Parachute Technique for Portal Vein Reconstruction during Pancreaticoduodenectomy with Portal Vein Resection in Patients with Pancreatic Head Cancer

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ABSTRACT

Background: The most appropriate venous reconstruction method remains debatable when a long section of portal vein (PV) and/or superior mesenteric vein (SMV) must be resected in patients undergoing a pancreaticoduodenectomy (PD). The aim of the present study was to describe the technical details of the parachute technique, a modified end-to-end anastomotic maneuver that can be used in the above-mentioned circumstances, and to investigate its safety and feasibility.

Study design: Patients who underwent venous reconstruction using the parachute technique after receiving a PD with PV resection for pancreatic cancer between January 2014 and March 2019 were retrospectively reviewed. For the parachute technique, the posterior wall was sutured in a continuous fashion while the stitches were left untightened. The stitches were then tightened from both sides after the running suture of the posterior wall had been completed, thereby dispersing the tension applied to the stitched venous wall when the venous ends were brought together and solving any problems that would otherwise have been caused by over-tension. The postoperative outcomes and PV patency were then investigated.

Results: Fifteen patients were identified. The median length of the resected PV/SMV measured in vivo was 5 cm (range, 3-6 cm). The splenic vein was resected in all the patients and was reconstructed in 13 patients (87%). The overall postoperative complication rate (≥ Clavien-Dindo grade I) was 60%, while a major complication (≥ Clavien-Dindo grade IIIa) occurred in 1 patient (7%). No postoperative deaths occurred in this series. The PV patency at 1 year was 87%.

Conclusion: The parachute technique is both safe and feasible and is a simple venous reconstruction procedure suitable for use in cases undergoing PD when the distance between the resected PV and SMV is relatively long.

Keywords: parachute technique, pancreaticoduodenectomy, portal vein resection, venous reconstruction, pancreas head cancer, pancreatic cancer.

Declarations: None of the authors have any actual or potential conflicts of interest in relation to the submission of this article.

Abbreviations:

PDAC: pancreatic ductal adenocarcinoma; PD: pancreaticoduodenectomy

PV: portal vein; SMV: superior mesenteric vein; PVR: portal vein resection

BR: borderline resectable; PMSC; porto-mesenterico-splenic confluence

RPD: regional pancreaticoduodenectomy

Pancreatic ductal adenocarcinoma (PDAC) has one of the most dismal prognoses among solid malignant tumors, and surgical resection plus a combination of pre- and/or post-operative chemotherapy offers the only chance for a cure.[1-3] In patients undergoing pancreaticoduodenectomy (PD), the region between the pancreas head and superior mesenteric veins, including the portal vein (PV), superior mesenteric vein (SMV), and splenic vein (SV), is at the greatest risk for a positive margin because of its anatomical proximity to these vessels, and a positive margin has been consistently reported as a strong factor associated with a poor survival outcome.[4, 5] Accordingly, concomitant portal vein resection (PVR) is often mandatory to secure a negative surgical margin (R0),[6, 7] and PD with PVR is currently accepted as a standard procedure in patients with PDAC involving the PV/SMV.[8]

Various techniques for PVR, ranging from simple venorrhaphy to major segmental resection, have been described, as have the corresponding reconstruction procedures such as primary closure, end-to-end anastomosis, and interposition grafts. [6] Nevertheless, the optimal method for venous reconstruction after segmental PVR remains a matter of debate. Although end-to-end anastomosis is simple and preferable to an interposition graft,[7, 9, 10, 8] the distance between the resected PV and SMV is occasionally so long that an end-to-end anastomosis becomes technically impossible. Even if such an anastomosis can be performed, the reconstruction creates undo tension, predisposing patients to thrombosis and stricture/occlusion. Fujii et al. reported that a resected PV length of more than 3 cm was a risk factor for postoperative stricture in anastomosed PV/SMV and recommended the use of interposition grafts in such cases.[9] In contrast, several authors have reported that they were able to execute end-to-end anastomoses even after resecting a long section of PV/SMV through the addition of various procedures such as the Cattell-Braasch maneuver (i.e., mobilization of the right colon and/or SV resection).[6, 11, 12] However, no previous study has attempted to overcome long distances between the resected PV and SMV through a technical modification of end-to-end vascular anastomosis itself.

The parachute technique, which leaves continuous sutures untied until all the stitches in the posterior wall are in place, was originally developed for vascular anastomosis in the field of cardiovascular surgery.[13] Nanashima et al. firstly applied this technique for PV anastomosis during PD with PVR. [23] We hypothesized that this technique might be useful for dispersing the tension applied to the stitched venous wall when the resected venous ends are approximated, compared with the tension produced by a

single stitch, and we applied this technique to venous reconstruction after a long section of PV/SMV had been resected in cases undergoing a PD. In the present study, we will describe the technical details of the parachute technique for PV/SMV anastomosis and investigate its safety and feasibility.

METHODS

Patients

Prospectively maintained databases were searched to identify patients who had undergone PVR followed by PV/SMV reconstruction using the parachute technique among all patients undergoing PD for PDAC between January 2014 and December 2018 at the Cancer Institute Hospital (CIH) and between January 2019 and March 2019 at Juntendo University Hospital (JUH). These study periods corresponded to periods when the corresponding author (S.A.) headed the division of hepatobiliary-pancreatic surgery in the respective institutes. All the analyses conducted in this study were performed in accordance with the ethical guidelines for clinical studies at both institutions and were approved by the respective Institutional Review Boards (#19-137).

Surgical techniques

PD was performed after a meticulous explorative laparotomy. A supra-mesocolic anterior artery first approach was routinely adopted, the technical details of which have been described previously.[17] PV/SMV resection was planned when the preoperative CT scan images showed that the tumor was in contact with or had invaded the PV/SMV regardless of the extent of the invasion so long as the involved section of the PV/SMV was judged to be reconstructable after the resection. Test dissection between the tumor and the PV/SMV, i.e., an effort to skeletonize the PV/SMV to minimize the length of the vessel resection, was not performed in any of the cases. We preferred to use a segmental PV resection rather than a wedge resection, and we also preferred using an end-to-end anastomosis rather than a graft interposition irrespective of the length of the resected section of PV/SMV. PVR was performed during the final phase of resection, that is, after the influent arteries, stomach, jejunum, hepatic duct, pancreas, and mesopancreas had been divided. After the length of the section of the PV/SMV to be resected was measured in vivo, the PV was resected with the specimen in an en bloc manner. In patients undergoing resection of the porto-mesenterico-splenic confluence (PMSC), the SV was reconstructed after PV/SMV reconstruction, mostly to the left renal vein in an end-to-side manner, according to previously described

criteria.[18] The resection of the PMSC during the study period was conducted under the concept of a regional pancreaticoduodenectomy (RPD), which is characterized by the en bloc resection of the PV/SMV/PMSC together with the surrounding soft tissue.[14]

We have been performing PV/SMV reconstruction using the parachute technique when we think the distance between the resected PV and SMV is too long to be reconstructed using conventional end-to-end anastomosis. We routinely placed large surgical gauzes behind the liver to reduce the tension, rather than mobilizing the liver downwards by dividing its attachments. We did not try to shorten the distance between the edges of the PV and SMV using procedures proposed by other authors, such as mobilization of the right colon (Cattell-Braasch maneuver) and/or mesentery root or dissection of the falciform, right coronary and/or right triangular ligament. All procedures performed in the present study were performed by one attending surgeon, who is the head of the department. After placing a stitch at both edges of the PV and SMV using 5-0 non-absorbable monofilament thread (PROLENE®; ETHICON, Inc., Somerville, NJ,USA), anastomosis using the parachute technique was begun from the left side (Figure1). The posterior wall was sutured intraluminally in a continuous fashion while leaving the stitches untightened. The stitches were then carefully tightened from both sides after the running suture of the posterior wall had been completed. During this procedure, normal saline was continuously poured over the thread to reduce friction resistance between the thread and the vessel walls. Then, a running suture of the anterior wall was commenced from the left side in the usual manner. Finally, the thread was tied with a growth factor equivalent to that of the anastomosed PV. Anticoagulant agents were not administered to any of the patients postoperatively. A representative operative video showing the parachute technique has been provided as supplemental multimedia content (Supplementary video).

Assessment of the results of PV reconstruction using the parachute technique

The short-term postoperative outcomes and the patency of the anastomosed PV/SMV were reviewed retrospectively. Postoperative complications were classified according to the Clavien-Dindo classification. The patency of the anastomfis was assessed by measuring the venous diameters of the pre- and post-operative anastomotic sites using axial images from follow up CT scans. Anastomotic stenosis was defined when the ratio of the anastomotic to preoperative venous diameter was equal to or less than 50%. Overall PV patency from the time of resection was estimated by plotting the Kaplan-Meier survival

function, setting PV stenosis or occlusion as an event. The statistical analysis was performed using IBM SPSS software (ver26.0; SPSS Inc., IL, USA).

RESULTS

Patient demographics

Out of 315 consecutive patients undergoing PD for PDAC during the study period, 182 patients underwent PVR and 15 patients (13 patients in CIH and 2 patients in JUH) underwent PV/SMV reconstruction using the parachute technique. The patient demographics are summarized in Table 1. According to the NCCN guidelines, 6 patients were classified into resectable PDAC and 9 into BR-PDAC, respectively. All the patients with resectable PDAC underwent upfront surgery. On the other hand, patients classified into BR-PDAC received preoperative treatments as follows: 7 patients received neoadjuvant chemotherapy composed of gemcitabine and nab paclitaxel in our institution, and the remaining 3 patients received chemotherapy or chemoradiotherapy, respectively, in other hospitals.

Operative and short-term outcomes

The operative and short-term outcomes are summarized in Table 2. Portal reconstruction was completed within 15 minutes in all the patients. The median (range) length of the resected PV/SMV section, as measured in vivo, was 5 (3-6) cm. All 15 patients underwent PMSC resection, and 13 (87%) patients underwent SV reconstruction. Overall postoperative complications (≥ Clavien-Dindo Grade I) were observed in 9 out of 13 patients (60%), and a major complication (≥ Clavien-Dindo Grade IIIa) occurred in 1 patient (7%) who developed postoperative intraperitoneal bleeding because of a pancreatic fistula. No postoperative deaths (Clavien-Dindo Grade V) occurred in this series.

A microscopically curative (R0) resection was achieved in 12 of the 15 patients (80%). Regarding the margin of the resected PV/SMV, a negative margin was achieved in 12 out of 15 patients (80%).

Patency of PV anastomosis

During the observation period (median [range]: 18 [1-45] months), 2 patients developed anastomotic stenosis of the PV/SMV. One had a total occlusion caused by venous invasion resulting from a local recurrence that was found during a scheduled follow-up CT examination performed 6 months after the operation. The other patient was identified as having stenosis at 1 month after surgery based on a CT scan that was performed because of an elevated postoperative serum CA19-9 level suggesting a possible recurrence. In this patient, the ratio of anastomotic to preoperative venous diameter was 0.36. Although

multiple liver metastases were found, local recurrence was not detected in either the region surrounding the anastomotic stenosis or other areas. Anastomotic stenosis of the PV/SMV was not found in the remaining 13 patients, and the median ratio of the anastomotic to preoperative venous diameter in these 13 patients was 0.69, ranging from 0.51 to 1.06. Overall, the estimated 1-year PV patency rate was 87% (Figure 2). Clinical signs of portal hypertension were not observed in any of the presently reported 15 patients, including the 2 patients with anastomotic stenosis.

DISCUSSION

The procedure and outcomes of the parachute technique, which was used when the distance between the resected PV and SMV was relatively long in patients undergoing PD with PVR, are described in the present report. The parachute technique was originally developed for vascular anastomosis in the field of cardiovascular surgery.[13] Because the continuous suture is left untied until all the stiches in the posterior wall have been placed, this technique secures good lumen visibility during anastomosis and has been applied to the anastomosis of small vessels, such as lymphaticovenular anastomoses,[20] as well as in pancreaticojejunostomy in cases with small pancreatic ducts[21] and the reconstruction of small bile ducts[22] [23][31] in the field of hepatobiliary-pancreatic surgery. On the other hand, Nanashima et al. applied this technique to end-to-end PV anastomoses with large caliber differences and reported that the parachute technique without stay sutures facilitated the modification of sutures during anastomosis, compared with the conventional method using two stay sutures.[23] In the present study, we applied this technique to venous reconstruction in patients undergoing PD with PVR when the distance between the resected PV and SMV was relatively long. If a thread to one edge was tightened using the conventional method in such cases, the venous wall tied with a single stitch would have been subjected to over-tension, increasing the risk of tears. In contrast, the parachute technique provides the following advantages: 1) good dispersion of the tension applied to the venous wall, 2) better visualization of the anastomosis, and 3) the blood vessel can be moved closer so that it is not torn while the force applied to the venous wall is being checked. The posterior wall is sutured intraluminally in a continuous fashion, with the stitches left untightened. Especially, we try to use a mattress suture for the first 2-3 sutures to provide reinforcement, as shown in Figure 1. The stitches are then tightened gently from both sides after the running suture of the posterior wall has been completed. We speculated that this process enables the tension applied to the stitched venous wall to be dispersed when the resected venous ends are brought together; thus, the

parachute technique can solve problems that would otherwise be caused by over-tension in the venous wall.

In the present series, the distance between the resected PV and SMV (median [range]: 5 [3-6] cm) was relatively long, compared with those reported in previous studies. Nevertheless, all the PV/SMV anastomoses were safely performed. During the study period, we did not encounter a single case in which the application of the parachute technique resulted in failure, an additional mobilization procedure was required for the reconstruction, or an interposition graft was required for PV/SMV reconstruction. The favorable postoperative short-term outcome, i.e., the low major morbidity rate (7%) and absence of post-operative mortality, supports the feasibility of our procedure. Although the mid- to long-term outcomes remain to be addressed since the anastomosis itself remained under tension after the completion of the procedure, the 1-year patency rate of 87%, which was comparable to rates in previous studies (49% to 96% at 1-5 years),[24-26, 9] supports the feasibility of this technique.

The optimal reconstruction method for avoiding the inevitable application of over-tension to the anastomosis in situations requiring venous reconstruction bridging over a long distance between the resected PV and SMV during PD has been controversial. Graft interposition, either using a synthetic or autologous venous graft, is useful for decreasing the tension. The use of a vascular graft adds a degree of complexity that could lead to longer operative and clamp times. In addition, autologous venous grafts, usually procured from the femoral or internal jugular vein, are reportedly associated with a more than 40% risk of complications at the donor site [27]. While synthetic grafts were previously considered to have a higher risk of infection and thrombosis, compared with native grafts, several recent reports have showed safety and feasibility outcomes similar to those for autologous vein grafts [32]. No graft infections or anticoagulant-related complications occurred in the present series. In addition, some authors have insisted that they were able to execute direct end-to-end anastomoses even in cases with relatively long lengths of resected PV (i.e., 5-7 cm and 7-10 cm, respectively[11, 12]) by increasing the mobility of the venous ends to be approximated through the use of additional procedures, such as the Cattell-Braasch mobilization maneuver and/or SV resection.[6, 11, 12] In contrast, the presently reported parachute technique is relatively simple and does not require any specific expertise or proficiency. Although the SV was resected in all the patients in this study, this procedure was performed as part of an en block resection of the PV/SMV/PMSC together with the surrounding tissue, and not for the purpose of creating a tension-

free anastomosis. Although other procedures reported to be helpful for achieving a tension-free anastomosis, such as the Cattell-Braasch maneuver, were not applied in the present study, the combination of such procedures and the parachute technique could simplify PV anastomosis in difficult situations. The results of this study are thought to be of major clinical relevance to the surgical treatment of PDAC in the present era based on the following considerations. First, in contrast to the historical notion that a tumor with local involvement of the PV/SMV was a contraindication to surgery, en block PD with PVR is currently accepted as an indispensable procedure to achieve a tumor-negative surgical margin and is being increasingly performed under these circumstances because of recent reductions in morbidity and mortality. Second, as more effective chemotherapeutic agents become available, patients who were previously thought to have non-surgical disease are now being reconsidered as candidates for surgery, and many of these patients require a concomitant PVR to achieve an R0 resection. Third, the concept of RPD, a radical operation first described by Fortner in 1973.[28] but not widely adopted because of the associated morbidity, is now being re-evaluated as a practical approach to increasing the margin and thereby the chance of an R0 resection in patients undergoing PD with PV/SMV invasion.[14, 29] In the RPD approach, the pancreas is divided at the longitudinal line of the superior mesenteric artery, followed by the removal of the retropancreatic segment of the PV/SMV/PMSC and surrounding tissue together with the specimen in an en block manner to secure the medial margin. And finally, the accurate assessment of tumor infiltration behind the PV is reportedly difficult;[30] therefore, it becomes crucial not to skeletonize the retropancreatic segment of the PV/SMV if preoperative CT images show any signs of tumor contact with the PV/SMV to avoid unexpected tumor exposure or a tumor remnant. Consequently, the indications for PVR have widened, and the lengths of resected PV/SMV now tend to be larger.

CONCLUSIONS

The parachute technique is a feasible and safe venous anastomotic method that can be adopted when the distance between the resected PV and SMV is relatively long. In the present era, in which PD with PV/SMV/PMSC resection (for example, RPD) is expected to be increasingly performed from an oncological point of view, this technique is a simple, safe, and feasible venous reconstruction method for use in such operations.

FIGURE LEGENDS

Figure 1. Schematic presentation of the parachute technique for reconstruction of the PV/SMV. (A) A stitch is placed at both edges of the PV and SMV using a 5-0 non-absorbable monofilament thread. (B) The posterior wall is sutured intraluminally in a continuous fashion with the stitches left untightened. (B') To avoid splitting the venous wall, a few beginning stiches were placed using the intraluminal matless suture. (C) The stitches are carefully tightened from both sides after the running suture of the posterior wall has been completed and both edges of the resected PV/SMV have been approximated. (D) A running suture of the anterior wall is commenced from the left side in the usual manner. (E) The thread is tied allowing for a growth factor.

Declarations

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained in the form of opt-out on the web-site of each institution.

Conflict of interest The authors declare no competing interests.

Disclaimer No animals were used in this study.

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Figure 1

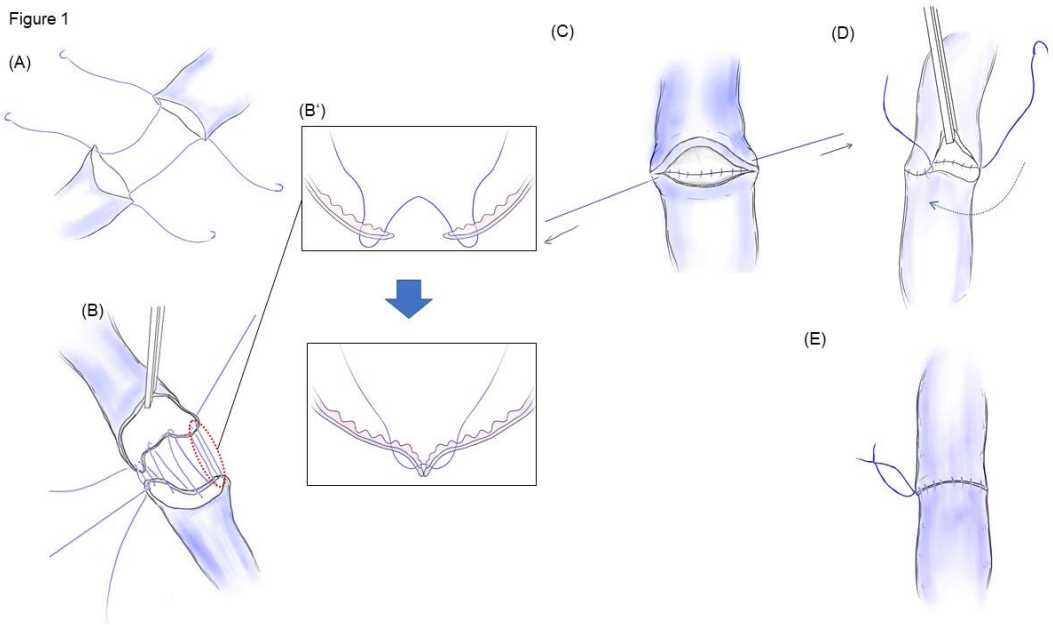

Table 1. Patient Demographics

Characteristic	
Age, year, median (range)	68(47-77)
Sex	
Male	7
Female	8
Preoperative CTx	
Yes	9*
No	6
Resectability	
R	6
BR	9
UICC 8th stage	
IA	1
IB	2
IIA	0
IIB	8
III	2

IV†	2	

CTx, Chemotherapy.

R, Resectable; BR, Borderline resectable.

* One patient had received chemoradiotherapy in other hospital.

† These patients had paraaortic lymph node metastases that were also resected.

Table 2. Operative and Short-term Outcomes

Characteristic	
Operation time, min, median (range)	511(389-660)
Blood loss, mL, median (range)	530(70-1040)
Length of resected PV, cm, median (range)	5(3-6)
SV resection, n (%)	15(100)
SV reconstruction, n (%)	13(87)
Postoperative hospital stays, day, median (range)	21(16-59)
Postoperative complications (Clavien-Dindo classification)	
0	4
I	0
II	8
IIIa	0
IIIb	1
IV	0
V	0
Radicality, n (%)	

R0	12(80)
R1	3(20)
90- day mortality	0
Ratio of anastomotic-/pre- operative venous diameter in patients without stenosis, median (range)	0.69(0.51-1.06)
Stenosis or occlusion, n (%)	2(13)

PV, Portal vein; SV, Splenic vein.