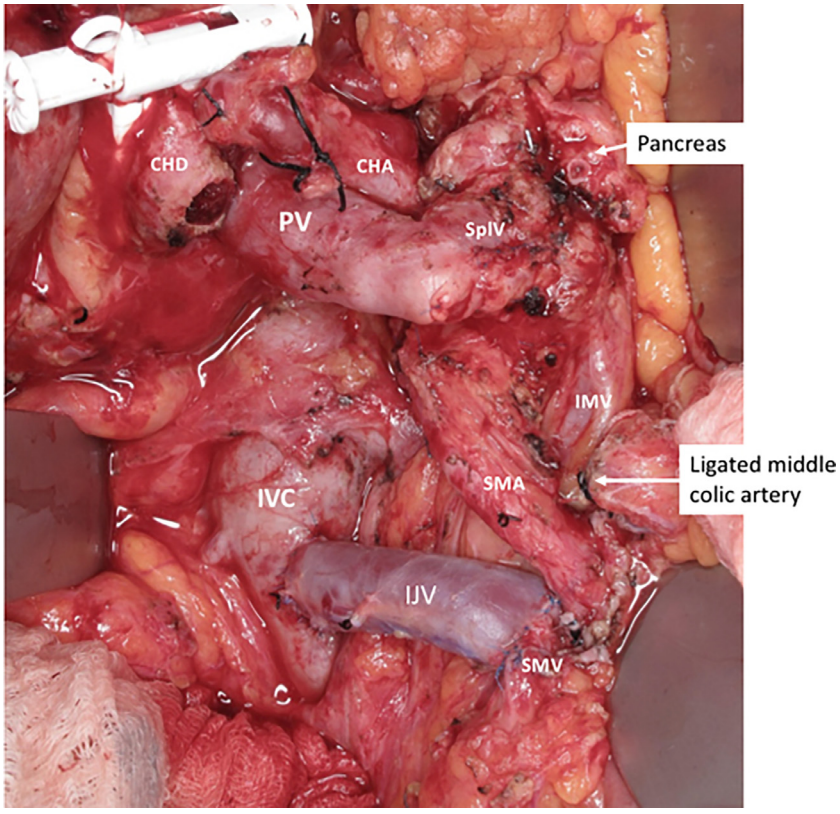

Fig. 4. Intraoperative photograph of a permanent mesocaval shunt (MCS). In this patient, the superior mesenteric vein was occluded distal to the portal vein–splenic vein (PV-SplV) confluence. A large inferior mesenteric vein drained into the splenic vein. Note the wide exposure of the root of the mesentery facilitating a difficult superior mesenteric artery (SMA) dissection and lessening the chance of inadvertent injury to the SMA. With an intact splenic-portal confluence we elected to leave the MCS intact, as discussed in the text in greater detail.
CHA = common hepatic artery; CHD = common hepatic duct.

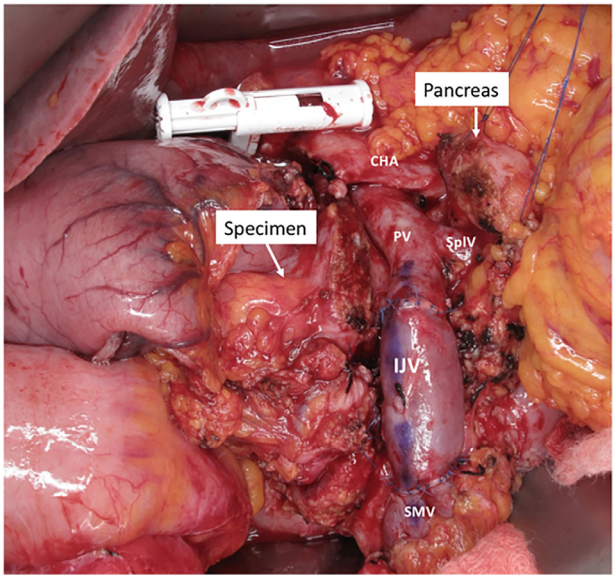

Fig. 5. Intraoperative photograph illustrating placement of an internal jugular vein interposition graft before dissecting the tumor off the superior mesenteric artery (SMA). This technique represents one technical option to handle a concomitant difficult SMA dissection and portal/superior mesenteric vein encasement.
CHA = common hepatic artery.

Delayed MCS

A final group of patients included in this analysis consisted of those who had previously undergone a standard or pylorus-preserving PD without vascular reconstruction and presented months to years after the operation with small bowel hemorrhage and evidence of jejunal varices on imaging. These patients all had developed short-segment SMV occlusion and mesenteric venous hypertension. This problem was treated with reoperation at which time a permanent MCS (SMV-IJV-IVC) was created which diverted blood into the central venous system and thereby relieved the mesenteric hypertension; gastrointestinal blood loss resolved in all patients (Fig. 6). Indications for DSRS and MCS procedures are summarized in Table 1.

Table 1
Indications for vascular shunts.

DSRS	MCS
PD and distal SplV ligated; IMV enters SMV at/below SMV-PV confluence and therefore, does not provide for retrograde decompression of the SplV. This scenario can occur with/without cavernous transformation of the PV	Cavernous transformation of the PV with porta hepatis varices Concomitant difficult SMV-PV resection/reconstruction and tumor abutment of the posterior aspect of the SMA or a lengthy segment of the right lateral wall of the SMA Prior pancreas resection and new onset GI hemorrhage due to short segment SMV occlusion and mesenteric venous hypertension

PD, pancreaticoduodenectomy; DSRS, distal splenorenal shunt; MCS, mesocaval shunt; SplV, splenic vein; IMV, inferior mesenteric vein; GI, gastrointestinal; SMV, superior mesenteric vein; PV, portal vein.

Perioperative care

Patients were systemically heparinized to achieve an activated clotting time (ACT) of >200 for venous resection or reconstruc-

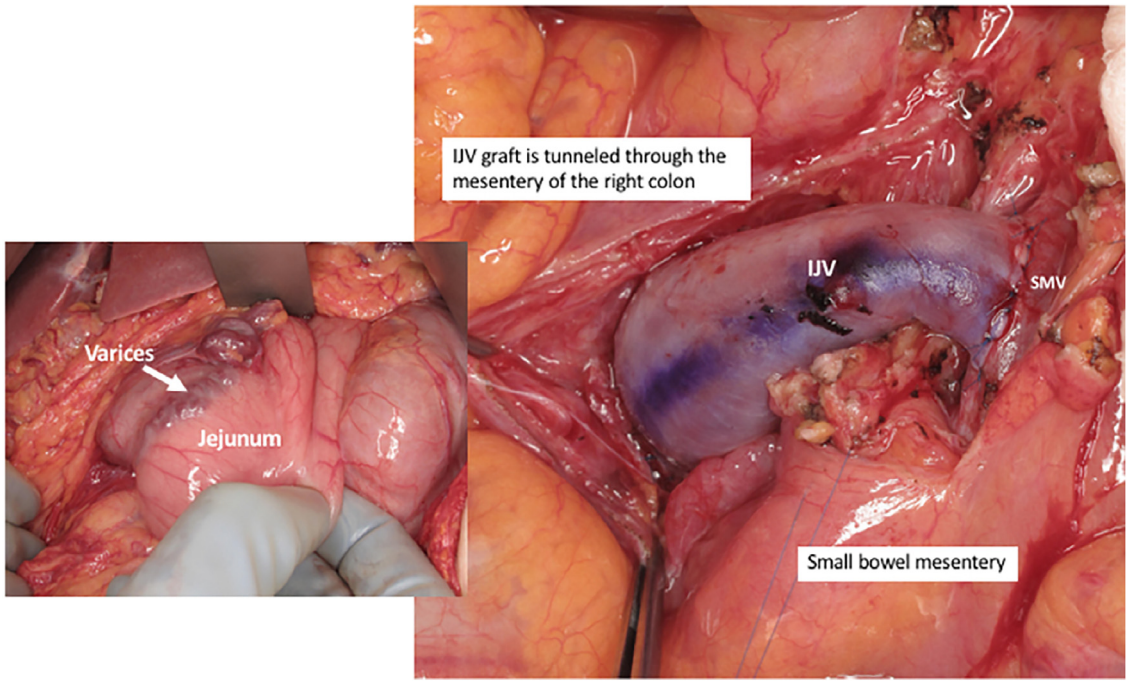

Fig. 6. Intraoperative photographs of a permanent mesocaval shunt (MCS; end-to-side into distal superior mesenteric vein [SMV]) that was performed because of gastrointestinal (GI) hemorrhage. This patient was found to have short segment SMV occlusion and massive jejunal varices (image inset). After creation of the MCS, there was no further evidence of GI blood loss.

tion and an ACT of >300 for any concomitant arterial resection/reconstruction. No reversal agents were given. The patients received 300 mg of aspirin per rectum in the recovery room and subcutaneous unfractionated heparin if postoperative coagulation parameters were near normal. All patients with venous grafts were discharged on 325 mg of enteric-coated aspirin daily.

Multimodal therapy for pain control consisted of intraoperative, transverse abdominis plane blocks followed by postoperative patient-controlled analgesia, acetaminophen, gabapentin, and occasionally nonsteroidal anti-inflammatories. Patients were evaluated initially at 1- to 2-week intervals in the outpatient clinic and then at 3- to 4-month intervals for cancer surveillance with particular attention to complications and disease recurrence (location specified as local, regional, distant). Patency of vascular grafts was noted on all follow-up imaging.

Results

A total of 34 patients received MCS or DSRS, including 31 at the time of pancreatectomy and 3 in a delayed fashion between 5 months and 2 years after the index pancreatectomy. The histologic diagnoses in all 34 patients included 30 with PDAC, 3 with pancreatic neuroendocrine tumor, and 1 with a solid pseudopapillary tumor. Median age was 61 years (range 21–80), a slight majority were men ($n = 18$, 52%), and the median Charlson Comorbidity Index was 4 (interquartile range:2; Table 2).

Among the 31 patients who had shunting procedures performed at the time of pancreatectomy, 27 had PDAC. These 27 patients included 1 with resectable disease, 20 (74%) with borderline resectable disease, and 6 (22%) with locally advanced, type-A disease.[11] All 26 patients with borderline resectable or locally advanced PDAC were treated with neoadjuvant chemotherapy followed by chemoradiation, whereas the patient with resectable disease received neoadjuvant chemotherapy alone. Of the 3 patients with pancreatic neuroendocrine tumors, 1 each received up-front operation, neoadjuvant chemotherapy, or neoadjuvant chemotherapy (very lengthy course) followed by chemoradiation. The patient

Table 2
Demographic characteristics of the 33 patients with PDAC or PNET (pseudopapillary tumor excluded).

Characteristics	PDAC $n = 30$	PNET $n = 3$
Age, years median (IQR)	64 (14)	48 (12)
Sex, *n* (%)		
Female	15 (50)	0
Male	15 (50)	3 (100)
BMI, median (IQR)	30 (8)	25 (5)
Charlson Comorbidity Index, median (IQR)	4 (2)	2 (2)
Clinical stage, *n* (%)		
Resectable	2 (7)	0
Borderline resectable	21 (70)	2 (67)
Locally advanced	7 (23)	1 (33)
Neoadjuvant therapy, *n* (%)		
None	0	1 (33)
Chemo-XRT alone	2 (7)	0
Chemotherapy alone	1 (3)	1 (33)
Chemotherapy and chemo-XRT	27 (90)	1 (33)
Operation, *n* (%)		
Standard Whipple	19 (63)	1 (33)
Pylorus preserving Whipple	1 (3)	0
Extended Whipple	6 (20)	0
Total pancreatectomy	4 (13)	2 (67)
TNM staging, *n* (%)		
T (tumor)		
TX	1 (3)	0
T1	1 (3)	0
T2	7 (23)	0
T3	21 (70)	3 (100)
N (nodal)		
N0	20 (67)	1 (33)
N1	8 (27)	2 (67)
N2	2 (6)	0
M (metastasis)		
M0	29 (97)	0
M1	1 (3)	0
Margin status, *n* (%)		
R0	29 (97)	3 (100)
R1	1 (3)	0
Duration of stay, days median (IQR)	12 (7)	11 (15)
Clavien-Dindo grade ≥3 complications, *n* (%)	3 (11)	1 (33)

PNET, pancreatic neuroendocrine tumor; *XRT*, radiation therapy.

Table 3
Operations performed in patients treated with venous shunts at the time of pancreatectomy.

Operation	Number of patients (%)	Number of patients with PDAC
DSRS with segmental resection of the SMV-PV and primary end-to-end venous anastomosis	14 (45)	13
DSRS with segmental resection of the SMV-PV and left internal jugular vein interposition graft	2	2
Distal splenoadrenal shunt with segmental resection of the SMV-PV and primary end-to-end venous anastomosis	1	1
Temporary MCS with segmental resection of the SMV-PV and left internal jugular vein interposition graft	9 (29)	6
DSRS and temporary MCS with segmental resection of the SMV-PV and left internal jugular vein interposition graft	2	2
Segmental resection of the SMV-PV, with preservation of SplV-PV confluence and permanent MCS	3 (10)	3
Total patients	**31**	**27**

with a pseudopapillary tumor did not receive any form of neoadjuvant therapy.

Pancreatic resections consisted of standard PD in 18 (58%) of the 31 patients, extended PD (to the left of the SMV/PV confluence) in 7 (23%), and total pancreatectomy in 6 (19%). These operations included 16 DSRS, 12 MCS, and 2 combined MCS/DSRS; 1 patient had a distal splenoadrenal shunt owing to a retroaortic left renal vein. Of the 14 patients with MCS, 11 were temporary and 3 were left as permanent shunts. Indications for performing an MCS included cavernous transformation of the PV in 10 patients and technical considerations at the root of mesentery in 4, including the combination of a difficult SMV resection or reconstruction and a challenging SMA exposure. The details of all operations performed are presented in Table 3.

There were 2 patients who required concomitant resection and reconstruction of the common hepatic artery with the use of a reversed saphenous vein graft. Spiral vein grafts (also using saphenous vein) were placed around the proximal SMA in 2 patients because tumor resection required complete removal of the entire root of small bowel mesentery and interruption of the adventitia of the SMA in 2 or 3 small areas. Because of the length of SMA exposed within the bed of the resected pancreas, these patients were believed to be at risk for pseudoaneurysm formation if an infected retroperitoneal fluid collection developed in the area.

Median operative time for the 31 patients who underwent venous shunt procedures at the time of pancreatectomy was 9 hours (range 6.5–13) with an estimated median blood loss of 950 mL (range 200–5,000). The patient with a 5-liter blood loss had a highly complex vascular resection and reconstruction done over a planned 2-day duration to assess for bowel viability. The duration of hospital stay was a median of 11 days (range 7–35). There were no in-hospital or 90-day mortalities. Four patients experienced Clavien-Dindo grade III or greater complications; 2 of these 4 patients required percutaneous, image-guided catheter drainage of a fluid collection compressing the vascular graft—1 for a seroma and the other for a chyle leak. One patient had a cardiopulmonary arrest immediately after extubation; the ACLS protocol was initiated, and he was re-explored immediately while still in the operating room because of the concern for abdominal hemorrhage; no intra-abdominal source was found. The patient had return of spontaneous circulation, recovered without incident, and remains alive without evidence of disease 3 years after treatment. The last patient required re-exploration during the immediate postoperative period owing to intra-abdominal hemorrhage, which proved to be due to coagulopathy believed to be secondary to NSAID abuse; no source of surgical bleeding was found. He recovered and was discharged without further complication.

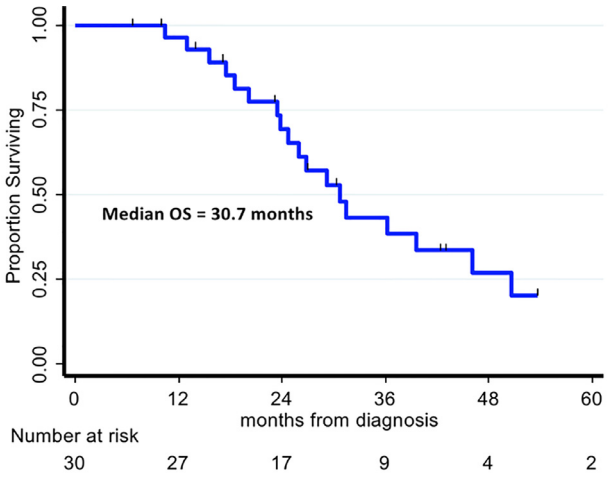

Fig. 7. Kaplan-Meier curve illustrating median overall survival for the 30 patients with pancreatic adenocarcinoma who completed all neoadjuvant therapy and operative resection.

A gross complete resection (RO) of all disease was accomplished in all 31 patients. The final pathology report confirmed an R0 resection in all but 1 of the 27 patients with PDAC. This patient had a positive pancreatic transection margin on permanent pathology, which was interpreted as negative on frozen section at the time of operation. Distance from the tumor to the closest margin was a median of 6 mm (range 1–40 mm). Regional lymph nodes were negative for metastatic disease in 17 (63%) of 27 patients with PDAC with a median of 26.5 nodes evaluated (range 15–41). One patient with PDAC underwent excisional biopsy of a subtle area on the peritoneum at the time of operation; intraoperative frozen section was negative for dysplasia or carcinoma, but on permanent sections, adenocarcinoma was seen. This patient had no evidence of disease at last follow-up 8 months from the date of diagnosis. For the 3 patients with neuroendocrine tumors, 1 patient was node-negative (0/36), whereas the other 2 patients had positive regional lymph nodes. The patient with the pseudopapillary tumor had 26 nodes examined, all of which were negative.

In addition, 3 of the 34 patients (all with PDAC) underwent reoperation 5 months to 2 years after the index pancreatectomy for creation of an MCS using the left IJV (end-to-side into both SMV and IVC). As explained previously, these patients all presented with GI hemorrhage owing to SMV occlusion and evidence of mesenteric venous hypertension. Upper and lower endoscopies were normal, and GI blood loss was repetitive, persistent, and required multiple red cell transfusions in all patients. After the MCS, GI blood loss resolved in all patients. Of the 3 patients, 1 experienced a mild degree of encephalopathy, which was treated with lactulose and rifaximin; she remains well 8 months after operation and lives independently at home.

Median follow-up from date of diagnosis in all 34 patients was 19 months (range 2–111). For patients with adenocarcinoma, median follow-up was 19 months (7–102), and median overall survival was 31 months (range 6.4–101; Fig. 7). Two interposition grafts in patients with locally advanced disease were narrowed on the most recent cross-sectional imaging but remained patent. One DSRS was occluded in the setting of local disease recurrence on CT imaging 7.4 months after operation; this patient was asymptomatic.

Discussion

Mesenteric venous shunts were developed by surgeons for the treatment of gastroesophageal variceal hemorrhage owing to end-stage liver disease and extrahepatic portal hypertension.

We have demonstrated their use in patients with advanced pancreatic tumors. MCS can facilitate a safe PD in the setting of cavernous transformation of the PV and enables exposure of the root of mesentery when a difficult SMA dissection is anticipated. More commonly, venous resection during pancreatectomy for cancer frequently requires ligation of the SplV owing to tumor abutment or encasement of the SMV-PV-SplV confluence. Ligation of the SplV also improves exposure of the SMA and often allows for a primary anastomosis of the SMV to the PV when segmental venous resection is required, which may avoid the need for interposition grafting.[12] Ligation of the SplV, however, may result in sinistral portal hypertension if the patient lives long enough for such a complication to occur. Sinistral portal hypertension after SplV ligation at the time of PD has been well documented.[4,8–10,19] Despite these reports, some investigators believe that ligation of the SplV is of little or no consequence.[15,20,21] This controversy has prompted further study of postoperative venous collateral flow to try to determine the reason for these divergent opinions.[4,9,10,20,22] Our group was an early proponent of anastomosing the SplV into the left renal vein (DSRS) in situations where the SMV-PV-SplV was encased by tumor, and the IMV entered the SMV or the SMV-PV-SplV confluence, and thereby the IMV could not serve to decompress the SplV after ligation and division of the distal SplV. We are among several groups who have reported GI hemorrhage from sinistral portal hypertension after SplV ligation when the IMV does not decompress the SplV.[9] Other authors suggest that 2 collateral pathways develop when the SplV is ligated (superior and inferior) and GI hemorrhage is uncommon.[20,22] We suspect that the incidence of symptomatic sinistral portal hypertension is influenced by the following of variables: (1) the success of oncologic therapy and operative resection (patients will need to be alive to experience this complication), (2) the extent of retroperitoneal dissection, especially to the left of midline, and (3) perhaps the use of multimodality treatment, especially radiation therapy, which may decrease collateral formation and encourage fibrosis over time. In contrast to Rosado et al,[22] at the Medical College of Wisconsin, we elevate the omentum off of the transverse colon (versus incising through the omentum inferior to the gastroepiploic arcade), oftentimes mobilize the right colon from the retroperitoneum (versus never doing this), and occasionally perform a Cattell-Braasch maneuver, which elevates the entire small bowel mesentery from its retroperitoneal attachments.[12–14,22] Finally, our patients with adenocarcinoma all received neoadjuvant chemoradiation in addition to chemotherapy, which may impact the development of retroperitoneal/mesenteric collaterals. It is likely that the pattern of collateral development that we have reported is the so-called superior route described by Rosado et al, making sinistral portal hypertension an expected result from SplV ligation in the absence of an intact IMV-SplV confluence to decompress the SplV.[22] Performance of a DSRS is 1 way to avoid this problem.

In light of the improved response rates seen with current systemic therapies (FOLFIRINOX, gemcitabine-nab-paclitaxel), patients with locally advanced PDAC who were thought previously to have inoperable disease are being reconsidered for exploration for potential resection.[23] Such patients have received a lengthy course (4–6 months) of systemic therapy, often followed by chemoradiation, and then are found to have a good performance status with a low or normalized serum level of carbohydrate antigen 19-9.[24] These patients are now being reconsidered for operative exploration because the primary tumor is the only measurable disease that can be seen on cross-sectional imaging. To the extent that systemic therapies are, or will be, more effective in the treatment of radiographically occult, extrapancreatic metastatic disease, patients with locally advanced PDAC will be seen in increasing numbers because complete response to induction therapy is uncommon at the site of the primary pancreatic tumor. Patients with borderline resectable or locally advanced PC often require a more complex operation as illustrated in this report. We have now successfully performed mesenteric venous shunt procedures in 34 very carefully selected patients. These techniques now offer patients with complex vascular involvement a possibility for operative resection of the pancreatic tumor through a safe and controlled operation, an operation that also is designed to prevent the long-term potential consequence of mesenteric venous hypertension and GI hemorrhage.

Conclusion

Portosystemic shunts facilitate safe resection in patients with locally advanced pancreatic tumors who may otherwise be deemed inoperable. In the era of more effective systemic therapy, it is critically important to know which patients are candidates for such extended resections and how to safely perform them.

Conflicts of interest

The authors have indicated that they have no conflicts of interest regarding the content of this article.

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